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Manual on Remotely Piloted Aircraft Systems (RPAS)

Approved by the Secretary General
and published under his authority

First Edition — 2015

International Civil Aviation Organization

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FOREWORD

Remotely piloted aircraft systems (RPAS) are a new component of the aviation system, one which the International Civil Aviation Organization (ICAO), States and the industry are working to understand, define and ultimately integrate. These systems are based on cutting-edge developments in aerospace technologies, offering advancements which may open new and improved civil/commercial applications as well as improvements to the safety and efficiency of all civil aviation. The safe integration of RPAS into non-segregated airspace is a long-term activity with many stakeholders adding their expertise on such diverse topics as licensing and medical qualification of remote pilots, technologies for detect and avoid systems, frequency spectrum (including its protection from unintentional or unlawful interference), separation standards from other aircraft and development of a robust regulatory framework.

Civil aviation has, to this point, been based on the notion of a pilot operating the aircraft from within the aircraft itself and more often than not with passengers on board. Removing the pilot from the aircraft raises important technical and operational issues, the extent of which is being actively studied by the aviation community. Guidance on many of these issues is provided in this manual. As knowledge increases in the coming years, guidance for resolving the issues will become ever more refined. It is anticipated that information and data pertaining to RPAS will evolve rapidly as States and the aerospace industry advance their work and bring their input to ICAO.

The goal of ICAO in addressing RPAS is to provide an international regulatory framework through Standards and Recommended Practices (SARPs), with supporting Procedures for Air Navigation Services (PANS) and guidance material, to underpin routine operation of RPAS throughout the world in a safe, harmonized and seamless manner comparable to that of manned operations. Most importantly, introduction of remotely piloted aircraft into non-segregated airspace and at aerodromes should in no way increase safety risks to manned aircraft.

The content of this manual was developed over a period of three years with input from many groups of experts from RPAS inspectors, operators and manufacturers, pilot representatives, air navigation service providers (ANSPs), air traffic control representatives, accident investigation bureaus, human performance specialists, surveillance and communications experts and others. It is based upon the latest forms of technology available at the time of its publication. As such, it will be subject to a regular revision process that will be based on development of SARPs and PANS and input from the RPAS community.

Numerous references are made herein to ICAO Annexes, PANS, manuals and circulars. Since these documents are frequently amended, one should ensure that the document in question is current. Nothing in this manual should be construed as contradicting or conflicting with the SARPs and procedures contained in the Annexes and PANS.

Future developments

Comments on this manual would be appreciated from all parties involved in the development, oversight and operation of RPAS. These comments should be addressed to:

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GLOSSARY

ABBREVIATIONS AND ACRONYMS

| | |
|---------|---|
| ACAS | airborne collision avoidance system |
| ACP | Aeronautical Communications Panel |
| ADS-B | automatic dependent surveillance — broadcast |
| AFIS | aerodrome flight information service |
| AGL | above ground level |
| ANC | Air Navigation Commission |
| ANSP | air navigation service provider |
| ATC | air traffic control |
| ATCO | air traffic control officer |
| ATM | air traffic management |
| ATPL | airline transport pilot licence |
| ATS | air traffic services |
| BRLOS | beyond radio line-of-sight |
| BVLOS | beyond visual line-of-sight |
| C2 | command and control |
| CA | collision avoidance |
| CDL | configuration deviation list |
| CofA | certificate of airworthiness |
| CNS | communication, navigation and surveillance |
| CPA | closest point of approach |
| CPDLC | controller-pilot data link communications |
| DAA | detect and avoid |
| ELT | emergency locator transmitter |
| EM | electromagnetic |
| EUROCAE | European Organisation for Civil Aviation Equipment |
| FCC | flight control computer |
| FMS | flight management system |
| FRMS | fatigue risk management system |
| FSS | fixed satellite service |
| FSTD | flight simulation training device |
| GPWS | ground proximity warning system |
| HALE | high-altitude, long-endurance |
| HF | high frequency |
| HMI | human-machine interface |
| ICA | instructions for continuing airworthiness |
| IFR | instrument flight rules |
| IMC | instrument meteorological conditions |
| ITU/WRC | International Telecommunication Union/World Radiocommunication Conference |
| LIDAR | light detection and ranging |
| MA | manoeuvre advisories |
| MAC | mid-air collision |
| MAWS | minimum altitude warning system |
| MCM | maintenance control manual |
| METAR | aerodrome routine meteorological report |

| | |
|---------|--|
| MMEL | master minimum equipment list |
| MPL | multi-crew pilot licence |
| MTOM | maximum take-off mass |
| NextGen | next generation air transportation system |
| NM | nautical mile |
| NMAC | near mid-air collision |
| NOTAM | notice to airmen |
| PBN | performance-based navigation |
| PIC | pilot-in-command |
| PPL | private pilot licence |
| RCP | required communication performance |
| RF | radio frequency |
| RLOS | radio line-of-sight |
| ROC | RPAS operator certificate |
| RPA | remotely piloted aircraft |
| RPAS | remotely piloted aircraft system(s) |
| RPASP | Remotely Piloted Aircraft Systems Panel |
| RPS | remote pilot station(s) |
| RVSM | reduced vertical separation minimum |
| RWC | remain-well-clear |
| SARPs | Standards and Recommended Practices |
| SATCOM | satellite communication |
| SESAR | single European Sky ATM research |
| SIP | structural integrity programme |
| SLA | service level agreement |
| SLS | service level specifications |
| SMS | safety management system |
| SPECI | aerodrome special meteorological report |
| SSP | State Safety Programme |
| SSR | secondary surveillance radar |
| SWIM | system-wide information management |
| TAWS | terrain awareness warning system |
| TC | type certificate |
| TCDS | type certificate data sheet |
| TEM | threat and error management |
| TLS | target level of safety |
| Tsloss | time (sustained loss of link) |
| TSO | technical standard order |
| UAS | unmanned aircraft system |
| UASSG | Unmanned Aircraft Systems Study Group |
| UAV | unmanned aerial vehicle (<i>obsolete term</i>) |
| VFR | visual flight rules |
| VHF | very high frequency |
| VLL | very low level |
| VLOS | visual line-of-sight |
| VMC | visual meteorological conditions |

DEFINITIONS

Note.— The terms contained herein are used in the context of this manual. Terms followed by one asterisk have no official status within ICAO. A term that is used differently from a formally recognized ICAO definition is noted with two asterisks**.*

Accident. An occurrence associated with the operation of an aircraft which, in the case of a manned aircraft, takes place between the time any person boards the aircraft with the intention of flight until such time as all such persons have disembarked, or in the case of an unmanned aircraft, takes place between the time the aircraft is ready to move with the purpose of flight until such time as it comes to rest at the end of the flight and the primary propulsion system is shut down, in which:

- a) a person is fatally or seriously injured as a result of:
 - being in the aircraft, or
 - direct contact with any part of the aircraft, including parts which have become detached from the aircraft, or
 - direct exposure to jet blast,

except when the injuries are from natural causes, self-inflicted or inflicted by other persons, or when the injuries are to stowaways hiding outside the areas normally available to the passengers and crew; or

- b) the aircraft sustains damage or structural failure which:
 - adversely affects the structural strength, performance or flight characteristics of the aircraft, and
 - would normally require major repair or replacement of the affected component,

except for engine failure or damage, when the damage is limited to a single engine (including its cowlings or accessories), to propellers, wing tips, antennas, probes, vanes, tires, brakes, wheels, fairings, panels, landing gear doors, windscreens, the aircraft skin (such as small dents or puncture holes), or for minor damages to main rotor blades, tail rotor blades, landing gear, and those resulting from hail or bird strike (including holes in the radome); or

- c) the aircraft is missing or is completely inaccessible.

Aerial work. An aircraft operation in which an aircraft is used for specialized services such as agriculture, construction, photography, surveying, observation and patrol, search and rescue, aerial advertisement.

Aerodrome. A defined area on land or water (including any buildings, installations and equipment) intended to be used either wholly or in part for the arrival, departure and surface movement of aircraft.

Aeroplane. A power-driven heavier-than-air aircraft, deriving its lift in flight chiefly from aerodynamic reactions on surfaces which remain fixed under given conditions of flight.

Airborne collision avoidance system (ACAS). An aircraft system based on secondary surveillance radar (SSR) transponder signals which operates independently of ground-based equipment to provide advice to the pilot on potential conflicting aircraft that are equipped with SSR transponders.

Aircraft. Any machine that can derive support in the atmosphere from the reactions of the air other than the reactions of the air against the earth's surface.

Aircraft category. Classification of aircraft according to specified basic characteristics, e.g. aeroplane, helicopter, glider, free balloon.

Air traffic. All aircraft in flight or operating on the manoeuvring area of an aerodrome.

Air traffic control clearance. Authorization for an aircraft to proceed under conditions specified by an air traffic control unit.

Note 1.— For convenience, the term “air traffic control clearance” is frequently abbreviated to “clearance” when used in appropriate contexts.

Note 2.— The abbreviated term “clearance” may be prefixed by the words “taxi”, “take-off”, “departure”, “en route”, “approach” or “landing” to indicate the particular portion of flight to which the air traffic control clearance relates.

Air traffic control service. A service provided for the purpose of:

- a) preventing collisions:
 - 1) between aircraft, and
 - 2) on the manoeuvring area between aircraft and obstructions; and
- b) expediting and maintaining an orderly flow of air traffic.

Air traffic control unit. A generic term meaning variously, area control centre, approach control unit or aerodrome control tower.

Air traffic service. A generic term meaning variously, flight information service, alerting service, air traffic advisory service, air traffic control service (area control service, approach control service or aerodrome control service).

Air traffic services unit. A generic term meaning variously, air traffic control unit, flight information centre or air traffic services reporting office.

Appropriate ATS authority. The relevant authority designated by the State responsible for providing air traffic services in the airspace concerned.

Appropriate authority.

- a) regarding flight over the high seas: the relevant authority of the State of Registry.
- b) regarding flight other than over the high seas: the relevant authority of the State having sovereignty over the territory being overflown.

Automatic dependent surveillance — broadcast (ADS-B). A means by which aircraft, aerodrome vehicles and other objects can automatically transmit and/or receive data such as identification, position and additional data, as appropriate, in a broadcast mode via a data link.

Autonomous aircraft*. An unmanned aircraft that does not allow pilot intervention in the management of the flight.

Autonomous operation*. An operation during which a remotely piloted aircraft is operating without pilot intervention in the management of the flight.

Command and control (C2) link. The data link between the remotely piloted aircraft and the remote pilot station for the purposes of managing the flight.

Commercial air transport operation. An aircraft operation involving the transport of passengers, cargo or mail for remuneration or hire.

Conspicuity*. Quality of an aircraft (e.g. lighting or paint scheme), allowing it to be easily seen or noticed by others (e.g. by pilots, ATCOs, aerodrome personnel).

Continuing airworthiness. The set of processes by which an aircraft, engine, propeller or part complies with the applicable airworthiness requirements and remains in a condition for safe operation throughout its operating life.

Control area. A controlled airspace extending upwards from a specified limit above the earth.

Controlled aerodrome. An aerodrome at which air traffic control service is provided to aerodrome traffic.

Note.— The term “controlled aerodrome” indicates that air traffic control service is provided to aerodrome traffic but does not necessarily imply that a control zone exists.

Controlled airspace. An airspace of defined dimensions within which air traffic control service is provided in accordance with the airspace classification.

Note.— Controlled airspace is a generic term which covers ATS airspace Classes A, B, C, D and E as described in Annex 11, 2.6.

Controlled flight. Any flight which is subject to an air traffic control clearance.

Controller-pilot data link communications (CPDLC). A means of communication between controller and pilot, using data link for ATC communications.

Control zone. A controlled airspace extending upwards from the surface of the earth to a specified upper limit.

Data link communications. A form of communication intended for the exchange of messages via a data link.

Detect and avoid. The capability to see, sense or detect conflicting traffic or other hazards and take the appropriate action.

Fatigue. A physiological state of reduced mental or physical performance capability resulting from sleep loss or extended wakefulness, circadian phase, or workload (mental and/or physical activity) that can impair a crew member's alertness and ability to safely operate an aircraft or perform safety-related duties.

Fatigue risk management system (FRMS). A data-driven means of continuously monitoring and managing fatigue-related safety risks, based upon scientific principles and knowledge as well as operational experience that aims to ensure relevant personnel are performing at adequate levels of alertness.

Flight data analysis. A process of analysing recorded flight data in order to improve the safety of flight operations.

Flight duty period**. A period which commences when a remote crew member is required to report for duty that includes a flight or a series of flights and which finishes when the remote crew member's duty ends.

Flight plan. Specified information provided to air traffic services units, relative to an intended flight or portion of a flight of an aircraft.

Flight recorder.** Any type of recorder installed in the aircraft for the purpose of complementing accident/incident investigation. In the case of remotely piloted aircraft, it also includes any type of recorder installed in a remote pilot station for the purpose of complementing accident/incident investigation.

Flight time — aeroplanes. The total time from the moment an aeroplane first moves for the purpose of taking off until the moment it finally comes to rest at the end of the flight.

Note.— Flight time as here defined is synonymous with the term “block to block” time or “chock to chock” time in general usage which is measured from the time an aircraft first moves for the purpose of taking off until it finally stops at the end of the flight.

Flight time — helicopters. The total time from the moment a helicopter’s rotor blades start turning until the moment the helicopter finally comes to rest at the end of the flight, and the rotor blades are stopped.

Note 1.— The State may provide guidance in those cases where the definition of flight time does not describe or permit normal practices. Examples are: crew change without stopping the rotors and rotors running engine wash procedure following a flight. In any case, the time when rotors are running between sectors of a flight is included within the calculation of flight time.

Note 2.— This definition is intended only for the purpose of flight and duty time regulations.

Flight visibility. The visibility forward from the cockpit of an aircraft in flight.

General aviation operation. An aircraft operation other than a commercial air transport operation or an aerial work operation.

Note.— General aviation operation is applicable for manned aviation only.

Handover*. The act of passing piloting control from one remote pilot station to another.

Helicopter. A heavier-than-air aircraft supported in flight chiefly by the reactions of the air on one or more power-driven rotors on substantially vertical axes.

Note.— Some States use the term “rotorcraft” as an alternative to “helicopter”.

Human Factors principles. Principles which apply to aeronautical design, certification, training, operations and maintenance and which seek safe interface between the human and other system components by proper consideration to human performance.

Human performance. Human capabilities and limitations which have an impact on the safety and efficiency of aeronautical operations.

IFR. The symbol used to designate the instrument flight rules.

IFR flight. A flight conducted in accordance with the instrument flight rules.

Incident. An occurrence, other than an accident, associated with the operation of an aircraft which affects or could affect the safety of operation.

Note.— The types of incidents which are of interest for safety-related studies include the incidents listed in Annex 13, Attachment C.

Instructions for continuing airworthiness (ICA). A set of descriptive data, maintenance planning and accomplishment instructions, developed by a design approval holder in accordance with the certification basis for the aeronautical product. The ICAs provide air operators with the necessary information to develop their own maintenance programme and also for approved maintenance organizations to establish the accomplishment instructions.

Instrument meteorological conditions (IMC). Meteorological conditions expressed in terms of visibility, distance from cloud, and ceiling, less than the minima specified for visual meteorological conditions.

Landing area. That part of a movement area intended for the landing or take-off of aircraft.

Maintenance. The performance of tasks required to ensure the continuing airworthiness of an aircraft, including any one or combination of overhaul, inspection, replacement, defect rectification and the embodiment of a modification or repair.

Maintenance organization's procedures manual. A document which details the maintenance organization's structure and management responsibilities, scope of work, description of facilities, maintenance procedures, and quality assurance, or inspection systems. This document is normally endorsed by the head of the maintenance organization.

Maintenance programme. A document which describes the specific scheduled maintenance tasks and their frequency of completion and related procedures, such as a reliability programme, necessary for the safe operation of those aircraft to which it applies.

Manoeuvring area. That part of an aerodrome to be used for the take-off, landing and taxiing of aircraft, excluding aprons.

Master minimum equipment list (MMEL). A list established for a particular aircraft type by the organization responsible for the type design with the approval of the State of Design containing items, one or more of which is permitted to be unserviceable at the commencement of a flight. The MMEL may be associated with special operating conditions, limitations or procedures.

Minimum equipment list (MEL). A list which provides for the operation of aircraft, subject to specified conditions, with particular equipment inoperative, prepared by an operator in conformity with, or more restrictive than, the MMEL established for the aircraft type.

Movement area. That part of an aerodrome to be used for the take-off, landing and taxiing of aircraft, consisting of the manoeuvring area and the apron(s).

Operational control. The exercise of authority over the initiation, continuation, diversion or termination of a flight in the interest of the safety of the aircraft and the regularity and efficiency of the flight.

Operations manual. A manual containing procedures, instructions and guidance for use by operational personnel in the execution of their duties.

Operations specifications.** The authorizations, conditions and limitations associated with the RPAS operator certificate and subject to the conditions in the operations manual.

Operator. A person, organization or enterprise engaged in or offering to engage in an aircraft operation.

Note.— In the context of remotely piloted aircraft, an aircraft operation includes the remotely piloted aircraft system.

Remote crew member.** A crew member charged with duties essential to the operation of a remotely piloted aircraft system during a flight duty period.

Remote cruise relief pilot.** A remote flight crew member who is assigned to perform remote pilot tasks during cruise flight, to allow the remote pilot-in-command to obtain planned rest.

Remote flight crew member.** A licensed crew member charged with duties essential to the operation of a remotely piloted aircraft system during a flight duty period.

Remote pilot. A person charged by the operator with duties essential to the operation of a remotely piloted aircraft and who manipulates the flight controls, as appropriate, during flight time.

Remote pilot-in-command.** The remote pilot designated by the operator as being in command and charged with the safe conduct of a flight.

Remote pilot station. The component of the remotely piloted aircraft system containing the equipment used to pilot the remotely piloted aircraft.

Remotely piloted aircraft (RPA). An unmanned aircraft which is piloted from a remote pilot station.

Remotely piloted aircraft system (RPAS). A remotely piloted aircraft, its associated remote pilot station(s), the required command and control links and any other components as specified in the type design.

Remotely piloted aircraft system operating manual.** A manual, acceptable to the State of the Operator, containing normal, abnormal and emergency procedures, checklists, limitations, performance information, details of the RPA and each associated RPS model and other material relevant to the operation of the remotely piloted aircraft system.

Note.— The remotely piloted aircraft system operating manual is part of the operations manual.

Required communication performance (RCP). A statement of the performance requirements for operational communication in support of specific ATM functions.

Required communication performance type (RCP type). A label (e.g. RCP 240) that represents the values assigned to RCP parameters for communication transaction time, continuity, availability and integrity.

Rest period.** A continuous and defined period of time, subsequent to and/or prior to duty, during which remote crew members are free of all duties.

Risk mitigation. The process of incorporating defences or preventive controls to lower the severity and/or likelihood of a hazard's projected consequence.

Rotorcraft. A power-driven heavier-than-air aircraft supported in flight by the reactions of the air on one or more rotors.

RPA observer. A trained and competent person designated by the operator who, by visual observation of the remotely piloted aircraft, assists the remote pilot in the safe conduct of the flight.

RPAS operator certificate (ROC)*. A certificate authorizing an operator to carry out specified RPAS operations.

Safety. The state in which risks associated with aviation activities, related to, or in direct support of the operation of aircraft, are reduced and controlled to an acceptable level.

Safety management system (SMS). A systematic approach to managing safety, including the necessary organizational structures, accountabilities, policies and procedures.

Safety performance. A State or a service provider's safety achievement as defined by its safety performance targets and safety performance indicators.

Safety performance indicator. A data-based safety parameter used for monitoring and assessing safety performance.

Safety risk. The predicted probability and severity of the consequences or outcomes of a hazard.

Segregated airspace*. Airspace of specified dimensions allocated for exclusive use to a specific user(s).

State of Design. The State having jurisdiction over the organization responsible for the type design.

State of Manufacture. The State having jurisdiction over the organization responsible for the final assembly of the aircraft.

State of Registry. The State on whose register the aircraft is entered.

State of the Operator. The State in which the operator's principal place of business is located or, if there is no such place of business, the operator's permanent residence.

State safety programme (SSP). An integrated set of regulations and activities aimed at improving safety.

Target level of safety (TLS). A generic term representing the level of risk which is considered acceptable in particular circumstances.

Traffic avoidance advice. Advice provided by an air traffic services unit specifying manoeuvres to assist a pilot to avoid a collision.

Traffic information. Information issued by an air traffic services unit to alert a pilot to other known or observed air traffic which may be in proximity to the position or intended route of flight and to help the pilot avoid a collision.

Type certificate. A document issued by a Contracting State to define the design of an aircraft type and to certify that this design meets the appropriate airworthiness requirements of that State.

Unmanned free balloon. A non-power-driven, unmanned, lighter-than-air aircraft in free flight.

VFR. The symbol used to designate the visual flight rules.

VFR flight. A flight conducted in accordance with the visual flight rules.

Visibility. Visibility for aeronautical purposes is the greater of:

- a) the greatest distance at which a black object of suitable dimensions, situated near the ground, can be seen and recognized when observed against a bright background;
- b) the greatest distance at which lights in the vicinity of 1 000 candelas can be seen and identified against an unlit background.

Note 1.— The two distances have different values in air of a given extinction coefficient, and the latter b) varies with the background illumination. The former a) is represented by the meteorological optical range (MOR).

Note 2.— The definition applies to the observations of visibility in local routine and special reports, to the observations of prevailing and minimum visibility reported in the aerodrome routine meteorological report (METAR) and aerodrome special meteorological report (SPECI) and to the observations of ground visibility.

Visual line-of-sight (VLOS) operation. An operation in which the remote pilot or RPA observer maintains direct unaided visual contact with the remotely piloted aircraft.

Visual meteorological conditions (VMC). Meteorological conditions expressed in terms of visibility, distance from cloud, and ceiling, equal to or better than specified minima.

PUBLICATIONS

(referred to in this manual)

ICAO documents

Annex 1 — *Personnel Licensing*

Annex 2 — *Rules of the Air*

Annex 3 — *Meteorological Service for International Air Navigation*

Annex 6 — *Operation of Aircraft*

Part I — *International Commercial Air Transport — Aeroplanes*

Part II — *International General Aviation — Aeroplanes*

Part III — *International Operations — Helicopters*

Annex 7 — *Aircraft Nationality and Registration Marks*

Annex 8 — *Airworthiness of Aircraft*

Annex 10 — *Aeronautical Telecommunications*

Volume I — *Radio Navigation Aids*

Volume II — *Communication Procedures including those with PANS status*

Volume III — *Communication Systems*

Volume IV — *Surveillance and Collision Avoidance Systems*

Volume V — *Aeronautical Radio Frequency Spectrum Utilization*

Annex 11 — *Air Traffic Services*

Annex 13 — *Aircraft Accident and Incident Investigation*

Annex 14 — *Aerodromes*

Volume I — *Aerodrome Design and Operations*

Volume II — *Heliports*

Annex 15 — *Aeronautical Information Services*

Annex 16 — *Environmental Protection*

Volume I — *Aircraft Noise*

Annex 17 — *Security*

Annex 18 — *The Safe Transport of Dangerous Goods by Air*

Annex 19 — *Safety Management*

Convention on International Civil Aviation (Doc 7300), signed at Chicago on 7 December 1944 and amended by the ICAO Assembly

Procedures for Air Navigation Services — Air Traffic Management (PANS-ATM, Doc 4444)

Procedures for Air Navigation Services — Aircraft Operations (PANS-OPS, Doc 8168)
 Volume I — *Flight Procedures*
 Volume II — *Construction of Visual and Instrument Flight Procedures*
Procedures for Air Navigation Services — Training (PANS-TRG, Doc 9868)
Technical Instructions for the Safe Transport of Dangerous Goods by Air (Doc 9284)
Aerodrome Flight Information Service (AFIS) (Cir 211)
Air Traffic Management Security Manual (Doc 9985 — *Restricted*)
Aircraft Type Designators (Doc 8643)
Airworthiness Manual (Doc 9760)
Aviation Security Manual (Doc 8973 — *Restricted*)
Human Factors Training Manual (Doc 9683)
Manual of Civil Aviation Medicine (Doc 8984)
Manual of Procedures for Establishment and Management of a State's Personnel Licensing System (Doc 9379)
Manual on Airspace Planning Methodology for the Determination of Separation Minima (Doc 9689)
Manual on a 300 m (1 000 ft) Vertical Separation Minimum Between FL 290 and FL 410 Inclusive (Doc 9574)
Manual on Required Communication Performance (RCP) (Doc 9869)
Safety Management Manual (SMM) (Doc 9859)
Manual of Procedures for Operations Inspection, Certification and Continued Surveillance (Doc 8335)
Unmanned Aircraft Systems (UAS) (Cir 328)

Chapter 1

ICAO REGULATORY FRAMEWORK AND SCOPE OF THE MANUAL

1.1 OVERVIEW

1.1.1 Remotely piloted aircraft are one type of unmanned aircraft.¹ All unmanned aircraft, whether remotely piloted, fully autonomous or combinations thereof, are subject to the provisions of Article 8 of the *Convention on International Civil Aviation* (Doc 7300), signed at Chicago on 7 December 1944 and amended by the ICAO Assembly.

1.1.2 This chapter addresses the history and the foundations of the legal framework as well as the purpose and scope of this manual.

1.2 HISTORY OF THE LEGAL FRAMEWORK

1.2.1 The development of the legal framework for international civil aviation started with the Paris Convention of 13 October 1919.

1.2.2 The Protocol of 15 June 1929 amending the Paris Convention refers to pilotless aircraft in a subparagraph of Article 15 as follows:

“No aircraft of a contracting State capable of being flown without a pilot shall, except by special authorization, fly without a pilot over the territory of another contracting State”².

1.2.3 The Chicago Convention of 7 December 1944 replaced the Paris Convention. Article 8 of the Chicago Convention entitled “Pilotless aircraft” provides that:

“No aircraft capable of being flown without a pilot shall be flown without a pilot over the territory of a contracting State without special authorization by that State and in accordance with the terms of such authorization. Each contracting State undertakes to insure that the flight of such aircraft without a pilot in regions open to civil aircraft shall be so controlled as to obviate danger to civil aircraft”.

1.2.4 To understand the implications of Article 8 and its incorporation from the Paris Convention of 1919 (Article 15) into the Chicago Convention of 1944, the intent of the drafters must be considered. Remotely controlled and uncontrolled (autonomous) aircraft were already in existence at the time of the First World War, operated by both civil and military entities. “Aircraft flown without a pilot” therefore refers to the situation where there is no pilot on board the aircraft.

1.2.5 The Eleventh Air Navigation Conference (ANConf/11), Montréal, 22 September to 3 October 2003)

1 Annex 7 — *Aircraft Nationality and Registration Marks*.

2 This subparagraph of the Article 15 was modified to read as above by a Protocol dated in Paris 15 June 1929, which entered into force on 17 May 1933.

endorsed the global air traffic management (ATM) operational concept which contains the following text: “[a]n unmanned aerial vehicle is a pilotless aircraft, in the sense of Article 8 of the Convention on International Civil Aviation, which is flown without a pilot in-command on-board and is either remotely and fully controlled from another place (ground, another aircraft, space) or programmed and fully autonomous.”

1.2.6 This understanding of unmanned aerial vehicles (UAVs) was endorsed by the 35th Session of the ICAO Assembly in 2004.

1.2.7 As a consequence, any unmanned aircraft is a “pilotless” aircraft, consistent with the intent of the drafters of Article 8. Emphasis was placed on the significance of the provision that aircraft flown without a pilot on board “should be so controlled as to obviate danger to civil aircraft”, indicating that the drafters recognized that “pilotless aircraft” must have a measure of control applied to them in relation to a so-called “due regard” obligation, similar to that of State aircraft.

1.2.8 On 12 April 2005, during the first meeting of its 169th Session, the Air Navigation Commission (ANC) requested the Secretary General to consult selected States and international organizations with respect to present and foreseen international civil unmanned aerial vehicle (UAV) activities in civil airspace; procedures to obviate danger to civil aircraft posed by UAVs operated as State aircraft; and procedures that might be in place for the issuance of special operating authorizations for international civil UAV operations.

1.2.9 Subsequently, a first ICAO exploratory meeting on UAVs was held in Montréal on 23 and 24 May 2006. Its objective was to determine the potential role of ICAO in UAV regulatory development work. The meeting agreed that, although there would eventually be a wide range of technical and performance specifications and standards, only a portion of those would need to become ICAO Standards and Recommended Practices (SARPs). It was also determined that ICAO was not the most suitable body to lead the effort to develop such specifications. However, it was agreed that there was a need for harmonization of terms, strategies and principles with respect to the regulatory framework and that ICAO should act as a focal point.

1.2.10 The second informal ICAO meeting (Palm Coast, Florida, 11 and 12 January 2007) concluded that work on technical specifications for UAV operations was well underway within both RTCA Inc. and the European Organisation for Civil Aviation Equipment (EUROCAE) and was being adequately coordinated through a joint committee of their two working groups. The main issue for ICAO was, therefore, related to the need to ensure safety and uniformity in international civil aviation operations. In this context, it was agreed that there was no specific need for new ICAO SARPs at that early stage. However, there was a need to harmonize notions, concepts and terms. The meeting agreed that ICAO should coordinate the development of a strategic guidance document that would guide the regulatory evolution. Even though non-binding, the guidance document would be used as the basis for development of regulations by the various States and organizations. As regulatory material developed by States and organizations gained maturity, such material could be proposed for inclusion in the ICAO guidance document. The document would then serve as the basis for achieving consensus in the later development of SARPs.

1.2.11 The meeting felt strongly that the eventual development of SARPs should be undertaken in a well-coordinated manner. Because this was a newly emerging technology, it was felt that there was a unique opportunity to ensure harmonization and uniformity at an early stage and that all ICAO efforts should be based on a strategic approach and should support the emerging work of other regulatory bodies. The meeting had also suggested that from this point onwards, the subject should be referred to as (UAS, in line with RTCA and EUROCAE agreements).

1.2.12 Finally, it was concluded that ICAO should serve as a focal point for global interoperability and harmonization, to develop a regulatory concept, to coordinate the development of UAS SARPs, to contribute to the development of technical specifications by other bodies, and to identify communication requirements for UAS activity.

1.2.13 In order to assist ICAO in fulfilling the identified aims, the ANC, at the Second Meeting of its 175th Session on 19 April 2007, approved the establishment of the Unmanned Aircraft Systems Study Group (UASSG), where the following Terms of Reference and Work Programme were defined:

UASSG Terms of Reference:

In light of rapid technological advances, to assist the Secretariat in coordinating the development of ICAO Standards and Recommended Practices (SARPs), Procedures and Guidance material for civil unmanned aircraft systems (UAS), to support a safe, secure and efficient integration of UAS into non-segregated airspace and aerodromes.

UASSG Work Programme:

- a) serve as the focal point and coordinator of all ICAO UAS related work, with the aim of ensuring global interoperability and harmonization;
- b) develop a UAS regulatory concept and associated guidance material to support and guide the regulatory process;
- c) review ICAO SARPs, propose amendments and coordinate the development of UAS SARPs with other ICAO bodies;
- d) contribute to the development of technical specifications by other bodies (e.g., terms, concepts), as requested; and
- e) coordinate with the ICAO Aeronautical Communications Panel (ACP), as needed, to support development of a common position on bandwidth and frequency spectrum requirements for command and control of UAS for the International Telecommunication Union (ITU)/World Radiocommunication Conference (WRC) negotiations.

1.2.14 The UASSG first considered introducing the term “remotely piloted” at its third meeting, 15 to 18 September 2009, after reaching the conclusion that only unmanned aircraft that are remotely piloted could be integrated alongside manned aircraft in non-segregated airspace and at aerodromes. The study group therefore decided to narrow its focus from all UAS to those that are remotely piloted.

1.2.15 The UASSG developed the *Unmanned Aircraft Systems (UAS)* (Cir 328) which was published in March 2011. The circular provided States with an overview of issues that would have to be addressed in the Annexes to ensure remotely piloted aircraft system(s) (RPAS) would be compliant with the provisions of the Chicago Convention. In March 2012, the first significant package of SARPs related to RPAS was adopted for Annex 2 — *Rules of the Air* and Annex 7 — *Aircraft Nationality and Registration Marks*. The UASSG then turned its attention to the development of the first edition of this manual.

Remotely Piloted Aircraft Systems Panel (RPASP)

1.2.16 On 6 May 2014, the ANC, at the Second Meeting of its 196th Session, agreed to the establishment of the RPASP which was tasked with progressing the work begun by the UASSG and given the following objectives:

- a) serve as the focal point and coordinator of all ICAO RPAS-related work, with the aim of ensuring global interoperability and harmonization;
- b) develop an RPAS regulatory concept and associated guidance material to support and guide the regulatory process;

- c) review ICAO SARPs, propose amendments and coordinate the development of RPAS SARPs with other ICAO expert groups;

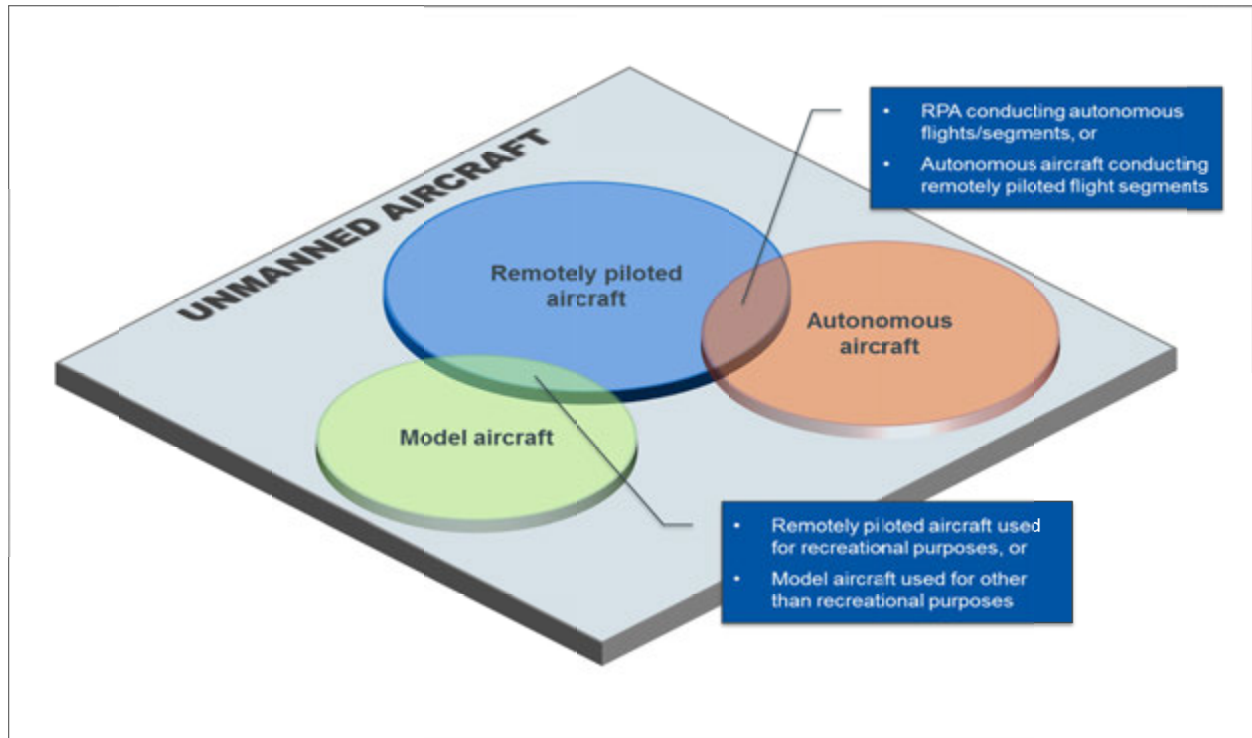


Figure 1-1. Unmanned aircraft

- d) assess impacts of proposed provisions on existing manned aviation; and
- e) coordinate, as needed, to support development of a common position on bandwidth and frequency spectrum requirements for command and control of RPAS for the International Telecommunication Union (ITU)/World Radio Communication Conference (WRC) negotiations.

1.3 FOUNDATIONS OF THE LEGAL FRAMEWORK

Introduction

1.3.1 Specific rights and obligations have been agreed by Contracting³ States in order that international civil aviation may be developed in a safe and orderly manner and that international air transport services may be established on the basis of equality of opportunity and operated soundly and economically. These rights and obligations will, in principle, apply equally to both manned and unmanned civil aircraft. Implications of several Articles of the Chicago Convention are addressed below.

³ The term Contracting State is used when reference is made to the Chicago Convention and Member State is used in connection with ICAO membership.

Specific articles and their applicability to RPAS

Article 3 bis

“... b) The contracting States recognize that every State, in the exercise of its sovereignty, is entitled to require the landing at some designated airport of a civil aircraft flying above its territory without authority ... it may also give such aircraft any other instructions to put an end to such violations. ...”

c) Every civil aircraft shall comply with an order given in conformity with paragraph b) of this Article ...”

1.3.2 Contracting States are entitled, in certain circumstances, to require civil aircraft flying above their territory to land at designated aerodromes, per Article 3 bis b) and c). Therefore, the pilot of the RPA will have to be able to comply with instructions provided by the State, including through electronic or visual means, and have the ability to divert to the specified airport at the State’s request. The requirement to respond to instructions based on such visual means may place significant requirements on certification of RPA detect and avoid (DAA) systems for international flight operations.

Article 8

“Pilotless aircraft

No aircraft capable of being flown without a pilot shall be flown without a pilot over the territory of a contracting State without special authorization by that State and in accordance with the terms of such authorization. Each contracting State undertakes to insure that the flight of such aircraft without a pilot in regions open to civil aircraft shall be so controlled as to obviate danger to civil aircraft.”

1.3.3 The background and implications of Article 8 are discussed above in 1.2.

1.3.4 Standards to facilitate application and processing of the mandated requests for authorization are contained in Appendix 4 to Annex 2. It is envisaged that once the broad range of SARPs are adopted for each of the Annexes affected, Contracting States will be able to facilitate and foster international operations of RPAS to a similar extent as that being enjoyed by manned aviation.

Article 12

Rules of the Air

“Each contracting State undertakes to adopt measures to insure that every aircraft flying over or maneuvering within its territory and that every aircraft carrying its nationality mark, wherever such aircraft may be, shall comply with the rules and regulations relating to the flight and maneuver of aircraft there in force. Each contracting State undertakes to keep its own regulations in these respects uniform, to the greatest possible extent, with those established from time to time under this Convention. Over the high seas, the rules in force shall be those established under this Convention. Each contracting State undertakes to insure the prosecution of all persons violating the regulations applicable.”

1.3.5 The rules of the air apply to all aircraft, manned or unmanned. Furthermore, they oblige Contracting States to maintain national regulations uniform with ICAO Standards, to the greatest possible extent, and to prosecute all persons violating them. This is the basis for international harmonization and interoperability, which is as essential for unmanned as manned operations to be conducted safely.

1.3.6 In accordance with Article 12 and Annex 2, the PIC is responsible for the operation of the aircraft in compliance with the rules of the air. This also extends to having final authority as to the disposition of the aircraft while in command. This is true whether serving as an on-board pilot or a remote pilot.

Article 15

Airport and similar charges

“Every airport in a contracting State which is open to public use by its national aircraft shall likewise, subject to the provisions of Article 68, be open under uniform conditions to the aircraft of all the other contracting States. ...”

1.3.7 This provision applies equally to RPA. Contracting States remain free to permit civil RPA operations only to/from designated aerodromes, providing that no discrimination is introduced with respect to national or foreign registration of the aircraft.

