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Copyright Statement

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Abstract

This document represents deliverable D2.3 of the INVIRCAT project and is titled "Initial CONOPS 'RPAS in the TMA'". The deliverable describes the initial Concept of Operations (CONOPS) for the integration of Remotely Piloted Aircraft Systems (RPAS) into the existing Air Traffic Control (ATC) procedures and infrastructures within Terminal Manoeuvring Areas (TMA) and at airports under Instrument Flight Rules (IFR).

The document builds on D2.1 "Current State-of-the-Art and regulatory basis" and D2.2 "Use Cases Definition and Concept Outline". After validation through the Real Time Simulations (RTS) and assessment of the CONOPS by the project's Advisory Board, this deliverable will be the base for D2.4 "Final CONOPS 'RPAS in the TMA'".

Table of Contents

List of Tables

List of Figures

1 Executive Summary

This document represents deliverable D2.3 of the INVIRCAT project and is titled "Initial CONOPS 'RPAS in the TMA'".[1] The deliverable describes the initial Concept of Operations (CONOPS) for the integration of Remotely Piloted Aircraft Systems (RPAS) into the existing Air Traffic Control (ATC) procedures and infrastructures within Terminal Manoeuvring Areas (TMA) and at airports under Instrument Flight Rules (IFR).

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The CONOPS is composed of two main chapters, describing the system and subsystems in multiple levels in chapter 3 and the RPAS operations, including the environment and nominal and non-nominal operations in chapter 4 to provide a holistic picture what it takes to integrate RPAS in TMAs and civil airports. The project focusses on fixed wing RPAS of the traffic class VI, defined by EUROCONTROL [1] as capable of flying IFR and Standard Instrument Departures (SIDs) and Standard Arrival Routes (STARs).

The goal of the CONOPS is to provide a guideline for the integration of fixed wing RPAS of varying sizes and performances in medium to complex TMAs and airports, envisioning the potential use of RPAS for a widespread array of civil and military applications, exceeding the often-found limitation to MALE (Medium Altitude Long Endurance) and HALE (High Altitude Long Endurance) configurations. Therefore, the document aims to define a concept of operations that is applicable multiple RPAS operating simultaneously in a shared environment with manned aviation. In order to minimize the risk associated with remotely piloted aircraft (RPA) in the TMA, the CONOPS introduces the use of automatic take-off and landing (ATOL) systems including the inherit system and operational requirements.

[1] The opinions expressed herein reflect the author's view only. Under no circumstances shall the SESAR Joint Undertaking be responsible for any use that may be made of the information contained herein.

2 Introduction

2.1 Purpose and Structure of the Document

This deliverable describes the initial CONOPS for the integration of RPAS into the existing ATC procedures and infrastructures within TMAs and at airports under IFR.

This document is structured in the following chapters:

- Chapter 3 gives an overview of the RPAS subsystems as well as adaptations to Air Traffic Management (ATM) systems and the airport infrastructure to allow the integration of RPAS in the TMA and airport environment. In addition, different system architectures for command and control (C2) and communication links are described and the system interfaces are defined. The chapter is concluded by a short excursion how future U-space services could be useful for the RPAS integration.
- Chapter 4 sketches the envisaged operations of RPAS in the TMA and airport and is subdivided in four main chapters:
    - As an introduction in Chapter 4.1 the Types of Operations and Operating Environment are depicted, including descriptions of the Flight Area, Airspace, Taxiing, Take-Off, and Landing Areas. In addition, relevant ATC procedures are outlined.
    - In Chapter 4.2 the Roles and Stakeholders concerned with the operation of RPAS and their responsibilities are described.
    - Chapter 4.3 (Standard Operational Procedures) introduces all aspects concerning the nominal operations, starting from the pre-flight phase and including the description of envisaged flight operations and handover procedures.
    - Finally, Chapter 4.4 covers Non-nominal Operation and Emergency Operation with a description of accidents, incidents and mishaps to be reported, an operational risk assessment, and an outline of contingency and abnormal procedures.

The document is complemented by a Bibliography (Chapter 5) as well as a list of the used acronyms (Appendix A) and a Glossary of Terms (Appendix B). The final Appendix C is a useful conglomerate of additional considerations concerning the introduction of RPAS in both, civil and military environments, that exceed the operations in the TMA and airport.

The mindful reader will notice that some descriptions of systems and operations in this document are of relatively high level. These are either only outlined on purpose, to leave room for different technological options, or will be further defined in the proceedings of the INVIRCAT project (as e.g. D3.3 the Use Cases Simulation Plan) and find their way into later deliverables, as D2.4 the Final CONOPS, deliverable D4.1 which will compare strategies on IFR RPAS operations, and D4.2 the Final Operational and Technical Requirements Definition.

2.2 Scope of the Concept of Operations

This concept of operations aims to define adequate systems and operations for the full integration of RPAS in the Air Traffic Management of airspaces[2] A-C in TMAs and airports under IFR conditions.

It builds on research results of SESAR PJ10 Solution 5 as well as projects of the consortium partners and is aligned with the rules and guidelines of international associations as e.g. ICAO, JARUS, and EUROCAE. Besides the use of valuable input from an extensive Advisory Board, the concept is produced in close collaboration with the SESAR projects

- PJ13 ERICA, the lead SESAR project for IFR RPAS integration in airspace classes A-C,
- URClearED, which focusses on Remain Well Clear (RWC) functionalities for RPAS integration in Class D-G Airspace, and
- SAFELAND, which investigates operational procedures for the safe landing of single pilot planes in case of pilot incapacitation.

The CONOPS feeds the Aviation Systems Block Upgrades (ASBU) phase two outlined by EUROCONTROL [2] and addresses the integration aspects highlighted in the following table and described in more detail thereafter.

Table 1: Integration aspects to be addressed for IFR RPAS ATM integration in ASBU 2 [2]

Airspace access	**ATM impact assessment** Impact on pan European network operations **Minimum performance requirements for IFR operations in core area** **Communications, Navigation & Surveillance (CNS)** **Integrated aerodrome operations**
Comms C2 datalink	Integrity Availability **Continuity of service** **Lost link** **Latency** Spectrum requirements Satcom
Detect And Avoid (DAA)	Minimum requirements Conspicuousness issues Interoperability Ground-based solutions Link to possible manned solutions
Human factors	**Human machine interface** **Impact on ATC ops**

[2] Airspace classes as defined in ICAO's standard 2001. Annex 11 - Air Traffic Services.

	Mixed operations
SESAR compatibility	MAP ATM Master Plan requirements Trajectory management for Unmanned Aircraft Systems (UAS) Initial 4D operations SWIM
Contingency	**Development of transparent contingency procedures**
Security	Ground station Jamming GPS vulnerability Hijacking

Airspace Access

The overall approach of this CONOPS is to integrate RPAS into Air Traffic Management (ATM) with minimal impact on other airspace users, airports, and ATC. It expands current communication standards between (remote) pilot and ATC to RPAS specific contingency procedures, as described in D2.2, utilising existing navigation and surveillance technology. Through the projects' validation activities, it delivers valuable data for the establishment of performance requirements for IFR operations in the TMA for integrated aerodrome operations.

Comms C2 datalink

Whilst the integrity and availability of communication (comms) and command and control (C2) datalinks are important enablers for this CONOPS, their description is not part of its scope. Neither are spectrum requirements and satcom solutions, as the document focusses on operations and procedures, rather than technological aspects.

Lost link and latency are the major RPAS specific causes of contingencies that shape the concept of operations. The continuity of service plays a central role for the safety of RPAS during the switch between radio and satellite based C2- and communication links.

Detect and Avoid (DAA)

Although the detailed description of the functionality and operations of Detect and Avoid (DAA) systems are out of scope of the INVIRCAT project, results on interfaces and boundary conditions from research projects PJ13 (in particular solution 111) and URClearED are incorporated to the possible extent in this initial CONOPS.

Human Factors

This CONOPS describes procedures for the mixed operation of manned and unmanned aircraft in TMA and airports, thriving to minimize the impact on ATC and other airspace users. Therefore, the CONOPS and the validation activities in the project (WP3) result in recommendations for the human machine interfaces of both, ATC and remote pilots (RPIL).

SESAR compatibility

Whilst current developments within and outside of SESAR, that will shape the future of manned and unmanned aviation within the targeted time frame of the INVIRCAT CONOPS are considered, neither the mapping of ATM Master Plan requirements, nor the development of Unmanned Aircraft Systems (UAS) trajectory management, initial 4D operations, or SWIM are within the scope.

Contingency

The development of safe and transparent contingency procedures for RPAS in the TMA under IFR is one of the main goals of this document and the INVIRCAT project.

Security

Security aspects are not considered in the INVIRCAT project. While the listed vulnerable systems and potential security breaches may be the cause of an applied contingency procedure described in this CONOPS (see Chapter 4.4), neither the threats and shortcomings of systems nor the required technology for mitigation are considered in this scope.

Figure 1 displays the typical phases of flight of an aircraft. The INVIRCAT project focuses exclusively on IFR RPAS operations within the Terminal Manoeuvring Area (TMA) airspace surrounding airports. The corresponding phases of flight in the TMA are shown in green colour [3].

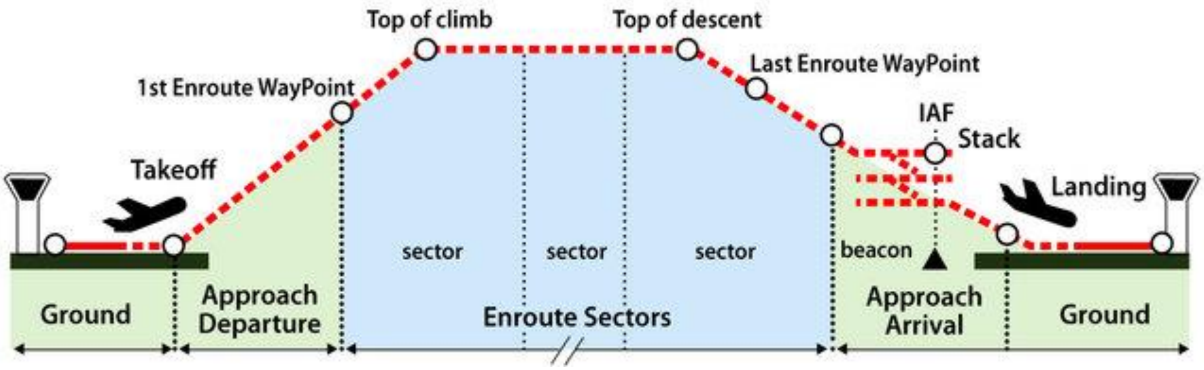


Figure 1: Aircraft Phases of Flight [4]

The phases of flight that occur within the TMA are:

- Ground
    - Taxi to/from runway/parking position
- Departure
    - Take-off
    - Climb-out via Standard Instrument Departure (SID)
- Arrival
    - Arrival via Standard Terminal Arrival Route (STAR)

- Holding

- Approach and Landing
  - Approach
  - Landing

To complement the scope of the project, ideas are introduced how RPAS flying IFR in airspaces A-C could benefit from emerging U-space services developed for the integration of small UAS in the air (chapter 3.7).

2.3 Key Assumptions and Considerations

This CONOPS describes operations of RPAS based on the definition of Unmanned Aircraft System (UAS) traffic class VI by EUROCONTROL [1], which implies certified operations of aircraft meeting the pan-European network performance requirements under IFR conditions. In addition, the CONOPS will exclusively focus on operations in airspace classes A-C in TMAs and airports. Specific assumptions regarding the RPAS and the RPIL are described below.

RPAS of UAS traffic class VI are assumed to be either manned transport aircraft enabled to fly unmanned with capabilities similar to the original aircraft type, or new types able to meet the set performance requirements for the network, TMA and airports [1] [2]. RPAS of UAS traffic class VI also need to

- be capable of flying IFR (in particular meet SID, STAR and holding requirements as designed for manned operations),
- meet the Communications, Navigation & Surveillance (CNS) airspace requirements,
- be able to establish two-way communication with ATC,
- remain separated to manned aircraft or be capable of self-separating in 3D,
- carry DAA equipment that is compatible with existing Airborne Collison Avoidance Systems (ACAS), and
- file a flight plan containing information on the type of the RPA, contingency procedure, planned operation (navigation, route, level etc.), and contact phone number.

In addition to the UAS traffic class VI requirements, this CONOPS assumes the RPAS to

- have a fixed-wing structure (or have comparable performance)[3],
- have an airworthiness certificate and, consequently, a type certificate,
- have a Command and Control (C2) link that might also be used for relaying voice communications (R/T) to ATC,

[3] This CONOPS does not focus on rotary wings/multirotor RPAS, as they do not typically fly SIDs and STARs, but does not exclude them, if their capabilities match the requirements that result from the CONOPS.

- have an Automatic Take-Off and Landing (ATOL) system operating assuring compliance with the same rules and procedures as the other airspace users without disruption of the current operations and without assistance of the RPIL based on visual aids, and
- be able to conduct taxi operations on their own power (besides pushback procedures) and without the support of ground vehicles (such as follow-me cars) to limit impact on throughput and capacity of the airport.

Following the ICAO Manual on RPAS, "it is foreseen that only one RPA may be controlled by an RPS at any given time" [5]. Additionally, this CONOPS assumes that an RPA is controlled by exactly one RPS at all times (except in the case of failure of the C2 link).

In accordance to EUROCONTROL's UAS traffic class VI [1] [2], the RPIL must be able to contact ATC (if required) in regard to special conditions such as data link loss, emergency, and controlled termination of flight. This CONOPS additionally assumes that the RPIL

- must be adequately trained and certified on IFR RPAS procedures,
- must refrain from using visual aids for flight-critical operations (opposed to mission-specific applications),
- must always fly under IFR, and therefore should not request, accept or perform any visual in-flight procedures, including take-off and landing procedures with the ATOL system, and
- is always monitoring (except in the case of failure of the C2 link) and is responsible for the highly automated, but not autonomous, RPAS.

This CONOPS aims to have as little impact to current ATC operations as possible. Additional assumptions are that ATC

- must also be able to contact the RPIL (if required) in regard to special conditions, and
- must be adequately trained in IFR RPAS procedures.

Notes:

1. This CONOPS does not draw requirements or assumptions on the number of flight crew that are necessary to control an IFR RPA in non-segregated airspace. Whenever it is used, the term remote pilot (RPIL) is to be understood in a generic way.

2. Usage of visual aids by the RPIL in flight-critical situations is refrained from to avoid pilot-induced oscillation (PIO) effects. Latency in the video signal, possibly even varying in severity, may have unwanted effects during visual segments.

3. Visual aids may be used by the RPIL for non-critical flight procedures, e.g. ground movement.

4. The ATOL capability is deemed essential for safe integration of RPAS into non-segregated areas considering non-normal situations such as the loss of the data-link used by the RPIL to control the RPA. Taking [6] as reference, the ATOL concept addressed in this CONOPS is specific to take-off, initial climb, approach, and landing operations that certified fixed-wing RPAS perform in terminal areas under IFR without visual assistance of the RPIL.

5. The use of a potentially available CPDLC is explicitly not assumed to be mandatory for transfer of critical in-flight parameters in the TMA due to lack of responsiveness and message size.

2.4 Relationship to Other Documents

This deliverable is based on the documents D2.1 'State of the Art', which identifies all relevant aspects involved in the RPAS operations and D2.2 'Use Cases Definition and Concept Outline', which provides a brief introduction to the CONOPS and describes in great detail the use cases of IFR RPAS in the TMA.

The CONOPS presented in this document will be validated against the goals outlined in D3.1 'Validation Plan' and the detailed test scenarios in D3.3 'Use Case Simulation Plan'. Together with the validation results described in D3.4 'Exploratory Research Validation Report' the present document will then feed the deliverable D2.4 'Final CONOPS "RPAS in the TMA"', as well as the deliverables D4.1 to D4.3 which will elaborate on alternative means of infrastructure and procedure implementations (D4.1), operational and technical requirements (D4.2), and impacts and recommendations for the integration of RPAS in TMA environments and airports (D4.3).

3 System Description

3.1 RPAS Aircraft Segment

The Remotely Piloted Aircraft (RPA) is the actual airborne vehicle of the RPAS. There is a wide array of types of RPA, some of them mimic conventional aircraft, particularly where RPA may be used in traditional manned operations, but, because the pilot is no longer situated within the aircraft, the opportunities in design are wide; new possibilities in airframes, powerplants, fuels, and materials can result in dramatically different flight characteristics from conventional aircraft, most notably extreme flight endurances, very high altitudes, and slow flight [7].

As already stated in section 2.3, within the RPAS classification proposed in [1], this CONOPS will exclusively consider IFR RPAS belonging to UAS traffic class VI, shown in Table 2.

Table 2: RPAS classification - Class VI [2]

	CLASS	EASA MAPPING	TRAFFIC TYPE	AIRSPACE	OPERATIONS	PURPOSE	SPECIFICITY
IFR/VFR	VI	Certified Operations	UAS meeting pan-European network performance requirements	From 500 FT AGL up to FL600, including aerodromes	IFR/ VFR According to airspace classes requirements Operating in the pan-European network, including SIDs and STARs	Any	- UAS operating in the environment will file a flight plan including information such as type of UAS, planned Contingency procedure and a contact phone number - UAS will meet CNS airspace requirements - UAS will be able to establish two-way communication with ATC - UAS operator must be able to contact ATC (if required) in regard to special conditions such as data link loss, emergency or controlled termination of flight - UAS D&A capability will be compatible with existing ACAS systems

In order to comply to class VI, and also to obtain airworthiness certification, an RPA, together with the rest of the components of the RPAS, have to fulfil the same performance requirements as any other manned aircraft flying in the same airspace. If an airspace requires a particular area navigation (RNAV) capability, the RPAS will also have to fulfil this capability. Additionally, the RPAS does not only have to be able to fly SIDs and STARs, but also comply with ATCO radar vectors.

This also applies to take-off and landing and this means that also the ATOL system, together with any other automatic functionality, needs to perform according to the regulation of the airspace where it will be used.

Indeed, ICAO specifies in [7] that traffic class VI actually includes either manned transport aircraft enabled to fly unmanned with similar capabilities or new aircraft types able to meet the performance requirements set for the network, TMA and airports. These same considerations also apply for communications, navigations and surveillance (CNS) and DAA capability.

In an RPA, DAA replaces the Sense And Avoid (SAA) capabilities of manned aircraft. This CONOPS will exclusively consider airspace where ATC is responsible for separation. In these areas procedures already exist to maintain safe separation and so the same have to be respected by the RPIL. More generally, the remain-well-clear capability of an RPA must be compatible with the Air Traffic Service (ATS).

This CONOPS will comply with [6] considering RPA ATOL functions. Under nominal conditions, ATOL functions will be automatically executed by the RPA based on high-level commands received from the Decision Maker (DM). The term DM could refer indistinctly to RPIL, for manually triggered actions, or to an RPA internal function in charge of supporting the RPIL or taking decisions in contingency situations.

The ATOL function shall automatically perform operations executed by on-board pilots in manned aviation during take-off, initial climb, approach and landing and missed approach flight phases, in nominal and in some contingency situations. Moreover, the ATOL capability shall perform automatically these actions:

- Monitor ATOL occurrences
- Report ATOL status to the DM
- Alert the DM in case of contingency
- Acquire contingency procedure commands by the DM.

To enable 0 m Decision Height (DH) for IFR landing without assistance of the RPIL based on visual aid, both the RPAS, together with the airport in some cases, shall be equipped to do so. Different technologies, involving both RPAS and airport, allow this kind of precision approach and thus can be considered:

- GLS (Landing Systems using GNSS, Global Navigation Satellite Systems)
    - GAST (Ground Based Augmentation System - Approach Service Type)
    - Multi-constellation solutions
- ILS (Instrument Landing System using radio navigation)
    - CAT III

To exploit these technologies RPA will need to be adequately equipped with a proper GNSS system to receive the VHF correction information for GAST [8], or two ILS receivers, a radio altimeter, an auto throttle, a failure warning system etc. for ILS [9]. GLS solutions will probably replace ILS completely in next future thanks to the lower costs.

It is worth to be specified that visual aid, electro-optical or infrared, might be used by ATOL system itself, alone or together with other sensors e.g. laser altimeters etc., to land without 0 m DH precision approach equipment at the airport and that assistance of the RPIL based on visual aid is refrained from to avoid PIO effects caused by latency in the video signal.

The basic performance characteristics of some common IFR RPAS models are listed in Table 3 below. Apart from their extremely high endurance, Table 3 indicates that the performance of IFR RPAS are comparable to those of manned general aviation aircraft models. Additionally, the performance of a Boeing 737 is included as an example of a manned aircraft that could be configured to be piloted remotely.

Table 3: Performance Characteristics of a Range of IFR RPAS Models (Source: Wikipedia)

Parameter	General Atomics MQ9A	IAI Heron	IAI Eitan (Heron TP)	Thales Watchkeeper WK450	BAE Systems Mantis	Euro MALE	Boeing 737-800 (optionally piloted)
Cruise Speed	169 kts	-	-	70 kts	200 kts	270 kts	455 kts
Max. Speed	260 kts	112 kts	220 kts	95 kts	300 kts	-	546 kts
Range	1,900 km	-	4,700 km	300 km	-	-	5436 km
Endurance	14 hours	52 hours	30+ hours	20 hours	30 hours	-	-
MTOW	4,763 kg	1,150 kg	5,400 kg	450 kg	9,000 kg	11,000 kg	79,016 kg
Ceiling	FL500	FL330	FL460	FL180	-	FL450	FL410
Powerplant	1 × Honeywell TPE331-10 turboprop, 900 hp	1 × Rotax 914 piston engine, 115 hp	1 × Pratt & Whitney Canada PT6-67A 1,200 hp	-	2 × Rolls-Royce M250B-17 turboprop, 380 hp each	2 x turboprop (unknown type)	2 x CFM56-7B24/26/27

3.2 RPAS Ground Segment

The Ground Control Station (GCS), or Remote Pilot Station (RPS), consists of all systems used to control and monitor the flight of the RPAS [7]. Various setups are currently being used. Single or multiple monitors and consoles are possible as well as different input systems and control devices. Designs range from traditional cockpit setups (displays, side sticks and throttle levers) to abstract designs in a control room setup. There can be multiple stations at different locations that are able to control multiple RPAS. However, a single RPA can only be controlled by a single RPS at a given time.

EUROCAE's MASPS for RPS with the focus on RPAS integration in controlled airspace in ED-272 [6] describes three subsystems for the Human Machine Interface (HMI) in the system architecture of the RPS: Critical C2 HMI, non-critical C2 HMI, and Voice Intercom HMI.

Critical components, dedicated to flight functions and monitoring of RPAS flight systems, are expected to be avionics-grade equipment. In general, the functions of the critical C2 HMI can be divided into two subcategories:

1) The monitoring segment: This segment comprises all functions required to monitor the RPAS. This includes the indication of aircraft data (position, attitude, air data) as well as the display of the system status of various sub-systems. It also includes the display of intended manoeuvres (flight trajectory, waypoints).

2) The command and control segment: This segment includes all functions that are required to command and control the RPA. Here, also different design levels are possible with the changing degrees of automation. Functions can range from direct control over the control surfaces (aileron, elevator and rudder) or inputs to the autopilot only (setting of flight levels, airspeed and waypoints). This segment also includes feedback regarding the execution of the transmitted commands.

Non-critical components, e.g. used for specific mission functions or flight planning, are expected to be standard IT equipment. For the use in critical components, data generated in non-critical components might need to be validated.

The voice intercom HMI is expected to provide hardware and functions to communicate with other actors (e.g. ATC), with the option to mute/unmute or push-to-talk.

This CONOPS will comply with [6] considering RPS ATOL functions as ground functions supporting the remote crew to track the RPA and to monitor, control and override the ATOL airborne functions. Specifically, the RPS ATOL system shall perform these actions:

- Provide the RPIL with control to start and stop the execution of the automatic tasks
- Allow the RPIL to react to ATC instruction
- Allow the RPIL to manually activate and manage the execution of
    - Contingency procedures
    - Holding procedure/ resume approach
- Provide the RPIL with situation awareness to
    - Monitor the status of the ATOL
    - Monitor the correct execution of the automatic task
    - Detect ATOL occurrences

When using multiple and distributed RPS setups for different flight segments, the transfer of control and the indication of the current control status is the most prominent aspect to be considered. Additionally, security aspects need to be considered (ranging from physical access to cyber-security).

