Faculty of Health, Engineering and Sciences

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A CRITERIA BASED APPROACH TO UNMANNED AERIAL VEHICLE REGULATIONS

A dissertation submitted by

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Abstract

The use of commercial and private Unmanned Aerial Vehicles (UAVs) is becoming increasingly popular for both commercial and private use. In Australian alone, the Civil Aviation Safety Authority stated that in 2018 the number of remote pilot licenses had increased by 53% over the previous year. Recent public discourse regarding UAV usage and regulation is centred around public privacy and safety which regulations aim to address. Whilst most jurisdictions have implemented key guidelines and licensing procedures for piloting UAVs, there is marginal consensus amongst regulators and a limited view towards a unified standard. Can there be marginal consensus between the regulations whilst still addressing the concerns identified in the research?

The purpose of this research project is to investigate what the key challenges and issues are that affect the use of UAVs and determine if current regulations are meeting those challenges. During an extensive literature review the primary issues revolving around privacy, safety, security, public nuisance and trespass were examined. From this research a set of criteria was developed to enable a comparative analysis to be performed against existing UAV regulations to determine how they were meeting the issues identified. Five countries were chosen from usage data and length of time between regulatory reviews ensuring any analysis was performed on regulations that were up to date. These countries were: Australia, Canada, EU, UK and the US.

The regulations from each of the countries were then compared against the developed criteria. During the comparative analysis there were clear shortfalls with all regulations falling to meet some of the criteria. These results confirmed what previous researchers had found as key issues were still failing to be addressed. From these results, recommendations were put forth providing avenues for closing the gaps in the regulations.

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Limitations of Use

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List of Abbreviations

ADS-B - Automatic Dependant Surveillance Broadcast

AIS - Abbreviated Injury Scale

ALRC - The Australian Law Reform Commission

ANO / ANO2016 - Air Navigation Order 2016

ATSB - The Australian Transport Safety Bureau

BVLOS – Beyond Visual Line of Sight

CAA - Civil Aviation Authority

CAP - Civil Aviation Publication

CASA - Civil Aviation Safety Authority

EASA - European Aviation Safety Agency

EU – European Union

EVLOS - Extended Visual Line of Sight

FAA- Federal Aviation Administration

GUAA - German Unmanned Aerial Association

IATA - The International Air Transport Association

ICAO - The International Civil Aviation Organisation

MTOW – Maximum Take Off Weight

PIPEDA - Protection and Electronic Documents Act

RePL – Remote Pilot Licence

ReOC - Remotely Piloted Aircraft Operator Certificate

RRATRC - Regional Affairs and Transport References Committee

SFOC - Special Flight Operations Certificate

SSID - Service Set Identifier

SUA – Small Unmanned Aircraft

UAS - Unmanned Aerial Systems

UAV- Unmanned Aerial Vehicle, Remotely Piloted Aircraft, Drone, Aircraft

USRP - Universal Software Radio Peripheral

VLOS - Visual Line of Sight

Statement of Original Authorship

The work contained in this dissertation has not been previously submitted to meet the requirements for an award at this or any other higher education institution. To the best of my knowledge and belief, the dissertation contains no material previously published or written by another person except where due reference is made.

Signature: Stephen John McTegg

Date: 17th October 2019

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Chapter 1: Introduction

1.1 BACKGROUND

The use of commercial and private Unmanned Aerial Vehicles (UAVs) is becoming increasingly popular for both commercial and private use. In Australian alone, the Civil Aviation Safety Authority stated that in 2018 the number of remote pilot licenses had increased by 53% over the previous year. With the increase in number of UAVs operating in the national airspace there comes a greater need for regulation to ensure the safety and privacy of the public. However, as politicians and regulators aim to catch up with the increasing number of UAVs, researchers urge caution should be applied as regulation can both promote and suppress innovation (Nakamura & Kajikawa 2017) as UAV use and development needs surety to continue to be viable. Molina and Campos (2018) state that within the European market the two most prevalent issues regarding regulation are security and safety considerations. However, as Europe contains multiple independent countries with scattered non uniform regulations, over regulation can be the principal hurdle to surmount (Molina & Campos 2018). Morales, Paez and Arangos (2015) multi-criteria analysis of UAV regulations stated that in certain countries the regulatory limitations imposed on the commercialisation of the technology were “notorious”.

Recent public discourse regarding UAV usage and regulation is centred around public privacy and safety which regulations aim to address (Nakamura & Kajikawa 2017; Luppicini & So 2016; Sanz et al. 2015). Whilst most jurisdictions have implemented key guidelines and licensing procedures for piloting UAVs, there is marginal consensus amongst regulatory bodies and a limited view towards a universal standard (Stöcker et al. 2017). The same UAVs operating in the same set of circumstances are bound by different guidelines and regulations depending on the country they are operating in. These regulations can differ wildly with respect to flying height, flying proximity to people/buildings and weight classes. These regulatory differences add additional complexities for a person to navigate when planning and flying UAVs, whether it’s for commercial or private use. Whilst UAV operators in Australia are bound by a single regulator, the Civil Aviation Authority (CASA), a person in the European Union (EU) could have to contend with and be well versed in a multitude of regulations encompassing numerous jurisdictions (Herrmann 2017).

1.2 AIMS

The aim of this project is to research and compare existing UAV regulations across diverse jurisdictions, determine the key problems and issues that arise from the use of UAVs, develop a set of criteria to attempt to resolve problems identified and determine if existing regulations address these issues. By identifying if the key issues such as privacy, safety and security are being addressed, recommendations will be made to mitigate any discrepancies found in the regulations.

1.3 OBJECTIVES

The objectives of this project are as follows:

1. Determine the existing state of UAV regulations.
2. Determine the similarities and differences in existing regulations.
3. Define the key problems that arise from the use of UAVs.
4. Develop a set of criteria to resolve the key problems.
5. Using the criteria, examine if existing regulations address the key problems.
6. Provide recommendations addressing any shortfalls in the regulations.

1.4 LIMITATIONS

Although this project seeks to research UAV regulations across a variety of jurisdictions, due to limited time and scope only a small selection of regulations has been analysed. These were chosen based on UAV usage numbers, existing established UAV regulations and length of time between regulatory reviews. Countries with limited regulations or limited usage data available were excluded from the analysis. Other limitations found during research for this paper were that although there is significant data available relating to use of UAVs by the military, the primary focus of this paper is on the commercial and private/recreational use of UAVs. Additionally, the research in this paper was completed during a time when there was an increased interest in UAV reform. Numerous countries were investigating the need for changes to their UAV guidelines with several jurisdictions in the process of transitioning to new regulations. As such, the intention of the research and analysis in this paper is to encompass this development.

Chapter 2: Literature Review

2.1 INTRODUCTION

The primary aim of this literature review is to identify the current challenges affecting the use of UAVs. Although this research will be guided by the key tenets of privacy, safety and security, additional issues found during the review will be open to examination. An investigation surrounding the development of regulations and any previous comparative analyses will also be identified. Key statistics such as types of users and user numbers will be investigated to determine the countries that will be chosen for analysis later in the project. The research contained in this literature review will form the foundation for the country selection component and criteria analysis discussed in the methodology chapter of this research paper.

2.2 UAV HISTORY

There is a belief by some that UAVs are new technology. However, like most introduced civilian technologies, it was a tool created for the military. UAVs, in their most primitive form date to 1849 during the Austrian blockade of the Republic of Venice where the Austrians launched explosive laden balloons with half hour timers towards Venetians (Custers 2016).

World War I and II saw an increase in sophistication and investment in unmanned aerial vehicles. In 1916 the Royal Air Force commissioned radio controlled remotely piloted planes fitted with explosives (Shaw 2014), whilst in 1917 in the United States radio controlled pilotless planes were being fitted with gyroscopes increasing their stability (Shaw 2014). In 1940 the Germans produced the V-1 rocket capable of hitting a target 250 kilometres away. The petrol-powered single engine rocket was guided by a gyrocompass which went against the radio-controlled trend of the time. Towards the end of World War II, the V-1 was striking approximately 25% of its targets (Carr 2016).

Carr (2016) defines the Vietnam War as the turning point for UAV development with increased focus on their research and development integrating UAVs into a modern military. Various autonomous navigation aids were implemented such as Star Tracker and the Transit System (Carr 2016). As UAVs were becoming more and more capable and with modern militaries seeing opportunities to reduce the risk of pilot casualties, UAVs were tasked towards the riskier missions such as high-altitude reconnaissance flights. With UAVs taking the place of airmen, pilots could then be diverted to less riskier missions (Buisan 2017).

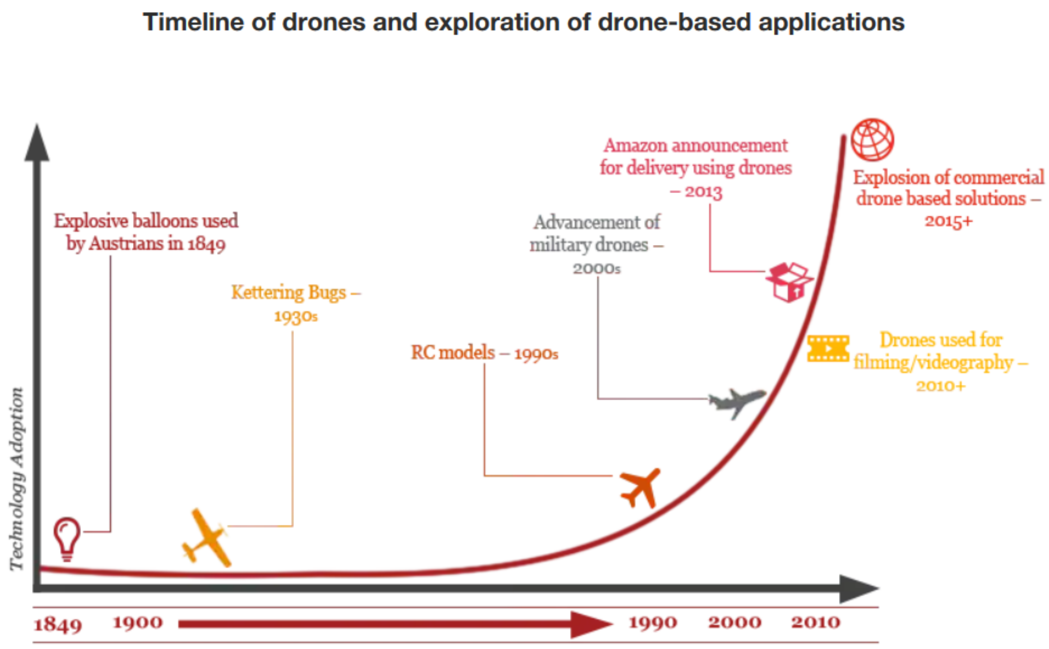

Figure 1: Timeline of the History of UAVs (Price Waterhouse Coopers 2019)

As shown in Figure 1, Modern UAVs have shifted from military use towards the science sector (Carr 2016) enabling them to take advantage of scientific advances which increased their applications in the commercial sector. Examples include the ability to stay airborne for over 24 hours and achieving higher altitudes thanks to new materials and construction techniques (Carr 2016).

2.3 REGULATORY DEVELOPMENT

In 1919 the Convention for the Regulation of Aerial Navigation (Paris Convention) validated the concept that the airspace above the seas was not in fact as free for navigation as the open ocean below (Marshall 2009). The member States that were a party to the convention recognised that the airspace above the land and the waters controlled by states remained the exclusive jurisdiction of said states. However, during peace times, providing the remaining provisions of the convention were adhered to, civilian aircraft would have free passage (Marshall 2009).

The convention put forth the following principles:

i. Each nation has sovereignty over their airspace.
ii. Airspace rules must be applied equally to foreign and their own aircraft.
iii. Aircraft from member states are to be treated equally.
iv. Aircraft must have state registration and declare their nationality.

(Paris Convention 1919)

The Paris Convention made no mention or attempt to address the need to regulate unmanned aircraft despite their extensive use during World War I. The earliest attempt to regulate UAVs on an international level was via The Convention of International Civil Aviation. The Convention of International Civil Aviation (Chicago Convention) came about in 1944 with the signatures of 52 states with the express intention of regulating international air travel (ICAO 2011). With the ratification of the Convention in 1947, the International Civil Aviation Organisation was established with the purpose of establishing regulations on aircraft registration and safety and the use of international airspace (ICAO 2011).

Detailed in Article 8 of the Chicago Convention is the first mention of pilotless aircraft with respect to international regulations.

> *No aircraft capable of being flown without a pilot shall be flown without a pilot over the territory of a contracting State without special authorisation by that State in accordance with the terms of such authorisation.*
>
> (ICAO 1944, Article 8; Bradly 2013)

The most recent step forward was in 2011 when The International Civil Aviation Organisation (ICAO) released the ICAO Circular 328 Unmanned Aircraft Systems (UAS) with the purpose to:

1. Apprise States of the emerging ICAO perspective on the integration of UAS into non-segregated airspace and at aerodromes.
2. Consider the fundamental differences from manned aviation that such integration will involve.
3. Encourage States to help with the development of ICAO policy on Unmanned Aerial Systems (UAS) by providing information on their own experiences associated with these aircraft.

(UAS Vision 2011)

The ICAO (2011) stated that the Circular was the first step in the development of a comprehensive UAS regulation with the possibility of the policy aiding as an interim solution to standardising UAS regulations in Europe. However, ICAOs Unmanned Aircraft Advisory Group is still working through Phase II by supporting the ICAO Secretariat in establishing a common global framework for unmanned aircraft system traffic management and no clear guideline has been established for global UAV regulation.

2.4 RECENT COMPARISONS

Morales, Paez and Arangos (2015) analysed the UAV regulations of six countries to put forth draft regulations for implementation in Columbia. They determined that the main restrictions to flying

UAVs in Colombia would be guided by the six analysed countries and would revolve around “weight class, energy source and places where it is allowed to fly” (Morales, Paez and Arangos 2015). They stated that their maximum values would be in line with French and Canadian regulations such as a 9 km restriction zone prohibiting UAVs from airspace surrounding airports, flying no closer than 150 m from people and reduced weight limits of under 2 kg not requiring operation certificates.

Similar weight and flying height approaches have been implemented in Europe. The International Civil Aviation Organisation (ICAO) regulates civil aviation in the European Union (EU). The European Aviation Safety Agency (EASA) was tasked by ICAO to implement UAV regulations throughout the EU. UAVs in excess of 150 kg are treated the same as manned aircraft and prior to 2020 UAVs below 150 kg are regulated by the individual nations within the EU (EASA 2017). Herrmann (2017) states that although each member state has introduced regulations it is not consistent from nation to nation with approvals granted in one country not recognised in another.

Stöcker et al. (2017) conducted the most comprehensive evaluation to date, reviewing the UAV regulations of nineteen countries and found that of the nations that have implemented regulations, most are bound by national legislation and concentrate on three main areas:

1. Identifying the need to regulate the airspace used by UAVs to reduce the danger to manned aircraft.
2. Defining operational limits on flights to ensure flights are appropriate (limiting height, weight).
3. Implementing licensing procedures to regulate flight permissions and data acquisition.

However, as per Figure 2, in 2016 only one third of countries had some form of UAV regulation with almost half detailing no information regarding UAV use for civilian purposes (Stöcker et al. 2017).