Article 29

Documents carried in aircraft

“Every aircraft of a contracting State, engaged in international navigation, shall carry the following documents in conformity with the conditions prescribed in this Convention:

- a) Its certificate of registration;
- b) Its certificate of airworthiness;
- c) The appropriate licenses for each member of the crew;
- d) Its journey log book;
- e) If it is equipped with radio apparatus, the aircraft radio station license;
- f) If it carries passengers, a list of their names and places of embarkation and destination; and
- g) If it carries cargo, a manifest and detailed declarations of the cargo.”

1.3.8 Regarding Article 29, every aircraft of a Contracting State engaged in international navigation shall carry the specified documents on board the aircraft. For an RPA, carrying paper originals of these documents may neither be practical nor appropriate. Use of electronic versions of these documents may be considered. This subject is addressed in Chapter 6, 6.6.

Article 31

Certificates of airworthiness

“Every aircraft engaged in international navigation shall be provided with a certificate of airworthiness issued or rendered valid by the State in which it is registered.”

1.3.9 Article 31 applies equally to remotely piloted aircraft (RPA) engaged in international navigation; however, differences will be faced on how airworthiness will be determined. Airworthiness and certification are addressed in Chapter 4.

Article 32

Licenses of personnel

“a) The pilot of every aircraft and the other members of the operating crew of every aircraft engaged in international navigation shall be provided with certificates of competency and licenses issued or rendered valid by the State in which the aircraft is registered. ...”

1.3.10 Remote pilots are not subject to Article 32 which was drafted specifically for those individuals who conduct their duties while on board aircraft. Appendix 4 to Annex 2 contains a Standard requiring remote pilots to be licensed in a manner consistent with Annex 1 — *Personnel Licensing*. (See Chapter 8 on licensing.)

Article 33

Recognition of certificates and licenses

“Certificates of airworthiness and certificates of competency and licenses issued or rendered valid by the contracting State in which the aircraft is registered, shall be recognized as valid by the other contracting States, provided that the requirements under which such certificates or licences were issued or rendered valid are equal to or above the minimum standards which may be established from time to time pursuant to this Convention.”

1.3.11 Article 33 is the basis for mutual recognition of certificates and licences. This Article applies to certificates of airworthiness for RPA; however, it should be noted that licences of remote pilots may not be subject to this Article since remote pilot licences are not encompassed by Article 32. Furthermore, proper oversight of remote pilot licences may dictate that they be issued or rendered valid by the licensing authority of the State in which the RPS is located, rather than the State of Registry of the RPA.

1.3.12 Assembly Resolution A38-12 — Consolidated statement of continuing ICAO policies and associated practices related specifically to air navigation, Appendix C — Certificates of airworthiness, certificates of competency and licences of flight crews (clause 2), resolves that pending the coming into force of international Standards respecting particular categories of aircraft or flight crew, Member States shall recognize the validity of certificates and licences issued or rendered valid, under national regulations, by the Member State in which the aircraft is registered.

Note 1.— Certification and licensing Standards are not yet developed. Thus, in the meantime, any certification and licensing need not be automatically deemed to comply with the SARPs of the related Annexes, including Annexes 1, 6 and 8, until such time as the related RPAS SARPs are developed.

Note 2.— Notwithstanding Assembly Resolution A38-12, Article 8 of the Chicago Convention assures each Contracting State of the absolute sovereignty over the authorization for RPA operations over its territory.

1.4 PURPOSE OF THE MANUAL

The purpose of this manual is to provide guidance on technical and operational issues applicable to the integration of RPA in non-segregated airspace and at aerodromes. The material contained herein is consistent with those standards already adopted for RPAS. The manual will be updated and expanded as additional provisions are developed.

1.5 SCOPE OF THE MANUAL

1.5.1 This manual addresses RPAS as one subset of UAS. RPAS are envisioned to be an equal partner in the civil aviation system, able to interact with air traffic control (ATC) and other aircraft on a real-time basis. The scope of ICAO provisions in the next 5 to 10 years is to facilitate integration of RPAS operating in accordance with instrument flight rules (IFR) in controlled airspace and at controlled aerodromes. While not excluding visual line-of-sight operations from consideration, these are viewed to be a lower priority for global harmonization of international flights.

1.5.2 The following subjects are not within the scope of this manual (see Figure 1-1):

- a) State aircraft, without prejudice to the obligation for “due regard” in Article 3 (d) of the Chicago Convention;
- b) autonomous unmanned aircraft and their operations including unmanned free balloons or other types of aircraft which cannot be managed on a real-time basis during flight;
- c) operations in which more than one RPA is being managed by an RPS at the same time; and
- d) model aircraft, which many States identify as those used for recreational purposes only, and for which globally harmonized standards are not considered necessary.

1.5.3 The guidance provided herein applies to any RPAS used for other than recreational purposes.

1.5.4 This guidance is consistent with the existing aviation regulatory framework and will assist in the development of future RPAS-specific SARPs.

1.5.5 The material is recommended for the benefit of the entire UAS community (e.g. regulators, manufacturers, operators, pilots, air navigation service providers (ANSPs)) and addresses the following domains:

- a) ICAO regulatory framework and scope of the manual (Chapter 1);
- b) introduction to RPAS (Chapter 2);
- c) special authorization (Chapter 3);
- d) type certification and airworthiness approvals (Chapter 4);
- e) RPA registration (Chapter 5);
- f) responsibilities of the RPAS operator (Chapter 6);
- g) safety management (Chapter 7);
- h) licensing and competencies (Chapter 8);
- i) RPAS operations (Chapter 9);
- j) detect and avoid (DAA) (Chapter 10);
- k) command and control (C2) link (Chapter 11);
- l) ATC communications (Chapter 12);
- m) remote pilot station (RPS) (Chapter 13);

- n) integration of RPAS operations into ATM and ATM procedures (Chapter 14); and
- o) use of aerodromes (Chapter 15).

1.6 GUIDING PRINCIPLES (CONSIDERATIONS)

1.6.1 Annex 2, Section 3.1.9 mandates that an RPA shall be operated in such a manner as to minimize hazards to persons, property or other aircraft and in accordance with the conditions specified in Appendix 4.

1.6.2 To ensure the above Standard is met, the main purpose of RPAS regulations is to address the protection of society from mid-air collisions (MACs) with aircraft and crashes.

1.6.3 These hazards relate to all RPAS operations irrespective of the purpose of the operation. Therefore, the recommendations in this manual, unless specified otherwise, apply equally to commercial air transport and general aviation, including aerial work, operations conducted by RPAS.

1.6.4 In order for RPAS to be widely accepted, they will have to be integrated into the existing aviation system without negatively affecting manned aviation (e.g. safety or capacity reduction). If this cannot be achieved (e.g. due to intrinsic limitations of RPAS design), the RPA may be accommodated by being restricted to specific conditions or areas (e.g. visual line-of-sight (VLOS), segregated airspace or away from heavily populated areas).

1.6.5 In order for RPA to be integrated into non-segregated airspace and at aerodromes, it is foreseen that only one RPA may be controlled by an RPS at any given time.

Chapter 2

INTRODUCTION TO RPAS

2.1 OVERVIEW

This chapter provides a brief description of topics related to introduction of RPAS into the existing regulatory framework of the civil air navigation system. This includes descriptions of RPA and their associated components, categorization of RPA, flight rules and operations, e.g. instrument and visual flight rules (VFR), VLOS and beyond visual line-of-sight (BVLOS).

2.2 DESCRIPTION OF RPA AND ASSOCIATED COMPONENTS

Remotely piloted aircraft

2.2.1 An aircraft is defined as any machine that can derive support in the atmosphere from the reactions of the air other than the reactions of the air against the earth's surface. An aircraft which is intended to be operated with no pilot on board is classified as unmanned. An unmanned aircraft which is piloted from a remote pilot station is an RPA. All aircraft classified in Table 2-1 could be remotely piloted.

Associated components

2.2.2 RPA are piloted from RPS utilizing a command and control (C2) link. Together with other components such as launch and recovery equipment, if utilized, the RPA, RPS and C2 link comprise an RPAS.

2.2.3 An RPA can be piloted from one of many RPS during a flight; however, only one RPS should be in control of the RPA at a given moment in time. (See Chapter 4 for configuration management aspects of RPAS.)

Remote pilot station (RPS)

2.2.4 The RPS is the component of the RPAS containing the equipment used to pilot the RPA. The RPS can range from a hand-held device up to a multi-console station. It may be located inside or outside; it may be stationary or mobile (installed in a vehicle/ship/aircraft).

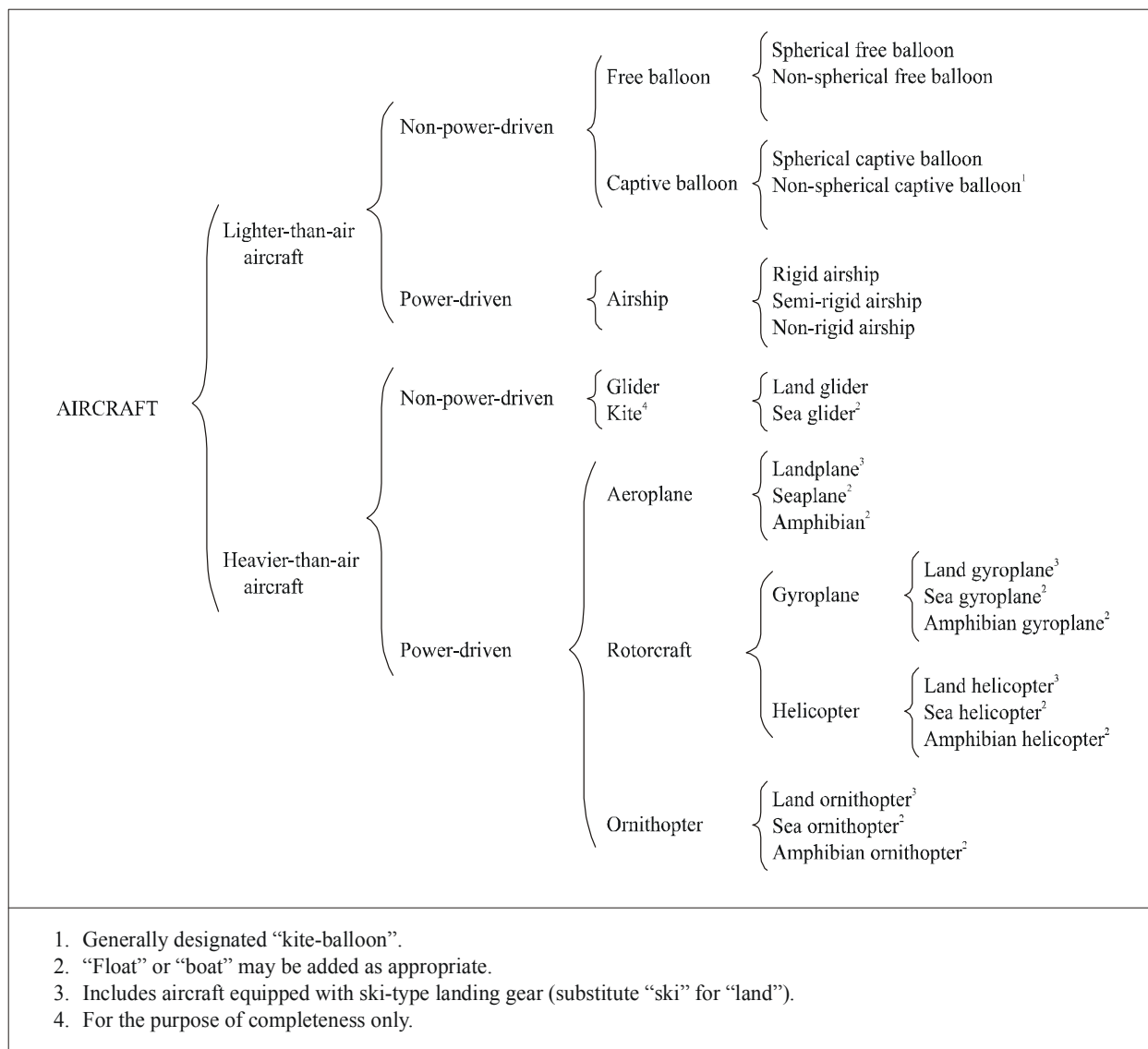
C2 link

2.2.5 The C2 link connects the RPS and the RPA for the purpose of managing the flight. The link may be simplex or duplex. It may be in direct radio line-of-sight (RLOS) or beyond radio line-of-sight (BRLOS) as described in a) and b).

- a) *RLOS*: refers to the situation in which the transmitter(s) and receiver(s) are within mutual radio link coverage and thus able to communicate directly or through a ground network provided that the remote transmitter has RLOS to the RPA and transmissions are completed in a comparable timeframe; and
- b) *BRLOS*: refers to any configuration in which the transmitters and receivers are not in RLOS. BRLOS thus includes all satellite systems and possibly any system where an RPS communicates with one or more ground stations via a terrestrial network which cannot complete transmissions in a timeframe comparable to that of an RLOS system.

The distinction between RLOS and BRLOS mainly concerns whether any part of the communications link introduces appreciable or variable delay into the communications than the architecture of the link.

Table 2-1. Classification of aircraft



Other components

2.2.6 The following components may be part of the RPAS:

- a) ATC communications and surveillance equipment (e.g. voice radio communication, controller/pilot data link communications (CPDLC), automatic dependent surveillance — broadcast (ADS-B), secondary surveillance radar (SSR) transponder);
- b) navigation equipment;
- c) launch and recovery equipment — equipment for RPA take-off and landing (e.g. catapult, winch, rocket, net, parachute, airbag);
- d) flight control computer (FCC), flight management system (FMS) and autopilot;
- e) system health monitoring equipment; and
- f) flight termination system — allowing the intentional process to end the flight in a controlled manner in case of an emergency.

Flight termination systems are designed to minimize the possibility of injury or damage to persons, property or other aircraft on the ground and in the air.

Categorization of RPA

2.2.7 Categorization of RPA may be useful for the purpose of a proportionate application of safety risk management, certification, operational and licensing requirements. RPA may be categorized according to criteria such as: maximum take-off mass (MTOM), kinetic energy, various performance criteria, type/area of operations, capabilities. Work is underway in many forums to develop a categorization scheme.

Handovers

2.2.8 Unlike in manned aviation where the cockpit is integral to the aircraft, RPA can be piloted from any approved RPS. When more than one RPS is used for a flight, they may be collocated or they may be spread across the globe. In either case, the safe and effective handover of piloting control from one station to another must be assured.

2.3 RPAS OPERATIONS

2.3.1 The operation of RPAS will be determined by the purpose of the flight, the flight rules, areas of operation and the functional levels of the C2 links.

2.3.2 In manned aviation, international operations are considered to be those in which the aircraft crosses an international border or operates in high seas airspace. RPAS present additional scenarios for consideration in which the RPA only, the RPS only or both the RPA and RPS are operated in other than the territory of the State of the Operator such as:

- a) the RPA is operating in the airspace of only one State (State X) while it is being remotely piloted from an RPS located in any other State (State Y);

- b) either the RPA or the RPS is operated in high seas airspace; or
- c) the RPA and RPS are both being operated in territory of a State other than the State of the Operator.

2.3.3 These new scenarios present issues affecting licensing (see Chapter 8) and accident investigation (see Chapter 9).

Type of operation

2.3.4 Annex 6 — *Operation of Aircraft* defines different types of operation for manned aviation:

- a) commercial air transport operation; and
- b) general aviation operation which includes corporate aviation and aerial work.

2.3.5 For RPAS operations, however, the distinction is not considered relevant. Regulatory distinctions will be based on the scale and complexity of the operation, rather than on the traditional types of operation or class of aircraft. This has implications on the responsibilities of RPAS operators, as explained in Chapter 6. It should be noted that carriage of persons on board an RPA will not be considered in the initial regulatory framework.

2.3.6 RPA designed and built for other than recreational purposes may be regulated under the jurisdiction of the civil aviation authority even if used for recreational purposes. Conversely, model aircraft designed and built for recreational purposes, if used for any purpose other than recreation, may be regulated under the jurisdiction of the civil aviation authority.

Flight rules

2.3.7 IFR and VFR apply, as they do for manned aircraft (e.g. requirements for equipment, operations and responsibility); however, the following situations may prove more difficult to address:

- a) IFR flight — a flight conducted in accordance with the IFR:
 - 1) when operating IFR in visual meteorological conditions (VMC), VFR traffic, possibly having right-of-way, may be encountered. The remote pilot must be able to identify these situations and take appropriate action;
- b) VFR flight — a flight conducted in accordance with the VFR:
 - 1) in order to conduct VFR flights, the remote pilot must have a means to comply with the visibility and distance from cloud minima; and
 - 2) when operating VFR, other traffic whether IFR or VFR, possibly having right-of-way, may be encountered. The remote pilot must be able to identify these situations and take appropriate action.

2.3.8 States should consider the implications of RPA operating in such proximity to other aircraft that the right-of-way rules would need to be applied, particularly if the RPA, due to its small size or other physical characteristics, will not be visually detectable in sufficient time to avoid unsafe proximity.

Area of operation

2.3.9 RPA that are intended to be operated in any given airspace must comply with the requirements of that airspace, e.g. certifications, approvals and equipment. Irrespective of these certifications, approvals or equipment requirements, RPA may be prohibited from operating in certain areas, such as above heavily populated areas, if so determined by the civil aviation authority.

VLOS operations

2.3.10 As defined in Annex 2, during VLOS operations, the remote pilot or RPA observer must maintain direct unaided visual contact with the remotely piloted aircraft.

2.3.11 The limits or range within which VLOS operations can be safely conducted are not defined. However, in determining the extent of the range, consideration must be given to the remote pilot and RPA observer capabilities, the meteorological conditions, the size and conspicuity of the RPA and any other relevant factors.

2.3.12 VLOS operations can be performed in a larger horizontal range when one or more RPA observer supports the pilot in keeping the RPA clear of other traffic and obstacles. The vertical range may also be increased depending on the location of the RPA observer (e.g. on board another aircraft).

BVLOS operations

2.3.13 When neither the remote pilot nor RPA observer(s) can maintain direct unaided visual contact with the RPA, the operations are considered BVLOS. Minimum equipment requirements to support BVLOS operations increase significantly as the range and complexity of such operations increase, as does the cost involved in ensuring the robustness of the C2 link. The ability to detect conflicting traffic or obstacles and take appropriate action to avoid them is essential.

Chapter 3

SPECIAL AUTHORIZATION

3.1 OVERVIEW

3.1.1 All unmanned aircraft, whether remotely piloted, fully autonomous or combinations thereof, are subject to the mandate of Article 8 of the Chicago Convention for special authorization. Annex 2, Appendix 4, contains Standards related to this authorization and is applicable to international operations of RPA. The operation of an RPA within the boundaries of its State of Registry remains under the purview of the respective national authority.

3.1.2 This chapter provides guidance on the implementation and use of the Standards contained in Annex 2, Appendix 4, related to the special authorization.

3.2 GENERAL OPERATING RULES (ANNEX 2, APPENDIX 4)

3.2.1 Article 8 of the Chicago Convention requires that pilotless aircraft intending to operate over the territory of another State obtain a special authorization from that State. To assist RPAS operators in submitting their request and State authorities in assessing such requests, items to be included are detailed in Annex 2, Appendix 4, Section 3. A template for use in this regard—Request for Authorization Form—is shown in Appendix A of this manual.

3.2.2 In order to facilitate the practical implementation and execution of the special authorization process, States may agree mutually upon simpler procedures through bilateral or multilateral agreements or arrangements for the operation of specific RPA or categories of RPA. This will reduce the workload on RPAS operators and the State authorities. The same objective may be reached through regulatory measures at regional levels.

3.2.3 Coordination with the appropriate air traffic services (ATS) authority is mandatory prior to the operation of RPA over the high seas. In accordance with Annex 2, 2.1.2, the appropriate ATS authority is the authority designated by the State responsible for providing those services over the high seas. Usually, the ATS authority is the designated ANSP for that volume of airspace.

3.2.4 It is recommended that the request for authorization form be used for the required coordination with the appropriate ATS authority for the operation of an RPA over the high seas (see Appendix A). The appropriate ATS authority may require additional information.

3.2.5 Prior authorization and coordination are required where it can be reasonably expected in the planning phase that the RPA will enter into the airspace of another State. For example, situations where conditions would require the remote pilot to fly alternate routes, avoiding hazardous meteorological conditions, restricted areas or where the alternate aerodrome in case of emergency is situated in another State. On the other hand, an unforeseen emergency would not require prior planning and prior special authorization, since it could not have been reasonably expected.

3.2.6 Conditions for the operation of the RPA specified by the State of Registry, the State of the Operator, if different, and by the State(s) in which the flight is to operate are to be observed. These conditions may stem from national and/or regional regulations regarding, for example, requirements in respect of:

- a) equipment (e.g. SSR transponder, ADS-B);
- b) operations (e.g. time of operations, altitude);
- c) performance criteria (e.g. speed, climb and descent rates, turn radius);
- d) airspace classes; and
- e) qualification of operations personnel.

3.2.7 As in the case of manned aircraft, a flight plan must be submitted for the flight of an RPA in accordance with Annex 2, Chapter 3, in particular, prior to operating across international borders. The flight plan must comply with the conditions in Annex 2, 3.3, and contain the information regarding the items listed in Annex 2, 3.3.2. Each State in which the flight is to operate may require additional information related to the planned operation of the RPA.

Certificates and licences

3.2.8 Copies of all pertinent certificates, the licences of the remote pilots and the radio station licence must be included with the request for authorization.

Request for authorization

3.2.9 The request for authorization, in accordance with Annex 2, shall be made to the appropriate authorities of the State(s) in which the RPA will operate not less than 7 days before the date of intended flight unless otherwise specified by the State.

Chapter 4

TYPE CERTIFICATION AND AIRWORTHINESS APPROVALS

4.1 INTRODUCTION

4.1.1 This chapter provides a discussion of the regulatory challenges and considerations for type and airworthiness approvals for RPA, RPS and RPAS as a complete system. Article 31 of the Chicago Convention requires every aircraft engaged in international navigation to be provided a CofA. Annex 2, Appendix 4, reiterates this and further requires the RPAS to be approved, taking into account the interdependencies of the components.

4.1.2 It is assumed that existing processes and procedures applied to traditional, manned aircraft type design approval (e.g. type certification and supplemental type certification), production approval, continuing airworthiness and modifications/alterations of aeronautical products are also applicable to RPAS, to the maximum extent practicable.

4.1.3 In this approach, it is recognized that there are potential configurations and operational arrangements that may not be accommodated. Once it is clear what the likely scenarios needed to support a successful RPAS industry are, and experience is gained in type and airworthiness approval processes, it may be necessary to revisit this issue.

4.2 GENERAL

4.2.1 The *Airworthiness Manual* (Doc 9760) is relevant and applicable to RPAS in most aspects of type design and airworthiness approval of the RPA. With unique characteristics to be considered; however, the RPAS is recognized to present some challenges for the airworthiness approval system. These characteristics mainly stem from the distributed nature of RPAS, consisting of an RPA and one or more RPS connected by the use of C2 link(s) and possibly other components. These differences are explained in this chapter.

4.2.2 Compared with manned aircraft, there may also be new multinational aspects due to the distributed nature of RPAS regarding the States of Design, Manufacture, Registry and the Operator and their respective oversight requirements.

4.2.3 The RPA must, whereas the RPS may, have type design approval for international operations. It is envisaged that RPA will be required to have a type design approval in the form of a type certificate (TC) which would be issued to an RPA TC holder when it has demonstrated, and the State of Design has confirmed, compliance to an appropriate and agreed type certification basis. The certification basis would include applicable requirements adopted or adapted from traditional manned aircraft in all appropriate areas of design and construction, for example, structures and materials, electrical and mechanical systems, propulsion and fuel systems, and flight testing. The distributed nature of RPAS also requires that the design approval scope expands from the RPA itself to include the RPS(s) (possibly of various types), the C2 link(s), as appropriate, and any other components of the system to enable safe flight from take-off to landing. The type design approval must include instructions for continuing airworthiness (ICA) and operational documentation (e.g. flight manual). Any limitation associated with the type design that affects the function and operation of the RPAS may require specific restrictions, operating limitations and supplemental operational controls or provisions to achieve an acceptable level of safety for operation in international airspace.

4.2.4 The RPA is the aircraft component of the RPAS and must hold a CofA. Whilst associated with the aircraft (and thus pertaining to the State of Registry of the RPA), the CofA attests that the RPAS, as a complete system, conforms to the RPA type design and is in a condition for safe operation.

4.2.5 In operation, the distributed nature of the RPAS implies that provisions to ensure the continued validity of an individual RPA CofA will need to address the RPS and specify other constituent components. The compliance demonstrations therefore also need to ensure that all components used during a flight are acceptable under the conditions of the CofA, including any instructions for ICA, maintenance and configuration control.

4.3 GOVERNING PRINCIPLES

4.3.1 In developing this material, certain governing principles were established:

- a) among RPAS components, only the RPA is recorded on the aircraft register;
- b) the RPA will hold a CofA, issued by the State of Registry, which will encompass all required components of the RPAS;
- c) individual RPS should not have piloting control of more than one RPA at a given time;
- d) the remote PIC is expected to have continuous control over the RPA under normal operating conditions. An interruption of the C2 link is considered an abnormal operating condition. RPAS design should, therefore, take into account potential interruption of the C2 link. Duration of the interruption or the phase of flight may elevate the situation to an emergency. Appropriate abnormal or emergency procedures should be established to cope with any C2 link interruption commensurate with the probability of occurrence (see Chapter 11);
- e) the RPAS as a system, comprised of the RPA, approved RPS(s) and the C2 link(s), is provided an implicit design approval through a TC issued to the RPA itself, but including the RPS(s) and the C2 link(s). Similarly, the RPA receives an individual airworthiness approval through a CofA which includes the RPS(s) and C2 link(s). In conclusion, the RPA receives the CofA for the entire RPAS based on the RPA TC and associated type design;
- f) an RPA is considered airworthy, when an RPAS, which includes the RPA, has been demonstrated to conform to an approved type design and is compliant with ICA through maintenance actions or inspections. Regulatory inspections and applicable airworthiness directives should ensure the RPAS is maintained in a condition for safe operation, and the RPA is operated with an RPS via a C2 link(s), both in full conformity to the RPAS design;
- g) an RPA should be equipped in accordance with operational equipment requirements applicable for operations in the type and class of airspace and flight rules, e.g. VFR or IFR. The RPS must likewise meet the equipment requirements; and
- h) there will only be one RPA type design, but there may be multiple RPS for that single RPA.

4.4 INITIAL CERTIFICATION

4.4.1 The RPA will be certificated by the issuance of a TC, which will include all the associated components required for controlled flight. The RPS, like the engine and propeller, could be certificated by a TC or a similar process.

4.4.2 Operation of an RPAS requires that the remote pilot have the ability to manage the flight on a real-time basis through use of a C2 link. Therefore, the C2 link is necessarily part of this safe flight principle, and must be addressed in the certification process. It is only considered possible to have the communication technology for the C2 link certificated as part of the total system under the responsibility of the RPA TC holder if it can be demonstrated that the appropriate level of safety performance is achieved. This C2 link could be procured from a service provider under contract to the RPAS operator; however, its safe integration into the RPAS design would remain under the overall responsibility of the RPA TC holder.

4.4.3 Where a contracted service is used in the type design, e.g. for C2 link, the RPAS operator must ensure adequate arrangements for this function. (See Chapter 11 for information on the C2 link).

4.4.4 It should be noted that reliance on communication technologies such as satellite could, if interrupted or lost, impair multiple RPA at the same time. This broad failure is not addressed in the type certification process as applied to manned aircraft, which focuses on independent failure conditions and consequences on individual aircraft. This issue will need further investigation.

Type design

4.4.5 In manned aviation, the aircraft is the single entity in which all aircraft components are integrated. Therefore, the airworthiness approach for manned aviation focuses on the aircraft. When considering an RPAS, the RPA is a component of the system; however, in accordance with the principle of aligning RPAS with the manned aviation framework as far as is practicable, the RPA is designated as the component which receives the type design approval. This means that the TC holder for the RPA is also responsible for the safe integration of all components, e.g. RPS and other required systems that would support the safe operation of the RPA, which is consistent with the Chicago Convention in respect of certificates.

4.4.6 It is envisaged that an RPAS consists of only one RPA, one or more RPS(s), one or more C2 link(s), and includes required additional components such as launch and recovery systems. An individual RPA type design is therefore limited to contain only one RPA but may have multiple RPS, C2 links and other essential components.

4.4.7 Like manned aircraft, multiple RPAS configurations (e.g. RPA model variants, RPS types/models and other essential components) can be defined within the type design definition documents (e.g. type certificate data sheet (TCDS)), as long as the individual approved RPAS configuration is clear. When an RPA is issued a type , the functionality of the various types of engines, propellers, RPS and components and their interchangeability to safely operate the aircraft will need to be considered and appropriately reflected in the approved type design.

Type certification

4.4.8 The original issuance of an aircraft TC by the State of Design provides satisfactory evidence that the design and details of such aircraft type have been reviewed and found to comply with the applicable airworthiness standards. The same principle applies for the RPAS, i.e. the RPA, the RPS, C2 links and other components of the RPAS.

4.4.9 Major components, such as engines or propellers could also hold TCs, as is sometimes the case in manned aviation; however, this is not essential as the RPA TC holder is responsible for fully integrating all components. Similarly, the TC applicable to the RPA should integrate all the various types of engines, propellers, RPS and components that could be used with the RPA. This provides the basis for the State of Registry to issue a CofA.

4.4.9.1 States of Design may identify a need for certification standards for an RPS TC. The RPS, if holding a TC, would be considered a new aeronautical product, but its TC would be part of the RPA TC, similar to those for engines and propellers.

4.4.10 The application for TC should be accompanied by all necessary documentation, including design documentation, flight manual, maintenance manual and other manuals, normal and emergency procedures and, where applicable, handover procedures between RPS and details of the required C2 link(s) (see Figure 4-1).

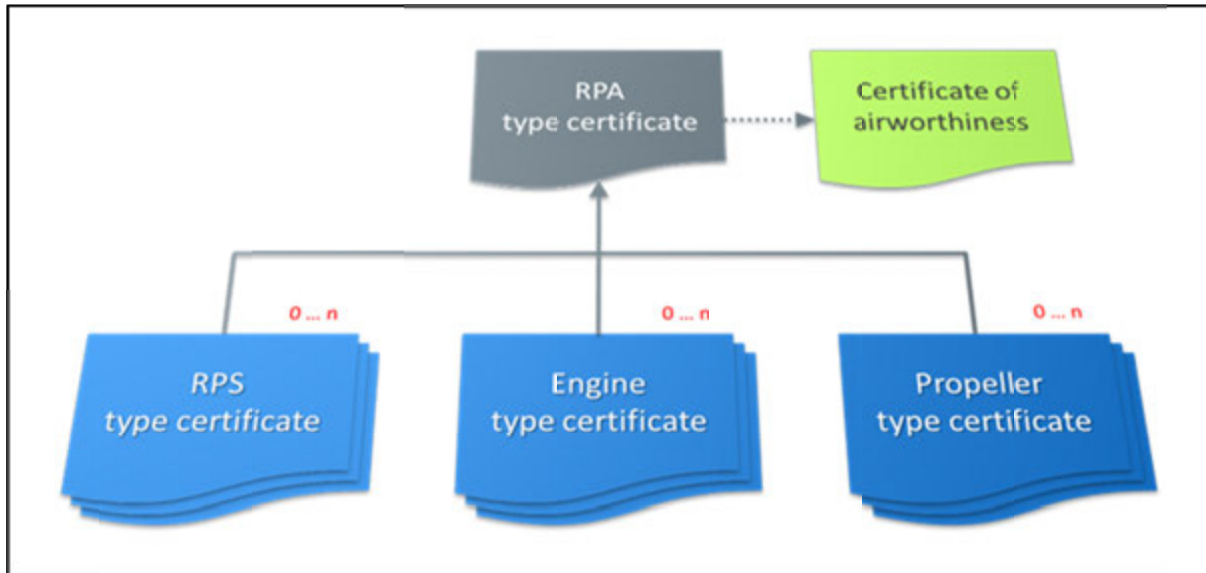


Figure 4-1. Relationship between TCs

4.4.11 There are only two ways of approving the design of an RPS: through an RPA TC or through an RPS TC. The RPA TC holder will demonstrate the integration of all the various types of engines, propellers, RPS and components that could be used with the RPA. Within this demonstration, the technical standard order (TSO) process may be applied to parts of the RPAS by the TC holder to reduce the burden of verification at the RPA level.

4.4.12 Prior to issuing a TC for the RPA, the State of Design will have to ensure compliance with all applicable certification requirements and the integration of all components for safe flight, including those major components that hold separate TCs or design approvals. It should be noted that while there are three aeronautical products defined for manned aviation, in the context of RPAS, that number could be four, as shown in Table 4-1.

Table 4-1. TCs for aeronautical products

| <i>Aeronautical products that may have a TC</i> | |
|---|----------------------------------|
| <i>Manned aircraft</i> | <i>Remotely piloted aircraft</i> |
| Aircraft (on which other products are mounted) | RPA |
| Engine | Engine |
| Propeller | Propeller |
| — | RPS |

4.5 C2 LINK

4.5.1 The C2 link is not a “product”, therefore it will not be independently type certificated.

4.5.2 There are two forms of operation related to the C2 link: within RLOS and beyond BRLOS. In either case, the link forms part of the overall type design and as such it will need to be defined and fully addressed within the certification process by the RPA TC holder. (See 2.2.5 and Chapter 11 for additional information on C2 links.)

4.5.3 The RPAS, as a system, may be designed for RLOS or BRLOS operations or a combination of operations utilizing C2 links contracted from different service providers. Whether the RPAS design uses an RLOS, BRLOS or a combination of the two, the RPA type design approval documentation should define all approved C2 links and the performance requirements necessary, as part of the approved RPA type design.

4.5.4 The C2 link capability, at the current state of the technology, may not be able to provide the reliability and integrity levels required for safe flight from take-off through landing under all operating conditions. Design constraints or operational mitigations may therefore be needed to ensure an acceptable level of safety performance for all functions implemented over the C2 link. The RPA design approval holder must demonstrate that safety critical functions implemented over the C2 link meet an acceptable level of safety performance.

4.5.5 Other important aspects related to the C2 link and airworthiness include the security of the C2 link against hacking, spoofing and other forms of interference or malicious hijack, as well as unintentional interference. Mitigations must be implemented to prevent the C2 link from connecting the RPS to an unintended RPA or vice versa. Information on these issues is contained in sections 9.11, 11.4 and 11.5.

4.5.6 During the conduct of any flight, all components that are used must be approved as defined in the approved type design (e.g. on the TCDS). In-flight change of components, particularly the C2 system/service or RPS is acceptable, as long as it is done in accordance with procedures established in the RPA type design, and each component is in the appropriate configuration to maintain the validity of the CofA.

4.6 FLIGHT MANUAL

4.6.1 The RPA flight manual should address all combinations of RPS models listed in the approved type design of the RPA. There may be substantial variations between different RPS used with the same RPA. In developing the RPA flight manual, specific consideration should be given to human performance aspects including crew communications e.g. remote pilot to remote pilot, remote pilot to RPA observer or other support personnel and remote pilot to ATC.

4.6.2 The RPA flight manual should contain all necessary information for operation of the RPAS. In addition to those required for manned aviation, the following procedures should be included, inter alia:

- a) RPA handover procedures from one RPS to another;
- b) C2 link specifications and procedures to respond to interruption or loss of the C2 link;
- c) flight termination procedures, if applicable; and
- d) security procedures unique to RPAS (e.g. RPS security, C2 link).

4.7 CONTINUING AIRWORTHINESS

4.7.1 ICA are required for each component of the RPAS in order for the State of Design to issue an RPA TC. The ICA should be prepared by the TC holder during the RPAS design phase to cover the complete system and be approved during the TC process.

4.7.2 The types of RPAS ICA are not envisaged to significantly deviate from those established for manned aviation; however, the manned aviation ICA process may need to be adjusted due to the unique characteristics of RPAS.

4.7.3 Such comprehensive instructions are aimed at defining when, what and how the relevant systems should be maintained throughout their service life in order to assure the required safety standard of each component of the RPAS.

Reliability monitoring and reporting

4.7.4 Existing State reporting requirements may require adaptation to address the specificities of RPAS. The level of reporting should not exceed what is currently required for manned aviation, and for small/simple RPAS, could be reduced to minimize the burden.

4.7.5 The reporting of failures, malfunctions and defects for RPAS should comprise the overall system; therefore, it applies to all States and organizations at their respective level of responsibility. With the certificate of airworthiness (CofA) framework as described herein, the following may help in identifying those aspects surrounding the RPAS continued operational safety to be considered with respect to manned aviation:

- a) identification of reportable failures, malfunctions or defects which could affect the airworthiness status and continuing safe operation of the RPAS;
- b) identification of critical components for the RPA and RPS; and
- c) establishment of RPAS accident and incident taxonomy.

4.8 CONFIGURATION DEVIATION LIST (CDL) AND MASTER MINIMUM EQUIPMENT LIST (MMEL)

The CDL and MMEL are established methods of supporting continued operation for limited time with minor defects which do not significantly affect flight safety, albeit additional maintenance or operational processes and procedures may be required to support them. This approach is also considered applicable for RPAS, and hence the process and procedures for the development and approval of these documents would be expected to be similar to those for manned aircraft.

4.9 DESIGN OVERSIGHT

Oversight in the initial certification phase should be conducted by the State of Design. Prior to issuing the TC to the RPA, the State of Design must confirm that the safe integration of all possible components has been satisfactorily demonstrated.

4.10 DESIGN ORGANIZATION APPROVAL

Some States define requirements for the type design organization to hold approvals in support of the range of products they design. For type design organizations undertaking RPAS, RPA and RPS work, the applicable manned aviation requirements established by their airworthiness authority are assumed to prevail, albeit that some alterations in terms of reference, scope of work, etc., may be necessary.

4.11 PRODUCTION

4.11.1 Some States define requirements for the production organization to hold approvals in support of the range of products they produce. For production organizations undertaking RPAS, RPA and RPS work, the applicable manned aviation requirements established by their airworthiness authority are assumed to prevail, albeit that some alterations in terms of reference, scope of work, etc., may be necessary.

4.11.2 An applicant (manufacturer) may be eligible for a production certificate or production organization approval from the airworthiness authority, subject to determination by said airworthiness authority, based on its examination of supporting data and inspection of the production facilities, processes and organization, that the applicant has complied with the relevant requirements.

4.11.3 The production organization must have an agreement with the design organization to ensure it has all necessary documentation to manufacture or build the product in conformity with the type design and, when appropriate, test the product.

4.11.4 The processes for the initial conformity inspections performed after the manufacturing and assembly, and attestation to the approved type design, are well established in manned aviation and will need to be followed for the RPA, RPS and all applicable parts of the approved type design, including the use of the applicable production release certificate.

4.11.5 Safety oversight in the production phase should be conducted by the State of Manufacture (e.g. approving the production organization and its quality system).

4.11.6 The State of Manufacture must organize, in agreement with the State of Design when different, a process to maintain the airworthiness of the products delivered under its oversight.