Note: This CONOPS does not consider the payload of the RPAS, if it is not required for the execution of the flight. Special ground station equipment might be required to control the payload and to fulfil the mission of the RPAS. Those systems are not considered here.

3.3 Air Traffic Controller Working Position

The Controller Working Position (CWP) consists of many systems including the radar display and communications systems used by the ATCO to attain situational awareness of the traffic situation and to relay voice communications to and from pilots. The design of CWPs depend on many factors and various different are currently used based on the specific needs of each ANSP.

In regards to RPAS operations, CWPs should enable the following functions in order to increase ATCO situational awareness of RPAS operations:

- Be able to highlight a change in the RPAS squawk code to 7400 to indicate a failure of the RPAS C2 link. 7400 is the C2 lost link squawk code adopted by ICAO [5].
- Display the RPAS using a dedicated aircraft symbol or callsign on the CWP [10]. Based on the type of CWP used by each ANSP, a different symbol and/or colour can be used for an RPAS [10].

3.4 RPAS C2 Data Link

This section provides a detailed description of the Command and Control (C2) link for RPAS operations in the TMA.

3.4.1 C2 Link Terminology

Figure 2 shows a summary of the terminology related to the C2 link. Here it can be seen that the C2 link is sometimes referred to as the Control and Non-Payload Communications (CNPC) link.

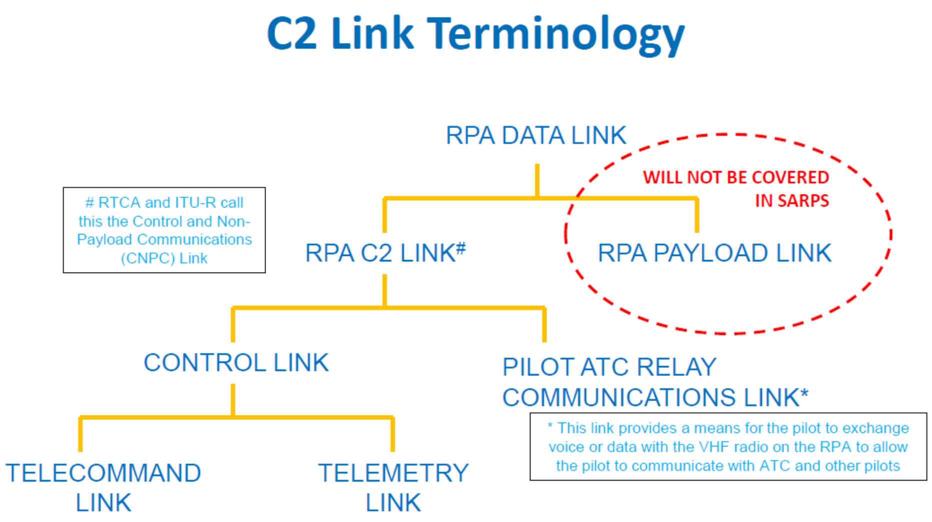


Figure 2: Terminology for C2 link [11]

3.4.2 Functions

The C2 link wirelessly connects the RPS to the RPA. It can be decomposed into separate uplink and downlink components. The C2 link has the following primary functions:

Control functions:

- Makes it possible for the RPIL to modify the behaviour of the RPA (uplink)
    - Inputs to the RPA flight control system
    - Controls the settings of onboard avionics (transponder, ADS-B etc.)
    - Supports RPA/RPS handover and flight data recording
- Enables the RPA to indicate its state to the RPIL (downlink)
    - RPA health and state (latitude, longitude, altitude, airspeed, bank, pitch, yaw, engine settings, system health/warnings etc.)
    - Supports RPA/RPS handover and flight data recording

Communication functions (uplink and downlink):

- Enables voice/data communications between RPIL and ATC (and other pilots)
- Voice may be relayed via the RPA or via other means

Figure 3 below summarizes the data flows facilitated by the C2 link. Note that Figure 3 also indicates other information flows that involve the RPA. Furthermore, it should be noted that the C2 link is not used to downlink payload data from the RPA to the RPS. Payload communications are done via a separate datalink – the payload link will not be considered in the scope of this CONOPS.

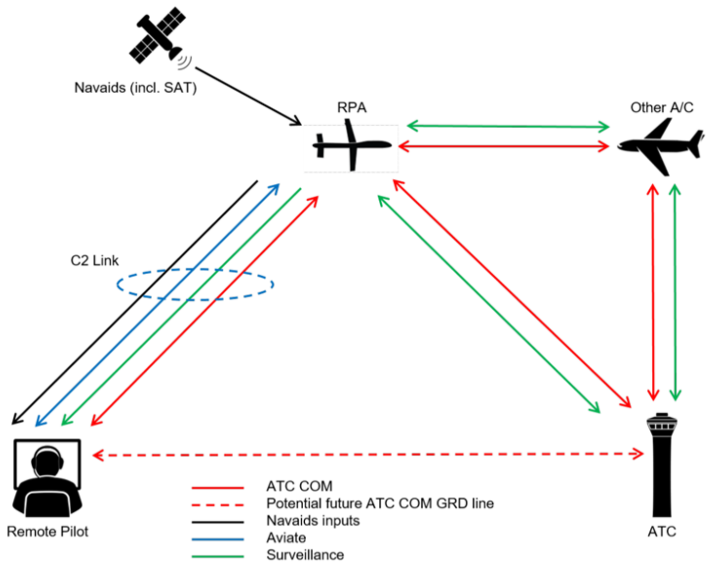


Figure 3: Data flows facilitated by the C2 link between the RPS and the RPA [7]

3.4.3 Architecture

Different architectures are possible for the control and communication functions of the C2 link.

3.4.3.1 Control Architecture

There are two distinct architectures possible to enable the control functions of the C2 link, namely Radio Line of Sight (RLOS) and Beyond Radio Line of Sight (BRLOS) [5]:

- 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 terrestrial network, provided that the remote transmitter has a RLOS connection to the RPA and transmissions are completed with negligible signal delay/latency.
- 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. Latency is higher during BRLOS than during RLOS.

The RLOS and BRLOS control architectures are more explicitly depicted in Figure 4 below.

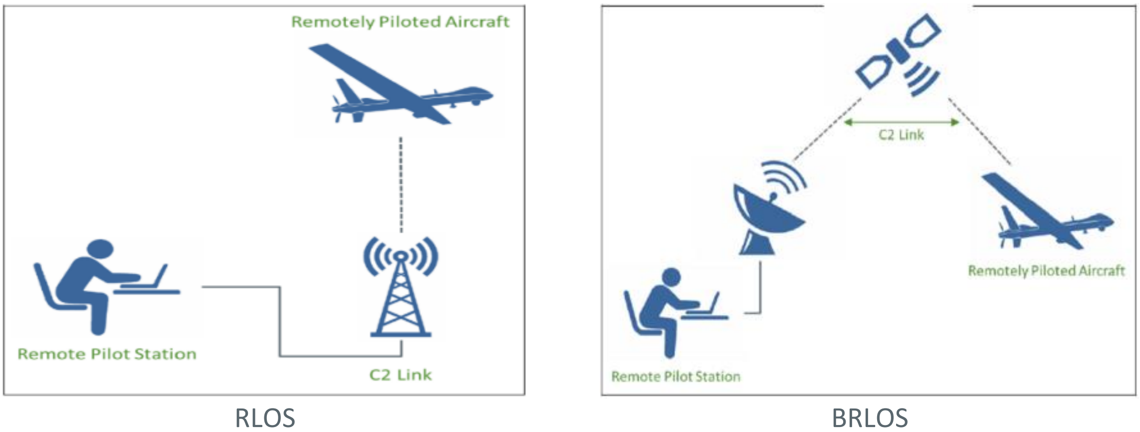


Figure 4: RLOS and BRLOS control architectures for the C2 link [5]

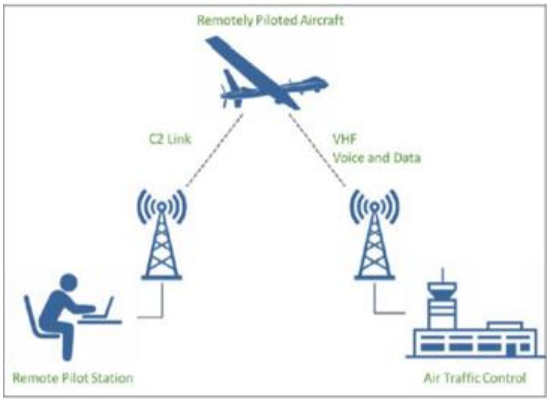
Because of the lower latency, RLOS should be used for take-off and landing if possible, even if BRLOS is used for en-route operations. Nonetheless, it should be noted that all flight phases can be controlled via BRLOS if necessary.

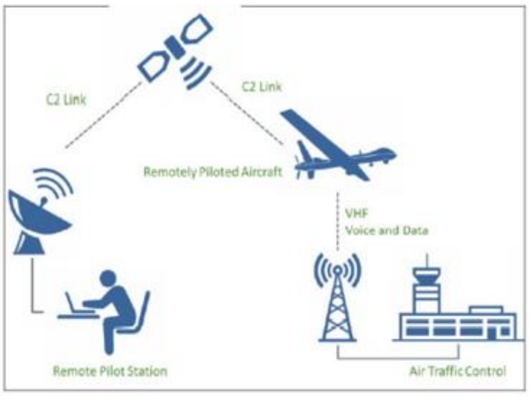
3.4.3.2 Communications Architecture

To facilitate the communication functions of the C2 link, there are two main possibilities: relay via the RPA and relay without the RPA.

Communications relay via the RPA

Standard Very High Frequency (VHF) ATC equipment on the RPA can be used to relay R/T between the RPIL and ATC. This can be done via RLOS relay or BRLOS relay; see Figure 5. According to ICAO, when BRLOS is used for communications, an additional one-way latency of approx. 0.5 seconds can be expected [11]. While no significant changes to ATC procedures are expected for RLOS operations, the latency experienced during BRLOS can potentially affect operations. Latency is described in more detail in section 3.4.4.3.





RLOS BRLOS

Figure 5: RLOS and BRLOS communications architectures for the C2 link [5]

Communications relay without the RPA

It is also possible for voice communications to be performed using a direct connection between the RPS and ATC, i.e., without involving the RPA. This can be done in two ways. The first option involves using standard VHF ATC equipment to link the RPS with ATC; see Figure 6. This option has limited range.

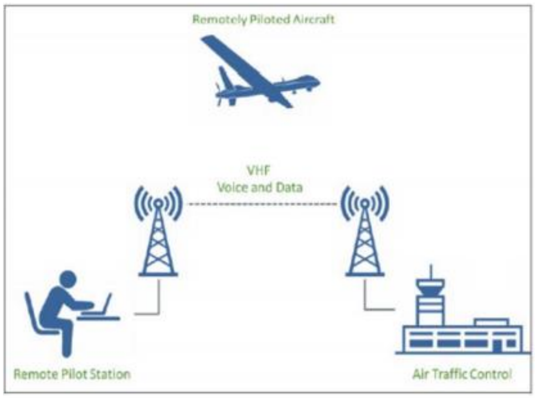


Figure 6: VHF radio to VHF radio for communications between RPS and ATC [5]

The second option uses a wired ground-ground link between the RPS and ATC; see Figure 7. This option has the lowest latency and the highest reliability when compared to all options that are based on radio connections, but requires a new network to be created between the RPS and ATC. Because of its high reliability, wired connections are often recommended as a backup means for voice communications between the RPIL and ATC if the R/T equipment on the RPS or RPA experiences a failure.

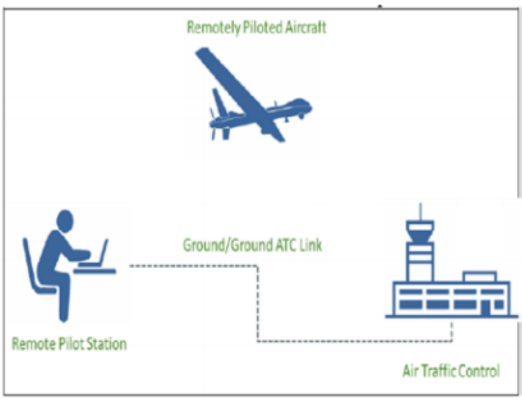


Figure 7: Wired ground communications between RPS and ATC [5]

As a final note, all the communications architectures mentioned above should ensure a so called "party line" to other pilots connected to the same ATC centre. This is essential for the situational awareness of the RPILs, other pilots and ATCOs. If a particular architecture does not directly provide a party line, one potential solution is to deploy a multi-link system that combines all voice sources in a seamless manner. The development of such a multi-link system is part of the focus of the SESAR PJ 14 EECNS (Essential and Efficient Communication, Navigation and Surveillance Integrated System) project.

3.4.4 Performance and Characteristics

3.4.4.1 Performance Requirements

C2 link performance requirements need to be adequate to not only allow the RPIL to safely fly the RPA but to also support other airspace performance requirements, such as Required Communication Performance (RCP) and Performance Based Navigation (PBN), which are agreed upon performance specifications on a global basis. States or ANSPs (Air Navigation Service Providers) use these specifications in designated airspaces to support operational requirements and separation standards. To access the airspace, operators must ensure their RPAS C2 link has been designed and operates in accordance with these performance specifications. The C2 link must have adequate performance to support the services it carries RCP (voice/data, if relayed through the RPA), RNP (navigation), RSP (surveillance), Detect and Avoid and Collision Avoidance. Data rates are not expected to be high (< 50 kbps) [11]:

- Low data rates make higher performance C2 links easier to achieve.
- There is not enough spectrum for every aircraft to use high data rate situational awareness enhancing video.

Some operational aspects to consider are that RLOS links suffer from large signal fades especially when the RPA is close to the ground. BRLOS (satellite links) can suffer from weather related signal fading and signal path obstruction by the RPA airframe can cause signal fading. Mitigations to combat these problems are the use multiple antennas on the RPA, and on the ground, frequency diversity and the use of multiple C2 links.

JARUS proposed the creation of the Required (C2) Link Performance concept (RLP), a concept similar to the RCP, but adapted to the RPAS C2 link communications [12]. The RLP assesses operational communication transactions in the context of a RPAS C2 function, taking into account human interactions, system design, procedures and environmental characteristics [12]:

- The contribution of the human can be significant to RLP. Communication is the accurate transfer between sender and receiver of information which can be readily understood by both.
- In some cases, C2 information might be exchanged between the RPA and the RPS systems without a human in the loop (for example internal systems parameter monitoring involving a threshold).
- An operational communication transaction is the process a human or a system initiator uses to send C2 information, and is completed when it is verified that the message was received, interpreted correctly and any action required as a result of that interpretation is correctly completed.
- Because of the numerous variants in the design of a RPAS C2 system, including different levels of automation, message transmission protocols and control mode classes, the RLP is designed to:

    - allow the same level of integrity of the C2 transactions for a given function, or group of functions, regardless of realization of the RPAS C2 system.
    - support the RPAS operator in contracting a communication service for RPAS C2 functions in a standardized way.

- The RLP is designed in order that the RPAS C2 link meets the performance or safety requirements and criteria of that airspace / operational context and needs to take into account the design of each C2 system. The RLP cannot be prescribed as an operational parameter only.

The RLP concept sets allocations on the performance required for communication capabilities without reference to any specific technology, making it open to new technologies. The C2 link performance parameters (non-functional requirements) are [12]:

- Communication transaction time: The maximum time for the completion of the operational communication transaction after which the initiator should revert to an alternative procedure;
- Continuity: The probability that an operational communication transaction can be completed within the communication transaction time;
- Availability: The probability that an operational communication transaction can be initiated when needed; and
- Integrity: The probability of one or more undetected errors in a completed communication transaction.

Table 4 shows C2 link RLP types envisaged for general application. When a state decides to prescribe a certain RLP, several factors shall be taken into account, such as the safety level required in the airspace and the type of operation that will be carried out. As can be seen in this table, envisioned failure rates of the C2 link are in the order of 10^{-4} - 10^{-5} failures per flight hour [13].

Table 4: Examples of RLP types (informative figures) [12]

RLP type	Transaction time (sec)	Continuity	Availability	Integrity (Acceptable rate per hour)
RLP A	3	0.999	0.9999	10^{-5}
RLP B	5	0.999	0.999	10^{-4}
…	15	0.999	0.999	10^{-4}

3.4.4.2 C2 Link Redundancy

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

- Cold standby: One link is working and is carrying all the message traffic, while 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.
- Hot standby: Both links are powered and connected and immediately available, although only one is being used to transfer C2 link data at any one time (the standby may be transferring low-rate data to keep the link immediately ready to take over).
- Dual operation: 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.

When a failure of the primary link in a dual redundant C2 link implementation occurs, this should cause the secondary link to take over. The RPIL should be provided with suitable status indications of the availability and functioning of the primary and secondary C2 links [5].

3.4.4.3 Latency

As explained above, different architectures can be used for the control and communications functionalities of the C2 link. As such, the latencies associated with the C2 link can be different for its control and communications functionalities, i.e., it is possible that the control latency is greater than the communication latency, and vice versa. Furthermore, it is important to note that the end-to-end control and voice communication latency not only depend on the distance a signal has to travel from sender to receiver (and therefore the current position of the RPA), but also on the system electronics and the processing of the transferred data, as encryption, compression, error correction, and computation [14]. Therefore, the occurring latencies are largely varying.

The following values in Table 5 and Table 6 are rough estimations for the maximum expected latencies in the TMA based on TNO Defence, Security and Safety [14], RTCA DO-377 [15], EURCOAE ED-137/1C [16], project SINUE [17] and ITU-T G.114 [18]. These numbers apply to RPS in sufficient proximity to the TMA to allow an RLOS link to the RPA flying in the TMA, or intra-regional distances between RPS and RPA (resulting in a single-hop connection for SATCOM).

Table 5: Expected maximum C2 link latencies (roundtrip) for the integration of RPAS in the TMA

RLOS Figure 4	SATCOM Figure 4	RLOS via relay Figure 7
1s	2s	1.5s

Table 6: Expected maximum voice communication latencies (one way) for the integration of RPAS in the TMA

RLOS Figure 5	SATCOM Figure 5	Ground network Figure 7
290ms	700ms	150ms

From the above tables, it is clear that architectures that use RLOS or ground network do not result in significant latencies in the TMA. On the other hand, BRLOS operations can lead to perceptible latencies for ATC. This is because with BRLOS operations, each message needs to be relayed to the RPA via communications satellites in geostationary orbit, i.e. at an altitude of approx. 36,000 km (see Figure 8). This latency can have a disruptive effect on ATC operations as the RPA may be slower to respond to ATCO commands compared to other traffic. This may force the ATCO to increase separation margins, and thereby reduce TMA/airport/runway capacity.

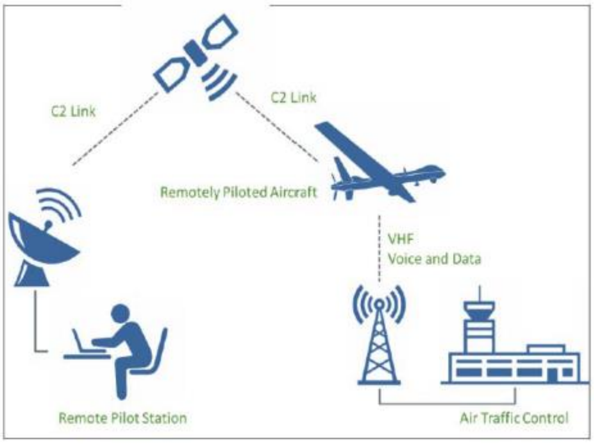


Figure 8: BRLOS architecture for the C2 link can lead to perceptible latencies that affect ATC operations at airports/in a TMA [5]

3.5 Airport Infrastructure

This section describes relevant airport infrastructure for IFR RPAS operations. Please refer to Appendix C.2 for additional airport aspects and lessons learned from military operations.

In general, large RPAS require the use of runways and taxiways and operate in a manner similar to manned aircraft. They require ramp space and hangar space, and fly in the same airspace. Unlike manned aircraft, RPAS need an RPS from which the pilot communicates with and flies the aircraft.

Basically, there are two types of airports, those who are already used by manned aviation and those who are solely designed to serve RPAS operations. The latter have already been developed around the world, serving the military at various locations for various purposes. This type of airports will not be addressed here. The focus will be on airports already used for manned aviation, where RPAS operations need to be integrated, addressing (mainly) towered large international airports.

Ongoing financial, environmental and political adjustments have shifted the role of large international airports. Many airports are expanding from a narrow concentration on operating as transportation centres to becoming regional economic hubs. Consequently, the evolving dissemination of RPAS into airport infrastructure addresses not only operational and technical aspects but should involve economic and scientific involvement from the start. Many types of physical infrastructure need to be in place to enable airports to meet these new dual roles of transportation hub and regional economic facilitator. These hard or economic infrastructures include large scale installations that connect and service commercial, industrial, residential, and cultural nodes of the region. Typical elements are roads, railways, utilities, ports, airports, freight and service interchanges, and of increasing importance, information and communication technology (ICT) – collectively, these provide the basis around which development is clustered and connected. Hard infrastructure provides the traditional network connectivity between the airport and the surrounding region.

There are two overarching considerations when developing the airport RPAS vision. First, the airport should consider the types of RPAS that can be expected and the number of operations anticipated. Second, the airport should determine the facilities necessary and currently available for RPAS activities, including a communications infrastructure. Both of these considerations will likely have major impacts on attracting and maintaining revenue streams from RPAS activities.

3.5.1 Airport Ground Infrastructure

The operation of RPAS will be conducted from ground-based facilities. These facilities can vary from small mobile units to elaborate, interconnected, global systems. Security requirements for these controlling facilities will need to be developed. Applying appropriate security measures for large centralized operations would presumably be easier than for the small, mobile facilities. Apart from the RPAS control facility, the communication infrastructure will need to have redundancies and alternate paths. The risks to implementation are low because the technology needed to secure physical facilities is well known. The cost of implementing security measures will likely be a big challenge. This becomes a more complex issue as the control functions and infrastructure of some ground operations may be distributed in various locations locally, regionally and around the world. The amount of security applied to the ground control facility will depend on the size of the RPA, the airspace being used, and the missions being flown. For large operations that may be controlling multiple vehicles from one site and that are networked with other facilities will require a much higher degree of security than a single control station responsible for a moderate to small size vehicle.

The airport operator should understand and plan for what facilities are available for RPAs, or facilities that may be repurposed in their use. Examples include:

- Vacant hangars, office space, and operational space

* Ramp space
* Industrial park space adjacent or in close proximity to airport property
* Vacant land that is planned for or has airfield access
* Utility capacity (e.g., water, sewer, electrical power, natural gas, and fuel access)

RPS may also require on-site storage (hangar capacity). The operators of the larger RPAs are often relatively self-sufficient, utilizing vehicles and mobile RPS that can be located within the hangars. There may not be a need to provide a special control room or centre for RPAS operations in a new facility. All of these types of facilities or property might have a purpose for RPAS operations. With little or no investment, they could provide the airport with an attractive environment for an RPAS operator. The airport operator should know what they have and what it might take to put the assets to use for RPAS operations.

Taxiing to and from a runway will require precise ground movements and the ability to search for other aircraft or obstacles (e.g., animals) that may be on or near the apron or taxiways. Consideration will be needed concerning airport infrastructure to accommodate secured communication/control and power generation backup facilities, as well as vehicle storage facilities. Further, special Navaids, such as differential GPS (DGPS) or laser guidance, may be used at airports to assist in precision landings and take-offs. Optical sensors, DGPS, ADS-B, taxiway-embedded induction sensors, and other technologies are potential guidance mechanisms for RPAS to assist in situational awareness during taxi operations. These technologies may also lessen any potential impact of RPAS on airport operations.

