



The European Organisation for Civil Aviation Equipment
L'Organisation Européenne pour l'Équipement de l'Aviation Civile

OPERATIONAL SERVICES AND ENVIRONMENT DEFINITION FOR RPAS AUTOMATIC TAXIING

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FOREWORD

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Unmanned, automated and autonomous flying is likely to be one of the most influential trends in the aviation industry in the decades to come. Small, tactical and large scale Remotely Piloted Aircraft System (RPAS) are increasingly being used by military and civilian operators worldwide, with steadily decreasing task ownership during flight by the Remote Pilot (RP).

The principles of basic automated functionality are largely solved today. However and without exception, RPAS operations today are generally still restricted to segregated airspaces, which make operations of them complex and expensive. This situation will continue until the full spectrum of standards, procedures, policy, performance specifications, human factors and enabling technologies are developed, validated and demonstrated to provide an acceptable level of safety for unmanned/manned flight operations.

The ERA programme (Enhanced RPAS Automation) was therefore created by the European Defence Agency (EDA) to address this problem. The principle objective of ERA is to define the necessary draft specifications and the related engineering and technological baseline for three functional domains or Systems Of Interest (SOI):

- Automation & Emergency Recovery (A&ER);
- Automatic Take-Off and Landing (ATOL);
- Automatic Taxiing (AutoTaxi).

Taxi is the phase of flight where an aircraft is moving on the aerodrome surface under its own power prior to take-off or after landing. Existing regulation on taxiing operations are:

- The one relevant to manned aviation which, for the integration of RPAS into non segregated airfields, must be followed as far as feasibly possible (ICAO Annex2 [Ref 1] and Annex14 [Ref 3], or ICAO Doc 8168 [Ref 4] and Doc 4444 [Ref 15]);
- The one relevant to taxiing of RPAS (STANAG 4671 [Ref 5], ICAO CIRCULAR 328 [Ref 13] and Document 10019 [Ref 14], or EUROCONTROL-SPEC-0102 [Ref 6]).

For the moment, the rules on taxiing operations only refers to manual taxiing (either for manned aircraft or for RPAS) with a pilot fully in charge of taxiing the aircraft and avoiding collisions. Only ICAO, at a high level, does address the specific risks introduced by the integration of RPAS into non-segregated airfields. No rules address the automatic Taxiing of an aircraft (manned or unmanned).

Taxiing of RPAS is an operational issue, in particular on busy aerodrome, due to:

- The limited situation awareness of RP compared to manned aviation which contributes to increase the collision risk with obstacles or other aircraft/vehicles, especially in degraded weather conditions;
- Delays introduced by the datalink between the Remotely Piloted Aircraft (RPA) and the RPS which might hamper aerodrome operations by requiring RPAS segregation on airfields or could induce very low taxiing speeds of RPAS compared to manned aviation (to limit the collision risks and the taxiway/runway incursion risks).

Therefore, in order to facilitate the insertion of RPAS into aerodrome operations, it is highly desirable:

- To develop RPAS functionalities that would allow automatic taxiing and automatic collision avoidance. Those automatic functions, on board the RPA, would not suffer any C2 link delays and therefore would avoid taxiway and

runway incursions or possible collisions with obstacles due to those delays. In addition those functions would also allow to taxi in case of loss of datalink between the RPA and the RPS; e.g. in order to free the runway or taxiway;

- To develop RPAS functionalities that would allow RP having a better situation awareness on aprons, taxiways, runways and their environments;
- To propose procedural and regulatory specifications for those RPAS functionalities.

As a beneficial side effect, the automation layer will relieve the RP from performing routine tasks and supports him in high workload situations, e.g. on busy airfields.

The analysis of the reference documentation concluded that the main top level functions for AutoTaxi are fully addressed by those from RTCA DO-304 [Ref 7]. They are at a proper level to describe the operational concept and process. The list of these functions and the associated capabilities is included in the following Table.

Table 1.1: AutoTaxi specific operational functions and Capabilities

Sub-Phase as per RTCA DO-304	Function	Traced to Capability Group
SURFACE OPERATIONS	Contact ground control for taxi clearance and assigned runway	Beginning and end of taxi phases
SURFACE OPERATIONS	Taxi aircraft	Taxi phase
SURFACE OPERATIONS	Avoid aircraft, vehicles or other hazards on the taxiway or apron	Taxi phase
BEFORE TAKEOFF / LAUNCH CHECKS	Obtain surface wind conditions	Beginning and end of taxi phases
BEFORE TAKEOFF / LAUNCH CHECKS	Listen to Common Traffic Advisory Frequency or ATC to establish situation awareness	Beginning and end of taxi phases
LANDING OPERATIONS	Exit the active runway	Taxi phase
LANDING OPERATIONS	Contact ground control and receive taxi instructions	Beginning and end of taxi phases
LANDING OPERATIONS	Taxi to parking area in compliance with taxi instructions or as indicated in surface markings (arrival)	Taxi phase

Capabilities which fall into the scope of AutoTaxi are derived from the analysis of the current situation for manned and unmanned A/C regarding the taxiing phase, both considering the existing systems and also the reference documentation such as certification documentation and procedures for aircraft operations. These capabilities are the ones which the pilot would usually carry out in manned aviation in Taxi phases other than abnormal circumstances.

1.2 SCOPE

The scope of the Automatic Taxiing, in relation with the different operational phases of flight, is reported in this paragraph, together with a schematic depiction in Figure 1-1.

