# RPAS Integration in Non-segregated Airspace: the SESAR Approach

## System interfaces needed for integration

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*Abstract*—**Airliners and Remotely Piloted Aircraft Systems (RPAS), with very different performances and features, will have to coexist in a seamless airspace whose definition and technological infrastructure, the Single European Sky ATM Research initiative (SESAR), is currently undertaking. This paper presents the Concept of Operations (CONOPS) of the integration of RPAS in non segregated airspace, from two perspectives that should be harmonized: the first one is the future Air Traffic Management (ATM) system defined by SESAR; and the second is the perspective of the RPAS operator or user. The objective of this paper is to present a well defined context of operations for the RPAS to be integrated in non segregated airspace, describing the basic interfaces which the RPAS user will need for the safe integration of the RPAS operations in non segregated airspace proposed in SESAR concept.**

*Remotely Piloted Aircraft Systems; System of Systems; Air Traffic Management; Non-segregated Airspace; SESAR*

## I. INTRODUCTION

The purpose of this paper is to provide a clear concept of operations (CONOPS) of the future integration of Remotely Piloted Aircraft Systems (RPAS) into non segregated airspace from the perspective of the future Air Traffic Management (ATM) system proposed and developed by the Single European Sky ATM Research (SESAR) initiative.

The first step is to present the essential requirements in terms of procedures, communications, navigation and Detect and Avoid (DAA) systems that RPAS and ATM will have to consider for the safe integration of RPAS in non segregated airspace.

The second step is to identify the roles and responsibilities among pilots of RPAS, Air Traffic Controllers (ATCos), and other airspace users involved in ATM processes in the future SESAR concept.

The operational environment set by SESAR concept of operations provides the baseline for operations and interactions that RPAS systems will have with the rest of the ATM elements and actors (which include operating aircraft of various categories, airports, air traffic service units, military units and authorized personal devices).

The integration is studied for both military and civil applications of the RPAS into the European Airspace through the operational procedures proposed by SESAR initiative for the timeframe 2020-2025.

Finally, this study establishes the high level interfaces required for the RPAS system through an analysis of all the phases of flight expected for the RPAS in nominal operation.

## II. SCOPE OF OPERATIONS

### A. System identification and description

The term UAS (Unmanned Aircraft System) refers to those systems which involve the movement of air vehicle without a human operator on board. These systems include not only the aircraft, but also the supporting ground, air, and communications infrastructure.

The RPAS is a subcategory of this family, indicating all those UAS that have a human operator (or Remote Pilot - RP) operating the air vehicle from a remote position (Remote Pilot Station - RPS) and in constant control of the vehicle [1]. The aerial vehicle, called Remotely Piloted Aircraft (RPA) has been considered by ICAO as an aircraft, so it has to comply with the Rules of the Air [2] as any other aircraft. The term system refers to the complex nature of the RPAS, where several components need to be coordinated (for instance, the Command and Control link (C2 link) between the RP and the RPA is also a component of the system).

This system is depicted in Figure 1 at a high level, including those possible interactions with the environment and other Airspace users (commercial manned aircraft, military aircraft,...).
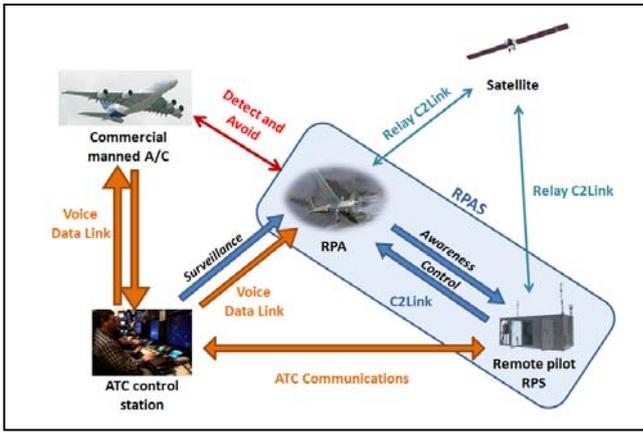
Figure 1.   RPAS system and interactions with other airspace users

To depict the RPAS system, a common structure established in NATO Architectural Framework (NAF) has been used in order to follow a system of systems structure [3].

Focusing on the RPAS system, several functions and interfaces are found with the environment, but the fact of having the pilot operating the aircraft from a remote position adds additional interfaces to the system. These interfaces of an unmanned aircraft with its environment and between the internal systems of the RPAS are shown at high level in Figure 2 following the NAF notation.