3.5.2 Airport Requirements

For the RPAS operator it is mandatory to better understand the ground facilities available to its RPA. It has been proven to have a checklist at hand to analyse whether that facilities conform the needs of the RPAS. Such a checklist may include items of the following categories:

* Communication requirements
* Navigation requirements
* Runway use and length requirements
* RPS logistical requirements
* Fuel and maintenance requirements

Concerning the navigation requirements in take-off and landing phases, this CONOPS will consider airports equipped to allow RPA to land without visual aid from the RPIL. Depending on the ATOL system capability of the RPAS a precision approach technology of the ones described in 3.1 could be required. Each of these technologies foresee the airport to be properly equipped, e.g. ILS navigation service and three or more GPS antennas, VHF Data Broadcast (VDB) transmitter for GAST [8].

* Frequency management coordination: Some RPAS may require data links with several frequencies across several bands, and these frequencies have to be managed accordingly and carefully.
* Restricted aircraft access: Some RPAS, especially for military operations, may require access control, which can pose challenges to the airport. Protected perimeters with surveillance might be necessary, even if only temporary.

3.6 Interfaces

This section identifies and describes the various internal and external interfaces of a system that allows RPAS operations in the TMA as well as communications between pilots and controllers and between pilots and RPAS.

3.6.1 Interface between RPA and RPS

The RPS is connected to the RPA via the C2 datalink. See sections 3.4 for more information about the C2 link.

3.6.2 Interface between RPS and ATC

The RPIL will need to listen to voice communication continuously on the appropriate communication channel and establish two-way communication, as necessary, with the appropriate air traffic control unit, except as may be prescribed by the appropriate ATS authority.

RPAS conducting IFR operations must communicate with ATC while in controlled airspace. The methods of communication may be via traditional air-ground very high frequency (VHF) radio or other means, such as satellite or terrestrial relays, data communications, internet-based systems, etc. Some options may involve reliance on third-party service providers. Whatever the ATC communication solution, it must be transparent to the controllers to maintain consistency with manned aircraft communications. Additionally, if alternative communications systems are used, the system should accommodate a transmission to and from the reception of the existing voice communications to facilitate shared awareness of communications to other airspace users [7].

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. These rules imply that, in principle, different technologies could be used to satisfy the requirement on-board manned airplanes. In the case of RPAS, since the RPIL 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.

There are four main communications modes between an RPIL and ATC:

- VHF voice communications
- SATCOM voice communications
- Controller Pilot Data-Link Communications
- Ground-ground link

3.6.2.1 VHF Voice Communications

The method used for VHF voice communications between the RPIL and ATC depends on the distance between the RPA and the RPS. If the RPA is within radio line of sight to the RPS, so called RLOS communications can be performed. If RPA is outside the radio line of sight, then radio communications can be performed via a BRLOS connection between the RPS and the RPA. RLOS and BRLOS communications architectures are explained in section 3.4.3.

3.6.2.2 SATCOM

Airborne radio telephone communication via satellite is usually abbreviated to the term SATCOM. Use of satellites for this purpose complements satellite-based navigation capability. Aircraft onboard equipment for SATCOM includes a satellite data unit, a high-power amplifier, and an antenna with a steerable beam. A typical aircraft SATCOM installation can support data link channels for 'packet data services' as well as voice channels. SATCOM data link is currently used for only a small proportion of en-route ATM communications in contrast to the much more extensive use as an alternative to VHF and HF for non-ATC purposes.

Even in non-ATC use, SATCOM voice communications still require standard radio discipline procedures (e.g. to avoid garbling). Any attempt to use a SATCOM link like a normal telephone can easily lead to misunderstandings. Satellite Voice-equipped aircraft can initiate calls using either INMARSAT or IRIDIUM assigned security phone numbers (ICAO short codes) or can direct dial be using commercial phone numbers and country codes. Ground Earth Stations can originate calls to SATCOM Voice-equipped aircraft using their unique 8-digit Aeronautical Earth Station (AES), aircraft ID (OCTAL) code, or phone number [19].

It is important to note that a so called "party line" is not automatically available during SATCOM communications. However, it is possible for the controller to initiate a conference between one more aircraft as and when necessary.

3.6.2.3 Controller-Pilot Data Link Communications (CPDLC)

Most communications between pilots and ATCOs are made via voice. A new data-link system called Controller-Pilot Data Link Communications (CPDLC) has been currently starting to connect pilots and controllers to routine communications using data link messages. One of the objectives of this system is to simplify or even automate some routine messages in the communications so that pilots and ATCOs can concentrate in other tasks. The RPAS CPDLC system (this could be a subsystem on board the RPA or in the RPS) [20] must be compatible with the CPDLC technology supported by the ATSU.

CPDLC is a two-way data link system by which controllers can transmit non- urgent strategic messages to an aircraft as an alternative to voice communications. The message is displayed on a flight deck visual display. The CPDLC application provides air-ground data communication for the ATC service. It enables several data link services (DLS) that provide for the exchange of communication management and clearance/information/request messages which correspond to voice phraseology employed by air traffic control procedures. The controllers are provided with the capability to issue ATC clearances (level assignments, lateral deviations/vectoring, speed assignments, etc.), radio frequency assignments, and various requests for information. The pilots are provided with the capability to respond to messages, to request/receive clearances and information, and to report information. A "free text" capability is also provided to exchange information not conforming to defined formats. The CPDLC is being globally implemented and currently is in different implementation stages. The global communication procedures are detailed in the ICAO. The CPDLC message set is contained in ICAO Doc 4444: PANS-ATM, Annex 5 [21].

The following data link services are available [22]:

- **Data Link Initiation Capability (DLIC):** this service provides the necessary information to make data link communications possible between an ATSU and RPAS. The DLIC service is executed prior to the first use of any other data link application.

- **ATC Communications Management Service (ACM):** this service provides automated assistance to RPILs and controllers for the transfer of ATC communications (voice and CPDLC).
- **ATC Clearances Service (ACL):** this service allows RPILs and controllers to conduct operational exchanges. Pilots can send requests and reports and controllers can issue clearances, instructions, and notifications.
- **ATC Microphone Check Service (AMC):** this service allows controllers to send an instruction to all CPDLC capable aircraft on a given frequency (at the same time) to verify that their voice communication equipment is not blocking a given voice channel.
- **Departure Clearance (DCL):** this service provides automated assistance for requesting and delivering departure clearances to RPAS.
- **Downstream Clearance Service (DSC):** this service is provided for flight crews who are required to request and obtain clearances from ATS units that are not yet in control of the aircraft when they cannot get the clearance information via the current ATS unit through unit-to-unit coordination.

The expected benefits of CPDLC are the following:

- Less communication on the ATC frequency;
- Increased sector capacities;
- More pilot requests can be dealt with simultaneously;
- Reduced probability of miscommunication (e.g., due call sign confusion);
- Safer frequency changes, hence fewer loss of communication events.

It has to be noted that this CONOPS does not foresee the use of CPDLC for time critical flight phases. As such CPDLC is not expected to play a major role in the TMA. It may have some applications while the RPAS is taxing at an airport.

3.6.2.4 Ground-ground link

The last option uses a wired ground-ground link between the RPS and ATC. This option has the lowest latency and the highest reliability when compared to all options that are based on radio connections, but requires a new network to be created between the RPS and ATC. Such ground connections are part of the plans of future communication infrastructure e.g. in Europe and the USA and standards have already been defined, but they have not yet been realized [15], [16].

As of today, due to their reliability, wired connections (using the regular telephone infrastructure) are often recommended as a backup means for voice communication between the RPIL and ATC if the R/T equipment on the RPS or RPA experiences a failure.

3.6.3 Interface between two or more RPS (handover)

Unlike in manned aviation where the cockpit is integral to the aircraft, RPA can potentially 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.

It is important to consider the compatibility of all RPS involved in the handover with the RPA in question. Additionally, there is no direct interface between the RPS involved in a handover except for a means for voice communications between the RPILs. Such communications can be established using ground-ground means for maximum reliability.

All handovers must be planned and coordinated as per the procedures in the operations and/or flight manual. Handover considerations should include [5]:

- Confirmation of the availability of a reliable voice communication link between the transferring and receiving RPILs in the RPS to support coordination of the handover (it is recommended that this communication is not relayed through the RPA)
- Status of the receiving RPS
- Compatibility of the C2 link
- Coordination between the respective RPILs
- ATC coordination

3.6.4 Interface between RPAS: Detect & Avoid

The conflict management approach towards DAA is comprised of three layers paralleling the manned aircraft approach towards avoiding hazards [5]:

- Strategic conflict management phase: This is generally considered the planning phase where sufficient data is obtained for the execution of the flight
- 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 RWC by RPILs are utilized in this phase
- Collision Avoidance (CA) phase: In this phase, last resort actions or manoeuvres are executed to resolve conflicts if the strategic or tactical phases did not prevent the hazards

DAA is mainly concerned with the second and third layers in the above taxonomy. It should be noted that DAA and associated procedures are outside the scope of the INVIRCAT project as it focusses on IFR operations in airspace classes A-C in which mainly ATC is responsible for the safe separation of aircraft. Nonetheless the following provides a short introduction to DAA for the interested reader.

The DAA system shall provide three main elements [23]:

- Situational awareness to the RPIL, at a suitable level for the operations to be handled.
- Separation provision (in terms of assistance to a RPAS flying in a managed airspace, or in terms of self-separation in an unmanaged airspace).
- Collision avoidance when separation provision failed.

Furthermore, DAA systems are classified into three main categories [24]:

- Class I: provides Remain Well Clear (RWC) alerts and guidance to support a pilot to maintain a safe distance from other traffic. RWC can be considered to be the technological counterpart to see and avoid.
- Class II: provides RWC alerts and guidance + collision avoidance using TCAS II.
- Class III: provides RWC alerts and guidance + collision avoidance using ACAS-Xu.

The detect and avoid (DAA) capability for RPAS is analogous to manned aviation's requirement to see and avoid and maintain vigilance for the purpose of detecting and avoiding potential collisions. It is considered a cornerstone necessary for enabling RPA integration. DAA capabilities include the ability to maintain vigilance while detecting and avoiding conflicting aircraft and other hazards (e.g., obstacles, terrain, and severe weather), determine an effective avoidance manoeuvre, execute the manoeuvre, and safely return to the original flight or ground trajectory. These capabilities must be available to the RPIL to enable the appropriate decision(s) and action(s) to assure safe flight. However, in the event of failure, e.g. a lost C2 link, it may be necessary for the DAA system to respond automatically to ensure enactment of the appropriate actions.

DAA technologies (airborne or ground-based) and procedures will need to be developed and certified/approved to ensure not only the safety of the RPA, but interoperability with other aircraft or obstacle collision avoidance systems (CA). New procedures for controllers and pilots may be needed to ensure DAA use is understood and integrated into normal and contingency operating procedures. Furthermore, the remain well clear capability (RWC) of the DAA system must be compatible with the rules of the air and with any separation provision services provided by ATS. The DAA solution must not degrade the level of safety of the RPA or the overall aviation system [4].

RPA may detect hazards, including conflicting traffic, using optical and non-optical technologies. Detection may be supported using a database. 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). However, 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 [7].

3.7 U-space Service Provisions

Generally, this CONOPS considers RPAS that are able to comply to Instrument Flight Rules (IFR) through the whole duration of the flight. That implies that the RPIL is in contact with air traffic control all of the time. This can be achieved through different means, but the RPAS behaviour is similar to manned aircraft operations, conducted according to IFR. However, in future operations it might be required to establish a link between U-space and ATC for IFR RPAS operations as well. One example is a flight of an air taxi from an urban environment (flight in very low-level airspace below 500 ft, enabled by U-space) to an airport. The approach could require a published IFR approach and that would require a switch from U-space based operations to “standard” IFR operations. Considering coordination procedures used by ATC, some form of data transfer (e.g. electronic flight strips or similar) might be required. In addition, some of the services developed for U-space could be beneficial for pure IFR-RPAS operations, as introduced below.

The CORUS U-space CONOPS [25] introduces the airspace type Za, that is identical to airspace controlled by ATM, immediately available and independent from the implemented U-space level (U1-U4). That comprises all airspace classes in the scope of INVIRCAT (A, B, and C in the TMA) in very low-level (VLL) airspace. All other U-space airspace types (X, Y, Zu) are segregated from Za and thus have no impact on controlled airspaces of INVIRCAT’s scope.

U-space service provisions can support RPAS by:

1. Connection to ATC:

   U-space foresees a procedural and a collaborative interface to ATC. The procedural interface is a mechanism to coordinate an entry of a flight from airspaces X, Y and Zu into controlled

airspace Za and works during the flight planning phase before flight. It enables ATC to e.g. accept or refuse a flight, or describe the requirements and process to be followed for a flight operation.
The collaborative interface could manage the connectivity to ATC during the flight, as e.g. dialling the frequency, setup the audio channel between the ATC frequency and drone pilot as well as handling of the “push-to-talk” functionality to enable communication for instructions and clearances from ATC.

2. Tracking and Monitoring Services:

   The CORUS U-space CONOPS foresees Tracking and Surveillance Data Services that shall be able to track aircraft positions from different sources such as primary radar, cellular telephone triangulation, or ADS-B and share them with the Traffic Information Service as well as with ATC in Za airspace. Similar to the traffic information provided via ADS-B In (Traffic Information Service-Broadcast, TIS-B) in manned aviation in the USA [26], the Traffic Information Service might be used to provide the RPIL or operator with traffic information and warnings about other flights - manned or unmanned - that may be of their interest.

3. Environment Services:

   Similar to the Traffic Information Service, the envisaged Weather Information Service described in the CORUS U-space CONOPS could be useful for RPAS in controlled airspace, providing weather information to the RPS and RPIL, similar to the Flight Information Services Broadcast (FIS-B) in the USA, that provides weather data as well as other important information, such as temporary flight restrictions and Notices to Airmen (NOTAM) [27].
   In similar manner, NOTAMs and other relevant information for RPILs located at the RPS could potentially be provided more conveniently and at lower cost by services that have been initially designed for the use in U-space, instead of systems designed for pilots that are located inside the aircraft.

4 Description of Operations

4.1 Types of Operations and Operating Environment

In SESAR, the operational environment refers to the operational nodes operational processes and systems, which facilitate ATM operations of civil and military Airspace Users, ANSPs and the Network Manager (NM). All the constituents of the operational environment play a vital role to ensure successful flight operations and maintain performance of the ATM network. The operational environment description will be limited to the nodes performing operational activities in the medium-to-short-term planning phase at local/sub-regional level.

The European Civil Aviation Conference ECAC airspace is constantly undertaking modernisation in order to optimise ATM network operations and satisfy performance targets set for different reference periods. This modernisation brings new design features and operational processes/procedures.

In general, there is a categorisation for three parts, the departure phase, the en-route phase and the arrival phase. Complementary the airport and its vicinity are concluded to be part, too.

The notion of operating environment provides a logical link between the operational needs expressed by Airspace Users and the need to deploy new ATM procedures and technologies. By definition, Operating Environment (OE) means an environment with a consistent type of flight operations. In fact, operating environment can equally be applicable to civil and military flight operations with slight difference in the description of categories of such an environment.

Military operating environment (MOE) has been created to analyse the contribution of civil-military coordination and interoperability solutions for mission effectiveness and overall network performance. Military's approach is to implement civil capabilities when possible and when those capabilities do not introduce constraints and limitations to higher military functions. While a large portion of civil operations at airports, in TMA and en-route are comparable, military flight operations are substantially different.

Military Airspace Users will be concerned with operating environments when deploying new operating methods, tools and procedures and consider both ground and airborne components.

4.1.1 Type of RPAS Operations

All types of RPAS operations may be possible within civilian airspaces either in commercial transport, general aviation, aerial work or leisure. Nevertheless, in order to unlock these opportunities, a seamless integration with VFR/IFR traffic is compulsory. In fact, RPAS should have the same behaviour as the manned aircraft would have in the same circumstances.

The RPAS operations should therefore be designed to ensure the capacity to pilot the aircraft in a timely manner in order to respond to ATC instructions or authorizations.

The following list outlines use cases that are expected to be performed by RPA that lie within traffic class VI and therefore within the scope of the INVIRCAT CONOPS. More detailed descriptions and a comprehensive overview of RPAS and RPAS operations can be found in the appendix.

- Civil and military operations
- Point-to-point operations (e.g. transport of goods, or passengers)
- Local area operations (e.g. surveillance, research, and humanitarian aid)

These widely spread use cases lead to a wide spread set of requirements, resulting in a large variety in size, shape and performance figures of RPAs to consider in the CONOPS.

As described in chapter 2.2, inside the TMA/airport environment the following operations are to be considered:

- Taxi to/from runway/parking position
- Take-off and Departure using SIDs
- Arrival using STARs, and Holding
- Approach and Landing

4.1.2 Flight Area and Airspace Description

This CONOPS focusses on the integration of RPAS in TMAs and airports, flying in airspace classes A to C under IFR, using SIDs for departures and STARs for arrivals. Airspace structures in the scope of this CONOPS are:

- CTR, control zones containing flight paths of arriving and departing IFR traffic [2], and
- TMA, defined as "a control area normally established at the confluence of ATS routes in the vicinity of one or more major aerodromes" [28]

The TMA connects the CTR of one or more airports to the en-route airspace as shown in Figure 9.

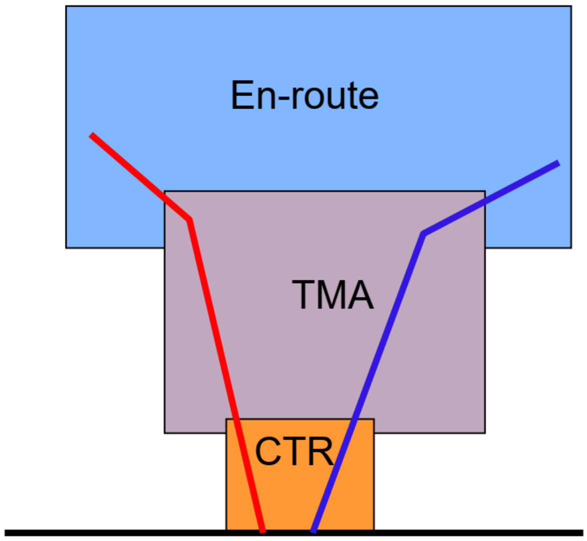


Figure 9: Schematic depiction of En-route airspace, TMA and CTR [29]

Surrounding airspace can either be controlled or uncontrolled. RPA traffic entering the TMA has to adhere to regulations existing in the TMA by appropriate means. RPA traffic leaving the TMA can remain in controlled airspace or can enter U-space when it qualifies for the X, Y, or Z(u) area (see also chapter 3.7).

Airspace classes used for TMAs and CTRs vary largely between different countries and extend from class A to E, i.e. the airspace classes controlled by ATC. Some examples are listed in Table 7, below.

Table 7: Examples of airspace classes used for TMA and CTR in different countries

Country	Canada	Denmark	Italy	UK	USA
TMA classes	A, B, C, D	C, D	A, D, E	A, C, D, E	B, C, D
CTR classes	B, C, D, E	D	A, D	A, D	B, C, D
Source	[30]	[31]	[32]	[33]	[34]

The INVIRCAT CONOPS focusses on the integration of IFR RPAS in airspace classes A to C, in which ATC provides separation for IFR traffic to all other airspace users.

Standard instrument departure (SID) and arrival (STAR) routes are designated

- Departure routes linking the aerodrome or a specified runway of the aerodrome with a specified significant point, normally on a designated ATS route, at which the en-route phase of a flight commences, and
- Arrival routes linking a significant point, normally on an ATS route, with a point from which a published instrument approach procedure can be commence

under instrument flight rules (IFR).

At aerodromes where SIDs/STARs have been established, departing/arriving aircraft should normally be cleared to follow the appropriate SID/STAR. Both, SIDs and STARs can contain level and speed restrictions. Clearances to aircraft on a SID/STAR with remaining published level and/or speed restrictions shall indicate if such restrictions are to be followed or are cancelled [28].

4.1.3 ATC Procedures

This subsection lists the lists the ATC procedures that need to be considered for operations of class VI RPAS in the TMA and airport contexts; see Figure 10. Here it can be seen that there are two main categories of ATC procedures: nominal operations and non-nominal operations. It should be noted that latency occurs for both nominal and non-nominal operations, which become perceptible if the RPAS is operated BRLOS. For each category, Figure 10 shows the specific procedures that need to be considered. These procedures are described in more detail in Table 8.

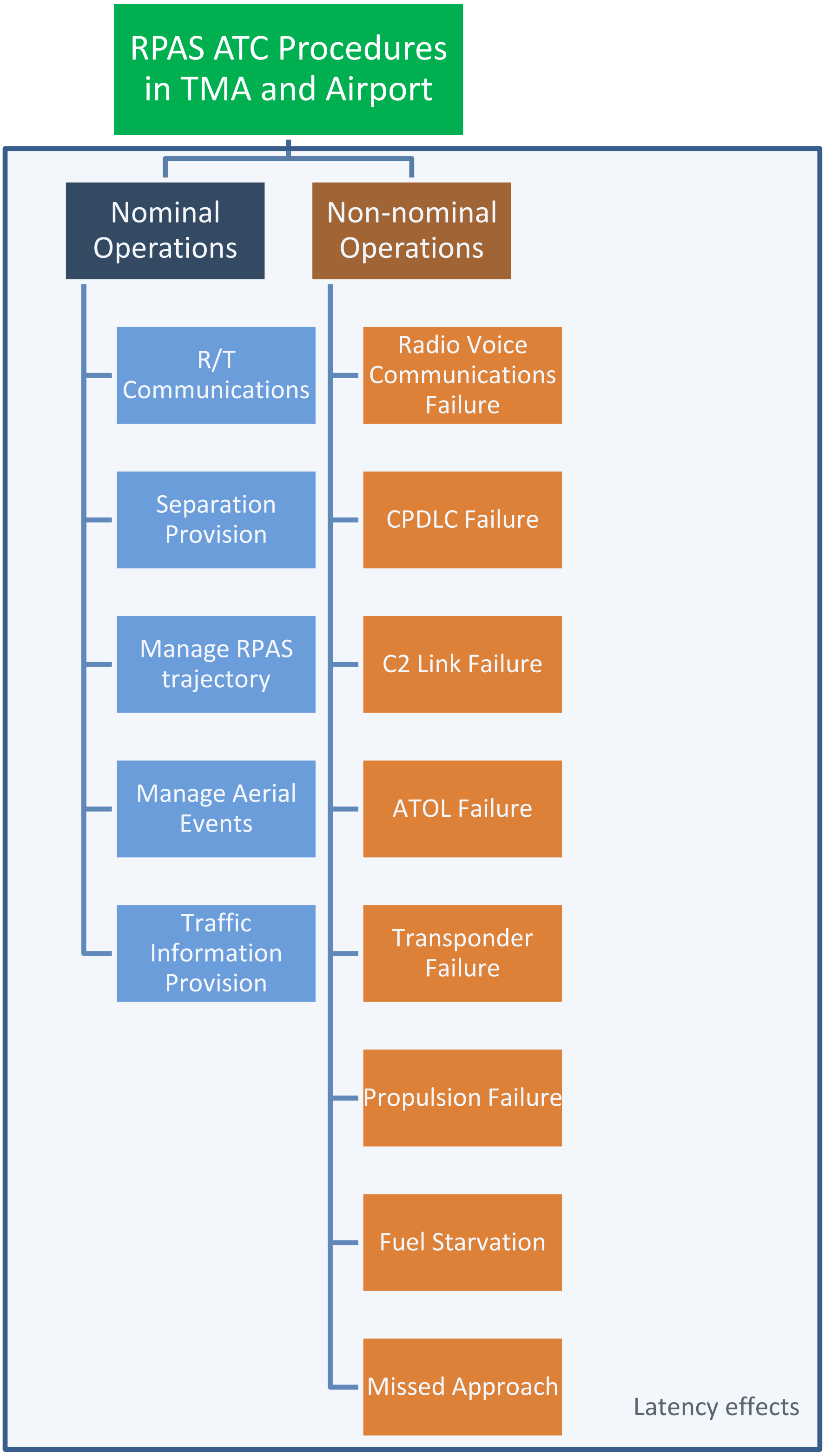


Figure 10: ATC procedures relevant for the TMA and airport contexts for class VI RPAS

Table 8: List of ATC procedures in relevant for the TMA and airport contexts for class VI RPAS

Category	Procedure	Description
Nominal Operations	R/T Communications	The guidelines dealing with communications between the RPIL and ATC.
	Separation Provision	The procedures needed to resolve conflicts and avoid reserved airspace volumes.
	Manage RPAS Trajectory	The procedures needed to: • Correct RPAS deviation from the filed flight plan. • Manage departure trajectories and associated clearances. • Manage arrival, approach and final flight paths and associated clearances. • Manage holding patterns.
	Manage Aerial Events	Procedures to deal with: • Fuel dumping. • RPAS specific mission profiles (e.g. loitering over a specific area).
	Traffic Information Provision	Procedures to provide traffic and weather information in a standardized format (e.g. METAR)
Non-Nominal Operations	Radio Voice Communications Failure	Contingency procedure if the R/T voice connection between the RPIL and ATC fails.
	CPDLC Failure	Contingency procedure to deal with the failure of Controller-Pilot Datalink Communications (CPDLC).
	C2 Link Failure	Contingency procedure to deal with the failure of the Command and Control (C2) link between the RPS and the RPA.
	ATOL Failure	Contingency procedure to cope with a failure of an RPA's Automatic Take-Off and Landing (ATOL) system.
	Transponder Failure	Contingency procedure for managing the failure of an RPA's transponder.
	Propulsion Failure	Emergency procedure for dealing with failure of the RPA's propulsion system. Different procedures may be required for partial and full engine failure.
	Fuel Starvation	Emergency procedure for dealing with scenarios where the RPA is out of fuel.
	Missed Approach	Procedures for declaring and recovering from an RPAS missed approach.