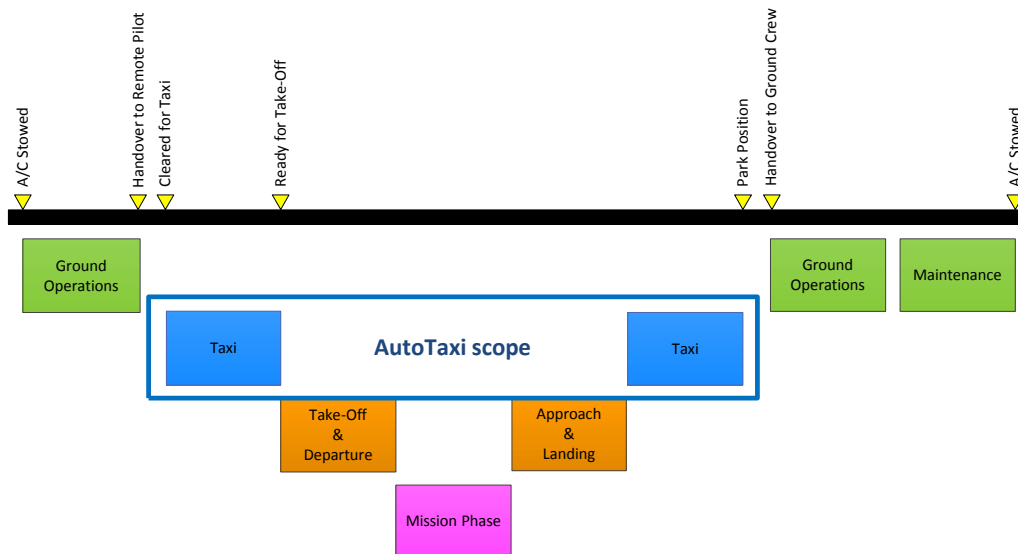


FIGURE 1-1: AUTOTAXI SCOPE OVER OPERATIONAL PHASES

AutoTaxi scope covers all certified fixed-wing RPAS (e.g. HALE, MALE or tactical RPAS) without passenger on-board. In accordance with the RPAS definition from ICAO, autonomous UAS, which do not allow pilot intervention during taxi, are out of scope.

Taxi operations are considered taking place on controlled or uncontrolled land aerodrome (civilian or military) with paved movement area. Moving platforms, such as carrier ships or maritime platforms, are out of scope.

1.3 DOCUMENT OVERVIEW

The purpose of this Operational Services and Environment Definition (OSED) is to provide a basis for assessing and establishing operational, safety, performance, and interoperability requirements for the Automatic Taxiing capabilities for a Remotely Piloted Aircraft System.

This document aims to describe the characteristics, behaviour and conditions of operation of a RPAS equipped with an Automatic Taxiing capability, operating on non-segregated airfield. It is intended to be used as a supporting document for implementation in the definition of Safety and Performances Requirements (SPR) and Interoperability requirements (INTEROP).

The intended audience is the future users and personnel whose work will be affected by the introduction of Automatic Taxiing. This includes RPAS Operators, RPAS Pilots and Ground Crew, RPAS System Developers, Air Navigation Service Providers, Air Traffic Controllers, Eurocontrol, Civil Aviation Authorities, Regulatory Authorities, Aircraft Operators, Flight Crew, Aircraft Manufacturers, Avionics Manufacturers, Military Authorities and Military Aircraft Operators.

At various stages of the development process of this document, Assumptions and Operational Requirements are derived and identified. Within this OSED, they are enumerated respectively with the "AS-#" and the "OR-#" tags.

The document is organized as follows:

Section 1 - Introduction;

Section 2 - Summary of the Concept;

Section 3 - Operational Services;

Section 3 - Operational Environment;

Section 4 - Scenarios description;

Section 5 - Summary.

Appendices:

Appendix A: Membership List.

Appendix B: Improvement Suggestion Form

This document leverages information from the on-going ERA project, in particular the ERA CONOPS [Ref 1].

1.4

ACRONYMS

AAR	Additional Analysis Required
A&ER	Automation and Emergency Recovery
A/C	Aircraft
ADS-B	Automatic Dependent Surveillance – Broadcast
AEEC	Airlines Electronic Engineering Committee
AFIS	Aerodrome Flight Information Service
AIP	Aeronautical Information Publication
AMM	Airport Moving Map
AMDB	Aerodrome Mapping Database
ATC	Air Traffic Control
ATCo	Air Traffic Controller
ATIS	Automatic Terminal Information Service
ATM	Air Traffic Management
ATOL	Automatic Take-Off and Landing
ATS	Air Traffic Service
ATSA	Airborne Traffic Situational Awareness
AVMS	Air Vehicle Management System
C2	Command and Control
CDTI	Cockpit Display of Traffic Information
CSR	Closely-Spaced Runways
CTAF	Common Traffic Advisory Frequency
CM	Crewmember
CONOPS	Concept of Operations
CPDLC	Controller-Pilot Data Link Communications
ED	EUROCAE Document
ERA	Enhanced RPAS Automation
FCS	Flight Control System
FOV	Field Of View

GNSS	Global Navigation Satellite System
HMI	Human Machine Interface
IFF	Identification Friend or Foe
IFR	Instrument Flight Rules
IMC	Instrument Meteorological Conditions
INS	Inertial Navigation System
INTEROP	Interoperability
ITP	In Trail Procedure
LOC	Loss Of Communications
MASPS	Minimum Aircraft System Performance Specification
MCC	Multi-Crew Co-Operation
MALE	Medium Altitude Long Endurance
METAR	METeorological Aerodrome Report
MOPS	Minimum Operational Performance Standards
N/A	Not Applicable
NOTAM	Notices to Airmen
OSED	Operational Services and Environment Description
PF	Pilot Flying
PM	Pilot Monitoring
RPA	Remotely Piloted Aircraft
RPAS	Remotely Piloted Aircraft System
RP	Remote Pilot
RPS	Remote Pilot Station
R/T	Radio Telephony
RTF	Radiotelephone/Radiotelephony
RVR	Runway Visual Range
SARPS	Standard and Recommended Practices
SID	Standard Instrument Departure
SOI	System Of Interest
SPR	System Performance Requirements
SSR	Secondary Surveillance Radar
SURF	Surface (Operation)
TAF	Terminal aerodrome forecast
TCAS	Traffic Collision Avoidance System
TIS-B	Traffic Information Services-Broadcast
VFR	Visual Flight Rules
VMC	Visual Meteorological Conditions
VTOL	Vertical Take-off and Landing