4.12 RPAS PRODUCT INTEGRATION

4.12.1 The final production of a manned aircraft may be performed by a single manufacturer who assembles the aircraft and integrates all the required systems. As outlined above, other production organizations can assemble parts in order to form complete assemblies, products, etc., for example an engine, which can subsequently be delivered with an appropriate release certificate, where applicable. These parts can then be integrated on the aircraft production line, as part of the final production process, or can be supplied to the field as replacement or spare parts which can be installed on an already delivered aircraft as a maintenance activity.

4.12.2 For RPAS, it is possible that an organization only integrates constituent components, such as RPA or RPS, from other suppliers into a system (RPAS), without producing or assembling components. In this case, the organization could be considered as the final production organization and therefore should hold the necessary production approvals in support of the system integration. If the RPA is manufactured by a different organization, it would have to be released by that organization prior to being integrated.

4.12.3 As a production matter, it is not considered within the scope of an operator, under its RPAS operator certificate (ROC), to purchase individual components of the system and perform the initial integration, unless the operator holds a production approval in addition to its ROC.

4.12.4 A change to the delivered RPAS is possible, for example the addition of a new RPS of the same model as previously integrated or a different, approved model. This change can be accommodated as a maintenance activity when carried out in accordance with processes and procedures approved by the State of Registry; however, the resulting configuration must comply with the approved type design. The applicable approved processes and procedures would need to be defined by the TC holder to verify correct integration and interoperability with the existing RPAS.

4.13 AIRWORTHINESS CERTIFICATION

Certificate of airworthiness (CofA)

The RPA is a component of the RPAS, and in accordance with Article 31 of the Chicago Convention, the aircraft is required to have a CofA if conducting international operations. The State of Registry, upon satisfactory evidence that the RPA, RPS(s) and other components conform to the type design and are in a condition for safe operation, will issue a CofA to the RPA.

4.14 RPAS CONFIGURATION MANAGEMENT RECORDS

4.14.1 It is necessary to be able to define the complete configuration of the RPA against which the CofA is issued, including all components constituting the RPAS. The configuration management record should therefore contain sufficient detail to describe all components of the RPAS to provide full traceability of reconfigurations or part changes.

4.14.2 The configuration management record should be similar to that used for manned aircraft, e.g. as a compilation of installed components; maintenance requirements and actions; parts by serial number, their changes and functionality checks; and any contracted services and their performance aspects.

4.14.3 This may require extension of current processes to cover all components of the RPAS and their integration.

4.15 CONTINUING VALIDITY OF CERTIFICATES

4.15.1 The validity of an RPA CofA should be controlled in the same way as is done in manned aviation. Therefore, the same processes and procedures used to ensure the continuing validity of the CofA should be applicable albeit that they will require extension to cover all components of the RPAS.

4.15.2 RPAS may be reconfigured during flight, such as by handover from one RPS to another or change from terrestrial to satellite C2 links. This has a new implication on maintaining the validity of the CofA for the RPA and additional requirements may be needed. The conditions specified in the CofA must be fulfilled throughout the flight. The operator must be able to demonstrate that all configurations used during flight remain valid, e.g. that an RPS to be used following a handover is in a valid configuration, holds appropriate maintenance release documents, as required by the State of Registry. The dynamic nature of this new scenario must be reflected in the configuration management record of the RPAS.

4.16 OPERATION

4.16.1 The following paragraphs outline areas that require further consideration and actions by the State of Registry to address operations and airworthiness aspects related to the novel characteristics of RPAS.

Oversight

4.16.2 As discussed above, RPAS configuration can be dynamic. Components of the RPAS may also be distributed across the globe, presenting very complex oversight situations. Arrangements to address these situations may be addressed by ICAO at a later stage. Therefore, initially all of the constituent components of the RPAS are expected to be managed under a single operator certificate with one State providing oversight of the operation and compliance with the applicable regulations, codes and standards, (e.g. CofA, configuration management record, remote pilot licensing and training).

4.16.3 RPAS operators may develop business cases that are dependent on the sharing of resources (e.g. contracting of local area RPS services, maintenance facilities and remote pilots). Hence, an international framework is needed to facilitate recognition of RPA-related certificates and licences issued by other Member States.

Continuing airworthiness

4.16.4 The processes to maintain conformity to the type design and ensure continuing airworthiness through periodic maintenance and inspections as well as mandatory corrective actions (e.g. airworthiness directives) are considered equally applicable to the individual components of the RPAS.

4.16.5 The necessary maintenance to assure conformity to the type design of the RPA and all other components of the RPAS must be defined and specified within the type design standard. The standards, procedures and documentation for release to service for all components need to conform to those for the RPA.

4.16.6 It must be recognized that the manned aviation process sets the configuration management system against only the aircraft via the CofA and the continuous revalidation under the approved maintenance systems, and thus provides a level of airworthiness assurance on a per flight basis. The distributed architectures of RPAS mean there is the possibility for changes in the configuration of the RPAS during flight. The continued demonstration of conformity to the type design and the requirements of the CofA during operations remain applicable but need to be able to cover this dynamic aspect. Whilst each change of configuration may be independently controlled and appropriately released under the basic airworthiness process, it is not yet agreed how to demonstrate that the RPAS performs within the approved configuration throughout the flight.

4.17 RESPONSIBILITY OF STATES OF DESIGN, MANUFACTURE, REGISTRY AND THE OPERATOR

4.17.1 States' responsibilities related to RPAS are largely similar to those for manned aviation, with a few exceptions, as described below.

State of Design

4.17.2 The State of Design issues a TC defining and approving the RPA type design upon acceptance of satisfactory evidence that the RPA, including the RPS and all associated components, is in compliance with the appropriate design requirements.

4.17.3 The State of Design of the RPA, where it is different from the State of Design of the RPS, engine or propeller, is responsible for the overall type certification activities, as well as post-type certification obligations.

State of Manufacture

4.17.4 No specific differences to existing manned aviation requirements have been identified.

State of Registry

4.17.5 The State of Registry is responsible for ensuring the development and promulgation of national regulations regarding import and export requirements of RPAS, if applicable. Further considerations are necessary regarding the exporting of RPA or RPS as standalone components.

Note.— RPS are not recorded on the aircraft register.

4.17.6 Due to the distributed nature of RPAS, the State of Registry will need to give special consideration to ensuring continuing airworthiness.

State of the Operator

4.17.7 No specific differences to existing manned aviation requirements have been identified.

4.18 CONSIDERATIONS FOR THE FUTURE

With the lack of sufficient operational service history and certification experience with RPAS, this chapter does not yet provide specific guidance on procedures for type design and airworthiness certification. States are encouraged to establish procedures which may be reflected by ICAO in future certification guidance and SARPs as such experience and service history are gained. It is foreseen that the complexity of the distributed RPAS system, based on configuration management focused at the aircraft, will be difficult to manage, from both the operational and regulatory oversight requirements. It is therefore expected that as the industry matures and demands greater flexibility, a need will arise to enable configuration management and maintenance management of RPS across multiple States based on international principles and standards.

Chapter 5

RPA REGISTRATION

5.1 NATIONALITY AND REGISTRATION MARKS

5.1.1 In accordance with Article 20 of the Chicago Convention, any aircraft engaged in international navigation shall bear its appropriate nationality and registration marks. Acknowledging that remotely piloted aircraft sizes and designs can differ significantly from those of current manned aircraft, Standards have been adopted in Annex 7 — *Aircraft Nationality and Registration Marks*, to accommodate these differences. If aircraft do not possess the parts mentioned in Annex 7, 4.3.1 and 4.3.2, or the parts are not of sufficient size to accommodate the marks described in 5.1.1, 5.2.1 or 5.2.2, the State of Registry shall determine the location and measurement of nationality or common marks and registration marks, taking account of the need for the aircraft to be identified readily.

Identification plate

5.1.2 Remotely piloted aircraft may not have a main entrance to the fuselage. Therefore, Annex 7 mandates that the State of Registry determine the appropriate location to secure the identification plate:

- a) in a prominent position near the main entrance or compartment; or
- b) affixed conspicuously to the exterior of the aircraft if there is no main entrance or compartment.

Chapter 6

RESPONSIBILITIES OF THE RPAS OPERATOR

6.1 OVERVIEW

6.1.1 This chapter provides guidance on the role and responsibilities of an RPAS operator, based upon provisions contained in Annex 6 — *Operation of Aircraft, Part I — International Commercial Air Transport — Aeroplanes* and related documents. An operator is defined as a person, organization or enterprise engaged in or offering to engage in an aircraft operation. In the context of RPA, an aircraft operation includes the RPAS.

6.1.2 Due to the distributed nature of RPAS components, RPAS operations can be more complex than those of manned aircraft. This leads to the requirement that RPAS operators must hold an ROC as specified in Annex 2, Appendix 4. When granting an ROC, the regulator will consider the RPAS operator's ability to meet specified responsibilities, many of which are described below.

6.1.3 As explained in Chapter 2, from a regulatory perspective no distinction is made between the types of operation as applied in manned aviation e.g. commercial air transport, general aviation, corporate aviation. It is considered that establishing a regulatory framework which considers all RPAS utilized for non-recreational purposes is paramount. Distinctions between types of operations may be considered at a later date. Likewise, no minimum weight limit has been established below which RPA are exempt from ICAO SARPs; these may be agreed at a later date.

6.2 GENERAL

6.2.1 Consistent with the provisions of Annex 6, the RPAS operator is responsible for the safe conduct of all operations. This includes establishing and implementing a safety management system (SMS) as described in Chapter 7.

6.2.2 The RPAS operator must comply with all requirements established by the State of the Operator regarding its operation. These requirements should be consistent with the size, structure and complexity of the RPAS operator's organization.

6.2.3 The RPAS operator is also responsible for contracting services from providers (e.g. communications service providers), as necessary, to carry out its operations.

6.2.4 An RPAS operator must ensure that all employees are familiar with the laws, regulations and procedures applicable to the performance of their duties, prescribed for the areas to be traversed, the aerodromes to be used and the air navigation facilities relating thereto.

6.2.5 RPAS operator procedures must not allow remote flight crew members to perform any activities during critical phases of flight other than those required for the safe operation of the RPAS.

6.2.6 The RPAS operator, or a designated representative, must have responsibility for operational control.

6.2.7 Responsibility for operational control should only be delegated to the remote pilot-in-command (PIC) and to a flight operations officer/flight dispatcher if an operator's approved method of control and supervision of flight operations requires the use of flight operations officer/flight dispatcher personnel.

6.3 RPAS OPERATOR CERTIFICATE (ROC)

6.3.1 As specified in Annex 2, Appendix 4, an RPAS operator must have an ROC issued in accordance with applicable regulations and in a manner that is consistent with the provisions of Annex 6. This certificate is comparable to the air operator certificate (AOC) for a commercial air transport operator.

6.3.2 The ROC grants the RPAS operator authority to conduct operations in accordance with the conditions and limitations detailed in the operations specifications attached to the ROC.

6.3.3 The issuance of an ROC by the State of the Operator is dependent upon the RPAS operator demonstrating an adequate organization, method of control and supervision of flight operations, training programme as well as ground handling and maintenance arrangements consistent with the nature and extent of the operations specified and commensurate with the size, structure and complexity of the organization.

6.3.4 The scope of control and supervision should include RPA "gate-to-gate" operations and use of one or more RPS located at one or more sites.

6.3.5 The State of the Operator should establish a system for both the certification and the continued surveillance of the RPAS operator to ensure that the required standards of operations are maintained.

6.3.5.1 The system for the certification and the continued surveillance of an RPAS operator can be based on the process described in Doc 8335, the *Manual of Procedures for Operations Inspection, Certification and Continued Surveillance*, for commercial air transport operators.

Contents of the ROC

6.3.6 The ROC should contain at least the following:

- a) the State of the Operator and issuing authority;
- b) the ROC number and its expiration date;
- c) the RPAS operator name, trading name (if different) and address of the principle place of business;
- d) the date of issue and the name, signature and title of the authority representative;
- e) the location where the contact details of operational management can be found;
- f) the description of the types of operations authorized;
- g) the type(s) or model(s) of RPA authorized for use;
- h) the models and locations of RPS authorized for use; and
- i) the authorized areas of operation or routes.

Recognition of ROC

Note 1.— Assembly Resolution A38-12, Appendix C, resolves that pending the coming into force of international Standards respecting particular categories, classes or types of aircraft, certificates issued or rendered valid, under national regulations, by the Member State in which the aircraft is registered shall be recognized by other Member States for the purposes of flight over their territories, including landings and take-offs.

Note 2.— In the case of RPAS, certification and licensing standards are not yet developed. Thus, in the meantime, any certification and licensing need not be automatically deemed to comply with the SARPs of the related Annexes, including Annexes 1, 6 and 8, until such time as the related RPAS SARPs are developed.

6.3.7 Member States should recognize as valid an ROC issued by another Member State, provided that the requirements under which the certificate was issued are consistent with the applicable Standards specified in Annex 6, Part I, for the air operator certificate, until such time as international standards come into force for the ROC.

Issue and format of the ROC

6.3.8 Consistent with the provisions of Annex 6, the State of the Operator, prior to certification of an RPAS operator, should require sufficient demonstrations by the RPAS operator, commensurate with the size, structure and complexity of its operation, to enable the State to evaluate the adequacy of the RPAS operator's organization, method of control and supervision of flight operations, ground handling and maintenance arrangements. These demonstrations should be in addition to the review or inspections of manuals, records, facilities and equipment.

6.3.9 Furthermore, and to remain consistent with the provisions of Annex 6, responsibility for initial certification, issuance of the ROC, and ongoing surveillance of the RPAS operator is placed on the State of the Operator. The State of the Operator should consider, or act in accordance with, various approvals and acceptances by the State of Registry. Under these provisions, the State of the Operator should ensure that its actions are consistent with the approvals and acceptances of the State of Registry and that the RPAS operator is in compliance with State of Registry requirements.

6.3.10 The privileges and scope of the activities that the RPAS operator is approved to conduct should be specified in the operations specifications attached to the ROC.

Continued validity of the ROC

6.3.11 The continued validity of an ROC will depend upon the RPAS operator maintaining the requirements of 6.3.8 under the supervision of the State of the Operator.

Amendments to the ROC

6.3.12 The certification of an RPAS operator is an ongoing process. RPAS operators may not be satisfied over time with the initial authorizations issued with their ROC. Evolving market opportunities may cause an operator to change RPAS models and seek approval for new operational areas requiring other additional capabilities. Additional technical evaluations should be required by the State before issuing the formal written instruments approving any changes to the original ROC and other authorizations. Where possible, each request should be "bridged", using the original authorization as the foundation to determine the extent of the State's impending evaluation before issuing the formal instrument.

6.4 PERSONNEL MANAGEMENT

Staff positions and requirements

6.4.1 Commensurate with the size, structure and complexity of the organization, the RPAS operator should:

- a) appoint an accountable executive, who has the authority for ensuring that all activities can be financed and carried out in accordance with the applicable requirements. The accountable executive should be responsible for establishing and maintaining an effective management system;
- b) nominate a person or group of persons with the responsibility for ensuring that the operator remains in compliance with the applicable regulations. Such person(s) should be ultimately responsible to the accountable executive;
- c) have sufficient qualified and competent personnel for the planned tasks and activities to be performed in accordance with the applicable requirements;
- d) maintain appropriate experience, qualification and training records to show compliance with c); and
- e) ensure that all personnel are familiar with the rules and procedures applicable to the performance of their duties.

Competence of personnel

6.4.2 An RPAS operator must ensure its personnel are properly qualified and competent to perform their allocated tasks and discharge their responsibilities. Such personnel should have the necessary set of competencies and the related knowledge, skills and attitudes, such as:

- a) theoretical knowledge (“to know”);
- b) practical skill (“to know how”); and
- c) attitudes commensurate with the scope of their duties in relation to RPAS operations (“to be”).

6.4.3 The combination and integration of these three elements constitute the standards of competence that personnel should demonstrate as individuals and as team members.

6.4.4 An RPAS operator should establish initial and recurrent training to ensure continuing competence of its personnel. These programmes should be addressed to all personnel assigned to, or directly involved in, ground and flight operations and ensure that all personnel have demonstrated their competence in their particular duties and are aware of their responsibilities and the relationship of such duties to the operation as a whole.

Record-keeping

6.4.5 An RPAS operator should establish a system of record-keeping that allows adequate storage and reliable traceability of all activities developed, covering at a minimum:

- a) operator’s organization;
- b) SMSs;

- c) personnel training and competence verification;
- d) documentation of all management system key processes;
- e) maintenance records; and
- f) security management records.

6.4.6 Records should be stored in a manner that ensures protection from damage, alteration and theft.

Contracted services other than for C2

6.4.7 When contracting or purchasing services as part of its activity, the RPAS operator must ensure that such services or products conform to the applicable requirements.

6.4.8 An RPAS operator may contract services from other organizations which are certified and under oversight of the relevant aviation safety oversight authority (e.g. approved maintenance organizations). In these cases, the contractual agreements may only cover commercial and technical matters. Safety matters will be addressed by the safety oversight authority (see Figure 6-1).

6.4.9 Information related to contracted services from an organization which is not certified or under direct oversight of the competent authority is provided in Chapter 7.

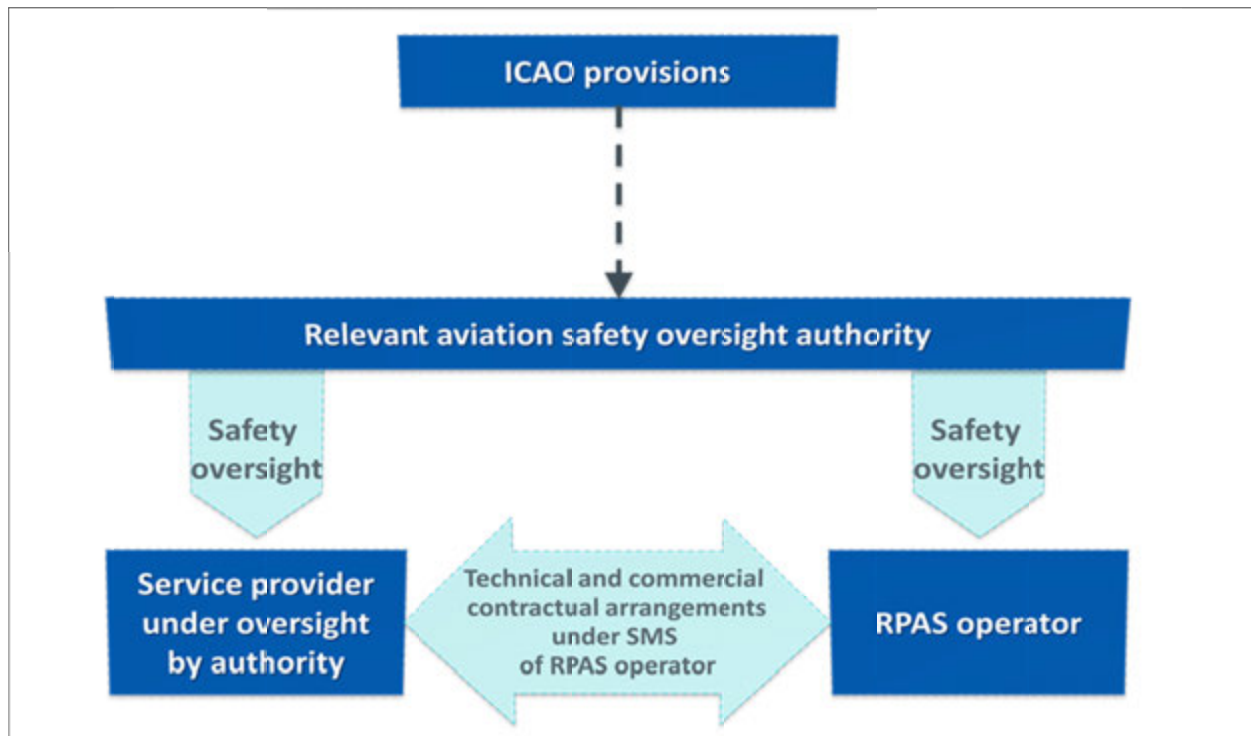


Figure 6-1. Oversight by aviation safety oversight authority

Contractual agreements between RPAS operators

6.4.10 An RPAS operator may identify a need to contract RPS services from another RPAS operator in order to achieve operational and business benefits. This sharing of resources would give RPAS operators flexibility and increase the range within which they are able to conduct operations.

6.4.11 In order to facilitate this arrangement, each State of the Operator would need to allow such contractual agreements through bilateral or multi-lateral agreements or national/regional legislation. This could involve oversight of RPAS operators located in another State.

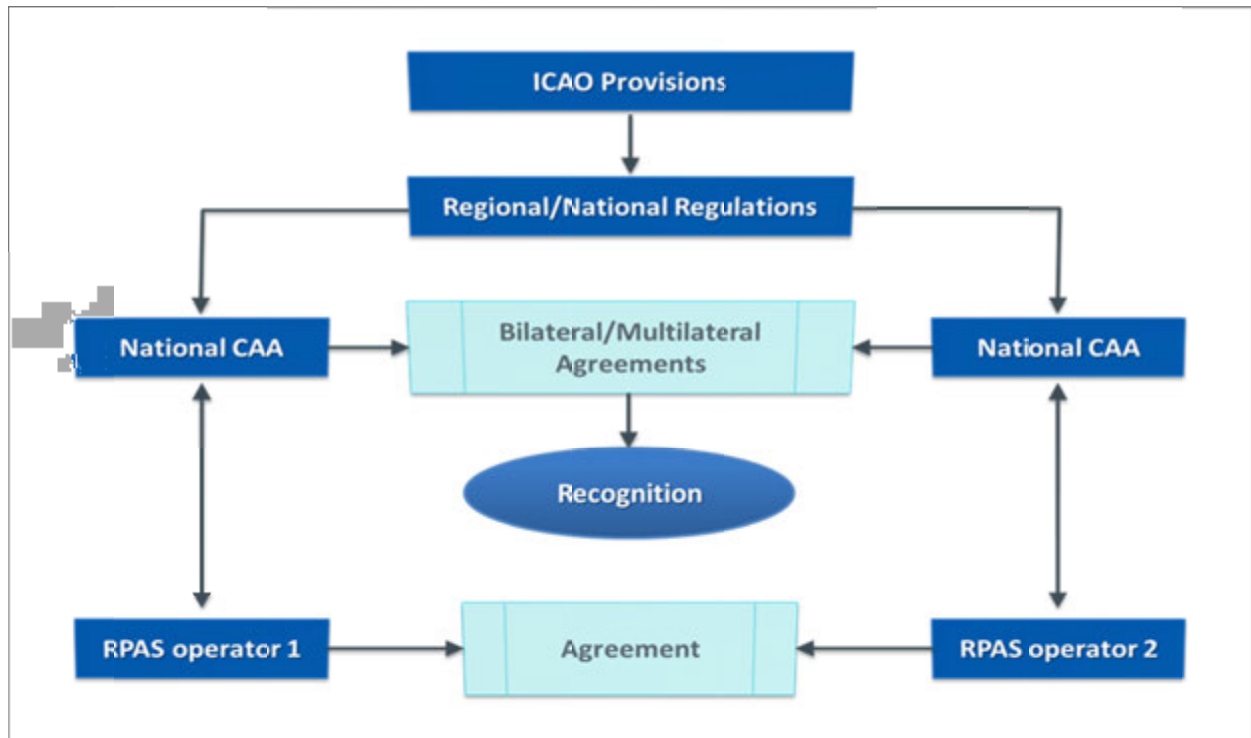


Figure 6-2. Recognition flow

6.4.12 Following implementation of national legislation or agreements between the State(s) of the Operator and agreements between the RPAS operators, RPS services could be contracted. Recognition of licences issued by other States may need to be addressed to support international operations (see Chapter 8 on licensing). Figure 6-2 illustrates how the recognition process might occur.

6.5 OVERSIGHT OF COMMUNICATIONS SERVICE PROVIDERS

6.5.1 Due to the complex situation presented by the C2 link, both the State of Registry and the State of the Operator have critical oversight roles that must be fulfilled since the C2 link serves as an essential component of the RPAS.

6.5.2 The State of Registry is responsible for ensuring the airworthiness of the RPA. The State of the Operator is responsible for ensuring the RPAS operator conducts a safe operation which includes ensuring that the RPA is operated and maintained in accordance with the conditions specified in the CofA.

6.5.3 The RPAS operator may procure C2 links from a communications service provider, subject to approval of the State of the Operator. These C2 links must comply with the conditions specified in the CofA issued by the State of Registry.

6.5.4 The RPAS operator should demonstrate to the State of the Operator that:

- a) the C2 service provider is under safety oversight of a recognized State civil aviation authority, or the safety aspects of the C2 link are included in the SMS of the RPAS operator;
- b) in the case that the C2 service provider has its own SMS, procedures are established to exchange safety information with the RPAS operator; and
- c) the C2 system complies with the performance requirements specified in the type design of the RPA.

6.5.5 The roles and responsibilities of the C2 service provider are described in Chapter 11.

6.6 DOCUMENT REQUIREMENTS

6.6.1 Article 29 of the Chicago Convention requires that various documents be carried on board aircraft. These documents are intended to be accessible to flight crews during flight and to be made available to inspectors when the aircraft is on the ground. The same requirements apply to unmanned aircraft; however, the size and configuration of the RPA may make placing original paper documents on board impractical. In order to satisfy the requirements of the Chicago Convention, new approaches are needed such as electronic versions of the documents which are accessible to remote pilots, inspectors and maintenance personnel, whether at the RPA or the RPS.

Documents held by the RPAS operator

6.6.2 The following documents, manuals and information specific to the RPAS operator, must be available, in the authentic form, at the location of the RPAS operator's operational management or other location specified by the State of the Operator:

- a) ROC;
- b) operations specifications relevant to the RPA and RPS models, associated with the ROC;
- c) operations manual, including the RPAS operating manual and the RPS manual;
- d) RPA/RPAS flight manual;
- e) maintenance control manual (MCM);
- f) third party liability insurance certificate(s);
- g) certificate of registration of each RPA;
- h) CofA of each RPA;

- i) certificates of any additional RPAS components, if applicable;
- j) all radio station licence(s), if applicable;
- k) all noise certificates, if applicable;
- l) notification of special loads, if applicable; and
- m) cargo manifests, if applicable.

Documents at the RPS(s)

6.6.3 Documents, manuals and information, including, but not limited to the following, must be available at the RPS(s) planned to be used during the flight:

- a) operations manual including the MEL, CDL, RPAS operating manual and RPS manual;
- b) RPA/RPAS flight manual;
- c) operations specifications relevant to the RPA and RPS models associated with the ROC;
- d) journey log book for the RPA;
- e) MCM, maintenance log book and technical log for the RPA;
- f) MCM, maintenance log book and technical log for the RPS;
- g) details of the filed, current, ATS and operational flight plans, if applicable;
- h) current and suitable aeronautical charts for the route of flight and all routes along which it is reasonable to expect that the flight may be diverted, including departure, arrival and approach charts for all relevant aerodromes/heliports;
- i) information concerning search and rescue services for the area of the intended flight;
- j) notice to airmen (NOTAM) and aeronautical information service (AIS) briefing documentation;
- k) meteorological information;
- l) fuel requirements, fuel load and records;
- m) cargo manifests and information on dangerous goods, if applicable;
- n) mass and balance documentation; and
- o) any other documentation that may be pertinent to the flight or required by the State(s) involved in the operation.

6.6.4 Technical information regarding the RPAS (e.g. journey and maintenance log books, flight plan changes and fuel status) must be updated and all pertinent information conveyed to successive remote pilots. Electronic log books should be updated as soon as practicable during or immediately after the flight segment of each remote pilot.

6.6.5 The format (e.g. electronic) of the documents listed above must be acceptable to the State of the Operator and to all other States involved in the operation.

Documents carried on board the RPA

6.6.6 The following documents must be available on board each RPA:

- a) ROC (certified true copy);
- b) certificate of registration of the RPA (certified true copy);
- c) CofA of the RPA (certified true copy);
- d) licences of each remote pilot involved in the current flight (certified true copies);
- e) journey log book;
- f) operations specifications;
- g) cargo manifests and information on dangerous goods, if applicable;
- h) noise certificate, if applicable; and
- i) aircraft radio station licence (certified true copy).

6.6.7 The format (e.g. electronic) of the documents listed above must be acceptable to the State of the Operator and to all other States involved in the operation.

Documents at or in close proximity of the RPA ground operations area

6.6.8 Documents, manuals and information, including, but not limited to the following, should be available at or in close proximity of the RPA ground operations area(s):

- a) RPA flight manual, or pertinent subset thereof; and
- b) cargo manifests and information on dangerous goods, if applicable;

6.7 OPERATING FACILITIES

6.7.1 Consistent with the provisions of Annex 6, the RPAS operator must ensure that a flight will not be commenced unless it has been ascertained by every reasonable means available that the ground, space, air and/or water facilities available and directly required on such flight, for the safe operation of the RPAS, are adequate for the type of operation under which the flight is to be conducted and are adequately operated for this purpose.

6.7.2 An RPAS operator must ensure that any inadequacy of facilities observed in the course of operations is reported, including to the concerned ATS provider, if applicable, without undue delay.

6.8 RPAS OPERATOR RESPONSIBILITIES FOR CONTINUING AIRWORTHINESS

RPAS operator's maintenance responsibilities

6.8.1 The RPAS operator is responsible for ensuring that all components of the RPAS are maintained in an airworthy condition. Furthermore, the RPAS operator must ensure that operational and emergency equipment necessary for the intended flight are serviceable.

6.8.2 The RPAS operator must establish and implement a maintenance programme in accordance with the manufacturer's recommendation and approved by the State of Registry.

6.8.3 An RPAS operator should not operate an RPAS unless it is maintained and released to service by an approved maintenance organization or under an equivalent system, either of which should be acceptable to the State of Registry. When the State of Registry accepts an equivalent system, the person signing the maintenance release should be licensed in accordance with Annex 1.

Note.— For the purpose of this manual, the term “maintenance organization” means either an approved maintenance organization or an equivalent system, either of which is acceptable to the State of Registry.

RPAS operator's maintenance control manual (MCM)

6.8.4 The operator should provide, for the use and guidance of maintenance and operational personnel concerned, an MCM, acceptable to the State of Registry.

6.8.5 The MCM should clearly describe maintenance procedures including the procedures for completing and signing a maintenance release when maintenance is performed and completed.

6.8.6 The RPAS operator should provide copies of the approved MCM at each RPS and maintenance location.

6.8.7 The RPAS operator must provide the State of the Operator and the State of Registry with a copy of the operator's MCM, together with all amendments and/or revisions to it and must incorporate in it such mandatory material as the State of the Operator or the State of Registry may require.

6.8.8 The design of the MCM should observe the Human Factors principles (see *Human Factors Training Manual* (Doc 9683)).

Maintenance programme

6.8.9 The RPAS operator should establish and provide, for the use and guidance of maintenance and operational personnel concerned, a maintenance programme, approved by the State of Registry.

6.8.10 When the State of Registry is different from the State of the Operator, the review of the programme may be coordinated through an approved procedure as defined in the MCM and company procedures manual.

6.8.11 The design and application of the RPAS operator's maintenance programme must observe Human Factors principles (see Doc 9683).

- 6.8.12 The maintenance programme must contain, but is not limited to, the following:
- a) maintenance tasks and the intervals at which these are to be performed based on the RPA, RPS, C2, and other components of the RPAS;
 - b) a continuing structural integrity programme (SIP);
 - c) procedures for deviating from a) and b) above for tasks that do not have mandatory designations from the State of Design; and
 - d) condition monitoring and reliability programme descriptions for RPA, RPS, launch/recovery equipment and other essential components.

Maintenance records

6.8.13 The RPAS operator must ensure that records associated with the maintenance of all components of the RPAS are received from the maintenance organization and retained in accordance with the RPAS operator's approved procedures, MCM and applicable State regulations.

6.8.14 The following maintenance records should be kept by the RPAS operator for a minimum period of 90 days after the unit to which they refer has been permanently withdrawn from service:

- a) the total time in service (hours, calendar time and cycles, as appropriate) of the RPA and all life-limited components;
- b) the current status of compliance with all mandatory continuing airworthiness information;
- c) appropriate details of modifications and repairs;
- d) the time in service (hours, calendar time and cycles, as appropriate) since the last overhaul of the RPA or its components subject to a mandatory overhaul life; and
- e) the current status of the RPA's compliance with the maintenance programme.

6.8.15 The detailed maintenance records should be kept for a minimum period of one year after the signing of the maintenance release to show that all requirements for the signing of a maintenance release have been met.

6.8.16 In cases where the State of Registry and State of the Operator are different, the RPAS operator should ensure that appropriate records for the RPA, RPS and launch/recovery equipment are available at each relevant location for inspection by the competent authority.

Continuing airworthiness information

6.8.17 The RPAS operator must ensure that all RPAS are maintained and operated in accordance with the State of Registry requirements and are in a condition for safe operation at any time during their service life.

6.8.18 Reporting systems should be established and mandatory continuing airworthiness information complied with, in a manner consistent with those contained in Annex 6, Part I, section 8.5; and Annex 8 — *Airworthiness of Aircraft*, Part II — *Procedures for Certification and Continuing Airworthiness*, Chapter 4. (See Doc 9760 for guidance on continuing airworthiness.)

Modifications and repairs

6.8.19 The RPAS operator must ensure that all modifications and repairs carried out on the RPAS components are in compliance with airworthiness requirements acceptable to the State of Registry.

6.8.20 The RPAS operator must establish procedures to ensure that the substantiating data supporting compliance with the airworthiness requirements are retained in accordance with State regulations.

RPAS maintenance and release to service

6.8.21 The RPAS operator must not operate the RPAS unless it is maintained and released to service by a maintenance organization.

6.8.22 In accordance with Annex 6, a maintenance release must be completed and signed, as prescribed by the State of Registry. In the case of RPAS, this may involve the use of separate log books for each RPA and RPS.

6.8.23 The RPAS operator must ensure that the maintenance of the RPAS is performed in accordance with the maintenance programme.

6.8.24 If an RPS or other essential component is located and maintained in a State other than the State of Registry, the RPAS operator must satisfy the State of Registry that the components are properly maintained. The State of Registry may require contractual arrangements, bilateral or multilateral agreements or national regulations as described in 6.4, to support such arrangements.

6.9 REMOTE FLIGHT CREW AND SUPPORT PERSONNEL

6.9.1 In manned aviation, a flight crew member is a licensed crew member charged with duties essential to the operation of an aircraft during a flight duty period. The terms “remote flight crew” and “remote flight crew member” have been developed as a means of referring to licensed remote pilots who are charged with duties essential to the operation of an RPAS during a flight duty period.

Composition and duties of the remote flight crew

6.9.2 The RPAS operator is responsible for compliance with the State requirements and the safe conduct of all operations.

6.9.3 The RPAS operator is responsible for designating and authorizing one remote pilot to act as remote PIC. In some cases, such as ultra-long duration flights where it is impractical for one person to be remote PIC continuously, the RPAS operator, if approved by the State, may establish appropriate policies and procedures for the transfer of remote PIC responsibilities. In these cases, only one remote pilot may hold remote PIC responsibility at any given time.

6.9.4 The RPAS operator is responsible for designating other members of the remote flight crew as necessary.

6.9.5 RPAS operators may consider the benefits of having all remote pilots involved in the intended operation included in the planning phase of the flight.

Remote PIC considerations

6.9.6 The RPAS operator is responsible for designating the remote PIC. This individual is responsible for the operation of the RPA in accordance with the rules of the air laws, regulations and procedures of those States in which operations are conducted, except that the remote PIC may depart from these in circumstances that render such departure absolutely necessary in the interests of safety. The remote PIC will have final authority as to the disposition of the RPA while in command (see Chapter 9 for remote PIC considerations).

Transfer of remote PIC responsibility during flight

6.9.7 RPAS operations can be of very long duration, potentially for several months, and have the potential to be piloted from different locations, possibly from different States. This creates significant legal issues as one individual cannot, in practice, fulfil the remote PIC responsibilities for the duration of the flight. If there is no transfer of command, the remote PIC will be off duty for some of the flight. If the State allows the transfer of remote PIC responsibilities, handovers between remote pilots, whether at collocated or widely spaced RPS, will need to explicitly identify whether or not the remote PIC responsibility is transferred coincident with the handover of the RPA.

Remote flight crew member training programmes

6.9.8 An RPAS operator should establish and maintain an RPAS training programme, approved by the State of the Operator, which ensures that all remote flight crew members acquire and maintain the competencies to perform their assigned duties in terms of knowledge, skills and attitude. The training programme should consist of training in the RPS model(s) from which the remote pilot will fly the specific RPA type(s) and should include:

- a) knowledge and skills related to the RPA operational procedures for the intended area of operation and in the transport of dangerous goods;
- b) remote flight crew coordination and handover procedures, if applicable;
- c) abnormal and emergency situations or procedures (e.g. loss of C2 link, flight termination);
- d) methods to maintain situational awareness of the RPA's environment; and
- e) human performance aspects related to crew resource management, threat and error management (TEM) and automation or human-machine interface (HMI) which are unique to unmanned aviation.

6.9.9 Training should be given on a recurrent basis, as determined by the State of the Operator and must include an assessment of competence.

Fatigue management

6.9.10 Remote pilots must be able to perform their duties at an adequate level of alertness. To ensure this, RPAS operators whose organizations include operation shifts and crew scheduling schemes should establish policies and procedures for flight and duty time, operation shift schedules and crew rest periods based on scientific principles. Such policies and procedures should be documented in the operations manual and may include:

- a) training and education on personal and operational fatigue-related risks and countermeasures;
- b) implementation of mitigations where necessary and monitoring of their effectiveness; and

- c) continued review of fatigue-related risks through safety management processes.

Support personnel

6.9.11 The RPAS operator, if utilizing dispatch services, should ensure that the training and competency of the flight dispatchers is commensurate with the duties they are assigned.

6.9.12 The RPAS operator is responsible for designating any other support personnel necessary for the safe conduct of its operation. This may include RPA observers, ground station technicians and other ground support crew for launch and recovery, etc. The RPAS operator is responsible for ensuring that the training and competency of these individuals is commensurate with the duties they are assigned.

Chapter 7

SAFETY MANAGEMENT

7.1 OVERVIEW

7.1.1 This chapter presents information regarding the roles and safety responsibilities of State aviation organizations and service providers under safety oversight with respect to RPAS. The areas covered are State Safety Programme (SSP), the oversight of service providers' SMS and the privileges of RPAS operators which include, among others, contracted service providers operating under the safety risk management of the RPAS operator's SMS.

7.1.2 These responsibilities are directly linked to provisions contained in Annex 19 — *Safety Management* and to guidance material in the *Safety Management Manual (SMM)* (Doc 9859).

7.1.3 One of the objectives of Annex 19 and its related guidance material is to harmonize the implementation of safety management practices for States and organizations involved in aviation activities. Therefore, the SARPs in Annex 19 are intended to assist States in managing aviation safety risks.

Note.— Additional guidance on the objectives and the establishment and implementation of SSPs and safety management systems are contained in Doc 9859.

7.2 STATE SAFETY PROGRAMME (SSP)

7.2.1 An 'SSR is a management system for the regulation and administration of safety by the State. According to Annex 19 (Standard 3.1.1 refers), each State shall establish an SSP in order to achieve an acceptable level of safety performance in civil aviation.

7.2.2 The SSP, and the SMS by its service providers, allow an effective identification of systemic safety deficiencies found in RPAS operations, as well as the resolution of safety concerns.

7.2.3 Provisions regarding safety data collection, analysis and exchange require that the voluntary incident reporting system be non-punitive and afford protection to the sources of the information. Each State is required to establish a mandatory and voluntary incident reporting system and facilitate and promote these reporting schemes by adjusting their applicable laws, regulations and policies, as necessary. RPAS operators, remote pilots and other stakeholders should report safety deficiencies using these systems.