As shown in Figure 10, these procedures are subject to communication and C2 latency effects, that have been introduced in chapter 3.4.4.3. In RLOS operations, procedures for ATC are needed to integrate/sequence a RPAS experiencing minor C2 link latency. In BRLOS operations, procedures for ATC are needed to integrate/sequence a RPAS experiencing major C2 link latency during BRLOS control.

It should be noted that this section only lists the relevant ATC procedures that need to be considered for RPAS operations in TMAs and airports. The procedures themselves are described and defined in more detail in section 4.3 and section 4.4. It should also be noted that procedures related to Detect and Avoid (DAA) are not considered here as operations with DAA are outside the scope of the INVIRCAT project. The reader is referred to the documents of PJ13 (ERICA) for information related to DAA operations in airspace classes A-C, and to the documents of the URClearED project for information related to DAA operations in airspace classes E and G.

4.1.4 Taxiing, Take-Off and Landing Areas

Similar to the general requirements for the integration if RPAS in the TMA the following premises are set for the integration of RPAS surface operations in the airport environment [35]:

- The integration of RPAS shall not imply a significant impact on the current users of airport;
- RPAS shall comply with existing and future regulations and procedures;
- RPAS integration shall be mitigated in any possible way in order to not compromise existing aviation safety levels nor increase risk: the way RPAS operations are conducted shall be equivalent to that of manned aircraft, as much as possible;
- RPAS must be transparent (alike) to ATC and other airspace users.

Despite considering only IFR RPAS belonging to UAS traffic class VI [2], meeting the set performance standards for the Network, TMA, and airports, for broad application of IFR RPAS traffic special equipment at airports may be needed to enable IFR ATOL capability and/or remote take-off and landing.

Following the assumption of [6], this CONOPS will only consider operations conducted under IFR without assistance of the RPIL based on visual aid, which means landings with 0 m DH are needed.

This capability could be implicit to the RPAS or could be achieved through specific airport technologies, as already described in 3.1, that allow this kind of precision approach and thus the following can be considered:

- GLS
    - GAST
    - Multi-constellation solutions

- ILS
    - CAT III

GLS solution will probably completely replace ILS in near future thanks to the lower costs. As derivable from [36], GLS based on multi-constellation solutions is very promising and will fully comply with CAT III requirements starting from 2025, allowing precision approaches without using any augmentation system.

Moreover, as stated in chapter 2.3, in order to integrate RPAS seamlessly into manned traffic operations at airports, this CONOPS foresees RPAS to be able to conduct taxi operations on their own power (besides push back procedures) and without the support of ground vehicles as e.g. follow me cars, similar to the majority of manned aircraft. The INVIRCAT CONOPS follows the OSED for safe integrated RPAS surface operations in the airport environment developed by the SESAR project PJ.03a-09 SUMO [35], which is outlined in the following.

The most relevant challenges for RPAS inside the taxiing area are:

- Implementation of collision avoidance tasks on the manoeuvring areas,

- Complying with ATC clearances, which may be require a different taxi routing, a spontaneous change of them or any other immediate reaction,
- Safety nets / buffers in case of contingency situations like a loss of the C2 link.

Three different modes of RPAS taxi operations are thinkable:

- Manual operations: all aircraft manoeuvres are controlled and initiated by the RPIL (maybe supported by simple autopilot functions).
- Automatic operations: all aircraft manoeuvres are programmed and uploaded before the flight phase which is foreseen for automatic operations while there is no reaction of the aircraft to any external conditions (such as unforeseen hazards or traffic).
- Autonomous operations: a mission profile is uploaded before the flight phase which is foreseen for autonomous operations during which the aircraft recognizes and reacts to external conditions (such as unforeseen hazards or traffic) without intervention from the pilot.

According to the definition of EUROCONTROL's UAS traffic class VI [1], as described in chapter 2.3, autonomous operations are not envisaged in the near future and therefore out of scope of this CONOPS.

For safe operations RPAS shall consider and comply with the following surface marks and signs:

- Markings related to navigation on ground
    - Centreline
    - Taxiway Edge
    - Taxi Shoulder Markings
    - Surface Painted Taxiway Direction
    - Surface Painted Location
    - Geographic Position
    - Direction/Runway Exit
- Operational guidance sign requiring a defined action of the RPA
    - Stop Bar
    - Runway Holding Position
    - Holding Position Markings for Taxiway/Taxiway intersections Surface Painted Holding Position
    - Frequency Change

The introduced new SESAR operating method minimizes the risk of collisions in nominal and non-nominal conditions and is based on the following principles [35]:

- All RPAS are only allowed to taxi along standard taxi routes which are defined and published for every Runway - Parking Spot Pairing.
- These standard routes are segmented by implementing mandatory holding points at taxiway hotspots or before crossing a runway.
- These segmented standard taxi routes are designed according to the one-way-principle where possible.
- ATC issues clearances separately for every segment in the form of a "go"-command (routing and stop points are standardized and published).

- ATC issues this "go"-command for one segment when it is ensured that it is clear and will remain clear of other traffic.
- ATC ensures only one RPA per segment.
- The RPA has to stop at a published mandatory holding point except it already received the "go"-command for the next segment.
- The way of transmitting this "go"-command is not further specified as this is not relevant for the concept itself. Due to the simple and very short message content, even a message of the size of 1 bit is sufficient.
- Segmented standard taxi routes are checked by ground personnel regularly to ensure a safe use avoiding the need of appropriate on-board sensors.
- The navigational performance of the RPA (without specifying the concrete method of navigation on ground) must fit to the taxiway / runway dimensions.
- The RPA should be marked with a special colour scheme to enable controllers and pilots to identify it as an RPA on the first look.
- In case of contingency, the RPA should show red flashing lights or any other visual warning signal to indicate the situation and to alert other airspace users and the tower controllers (especially in case the RPIL is not able to communicate the situation).

The main advantage of the introduced concept is that, as intended, working methods of ATC in nominal operations are very close to the ones for manned aviation, especially to those procedures used in low visibility conditions (LVP). In contingency cases, as C2 link loss or communication loss, the overall safety is assured by an automated breaking system, that stops the RPA at the next holding point/ end of the taxi segment that it has been cleared for. That limits the number of towing vehicles that (in addition to pushback procedures) are only needed in contingency situations to vacate the runway or taxiway, or for special RPA that cannot use their propulsion system for taxi manoeuvres. As ATC is responsible for the separation of aircraft and other vehicles on ground, a DAA system is only necessary to prevent unexpected events, such as rogue drivers, errant workmen or intruding wildlife encounters, thus allowing a high level of automation.

The proposed operating method has been validated in a qualitative study regarding safety, access and equity, interoperability and human performance [37] and in Fast Time Simulations (FTS) using the Stuttgart airport in Germany as reference regarding capacity, efficiency, and environmental impact [38]. It has been shown to be the preferred solution for the integration of RPAS (compared to segregated operations or the use of towing vehicles) in surface operations with more than 10% RPA traffic share on medium-sized airports and/or airports with higher traffic demand [39].

4.2 Roles and Stakeholders

This section contains the description of the roles and responsibilities for the human actors involved in INVIRCAT CONOPS. The main references are the ICAO - Manual on Remotely Piloted Aircraft Systems (RPAS) edition 2015 [5] and ICAO Annex 2 - Rules of the Air [40]. These roles and responsibilities have adapted according to the needs of the INVIRCAT CONOPS.

4.2.1 RPAS Aircraft Operator

An Aircraft operator is an organization in charge of an aircraft commercial operation. In the RPAS framework, this involves an RPA. In order to carry out RPAS operations, the operator must hold an ROC (RPAS Operator Certificate), since RPAS operations may be more complex than conventionally-piloted aircraft and need to ensure reliability levels comparable to manned aircraft operations. From a regulatory point-of-view, no distinctions are made between conventionally-piloted aircraft and RPAS. Holding an ROC, the RPAS operator is considered able to meet specified responsibilities.

The RPAS aircraft operator's responsibilities include:

- The RPAS operator is responsible for the pre-condition for the safe conduct of the flight and the consequent missions/operations. This includes establishing and implementing a safety management system (SMS).
- According to size, structure and complexity of the organization, the RPAS operator must comply with all requirements established by the State of the operator regarding its mission/operation.
- An ROC must ensure that appointed RPIL has adequate training, is familiar with the regulations and procedures applicable to the performance of his responsibilities, prescribed for the areas to be traversed, the aerodromes to be used, and the air navigation facilities relating thereto.
- Responsibility for operational control should only be delegated to the RPIL 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.
- The aircraft operator is responsible of the flight planning for IFR flight in controlled airspace following ICAO rules.

The RPAS operator must know contingency procedures and share them with specified authorities.

4.2.2 Remote Pilot

The remote pilot (RPIL) remains ultimately responsible for the safe and orderly operation of the RPAS flight in compliance with the ICAO Annex 2 - Rules of the Air [40], other relevant ICAO and CAA/EASA provisions, and within RPAS operating procedures. The pilot (manned or unmanned) is always responsible for the operation of an aircraft in accordance with the rules of the air, except that the pilot may depart from these rules in circumstances that render such departure absolutely necessary in the interests of safety [41]. Furthermore, he/she operates in accordance with ATC clearances and with the Reference Business Trajectory in accordance with the pre-programmed flight plan.

However, many areas of responsibility are common to both, conventionally-piloted aircraft and RPAS [42]. Indeed, RPAS follow ATCOs clearances/instructions the same as manned operations. This includes especially a study of weather reports and forecasts, fuel requirements and alternative course, in case the flight cannot be completed as planned. Furthermore, he/she is responsible of taking action based on the resolution advisories provided by ACAS equipment in order to avoid collisions. On the airport surface, pilots will request to the Ground ATCO permission to taxi, and other clearances/instructions related to the surface movements.

The pilot (or flight dispatcher) before departure shall provide to the appropriate ATSUs (Air Traffic Service Units) the flight plan with all information required by the ATS authority. In accordance with the flight plan, the ATS authority can provide clearances to the controlled aircraft. If a clearance is not satisfactory to a pilot, he/she may request and, if practicable, will be issued an amended clearance. An aircraft (manned or unmanned) shall adhere to the current fight plan submitted. In fact, the aircraft shall operate along the defined centre line of that route and operate between the navigation facilities points defining that route. Deviations from the above-mentioned flight plan shall be notified to the appropriate ATSU. In case the aircraft is off-track, the pilot shall adjust its heading to regain track as soon as practicable. In addition, he/she shall report variation in true airspeed and changes in time estimates.

A controlled flight shall report to the appropriate ATSU, the time and level of passing each designated reporting point, together with any other required information. In absence of designated reporting points, position reports shall be made at intervals in accordance with ATS authority. An aircraft operating in controlled airspace shall maintain continuous air-ground voice communication watch on the appropriate communication channel and establish two-way communication as necessary with the appropriate ATS authority. Finally, abnormal and emergency operations are described in chapter 4.4.

However, the pilot's responsibilities follow a scheme that include 4 features: Manage, Aviate, Navigate and Communicate. For each of these features, responsibilities of pilots are listed. Responsibilities that are **special for RPILs** are highlighted.

Manage: includes the overall planning, decision-making, and management responsibilities that must be accomplished by the pilot, supported by the HMI.

Aviate:

- Execute the flight according to the current flight plan.
- Perform flight according to IFR.
- Monitor and control aircraft systems, including automation.
- Monitor consumable resources.
- **Monitor and configure control station**.
- **Monitor and control status of links**.
- **Transfer control**.
- Control and monitor location and flight path of aircraft.

Navigate:

- Comply with clearances and instructions given by ATC.
- Accept/reject ATC proposed alternative routings based on safety and feasibility.
- Check NOTAM and other environmental information relevant to the flight.
- Assume responsibility to remain inside /outside segregated areas according the case.
- Assume responsibility to maintain own spacing from other airborne when temporarily delegated by ATC.
- Assume responsibility to maintain own spacing from terrain and obstacles on ground.
- **Review and refresh lost link mission as necessary**.
- **Terminate the flight, in the event such an action is deemed necessary, performing the termination procedure in the least harmful way to people or things as predictable**.
- In general, stop the aircraft immediately if required for safety reasons or at the clearance limit during taxi operations.

Communicate:

- In order to perform its mission/operation the RPIL is responsible for communicate with ATC (or service providers).

- Obtain information about present and forecasted weather for the pre-programmed flight plan.
- Maintain a continuous listening watch on the appropriate ATC communications channels.
- Request deviations of flight plan route if deemed necessary mainly for safety, operational and/or economic reasons.
- Obtain a clearance from ATC prior to deviating from the cleared flight plan route.
- When, for reasons of flight safety deviation from the cleared flight plan route must be taken without clearance (e.g. following a TCAS advisory), inform ATC of actions taken as expeditiously as possible.
- Obtain information on landing conditions from the destination airport's information service (ATIS).
- Provide ATC with mandatory information calls e.g. "on frequency, leaving frequency, leaving altitude, reaching altitude, start-up-request, taxi request, reaching assigned position" etc.
- **In case of failure, perform appropriate Contingency Procedures, in particular**:
    - Contact ATC with any other available mean.
    - In case of C2 link loss (see chapter 4.4.3):
        - Contact ATC with any available mean.
        - In case of degradation of Detect & Avoid capabilities, stop the RPAS and contact ATC with any available mean.
- Communicate with other airspace users.
- Communicate with crew members or ground support.

4.2.3 Air Navigation Service Providers

4.2.3.1 Planner Controller

The planner controller is mainly responsible for planning and coordination of the traffic entering, exiting or existing within the sector.

According to the company policy, local procedures, operating methods and traffic environment, the Planner Controller could adopt responsibilities belonging to different roles. Depending on the ANSP local practice and under specified conditions, Single Person Operations (SPO) could be carried out. In the case of Single Person Operations: a single Controller will take the responsibility for both planning and tactical aspects of the sector operation. Furthermore, the Planner controller provides tactical flight control assistance to the Executive Controller.

Specifically, in relation to RPAS operations:

The basic responsibilities given to the Planner Controller are not changed by the introduction of RPAS operations: The basic task of the controller to ensure a conflict-free flight as well as safety and optimization of traffic flows remains untouched.

However, some novel responsibilities for the Planner Controller will be introduced for RPAS operations. These include:

- Familiarise themselves with contingency arrangements (e.g. contingency procedure(s) and contact details) for the RPAS flights operating within their area of responsibility;

- When/if required, coordinate with, and provide information to, the Executive Controller on RPAS contingency procedures and contact details;
- When/if required (e.g. in the event of C2 failure), coordinate with RPAS ground stations and RPILs in the appropriate manner;
- When/if required (e.g. in the event of C2 failure), coordinate with Tower Controller in order to maintain clear the designated area for the flight termination procedure;
- Check RPAS flight-plans, or any other relevant sources of information, for mission details for the RPAS flights operating within their area of responsibility, and coordinate any constraints and/or performance-related aspects arising from the flight/mission with the Executive Controller as needed.

4.2.3.2 Executive Controller

The Executive Controller has responsibility for traffic management within the Area of Responsibility (AoR) and for the tactical tasks. Executive controllers are responsible for the safety and the flow of all flights operating within their AoR. Their principal tasks are, in compliance with the ICAO Rules of the Air [40], other relevant ICAO (e.g. Doc. 4444 [28]) and European/National provisions to separate known flights operating within their AoR and to issue instructions to pilots for conflict resolution and segregated airspace circumnavigation. Additionally, they monitor the trajectory (4D and 3D) of aircraft, according to the clearance the aircraft have received. The basic tasks of the controllers remain untouched: They have to ensure a conflict-free flight as well as safety and optimization of traffic flows.

Specifically, in relation to RPAS:

The basic responsibilities given to the Executive Controller are not going to be changed by the introduction of RPAS. The basic task of the controller as stated above remains untouched.

Nevertheless, some additional responsibilities for the Executive Controller will be introduced for RPAS operations. These include:

- Be aware of RPAS mission details, including any constraints and/or performance-related aspects arising from the flight/mission, for the RPAS flights operating within their AoR.
- When/if required (e.g. in the event of C2 failure), provide instructions/clearances to the other aircraft in order to maintain a safe separation from the RPAS in contingency, when the drone activate the loiter waypoint procedure as described in chapter 4.4.

4.2.3.3 Tower Runway Controller

The Tower Runway Controller is responsible for the provision of Air Traffic Services to aircraft within the control zone, or otherwise operating in the vicinity of controlled aerodromes (unless transferred to Approach Control/ACC, or to the Tower Ground Controller), by issuing clearances, instructions and permission to aircraft, vehicles and persons as required for the safe and efficient flow of traffic. The Tower Runway Controller is assisted by arrival, departure and surface management systems, where available.

Specifically, in relation to RPAS:

The basic responsibilities given to the Tower Controller stated above are not going to be changed by the introduction of RPAS.

Nevertheless, some additional responsibilities for the Tower Controller will be introduced for RPAS operations. These include:

- When/if required (e.g. in the event of C2 failure), coordinate with RPAS ground stations and RPILs in the appropriate manner.
- When/if required, coordinate with, and provide information to, the Planner Controller on RPAS contingency procedures and contact details.
- When/if required (e.g. in the event of C2 failure), provide instructions/clearances to the other aircraft in order to maintain a safe separation from the RPAS.
- When/if required (e.g. in the event of C2 failure), provide instructions in order assure that the termination area will be clear and ready for activation.

4.2.3.4 Ground Controller

The Ground Controller is part of the controller team responsible for providing an Air Traffic Service at controlled aerodromes. His main task is the provision of ATS to aircraft and vehicles in the manoeuvring area. He must also ensure that airport maintenance vehicles carrying out necessary improvements on an active manoeuvring area do not interfere with the movement of aircraft.

Specifically, in relation to RPAS:

The basic responsibilities given to the Ground Controller stated above are not going to be changed by the introduction of RPAS.

Nevertheless, some additional responsibilities for the Tower Controller will be introduced for RPAS operations. These include:

- When/if required (e.g. in the event of C2 failure), coordinate with RPAS ground stations and RPILs in the appropriate manner.
- When/if required (e.g. in the event of C2 failure) clear the manoeuvring area.
- When/if required (e.g. in the event of C2 failure) maintain a safe separation from the RPAS in contingency on the manoeuvring area.

4.2.3.5 Clearance Delivery Controller

Clearance Delivery Controller (CLD) issues route clearances to aircraft, typically before they commence taxiing. These clearances contain details of the route that the aircraft is expected to fly after departure. Clearance delivery if necessary, will coordinate with the relevant radar centre or flow control unit to obtain releases for aircraft. The primary responsibility of CLD is to ensure that the aircraft has the correct aerodrome information, such as weather and airport conditions, the correct route after take-off and time restrictions relating to that flight. This information is also coordinated with the relevant radar centre or flow control unit and ground control in order to ensure that the aircraft reaches the runway in time to meet the time restriction provided by the relevant unit. At some airports, clearance delivery also plans aircraft push-backs and engine starts.

Specifically, in relation to RPAS:

The basic responsibilities given to the clearance delivery controller are not going to be changed by the introduction of RPAS: Details of the route that the aircraft is expected to fly after departure, push-backs and engine starts.

Nevertheless, additional responsibility for the Clearance Delivery Controller will be introduced for RPAS operations:

- When/if required (e.g. in the event of C2 failure), coordinate with RPAS ground stations and RPILs in the appropriate manner.

4.2.4 Military Considerations

NATO RPAS operational procedures are widely harmonised to the extent possible. NATO standardisation agreements, STANAGs, are written to ensure such behaviour. They always build upon ICAO SARPS and add those military specific requirements on top. That way the least impact or limitation can be expected to ensure military mission effectiveness that all states are aiming at to ensure a secure national airspace. Being alike ICAO SARPS, states are also able to claim national reservations that will be shared with all NATO member states. For the European airspace, non-NATO member states are in close contact and harmonise their procedures indirectly with NATO through participation in common exercises.

4.3 Standard Operational Procedures

The safe operation of unmanned aircraft systems (UAS) will be governed by Implementing Regulation (EU) 2019/947, which is applicable as of December 31, 2020, establishing a transition period.

The European regulation applies to any unmanned aircraft regardless of its mass and use, whether professional or recreational (including model aircraft).

In addition, 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. [5]

4.3.1 Standard Operations performed by RPAS

4.3.1.1 Taxi Operations

It should be noted that this type of operation is looking to the future, as they are not fully implemented today. It is expected that on the aerodrome surface, RPAS will interact with ATC in the same way as manned operations.

As previously stated in 4.1.4, the INVIRCAT CONOPS follows the OSED for the safe integration of RPAS for surface operations in the airport environment develop by the SESAR project PJ.03a-09 SUMO [35]. It proposes the concept of segmented standard taxi routes as a new method to achieve a fast-and-easy integration of RPAS into controlled aerodrome traffic while maintaining the same level of safety compared to pure manned aerodrome traffic.

RPILs will request permission to taxi along the standard taxi routes defined following mandatory holding points at taxiway hotspots or before crossing a runway. ATC issues clearances separately for every segment in the form of a "go"-command when it is ensured that it is clear and will remain clear of other traffic, with only one RPA per segment.

The collision avoidance task for ground movements is expected to be taken over ATC. A high level of automation on board of the RPA is allowed due to the very definite procedure. Further, this procedure should be very transparent and predictable to other aerodrome users and to ATC. Finally, it introduces additional safety in case of contingency situations such as a loss of communication RPIL-ATCO or C2 link loss through an auto breaking system which stops the RPA at the next mandatory holding point/end of the taxi segment that is has been cleared for.

The participants involved in taxi operations of an RPAS on the airport grounds are: Tower (TWR) ATCO (Ground), TWR ATCO (Runway), RPIL and RPA. The taxi procedure is described in D2.2 [3].

4.3.1.2 Take-off

The take-off of the RPA is considered from the alignment position on the runway to the indicated positive climb rate. The operation of a RPAS is described as a representative example.

Firstly, the RPIL notifies the TWR ATCO that he is ready for take-off and requests departure clearance. He receives departure information and permission to line up on the runway. Once the RPAS is fully operational, the take-off checklist completed and the ATOL system available (if applicable), the RPA rises to the permitted altitude along the route of the SID according to its flight plan.