1.5 GLOSSARY

Term	Definition	Source
Aerodrome	A defined area (including any buildings, installations and equipment) on land or water or on a fixed off-shore or floating structure intended to be used either wholly or in part for the arrival, departure and surface movement of aircraft	EU 923/2012
Aerodrome Control Service	Air traffic control service for aerodrome traffic	EU 923/2012
Aerodrome Information (AFIS) Flight Service	The term used to describe the provision of information useful for the safe and efficient conduct of aerodrome traffic at those aerodromes where the appropriate authority determines that the provision of aerodrome control service is not justified, or is not justified on a 24-hour basis.	Eurocontrol AFIS Manual
Aerodrome Mapping DataBase (AMDB)	A collection of aerodrome mapping data organized and arranged as a structured data set	ICAO Annex 14
Aerodrome Operating Minima	In relation to the operation of an aircraft at an aerodrome means the cloud ceiling and runway visual range for take-off, and the decision height or minimum descent height, runway visual range and visual reference for landing, which are the minimum for the operation of that aircraft at that aerodrome	ANO
Aerodrome Traffic Zone	Airspace of defined dimensions established around an aerodrome for the protection of aerodrome traffic	EU 923/2012
Air-ground Communications	Two-way communication between aircraft and stations or locations on the surface of the earth	EU 923/2012
Air/Ground Communication Service	A service provided from an aerodrome to give information to pilots of aircraft flying in the vicinity of the aerodrome by means of radio signals and 'air/ground communications service unit' shall be construed accordingly	ANO
Air-taxiing	Movement of a helicopter/VTOL above the surface of an aerodrome, normally in ground effect and at a ground speed normally less than 37 km/h (20 kt)	ICAO Annex 2
Air Traffic	All aircraft in flight or operating on the manoeuvring area of an aerodrome	EU 923/2012, PANS-ATM
Air Traffic Control (ATC)	A service provided for the purpose of: a) preventing collisions: 1) between aircraft, and 2) on the manoeuvring area between aircraft and obstructions; and b) expediting and maintaining an orderly flow of air traffic	EU 923/2012
Air Traffic Control Clearance	Authorisation for an aircraft to proceed under conditions specified by an air traffic control unit	EU 923/2012
Air Traffic Control Instruction	Directives issued by ATC for the purpose of requiring a Flight Crew to take a specific action	SESAR Concept of Operations Step 2 Ed. 2014

Air Traffic Service (ATS)	A generic term meaning variously: flight information service, alerting service, air traffic advisory service, air traffic control service, (area control service, approach control service or aerodrome control service)	EU 923/2012
Apron	A defined area, on a land aerodrome, intended to accommodate aircraft for purposes of loading or unloading passengers, mail or cargo, fuelling, parking or maintenance	ICAO Annex 2
Automatic Mode	In this mode the RPA attitude, speed and flight path are fully controlled by the flight control system. No input from the RPS is needed other than to load or modify the required flight plan or trajectory.	
Automatic Information Service (ATIS)	The automatic provision of current, routine information to arriving and departing aircraft throughout 24 hours or a specified portion thereof	ICAO
Backtrack	To taxi on a runway-in-use, in the opposite direction to the aircraft's take-off or landing direction	
Capability	The ability to execute a specified course of action	
Clearance Limit	The point to which an aircraft is granted an air traffic control clearance. A clearance limit shall be described by specifying the name of the appropriate significant point, or aerodrome or controlled airspace boundary	EU 923/2012
Command and Control Link (C2)	The C2 link connects the RPS and the RPA for the purpose of managing the flight. The link may be simplex or duplex. It may be in direct radio line-of-sight (RLOS) or beyond radio line-of-sight (BRLOS)	ICAO Doc 10019
Conditional Clearance	Clearance issued by an air traffic controller which does not become effective until a specified condition has been satisfied. Examples of conditions that may be included in a conditional clearance include: AFTER THE DEPARTING AIRCRAFT; BEHIND THE LANDING AIRCRAFT; BEHIND THE LUFTHANSA A340.	
Contingency	An event that may occur but that is not likely or intended (e.g. an emergency). Due to the uncertainty of the situation, contingencies require plans, rapid response, and special procedures to ensure the safety and readiness of personnel, installations, and equipment.	
Controller-pilot data link communications (CPDLC)	A means of communication between controller and pilot, using data link for ATC communications	ICAO Annex 2
CPDLC Message	Information exchanged between an airborne system and its ground counterpart. A CPDLC message consists of a single message element or a combination of message elements conveyed in a single transmission by the initiator.	
Control Link Failure	Loss of utility of a control link NOTE: Typically, if a control link interruption is not restored by the end of a specified period, a "link failure" is declared, leading to link failure	

	<i>contingency procedures</i>	
Failure	A loss of function, or malfunction, of a system or part thereof resulting in the inability of an item to perform its intended function	DO-264
Function	A specific process, action or task that a system is able to perform	
Holding Point	In radiotelephony phraseologies, the expression "holding point" is used to designate the runway-holding position	ICAO Annex 14
Hold Short	Stop before reaching the specified location	
Instrument Meteorological Conditions (IMC)	Meteorological weather conditions expressed in terms of visibility, distance from cloud, and ceiling, less than the minima specified for visual meteorological conditions	ICAO Doc 9713
Landmark	A point on the movement area of an aerodrome defined by its latitude/longitude in the airport database and associated with a visual aid (marking, lightning, sign...)	
"Line up" or "Line up and wait"	Used by ATC to instruct a pilot to taxi onto the departure runway in take-off position and wait (hold). It is not a clearance for take-off	
Manoeuvring area	That part of an aerodrome to be used for the take-off, landing and taxiing of aircraft, excluding aprons	ICAO Annex 2
Marking	A symbol or group of symbols displayed on the surface of the movement area in order to convey aeronautical information	ICAO Annex 14
Movement Area	That part of an aerodrome to be used for the take-off, landing and taxiing of aircraft, consisting of the manoeuvring area and the apron(s)	ICAO Annex 2
Obstacle	All fixed (whether temporary or permanent) and mobile objects, or parts thereof, that a) are located on an area intended for the surface movement of aircraft; or b) extend above a defined surface intended to protect aircraft in flight; or c) stand outside those defined surfaces and that have been assessed as being a hazard to air navigation	ICAO Annex 14, Volume 1
Operational Concept	An Operational Concept is a description of a set of concept elements and the manner in which they are configured and operated.	Eurocontrol, E-OCVM, v3
Operational Concept Scenario	Operational Concept Scenario tells the story of how the concept will operate to meet operational requirements.	Eurocontrol, E-OCVM, v3
Operational Requirement (OR)	An Operational Requirement is a statement of the operational attributes of a system needed for the effective and/or efficient provision of services to users.	Eurocontrol, E-OCVM, v3
Remote Pilot (RP)	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