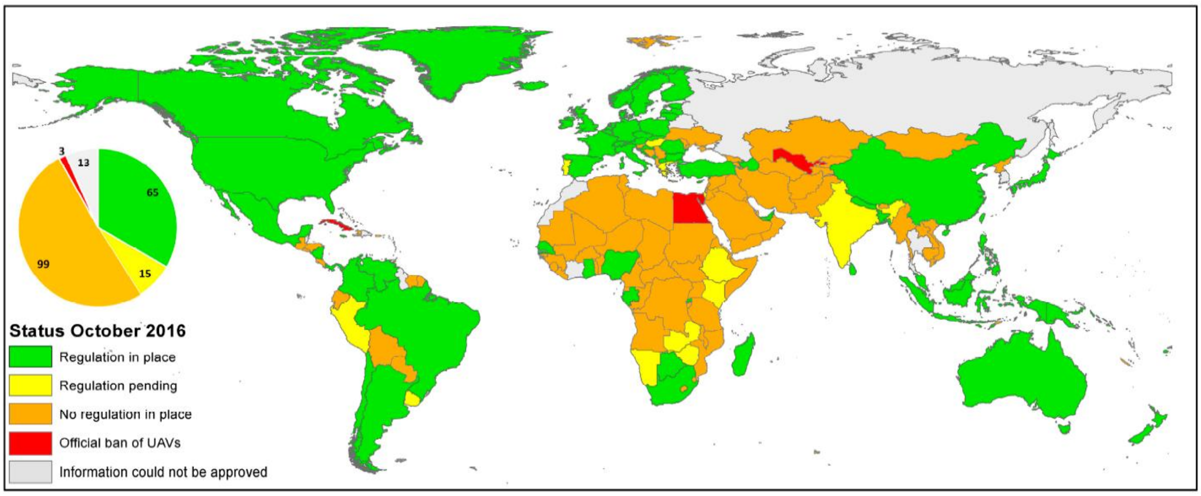

Figure 2: Global UAV Regulations in 2016 (Stöcker et al. 2017, p. 7)

Stöcker et al. (2017) further explains that from a national context, a detailed analysis "reveals a clear heterogeneity of national UAV regulations" siting only two out of twenty-one variables that were analysed showed any sign of similarity (being vertical line of sight and lateral distance to pilot), with the remaining nineteen variables showing no widespread accordance across all cases.

Vacca and Onishi (2017) also found that there is a lack of a "single harmonised international instrument" with respect to UAV legislation and that pilotless aircraft raise important technical issues. Also, UAVs are part of the aviation system that's integral to improving safety. ICAOs published Circular 328 in 2011 which aimed to inform States about the emergence of UAS policy, was a move in the right direction that aimed to provide a "fundamental international regulatory framework through Standards and Recommended Practices" (ICAO 2011). However, prior to 2020 within the European Union there is still no common recognition between member states regarding UAV regulations and as such there exists a disjoin between national frameworks with respect to weight, and operational and altitude limits (Vacca & Onishi 2017).

Clarke and Moses (2014) put forth that the reason behind this lack of UAV specific regulations at an international level could be due to the fact that civilian UAV use was limited in the years after the creation of ICAO and that although processes have been implemented to regulate the use of UAVs, the organisations "cumbersome" multilateral processes are a significant shortcoming affecting the speed of development.

2.5 PROBLEMS IDENTIFIED

2.5.1 Privacy

> *Instantaneous photographs and newspaper enterprise have invaded the sacred precincts of private and domestic life and numerous mechanical devices threaten to make good the prediction that what is whispered in the closet shall be proclaimed from the house-tops.*
>
> (Warren & Brandeis 1890)

The primary concern with the increase use and development of UAVs is what Finn and Wright (2012) describe as the potential for UAVs to infringe on the ethical and privacy rights of people as a threat to civil liberties. Historically, privacy has proven difficult to define with studies outlining parameters relating privacy to their area of discipline without a consistent uniform theory being produced (Vasalou et al. 2011). Judge Cooley (1888) defined privacy "as the right to be let alone" (Warren & Brandeis 1890) with others following the same vein stating that privacy "is the right that protects freedom from surveillance by others" and that individuals, groups or institutions determine what information they communicate to others (Westin 1967). Nelson et al. (2019) uses Floridi's notions of privacy to ascribe tangibility to privacy and define private space as areas "free from sensory interference or intrusion, void of unwarranted interruptions" like sound, touch and sight. He further states that surveillance-based technologies pose one of the largest challenges to privacy due to the uncertainty of how they would be used. It can be easily understood how UAVs could infringe on private space as most UAVs have cameras capable of recording sound and vision with the noise from the engines being deemed sensory interference.

Clarke (2014) ties the issue of privacy to UAVs and surveillance through his five dimensions of privacy. The five dimensions consist of:

- privacy of the person.
- privacy of personal data.
- privacy of personal behaviour.
- privacy of personal communication and
- privacy of personal experience.

Clarke (2014)

He attributes behavioural privacy and privacy of personal experience as being the most important as they incorporate "the interests that are most directly impinged upon by drone-base surveillance" (Clarke 2014). Finn, Wright and Friedewald (2013) define Clarkes behavioural privacy as protection against disclosure of sensitive information such as religious practices, sexual practices or political activities. Clarke (2014) later states that the term "encompasses the individuals' activities, movements and associations". Privacy of personal experience is defined by the Queensland Law Reform Commission (2018) as the concerns the individual has regarding the collection and storage of data about personal experiences including what they "read and view and who they interact and associate with". Clarke (2014) further clarifies that these 'experiences' influence a person's attitudes and opinions and skirts the edge of "surveillance of beliefs and thoughts". Privacy of personal experience is closely aligned with what Finn, Wright and Friedewald (2013) describe as privacy of association which they define as the "right to associate with whomever they wish, without being monitored".

Warren and Brandeis (1890) comments "the invasion of privacy constitutes a legal injuria and elements for demanding redress exist", however in 2014 The Australian Law Reform Commission (ALRC) found that Australia's privacy regime is fractured and complex. The State and Territory statutes and common law principles applicable to privacy are often out of date with current technology and overly complex with significant variation between jurisdictions (ALRC 2014). It also identifies the ability for UAVs to "enter private property, travel unnoticed and record or live stream images and sounds which create significant opportunities for privacy breaches" (ALRC 2014). In 2014 the then Privacy Commissioner Timothy Pilgrim was asked how the potential privacy issues relating to UAVs could be addressed. He replied that the question comes down to how it will be regulated and finding the line between regulation that achieves the technological benefits without removing the right of recourse and remedy if people's privacy has been invaded (ALRC 2014).

The Privacy Act 1988 contains specific Australian laws that regulate the handling of personal information. It contains thirteen principles (see Appendix B) that provide direction applicable to most Australian government agencies and private organisations with respect to the collection and management of personal information (ALRC 2014). However, as noted in the 2014 Australian Law Reform Commission paper, the Act does not apply to "the collection and use of personal information by private citizens nor does it provide overarching privacy protection for the individual". The Australian Information and Privacy Commissioner stated that through community research it was evident that people remained concerned for the privacy of their personal information with an increase of 69% of Australians being more concerned about their online privacy than five years ago (Office of the Australian Information Commissioner 2017). During this research it became apparent that just under half of the Australians surveyed were aware of the position of Privacy Commissioner and of the people who were aware they appeared to overestimate the reach of the Privacy Act by assuming that that all organisations were in fact covered by the Act. Mistakenly they believed schools, universities and state government agencies were covered. Most States and Territories in Australia have privacy laws but are limited in scope much like their Federal counterparts. Pilgrim (cited in Christianson 2014, p. 36) states that these privacy laws generally are only applicable to state and territory government agencies.

UAVs have been classified under the Surveillance Devices Act 2004, falling under the definition of optical surveillance device or listening device. In 2014 Australia's Attorney General Catherine Smith however noted that the Surveillance Devices Act 2004 was not written with mobile surveillance systems in mind but with its primary focus being devices attached to physical property (cited in Christianson 2014, p. 37). State and Territory laws define indecent photography as a criminal offence and prohibit observing and filming people in a private place or engaging in a private act.

However, as an example of the previously mentioned variation amongst State and Territory laws, Victoria, Queensland and the Northern Territory permit people to record a private activity without the consent of other parties which contravenes the laws of the remaining states. (Australian Law Reform Commission 2014).

The issue of privacy law and the use of UAVs continues to be extensively researched. However, existing laws are either outdated or are lacking in definition and provide remedy only in limited circumstances (Clarke 2014).

2.5.2 Safety

Sanz et al. (2015) defines safety as "the state in which the system is not in danger or at risk, free of injuries or losses". This state should be the primary goal if UAVs are to be held in the same regard with respect to safety and airworthiness as piloted aircraft. Clothier and Walker (2006) conclude that for routine UAV operations to be integrated into the civilian airspace, UAV developers, operators and regulators must prove that the safety of UAVs is at a minimum, equal to conventionally piloted aircraft. Others have stated that there are challenges to attaining this standard due to low costs, limited safety features and the increasing volume of UAVs that there will inevitably be “low standards of pilot performance” and the usual high costs in detection, investigation and defining responsibility (Clarke & Moses 2014).

Lack of Operator Knowledge

Evidence of these challenges can be seen in data produced in 2017 by The Australian Transport Safety Bureau (ATSB). Between 2012 - 2017 of the 154 reported near encounters with UAVs and other aircraft, 114 occurred from the beginning of 2016. This increase in near encounters correlates with the increase in UAV licenses. Others have stated that low standards of pilot performance especially in relation to smaller UAVs can be attributed to people being unaware of civil aviation regulations or are unfamiliar with the safety risks (The International Air Transport Association 2018). The ATSB (2017) also stated that with most reported near encounters the operators were not following CASR Part 101 regulations for uncertified UAVs and that it appears that the operators were either unaware or unconcerned with the regulations. In September 2016 a UAV was lost when “during pre-flight programming the south-eastern point used to georeference the image on the ground control station map was selected to a northern hemisphere latitude which resulted in incorrect way points and home position for the mission”. After an extensive search the Pulse Aerospace Vapor 55 was not found as the UAV had commenced tracking towards its home position twelve hundred kilometres away in the Coral Sea (ATSB 2016, see Appendix C).

Collision – Aircraft

Prior to existing regulations both commercial and private UAV flights remained unimpeded and were able to fly close to airports, secure facilities and overpopulated areas (Vela, Ferreira & Babin 2018). This initial free for all posed a serious threat to safety and security. In 2018 the Rural and Regional Affairs and Transport References Committee (RRATRC) stated that an increasing number of ICAO members were becoming concerned with UAVs flying within close proximity to commercial aircraft which was proving hazardous to commercial aircraft. Over half of all incidences involving UAVs reported to ATSB were near encounters involving manned aircraft and half of those again involved high capacity air transport aircraft (ATSB 2017). The ATSB (2017) defines a near encounter as “when a UAV interrupts or is sighted in the proximity of another aircraft”. Because there have been no actual collisions between UAVs and manned aircraft in Australia, the ATSB has used bird strike data to model damage to manned aircraft from collisions with UAVs. It was found that in 8% of cases, engine ingestion can be expected, and it is likely that when compared with bird ingestion, engine damage and engine shutdown is expected to be higher (ATSB 2017). This increase in damage was explained by UAVs being heavier and more ridged than most birds. Figure 3 demonstrates the increase in reported near encounters involving UAVs from 2014-2018.

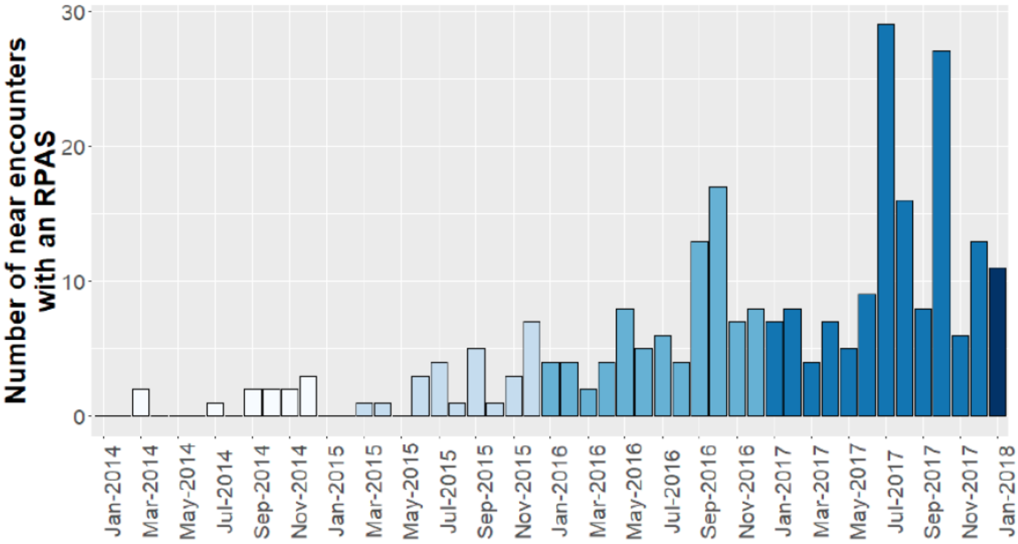

Figure 3: Proportion of Near Encounters with UAVs by Year (CASA 2018)

IATA conducted a study in 2018 of five years' worth of aircraft encounter reports from the Global Aviation Data Management database. The purpose of the study was to identify specific issues caused by UAV encounters and 480 reports were analysed. It was reported that manned aircraft encounters with UAVs were the top safety risk to the aviation industry (IATA 2018). They noted that the highest number of reports were from the European region accounting for 50% of occurrences and that the most frequently reported size of the UAV was greater than one metre wide (IATA 2018). This indicates that due to the size of the UAV involved in the aircraft encounter reports it was most likely not a commonly purchased UAV as most recreational UAVs are well under half a metre. Near collision was also the most common aircraft encounter accounting for 80% of the reports (IATA 2018). Near collision is defined as less than three nautical miles separation horizontally and one thousand feet vertically between the UAV and the manned aircraft. These near collisions were most likely to happen during the initial climb or approach phase of the flight which is commonly referred to as the most dangerous time of a flight (IATA 2018).

Collision - Terrain

Terrain collisions accounted for 26% of all reported UAV accidents between 2012 and 2017 with almost half of these events occurring from loss of control of the aircraft (ATSB 2017). As demonstrated in Figure 4, collision with the terrain had the second highest incident occurrence out of all incidents. Of these accidents 84% resulted in the UAV being significantly damaged or destroyed. Of these terrain collisions the most common UAV mass was 2.9 kg accounting for 19% of occurrences (ATSB 2017). A terrain collision can occur when the operator fails to maintain visual line of sight with the UAV and is unable to account for changes in elevation in the terrain or obstacles such as trees and buildings.