7.2.4 Guidance on a State's mandatory reporting procedures and its voluntary and confidential reporting system can be found in Appendices 2 and 3 to Chapter 4 of Doc 9859.

7.3 RPAS OPERATOR

7.3.1 The RPAS operator is a person, organization or enterprise engaged in or offering to engage in an RPAS operation.

7.3.2 Irrespective of the type of operation (e.g. private, corporate, commercial), all RPAS operators must be certified by the State. One of the requirements for certification is expected to be that the RPAS operator has implemented an effective SMS.

7.4 RPAS OPERATOR'S SAFETY MANAGEMENT SYSTEM (SMS)

7.4.1 As part of its SSP, each State must therefore, require that service providers under its authority implement an SMS. In accordance with Annex 19, aircraft operators are service providers and must implement an SMS. This applies equally to RPAS operators.

7.4.2 The potential impact on the organization's safety performance resulting from interaction of internal and external aviation system stakeholders must be taken into consideration when implementing an SMS. It is important to evaluate the risks associated with the RPAS operations being conducted, especially the potential impact on other service providers. The introduction of RPA into non-segregated airspace requires a thorough assessment of the safety performance of the RPAS operations. Based on this, an SMS of an RPAS operator should be:

- a) established in accordance with the SMS framework elements contained in Appendix 2 to Annex 19; and
- b) commensurate with the size of the service provider and the complexity of its aviation products or services.

7.5 SAFETY RESPONSIBILITIES AND ACCOUNTABILITIES

7.5.1 The SMS-related accountabilities, responsibilities and authorities of all appropriate senior managers must be described in the RPAS operator's SMS documentation. Mandatory safety functions performed by the technical staff involved in the establishment and implementation of an RPAS operator's SMS may be embedded into existing job descriptions, processes and procedures. The size, structure and complexity of the organization may vary, but the safety functions must remain.

7.5.2 An RPAS operator is responsible for the safety performance of products or services provided by contractors that do not separately require safety certification or approval, including when the products and services are available directly from the service provider via a worldwide network of independent distribution partners and third parties in different locations (e.g. Inmarsat, SITA, ARINC). In this case the RPAS operator should, under its SMS, ensure the safety performance of the contracted services (see Figure 7-1).

7.5.3 In contrast, if the contractor is certified or approved by the State civil aviation authority, the RPAS operator does not need to include the safety of the provided services or products under its SMS. While all contractors may not necessarily be required to have an SMS, it is nevertheless the RPAS operator's responsibility to ensure that its own safety performance requirements are met.

Note.— Contractual agreements with service providers are addressed in Chapter 6.

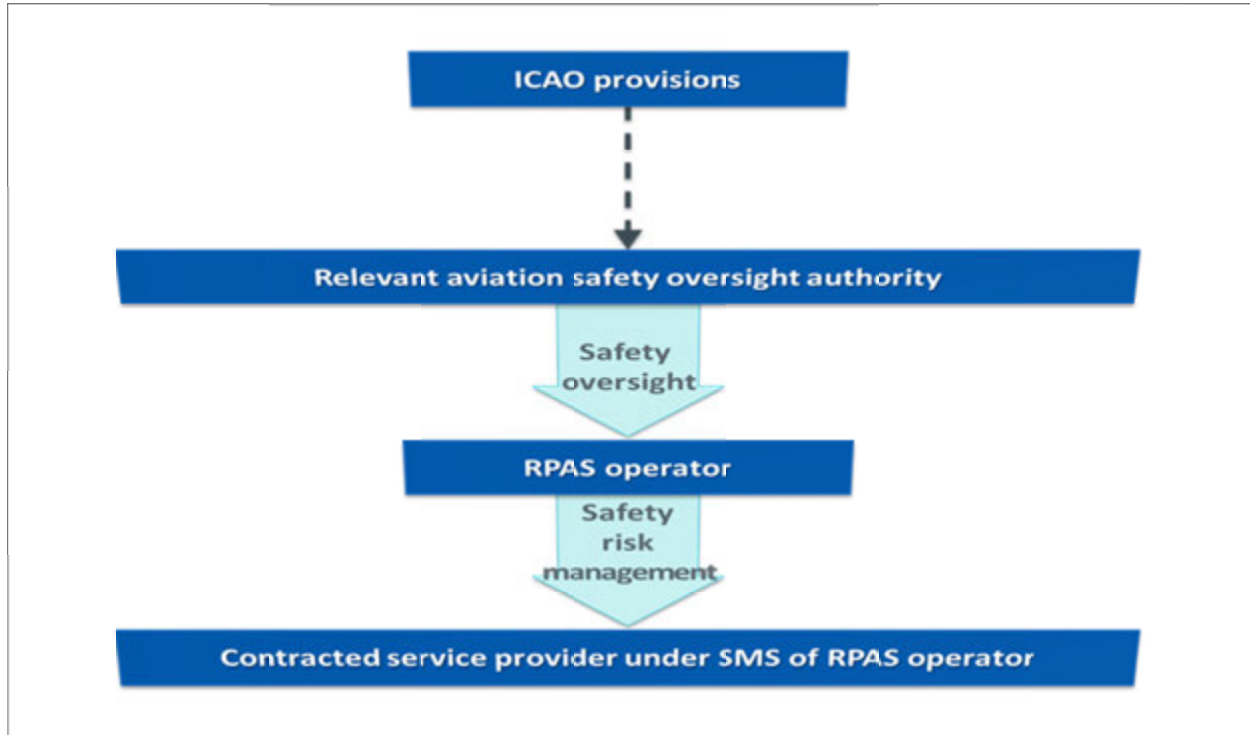


Figure 7-1. Contracted service provider under the SMS of the RPAS operator

7.6 HAZARD IDENTIFICATION AND SAFETY RISK MANAGEMENT IN RPAS OPERATIONS

Hazards exist in aviation activities. They may also be introduced inadvertently into an operation whenever changes are made to the aviation system. It is necessary to have an effective reporting system in place in order to identify hazards, assess the related risks and develop appropriate mitigations in the context of the RPAS products or services. The establishment of safety-reporting procedures should be addressed and endorsed in the RPAS operator's safety policy, commensurate with the size, structure and complexity of the operations. Guidance on hazard identification and safety risk management processes are provided in Chapter 5 of Doc 9859.

7.7 COORDINATION OF EMERGENCY RESPONSE PLANNING

The applicability of emergency response planning by RPAS operators may be extended to other service providers affected by a safety occurrence generated by an RPAS or its operation. Therefore, an RPAS operator should ensure that an emergency response plan is coordinated with the emergency response plans of those organizations with which it would interface.

Chapter 8

LICENSING AND COMPETENCIES

8.1 OVERVIEW

8.1.1 Remote pilots are fundamental to the safe operation of RPAS. They have the same basic responsibilities as pilots of manned aircraft for the operation of the aircraft in accordance with the rules of the air, and the laws, regulations and procedures of those States in which operations are conducted. However, the competencies of these individuals will have to be carefully reviewed to ensure that the knowledge, skills and attitude are relevant for these new types of operations.

8.1.2 This chapter provides guidance material concerning harmonized remote pilot licensing and RPA observer competency. In Annex 1, multiple types of pilot licences (private pilot licence (PPL), commercial pilot licence (CPL), multi-crew pilot licence (MPL) and airline transport pilot licence (ATPL)) are addressed. The remote pilot is a new category of aviation professional. Unlike manned aviation, a single remote pilot licence which covers all types of scenarios is expected to be developed. This licence will be annotated with ratings, limitations and endorsements, as appropriate.

8.1.3 The guidance presented in this document represents the culmination of best practices and procedures used in prior RPAS approvals, as well as input from government agencies, industry and other stakeholders. It should be noted that the material presented in this chapter is a recommended harmonized approach to remote pilot licensing and RPA observer competency. Because RPAS are a new part of aviation, each application for remote pilot licensing should be assessed by the regulator on its own technical merits and may require unique authorizations which are based on the specific needs or capabilities of the RPAS in question.

8.1.4 The guidelines in this chapter do not apply to persons flying toys or model aircraft when these systems are used exclusively for sport or recreational purposes. However, these persons must comply with regional or national legislation, ordinances, restrictions or other agreed upon guidance regarding the flight of model aircraft and/or toys.

8.1.5 Licensing of air traffic controllers will not be affected by the introduction of RPAS. However, when RPAS are introduced within an ATC environment, additional training requirements specific to different types of RPAS characteristics could be required for ATC personnel including, inter alia, performance, behaviour, communication, operating limitations and emergency procedures.

8.1.6 It should be further noted that due to the rapid evolution of RPAS technology, this guidance material will be subject to continuous review and will be updated when appropriate.

8.2 FUNDAMENTALS

8.2.1 There are many categories of aircraft, among them aeroplanes, airships, free balloons, gliders, helicopters and powered-lift. Aircraft from each of these categories can potentially be remotely piloted. For manned aircraft, class ratings distinguish single versus multi-engine, and land planes versus sea planes; however, for unmanned aircraft, class ratings must also address the RPS and its interaction with the RPA. These considerations require a new approach for licensing.

8.3 LICENSING AUTHORITY

8.3.1 The licences of remote pilots should be issued or rendered valid by the licensing authority of the State in which the RPS is located, even if the RPS is only temporarily located in the State. This facilitates oversight of the remote pilot by the licensing authority.

Note.— Article 32 of the Chicago Convention which stipulates that the licences of the pilot and other members of the operating crew of an aircraft engaged in international navigation shall be issued or rendered valid by the State in which the aircraft is registered does not apply to remote pilot licences.

8.4 GUIDANCE FOR THE REGULATOR ON RULES FOR THE REMOTE PILOT LICENCE AND RPA OBSERVER COMPETENCY

General rules

8.4.1 A person should not act either as remote PIC or as a remote co-pilot of an RPA unless that person is the holder of a remote pilot licence, containing the ratings suitable for the purpose of executing the operation.

8.4.2 A person should not act as an RPA observer unless that person has undergone a competency-based training on visual observer duties concerning RPA VLOS operations.

Human performance

8.4.3 Remote pilot licence requirements and the requirements for the RPA observer competencies should consider the integration of human performance issues within a competency-based training and assessment approach.

8.4.4 All stakeholders (instructors, assessors, course developers, training providers, inspectors, etc.) involved in the training and assessment process should be provided with guidance on how to develop, implement and manage or oversee competency-based training and assessments that integrate human performance elements. Human performance training should not stand out as a separate subject.

Obligation for personnel to carry documents

8.4.5 When operating an RPA or RPS:

- a) a remote pilot must hold a current medical assessment;
- b) a remote pilot must have in his/her possession a valid remote pilot licence;
- c) an RPA observer should have proof of RPA observer competency issued by the RPAS operator or an approved training organization in his/her possession;
- d) the remote pilot must meet the requirements for recent experience established by the licensing authority or, if greater, the requirements for recent experience established by the State of the Operator; and
- e) in case of international flights, a copy of the remote pilot licence(s), must be provided to the involved authorities as per Annex 2, Appendix 4, 3.2 g).

Language proficiency

8.4.6 Remote pilots that are required to communicate with ATS must demonstrate the ability to speak and understand the language used for ATS communications to the level specified in the language proficiency requirements in Annex 1, Appendix 1, and have proof of language proficiency.

8.4.7 Proof of language proficiency in either English or the language used for communications involved in the remotely piloted flight should be endorsed on the remote pilot licence.

8.4.8 Such proof of language proficiency should indicate the language, the proficiency level and the validity date.

8.4.9 The applicant for a proof of language proficiency should demonstrate at least an operational level of language proficiency both in the use of phraseologies and plain language. To do so, the applicant should demonstrate, in a manner acceptable to the licensing authority, the ability to:

- a) communicate effectively in voice-only and in face-to-face situations;
- b) communicate on common and work-related topics with accuracy and clarity;
- c) use appropriate communicative strategies to exchange messages and to recognize and resolve misunderstandings in a general or work-related context; and
- d) handle successfully, and with relative ease, the linguistic challenges presented by a complication or unexpected turn of events that occurs within the context of a routine work situation or communicative task with which they are otherwise familiar; and
- e) use a dialect or accent which is intelligible to the aeronautical community.

8.4.10 Except for remote pilots who have demonstrated language proficiency at an expert level, the language proficiency endorsement should be re-evaluated periodically, according to the level of language proficiency.

Credit for remote pilot licences

8.4.11 The licensing authority should establish methods and criteria for crediting prior demonstrated knowledge, experience and skill acquired in manned or unmanned aviation.

Rendering remote pilot licences valid

8.4.12 When a Member State renders valid a remote pilot licence issued by another Member State, as an alternative to the issuance of its own licence, it should establish validity by suitable authorization to be carried with the remote pilot licence.

Credit for remote pilot licences obtained during military service

8.4.13 In order for holders of military pilot licences or military remote pilot licences to obtain civil remote pilot licences, they should apply to the Member State where they served.

8.4.14 The knowledge, experience and skill obtained in military service should be given credit by the licensing authority.

8.4.15 The licensing authority should establish methods and criteria for crediting prior demonstrated knowledge, experience and skill obtained during military service.

Student remote pilot

8.4.16 A student remote pilot should meet requirements prescribed by the Member State concerned. Additionally, a student remote pilot should not act as solo remote pilot of an RPAS:

- a) unless under the supervision of, or with the authority of, an authorized RPAS instructor; or
- b) on an international RPA flight unless by special or general arrangement between the Member States concerned.

8.4.17 A Member State should not permit a student remote pilot to fly an RPA unless that student holds a current medical assessment.

Remote pilot licence — minimum age

8.4.18 An applicant for a remote pilot licence should be no less than 18 years of age.

Application and issue of remote pilot licences and associated ratings, limitations and endorsement

8.4.19 Any person satisfying the eligibility requirements should be able to file an application for a remote pilot licence.

8.4.20 While possessing (or having possessed) a valid pilot licence may provide credit toward knowledge, experience and skill related to a remote pilot licence, the possession of a valid pilot licence for manned aviation is not a prerequisite.

8.4.21 An application should be submitted to the licensing authority in a form and manner established by this authority for:

- a) the issuance, revalidation or renewal of the remote pilot licence and associated ratings, limitations and endorsements; or
- b) additional ratings, removal of limitations or amendments of endorsements.

8.4.22 The application should be accompanied by evidence that the applicant complies with the requirements as mentioned above.

Privileges and conditions

8.4.23 *Privileges.* The privileges of the holder of a remote pilot licence including any associated ratings, limitations and endorsements are, within the appropriate RPA category and RPS type, to act as remote pilot of an RPAS for the type of operation being conducted. A remote pilot may also act as an RPA observer, if appropriately trained.

8.4.24 The exercise of the privileges granted by a remote pilot licence is dependent upon the validity of the licence and of the ratings contained therein, if applicable, and of the medical assessment.

8.4.25 *Conditions.* Once requirements for the category and type rating of RPA are developed, and the type or class ratings for RPS are defined, these should be included in the skill test of an applicant for the issue of a remote pilot licence.

Theoretical knowledge examinations

8.4.26 Applicants for a remote pilot licence should:

- a) take those examinations applicable for the remote pilot licence and associated ratings they seek from the licensing authority of one Member State; and
- b) only take the examination when recommended by the authorized instructor or approved training organization responsible for their training and upon completion of the appropriate elements of the training course to a satisfactory standard.

8.4.27 The recommendation by an authorized instructor or approved training organization should be valid for a period established by the licensing authority. If the applicant has failed to attempt at least one theoretical knowledge examination within this period of validity, the need for further training should be determined by the authorized instructor or approved training organization, based on the needs of the applicant.

Pass standards

8.4.28 A pass in a theoretical knowledge examination should be awarded to an applicant achieving the minimum percentage established by the licensing authority for that examination.

8.4.29 Theoretical knowledge examinations, comprised of more than one test, should be completed by the applicant within a time period established by the licensing authority.

Validity period

8.4.30 The successful completion of the theoretical knowledge examination should be valid for a period established by the licensing authority.

Subjects of knowledge

8.4.31 The applicant for a remote pilot licence should have demonstrated a level of knowledge appropriate to the privileges granted to the holder of a remote pilot licence and appropriate to the category of RPA intended to be included in the remote pilot licence, in at least the following subjects:

- a) air law;
- b) RPAS general knowledge;
- c) flight performance, planning and loading;
- d) human performance;
- e) meteorology;

- f) navigation;
- g) operational procedures;
- h) principles of flight; and
- i) radiotelephony.

Practical skill test

8.4.32 Before a skill test for the issue of a remote pilot licence is taken, the applicant should have passed the required theoretical knowledge examination(s). The theoretical knowledge instruction should always be completed before skill tests are taken.

8.4.33 The applicant for a skill test should be recommended for the test by the authorized instructor or approved training organization responsible for the training, once the required training has been completed. The training records should be made available to the RPA examiner.

8.4.34 An applicant for a remote pilot licence should pass a skill test to demonstrate the ability to perform, as remote PIC of the appropriate RPA category and associated RPS, the relevant procedures and manoeuvres with the competency appropriate to the privileges granted.

8.4.35 An applicant for a skill test for the remote pilot licence should have received instruction for operations on the same RPA category and associated RPS to be used in the test.

8.4.36 The applicant for the issue of a remote pilot licence should demonstrate the ability to:

- a) recognize and manage threats and errors;
- b) operate the RPA within its limitations or those limitations imposed by regulation;
- c) complete all manoeuvres with smoothness and accuracy;
- d) exercise good judgement and airmanship;
- e) apply aeronautical knowledge; and
- f) maintain control of the RPA at all times in a manner such that the successful outcome of a procedure or manoeuvre is assured.

8.4.37 Progress in acquiring the required skills should be continually assessed.

Experience requirement

8.4.38 An applicant for a remote pilot licence should have appropriate experience flying an RPA in actual or simulated flight.

8.4.39 An applicant for a remote pilot licence should have completed the experience in an approved training course. The training should be competency-based and conducted in an appropriate RPAS environment.

RPAS instruction

8.4.40 The applicant for a remote pilot licence should have received dual RPAS instruction from an authorized RPAS instructor in the appropriate RPA category and associated RPS for the category, type and class rating(s) sought.

8.4.41 The RPAS instructor should ensure that the applicant for a remote pilot licence has operational experience in the following areas to the level of performance required for the remote pilot, if applicable:

- a) recognize and manage threats and errors;
- b) pre-flight operations, including RPA and RPS inspection and servicing, communications checks and control function verification, setup of RPS, loading and validation of flight planning information, and obtaining ATC clearances where appropriate;
- c) aerodrome ground operations and traffic pattern operations where applicable, ground and airborne collision (CA) avoidance precautions and procedures including use of RPA observers and communications services if required;
- d) control of the RPA by visual reference unless the RPAS does not provide for manoeuvres by visual reference;
- e) recovery from flight at critically slow airspeeds, high sink rates and, in the case of RPA aeroplanes, spin avoidance;
- f) recovery from unusual attitudes using flight instrumentation or by use of camera systems;
- g) normal and crosswind take-offs and landings;
- h) navigation procedures using all available means including change of destination or in-flight change of lost C2 link flight plan programming;
- i) identification of hazardous meteorological conditions and avoidance procedures thereof;
- j) abnormal and emergency procedures and manoeuvres including simulated aircraft engine and electrical failures, software failures, loss of C2 link, failures and malfunctions limited to the RPS, communications failure;
- k) in the case of RPA helicopters: abnormal and emergency procedures; autorotation, retreating blade stall, lower rotor rpm settling with power, forced landings, sloped ground operations, max performance take-off, steep approach, run-on landing and take-off.
- l) compliance with airspace restrictions, lateral and vertical, compliance with ATC services instructions and procedures; and
- m) in the case of RPA helicopters: hovering — taxi and turns; transition from hovering to flight and from flight to hovering.

Crediting of flight time

8.4.42 Crediting of flight time:

- a) unless otherwise specified in by the licensing authority, time to be credited for a remote pilot licence should have been acquired in operations of RPAS;
- b) an applicant for a remote pilot licence and associated rating should be credited in full with all flight time in the appropriate RPA category and associated RPS, for which the remote pilot licence and associated ratings are sought;
- c) the licensing authority should determine whether experience as a remote pilot under instruction in an RPA flight simulation training device (FSTD) is acceptable as part of the total RPA flight time required and to what extent such credit for experience will be granted; and
- d) when the applicant for a remote pilot licence has flight time as a pilot of manned aircraft or as a remote pilot of RPA in other categories, the licensing authority should determine whether such experience is acceptable and, if so, the extent to which the flight time requirements may be reduced.

Crediting of theoretical knowledge

8.4.43 The applicant for a remote pilot licence should be credited towards the requirements for theoretical knowledge instruction and examination for a remote pilot licence in another category of RPA or type of RPS. This credit also applies to applicants for a remote pilot licence who have already successfully completed the theoretical knowledge examinations for the issuance of a remote pilot licence in another category of RPA or type of RPS.

Recording of RPA flight time

8.4.44 The remote pilot should keep a reliable record of the details of all RPA flights exercised in a form and manner established by the licensing authority.

Class and type ratings

8.4.45 Holders of a remote pilot licence should not act in any capacity as remote pilots unless they have a valid and appropriate class or type rating, except when undergoing skill tests, or proficiency checks for issue or renewal of class or type ratings, or receiving RPAS instruction.

8.4.46 If modification is made to the RPA or RPS type(s) for which the remote pilot is rated and that does not require the establishment of a different type, the remote pilot should be trained by the RPAS operator to perform the remotely piloted flights using the modified RPA/RPS types.

8.4.47 A class rating should be established for RPA and RPS certificated for single-remote pilot operation, which have comparable handling, performance and characteristics, unless a type rating is considered necessary by the licensing authority.

8.4.48 A type rating should be established for RPA and RPS certificated for operation with a minimum crew of at least two remote pilots or when considered necessary by the licensing authority.

8.4.49 When a class rating is issued limiting the privileges to act as remote pilot only during the cruise phase of the flight, such limitation should be endorsed on the rating.

8.4.50 When a type rating is issued limiting the privileges to act as remote co-pilot, or limiting the privileges to act as remote pilot only during the cruise phase of the flight, such limitation should be endorsed on the rating.

Night operations

8.4.51 Night operations involve distinct skills and areas of knowledge, and it is expected that training programmes will incorporate those aspects into the training and testing of the remote pilot when practical.

8.4.52 The licensing authority should require remote pilots to receive dual instruction in RPA night operations including take-off, landing and navigation before exercising the privilege of the remote pilot licence at night.

Medical fitness

8.4.53 The remote pilot should hold a current medical assessment.

Note.— Guidance on the medical assessment for remote pilots is in 8.7.

8.5 RPAS INSTRUCTOR

General prerequisites and requirements

8.5.1 Prior to the issuance of an RPAS instructor authorization by the licensing authority, an RPAS instructor applicant should:

- a) hold a remote pilot licence with appropriate category, class and type rating(s) for which the privilege to instruct is being sought;
- b) have sufficient training and experience to attain the required level of proficiency in all of the required tasks, manoeuvres, operations and principles, and methods of instruction; and
- c) be entitled to act as remote PIC of the RPAS during such RPAS instruction.

8.5.2 Qualified and authorized RPAS instructors may be assigned to carry out specific assessment, checking or testing duties in instruction techniques for the relevant category or type of RPA and type of RPS to determine that all required performance standards have been satisfactorily achieved. These performance standards may be required as an end-state objective or on a continuous basis in competency-based training. In either case, the RPAS instructor is responsible for making a determination of the actual standards attained and any recommendation for immediate remediation, if necessary.

8.5.3 Prior to training, RPAS instructors should be selected as being suitable for the RPAS instructor role, based upon appropriate motivation for the training role.

8.5.4 In addition, selection of an RPAS instructor should be based on criteria intended to define proven capabilities for which he/she intends to instruct.

8.5.5 Training programmes for the RPAS instructor role should focus on development of the competencies in the following areas:

- a) managing safety;
- b) preparing the training environment;
- c) managing the trainee;
- d) conducting training;
- e) performing trainee assessment;
- f) performing course evaluation; and
- g) continuously improving performance.

Note.— Guidance on instructor competencies is contained in PANS-TRG (Doc 9868).

Competencies

8.5.6 All RPAS instructors should be trained to:

- a) prepare resources;
- b) create a climate conducive to learning;
- c) present knowledge;
- d) integrate TEM and crew resource management;
- e) manage time to achieve training objectives;
- f) facilitate learning;
- g) assess trainee performance;
- h) monitor and review progress;
- i) evaluate training sessions; and
- j) report outcomes.

Assessment of competence

8.5.7 An applicant for an RPAS instructor authorization should pass an assessment of competence in the relevant type or class of RPA and type of RPS to demonstrate the ability to instruct a student remote pilot to the level required for the issue of the remote pilot licence.

8.5.8 The assessment should be performed on the same type or class of RPA or type of RPS or FSTD used for the RPAS instruction.

8.5.9 All RPAS instructors should receive refresher training, and be reassessed using a documented training and assessment process acceptable to the licensing authority, implemented by a certificated or approved organization, at intervals established by the licensing authority but not greater than 3 years.

Special conditions

8.5.10 In the case of introduction of a new RPA or RPS in an operator's fleet, when compliance with the requirements established by the licensing authority is not possible, the licensing authority may consider issuing a specific authorization giving privileges for RPAS instruction. Such an authorization should be limited to the instruction flights necessary for the introduction of the new type of RPA or RPS. The licensing authority should determine the validity period of this authorization.

Revalidation and renewal of RPAS instructor rating

8.5.11 When issuing further RPAS instructor authorizations, and for the purpose of revalidation, the licensing authority should credit:

- a) applicants with the teaching and learning skills already demonstrated for the RPAS instructor authorization held; and
- b) hours in the role of an RPAS examiner during skill test or proficiency checks in full towards revalidation requirements for all RPAS instructor authorizations held.

8.5.12 The licensing authority should:

- a) determine the validity period for the RPAS instructor authorization; and
- b) establish methods for the revalidation and renewal of the RPAS instructor authorization.

8.6 RPA OBSERVER COMPETENCY

General

8.6.1 Any individual satisfying the competency requirements may be assigned duties as an RPA observer.

8.6.2 The possession of a valid flight crew licence for manned aviation or valid remote pilot licence should not be a prerequisite but may be considered when assessing the competency of the individual to serve as an RPA observer.

Minimum age

8.6.3 A person assigned duties as an RPA observer by the operator should be no less than 18 years of age.

Training course

8.6.4 A person assigned duties as an RPA observer by the operator should complete an appropriate competency-based training course. A record of this training should be kept and made available for inspection.

8.7 MEDICAL ASSESSMENT

8.7.1 The Class 3 medical assessment, applicable to air traffic controllers, is considered to be appropriate for remote pilots.

8.7.2 If the medical Standards prescribed in Annex 1, Chapter 6, are not met, the flexibility provided by Annex 1, 1.2.4.9, may be considered given the particular environment of the RPS and the conduct of the RPAS operations.

Note.— Guidance material to apply Annex 1, 1.2.4.9, is contained in the Manual of Procedures for Establishment and Management of a State's Personnel Licensing System (Doc 9379).

8.7.3 The period of validity of a Class 3 medical assessment is from the date of the medical examination for a period not greater than 48 months, reduced to 24 months when the licence holder has passed his/her 40th birthday.

Note.— Guidance material to assist Licensing Authorities and medical examiners is published separately in the current edition of the Manual of Civil Aviation Medicine (Doc 8984).

8.7.4 The Class 3 medical assessment issued to an air traffic controller should not automatically be considered valid for a remote pilot and vice versa. The medical examiner has the flexibility to consider the work environment of the applicant when assessing medical fitness and may determine that what is acceptable for one is unacceptable for the other. For this reason, the Class 3 medical assessment should reflect that it has been issued for a remote pilot.

Chapter 9

RPAS OPERATIONS

9.1 OVERVIEW

The safe operation of aircraft necessitates compliance with a number of requirements which are established in the Annexes to the Chicago Convention. These requirements apply equally to RPAS operations and are intended to mitigate risk to persons and property on the ground and other airspace users. Where differences occur from manned aviation, they are addressed below.

9.2 OPERATIONAL FLIGHT PLANNING

Operational flight planning should include provisions similar to those in manned operation. In addition, specific needs for RPAS such as the number of remote pilots and crew duty time planning for long endurance missions or the availability of RPS may be required. Such requirements may not be available at the time of departure but may be necessary for operation in a later phase of the flight. The RPAS operator should establish procedures to ensure a seamless operation throughout the duration of the flight, including remote pilots who can carry out the responsibilities for the different phases of the flight such as take-off, climb, cruise, approach and landing, all of which should be included in the operations manual.

9.3 RPAS MANUALS

Operations manual

9.3.1 An RPAS operator must provide an operations manual for the use and guidance of the RPAS operations personnel concerned. The operations manual must be amended or revised as is necessary to ensure that the information contained therein is kept up to date. All such amendments or revisions must be issued to all personnel that are required to use this manual.

9.3.2 The State of the Operator should establish a requirement for the RPAS operator to provide a copy of the operations manual together with all amendments and/or revisions, for review and acceptance and, where required, approval. The RPAS operator must incorporate in the operations manual such mandatory material as the State of the Operator may require.

9.3.3 The operations manual, which may be issued in separate parts corresponding to specific aspects of operations, should be organized in the following structure:

- a) general;
- b) RPAS operating information;

- c) areas, routes and aerodromes; and
- d) training.

9.3.4 *RPAS operating manual.* The RPAS operator should provide the remote flight crew and designated operations staff with an RPAS operating manual, for each RPA type operated, which includes each associated RPS model, containing the normal, abnormal and emergency procedures relating to the operation of all the relevant systems associated with the operation of each RPA and of the checklists to be used.

Note 1.— The RPAS operating manual is part of the operations manual.

Note 2.— The design of RPAS operating manuals should observe human performance principles.

9.4 ENVIRONMENTAL CONSIDERATIONS

Meteorological conditions — consistent with performance limitations

9.4.1 The remote pilot should review all available meteorological information pertaining to the operation and performance limitations of the RPAS. Particular attention should be given to such conditions as:

- a) surface visibility;
- b) wind direction/speed;
- c) hazardous meteorological conditions including cumulonimbus, icing and turbulence; and
- d) upper air temperature.

9.4.2 Flight into known or expected icing conditions should not be conducted unless the system is certificated and equipped for flight into those conditions, with the icing protection systems operational in accordance with the MEL, and the remote pilot is current in, and qualified for, cold weather operations.

Impacts on radio frequencies (RFs)

9.4.3 Electromagnetic (EM) interference (e.g. solar flares, volcanic ash, ionospheric activity) may affect performance of C2 links and GPS reception and should be considered by the remote pilot prior to, and during, flight.

9.4.4 The remote pilot should consider the available information regarding potential EM interference and its impact on the RPAS and flight completion. Additional considerations should be given to possible intentional or inadvertent electronic interference.

9.4.5 Operations in areas of high RF transmission/interference (e.g. radar sites, high tension wires) should be avoided unless engineering testing has confirmed that operations in these areas will not impact safe operation of the RPAS.

9.5 OPERATIONS CONSIDERATIONS

Visual line-of-sight operations (VLOS)

9.5.1 A VLOS operation is one in which the remote pilot or RPA observer maintains direct, unaided, visual contact with the RPA.

9.5.2 For VLOS, the visual contact has to be direct, meaning that the remote pilot or RPA observer must maintain a continuous unobstructed view of the RPA, allowing the remote pilot and/or RPA observer to monitor the RPA's flight path in relation to other aircraft, persons, obstacles (e.g. vehicles, vessels, structures, terrain), for the purpose of maintaining separation and avoiding collisions. The direct visual contact must be ensured without visual aids (e.g. telescope, binoculars, electro-optical reproduced/enhanced vision) other than corrective lenses. VLOS operations should be operated in such meteorological conditions that the remote pilot or RPA observer is able to avoid conflicting traffic and other safety risks related to the hazards present in the operating environment.

9.5.3 The flight planning should ensure the remote pilot and/or RPA observer will have sufficient ceiling and visibility and terrain/obstacle clearance to maintain continuous visual contact with the RPA with conditions forecast to continue throughout the duration of the flight. Additionally, the conditions must allow for visual detection of other aircraft in the vicinity.

9.5.4 VLOS operations, in which the RPA is operated at relatively short ranges from the remote pilot or RPA observer and at relatively low altitudes, typically employ a hand-held RPS with limited displays. The term "relative" is used to indicate that the acceptable ranges and altitudes are linked to the conspicuity of the RPA and possible intruders (e.g. other aircraft, including RPA) in the operating environment which is dependent on their colour, size, speed, lighting).

9.5.5 The pilot requires real-time communication capability with any RPA observers and, if a handover will occur, with the other remote pilot(s). In some situations, the remote pilot will also need real-time communications with the local ATC unit.

9.5.6 If the remote pilot cannot visually monitor the RPA and is relying on RPA observers, numerous additional factors need to be considered including:

- a) remote pilot and RPA observer training and competence;
- b) communication delays between RPA observer and remote pilot;
- c) simultaneous communication from multiple RPA observers or conflicting instructions;
- d) communication failure procedures between the RPA observer and remote pilot;
- e) remote pilot's ability to determine the optimum CA manoeuvre when not in visual contact with the RPA or the conflicting traffic; and
- f) remote pilot response time.

9.5.7 Predetermined manoeuvres and phraseology for use by RPA observers and remote pilots to change the flight trajectory may contribute to reduce exposure to conflicting traffic or obstacles and to restore normal flight after carrying out a plan to avoid or mitigate each threat. These predetermined manoeuvres might include direction, rate and extent of turn, climb/descent to a specific altitude, etc.

VLOS operations at night

9.5.8 The remote pilot and/or RPA observer will have an additional challenge at night to judge distance, relative distance and trajectory. VLOS operations should not be conducted at night unless adequate means to mitigate the different possible threats have been established and can be met.

Beyond VLOS operations

9.5.9 To conduct flights beyond VLOS of the remote pilot or RPA observer, a means to DAA traffic and all other hazards such as hazardous meteorological conditions, terrain and obstacles must be available to the remote pilot.

9.5.10 Prior to conducting a controlled BVLOS operation, coordination should be effected with the ATC unit(s) involved regarding:

- a) any operational performance limitations or restrictions unique to the RPA (e.g. unable to perform standard rate turns);
- b) any preprogrammed lost C2 link flight profile and/or flight termination procedures; and
- c) direct telephone communication between the RPS and the ATC unit(s) for contingency use, unless otherwise approved by the ATC unit(s) involved.

9.5.11 Communication between the RPS and the ATC unit(s) should be as required for the class of airspace in which operations occur and should utilize standard ATC communications equipment and procedures, unless otherwise approved by the ATC unit(s) involved.

9.5.12 C2 link transaction time should be minimized so as not to inhibit the remote pilot's ability to interface with the RPA compared to that of a manned aircraft.

9.5.13 The nature of the C2 link (whether RLOS or BRLOS) will also influence the design of the RPAS. From an operational perspective, the main difference between an RLOS operation and a BRLOS operation of a BVLOS RPAS will be the delays associated with control and display information and the design features selected to accommodate the available C2 link capacity.

9.5.14 BRLOS C2 links in general are expected to have lower data capacity (due to cost and bandwidth limitations) and higher message delays than RLOS C2 links. BVLOS RPS will be designed to match the performance of the type of C2 link (BRLOS/RLOS) with which they will be used.

Note.— The more time critical the control function, the higher the level of RPA automation that is required to maintain normal safe flight.

9.5.15 BVLOS operations conducted under VFR should only be considered when the following conditions are met:

- a) the State of the Operator and the State in whose airspace the operation occurs have approved the operation;
- b) the RPA remains in VMC throughout the flight; and
- c) a DAA capability or other mitigation is used to assure the RPA remains well clear of all other traffic; or
- d) the area is void of other traffic; or

- e) the operation occurs in specifically delimited or segregated airspace.

Populated areas

9.5.16 Operations over heavily populated areas or over open air assemblies of people may require special considerations and should consider the following:

- a) altitudes for safe operation;
- b) consequences of uncontrolled landing;
- c) obstructions;
- d) proximity to airports/emergency landing fields;
- e) local restrictions regarding RPAS operations over heavily populated areas; and
- f) the emergency termination of an RPA flight.

Take-off launch

9.5.17 RPAS may be operated from established aerodromes or from almost any other location depending on operational requirements and system configuration, design and performance.

Take-off/launch from aerodromes

9.5.18 For operations from established aerodromes, the remote pilot should consider the following:

- a) regulations pertaining to RPAS operations on or near an aerodrome;
- b) complexity and density of aircraft operations;
- c) ground operations (e.g. taxiway width, condition, other ground traffic);
- d) C2 link continuity;
- e) payload considerations;
- f) wake turbulence;
- g) performance and capability related to take-off distance/run available and minimum obstruction climb requirements, departure procedures and any flight restricting conditions associated with operations to or from the aerodrome; and
- h) availability of emergency recovery areas.

Take-off/launch from other than aerodromes

9.5.19 For operations from other than established aerodromes, the remote pilot should consider the following:

- a) take-off/launch area and condition;
- b) location and height of all obstructions that could hinder launch and recovery;
- c) performance and capability related to obstacle clearance, departure procedures (if applicable) and any flight-restricting conditions;
- d) availability of emergency recovery areas;
- e) ATC communications, if required;
- f) C2 link continuity;
- g) payload considerations; and
- h) density and proximity of overflight traffic.

Landing/recovery

9.5.20 RPAS may land at aerodromes or at almost any other location depending on operational requirements and system configuration, design and performance.

Landing/recovery at aerodromes

9.5.21 For operations at aerodromes, the remote pilot should consider the following:

- a) regulations pertaining to RPAS operations on or near an aerodrome;
- b) complexity and density of aircraft operations;
- c) performance and capability related to landing distance available and obstacle clearance, arrival procedures and any flight-restricting conditions;
- d) wake turbulence;
- e) ground operations (e.g. taxiway width, condition, other ground traffic);
- f) C2 link continuity;
- g) payload considerations; and
- h) availability of emergency recovery areas.

Landing/recovery at other than aerodromes

9.5.22 For operations at other than aerodromes, the remote pilot should consider the following:

- a) landing/recovery area and condition;
- b) location and height of all obstructions that could hinder landing or recovery (e.g. cables, towers, trees);

- c) performance and capability related to obstacle clearance, arrival procedures (if applicable) and any flight-restricting conditions;
- d) availability of emergency recovery areas;
- f) ATC communications, if required;
- g) C2 link continuity;
- h) payload considerations; and
- i) density and proximity of overflight traffic.

Recovery equipment preparation/set-up/inspection

9.5.23 Set-up, positioning and operation of recovery equipment, if applicable, should be as recommended by the manufacturer and, if located at an aerodrome, should be coordinated with the aerodrome operator. The condition and operability of all recovery hardware, direction and positioning of the recovery crew, and ensuring persons not associated with recovery or landing of the RPA are well clear of the operational area, must be assured. Similarly, the set-up, positioning and operation of recovery equipment should not adversely affect aerodrome operations.

Special operations

9.5.24 Due to their unique characteristics such as type, size and configuration, and that no persons are on board, some RPA are envisaged to operate in areas and conditions where manned aircraft are not able or approved to operate. These operations include inside buildings, in close proximity of structures on the ground or water and in dangerous areas or conditions. Since existing rules prohibit such aircraft operations, States may want to adapt the rules to RPA. The following sections provide information and considerations for these types of special operations.

RPA operations in proximity of aerodromes, other than for take-off and landing purposes

9.5.25 These operations may include control of birds at or in proximity to aerodromes or inspection of facilities. In order to avoid conflict with other aerodrome users, these types of operations should be regulated to ensure safety of ground vehicles and other aircraft.