Remote Pilot Station (RPS)	The component of the remotely piloted aircraft system containing the equipment used to pilot the remotely piloted aircraft	ICAO Doc 10019
Remotely Piloted Aircraft (RPA)	An unmanned aircraft which is piloted from a remote pilot station	ICAO Doc 10019
Remotely piloted aircraft system (RPAS)	A remotely piloted aircraft, its associated remote pilot station(s), the required command and control links and any other components as specified in the type design	ICAO Doc 10019
Runway	A defined rectangular area on a land aerodrome prepared for the landing and take-off of aircraft	EU 923/2012
Runway-holding position	A designated position intended to protect a runway, an obstacle limitation surface, or an ILS/MLS critical/sensitive area at which taxiing aircraft and vehicles shall stop and hold, unless otherwise authorized by the aerodrome control tower	ICAO Annex 14
Runway Visual Range	The range over which the pilot of an aircraft on the centre line of a runway can expect to see the runway surface markings, or the lights delineating the runway or identifying its centre line	EU 923/2012
Signal Area	An area on an aerodrome used for the display of ground signals	ICAO Annex 14
Taxiing	Movement of an aircraft on the surface of an aerodrome under its own power, excluding take-off and landing	ICAO Annex 2
Taxiway	A defined path on a land aerodrome established for the taxiing of aircraft and intended to provide a link between one part of the aerodrome and another, including: a) Aircraft stand taxi lane. A portion of an apron designated as a taxiway and intended to provide access to aircraft stands only. b) Apron taxiway. A portion of a taxiway system located on an apron and intended to provide a through taxi route across the apron. c) Rapid exit taxiway. A taxiway connected to a runway at an acute angle and designed to allow landing aeroplanes to turn off at higher speeds than are achieved on other exit taxiways thereby minimizing runway occupancy times	ICAO Annex 14
Threshold	The beginning of that portion of the runway useable for landing	EU 923/2012
Visual Meteorological Conditions (VMC)	Meteorological conditions expressed in terms of visibility, distance from cloud, and ceiling, equal to or better than specified minima	EU 923/2012, PANS-ATM

1.6

REFERENCE DOCUMENTS

NOTE: *Manned aircraft requirements are quoted here as reference only and may not be necessarily appropriate in the case of UAS applications. They are likely to be complemented or replaced in the future by dedicated RPAS Certification Specifications or Special Conditions, as per currently emerging EASA Rule-making process.*

- [Ref 1] ERA, CONOPS, ERA-T-0006, issue 1.1
- [Ref 2] ICAO, "Annex 2 - Rules of the Air"
- [Ref 3] ICAO, "Annex 14 to the Convention on International Civil Aviation, Volume I, AERODROME DESIGN AND OPERATIONS"
- [Ref 4] ICAO Doc 8168 OPS/611 ("PANS-OPS"), Procedures for Air Navigation Services – Aircraft Operations
- [Ref 5] NATO, STANAG 4671, UAV Systems Airworthiness Requirements
- [Ref 6] EUROCONTROL Specification for the use of military remotely piloted aircraft as Operational Air Traffic outside segregated airspace, EUROCONTROL-SPEC-0102
- [Ref 7] RTCA, DO-304 "Guidance Material and Considerations for Unmanned Aircraft Systems",
- [Ref 8] ICAO, Annex 11 to the Convention on International Civil Aviation, Volume I, "AIR TRAFFIC SERVICES"
- [Ref 9] EU, Commission Implementing Regulation EU 923/2012, "Standardised European Rules of the Air SERA"
- [Ref 10] ICAO, "Annex 10 Aeronautical communications", Volume II Communication Procedures including those with PANS status
- [Ref 11] ICAO, "Annex 10 Aeronautical communications", Volume III Communications Systems
- [Ref 12] ICAO, "Annex 10 Aeronautical communications", Volume IV Surveillance Radar and Collision Avoidance Systems"
- [Ref 13] ICAO, Circular 328 "Unmanned Aircraft Systems UAS"
- [Ref 14] ICAO, Doc 10019 AN/507 Manual on Remotely Piloted Aircraft Systems (RPAS)
- [Ref 15] ICAO, Doc 4444 ATM/501 Air Traffic Management
- [Ref 16] ICAO, Doc 9830 AN/452, "Advanced Surface Movement Guidance and Control Systems (A-SMGCS) Manual"
- [Ref 17] AEEC, "ARINC 816-2: Embedded Interchange Format for Airport Mapping Database"
- [Ref 18] EUROCAE, "ED-119 Rev C / RTCA DO-291 Rev C: "Minimum interchange Format for Terrain, Obstacle, and Aerodrome Mapping Data""
- [Ref 19] EUROCAE ED-99D/RTCA DO-272D "User Requirements for Aerodrome Mapping Information"
- [Ref 20] EUROCAE ED-194B/RTCA DO-317B "Minimum Operational Performance Standards (MOPS) for Aircraft Surveillance Applications (ASA) System"
- [Ref 21] EUROCAE ED-165/RTCA DO-322 "Safety, Performance and Interoperability Requirements Document for ATSA-SURF Application"
- [Ref 22] RTCA, DO-323 "Safety, Performance and Interoperability Requirements Document for Enhanced Traffic Situational Awareness on the Airport Surface with Indications and Alerts (SURF IA)"
- [Ref 23] EUROCAE ED-222/RTCA DO-345: Aeronautical Mobile Airport Communications System (AeroMACS) profile.
- [Ref 24] EUROCAE ED-223/RTCA DO-346: Minimum Operational Performance Standards (MOPS) for the Aeronautical Mobile Airport Communication System.

