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Integration of NZDF Remotely Piloted Aircraft Systems (RPAS) into New Zealand Civil Airspace

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December 2018

ABSTRACT

Integration of Remotely Piloted Aircraft Systems (RPAS) into civil airspace is a complex problem that is being investigated within New Zealand and internationally. For the New Zealand Defence Force (NZDF) seamless access to civil airspace would enhance RPAS operational capability for military training and non-military tasks, whereas current operational restrictions are likely to limit or preclude the use of RPAS for certain roles.

This report identifies the current issues associated with integration of NZDF RPAS into New Zealand civil airspace. This is based on a DTA review of public domain information, which illustrates the underlying principles and assumptions currently put forward by various stakeholders involved in addressing RPAS integration in New Zealand and internationally.

Technological solutions and other airspace integration enablers are also identified and discussed. Near term NZDF Beyond Visual Line Of Sight (BVLOS) RPAS operations in civil airspace will need to be accommodated via procedural air traffic separation. Seamless airspace integration for RPAS will require Detect-And-Avoid (DAA) technology that is currently in development. An opportunity is identified to facilitate RPAS operations throughout New Zealand by extending current proposals for air traffic surveillance via Automatic Dependent Surveillance–Broadcast (ADS-B) to include uncontrolled airspace.

It is recommended that demonstrations or initial restricted operations may be appropriate to gain confidence that the associated technologies and procedures are fit-for-purpose. The NZDF may also be able to leverage experience from partner countries and is well placed to take a lead role where a clear need or benefit exists.

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EXECUTIVE SUMMARY

BACKGROUND

Integration of Remotely Piloted Aircraft Systems (RPAS) into civil airspace is a complex problem that is being investigated within New Zealand and internationally, for both civil and military RPAS. For the New Zealand Defence Force (NZDF) seamless access to civil airspace would enhance RPAS operational capability. Conversely, current operational restrictions are likely to limit or preclude the use of RPAS for certain roles.

The NZDF is planning to field greater numbers of small and tactical RPAS in the near future, and is also planning to study Medium Altitude, Long Endurance (MALE) RPAS as a candidate platform type for future air surveillance. Solutions will be needed to enable NZDF RPAS to fly Beyond Visual Line-Of-Sight (BVLOS) in civil airspace for military training and non-military tasks.

In order to be a 'fast follower' the NZDF will benefit from a holistic understanding of the requirements and challenges associated with integrating RPAS into civil airspace, as well as an awareness of the solutions being developed. Defence Technology Agency (DTA) interest in this area stems from an expectation that technological solutions will play a central role in advancing airspace integration for RPAS.

AIM

Identify the current issues associated with integration of RPAS into civil airspace, with the aim of promoting awareness and a common understanding of the airspace integration problem in a New Zealand context.

RESULTS

This report highlights current issues associated with integration of NZDF RPAS into New Zealand civil airspace. This information is primarily based on a DTA review of public domain information, which illustrates the underlying principles and assumptions currently put forward by civil aviation regulators, organisations representing pilots and air navigation service providers, as well as industry working groups tasked with RPAS integration in New Zealand and internationally.

RPAS offer potentially significant advantages over inhabited aircraft. In particular, they provide an opportunity to accept more risk to the aircraft platform where there is an operational benefit. They also present an opportunity to mitigate risks associated with current practices. The ability to operate BVLOS in civil airspace will enable the NZDF to detect and observe areas of interest and potential threats, and respond to them, from long ranges without putting people or crewed aircraft into harm's way.

However, current RPAS cannot meet extant regulations applied to manned aircraft flying in New Zealand. As such, RPAS are currently segregated – confined to special use airspace or operations below 500 ft Above Ground Level (AGL) – or must remain within Visual Line Of Sight (VLOS) of the remote pilot or observers on the ground.

It is planned that civil and military RPAS will eventually operate alongside manned aircraft within New Zealand civil airspace. This is a significant undertaking and efforts to integrate RPAS into civil airspace in other countries have progressed more slowly than originally planned. Key challenges relate to enabling safe BVLOS flight in shared airspace environments, over populated areas and in uncontrolled airspace where RPAS must be capable of self-separation and collision avoidance. Solutions are needed to replace natural pilot vision with a technology-based Detect-And-Avoid (DAA) capability for RPAS and to ensure the robustness of Command and Control (C2) data links.

As DAA technology has yet to progress beyond development, near term NZDF RPAS BVLOS operations in controlled airspace will require an interim approach based on resilient procedures for air traffic separation. Such an approach is already utilised in other countries on a limited basis. Procedures adopted in New Zealand should aim to facilitate the potential capabilities and advantages that RPAS provide.

Longer term, concurrent use of airspace by RPAS and manned aircraft on a widespread basis will require DAA systems based on surveillance technology. Whilst the current proposals for air traffic surveillance in New Zealand via Automatic Dependent Surveillance – Broadcast (ADS-B) only address controlled airspace, extending the use of this technology to uncontrolled airspace would provide a complete picture of air traffic operating in New Zealand. This could significantly enhance the situational awareness of all airspace users and could allow RPAS to be fully integrated into all classes of domestic airspace. There appears to be an opportunity for New Zealand to be a world leader in this area, consistent with the Government's vision for a thriving, innovate and safe Unmanned Aircraft (UA) sector.

Robust technology is needed for RPAS to ensure their airworthiness as a fundamental tenet of maintaining (or improving upon) existing levels of safety for the aviation system. Approval of RPAS technologies may initially prove challenging in the absence of comprehensive standards or operational experience. Demonstrations or interim restricted operations may be appropriate to gain confidence that the technology is fit-for-purpose. Contingency measures must also be developed.

Whilst this report is primarily concerned with NZDF RPAS exploitation, counter-RPAS (C-RPAS) approaches will also be needed to mitigate negligent and nefarious RPAS use or out-of-control RPAS due to technical failures. Roles, responsibilities and procedures for authorising and using C-RPAS techniques will need to be established in compliance with New Zealand legal constructs.

Integration of NZDF (and other) RPAS into New Zealand civil airspace promises to bring significant advantages and opportunities. Realising these will require collaboration between the NZDF, the Civil Aviation Authority (CAA), Airways and other stakeholders. The NZDF may also be able to leverage experience from partner countries and is well placed to take a lead role where a clear need or benefit exists.

SPONSOR

OAR (WGCDR A. J. McWilliam)

CONTENTS

1. INTRODUCTION

This report provides an overview of the current issues associated with integrating New Zealand Defence Force (NZDF) Remotely Piloted Aircraft Systems (RPAS) into New Zealand civil airspace. The aim is to promote awareness and a common understanding of the airspace integration problem in a New Zealand context.

Integration of RPAS into civil airspace is a complex problem that is being investigated within New Zealand and internationally, for both civil and military RPAS. For the NZDF, seamless access to civil airspace would enhance RPAS operational capability. Conversely, current operational restrictions are likely to limit or preclude the use of RPAS for certain roles. The NZDF is exploring the use of RPAS for applications including:

a. Small RPAS to provide tactical Intelligence, Surveillance and Reconnaissance (ISR) and Electronic Warfare (EW) capability for Army mobile platoons, as well as domestic force protection.

b. Tactical RPAS to provide an organic ISR capability for the Navy and Army in the maritime, littoral and land domains. Potential tasks include observing vessels during boarding party operations, assisting naval vessels to detect and avoid sea ice, and providing support to amphibious operations.

c. Medium Altitude Long Endurance (MALE) RPAS capable of long range, persistent ISR for wide area maritime domain awareness.

The scope of this report includes:

a. *The New Zealand airspace and aviation environment.* Current airspace design, airspace access requirements and civil RPAS rules, as well as the future aviation environment.

b. *Military RPAS.* Airworthiness policy and current military RPAS utilisation.

c. *RPAS integration into civil airspace.* Requirements, challenges, Concepts of Operation (CONOPS) and possible solutions.

d. *Near term NZDF RPAS Beyond Visual Line Of Sight (BVLOS) operations in civil airspace.* Discussion regarding how such operations might be facilitated.

In order to be a ‘fast follower’ the NZDF will benefit from a holistic understanding of the requirements and technological challenges associated with airspace integration, as well as an awareness of the solutions being developed. Defence Technology Agency (DTA) interest in this area stems from an expectation that technological solutions will play a central role in advancing airspace integration for RPAS [1].

The information in this report is collated from public domain sources, as well as initial discussions with stakeholders within the NZDF, Ministry of Defence (MoD), New Zealand Civil Aviation Authority (CAA) and Airways New Zealand.

This report considers RPAS, e.g. Unmanned Aircraft Systems (UAS) with a human-in-the-loop at all times, flying in New Zealand airspace. The term RPAS is used whether referring to the air vehicle or the entire system including Remote Pilot Station (RPS), launch/recovery equipment etc. A glossary of other key terms is provided on page 41. The report refers to RPAS categories and groups as defined in Appendix A.

2. NEW ZEALAND AIRSPACE

2.1. New Zealand Airspace Design and Classification

New Zealand airspace is governed by Civil Aviation Rule (CAR) Part 71 [2]. Airspace areas are defined in the Air Navigation Register (ANR) which is available via the Aeronautical Information Publication New Zealand (AIP) [3].

For the purpose of this report, New Zealand airspace (Figure 1) is considered to include the New Zealand Flight Information Region (FIR), which is New Zealand's domestic airspace, and the Auckland Oceanic FIR, which New Zealand manages under an International Civil Aviation Organization (ICAO) Regional Air Navigation Agreement.

Figure 1 – New Zealand airspace (ICAO codes in parentheses)

Figure 2 provides a simplified illustration of the configuration of New Zealand airspace, as well as associated terminology.

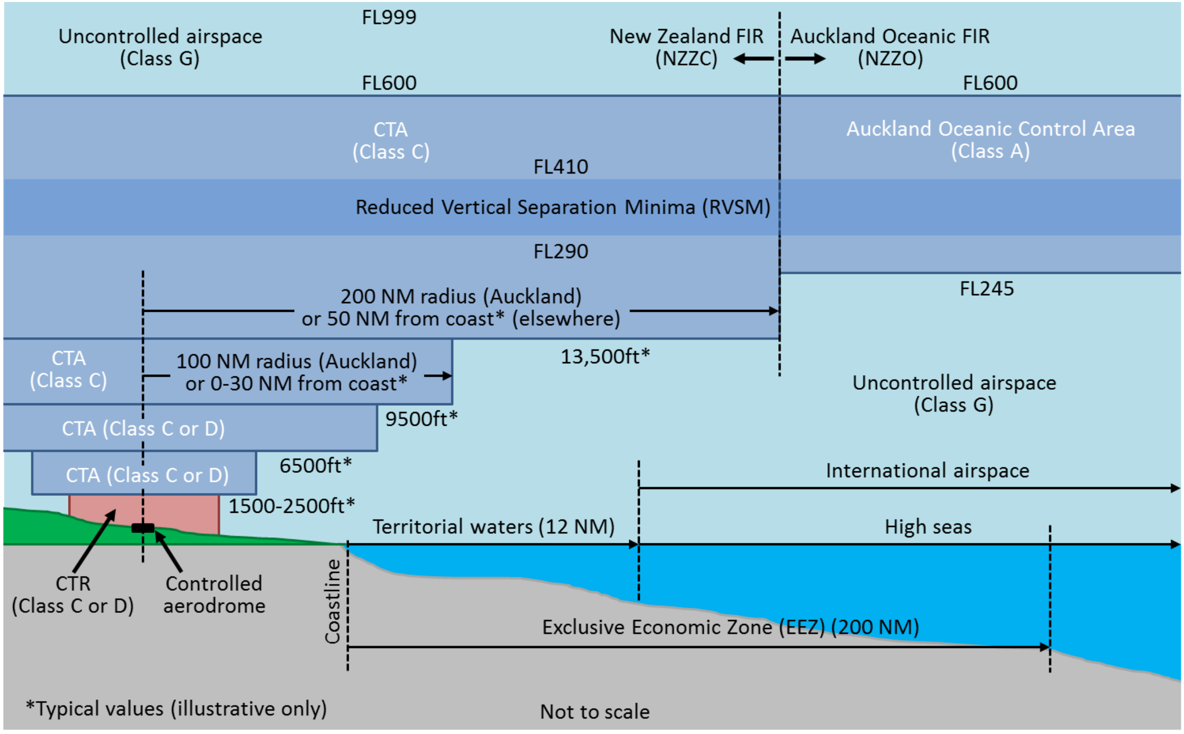

Figure 2 - New Zealand airspace structure (simplified)

New Zealand airspace includes:

a. Control Zones (CTR) and Control Areas (CTA) comprising controlled airspace classes A, C and D (see airspace class definitions in [2]).

b. Uncontrolled airspace (class G). New Zealand has a high proportion of uncontrolled airspace compared to many other countries.

c. Special Use Airspace, such as Military Operating Areas (MOA), Danger Areas (DA), Restricted Areas and Volcanic Hazard Zones.

For the purpose of this report, civil airspace is considered to include all airspace outside NZDF managed Military Operating Areas and Danger Areas.

Figure 3 and Figure 4 illustrate current designated Special Use Airspace at low levels (e.g. beginning at the earth's surface) as well as aerodrome locations.

Appendix B gives further details of the Special Use Airspace that is currently identified for flying RPAS BVLOS. These areas are highlighted with an asterisk in Figure 3 and Figure 4. The NZDF manages much of this airspace.

In general, aircraft operating in New Zealand must be equipped with a transponder[1] when operating in controlled airspace and certain areas of Special Use Airspace. This is collectively referred to as Transponder Mandatory (TM) airspace.

[1] Or Identification Friend or Foe (IFF) system for military aircraft.

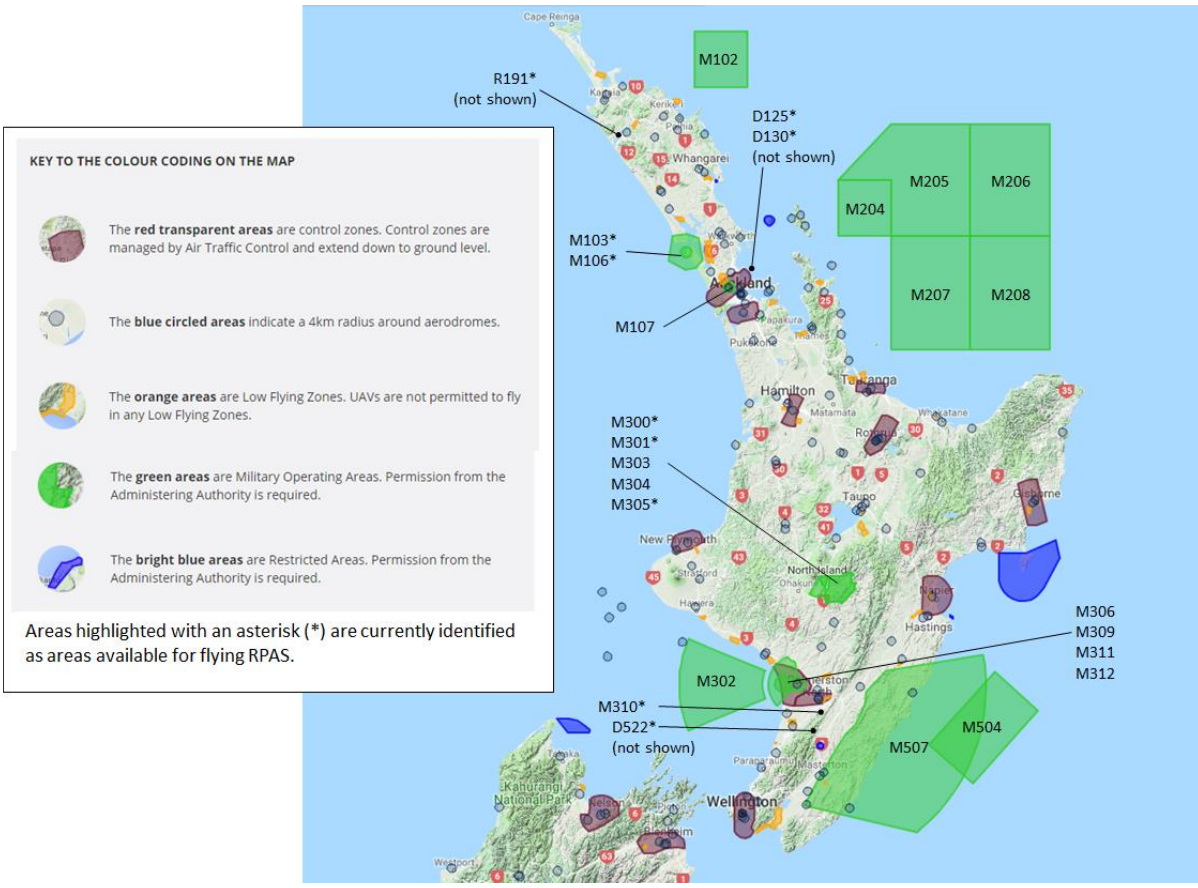

Figure 3 – Low level airspace in the North Island (modified from [4])