RPA operations in proximity of structures on the ground or water

9.5.26 These operations include inspections of structures such as towers, buildings and bridges where inspections by other means require extensive resources. Since RPA may operate at lower altitude and closer to obstacles than the minima required by civil aviation regulations, States may consider waiving existing rules or establishing new ones for this specific type of operation.

RPA operations in dangerous areas and conditions

9.5.27 Without persons on board, RPA can operate in dangerous areas and conditions such as in proximity of venting or erupting volcanoes, chemical and nuclear accidents and in hazardous meteorological conditions. These types of operations will need to be carefully considered to ensure persons, property and other aircraft are not subject to increased risk. In order to reduce failures and malfunctions of RPA associated with such operations, the following should be taken into consideration:

- a) particles in or in proximity of volcanic, chemical or nuclear clouds can damage moving or rotating elements such as engine(s) and actuators;
- b) particles in or in proximity of volcanic, chemical or nuclear clouds can clog or plug pressure systems such as pitot or pitot-static tubes;
- c) particles in or in proximity of volcanic, chemical or nuclear clouds can clog or plug filters for engine air intakes and radiators for cooling systems;
- d) particles in or in proximity of volcanic, chemical or nuclear clouds can erode leading edges of propellers in a shorter time than normal;
- e) gas(es) in or in proximity of volcanic, chemical or nuclear clouds can corrode RPA parts especially those made of metals;
- f) gas(es) in or in proximity of volcanic, chemical or nuclear clouds may adversely affect engine performance; and
- g) nuclear radiation by ionization can cause electrical breakdown in semiconductors used in elements such as FCCs, FMSs or other on-board electronic devices.

Diversion to alternate aerodromes

9.5.28 Pre-flight planning should include consideration of alternate aerodromes/recovery sites, as appropriate, in the event of an emergency or meteorological-related contingency. Adequate fuel/energy reserves should be included in pre-flight preparation such that the RPA can deviate from a landing/recovery at the planned location, proceed safely to the alternate aerodrome/recovery site, and execute an approach and landing. Before selecting an alternate recovery/landing location, the remote pilot should consider, at a minimum, the adequacy of fuel/energy reserves, the reliability of C2 links with the RPA, ATC communications capability as necessary and meteorological conditions at the alternate.

9.6 RPS HANDOVER

General

9.6.1 Handover of the RPA from one RPS to another is used for many reasons, including to extend the operational range or to permit precision control such as for a terminal area or for maintenance reasons. RPS handovers may happen in two common scenarios:

- a) handover of piloting control to a collocated, but not coupled, RPS. This handover may be to a second remote pilot or, in the event of an RPS malfunction, the remote pilot moving to a standby RPS; or
- b) handover of piloting control to an RPS at another location.

Note 1.— A remote pilot relieved by another at the same RPS is considered to be similar in nature to a relief pilot/crew taking over on board an aircraft, rather than a handover.

Note 2.— A remote pilot transferring piloting control to another within a dual seat RPS is considered to be similar in nature to exchanging control in a manned aircraft, rather than a handover.

Note 3.— Transfer of remote PIC responsibilities is addressed in section 9.9.

Handover coordination between RPS

9.6.2 All handovers must be planned and coordinated as per the procedures in the operations and/or flight manual. Handover considerations should include:

- a) confirmation of the availability of a reliable voice communication link between the transferring and receiving remote pilots in the RPS to support coordination of the handover (it is recommended that this communication is not relayed through the RPA);
- b) status of the receiving RPS (e.g. its readiness and availability, its software configuration and compatibility with the RPA to be handed over);
- c) compatibility of the C2 link (e.g. IP address, frequency);
- d) coordination between the respective remote pilots; and
- e) ATC coordination (e.g. emergency contact telephone number), as necessary.

9.6.3 Before transferring an RPA, a handover briefing must be conducted between the transferring and receiving remote pilots to ensure the status of the RPA is understood. This briefing should be conducted in adequate time before the actual handover and should include, at a minimum:

- a) confirmation by the receiving remote pilot that the RPA is within the accepting RPS C2 link range;
- b) current status of the RPAS and location of the RPA;
- c) faults/system failures with the RPAS;
- d) status of fuel/energy and other consumables;
- e) C2 link configuration; and
- f) changes or limitations to the intended flight or RPA performance.

9.6.4 The receiving remote pilot should be satisfied with all of the above before accepting responsibility for the safe continuation of the flight.

Remote relief pilot briefings at a single RPS

9.6.5 Unlike manned aviation, remote pilots may be assigned shift work that commences or ends while the aircraft is airborne. In these cases, as one remote pilot relieves the other at the same RPS, a relief briefing will be necessary, which should include, at a minimum:

- a) current status of the RPAS and location of the RPA;
- b) meteorological conditions;
- c) aerodrome/recovery site conditions;

- d) faults/system failures with the RPAS;
- e) status of fuel/energy and other consumables;
- f) C2 link configuration; and
- g) changes or limitations to the intended flight or RPA performance.

9.6.6 The receiving remote pilot should be satisfied with all of the above before accepting responsibility for the safe continuation of the flight.

9.7 EMERGENCIES AND CONTINGENCIES

Emergency landing/ditching locations

9.7.1 RPAS flight planning should include provisions for emergency landing of the RPA in locations that minimize the safety risks to people or property on the ground. Remote pilots, unlike pilots of manned aircraft in visual conditions, have little chance to observe actual details on the ground in the vicinity of their aircraft during an emergency. They must therefore rely to a much greater extent on preplanning emergency scenarios that may occur along their intended route of flight.

9.7.2 When selecting emergency landing locations, the remote pilot should consider the following conditions:

- a) terrain, ground obstructions, population density, open air assemblies of people; and
- b) landing/ditching areas including accessibility for recovery or fire suppression.

Loss of C2 link

9.7.3 Flight planning should include provisions for loss of the C2 link and should be in accordance with guidance contained in the flight manual and/or operations manual. Procedures for the loss of the C2 link for RPA conducting controlled flights should be pre-approved by the ATC units involved in each portion of the flight planned route, if so stipulated by the ANSP(s). Remote pilots must notify the ATC unit immediately upon the procedures being activated for any flight under ATC control or any flight that may affect other ATC controlled flights, manned or unmanned.

9.7.4 Additional information on procedures for the loss of C2 link is contained in Chapter 11.

Interception operations

9.7.5 RPAS operators must comply with Annex 2 Standards regarding intercept operations. It is not envisaged that these requirements will be modified in the near term to accommodate RPA. Consequently, State authorities should consider implications for both RPA and intercept aircraft during an intercept manoeuvre.

9.8 RPA PERFORMANCE OPERATING LIMITATIONS

Remotely piloted aeroplanes

9.8.1 For remotely piloted aeroplanes, the performance and operating limitations should be consistent with provisions contained in Annex 6 — *Operation of Aircraft, Part I — International Commercial Air Transport — Aeroplanes* or Annex 6 — *Operation of Aircraft, Part II — International General Aviation — Aeroplanes*.

Remotely piloted rotorcraft

9.8.2 For remotely piloted rotorcraft, the performance and operating limitations should be consistent with provisions contained in Annex 6 — *Operation of Aircraft, Part III — International Operations — Helicopters*.

Remotely piloted aircraft other than aeroplanes or rotorcraft

9.8.3 Unmanned aircraft design characteristics do not need to make allowances for the safe accommodation of persons on board the aircraft. As a result, the types, sizes and configurations of these aircraft can vary dramatically from manned aviation.

9.8.4 ICAO provisions have focused on those categories of aircraft most often used in international aviation — aeroplanes, helicopters and balloons. It is not foreseen that provisions will be developed for adoption into Annexes 6 or 8 for the wide range of new aircraft categories in the near- or medium-term.

9.9 REMOTE FLIGHT CREW

Duties of the remote pilot-in-command (PIC)

9.9.1 Each remote PIC is responsible for the operation and safety of the RPA and RPS for the respective segment of flight assigned by the RPAS operator. Transfer of remote PIC responsibilities, if applicable, must be effected in accordance with procedures established by the RPAS operator and approved by the State of the Operator. These procedures should include a record identifying when the transfer occurred and the remote pilots involved. (See Chapter 6 for additional information on remote PICs.)

9.9.2 The remote PIC is responsible for terminating the flight, in the event such an action is deemed necessary.

9.9.3 The remote PIC should be assigned responsibility by the RPAS operator for ensuring that any handover from one RPS to another is completed in accordance with the procedures contained in the operations manual and/or flight manual, as applicable.

9.9.4 The remote PIC(s) should be responsible for updating all documents for the respective segment of the flight (e.g. the journey log book, maintenance logs).

Remote flight crew members at duty stations

9.9.5 All remote flight crew members required to be on duty should remain at their RPS as necessary for the safe operation of the RPAS, except when their absence is necessary for the performance of duties in connection with

the operation of the system or for physiological needs. In a single remote pilot operation, a relief remote pilot should relieve the remote pilot if the latter needs to be absent from the RPS for any reason.

9.10 ACCIDENTS AND SERIOUS INCIDENTS

Flight and ground recorder records

9.10.1 Annex 13 — *Aircraft Accident and Incident Investigation* requires that accidents and incidents involving unmanned aircraft be investigated. According to Annex 13, Chapter 5, 5.1.2, Note 3, only UAS with a design and/or operational approval need to be considered. It is anticipated that SARPs related to RPAS flight recorders will be developed in the near future.

9.10.2 Adequate recording of RPAS operations will be required to support accident and incident investigations as well as for flight data analysis. It is anticipated that this will apply particularly for BVLOS operations in the near future and perhaps for VLOS operations.

9.10.3 Due to the uniqueness of RPAS and the large variation in system size, provisions for recording system requirements in terms of scale and complexity need to be determined relative to the type of operation in which the RPAS will be involved.

9.10.4 Procedures to support handover of piloting control from one RPS to another must include definition of any specific data or communications that need to be recorded to ensure that the event can be properly reconstructed.

Downlinking RPA recorded data

9.10.5 Recording of all data on the RPA and RPS may be required to ensure data collection is not affected by a C2 link loss.

9.10.6 During extra-long duration missions, the RPA flight recorder may have a storage capacity that is less than the anticipated duration of the flight. To prevent overwriting valuable recorded data, it may be prudent to downlink the recorded data periodically or continuously before reaching the maximum storage capacity on board the RPA. The minimum storage capacity of the flight recorders on board RPA is not yet defined.

Accident and incident investigation

9.10.7 Adequate recording of RPAS flight command, trajectory and systems will be essential in determining events leading up to an accident or incident. Investigations where an RPAS was involved in an international operation could involve multiple States with the location of wreckage and the RPS locations in different States. The State of Occurrence, or if the investigation is delegated to another State or regional organization, the State responsible for investigating, must have access to all the data as per the provisions of Annex 13, including data from the RPS. Other States involved will be able to participate in the investigation by appointing accredited representatives. Access to data available in the other States will be arranged according to the above-mentioned provisions of Annex 13.

9.10.8 An RPAS operator should ensure, to the extent possible, that all related RPAS data is preserved in the event the RPA becomes involved in an accident or incident and, if necessary, the associated flight recorders and their retention in safe custody, pending the accident or incident investigation as per Annex 13.

9.10.9 For accident investigation and flight data recovery purposes, the accident site of an RPA may need to be established within a 6 NM radius. In this case, the RPA will need to be fitted with a system that can automatically transmit or broadcast positional information. Depending on the size of the RPA, this may be accomplished by means of a triggered emergency data transmission/broadcast method which includes positional information, a locator transmitter or an automatic deployable flight recorder.

9.10.10 The choice of equipment type and placement on the RPA will need to ensure the transmission/broadcast activation in the event of an accident. For RPA operating over water or land, including areas especially difficult for search and rescue, placement of the transmitter unit will be a vital factor in ensuring optimal crash and fire protection.

9.10.11 The placement of the control and switching devices (activation monitors) of automatic fixed emergency locator transmitters (ELTs) and their associated operational procedures will have to take into consideration the need for rapid detection of inadvertent activation.

9.11 SECURITY REQUIREMENTS

9.11.1 Security is a vital issue for RPA with aspects that are both similar and unique when compared with manned aircraft. As an RPS is similar in purpose and design to a cockpit, it must likewise be secure from sabotage or unlawful malicious interference. Annex 6, Part I, Chapter 13, contains SARPs to secure the flight crew compartment. However, due to the fixed and exposed nature of the RPS (as opposed to the restricted nature of a commercial aeroplane where the intrusion and use of heavier weapons is less likely) further consideration should be given to the potential vulnerability of the premises against unlawful interference.

9.11.2 Similarly, the RPA should be stored and prepared for flight in a manner that will prevent and detect tampering and ensure the integrity of vital components. The *Aviation Security Manual* (Doc 8973 — Restricted) provides further details concerning protection of aircraft.

9.11.3 Systems for controlling access to the RPS should be at least of equal standard to those already in place in the commercial aviation industry. In that regard, ICAO publishes information on procedures to be followed and systems to be implemented to ensure the security of the flight crew compartment, and this may be used as general reference material when addressing the unique nature of the RPS. An additional source of guidance is the *Air Traffic Management Security Manual* (Doc 9985 — Restricted) which may provide relevant material for the security of the RPS.

9.11.4 Identification technologies such as the use of biometrics for access control systems may offer a high degree of security for the RPS. Furthermore, distinction in access control level may be considered between the RPS and the premises wherein it resides.

9.11.5 Remote pilots should be subjected, at a minimum, to the same background check standards as persons granted unescorted access to security restricted areas of airports (Annex 17 — *Security*, 4.2.4). Further details concerning background checks can be found in Doc 8973.

9.11.6 The C2 link provides functions as vital as traditional wiring, control cables and other essential systems. These links may utilize diverse hardware and software that may be provided and managed by third parties. Safety and security of these links and services are equally important as those for the RPA and RPS. They must be free from hacking, spoofing and other forms of interference or malicious hijack. Doc 9985 may provide general reference material when addressing the unique nature of the C2 link.

9.12 SAFE TRANSPORT OF DANGEROUS GOODS BY AIR

9.12.1 Article 35 of the Chicago Convention addresses cargo restrictions, specifically regarding the carriage of munitions or implements of war and other dangerous goods. The provisions of Annex 18 — *The Safe Transport of Dangerous Goods by Air* further govern the international transport of dangerous goods by air. The broad provisions of this Annex are amplified by the detailed specifications of the *Technical Instructions for the Safe Transport of Dangerous Goods by Air* (Doc 9284) and its supplement, *Supplement to the Technical Instructions for the Safe Transport of Dangerous Goods by Air* (Doc 9284SU). Most of the dangerous goods carriage requirements contained in Article 35 and Annex 18 are considered applicable to RPA as written. While there are references to crew, these relate to the crew being informed about the dangerous goods or informing other parties. Again, RPAS operators would be expected to comply with the requirements.

9.12.2 At such time as civil RPA are utilized for the transportation of goods internationally, the provisions of Annex 18 and Article 35 of the Chicago Convention will be applicable.

Chapter 10

DETECT AND AVOID (DAA)

10.1 OVERVIEW

10.1.1 DAA is defined in Annex 2 as “the capability to see, sense or detect conflicting traffic or other hazards and take the appropriate action”. This capability aims to ensure the safe execution of an RPA flight and to enable full integration in all airspace classes with all airspace users.

10.1.2 For RPA, appropriate technology and/or procedures may be needed to provide capabilities analogous to those which pilots of manned aircraft have, using one or more senses (e.g. vision, hearing, touch) and associated cognitive processes. The appropriate action is to avoid the hazard (e.g. potentially conflicting traffic) to assure safety objectives for specific airspace or operations are met.

10.1.3 RPAS may be designed with different systems and sensors to DAA different hazards. Some of these systems may use more than one sensor to assure reliable hazard detection under a variety of environmental conditions. When an RPAS is equipped with more than one DAA system (i.e. to detect and avoid different hazards), these systems may need to be interoperable to assure an appropriate, coordinated (when applicable) avoidance action is taken when different hazards are present at the same time (e.g. conflict traffic versus terrain or obstacles).

10.1.4 In airspace where ATC provides separation services between all aircraft, ATC procedures, flight crew procedures and aircraft equipage requirements (e.g. transponders) already exist to maintain safe separation. However, DAA equipment and associated procedures may also be needed for other airspace classes as well as for hazards other than MACs.

10.1.5 RPAS will have to be as safe as, or safer than, present manned operations.

10.2 HAZARD IDENTIFICATION

10.2.1 RPA may encounter many types of hazards. The *Global Air Traffic Management Operational Concept* (Doc 9854) identifies the need to limit the risk of collision to an acceptable level between an aircraft and the following hazards: “other aircraft, terrain, weather, wake turbulence, incompatible airspace activity and, when the aircraft is on the ground, surface vehicles and other obstructions on the apron and manoeuvring area”. Doc 9854 also notes “for any hazard (i.e. any condition, event or circumstance that could induce an accident), a risk can be identified as the combination of the overall probability or frequency of occurrence of a harmful effect induced by the hazard, and the severity of that effect.”

Note.— The definition of “hazard” is undergoing review. The current accepted terminology refers to “an object or condition that has the potential to induce an accident or incident.”

10.2.2 It is important to recognize that whilst the severity of the risk of the hazard may be minor for an RPA, the same may not be true for manned aircraft encountering the same hazard in the same airspace and vice versa. For a single hazard, two risk analyses may be needed, one for manned aircraft and one for unmanned aircraft. One should not assume that the hazard, the severity of the risk or the mitigation strategies will be the same.

10.2.3 In order for RPAS to be fully integrated into non-segregated airspace and at aerodromes, mitigations to the hazards noted above will be needed. Air traffic management will help mitigate the risk from these hazards (e.g. incompatible airspace activity) for RPA as for other aircraft. However, DAA capabilities or other mitigations (e.g. operational procedures) are required for RPA to limit the risk from the following hazards:

- a) conflicting traffic;
- b) terrain and obstacles;
- c) hazardous meteorological conditions (i.e. thunderstorms, icing, turbulence);
- d) ground operations (aircraft, vehicles, structures or people on the ground); and
- e) other airborne hazards, including wake turbulence, wind shear, birds or volcanic ash.

10.2.4 RPAS need to comply with airspace rules and procedures and associated safety requirements established by the State and/or ANSP. One or more DAA capabilities may be needed to meet requirements to address the hazards listed above unless the RPA exposure to these hazards and risk to persons, property or other aircraft can be reduced to an acceptable level through restrictions to the RPA operating environment, flight timing or flight profile. For example, if an RPA flies in segregated airspace (i.e. no other aircraft present), then a DAA capability to DAA other airborne aircraft may not be required. Likewise, if an RPA will only be operated in fair meteorological conditions, then the capability to detect and help the pilot avoid hazardous meteorological conditions may not be required. However, if an RPA cannot be prevented from encountering these hazards, then systems and procedures may be needed to provide appropriate DAA capabilities for each hazard.

10.2.5 Safety analyses may be needed to establish RPAS capabilities to mitigate consequences of each specific hazard that may be encountered.

10.3 DETECTABILITY AND CONSPICUITY

10.3.1 Detectability and conspicuity both refer to the ability of an RPA to be identified by pilots of manned aircraft, other remote pilots, air traffic control officers (ATCOs) and other personnel. This may be achieved through a transponder or strobe light on the RPA or through various other means, as approved by the appropriate State authority.

10.3.2 The detectability and conspicuity of RPA will have to be sufficient to ensure timely identification by other airspace users and ATC in all phases of flight (including ground operations). Timely detection (by visual or electronic means) will ensure that the rules of the air can be applied safely.

10.3.3 If a very small RPA is to be integrated into non-segregated airspace, it is doubtful that it will be visible to manned aircraft. Even if the RPA has a transponder or ADS-B, not all manned aircraft will have the capability to detect it. As a result, it may be difficult to integrate such non-conspicuous RPA into non-segregated airspace unless they can be made visible to pilots of manned aircraft.

10.4 CONFLICT MANAGEMENT APPROACH TOWARDS DAA

10.4.1 The conflict management approach towards DAA is comprised of three layers paralleling the manned aircraft approach towards avoiding hazards outlined in Doc 9854. This approach may be applied for avoiding conflicting traffic, as well as for avoiding other hazards. It includes three phases:

- a) *strategic conflict management phase*. This is generally considered the planning phase where sufficient data is obtained for the execution of the flight;
- b) *separation provision phase*. In this phase, actions are undertaken by all participants to ensure the safe execution of the flight depending on the airspace classification. Separation provisions by ATC and “remain-well-clear (RWC)” by pilots/remote pilots are utilized in this phase; and
- c) *CA phase*. In this phase, last resort actions or manoeuvres are executed to resolve conflicts if the strategic or tactical phases above did not prevent the hazard from being encountered.

10.4.2 The strategic conflict management phase raises awareness of each hazard and supports the pilot in planning mitigations, as appropriate, but is not considered an active part of the actual DAA functionality.

10.4.3 Figure 10-1 shows how the conflict management process for DAA may be applied specifically for a DAA capability addressing the hazard of conflicting traffic.

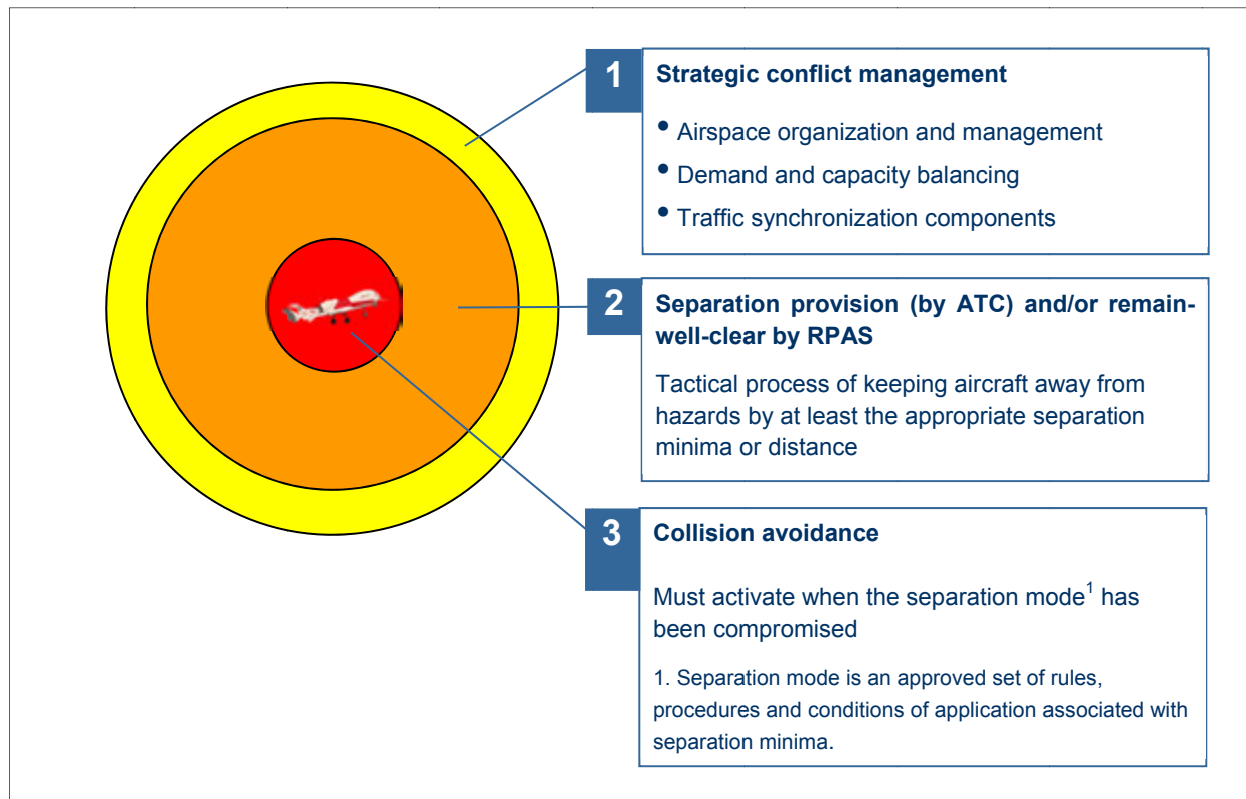


Figure 10-1. Protection layers

First layer: strategic conflict management

10.4.3.1 The remote pilot is responsible for planning a safe flight, which may include the submission of a flight plan before the flight. The RPA adheres to the flight plan and/or ATC clearances, as applicable.

Second layer: separation provision or remain-well-clear (RWC)

10.4.3.2 The separator or agent responsible for separation provision can be:

- a) the corresponding ATC unit; or
- b) the airspace user, in which case the separation provision is referred to as RWC.

Third layer: collision avoidance (CA)

10.4.3.3 CA may be achieved through use of an approved DAA capability for conflicting traffic. If installed, a DAA system for conflicting traffic should alert the remote pilot of impending collisions in order that last resort actions or manoeuvres can be executed.

10.4.3.4 If the DAA system design allows automated CA, the RPA may perform the CA manoeuvre despite loss of the C2 link. Conversely, if the DAA capability does not allow automated CA manoeuvres during lost C2 link situations, the remote pilot is responsible for following established contingency procedures.

10.5 RPA DETECTION OF HAZARDS

10.5.1 RPA may detect hazards, including conflicting traffic, using optical and non-optical technologies. Detection may be supported by the use of a database (e.g. terrain and obstacles).

10.5.2 *Optical techniques.* Optical techniques are based on visible and near-visible (ultraviolet and infrared) EM radiation. Examples include video, light detection and ranging (LIDAR) and thermal imaging. Optical techniques are generally ineffective in instrument meteorological conditions (IMC).

10.5.3 *Non-optical techniques.* Non-optical techniques are based mainly on radio-frequency electro-magnetic (including microwave) radiation. Examples include primary radar, SSR, ADS-B and multilateration. Non-optical techniques are generally not dependent on meteorological conditions.

10.6 SPECIAL CONSIDERATIONS FOR VERY LOW LEVEL (VLL) OPERATIONS OF RPAS

Special consideration will be required for VLL operations since RPA in this environment are normally operating below 500 feet above ground level (AGL). Provisions to facilitate VLL operations are not in the work programme of ICAO.

10.7 SITUATIONAL AWARENESS

10.7.1 Situational awareness involves the remote pilot being aware of what is happening in the vicinity of the RPA, in order to understand how information, events and the remote pilot's own actions will impact goals and objectives, both immediately and in the near future.

10.7.2 Whether conducting IFR or VFR operations, the remote pilot's situational awareness is dependent on a combination of support from the RPAS DAA capability, flight instruments and/or external contributors (ATC instructions, flight preparation).

10.7.3 Situational awareness is the critical foundation for successful decision-making across a broad range of complex and dynamic systems. The DAA capability will not provide the remote pilot with situational awareness as such; rather it provides essential information to build the remote pilot's situational awareness of the operating environment.

10.7.4 The remote pilot's situational awareness of what is happening in the vicinity of the RPA helps him understand how other information, events and his own actions will impact the goal of avoiding each hazard. The remote pilot's awareness may develop throughout the three phases of the conflict management approach:

- a) during the strategic conflict management phase, the following elements help develop awareness:
 - 1) flight planning;
 - 2) NOTAMs;
 - 3) meteorological information;
 - 4) operating environment;
 - 5) other relevant information;
- b) during the separation provision or RWC phase, the following elements help maintain awareness:
 - 1) on-board equipment (surveillance information, DAA RWC information, airborne collision avoidance system (ACAS), terrain awareness warning system (TAWS), etc.);
 - 2) ATC;
 - 3) meteorological information;
 - 4) general flight conditions; and
- c) during the CA phase the situational awareness of the pilot may be affected by alerts from a DAA system or ATC.

10.8 DAA EQUIPMENT FOR RPAS

10.8.1 It is not foreseen to have a single DAA system that caters for all five types of hazards identified above. The scalability of the functionality will enable early integration of RPAS.

10.8.2 Some certification specifications require installed equipment to be of "a kind and design appropriate to its intended function". Performance requirements for installed DAA equipment will be developed in due course. Requirements for any specific equipment to be used to address particular hazards in a given environment are the purview of the appropriate State authority.

10.8.3 A DAA system may have distributed components (e.g. on the ground, in the air, in the RPA, in the RPS, satellite-based, or any other location suitable for their intended function).

DAA equipment

10.8.4 The DAA capability for RPAS may have one of the following kinds of equipment:

- a) *detect and avoid*. DAA capability to provide specific resolution manoeuvres to avoid a hazard with manual or automated execution. An example for manned aircraft is an ACAS system integrated into the autoflight system;
- b) *detect and advise*. DAA capability to propose a range of potential resolution manoeuvres to avoid a hazard with manual execution. An example for manned aircraft is the traditional ACAS system; or
- c) *detect and inform*. DAA capability to provide essential information for the hazard that the remote pilot may use along with other information to develop and execute an avoidance manoeuvre. An example for manned aircraft is weather radar and associated display.

10.9 INTEGRITY SUPERVISION

The DAA capability may be provided by a system of systems that enables the remote pilot to ensure a safe flight by managing one or more of the five types of hazards described earlier. To ensure that a system is functioning correctly, an integrity monitoring system may be required. The integrity supervision function provides information on the health and current mode of the DAA system to the remote pilot.

10.10 SAFETY CONSIDERATIONS IN THE TOTAL AVIATION SYSTEM

10.10.1 DAA capability in IFR/VFR operations should be demonstrated to meet the safety, performance and interoperability of this functionality with manned aviation as a prerequisite to be integrated in non-segregated airspace.

10.10.2 This requires quantification of several aspects of “see and avoid” that are normally determined subjectively by the pilot.

10.10.3 One example is the quantification of the term “well clear”, which may need to be set, from a system design perspective, at a defined distance or time in order for the system to operate effectively.

10.10.4 Participants and technical systems have an interdependent relationship in the total aviation system. In order to reduce the risk of hazards addressed by DAA to an acceptable level (i.e. the safety objective), the DAA capability and all the contributing participants, including ATC and other aircraft, should be considered.

10.10.5 The principle of considering all participants in the total aviation system has been documented in the *Manual on Airspace Planning Methodology for the Determination of Separation Minima* (Doc 9689), which acknowledges that the influence of ATC intervention can be considered in relation to the risk of infringing lateral separation. This approach was used for implementation of reduced vertical separation minimum (RVSM) where it was agreed that limiting the risk of collision due to the loss of planned vertical separation as a consequence of operational events should receive attention at least equal to that devoted to limiting the effects of technical errors (i.e. errors of aircraft height-keeping systems).

10.11 INTEROPERABILITY OF DAA FOR CONFLICTING TRAFFIC

10.11.1 The generic approach to DAA as described above should be consistent with current CA manoeuvres used in manned aviation. This will reduce occurrences of conflicting responses when encountering other aircraft, whether equipped with ACAS or not. During an encounter between an ACAS-equipped aircraft and an RPA with a DAA capability for conflicting traffic, the two aircraft must implicitly or explicitly coordinate resolution advisories that will not conflict.

During an encounter between an aircraft without ACAS and an RPA, the RPA's DAA system should propose a resolution advisory that will be consistent with the rules of the air. In case the RPA is not equipped with a DAA system, the pilot will take action and follow the rules of the air.

10.11.2 False alarms (e.g. alarms triggered due to surveillance or other technical errors) and nuisance alarms (e.g. the equipment worked nominally, but the situation is considered unworthy of an alarm by operational personnel) should be minimized to the extent possible so as not to detract from valid alarms requiring remote pilot action.

10.12 DAA FOR CONFLICTING TRAFFIC — OPERATIONAL ASSUMPTIONS AND POLICIES

General operating assumptions

10.12.1 For all classes of airspace the following assumptions/principles apply for IFR/VFR operations BVLOS:

- a) RPAS must meet the communication, navigation and surveillance (CNS) requirements for the airspace. States or ANSPs may require RPA to have Mode S 1 090 extended squitter transponders in some areas or for some types of operation;
- b) the RPA will be conspicuous to manned aircraft when in VMC using lighting (e.g. strobe light), paint scheme or other means to compensate for a small visual cross-section, if applicable;
- c) remote pilots will be able to react in a timely manner to ATC instructions, similar to a pilot in a manned aircraft;
- d) the RPA is certified according to the appropriate certification specifications (see Chapter 4);
- e) the RPAS will only use DAA system(s) approved by the State of Registry;
- f) a DAA system providing a RWC capability may need quantitative definitions of minima for well-clear, which considers operational acceptability as well as analytical derivations; and
- g) the quantitative definition of well-clear minima may be based on collision risks taking into consideration the operating environment (e.g. airspace class and associated ATC separation standards), aircraft performance and interoperability with ACAS.

Operational policies

10.12.2 DAA for conflicting traffic, as for all DAA hazards, needs to be applied under ICAO rules of the air and relevant documents such as Annex 2, *Procedures for Air Navigation Services — Aircraft Operations* (Doc 8168), Volumes I and II; *Procedures for Air Navigation Services — Air Traffic Management* (PANS-ATM, Doc 4444); and the *Safety Management Manual (SMM)* (Doc 9859).

DAA for conflicting traffic — RWC

10.12.3 RWC is the ability to detect, analyse and manoeuvre to avoid a potential conflict by applying adjustments to the current flight path in order to prevent the conflict from developing into a collision hazard. The use of this DAA capability must be compatible with the rules of the air and with any separation provision services provided by ATS in a given airspace class. The use of a DAA system for the RWC function must be an approved mode with associated criteria in time and/or distance.

10.12.4 An RWC manoeuvre can be seen as similar to an on-board pilot carrying out a see and avoid manoeuvre to RWC. The RWC function monitors possible hazards (e.g. surrounding traffic) and, if necessary, calculates and provides an RWC manoeuvre advisory (MA) to the remote pilot. The RWC function should be able to continuously assess the surrounding traffic for conflicts and provide updated MAs until the RPA is clear of each successive conflict. The remote pilot is expected to execute the MA through normal control means.

DAA for conflicting traffic — collision avoidance (CA)

10.12.5 According to Annex 2, Chapter 3, “An aircraft shall not be operated in such proximity to other aircraft as to create a collision hazard” and “nothing in these rules shall relieve the PIC of an aircraft from the responsibility of taking such action, including CA manoeuvres based on resolution advisories provided by ACAS equipment, as will best avert collision.” Additionally, “It is important that vigilance for the purpose of detecting potential collisions be exercised on board an aircraft, regardless of type of flight or the class of airspace in which the aircraft is operating, and while operating on the movement area of an aerodrome.”

10.12.6 The RPAS may be equipped with a CA DAA system which will help prevent the RPA from penetrating the volume of airspace around the conflict traffic considered a near mid-air collision (NMAC) (see Figure 10-2). This DAA system should:

- a) alert the remote pilot whenever the RPAS (including remote pilot) identifies that a threat aircraft is penetrating the CA threshold. A CA manoeuvre is expected to be initiated when the threat aircraft approaches the collision volume;
- b) provide its intended function on aircraft of any size, weight and configuration expected to be regulated for operation in all classes of airspace;
- c) be transparent with respect to the types and locations of sensors and systems employed;
- d) be consistent with current regulatory equipage requirements in terms of cooperative systems (e.g. Mode-C/S transponders, ADS-B, ACAS);
- e) be interoperable with ACAS; and
- f) observe right-of-way rules unless observing them is detrimental to safety (i.e. results in a more hazardous manoeuvre than one which does not observe the right-of-way rules).

Note.— Figure 10-2 shows the spatial relationships of the volumes of airspace associated with RWC and CA. The actual shapes and relative sizes of these volumes remain to be determined.

10.12.7 When a conflicting traffic crosses the RWC threshold of an RPA, a DAA system should alert the remote pilot to take action so as to prevent this intruder from entering the RWC volume and becoming a threat to the RPA. Likewise if a threat crosses the CA threshold of the RPA, a DAA system should alert the remote pilot to take action so as to prevent this intruder from entering the collision volume and risk colliding with the RPA (see Figure 10-3).

10.12.8 To take into account complex situations such as multiple conflicting intruders, the DAA CA capability should be able to simultaneously consider and prioritize CA manoeuvres (e.g. least time to the closest point of approach (CPA) and within certain range/combined CA manoeuvres).

10.12.9 If CA is performed manually (human-in-the-loop) the RPAS system design and associated safety analysis will need to show that the required manoeuvres can be completed in a timely manner to avoid a collision.

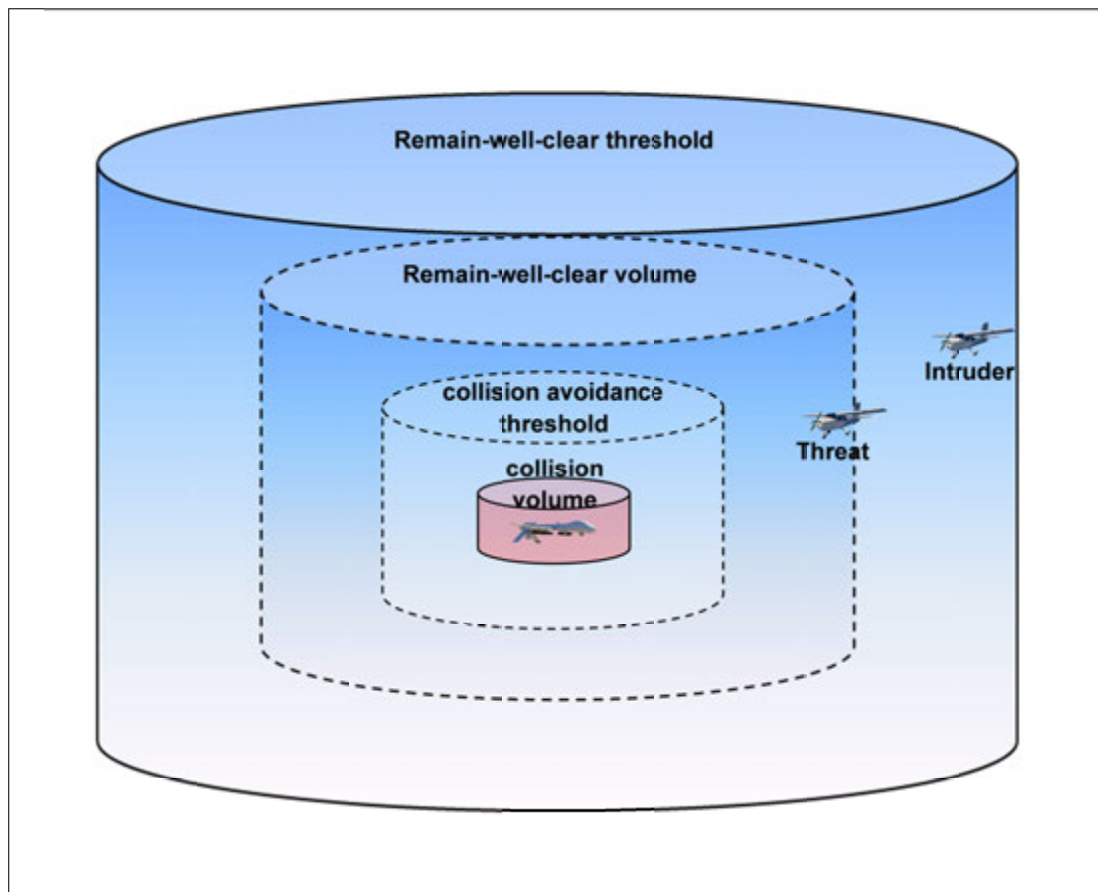


Figure 10-2. Geometry of RWC assurance and CA

10.12.10 If CA is automated and CA is performed by default (human-on-the-loop), it should have an abort/inhibit capability for the remote pilot. Remote pilot intervention to abort/inhibit the manoeuvre would only be expected in the rare event that the remote pilot has sufficient information to conclude that allowing the automated manoeuvre to occur would be more hazardous than aborting it.