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- [Ref 25] EUROCAE ED-227: Minimum Aviation System Performance Specification (MASPS) AeroMACS.
- [Ref 26] ICAO, Doc 10044 (to be published): Manual on Aeronautical Mobile Airport Communications System (AeroMACS)
- [Ref 27] ED-228/DO-350: Safety and Performance Standard for Baseline 2 ATS Data Communication;
- [Ref 28] ED-229/DO-351: Interoperability Requirements Standard For Baseline 2 ATS Data Communications.

Relevant documents

- [O1] FAA, "Pilot's Handbook of Aeronautical Knowledge, Airport Operations"
- [O2] FAA, "Aeronautical Information Manual", April 3, 2014
- [O3] CAST, "Phase of Flight – Definitions and Usage Notes", V 1.3, April 2013
<http://www.intlaviationstandards.org/>
- [O4] CAA, "Radiotelephony Manual"
- [O5] ICAO, Circular 211-AN/128 " Aerodrome Flight Information Service (AFIS)"
- [O6] FAA, Airworthiness Approval for ADS-B In Systems and Applications, AC 20-172A

CHAPTER 2

CONCEPT SUMMARY

The desired Automatic Taxiing will be an enabler for the operational use of RPAS. The functional performance should be compliant with the applicable aviation regulations and it should provide levels of safety which are comparable or exceed those for manned aircraft.

- OR-01 *The functional performance of AutoTaxi should be compliant with the applicable aviation regulations*
- OR-02 *AutoTaxi shall achieve an overall safety level appropriate to the relevant UAS category and kind of operations.*

2.1

CONCEPT DESCRIPTION

The main functions to be performed during AutoTaxi are:

- To move the aircraft under its own power along the path defined in the taxi instructions provided by the Air Traffic Controller or according to the airfield taxi procedures, following and reacting accordingly to the landmarks, lightings and visual signs;
- To provide safe separation from, and avoid collision with, fixed or mobile obstacles (e.g. aircraft, ground vehicle or other hazards) during the taxi phases.

The AutoTaxi capability provides 2 modes of operation:

- Automatic mode: Situation awareness is provided as well as automatic taxiing along a taxi route. In case of collision risk, the RPA will automatically react to avoid the collision. The RP can override the system; if not done, the RPA will stop;
- Improved Manual mode: Situation awareness only is provided to the RP from sensors inputs. No automatic taxiing is provided; the RPA is manually controlled by the RP.

Communication exchange between RP and other aerodrome users, mainly Air Traffic Controller (ATCo), management of the RPA configuration (e.g. external lights, high lift devices, payloads like radar, ground lock...) in accordance with applicable taxiing rules, are not covered by AutoTaxi.

AutoTaxi is applicable to any RPAS (e.g. MALE type RPAS or suitable tactical RPAS), as long as a manual taxi capability is available (RPA moving on the aerodrome surface under its own power with a RP fully in charge of taxiing the aircraft and avoiding collisions) and the implementation of appropriate Autotaxi equipment is feasible (sufficient available space, weight and power).

- AS-01 *RPAS are assumed to have a manual taxi functionality allowing the RPA to taxi under its own power on movement areas.*
- AS-02 *RPAS are assumed to be equipped with the capability to provide the RP with the possibility to identify, in real-time, the physical layout of the aerodrome and associated equipment for manual taxi (e.g. on-board forward looking camera).*
- AS-03 *RPAS are assumed to be equipped with a positioning and navigation system (e.g. GNSS-coupled INS).*
- AS-04 *RPAS should allow the Hardware/Software implementation of AutoTaxi functions and the installation of necessary equipment, e.g. having the installation capabilities, power consumptions, generators, architecture requirements, payload capability etc.*
- AS-05 *RPAS are assumed to be fixed-wing type.*

NOTE: Applicability to rotary wing (Helicopter/VTOL) RPAS, performing taxiing or air-taxiing, is not addressed in this OSED.