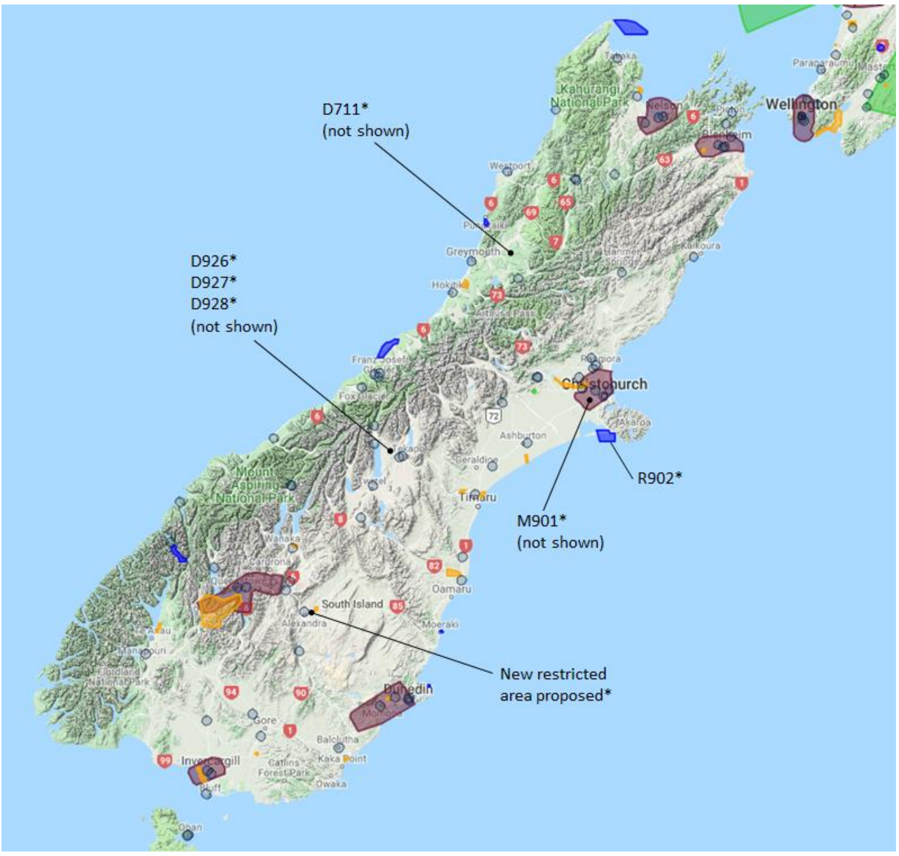

Figure 4 – Low level airspace in the South Island (modified from [4])

2.2. Access to Civil Airspace

Access to New Zealand airspace is managed via civil or military regulatory approval or certification via the New Zealand Civil Aviation Authority (CAA) or the NZDF Airworthiness Authority (NZDF AA) respectively. Whilst the NZDF is not strictly bound by civil aviation regulations, it is obliged (due to concurrent civil and military use of airspace) to adhere to civil regulations as far as is practicable. Manned aircraft flying in New Zealand comply with the Visual Flight Rules (VFR) or Instrument Flight Rules (IFR) laid out in CAR Part 91 [5]. The corresponding responsibilities placed on pilots and Air Traffic Control (ATC) to ensure separation and collision avoidance are summarised in Table 1.

Table 1 – Responsibilities for separation and collision avoidance by airspace class

Airspace class	Collision avoidance	Separation VFR/VFR	Separation IFR/VFR	Separation IFR/IFR
A	Pilot	-	-	ATC
C	Pilot	Pilot with TI	ATC	ATC
D	Pilot	Pilot with TI	Pilot with TI	ATC
G	Pilot	Pilot with FIS	Pilot with FIS	Pilot with FIS

ATC: Air Traffic Control. TI: Traffic Information[2]. FIS: Flight Information Service[3].

The emergence of RPAS represents a challenge to the traditional manned aviation model due to the prevalence of uncertified RPAS and recreational operators, as well as the inability of current RPAS to meet existing airspace access requirements and operating rules. In particular:

a. RPAS cannot currently operate in accordance with VFR in the same way as manned aircraft. More specifically, RPAS cannot ensure compliance with visual separation requirements (e.g. the ability to ‘see and avoid’ other air traffic), right-of-way rules and adherence to Air Traffic Control (ATC) visual instructions when operating BVLOS. Small RPAS may also be very difficult for pilots of other VFR aircraft to see and avoid.

b. Whilst certain RPAS are potentially capable of operating in a similar manner to manned aircraft flying IFR, current RPAS are not certified for instrument flight and are typically fitted with equipment that is not approved to existing aviation standards. There are also visual functions required under IFR, which current RPAS cannot satisfy (discussed further in section 4.3).

2.3. Rules for Civil RPAS

CAR Part 101 [6] and Part 102 [7] cater for the inability of current RPAS to comply with the existing rules for manned aviation. Part 101 permits low risk RPAS operations on an uncertified basis. Such operations are generally segregated from

[2] Information provided to alert a pilot to other air traffic. Traffic avoidance advice provided on request.

[3] Includes provision of information relating to potential collision hazards.

manned aviation through operating area and height restrictions, as summarised below. Allowing low risk RPAS operations on an uncertified basis is a stance currently adopted by many countries[4].

Key requirements and limitations for Part 101 operations include:

a. Maximum aircraft weight 15 kg (or 25 kg for approved operators)

b. Maximum operating height 120 m (400 ft) above ground level, unless certain conditions are met

c. No flight within 4 km of any aerodrome, unless certain conditions are met

d. Daylight flight only

e. Visual Line-Of-Sight (VLOS) operation only, e.g. the remote pilot must be able to see the RPAS visually and unaided to ensure separation from other aircraft, or use an observer to do this (referred to as Extended Visual Line-Of-Sight, EVLOS)

f. RPAS must give way to all manned aircraft

g. Prior consent must be obtained from anyone to be overflown and/or the property owner or person in charge of any area to be flown above

For all operations that do not fall within the Part 101 criteria, the RPAS operator and the intended operation require CAA approval based on a safety case risk assessment in accordance with Part 102. New Zealand RPAS regulations are considered less restrictive than those of many countries due to the flexibility of the Part 102 risk-based approach.

Current Part 102 operations in non-segregated airspace are typically preceded by a Notice to Airmen (NOTAM) being issued to advise other airspace users of the intended RPAS operation. In addition, such operations currently require visual observers on the ground or in a chase aircraft if the RPAS will operate outside the visual line of sight of the remote pilot (e.g. EVLOS). To date, BVLOS operations (e.g. flights beyond visual range and without observers or chase aircraft) have only been authorised for specific demonstration activities.

The current Part 101 and 102 rules do not prescribe minimum requirements for RPAS performance, equipage or operator training/qualification, nor do they mandate technical standards required for RPAS airworthiness approval. However, the CAA may specify such requirements as a condition for approval of a particular operation under Part 102. In such cases, the CAA may stipulate RPAS-specific standards to be met (examples of such standards are listed in Appendix J[5]) or may read across existing manned aircraft certification requirements where applicable.

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[4] A summary of current RPAS regulations for a number of countries is given in [8], [9] and [10].

[5] Due to the current immaturity of RPAS, the list of RPAS-specific standards is constantly changing. The list provided in Appendix J should not be considered comprehensive.

The Part 101 and 102 regulatory framework is expected to remain in place for the foreseeable future, although specific rules may evolve where a need is identified. It has recently been reported that the Ministry of Transport is considering whether changes are necessary following a number of media reports of 'near misses' between RPAS and commercial passenger aircraft [11].

In addition to the Civil Aviation Rules, the following national regulations are also relevant to domestic RPAS operations:

a. New Zealand Radio Spectrum Regulations. See [12] for information.

b. The Telecommunications Act 2001

c. The Privacy Act 1993. Guidance relevant to RPAS is available via [13].

d. The Search and Surveillance Act 2012

2.4. Civil RPAS Use

RPAS use in New Zealand has recently been surveyed by Colmar Brunton[6] [14] and Airways [15]. Based on the survey data, it is estimated that there are approximately 280,000 RPAS users in New Zealand today as well as significant numbers of RPAS operated by people visiting New Zealand. The majority of domestic RPAS flying relates to small platforms used for recreation, as well as commercial photography, filming, aerial survey/mapping and support to agriculture. The majority of RPAS operate under Part 101 [15] and around half of all RPAS operations take place in controlled airspace [16].

All New Zealand universities are using RPAS in some capacity [17] including surveying for conservation and ecological research [18]. In addition, the Massey University School of Aviation offers a 3-day training course for multi-rotor RPAS operators [19].

Several companies operating in New Zealand are involved in the design, development and manufacture of RPAS and related technologies. Examples include Altus Intelligence and Aeronavics (both with offices in the Waikato) as well as X-Craft (Auckland).

The Ministry of Transport and the Ministry of Business, Innovation and Employment (MBIE) are also promoting New Zealand to foreign companies as a destination for unmanned aircraft development, which includes RPAS [20]. An example is the Kitty Hawk 'Cora' air taxi, a US-designed all-electric remotely piloted aircraft that is currently being flight tested by Zephyr Airworks at a private airfield in the South Island [21].

[6] For the CAA.

3. MILITARY RPAS

3.1. NZDF Policy

The current NZDF policy framework for RPAS comprises:

a. *Defence Force Order (DFO) 9 – Operating Airworthiness* [22]

   i. *Operating Airworthiness Standard (OAS) 8 – Operation of Category 1 RPAS*

   ii. *OAS 9 – Operation of Category 2 RPAS*

   iii. *OAS 16 – RPAS acquisition*

b. *Aviation Order (AVO) Part 1 Chapter 2 Leaflet E45* [23]

All NZDF units that operate RPAS require a Flying Management System (FMS). The specific operating airworthiness measures applied to each RPAS type depend on the level of risk each platform is considered to pose. This is reflected in the NZDF RPAS categorisation:

a. *Category 1*. Those RPAS that are considered to pose levels of risk similar to manned aircraft. NZDF policy states that Category 1 RPAS will be managed in an equivalent manner to NZDF manned aircraft. To date, the NZDF has not operated any Category 1 RPAS.

b. *Category 2*. This encompasses all other RPAS, which are managed via application of tailored risk mitigation measures. The NZDF Operating Airworthiness Authority (OAA) issues a Permit to Operate (PTO) for each Category 2 RPAS type and specific operating units. The PTO provides guidance, rules, limitations and constraints that govern how the RPAS can be used.

Whilst the NZDF has established an operating airworthiness framework, it does not currently have RPAS-specific regulations for technical airworthiness. This will likely need to be addressed if larger and more complex RPAS (e.g. Category 1) are introduced in the future.

Appendix D provides a summary of the airspace currently available to NZDF RPAS on a routine basis. Whilst the restrictions are not identical for all RPAS types, current PTOs typically allow NZDF RPAS to be operated at heights greater than 400 ft AGL, BVLOS and at night in certain areas of NZDF managed (segregated) airspace only. Flights outside NZDF airspace are permitted on the basis of adherence to CAR Part 101 restrictions (as listed in section 2.3). Operations in civil airspace outside Part 101 criteria require case-by-case approval from the NZDF OAA, which would also likely require CAA involvement. The NZDF has engaged with the CAA on previous occasions to enable specific experimentation and demonstration of contractor owned and operated RPAS outside NZDF managed airspace.

3.2. Use of RPAS by the NZDF

The NZDF aims to be a ‘fast follower’ in employing RPAS. This strategy aims to leverage RPAS technologies and experience from partner nations whilst minimising the burden and risk associated with large-scale technology development. However, due to the rapid growth in RPAS use by the other Five Eyes[7] militaries (discussed further in section 3.3) the NZDF currently has comparatively little experience as an RPAS operator.

Appendix C outlines the RPAS types currently in NZDF use. All are relatively small and portable types that do not rely on special equipment or runways for launch and recovery[8]. The NZDF does not currently operate any large RPAS of a size comparable to manned aircraft[9].

Much of the NZDF’s RPAS technical expertise originates from the Kahu fixed-wing RPAS that was developed by DTA from 2006 to 2015. Kahu served as a vehicle for technology development and enabled the NZDF to gain first-hand experience as an RPAS operator. Kahu has also been deployed operationally on a limited basis.

Current RPAS use within the NZDF includes:

a. New Zealand Special Air Service (SAS) use of the Black Hornet micro RPAS. Black Hornet is the only other RPAS type currently in NZDF service with declared operational (deployable) capability.

b. Navy experiments and Army battle-labs are currently trialling various Commercial Off The Shelf (COTS) and Military Off The Shelf (MOTS) RPAS types to explore the capabilities of these systems, primarily for ISR roles in the maritime, littoral and land domains. These activities are also developing user requirements to support future RPAS acquisitions – discussed below.

c. The Royal New Zealand Air Force (RNZAF) currently operates a small number of COTS RPAS for training and limited ISR roles including airfield and MOA security, emergency response and flight safety investigations.

d. Defence Public Affairs (DPA) also recently acquired small COTS RPAS to be used to capture digital images.

e. DTA continues to investigate technologies for RPAS and counter-RPAS.

f. The NZDF has also engaged third parties to carry out contractor operated RPAS demonstrations. These have taken place in NZDF managed (segregated) airspace, as well as launch and recovery from a Navy Offshore Patrol Vessel (OPV) in the Southern Ocean[10].

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[7] The Five Eyes (abbreviated FVEY) is an intelligence alliance comprising Australia, Canada, New Zealand, the United Kingdom and the United States.

[8] NZDF Category 2. US DoD Groups 1-2. See Appendix A for definitions.

[9] NZDF Category 1. US DoD Groups 3-5. See Appendix A for definitions.

[10] This involved BVLOS flight in a remote area of international airspace. BVLOS flight was permitted on the basis that the area of operation was void of other air traffic.

The RNZAF maintains operating airworthiness oversight across all NZDF RPAS activities and is leading the development of NZDF strategy for RPAS.

These flying activities, demonstrations and technology studies are building a foundation of RPAS knowledge and skills across the Defence Force. NZDF RPAS operators currently undertake basic training through Massey University, whilst military-specific aspects of RPAS operation and training are managed by individual NZDF units. To date, approximately 200 NZDF personnel have completed the Massey course.

The NZDF is planning to increase its use of RPAS in the near future. In particular, the Network Enabled Army (NEA) Tranche 2 and Joint RPAS (JRPAS) projects aim to deliver small and tactical RPAS to the New Zealand Army and Royal New Zealand Navy by 2021. There is no current plan to significantly expand RPAS use within the RNZAF, however an upcoming project to acquire an Air Surveillance Complementary Capability (ASCC) is expected to consider Medium Altitude, Long Endurance (MALE) RPAS as a potential solution[11]. There is currently no precedent for operating MALE RPAS in New Zealand.

The NZDF will have, at the very least, a near term need to conduct military mission training with small and tactical RPAS in New Zealand in support of deployments. Whilst military RPAS deployed in-theatre may have freedom of operation (due to complete military control of the airspace) domestic training may be restricted as a result of concurrent use of airspace by military and civil operators. Therefore, the NZDF will need to understand how military RPAS training can be achieved within the current and future New Zealand airspace environment. If the NZDF were to pursue MALE RPAS (for example, to allow near-term demonstration of capability in a New Zealand context) additional aspects such as operation from aerodromes and transiting through shared airspace would need to be addressed.

3.3. Use of RPAS by Other Militaries

Excluding New Zealand, all Five Eyes militaries currently employ significant numbers of RPAS in operational service. These are primarily used for ISR roles, with RPAS ranging from small hand-launched types up to platform sizes comparable to manned aircraft. The US Department of Defense (DoD) alone operates over 11,000 RPAS [25]. Appendix E identifies the military RPAS types currently in service with each of the FVEY nations, as well as near term acquisitions.

Many of the RPAS types currently used by the FVEY militaries have been developed to fulfil urgent operational requirements. They have not necessarily been designed or equipped with the intent to enable their integration into national airspace systems outside military controlled airspace [26].

[11] The NZ MoD has recently announced the acquisition of four Boeing P-8A aircraft for future air surveillance [24]. ‘Complementary capability’ refers to an additional capability to carry out lower-end civilian surveillance tasks, which are expected to include resource and border protection operations and persistent overland ISR. Possible solutions include manned aircraft, RPAS and satellites.

To date, even large and sophisticated military RPAS do not meet airworthiness certification requirements equivalent to those applied to manned aircraft[12], although platforms currently in development are being marketed as certifiable[13]. Typical shortcomings of current military RPAS relative to manned aircraft certification standards include:

a. Structural design (e.g. limited damage tolerance)

b. Inferior levels of reliability and systems redundancy

c. Inability to detect and avoid other air traffic

d. Non-approved software and avionics standards, including uncertified Communication, Navigation and Surveillance (CNS) equipment

e. Lack of environmental capability including protection from icing and lightning

Domestic RPAS flying for training and military exercises is typically carried out in designated restricted (segregated) airspace, with any transit through civil airspace accommodated via measures including carefully pre-planned and coordinated ATC separation/vectoring, the use of manned chase aircraft or segregation from other air traffic by activating temporary special use airspace [28]. Appendix F illustrates the segregated airspace currently available for military RPAS in Australia[14], the UK and the US. In all cases, the available airspace, whilst significant, represents a very small proportion of the national airspace. Certain RPAS, such as the UK MoD’s Watchkeeper, are certified to fly in controlled airspace. However, such flights are not routine and, to date, have involved establishing temporary danger areas beneath the aircraft flight path [29]. In the US, a Federal Aviation Authority (FAA) Certificate of Waiver or Authorisation (COA) is required for all military RPAS operating in civil airspace [30][31].

Whilst domestic operations of military MALE RPAS typically take place exclusively within segregated airspace, the missions flown by High Altitude Long Endurance (HALE) RPAS, such as the RQ-4 Global Hawk and MQ-4C Triton, require access to civil airspace for high altitude cruise. The cruise phase of HALE flight profiles typically takes place at altitudes of 50,000 ft or higher, above the flight levels occupied by commercial air traffic. Temporary airspace restrictions are put in place to ensure segregation from other air traffic during the climb and descent phases [32]. ATC separation service is provided during all phases of flight, with operation in uncontrolled airspace remaining unachievable[15]. HALE RPAS are fitted with equipment that enables them to operate in a manner similar to manned aircraft flying IFR, including transponders, IFF or ADS-B[16], which allows them to be monitored by

[12] For example, the Euro Hawk (Global Hawk derivative) programme was cancelled in 2013 due to difficulties associated with certification for flight in European airspace [27].