It can be noted that, unlike the case of manned aviation, the RP is physically outside the vehicle, and the interface between them should be necessarily be placed into the RPS. The RPS and the aerial vehicle (RPA) are physically separated, and the RP operates physically inside the RPS. The pilot operates the RPA through a Human Machine Interface (HMI).
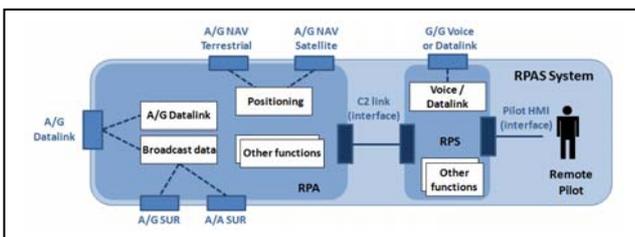


Figure 2.   RPAS system interfaces

A first approach of the main functions indicates that, if the RPAS operations should mirror those of the manned aircraft, the critical point of the RPAS system lies thus on the Communications and Control (C2) link between the RPS and the RPA.

*B.   Background*

RPAS integration in non segregated airspace has been set as an objective for the future of several Civil Aviation Authorities and the industry alike. The expected integration is being studied by several agencies, providing detailed and valuable information on how to proceed step by step. Such is the case of the European RPAS Steering Group in their European Roadmap for RPAS integration [4] and the Federal Aviation Administration [5].

Also, the International Civil Aviation Organization (ICAO) has set the objective of establishing the principles and rules for the RPAS to operate in airspace mixed with manned aircraft, under Instrumental Flight Rules (IFR) and Visual Flight Rules (VFR) adhering to the requirements of the specific airspace in which they are operating [6][7].

The study of RPAS operations involve several perspectives to consider, like regulation, airworthiness, communications and interoperability. The current lack of a common and specific regulation makes the RPAS operations only available into segregated airspace for specific military or experimental operations (after the issue of a notification of approval by the authorities). The regulation is usually beyond technical improvements so that in the RPAS operations, there are no valid standards for their integration in non segregated airspace with the required level of safety [8].

If RPAS are to be integrated, either for civil or military applications, they will have to comply with the same rules and procedures as the other airspace users, without degradation of the level of safety, without disruption of current operations and without roughly modifying ATC procedures. Therefore, it is considered that RPAS behaviour in operations must be equivalent to manned aviation, including for the interaction with air traffic control (ATC).

RPAS must adhere to the rules of the airspace and must comply with the CNS requirements in ATM context (Communication (provide corrective actions in tactical time, as well as flight information), Navigation (materialise and maintain position between two points of the trajectory) and Surveillance (control and verify that the aircraft is where it should be)) applicable to the class of airspace within which they intent to operate.

The rules and requirements for operation are set in the SESAR ATM context. According to this, the airspace which is not segregated (which also has its own rules and procedures) is divided into managed (MAS) and unmanaged (UMAS) airspace. RPAS, as any other user, are required to comply with the different operational requirements of both.

The tasks to be performed by the RP would be different in both cases. In case of operation in UMAS airspace, where no separation provision is given by ATM system, the responsible for keeping minimum separation distances from the rest of the users is the pilot. In case of violation of minimum separation distance, the DAA system onboard the RPA should be a robust one so that the conflict is avoided. In case of emergency where the C2 link is lost, the option of increasing the level of autonomy of the vehicle should be considered as well.

In case of operation in MAS airspace, the separation provision is given by the Air Navigation Service Provider or ATC unit to the Pilot. In this case, the focus is made on the communication link between the responsible ATC unit and the Pilot (ATC communications). Depending on the distance between them (ATC unit, RPS and RPA) this communication link should be different (direct or relay), but should keep similar performances as that of manned aircraft, meaning that the time of response of an instruction provided by an ATC unit should be comparable.

Additionally, the volume of information to share with ATC should be managed in a way that the communications are carried out continuously. To comply with ATS instructions in a timescale comparable with that of a manned aircraft, it is imperative that the capability of taking immediate active control of the aircraft exists at all times (or maybe a level of autonomy that is able to react to ATS instructions in specific cases, like the loss of C2 link between RPS and RPA). Again in this case, a robust DAA system is paramount for the safe operation.

*C.  RPAS classification*

RPAS would be categorized according to their operation and flight rules under which they have to operate.