It is assumed that the ATCO of the TWR can monitor the RPAS using radar, or alternatively, the TWR will use airport specific procedures to be able to monitor the RPAS.

4.3.1.3 Departure via SID

The departure operation via SID of an RPAS covers the ascent of the IFR RPAS through a defined standard instrument output. RPAS has been identified by ATC and received a clearance from either the TWR/Ground/Delivery ATCO to fly the SID, as well as permission to climb to an initial altitude after take-off. Strategic coordination between TWR and APP is in place. The RPA is airborne and climbing to the permitted altitude along the SID route according its flight plan. After the RPAS reaches the location and altitude of the final SID waypoint/fix, it is transferred into en-route airspace (ATS route network or free-routing airspace) according to flight plan.

It is assumed that the ATCO of the TWR can monitor the RPA using radar, or alternatively, the TWR will use airport specific procedures to be able to monitor the RPA.

4.3.1.4 Arrival via STAR

This operation considers the arrival of an RPA in the TMA through a Standard Terminal Arrival Route (STAR). It begins with the RPA en-route approaching the transition. The RPIL contacts the APP ATCO and informs him/her of the position, cleared STAR procedure, speed and altitude. Before, or at the STAR clearance limit, the APP ATCO gives the go-ahead for the IFR approach. The RPA proceeds to the Initial Approach Fixture (IAF) of the IFR approach.

It is assumed that ANSPs can monitor the RPA using radar.

4.3.1.5 Holding

This case considers the execution of an IFR Holding Pattern (HP) of an RPA in the TMA e.g. due to traffic congestion at the airport or for improved sequencing.

ATC commands a HP via voice communication, or the RPA reaches clearance limit with designated HP in STAR map and has no clearance to proceed with the approach. The RPIL keeps the RPA in a holding pattern according to STAR, obeying altitude and speed restrictions/ following instructions from ATC. ATC releases the RPA from the holding pattern with instructions to proceed STAR, or clearance for IFR approach, if the HP was performed at IAF.

4.3.1.6 Approach

Here the IFR approach of an RPA in the TMA using its ATOL system is considered.

The APP ATCO coordinates the landing sequence and monitors the separation of the RPA from other aircraft. The RPIL reads back and follows the instructions. The ATCO then grants ILS (or another precision approach) authorization according to weather and traffic conditions. As soon as the RPA is established at the ILS, the RPIL activates the ATOL system. The APP ATCO then transfers radio and radar control of the RPAS to the TWR ATCO, who takes over. The RPIL contacts the TWR ATCO and informs him/her of the position of the RPA and the approach of the ILS/ precision approach.

4.3.1.7 Landing

This operation is considered a precision approximation of an RPA using its ATOL system.

Landing clearance is granted by the TWR ATCO. The RPIL reads back the landing authorisation and follows the ATOL landing surveillance. The ATOL system lands the RPA on the runway and automatically slows down under the supervision of the RPIL. The RPIL directs the RPA from the runway to the cleared taxi holding position. [3]

4.3.1.8 Low Visibility Procedures (LVP)

RPIL should have a clear visual picture of airport surrounding environment during airport operations in low visibility conditions. When Low Visibility Operations (LVO) are declared, equipped RPA can use combined vision systems, mixing enhanced and synthetic vision systems, Infrared cameras, thermo-camera, Laser scanner, for improving RPIL situational awareness, out of the window view, and its steering ability in adverse weather conditions. Additionally, GNSS equipped aircraft navigation on the airport surface reduces the negative impact of LVO operations, increasing the accuracy of aircraft positioning and feeding ATC Tower systems with better aircraft positioning on the surface [35].

RPAS need to be equipped with ADS-B in, so ADS-B out equipped aircraft and vehicles are displayed on the ground control station HMI, providing RPIL with information on adjacent surface traffic, supplementing visual observations and enhancing see-and-be-seen procedures especially in Low Visibility Operations. RPIL correlates the traffic information displayed within the RPS and visible externally with the alerts and instructions received from the TWR ATCO and manoeuvres the RPA accordingly.

4.3.2 Pre-Flight Phase (Flight Planning, Flight Preparation)

4.3.2.1 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 RPILs 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 RPILs 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. [5]

As in the case of manned aircraft, a flight plan must be submitted for the flight of an RPAS in accordance with ICAO Annex 2 [40], Chapter 3, in particular, prior to operating across international borders. Each State in which the flight is to operate may require additional information related to the planned operation of the RPAS. Flight and flow for a collaborative environment (FF-ICE9) will contain the necessary information to support RPAS operations. Each State in which the flight is to operate may require additional information related to the planned operation of the RPAS [7].

ANSPs or other responsible bodies review, accept, and modify submitted flight plans based on the timing, requested route, and any unique considerations associated with the aircraft, equipage, cargo, route or contingency procedures. For RPAS, ATM automation may be enhanced to enable approval or modification of route requests and recognition of user requests for off-nominal volumes of airspace. Any amended flight plan should be sent to the operator for concurrence or negotiation. Until such time as standardized procedures are established, the ANSP should be provided with, and approve the contingency plans for each IFR RPAS flight plan prior to the operation in case a contingency condition occurs. [7]

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. [5]

4.3.2.2 Diversion to Alternate Aerodromes

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 RPAS 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 RPIL 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.

4.3.3 Radar Vectoring

The radar vectoring procedure is one of the management tools which can be used by ATC in areas where ATS is provided. The basic methods of radar vectoring are constituted of several rules to handle all aircraft to achieve maximum use of airspace. The operation in the case of aircraft will be conducted in the same way as manned aircraft operation. During increased traffic at the airport, radar vectoring becomes the standard procedure in most of the large airports to arrange aircraft in sequence to ensure air traffic flow management for the most efficient use of airspace. The radar vectoring procedure shall be used by air traffic controllers only for identified aircraft on the radar system whilst maintaining two-way radio communications all the time.

In the radar vectoring procedure, the controller can assign headings, altitudes, and speeds to IFR aircraft to guide aircraft in his area of responsibility. Radar vectoring is mainly used by the ATC as a tool to ensure and enhance [43]:

- The air traffic flow management in the arrival and/or approach phase of an instrument approach procedure.
- The IFR aircraft arrangement in sequence in the arrival and/or approach phase of an instrument approach procedure.
- The horizontal and vertical separation between all departing and/or approaching IFR aircraft.
- The optimization of departing IFR aircraft climb inside or outside an arrival flow.
- The assistance to IFR or VFR aircraft in emergency or pan.
- The assistance to lost pilots or deviating pilots from their cleared track.
- Other cases where the situation needs it like specific pilot requests.

The ATC must pay attention to [43]:

- The aircraft safety by ensuring that radar separation minima are always fulfilled and for all airplanes, whether they are under his responsibility or not.
- Not to issue any altitude clearance below minimum vectoring altitudes (MRVA for Minimum Radar Vectoring Altitude) during radar vectoring (prevent any potential terrain collision) outside any procedure tracks.
- Not to issue any altitude clearance below minimum safety altitudes (MSA for Minimum Safety Altitude) during radar vectoring (prevent any potential terrain collision) outside any procedure tracks.
- Not to issue any altitude clearance below minimum procedural altitudes published (Minimum altitude to respect on IAF).

4.3.4 Point Merge and Trombone

Point Merge is designed to work in high traffic loads without radar vectoring. It is based on a specific P-RNAV (Precision Area Navigation) route structure, consisting of a point (the merge point) and pre-defined legs (the sequencing legs) equidistant from this point. The sequencing is achieved with a "direct-to" instruction to the merge point at the appropriate time. The legs are only used to delay aircraft when necessary ("path stretching"); the length of the legs reflects the required delay absorption capacity [44].

On the other hand, to integrate arrival flows in dense traffic situations, 'trombone' shaped RNAV transitions have been in use for a significant period now. Typically, trombone-shaped routes including a series of tactical waypoints. Such designs aim at providing high capacity and acceptability for controllers. However, experience has shown that when traffic rises, controllers tend to revert to tactical vectoring to join the final due to lack of flexibility [45].

4.3.5 In-Flight Phase (Flight Execution)

For the RPA the same general rules apply as for manned aircraft. Starting from this assumption, IFR flight (manned or unmanned) shall be equipped with suitable instruments and with navigation equipment appropriate to the route to be flown and shall be flown at a level which is not below the minimum flight altitude established. The aircraft shall follow clearances/instructions provided by the appropriate ATSU. Furthermore, the IFR aircraft shall not fly over the crowded areas of cities/towns, except by clearances from the appropriate authority or in case of landing and take-off. Aircraft shall not fly in the prohibited /restricted areas especially when they are published, in accordance with the restriction of the State flown.

The operational, equipage and performance requirements imposed on the RPAS will again depend upon the class of airspace through which the RPAS 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).

4.3.5.1 Right-of-way

As with manned aircraft, RPAS 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 RPAS, it may be difficult for pilots of manned aircraft and other RPILs to visually acquire the RPAS.

4.3.5.2 RPAS Performance Considerations

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.

Control instruction response times (e.g. the length of time between ATC issuing an instruction, the RPIL 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 is 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.

As for any new type of aircraft, ATCO must have a general knowledge of RPAS performance characteristics and be familiar with specific characteristics of RPAS 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 [5].

4.3.6 Approach, Arrival, Ground Handling, Taxiing, Departure

4.3.6.1 Aerodrome Surface Operations

On the aerodrome surface, RPAS will interact with ATC much the same as manned operations. RPILs will request permission to taxi, report aerodrome hazards, and accept clearances and instructions concerning surface movement. Upon request, RPILs will receive ATC clearance information. The clearance may be loaded to RPAS automation or carried out manually by the remote pilot-in-command (PIC) or ground support personnel overseen by the remote PIC.

When taxiing on the surface, RPA will need to be capable of identifying and avoiding surface hazards (e.g., vehicles), adhering to ATC movement clearances, and abiding by all aerodrome signage and markings unless alternate methods are developed and agreed upon. [7]

4.3.6.2 RPAS Landing

As described in chapter 2, this CONOPS describes operations of aircraft in traffic class VI, which will be able to land similar RPA may land similar to manned aircraft including the sub-phases from flare to the landing roll and/or aborted landing. This may lead to a need to define landing/recovery areas that are not part of the formal runway/taxiway infrastructure. [7]

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

4.3.6.2.1 Landing at Aerodromes

For operations at aerodromes, the RPIL 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.

4.3.7 RPAS Handover Procedures

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 [5]:

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

A RPIL 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.

A RPIL 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.

The main RPAS handover considerations should ensure that at any time, an RPIL should be in command of the RPA.

4.3.7.1 Handover Coordination between RPS

All handovers must be planned and coordinated as per the procedures in the operations and/or flight manual. Handover considerations should include [5]:

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

Before transferring an RPAS, a handover briefing must be conducted between the transferring and receiving RPILs to ensure the status of the RPAS 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 RPIL that the RPAS is within the accepting RPS C2 link range;
b) current status of the RPAS and location;
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 RPAS performance.

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

4.3.7.2 Remote Relief Pilot Briefings at a Single RPS

Unlike manned aviation, RPILs may be assigned shift work that commences or ends while the aircraft is airborne. In these cases, as one RPIL 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;
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.

The receiving RPIL should be satisfied with all of the above before accepting responsibility for the safe continuation of the flight [5]. Although such an action is not deemed to be executed within the initial and final flight phases within the TMA, the concept is introduced for the sake of completeness.

4.4 Non-nominal Operation and Emergency Operation

4.4.1 Accidents, Incidents and Mishaps to be Reported

INVIRCAT, being exploratory research, addresses mainly the future environment in which RPAS should be fully integrated into the ATM system. Therefore, and as a basic rule depending from a functional Detect and Avoid (DAA) system, for an ATCO it should not be the question when talking to a pilot, whether this pilot is sitting on board or on the ground. Nevertheless, and considering this happening may be too far in the future it proves to be more logical to also keep in mind operations that occur prior to this ideal situation. So, relating to accidents, incidents and emergencies, it is considered to be of value highlighting first similarities and second differences of RPAS and their specific occurrences in regard to manned aviation.

4.4.1.1 Similarities

The European airspace is complex and busy, and is served by a large number of ANSPs. This is very relevant while RPAS are within the operating environment, here specifically in departure or approach phase, in the event of an emergency that results in an RPA having to descend through levels occupied by manned aviation. It is therefore necessary that RPA pilots-in-command understand not only the airspace that the RPA is transiting, but also the nature of the airspace which lies beneath, including corresponding (if existing) buffers.

Notwithstanding the programmed nature of a typical RPAS mission, the RPIL remains central to the ATM established for RPAS flying in European airspace, and to ensure flights take place safely and with negligible impact on other airspace users. The RPIL shall conduct position reporting to ATC in terms that are readily understandable to controllers and that accord with procedures and phraseology contained in ICAO PANS-ATM (Doc 4444) [28].

Like in manned aviation, ATM itself can increase the risk of an accident, albeit slightly, through failure within the ATM system. These are known as system-generated hazards/risks. Although these are usually small compared with the much larger benefit brought about by ATM to mitigate the pre-existing hazards/risks, they usually constitute a very significant part of the overall, residual risk of an accident. However, they are not addressed here.

Each RPAS operating entity carries out a specific safety assessment to show that the residual risk of an accident, associated with RPAS operations in European airspace, is acceptable compared with equivalent manned-aircraft operations, see chapter 4.4.2.

The proposed safety targets are:

The risk of an accident from RPA OAT (Operational Air Traffic)/GAT (General Air Traffic) operations will be acceptably safe if the risk:

- is no greater than that for manned OAT operations in non-segregated airspace; and
- will be reduced as far as reasonably practicable (AFARP), as required by EU regulation (IR) 2017/373 [46] respectively ESARR 3 [47].

Thus, a comparative assessment of safety rather than an absolute assessment (an absolute assessment being a quantitative assessment with absolute numbers) should be performed.

4.4.1.2 Differences

It is in the context of emergencies that RPAS contrast with manned aviation, as far as the RPA lacks a collision-avoidance capability in the event that it is forced to descend through airspace where other airspace users are flying, and, if the control link is lost, the RPA reverts to automatic flight which the RPIL is unable to influence. Nevertheless, the following considerations should apply:

- RPA tracks will be coordinated and agreed beforehand with ANSPs.

- All divert-alternate and emergency-alternate airfields will be subject to prior negotiation and agreement.
- All divert-alternate and emergency-alternate airfields will be included in the flight plan.
- Procedures to be followed in the event of RPA needing to make an emergency landing will be coordinated beforehand with relevant ANSPs.
- Although the response of RPA to emergency contingencies is programmed into its mission computer, the RPIL can override this provided the control link is working.
- Landline telephones provide a back-up means of voice communication between ATC and the RPIL.
- In the event of automatic flight with a high level of automation, the RPIL will know exactly what the RPA is programmed to do and will apprise ATC of this immediately by R/T if available or otherwise by telephone.
- ICAO procedures already cater for manned aircraft making emergency descents and/or emergency landings in circumstances that limit or prevent the pilot from undertaking collision-avoidance. RPAS should to the extent possible adhere to this.

It is not possible to detail all the imaginable emergencies that an RPA might be confronted with during a mission. However, those involving loss of radio communication with ATC and loss of control link are addressed in the respective chapter 4.4.3 of this CONOPS.

According to the ICAO RPAS manual [5], ditching is the controlled emergency landing of an aircraft on water. In INVIRCAT we extend this to also on land, understanding very well that this is not a preferred option, as authorities are very reserved with respect to the concept of specifying a specific area to be a recognized ditching area. The reasons run long, but they include the legal problems with specifying that an area will be used for a potential crash, and the airspace and land restrictions that would have to be enforced around the area. Still, it seems better to have a controlled ditching than an uncontrolled crash somewhere.

4.4.1.2.1 Emergency Ditching

According to the ICAO manual on RPAS [5], given the absence of persons on board the RPA, in certain emergency situations, the RPIL may elect to make an emergency landing/ditching of the RPA at a location that minimizes the risks to people or property on the ground. RPILs may rely on pre-planned emergency scenarios that could occur along the intended route of flight that identify possible locations where an emergency landing or ditching could be made with the least risk to people or property on the ground.

4.4.1.2.2 Emergency Landing

According to ICAO manual on RPAS [5], emergency response plans, specific to RPAS, should be established at aerodromes, commensurate with the aircraft operations and other activities conducted at that aerodrome. The plan must provide for the coordination actions to be taken in an emergency occurring both at the aerodrome and in its immediate vicinity.

4.4.1.2.3 Communication with ATC in the Event of a Contingency

A RPIL who notifies ATC of a contingency using the distress signal (MAYDAY) or urgency signal (PAN PAN), as defined in PANS ATM Doc 4444 section 15.2.2.2 [28], should ensure that ATC is aware that the aircraft is an RPA. ATC may apply special procedures for the handling of an RPA in distress or urgency.

4.4.1.2.4 Contingency and Emergency Procedures

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 pre-programmed routing, landing or activation of the flight termination plan, for further delineation see chapter 4.4.3.

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.

Failure of RPIL/RPA observer communications — describe the procedures in the event of a RPIL/RPA observer communications failure, such as back-up communications possibilities or flight termination plan.

Other emergencies — provide a copy of the emergency procedures contained in the RPA flight manual.

4.4.1.2.5 Incidents

According to the ICAO manual on RPAS [5], the incidents listed below are typical examples that are likely to be serious incidents, which as per ICAO Annex 13 definition, are defined as incidents involving circumstances indicating that an accident nearly occurred and should be reported.

- Incidents related to C2 link, which could include:
    - System failures;
    - Weather conditions;
    - Electromagnetic environmental interference; or
    - Malicious interference.
- Loss of Detect and Avoid System, either on RPA or in RPS
- Technical malfunctions of, or security threats to the RPS
- Ground incidents or near on-ground collisions with ground vehicle, or obstruction(s), person, or another RPA.

4.4.1.2.6 Accidents

For accident investigation, an RPAS operator should ensure RPAS data can be preserved in the event the RPA becomes involved in an accident or incident and retain all the electronic records obtained from any associated data or voice recorders in safe custody, if needed for an accident or incident investigation as described in ICAO Annex 13.

Monitoring and oversight of the C2 Link Communications Service Provision is necessary for contractual and safety reasons, including incident and accident investigations. Approval to act as a C2 Link Communications Service Provider (C2CSP) may be required before being authorized to provide the C2 Link Communications Service. A C2CSP will have approval from all States in which it intends to offer a service, including for overflight by an operator under contract. Global or regional agreements for C2CSP authorizations are encouraged.

4.4.2 Operational Risk Assessment

The ICAO defines safety as "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" [48]. This definition is focused on two aspects: risks and acceptable level. Obviously, they have their own meaning, but both are linked between them. The aviation system uses a predictive approach and, for this reason, requires the assessment of risks in ATM in order to minimize the probability and severity of hazards.

In the INVIRCAT CONOPS purpose, the operational risk assessment is meant as a tool used to describe the overall process aimed at:

- Identifying hazards and risk factors that have the potential to cause harm (hazard identification).
- Analysing and evaluating the risk associated with that hazards (risk evaluation).
- Determining appropriate ways to mitigate the hazards (mitigation).

A qualitative assessment is conducted based on a high-level risk assessment approach described in the figure below. Qualitative risk analysis describes risks using defined descriptive terms.

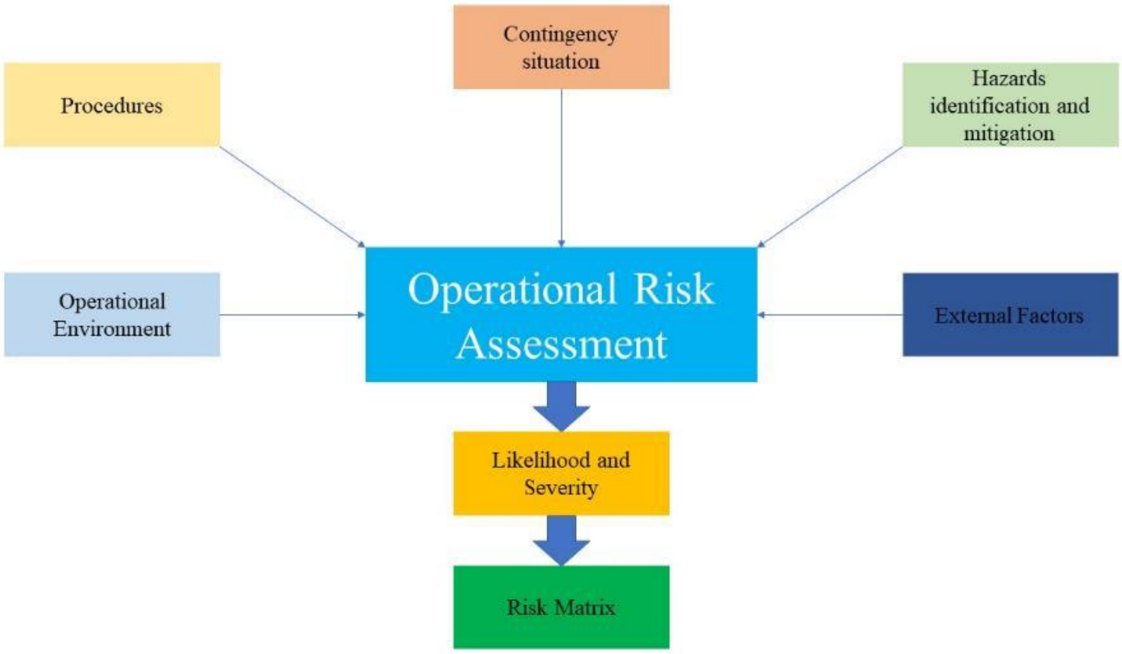


Figure 11: High-level risk assessment approach

A qualitative risk assessment foresees:

- A detailed description of the operational environment. All the elements of the operational environment have a vital role to ensure successful flight operations and maintain performance of the ATM network. The INVIRCAT project is targeting, the introduction of IFR RPAS class VI into TMA controlled airspace class A, B and C and airport (for further details please refer to section 4.1).
- A detailed description of procedures. This block refers to procedures of the whole ATM network including ATC (section 4.1.3) and standard operational procedures (section 4.2.4) followed by manned and unmanned aircraft during the execution of flight in nominal conditions considering all the flight phases foreseen in the INVIRCAT project.
- Identification of contingency situations. It is important to assess the ability of the new operational concept to work through (robustness), or at least recover from (resilience) any

contingency situation, external to the concept and not under control, that might be encountered relatively infrequently. In the INVIRCAT project, contingency situations such as propulsion failure, partial propulsion failure, ATOL failure, C2 link failure, transponder failure, radio voice communication failure, missed approach, conflict and fuel starvation are considered (for further details about the procedures and description of non-nominal use cases, please refer to D2.2 INVIRCAT Use cases and concept outline [3]).

- Identification of hazards. "*Before the risks associated with introduction of a change to the ATM System in a given environment of operations can be assessed, a systematic identification of the hazards shall be conducted*" [49]. In fact, a pre-condition for performing the safety assessment for the introduction of a new concept is to understand the impact it would have in the overall ATM risk picture. In the following section will be detailed the hazards related to the IFR RPAS and their mitigation.
- External factors identification (e.g. bad weather conditions, bird strikes etc.).

Qualitative risk assessment based on a risk matrix allows to determine safety risk tolerability. Table 9 presents a typical safety risk probability classification. It includes five categories to denote the probability related to an unsafe event or condition, the description of each category, and an assignment of a value to each category [50].

Table 9: Probability class used in the operational risk assessment

Likelihood Class	Qualitative
Frequent (5)	Likely to occur many times (has occurred frequently)
Occasional (4)	Likely to occur sometimes (has occurred infrequently)
Remote (3)	Unlikely to occur, but possible (has occurred rarely)
Improbable (2)	Very unlikely to occur (not known to have occurred)
Extremely Improbable (1)	Almost inconceivable that the event will occur

Unmanned aircraft system failures involve both aircraft and person (Table 10). The effects of catastrophic hazards involve multiple fatalities, loss of the aircraft or incapacitation of the flight crew. A hazardous event is one that involves a large reduction in safety margins, physical distress or a workload such that operational personnel cannot be relied upon to perform their tasks accurately or completely: a serious injury and a major equipment damage. A major hazard involves significant reduction of safety and a significant increase of workload for the crew to perform their task. A minor hazard involves no injuries for the people, a slight decrease of safety and a slight increase of workload for the crew to perform their task. Finally, "no safety effect" do not have effect on the people, safety and crew workload.