[13] Discussed further in section 4.7. Examples include the Boeing/Insitu ScanEagle 3 (US), GA-ASI MQ-9B SkyGuardian (US) and Elbit Systems Hermes 900 StarLiner (Israel).

[14] Appendix F shows Restricted and Danger Areas in Australia. These may not all be accessible to military RPAS.

[15] Except at very high altitudes above the upper limits of controlled airspace.

[16] Automatic Dependent Surveillance – Broadcast.

Air Traffic Management (ATM) surveillance systems and other suitably equipped aircraft. In the US, operation of military MALE/HALE RPAS outside DoD special use airspace requires prior notification to the Secretary of Defense, or prior approval from the Secretary of Defense in the case of armed RPAS [31]. Additional information regarding MALE/HALE RPAS operations is available in [27], [32] and [33].

Certain military RPAS are known to be flown in controlled civil airspace on a routine basis in other countries. An example is the Ranger RPAS flown by the Swiss Air Force in Class C controlled airspace in Switzerland [28]. This is enabled through coordinated flight planning with civil ATC, positive ATC separation at all times and contingency measures including automated return-to-base functionality and parachute landing capability [28].

Of the FVEY nations, the US and UK are particularly active in extending military RPAS technology and capabilities into more complex roles, including:

a. Unmanned Combat Air Vehicles (UCAV) capable of operating in contested environments

b. Integration of large RPAS onboard aircraft carriers, including catapult launch and recovery

c. RPAS flying in close proximity to other aircraft for air-to-air refuelling and 'loyal wingman' operations

d. Solar-electric High Altitude Pseudo-Satellites (HAPS) capable of remaining aloft for weeks, or even months, at a time[17]

The technologies needed to enable RPAS to operate safely in these complex applications and environments may also facilitate future integration into civil airspace.

4. INTEGRATION OF RPAS INTO CIVIL AIRSPACE

4.1. Airspace Integration for RPAS

The present approach to RPAS regulation and operation in New Zealand is one of 'accommodation', meaning RPAS can operate with some level of adaptation or support that compensates for their inability to comply within existing operational constructs[18]. Accommodation allows for early RPAS flights on a temporary and transitional basis and in limited numbers before the required technology, standards and regulations are in place. Internationally, accommodation of RPAS within national airspace systems is the current norm.

In contrast, complete 'integration' refers to routine operation of RPAS in non-segregated airspace, alongside manned aviation. Complete integration will give RPAS wider access to airspace, with freedom of navigation comparable to that of

[17] Such as the Airbus Defence and Space Zephyr. HAPS may pose a particular challenge for airspace integration due to extremely limited air vehicle performance.

[18] This is based on the ICAO definition of accommodation for RPAS as stated in [35].

manned aircraft within the same class of airspace and without requiring special provisions. Integration promises to open up new commercial opportunities for civil RPAS ('drone' delivery services is an often-quoted example) and will provide greater flexibility for military RPAS. Introduction of associated technologies and procedures can be expected to result in greater operational efficiency and safety. Application of existing accommodation measures to growing numbers of RPAS may become impractical in future, leading to additional pressure for integration.

Many of the issues associated with integrating RPAS into civil airspace are outlined in [26], [28] and [34] as well as the documents listed in Appendix H.

The technological and other requirements to enable RPAS integration are discussed in section 4.2. These will likely differ across the range of RPAS platforms, mission types and classes of airspace. In some cases complete integration may not be desirable or may prove impractical. Therefore, the target level of integration needs to be defined for each use-case scenario.

The achievable level of integration is likely to be driven by three main factors:

a. *Complexity of the operating environment.* Including density and type of air traffic (e.g. IFR/VFR, transponder equipage), launch and recovery location (aerodrome, other land base or embarked on a ship), availability of ATM services etc.

b. *Capability of the RPAS.* For example, the ability to meet technical and functional requirements for the classes of airspace occupied.

c. *Mission-specific requirements.* For example, flight profile (pre-defined or dynamic/reactive[19]), time criticality, or a requirement to operate covertly.

RPAS integration is an internationally accepted goal and is included in the ICAO Aviation System Block Upgrade (ASBU) objectives[20]. In New Zealand, the Ministry of Transport is leading the development of government policy for integration of unmanned aircraft (including RPAS) into civil airspace. The National Airspace and Air Navigation Plan 2014 [36] also refers to RPAS integration.

Appendix G provides a timeline of past and planned events pertinent to RPAS integration into civil airspace in New Zealand and internationally. ICAO ASBU timescales call for accommodation until 2025, with an incremental transition towards integration from 2025 and full integration from 2031 [37]. These timescales do not preclude individual states from integrating RPAS earlier as the required technologies and other enablers become available.

However, efforts to integrate RPAS into civil airspace in other countries have not progressed at the rates originally planned. For example, the US previously aimed to have RPAS integrated into civil airspace by September 2015 [38]. The latest RPAS

[19] Dynamic/reactive refers to flight profiles that are subject to change due to inflight events. For example, the need to orbit or change altitude to inspect a contact of interest detected during the flight.

[20] The ICAO Aviation System Block Upgrade (ASBU) is a global framework for aviation system modernisation.

integration roadmaps for the US indicate that the associated development and demonstration activities will continue into the mid-2020's [39].

The following sections outline many of the fundamental principles, requirements and challenges associated with integration of RPAS into civil airspace.

4.2. Requirements for RPAS Integration into Civil Airspace

Based on a DTA review of public domain information, the requirements below appear to be widely identified in the context of enabling RPAS to be integrated into civil airspace[21,22]. This list is not exhaustive but illustrates key principles and assumptions currently put forward by civil aviation regulators, organisations representing pilots and air navigation service providers, as well as industry working groups tasked with RPAS integration in New Zealand and internationally. Most essentially require RPAS to behave like manned powered aircraft wherever possible, whilst anticipating some level of change will be required for existing aviation systems. However, some of these requirements may become superfluous as technology advances. It may also be necessary to remove traditional operational conservatisms in order to exploit the advantages offered by RPAS (such as reduced cost, or the ability to utilise RPAS in conditions that would prevent manned aircraft from flying).

a. *Maintain aviation system safety and capacity.* RPAS will need to be integrated without reducing existing capacity, decreasing safety, negatively impacting current (manned) operators, or increasing the risk to airspace users or persons and property on the ground any more than the integration of comparable novel technologies. It follows that RPAS integration should ideally not require new RPAS-specific classes of airspace between 500 ft above ground level and FL600 (the lower and upper limits of airspace typically occupied by manned aircraft) as this could reduce the airspace available for manned aviation, thereby reducing capacity[23].

b. *Compliance with existing airspace requirements and operating procedures.* Several sources state that RPAS should, as far as practicable, comply with the operational procedures and airspace requirements that exist for manned aircraft and the airspace classes in which the RPAS is operating. This includes aspects such as conformance with airspace boundaries, flight rules (VFR/IFR) including air traffic separation, as well as Communication, Navigation and Surveillance (CNS) requirements. Whilst the intent is to limit the number of new RPAS-specific requirements and procedures, the airspace and procedural requirements imposed on RPAS need to be considered relative to the capabilities of current and future RPAS technology.

[21] This review included the documents listed in Appendix H ([40], [41] and [42] are particularly relevant) as well as [28] and [43].

[22] In general, these apply only to RPAS requiring access to non-segregated airspace.

[23] Certain concepts being proposed for RPAS, such as UAS Traffic Management (UTM) and U-Space (discussed in section 4.5) may be considered a form of new RPAS-specific airspace. These concepts are primarily, but not exclusively, associated with RPAS operations at very low levels below 500 ft (below the airspace typically occupied by manned aircraft).

c. *Conformance to manned aircraft standards.* Several sources state or imply that RPAS should conform to manned aircraft standards where possible. This may include requirements for identification and registration, as well as technical requirements such as reliability, system redundancy and minimum equipage. Again, consideration will need to be given to ensuring that any standards mandated for RPAS are proportionate to the intended operations and do not inadvertently reduce the advantages that RPAS offer (such as small size, low cost and long endurance).

d. *Threshold performance requirements.* Performance requirements need to be established for RPAS, supported by appropriate infrastructure, regulations, policies, procedures, enforcement mechanisms, guidance material and training. These must be based on a detailed understanding of the unique features and capabilities of RPAS and their operations.

e. *Self-separation and collision avoidance.* Full integration will require robust technology-based solutions for RPAS as a means of ensuring airborne collision avoidance at all times and to provide safe air traffic separation whenever ATC separation service is not provided. This will represent the RPAS equivalent to the 'see and avoid' principle for manned aircraft.

f. *Detectability.* RPAS should be conspicuous to other airspace users and ATM surveillance systems as far as is practicable.

g. *Ability to communicate.* RPAS will need to maintain continuous two-way communication with ATC units when operating in controlled airspace. However, this does not imply voice over radio as the sole means of communication.

h. *Human-in-the-loop.* Several sources state that only unmanned aircraft with a designated Pilot-in-Command (e.g. RPAS) should be allowed in non-segregated airspace. This does not preclude the use of automation to carry out or augment particular functions, such as collision avoidance manoeuvres and contingency procedures. This requirement is likely to be challenged in future as automated systems become proven through extensive service experience.

i. *RPAS operator qualifications.* RPAS operators should possess appropriate aviation knowledge and qualifications to a level equivalent to pilots of manned aircraft, dependent on the nature of the operation and the type of RPAS equipment being operated.

j. *RPAS certification.* Remotely Piloted Aircraft (RPA) should be certified. Remote Pilot Stations (RPS) and control link avionics should be certified as part of the RPA certification.

k. *Contingency measures.* Procedures must be developed for RPAS failure scenarios, including events such as loss of communications, loss of Command and Control (C2) data link and loss of collision avoidance system functionality. The procedures must ensure that the RPAS executes a known and predictable response (flight trajectory) and should enable identification of the RPAS experiencing the failure condition[24].

4.3. Issues and Challenges

The complete set of issues and challenges to integrate RPAS into civil airspace depends in part on the specific RPAS platforms, capabilities and Concepts of Operation (CONOPS). However, a DTA review of public domain information identified the following issues as being broadly applicable[25]:

a. *Allowing safe BVLOS operations without natural pilot vision.* This relies on enabling RPAS to fulfil functions that are traditionally reliant on natural pilot vision and associated decision-making. Today's rules and procedures provide a basis for flying without natural pilot visibility of the surrounding environment via Instrument Flight Rules (IFR). However, there are still many visual tasks required under IFR including the responsibility placed on pilots to maintain visual separation and collision avoidance when operating outside of controlled airspace or in Visual Meteorological Conditions (VMC). Achieving an equivalent functionality for RPAS requires development of Detect-And-Avoid (DAA) technology. Video-based First Person View (FPV) systems are not currently considered to be an acceptable DAA capability due to limitations of field of view, depth perception, downlink bandwidth and signal reliability. Whilst novel DAA technology concepts are being developed with the primary aim to prevent mid-air collisions with other aircraft, it is important to note that other functions also need to be achieved to fully replace natural pilot vision (via technology or other means). These functions include the ability to:

   i. Follow 'right of way' rules for airborne and ground traffic

   ii. Detect and avoid all airborne objects, including gliders, hang-gliders, paragliders, microlights, balloons, parachutists and birds.

   iii. Determine in-flight meteorological conditions, avoid hazardous weather and comply with VFR distance-from-cloud and visibility minima

   iv. Respond to aerodrome signs, markings etc.

   v. Avoid terrain and man-made obstacles by minimum separation distances

   vi. Comply with airspace boundaries

   vii. Visually separate, sequence and follow traffic as directed by ATC

   viii. Operate during the day and at night

   ix. Operate in Visual or Instrument Meteorological Conditions (VMC/IMC)

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[24] For example, via a transponder squawk code for lost-link scenarios, as is proposed by ICAO.

[25] This review included the sources listed in Appendix H. In particular, [34], [38] and [40] identify many of the RPAS integration challenges discussed in section 4.3.

x. Respond to visual signals from intercepting aircraft, or emergency signals from the ground

b. *Satisfying Command and Control (C2) data link concerns.* These include:

i. Data link latency (communication transaction time), continuity, availability, integrity and vulnerability to interference

ii. Reliance on third party communication service providers for Beyond Radio Line Of Sight (BRLOS) operations[26]

iii. Development of acceptable contingency procedures and autonomous recovery actions to cater for C2 lost link scenarios. Common actions include returning to the point of origin, loitering in an attempt to recover the C2 link, or flight termination at or close to the current location.

iv. Radio spectrum allocation and bandwidth. New Zealand radio spectrum availability for RPAS has been raised as a particular concern by the NZDF and directly affects the use of US developed RPAS in New Zealand, as well as interoperability between NZDF RPAS and the systems of partner nations.

c. *Addressing interactions with the ATM system.* This may involve:

i. Compliance with Communication, Navigation and Surveillance (CNS) requirements for each airspace class

ii. Accommodation of unique RPAS flight profiles, which may differ significantly from point-to-point air transport profiles

iii. Unique or limited RPAS performance characteristics such as climb and descent rates, the ability to execute standard rate turns, etc.

d. *Enabling operations within complex or congested environments.* For example, wake turbulence and separation standards will have to be addressed. Integration with aerodromes may require surface manoeuvring capability (including the ability to follow taxiways and stop short at holding points) and the ability to safely launch and recover in the presence of other traffic.

e. *Establishing airworthiness certification requirements.* Applicable and sufficient certification requirements and acceptable means of compliance must be defined for RPAS. These must be supported by technical standards that cater for RPAS characteristics including:

i. New platform types and classes or categories

[26] Radio Line of Sight (RLOS) is analogous to Visual Line Of Sight (VLOS). However, RLOS and VLOS operating envelopes (e.g. maximum range) differ based on the unique transmission characteristics of radio and light.

ii. Unique performance characteristics, operating profiles, launch and recovery techniques

iii. The distributed nature of the Remotely Piloted Aircraft (RPA), Remote Pilot Station (RPS), C2 link and Launch/Recovery Equipment (LRE)

iv. New system technologies (e.g. DAA) and increased levels of automation

f. *Managing public perception.* Areas to be addressed by the NZDF include:

i. Legal and privacy concerns around the use of RPAS for surveillance

ii. How to manage potential fallout from any accidents involving NZDF RPAS operating in civil airspace

iii. Overcoming misconceptions of military RPAS being ‘killer drones’

4.4. RPAS Compatibility with the Future Aviation Environment

Major modernisation of ATM systems is currently taking place globally in line with the ICAO Aviation System Block Upgrade framework. Key national and regional programmes include the Single European Sky ATM Research Joint Undertaking (SESAR JU) in Europe, Next Generation Air Transportation System (NextGen) in the USA, OneSky in Australia and New Southern Sky (NSS) in New Zealand. Solutions for RPAS integration will need to be compatible with the future aviation environment and operating concepts that will emerge from these programmes.

Appendix H provides links to a number of CONOPS and RPAS integration roadmaps from these initiatives and others. The anticipated operating concepts for aviation in New Zealand from 2023 (which include RPAS integration) are outlined in [44].

The following concepts and technologies are being adopted in New Zealand and in many other countries. These may place requirements on RPAS, or provide new functionality and opportunities, to enable seamless airspace integration.

a. Performance Based Navigation (PBN) is being progressively introduced to enable Area Navigation (RNAV) and Required Navigation Performance (RNP) compliant operations, whereby aircraft fly optimised trajectories between waypoints instead of between ground based Navigation Aids (NAVAIDs).

b. ATM surveillance functions are transitioning from Secondary Surveillance Radar (SSR) to Global Navigation System Service (e.g. GPS) based systems such as ADS-B[27]. ADS-B offers significant advantages in terms of positional accuracy, update frequency and coverage relative to the SSR technology it will replace. A network of ground based ADS-B receivers is already

[27] A limited number of Primary Surveillance Radar (PSR) will continue to be available as a back-up surveillance system, along with a reduced network of ground based NAVAIDs.

operational in New Zealand. ADS-B OUT[28] will become mandatory for aircraft operating in New Zealand controlled airspace above Flight Level 245 (FL245) from 31 December 2018 and it is proposed that this requirement will extend to all transponder mandatory airspace from 31 December 2021 [45]. There is currently no plan to require aircraft operating outside transponder mandatory airspace to be equipped with ADS-B [45].

c. Performance-Based Communication and Surveillance (PBCS) has been implemented in the Auckland Oceanic FIR and will likely be introduced into New Zealand domestic airspace in the future. The PBCS concept specifies minimum requirements for Required Communication Performance (RCP) and Required Surveillance Performance (RSP).

d. Aeronautical information services will be increasingly based on digital systems that are capable of updating, integrating and distributing many types of aeronautical and supporting information to users in near real-time.

e. Remote ATC tower technology will be introduced at some airports.

f. Space-based (e.g. satellite-based) ADS-B surveillance may be introduced as an adjunct to the ground based ADS-B receiver network.

Other emerging aviation technologies are also likely to become available within a similar timeframe to the ATM modernisation programmes listed above. An example is ACAS X, which is expected to begin to replace TCAS II[29] (TCAS is discussed further in section 4.6.2). It is likely that RPAS will also need to be compatible with these systems.