Flight rules are those set of rules which apply to the aircraft operation depending on the meteorological conditions and the airspace in which the aircraft is flying [2]. As the RPAS is considered an aircraft [1][6], the RPAS will be operating in non-segregated airspace with a mixed variety of manned aircraft (e.g. from gliders to large airliners) either under instrumental flight rules (IFR) or visual flight rules (VFR) adhering to their specific requirements. This involves operating either under Visual Meteorological Conditions (VMC) or Instrumental Meteorological Conditions (IMC). The possibility to fly under VFR or IFR affects the procedures established for the operation and communications of the RPAS with its environment [9]. These rules of operation have their equivalent in the SESAR ATM concept as the Managed - MAS (for IFR, A to E classes) and Unmanaged - UMAS (for VFR F and G classes) airspace distinction [10].

To comply with the rules of the Air, independently of the airspace or the meteorological conditions the RPA is into; the pilot should observe the surrounding in order to avoid obstacles or other traffic. This function is called DAA [11]. This observation capability can be achieved in RPAS case through sensors or the automatic sharing of information with other aircraft in the surrounding area (generically called Airborne Collision Avoidance System (ACAS) [12].

Regarding the type of operation, the first difference is found when, while commercial air transport (CAT) aircraft normally flies to move passengers, freight or mail from two different aerodromes, following a flight profile which includes a climb phase, en-route at relatively high altitude (composed mainly by straight segments), descent and landing, RPA flights comprise a much wider range of possible operations, and in many ways similar to the operations of General Aviation (GAT), Rotorcraft, and Military missions and State flights (OAT).  These operations include a wider range of scenarios and higher flexibility in the manoeuvres.

The classification which is considered best suited for RPAS integration study is the one of operations, which is generally accepted against that of the weight or others. It is also found in the approved Amendment 43 [7] of the ICAO Annex 2 [2]. This classification takes into account the physical distance between the human operator into the RPS and the RPA, but also the range it can achieve (affecting the communications range that can be expected between the RPS and the RPA). The classification distinguishes between Radio Line of Sight (RLOS) and Beyond Radio Line of Sight (BRLOS).

## III.  Principles of integration

RPAS operations are currently performed in segregated airspace or under strict conditions of operation as in [12]. This means that the operators need a special authorization to fly the RPAS in very restricted portions of airspace for their exclusive use (where other traffic is not allowed to fly) [13], and which is made public for the rest of the airspace users.

The segregation of RPAS from other airspace users provides a safe operating environment, but the process for establishing such airspace restrictions reduces the flexibility of operation sought by the ATM community and limits the range and capabilities of operation for all the users. This is why, not only RPAS operators, but also the ATM community are working on the integration of RPAS in non segregated airspace.

The purpose of this paper is to provide a clear view of how to solve the operational challenges and constraints. A first approach for the integration involves a list of general requirements that should be accomplished as a minimum, and which are presented hereafter.

*A.  General principles*
- RPAS shall comply with existing and future regulations and procedures.

- RPAS operations should not increase the risk to other users.

- RPAS integration should not force other users to carry additional equipment.

- The way RPAS operations shall be equivalent to manned aircraft, as much as possible. The human operator is responsible for the operation of the RPA.

*B.  ATM integration*
- The integration of RPAS shall not imply a significant impact on the current users of the airspace.

- Provision of Air Traffic Services (ATS) to RPAS should be transparent to ATC controllers.

- RPAS shall be able to comply with air traffic control rules and procedures mirroring where possible those applied to manned aircraft. This involves that in the future, RPAS shall comply with the SESAR trajectory management process and share of information.

- RPAS shall comply with the capability requirements applicable to the airspace within which they are intended to operate (MAS or UMAS).

- Aircraft communications performance with the ATS provider must be continuously monitored by the Remote Pilot.

*C.  Other requirements*
- RPAS integration shall not compromise existing aviation safety levels, nor increase risk.

- RPAS should have the minimum requirements of equipment in order to be integrated in the airspace class they intent to fly (MAS or UMAS).

- RPAS should have an approved method for assuring separation provision and collision avoidance. All RPAS operations in BRLOS will not be permitted without an acceptable DAA system (for cooperative and non cooperative traffic, especially when operating in UMAS).

## IV. RPAS INTEGRATION IN FUTURE ATM SESAR CONCEPT

For flights that will take place wholly or partly in the SESAR area, the traditional filing of flights plans is replaced by the action of sharing the information required about the flight, making it accessible for all actors concerned in accordance with predetermined rules.