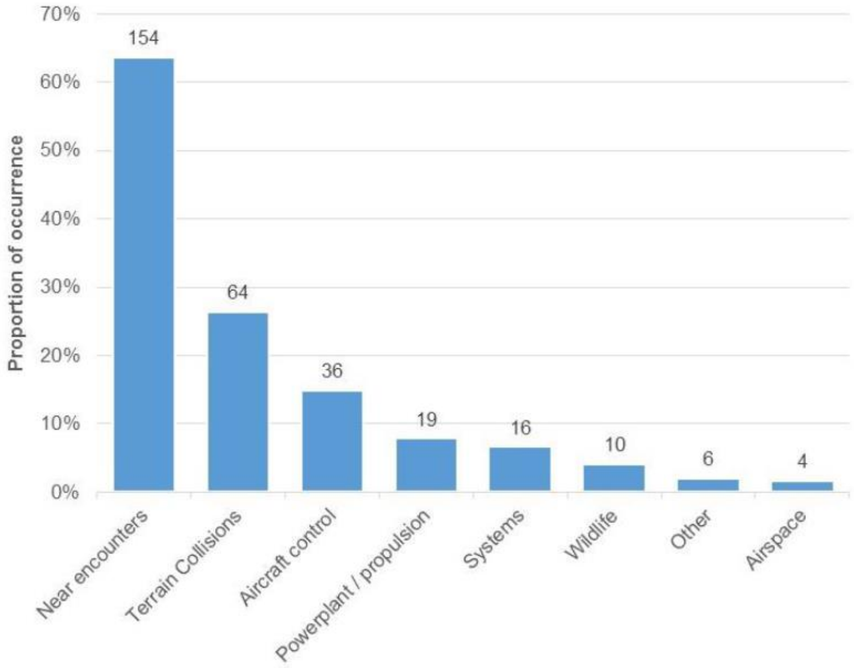

Figure 4: UAV Accident Occurrence (CASA 2018)

Line of Sight

Vela, Ferreira & Babin (2018) found that there exists a knowledge gap quantifying the definition of visual line of sight (VLOS). In an analysis of UAV flight operations in different countries garnered from public data available online and through social media, the authors found that most of the flight distances were 0.5 miles (≈ 805 metres) from their home position. They suggest that this distance is verging on being outside the limits of human perception. Humans are said to have "normal" vision if their binocular acuity measures at 6/6 (20/20). A person has 20/20 vision when at a distance of 20 feet they can correctly identify a letter that is 5 arc minutes in height and any horizontal component of that letter at 1 arc minute in width (Curry et al. 2003). In attempting to define the maximum VLOS Vela, Ferreira & Babin (2018) use the idea that people can distinguish horizontal lines in their field of view that are 1 arc minute (1/60°) in length and correlate that to a UAV being a single line at distance. However, in order to determine the orientation of the UAV the authors suggest that line should be 3 arc minutes (3/60°) in length to provide a safety margin. Using the equation below and the dimensions of a popular brand of recreational UAV that has a width of 350 mm, they calculate that in order to correctly distinguish and orientate a UAV by VLOS the permissible distance would be ≈ 401 metres.

$$D_{max} = \frac{w/2}{\arcsin\left(3\theta_{acc}/2\right)}$$

$$w = width\ of\ UAV, \quad \theta acc = Visual\ Accuity$$

Impact

The issue of direct physical UAV impact gives rise to potential harm to public safety. Clark and Moses (2014) state there are also the indirect threats where impact can lead to fire or explosion. Magister (2010) correlated UAV design shape and injury biomechanics relating to blunt ballistic impact of UAVs and found that the severity of injury in small UAVs (< 15 kg) when operating at minimal airspeed was "less than serious" when contacted with a blunt section of the UAV. He also states that the most important finding is that regardless of the mass of the UAV, lethal injury was possible if the impact was with a sharper part of the UAV and that a UAV weighing up to four kilograms and travelling at its maximum speed (diving straight down) with a diameter of at least thirty centimetres would have an Abbreviated Injury Scale (AIS) value of < 3 (Serious; 8-10% chance of death (CASA 2013).

AIS code	Injury	Example	AIS % prob. of death
1	Minor	superficial laceration	0
2	Moderate	fractured sternum	1–2
3	Serious	open fracture of humerus	8–10
4	Severe	perforated trachea	5–50
5	Critical	ruptured liver with tissue loss	5–50
6	Maximum	total severance of aorta	100

Figure 5: Abbreviated Injury Scale (CASA 2013)

However, CASA (2013) modelled human injury potential from impacts of small unmanned aircraft impacts and used an AIS of 3 as the highest acceptable injury allowed in the study. They found UAV mass and velocity as well as the diameter of the UAV determined how severe the injury would be. They noted that for a 2 kg UAV travelling at 10 m/s for a head impact it would cause a fractured skull when impacting with the flat side of the UAV. In a total loss of control scenario where the UAV falls, reaching its terminal velocity, any impact at such high speeds (> 30 m/s) would cause unacceptably severe injuries regardless of the weight of the UAV (CASA 2013). CASA (2013) put forth recommendations for UAVs to be designed with large curves with minimal protrusions to minimise penetrating injuries and frangible airframes to reduce impact loads. They recommend the largest category of UAV should be 2 kg with a limited airspeed of 7.5 m/s (27 kph).

These results provide evidence that with certain design and operational criteria the risk of injury could be reduced and possibly the need for certain regulations.

2.5.3 Security

Loss of Control

Impact and collision avoidance can only be achieved when the UAV is under control of the pilot. Loss of control removes the connection between the pilot and the vehicle whilst also removing any existing safety implementations. In 2014 a triathlete received minor injuries whilst competing in an event in Geraldton, Western Australia after the pilot of a UAV lost control of the aircraft and it struck the athlete (ATSB 2017). The matter was referred to Commonwealth Director of Public Prosecutions which later released a statement saying the radio interference with the race timing equipment was the cause of the incident as it had interfered with the operation of the UAV causing the loss of control (Australian Broadcasting Corporation 2014).

CASA (2018) states that a loss of control of a UAV "can be sudden and recovery very difficult even for experienced remote pilots". Research, shown after this list, has identified that loss of control over a UAV can happen through the following ways:

- Hijacking.
- GNSS jamming and spoofing.
- Hardware / software malfunction.
- Electromagnetic interference (high voltage powerlines, cell phone towers).
- Exceeding the aircrafts limitations (flying to high or out of range).
- Malicious software.
- User error.

Shepard, Bhatti & Humphreys (2012) discussed in December 2011 a CIA surveillance drone was captured by Iranian forces by jamming the UAVs communication link forcing the UAV into autopilot mode which uses predetermined GPS guidance to return to its base in Afghanistan. The UAV was then commandeered by spoofing the UAV with new GPS coordinates causing it to land in Iranian territory.

Commercial UAVs on the market today are open to hijacking or hacking by electronic interference. Skyjack is a UAV created by Samy Kamkar that will find vulnerable UAVs in the air, discover an open network and change its Service Set Identifier (SSID) which eliminates any connected users (Arteaga et al. 2019). Kamkar (2015) states that the UAV looks for a wireless signal from drones in the area, forcefully disconnects the original wireless connection and authenticates with the target drone which enables him to send commands to it taking control over it. It can also be run from a laptop from the ground.

Zhi et al. (2019) discusses a hijack method which involves GPS spoofing by broadcasting a false location and time with a Universal Software Radio Peripheral (USRP) which leads to control over the target UAV. GPS signals are susceptible to interference (both intentional and unintentional) due to low power they have at the earth's surface (Arteaga et al. 2019)

Arteaga et al. (2019) have noted that radiofrequency communications purely by design can be exploited. They discuss a process called flooding where an adversary floods the WIFI channel with information interrupting the communication on the channel. This is commonly referred to as Denial of Service (DoS). Zhi et al. (2019) state that the two main methods of communication between the UAV and ground controller are radio and WIFI and both have security risks. They present a method of gaining control over a target UAV by finding the target UAV WIFI and monitoring it, launching a de-authentication attack which kicks the operator off the network, forcing them to reconnect which gives the attacker the necessary information to crack the password and take control of the UAV.

Electromagnetic interference can cause loss of connection. In 2018 a UAV collided with a cruise ship near Fort Hill Wharf Northern Territory when the UAV lost signal. The UAV operator started return home procedures when the UAV deviated from its path and collided with the ship and was destroyed. It was the operator's opinion that cruise ship had caused "interference with the datalink signal" which resulted in the collision (ATSB 2018).

Well known UAV brands have had to increase the security of their products through user updates. A popular brand of UAV maker had to remove third party plug-ins for Android platforms as it was found that the application was sending information to the applications server about the user's device information as well as personal information (Zhi et al. 2019).

Maldrone is software that creates a backdoor in a victim's UAV software and waits for a reverse TCP connection which once received allows an attacker to gain control over the infected UAV (Arteaga et al. 2019).

Anonymity

UAVs can be purchased and flown anonymously. A person can purchase a UAV off the shelf and fly it without the need to register it. This creates security problems as it is difficult to track and identify an offending UAV pilot that breaks the law. One possible way to avoid this issue is to incorporate a subscriber identity module (SIM card) within the hardware of the UAV. This would mean the purchaser would register the SIM with a telecommunication company which would then register their details against the SIM card. When the UAV pilot operates their UAV, it would connect with the nearest cell tower, thus providing a record and traceability of the UAV movements, flying time and other tracking data, much like a mobile phone.

Automatic Dependant Surveillance Broadcast (ADS-B) transponders are used on aircraft and obtain their position via GNSS. This position is then broadcast to control towers and other aircraft which helps maintain safe self-separation while in the air. A leading drone manufacturer is installing ADS-B receivers in all drones above 250 grams (DJI 2019). Another parts manufacturer has developed an ADS-B beacon 50 mm x 50 mm and weighing 50 grams. This allows it to be placed on smaller UAVs allowing their position to be tracked (uAvionix 2019).

2.5.4 Public Nuisance

Noise

Queensland's Environmental Protection Act provides guidelines regarding requirements for activities with noise impacts (1994). The Act identifies noise as a form of contaminant and that noise nuisance can cause environmental harm. Noise causing environmental harm/nuisance negatively affects human health and wellbeing by interfering with recreational activities, sleep and relaxation (Environment Protection Act 1994 (Qld)). The Queensland Environmental Protection (Noise) Policy (2008) gives acoustic quality objectives (see Appendix D) at different places such as dwellings, libraries, childcare centres and hospitals. These quality objectives are designed to protect the environmental amenity, health and wellbeing of people at those places. An example of the objective values are as follows:

- The $L_{Aeq,adj,1hr}$ for a dwelling (measured outdoors) at daytime and evening is 50 db
- The $L_{Aeq,adj,1hr}$ for a dwelling (measured indoors) at daytime and evening is 35 db
- The $L_{Aeq,adj,1hr}$ for a school or playground during playtime hours is 55 db

(Environment Protection Policy (Qld) 2008)

UAVs are not quiet in their operation. A NASA study by Christian & Cabell (2017) performed a psychoacoustic test on participants by comparing the sound generated by UAVs to the sound generated by passing road vehicles. Although both sets of sounds were of equivalent decibels it was found that there was a "systemic difference between the annoyance response generated by the noise of the UAVs and that of the road vehicles" (Christian & Cabell 2017). The authors also noted that when all other parameters were held constant and only UAV height is varied, they found that there was insignificant change in annoyance response (Figure 6).

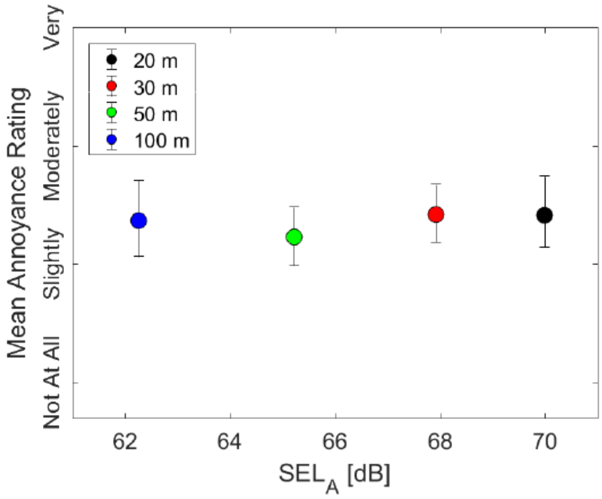

Figure 6: UAV Annoyance Rating (Christian & Cabell 2017)

Intaratep, Alexander and Devenport (2016) analysed the acoustic properties of a popular brand of quadcopter UAV and found that at maximum thrust (i.e. take off) the sound (80 db) was equivalent to a freight train passing at fifteen metres away. The authors note that at this level it would cause annoyance in populated areas subject to high drone usage. This study was performed in an anechoic chamber with the microphone placed 0.77m below and 1.30m to the side of the quadcopter. These distances would be considered conservative when compared to real life applications.

Christiansen et al. (2016) measured the noise level of two multi-rotor UAVs to determine the negative impact on UAVs flying over marine animals. The authors measured both in-air and underwater recordings at altitudes of 40 m, 20 m, 10 m, 5 m and with the microphones 3 m above ground and 1 m below the water line. A mean value measured at a height of 10 m for each UAV was 80 and 81 dB re 20 μPa for the in-air recordings and 95 and 101 dB re 1 μPa for the underwater recordings. However, decibels measured in air do not directly correlate to decibels measured underwater. Finfer, Leighton and White (2007) describe the derivation of a conversion factor of 61.5 dB that allows the transfer from underwater dB to air dB. This conversion factor is composed of two components - a 26 dB correction for sound pressure reference quantities and a 35.5 dB correction to incorporate any acoustic impedances between the air and water sound propagation media (Katz et al 2010). Applying this conversion factor to the underwater results obtained by Christiansen et al. (2016) reduces the dB readings to 33.5 and 39.5 dB. Christiansen et al. (2016) discuss the need for UAVs in certain applications to fly in close proximity to marine animals (< 10 m) and found that the in air dB values of UAVs flying at low altitude would most likely have a disturbing effect on sea otters and pinnipeds (seals, sea lions and walruses) when they were on land or with their heads protruded from the water. However, the in-water dB readings at altitudes of 5 and 10 m were "many orders of magnitude below" what would cause auditory damage to marine life (Christiansen et al 2016)

Nuisance

Zwanikken (cited in RRATRC 2018, pp. 68) stated during the 2017 fire season in Victoria there were four instances where hobbyist UAV operators had engaged in nuisance behaviour during fire suppression activities and standard operating procedure when unauthorised UAVs are flying over emergency areas is to ground the aerial fleet (RRATRC 2018). Manning (cited in RRATRC 2018, pp. 68) discussed an incident in 2017 where a rescue helicopter had a near miss with a UAV at Burleigh Heads, Gold Coast. These examples of nuisance behaviour from UAV operators adversely affects the public safety through the possibility of cessation of emergency operations (RRATRC 2018).

Pomeroy, O'Conner and Davies (2014) investigated how UAV flights collecting photogrammetric data affected Gray and Harbour seals. They found that flights over both Gray and Harbour seals were variable, with individual variation amongst seals of the same species. Gray seals generally changed behaviour from alert to moving at an altitude from 10 – 50 m and a lateral distance of 15 – 210 m and the Harbour seals showed little reaction at a 30 m altitude (Pomeroy, O'Conner and Davies 2014).

Nelson et al. (2019) posits that as UAVs become more ubiquitous and people become more familiar with them, a decrease in concern for privacy will occur and the issues of UAV-bystander interaction will more likely shift towards nuisance rather than privacy. Nelson et al. (2019) goes on to state that the focus should be more on creating noise and nuisance ordinances as these would be a more effective than focusing on privacy.

2.5.5 Trespass

Rural and Regional Affairs and Transport References Committee (2018) noted that New South Wales farmers had limited legal remedy when they've caught UAVs trespassing on their property. The farmers suggested a base penalty rate of $50,000 for the lack of due diligence and potential harm caused by UAV operators. Also discussed by the Committee was the use of geofencing to prevent access to private property by limiting the distance the UAV could travel from its pilot thus reducing the risk of trespass and privacy infringement.

New South Wales, South Australian, Tasmanian, Victorian and Western Australian legislation states that there is no trespass or nuisance by aircraft flying over property at a reasonable height as long as air navigation regulations are adhered to (Stewart 2016).

2.6 UAV DEMOGRAPHICS

2.6.1 UAVs by Country

Choi-Fitzpatrick (2016) analysed over 15,000 news articles finding 1145 distinct cases of non-military UAV use and identified six nations that were most commonly mentioned in the articles. Those nations are as follows:

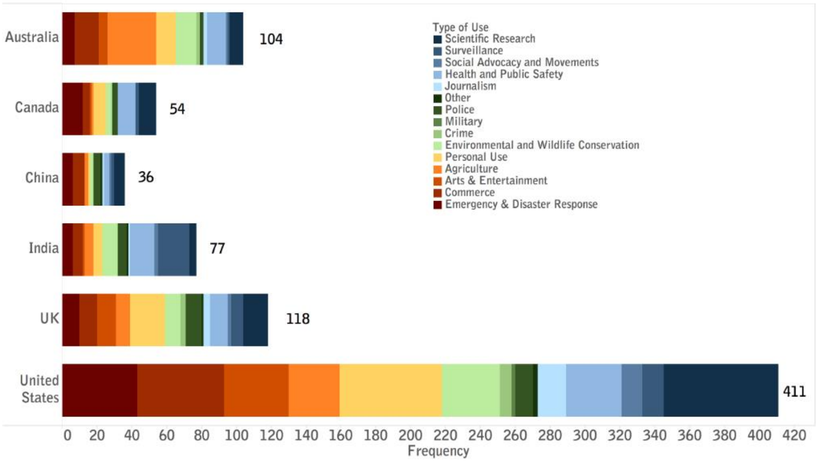

Figure 7: Nations Mentioned in Online Articles (Choi-Fitzpatrick 2016)

However, as noted by the authors, this study focused mainly on English language reports that would most likely have skewed the results towards English language countries and that this could be the reason why China's percentage is lower than others. They also noted that with the United States' large number of technology journalists and the size of their consumer market would have disproportionately increased their reported drone use Choi-Fitzpatrick (2016).