Table 10: Proposed hazard severity categories

Severity Category	Injuries	Safety	Crew workload
Catastrophic (A)	Aircraft or equipment destroyed / Multiple fatalities		
Hazardous (B)	Single fatality and/or Multiple serious injuries / Major equipment damage	Large decrease	Compromises safety
Major (C)	Non-serious injuries / Serious incident	Significant decrease	Significant increase
Minor (D)	None	Slight decrease	Slight increase
Negligible (E)	None	No effect	No effect

The combination of likelihood and severity generates the risk matrix, used to assign a risk level for each identified hazard.

Table 11: Risk Matrix

Safety Risk	Severity				
Probability	**Catastrophic (A)**	**Hazardous (B)**	**Major (C)**	**Minor (D)**	**Negligible (E)**
Frequent (5)	5A	5B	5C	5D	5E
Occasional (4)	4A	4B	4C	4D	4E
Remote (3)	3A	3B	3C	3D	3E
Improbable (2)	2A	2B	2C	2D	2E
Extremely improbable (1)	1A	1B	1C	1D	1E

The index obtained shall be exported to a safety risk tolerability table that describes the tolerability criteria. Safety risks are assessed as acceptable, tolerable or intolerable.

Table 12: Tolerability index

Safety Risk Description	Recommended Action
Intolerable	Take immediate action to mitigate the risk or stop the activity. Perform priority safety risk mitigation to ensure additional or enhanced preventative controls are in place to bring down the safety risk index to tolerable.
Tolerable	Can be tolerated based on the safety risk mitigation. It may require management decision to accept the risk.
Acceptable	Acceptable as is. No further safety risk mitigation required.

4.4.2.1 Identification of Hazards

The purpose of most safety-related systems is to mitigate the hazards (and associated risks) that are existing in the operational environment of the system concerned. These hazards are, therefore, not caused by the system – rather, the main purpose of introducing the system is to eliminate those hazards or at least maintain the associated risks at a tolerably low level.

For an ATM system the hazards and risks are generally those that are inherent in aviation and for which the main *raison d'être* of ATM is to provide as much mitigation as possible. The approach taken is to identify current hazards based on the assumptions that IFR RPAS performances are comparable to conventionally-manned aircraft. For this reason, the identification of hazards refers to hazards in TMA for manned aircraft and in addition some hazards are adopted for the case of RPAS.

Based on Guidance to Apply SESAR Safety Reference Material (Guidance E.2 suggested list of Pre-existing Hazards [51]), a list of hazards has been identified in TMA environment (Table 13).

Table 13: List of hazards

Hazard No.	Hazard	Hazard category
Hz#1	The intended trajectories of two or more aircraft (manned and unmanned) are in conflict	Loss of aircraft separation
Hz#2	The intended trajectory of an aircraft is in a conflict with terrain or an obstacle	Loss of ground separation
Hz#3	Penetration of unauthorized airspace	Infringement
Hz#4	Situation leading to wake vortex encounter (WVE)	Wake Vortex
Hz#5	Encounters with adverse weather	Adverse weather conditions

Hz#6	Situation in which there is an IFR RPAS partial failure or loss of navigation systems	IFR RPAS loss of navigation capability
Hz#7	Situation in which there is a loss of communication between the ATCO and RPIL	loss of communication
Hz#8	Situation in which the IFR RPAS loss command and control	C2L loss
Hz#9	Wrong read-back of ATC clearance	Clearance misunderstanding
Hz#10	Situation in which the handover between the RPILs would be affected by contingency situation	Handover in contingency
Hz#11	Data from CWP/GCS is delivered to late due to high-latency	Latency
Hz#12	Situation in which the aircraft (manned or unmanned) losses of transponder transmission	Loss of transponder transmission
Hz#13	Situation in which IFR RPAS unintentional/unsuccessful flight termination procedure	Flight Termination failure
Hz#14	Direct attacks on onboard data and code or through installation of toxic components. Sensors attack and security of command and control.	Security threats

4.4.2.2 Preliminary Operational Risk Assessment

This section provides a full set of a preliminary operational risk assessment evaluation. For each of the above-mentioned hazards will be assigned a combination of likelihood and severity which will determine whether a recommended action is needed based on the tolerability index:

Table 14: Preliminary Risk assessment

Hazard No.	Hazard Category	Severity /Likelihood	Mitigation mean	Class
Hz#1	Loss of aircraft separation	Catastrophic/ Extremely Improbable	ATC separation recovery, TCAS, DAA	1A
Hz#2	Loss of ground separation	Catastrophic/ Extremely Improbable	ATC separation recovery, TCAS	1A

Hz#3	Infringement	Minor/Improbable	ATC separation recovery, NOTAM	2D
Hz#4	Wake Vortex	Hazardous/Remote	ATC/RPIL recovery from wake vortex encounter	3B
Hz#5	Adverse weather conditions	Minor/Improbable	METAR, ATC instructions	2D
Hz#6	IFR RPAS loss of navigation capability	Hazardous/Improbable Remote	Termination procedure	3B
Hz#7	loss of communication	Major/Remote	Availability of other Communication means	3C
Hz#8	C2L loss	Hazardous/Remote	DAA, availability of termination procedure, increase of separation	3B
Hz#9	Clearance misunderstanding	Minor/Remote	CPDLC available	3D
Hz#10	Handover in contingency	Major/Improbable	RPIL takes back the control	2C
Hz#11	Data latency	Major/Remote	Redundant system to ensure services in minimum time	3C
Hz#12	Loss of transponder transmission	Hazardous/Extremely Improbable	Appropriate procedures designed for transponder malfunction	1B
Hz#13	Flight Termination failure	Catastrophic/ Extremely improbable	Identification of area of impact, Parachute	1A
Hz#14	Security threats	Major/ Improbable	Anti-spoofing system, Segregated network, regularly backup, anti-jamming system	2C

It is necessary to identify proper mitigation means that are procedures helping to reduce the hazard operational effects. For the above-mentioned Hz(s), operational mitigation strategies such as restriction on the flight over-populated area, provision of METeorological Aerodrome Report (METAR) and NOTAM, Air Traffic Control Service (ATCS) and other services are fundamental for obtaining operational approvals. Furthermore, mitigation technologies such as TCAS, DAA, ACAS and ATOL contribute to a remarkable reduction of hazard.

4.4.3 Contingency and Non-nominal Procedures

For contingency and abnormal situations that can happen to both manned aircraft and RPAS, procedures from manned aviation have to be taken over in order to generate the least impact on ATC and other airspace users. In contrast to manned aircraft, RPAS add a layer of complexity due to different levels of latency of the C2- as well as communication links to the procedures, that depend on the systems' architecture, as described in chapter 3.4.

The following subchapters will be limited to the introduction of contingency situations that are specific to RPAS and those known from manned aviation, that require special procedures for RPAS inside the TMA:

- ATOL failure
- C2 link failure
- Voice communication failure
- Missed approach

A detailed list of use cases and proposed procedures can be found in the published INVIRCAT deliverable D2.2 Use cases Definition and Concept Outline [3]. These procedures are mainly based on

- ICAO Doc 10019 Manual on RPAS [5]
- EUROCAE ED-281 MASPS for RPAS automation and emergency recovery [52]
- EUROCAE ED-283 MASPS for RPAS ATOL incl. updated OSED (superseding ED-252) [9]

as well as lessons learned from finalized and the collaboration with ongoing research projects within SESAR and other RPAS related research within the consortium, as outlined in Chapter 2.2.

4.4.3.1 ATOL Failure

In this CONOPS, as in [9], the ATOL system is considered Failure Operational, i.e. a single failure should not prevent the system from performing its operation. Therefore, ATOL occurrences (instead of ATOL failures) will be considered to evaluate contingency procedures. ATOL occurrences are defined in [9] as "any cause that prevents the ATOL capability from performing routine operations", i.e. automatic take-off or approach and landing.

Those causes can be intrinsic to the ATOL functions, i.e. effecting elements directly used to by ATOL function to automatically control the RPA (e.g. sensor fail, actuator fail), or external events preventing its normal use or supervision by the RPIL (e.g. landing gear failure, loss of communications link to ATC).

The appearance of any ATOL occurrences is monitored by a specific ATOL situation awareness function.

Depending on the flight phase in which an ATOL occurrence happens, one of the following contingency procedures could be required:

- Rejected Take-Off (RTO): a procedure performed during the take-off roll if the take-off shall not be continued (aircraft stays on the ground)

- Return-To-Base (RTB): a procedure performed during the take-off, if after v1, or the initial climb (ICL) if the flight shall not be continued

- go-around/missed approach (GA/MA): a procedure performed during the approach if the landing shall not be performed (this will be better described in 4.4.3.4)

As described in [3], these procedures can be executed automatically by the ATOL system or manually by the RPIL after the ATOL have reported the occurrence to him/her and, in some cases, the ATCO clearance.

4.4.3.2 C2 Link Failure

In general, RPAS should have system redundancies and independent functionality to ensure the overall safety and predictability of the system. The operator must develop detailed plans for all operations to mitigate the risk of collision with other aircraft and the risk posed to persons and property on the ground in the event the RPA experiences a lost link, needs to divert, or the flight needs to be terminated. These plans must take into consideration all airspace constructs and minimize risk to other aircraft by avoiding published airways, navigational aids, and congested areas. Contingency plans must address emergency recovery or flight termination of the RPA in the event of unrecoverable system failure. These plans should include the latitude/longitude of lost link loiter/ holding points (LLP), divert/contingency points (DCP), and Flight Termination Points (FTP) for each operation, together with graphical representations plotted on aviation charts. If the RPA requires a precautionary landing, consideration should be taken for the system requirements (e.g., navigation and/or communication) at the divert location [53].

The C2 link from the RPIL in the RPS to the RPA can be considered equivalent to the linkage between pilot and the control surfaces in a manned aircraft. If the C2 link is lost, the RPIL will be unable to maintain operational control of the RPA. There are many possible causes of a loss of C2 link between the RPS and RPA that include:

- Screening by terrain
- Weather interference
- Man-made interference, either unintentional (e.g., television broadcast) or malicious (e.g., jamming)
- Out of range
- Equipment failures on the RPA, in the RPS or the network (e.g., satellite)
- Human error in the RPS (frequency setting, switches)

In the event of a lost C2 link, the RPA should follow procedures and manoeuvres that have been pre-programmed prior to departure and coordinated with appropriate ATC facilities, to minimize their impact on ATC and other airspace users to the greatest extent possible. In all cases, the RPAS must be provided with a means of automatic recovery in the event of a lost link. There are many acceptable approaches to satisfy the requirement. The intent is to ensure airborne operations are predictable in the event of a lost link [46].

It is important to note, that a C2 link loss could occur for multiple RPA flying in the same airspace at a time (e.g. due to a satellite defect), triggering the same pre-programmed contingency procedures. In this situation the onboard DAA systems have to be able to maintain separation between the RPA, which will probably limit the number of RPA flying in an airspace, depending on the number of available loiter waypoints and the possibility for horizontal separation during the loiter procedures in case of a C2 link loss contingency. In addition, the flightpaths to enter these loiter points have to be well defined in order to mitigate possible conflicts of the aircraft. Following the PJ13 Sol. 111 OSED [54], any necessary evasive manoeuvres have to be triggered by the CA systems, as in airspaces A-C amended clearances from ATC are required before initiating any RWC manoeuvres.

4.4.3.3 Voice Communications Failure

Standard radio communication procedures for flights under Instrument Flight Rules according to ICAO Doc 4444 shall be followed in case of a loss of voice communication link between the RPIL and ATC. RPILs operating at or in the vicinity of controlled aerodromes must maintain two-way communication with ATC and acknowledge and comply with ATC instructions in the air and on the surface. They 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. [5]

When primary two-way radio communication with ATC has been lost, it is expected that the RPIL will attempt to establish an alternative means of communication. For operations at aerodromes, this alternative means of communication can be predetermined and standardized for all RPA Operators prior to operations being approved. This should preclude the need for traditional visual methods (i.e. light signals) of communication during RPA operations. ATC may elect to continue to use visual means to maintain the awareness of other aerodrome users. [5]

Loss of radio communications between the RPIL and ATC may or may not happen in conjunction with loss of control link. Regardless, it can be circumvented by use of alternative means of communication, i.e. telephone, to agree a course of action. Thus, in addition to ATC being provided with a telephone number for the RPIL via the flight plan, it should be a requirement for RPILs to hold the telephone numbers of duty supervisors (or as agreed upon) of the air traffic control units that are expected to provide an air traffic service to the RPA. A test call must be made to these numbers by ground handling operators within certain days prior to each individual flight.

4.4.3.4 Missed Approach

A missed approach requires the RPAS to abort its landing attempt. It can be triggered by the TWR ATCO or by the RPIL if any situation is detected that prevents the RPAS from performing an approach.

From [9], The Missed Approach (MA) begins at the Decision Height (DH) in precision approach and ends at the point at which a new approach, holding or return to en-route flight is initiated.

It is important to highlight that due to the assumption of IFR only operations, after a missed approach occurs, the RPAS cannot be cleared for any visual manoeuvres as e.g. a visual go around, or visual approaches during its second landing attempt.

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Appendix A Acronyms

Term	Definition
A-FUA	Advanced – Flexible Use of Airspace
ACAS	Airborne Collison Avoidance System
ACC	Area Control Centre
ACL	ATC Clearances Service
ACM	ATC Communications Management Service
ADS-B	Automatic Dependent Surveillance - Broadcast
ADS-C	Automatic dependent surveillance - Contract
AES	Aeronautical Earth Station
AH	Alert Height
AHRS	Attitude and Heading Reference System
AIP	Aeronautical Information Publication
AMC	Acceptable Means of Compliance
ANSP	Air Navigation Service Provider
AoR	Area of Responsibility
APP Exe. ATCO	Approach Executive Air Traffic Controller
APR	Approach
ASBU	Aviation System Block Upgrade
ASR	Air Surveillance Radar
ATC	Air Traffic Control
ATCO	Air Traffic Controller
ATCS	Air Traffic Control Service
ATFCM	Air Traffic Flow and Capacity Management
ATM	Air Traffic Management

ATOL	Automatic Take-Off and Landing
ATS	Air Traffic Service
ATSU	Air Traffic Services Unit
AU	Airspace User
BADA	Base of Aircraft Data
BLOS	Beyond Line-of-Sight
BRLOS	Beyond Radio Line-of-Sight
BVLOS	Beyond Visual Line-of-Sight
C2	Command and Control
CA	Collision Avoidance
CAA	Civil Aviation Authority
CDM	Collaborative Decision Making
CDTI	Cockpit Display of Traffic Information
CIRA	Centro Italiano Ricerche Aerospaziali (Italian Aerospace Research Centre)
CFIT	Controlled Flight Into Terrain
CLS	Calculated Level of Safety
CNS	Communication, Navigation and Surveillance
CNPC	Control and Non-Payload Communication
CPDLC	Controller Pilot Data Link Communications
CONOPS	Concept of Operations
CWP	Controller Working Position
DA	Decision Altitude
DAA	Detect and Avoid
DCL	Departure Clearance
DGPS	Differential Global Positioning System

DH	Decision Height
DLIC	Data Link Initiation Capability
DLR	Deutsches Zentrum für Luft- und Raumfahrt (German Aerospace Center)
DLS	Data Link Services
DMA	Dynamic mobile area
DME	Distance Measuring Equipment
DMZ	De-Militarized Zone
DOF	Degrees of Freedom
DSC	Downstream Clearance Service
DTA	DAA Terminal Area
DWC	DAA Well Clear
EASA	European Aviation Safety Agency
EAT	Estimated Approach Time
ECAC	European Civil Aviation Conference
ECAM	Electronic Centralized Aircraft Monitoring
EGNOS	European Geostationary Navigation Overlay Service
EMI	Electromagnetic Interference
ESC	Electronic Speed Controller
EVLOS	Extended Visual Line of Sight
FCC	Flight Control Computer
FDPS	Flight Data Processing system
FIS	Flight information service
FIS-B	Flight information service broadcast
FLARE	Flight Laboratory for Aeronautical REsearch
FMS	Flight management system

FPV	First-Person View
FSS	Fixed Satellite Service
FSTD	Flight Simulation Training Device
FTP	Flight Termination Points
GA	General Aviation
GAST	GBAS Approach Service Type
GAT	General Air Traffic
GBAS	Ground Based Augmentation System
GCS	Ground Control Station
GDPR	General Data Protection Regulation
GES	Ground Earth Station
GLS	GBAS Landing System
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HD	High Definition
HIL	Human-in-the-Loop
HMI	Human Machine Interface
HP	Holding Pattern
HW	Hardware
IAF	Initial Approach Fix
ICAO	International Civil Aviation Organization
ICL	Initial Climb
ICT	Information and Communication Technology
IEEE	Institute of Electrical and Electronics Engineers
IFF	Identification Friend or Foe

IFR	Instrument Flight Rules
ILS	Instrument Landing System
INVIRCAT	Investigation of IFR RPAS Control at Airports and in the TMA
I/O	Input/Output
ISF	Integrated Simulation Facility
LIDAR	Light Detection and Ranging
LPV	Localizer Performance with Vertical guidance
MA	Missed Approach
MALE	Medium altitude long endurance
MAS	Managed Airspace
MCM	Maintenance Control Manual
METAR	METeorological Aerodrome Report
MFD	Multi-Function Display
MLS	Microwave Landing System
MOPS	Minimum Operational Performance Specifications
MTOW	Maximum Take-Off Weight
MUST	Multi UAV Simulated Testbed
NAA	National Aviation Authority
NARSIM	NLR ATC Research SIMulator
NDB	Non-Directional Beacon
NLR	Nederlands Lucht- en Ruimtevaartcentrum (Netherlands Aerospace Centre)
NM	Network Manager
NOP	Network Operations Plan
NOTAM	Notice to Airmen
NPA	Notice of Proposed Amendment

OAT	Operational Air Traffic
OCD	Operational Concept Document
OSED	Operational Services and Environment Definitions
OTW	Out-the-Window
PA	Precision Approach
PAR	Precision Approach Radar
PBN	Performance Based Navigation
PFD	Primary Flight Display
PIC	Pilot in Command
PIO	Pilot-induced oscillation
PPS	Packets Per Second
PPS	Precise Positioning Service
PSR	Primary Surveillance Radar
R/T	Radio/Telephony
RAIM	Receiver Autonomous Integrity Monitoring
RCP	Required Communication Performance
RF	Radio Frequency
RLOS	Radio Line of Sight
RNAV	Area navigation
RNP	Required Navigation Performance
ROC	RPAS Operator Certificate
RPA	Remotely Piloted Aircraft
RPAS	Remotely Piloted Aircraft System
RPIL	Remote Pilot
RPS	Remote Pilot Station

RTB	Return to Base
RTO	Rejected take-off
RTS	Real Time Simulation
RWC	Remain Well Clear
SAA	Sense And Avoid
SARP	Standard And Recommended Practice
SATCOM	Satellite Communication
SBAS	Satellite Based Augmentation System
SCB	Stakeholder Consultation Body
SERA	Standardised European Rules of the Air
SESAR	Single European Sky ATM Research Programme
ShMem	Shared Memory
SID	Standard Instrument Departure
SIP	Structural Integrity Program
SiS	Signal in Space
SJU	SESAR Joint Undertaking (Agency of the European Commission)
SMR	Surface Movement Radars
SMS	Safety Management System
SPR	Safety Performance Requirements
SPS	Standard Positioning Service
SSR	Secondary Surveillance Radar
STAR	Standard Terminal Arrival Route
SVS	Synthetic Vision System
SW	Software
SWaP	Size, Weight, and Power

SWIM	System Wide Information Management
TAR	Terminal Approach Radar
TCAS	Traffic Alert and Collision Avoidance System
TCP	Transmission Control Protocol
TIS	Traffic Information System
TLS	Target Level of Safety
TMA	Terminal Manoeuvring Area
TRL	Technology Readiness Level
TSA	(Static) temporary restricted area
TWR	Tower
UAM	Urban Air Mobility
UAS	Unmanned Aircraft System
UHF	Ultra High Frequency
USP	U-Space/UTM Service Provider
UTC	Universal Time Coordinated
UTM	Unmanned Traffic Management
V&V	Verification & Validation
V1	Take-off Decision Speed for Multi Engine Aircraft
VFR	Visual Flight Rules
VHF	Very high frequency
VLD	Very Large Demonstration
VLL/VHL	Very Low Level/Very High Level
VLOS	Visual Line-of-Sight
VOIP	Voice Over Internet Protocol
VOR	VHF Omnidirectional Range

VR	Rotation Speed
VTOL	Vertical Take-Off and Landing
WAGE	Wide Area GPS Enhancements
WP	Work Package
WRC-15	World Radiocommunication Conference 2015
XPDR	Transponder

Appendix B Glossary of Terms

Term	Definition	Source of the Definition
ADS-B	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.	ICAO Doc 4444 PANS-ATM
AH	The alert height (AH) is a specified radio height for CAT III operations, based on the characteristics of the aeroplane and its fail-operational landing system. In operational use, if a failure occurred above the alert height in one of the redundant operational parts of the landing system in the aeroplane or relevant ground equipment, the approach would be discontinued and a go-around executed unless reversion to a higher decision height is possible. If a failure in one of the required redundant operational systems occurred below the alert height, it would be ignored and the approach continued	N/A
AoR	Area of Responsibility: An airspace of defined dimensions within which an ATC unit provides air traffic services.	EUROCONTROL ATM Lexicon
ATS surveillance system	A generic term meaning variously, ADS-B, PSR, SSR or any comparable ground-based system that enables the identification of aircraft.	ICAO RPAS CONOPS for international IFR Operations
BVLOS operation	Beyond visual line-of-sight (BVLOS) operation. An operation in which the remote pilot or RPA observer does not use visual reference to the remotely piloted aircraft in the conduct of flight	ICAO RPAS CONOPS for international IFR Operations
C2 Link	Command and Control Link: The datalink used for the purpose of command and control (C2) functions in an RPAS.	JARUS: RPAS Required C2 Performance (RLP) Concept

DAA	Detect and avoid (DAA): The capability to see, sense, or detect conflicting traffic or other hazards and take appropriate action.	ICAO RPAS CONOPS for international IFR Operations
Drone	Synonym for UAS. Any aircraft and related systems without a pilot on board, either remotely piloted or autonomous.	N/A
GCS	Ground Control Station: RPS are sometimes named Ground Control Stations (GCS)	JARUS: RPAS Required C2 Performance (RLP) Concept
Handover	The act of passing the control of an operation from a human operator to another. The handover could be executed between Air Traffic Control Officers (e.g. in the control transfer from one sector to another, or from ACC to APP controllers). Namely for RPAS operations, the handover refers to passing piloting control from one remote pilot station to another.	N/A
PA	A precision approach (PA) is an instrument approach and landing using precision lateral and vertical guidance with minima as determined by the category of operation, namely CAT I, CAT II, CAT III operations, each related to progressively reducing decision minima.	ICAO Annex 6: Operation of Aircraft, extended
RPA	Remotely Piloted Aircraft: An unmanned aircraft which is piloted from a remote pilot station.	ICAO Annex 2: Rules of the Air ICAO Doc 10019: Manual on Remotely Piloted Aircraft Systems (RPAS)
RPAS	Remotely Piloted Aircraft System: A set of configurable elements consisting of a remotely-piloted aircraft, its associated remote pilot station(s), the required command and control links and any other system elements as may be required, at any point during flight operation.	ICAO Cir 328
RPIL	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.	ICAO Doc 10019: Manual on Remotely Piloted Aircraft Systems (RPAS)

		JARUS: RPAS Required C2 Performance (RLP) Concept
RPS	Remote Pilot Station: The component of the remotely piloted aircraft system containing the equipment used to pilot the remotely piloted aircraft.	ICAO Doc 10019: Manual on Remotely Piloted Aircraft Systems (RPAS)
Segregated airspace	Airspace of specified dimensions allocated for exclusive use to a specific user(s).	ICAO RPAS CONOPS for international IFR Operations
TMA	Terminal Manoeuvring Area (TMA): Controlled airspace around an airport.	N/A
TWR ATCO	Tower Air Traffic Controller	N/A
UAS	Unmanned Aircraft System (UAS): Any aircraft and related systems without a pilot on board, either remotely piloted or autonomous.	N/A

Appendix C Additional Concepts and Considerations

C.1 Operational Environment

The operational environment differs for the types and classes of airspace it is located in. Thus, there is no common internationally agreed definition available. But there are some obligatory typical subjects that need to be referenced. A sample, maybe not comprehensive, of such subjects could look like:

Air Traffic Service is rendered to all IFR flights in controlled airspace of ICAO regions depending on the traffic demand, including separation and complexity management. For military IFR flight requiring special handling, the tactical control is available on demand and must be coordinated with respective ATS authorities civil and military. The transit service for military IFR flights should be seen as a holistic part of the ATM system providing services to the military cross-border IFR flights in controlled airspace. Such services also require specific CNC features to be eligible to receiving them. Also, national standards and laws are applied that potentially exempt or derogate such ICAO rules and contribute to the complexity of the operational environment.