The information to be shared will be more extensive than that which is carried in today's Flight Plan (FP) message, including both trajectory information (the Business Trajectory – BT) and non-trajectory related information about the flight such as equipment, status, airframe identification, etc. as required and appropriate.

In SESAR Concept, this information will be contained in the Flight Object (which is the equivalent Flight Plan) for commercial aviation. Some State or military information may legitimately be omitted. This sharing follows a standardized process aligned with the lifecycle of the trajectory, ensuring that the information becomes available to the various partners at a specified time.

User applications employed to submit the flight information of RPAS (whether by Operation Centres or from the RPS) automatically ensure that all the required information is provided and properly shared.

Since SESAR information-sharing environment will be licensed to handle aeronautical information, the licensing will also cover how trajectory management based flight intention submission is allowed to satisfy the ICAO FP submission provisions [14].

For flights leaving the SESAR area, the aircraft operator will ensure that the necessary type of ICAO flight plan will be generated and sent by the appropriate applications.

In case of data sharing of a military flight (a Mission Trajectory – MT), the information to be shared can be planning data as well as real-time exchange of flight data. Depending of the nature of the operation, MTs can contain parts during which the profile of the flight is similar to a BT and parts during which the flight is randomly executed within a specific airspace structure (e.g. Temporary Segregations of Airspace (TSA)), or executed within UMAS, or over high seas. The latter parts of the flight can be unshareable due to security or immediacy reasons. However, the activation/de-activation times of the specific airspace structures (TSA) and their descriptions are always shareable with the other users.

Similarly, the times and positions of entry and exit from UMAS can be shared. The MT will contain the climb, the transit to and from an area and the descent phases. It is obvious

that the shared data will not include military confidential information. A special requirement for the MT will also be the possibility to stop sharing sensitive information data for security reasons at certain times.

### A. RPAS interfaces according to SESAR

This section will follow the progression of tasks that the RPAS operator should perform in order to accomplish the flight (or mission) requirements in SESAR airspace at a high level.

Regardless of the difference between RPAS and manned aviation, the flight phases in which the flight of the vehicle are divided can be considered to be the same. To maintain a common structure, the flight phases of an RPAS flight are divided in three: flight preparation, flight execution and flight termination.

The length and duration of each of these flight phases can be established by the user (while taking into account the rest of user intentions). The Advanced Flexible Use of Airspace (AFUA) concept [15] helps in the definition of the area of operation (which can also include the transition from en route, the ingress/egress phase) as an area where the RPA can make extensive use of payload sensors (and which justify the RPA flight and flexibility requirements).

The interfaces needed in each phase of flight/mission are presented hereafter. They represent the requirements that SESAR need for RPAS for be integrated.

### 1) Flight preparation

During flight preparation, SESAR request is to prepare and provide the user with the minimum parameters and constraints needed to define the Business/Mission Development Trajectory (BDT/MDT). After the definition, the information would be shared with the rest of the users as the initial shared trajectory (SBT/SMT). Once shared with the Network Manager (NM) system, this SBT/SMT would be subject of several iterations until it becomes the final reference Business/Mission trajectory (RBT/RMT). The objective for SESAR is to solve all issues regarding ATM which can be solved in the strategic phase.

The flight preparation includes the phases of long term planning; medium/short term planning and day of operation. The interfaces are identified in the presented in Table I.

TABLE I.     FLIGHT PREPARATION

| Flight phase task | RPAS-SESAR Interfaces needed |
|---|---|
| Flight planning | The RPAS interface should be able to permit the access to relevant information for flight planning in the SESAR Network (SWIM)[a]. |
| Definition of flight and type of operation | RPAS interface should be able to fill the required information in the specific format requested by the Network Manager. |
| Definition of the BDT/MDT | The RPAS interface should be able to fill the initial trajectory information in the format specified by the NOP[b]. |
| Acknowledgement of already existing constraints and resources available | The RPAS interface should be able to receive and read this information provided by the NOP. |
| Initial SBT/SMT publication. | RPAS interface should be able to fill in the NM request in the appropriate format, taking into account that a minimum set of trajectory |