From 2016 to 2017 Vela et al. (2018) gathered two years' worth of UAV trajectory data primarily from social media platforms and publicly available information online. The data equated to 168,000 real world UAV mapping operations with the aim of determining if operators were adhering to specific guidelines such as visual line of sight and altitude restrictions. Figure 8 details a breakdown of total number of flight operations by country showing a significant difference between the country with the most flight operations and the preceding countries. The United States tops out at 38% of total flight operations with the next country, Brazil, accounting for 7% of operations. This large gap between the top two countries could be attributed to a similar research methodology implemented by Choi-Fitzpatrick (2016), most notably utilising online data skewed towards the US.

Country	Number	Percentage
United States	64142	38.04
Brazil	11664	6.92
Australia	7556	4.48
Canada	6926	4.11
United Kingdom	6314	3.74
Indonesia	5298	3.14
Mexico	4402	2.61
South Africa	3879	2.30
Chile	3865	2.29
Colombia	3163	1.88
New Zealand	3146	1.87
Russia	2619	1.55
China	2575	1.53
India	2412	1.43
Ukraine	2380	1.41
Uruguay	2110	1.25
Spain	1701	1.01
Germany	1579	0.94
Thailand	1471	0.87
Argentina	1440	0.85
France	1302	0.77
Japan	1271	0.75
Korea	1188	0.70
Finland	1040	0.62

Figure 8: Countries Identified in UAV Discussions Online (Vela et al. 2018)

Vela et al. (2018) presented an opportunity to investigate an alternative method of country selection. Instead of analysing total number of flights, total area surveyed could give a better insight into the “quality” of mapping operations. Larger survey areas require greater planning, more variables with respect to survey specifications, more resources and wider expertise.

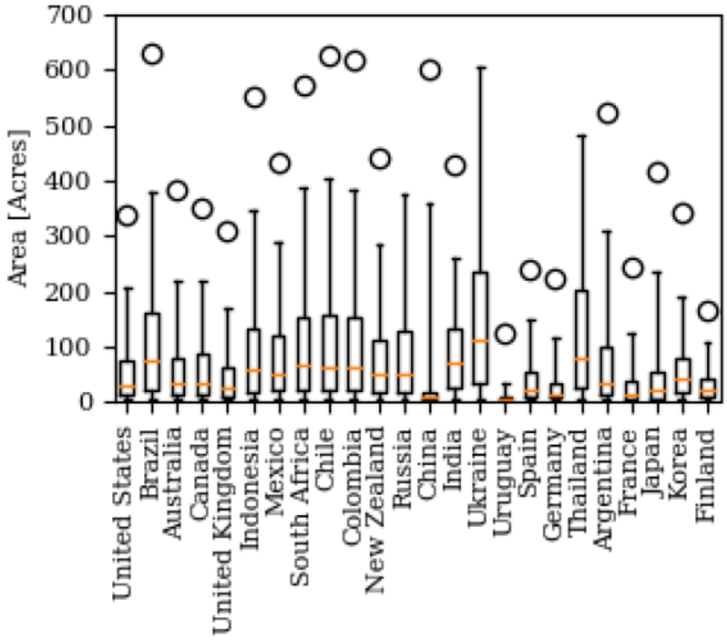

Figure 9: Countries by UAV Survey Area (Vela et al 2018)

Figure 9 shows that of the 24 countries analysed 14 had surveyed a larger area than the United States. However, actual figures detailing area was not available preventing further analysis.

The German Unmanned Aerial Association (GUAA) published a report analysed the German UAV market and focused on private and commercial use. They ranked the largest commercial UAV markets worldwide and found that the United States and China were the largest drone markets with France, Germany, Great Britain and Australia following respectively (GUAA 2019).

Figure 10: UAV Market Size by Country (GUAA 2019)

2.6.2 Users and Numbers

Data available on usage and total number of UAVs was rare and based on estimates at best with some articles proving difficult to verify. The primary sources of information were from research papers, publicly available information and data available from government reports. An alternative approach to verify data was to analyse sales data by country, however as most major UAV manufacturers are privately held companies this data proved problematic to find. The difficulty lay with detailing actual drone purchases which the Rural and Regional Affairs and Transport References Committee (2018) stated was because a large portion of purchases were over the internet and second-hand sales that were difficult to collate.

Alternative avenues of research were investigated such as focusing on just licensed or registered users to obtain a benchmark. Molina and Campos (2018) tabulated data on certified UAV operators within countries of the current European Union (EU) and although some data was available on the number of licence holders it was decided that focusing solely on certified/licensed operators would exclude countries that have no licensing requirements and therefore limit the analysis.

Country	Operators	Source
United Kingdom	3046	Civil Aviation Authority (2017)
Ireland	172	IAA (2017)
France	2250	Statista (2016)
Spain	2420	AESA (2017)
Italy	972	ENAC (2017)
Germany	n.a.	n.a.
Switzerland	n.a.	n.a.
Belgium	152	www.beuas.be/fr/membership/licentie

Source different sources (n.a.: not available)

Figure 11: UAV Operator Numbers by Country (Molina & Campos 2018)

An overview of the estimated numbers of UAVs and recreational/commercial users from the most commonly mentioned countries from the previous studies is detailed below.

Australia **-** estimated 100,000 and 150,000 UAVs in the country and estimate of 50,000 recreational users and 1,720 commercial users (CASA 2019).

Brazil – 34,000 civil UAS registered with 65% being for recreational purposes and 35% for commercial, estimated actual total numbers 100,000 (Unmanned Airspace 2018).

Canada **–** 337,468 UAVs in Canada 74% recreational and 26% commercial. 12% is the ratio between manned aircraft pilots between the US and Canada. The same ratio was used to compare the number of UAVs in the US to estimate the number of UAVs in Canada (Library of Parliament 2017).

However, this number was revised down in 2018 to 193,500 estimated UAVs being flown in Canada by 140,800 operators (Canadian Government Gazette 2018).

China – 24,407 certificates to fly were administered at the end on 2017, however certification is only needed if the UAV weighs over 7 kg (Wangshu 2019).

European Union **-** 1-1.5 million leisure UAVs and 10,000 commercial UAVs (SESAR 2016).

France **–** 7,471 referenced operators and 13,647 referenced UAVs in December 2018 (French Civil Aviation Authority 2018).

Germany **-** 500,000 drones in Germany. 455,000 are for private use and 19,000 for commercial use. Over 10,000 employed in the drone industry (German Unmanned Aviation Association 2019).

India – A rough calculation of 40,000 UAVs, predominately civilian, but including military and law enforcement UAVs as well (The Economic Times India 2017).

Spain – 2,420 certified UAV operators in 2017 (Molina & Campos 2018).

United Kingdom **-** CAA estimated that during 2018 there would be 170,000 registered drone operators. These estimates were based on registrations in other countries such as the US and Ireland. (CAA 2019). There were 5,383 registered commercial UAV operators as of September 2019 (CAA 2019).

United States **-** 900,000 registered owners and 1.25 million estimated UAVs (FAA 2018).

2.7 CONCLUSION

A thorough search of the literature established that globally there is marginal consensus amongst UAV regulations. Research identified five challenges affecting the use of UAVs and although prior investigations had uncovered privacy, safety, and security as being the most probable issues affecting the use of UAVs, public nuisance and trespass proved equally concerning. Key UAV demographics were identified such as types of users and user numbers, but reliable research that was not based on estimates and forecasts proved difficult to find.

Chapter 3: Methodology

3.1 INTRODUCTION

Information obtained in the literature review identified problems associated with UAV use and the current level of UAV regulations employed by certain countries. To achieve the project objectives this chapter will define a process for selecting five countries for analysis, develop criteria from the identified problems and issues found in the literature review and detail a process for examining how existing regulations compare against the prescribed issues using the developed criteria.

3.2 COUNTRY SELECTION

The purpose of this section is to outline the method of how the countries that will be included in the comparison will be selected. Two questions were used to define the selection process:

1. Does the country have a significant UAV user base?
2. Is there an effective contemporary regulatory system in place governing the use of UAVs?

The first question seeks to define the number of users and ascertain if there is a strong user base. The premise behind this question is that if a country has a large number of users then through a natural evolution the regulations should be more comprehensive and robust as there would be a greater opportunity for issues and problems to present themselves.

The second question will ensure that any comparison performed against the criteria will be completed on regulations that are current and up to date with changes in technology and how UAVs are used commercially and for recreation. Consequently, greater consideration will be given to countries that are in the process of amending or transitioning to new regulations.

3.2.1 Users

Research was conducted to gain information on UAV use and numbers. The results were documented in the literature review which have been summarised below. Primary sources of information were government publications, research papers and open source data online. However open source data that was difficult to verify will be precluded from the comparison and is shown below for completeness. Three research segments were identified to direct how the user base will be determined. These were:

- Countries that were acknowledged in prior research and market analyses
- Estimated numbers of UAVs
- Estimated users including reported licensed or certified operators

Prior Research/Market Analysis

Limited research was available that could be directly attributed to total number of UAVs per country. Complete market analyses were available but were fiscally prohibitive to obtain and mostly focused on market forecasts instead of real data.

Figure 12 below provides a summary of the countries most often identified from the research in the literature review. Their respective authors are located at the top of the columns with the countries following in from most to least identified.

Chavarria et al (2016)	Vela, Ferreira & Babin (2018)	GUAA (2019)
The United States	The United States	The United States
The United Kingdom	Brazil	China
Australia	Australia	France
India	Canada	Germany
Canada	United Kingdom	Great Britain
China	Indonesia	Australia
	Mexico	Japan
	South Africa	Canada
	Chile	Switzerland
	Columbia	Korea

Figure 12: Countries Most Mentioned in the Literature Review

From the figure above it can be seen that Australia, Canada and the United States were mentioned across the three research papers with China and the United Kingdom mentioned twice. The United States had the largest market size, was the most active country online and had the most documented flight operations per country. China and France followed in second and third place respectively.

Estimated Numbers of UAVs

UAVs	
Australia	150,000
Brazil	100,000
Canada	193,500
China	280,000
European Union	1,510,000
France	13,647
Germany	500,000
India	40,000
Japan	NA
Spain	NA
The United Kingdom	NA
The United States	1,250,000

Figure 13: Estimated Numbers of UAVs from the Literature Review

The European Union, the United States, Germany, Canada, China and Australia had the largest documented numbers of UAVs reported.

License / Certified / Other Operators

<table>
<tr><th></th><th colspan="2">Users</th><th></th></tr>
<tr><th></th><th>Recreational</th><th>Commercial</th><th>Total Users</th></tr>
<tr><td>Australia</td><td>50,000</td><td>1,720</td><td>51,720</td></tr>
<tr><td>Brazil</td><td></td><td>34,000</td><td>34,000</td></tr>
<tr><td>Canada</td><td colspan="2">140,800</td><td>140,800</td></tr>
<tr><td>China</td><td colspan="2">24,407</td><td>24,407</td></tr>
<tr><td>European Union</td><td colspan="2">NA</td><td></td></tr>
<tr><td>France</td><td colspan="2">7,471</td><td>7,471</td></tr>
<tr><td>Germany</td><td colspan="2">NA</td><td></td></tr>
<tr><td>India</td><td colspan="2">NA</td><td></td></tr>
<tr><td>Japan</td><td></td><td>2,250</td><td>2,250</td></tr>
<tr><td>Spain</td><td></td><td>2,420</td><td>2,420</td></tr>
<tr><td>The United Kingdom</td><td>170,000</td><td>5,383</td><td>175,383</td></tr>
<tr><td>The United States</td><td>900,000</td><td></td><td>900,000</td></tr>
</table>

Figure 14: Estimated Numbers of Licenced Operators from the Literature Review

The United States had the highest number of users by far, followed by the United Kingdom and Canada. Of the countries mentioned in the table above Australia, Canada, Germany, the United Kingdom and the United States had data available from government sources. The remaining countries were sourced from open source data online where available.

3.2.2 Current Regulations

Regulations for the countries identified in the usage analysis were then researched. The primary source of information for the regulations was the respective government bodies which were available online. These regulations were collated by year of inception and regulations that had not been amended or revised in the last three years would be excluded from the analysis. This ensured that comparisons were performed against regulations that were attempting to address recent developments in technology and user requirements. The new European regulations will be included in the comparison because no other regulation will encompass such a wide variety of jurisdictions and large population base.

3.2.3 Countries

For the purposes of further analysis, the following countries were selected for the criteria comparison with the reasons outlined.

Australia – Large numbers of UAVs with large user base. Recently update regulations.

Canada - Large numbers of UAVs with large user base. Recently update regulations.

European Union – Currently in regulatory transition, encompasses large population and numerous jurisdictions.

United Kingdom – Large numbers of UAVs with large user base. Recently update regulations.

United States – The largest market of UAV operators with recently updated regulations.

3.3 EXISTING REGULATIONS

3.3.1 Australia

In the beginning of 2002 Australia introduce regulations making them the first country to regulate UAVs (Buchannan 2019). The Civil Aviation Safety Authority (CASA) is the principal government body charged with regulating the flying of UAVs in Australia. The legislative instrument used to regulate the flying of UAVs is the Civil Aviation Safety Regulations Part 101 (Unmanned Aircraft and Rockets) Manual of Standards 2019. This was registered in April 2019. The information below provides a brief summary of the regulations applicable to recreation and commercial users. This information was sourced from CASA.

Recreational users follow what's officially known as "standard operating conditions" which are designed to protect the operator and the people around them. They include only flying one UAV at a time and only flying within visual line of sight (VLOS). Flights must remain under 120 m (400 ft) above ground level and no closer than 30 m to people and not over or above people at any time. Operators must not fly near emergency situations, in prohibited or restricted airspace and no closer than 5.5 km to a controlled aerodrome or airfield. Recreational UAVs are limited to a maximum weight of 2 kg.

Commercial users operating UAVs under 2 kg can operate under an excluded category provided they adhere to the standard operating conditions, apply for an aviation reference number and notify CASA prior to completing the flight.

Commercial users operating UAVs over 2 kg must have a remote pilot licence (RePL) and a remotely piloted aircraft operator's certificate (ReOC) or be working for a ReOC holder. ReOC's and RePL's enable pilots to fly outside the standard operating conditions, such as:

Flying closer than 30 m to people

- Closer than 30 m but not closer than 15 m providing that the UAV has dual parallel redundant battery system with duplicated battery mounting and able to fly with one motor inoperative at the maximum take-off weight (MTOW). Return Home functions must be operational with at least 7 GNSS satellites. A risk assessment must be performed with all identified risks appropriately mitigated and consent from all people located within 30 m of the UAV. Written consent is preferred but not mandatory.

Area Approvals and Permissions

- Flying 120 m above ground level in or within 5.5 km of a controlled and non-controlled airspace.
- Flying over or within 5.5 km of a controlled and non-controlled aerodrome or movement area.

Extended Visual Line of Sight (EVLOS)

- A risk assessment must be performed with all identified risks appropriately mitigated prior to application. All areas of the operational area must always be under supervision from an observer. Either the pilot or an observer must always have direct visual line of sight to the UAV. Both pilot an observer needs CASA approval to conduct EVLOS.