Aircraft operations are conducted in accordance with Airspace User (AU) operational requirements in all classes of controlled airspace. Such operations own individual trajectories, that are following (nearly) identical trajectories or differ from flight to flight. Military IFR flights are subject to ATS provision and can be divided on two categories; military IFR flights compatible with ICAO provisions and non-compatible. From time duration perspectives military flights can be a long-haul transit IFR flights across an airspace and short transit flights flying into and from military training/exercise areas including CBA. This includes individual aircraft capabilities, depending on the individual type of aircraft. They consequently differ and pose a challenge on the management of the operational environment.

Aircraft capabilities allow airspace users to meet the requirements for airborne and ground operations. Military aircraft capability could significantly differ from civil one and often depend on the military aircraft type and equipment. Given the capabilities of military aircraft, the minimum requirements for aircraft equipment shall meet the military needs and guarantee safety of air traffic. These minimum military equipage requirements as well as procedures to obtain exemptions or derogations on these requirements are available in National Aeronautical Information Publications AIPs.

Free routing operations take place in low to medium complexity environments mainly in upper airspace. Flight Operations are not constrained by military activities due to efficient application of advanced flexible use of airspace principles. Flight planning for military flights will be a necessary condition to fly in FRA unless otherwise specified in national regulations. States may decide to retain tactical route network TACAN within the borders of the FRA.

The Network Manager (in European Airspace or an international equivalent) acts as a competent single body to coordinate the various network functions. The NM provides wide range of ATM services facilitating ATM network operations and optimizing the network performance. The NM maintains interface with the military operational stakeholders through civil-military cooperation and coordination.

Military Tactical Control applies when and where ATS provision is not possible/required due to the nature of the military operations in the volume of airspace under responsibility of the military authorities. Military tactical control should be perceived as the action of a qualified military controller in his / her area of responsibility (e.g. ARES, QRA), who guides a military aircraft towards a point (in time or space) where pilots take responsibility for carrying out a mission and / or continue monitoring the position of the aircraft providing flight information support.

EUROCONTROL proposes in the RPAS ATM CONOPS [1] the organization of RPAS traffic into seven classes and defines four types of RPAS operations. These are summarized in Table 15.

Table 15: RPAS types of operation and classes [1]

Altitude	Type of Operation	RPAS Classes
0-500 ft	Very Low Level operation (VLL)	I, II, III, IV
500 ft – FL600 (incl. airports)	IFR/VFR operation	V, VI
FL600 – 100 km	Very High Level operation (VHL)	VII
100 km and above	Space operation	VII

Excluding space operations, the three types of RPAS operations identified in are summarized below:

1. Very Low Level operations (VLL), which deal with operations below 500ft. Currently this environment is used by numerous operators such as the police, armed forces, gliders, fire-fighters and ultra-light aircraft. This category can be subdivided into the following sub-categories:

    a. Visual line-of-sight (VLOS): RP and RPA are in direct unaided visual contact and no further than 500 meters away.

    b. Extended visual line-of-sight (E-VLOS): when additional observers are present, the VLOS range can be extended.

    c. Beyond visual line-of-sight (B-VLOS): when neither RP nor RPA can maintain direct visual contact

2. Very High Level operations (VHL), which refer to suborbital unmanned flights, operating at altitudes above FL600. Currently this airspace is used by space rockets and the military.

3. IFR/VFR Operations, which refer to airports, TMA and en-route airspaces that the RPAS will be sharing with normal transport aircraft. This will require the RPA to meet certain minimum performance requirements with respect to speed, climb/descend rates, turn performance and communication latency. Because RPAS can have different shapes, sizes and performances, the classification proposed by EUROCONTROL in the ATM CONOPS [1] distinguishes between remotely piloted aircraft based on the flight rules, procedures and system capabilities of the RPAS and the operator during the flight. The seven classes are summarized below:

a. Class I: the "buy-and-fly" drones that are operated in VLOS and flown in low risk environments, staying clear of airports and other no-drone zones.

b. Class II: free flights (VLOS or BVLOS) either specific or certified category according to EASA

c. Class III: BVLOS medium/long-haul flights (free flight or structured commercial route). Either a specific RPAS, or one certified for longer routes.

d. Class IV: special operations (VLOS or BVLOS) by either specific or certified RPAS. This category is to be assessed on a case by case basis.

e. Class V: IFR/VFR operations outside the Network. The RPAS is not flying SID/STARs. Segregation will be enforced around airports for launch and recovery and manned aviation will not be impacted. No additional performance requirements to be imposed on the RPAS compared to manned aviation.

f. Class VI: IFR operations (Network/ TMA/ Airport operations) capable of flying SID/STARs. Manned transport aircraft capable to fly without a pilot, or new types that are able to meet the performance requirements of the Network, TMA and airports.

g. Class VII: IFR operations above FL600, involving the RPAS to transit through segregated / non-segregated airspace. Dedicated launch and recovery sites unless performance requirements of Class VI are met.

C.1.1 Civil Types of Operations

While the market and the number of civil operations involving smaller class of RPAS (cat. I-IV) at Very Low Level is growing fast, IFR/VFR operations (involving RPAS cat. V and VI between 500 ft and FL600) are still mostly of military nature. Nevertheless, as technology developed by the military becomes wider available and less costly and transfers to the civilian, a transition is expected to the civilian world (both commercial and not commercial) of these class of RPAS enabling a wide range of uses.

Table 16 below describes some of the most promising civil operations (both VLL and IFR/VFR) enabled by RPAS:

Table 16: Professional RPAS Market Sectors [55]

RPAS Market Sectors	Explanation
Aerial Photography, Audio-Visual Production, Advertising	Flight operations relative to the production of aerial imagery for educational & publicity & informational purposes.
Agriculture, Fishery/Pisciculture, Forestry	Flight operations relative to farming (crop cultivation & life stock breeding), inshore & offshore fishing, fish farming, tree cultivation.

Cinema & TV Industry	Flight operations for the cinema & TV industry relative to the production of feature & documentary films and the creation of special effects.
Construction & Real Estate	Flight operations for various purposes relative to all phases of construction & related promotional & sales activities. All applications except maintenance.
Entertainment & Artistic Expression	Flight operations for public entertainment purposes and for artistic expression.
Environmental Protection & Wildlife Conservation	Flight operations carried out with the purpose to contribute to maintaining or restoring the quality of the natural environment and protecting wildlife.
Flight Training/Instruction	Flight operations conducted by flight schools for the purpose of training/instruction of drone pilots (Duo & Solo Flights), qualification verification of pilot license holder (Check Flights) and flights conducted to maintain pilot competence.
Heritage Site & Historical Monument Management	Flight operations (incl. maintenance) relative to the conservation & documentation of historical sites & monuments.
Humanitarian Aid	Flight operations carried out within the context of natural & man-made disasters by or for non-governmental organisations (NGOs) with the purpose to assist people in need.
Insurance (Accident & Claim Investigation)	Flight operations by or for insurance companies.
Maintenance	Flight operations conducted for maintenance purposes [of aircraft (hull), antennae, breakwaters, bridges, buildings (internally & externally), cable cars, canals & locks, chimneys, cooling towers, dams, dikes, flare stacks, harbours, holding tanks, houses & buildings (thermal isolation mapping), industrial installations (e.g. power plants; refineries), infrastructure, objects, pipelines, power lines & pylons, quarries, railway cars, railway overhead power lines, railway tracks, rivers, roads & highways, roofs, runways, ships, shipping locks, ski slopes, solar farms, structures (incl. offshore platforms), tunnels, wind turbines].
Mining & Exploration	Flight operations related to exploration (incl. oil & gas), mining and quarry exploitation. All applications, except maintenance.

Miscellaneous – Demonstration	Flight operations conducted for regulatory (certification) authorities or potential customers.
Miscellaneous - Ferry/Positioning	Delivery flights for the purpose of returning a drone to its base of operations, delivering a new drone from its place of manufacture to its customer, flying a drone from one base of operations to another or flying a drone to or from a maintenance facility for repairs, overhaul or other work.
Miscellaneous - Air Show/Racing	Flight operation conducted within the context of a public air show or drone race.
News Gathering & Broadcasting	Flight operations carried out for journalistic purposes.
Policy Compliance & Obtaining Legal Proof	Flight missions conducted by international, regional or national governmental organisations (e.g. United Nations agencies, European Commission agencies, national agencies) or by contractors for such organisations, to verify compliance with specific policies and/or to obtain specific legal proof of non-compliance (e.g. International Criminal Court; illegal construction verification; non-respect of agricultural policies).
Public Safety	Flight operations conducted by or for civil protection/defence, emergency services, fire brigades & firefighting services, public services, rescue services and utility companies, relative to safety of the general public.
Public Security & Law Enforcement	Flight operations conducted by or for municipal, regional or state police, border guards, coast guard, custom authorities, harbour authorities.
Remote Operations – Sensing	Flight operations with drones equipped with imaging & non-imaging payloads for remote sensing purposes other than indicated in this list.
Remote Operations - Non-Sensing	Flight operations with drones equipped with non-imaging payloads, or without any payload, for specific purposes other than indicated in this list.
Research & Science	Flight operations conducted for private or public research or scientific purposes. Includes flight operations carried out for the purpose of testing, experimentation, or validation of new concepts and/or technologies for company internal assessment purposes.
Transport	Flight carried out for the carriage & delivery of goods or persons.

Utility Companies (Public & Private)	Corporate entity or governmental agency performing a public service subject to governmental regulation (e.g. communications, gas, railways, transportation, water, WIFI). All applications, except maintenance.

C.1.2 Military Types of Operations

Transit operations

Military unmanned aircraft (RPAS) need the ability to transit from one military operating base to another in order to change theatres of operation, deliver supplies to another location, or reach a designated military operating area. These operations will depart from airfields that are under military control or where military operate by agreement, on an IFR flight plan, enter Class A airspace, transit through Class A, and then exit Class A into upper or lower airspace (Figure 12). When operating under IFR within Class A airspace, it is assumed that Air Traffic Control (ATC) will be responsible for aircraft separation. This does not alleviate the responsibility of the RPIL to be able to sense and avoid (SAA) other airborne traffic. Additionally, the UA will be expected to meet equipment requirements associated with IFR operations, the UA will navigate along established airways or between established waypoints while communicating with ATC to change altitudes and dynamically route around severe weather and other hazards.

In addition to operations that will take place primarily in Class A airspace, there are RPAS operations that will transit through Class A airspace on their way to “Class E above A” (i.e. Above FL600 in U.S. NAS). This airspace is not consistently managed around the world, and efforts are underway to bring harmonization to the system. Because of the lack of consistency, it is important for military UA to be able to provide a SAA capability to the RPIL or an automated system if autonomous operations are planned.

A unique feature of RPAS is the capability to transfer control authority within the system (e.g. datalink radio station switch overs), between systems (e.g. one Ground Control Station [GCS] to another GCS), or simply between RPILs (e.g. RPIL transfer during long duration flights). The procedures for all these types of transfers must include clear guidance as to with whom the responsibility for SAA relies.

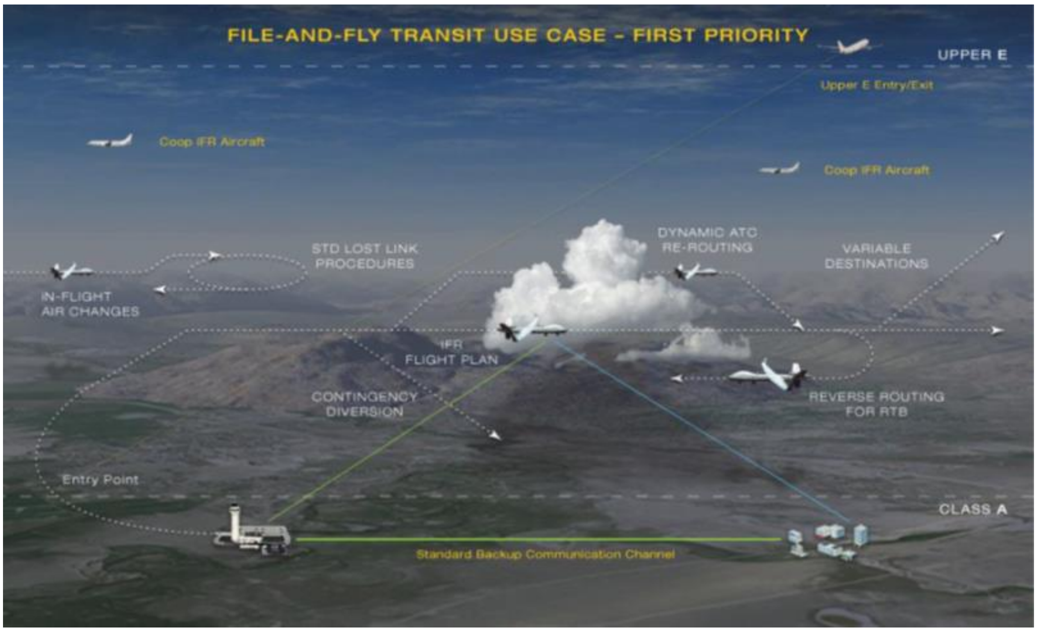

Figure 12: RPAS will "file and fly" under IFR in Controlled Airspace with the safety and operational flexibility of today's IFR operations [56]

The Transit use case is the most used operation by RPAS in controlled airspace under IFR without adding undue burden to the existing ATM system and with the least impact to other airspace users. Furthermore, transiting through Class A airspace is the foundational building block of all operational concepts and use cases for other airspace categories.

The Transit use case is also consistent with military UA desire to operate internationally. While work remains to define the responsibilities of a RPIL and a remote pilot in command (PIC), it is necessary to consider how autonomous operation by military UA might affect the civil airspace management system. Certified SAA systems will ease concerns expressed by air navigation service providers (ANSPs) and the manned aircraft community. Certified C2 Datalinks will reduce the occurrence of cases such as loss of C2 Link while standardized procedures for loss of C2 link events will ensure the contingency becomes a predictable, repeatable, safe, and efficient event.

Local Area Operations

The type of missions that have historically characterized the military applications of RPAS are being labelled in the civil community as "local area operations" and represent perhaps the most prevalent use of military RPAS to date. This is to differentiate flight profiles that don't look like typical IFR flight paths (i.e., point-to-point). Some examples include loitering and search patterns, which are routinely conducted under VFR in controlled and uncontrolled airspace with manned aircraft today. Figure 13 illustrates this use case. One concept for implementation would be the desire of the RPAS operator to be able to file a flight plan and designate a volume of airspace to conduct the operation and have the RPIL be responsible for SAA within that volume of airspace. Once established inside the lateral boundaries, vertical boundaries, and time limits of the desired airspace volume, ATC would still separate traffic from the area, but the RPIL would have responsibility for avoiding intruders or other traffic admitted to the airspace (i.e. a second RPA). The RPAS would be free to move within the defined volume, subject to ATC intervention if necessary, to address safety or other operational priorities, and the RPIL could be able to dynamically request extensions to areas based on size or time and new areas based on changing mission requirements.

As in the Transit use case, many transfers of authority could occur during a Local Area of Operation flight. Where this does not occur in military controlled airspace/operating areas, it will be necessary to coordinate separation responsibilities with ATC.

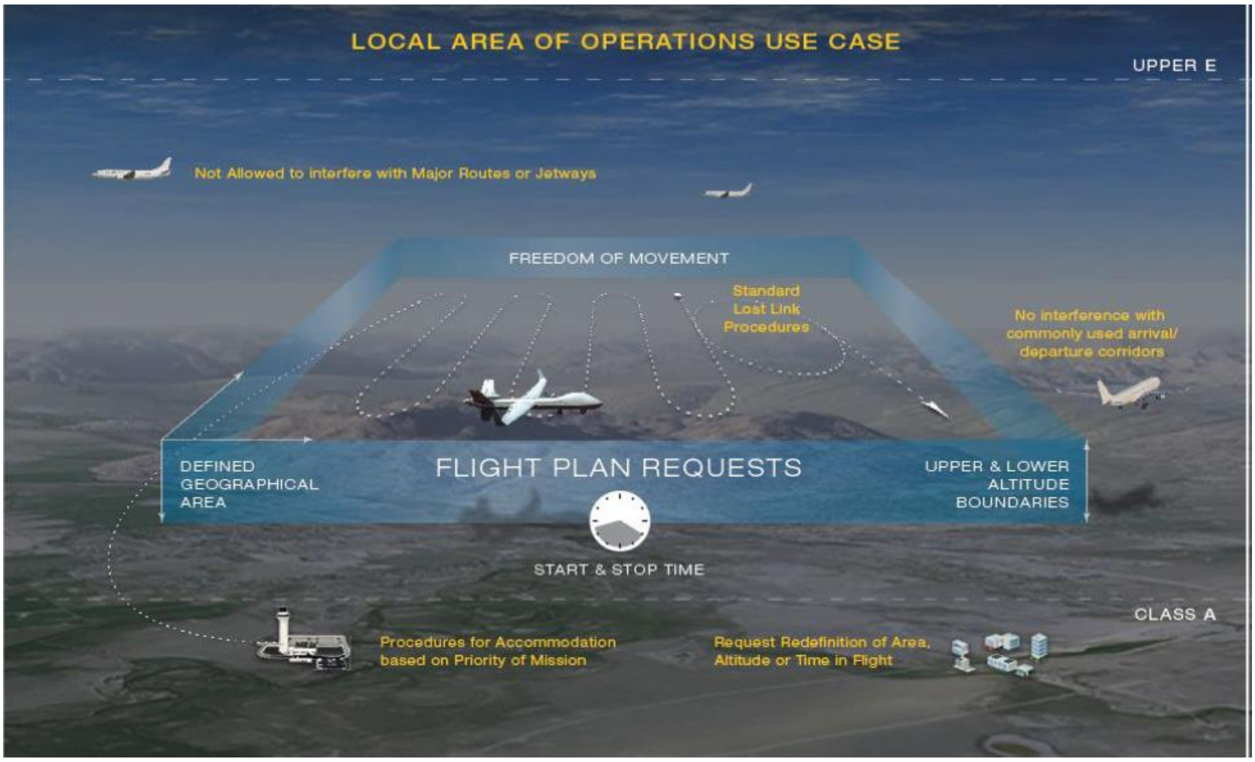

Figure 13: The unique capabilities of today's long-endurance RPAS are best utilized in Local Area Operations under IFR [56]

Another example of a local area operation would be similar to that in Figure 14. Manned Local Area Operations are conducted today both below and within Class A airspace. Such an operation in a manned aircraft today would be conducted, weather permitting, under VFR, but if done by a RPAS, then this operation will have to be integrated into the IFR system. Local Area Operations in Class A are required to be performed under IFR. By extending existing performance-based navigation (PBN) standards and concepts, such as Required Navigation Performance (RNP) and integrated Trajectory Based Operations, ATC will have options when determining separation and service strategies for Local Area of Operations missions. Separation from the Local Area Operations airspace volume significantly simplifies both the RPAS operations and amount of communication needed between ATC and the RPIL; however, it may be a less efficient use of airspace. The balance between these competing values must be determined based on time and location.

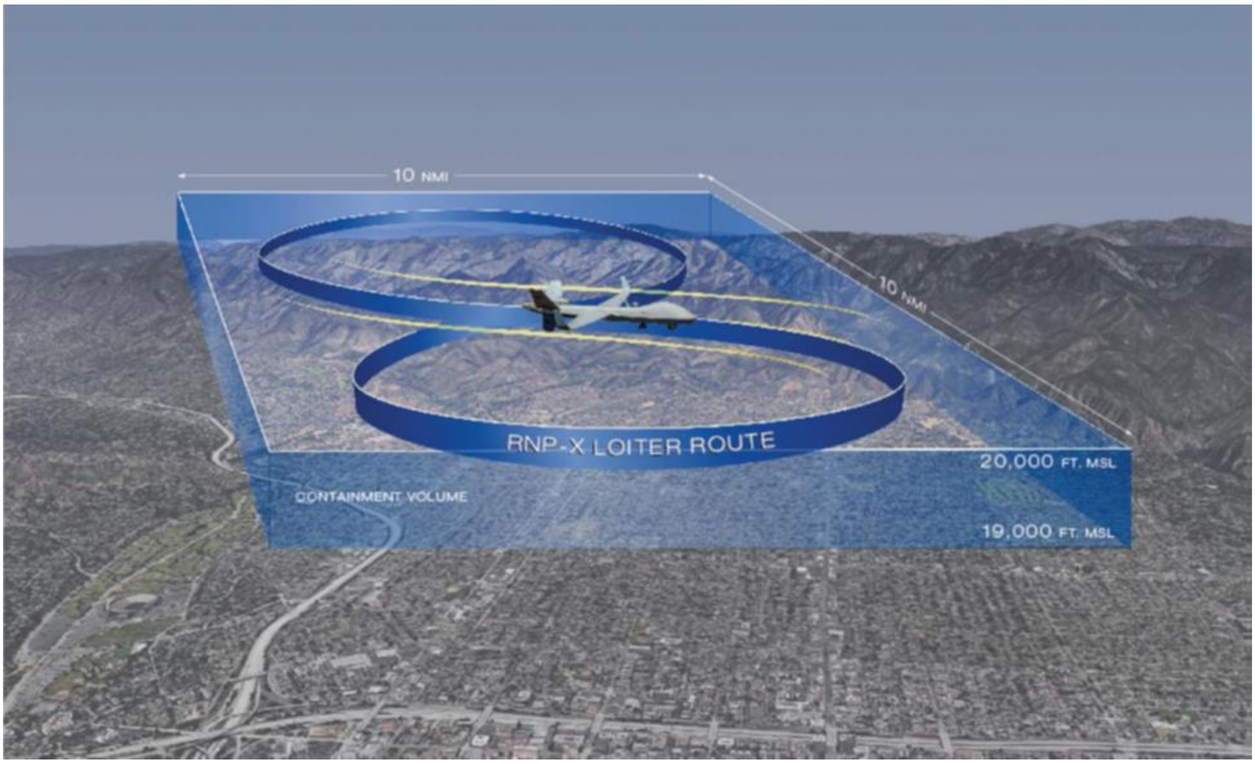

Figure 14: Application of existing PBN standards to new procedures, could enable Local Area of Operations being integrated into the IFR system [56]

When either of these types of operations are executed in airspace above Class A, the RPAS will need to have an SAA capability to detect a wide variety of airborne systems. There is tremendous pressure to establish operations in what has typically been airspace dominated by military technology. From civil supersonic aircraft to balloons and solar aircraft that have almost no forward airspeed at times, the challenge to maintain safe separation between those aircraft will continue to grow and there is no clear path for ANSPs to start providing that service. Until there are civil options for separation services, it will remain the responsibility of the military aircraft to avoid civil assets, both manned and unmanned.