2.2

AUTOTAXI FUNCTIONS

2.2.1

Preliminary AutoTaxi functional architecture

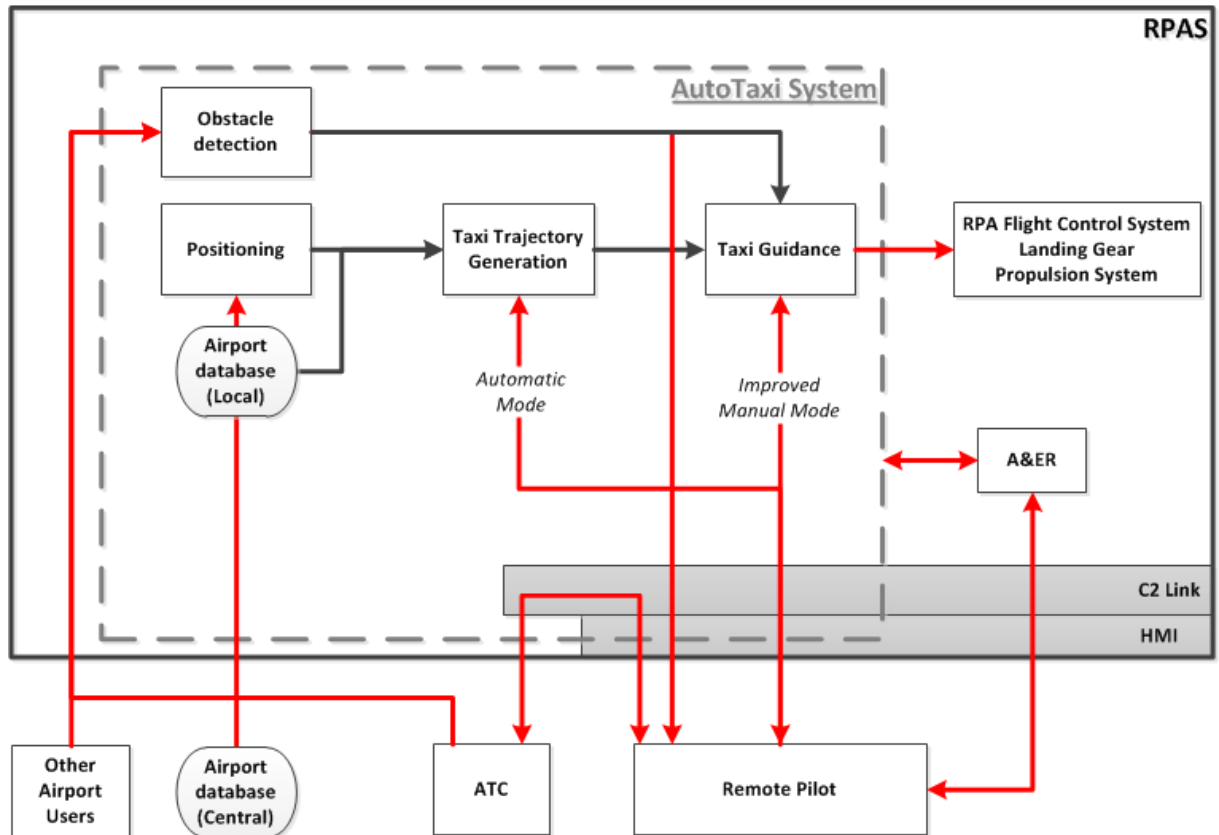


FIGURE 2-1: PRELIMINARY AUTOTAXI FUNCTIONAL ARCHITECTURE

To support its two main functions, the AutoTaxi system is composed of the following functional blocks (internal AutoTaxi interfaces):

- The "Airport Database": provides the AutoTaxi with the appropriate airport infrastructure information (nature, type, position...) for generation of taxi trajectories and positioning of the RPA. Connection to an external data base allows the update or the management of the local database;
- The "Positioning" function: provides absolute and/or relative localisation of the aircraft on the airport movement area. This function uses information from positioning sensors, imagery sensors and/or from the airport database;
- The "Taxi trajectory generation" function: provides the RP with means to plan/modify the Taxi route for the RPA. Direct inputs of the taxi clearance from Controller-Pilot Data Link Communications (CPDLC) data is also considered under validation of the RP (pilot-in-the-loop);
- The "Taxi guidance" function: computes the right trajectories based on the airfield mapping information and in strict compliance to ATC clearance. Taxi guidance should maintain the planned and cleared taxi trajectory and react to a risk of collision by regulating speed to maintain a safe distance from obstacles and, if required, by stopping the RPA. The function elaborates the orders to pilot the RPA on the ground through the "Flight Control System" (FCS), the "Landing Gear" (brakes and steering) and the "Propulsion System";
- The "Obstacle Detection" function: detects obstacles that may endanger the taxi of the aircraft, based on various active or passive sensors (e.g. Electro-optical

sensors, ADS-B...). This function assesses the collision risks with detected obstacles and issues the obstacle detection alerts and appropriate information to the RP and the Taxi guidance function.

2.2.2 External Interfaces

2.2.2.1 RPAS components

Main components and functions of the RPAS in interface with the AutoTaxi system are the following:

- RPA Flight Control System and Propulsion System
This interface implies exchange of commands and reports to control the air vehicle in the Automatic AutoTaxi mode: control of thrust setting, change of the steering wheel direction, application of the brake, etc.
- A&ER Function
This interface allows the A&ER function to manage the operation of the AutoTaxi system during abnormal situation in accordance with approved rules and procedures.
- C2 Link and Human Machine Interface (HMI) Functions
These interfaces are directly involved for exchange of information and control between the RPA and the RPS. An adaptation of the HMI will be needed to provide the appropriate interface between the RP and the AutoTaxi functions.

NOTE: *The HI-level Preliminary AutoTaxi functional architecture in [FIGURE 2-1](#) is independent of the physical RPAS architecture and the location of AutoTaxi sub-systems, e.g.:*

- *Taxi trajectories can be generated from the RPS only, or also in the RPA;*
- *The local airport database can be available in the RPS only, or also in the RPA;*
- *Use of internal (AutoTaxi specific) or external sensors (e.g. forward-looking camera, payload sensors, position and navigation...) can be considered;*
- *etc.*

NOTE: *Additional external interface may then be further identified and detailed, following future work on architecture and on SPR/INTEROP standards.*

2.2.2.2 Airport Database

In relation with the positioning and trajectory generation functions, the AutoTaxi system will make use of the appropriate Aerodrome Mapping DataBase (AMDB) for the operating airfields (departure, arrival, diversion...) [§ 4.3.2]. Data include information that will be used for taxi trajectories: e.g. taxiways, aprons, runways, markings, signs, lightings...

A central Airport Database, at the RPAS Operator level or available from an approved service provider, will be used before flight to manage and configure the internal (local to the RPAS) database, according to e.g. regular updates, the operation area, the mission....

2.2.2.3 Remote Pilot

An "AutoTaxi HMI" function will be needed to provide the appropriate interface between the RP and the AutoTaxi functions at the RPS level to monitor and control the behaviour of the AutoTaxi system as well as an optimal display of situational awareness (airport features, obstacles and alerts) along the RPA trajectory.

Additional capabilities will be needed to inform about the AutoTaxi system and components status. As required, and in relation with the A&ER system, HMI should also allow operation in the contingency situations, as described in § 3.5.

2.2.2.4 ATC

As for manned aviation, standard aeronautical communication links (V/UHF) will allow exchange of information (report, clearance, information...) between ATCo and RP. Noting that this link usually transits through the RPAS via the C2 link and future systems are currently being defined and developed in the SESAR project.

As indicated § 4.3.7, ATC may use CPDLC taxi messages to exchange with the RP (through the RPS) in the same manner as manned aviation. Appropriate information should be accessible at the Autotaxi system level for generation of taxi trajectories.