Beyond Visual Line of Sight (BVLOS)

- A risk assessment must be performed with all identified risks appropriately mitigated prior to application. All flights must be conducted to the same level of safety as manned flights focusing on aircraft controllability, fail-safe mechanisms, collision avoidance and navigational and height accuracy. The UAV must be equipped with position lights, anti-collision/strobe lights and landing lights, transponders such as an ADS-B unit, navigation equipment and aeronautical radio.

3.3.2 Canada

Transport Canada is responsible for the development of aviation regulations in Canada. In the beginning of 2019 Transport Canada published updated regulations for flying UAVs with the new regulations apply to UAVs that weigh from 0.25 kg to 25 kg and that are operated within the pilots VLOS. All UAVs must be registered and marked with a registration number and all pilots are required to pass an online exam to be awarded a pilot certificate in their operational category of choice. Two operational categories were introduced – basic and advanced. Commercial and recreational pilots are not treated differently and what defines which category is weight, distance from bystanders and the airspace rules for the area the UAV will be flown (Transport Canada 2019). The information below provides a brief summary of the regulations applicable to recreation and commercial users. This information was sourced from Transport Canada.

Basic

- Must be over the age of 14 or under supervision of a person who is.
- Holds a "basic" pilot certificate.
- Fly in uncontrolled airspace.
- Fly more than 30 m horizontally from bystanders.
- Don't fly over bystanders.

Advanced

- Must be over 16 years of age or under supervision of a person who is.
- Holds an "advanced" pilot certificate.
- Fly within controlled airspace.
- Fly over bystanders.
- Fly closer than 30 m to bystanders but not less than 5 m,

Any flights that deviate from the basic category automatically fall under the advanced category. Additional rules apply to the advanced category depending on which condition won't be met, such as seeking permission from air traffic control to fly in controlled.

Standard guidelines such as flying within VLOS, below 122 m and no closer than 30 m apply to all flights. As well as avoiding emergency operations (bushfires) and advertised events (parades) and 5.6 km from airports and 1.9 km from heliports as well as far away from other aircraft such as other UAVs, helicopters and airplanes.

UAVs that weigh under 0.25 kg do not fall under the new guidelines however they must fly within VLOS and always fly responsibly. UAVs that weigh more than 25 kg must obtain special permission from Transport Canada and apply for a Special Flight Operations Certificate (SFOC).

A SFOC is also required for:

- Flights BVLOS.
- Flights by a foreign operator or a pilot authorised to fly UAVs by a foreign state.
- Flights above 122 m.
- Operating more than five UAVs from a single control station.
- Flying over an advertised event.
- Transporting payloads.

Transport Canada provides privacy guidelines for both recreational and commercial UAV users. Recreational users are advised to follow five privacy principles:

1. Be accountable – the pilot is responsible for all personal information collected during flights.
2. Limit collection – take steps to avoid blanket collection of information and only record data that is needed. Anonymising data such as blurring faces and number plates is suggested.
3. Obtain consent – take all reasonable steps to obtain consent from people who will be incorporated into the capture area.
4. Store information securely – Prohibit access to data that may contain personal information.
5. Be open and responsive about your activities – Respect the rights of others especially if people complain that flights are infringing on their privacy.

(Transport Canada 2019)

Commercial users, like all other businesses in Canada, are bound by the Personal Information Protection and Electronic Documents Act (PIPEDA). Consent must be obtained when collecting, using and sharing personal information and for that consent to be valid people must comprehend the consequences of consenting to the collection of personal information. The Privacy Commissioner for Canada outlines an additional 5 steps on top of the principles guiding recreational users. They are:

6. Identify the purpose of the data collection.
7. Data collected must only be used for the purpose it was collected.
8. Personal information collected must be accurate, complete and up to date.

9. Individuals must be informed of the use and disclosure of their personal information and have the right to access the information.
10. The privacy principles of the organisation can be challenged by an individual ensuring compliance.

(Office of the Privacy Commissioner of Canada 2019)

3.3.3 Europe

In June 2019 the European Union Aviation Safety Agency (EASA) published preliminary UAV regulations that are applicable across all member states of the European Union. At the time of writing two primary acts contain the regulations – The Implementing Act and The Delegated Act. These acts were in force at the end of June 2019 but will only be applicable from June 2020. The aim of implementing new regulations was to enable free movement of UAV operators across borders and to ensure UAV flights are safe and secure. Previously operators were bound by different regulations from all the member nations and these regulations could differ radically.

Recreational and commercial users are now viewed similarly with the main intention being a risk-based approach. Three new categories are introduced – open (low risk), specific (medium risk) and certified (high risk). The certified category relates to larger UAVs that fly in controlled airspace and will require the pilot to be licensed, the UAV to have an airworthy certificate and safety controlled by the National Aviation Authority. The open category is considered to cover 90% of recreational and commercial flights. It has three subcategories A1, A2 and A3 and depending on the operational limits, requirements of the pilot and technical requirements for the UAV, these will decide which subcategory the operation falls under. The open category does not need prior authorisation for flights and there is no requirement for a pilot’s license, however online training and examination is necessary for some of the subcategories depending on operational requirements.

The general provisions for the open category are flights cannot go above 120 m and when flying within a horizontal distance of 50 m from a manmade structure greater than 105 m in height then the maximum height can be increased by a further 15 m at the request of the person responsible for the structure. The minimum age for the open and specific categories is 16 years, however there is no age restriction if flying a toy UAV with a MTOW less than 250 g and operating under the supervision of remote pilot. Additionally, from 2022 UAVs will be required to have CE or product regulation markings/labelling which will detail the technical specifications of the aircraft. The labels will include information such as:

- MTOW
- Maximum speed
- Maximum height attainable

- Electrical voltage
- Geo awareness systems allowing airspace and altitude restrictions to be uploaded with appropriate warning systems in place alerting when nearing those restrictions.

There are four categories of CE markings (C0 - C4) with each marking indicating a larger, heavier, more technical UAV. The purpose of these markings is to help identify which subcategory the operator will fly in.

The information below provides a brief summary of the regulations applicable to both recreational and commercial users. This information was sourced from EASA.

Open – A1

- Never fly over groups of people.
- Flying over bystanders is allowed if flying C0 rated UAV.
- Flying over bystanders is only allowed if flying C1 rated UAV and fly over time is as short as possible.
- Flying a C1 rated UAV requires online training and examination.

Open – A2 (Only applies when operating a C2 rated UAV)

- Don't fly over people or crowds.
- Don't fly closer than 5 m to people and only if active low speed function is activated, otherwise stay back 30 m.
- Pilot must hold a certificate of remote pilot competency, completed online training course, self-practical training and pass theoretical exam.

Open – A3 (Only applies when operating a C2, C3 or C4 rated UAV or a self-built UAV)

- Only fly where the operator reasonably expects no bystander will be put in danger during the flight.
- Don't fly closer than 150 m from residential, commercial, industrial or recreational areas.
- Same pilot competencies regarding certificate and training as Open – A2.

Specific Category

All flights operating outside the general provisions of the open category fall under the specific category as they are deemed to have an increased risk. If a standard scenario is not available for the intended operation, then a risk assessment needs to be provided to authorities using a specified methodology. Standard scenarios relate to particular flight operations and have had predetermined safety objectives and mitigation steps established by EASA. The advantage of these pre-package risk assessments is that it reduces the burden on the operator and the official assessing the application. An example of a standard scenario would be flying BVLOS above 120 m over sparsely populated areas.

In October 2019 EASA is expected to release the Publication of Guidance Material as well as the first set of standard scenarios. This release will detail more information about flights in the specific category.

3.3.4 United Kingdom

The Civil Aviation Act and the Air Navigation Order 2016 (ANO) are the principal pieces of legislation governing the use of UAVs in the UK. The regulations have been updated to allow for a simpler set of rules to apply to all UAVs that weigh 20 kg or less which under the legislation are viewed as small unmanned aircraft (SUA). UAVs that have a mass greater than 20 kg are not deemed to be SUA and must comply with all the requirements of the ANO such as licensed flight crew, airworthiness certificates and permits to fly. Recreational and commercial operators follow different permissions and exemptions. Exemptions allow for exceptions to the law whilst permissions are used when the law prevents the activity but has enabled the possibility within the law to for that activity to take place. The information below provides a brief summary of the regulations applicable to recreation and commercial users. This information was sourced from the Civil Aviation Authority.

Recreational Operators

- Responsibility falls on the pilot to ensure all flights are performed in a safe and responsible manner.
- Flying UAVs over 0.25 kg require passing a test and registering the UAV with the CAA.
- The UAV must always be within VLOS.
- Flights must remain under 400 ft (122 m).
- Flights remain clear of flight restriction zones of protected aerodromes such as depicted below.

Figure 15: Flight Restriction Rules for Airports and Airfields (CAA 2019)

- Additional restrictions apply if flying a UAV weighing more than 7 kg in certain types of airspace.

If the UAV is fitted with equipment capable of performing surveillance or capturing data, such as a camera, then it is classed as a small unmanned surveillance aircraft (SUSA) and must adhere to additional regulations.

- Flights must remain 150 ft (50 m) from people, vessels, vehicles and structures.
- Flights must remain 500 ft (150 m) from congested areas (areas that are used for residential, commercial, industrial or recreational and built up areas).
- Flights must remain 500 ft (150 m) from open-air assemblies of more than 1,000 from any person.
- During take-off and landing the SUSA must remain 30 m from any person.

To operate beyond the regulations the CAA allows for permissions and exemptions to be granted. There is a general exemption in place to allow for first person view flying (FPV). Ordinarily the headset would obstruct the operator's field of view to the UAV and therefore violate the VLOS rule. However, CAA has given an exemption to this rule providing the operator follows the remaining rules and is accompanied by a competent observer.

Commercial Operators

- Any commercial operation using UAVs must have a Permission issued by the CAA.
- Operators must have appropriate insurance coverage which is a condition of all exemptions and permissions granted by CAA.
- Commercial operators must adhere to the same regulations as recreational operators.
- Permissions are required from the CAA to fly outside the standard.
- A 'Standard Permission' enables commercial flight over or within 150 m of congested areas provided the pilot submits an operations manual, evidence of competency and proof of insurance cover.
- Reduced distance permissions allow UAVs to fly within 50 m of people within a congested area and less than 150 m from open air assemblies.
- Flights above 400 ft require operators to submit a risk assessment demonstrating the flight will be performed safely.
- BVLOS / EVLOS and UAVs over 20 kg require exemptions and pilots must submit a safety case with risk assessment proving flights will be conducted safely.

- BVLOS flights require the aircraft to have onboard collision avoidance equivalent to manned aircraft such as a detect and avoid capability and a block of airspace enabling the UAV to be segregated from other aircraft.
- The collection of images of recognizable people are subject to the General Data Protection Regulation and the Data Protection ACT 2018.

3.3.5 United States

The Federal Aviation Administration is an agency of the U.S. Department of Transportation which is charged with the regulation of all civil aviation. The Federal Aviation Administration Reauthorisation Act of 2018 was signed in October 2018 and establishes changes for the safe integration and use of UAVs including new rules regarding recreational use of UAVs. Section 349 of said act lays out the regulations pertaining to *recreational operators* as follows:

- The aircraft must be flown for recreation purposes only.
- The aircraft must weigh less than 55 pounds (25 kg).
- The aircraft is operated within the safety guidelines of a community-based organisation (CBO) which were codeveloped with the FAA.
- VLOS must be maintained at all times.
- Flights must not enter prohibited airspace or fly near other aircraft.
- Operators must not fly over groups of people, public events or stadiums.
- Flights must not fly near emergencies such as brushfires and law enforcement activities.
- Flights close or within airspace at or near airports must comply with airspace restrictions and prohibitions and must have prior authorisation from an administrator.
- In uncontrolled airspace flights must be below 400 ft.
- The aircraft must be registered with registration number marked on the outside of the aircraft by engraving, permanent label or permanent marker.
- Operators must pass an aeronautical knowledge and safety test with proof of passing carried during flights.

Commercial Operators can operate UAVs weighing less than 55 pounds under Part 107 of the Federal Aviation Regulations. A brief overview of the rules are as follows:

- Aircraft must weigh under 55 pounds.
- Operator must hold a remote pilot airman certificate with a small UAV rating or be supervised by someone who has one.

- UAVs must be registered and marked as per recreational rules.
- VLOS maintained at all times either by the pilot or by an observer and the aircraft must remain close enough to the pilot/operator to be seen with the naked eye.
- Aircraft must not operate over bystanders.
- Daylight operations only.
- Maximum ground speed of 100 mph (160 km/h).
- FPV can be used if see and avoid requirements are met in other ways.
- Maximum altitude of 400 ft above ground level.
- External payloads are allowed provided it is securely attached and aircraft airworthiness is not unfavourably affected.

Waivers are documents issued by the FAA which allows flight operations that deviate from the standard regulations. Waivers provide an opportunity for pilots to, for example, fly at night, fly over people and fly BVLOS. Appendix E provides an example of the information expected when filling out a waiver with respect to flying over people.

3.4 CRITERIA

The literature review identified privacy, safety, security, public nuisance and trespass as the overarching challenges with UAVs use. Privacy proved to be one of the most researched issues with the primary concern being the ability for UAVs to infringe on people's privacy rights. Although no author outlined guidelines allowing for the practical avoidance of privacy infringement, details could be inferred from the inherent nature for UAVs to "enter private property, travel unnoticed and record or live stream images and sounds create significant opportunities for privacy breaches" (ALRC 2014).

Research surrounding UAV safety of course proved to be munificent in highlighting numerous challenges to UAV flight. Lack of operator knowledge was demonstrated to be the primary cause of most reported near encounters with the risk of collision being the consequence of this lack of knowledge with over half of near encounters involving UAVs. Researchers established that visual line of sight was difficult to quantify and demonstrated a formula enabling maximum VLOS to be determined using the width of the UAV whilst being predicated on perfect vision in perfect visibility. Impact could be tied in with collision but was separated as research was primarily focused on UAV design and specifications such as weight and flight speed instead of operator interference.

Security issues were at the forefront of the research with terrorism and loss of control being of primary concerns. There are numerous ways an operator can lose control of a UAV with user error and pushing the aircraft beyond its operational limits being most likely, whilst others can be put down to a technologically sophisticated adversary or factors beyond control of the operator. Anonymity was discussed with the main risk being UAVs purchased and flown without the need for registration. However major manufacturers are stepping in with hardware developments such as ADS-B beacons being installed on UAVs above a certain weight class and now most manufacturers require registration prior to first flight.

Regarding public nuisance, UAV noise was a cause for concern with research stating that decibel readings taken close to the UAV were equivalent to a freight train passing 15 m away. NASA concluded that UAVs were between slightly and moderately annoying even up to 100 m away. Nuisance behaviour created the greatest problems causing the cessation of emergency operations when UAV operators were flying within proximity to water bombers during firefighting operations or near rescue helicopters hindering rescues.

It was noted that with trespass NSW farmers had little legal remedy when UAVs were caught operating over their land and that (RRATRC 2018)

The following criteria (see Appendix F for additional copy), were developed from the issues identified during the literature review. The purpose of the criteria below is to interrogate the regulations and determine if and how they are addressing those issues.

1. **Privacy**

    a. The regulations shall address the privacy concerns of the general public or provide guidelines to reduce the risk of infringing on a person's right to privacy.

2. **Safety**

    a. Operators shall possess a minimum level of knowledge to operate the UAV in a safe manner to reduce the risk of injury to people or property. Knowledge could be demonstrated in the form of an online examination, accreditation or a pilot's certificate.

    b. The regulations will contain guidelines reducing the risk of collision including onboard collision sensors and alarms.

    c. Maximum visual line of sight shall be defined as visual confirmation of the UAV with the naked eye but not further than 400 m.

    d. The regulations will contain limitations on the design of the UAV and the flight parameters reducing the risk of harm to people from direct impact. Weight classes and flying speed limitations shall be implemented.