4.5. Concepts of Operation for RPAS

Anticipated concepts for future integration of RPAS in New Zealand civil airspace are outlined in [44]. These include:

a. Civil RPAS operations will continue to be managed under Part 101 (for operations below 400 ft AGL) and under Part 102 for RPAS requiring access to civil airspace (e.g. above 500 ft AGL).

b. RPAS will operate BVLOS in a similar way to manned aircraft operating IFR in controlled airspace[30]. This will require the RPAS to have similar CNS equipment and potentially PBN capability, as well as automated return-to-base functionality to enable safe recovery in C2 lost link scenarios. DAA

[28] ADS-B OUT provides a transmit function only. ADS-B IN transmits ownship information and also receives traffic information from other ADS-B equipped aircraft.

[29] ACAS X is a next generation collision avoidance technology being developed by MIT and NASA. The system uses probabilistic models rather than hard-coded de-confliction rules. It is intended that ACAS X will provide pilots with advisories in the horizontal plane (TCAS II offers advisories in the vertical plane only, e.g. climb or descend).

[30] It is not stated in [44] how RPAS will be separated from VFR aircraft in Class D airspace. Until approved DAA systems become available, this may require positive ATC separation/vectoring (which would not usually be provided between IFR and VFR aircraft operating in Class D airspace).

technology is expected to eventually enable RPAS to operate BVLOS in a manner analogous to VFR for manned aircraft.

c. RPAS flying within VLOS will continue to operate on the basis of 'seeing and avoiding' other air traffic (as per current practice) akin to manned aircraft flying VFR.

d. Communication between remote pilots and ATC will be via VHF radio, Voice over Internet Protocol (VoIP) or digital data link.

e. Surveillance of RPAS will be via ADS-B.

It is also anticipated that frameworks and services will be introduced to manage increasing numbers of small UAS and RPAS operating in areas of otherwise uncontrolled airspace, typically at Very Low Levels (VLL) below 500 ft AGL. This domain is expected to see significant increases in automation and eventually BVLOS flights, including flights over populated areas. The terms UAS Traffic Management (UTM) and U-Space[31] are used to describe the associated concepts and systems, which include elements relating to information management, situational awareness and traffic management.

4.6. Solutions for Airspace Integration

4.6.1. Novel Technologies

Full RPAS integration and realisation of the operating concepts outlined in section 4.5 is likely to depend on successful development, demonstration and certification or approval of the following novel technologies:

a. *Detect-And-Avoid (DAA) systems.* Appendix I describes the fundamentals of DAA. Two concepts are in development:

    i. *Airborne DAA.* These systems either receive traffic information broadcast from other aircraft (via ADS-B, transponders/IFF or similar) or incorporate sensors (e.g. radar, LIDAR, EO, IR, acoustic) onboard the RPAS to detect other air traffic. The traffic information provided by these systems or sensors is combined with sensor/data fusion and threat detection, tracking and resolution logic necessary to provide self-separation and collision avoidance functions[32]. Having the entire system contained within the aircraft offers complete mobility. 'Cooperative' airborne DAA systems are already available but these are only capable of detecting other aircraft that are similarly equipped[33]. For

[31] U-Space encompasses future UTM concepts and systems for Europe. Elsewhere, the generic term UTM is used.

[32] RPAS-specific collision avoidance technologies are being developed. For example, ACAS Xu (an RPAS equivalent to ACAS X for manned aircraft) which is planned to be installed on the MQ-4C Triton RPAS [46].

[33] An example is FLARM, a DAA collision avoidance technology originally developed for gliders but also applicable to VFR aircraft and UAS/RPAS. Certain FLARM systems also incorporate additional sources of traffic information such as ADS-B, Mode C and Mode S (see [47] for details).

‘non-cooperative’ airborne DAA systems (e.g. systems capable of detecting aircraft that do not broadcast their position) the size, weight and power requirements of the airborne sensors may limit their application to large RPAS platforms only. Appendix I describes an example airborne DAA system.

ii. *Ground Based DAA.* These systems use ground based sensors (e.g. radar and/or ground based ADS-B receivers) to provide near real-time traffic visualisation to airspace users and ATC. Such a system can provide situational awareness for remote pilots of smaller RPAS platforms that are unable to accommodate their own airborne DAA systems, as well as larger legacy RPAS that are not equipped with airborne DAA[34]. Ground based DAA is, however, inherently limited to the coverage area of the fixed sensors. Appendix I describes examples of ground based DAA systems.

b. *Low Power ADS-B.* Low power, miniature ADS-B systems will help to ensure small RPAS can be monitored by suitably equipped aircraft and ATM surveillance systems (often referred to as ‘electronic conspicuity’) whilst minimising the impacts on RPAS payload capacity and radio frequency spectrum congestion[35]. Low power ADS-B systems are already commercially available but, as ADS-B only provides traffic information, it must be integrated with self-separation and collision avoidance algorithms to fulfil the functionality of a complete DAA solution. ADS-B is also limited in that it only provides the whereabouts of equipped aircraft (as discussed in section 4.4, current plans do not call for mandatory ADS-B for aircraft operating in uncontrolled airspace in New Zealand).

c. *Command and Control (C2) link technologies.* Approved digital data links are required, which will need to comply with emerging performance standards and concepts including the JARUS Required Link Performance (RLP) concept [49] and ICAO Required Communication Performance (RCP) for any ATM communications [50] transferred via the C2 data link. Data links will need to be compatible with the available radio frequency spectrum and will also need to cater for RPAS operations that extend Beyond Radio Line of Sight (BRLOS). Relevant technologies include:

i. Direct radio transmissions

ii. Terrestrial cellular networks (3G, 4G, LTE etc. and 5G in future)

iii. Radio over Internet Protocol (RoIP) / Wireless mesh networks

iv. Satellite links

[34] Such a system (Sense-And-Avoid Assistant 3 or SA3) was developed to support previous plans to operate Euro Hawk in Europe [48].

[35] For intermittent broadcasts such as ADS-B, radio spectrum congestion (e.g. co-channel interference) is a function of the output power (e.g. range) of each broadcast, the time period between broadcasts and the number of entities broadcasting on a given frequency (1090 MHz for ADS-B in New Zealand).

v. Associated security protocols and encryption

d. *UAS Traffic Management (UTM) systems.* UTM services are expected to include electronic RPAS registration and identification, electronic flight plan submission and approval, access to air traffic information to provide common situational awareness and geo-fencing[36]. A prime focus of UTM will be small UAS flying below 500 ft AGL, although UTM is not necessarily associated with specific volumes of airspace. UTM systems will not duplicate existing ATM services but will enable RPAS to interface efficiently with ATM where required.

e. *Supporting technologies such as Counter-RPAS (C-RPAS) systems.* These are likely to feature in order to address specific safety and security needs but will require legal concerns around their use to be addressed[37].

4.6.2. ACAS/TCAS

Airborne Collision Avoidance System (ACAS) or Traffic Collision Avoidance System (TCAS)[38] is also often discussed in the context of DAA solutions for RPAS. TCAS comprises airborne equipment that enables TCAS-equipped aircraft to detect nearby cooperative air traffic (e.g. aircraft equipped with a compatible altitude reporting transponder) and provides advisories to pilots when potential conflicts are identified. The current standard is TCAS II.

Whilst RPAS DAA solutions will need to be compatible with TCAS, and may even incorporate TCAS as part of a DAA system, TCAS alone does not offer a complete DAA solution:

a. TCAS II is limited to categories of aircraft capable of achieving specified performance criteria (e.g. 2500 ft per minute rate of climb) which excludes many General Aviation aircraft and RPAS.

b. TCAS is certified only as a mitigation measure for collision avoidance. TCAS is not approved as a sole means of manoeuvring aircraft and, whilst the system provides a display of nearby traffic, it provides no information regarding adherence to minimum separation standards required for normal operations.

c. TCAS only provides advisories to guide a pilot to manually control an aircraft to avoid mid-air collisions. TCAS II is not designed for RPAS, it cannot manoeuvre the aircraft automatically (which would be required in C2 lost link scenarios) and pilot advisories take no account of increased response times for RPAS due to C2 link latency.

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[36] Geo-fencing refers to the use of a virtual (GNSS based) perimeter to limit the operating area for UAS/RPAS.

[37] For example, C-RPAS techniques include those that may constitute interference with aircraft or interference with communications spectrum under existing legislation (which almost certainly did not foresee the need for C-RPAS).

[38] The terms ACAS and TCAS are often used interchangeably. Strictly speaking, ACAS refers to the performance standard and TCAS refers to the system implementation.

d. TCAS cannot detect non-cooperative traffic (e.g. aircraft without an altitude reporting transponder).

4.6.3. Other Enablers

As well as technological solutions, the broader solution space can also be expected to encompass:

a. Supporting infrastructure (e.g. ground-based ATM and related systems)

b. Technical standards to address RPAS minimum performance and interoperability. Appendix J lists standards and guidance already available, as well as a number of proposed future standards.

c. Operating procedures that cater for the unique characteristics of RPAS

d. Regulations and associated enforcement mechanisms

e. Airworthiness certification requirements and acceptable means of compliance

f. Education and training

g. NZDF policy, orders, instructions and procedures that address the specific issues associated with flying military RPAS in civil airspace

4.7. Current Developments

Whilst the activities currently being carried out to develop and demonstrate solutions relevant to RPAS integration are too numerous to adequately describe in a short report, Appendix K identifies some of the major organisations involved and the key outputs to date. Many of the activities are linked to the SESAR JU in Europe and/or NextGen in the US.

In particular, certification of airborne DAA systems will represent a significant milestone in allowing RPAS to fly BVLOS in civil airspace without complete reliance on ATC procedural separation. Cooperative DAA systems (capable of detecting other air traffic with transponders/ADS-B) may be sufficient for RPAS flying solely in transponder mandatory airspace (including all controlled airspace in New Zealand). The greater technical challenge is in developing non-cooperative DAA systems capable of detecting all airborne objects, including vintage aircraft, gliders, microlights and parachutists, which may not carry transponders or ADS-B. Non-cooperative DAA systems are likely to be required to enable unrestricted RPAS BVLOS operations in uncontrolled airspace, unless electronic conspicuity devices such as ADS-B were to be mandated for all airspace users.

To accurately assess when DAA technology might become available for widespread use, care must be taken to distinguish between DAA system certification and certification of the associated RPAS platforms for flight in civil airspace. The latter does not necessarily mean that the RPAS incorporates a certified DAA system or, in fact, any DAA system[39]. Several RPAS manufacturers claim that their RPAS products are 'certifiable' for operation in civil airspace based on compliance with the RPAS airworthiness requirements of NATO STANAG 4671 [52]. However, STANAG 4671 explicitly does not cover functional requirements for airspace integration and self-separation of aircraft via DAA systems.

A broad survey of DAA technology is provided in [51]. Examples of non-cooperative DAA systems currently in development include those for the:

a. *Elbit Systems Hermes 900 StarLiner*. The StarLiner is claimed to be qualified for flight in civil airspace [53] and is planned to be integrated into Swiss civil airspace in 2019 [54]. The aircraft incorporates cooperative and non-cooperative DAA systems (the latter using air-to-air radar), terrain avoidance warning system and automatic take-off and landing capability in near zero visibility. However, details appear to be scarce in the public domain regarding the qualification of the aircraft's DAA system and the level of integration being targeted in Switzerland.

b. *Northrop Grumman MQ-4C Triton.* Triton is expected to become the first RPAS type in service with a FVEY military to incorporate a certified non-cooperative DAA system. Whilst Triton is already flying with the US Navy, it has been reported that its DAA capability will not be available until 2021 at the earliest [55] and may not be incorporated into the US Navy fleet until 2023 [56]. The Royal Australian Air Force (RAAF) has committed to the acquisition of six Triton aircraft, which are expected to enter service in 2023 [57].

c. *GA-ASI MQ-9B SkyGuardian/SeaGuardian (Certifiable Predator B).* The associated DAA system is being developed in collaboration with NASA and the FAA. Flight testing has taken place onboard manned aircraft and the NASA Ikhana RPAS (Predator B) since 2015. Whilst SeaGuardian is planned to be certified by the lead customer (the UK MoD) in 2024, the timeframe for DAA system certification is currently unclear as the UK acquisition does not include the DAA capability[40].

In New Zealand, the following activities have demonstrated, or aim to demonstrate, aspects of RPAS integration into a shared airspace environment and/or BVLOS operation:

a. Transpower and Drone Technologies BVLOS trial using RPAS for transmission line inspections in the Remutaka Ranges (completed in February 2017). Further details are available in [60].

b. AirMap UTM system trial in Canterbury and Queenstown Lakes areas (completed in May 2018). Further details are provided in [61].

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[39] The Watchkeeper RPAS is an example. As discussed in section 3.3, this aircraft is certified to fly in UK civil airspace, however this is not routine and requires special ATM provisions as the aircraft does not have an onboard DAA system.

[40] The UK acquisition is reported to exclude the Due Regard Radar needed to detect non-cooperative aircraft [58]. The GA-ASI website also refers to the Due Regard Radar as a retrofit capability [59].

c. UTM trial in the Auckland central business district (planned for Spring 2018)

d. Trial of low power ADS-B systems onboard General Aviation aircraft and RPAS (planned for Spring 2018)

e. RPAS detection trial at Auckland International Airport (planned)

f. A number of New Zealand universities, commercial operators and RPAS manufacturers are also exploring the technology requirements to enable BVLOS operations and have signalled their intent to carry out trials. Organisations active in this area include Aeronavics, SkyBase, X-Craft, Zephyr Airworks and the University of Canterbury.

Initial discussions with stakeholders within the NZDF, CAA and Airways have indicated a level of NZDF support and engagement for these, and potentially other, development and demonstration activities.

5. CONCLUSIONS

5.1. Near Term BVLOS via Procedural Separation

The technological solutions and other enablers that are needed to enable RPAS to operate seamlessly in civil airspace are currently at varying levels of maturity. Therefore, near term NZDF RPAS BVLOS operations will require an interim approach based on resilient procedures to separate RPAS from other air traffic operating in the same airspace. Such procedures should aim to facilitate the potential capabilities and advantages that RPAS provide.

Experience from other countries has demonstrated the feasibility of using ATC procedural separation to enable safe BVLOS RPAS operations in controlled airspace on a limited basis. Whilst the approach to enable such operations will need to be agreed between the NZDF, CAA and Airways, it is likely that the procedures developed by other FVEY militaries and air navigation service providers could be adopted in a New Zealand context (or suitably adapted). This would involve:

a. *ATC separation at all times for BVLOS flights in non-segregated domestic airspace.* This will restrict RPAS to operating BVLOS in controlled airspace or in areas of uncontrolled airspace within radar or ADS-B coverage, where ATC separation service could be provided with agreement from Airways. A ground-based DAA system could also be used to provide additional awareness to the RPAS remote pilots. Ground-based DAA systems have been used by military RPAS operators in other countries since at least 2014. Such systems are commercially available and could be used as an additional mitigation for ATC-separated NZDF RPAS BVLOS operations over land. Mobile ground-based DAA systems may be able to provide the geographic flexibility needed by the NZDF.

b. *Extensive and collaborative flight planning.* This will be required to prevent or minimise potential air traffic encounters. Restrictions are likely to include avoiding populated areas and congested airspace, especially around airports and areas with a high density of VFR traffic (e.g. General Aviation), gliders, parachutists and the like.

c. *IFR flight plans for all BVLOS flights.* This may impact the ability to carry out dynamic/reactive or covert operations.

d. *BVLOS operations without ATC separation only in remote maritime areas (international airspace) void of air traffic.* Such flights will nonetheless require prior approval to ensure the level of risk is acceptable on the basis of extremely low likelihood of encountering other aircraft. Flights originating from New Zealand domestic airspace may require ATC separation during the departure and arrival phases, or activation of temporary special use airspace to provide a segregated corridor to allow the RPAS to transit to and from the remote area of operation.

e. *Approval of each BVLOS operation on the basis of a safety case risk assessment.* Development of an acceptable safety case and CONOPS for each type of operation will require close engagement between the NZDF, CAA and Airways. As applicable precedents may not exist, development of initial BVLOS safety cases is likely to involve an iterative approach. This may also be an opportunity to apply the JARUS Specific Operation Risk Assessment (SORA) framework [62]. Significant benefit might be derived from trialling the development of a BVLOS safety case on a targeted demonstration activity. In particular, flight demonstrations may be necessary to generate evidence to de-risk certain aspects of the operation. Trialling the process would also enable iterative tasks to be completed early, providing a robust foundation for subsequent NZDF RPAS introduction into service activities.

5.2. Seamless Integration via Detect-And-Avoid Technology

DAA technology will be required for NZDF RPAS to operate alongside other RPAS and inhabited aircraft in a truly integrated and seamless manner. DAA is particularly important for enabling BVLOS operations in uncontrolled airspace, where RPAS must be able to ensure self-separation and collision avoidance in the presence of cooperative and non-cooperative air traffic.

Non-cooperative airborne DAA systems are expected to be fielded on several large military RPAS types in the short to medium term. The NZDF will benefit from maintaining an awareness of relevant technology developments and certification activities carried out by the FVEY aviation authorities (military and civilian).

5.3. RPAS Integration requires Comprehensive Surveillance

Those who are responsible for air traffic separation and collision avoidance (whether air traffic controllers, pilots or RPAS remote pilots) must possess situational awareness based on comprehensive air traffic information. This is true regardless of the approach taken to fulfil these functions, e.g. procedural separation, visual self-separation, airborne DAA, ground-based DAA or combinations thereof. For RPAS and inhabited aircraft operating concurrently in shared airspace, it is likely that complete situational awareness can only be achieved via comprehensive sensor technology based surveillance.