10.12.11 It might not be safe or efficient to have a universal requirement for automated CA under all lost C2 link conditions. While it may be of concern to prohibit use of CA automation under some circumstances, it can be of equal concern to allow automated manoeuvres for an extended period of time when the remote pilot has no ability to intervene. Extensive research, combined with hazard identification and risk management, is needed to support a decision being made to employ one approach or the other and under what circumstances.

10.12.12 If the C2 link is lost during a CA manoeuvre, the completion of this manoeuvre should be performed by the automated system. For a longer duration loss, once ATC is aware of the situation (e.g. if allocated, a lost C2 link transponder code), contingency procedures may mitigate the exposure to conflict traffic in controlled airspace. Lost C2 link contingency procedures can reduce the exposure of RPA to other aircraft and ATC may clear the flight path of a controlled RPA to limit the risk in the rare event that the C2 link is lost for a significant period of time. The assumption that ATC will always prefer automated manoeuvres for extended periods of time or that loss of the C2 link will be a simple malfunction (i.e. not associated with other RPA malfunctions that might also affect the CA manoeuvre) are far from granted.

10.12.13 States, ANSPs and RPAS operators will need to agree on whether automated CA manoeuvres will be used during lost C2 link situations and under what conditions.

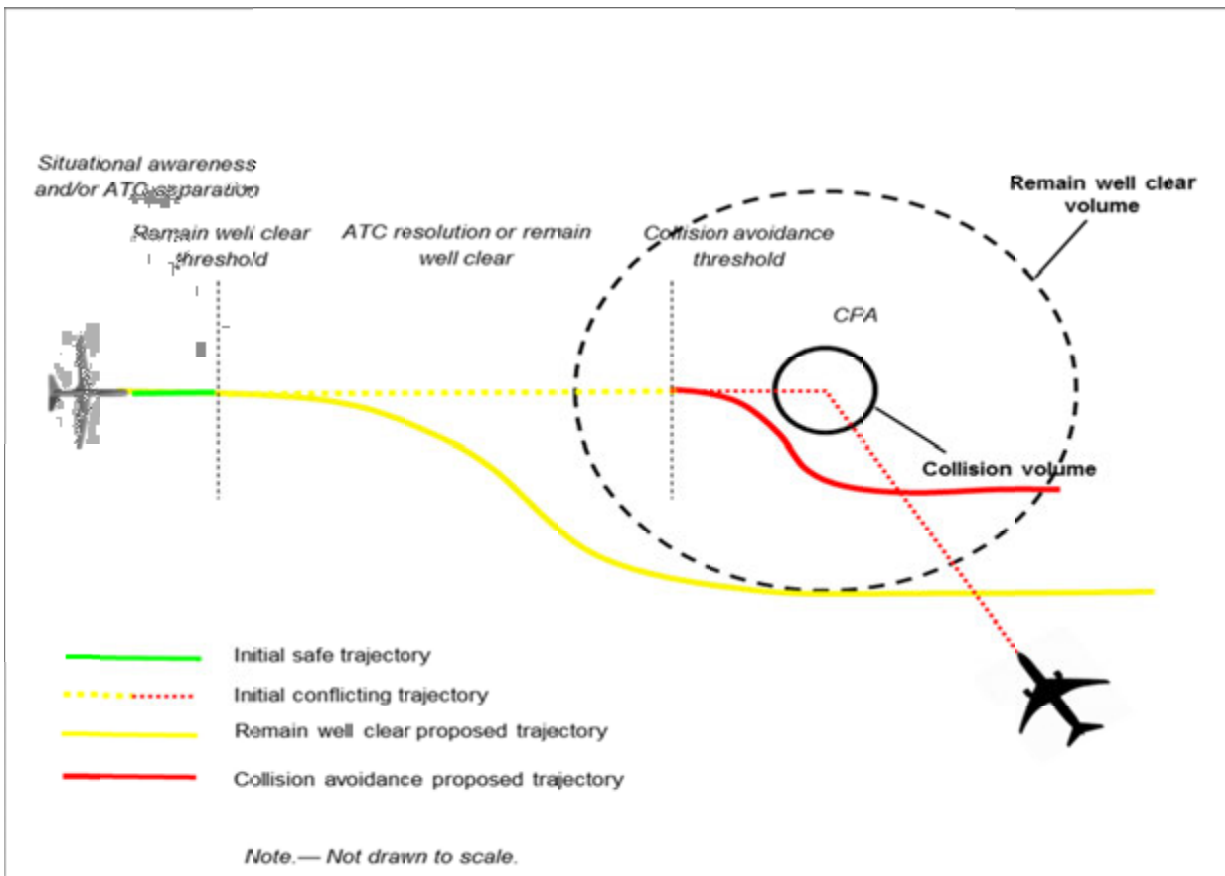


Figure 10-3. Examples of horizontal resolution for RWC and CA

10.13 MITIGATING THE RISK OF COLLISION WITH TERRAIN AND OBSTACLES

10.13.1 Terrain and obstacle avoidance covers the ability of the RPA to avoid inadvertent impact into the ground or obstacles during flight.

10.13.2 The pilot must be able to identify proximity to terrain and obstacles in a timely manner to execute a safe flight. How this is achieved by a remote pilot may have few differences from manned aviation because in both cases the pilot can plan and execute flight profiles to remain horizontally and vertically clear of terrain and obstacles. For example, if an RPA has aircraft and navigation performance capability to ensure it can take-off, climb, cruise, descend and land at or above IFR altitudes along routes charted in accordance with *Procedures for Air Navigation Services — Aircraft Operations*, Volume I — *Flight Procedures* (Doc 8168) for IFR operations, then terrain and obstacle clearance can be assured without a DAA system.

10.13.3 DAA systems designed to address terrain and obstacles may be similar to ground proximity warning systems (GPWSs), TAWS and minimum altitude warning systems (MAWSs) on manned aircraft.

Special considerations for low-level flights

10.13.4 Many RPA will be employed in low-level operations, putting the aircraft in close proximity to terrain and obstacles. The DAA capability will need to account for this type of operation.

10.13.5 The appropriate State authority will need to be satisfied that, based upon the DAA capability, the proposed low level operations can be conducted safely.

10.13.6 If terrain and obstacle avoidance is automated, the avoidance manoeuvre is performed by default (human-on-the-loop). However, it should have an abort/inhibit capability for the remote pilot. Remote pilot intervention to abort/inhibit the manoeuvre would only be expected in the rare event that the remote pilot has sufficient information to conclude that allowing the automated manoeuvre to occur would be more hazardous than aborting it.

Database considerations

10.13.7 It is expected that the current databases related to terrain and obstacles for manned aviation may not have the right level of detail for very low-level operations.

10.13.8 If terrain and obstacle data to support RPA flight operations below IFR altitudes are required, changes or additions to the existing terrain and obstacle databases may be needed. Any such database changes should be designed in accordance with public standards such as RTCA DO-200A — *Standards for Processing Aeronautical Data* and EUROCAE ED-76 — *Standards for Processing Aeronautical Data*.

10.14 MITIGATING THE RISK OF HAZARDOUS METEOROLOGICAL CONDITIONS

10.14.1 All aircraft are affected by meteorological conditions. In manned aviation, the pilot is able to monitor changes to the conditions visually and through use of sensors and the display of their information. Remote pilots conducting BVLOS operations must rely to a far greater extent on sensors and the display of sensor information.

Considerations for DAA capability for hazardous meteorological conditions

10.14.2 Remote pilots may be able to combine DAA information from the detection of hazardous meteorological conditions with information from other systems (e.g. ambient air temperature, winds from navigation systems, forecasts) to take action to avoid meteorological hazards such as icing, wind shear or turbulence.

10.14.3 Remote pilots should consider the effects of meteorological conditions along the flight path, in order to avoid or be aware of possible interference with the C2 link.

10.14.4 DAA capability needs to be related to the RPA operational flight envelope and any hazardous meteorological limitations associated with the RPA, especially in regard to icing and turbulence. If the RPA is not capable of flight in icing conditions for example, then the detection capability must be appropriately sensitive to alert the remote pilot to any indication of potential icing conditions with an appropriate sense of urgency.

10.14.5 A DAA system for hazardous meteorological conditions may not be needed if the RPA flies IFR routes and altitudes based on forecast and reported conditions where the likelihood of encountering hazardous meteorological conditions is below an acceptable level. For example, if an RPA flies for a relatively short duration in an area where no turbulence, icing or thunderstorms are forecast or reported, then operation of a DAA system for these conditions may not be required.

10.15 MITIGATING THE RISK OF COLLISION DURING GROUND OPERATIONS

10.15.1 Ground operations involve all aspects of aircraft handling on the airport surface as well as aircraft movement on the aerodrome including on active runways.

10.15.2 The remote pilot needs to be able to DAA potential hazards on the surface, identify applicable aerodrome markings (e.g. runway hold lines) and be able to follow ATC instructions in order to mitigate the risk of collision with other aircraft, ground vehicles or obstructions.

10.15.3 DAA systems on the RPA to assist the pilot in avoiding collisions on the ground may not be needed if special ground handling procedures, such as towing the RPA to the end of the runway/launch point or controlling the aircraft taxi to the same point from a position in close proximity to the RPA, are used.

10.15.4 RPA observers may be necessary as a mitigation to overcome any safety concerns for initial operation of DAA systems on the ground.

10.16 MITIGATING THE RISK OF OTHER AIRBORNE HAZARDS

10.16.1 Other hazards which may be encountered by RPA include, but are not limited to, wake turbulence, wind shear, birds and volcanic ash.

10.16.2 RPAS may be able to leverage standards development efforts for manned aircraft systems with respect to wake turbulence applications. RTCA has defined a concept of operations for transmitting aircraft-derived meteorological data to enable applications for wake turbulence to support next generation air transportation system (NextGen) and single European sky ATM research (SESAR) initiatives. Standards development work to support specific airborne wake turbulence applications needs to consider RPAS requirements in addition to other aircraft.

10.16.3 Annex 2, 3.2.1, requires an aircraft to “keep out of the way of another” per right-of-way rules and “avoid passing over, under or in front of the other, unless it passes well clear and takes into account the effect of wake turbulence”. DAA for conflicting traffic will need to consider aircraft wake turbulence in conducting well clear manoeuvres with respect to right-of-way rules that also account for wake turbulence.

10.16.4 RPAS designed to allow RPA to conduct approaches in a manner similar to current visual approaches may need to include DAA to address wake turbulence. The safety and efficiency of visual approach operations relies on the PIC’s ability to accept responsibility for “ensuring that the spacing from a preceding aircraft of a heavier wake category is acceptable” in accordance with Doc 4444, 5.9. The PIC of an RPA may need DAA for wake turbulence to efficiently integrate RPA arrivals with other aircraft when visual approach operations are being conducted.

10.16.5 The RPA may need a DAA system to detect other airborne hazards such as wind shear, birds or volcanic ash if exposure to them will place the safe continuation of the flight in jeopardy. DAA for volcanic ash exposure may not be needed if RPA flight is restricted to remain away from areas of forecast or reported ash. In a similar manner, a DAA system for wind shear or birds may not be required if the RPA flight is planned and executed to remain clear of these hazards or if the flight control and performance of the RPA allows recovery of safe flight continuation or termination after exposure to these hazards.

Chapter 11

COMMAND AND CONTROL (C2) LINK

11.1 GENERAL

11.1.1 This chapter addresses the C2 link: the information flows and performance requirements, including quality of service, related to the transfer of data and information between the RPS and the RPA.

11.1.2 The C2 link typically supports the following communication tasks:

- a) control uplink to RPA: data to modify behaviour and state of the RPA;
- b) control downlink from RPA: data to indicate the position and status of the RPA;
- c) DAA uplink: sensor selection/control and, if applicable, auto response state select (on/off) and override (remote pilot option to cancel the manoeuvres);
- d) DAA downlink: sensor data and processed sensor information (related to traffic, weather, terrain, airport visual data, etc.), conflict alert and terrain/obstacle alert and manoeuvre advisories (MA) and, if applicable, DAA automatic response (initiation and description), etc.;
- e) data to support RPS handover, uplink and downlink (see Chapter 13); and
- f) data to support flight data recording requirements, uplink and downlink (see Chapter 9).

11.1.3 In addition, the C2 link should support a range of data link health monitoring functions, including a heartbeat, or positive and negative acknowledgements of messages exchanged in either direction. These could be used to provide data link status information to the remote pilot.

11.1.4 The C2 link technical solution offered by a manufacturer or RPAS operator should comply with availability requirements and may be implemented by a single data link or multiple redundant data links. It is anticipated that any payload data link requirements will normally need to be provided by an independent data link which does not use aeronautical protected spectrum.

11.1.5 In addition, ATC voice and data communication tasks may be relayed between the RPA and the RPS on the same C2 link. Specific requirements for ATC communications are addressed in Chapter 12.

- a) ATC voice communication relay (ATC to remote pilot via RPA);
- b) ATC voice communication relay (remote pilot to ATC via RPA);
- c) ATC data link relay (ATC to remote pilot via RPA); and
- d) ATC data link relay (remote pilot to ATC via RPA).

11.2 SCOPE OF PLANNED SARPS FOR C2 LINK

11.2.1 The C2 link provides the connection between the remote pilot and the RPA controls and may be considered functionally equivalent to, for example, the control wires or databus between the cockpit and the control surfaces possibly via the FCC. The RPA should therefore use data links that can be assured to meet communication transaction time, continuity, availability and integrity levels appropriate for the airspace and operation. SARPs related to these parameters will be needed.

11.2.2 There will be multiple types of RPA and RPS on the market. Some types of operation may, from time to time, lead to an RPA from one manufacturer being controlled by an RPS provided by another manufacturer. The type certification must verify that all combinations of RPA and RPS that will become involved in such operations can coexist, interwork, i.e. exchange C2 protocol syntax, and interoperate, i.e. act correctly on C2 protocol semantics, (see Chapter 4).

11.3 C2 LINK ARCHITECTURE AND REQUIREMENTS

Introduction

11.3.1 C2 link architectures to support RPAS operations are usually classified as RLOS or BRLOS, which reflect both the type of architecture and the timeframe within which transmissions are completed.

11.3.2 *RLOS*. RLOS refers to the situation in which the transmitter(s) and receiver(s) are within mutual radio link coverage and thus able to communicate directly or through a ground network provided that the remote transmitter has direct RLOS to the RPA, and transmissions are completed in a comparable timeframe (see Figure 11-1). The timeframe within which transmissions must be completed for RLOS is not currently defined.

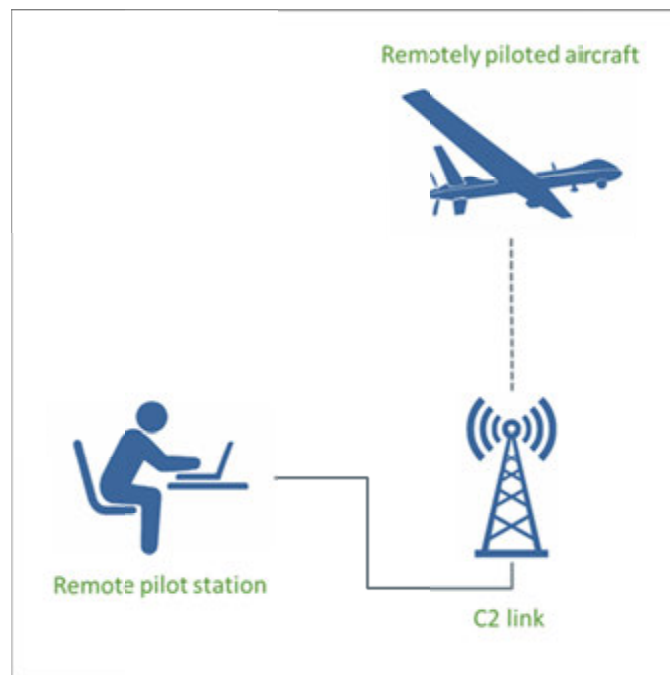


Figure 11-1. RLOS — RPS and RPA direct access

11.3.3 **BRLOS.** BRLOS refers to any configuration in which the transmitters and receivers are not in RLOS. BRLOS thus includes all satellite systems and possibly any system where an RPS communicates with one or more ground stations via a terrestrial network which cannot complete transmissions in a timeframe comparable to that of an RLOS system (see Figure 11-2).

11.3.4 Any system, RLOS or BRLOS, must meet required communications performance parameters for latency and availability established for the airspace and/or operation.

11.3.5 The BRLOS label provides no information about the network between the RPS and the satellite as shown in Figure 11-2. In the nominal case, there is a single satellite relay. Alternatively, a double satellite hop might be needed if it is required to go through a central gateway and if there is no ground link between the RPS and this central gateway. While the propagation delay of the satellite link is fully predictable, the total end-to-end link delay will depend on other factors as well, such as any ground-ground links in the path between the RPA and the RPS.

11.3.6 The key challenges of BRLOS, such as increased signal delay and the involvement of an external communications service provider, may also be present in some terrestrial networks, therefore putting them in the category of BRLOS.

11.3.7 It should be noted that there is no agreed term for situations where a satellite link is used as part of the “ground network” (described in RLOS) if the final link to the RPA is from a ground relay station located at a significant distance from the RPS.

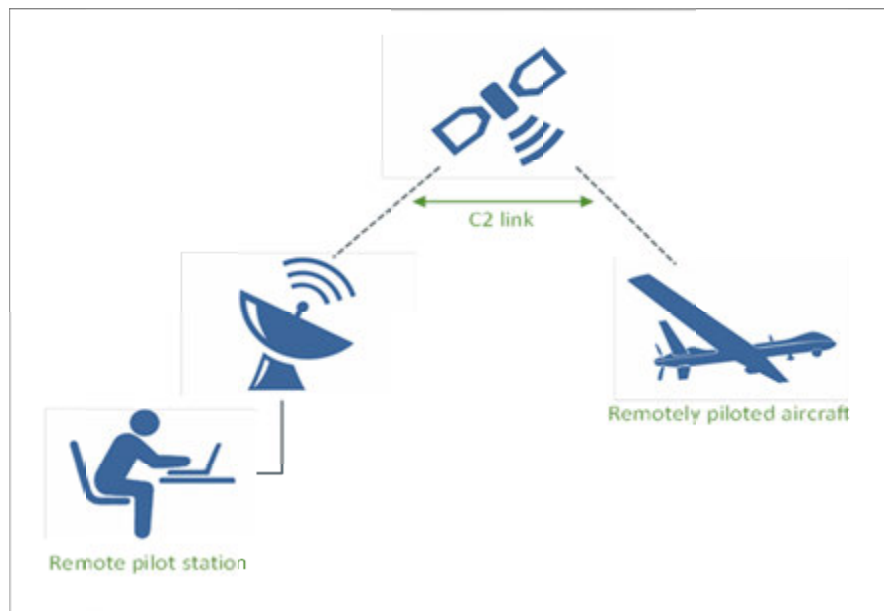


Figure 11-2. Example of BRLOS — RPS and RPA via satellite access

C2 link architectures

11.3.8 **RLOS C2 link.**

- a) collocated RPS and transceiver;
- b) single remote transceiver:

- 1) linked to RPS via private network (RPAS operator controlled); and
 - 2) linked to RPS via a C2 service provider network;
- c) multiple remote transceivers:
- 1) linked to RPS via private network (RPAS operator controlled); and
 - 2) linked to RPS via a C2 service provider network.

11.3.9 *BRLOS C2 link*. Satellite or airborne relay:

- a) collocated RPS and satellite/airborne relay transceiver:
- 1) private (RPAS operator controlled) satellite network:
 - i) single satellite/airborne relay;
 - ii) multiple satellite/airborne relay;
 - 2) C2 service provider satellite network:
 - i) single satellite/airborne relay;
 - ii) multiple satellite/airborne relay;
- b) remote satellite/airborne relay transceiver:
- 1) private (RPAS operator controlled) satellite/airborne relay network:
 - i) single satellite/airborne relay;
 - ii) multiple satellite/airborne relay;
 - 2) C2 service provider satellite/airborne relay network:
 - i) single satellite/airborne relay: and
 - ii) multiple satellite/airborne relay.

Additional capability can be provided using:

- a) link architecture using dual simultaneous decorrelated links (e.g. using both RLOS and BRLOS or either dual RLOS or dual BRLOS with different frequency to increase link availability/quality of service); or
- b) link architecture using dual redundant active/standby decorrelated links (using both RLOS and BRLOS or either dual RLOS or dual BRLOS with different frequency to increase link availability/quality of service).

Note.— While in principle, all of the above options could be used to support VLOS operations it is likely that most VLOS activities will use an RLOS option, with a collocated RPS and antenna, typically in a handheld configuration.

C2 link spectrum

11.3.10 The C2 link between the RPA and the RPS plays a major role in maintaining safety and regularity of flight of the RPA and the safety and efficiency of operation of proximate users of the airspace. Protecting the spectrum this link uses from harmful interference which could affect the availability, continuity and integrity of the information being transmitted between the remote pilot and the RPA is therefore a high priority.

11.3.11 The spectrum most protected from harmful interference that is available for this type of application is identified as route (R) service spectrum by the International Telecommunication Union (ITU). This class of spectrum is typically not shared with other non-safety of life services, is subject to the most rigorous technical analysis for harmful interference before new services are introduced into the spectrum or spectrum adjacent to these (R) service bands and is protected by international agreement so that effective action can be taken against anyone causing harmful interference.

11.3.12 In 2007 work began in the ITU to perform the necessary studies to identify spectrum for the RPAS C2 link. These studies culminated in both the identification of bands that were already suitable for both RLOS and BRLOS C2 links as well as modifications to the ITU Radio Regulations to make other spectrum suitable.

11.3.13 In accordance with ITU Radio Regulation, as of 2012 the following bands are potential candidates for RPAS C2 links:

- a) 960–1 164 MHz for RLOS;
- b) 1 545–1 555/1 646.5–1 656.5 MHz and 1 610–1 626.5 MHz for BRLOS; and
- c) 5 030– 5 091 MHz for RLOS and BRLOS.

Note.— Other frequency bands, with suitable technical and regulatory provisions, may also be potential candidates for RPAS C2 links.

11.3.14 Work is now underway in ICAO's Frequency Spectrum Panel to develop a band plan to allow sharing between the terrestrial and satellite RPAS users of the 5 030–5 091 MHz allocation.

11.3.15 Although a significant amount of interest had been shown in using the 12/14 GHz and 20/30 GHz fixed satellite service (FSS) bands, the WRC concluded that more study was needed before a decision could be made on the suitability of the bands allocated to FSS to support RPAS. Consequently, the ITU is continuing its studies on these bands and, working in collaboration with ICAO, will provide a final report on their suitability at the 2015 World Radiocommunication Conference.

C2 link required communication performance (C2 link RCP)

11.3.16 The C2 link RCP concept is derived from *Manual on Required Communication Performance (RCP)* (Doc 9869) providing confidence that the operational communications supporting the RPAS functions that depend on the C2 link will be conducted in an acceptably safe manner.

11.3.17 The RCP values for the C2 link will need to be derived by the manufacturer specifically for the RPAS control and monitoring requirements including DAA.

11.3.18 The capability of the RPA, RPS, their control interfaces and any communications system connecting them, including the C2 link, as implemented by a manufacturer/operator, must comply with the RCP type parameters for the specific type of operation and phase of flight. The specific C2 link RCP values will depend on the design and performance characteristics of the RPA and RPS as determined by the manufacturer. These parameters include:

- a) *communication transaction time*: the maximum time for the completion of the operational communication transaction after which the initiator should revert to an alternative procedure;
- b) *continuity*: the probability that an operational communication transaction can be completed within the communication transaction time;
- c) *availability*: the probability that an operational communication transaction can be initiated when needed; and
- d) *integrity*: the probability of one or more undetected errors in a completed communication transaction.

Note.— Additional information on RCP can be found in Doc 9869.

11.3.19 If ATC voice and C2 messages are transmitted on the same data link, then the worst case combination of availability, continuity and transaction time must not reduce the minimum availability or continuity nor exceed the maximum transaction time of the most demanding RCP type.

11.3.20 The availability of the C2 link will be affected by the type of architecture used, the relative positions of the transmitter(s) and receiver(s) and the presence, or not, of rain or other forms of interference. Figure 11-3 shows example levels of availability that may be expected in several scenarios.

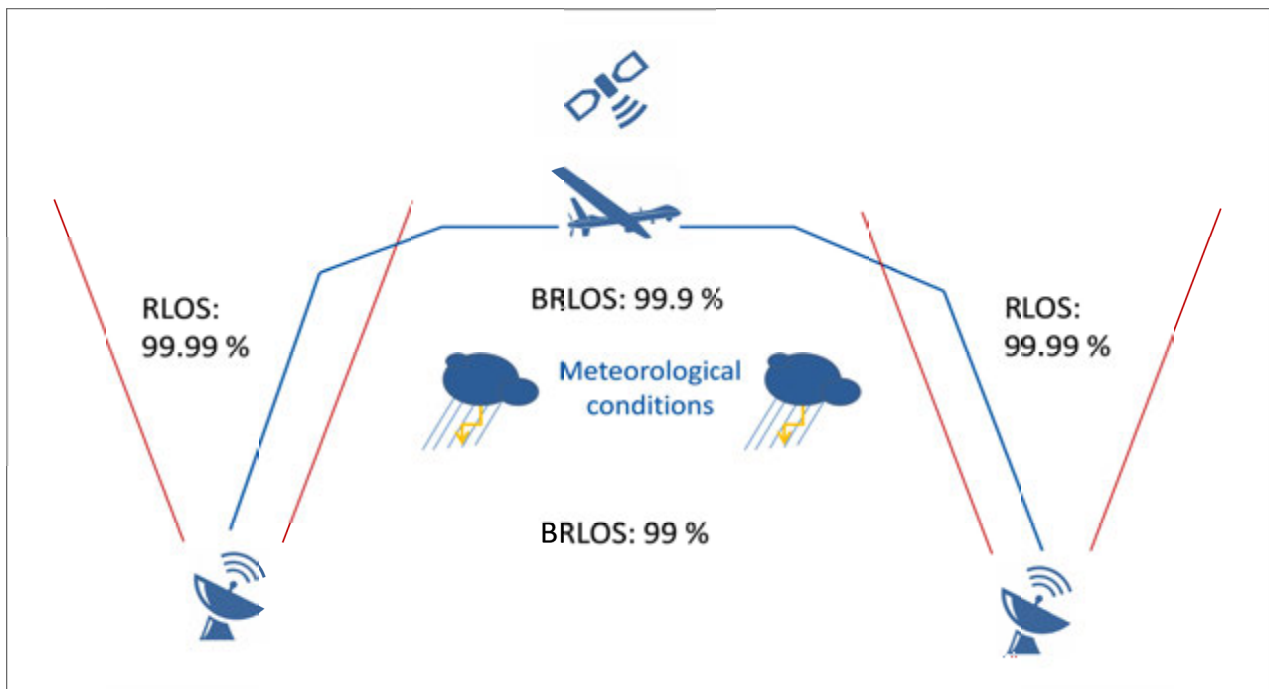


Figure 11-3. Example availability of the C2 Link

Implications of C2 link RCP value

11.3.21 The required C2 link performance parameters will be defined by the manufacturer/operator and agreed with the relevant regulator. The required performance of the link depends on the capability of the RPA and its control interface.

11.3.22 RPAS system design and operating procedures should be such that either:

- a) the loss of the C2 link will not lead directly to injury to people or damage to property; or
- b) the probability of loss of the C2 link due to all possible causes should be lower than the allowed probability of injury to people or damage to property.

Certification and operational approval of C2 link component and service providers

11.3.23 Regulatory oversight of the C2 link performance will be required to verify that the minimum standards are maintained. However, at the current time there is insufficient operational service history and certification experience with the RPAS C2 link to determine minimum standards. More detailed guidance and related SARPs can be expected as such operational service history and certification experience are gained.

11.3.24 When all the components of the link are under the direct control of the TC holder or RPAS operator, the components of the communication system will be certified by the civil aviation authority as part of the system. The type certification may be limited to certain types of operation and combinations of RPA, RPS and communication systems.

11.3.25 When some of the components are controlled by a C2 service provider, the C2 service provider will either need to be under safety oversight of a recognized civil aviation authority, or the safety aspects of the C2 link must be under the SMS of the RPAS operator who has contracted the service. In both cases, the C2 service provider must be acceptable to the State of Registry. This will be necessary to ensure that the end-to-end performance of the C2 link application, as required by the applicable RCP type, is achieved and maintained.

11.3.26 Communications services provided to support C2 and ATC/remote pilot voice services must meet the RCP criteria. The performance requirements of the communications services procured from a C2 service provider are defined by service level specifications (SLS) in agreement with the appropriate State authority. The SLS address the RCP parameters that are part of a service level agreement (SLA) entered into between the RPAS operator and the C2 service provider.

C2 link information flow

11.3.27 C2 link information flow requirements include update rate and support of specific data types. The optional support of ATC voice/data relay is described in Chapter 12.

11.3.28 Information flows and related details will be RPA/RPS specific. The precise list of parameters and their format should be defined by the manufacturer/operator and agreed by the competent authority. Examples of typical C2 link information flows are provided in Appendix B.

11.4 C2 LINK MANAGEMENT PROCEDURES

Frequency/bandwidth

11.4.1 There will be a need to dynamically assign specific frequencies as required on a daily/hourly basis. The frequency assignment for the C2 link will need to accommodate the requirements for a specific area and the requirements of flights which transit from one area to another. This may become a particular challenge in areas where large numbers of RPAS operations are taking place. Without some form of regional assignment there is a risk of harmful interference.

Link discrimination

11.4.2 The use of a centralized network for C2 link communication provision may be a long-term solution to the challenge of dynamic frequency or channel assignment. This will eventually need international harmonization.

11.4.3 To provide unique link discrimination, a means must be provided to ensure that data transmitted via the C2 link are “coded” in a unique manner (e.g. the ICAO 24-bit address) in order to ensure that the RPA communicates only with the appropriate RPS. (See 4.5 for additional information on C2 links related to airworthiness.)

Link and avionic system performance requirements

11.4.4 An RPAS C2 link allows the remote pilot to manage the flight. The required performance of the C2 link is dependent on the level of automation provided by the FCC or FMS. Categories of control based on the level of automation are described in Chapter 13.

11.4.5 The required performance of the C2 link is also dependent on the capability of on-board systems. For example, if the systems are capable of ensuring the safe flight of the RPA in the event of a short duration loss of the C2 link, the required performance may be lower.

11.4.6 These considerations will determine C2 link performance requirements and in turn the need for link redundancy.

Considerations for redundant C2 link

11.4.7 Configuration options include, “cold standby”, “hot standby” and “dual operation”.

- a) *cold standby*: where one link is working and carrying all the message traffic, the other link is powered down. In the event the first link is lost, before the standby link can be used, it needs to power up and initiate the link connection/log-in procedure to establish a connection to the other end of the link (e.g. at the RPS or RPA). This may involve a sign-in protocol with any third party network provider. The time delay associated with this procedure should be sufficiently short to avoid the need to trigger the lost C2 link procedure;
- b) *hot standby*: where both links are powered and connected and immediately available, although only one is being used to transfer C2 link data at any time. (The standby may be transferring low rate data to keep the link immediately ready to take over.); and
- c) *dual operation*: where all C2 link data messages are sent on both links simultaneously and the flight computer chooses the message from the link with the best integrity. This mode of operation minimizes the probability that there will be an interruption in C2 link data flow in the event of a single link interruption or failure.

11.4.8 It is recommended that the two links employ different frequencies/technologies (e.g. terrestrial radio line-of-sight and satellite-based BRLOS) as this will provide significantly greater protection against possible loss of the C2 link.

11.4.9 The remote pilot should be provided with a continuous indication of the operational status of all C2 links.

Note.— If necessary to achieve the required safety level, there may be a case for having more than two links.

11.5 C2 LINK PROTECTION REQUIREMENTS

Note.— See 4.5 for additional information on C2 links related to airworthiness.

Non-malicious/unintended interference

11.5.1 The data link(s) should be robust enough to survive the modest levels of interference that will be present from time to time.

11.5.2 Due to the risk of interference of the C2 link, it is recommended that there be a means to test or confirm that no harmful RF interference is present prior to and during flight; this requirement also applies to VLOS operations.

Security threats/malicious interference

11.5.3 The requirements for protection against malicious interference of the data link need to be harmonized based on an assessment by the competent authority.

11.5.4 The protection of the C2 link by encryption using security keys incurs a logistical overhead that requires careful management.

11.6 CHARACTERISTICS OF LOSS OF THE C2 LINK AND ASSOCIATED PROCEDURES

Background

11.6.1 As described in 11.2, the C2 link provides the connection between the remote pilot and the RPA controls and may be considered functionally equivalent to, for example, the control wires or databus between the cockpit and the control surfaces possibly via the FCC. However, for RPA this control information is routed via one or more radio links, potentially via extensive communication networks, which may involve satellites. It is anticipated that, due to the nature of radio waves and the EM environment, at least for the foreseeable future, occasional degradation or even loss of the C2 link may occur. This is likely even when redundant data link architectures are provided.

11.6.2 In manned aircraft, the connection between the pilot and the control surfaces is one of the most critical systems; a failure of the connection may result in the loss of the aircraft.

11.6.3 In order to allow RPA to fly without undue restrictions, the RPA total system design must be such that loss of the C2 link, while it may restrict the operation of the RPA, should not result in a hazardous or catastrophic event (e.g. collision with another aircraft or uncontrolled collision with the ground or obstacle).

11.6.4 C2 link loss is considered to be any situation in which the RPA can no longer be controlled by the remote pilot due to the degradation or failure of the communication channel between the RPS and RPA. The degradation or failure may be temporary or permanent and can result from a wide range of factors. RPA or RPS faults, such as failure of flight control systems, are not considered as a loss of C2 link.

11.6.5 Whilst it is possible to suffer a unidirectional loss of communication, either uplink to the RPA or downlink from it to the RPS, this is less likely with a data link than with a voice link and should still be considered a lost C2 link situation. Depending on the communications architecture, C2 link loss may not be coincident with the failure of voice communications between the remote pilot and ATC.

11.6.6 Three basic states can be envisaged:

- a) the C2 link works within the values specified in the RCP — the remote pilot is able to intervene as required;
- b) the C2 link works outside the limits of the RCP to the extent that control instructions are received without error but with a delay greater than the RCP allows — the remote pilot control is restricted, but providing the delay or unavailability persists for less than the sustained loss of link (T_{loss}) functionality seconds, normal flight can be maintained. The value of T_{loss} is dependent on the categories of control and potentially the phase of flight and the local airspace environment; and
- c) the C2 link is lost or is degraded to the extent that control instructions are delayed by more than T_{loss} . Normal flight can no longer be assumed to be safe as the remote pilot cannot intervene; the RPA design and operational contingency procedures should be sufficient to ensure a safe and predictable landing (or flight termination).

Decoupling C2 link and CA

11.6.7 If the RPA is equipped with an automatic CA function, the function must be able to operate correctly in the event of a C2 link loss. In this case, the required C2 link RCP would be independent of the required integrity and availability of the CA function. However, in a lost C2 link situation, the potential for remote pilot initiated traffic avoidance/separation manoeuvres or manual CA capability will not be available. This may need to be considered when determining the required availability and integrity of any automatic CA function.

Differentiation between loss of C2 link and failure of ATC voice communications

11.6.8 Loss of the C2 link should not be equated with a failure of voice communications with ATC. When voice communications with ATC fail, and depending on the communications architecture of the RPAS, the RPA will likely still be under the remote pilot's command, e.g. the remote pilot may still be able to manage the flight of the RPA. However, when there is a loss of the C2 link, the remote pilot cannot intervene in the flight's trajectory, and the RPA will be limited to performing automated actions. It is recommended that States harmonize the procedures including the actions pre-programmed into each RPA to best ensure that the safety of the air navigation system is maintained if the C2 link is lost.

11.6.9 Different procedures may be required for C2 link loss and ATC voice communications failure events; it will be necessary for ATC to be able to distinguish between these situations. In airspace where SSR transponder carriage is required, this can best be achieved by use of a dedicated SSR code. ADS-B emergency/urgency modes may also be used.

Possible causes of C2 link loss

11.6.10 There are a range of possible causes of RPS to RPA C2 link loss which are linked to architecture, environment as well as equipment characteristics. These include:

- a) screening terrain, buildings and (at low altitude) vegetation, other ground clutter and ocean wave effects;
- b) natural interference (meteorological conditions and space weather);
- c) unintentional interference by human activities (e.g. television broadcast);

- d) malicious or intentional interference (e.g. jamming) by humans;
- e) out of range (often linked to flying too low);
- f) equipment failure on the RPA;
- g) equipment failure in the RPS;
- h) equipment failures in the network (e.g. satellite);
- i) human error in the RPS (e.g. frequency setting, switches);
- j) aircraft manoeuvres (attitude-induced antenna screening, velocities and acceleration effects); and
- k) loss of the link resulting from a failed RPS/remote pilot handover operation.

11.6.11 Some of these effects may persist for short periods of time (less than 1 second) while others may endure for several minutes or may be permanent. In general, information on cause of the loss of a C2 link will not be available, although with appropriate monitoring systems the remote pilot may be able to infer the likely cause.

11.6.12 The following are not considered lost C2 link situations (although they will need to be considered in an overall safety assessment):

- a) erroneous messages on the C2 link resulting from undetected RPS faults;
- b) erroneous messages on the C2 link resulting from undetected RPA faults;
- c) failure of one link in a dual redundant C2 link implementation — this should trigger an appropriate reversionary procedure (but not the lost C2 link procedure). The remote pilot should be provided with suitable status indications;
- d) system failures in the RPA or RPS which result in the RPA no longer being able to maintain controlled flight; and
- e) short-term planned interruption of the C2 link during handovers.

Criteria for identification of lost C2 link condition

11.6.13 Degradations in the C2 link transaction time and availability from whatever cause will, if severe enough, result in a lost C2 link condition. The lost C2 link procedure should be initiated once the C2 link cannot be used to control the RPA (regardless of whether the remote pilot is attempting to use the link at the time). Partial degradation of the performance of the C2 link (typically characterized by an increased delay in the end-to-end transmission of a control instruction), which still allows safe control of the RPA, should not trigger the lost C2 link procedure. However, it will be up to the RPAS TC holder to agree with the certifying authorities on the maximum level of degradation that can be allowed before the lost C2 link procedure is initiated.

11.6.14 Temporary interruptions to C2 link transmissions can occur at times due to normal variations in the strength of the received signal. The duration of these interruptions can span from very small fractions of a second to minutes or even longer. Short-term interruptions should not have any significant effect on the flight and may not even be noticed by the remote pilot. It is clearly impractical for a lost C2 link procedure to be initiated for such events.

11.6.15 While the C2 link is not available, the RPA is flying in a state where it is “not under the command” of the remote pilot, and there will be a time period beyond which continued flight in this manner may not be considered acceptable. It is therefore important to determine the point at which a C2 link should be declared as being lost, (e.g. by display of a lost C2 link SSR code) at which point the lost C2 link procedure is initiated. This time period may need to be standardized; it should be long enough to minimize nuisance alerts but also be short enough to ensure that the safe operation of other airspace users is not compromised.

11.6.16 From an airworthiness perspective, it will be up to the RPAS TC holder to agree with the certifying authorities on the maximum duration of interruptions which can be allowed before the lost C2 link procedure is initiated. From an ATC voice communication perspective, if relayed via the C2 link, the acceptable duration of interruption may be different and will need to be agreed by the competent authority responsible for operational approvals.