NOTE: *The possibility to exchange directly between ATC and the RPA (eventually through the A&ER function) is not considered in this OSED, in accordance with ICAO rules and definition of RPAS.*

2.2.3 **Other Airport Users**

Additional surveillance concepts are under study to provide an improved situational awareness to the RP (ADS-B, TIS-B... as per § 4.3.3 to § 4.3.5). All actors in the vicinity of the airport movement area (other A/C, vehicles, ATC...) are contributors to this capacity that will induce exchange of information with the AutoTaxi system (and potentially directly with the RPAS).

2.3 **MODES OF OPERATIONS**

For nominal scenarios, three modes of operation of the AutoTaxi system are considered:

- Off: AutoTaxi system powered off or disabled.
- Improved Manual: Situation Awareness is provided to the RP and the AutoTaxi system, based on inputs from sensors. Information involved relates to: taxiway and surrounding area, RPA position and trajectory, markings, signs and obstacles. No automatic taxiing is provided; the RPA is manually controlled, as required, by the RP through direct manipulation of controls (e.g. power, brakes and directional control);
- Automatic: Situation Awareness (as described in the previous mode) is provided. Automatic taxiing is performed based on a route entered by the RP, in line with the respective ATC clearance. The RP can modify the taxi route if needed, after coordination with ATC. In this mode the system controls, as required, the directional control, the brakes and the throttle of the RPA. In case of collision risk, the RP can take back the control of these inputs. If he does not do so, the RPA will take the appropriate action: adapt its speed to maintain a safe distance or stop.

NOTE: *System checks will be performed after initiation of the AutoTaxi system, and periodically while in Improved Manual or Automatic modes, to validate the internal status of the AutoTaxi sub-systems.*

CHAPTER 3

OPERATIONAL SERVICES

In the following sections, the AutoTaxi operational services (capabilities and functions) are presented and analysed. Reference to existing manned aviation as well as existing RPAS taxi operations is also considered.

3.1 INITIAL TAXI CLEARANCE

Controlled airfields (both civil and military) need clearances for movements. The following scenario shows a typical flight preparation and initial taxi clearance process for commercial aviation considering two pilots (with one pilot designated as PF - Pilot Flying - and the other pilot as PM - Pilot Monitoring) taxiing out a commercial aircraft equipped with Airport Moving Maps (AMM) on a controlled airfield is given below as an example:

- PM contacts GROUND controller for requesting taxi.
- PM copies the taxi clearance.
- PM reads back the message:
- Start Up Request: The PRE-FLIGHT is contacted for engine start up. Once contacted, the ATC delivers the IFR clearance indicating the runway, the SID (Standard Instrument Departure) after take-off, the initial flight level cleared and the transponder code ("Squawk") assigned to the aircraft.
- Pushback Request: The APRON controller is contacted for push back request (possibly with a different frequency from the start up frequency). At this stage, PM and PF prepare the route to taxi. Note that they have not yet received the clearance from the ATC so it is an expected route based on:
 - The active runway
 - The aircraft performance (conditioning Take-off distance and thus the runway entry)
 - NOTAMS (closed taxiway, closed exit etc.)
 - Their knowledge of the airport
- Once pushback is performed and A/C ready for Taxi, the APRON controller transfers the A/C to the GROUND controller:
- Taxi-Out Request: The GROUND controller is contacted. The pilot receives its taxi-out clearance and notes it. Example of dialog between ATC and A/C:
 - A/C: AFR00, REQUEST TAXI
 - ATC: TAXI HOLDING POINT RUNWAY 04 LEFT VIA TANGO, BRAVO ONE
 - A/C: TAXI HOLDING POINT RUNWAY 04 LEFT VIA TANGO, BRAVO ONE, AFR00

This will also apply at aerodromes where Aerodrome Flight Information Service (AFIS) is provided and where Start Up procedures are requested. At uncontrolled airfield, information about start of Taxiing and vehicle movements are transmitted on a Common Traffic Advisory Frequency to inform other users of the airfield.

Similar procedures will apply to RPAS, adapted to the appropriate RP crew composition and role (cf. § 4.4.1), noting that for the moment, no push back phase is considered necessary.

NOTE: *Future use of RPAS for commercial activities including passenger transport may imply use of gates and then push back phases. But this capability is not considered in this OSED.*

As for manned aircraft, the use of taxi aids like Airport Moving Maps (§ 4.3.2) will require the use of appropriate information from the Aerodrome Mapping DataBase (AMDB), organised in an "airport taxi database". Such activities include:

- Management and maintenance of the database before the flight: update, upload of selected operation areas or airfield...
- Management of the taxi route before or during taxi: selection of planned trajectory, authorisation of trajectory according to clearance, change of routes....

OR-03 AutoTaxi shall allow the selection of planned and cleared taxi route by the RP.

OR-04 AutoTaxi shall allow the management of an airport taxiway database, containing all information on airport layout necessary for Taxiing operation.

3.2 TAXIING PHASE

3.2.1 Taxi Procedures for Manned Aircraft

There are several general types of procedures to taxi a manned aircraft:

- By following the ATC instructions, landmarks, panels and/or lights all along the taxi path.
- By following the standard operating procedures established in non-towered airports, landmarks, panels and/or lights all along the taxi path.
- By following a "follow-me" vehicle. The concept for the use of "Follow-me" vehicles varies from airport to airport. Those vehicles may be provided for convenience or safety or both.
- By towing the aircraft¹: the aircraft, usually with engines off, is moved forward using the power of a specialised ground vehicle attached to or supporting the nose landing gear. It may occur for the movement of both in service and out of service aircraft.

Regarding guidance and control, manned aircraft when taxiing without the help of a towing car, are currently "manually" controlled directly by the pilot, using engine throttles and pedals inputs for small aircraft, or nose wheel tiller for airliners. Elevator and ailerons may also be used when wind is strong. Automatic ground roll control is only provided by Flight Guidance system for landing purpose, and pilot needs to take over the automatic AFCS at the end of the aircraft deceleration phase, once a safe taxi speed is reached.