The current proposals for air traffic surveillance in New Zealand would require aircraft to be equipped with ADS-B OUT only when operating in transponder mandatory airspace (e.g. controlled airspace). Assuming the weight and power requirements of non-cooperative airborne DAA systems will preclude their use on small and medium sized RPAS, an equivalent electronic conspicuity solution will be needed to allow BVLOS operations in uncontrolled airspace, which covers large areas of New Zealand where the NZDF will have a need to operate RPAS.

A universal mandate for all aircraft (including RPAS) operating above 500 ft AGL to equip with ADS-B OUT could facilitate BVLOS RPAS operations throughout the country, provided other risks are mitigated. ADS-B traffic data could be used directly by aircraft (including RPAS) equipped with ADS-B IN, or it could be provided indirectly via ground-based ATM infrastructure (e.g. Traffic Information Service–Broadcast, TIS-B). Separation and collision avoidance for RPAS operating in the presence of gliders, parachutists, hang gliders and microlights may need further consideration, although miniature, portable ADS-B OUT technology is already available and could potentially be employed in such activities.

The application of a single system such as ADS-B to provide positional data for every airspace user provides a unique opportunity to vastly improve situational awareness for all airspace users, with a resulting increase in safety. The ability to quickly determine the track and position of overdue aircraft should also be noted. There appears to be an opportunity for New Zealand to be a world leader in this area, consistent with the Government’s vision for a thriving, innovate and safe unmanned aircraft sector.

Current RPAS are also already fitted with uncertified GPS receivers that supply aircraft positional information to remote pilot stations in near real-time, allowing RPAS to be flown in relation to geographic features or coordinates. Integrating this positional data into ATM systems (if demonstrated to be sufficiently accurate and reliable) could provide an alternative, or additional, source of RPAS traffic information for ATC and potential distribution to airspace users.

5.4. Resilient Technology for RPAS

Robust technology is needed to ensure acceptable levels of airworthiness are achieved for RPAS, as a fundamental tenet of maintaining (or improving upon) existing levels of safety for the aviation system. Approval of RPAS technologies may initially prove challenging in the absence of comprehensive technical standards or operational experience. In such cases, demonstrations or initial restricted operations may be appropriate to gain confidence that the technology is fit-for-purpose and sufficiently robust for the level of risk associated with the intended RPAS operation.

Nonetheless, RPAS failures will inevitably occur (as they do for inhabited aircraft) so contingency measures must be developed and approved. For example:

a. Standardised C2 lost link procedures

b. Automated return-to-base or emergency landing functionality

c. Flight termination devices (such as parachutes) and procedures

In addition to safety considerations, RPAS technology adopted by the NZDF must be reliable to ensure its effectiveness from operational and cost perspectives.

5.5. Solutions to Counter Negligent and Nefarious RPAS Use

Whilst this report is primarily concerned with NZDF RPAS exploitation, counter-RPAS (C-RPAS) approaches to mitigate negligent and nefarious RPAS use, or technical failures leading to out-of-control RPAS, also need to be developed to safeguard national security.

C-RPAS considerations include a need to ensure that the technology, or combination of technologies, is sufficient for the anticipated variety of RPAS types and associated threat scenarios. Roles and responsibilities for authorising and using C-RPAS techniques will need to be determined.

C-RPAS procedures and technologies need to be assessed for compliance with respect to existing New Zealand legislation for aviation and telecommunications. This may influence the adoption of particular technologies or may indicate areas of legislation where changes should be considered.

5.6. Airspace Integration Should Support RPAS Advantages

RPAS offer potentially significant advantages over inhabited aircraft. In particular, RPAS provide an opportunity to accept more risk to the aircraft platform where there is an operational benefit. For example, RPAS could be used in conditions in which inhabited aircraft could not operate, such as search and rescue missions amongst low cloud in mountainous terrain. They also present an opportunity to mitigate risks associated with current practices. Fleeing drivers could, for example, be pursued by semi-covert RPAS, rather than police cars or helicopters, thereby reducing the risk to police personnel and other road users.

Activities are currently underway within the NZDF to identify where RPAS offer advantages for military and non-military tasks, from which NZDF RPAS CONOPS will be developed. The ability to operate BVLOS in civil airspace will enable the NZDF to detect and observe areas of interest and potential threats, and respond to them, from long ranges without putting people or crewed aircraft into harm’s way.

The operating procedures adopted to enable NZDF (and other) RPAS to be accommodated, and eventually integrated, into New Zealand civil airspace should not needlessly restrict the ability to exploit these advantages, provided mitigations are in place to enable more challenging operations.

6. RECOMMENDATIONS

6.1. Leverage Experience from FVEY Partners

The NZDF should continue engagement with the FVEY partner nations to further understand the approaches that have been used to accommodate military RPAS flights in civil airspace to date, as well as the approaches that are being developed to integrate military RPAS into civil airspace in the future. Where applicable, the NZDF should determine how these models might be implemented in New Zealand.

The NZDF should also seek to understand how the FVEY nations are intending to certify new military RPAS, particularly those with DAA capability.

6.2. NZDF RPAS CONOPS Development

The NZDF should define the anticipated CONOPS for NZDF RPAS operating in New Zealand airspace based on the mission scenarios and platform types that are emerging from the NEA, JRPAS and ASCC projects. The CONOPS should be sufficiently detailed to enable identification of NZDF requirements for RPAS access to specific areas or classes of New Zealand airspace. Robust CONOPS will be fundamental to developing a safety case for the intended operations and will be required at an early stage to support timely engagement with the CAA and Airways.

This work may also identify particular areas where the NZDF may need to take a lead in establishing solutions for RPAS integration into New Zealand civil airspace (for example, due to unique requirements or timescales).

6.3. BVLOS Flight Demonstrations

Flight demonstrations are seen as playing a key role in enabling BVLOS operations to move from the exception to the norm. The NZDF should determine how targeted BVLOS flight demonstrations could be used to:

a. Further develop NZDF understanding of RPAS airspace integration requirements, as well as identify and select optimum solutions. It is envisaged that this will involve further engagement with the CAA, Airways and potentially other RPAS operators, to develop an acceptable RPAS technical specification, operating procedures and safety case to enable BVLOS flights for NZDF RPAS in civil airspace. Potential aspects for demonstration include:

   i. Operating procedures including ATC separation for RPAS

   ii. Surveillance using low power ADS-B

   iii. Ground-based DAA systems

   iv. Geo-fencing

   v. Contingency measures for RPAS failure and malfunction scenarios

b. Prove the selected technologies and other enablers, as well as providing an opportunity to uncover and address any emergent issues, up-front of planned activities to introduce new RPAS types into NZDF service.

It may be appropriate to contract these activities to a qualified third party.

6.4. Counter-RPAS Development

The NZDF should consider its needs in relation to counter-RPAS technology and its potential role in the use of such technology within New Zealand. The NZDF should engage in any all-of-government efforts to address domestic counter-RPAS.

6.5. Consider Airspace Integration during RPAS Acquisition

The MoD and NZDF should take airspace integration requirements into account for each RPAS acquisition programme. In particular, it is recommended that Requests for Tender (RFT) incorporate appropriate wording to ensure that technical or regulatory requirements associated with airspace integration will be met within the planned timeframes for Initial Operational Capability (IOC).

6.6. Surveillance Solutions for RPAS Airspace Integration

The CAA and Airways could consider technology solutions that are capable of delivering a complete picture of air traffic operating in all classes of controlled and uncontrolled airspace. This could ensure complete situational awareness for:

a. Remote pilots operating RPAS BVLOS in all classes of airspace

b. Remote pilots operating RPAS BVLOS in airspace that may be shared with gliders, parachutists, hang gliders and microlights

c. Pilots of inhabited aircraft operating in the vicinity of small RPAS in all classes of airspace

In particular, self-separation and collision avoidance for RPAS operating BVLOS in uncontrolled airspace will likely require all air traffic to be detectable via electronic means (e.g. to carry an electronic conspicuity device).

Surveillance technologies such as ADS-B IN are available as miniature portable devices suitable for RPAS, gliders and the like, but these rely on other air traffic being suitably equipped. Broadening the proposed ADS-B OUT mandate to include uncontrolled (class G) airspace, and a wider range of airspace users, could be a significant, and relatively straightforward, step towards integration of RPAS into uncontrolled airspace and towards enhancing the safety of all airspace users[41].

[41] The National Airspace and Air Navigation Plan 2014 [36] also calls for a review of transponder requirements for uncontrolled airspace.

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75	*Due Regard Radar.* General Atomics Aeronautical Systems Inc., 2018 [viewed 22 August 2018]. Available from: http://www.ga-asi.com/due-regard-radar-developmental
76	*System Enables Drone Operators to Detect and Avoid Other Aircraft* [online]. US Department of Transportation, 2018 [viewed 12 September 2018]. Available from: https://www.volpe.dot.gov/air-traffic-systems-operations/air-traffic-management-systems/ground-based-sense-and-avoid
77	*Ground-Based Sense and Avoid Radar System.* SRC Inc., 2018 [viewed 15 October 2018]. Available from: https://www.srcinc.com/what-we-do/radar-and-sensors/gbsaa-radar-system.html

ACRONYMS

ACAS	Airborne Collision Avoidance System
ADS-B	Automatic Dependent Surveillance – Broadcast
AGL	Above Ground Level
AIP	Aeronautical Information Publication
AMSL	Above Mean Sea Level
ASBU	Aviation System Block Upgrade
ASCC	Air Surveillance Complementary Capability
ASIC	Air and Space Interoperability Council
ASTM	ASTM International (formerly American Society for Testing Materials)
ATC	Air Traffic Control
ATM	Air Traffic Management
AVO	Aviation Order
BRLOS	Beyond Radio Line Of Sight
BVLOS	Beyond Visual Line Of Sight
C2	Command and Control
CAA	Civil Aviation Authority (NZ)
CANSO	Civil Air Navigation Services Organisation
CAR	Civil Aviation Rule
CNS	Communications, Navigation and Surveillance
CONOPS	Concept of Operations
CTA	Control Area
CTR	Control Zone
DAA	Detect And Avoid
DFO	Defence Force Order
DoD	Department of Defense (US)
DTA	Defence Technology Agency (NZ)
EEZ	Exclusive Economic Zone
EVLOS	Extended Visual Line-Of-Sight
FAA	Federal Aviation Administration (US)
FASC	Future Air Surveillance Capability
FIR	Flight Information Region
FL	Flight Level
FLARM	Flight Alarm
FOV	Field Of View
FVEY	Five Eyes alliance (Australia, Canada, New Zealand, UK, USA)
GA-ASI	General Atomics Aeronautical Systems Inc.
GBDAA	Ground Based Detect And Avoid
GNSS	Global Navigation Satellite System (e.g. GPS)
GPS	Global Positioning System
HALE	High Altitude Long Endurance

HAPS	High Altitude Pseudo-Satellite
HF	High Frequency
ICAO	International Civil Aviation Organization
IFF	Identification Friend or Foe
IFR	Instrument Flight Rules
IMC	Instrument Meteorological Conditions
JARUS	Joint Authorities for Rulemaking on Unmanned Systems
JDPO	Joint Development and Planning Office
JRPAS	Joint RPAS
LIDAR	Light Detection and Ranging
LRE	Launch and Recovery Equipment
MALE	Medium Altitude Long Endurance
MASPS	Minimum Aviation System Performance Standards
MBIE	Ministry of Business, Innovation and Employment
MIT	Massachusetts Institute of Technology
MoD	Ministry of Defence
MOPS	Minimum Operational Performance Standard
MPA	Manned Powered Aircraft
MTOW	Maximum Take-Off Weight
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NATO	North Atlantic Treaty Organization
NAVAID	Navigation Aid
NEA	Network Enabled Army
NM	Nautical Mile
NOTAM	Notice to Airmen
NSS	New Southern Sky
NZDF	New Zealand Defence Force
OAA	Operating Airworthiness Authority (NZDF)
OAR	Operating Airworthiness Regulator
OAS	Operating Airworthiness Standard
PSR	Primary Surveillance Radar
PTO	Permit To Operate
RCP	Required Communications Performance
RLOS	Radio Line Of Sight
RLP	Required Link Performance
RNAV	Area Navigation
RNP	Required Navigation Performance
RNZAF	Royal New Zealand Air Force
RoIP	Radio over Internet Protocol
RPA	Remotely Piloted Aircraft
RPAS	Remotely Piloted Aircraft System
RPS	Remote Pilot Station (also known as a Ground Control Station)

RTCA	Radio Technical Commission for Aeronautics
SAA	Sense And Avoid
SAE	SAE International (formerly the Society of Automobile Engineers)
SFC	Surface
SSR	Secondary Surveillance Radar
TCAS	Traffic Alert and Collision Avoidance System
UAS	Unmanned Aircraft System
UCAV	Unmanned Combat Air Vehicle
UTM	UAS Traffic Management
VFR	Visual Flight Rules
VHF	Very High Frequency
VLL	Very Low Level (e.g. below 500 ft above ground level)
VLOS	Visual Line Of Sight
VMC	Visual Meteorological Conditions
VoIP	Voice over Internet Protocol
VTOL	Vertical Take-off and Landing

GLOSSARY OF TERMS

ADS-B IN	An ADS-B system that broadcasts ownship information (identification, position, velocity etc.) and is able to receive ADS-B information transmitted from other aircraft.
ADS-B OUT	An ADS-B system that broadcasts ownship information (identification, position, velocity etc.) only.
C2 link	The digital data link between a Remotely Piloted Aircraft (RPA) and the Remote Pilot Station (RPS) used for Command and Control (C2). The same C2 link may, or may not, also be used ATC voice and data communication. In ICAO terminology, the C2 link excludes any data link associated with the RPAS payload/sensors.
Civil Airspace	For the purpose of this report, Civil Airspace describes all areas of shared (non-segregated) airspace in the New Zealand Flight Information Region (NZ FIR) and the Auckland Oceanic FIR.
Detect-And-Avoid (DAA)	Also referred to as Sense-And-Avoid (SAA). This typically refers to a technological solution for unmanned aircraft to detect nearby air traffic, determine potential conflicts and take corrective action (e.g. achieve self-separation and avoid mid-air collisions).
New Zealand Airspace	For the purpose of this report, New Zealand airspace is considered to include all airspace in the New Zealand Flight Information Region and the Auckland Oceanic Flight Information Region. See section 2.1 for details.
Non-Cooperative	An aircraft, or other airspace user, that does not transmit an identification signal and position, either because it is not equipped with a transponder or its transponder is not functioning (e.g. unserviceable or turned off).
Segregated Airspace	Airspace designated for the exclusive use of a particular user or users.
Special Use Airspace	In New Zealand, this includes designated Danger Areas, Military Operating Areas, Restricted Areas and Volcanic Hazard Zones per CAR Part 71.
Transponder Mandatory Airspace	In New Zealand, all controlled airspace (classes A, C and D) and certain areas of Special Use Airspace may be designated as Transponder Mandatory (TM) per CAR Part 71.
Visual Line-of-Sight (VLOS)	An operation in which the remote pilot or observer maintains direct unaided visual contact with the Remotely Piloted Aircraft. There is no prescribed maximum distance and height of the Remotely Piloted Aircraft for VLOS operation in New Zealand.

APPENDIX A: RPAS CLASSIFICATION

1. INTERNATIONAL CLASSIFICATION SCHEMES

There is currently no internationally agreed classification or categorisation for Unmanned Aircraft Systems (UAS) or RPAS. Figure 5 illustrates the classification schemes adopted by a number of countries and organisations, shown on the basis of aircraft weight in kilograms.

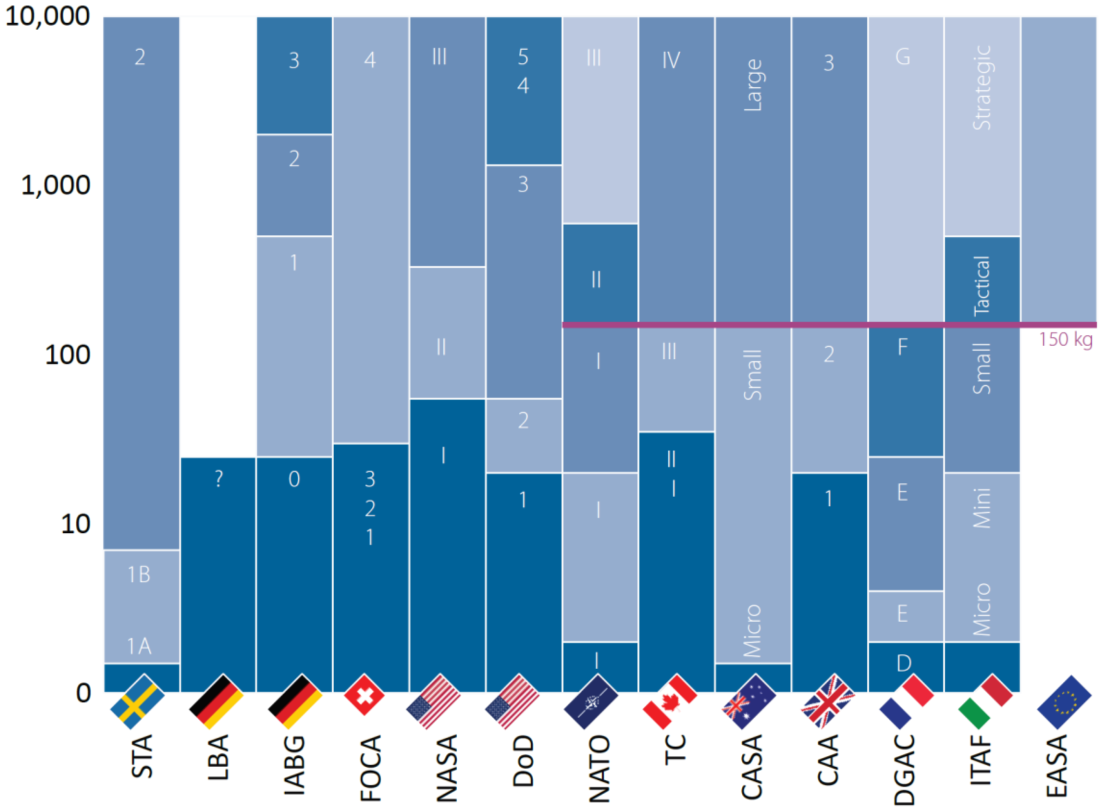

Figure 5 - RPAS classification schemes by aircraft weight (from [26])

2. NZDF RPAS CATEGORIES

The NZDF currently defines two categories of RPAS [22]:

a. *Category 1.* Any RPAS designed, constructed and maintained to standards equivalent to a Manned Powered Aircraft (MPA) and intended for use in roles and environments similar to a MPA.

b. *Category 2.* All other RPAS, for which the consequence of a catastrophic failure can reasonably be expected not to result in death or serious injury, or significant damage to property.