3. **Security**

a. The regulations have stipulated guidelines including limitations reducing the risk of losing control of the UAV.

b. The regulations have ensured that UAVs and operators are identifiable and have reduced the risk of UAVs being flown anonymously.

4. **Public Nuisance**

a. The regulations will implement guidelines addressing the issue of noise pollution from the use of UAVs such as a maximum decibel value from an environmental agency or placing limitations on flying times and distances.

b. The regulations have implemented guidelines reducing the risk of nuisance behaviour and specifically mention avoiding emergency personnel or by placing limitations on flying times and distances.

5. **Trespass**

a. The regulations will implement limitations and guidelines preventing the act of trespass.

3.5 CRITERIA COMPARISON

The regulations of the selected countries will be directly compared with the developed criteria by a simple comparative analysis. The regulation relevant to each subheading of the designed criteria will be assessed against said criteria.

3.6 CONCLUSION

Discussed in this chapter was the methodology detailing the process of how the countries were selected to have their regulations compared to the developed criteria. Using user numbers and contemporary regulations to define the selection process Australia, Canada, EU, UK and US were selected for analysis. A set of criteria were then developed from the problems and issues discovered in the literature review which were centred around the overarching tenets of privacy, safety, security, public nuisance and trespass. These criteria will be compared to the selected countries regulations to establish whether the regulations address these issues.

Chapter 4: Results

4.1 INTRODUCTION

The aim of this chapter is to present the results of the comparison of the criteria formed from the issues identified in literature review and the regulations of the selected countries. This chapter will determine if the regulations are meeting the developed criteria, and if so, highlight how by focusing on the differences and similarities between the regulations and the criteria.

4.2 CRITERIA COMPARISON

4.2.1 Australia

Privacy (a)

CASA (2018 advisory circular) stipulates that it does not consider privacy concerns when issuing approvals. However, it does recommend that operators include privacy provisions in their operations manuals. Recreational users are advised to respect personal privacy and not record or photograph people without their consent. There are no guidelines within the Civil Aviation Safety Regulations 1998 Part 101 Unmanned Aircraft and Rockets detailing how pilots can reduce the risk of privacy infringement.

Safety (a) Knowledge

Drone accreditation is needed if pilots are flying for fun (recreational users), flying over their own land or flying a UAV weighing less than 2 kg. Accreditation involves passing an online quiz after watching a safety video.

Commercial users need a remotely piloted aircraft operator's certificate (ReOC) which is obtained by submitting an operations and procedures manual outlining how flights will operate safely and legally. Also, a remote pilot's licence (RePL) is needed to fly outside the drone safety regulations or fly UAVs weighing more than 2 kg, operators need to complete theory and practical training provided by CASA certified training providers.

Safety (b) Collision

There are no guidelines within the Civil Aviation Safety Regulations 1998 Part 101 Unmanned Aircraft and Rockets stipulating the need for collision sensors or alarms on board UAVs. There are defined operational limits such as maximum flying heights and distances to aerodromes, however, collision is only mentioned within the definition of "operated within visual line of sight" which states that a person must be able to see the aircraft to maintain the operator's separation and collision avoidance responsibilities. Advisory Circulars released by CASA provide guidance on how the regulations should be interpreted. Advisory Circular AC 101-01 v2.1 (CASA 2019) states that all UAVs operating in the non-excluded (included) category should be painted for maximum visibility including collision avoidance lights such as strobe lights. Also, if ADS-B transponders are fitted they should meet the required standards and be turned on.

Safety (c) VLOS

Subpart 101.074 (3) of the regulations provides this definition of VLOS:

> An unmanned aircraft is being ***operated within the visual line of sight*** of the person operating the aircraft if the person can continually see, orient and navigate the aircraft to meet the person's separation and collision avoidance responsibilities, with or without corrective lenses, but without the use of binoculars, a telescope or other similar device.
>
> (CASA 2019)

The definition provided by CASA gives guidance on how an operator would define the VLOS to their aircraft. It places the onus on the operator to determine the maximum VLOS without providing a quantitative value which would reduce the risk of operators flying outside their visual limits.

Safety (d) Impact

Recreational users are limited to UAVs that weigh up 2 kg. Commercial operators are bound by the same weight restrictions unless they hold and a remote pilots licence and operate under a remotely piloted aircraft operators certificate.

The regulations provide no speed limitations on UAV flights and there is no mention of design parameters that would reduce the risk of harm from direct impact.

Security (a) Loss of Control

There are no guidelines within the Civil Aviation Safety Regulations 1998 Part 101 Unmanned aircraft and rockets specifying procedures on mitigating the risk of losing control of a UAV. CASAs Part 101 (Unmanned Aircraft and Rockets) Manual of Standards 2019 does however give a brief overview of procedures for loss of control in an EVLOS flight. The manual mainly states that the operator's procedures should ensure that the pilot can re-establish control or end the flight without causing a hazard to life or property e.g. a controlled flight into terrain. Advisory Circular AC 101-01 v2.1 (2018) discusses how losing power can be harmful to people below. It also details how mission plans should have procedures relating to how emergencies like loss of control would be handled by the operator and provides examples of how fail-safe devices would reduce the injury to bystanders. CASA also notes that data links between the UAV and the operator should be monitored in real time with warnings given in case of failure.

Security (b) Anonymity

At the time of writing, CASA is introducing registration for all UAVs flown for both commercial and recreational purposes. CASA states that the primary purpose of the registration initiative is to ensure that people fly their UAVs responsibly and safely. Apart from the ADS-B requirements for larger UAVs no other de-anonymizing requirement was found in the regulations.

Public Nuisance (a) Noise

There are no guidelines within the Civil Aviation Safety Regulations 1998 Part 101 Unmanned aircraft and rockets specifying procedures on reducing the issue of noise pollution generated by UAVs. Both Advisory Circular AC 101-01 v2.1 (CASA 2019) and AC 101-10 v1.3 (CASA 2019) state that UAV operators are bound by local noise abatement laws. These include restrictions on altitude, flight path and the time of day of flights. Also, the regulations state that unless additional flight permissions are obtained, the operational hours for flying a UAV are during daylight hours as flights must be within VLOS.

Public Nuisance (b) Nuisance behaviour

Civil Aviation Safety Regulations 1998 Part 101 Unmanned aircraft and rockets specify that UAVs must not be flown over an emergency operation or public safety event without the approval of the person in charge. As noted above, the risk of nuisance behaviour at night is reduced as most UAV operators can only fly during daylight hours as flights must remain within VLOS.

Trespass (i)

There are no guidelines within the Civil Aviation Safety Regulations 1998 Part 101 Unmanned Aircraft and Rockets addressing the issue of trespass.

4.2.2 Canada

Privacy (a)

Although not preserved within the Canadian Aviation Regulations, Transport Canada provides clear privacy guidelines for both recreational and commercial UAV users. Operators are directed to a dedicated online resource specifically detailing the privacy guidelines for flying UAVs. This resource discusses that although Canadas privacy regulations do not specifically reference UAVs, the privacy laws in Canada do apply to information that could be collected such as video and pictures.

Recreational users must abide by the previously mentioned five privacy principles, while commercial operators are bound by the Personal Information Protection and Electronic Documents Act (PIPEDA). PIPEDA applies to all businesses within Canada and ensures that consent is obtained when collecting personal information and that the information is handled with a high degree of professionalism.

Safety (a) Knowledge

To be allowed to fly a UAV in Canada with a MTOW between 250 grams and 25 kg, recreational and commercial operators must obtain a Pilot Certificate with either basic or advanced endorsement. The basic operations certificate consists of 35 multiple choice exam questions delivered online and completed in 90 minutes with a 65% score minimum to pass. Topics include air traffic rules, air law, meteorology and navigation. The advanced operations certificate requires completing an online exam consisting of 50 multiple choice questions in 60 minutes with at least an 80% score to pass.

Safety (b) Collision

Part IX – Remotely Piloted Aircraft Systems - Division III - General Operating and Flight Rules specifically mentions the risk of collision and provides procedures and guidelines to reduce its risk. The regulations state that pilots should not increase the risk of collisions by flying in close proximity to other aircraft (901.18). Take-off and landing sites must be suitable for the operation and that there is no risk of collision with aircraft, bystanders or obstacles (901.33) and if the risk of collision becomes too great then operators must cease any flights immediately (901.49).

Safety (c) VLOS

900.01 provides the following definition under the regulation for visual line of sight:

> *Visual line-of-sight* or *VLOS* means unaided visual contact at all times with a remotely piloted aircraft that is sufficient to be able to maintain control of the aircraft, know its location, and be able to scan the airspace in which it is operating in order to perform the detect and avoid functions in respect of other aircraft or objects.

No pre-defined distance is given regarding maximum visual line of sight. The responsibility is placed on the pilot to ensure that they believe they have control of the UAV at all times.

Safety (d) Impact

The main operating categories being basic and advanced have weight limitations on the types of UAVs that can be flown. UAVs weighing up to 25 kg can be flown providing the operators adhere to the regulations under each of those categories. Drones weighing over 25 kg can be flown but need special permission from Transport Canada in the form of a Special Flight Operations Certificate.

The regulations provide no speed limitations on UAV flights and there is no mention of design parameters that would reduce the risk of harm from direct impact.

Security (a) Loss of Control

Loss of control is termed a "fly-away" within the regulations and defined as a loss of the command and control link between the operator and the UAV in which the operator is unable to control the UAV. Minimal advice can be found within the regulations regarding how an operator would limit the risk of a fly-away. 901.23 (1) states that an operator should not pilot a UAV unless they have procedures to handle emergencies such as (iv) loss of the command and control link or (v) a fly-away. Pilots should cease operations 901.49 (1)(f) if the UAV becomes uncontrollable.

Security (b) Anonymity

All UAVs weighing from 250 grams and up to and including 25 kg need to be registered with Transport Canada. The operators name and address, DOB, purchase date, make, model, serial number, weight and type of UAV are recorded against a registration number. This registration number must be marked on the UAV with permanent marker, permanent label or engraving. There are no other real time identification requirements within the regulations.

Public Nuisance (a) Noise

There are no guidelines within the Canadian Aviation Regulations addressing the issue of noise pollution from the use of UAVs. Compounding the issue, night flights are permitted as well providing the UAV has position lights enabling it to be seen during the night either with or without night vision goggles worn by the operator (901.39 (1)).

Public Nuisance (b) Nuisance Behaviour

901.12 (1) states that a UAV must not be flown over or within an emergency security perimeter established by a public authority responding to an emergency. As noted above, nuisance behaviour is not limited to day light hours as the regulations allow for UAV flights at night as VLOS can be established using positioning lights.

Trespass (a)

There are no guidelines within the Canadian Aviation Regulations addressing the issue of trespass.

4.2.3 European Union

Privacy (a)

EASA has established regulations with the aim of addressing the risk of privacy infringement. EASA has stated that one of the main aims of the regulations is to mitigate the hazards pertaining to the protection of personal data and privacy.

Article 14 (5)(a)(ii) of the Commission Implementing Regulation states that if a UAV is capable of capturing personal data via a sensor (e.g. camera) attached to the UAV then the operator must be registered within a Member State. Article 18 (m) tasks a competent authority with maintaining a registration system for operators whose operations present a risk to privacy and personal data protection. Article 12 (1)(c) requires a statement from the operator confirming that the planned operation will comply with all EU and national rules in particular, how it will address privacy and data protection. Article 15 (1) defines privacy as one of the deciding factors when determining geographical areas where UAVs can operate. Within the Annex of the Implementing Regulation, UAS.OPEN.020 (4)(b) requires knowledge regarding privacy and data protection (vii) to be demonstrated via an examination delivered by a competent authority.

These regulations are aimed towards operator awareness and education rather than hard guidelines. Operators must demonstrate knowledge regarding privacy issues and the regulations have been constructed with the aim of reducing risk of privacy breeches.

Safety (a) Knowledge

All operators wishing to operate UAVs with CE markings from C1 to C4 must pass an online exam. If operators want to fly close to bystanders, an additional theoretical exam must be taken and delivered by a recognised entity.

UAS.OPEN.020 (4)(b), UAS.OPEN.030 (2)(a) and UAS.OPEN.040 (3) state that operations shall be performed by remote pilots that have completed an online training course and successfully passed a theoretical exam provided by a competent authority. The aforementioned training course must cover the following subjects:

- air safety
- airspace restrictions
- aviation regulations
- human performance limitations
- operational procedures
- general knowledge
- privacy and data protection
- insurance
- security

UAS.OPEN.030 (2)(b) requires self-guided practical training with an additional theoretical examination (c) to be completed covering the following topics: meteorology, flight performance and technical and operational mitigations for ground risk.

Safety (b) Collision

The only guideline in place within the regulations for reducing the risk of collision was UAS.OPEN.060 (2) during the flight the remote pilot shall (b) keep the UAV in VLOS to reduce the risk of collision with manned aircraft with the flight being discontinued if there is an increase risk to aircraft, people, animals, environment or property. Article 7 (3) requires that any UAV operations in the certified category must abide by Commission Regulation (EU) No 1332/2011 which define operating procedures for airborne collision avoidance. These regulations include the need for airborne collision avoidance systems (ACAS) AUR.ACAS.1005 (3) and what to do when the ACAS sounds a collision alarm AUR.ACAS.2005 (1) (2). These regulations however only apply to the certified category of flight operations which are deemed high risk and form a small portion of total flights.

Part 2 - 5 of the Commission Delegated Regulations requires all C1, C2, C3 and C4 class UAVs to be equipped with a geo-awareness system that allows for uploading and updating airspace limitations, warning alerts to the remote pilot of imminent airspace breech detections and also be able to alert the operator if the geo-awareness system is not functioning properly. Part 2 also requires C1, C2 and C3 UAVs to be equipped with lights with the stated purpose being to aid in controlling the UAV and for increased visibility at night to able people to distinguish between manned aircraft and the UAV.

Safety (c) VLOS

Article 2 of the Implementing Regulation - Definitions (7) describes VLOS as:

> a type of UAS operation in which, the remote pilot is able to maintain continuous unaided visual contact with the unmanned aircraft, allowing the remote pilot to control the flight path of the unmanned aircraft in relation to other aircraft, people and obstacles for the purpose of avoiding collisions.

No pre-defined distance is given regarding maximum visual line of sight. UAS.OPEN.060 (2) states that during a flight the pilot shall (b) maintain VLOS and consistently scan the surrounding airspace to avoid the risk of collision.

Safety (d) Impact

Part 1 of the Commission Delegated Regulations states that for a C0 class UAV (1) the MTOM is less than 250 g and (2) a maximum speed of 19 m/s. A C0 class UAV must also be designed to minimise injury to people from impact such as no sharp edges and design limitations on propellers to reduce injury from the propeller blades. Part 2 (1) requires a C1 class UAV (1) to be made from materials and have physical and performance specifications that if an impact at its maximum speed (terminal velocity) to the human head exerts less than 80 J or has an MTOM of less than 900 g and a maximum speed limitation of 19 m/s (2). Part 3 states that a C2 class UAV (1) must weigh less than 4 kg and (6) by the nature of its design, limit the injury caused to people from impact by avoiding sharp edges and reducing the damage that can be caused from propeller blades. Part 4 and 5 require class C3 vehicles to be under 25 kg with Part 4 limiting the physical dimensions of the UAV to less than 3 m.

Security (a) Loss of Control

Parts 1 – 5 of the Commission Delegated Regulations provide guidelines for how UAV manufacturers can provide solutions to mitigating the risk of losing control of the UAV unexpectedly. The regulations stipulate that for classes C0 – C4 the manufacturer of the UAV must place on the market a manual of operations which states how the UAV will behave during a loss of data link. There is also a requirement under each of the classes that when a loss of data link has occurred, there will be a reliable and predictable way to recover the data link or the flight will be terminated.