3.2.1.1 Example of "taxiing-out" scenario

A typical scenario considering two pilots (with one pilot designated as PF - Pilot Flying - and the other pilot as PM - Pilot Monitoring) taxiing out a commercial aircraft equipped with an AMM on a controlled airfield is given below as an example:

- As soon as the taxi out clearance phase is finished (§ 3.1) and the ATC elements are entered in the Taxi routing HMI, a taxi route is computed, taking into account the constraints. If a route was previously displayed, then the older one is removed from AMM
- PM and PF cross check the displayed route with elements entered in Taxi routing HMI

¹ Not formally a taxiing procedure, as the aircraft is not moving by its own power, towing is however included here as a potential means of moving the aircraft on the aerodrome surface

- If route is agreed by PF, PM sets the taxi route to “cleared” which modifies its representation for non-ambiguous interpretation
- PM and PF perform external check before taxiing
- PF release brakes and start manual taxiing.
- The Taxi routing HMI is used to anticipate turns and to announce them to PF
- PF and PM shall perform permanent checking of the environment to detect any conflict and/or risk of collision with other aircraft and/or ground vehicle and/or personnel.
- PF shall adjust speed according to the density of traffic and to the visibility mainly.
- Once A/C has arrived on clearance limit, the GROUND controller contacts the A/C and either delivers a new clearance or transfers the A/C to another GROUND controller (if the A/C goes out of its area responsibility). In all the case, if the pilots have not received a new clearance from the controller, PF must stop to the holding position specified in the last clearance received. PM changes active frequency and wait for ATC contact. Another clearance is issued.
- In case of inconsistency of the taxi route being executed, PM shall ask for clearance clarification.
- The taxi ends when the aircraft is lined up on the runway, stopped and waiting for a take-off clearance.
- If a take-off clearance is directly issued with no requirement to line up and wait, then the taxi ends when the aircraft is lined up on the runway and take-off power is applied.

3.2.1.2 Example of “taxiing-in” scenario

- A typical “taxiing-in” scenario for the same type of commercial aircraft and airport is considered:
- Approach and landing briefing: When A/C is in cruise, one hour before landing and in a low workload period, the Approach and landing briefing can start.
- Flight crew prepares the descent, the approach, the go-around and the taxi-in scenario.
- During Taxi-in briefing, the following items are reviewed and discussed:
 - Anticipated taxiways to taxi to the assigned gate (e.g., back-track on active runway or on parallel runway, with special emphasis on the possible crossing of active runways).
 - Non-standard lighting and/or marking of taxiways
 - Possible work in progress on runways and taxiways. (based on NOTAM information)
- The Taxi-in briefing (depending on Flight crew knowledge of the airport) can be delayed after landing.
- The Flight crew can use the AMM and taxi route function (DIR TO) to pre check potential taxi path. Anyway, this expected route will be cancelled at landing.
- After this briefing, Flight crew is focused on landing and the taxi operations are no longer addressed until the A/C has landed and vacated the runway.
- After landing, PF switches to Airport Moving Map range. Taxi-In starts when A/C has stopped on the runway or when it exits runway in case it does not come to a full stop on runway. To do so, PF must entirely set the A/C beyond the runway holding position line (cat II/III or cat I according to weather). PM contacts GROUND controller and receives a cleared taxi route entered into the AMM. The taxi-in operations are then the same as the taxi-out.
- When required, the APRON controller is contacted by PM; he delivers a clearance to reach the Stand or Gate.

NOTE: *Similar scenarios can also apply considering a single pilot, in charge of all the above tasks.*

3.2.2

RPAS Taxi Operations

Current RPAS operations in aerodromes are mostly military. Operation in civil aerodromes is subject to special authorisations, based on a case by case RPAS and procedures evaluation

RPAS are usually allowed to taxi on airfields shared with manned aircraft if at least one of these points is applied:

- RPAS and manned A/C are parked on different and well defined parking area, and RPAS and manned A/C never use simultaneously same taxiways and runways;
- The ATC provides separation between RPAS and manned A/C;
- The ATC temporary stops all manned aircraft operations when an RPAS is taxiing.

The two main general types of RPAS taxiing procedures are:

- Behind a “follow-me” vehicle, in charge of following taxi instructions and clearance;
- Manual taxi, complying with the ATC instructions/clearances.

To perform a manual taxi, existing RPAS are controlled by the RP from a ground control station. The RP controls the RPAS on the taxiway using a forward view from the RPAS camera displayed on the piloting screen. The RP is usually located close to the landing and take-off airfield of the RPAS, and is familiar with the aerodrome configuration. The RP could also follow the RPA, in that case using a mobile RPS. The RP is responsible for collision avoidance as well as for listening to ATC or Common Traffic Advisory Frequency.

Following introduction of the AutoTaxi capability, RPAS will be able to operate on civil and military airfields in a similar manner as manned aircraft, taxiing along planned and authorised trajectories and reacting to obstacles.

Two modes for taxi will be proposed:

- Automatic: the RPA will automatically perform the planned taxi phase and react to any collision risk. RP remains on the loop, provided with situation awareness from RPA AutoTaxi sensors and data, and informed of the RPA intentions, able to react and override the RPA as required;
- Improved Manual: the RP controls directly the RPA on the planned taxi phase. RP remains at all times in the loop, provided with situation awareness from RPA AutoTaxi sensors and data, able to react to any collision avoidance alert.

NOTE: *According to assumptions AS-01 to AS-03, the RPAS is supposed to have a manual taxi capability that will constitute the basis of the 2 AutoTaxi modes.*

The main phases of taxiing are considered:

- From the parking position on the apron to the runway holding point (taxi-out phase);
- From the holding point to the runway, lined up and ready to take-off (line up phase);
- From the runway, stopped after landing and on runway axis, to crossbars clearing (vacate phase);
- From crossbars clearing to a parking position on the apron (taxi-in phase).

NOTE: *Capability to initiate the taxi-in phase while still moving after landing, and before full stop on the runway, is not within the scope of AutoTaxi at that stage and is not addressed in this OSED.*

OR-05 *If the ATOL function is not engaged, or if the RP does not take manual control, the AutoTaxi shall operate according to the following rules:*