3. US MILITARY UAS GROUPS

The NZDF also refers to the US Department of Defense (DoD) UAS groups to describe RPAS based on aircraft physical characteristics and performance (Table 2).

Table 2 - US DoD UAS groups (from [63])

<table>
<tr><th>UAS Group</th><th>MTOW (lb)</th><th>Nominal operating altitude (ft)</th><th>Speed (kt)</th><th>Representative UAS</th></tr>
<tr><td>Group 1</td><td>0–20</td><td>< 1,200 AGL</td><td>100</td><td>RQ-11 Raven, WASP</td></tr>
<tr><td>Group 2</td><td>21–55</td><td>< 3,500 AGL</td><td rowspan="2">< 250</td><td>ScanEagle</td></tr>
<tr><td>Group 3</td><td>< 1,320</td><td rowspan="2">< FL180</td><td>RQ-7B Shadow, RQ-21 Blackjack</td></tr>
<tr><td>Group 4</td><td rowspan="2">> 1,320</td><td rowspan="2">Any</td><td>MQ-8B Fire Scout, MQ-1A/B Predator, MQ-1C Gray Eagle</td></tr>
<tr><td>Group 5</td><td>> FL180</td><td>MQ-9 Reaper, RQ-4 Global Hawk, MQ-4C Triton</td></tr>
</table>

4. NATO UAS CLASSES

The NATO UAS category descriptions (Table 3) are in common use within the NZDF, as well as 'nano' to describe RPAS <200 g.

Table 3 - NATO UAS classes and categories (from [64])

Class	Category	Normal employment	Normal Operating Altitude	Normal Mission Radius	Primary Supported Commander	Example platform
CLASS I (less than 150 kg)	SMALL >20 kg	Tactical Unit (employs launch system)	Up to 5K ft AGL	50 km (LOS)	BN/Regt, BG	Luna, Hermes 90
	MINI 2-20 kg	Tactical Sub-unit (manual launch)	Up to 3K ft AGL	25 km (LOS)	Coy/Sqn	Scan Eagle, Skylark, Raven, DH3, Aladin, Strix
	MICRO <2 kg	Tactical Pl, Sect, Individual (single operator)	Up to 200 ft AGL	5 km (LOS)	Pl, Sect	Black Widow
CLASS II (150 kg to 600 kg)	TACTICAL	Tactical Formation	Up to 10,000 ft AGL	200 km (LOS)	Bde Comd	Sperwer, Iview 250, Hermes 450, Aerostar, Ranger
CLASS III (more than 600 kg)	Strike/ Combat	Strategic/National	Up to 65,000 ft	Unlimited (BLOS)	Theatre COM	
	HALE	Strategic/National	Up to 65,000 ft	Unlimited (BLOS)	Theatre COM	Global Hawk
	MALE	Operational/Theatre	Up to 45,000 ft MSL	Unlimited (BLOS)	JTF COM	Predator B, Predator A, Heron, Heron TP, Hermes 900

APPENDIX B: AIRSPACE FOR RPAS BVLOS OPERATIONS

Table 4 lists NZDF administered airspace areas currently identified for flying RPAS BVLOS. Table 5 lists areas administered by other organisations.

Table 4 - NZDF airspace for RPAS BLVOS operations (data from [3])

<table>
<tr><th>Name</th><th>ID</th><th>Lower Limit</th><th>Upper Limit (ft)</th><th>Active</th><th>Notes</th></tr>
<tr><td>Tiritiri Matangi</td><td>NZD125</td><td>SFC</td><td>NOTAM</td><td>24h</td><td>-</td></tr>
<tr><td>Whangaparaoa Head</td><td>NZD130</td><td>SFC</td><td>1,200</td><td>24h</td><td>-</td></tr>
<tr><td>Linton Military Camp</td><td>NZM310</td><td>SFC</td><td>1200</td><td>NOTAM</td><td rowspan="7">Current NZDF RPAS Permits To Operate typically allow BVLOS operations by day and night in this airspace.</td></tr>
<tr><td>Mangahao, Wairarapa</td><td>NZD522</td><td>SFC</td><td>2500</td><td>24h</td></tr>
<tr><td>Burnham Military Camp</td><td>NZM901</td><td>SFC</td><td>1300</td><td></td></tr>
<tr><td>Kaipara Air Weapons Range:
South Head
Kaipara</td><td>
NZM103
NZM106</td><td>
SFC
SFC</td><td>
NOTAM
NOTAM</td><td>
NOTAM
NOTAM</td></tr>
<tr><td>Tekapo Military Training Area:
Pukaki
Braemar
Tekapo</td><td>
NZD926
NZD927
NZD928</td><td>
SFC
SFC
SFC</td><td>
12,500
NOTAM
NOTAM</td><td>
24h
24h
24h</td></tr>
<tr><td>Waiouru Military Training Area:
Rangipo Desert
Moawhango
Karioi Forest</td><td>
NZM300
NZM301
NZM305</td><td>
SFC
SFC
SFC</td><td>
13,000
13,000
4,500</td><td>
24h
24h
NOTAM</td></tr>
</table>

Table 5 - Other airspace for RPAS BVLOS operations (data from [3])

Name	ID	Lower Limit	Upper Limit (ft)	Active	Administering Organisation/ Authority
Kaitorete Spit, Canterbury	NZR902	SFC	1500	24h	University of Canterbury Spatial Engineering Research Centre (SERC)
Hokianga Harbour (Temporary Restricted Area)	NZR191	SFC	3000	NOTAM	Paua Interface Ltd.
Alexandra, Central Otago (proposed)*	-	SFC	7000	NOTAM	SkyBase Ltd.

In the tables above, ‘24h’ indicates permanently active airspace. ‘NOTAM’ refers to airspace activation or upper limits promulgated via a Notice to Airmen (NOTAM).

*Christchurch company SkyBase has applied for a new restricted airspace area near Alexandra aerodrome. This application is currently under public consultation. The restricted area is intended to be used for RPAS operations including BVLOS flights.

APPENDIX C: CURRENT NZDF RPAS

Table 6 identifies RPAS currently in use within the NZDF. Weight and performance data in Table 6 is based on public domain information as is indicative only.

Table 6 - NZDF RPAS

Manufacturer	Model	Image	MTOW	Performance
Aeryon	SkyRanger		2.4 kg (5.3 lb)	Endurance 50 mins Max speed 65 km/h Range 3 km Ceiling 15,000 ft
ARA Robotics	NightHawk IV		0.5 kg (1.1 lb)	Endurance 60 mins Max speed 55 km/h Range 10 km
Skycam	Kahu		3.9 kg (8.6 lb)	Endurance 2 hours Cruise speed 60 km/h Range 25 km Ceiling 16,500 ft
Physical Sciences Inc. (PSI)	InstantEye		0.7 kg (1.5 lb)	Endurance 30 mins Cruise speed 50 km/h Range 1 km Ceiling 12,000 ft
DJI	Mavic Pro		0.74 kg (1.6 lb)	Endurance 21 mins Max speed 65 km/h Range 13 km Ceiling 16,400 ft
	Phantom 4		1.4 kg (3.1 lb)	Endurance 28 mins Max speed 72 km/h Range 33 km Ceiling 19,700 ft
FLIR Systems/ Prox Dynamics	Black Hornet		16 g (0.6 oz)	Endurance 25 mins Max speed 18 km/h Range <1 km
AeroVironment	RQ-20B Puma*		6.3 kg (14 lb)	Endurance >3 hours Max speed 83 km/h Range 20 km

*Planned for future use

APPENDIX D: NZDF RPAS AIRSPACE ACCESS

Table 6 provides a general summary of the level of airspace access available to NZDF RPAS based on current Permits to Operate (PTO). Precise PTO airspace restrictions are not identical for all NZDF RPAS types.

Table 7 - Current NZDF RPAS Airspace Access

Allowed as 'routine' operations
Allowed with special req'ts or provisions
Not currently allowed

<table>
<tr><th colspan="4" rowspan="4"></th><th colspan="7">Airspace</th></tr>
<tr><th colspan="4">Non-segregated</th><th colspan="3">Segregated</th></tr>
<tr><th colspan="3">Controlled</th><th>Uncontrolled</th><th colspan="3">Special Use</th></tr>
<tr><th>Class A</th><th>Class C</th><th>Class D</th><th>Class G</th><th>Danger Area</th><th>Restricted Area</th><th>Military Operating Area</th></tr>
<tr><td rowspan="5">Air Traffic Management (ATM)</td><td>Very High Level
Instrument Flight Rules</td><td>VHL
IFR</td><td>>FL600</td><td colspan="3">N/A</td><td rowspan="5"></td><td colspan="3">N/A</td></tr>
<tr><td>Instrument Flight Rules</td><td>IFR</td><td>500 ft AGL
to FL600</td><td></td><td colspan="2" rowspan="4">PTOs do not allow flight above 400 ft AGL outside DA/MOA.
OAA approval required.</td><td rowspan="2">Current NZDF RPAS cannot fully comply with IFR or VFR</td><td rowspan="4">PTOs do not allow flight above 400 ft AGL outside DA/MOA. OAA approval required.</td><td rowspan="2">Current NZDF RPAS cannot fully comply with IFR or VFR</td></tr>
<tr><td>Visual Flight Rules</td><td>VFR</td><td>500 ft AGL
to FL275</td><td rowspan="6">N/A</td></tr>
<tr><td>Beyond Visual Line-Of-Sight</td><td>BVLOS</td><td>>400 ft AGL
>Visual range</td><td rowspan="2">Allowed, including night operations at certain camps and ranges, up to NOTAM max altitude.</td><td rowspan="2">Allowed, including night operations at certain camps and ranges, up to NOTAM max altitude.</td></tr>
<tr><td>Visual Line-Of-Sight</td><td>VLOS</td><td>>400 ft AGL
<Visual range</td></tr>
<tr><td rowspan="3">UAS Traffic Management (UTM)</td><td>Very Low Level
Beyond Visual Line-Of-Sight</td><td>VLL
BVLOS</td><td><400 ft AGL
>Visual range</td><td colspan="2">OAA approval and Air Traffic Management Plan required.</td><td>OAA approval required for BVLOS outside DA/MOA.</td><td rowspan="3">Allowed, including night operations at certain camps and ranges.</td><td>OAA approval required for BVLOS outside DA/MOA.</td><td rowspan="3">Allowed, including night operations at certain camps and ranges.</td></tr>
<tr><td>Very Low Level
Extended Visual Line-Of-Sight</td><td>VLL
EVLOS</td><td><400 ft AGL
<Visual range
(observer)</td><td colspan="2" rowspan="2">PTOs allow operations per Part 101.
Air Traffic Management Plan required.</td><td rowspan="2">PTOs allow operations per Part 101.</td><td rowspan="2">PTOs allow operations per Part 101. Approval required prior to entry.</td></tr>
<tr><td>Very Low Level
Visual Line-Of-Sight</td><td>VLL VLOS</td><td><400 ft AGL
<Visual range</td></tr>
</table>

APPENDIX E: RPAS OPERATED BY FVEY MILITARIES

Table 8 identifies RPAS types currently in operational service with the Five Eyes nations, listed in terms of US DoD UAS groups (see Appendix A for group definitions). Numbers in parentheses are indicative fleet sizes where known.

Table 8 - RPAS operated by the FVEY nations

Country	Group 1	Group 2	Group 3	Group 4	Group 5	Comments
Australia	Black Hornet RQ-11 Raven RQ-12 Wasp Phantom 4 (350*)	ScanEagle	RQ-7 Shadow S-11 Camcopter*	MQ-9 Reaper* or MQ-9B SkyGuardian*	MQ-4C Triton (6*)	Project AIR 7003 MALE RPAS selection yet to be confirmed
Canada	RQ-11 Raven	ScanEagle	RQ-21 Blackjack (5)	Heron (2)	-	Projects underway to acquire MALE RPAS, VTOL RPAS for naval frigates
New Zealand	Black Hornet NEA RPAS*	JRPAS*	-	-	-	Project to study MALE RPAS
UK	Black Hornet (324) Desert Hawk III (300)	ScanEagle	Watchkeeper (29)	-	MQ-9 Reaper (10) MQ-9B SkyGuardian (20*)	Plus various demonstrators including UCAVs
USA	Black Hornet RQ-11 Raven RQ-12 Wasp RQ-20 Puma	ScanEagle	MQ-19 Aerosonde RQ-7B Shadow (500) RQ-21 Blackjack	CQ-10 Snowgoose (15) MQ-8 Fire Scout (54) MQ-1A/B Predator MQ-1C Gray Eagle (75) MQ-25 Stringray (4*)	MQ-9 Reaper (93) RQ-4 Global Hawk (37) RQ-170 Sentinel RQ-180* MQ-4C Triton*	Plus various demonstrators including UCAVs

*Planned

Source data: Australia [65], Canada [66], UK [67], US [68] and [69]

APPENDIX F: FVEY NATIONS MILITARY AIRSPACE

Figure 6, Figure 7 and Figure 8 illustrate the areas of segregated airspace currently available for military RPAS in Australia, the US and the UK, respectively.

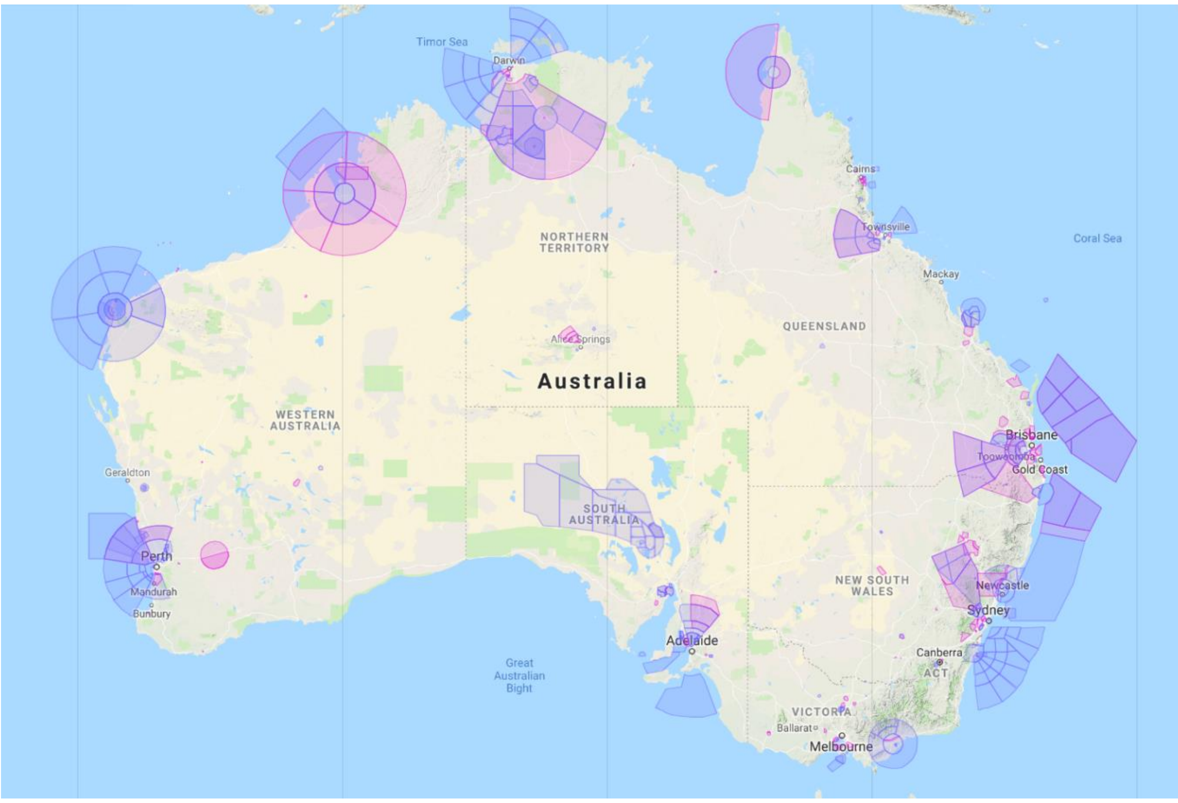

Figure 6 – Australia restricted airspace (purple) and danger areas (pink) (from [70])