11.6.17 The supporting C2 link monitor functions (in the RPA and RPS) must automatically detect the agreed level of degradation. The maximum allowed degradation will usually depend on the airspace and the type of operation as well as the control interface available or in use. Operations near busy aerodromes and manual landings will be more critical than during cruise flight in class A, B or C airspace. The monitor should, as a minimum, detect total C2 link unavailability and end-to-end message delays of T_{loss} .

11.6.18 The hazards associated with loss of the C2 link during particular phases of flight (e.g. the final stages of a manually controlled approach) will need to be assessed and mitigated by the RPA manufacturer. The C2 link RCP may, as a result, be more demanding for particular flight phases and may preclude the use of some communication networks.

11.6.19 The RPA and the RPS will need to continuously monitor the C2 link for degraded operation.

Note 1.— The indication of the C2 link status to the remote pilot should be updated at a sufficient rate to ensure that C2 link RCP (for the phase flight) can be correctly monitored.

Note 2.— The lost C2 link procedure provides no protection against undetected errors in a completed communication transaction. The probability of undetected errors must be sufficiently low that when combined with the severity of any possible outcome, the resulting probability of a catastrophic event is acceptable.

Intermittent link degradation

11.6.20 Short-term degradation of C2 link performance of less than T_{loss} should not result in the initiation of the lost C2 link message to ATC (e.g. SSR code, if equipped); however, such dropouts may indicate a reduction in the overall quality of the C2 link. Repeated, intermittent degradation of the C2 link, even if only for a short duration, should be assessed by the remote pilot with regard to the acceptability of continuing the planned flight. Such conditions may require the remote pilot to initiate the lost C2 link procedure, even while some partial link availability exists in order to maintain a safe, predictable and ATC-compliant flight.

Selection and notification of alternate aerodromes in the event of a lost C2 link condition

11.6.21 For long distance flights, there may be several alternate aerodromes identified for use in the event of a lost C2 link. Selection of the alternate to be used will depend not only on the RPA's position but also on the meteorological conditions at the aerodromes. The remote pilot is responsible for selecting the alternates. During the flight, based on position and latest meteorological information, the remote pilot should update the current alternate aerodrome in the RPA FMS so that in the event of a lost C2 link, the RPA's expected route will be predictable.

11.6.22 Once a lost C2 link condition occurs, the remote pilot is responsible for informing ATC which of the available lost C2 link alternate flight options will be executed by the RPA. Therefore, it is likely that the criteria for selecting lost C2 link alternate flight options will need to be agreed by ATC on a case-by-case basis until ATC has confidence in the process. It may be possible to use the Mode S data link to provide the information to ATC.

Discussion of lost C2 link contingency options

11.6.23 There are five basic contingency options to be considered by the RPAS operator, State authorities and ANSPs for action following a loss of the C2 link. Decisions regarding the option to be taken may be different depending on the segment of flight where the failure occurs, the type of RPA and its risk to other airspace users, as well as persons and property on the ground. In all cases, the contingency option(s) should be preprogrammed, although generally not hardwired, into the RPA for automatic activation when specified conditions are met.

- a) *continue original flight plan*: this may be appropriate if the planned flight is short and the planned destination is a low density aerodrome or landing site or if the planned flight occurs in low density airspace. However in general, this option could result in the RPA flying “not under command” for long duration (or even days), crossing numerous national borders, and ultimately attempting to approach and land at a congested aerodrome under meteorological conditions (wind direction and speed and visibility) different from those expected when the flight commenced. As a minimum this would imply a high integrity flight management function. This option might not be acceptable to State authorities, ATC units or other airspace users;
- b) *land at nearest appropriate designated landing site*: this ensures that the duration of the RPA flight when not under command is minimized and that the landing site used has agreed to approach and landing by RPA that are not under command. (The nearest appropriate diversion/alternate aerodrome or landing site may, depending on the characteristics of the flight, be the planned destination or departure aerodrome or departure site);
- c) *direct return to departure aerodrome or departure site*: this has the same issues as option a) in that the RPA may be many hours flying time from the departure aerodrome or departure site, which may no longer be able to accept an automatic not under command approach. As indicated in option b), in some situations the departure aerodrome may be the nearest appropriate designated landing site;
- d) *flight termination*: in general, immediate termination of the flight should be avoided as it presents a risk to people and property on the ground, a risk to other airspace users as it descends and can result in hull loss. However, this option may be specified by regulators in certain situations; and
- e) *climb to altitude to attempt to regain the C2 link*: this may not be acceptable in controlled airspace if the ATC unit is not provided sufficient time to clear other aircraft from the area, thus posing a significant risk to other airspace users. While this could be undertaken as an agreed contingency plan (e.g. fly to a known point and then climb 5 000 feet in an effort to recapture the C2 link), there are many scenarios where this would not be effective and an alternative procedure would have to be initiated.

11.6.24 Given the above, it is expected that option b) is preferred for most RPAS operations.

11.7 RECOVERY OF THE C2 LINK

When flying under an ATC clearance

11.7.1 If the C2 link is recovered after the lost C2 link procedure was initiated, the remote pilot should coordinate with ATC prior to taking any action to alter the trajectory of the RPA. A revised ATC clearance should be obtained which could allow the original flight plan to be resumed.

Note.— In event of loss of the C2 link, it should be assumed that RVSM and performance-based navigation (PBN) are no longer available as these performance requirements can only be maintained if actual performance is continuously monitored by the remote pilot(s).

Flights not under ATC control

11.7.2 In the event of C2 link recovery, the remote pilot is responsible for deciding on the appropriate course of action, taking into account the overall situation, the likely reliability of the C2 link and the risk to other airspace users. The general principles of remaining predictable to other airspace users and minimizing the time of flight while not under command should be adhered to.

Chapter 12

ATC COMMUNICATIONS

12.1 OVERVIEW

12.1.1 The general requirements for ATC communications, to and from the remote pilot, are the same as for manned aviation operating in the same airspace. In addition to very high frequency (VHF) voice, this may also include the requirement to support ATC data link.

12.1.2 However, because the remote pilot is not on board the aircraft, a range of alternative communication architectures are possible which are outlined in 12.2 to 12.4.

12.1.3 Whichever architecture is employed, the ATC communications function will be expected to meet the RCP specified for the airspace in which the RPA is operating. In the case that ATC communications are relayed via the RPA, a reversion/backup means of communication with ATC may be required in order to mitigate any failure of the RPA relay function.

12.1.4 If approved by the ATC unit(s) involved, this could include a telephone backup. Where connections to ATC are discussed, the ATC “system” is assumed to include any already approved communications service providers as appropriate.

12.2 ATC VOICE AND DATA LINK COMMUNICATIONS ARCHITECTURE OPTIONS

12.2.1 The communications links between ATC and remote pilot, RPS and RPA may be implemented by any network service that meets the required communications performance, e.g. a private network or a service provided by a third party.

12.2.2 The various options for providing voice and data communications between ATC units and the remote pilot are divided in two main groups:

- a) via the RPA, which is transparent to ATC and requires no additional infrastructure or equipment in the ATC unit. This approach also has the advantage that it is compatible with existing ATC operations across the globe. However, it may require more communications bandwidth on the C2 link to support the ATC voice and data relay between the RPA and the remote pilot; or
- b) via a new broadcast, private or networked communications link, directly between the ATC unit and the remote pilot. The alternatives and the implications are described in 12.4.

Note 1.— All of these communications options can apply to either VLOS or BVLOS operations.

Note 2.— Where all the new elements of the communications system are under the direct control of the RPAS operator, the regulatory approval of the system may be simpler than if a third party commercial network is used.

12.3 VOICE AND DATA TO/FROM THE RPS, RELAYED VIA THE RPA

12.3.1 RLOS operations may be conducted using the RPA as a relay point for ATC voice and data communications. In this case, the C2 link may be used to support the segment between the RPA and the RPS. This RLOS option requires at least one VHF radio on board the RPA and assumes that the C2 link has the bandwidth to support the ATC voice and, if required, data communications, e.g. CPDLC (see Figure 12-1).

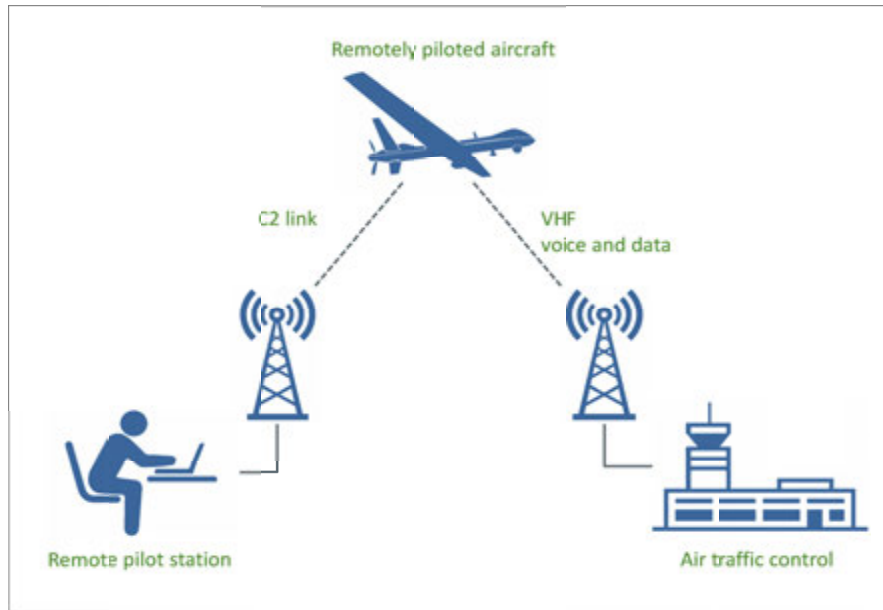


Figure 12-1. Radio line-of-sight

12.3.2 The standard minimum equipment requirement for manned aircraft (for operation where a radio is required) is for two VHF radios to be carried. However, this may be revised for RPAS if an additional independent communications channel between the ATC unit and the remote pilot is available or required. This will enable ATC/remote pilot communication in the event that the primary communications route fails. Such a failure may be caused by VHF equipment failure or by failure of the C2 link used as the relay.

12.3.3 In this scenario, VHF voice messages from the ATC unit to the remote pilot are received by the RPA, digitized and relayed to the RPS via the C2 link. Remote pilot voice messages to the ATC unit are digitized in the RPS, sent to the RPA via the C2 link, converted to analogue voice and transmitted via the VHF radio (see Figure 12-2).

12.3.4 It is important to note that there may be a data communications network between the ATC unit and the VHF antenna used to broadcast the message to the RPA. The link between the RPA and RPS may also include a network operated by a communications service provider and potentially involve routing via multiple satellites. These networks can introduce additional delays which need to be included in the assessment of overall communication transaction time (see Figure 12-3).

12.3.5 A particular feature of the ATC communications BRLOS relay approach, as with any situation where ATC communications is routed through the RPA, is that it is universal and should operate seamlessly anywhere in the world, without changes to local infrastructure being required. Although this provides a long-range capability from a single RPS, it may be more difficult to achieve the necessary RCP (transaction time, continuity, availability and integrity) compared to the short-range RLOS situation.

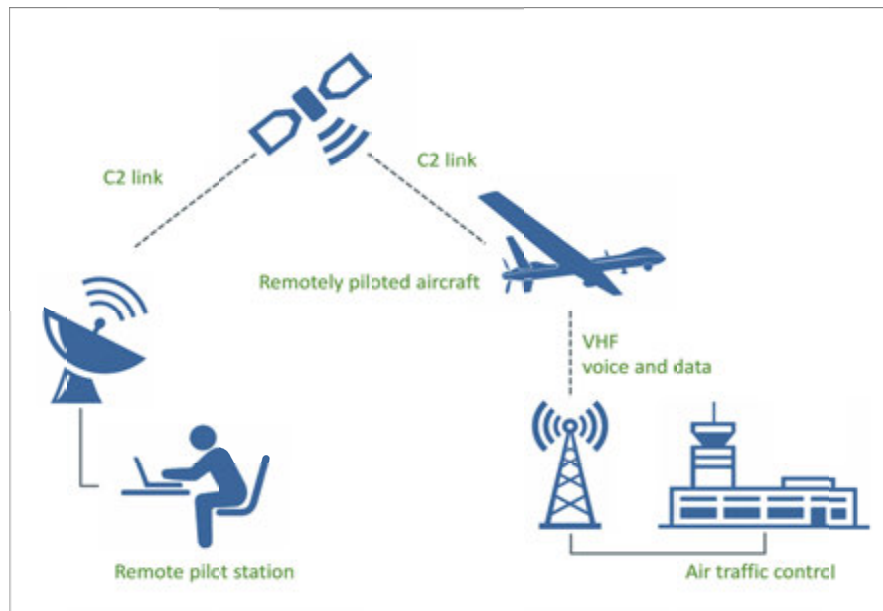


Figure 12-2. Beyond RLOS (BRLOS) via a relay (typically via satellite)

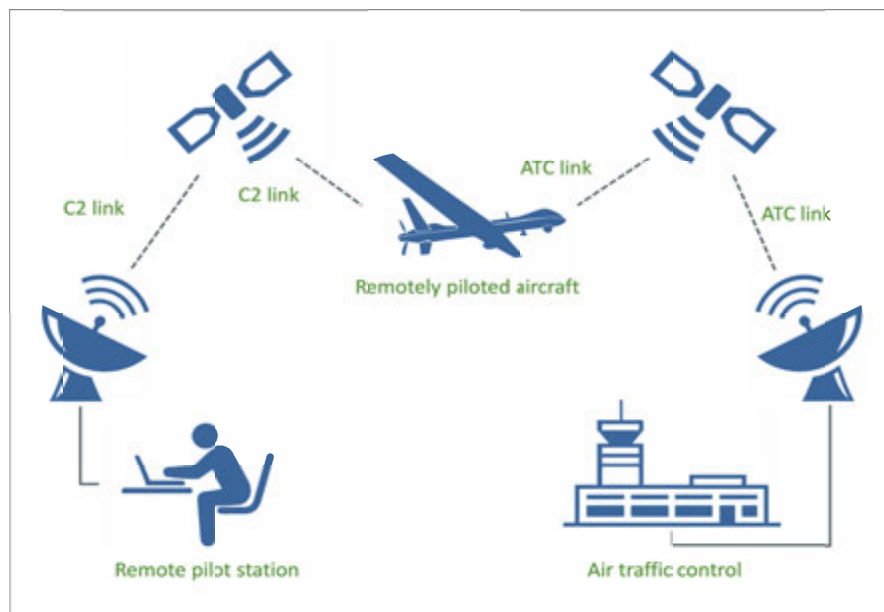


Figure 12-3. Oceanic/remote area operations, ATC voice and data via satellite

12.3.6 Existing third party networks contracted by relevant ATC authorities are already approved to the required ATC RCP levels; however, because of the additional transmission path from the RPA to the RPS, these levels may need to be reviewed.

12.4 ATC VOICE AND DATA TO/FROM THE RPS WITHOUT A RELAY VIA THE RPA

12.4.1 These options do not require a VHF radio on the RPA and use direct or indirect (through a service provider network) communications pathway between the ATC unit and the remote pilot.

12.4.2 A key requirement of this approach is that the solution is transparent to the controller (i.e. the controller's procedures and actions remain the same as for the management of manned aircraft). Although new equipment would be required at the ATC unit, no additional operational requirements relating to the communications architecture should be apparent to the ATCO.

12.4.3 Whenever possible, the party-line effect provided by VHF voice should be maintained to ensure that all voice communications between the remote pilot and ATC are broadcast on the sector frequency for other airspace users to hear, and all voice communications on the sector frequency should be available to the remote pilot. This assists the remote pilot in building and maintaining situational awareness in the airspace.

12.4.4 There are a number of possible architectures:

- a) ATC voice on the sector frequency received directly from a VHF radio in the RPS (see Figure 12-4):
 - 1) this is the simplest alternative to using the RPA as a relay and can be suitable for short range operations. The RPS is connected to a VHF radio antenna located within range of the ATC unit antennas for the airspace in which the RPA is intended to be flown. The link between the RPS and its antenna could be a short, direct line or be routed for longer ranges via a network. This is likely to be very effective where the RPA is routinely operated in one location. Additional RPS antennas will be required to support operation in larger ATC airspaces;

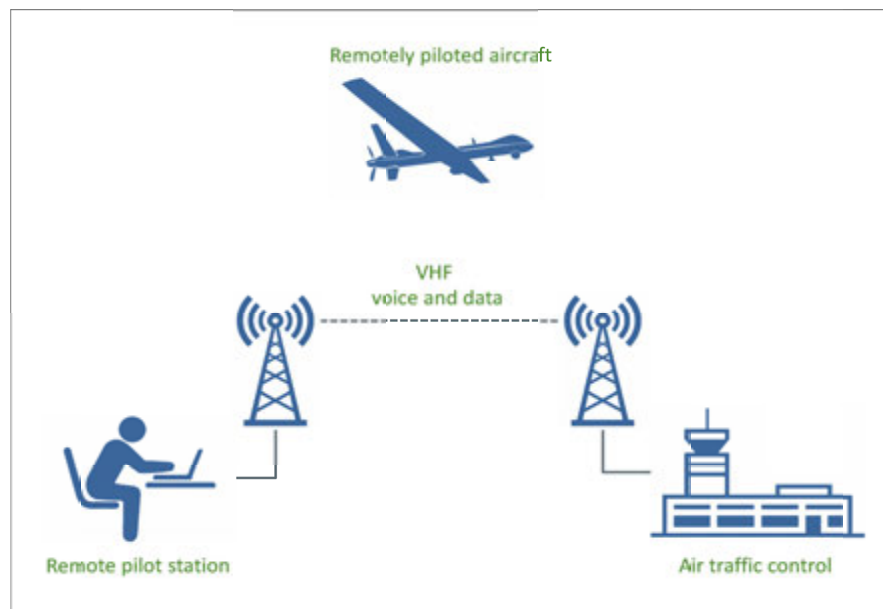


Figure 12-4. VHF ground to ground radio link

- b) ATC voice and data to/from the RPS via a dedicated/private connection (see Figure 12-5):

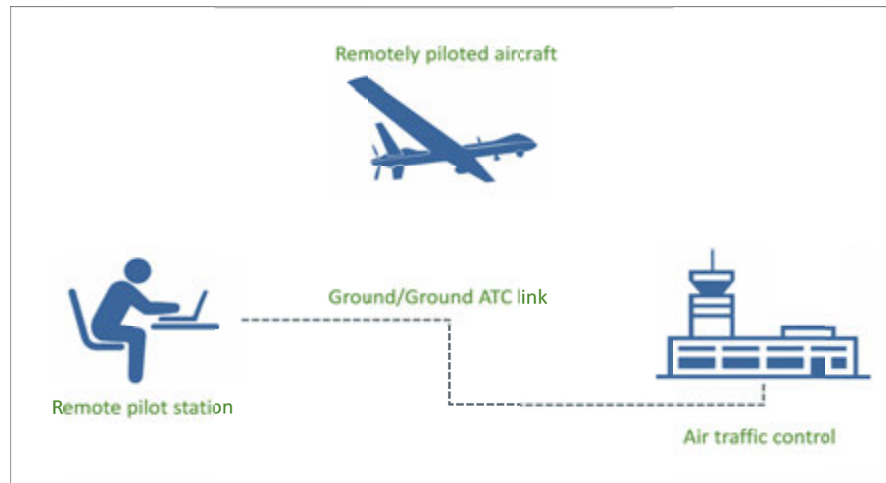


Figure 12-5. Ground only network

- 1) this requires a direct interface into the ATC unit's voice control system such that when the ATCO communicates on a frequency, the information is captured, digitized (along with any CPDLC messages) and relayed to the RPS via a dedicated connection, with a similar arrangement for communications from the RPS to the ATC unit. Systems or procedures should be provided to ensure that the voice input from the RPA does not have higher priority than normal VHF transmissions;
 - 2) a key advantage of this option is that the location of the RPS is not constrained and, providing the logic in the ATC unit will support it, the RPA can operate anywhere in the full volume of airspace supported by the ATC unit;
 - 3) a simple phone link (hand-held receiver) may not be acceptable as the primary communications between RPS and ATC. The overall integrity and availability of the link used may need to be approved by the appropriate aviation authority;
 - 4) as for all alternate architectures, the remote pilot will be expected to have an appropriate alternative method of communicating with the ATCO in case the primary link fails. The ATCO should also have a means of contacting the remote pilot when necessary (e.g. the phone number of the RPS provided prior to the flight);
- c) ATC voice and data to/from RPS via a communications service provider network (see Figure 12-6):
- 1) this approach is the same as the previous option except that it involves a third party communications service provider. In practice this option, rather than the previous one, is likely to be more generally employed, except in situations where the local ATC service provider provides, under its own responsibility, ground links for the RPAS operator to tap into;
 - 2) this will again require specific equipment to be installed in the ATC unit and while it would be effective within the airspace covered by a specific unit, it would not easily support crossing ATC sectors, especially if these were planned at short notice;

- 3) some reversionary/backup capability is still likely to be required; however, possibly only dual redundant terminals in the RPS, if the communications network has sufficient integrity (e.g. based on multiple communications paths);
- 4) the key challenge with this option is regulatory oversight of the communications service provider, especially if this is under contract with the RPAS operator rather than with the ANSP. However, the oversight/approval challenge for the ATC communications link will typically be less than that for the C2 link, given the expected higher RCP for C2 link than for ATC communications; and

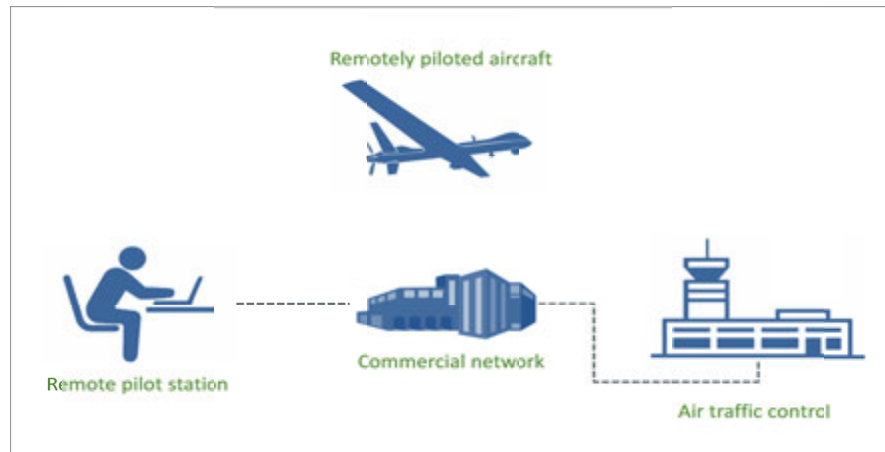


Figure 12-6. Ground link via communications service provider

- 5) one feature of communications service provider networks is that they may involve a range of technology and links to provide the service, which could involve the use of the internet and or satellite networks (see Figure 12-7). Certification of such systems is expected to be very difficult and procedures for appropriate regulatory oversight are still to be developed. One specific concern may be the use of different routes (e.g. terrestrial or satellite) based on the logic internal to the service provider's system. Guaranteeing a particular RCP may be difficult with such a system.

12.5 SPECIFIC COMMUNICATION REQUIREMENTS FOR OPERATIONS IN VLOS

12.5.1 Most VLOS operations will be operated either below the altitude where ATC communications is required or in situations where ATC prior approval and operating constraints have been agreed, making routine ATC communications unnecessary. However, ATC may still require a method to contact the remote pilot in an emergency, and the remote pilot should know how to contact the local ATC unit if the need arises. In both cases this would normally be achieved by telephone.

12.5.2 In exceptional circumstances for particular operations (e.g. low level surveillance of an active airfield), direct communication between the ATC unit and the remote pilot may be required. In these cases, any of the architectures outlined above for BVLOS operations could be used although ground/ground VHF voice is likely to be the most appropriate (see Chapter 15, 15.2).

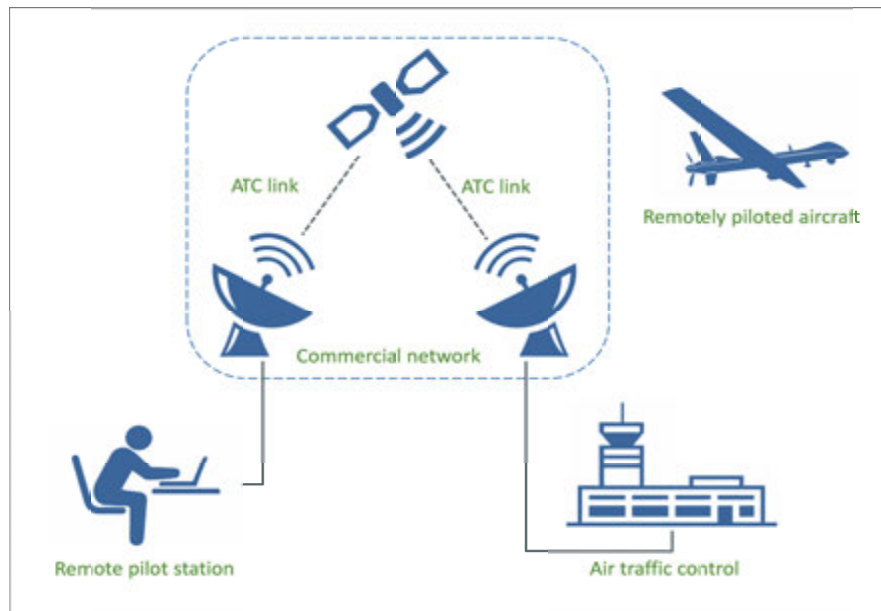


Figure 12-7. Including satellite network

12.5.3 More frequently, it may be appropriate for the remote pilot of a VLOS RPA to broadcast a short range (i.e. low power) periodic message to other unspecified airspace users to warn them of the ongoing operation. This would normally be on the recommendation of the local regulators.

Note.— Satellite communications equipment on small VLOS RPA, while unusual, is in use today.

12.6 ATC COMMUNICATIONS — REQUIRED COMMUNICATION PERFORMANCE (RCP)

12.6.1 In order to provide a means for assessing the performance requirements of ATC communications in support of RPAS operations, the principles of the RCP concept described in Doc 9869 should be employed. This is based upon “operationally significant” benchmarks which, when attained, provide confidence that the ATC communications will safely support the RPAS operations.

12.6.2 The values for a specific C2 link RCP will depend on:

- a) the requirements of the specific airspace;
- b) the phase of flight; and
- c) The degree of automatic operation of the RPAS.

12.6.3 An assessment of RCP has been made for ATC communications data links, and it is expected, taking into account the implications that the various RPAS link architecture options may have on communication transaction time, continuity, availability and integrity of the total system, to accommodate RPAS ATC communications within the current requirements.

12.6.4 The ATC RCP provides the end-to-end performance requirement based on the assumption that the pilot is in the aircraft. For RPAS, the additional relay of the message via the C2 link to the remote pilot (if used) should be included in the assessment of the RCP.

12.7 MINIMUM COMMUNICATIONS AIRBORNE EQUIPMENT

12.7.1 Aircraft must meet the minimum number of short- or long-range radio equipage requirements to be carried on board, as established by the competent authorities.

12.7.2 These rules imply that, in principle, different technologies could be used to satisfy the requirement on-board manned aeroplanes (e.g. one set of satellite communication (SATCOM) and one set high frequency (HF) could be approved in regions where both services are available for routine communications along oceanic routes).

12.7.3 In the case of RPAS, since the remote pilot and the RPS are not installed in the RPA, the competent authorities may consider whether alternative ATC VHF radio equipage requirements may be utilized. For example, one radio on board and a second alternative communications path between the RPS and the ATS unit(s) could provide the necessary redundancy.

12.7.4 In principle, installed equipment must be operational when commencing a flight. However, experience has demonstrated that temporary unserviceability may, in some cases, be tolerated. In such cases, the MMEL must be complied with. The MMEL contains a list of equipment which can be tolerated as unserviceable at commencement of flight and for how long. The MMEL is approved by the authority designated by the State of Design. The MMEL for RPAS relating to communications equipment will likely be related to the specific communications architecture adopted. Requirements for C2 link and ATC communications will need to be specified separately although depending on the architecture, they will not, necessarily, be independent.

12.7.5 In manned aviation, aircraft operators are usually mandated to establish a minimum equipment list (MEL), based upon, but no less restrictive than, the relevant MMEL. The MEL is approved by the competent authority established by the State of the Operator or State of Registry. This same procedure can be expected for RPAS operators.

12.7.6 If changes to the MEL to allow dispatch are desired, the operator should obtain operational approval or at least notify the change to the State of the Operator or State of Registry.

12.8 FUTURE DEVELOPMENTS

RPAS will likely be required to be compatible with system-wide information management (SWIM) requirements when they are defined.

Chapter 13

REMOTE PILOT STATION (RPS)

13.1 OVERVIEW

13.1.1 The RPS is defined as "... the component of the remotely piloted aircraft system containing the equipment used to pilot the remotely piloted aircraft." As a general principle, the RPS functions in the same manner as the cockpit/flight deck of a manned aircraft and should therefore offer the remote pilot an equivalent capability to command/manage the flight.

13.1.2 While the basic functions are similar to those of a manned cockpit/flight deck, the specific shape, size, contents and layout of any RPS will vary due to aspects such as:

- a) the type of operation conducted (VLOS or BVLOS);
- b) the complexity of the RPAS;
- c) the type of control interface used;
- d) the number of remote pilots required to operate the RPA; and
- e) the location of the RPS — fixed position on the ground or within another vehicle/platform (e.g. ship or aircraft).

13.1.3 This chapter outlines specific factors that should be taken into account when considering the design and operational use of an RPS. It covers both the technical and the operational aspects (e.g. displays and controls). In addition, due to the likelihood that a significant proportion of RPAS operations will be involved in aerial work, often of long duration, it will be important to ensure that the separation of any piloting and payload (e.g. sensors) operations/displays/controls is appropriately considered, particularly if the remote pilot is intended to become involved in any aspect of the payload operation.

13.2 FUNCTIONAL OVERVIEW

13.2.1 The RPS provides the means for the remote pilots of the RPAS to monitor and control the operation of the RPA both on the ground and in the air. However, the interface between the remote pilot/RPS and the RPA is via a C2 link. The RPAS must therefore be designed to provide the remote pilot with the tools necessary to effectively manage the flight. This may result in controls, displays and alarms that are different from those of manned aircraft with consequences for remote flight crew procedures, training and licensing as well as the airworthiness requirement of the components.

13.2.2 Notwithstanding these potential differences, the fundamental requirements of the remote pilot/RPS interface remain the same as for manned aircraft and can be summarized as follows (based on Annex 8, Part IIIB):

- a) the design of the controls and control systems must be such as to minimize the possibility of mechanical jamming, inadvertent operations and unintentional engagement of control surface locking devices;
- b) the design of the RPS must be such as to minimize the possibility of incorrect or restricted operation of the controls by the remote flight crew due to fatigue, confusion or interference. Consideration must be given at least to the following:
 - 1) layout and identification of controls and instruments;
 - 2) rapid identification of emergency situations;
 - 3) sense of controls; and
 - 4) ventilation, heating and noise;
- c) means must be provided which will either automatically prevent or enable the remote pilot to deal with emergencies resulting from foreseeable failures of equipment and systems, the failure of which would endanger the aircraft; and
- d) markings and placards on instruments, equipment, controls, etc., must include such limitations or information as necessary for the direct attention of the remote pilot during flight;

Additionally, for BVLOS RPS:

- e) adequate information on the environment in which the RPA is operating to provide the remote pilot sufficient situational awareness to enable the safe operation of the RPA. These displays should include those necessary to support the DAA functions.

13.2.3 Controls and displays provided within the RPS must meet appropriate human performance principles/requirements.

13.2.4 RPS systems and displays will not necessarily be required to comply with manned aircraft flight deck level environmental standards; however, they will have to meet appropriate reliability, integrity and environmental requirements, as determined by the State.

13.2.5 Performance of the C2 link will likely limit the controls and displays available to the remote pilot. In particular, certain traditional controls such as the stick and throttle may not be provided in the RPS. Manufacturers will have to demonstrate that the controls and displays that are provided are sufficient to safely and effectively pilot the RPA in normal operation as well as in the event of system failures. The design and approval of automatic systems on the RPA which replace a control function in the RPS, must take into account that the remote pilot may not be able to compensate for failures of these systems.

13.2.6 Information on the quality of the C2 link must be available to the remote pilot, particularly if the quality of service is degrading to a level at which remedial action must be taken.

13.2.7 RPS components exposed to the elements should be secured, typically the antenna and other masts, as these can suffer damage due to lightning and severe winds.

13.3 RPS CONSIDERATIONS FOR DIFFERENT OPERATIONAL CONFIGURATIONS

BVLOS Category A — direct control

13.3.1 Category A control provides the greatest level of remote pilot control of the RPA, allowing inputs equivalent to a control stick, rudder pedals and throttle to actuate flight control surfaces and power settings, or via autopilot. The transaction time and update rate for primary flight data (e.g. speed, altitude, heading, attitude, vertical speed and yaw) to be received from the RPA and displayed to the remote pilot must be able to support the operational requirements. Likewise, the transaction time and update rate for remote pilot inputs to be received and processed by the RPA must be able to support the operational requirements. This direct control places the greatest demands on the C2 link capability and performance.

BVLOS Category B — autopilot control

13.3.2 Category B control provides less control of the RPA, still allowing speed, altitude, heading and vertical speed to be controlled, although changes are only effected through autopilot entries. The transaction time and update rate for flight data to be received from the RPA and displayed to the remote pilot are less stringent than for Category A RPS; however, they must be able to support the operational requirements. Likewise, the transaction time and update rate for remote pilot inputs to be received and processed by the RPA, while less stringent than for Category A RPS, must also be able to support the operational requirements. This autopilot control places less stringent demands on the C2 link capability and performance than direct control.

13.3.3 RPA flown from a Category B RPS may have less ability to manoeuvre rapidly or abnormally due to autopilot design characteristics (e.g. fixed bank angle) and transaction times. It may be possible to mitigate this limitation and come closer to the flexibility of a stick and throttle interface by including emergency command options within the autopilot interface.

BVLOS Category C — waypoint control

13.3.4 Category C control provides limited control by the remote pilot of the RPA during flight. The flight planned route can only be altered through waypoint entries and/or deletions into the programmed flight plan.

13.3.5 The transaction time and update rate for flight data to be received from the RPA and displayed to the remote pilot are less stringent than for Category B RPS; however, they must be able to support the operational requirements. Likewise, the transaction time and update rate for remote pilot inputs to be received and processed by the RPA, while less stringent than for Category B RPS, must also be able to support the operational requirements. This waypoint control places limited demands on the C2 link capability and performance.

13.3.6 This level of control, while supporting the management of preplanned flights, limits the ability of the remote pilot to respond promptly to ATC instructions with accuracy (e.g. it is not possible to directly enter a specific heading to be flown). Although the requirement may be met by insertion of a new waypoint approximately on the required track, this takes time for the remote pilot to estimate and enter, adding to the delay. This performance constraint is likely to restrict routine operation in busy airspace where ATC vectoring is used.

Note.— While VLOS operation assumes the remote pilot has direct control of the RPA attitude and speed, the use of automation, including waypoint control, may also be possible. This “indirect control” inevitably isolates the remote pilot from the RPA to some extent and potentially reduces the remote pilot’s ability to react in a timely manner.

VLOS control for take-off and/or landing with handover to BVLOS

13.3.7 When VLOS control is used during take-off or landing, with handover to BVLOS control for the en-route segment, for example, when automatic take-off or landing is not available or approved by the aerodrome operator, the following points should be considered:

- a) operational requirements may necessitate use of an RPA observer or additional remote pilot to maintain visual contact with the RPA; and
- b) VLOS operation of a BVLOS RPA may require use of a different RPS than for the en-route segment.

13.4 DISPLAY AND CONTROL REQUIREMENTS FOR BVLOS CAPABLE RPS

General requirements

13.4.1 The RPS must be equipped with controls and displays which will enable the remote pilot to control the flight path of the RPA, carry out any required manoeuvres and deal with emergencies while observing operating limitations.

13.4.2 Whereas the pilot control interface requirements laid down in Annex 6 will, in principle, apply to the RPS, the unique nature of RPA operations may necessitate new requirements. HMI should allow the remote pilot to operate the RPA by monitoring normal flight characteristics, status, navigation information and DAA functions. Additionally, there should be warning of RPA failures, potential losses or degradation of the C2 link and relevant meteorological effects on the aircraft. When designing such functions, consideration should be taken of the update rate of the information being supplied and also the potential robustness of the control interfaces. All of these functions contribute to the remote pilot's situational awareness.

13.4.3 All warnings and alerts currently provided for manned aircraft should be considered for inclusion in the RPS.

13.4.4 Any payload-related displays or controls must be designed and positioned so as not to distract the remote pilot from the primary task of maintaining safe flight.

Remote pilot access control

13.4.5 The RPS is equivalent to the flight deck of a manned aircraft. Security of the station and the remote pilot are therefore of paramount concern to overall air navigation system safety. Access to an RPS should be restricted commensurate with the size and capability of the RPAS.

13.4.6 RPS logon and logoff functions are critical security features to reduce unapproved access to the RPAS. The logon provides identified control over the RPAS and the logoff ends such control; failure in either process may enable an unauthorized individual to gain control over the RPA. RPS logon should include identification and authentication of the remote pilot.

13.4.7 Handovers between non-collocated RPS may necessitate additional verifications and controls to assure the process is not interfered with by unauthorized individuals.

13.5 RPS CAPABLE OF OPERATING RPA OF ONE OR MORE TYPES

General

13.5.1 An RPS can be designed to control one or more types of RPA. However, an individual RPS should not have piloting control of more than one RPA at a given time. The following sections identify some of the possible capabilities that might be considered within a future RPS classification scheme.

Note.— While swarms of RPA are a likely scenario, they are not within the scope of this manual.

VLOS RPS

13.5.2 Since VLOS operations require remote pilots or RPA observers to maintain visual contact with the RPA, it is likely that VLOS RPS will only support a limited set of displays to minimize a “head down” operation.

13.5.3 If a VLOS RPS is used to control multiple types of RPA, common control and display interfaces will be needed to minimize remote pilot workload and confusion. This may therefore limit the types of RPA that may be effectively controlled by the RPS.

BVLOS capable RPS

13.5.4 RPAS operators may identify a business case for utilizing a BVLOS capable RPS to handle many types of RPA in order to satisfy different operations economically. In order for this scenario to be feasible, the RPS will have to be approved for use with each model of RPA and documented on the TCDS by the TC holder.

13.5.5 If a BVLOS capable RPS is used to control multiple types of RPA, common control and display interfaces will be needed to minimize remote pilot workload and confusion. This may, therefore, limit the types of RPA that may be effectively controlled by the RPS. Furthermore, the remote pilot must have clear indication of the model of RPA currently being controlled.

13.6 HUMAN PERFORMANCE IMPLICATIONS

General

13.6.1 The human performance implications of the lack of sensory information resulting from the remote pilot not being on board the aircraft must be considered and, where necessary, adequately substituted. This may involve the use of non-visual cues, such as vibration or audio alerts. At this time, the range of information to be provided to the remote pilot through sensors or displays has not been determined. However, the following items, including substitute means based on hazard cause analysis of the sensory information, should be considered as a minimum:

- a) visual sensory information (e.g. light and flash);
- b) auditory sensory information (noise environment including engine and airframe noise);
- c) proprioceptive sensory information (e.g. vibration and acceleration);

- d) olfactory sensory information (smell);
- e) tactile sensory information (e.g. heat and vibration); and
- f) other sensory information (e.g. heat and pressure).