Security (b) Anonymity

The Commission Delegated Regulations have provided clear procedures to reduce the possibility of operators flying UAVs anonymously. All UAVs with a MTOM of more than 250 g must have a direct remote identification system equipped on the UAV. Article 2 of the Commission Implementing Regulations defines direct remote identification as a system that broadcasts information locally about the UAV, such as the operators details and UAV specifications, without the need to physically access aircraft. The Commission Delegated Regulations state that a UAV shall have a direct remote identification system that will periodically broadcast from the UAV, in real time during flight, on an open transmission protocol that can be received by existing mobile devices in broadcast range, the following information:

- operator registration number
- unique physical serial number of the UAV
- the geographical position, height above surface and take off point
- the route taken by the UAV
- the geographical position of the UAV

Public Nuisance (a) Noise

The Commission Delegated Regulations state that it is important to limit the noise emissions generated by UAVs to the greatest possible extent in order to provide the highest level of environmental protection. Part 13 of the regulation provides the Noise Test Code which provides procedures for manufacturers to measure the noise generated from their UAVs including microphone placement and operating conditions during the test. Part 15 of the Regulations provides maximum sound power levels per class of UAV with those levels reducing over the course of a two and four year period to give manufacturers a grace period to adjust their UAV designs.

The Commission Implementing Regulations UAS.SPEC.050 (1)(a)(v) requires operators to plan all flights so as to minimise nuisances including noise to people and animals. Whilst UAS.SPEC.050

(1)(i)(iii) specifies that operators should choose a UAV for the operation it is designed for to minimise noise and other emissions.

Public Nuisance (b) Nuisance Behaviour

The Commission Implementing Regulations UAS.SPEC.060 (3) states that UAV operators must not fly close to areas where an emergency situation is ongoing unless they have permission from the emergency services. Nuisance is mentioned throughout the Regulations and is generally coupled with noise emissions requiring operators to plan flights to minimise nuisances UAS.SPEC.050 (1)(a)(v).

Trespass (a)

Neither the Commission Implementing Regulations or the Commission Delegated Regulations provide guidelines regarding UAVs and trespass.

4.2.4 United Kingdom

Privacy (a)

The CAA states that its duty is limited to safety and ensuring pilots are operating within the confines of their granted permissions. They state that their responsibility does not include concerns over privacy and direct people to the Information Commissioners Office as any privacy issues will not be dealt with by the CAA. However, Air Navigation Order 2016 (ANO2016) provides guidelines for UAV operators to avoid privacy issues by clearly delineating between UAVs that have surveillance capabilities and UAVs that do not. The ANO2016 states that small unmanned surveillance aircraft are UAVs that are able to perform surveillance and data acquisition. These aircraft have greater flight restrictions placed on them with the regulations defining guidelines such as keeping greater distances from people during take-off or landing and increasing the distance when flights are planned over or within congested areas and open-air assemblies. It can be inferred that the purpose for defining UAVs with surveillance capabilities and placing tighter flight restrictions on those aircraft, is to reduce the risk of the general public being surveilled and having their right to privacy invaded.

Safety (a) Knowledge

Currently, recreational users are not required to demonstrate a minimum level of knowledge and can fly UAVs legally following the regulations. However, from November 2019, recreational users will have to pass a “drone test” and register with the CAA.

Civil Aviation Publication (CAP) 722 provides additional guidance on the regulations and requires that commercial UAV operators must be able to prove pilot competence in areas such as: general airmanship and successfully completing a practical flight assessment under the appropriate classification.

Safety (b) Collision

ANO2016 article 94(4) provides guidelines for collision avoidance with manned aircraft by restricting flights in certain airspaces involving the aerodrome traffic, close proximity to aerodrome boundaries and restricting the flying height of the UAV. 94(3) states that the UAV must be in constant unaided visual contact (VLOS) with operators to maintain their collision avoidance responsibilities. CAP 722 states sensors and collision alarms forming part of an onboard collision avoidance system of a technical ability at least equivalent to manned aircraft specifications are only required on BVLOS flights and are not required for recreational and most commercial applications.

Safety (c) VLOS

ANO2016 requires that the UAV must be in constant unaided visual contact (VLOS) with the operator to maintain their collision avoidance responsibilities. CAP 722 also defines extended VLOS operations as flights that are performed beyond 500 m. Therefore, it can be construed from the regulations that the maximum VLOS before entering into extended VLOS operations is up to 500 m.

Safety (d) Impact

Two main operating categories are defined in the regulations, small unmanned aerial vehicle and unmanned aerial vehicles. Small unmanned aerial vehicles are defined under ANO2016 as any unmanned aircraft weighing not more than 20 kg without its fuel. Small UAVs are bound by the operating guidelines in ANO2016 whereas UAVs weighing more than 20 kg around subject to the entire UK aviation regulations.

No speed guidelines were found in the regulations or design limitations to reduce the severity of the injury to a person from an impact with a UAV.

Security (a) Loss of Control

CAP 722 states that UAV operations in both segregated and non-segregated airspace must have procedures in place for emergency recovery after a loss of control data link. Standard operating procedures should contain guidelines for loss of data link and abort procedures after a critical system failure. These recommendations are aimed at commercial operators flying in an Air Traffic Service area. No loss of control procedures were found in the regulations for recreational users.

Security (b) Anonymity

No procedures were found in the regulations to ensure UAVs and their operators are identifiable and unable to fly UAVs anonymously. CAA proposes to introduce a registration scheme by November 2019 for all UAVs weighing over 250 g to be required to be registered with the CAA. The CAA states that operators will be registered instead of drones with the registration number of the operator to be applied to all UAVs flown by that operator.

Public Nuisance (a) Noise

No guidelines addressing the issue of noise pollution regarding the use of UAVs were found in ANO2016. The CAA states that it does not make decisions regarding whether an amount of noise would be annoying or damaging to people.

Public Nuisance (b) Nuisance Behaviour

No information was found within ANO2016 regarding nuisance flying such as avoiding emergency personnel. Limitations on how close operators can fly to people are clearly defined in the regulations. CAP 722 states that night-time VLOS flights are permitted provided the guidelines for VLOS are adhered to. This criterion however may be satisfied by an alternative Act outside the scope of this project.

Trespass (a)

CAP 722 requires that operators must be aware of relevant trespass laws when conducting a flight and to obtain permission before entering or operating from private property.

4.2.5 United States

Privacy (a)

No mention of guidelines addressing privacy concerns was found in Part 107 of the Federal Aviation Regulations. Section 357 of FAA Reauthorisation Act 2018 declares an unmanned aircraft systems privacy policy which states that:

> It is the policy of the United States that the operation of any unmanned aircraft or unmanned aircraft system shall be carried out in a manner that respects and protects personal privacy consistent with the United States Constitution and Federal, State, and local law.

The FAA considered including privacy provisions in Part 107 of the Federal Aviation Regulations however it stated that "given the FAA's longstanding mission and authority as a safety agency, it would be overreaching for the FAA to enact regulations concerning privacy rights" FAA (2016).

Safety (a) Knowledge

No minimum level of knowledge is required under the regulations for recreation users to fly UAVs, however the FAA is implementing an aeronautical knowledge and safety test and is current developing a training module and exam in consultation with the industry.

Commercial operators must pass a knowledge test as regulated under Part 107 which includes the following subject areas:

- Regulations
- Airspace classifications
- Meteorology
- Emergency procedures
- Maintenance
- Airport operations
- Physiological effects of drugs and alcohol
- Communications
- Decision making and judgement

Safety (b) Collision

Part 107.29 (a) states that UAVs are prohibited to fly at night and (b) can only fly at civil twilight if fitted with anti-collision lights which are visible for 3 statute miles. 107.37 (a) requires all small unmanned aircraft to yield to all aircraft and that (b) no one should create a collision hazard by flying a UAV to close to another aircraft. 107.43 stipulates that UAVs must not interfere with the operations of any airports with 107.41 declaring classes of prohibited airspace. No reference has been made in the regulations necessitating collision sensors or collision alarm to be equipped to UAVs.

Safety (c) VLOS

107.31 (a) defines VLOS as with vision unaided by any device other than corrective lenses the operator of the UAV must be able to see the UAV throughout the entire flight. No pre-defined distance is given regarding maximum visual line of sight.

Safety (d) Impact

107.51 (a) limits the ground speed of small UAVs (55 lbs; 25 kg) to 44 m/s. No design limitations to reduce the severity of the injury to a person from an impact with a UAV were present in the regulations.

Security (a) Loss of Control

No loss of control guidelines were found in the regulations. 107.21 (a) states that during an in-flight emergency the operator can deviate from any rule necessary to meet the emergency.

Security (b) Anonymity

All UAVs flown either recreationally or commercially must be registered and the UAV marked with the registration number by engraving, permanent label or permanent marker. There is no other real time, in flight identification requirements within the regulations.

Public Nuisance (a) Noise

No guidelines addressing the issue of noise pollution were found in the regulations.

Public Nuisance (b) Nuisance Behaviour

Operators are advised not to fly near emergencies such as accident response, firefighting and hurricane recovery.

Trespass (a)

There are no guidelines within Part 107 or FAA Reauthorisation Act 2018 addressing the issue of UAVs and trespass.

4.3 CONCLUSION

The result of the comparative analysis performed in this chapter provides a detailed insight into how current regulations are addressing the privacy, safety and security concerns of the general public. As was expected and noted during the research phase of this project, not all criteria were met by the regulations. This issue will be explored in further detail in the discussion portion of this paper.

Chapter 5: Discussion

5.1 INTRODUCTION

This chapter will discuss whether the regulations have met the prescribed criteria developed from the literature review in Chapter 2. The differences and similarities between the regulations and criteria will be highlighted and critiqued. Finally, recommendations will be put forth suggesting how the regulatory shortfalls and existing gaps can be addressed therefore meeting the concerns of researchers and the general public.

5.2 PRIVACY

Whether the regulations addressed the privacy concerns of the general public proved to be a complex question. There was no common theme running through each of the regulations tying into what the general public would see as a simple remit, protect a person's right to privacy. The regulations traversed the full breadth of the issue, from deflecting the issue of privacy to another authority, to regulations whose primary aim is to address privacy issues. Only Canada and the EU have attempted to provide guidance for operators to uphold the rights to privacy.

From the regulations of the five countries that were analysed, all five were administered by safety authorities. Three of the regulators stated that privacy was not part of their responsibilities. However, two of these regulators included privacy provisions in their regulations with one delineating between surveillance and non-surveillance UAVs and the other providing a privacy policy. One of the countries provided robust privacy guidelines external to the regulations with detailed information regarding operator's responsibilities and applicable Acts. Two countries placed restrictions on UAVs that were capable of surveillance with only one stating these restrictions were for privacy purposes.

Australian regulations provide limited guidance on reducing the risk of infringing on people's privacy. For example, there are no additional limitations placed on UAVs equipped with surveillance equipment, no requirement for real time inflight identification of the operator and UAV, and no requirement for operators to demonstrate knowledge regarding privacy. Operators look to the regulator seeking guidance on how to navigate the privacy issues but find limited information and are advised external to the regulations to respect personal privacy and not record or photograph people without their consent. Newly designed regulations have provided opportune time to address the concerns of the general public. Through consultation with the Office of the Australian Information Commissioner, privacy guidelines could have been developed that would put them in line with their equivalent safety authorities in other countries that have been successful in addressing privacy concerns.

Canada also provides no privacy guidelines within their regulations. However, Transport Canada has given guidance to recreational users by providing an online resource which details how users can apply privacy principles to the flying of UAVs. Commercial users are directed to the relevant privacy information and given a brief description of how they can protect people's privacy.

The EU is implementing the most robust and progressive privacy guidelines of any regulator. Operator registration is needed for flying UAVs capable of performing surveillance, flight planning must take into account privacy concerns and operators must demonstrate knowledge of privacy and data protection. Additionally, operators will be able to be identified in real time during flights, reducing the ability for operators to infringe on privacy rights anonymously

Although the UK's CAA has stated that its responsibility does not concern privacy, it has segregated UAVs that can conduct surveillance from those that cannot and included greater flight restrictions distancing UAVs from bystanders. However, distance does not negate the ability for sensors to capture and store private information and data. The CAA has stated that privacy issues should be directed to the Information Commissioners Office or to local police.

The US provides a privacy policy within its regulations stating that UAV flights should protect and respect personal privacy consistent with law, but provides no guidelines directing operators on how those flights can stay within those legal boundaries.

UAVs and privacy ultimately are a multifaceted complex issue that is far beyond the scope of this project. And although the use of UAVs is regulated primarily by safety authorities, no other organisation is better positioned to provide guidelines for the protection of privacy as these safety authorities have extensive knowledge of the minutia of UAVs and their applications.

5.3 SAFETY

All regulations surveyed required operators to have some form of prerequisite knowledge demonstrated prior to operating UAVs. The depth of this knowledge varied greatly however, with some regulators only requiring a basic understanding of general safety, while other regulators were expecting broader knowledge on topics such as meteorology, navigation and air law.

All regulations in the comparison had limitations in place on how close UAVs can be flown to aerodromes with the intention on reducing the risk of collision. Equally, height restrictions were in place limiting the risk of UAV incursion into regulated airspace and therefore collision as well. Regarding the implementation of collision sensors and alarms including broadcast beacons, this was only a requirement on larger UAVs above certain weight / size class or operations performed BVLOS for all regulations.

All regulations analysed included a clear definition of VLOS based on continuous unaided visual contact with the UAV at all times. However, within their definitions, no regulator has set a maximum distance that operations can be performed and still be within VLOS. The regulators have put the onus onto the operators to use their best judgement without providing a best-case scenario distance limitation.

The UK regulations came close to defining a limit stating that EVLOS is either within or beyond 500 m. Considering that within most regulations the transition of line of sight is VLOS – EVLOS – BVLOS, then under the UK regulations it would then be assumed that the boundary between VLOS and EVLOS is 500 m.

All regulations included in the analysis had weight class restrictions. Once again, these weight classes varied throughout the regulations with some regulators limiting users to UAVs with a maximum weight of 2 kg, whilst a majority of the regulations allowing up to 20 – 25 kg. Australia and the EU focused on keeping UAV weight classes low with Australia limiting UAVs to 2 kg without the need for a licene and certification whilst the EU requires UAVs weighing up to 2 kg to keep 50 m clear of people and a 150 m for UAVs weighing more up to 25 kg. The regulations of the remaining countries allow UAVs up to 20 - 25 kg which increases the risk of injury and falls outside the recommended weights stated in the research.

UAV speed was only regulated in two countries, the US and the EU. The US regulations have limited all small UAVs (< 25 kg) to 44 m/s and the EU have stated that C0 class under 250 g and C1 class under 900 g must be kept under 19 m/s. These speeds are outside the recommendations put forth by researchers. The EU regulators have set specific design constraints for each class of UAV. The design specifications cover maximum energy levels when impacting the human body and travelling at maximum speed. No sharp edges are permitted on the UAV and propeller blades must be designed to limit injury. No other regulations analysed have applied limitations to UAV design apart from weight restrictions.

5.4 SECURITY

No regulator provided guidelines on preventing the loss of the control of the UAV during a flight within their regulations. The responsibility was predominantly placed on the operator to develop detailed protocols to be included in their standard operating procedures.

All regulators require either the operator or the UAV to be registered with a competent authority allowing for the possible identification of the operator or UAV. The EU goes even further and requires all UAVs weighing greater than 250 g to have a direct remote identification system onboard that will allow the operators details, geographical location of the UAV and operator and the route taken during the flight, to be accessible by a mobile device without the need to access the UAV. This system is considerable step forward in eliminating the possibility of UAVs being flown anonymously and could solve numerous other issues such as invasion of privacy, ensuring safety regulations are being adhered to and determining if a UAV has flown over private property without permission.