C.2 Airport Infrastructure Aspects

The RPAS industry is still in the early stages of integration and widespread commercial operations from airports are still believed to be years away. Some airports are actively pursuing RPAS business, and others are energetically engaged in research efforts with universities. A smaller number of airports that share runways with military airfields are actually supporting RPAS operations while commercial air carriers transport passengers to and from their civil terminals.

C.2.1 Airport Involvement

The speed of advancement in the RPAS community is not slowing. The airport industry is looking into the future and has a view of what is ahead. Through education and research, the airport industry will be ready to attract RPAS business to their facilities and be prepared when the opportunity to support RPAS companies arises. Although the accommodation and integration of RPAS into the non - segregated airspace is evident, airports are not directly affected, but airports do not exist in a vacuum; what happens in the skies directly above impacts facilities and runways on the ground.

As each airport is unique, so is each unmanned system. Every RPAS has its own capabilities, nuances, and requirements. Each system needs to be analysed separately, looking at vehicle size, vehicle performance, operator qualifications, operating procedures, and emergency profiles/procedures. Most of these are addressed during RPAS certification, and may or may not be of concern to the airport operator. However, it will help the airport operator to understand the capabilities and restrictions of the systems so that challenges can be addressed proactively.

In general, large RPAS can require the use of runways and taxiways and operate in a manner similar to manned aircraft. Many large RPAS move about the airport like a manned aircraft, they require ramp space and hangar space, and fly in the same airspace. Unlike manned aircraft, RPAS need a ground control facility from which the pilot communicates with and flies the aircraft. A number of RPAS types also require more direct monitoring and control while in the movement area or flying in the airspace in order to maintain separation with other aircraft.

Basically, there are two types of airports, those who are already used by manned aviation and those who are solely designed to serve RPAS operations. The latter have already been developed around the world, serving the Military at various locations for various purposes. This type of airports will not be addressed here. The focus will be on airports already used for manned aviation where RPAS operations need to be integrated, addressing (mainly) towered large international airports.

C.2.2 Airports for Manned Aviation

Ongoing financial, environmental and political adjustments have shifted the role of large international airports. Many airports are expanding from a narrow concentration on operating as transportation centres to becoming regional economic hubs. Consequently, the evolving dissemination of RPAS into airport infrastructure addresses not only operational and technical aspects but should involve economic and scientific involvement from the start. Many types of physical infrastructure should be in place to enable airports to meet these new dual roles of transportation hub and regional economic facilitator. These hard or economic infrastructures include large scale installations that connect and service commercial, industrial, residential, and cultural nodes of the region. Typical elements are roads, railways, utilities, ports, airports, freight and service interchanges, and of increasing importance, information and communication technology (ICT) – collectively, these provide the basis around which development is clustered and connected. Hard infrastructure provides the traditional network connectivity between the airport and the surrounding region.

There are two overarching considerations that stakeholders would be well served by addressing when developing the airport RPAS vision. First, the airport should consider the types of RPAS that can be expected and the number of operations anticipated. Second, the airport should determine the facilities necessary and currently available for RPAS activities, including a communications infrastructure. Both of these considerations will likely have major impacts on attracting and maintaining revenue streams from RPAS activities.

C.2.3 Types of RPAS

The type of RPAS operating from the airport will likely drive the possible revenue streams. Larger RPAS that require runways, ramps, and hangar space are likely to provide more opportunity for revenue to the airport and the surrounding community. The larger RPAS will utilize more facilities and require more support than smaller RPAS. Many small RPAS are hand or truck launched and considered airport independent. While small system operators may desire to use an airport as a base of operations, their independence can limit the potential for increased revenue to the airport and the community.

The operational requirements for runway dependent RPAS vary from system to system. Airport planners and operations personnel will need to understand the system requirements prior to commencing the planning for operations.

C.2.4 Ground Infrastructure

The operation of RPAS will be conducted from ground-based facilities. These facilities can vary from small mobile units to elaborate, interconnected, global systems. Security requirements for these controlling facilities will need to be developed. Applying appropriate security measures for large centralized operations would presumably be easier than for the small, mobile facilities. Apart from the RPAS control facility, the communication infrastructure will need to have redundancies and alternate paths. The risks to implementation are low because the technology needed to secure physical facilities is well known. The cost of implementing security measures will likely be a big challenge. This becomes a more complex issue as the control functions and infrastructure of some ground operations may be distributed in various locations locally, regionally and around the world. The amount of security applied to the ground control facility will depend on the size of the RPA, the airspace being used, and the missions being flown. For large operations that may be controlling multiple vehicles from one site and that are networked with other facilities will require a much higher degree of security than a single control station responsible for a moderate to small size vehicle.

Airports today have either fully utilized facilities or are looking to remove or transform existing, older facilities. But new investment is often hard to come by and therefore new facilities that could be available for immediate RPAS use are equally hard to establish. The airport operator should understand and plan for what facilities are now available for unmanned systems, or facilities that may be repurposed in their use. Examples include:

- Vacant hangars (even general aviation T-hangars might serve a RPAS purpose)
- Vacant office space
- Industrial park space adjacent or in close proximity to airport property
- Vacant operational space (perhaps an available communications centre left by an air cargo operator)
- Ramp space
- Vacant land that is planned for or has airfield access
- Utility capacity (e.g., water, sewer, electrical power, natural gas, and fuel access)

RPS may also require on-site storage (hangar capacity). The operators of the larger RPAS are often relatively self-sufficient, utilizing vehicles and mobile control stations that can be located within the hangars. There may not be a need to provide a special control room or centre for RPAS operations in a new facility. All of these types of facilities or property might have a purpose for RPAS operations. With little or no investment, they could provide the airport with an attractive environment for a RPAS operator. The airport operator should know what they have and what it might take to put the assets to use for RPAS operations.

C.2.5 Air Traffic Management

Future RPAS designs and capabilities will vary widely and their performance characteristics will differ significantly from those of manned aircraft. Many will fly slowly and lack manoeuvrability while others will operate at very high speeds with great agility. Sophistication will vary among vehicles, from those having high Levels of Automation flight controls to those requiring more direct pilot inputs. Further, the types of missions being planned for RPAS are rarely point-to-point, but typically involve some form of patterned flight or tracking activity that may include intermittent short- or long-term orbits. Endurance will last from hours to months depending on the vehicle and mission. Taken together, these variations have the potential to significantly affect air traffic operations also at airports, e.g. opening times vs noise abatement etc. To accommodate RPAS, operational procedures are required to enable consistent handling by RPA pilots and ATC. The ATM system, too, will need to be adequately structured to manage the additional complexity related to the rise of RPAS. The extent of RPAS impacts on air traffic management will be dictated as much by RPA performance as by market developments. Some RPAS are clearly more capable of fitting within the existing environment than others, but the market will ultimately determine the number and type that are present in the system.

The varied vehicle performance and flight characteristic of RPA may prove challenging to air traffic service providers and their supporting systems. Because so few RPA have interacted with the air traffic system to date, it is difficult to predict their impacts, aggregating uncertainty of a specific technical challenge, as some RPA may be unable to climb and manoeuvre along designated IFR departure, arrival and approach routes (STAR and SID) within the designed and approved parameters of those procedures. As a result, some RPA, particularly the low-performance variants, may require exclusion from particular published routes or airspace, or may require the development of specific routes or procedures that consider the unique performance characteristics of those RPA. It is clear that many RPAs will not be using traditional flight procedures, given the unique mission and take - off/landing sites that manned aviation uses.

C.2.6 Controller Impacts

Controller roles may also be affected by RPAS operations although, in instances where controllers have handled RPAs to date, the procedures and communications were transparent; most were not aware they were controlling an RPA, if not so indicated in the flight plan. This has at least been the case with the larger, sophisticated RPAs that operate within manned aircraft performance parameters, however this may not be the case for other RPA that are typically slower, cannot perform standard rate turns at altitude, and may be unable to climb or descend at rates familiar to controllers.

Because RPAS exhibit unique performance and capability issues, they would likely require specialized notification or treatment by a controller and therefore require a special designation in the flight plan and/or on the controller display. This may entail modifications to existing air traffic radar symbols and require changes to the ATC and Flight Data Processing system (FDPS).

Dealing with mixed RPAS/manned aircraft operations will present one of the greatest challenges to the air traffic management system. Many aircraft, manned and unmanned, will be employing advanced avionics to permit more accurate and predictable flights, but there will also be RPAS and manned aircraft having less capable systems. This difficulty will be made more complex as ground-based air traffic decision aids and RPAS airborne systems each seek to evaluate the environment and plan for movements that may not align with the ground systems or other aircraft in the vicinity. Studies and simulations will be required to demonstrate safe operating concepts of these mixed operations [57].

Contingency and emergency procedures will also need to be understood by controllers in case of lost communications or if an aircraft malfunction affects a change in the planned route. The procedures to be taken by the aircraft will need to be communicated or predictable to the controller. This is especially important if either the communications link or the command and control link to the RPA are lost.

C.2.7 Surface Operations

Current RPAS operations in civil airspace are confined to take-offs and landings in restricted airspace, typically from military controlled airfields. Some proposals suggest that civil and commercial RPAS operations, if permitted access to surrounding airspace, will increasingly make use of public airports, primarily to those currently serving only general aviation. Such operations may create issues for existing manned operations, particularly at the smaller towered and uncontrolled airports, though it is anticipated that most initial RPAS operations at airports are assumed to be scheduled during non-peak times to avoid mingling with manned aircraft operations. Taxiing to and from a runway will require precise ground movements and the ability to search for other aircraft or obstacles (e.g., animals, snow banks, construction vehicles) that may be on or near the apron or taxiways. Most RPAS today operating at airports do not have this capability and therefore require being towed to the runway. However, future RPAS will likely be able to taxi via remote control or highly automated. Consideration will be needed concerning airport infrastructure to accommodate secured communication/control and power generation backup facilities, as well as vehicle storage facilities. Further, special Navaids, such as Differential GPS (DGPS) or laser guidance, may be used at airports to assist in precision landings and take - offs, as well as for taxiing on the airport surface. And some RPAS may be unable to fly airfield pattern landings but must instead perform straight in approaches. If changes to existing airport operations are significant enough, there may be special certification requirements and/or training for RPAS operators, tower controllers, and possibly even pilots who operate into and out of airports where RPAS operations take place. New airport procedures may also be needed to handle normal as well as emergency RPAS operations. Optical sensors, DGPS, ADS-B, taxiway-embedded induction sensors, and other technologies are currently being looked at as potential guidance mechanisms for both manned and unmanned aircraft to assist in situational awareness during taxi operations. These technologies may lessen any potential impacts of RPAs on airport operations.

There is still a need to define standard operating procedures for RPAS surface operations at an airport to ensure the safety of others using the facility. RPAS will need to consider the possible inability of their vehicles and its operators to see or read surface marking in the same manner as manned aircraft. For Europe the issue of RPAS on airport surfaces to be studied by the European Group of Airport Safety Regulators (GASR) has been recommended.

Initial surface operations questions

The considerations for infrastructure requirements should start with some basic questions from the airport to the RPAS operator:

- Does the RPA need a runway for take - off, landing, or both? If so, what runway length and width is required?
- Can the RPA taxi to/from the runway and follow ATC commands and other voice commands?
- Does the RPA need hangar space when not flying?
- Does the RPA need ramp space prior to or after flight?
- What sort of control station is required (truck, trailer, office space, etc.)?
- Does the RPA need termination areas? If so, how close to the airport does this space need to be?
- What sort of communications infrastructure is needed? Does the RPAS operator need special towers of antennas in order to ensure communications are established and maintained with the RPAS?

- Will the required communication frequencies create conflicts? Will they interfere with existing frequencies used by airport staff, tenants, airlines, fixed base operators, or others?
- Will the RPAS need special emergency standby equipment? Is it available at the airport or does it need to be brought in from an outside source? As an example, a large general aviation airport might need to bring in a local fire department truck to standby for RPAS operations as a matter of protocol.

C.2.8 Airport Requirements

For the RPAS operator it is mandatory to better understand the ground facilities available to its RPA. It has been proven to have a checklist at hand to analyse whether that facilities conform the needs of the RPAS. An example:

- Communication requirements to include radio frequencies
- Data collection and storage
- Hangar space or aircraft storage space
- Ramp space and aircraft preparation areas
- Runway use and length requirements (to include time required on the runway prior to take - off)
- Launch areas (if different from a runway)
- Recovery areas (if different from a runway)
- Ground control station space (office space or mobile office space)
- Ground support equipment area (equipment space necessary within close proximity to the RPAS launch site or runway end)
- Fuel type and storage requirements
- Maintenance and parts storage areas
- Classroom and briefing space

C.2.9 Lessons Learned from Airports That Are Already Facilitating RPAS Operations

The following experience-based outcomes of RPAS operations at several civil and civil / military airports from the US were collected by airport operators (no priority and importance order):

- Use all available resources to ensure traffic separation and safety
- Familiarize ATC
- Get confidence in lost link procedures and holding locations and Lost link loiter point planning
- Prepare specialized power and ground procedures
- Line-of-sight ground communications (Communications antenna placement on the airport is an important factor in safely taxiing some unmanned systems)
- Division of airspace (The only time complete segregation of aircraft was required was when the RPAS aircraft was on the runway. Otherwise, aircraft could come and go from the airport and separation was to be managed by ATC)
- Airfield education for RPAS maintenance personnel, enhancing Situational Awareness (SA)
- Standard operating procedures and airfield doctrine,
- Use of NOTAM to the highest extend necessary
- Regular and frequent coordination meetings

- Airline-RPAS schedule deconfliction
- Develop specific RPAS ground operations deconflicted from those of manned aviation where needed

From military operations the following experiences should be considered:

- Frequency Management Coordination. The RQ-4D uses data links with several frequencies, across several bands. The RQ-4D ground and air segments will operate only within the predesignated Radio Frequency (RF) spectrum in accordance with NATO frequency management guidelines and will only transmit on frequencies approved by national authorities.

  Hence, some RPAS may require data links with several frequencies across several bands, and these frequencies have to be managed accordingly and carefully.
- Restricted Aircraft Access. The preferred method of aircraft storage is within a NATO Class II (protected) equivalent hangar with access control. If this cannot be provided, aircraft may be located within a clearly defined and protected perimeter through which all entry and exit is controlled (i.e. elevated ropes and stanchions, fence, or moveable barriers). It should be monitored and recorded by 24/7 CCTV-footage, if available, for NAGSF SF viewing with host security element. Restricted Area signage in English and host nation languages should be posted at entry control points, along the exterior of the hangars, aprons, parking areas, and clear zones.

  Especially for military operations some RPAS may require access control, which can pose challenges to the airport. Protected perimeters with surveillance might be necessary, even if only temporary.

C.3 C2 link considerations

C.3.1 Stakeholders

The following paragraphs list the roles of the stakeholders involved in providing and regulating the performance of the C2 link.

RPAS operator/manufacturer

The concept of C2 link RCP is based on the expected communication performance of all relevant communication capabilities used to support RPAS C2 functions. There is an obligation on designers/manufacturers of RPAS and RPAS operators to achieve the communication performance for a specific C2-RCP type. This includes equipage performance and corresponding training. The designer/manufacturer of the RPAS must provide the operator with details of the C2-RCP(s), which is/are required to operate safely in each environment.

C2 Link Communication Service Provider

The C2 Link Communications Service Provider (C2-CSP) can be internal or external to the operator. The C2-CSP must provide the expected performance through the appropriate legal contracting means to provide the expected performance. C2-CSP must inform the RPAS operator in due time of any expected or current communication performance degradation outside of the C2 link RCP type parameters.

The equipment and associated specifications necessary to enable the C2 link between the RPS and RPA are considered components of the RPAS, whereas the provision of a third-party C2-CSP is not. The transmitters and receivers used by data link service providers may be distributed in different States and belong to a single entity or be shared by others. When some of the components are controlled by a C2-CSP, the C2-CSP must be under the safety and security oversight of a civil aviation authority or other competent authority of a State. Alternatively, the RPAS operator must ensure that the C2-CSP and the corresponding C2 link service provision is in accordance with the safety management system approved by the State of the operator. [7]

It must also be recognized that the C2 Link service provider will likely support multiple operators and aircraft. This introduces a potential failure element within shared C2 systems and thus the challenge to mitigate the consequences of the loss of the C2 link when involving more than a single aircraft. [7]

The State

The State will impose requirements in case of the RPAS operator uses a RPAS C2 Communications Service Provider, since the C2 link Required Communication Performance (RCP) is a statement of required capability and of operational communication performance. If an RPAS operator uses a communications service provider (C2-CSP) for any element of the C2 service, there is an obligation on the part of the State to have oversight of the capability of the communication service to achieve the required level of safety and maintain the required communication performance. The State must ensure that changes to services that rely on communication performance within a given airspace maintain the safety levels and must ensure that communication service providers intending to support RPAS operators with a mandated C2 link RCP type are qualified and approved for such operations [58].

It should be noted that compliance with a C2 link RCP type can be achieved in many ways, and the State may provide guidance on acceptable means through which the communications service provider and the RPAS operator can demonstrate how C2 link RCP is achieved.

Monitoring communication performance

Monitoring provides objective operational data to determine that the C2 communication service provider continues to meet the C2 link RCP type. Monitoring includes data collection on a routine basis and as problems or abnormalities arise.

Monitoring is performed by organizations in control of or responsible for a component of the communication system in operation. Authorities shall oversee the monitoring processes to avoid any conflict of interest.

C.3.2 Spectrum

Appropriately allocated frequency bands for the provision of an aeronautical safety service will be used for the provision of the C2 link. An example of such a frequency band is 5 030 – 5 091 MHz. This band is allocated to the aeronautical mobile route service (AM(R)S) and the aeronautical mobile satellite route service (AMS(R)S) and may be used for provision of both the terrestrial and the satellite C2 link. Systems providing satellite services are not available in this band at present, however the feasibility of launching such a system is currently being studied [7]. FSS (Fixed Satellite Service) systems are designed to give each user a dedicated Channels for permanent use but is restricted to stations at fixed points. FSS is a radiocommunication service between earth stations at given positions, when one or more satellites are used; the given position may be a specified fixed point or any fixed point within specified areas; in some cases, this service includes satellite-to-satellite links, which may also be operated in the inter-satellite service; the fixed-satellite service may also include feeder links for other space radiocommunication services.

A few frequency bands in the fixed satellite service (FSS) are also being considered for the provision of the C2 link. The FSS has an abundance of satellite networks, however the radio regulatory conditions governing the use of these frequency bands are not comparable to those for frequency bands traditionally considered appropriate for the provision of aeronautical or other safety critical links.

The ITU World Radiocommunication Conference 2015 (WRC-15) developed Resolution 155, allocating the FSS for use by the RPAS control and non-payload communications (CNPC) conditional to several specific conditions. These conditions will require further work within ITU and ICAO in defining the required technical characteristics for the space and earth stations, the interference environment within which they will be required to operate and the required performance of the C2 link. The allocation of the FSS will be reviewed again by ITU WRC-23 (in 2023) to finalize any supporting radio regulatory provisions required.

ICAO provisions for C2 link spectrum use will need to consider aeronautical safety implications due to potential link outages as well as data transmission latency, integrity, and security. A risk-based approach to C2 link approval may be considered. Additionally, there may be a need to manage frequency assignments for the C2 link, especially in areas where large numbers of RPAS operations are expected to take place.

C.3.3 Security

The security of the data exchange between the RPA and RPS will need to be specified in technical standards to address vulnerabilities and associated mitigations. Security requirements need to be internationally harmonized and be a multi- level consideration. Many aspects are like manned aviation (e.g., physical security).

The link message security will need an authentication, integrity, and confidentiality; therefore, an end-to-end encryption can provide adequate protection.

Considering the C2 link RF (Radio Frequency) security, there are methods to protect the RF, but is impractical to completely protect the C2 RF signal. Therefore, Lost C2 procedure and ATC procedures will be required to handle lost C2 link.

C.4 FAA UAS Traffic Management (UTM) Concept

In a similar manner to U-space, the FAA UTM concept [59] describes two key elements to enable RPAS operations in controlled airspace.

On the hand side, all UTM operations that are planned to be operated within controlled airspace (Class B/C/D/E surface) are required to obtain FAA authorization prior to entering controlled airspace. This authorization is referred to as Airspace Authorization. Hereby, the FAA grants access to the UTM operation to enter controlled airspace, and provides all the required information of the UTM to the responsible Air Traffic facility (e.g. Air Traffic Control, Airport Tower). This information includes (but is not limited to) remote identification (RID) of UAS Operator as well as operated vehicle, planned 4D trajectory and time period (i.e. date and timeslot). An airspace authorization is typically granted for of period of time (less than 24h). UTM operators can apply for airspace authorization via FAA systems or UAS service suppliers (USS), which still have to be developed and become operational.

On the other hand, the FAA UTM concept is based on the paradigm that UTM operations are required to obtain Performance Authorization for each airspace class, in which they substantiate their ability to meet flight performance capabilities in their intended area of operation. The aim is to ensure the credibility, stability, uniformity, and accountability of UTM operations for any given airspace class. In order to obtain performance authorization, the UTM operator is obliged to submit a Performance Authorization Request to the FAA for assessment. Hereby, the operator has to establish the compliance of the overall system (e.g. air & ground assets, personnel, training, insurances, etc.) and associated capabilities to comply with performance standards required for the intended area of operation. As an example, the FAA evaluates each request with regards to the CNS capabilities of the UTM operations. However, for low risk operators (e.g. VLOS, rural area) the UTM operator is able to self-declare the compliance to the performance standards. In the end, the FAA grants a Performance Authorization only if the performance standards can be achieved by the UTM operations.

C.5 Operational Considerations VLOS/BVLOS

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

For operations from established aerodromes, the RPIL 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.

For operations from other than established aerodromes, the RPIL 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. [5]

RPAS operating internationally must comply with the framework regulations and requirements defined under the Convention on International Civil Aviation. At the highest level, this means that:

- RPAS operator must have obtained special authorization from all affected States;
- RPA must be so controlled as to obviate danger to civil aircraft;
- RPAS operators must hold an RPAS operator certificate;
- RPA must hold a valid certificate of airworthiness, issued against the approved type design (as recorded in the type certificate);

- RPA must meet the communications, navigations and surveillance (CNS) requirements for the airspace in which it flies;
- flight crew (RPIL(s)) must hold valid licenses appropriate to the RPA and RPS;
- the flight plan must comply with the conditions in Annex 2 — Rules of the Air, Chapter 3, 3.3; and
- RPAS must meet the DAA capability requirements for the airspace in which it flies and the operations to be performed.

Additionally, RPAS operations will require approvals encompassing the processes, manuals, procedures, and safety management systems applicable to the organization, its staff, and methods of operation. Although similar in arrangement to manned operators, distinctions will exist in the information recorded in this approval document. The distinctions will primarily pertain to the types and methods of flights permitted [7].

C.5.1 Visual line-of-sight Operations (VLOS)

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

For VLOS, the visual contact has to be direct, meaning that the RPIL or RPA observer must maintain a continuous unobstructed view of the RPA, allowing the RPIL 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 RPIL or RPA observer is able to avoid conflicting traffic and other safety risks related to the hazards present in the operating environment.

The flight planning should ensure the RPIL 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.

VLOS operations, in which the RPA is operated at relatively short ranges from the RPIL 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).

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

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

a) RPIL and RPA observer training and competence;
b) communication delays between RPA observer and RPIL;
c) simultaneous communication from multiple RPA observers or conflicting instructions;
d) communication failure procedures between the RPA observer and RPIL;

e) RPIL's ability to determine the optimum CA manoeuvre when not in visual contact with the RPA or the conflicting traffic; and
f) RPIL response time.

Predetermined manoeuvres and phraseology for use by RPA observers and RPILs 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.

C.5.2 VLOS Operations at Night

The RPIL 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.

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 RPIL when practical.

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

C.5.3 Beyond VLOS Operations

To conduct flights beyond VLOS of the RPIL 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 RPIL.

Prior to conducting a controlled BVLOS operation, coordination should be affected 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 pre-programmed 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.

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.

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

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.

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

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.