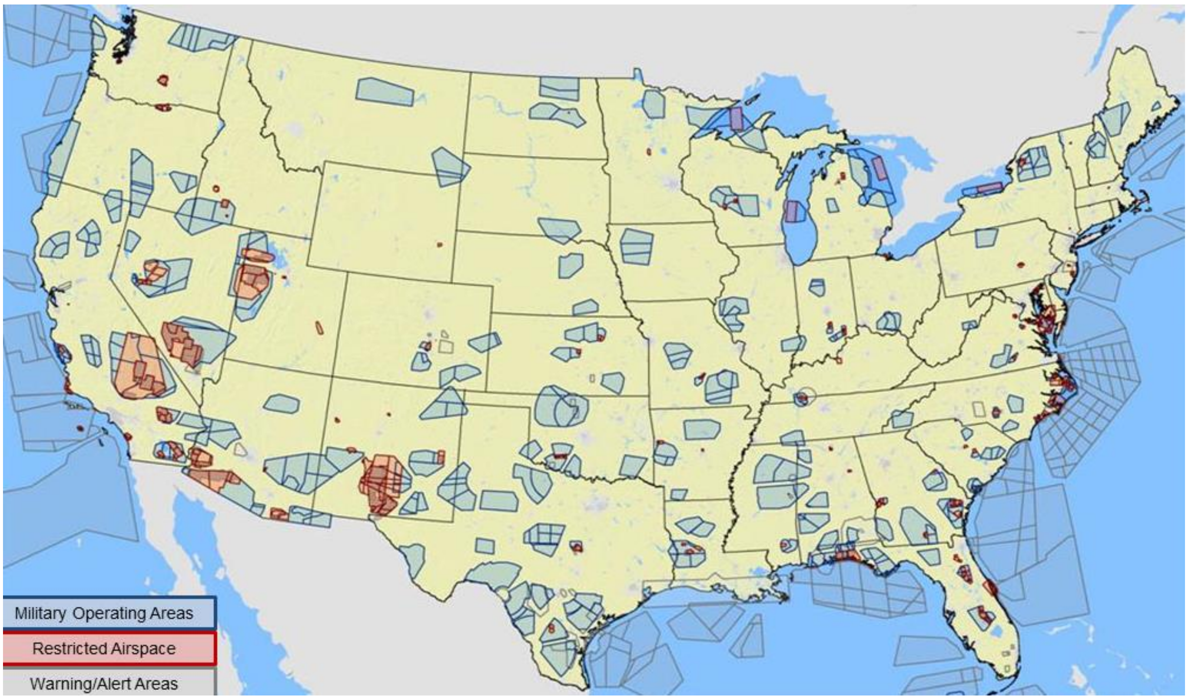

Figure 7 – US DoD special use airspace (from [72])

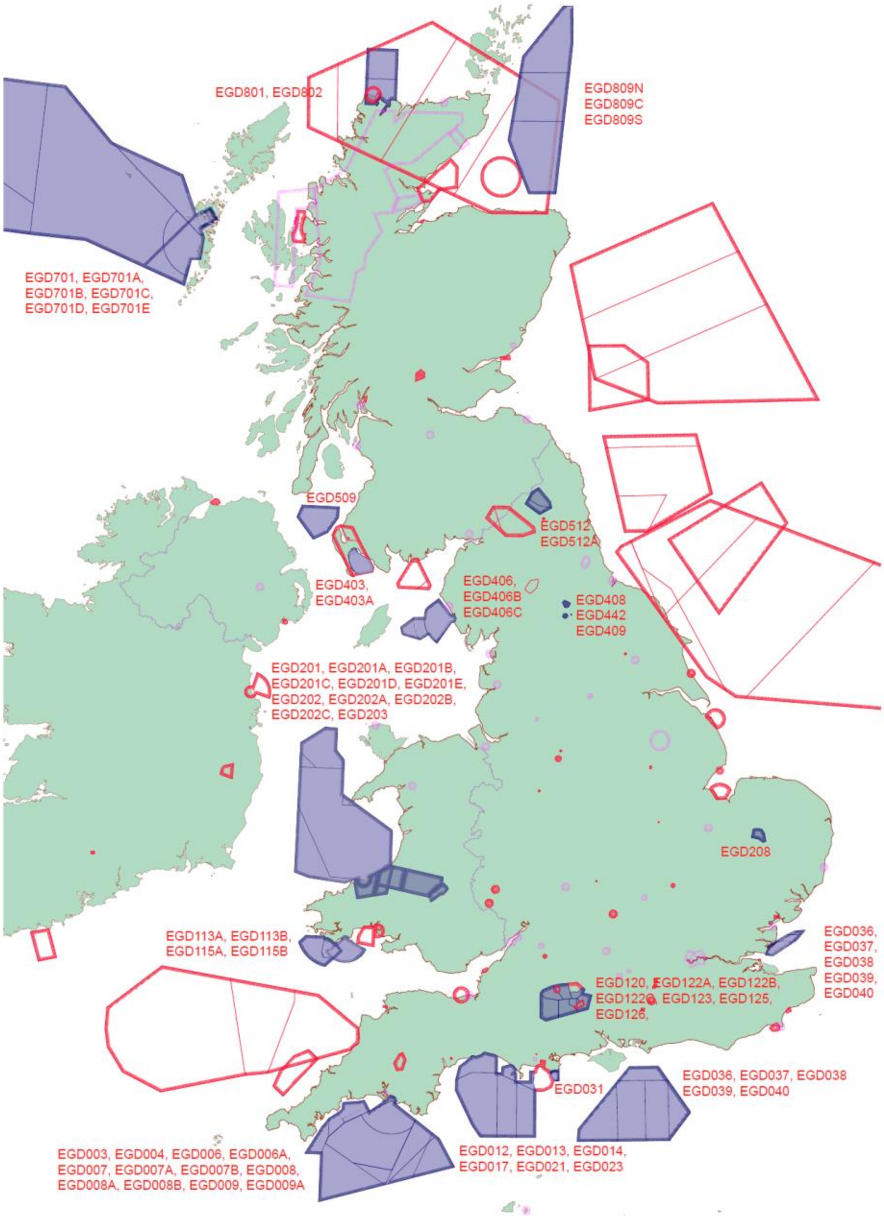

Figure 8 - Special use airspace (purple areas) for UK MoD RPAS (from [71])

APPENDIX G: RPAS AIRSPACE INTEGRATION TIMELINE

Table 9 and Table 10 illustrate the timeline of past and planned future events relating to integration of RPAS into civil airspace, respectively.

Table 9 - Past events relevant to airspace integration for RPAS

Year	Events
1997	NZ CAA introduces CAR Part 101 for model aircraft.
2004	RTCA Special Committee 203 established to address operation of UAS within the US NAS.
2007	ICAO Unmanned Aircraft Systems Study Group (UASSG) established. European Commission begins investigation of UAS regulatory framework.
2011	ICAO Circular 328 AN/190 published – first step towards international UAS regulation. NASA ‘UAS Integration in the National Airspace System’ project launched.
2012	European Commission assembles experts to develop roadmap for integration of civil RPAS.
2013	European RPAS Steering Group (ERSG) roadmap issued. RPAS added into SESAR JU objectives. RTCA Special Committee 228 replaces Special Committee 203.
2014	ICAO Remotely Piloted Aircraft Systems Panel (RPASP) established. NZ National Airspace and Air Navigation Plan ‘New Southern Sky’ approved by Cabinet.
2015	NZ CAA updated Part 101 and Part 102 promulgated. NZ strategic level Cross-Government RPAS Group established. Original planned date for RPAS integration into US civil airspace (not achieved) [35]
2016	RTCA Special Committee 228 publishes Minimum Operational Performance Standards (MOPS) for C2 links (DO-362)
2017	RTCA Special Committee 228 publishes Minimum Operational Performance Standards (MOPS) for airborne DAA (DO-365/366) Airways NZ ADS-B ground systems installation begins.
2018	First RPAS (NASA Ikhana) flight in US NAS without chase plane (e.g. reliant on DAA/TCAS for traffic separation).

Table 10 - Planned events relevant to airspace integration for RPAS

Year	Events
2018	Airways NZ ADS-B ground systems installation complete (planned). ADS-B OUT becomes mandatory for all aircraft in NZ controlled airspace above FL245.
2019	Initial operating capability for RPAS flying IFR in Class A-C airspace in Europe [42].
2020	ICAO ASBU Block 1 calls for implementation of basic procedures for operating RPAS in non-segregated airspace [73]. RTCA Special Committee 228 Phase 2 Minimum Operational Performance Standards (MOPS) for DAA and C2. Delivery of JPRAS and NEA RPAS to NZ Army and Royal NZ Navy planned to commence.
2021	ADS-B OUT proposed to become mandatory for all aircraft in transponder mandatory airspace in NZ.
2022	Initial operating capability for RPAS flying IFR in all airspace classes in Europe [42].
2023	New Southern Sky CONOPS 2023 [44] planned to be realised.
2025	ICAO ASBU Block 2 implementation calls for transition from accommodation measures towards full RPAS integration including DAA, standard C2 lost link procedures etc. [73].
2030	Initial operating capability for RPAS flying IFR and VFR in all airspace in Europe [42].
2031	ICAO ASBU Block 3 implementation calls for widespread seamless integration of RPAS into non-segregated airspace and aerodromes [73].

APPENDIX H: RPAS CONOPS AND INTEGRATION PLANS

Table 11 lists available guidance regarding the approach being adopted in New Zealand and internationally for RPAS operations and integration into civil airspace.

Table 11 – RPAS CONOPS and airspace integration roadmaps

Location	Organisation	Document
International	ICAO	RPAS CONOPS for International IFR Operations
	NATO	JAPCC Journal 20 – Article: Integrating RPAS into Non-Segregated Airspace (2015)
		JAPCC Flight Plan for UAS in NATO (2008)
		Strategic Concept of Employment for UAS in NATO (2010)
Europe	European RPAS Steering Group	Roadmap for the integration of Civil RPAS into the European Aviation System (2013)
	EASA	UAS ATM Integration Operational Concept (2018)
	Eurocontrol	U-Space CONOPS (due Jan 2019)
		RPAS ATM CONOPS Ed.4.0 (2017)
		Droning on about RPAS Integration (2016)
	SESAR JU	European ATM Master Plan: Roadmap for the Safe Integration of Drones into All Classes of Airspace (2018)
USA	NextGen JDPO	NextGen UAS R&D Roadmap v1.0 (2012)
	FAA	Integration of Civil UAS in the NAS Roadmap 2nd Ed. (2018)
		Integration of Civil UAS in the NAS Roadmap 1st Ed. (2013)
		Integration of UAS in the NAS CONOPS v2.0 (2012)
		LAANCE CONOPS v1.1 (2017)
	NASA	UTM CONOPS v1.0 (2018)
	US DoD / USAF	UAS Airspace Integration Plan v2.0 (2011)
		RPA Vector: Vision and Enabling Concepts 2013-2038
Australia	AirServices	Management of RPAS in ATM Operations v2.0 (2018)
	CASA	RPAS Integration Roadmap (due late 2018)
New Zealand	New Southern Sky Working Group	New Southern Sky CONOPS 2023 v1.0

APPENDIX I: DETECT-AND-AVOID (DAA)

1. AIRCRAFT SEPARATION AND COLLISION AVOIDANCE

Collision avoidance between aircraft in flight is achieved via a multi-layered approach that incorporates technological and procedural elements (Figure 9). Failures must occur at every level for a collision to result. The outer layers (blue) ensure separation of aircraft, while the inner layers provide collision avoidance if inadequate separation occurs. Table 12 identifies the primary measures implemented at each layer.

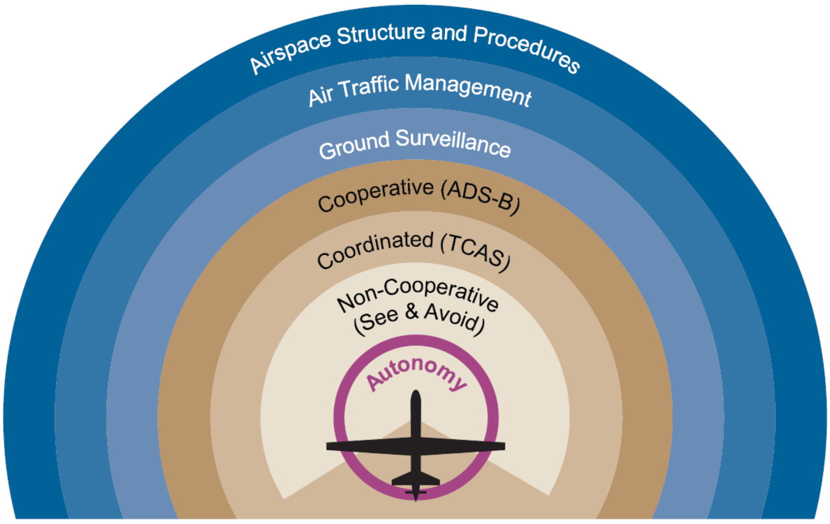

Figure 9 - Aircraft separation and collision avoidance layers (from [26])

Table 12 - Aircraft separation and collision avoidance

Layer	Function	Implementation	Details
Airspace & procedures	Separation	Airspace classes Operating rules (VFR/IFR) Minimum equipage (CNS)	
Air traffic management		ATC instructions Secondary surveillance radar and transponders/IFF ADS-B	Requires cooperative aircraft (e.g. transponder equipped)
Ground surveillance		Primary surveillance radar	Able to track non-cooperative traffic but geographically limited
Cooperative	Collision avoidance	Aircraft detect potential conflicts using transponder/ ADS-B data	Both aircraft must be equipped
Coordinated		TCAS II (provides pilot alerts and coordinated manoeuvres)	Coordinated manoeuvres requires both aircraft to be TCAS equipped
Non-cooperative		See-and-avoid (pilot vision)	RPAS equivalent will require sensors

The following considerations may dictate different DAA solutions for particular RPAS applications:

a. *DAA functionality required.* Collision avoidance and/or self-separation, ability to detect cooperative and non-cooperative traffic or cooperative traffic only.

b. *Level of automation.* For example, automated aircraft manoeuvres versus provision of guidance to enable the remote pilot to determine and execute manoeuvres.

c. *Sensor type(s).* Active (such as radar) and/or passive (such as electro-optical), adverse weather and day/night capability. This may necessitate multiple sensor types.

d. *Sensor detection range and Field Of View (FOV).* Airborne sensor positions on the airframe, sensor coverage (in azimuth and elevation) and coverage area for ground based (fixed sensor) systems.

e. *Applicability to, and compatibility with, different RPAS types.* This includes accommodating RPAS performance characteristics that may vary dramatically between different platform types and categories. Sensor size, weight and power requirements may be limiting factors for airborne DAA.

f. *Compatibility with TCAS.* This includes minimising erroneous or unnecessary TCAS advisories.

g. *The need to accommodate C2 data link latency.*

h. *The ability to function in contingency scenarios.* e.g. C2 lost link.

i. *Basic design considerations.* Such as system reliability, cost and failure modes.

2. AIRBORNE DAA – EXAMPLES

Airborne DAA technologies that rely on similar equipment being installed on conflicting aircraft are already commercially available, such as FLARM [46]. However, the major limitations of these systems are that they are not ubiquitous or mandated and are not fully interoperable with other surveillance technologies (e.g. SSR, TCAS). As a result, they do not ensure self-separation and collision avoidance for all air traffic and can only be used to complement pilot visual scans.

Development of DAA systems that are also capable of detecting non-cooperative air traffic is an ongoing challenge. The DAA system currently in development for the MQ-9B SkyGuardian offers an example of the typical components required. The system comprises:

a. ‘Due regard’ air-to-air radar (Figure 10) including a 2-piece X-band Active Electronically Scanned Array (AESA) and associated electronics to detect non-cooperative traffic. This radar has a claimed detection range of more than 10 nautical miles for small aircraft [74].

b. TCAS II (surveillance of cooperative traffic, calculates potential conflicts and alerts)

c. IFF / ADS-B (provides Mode S and ADS-B IN/OUT)

d. Sense-And-Avoid Processor including Target Tracking Module

e. Interfaces with the RPS (self-separation module, Head-Up Display (HUD) and pilot inceptors) via the RPAS digital flight control system.

Figure 10 - Due regard radar (left) installed in MQ-9B nose (right) (from [75])

3. GROUND BASED DAA – EXAMPLES

A Ground Based Detect-And-Avoid (GBDAA) system has been developed for the US Air Force (USAF) through a collaborative effort involving Raytheon, the US Department of Transportation (DoT), MIT and MITRE Corporation [76]. The USAF has utilised the system at Cannon Air Force Base in New Mexico since 2014, where it is routinely used to de-conflict military RPAS from civil air traffic. This is understood to be one of the first examples of operational GBDAA implementation for RPAS.

The GBDAA system fuses existing ATM surveillance data from three FAA radar sites to produce a common operating picture in real time. The system is capable of detecting air traffic ranging from manned aircraft to small RPAS and recommends avoidance manoeuvres for RPAS in the event that a conflict may occur. A self-contained version of this GBDAA system has also been installed within a mobile command centre that can be driven to different locations. Figure 11 illustrates a typical graphical user interface from the GBDAA system, with RPAS operating areas (green boundary), aircraft surveillance coverage area (yellow boundary) and real-time air traffic positions (blue dots) overlaid.

Another GBDAA system, called Sense-And-Avoid Assistant 3 (SA3) was developed for Euro Hawk (a derivative of the RQ-4 Global Hawk) based on a requirement identified as part of the safety case to fly the aircraft in European airspace. SA3 displays traffic detected by existing ground based radar, as well as information relating to potential conflicts, to the Euro Hawk remote pilot (Figure 12).

GBDAA systems are commercially available. An example is the Lightweight Surveillance and Target Acquisition Radar (LSTAR) based GBDAA system produced by SRC (further details are available at [77]).