Mobile RPS

13.6.2 When RPS are located on mobile platforms, such as aircraft or ships, the human performance issues of being located on a moving platform, such as conflicting inputs from equipment-based sources versus from sensory sources (e.g. instruments indicating the RPA is turning right while the RPS platform is turning left), should be addressed.

Controls and switches

13.6.3 The wide range of RPS types may make a common standard remote pilot interface impractical. Varying levels of automation result in many different levels of control and control interfaces being proposed. Remote pilots will have to adapt to the RPS in use, executing tasks in different ways and adjusting to the level of automation provided. These differences will have human performance implications for the remote pilot. This implies that:

- a) adequate, potentially continuous, display of essential information and access to all secondary information that may contribute to the remote pilot's decision-making process is required;
- b) the data provided must be clear and unambiguous;
- c) control of aircraft systems and functions should:
 - 1) be intuitive;
 - 2) induce direct RPA response;
 - 3) provide appropriate feedback; and
 - 4) respond within an acceptable time; and
- d) the controls and switches must not be open to inadvertent operation.

13.7 DISPLAY OF INFORMATION FOR DAA

General

13.7.1 Providing RPAS capabilities to replace visual capabilities traditionally performed by pilots of manned aircraft may require the use of sensors and RPS displays. The following capabilities include those required to support DAA, as noted, and other capabilities that may be required to enhance the efficiency and flexibility of RPAS operations:

- a) obtaining information provided by aerodrome signs, markings and lighting;
- b) obtaining information provided by visual signals (e.g. interception);

- c) identifying and avoiding terrain and obstacles;
- d) identifying and avoiding hazardous meteorological conditions;
- e) maintaining at least the minimum applicable distances from cloud when operating under VFR;
- f) remaining well clear of other aircraft or vehicles; and
- g) avoiding collisions.

13.7.2 With such a wide range of differing requirements, and also the means by which these can be achieved, it is likely that numerous different systems and sensors will be required to gather, process and display all the information to the remote pilot.

13.7.3 Additional information may have to be displayed to the remote pilot to support efficient airfield operations between RPA and other aircraft. This information should include positional information with respect to airport features (e.g. runway centre line, aerodrome signs, marking and lighting). Information on the relative position and movement of other aircraft or surface vehicles is also essential. Annex 2 requires pilots to be able to recognize visual interception signals from other aircraft, such as intercept aircraft wing rocking, flashing lights or landing gear lowering; RPA will need to be able to obtain this information through visual or alternate means.

13.7.4 The remote pilot should be provided with the means to identify proximity to terrain and obstacles unless the approved use of autoflight systems and planned flight trajectories mitigates the risk from these hazards. The information could be provided by a moving map with terrain overlay enhanced with alerts indicating rapid descent rate and close proximity to the ground. Such systems are well established for manned aircraft and typically use standard digital elevation models for the terrain information. However, as the remote pilot is not on board the aircraft, the necessary information, e.g. horizontal position, barometric altitude, height above ground, would need to be downlinked to the RPS at a suitable rate for the situation to be displayed and alerts generated.

13.7.5 Pilots in manned aircraft, when operating under VFR, need to be able to recognize and assess the in-flight visibility and estimate horizontal and vertical distances from clouds. Meeting this same requirement for remote pilots is expected to necessitate new technology and appropriate displays if operating under VFR and BVLOS. It can be assumed that the data will be captured on the aircraft using suitable sensors and downlinked to the RPS. However, it is unlikely that a video downlink would be suitable. Processing on board should therefore be considered in order to minimize the volume of downlinked information.

Traffic display

13.7.6 The RPS should have the ability to display the location of all other traffic in the vicinity. In addition to the display, audible and visual alerts should be provided to warn the remote pilot of any significant traffic.

13.7.7 Human performance issues should be assessed to determine the optimum methods to support the remote pilot's requirement to RWC of traffic and avoid collisions. Remote pilots must be trained to interpret the display of traffic and all guidance and alerting required to DAA other aircraft.

Chapter 14

INTEGRATION OF RPAS OPERATIONS INTO ATM AND ATM PROCEDURES

14.1 OVERVIEW

14.1.1 This chapter provides guidance to States, ANSPs, regulatory authorities and industry regarding the safe introduction of RPAS operations into the air navigation system. The scope of this section will be limited to the following areas:

- a) the recommendation of best practices and procedures that can be used for the safe integration of RPAS, taking into consideration the current technological limitations;
- b) identification of current best practices for consideration by States and aviation standards organizations (e.g. RSOOs, RTCA, EUROCAE); and
- c) operations in non-segregated airspace, controlled and uncontrolled.

14.1.2 The following are not within the scope of this chapter:

- a) ground operations (see 15.4); and
- b) operations in segregated airspace.

14.2 INTEGRATION PRINCIPLES

14.2.1 The integration of RPA in non-segregated airspace will be a gradual process that builds upon technological advances and development of associated procedures. The process begins with limited access to airspace, and while some RPA may eventually be able to seamlessly integrate with manned flights, many may not.

14.2.2 When adding any new type of airspace user into the existing air navigation system, consideration must be given to minimizing risk to all airspace users. States and service providers under oversight should therefore apply safety management principles and analyses to the introduction of RPAS operations. These principles and analyses should reflect on-going developments in RPAS capabilities.

14.2.3 RPAS operations should conform to the existing airspace requirements. These airspace requirements include, but are not limited to, communication, navigation and surveillance requirements, separation from traffic and distances from clouds.

14.2.3.1 *Controlled airspace.* In order for RPA to be integrated into non-segregated controlled airspace, the RPA must be able to comply with existing ATM procedures. In the event that full compliance is not possible, new ATM procedures should be considered by the aviation authorities and/or ANSPs in consultation with the RPAS operator and representatives of other airspace user groups. Any new ATM procedures should be kept as consistent as possible with those for manned flights to minimize disruption of the ATM system.

14.2.3.2 *Uncontrolled airspace.* In order for RPA to be integrated into non-segregated uncontrolled airspace, the RPA will need to be able to interact with other airspace users, without impacting the safety or efficiency of existing flight operations.

Airspace requirements

14.2.4 The operational and equipage requirements of RPA will be governed, as per manned aviation, by the class of airspace in which they will be operating. Airspace class definitions are defined in Annex 11 — *Air Traffic Services*.

Take-off and landing phases

14.2.5 RPAS may be operated in either VMC or IMC, and the associated VFR and IFR restrictions applicable to manned aircraft will apply. These operations may also be conducted within VLOS or BVLOS depending on the capability of the RPAS involved. Of particular note is the requirement for the RPAS operator to be able to determine the meteorological conditions in which the RPA is operating during these phases, in order to ensure the RPA is indeed operating in accordance with applicable flight rules.

En-route phase

14.2.6 The operational, equipage and performance requirements imposed on the RPAS will again depend upon the class of airspace through which the RPA will be transiting and any additional requirements prescribed for the airspace or operation (e.g. RVSM, PBN, 8.33 KHz channel spacing capable radio equipment).

VFR

14.2.7 The remote pilot or RPAS operator must be able to assess the meteorological conditions throughout the flight. In the event the RPA, on a VFR flight, encounters IMC, appropriate action must be taken.

IFR

14.2.8 RPAS must be equipped with suitable instruments and with navigation equipment appropriate to the route to be flown.

Communication, navigation and surveillance (CNS)

14.2.9 Functionality and performance requirements for RPA should ideally be equivalent to those established for manned aircraft and appropriate to the airspace within which the RPA is operated and where ATS is being provided. The performance and equipage requirements will be determined by factors associated with the operating environment which may include classes of airspace, proximity to heavily populated areas, terrain, etc.

Transponder operations

14.2.10 RPA, in the majority of cases, will need to comply with existing transponder operating rules in the same way as manned aircraft and as required by the class of airspace within which they are operating. As with current manned operations; however, there may be circumstances that will call for a deviation from existing practices due to the context within which a particular RPA will be operating, such as low-level operations within areas where manned aircraft

are not operating. While it is impossible to identify all potential circumstances where this would be acceptable, these exceptions should be considered in the same way as a request from a manned aircraft to operate without a transponder.

RPAS unique procedures

14.2.11 The lost C2 link procedure, unique to RPAS, necessitates a specific approach with respect to transponder operation. A lost C2 link is not necessarily an emergency situation that would warrant setting the Mode A code to 7700 or the ADS-B emergency mode, however use of code 7600 or specific ADS-B emergency mode indicating voice communication failure may be equally inappropriate. A new non-discrete code may be warranted for use by RPA to indicate loss of the C2 link.

14.2.12 It is expected that RPA will use Mode A code 7700 or equivalent ADS-B emergency mode for those emergencies that are common to manned aircraft (e.g. engine failure), but consideration must also be given to those circumstances that are unique to RPA (e.g. flight termination). The procedures addressing coordination with ATC relating to transition from one code to another need to be clearly identified to ensure a common understanding and expectations of how the RPA will operate in a given situation.

14.3 FLIGHT RULES

Right-of-way

14.3.1 As with manned aircraft, RPA are obliged to comply with the Annex 2 right-of-way rules and RWC of other aircraft (manned or unmanned). They must avoid passing over, under or in front of other aircraft, unless it passes well clear and takes into account the effect of aircraft wake turbulence. Owing to the relatively small size and low conspicuity of some RPA, it may be difficult for pilots of manned aircraft and other remote pilots to visually acquire the RPA.

RPAS performance requirements

14.3.2 The performance characteristics of the RPAS will require additional consideration when planning their integration within the ATM system, as their performance characteristics will affect how ATS providers manage their integration with conventional traffic. For example, high-altitude, long-endurance (HALE) RPA that typically operate at lower speeds in climb to and descent from high flight levels, pass through levels at which manned aircraft are cruising at high speeds. This speed differential may pose separation challenges in a mixed environment.

14.3.3 Control instruction response times (e.g. the length of time between ATC issuing an instruction, the remote pilot complying with the instruction and the RPA responding to the inputs) may affect the controller's ability to support RPA operations if an inordinate amount of resources are allocated to a single aircraft. This can also be a result of other performance characteristics such as climb, descent or turn rate that may differ substantially from those of conventional aircraft. Thus, it will be essential that the ATCO be aware of and anticipate these potential underperformances and plan accordingly. Conventional instructions such as "expedite" and "immediate" may not be practical in many cases.

14.3.4 ATCO must have a general knowledge of RPA performance characteristics and be familiar with specific characteristics of RPA operating in the airspace. The following performance characteristics should be considered:

- a) speed;
- b) climb, descent or turn rates;

- c) wake turbulence;
- d) endurance;
- e) latency; and
- f) effect of bank angle on C2 and ATC communications link capability and reliability.

ATM procedures

14.3.5 The absence of an on-board pilot will necessitate some unique procedures in the integration of RPA into non-segregated airspace. To the greatest extent practicable, procedures should be identical to those developed for manned aircraft.

14.3.6 Some of the issues that will need to be addressed to integrate RPA flights include the following:

- a) flight planning:
 - 1) RPA type designators;
 - 2) phraseology (to be used with/by ATC);
- b) VFR flight:
 - 1) separation standards;
 - 2) right-of-way rules;
- c) IFR flight:
 - 1) separation standards;
 - 2) right-of-way rules;
- d) contingency and emergency procedures:
 - 1) C2 link failure;
 - 2) ATC communications failure with remote pilot; and
 - 3) intercept procedures/compliance with air defence.

Flight plan

14.3.7 RPAS operators will need to file flight plans in accordance with Annex 2.

14.3.8 Aircraft type designators will need to be established and documented in *Aircraft Type Designators* (Doc 8643). Until this is done, "ZZZZ" should be entered in item 9 of the flight plan form and the RPA type specified in item 18, as per Doc 4444, PANS-ATM.

14.3.9 Due to the limited capacity of the flight plan, ANSPs will need to consider how to convey to ATCOs and specialists responsible for the airspace in which the RPA is operating, unique information related to the flight, particularly regarding lost C2 link procedures.

Controller training

14.3.10 ATCOs need to adapt to emerging technologies and new regulations that affect both airspace and aircraft performance characteristics. The introduction of RPA into non-segregated airspace will require a comprehensive training programme that provides ATCOs with the necessary knowledge and tools to ensure the safe integration of RPA into the ATM system. This training should include the inherent differences between RPA and conventional manned aircraft, from performance characteristics to remote pilot communications and contingency/emergency procedures.

14.3.11 The following generic training outline provides areas of RPAS knowledge that should be considered and addressed in a comprehensive ATCO training programme:

- a) RPAS system information:
 - 1) terminology/phraseology;
 - 2) RPAS architecture: RPA, RPS, C2 link, ATC communications methods, remote pilot, RPA observer;
 - 3) RPA performance characteristics:
 - i) speed, climb, descent and turn rates;
 - ii) wake turbulence implications;
 - iii) operating altitudes;
 - iv) minimum line-of-sight altitude;
- b) operational characteristics:
 - 1) DAA capability;
 - 2) direct control, autopilot control versus waypoint control;
 - 3) VLOS versus BVLOS operation;
 - 4) RPS handover procedures (internal/external);
 - 5) transparency to ATC;
 - 6) remote pilot human performance capabilities related to ATC;
- c) concepts of operation;
- d) types of operation;
- e) operational specificities:

- 1) priorities;
 - 2) flight plan elements/filing;
 - 3) aerodrome procedures;
 - 4) taxiing;
 - 5) wingwalker concept;
 - 6) remote pilot control;
 - 7) launch/take-off;
 - 8) automatic take-off/landing systems;
 - 9) climb out/shuttle climb procedures;
 - 10) airspace transit procedures;
 - 11) recovery;
 - 12) circuit;
 - 13) landing;
- f) civil versus military operations;
- g) RPA-specific airspace/procedure requirements:
- 1) ability to accept visual separation clearances;
 - 2) general ATC procedures requirements;
 - 3) cross-border implications;
 - 4) separation standards and traffic information;
 - 5) conflict alert capability;
- h) communications:
- 1) C2 link;
 - 2) radiotelephony procedures;
 - 3) response times;
 - 4) RLOS versus satellite/relay (ground-based or airborne);
 - 5) ATC data link versus voice;
- i) contingency/emergency scenarios:

- 1) contingency operations;
- 2) power supply issues; and
- 3) emergency procedures.

14.4 ANSP SMS

14.4.1 ANSPs should use a safety management approach to determine how to integrate RPA within their airspace by including a hazard identification and risk management assessment associated with the types of operations anticipated. This might include the airspace design, volume and complexity of traffic, operating procedures, meteorological conditions, etc.

14.4.2 The following topics merit consideration by States and ANSPs in developing their respective RPA integration plans.

Traffic complexity

14.4.3 The operation of RPA within an airspace may increase the complexity of the traffic. If multiple RPA are in a particular area concurrently, the complexity may increase more significantly than the introduction of multiple manned aircraft. ANSPs should consider, on a case-by-case basis, whether the characteristics of the RPAS operation, including flight performance, communications methods, etc., can be supported without additional resources or procedures.

Latency of RPA response

14.4.4 RPA response times to control instructions issued by the ATCO may be longer than those of manned aircraft in the airspace. The effects of this should be assessed to determine whether ATCOs can plan and issue instructions in an acceptable timeframe to obtain the desired actions.

Conspicuity

14.4.5 Owing to the relatively small size and low conspicuity of some RPA, it may be difficult for ATCOs, pilots of manned aircraft and other remote pilots to acquire visual contact with the RPA. It may also be difficult to give conditional clearances or effectively pass traffic information to other airspace users with reference to the RPA. This may affect the number and type of clearances issued and subsequently the operational safety and efficiency of the airspace. ATS authorities and ANSPs should be mindful of this when granting permission for RPA operations to be integrated into non-segregated airspace. One of the factors to be considered will be the number and complexity of operations within the particular volume of airspace.

Non-standard method of communication

14.4.6 For small RPA, due to RLOS challenges, the remote pilot may need to communicate with ATC through means other than the published VHF/HF radio frequency (RF) for the airspace in which the RPA will be operating. Prior to approving use of a non-standard method of communication, the ANSP should assess the implications on the overall traffic situation for the airspace and on the ATCO's ability to effectively manage different methods of communication.

RPA sensitive to hazardous meteorological conditions

14.4.7 Small RPA may be more sensitive to hazardous meteorological conditions due to their low MTOM and, more specifically, the wing/power loading of the aircraft.

Acceptance by airspace users and ATCOs

14.4.8 There may be compatibility issues in terms of operating procedures and demands for airspace access between manned and unmanned aircraft operators. It is recommended that aviation community outreach programmes address this knowledge gap for ATCOs and airspace users to ensure mutual awareness of RPA performance characteristics and the types of operation they will be conducting, etc. RPAS operators will need to actively participate in these programmes to share information and contribute to the effective integration of RPA.

Chapter 15

USE OF AERODROMES

15.1 OVERVIEW

This chapter discusses issues related to integration of RPAS operations at aerodromes open to public use.

15.2 GENERAL

Integration of RPA into aerodrome operations will require the remote pilot to identify, in real-time, the physical layout of the aerodrome and associated equipment, such as aerodrome lighting and markings, so as to manoeuvre the aircraft safely and correctly, regardless of the location of the RPS. To achieve this goal, advances in technology and procedures will be required, e.g. surveillance, detection and other systems or methods, internal or external to the RPA, capable of providing sufficient awareness and resolution to allow the remote pilot to safely operate the RPA without causing undue disruption to other traffic.

15.3 ANNEX 14 AND APPLICATION OF AERODROME SPECIFICATIONS TO RPA

15.3.1 Annex 14 — *Aerodromes* sets forth the specifications for aerodromes and requires that States certify aerodromes used for international operations in accordance with the specifications contained in the Annex as well as other relevant ICAO provisions through an appropriate regulatory framework. Annex 14 also requires that States' regulatory framework include the establishment of criteria and procedures for certification and recommends that States certify aerodromes open to public use.

15.3.2 States will need to determine whether RPA can be safely integrated without presenting new hazards to, or placing new burdens on, manned aircraft. They will also need to evaluate the applicability of applying aerodrome specifications to RPA operations.

15.4 AERODROME INTEGRATION ISSUES

Several unique characteristics of RPA that may affect aerodrome operations and should be considered by States, aerodrome operators, RPAS operators and manufacturers include:

- a) the RPA's ability to detect aerodrome signs and markings;
- b) the RPA's ability to avoid collisions while manoeuvring;

- c) the RPA's ability to follow ATC instructions in the air or on the manoeuvring area (e.g. "follow green Cessna 172" or "cross behind the Air France A320");
- d) applicability of instrument approach minima to RPA operations;
- e) necessity of RPA observers at aerodromes to assist the remote pilot with CA requirements;
- f) implications for aerodrome certification requirements of RPA;
- g) infrastructure, such as approach aids, ground handling vehicles, landing aids, launch/recovery aids;
- h) rescue and fire-fighting requirements for RPA (and RPS, if applicable);
- h) integration of RPA with manned aircraft in the vicinity of, and on the movement area of, an aerodrome; and
- i) aerodrome implications for RPAS specific equipment.

15.5 CONTROLLED AERODROME ENVIRONMENT

15.5.1 For RPA integration into controlled aerodromes where ATC services are provided for safe, orderly and expeditious flow of aircraft and vehicular movement, the RPAS needs to have the ability to communicate and manoeuvre in a similar manner to manned aircraft.

15.5.2 Remote pilots operating at controlled aerodromes must maintain two-way communication with ATC and acknowledge and comply with ATC instructions in the air and on the surface. Remote pilots must be able to comply with all instructions during all phases of operations associated with aerodrome operations, e.g. take-off, approach and landing and manoeuvring on aprons, taxiways and runways.

15.5.3 RPA will need to be able to comply with airport markings, signage lighting and signals, and respond, as appropriate, to maintain safety as conditions on the aerodrome surface change. Avoidance of people, aircraft, vehicles, buildings and obstacles on or near the designated surface movement areas will be required as well as avoidance of restricted or other areas not intended for aircraft.

15.6 AERODROME FLIGHT INFORMATION SERVICE (AFIS)

15.6.1 For RPA integration into uncontrolled AFIS aerodromes used for international general aviation, the RPA should be able to operate in the same manner as manned aircraft. Remote pilots should be able to communicate with the AFIS officer in a timely and effective manner in order to pass and receive safety related traffic information. Requirements for remote pilots to identify and comply with airport markings and signage and to safely and efficiently manoeuvre among other aircraft and other airport users will be the same as the requirements for operations at controlled aerodromes. Additional information on AFIS aerodromes can be found in *Aerodrome Flight Information Service (AFIS)* (Cir 211).

RPA-only aerodromes

15.6.2 States may decide to establish aerodromes that would be open to RPAS operations only.

Aerodrome emergency response plan

15.6.3 Emergency response plans should be established at aerodromes, commensurate with the aircraft operations and other activities conducted at that aerodrome. The plan must provide for the coordination of actions to be taken in an emergency occurring both at the aerodrome and in its immediate vicinity.

Aerodrome operator safety management system

15.6.4 Aerodrome operator safety management systems may need to be amended to include additional requirements as a result of RPA operations at the aerodrome.

Appendix A

REQUEST FOR AUTHORIZATION FORM

Note.— For details on completing this form, and for definitions of acronyms and abbreviations, see section on Information Required for the Assessment of Authorization following this form.

| RPAS operator information | | |
|--|--|--|
| 1. Name of RPAS operator: _____ | | |
| 2. State of RPAS operator: _____ | | |
| 3. Mailing address: _____ _____ | | |
| 4. Contact numbers: tel.: _____ cell: _____ fax: _____ | | |
| 5. Email: _____ | | |
| 6. State of the RPAS operator, RPAS operator certificate number _____ <i>(attach copy of RPAS operator certificate).</i> Alternative documents <i>(attach copy)</i> . | | |
| RPAS information | | |
| 7. State of Registry and aircraft registration <i>(attach copies of certificate of registration and certificate of airworthiness)</i> . _____ Alternative airworthiness documents <i>(attach copy)</i> . | | |
| 8. Aircraft radio station licence number <i>(attach copy of aircraft radio station licence)</i> : _____ | | |
| 9. Noise certificate <i>(attach copy of certificate)</i> . | | |
| Remote pilot(s) and RPA observer(s) information | | |
| 10. Name: | 11. Type of licence or certificate and number <i>(attach copy of licences or certificates)</i> : | 12. Experience of remote pilot or RPA observer (detailed description): |
| a) | a) | a) |
| b) | b) | b) |
| c) | c) | c) |
| d) | d) | d) |

| | | |
|--|--|--|
| e) | e) | e) |
| f) | f) | f) |
| <p>RPA performance characteristics (including appropriate units of measurement) <i>(attach picture or sketch of RPA)</i></p> | | |
| <p>13. Type of aircraft: _____</p> | <p>14. Maximum take-off mass: _____</p> | <p>15. Wake turbulence category: _____</p> |
| <p>16. Number and type of engine(s): _____</p> | <p>17. RPA dimensions (wing span/ rotor diameter): _____</p> | <p>18. Maximum speed: _____</p> |
| <p>19. Minimum speed: _____ 20. Cruising speed: _____</p> | | |
| <p>21. Typical and maximum climb rates: _____ 22. Typical and maximum descent rates: _____</p> | | |
| <p>23. Typical and maximum turn rates: _____ 24. Maximum aircraft endurance: _____</p> | | |
| <p>25. Other relevant performance data or information to declare (maximum operating altitude): _____ _____</p> | | |
| <p>26. CNS capabilities (including alternate means of communication with remote pilot station(s)):</p> <p>Communications: CPDLC <input type="checkbox"/> VHF <input type="checkbox"/> UHF <input type="checkbox"/> SATCOM <input type="checkbox"/> HF <input type="checkbox"/> Telephone: landline <input type="checkbox"/> mobile phone <input type="checkbox"/></p> <p>Navigation: DME <input type="checkbox"/> VOR <input type="checkbox"/> GNSS <input type="checkbox"/> ADF <input type="checkbox"/> ILS <input type="checkbox"/> GBAS <input type="checkbox"/> RNAV _____ RNP _____ RVSM _____</p> <p>Surveillance: transponder mode(s): _____ ADS-B <input type="checkbox"/> ADS-C <input type="checkbox"/> ACAS <input type="checkbox"/></p> <p>Other: _____</p> | | |
| <p>27. Detect and avoid capabilities: _____</p> | | |
| <p>Operations</p> | | |
| <p>28. Purpose of operation: _____</p> | | |
| <p>29. Aircraft identification to be used in radiotelephony, if applicable: _____</p> | | |
| <p>30. Date of flight(s): _____ 31. Duration/frequency of flight(s): _____</p> | | |
| <p>32. Flight rules: I <input type="checkbox"/> V <input type="checkbox"/> Y <input type="checkbox"/> Z <input type="checkbox"/> 33. Type of operation: VLOS <input type="checkbox"/> BVLOS <input type="checkbox"/></p> | | |
| <p>34. Number and location(s) of remote pilot station(s): _____ _____</p> | | |
| <p>35. Handover procedures between remote pilot stations: _____</p> | | |
| <p>36. Point of departure: _____ 37. Point of destination: _____</p> | | |
| <p>39. Route: _____ 40. Cruising level: _____</p> | | |

41. Payload information/description: _____

Use of communication capabilities

42. ATS communications: _____

43. Command and control (C2) link: _____

44. Communications between remote pilot and RPA observer, if applicable: _____

45. Payload data link: _____

Contingency and emergency procedures

46. Loss of C2 link (partial or total): _____

47. Failure of ATC communications (partial or total): _____

48. Failure of remote pilot/RPA observer communications: _____

49. Other emergencies: _____

Security measures associated with the RPA operation

50. Physical security of remote pilot station(s): _____

51. Physical security of RPA while on the ground: _____

52. Security of C2 link: _____

Liability and insurance

53. Document number of insurance policy (*attach copy of liability and insurance document*): _____

54. Attachments:

- copy of certificate of registration (one for each RPA)
- copy of certificate of airworthiness (one for each RPA)
- copy of associated RPAS components certificate(s)
- copy of RPAS approval
- copy of RPAS operator certificate
- copy of aircraft radio station licence(s)
- copy of licence(s) or certificate(s) of remote pilot(s) and RPA observer(s)
- copy of all relevant operations specifications
- rendering or photographic depiction of RPA
- copy of RPA flight manual emergency procedures
- copy of liability insurance document(s)
- copy of RPA noise certificate
- other attachment(s)

55. **Signature of applicant:** _____

56. **Date:** _____

INFORMATION REQUIRED FOR THE ASSESSMENT OF AUTHORIZATION

(for completion of Request for Authorization Form)

RPAS operator information

- Item 1. Name of RPAS operator — indicate the name of a person, organization or enterprise engaged in, or offering to engage in, the RPAS operation.
- Item 2. State of RPAS operator — indicate the State in which the RPAS operator's principal place of business is located, or if there is no such place of business, the operator's permanent residence.
- Item 3. Mailing address — indicate the current contact mailing address of the operator.
- Item 4. Contact numbers — indicate the current telephone, cellular and fax number of the operator.
- Item 5. Email address — indicate the current email address of the operator.
- Item 6. State of the RPAS operator and RPAS operator certificate number — indicate the State of the RPAS operator and the number indicated on the RPAS operator certificate.

RPAS information

- Item 7. State of Registry and aircraft registration — indicate the name of the State on whose register the RPA is entered as well as the aircraft registration marks. Copies of the certificate of registration and certificate of airworthiness issued by the State must be attached. The specific titles of any alternative airworthiness documents must be indicated. These may include, for example, a temporary flight permit.
- Item 8. Aircraft radio station licence number — indicate the aircraft radio station licence number. If the remote pilot station(s) contains an aircraft radio station, indicate the appropriate licence number as well.
- Item 9. Noise certificate — indicate title and number of the document attesting noise certification of the RPA in accordance with the applicable Standards specified in Annex 16 — *Environmental Protection*, Volume I — *Aircraft Noise*, if applicable.

Remote pilot(s) and RPA observer(s) information

- Item 10. Name — indicate the name(s) of the remote pilot(s) who will operate the RPAS and of any RPA observer(s).
- Item 11. Type of licence or certificate and number — indicate the licences or certificates issued by the State for remote pilot(s) certifying their respective qualifications.
- Item 12. Experience of remote pilot or RPA observer (detailed description) — indicate the RPA or related experience (e.g. manned) of the remote pilot(s) and, if applicable, of the RPA observer(s).

RPA performance characteristics (including appropriate units of measurement)

Indicate the basic performance characteristics of the RPA using the relevant units of measurement specified by the State(s).

- Item 13. Type of aircraft — indicate the type of aircraft and attach a rendering or photographic depiction of the RPA.
- Item 14. Maximum take-off mass — indicate the maximum certificated take-off mass.
- Item 15. Wake turbulence category — indicate the appropriate wake turbulence category of the RPA, in accordance with *Aircraft Type Designators* (Doc 8643).
- Item 16. Number and type of engine(s) — indicate number and type of engine(s).
- Item 17. RPA dimensions (wing span/rotor diameter) — indicate the wingspan or main rotor diameter, or in the case of multicopter, indicate the maximum width.
- Item 18. Maximum speed — indicate the maximum operating speed of the RPA.
- Item 19. Minimum speed — indicate the minimum operating speed of the RPA.
- Item 20. Cruising speed — indicate the cruising speed of the RPA.
- Item 21. Typical and maximum climb rate — indicate the normal operational climb rate and maximum climb rate of the RPA.
- Item 22. Typical and maximum descent rate — indicate the normal operational descent rate and maximum descent rate of the RPA.
- Item 23. Typical and maximum turn rate — indicate the normal operational turn rate and maximum turn rate of the RPA.
- Item 24. Maximum aircraft endurance — indicate maximum endurance of the RPA.
- Item 25. Other relevant performance data or information to declare — include any other performance data needed by the approval authority or ATS unit.
- Item 26. CNS capabilities (including alternate means of communication with remote pilot station(s)). Mark the applicable boxes and indicate the equipment and capabilities of the RPAS. This item may include: communication and/or surveillance capabilities between the RPA and remote pilot station, between the RPA and ATS unit, between the remote pilot station and the ATS unit, and between the RPA observer and remote pilot. It also includes operational approvals for PBN, i.e. RNAV and RNP, and reduced vertical separation minimum (RVSM), if applicable.
- Item 27. Detect and avoid capabilities — describe the equipment, capabilities and any limitations.

Operations

- Item 28. Purpose of operation — indicate the reason(s) for conducting one, or a series of, RPA flight(s): e.g. aerial survey, meteorological survey, aerial photography, scientific experiment, cargo delivery.
- Item 29. Aircraft identification — indicate the call-sign to be used in radiotelephony.
- Item 30. Date of flight(s) — indicate the date(s) on which the flight(s) will occur.
- Item 31. Duration/frequency of flight(s) — indicate the duration of flight and also the number of flights that will be conducted within the date(s) of flight(s) indicated in Item 30.

- Item 32. Flight rules IFR/VFR — mark the relevant box to denote the category of flight rules with which the remote pilot intends to comply: I if IFR; V if VFR; Y if IFR first; Z if VFR first.
- Item 33. Type of operation VLOS/BVLOS — mark the relevant box.
- Item 34. Number and location(s) of remote pilot station(s) — indicate the number and location(s) of the remote pilot station(s).
- Item 35. Handover procedures between remote pilot stations — describe the handover procedures from one remote pilot station to another when more than one is involved.
- Item 36. Point of departure — indicate the name and the ICAO four-letter designator of the departure aerodrome. In the event the departure is not conducted from an aerodrome, coordinates, in accordance with WGS-84 format, of the specific location should be included.
- Item 37. Point of destination — indicate the name and the ICAO four-letter designator of the destination aerodrome. In the event that the destination is not an aerodrome, coordinates, in accordance with WGS-84 format, of the specific location should be included.
- Item 38. Take-off and landing requirements — describe how the RPA will take-off (e.g. vertical, rolling, catapult) and landing (e.g. vertical, rolling, parachute deployment, net). Additional information such as deployment of safety personnel during take-off and landing phases should be included.
- Item 39. Route — indicate the planned route of flight.
- Item 40. Cruising level — indicate the intended level(s) to be maintained during each segment of the flight.
- Item 41. Payload information/description — indicate any payload or equipment to be carried on the RPA. This includes equipment which is not flight essential but may be used for a specific purpose during the flight (e.g. photographic equipment).

Note.— The operation of some equipment or carriage of dangerous goods may be subject to special legislative requirements.

Use of communication capabilities

- Item 42. ATS communications — specify the intended methods of communication between air traffic services and the remote pilot, e.g. VHF voice, data link, telephone.
- Item 43. Command and control (C2) link — describe the type of data link to be utilized between the remotely piloted aircraft and the remote pilot station for the purposes of managing the flight.
- Item 44. Communications between remote pilot and RPA observer — specify the means of communication between the remote pilot and RPA observer, if applicable.
- Item 45. Payload data link — indicate specifications such as frequency and output power used for the data link between the remotely piloted aircraft and the remote pilot station (or payload station) for purposes other than those of managing the flight.

Contingency and emergency procedures

Item 46. Loss of C2 link (partial or total) — describe the intended procedures in the event of a loss of the C2 link such as automatic flight using preprogrammed routing, landing or activation of the flight termination plan.

Item 47. Failure of ATC communications (partial or total) — describe the intended procedures in the event of communications failure, such as use of telephone or other back-up procedures.

Item 48. Failure of remote pilot/RPA observer communications — describe the procedures in the event of a remote pilot/RPA observer communications failure, such as back-up communications possibilities or flight termination plan.

Item 49. Other emergencies — provide a copy of the emergency procedures contained in the RPA flight manual.

Security measures associated with the RPA operation

Item 50. Physical security of remote pilot station — indicate the measures and resources employed to ensure the safeguarding of the remote pilot station against unlawful interference during flight.

Item 51. Physical security of RPA while on the ground — if applicable, indicate the measures and resources employed to ensure the safeguarding of the remotely piloted aircraft (RPA) against unlawful interference while on the ground.

Item 52. Security of the C2 link — indicate the measures and technical procedures to protect the C2 link against unlawful or unintentional interference.

Liability and insurance

Item 53. Liability and insurance — indicate the insurance policy number and provide proof of adequate insurance/liability coverage.

Attachments

Item 54. Attachments — mark the applicable boxes and attach a copy of the relevant document(s). If including additional documents, mark the box “other attachment(s)”, describe them in the field provided and attach them to the Request for Authorization Form.

Acronyms and abbreviations

| | |
|--------|---|
| ACAS | airborne collision avoidance system |
| ADF | automatic direction finder |
| ADS-B | automatic dependent surveillance — broadcast |
| ADS-C | automatic dependent surveillance — contract |
| ATS | air traffic services |
| C2 | command and control |
| CNS | communication, navigation and surveillance |
| CPDLC | controller-pilot data link communications |
| DME | distance measuring equipment |
| GBAS | ground-based augmentation system |
| GNSS | global navigation satellite system |
| HF | high frequency |
| I | the entire flight will be operated under the IFR |
| IFR | instrument flight rules |
| ILS | instrument landing system |
| PBN | performance-based navigation |
| RNAV | area navigation |
| RNP | required navigation performance |
| RPA | remotely piloted aircraft |
| RPAS | remotely piloted aircraft system |
| RVSM | reduced vertical separation minimum |
| SATCOM | satellite communication |
| UHF | ultra high frequency |
| V | the entire flight will be operated under the VFR |
| VFR | visual flight rules |
| VHF | very high frequency |
| VOR | VHF omnidirectional radio range |
| Y | the flight initially will be operated under the IFR, followed by one or more subsequent changes of flight rules |
| Z | the flight initially will be operated under the VFR, followed by one or more subsequent changes of flight rules |

Appendix B

C2 LINK INFORMATION FLOW

C2 link information flow requirements include update rate and support of specific data types. The optional support of ATC voice/data relay is described in Chapter 12.

Examples of typical information flows are given in a) to c); the details are RPA/RPS specific. The precise list of parameters and their format are for the manufacturer/operator to define and agree with the competent authority.

a) uplink information flows (RPS to RPA):

- 1) aircraft and flight management control commands such as inputs to control surfaces and throttle(s); motion or flight status inputs into an FCC, and waypoint data into an FCC:
 - i) stick and throttle signals (if used or provided for reversionary operations);
 - ii) heading, altitude, speed, climb and descent rate inputs (if used);
 - iii) waypoint data;
 - iv) pressure altitude;
 - v) ATC RF changes (sector handover);
 - vi) SSR transponder code changes;
 - vii) detect and avoid (DAA) control parameters;

fuel and other aircraft system management required for the specific aircraft;

- 2) additionally, for long duration flights, updates of information may be required such as flight plan, navigation database, NOTAMS and meteorological information for alternate aerodromes or landing sites, RPS handover:
 - i) flight plan update;
 - ii) navigation database — updates in flight may be necessary for long duration flights;
 - iii) NOTAMS — updates in flight may be necessary for long duration flights;
 - iv) meteorological updates for alternate aerodromes;
 - v) RPS handover information, including aircraft status, could include flight plan and accepting RPS status (if the handover information exchange is conducted over the aircraft relay);
 - vi) when an airborne network is used, data are necessary to support its operation;

- b) downlink information flows (RPA to RPS):
- 1) information on flight status, including engine, navigation, C2 link, DAA, etc. With the lack of sensory information such as attitude and motion, attitude information is important. Requirements for communication transaction time and update rate should be assessed depending on categories of control;

Note.— Under VLOS operation, the high rate downlink may not be required.

- i) system status: data link(s), engine(s), fuel quantity/electric power, hydraulics, etc., as required, and if used, communication relay network status;
- 2) situational awareness:
- i) navigation status including position and sufficient information to allow RVSM and RNP status to be monitored, if applicable;
 - ii) DAA information sufficient to recognize and interpret:
 - a) aerodrome markings;
 - b) visual signals (interception);
 - c) terrain proximity;
 - d) severe meteorological conditions including turbulence, icing, etc.;
 - e) wake turbulence;
 - f) distance from cloud (to enable determination of flight conditions);
 - g) flight visibility (to enable determination of flight conditions), traffic awareness and, under VFR, “visual” separation, RWC and collision avoidance (CA).

Note.— The downlink of raw imaging sensor data is unlikely to be feasible due to bandwidth limitations. It is likely that sensor data will need to be processed on board before being transmitted to the remote pilot.

- 3) data recording:
- i) the specific requirements for data recording will depend on the classification of the RPA;
 - ii) the C2 link should support the downlink of all the parameters that will be required to be recorded on the ground, at the appropriate rate;
 - iii) some data will be required to be recorded on board the aircraft;
 - iv) as a result, a trade-off between data link bandwidth/on-board recording capacity and data availability in the event of C2 link loss/non-recoverable aircraft, needs to be undertaken;

-
- c) special information flows:
 - 1) specific information flows to support RPS handover including:
 - i) exchange of relevant documents (e.g. flight plans, RPAS operating manual, RPA flight manual, journey log book, maintenance log book(s));
 - ii) information exchanges between the two RPS and the RPA in order to manage the RPS handover;
 - 2) use of C2 link for applications not directly related to the control of the aircraft;
 - i) criteria need to be agreed for determining the acceptability and the potential amount of additional data that is acceptable on the C2 link;
 - 3) in order to ensure safe operation, the update rate of the information provided on the link should, as a minimum, be sufficient to support:
 - i) management of the flight including situational awareness;
 - ii) information to compensate for the loss of pilot sensory inputs (noise, vibration etc.), if required; and
 - iii) data recording and handover support.

— END —