5.5 PUBLIC NUISANCE

Once again, only the EU regulations provided guidelines addressing the issue of noise pollution. The regulators state that noise emissions generated by UAVs must be limited to the greatest possible extent and provide a Noise Test Code within the regulations. The aim of the Noise Test Code is to direct manufacturers on how to measure the noise generated by their UAVs in order to meet the maximum sound power levels laid out in the regulations. Operators are also required to plan their flights to minimise nuisance caused by noise pollution. No other regulations analysed included noise pollution reduction guidelines. Australian regulators directed the user to local noise abatement laws, whilst Canada and the UK went the other way and allowed night flights provided safety regulations are adhered to. These night flights can increase the risk of nuisance behaviour through the interruption of peoples sleep.

All regulations included in the analysis provided relief to emergency personnel from the incursion of UAVs into airspace near emergency operations or public safety events by prohibiting flights unless permission is granted from the person in charge. Throughout the regulations, nuisance behaviour was also tied to noise pollution requiring operators plan flights to reduce nuisances.

5.6 TRESPASS

No regulator attempted to address or provide guidelines regarding the issue of trespass.

5.7 RECOMMENDATIONS

From the comparative analysis it is clear that deficiencies have been identified in the regulations. Existing research aimed to identify and address these deficiencies. However, there still appears to be marginal consensus which is evidenced when the regulations are positioned against the prescribed criteria. What is apparent is regulators within their distinct regulatory environments have attempted to amalgamate the necessary guidelines and relevant Acts making it easier for operators to identify information relevant to their area of interest. Some regulations have still proven to be either ambiguous in their guidelines placing the burden on the operator to decide on the most appropriate course of action, or have become overly complex when trying to address the plethora of issues that present when dealing with what is ultimately an extremely complicated matter.

The following recommendations aim to address the shortfall within the regulations and provide a basis for future investigations:

1. Provide a clear mandate including procedures and guidelines on how to mitigate the risk of unmanned aerial vehicles infringing on the privacy rights of people.

2. Specify guidelines and procedures centred around sound privacy principles informing unmanned aerial vehicle operators of their obligations to protect a persons' right to privacy.
3. Ensure all operators attain a minimum level of knowledge regardless of MTOW and usage.
4. Existing requirements for demonstrating a minimum level of knowledge shall include topics beyond the scope of safety and shall include a broader level of aeronautical knowledge.
5. Set a maximum visual line of sight (VLOS) for a UAV under 350 mm in diameter to no greater than 400 m in accordance with existing visual acuity research to reduce the risk of collision and losing control of the aircraft.
6. Limit aircraft MTOW to no greater than 2 kg and limit airspeed to 7.5 m/s in accordance with existing research thus reducing the potential for impact injury.
7. Place design restraints on UAVs limiting sharp edges, increasing large curves and implement frangible parts to absorb impact loads.
8. Mandate clear loss of control protocols and procedures by incorporating manufacturing and design input and provide guidance on how to regain control of the UAV including reference to how interference can affect flight control.
9. Require all aircraft regardless of MTOW and usage to incorporate direct remote identification allowing real time identification of the operator and UAV during flights reducing the risk of privacy, safety and security infringements including trespass.
10. Specify an upper limit on the noise generated by UAVs in accordance with existing environmental protection guidelines and reduce noise pollution that would otherwise cause harm / nuisance and negatively affect human health.

5.8 CONCLUSION

This chapter demonstrated how the regulations of the selected countries performed against the developed criteria. It proved obvious where the regulations were falling short of the expectations of the general public and researchers. These shortfalls when compared to the developed criteria provided the bases for the list of recommendations. These recommendations provide guidelines on how the disparities in the regulations can be reduced and ensure that the key tenets of privacy, safety and security are addressed.

Chapter 6: Conclusion

6.1 CONCLUSION

The aim of this project was to examine how the current unmanned aerial vehicle regulations are addressing the challenges and issues affecting the use of UAVs. From these issues criteria were created that enabled a comparative analysis between the criteria and the regulations to gain insight into whether the regulations were addressing the problems identified.

Initial research aimed to clarify what those challenges were and found that the primary issues were centred on privacy, safety and security. Researchers found little consensus amongst regulatory bodies with the regulations differing greatly between countries. Privacy issues were a primary concern and although it has been extensively researched, UAVs and their privacy implications were tethered only lightly to privacy law. Research surrounding the safety issues found a lack of operator knowledge to be the main driver in the increase of near encounters as people are unaware of the regulations or unfamiliar with the safety risks (IATA 2018). Security research regarding UAVs focused on loss of control and anonymity which technology was aiming to address. The challenges and issues found in the literature review formed the basis for the criteria used in the comparative analysis.

Usage statistics, existing regulations and length of time between regulatory reviews decided which countries to include in the analysis. Australia, Canada, EU, UK and the US were chosen to analyse. Criteria were then developed from the issues found in the literature review which included five themes: Privacy, Safety, Security, Public Nuisance and Trespass.

The regulations of the five countries were analysed and compared against the developed criteria which demonstrated a shortfall in the regulations with all regulations failing to meet some of the criteria. These results confirmed the research that was found in the literature review finding that although there have been new regulations developed, privacy, safety and security were still issues needing attention. From these results ten recommendations were developed to act as a guide for closing the gaps found in the regulations.

6.2 LIMITATIONS

Trespass proved to be a complex issue that ultimately fell outside the scope of this project and was included for research sake. Astute researchers and regulators are struggling to define if and how UAVs can trespass. Terrorism was also excluded from the research conducted in this project as it would prove difficult to regulate against although the safety recommendations suggested in this project could provide opportunity for further research.

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Appendix A – Project Specification

ENG4111/4112 Research Project

Project Specification

For: Stephen McTegg

Title: A Criteria Based Approach to Unmanned Aerial Vehicle Regulations

Major: Surveying

Supervisor: Mr. Shane Simmons

Enrolment: ENG4111 – EXT S1, 2019

ENG4112 – EXT S2, 2019

Project Aim: To define the key challenges affecting UAV use and determine if the regulations are addressing those challenges.

Programme: Version 2, October 2019

1. Provide a general discussion on the history and regulation of UAVs.
2. Investigate countries that have high UAV usage and have existing well defined UAV regulations.
3. Research existing standards and regulations of the selected countries.
4. Examine the problems affecting the use of private and commercial UAVs with respect to privacy, security and safety.
5. Develop criteria addressing how these problems can be resolved.
6. Using the criteria, determine if existing UAV standards and regulations are addressing the key issues.
7. Provide recommendations on how the regulatory bodies can address any shortfalls.

Appendix B – Privacy Principles

Australian Privacy Principles — a summary for APP entities

from 12 March 2014

Australian Government
Office of the Australian Information Commissioner

APP 1 — Open and transparent management of personal information

Ensures that APP entities manage personal information in an open and transparent way. This includes having a clearly expressed and up to date APP privacy policy.

APP 2 — Anonymity and pseudonymity

Requires APP entities to give individuals the option of not identifying themselves, or of using a pseudonym. Limited exceptions apply.

APP 3 — Collection of solicited personal information

Outlines when an APP entity can collect personal information that is solicited. It applies higher standards to the collection of 'sensitive' information.

APP 4 — Dealing with unsolicited personal information

Outlines how APP entities must deal with unsolicited personal information.

APP 5 — Notification of the collection of personal information

Outlines when and in what circumstances an APP entity that collects personal information must notify an individual of certain matters.

APP 6 — Use or disclosure of personal information

Outlines the circumstances in which an APP entity may use or disclose personal information that it holds.

APP 7 — Direct marketing

An organisation may only use or disclose personal information for direct marketing purposes if certain conditions are met.

APP 8 — Cross-border disclosure of personal information

Outlines the steps an APP entity must take to protect personal information before it is disclosed overseas.

APP 9 — Adoption, use or disclosure of government related identifiers

Outlines the limited circumstances when an organisation may adopt a government related identifier of an individual as its own identifier, or use or disclose a government related identifier of an individual.

APP 10 — Quality of personal information

An APP entity must take reasonable steps to ensure the personal information it collects is accurate, up to date and complete. An entity must also take reasonable steps to ensure the personal information it uses or discloses is accurate, up to date, complete and relevant, having regard to the purpose of the use or disclosure.

APP 11 — Security of personal information

An APP entity must take reasonable steps to protect personal information it holds from misuse, interference and loss, and from unauthorised access, modification or disclosure. An entity has obligations to destroy or de-identify personal information in certain circumstances.

APP 12 — Access to personal information

Outlines an APP entity's obligations when an individual requests to be given access to personal information held about them by the entity. This includes a requirement to provide access unless a specific exception applies.

APP 13 — Correction of personal information

Outlines an APP entity's obligations in relation to correcting the personal information it holds about individuals.

www.oaic.gov.au

For private sector organisations, Australian Government and Norfolk Island agencies covered by the *Privacy Act 1988*

Appendix C – ATSB-AO-2016-128

Loss of control involving remotely piloted aircraft Pulse Aerospace Vapor 55

What happened

On 27 September 2016, a Pulse Aerospace Vapor 55[1] remotely piloted aircraft (RPA), was operating a test flight at Lighthouse Beach, Ballina, New South Wales (Figure 1).

Figure 1: Photo of a (different) Vapor 55 RPA

Source: www.skylineuav.com.au

According to telemetry data[2] recorded on the remotely piloted aircraft system's ground control station (GCS), at about 0910 Eastern Standard Time (EST), the RPA lifted off from its start position in front of the surf clubhouse (Figure 2). About 30 seconds later, when the RPA was at an altitude of about 36 ft, it entered 'manual' flight mode. The RPA then tracked according to manual inputs from the pilot for about 7 minutes, at which time (when at 124 ft altitude) the data-link signal was lost. Thirty seconds later, the RPA entered the 'home' flight mode, and commenced tracking to the programmed home position at an altitude of 154 ft. The last position of the RPA recorded by the GCS was about 165 m NNE of the start position, and about 4 km SE of Ballina/Byron Gateway Airport.

In the home flight mode, the RPA did not respond to the flight control inputs made by the pilot and the pilot subsequently lost sight of the RPA. The RPA was not found despite an extensive search.

Appendix D – Acoustic Quality Objectives

Schedule 1 Acoustic quality objectives

section 8

Column 1	Column 2	Column 3			Column 4
Sensitive receptor	**Time of day**	**Acoustic quality objectives (measured at the receptor)** ***dB(A)***			**Environmental value**
		$L_{Aeq,adj,1hr}$	$L_{A10,adj,1hr}$	$L_{A1,adj,1hr}$	
dwelling (for outdoors)	daytime and evening	50	55	65	health and wellbeing
dwelling (for indoors)	daytime and evening	35	40	45	health and wellbeing
	night-time	30	35	40	health and wellbeing, in relation to the ability to sleep
library and educational institution (including a school, college and university) (for indoors)	when open for business or when classes are being offered	35			health and wellbeing
childcare centre or kindergarten (for indoors)	when open for business, other than when the children usually sleep	35			health and wellbeing
childcare centre or kindergarten (for indoors)	when the children usually sleep	30			health and wellbeing, in relation to the ability to sleep
school or playground (for outdoors)	when the children usually play outside	55			health and wellbeing, and community amenity
hospital, surgery or other medical institution (for indoors)	visiting hours	35			health and wellbeing

Appendix E – FAA Waiver (BVLOS)

	Operations Over People (107.39(a)) Waiver Trend Analysis			
Waiver Application Elements	**Ground Collision Severity**	**Laceration Injuries**	**Description of the Operation**	**Unique Remote Pilot Experience**
Sufficient Information -- Characteristics of the Operations Over People (OOP) applications approved after requests for additional information	Applicants **provided their own impact / injury severity tests** for their requested small unmanned aircraft system (sUAS). --OR— Applicants chose a sUAS which had **impact / injury severity test data readily available and submitted the data in their waiver application.** Applicant provided a **mitigation that reduced impact severity**, e.g. use of an industry standard such as ASTM F3322-18 Standard Specification for sUAS Parachutes Note: The FAA has issued other waivers after assessing **vehicle design and operational reliability data**, with operational mitigations, such as population size and density or the duration of time the small UAS will be over people, to determine the operation could be completed safely.	Applicants **provided their own laceration tests** for their requested sUAS. --OR— Applicants chose a sUAS which had **laceration test data readily available and submitted the data in their waiver application.** Applicant provided **mitigation that reduced laceration injury**, e.g. use of an industry standard such as ASTM F3322-18 Standard Specification for sUAS Parachutes Note: The FAA has issued other waivers after assessing **vehicle design and operational reliability data**, with operational mitigations, such as population size and density or the duration of time the small UAS will be over people, to determine the operation could be completed safely.	Applicant proposed operational **limitations**: - Altitude; Airspeed (needed to protect people on the ground) - Time flown over people; population size & density – (minimizing is a plus) - Confined area of operation (most applicants geo-fenced) - Environmental limitations: maximum wind speeds, minimum visibility, temperature range Applicant described operating **conditions**: - Equipment that enhances safety (i.e., prop guards, parachute) - Training taken by Remote Pilot / Visual Observers Applicant described **procedures**: - Contingency actions for system faults (Ex: Return to Home mode)	Applicants provided an **extensive list of qualifications / experience** prior to operating over people. **Example** qualifications / experience that affected approval: - Remote pilot certificate - Total hours operating sUAS - Total hours operating the specific make and model of sUAS - Remote pilot specific Ops Over People training and testing to ensure pilot has appropriate knowledge and skills. Applicant provides detailed description / curriculum for training. May include flight training and site training.
Insufficient Information -- Characteristics of the Operations Over People (OOP) applications after requests for additional information	Applicants provided: (1) Impact / injury severity **test data that was not for the specific sUAS proposed for the operation** (2) Mathematical formulas and **calculations in place of test data** which were not sufficient for the operation Applicants stated a parachute will be used, but did not provide test data.	Applicants provided: (1) Laceration injury **test data that was not for the specific sUAS proposed for the operation** (2) A **statement** that propeller guards will be used, and/or the motors will stop upon impact, but **no supporting test data**. (3) No mention of laceration injury prevention / test data at all.	Applicants did not describe enough operating limitations / conditions / procedures. Applicants who mentioned use of return to home mode as a fail safe did not provide method(s) to **mitigate the risk** of the sUAS entering the path of another aircraft or impacting people or structures while operating in return to home mode.	Applicants stated RPIC has a remote pilot certificate, but give **no other qualifications or experience** to show the FAA the pilot could safely operate over people.

Appendix F - Criteria

1. **Privacy**
   a. The regulations shall address the privacy concerns of the general public or provide guidelines to reduce the risk of infringing on a person's right to privacy.
2. **Safety**
   a. Operators shall possess a minimum level of knowledge to operate the UAV in a safe manner to reduce the risk of injury to people or property. Knowledge could be demonstrated in the form of an online examination, accreditation or a pilot's certificate.
   b. The regulations will contain guidelines reducing the risk of collision including onboard collision sensors and alarms.
   c. Maximum visual line of sight shall be defined as visual confirmation of the UAV with the naked eye but not further than 400 m.
   d. The regulations will contain limitations on the design of the UAV and the flight parameters reducing the risk of harm to people from direct impact. Weight classes and flying speed limitations shall be implemented.
3. **Security**
   a. The regulations have stipulated guidelines including limitations reducing the risk of losing control of the UAV.
   b. The regulations have ensured that UAVs and operators are identifiable and have reduced the risk of UAVs being flown anonymously.
4. **Public Nuisance**
   a. The regulations will implement guidelines addressing the issue of noise pollution from the use of UAVs such as a maximum decibel value from an environmental agency or placing limitations on flying times and distances.
   b. The regulations have implemented guidelines reducing the risk of nuisance behaviour and specifically mention avoiding emergency personnel or by placing limitations on flying times and distances.
5. **Trespass**
   a. The regulations will implement limitations and guidelines preventing the act of trespass.