Figure 11 – US DoT GBDAA user interface (from [76])

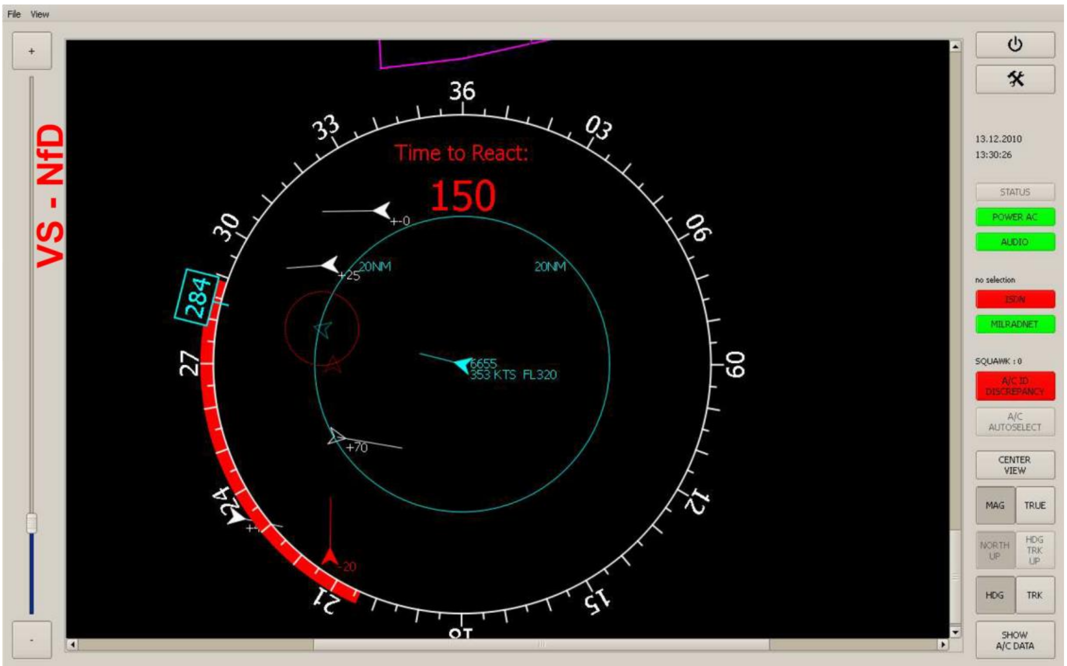

Figure 12 - Euro Hawk Sense-And-Avoid Assistant 3 user interface (from [48])

APPENDIX J: RPAS STANDARDS AND GUIDANCE

Table 13 and Table 14 list currently available and proposed future RPAS standards, respectively, as well as guidance relevant to the topics addressed within this report. As RPAS standards are evolving rapidly, these lists are not exhaustive.

Table 13 - RPAS standards and guidance documents

Topic	Document	Source
UAS General	Circular 328 AN/190 Unmanned Aircraft Systems (UAS)	ICAO
	ICAO Doc. 10019 Manual on Remotely Piloted Aircraft Systems (RPAS)	ICAO
	DO-304 Guidance Material and Considerations for UAS	RTCA
	F2851-10 UAS Registration and Marking (Excluding Small UAS)	ASTM
	F2908-16 Aircraft Flight Manual (AFM) for a Small UAS	ASTM
UAS Operations	DO-320 Operational Services and Environmental Definition for UAS	RTCA
	DO-344 Operational and Functional Requirements and Safety Objectives (OFSRO) for UAS Standards	RTCA
	ER-012 Command and Control and ATC Communications Operational Concept for RPAS	EUROCAE
	ER-014 Light RPAS Visual Line of Sight (VLOS) Operations Guidance material for Regulators and Operators	EUROCAE
	ED-238 Operational Services and Environment Definition (OSED) for Traffic Awareness and Collision Avoidance (TAACAS) in Class A and B and C Airspace for RPAS Operating under IFR	EUROCAE
	ED-251 Operational Services and Environment Definition for RPAS Automatic Taxiing	EUROCAE
	ED-252 Operational Services and Environment Definition for RPAS Automatic Take-off and Landing	EUROCAE
	EUROCONTROL-SPEC-0102 The Use of Military Unmanned Aerial Vehicles as Operational Air Traffic Outside Segregated Airspace	EURO-CONTROL
	F2849-10 Handling of UAS at Divert Airfields	ASTM
	F3178-16 Operational Risk Assessment of Small UAS	ASTM
	F3196-17 Seeking Approval for EVLOS or BVLOS Small UAS Operations	ASTM
	F3269-17 Methods to Safely Bound Flight Behavior of UAS Containing Complex Functions	ASTM

Topic	Document	Source
Airworthiness	ARP94910 Flight Control Design, Installation and Test of, Military UA	SAE
Airworthiness	ER-004 UAS Airworthiness Certification and Operational Approval	EUROCAE
Airworthiness	ER-010 UAS/RPAS Airworthiness Certification - “1309” System Safety Objectives and Assessment Criteria	EUROCAE
Airworthiness	F2909-14 Maintenance and Continued Airworthiness of Small UAS	ASTM
Airworthiness	F2910-14 Design and Construction of a Small UAS	ASTM
Airworthiness	F2911-14e1 Production Acceptance of Small UAS	ASTM
Airworthiness	F3003-14 Quality Assurance of a Small UAS	ASTM
Airworthiness	F3005-14a Batteries for Use in Small UAS	ASTM
Airworthiness	F3298-18 Design, Construction, and Verification of Fixed-Wing UAS	ASTM
Airworthiness	STANAG 4671 UAS Airworthiness Requirements	NATO
Airworthiness	STANAG 4702 Rotary Wing UAS Airworthiness Requirements	NATO
Airworthiness	STANAG 4703 Light UAS Airworthiness Requirements	NATO
Detect-And-Avoid	DO-289 Minimum Aviation System Performance Standards (MASPS) for Aircraft Surveillance Applications	RTCA
Detect-And-Avoid	DO-365 MOPS for Detect and Avoid (DAA) Systems	RTCA
Detect-And-Avoid	DO-366 Minimum Operational Performance Standards (MOPS) for Air-to-Air Radar for Traffic Surveillance	RTCA
Detect-And-Avoid	ITU-R Report M.2204 Characteristics and Spectrum Considerations for Sense-And-Avoid Systems Use on Unmanned Aircraft Systems	ITU
Software	F3201-16 Ensuring Dependability of Software Used in UAS	ASTM
Control Systems	F3002-14a Design of the Command and Control System for Small UAS	ASTM
Control Systems	STANAG 4586 Standard Interfaces of UAV Control System for NATO UAV Interoperability	NATO
C2 Data Link	AIR5645A JAUS Transport Considerations	SAE
C2 Data Link	AS5669A JAUS / SDP Transport Specification	SAE
C2 Data Link	Doc. 9869 Performance-Based Communication and Surveillance (PBCS) Manual	ICAO

Topic	Document	Source
C2 Data Link (continued)	DO-264 Guidelines for Approval of the Prevision and Use of Air Traffic Services Supported by Data Communications	RTCA
	DO-362 Command and Control (C2) Data Link MOPS (Terrestrial)	RTCA
	ER-016 RPAS 5030-5091 MHz CNPC LOS and BLOS Compatibility Study	EUROCAE
	ITU-R Report M.2171 Characteristics of UAS and Spectrum Requirements to Support their Safe Operation in Non-Segregated Airspace	ITU
	JAR_DEL_WG5_D.04 RPAS Required C2 Performance (RLP) Concept	JARUS
	STANAG 4660 – Interoperable Command and Control Data Link for Unmanned Systems (Restricted*)	NATO
	STANAG 7085 – Interoperable Data Links for Imaging Systems (Restricted*)	NATO
Training, Qualifications	AIR STD ASMG 6005 Ed 1 v1 UAS Operator Medical Standards*	ASIC
	ARP5707 Pilot Training Recommendations for UAS Civil Operations	SAE
	F3266-18 Training for Remote Pilot in Command of UAS Endorsement	ASTM

*Restricted and ASIC documents are not publicly available

Table 14 - Proposed RPAS standards and guidance documents

Topic	Document	Source
UAS General	ISO/CD 21384-1 Unmanned Aircraft Systems -- Part 1: General Specification	ISO
	ISO/CD 21895 Categorization and Classification of Civil UAS	ISO
	WK62416 Unmanned Aircraft Systems	ASTM
UAS Operations	ISO/CD 21384-3 Unmanned Aircraft Systems -- Part 3: Operational Procedures	ISO
	WK27055 Practice for UAS Remote ID and Tracking	ASTM
	WK52089 Specification for Operation over People	ASTM
	WK56338 Safety of UAS for Flying Over People	ASTM
	WK62730 for UAS Operator Audit Programs	ASTM
	WK62731 UAS Operator Compliance Audits	ASTM

Topic	Document	Source
UAS Operations	WK62744 General Operations Manual for Operator of Light UAS	ASTM
Airworthiness	ISO/CD 21384-2 Unmanned Aircraft Systems -- Part 2: Product Systems	ISO
	WK16285 Specification for Design and Performance of an Unmanned Aircraft System-Class 1320	ASTM
	WK53964 Design, Construct, and Test of VTOL	ASTM
	WK57659 Design, Construction, and Verification of Fixed-Wing UAS	ASTM
	WK59171 SUAS parachutes	ASTM
	WK60937 Design of Fuel Cells for Use in UAS	ASTM
	WK62670 Large UAS Design and Construction	ASTM
	WK62734 Development of Maintenance Manual for Lightweight UAS	ASTM
	WK62743 Development of Maintenance Manual for Small UAS	ASTM
	WK63407 Product Information to be Provided with a Small UAS	ASTM
Detect-And-Avoid	WK60936 Acoustic-based Detect and Avoid for sUAS	ASTM
	WK62668 Detect and Avoid Performance Requirements	ASTM
	WK62669 Detect and Avoid	ASTM
Training and Qualifications	WK29229 Training for Remote Pilot in Command of UAS Endorsement	ASTM
	WK60659 UAS Maintenance Technician Qualification	ASTM
	WK61763 Training for Remote Pilot Instructor (RPI) of UAS Endorsement	ASTM
	WK61764 Training for Public Safety Remote Pilot of UAS Endorsement	ASTM
	WK62733 Training and the Development of Training Manuals for the UAS Operator	ASTM
	WK62741 Training UAS Visual Observers	ASTM

APPENDIX K: ORGANISATIONS AND WORKING GROUPS

Table 15 identifies many of the key organisations and working groups that are addressing airspace integration for RPAS.

Table 15 - Organisations and working groups related to RPAS integration

Location	Organisation	Activities and Working Groups	Outputs
International	AIA	Aerospace Industries Association (https://www.aia-aerospace.org/)	Input to ISO standards (Appendix J)
	CANSO	Civil Air Navigation Services Organisation (https://www.canso.org/)	ANSP Considerations for RPAS Operations
	GUTMA	Global UAS Traffic Management Association (https://gutma.org)	UTM Architecture report
	ICAO	Unmanned Aircraft Systems Advisory Group (UAS-AG) (link)	UAS Toolkit RPAS Manual (Doc. no. 10019)
		Remotely Piloted Aircraft Systems Panel (RPASP) (link)	
	ISO	International Organization for Standardization Technical Committee 20, Sub-Committee 16 – UAS (link)	See list of standards (Appendix J)
	JARUS	Joint Authorities for Rulemaking on Unmanned Systems. Recommends requirements for UAS certification and integration on behalf of 55 NAAs. (http://jarus-rpas.org/)	JARUS publications
			Special Operations Risk Assessment (SORA)
	NATO	Joint Capability Group Unmanned Aircraft Systems (JCGUAS). Working group for organising the integration of UAS into non-segregated airspace.	See STANAGs (Appendix J)
		Flight In Non-segregated Airspace (FINAS) working group. Compiling civil documents and developing procedures for specific military requirements.	See STANAGs (Appendix J)
		Joint Air Power Competence Centre (JAPCC) (https://www.japcc.org/)	RPAS integration summary paper

Location	Organisation	Activities and Working Groups	Outputs
Europe	European Commission	European Commission (EC) (http://ec.europa.eu/growth/sectors/aeronautics/rpas_en)	-
		Expert Group on Drones (link)	-
		European RPAS Steering Group	Europe RPAS Roadmap (Appendix H)
	EASA	European Aviation Safety Agency (https://www.easa.europa.eu/)	European UAS regulation overview
	EDA	European Defence Agency (https://www.eda.europa.eu/)	EDA RPAS activities
	EURO-CONTROL	European Organisation for the Safety of Air Navigation (https://www.eurocontrol.int/)	Specifications for the use of Military RPAs outside segregated airspace
	EUROCAE	European Organisation for Civil Aviation Equipment Working Group 105 – UAS (https://www.eurocae.net/about-us/working-groups/)	See list of standards (Appendix J)
	EUSCG	European UAS Standards Coordination Group (http://www.euscg.eu/)	See list of standards (Appendix J)
			UAS Standardisation Rolling Development Plan
	ICB	Industry Consultation Body (ICB)	Impact of RPAS on ATM
	SESAR JU	Single European Sky ATM Research Joint Undertaking (https://www.sesarju.eu/) RPAS Working Group 1 – Large/MALE RPAS RPAS Working Group 2 – U-Space (key projects include CORUS for CONOPS and PODIUM for UTM demo) RPAS Working Group 3 – Standardisation and Regulation	European ATM Master Plan (eATM Portal)
			U-Space Blueprint UAS ATM Integration Concept

Location	Organisation	Activities and Working Groups	Outputs
USA	UAS Ex. Com.	Cross-Agency UAS Executive Committee	-
	ASTM	Committee F38 for UAS (https://www.astm.org/COMMITTEE/F38.htm)	See list of standards (Appendix J)
	FAA	Federal Aviation Administration (http://www.faa.gov/)	FAA UAS website
			UAS policy and regulations
		Next Generation Air Transportation System (NextGen) program (https://www.faa.gov/nextgen/)	See UAS plans and roadmaps (Appendix H)
		UAS Integration Pilot Program (IPP) (https://www.faa.gov/uas/programs_partnerships/uas_integration_pilot_program/)	-
		Alliance for System Safety of UAS through Research Excellence (ASSURE) (www.assureuas.org/)	ASSURE research outputs
	NASA	‘UAS in the National Airspace System’ project (https://www.nasa.gov/aeroresearch/programs/iasp/uas)	UAS-NAS research outputs
		‘Low Altitude UAS Traffic Management’ project (https://www.nasa.gov/ames/utm)	-
	NextGen JPDO	NextGen Joint Planning & Development Office (ceased 2014)	NextGen CONOPS (Appendix J)
	MITRE/CAASD	MITRE Corporation – Center for Advanced Aviation System Development (link)	-
	RTCA	Special Committee 228 (203) – Standards for DAA and C2 https://www.rtca.org/content/sc-228	See list of standards (Appendix J)

Location	Organisation	Activities and Working Groups	Outputs
Australia	CASA	Civil Aviation Safety Authority (https://www.casa.gov.au/)	Review of aviation safety regulation of RPAS (2018)
	AirServices	AirServices Australia (http://www.airservicesaustralia.com/)	See CONOPS (Appendix H)
New Zealand	Airways	Airways New Zealand (https://www.airways.co.nz/)	Airshare web portal
	CAA	New Zealand Civil Aviation Authority (https://www.caa.govt.nz/)	UA drones webpage
	MoT	Ministry of Transport (https://www.transport.govt.nz/)	National Airspace Policy 2012
			MoT RPA website
	NSS	New Southern Sky Working Group (https://www.nss.govt.nz/)	National Airspace and Air Navigation Plan (NAANP) 2014
	All of Government RPAS Working Groups	Strategic Level Cross-Government RPAS Group. Established 2015. Members include MoT, CAA, Airways, Callaghan Innovation, NZ Trade & Enterprise, NZDF, NZ Police, Local Govt. NZ, and Office of the Privacy Commissioner.	-
		RPAS Operators Group. Established 2017. Members: Fire and Emergency New Zealand (FENZ), Police, NZDF, Dept. of Corrections, Customs, Ministry of Primary Industries (MPI), Land Search and Rescue (LandSAR), Transpower, Department of Conservation (DOC).	-
	UAVNZ	Unmanned Aerial Vehicles New Zealand (industry body) (https://www.uavnz.com/)	-

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13. ABSTRACT

Integration of Remotely Piloted Aircraft Systems (RPAS) into civil airspace is a complex problem that is being investigated within New Zealand and internationally. For the New Zealand Defence Force (NZDF) seamless access to civil airspace would enhance RPAS operational capability for military training and non-military tasks, whereas current operational restrictions are likely to limit or preclude the use of RPAS for certain roles.

This report identifies the current issues associated with integration of NZDF RPAS into New Zealand civil airspace. This is based on a DTA review of public domain information, which illustrates the underlying principles and assumptions currently put forward by various stakeholders involved in addressing RPAS integration in New Zealand and internationally.

Technological solutions and other airspace integration enablers are also identified and discussed. Near term NZDF Beyond Visual Line Of Sight (BVLOS) RPAS operations in civil airspace will need to be accommodated via procedural air traffic separation. Seamless airspace integration for RPAS will require Detect-And-Avoid (DAA) technology that is currently in development. An opportunity is identified to facilitate RPAS operations throughout New Zealand by extending current proposals for air traffic surveillance via Automatic Dependent Surveillance–Broadcast (ADS-B) to include uncontrolled airspace.

It is recommended that demonstrations or initial restricted operations may be appropriate to gain confidence that the associated technologies and procedures are fit-for-purpose. The NZDF may also be able to leverage experience from partner countries and is well placed to take a lead role where a clear need or benefit exists.

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