| Flight phase task | RPAS-SESAR Interfaces needed |
|---|---|
| | parameters should already be known by the system. |
| Monitor modifications to the SBT/SMT given by SESAR. | RPAS interface should be able to continuously monitor its SBT/SMT status through the SWIM by accessing to the updated information published in the NOP. |
| RPAS operator elaborates the latest SBT/SMT trajectory | RPAS interface should be able to communicate/upload modifications to the current SBT/SMT. Interface with the NOP is needed to accept or request modification to the trajectory. |
| Final iteration the day before operation. | RPAS interface should be able to define the last accepted version of the SBT/SMT as Flight Plan in the NOP. |
| RPAS operator verifies/validates the final accepted SBT/SMT which becomes the RBT/RMT. | RPAS interface should be able to receive the notification of acceptance of the last SBT/SMT as RBT/RMT and the expected times of flight. |
| Monitor modifications to the RBT/RMT given by SESAR. | RPAS interface should be able to continuously monitor NOP updated information for possible last minute modifications. |
| Upload Flight Plan (RBT/RMT) and Payload Plan to the RPS and RPA. | RPAS interface should be able to translate the information of RBT/RMT into SESAR network as FP plan to be delivered to the entities affected by this flight. |

a. Note: The RPAS interface should also be able to access the information about tasks and objectives provided by the AOC/WOC (superior authority), although this information is not in SESAR Network.

b. Note: The Network Operations Plan (NOP), is a dynamic rolling plan providing a detailed overview (past, current and forecast) of the European ATM environment to those concerned.

*2) Flight execution*

During flight execution, the objective of SESAR is to help the user follow the agreed trajectory RBT/RMT and provide support in case of non compliance to both RPAS operator and ANSP.

The flight execution includes the phases of pre-departure, taxi-out and takeoff, climb and cruise, en-route, ingress into and egress out from the area of operations, area of operations, arrival, approach, landing and taxi-in. The interfaces are identified in the presented in Table II.

TABLE II. FLIGHT EXECUTION

| Flight phase task | RPAS-SESAR Interfaces needed |
|---|---|
| RP loads preflight information to the RPS | RPS should have an interface with NOP allowing to share with the rest of ATM system (trajectory, Meteo, NOTAM, AIC, ATS, ATIS, frequencies of use).. |
| RP updates pre-flight information while SESAR ATM sends the information available through SWIM | RPS should have an interface which is able to download the information of the RBT/RMT through the NOP and the latest information affecting the flight through SWIM. |
| RPAS requests and receives approval/clearance for Taxi out from ANSP/Airport | RP within RPS should have an interface to communicate with the responsible Airport/ANSP facility and request for the taxi out clearance. |
| RPAS requests approval/clearance for Takeoff from ANSP/Airport | RP within RPS should have an interface to communicate with the responsible Airport/ANSP facility and request for the takeoff (and climb) clearance. |
| RPAS sends the information of the | RPA should have an interface with ATM system to communicate the RPA position |

| Flight phase task | RPAS-SESAR Interfaces needed |
|---|---|
| RPA position ANSP needs to monitor the departure operation of the RPA from the. | information and status. The RPS should have an interface that allows monitoring the cleared sections of the RBT/RMT, and that they are executed with the required navigational performances (NAV). |
| Monitor possible modifications to the RBT/RMT (in tactical phase) | RPAS interface should be able to continuously monitor NOP updated information for possible trajectory modifications/deviations. (Such as weather, winds or unpredicted actions). An update of the RBT/RMT is automatically triggered by the NM if the trajectory predictions continuously computed by the RPA FMS system differ from the agreed/cleared trajectory predictions. |
| RPAS flight/mission execution and monitoring | RPAS should have an interface with ATM system to communicate the status and position of the RPA and provide information of contingencies or unpredicted actions. |
| RPAS inform about inflight contingencies. | RPAS needs an interface with SESAR to inform about contingencies. |
| RPAS requests and receives approval/clearance for Landing from ANSP/Airport | RPAS (RPS) should have an interface to communicate with the responsible Airport/ANSP facility and request for the landing clearance. |
| RPAS requests and receives approval/clearance for Taxi in from ANSP/Airport. | RPAS (RPS) should have an interface to communicate with the responsible Airport/ANSP facility and request for the taxi in clearance. |

*B. RPAS general interfaces*

The following interfaces are not SESAR specific, and can be considered for today operations.

*1) RPAS - ATM system interfaces*

The RPAS system should support communications between the RP and ATC unit. The communication with ATC is essential for coordination and provision of ATS services and issue of clearances during the entire flight and for both tactical and strategic instructions.

The majority of communications between pilots and ATCos are made via voice. A new data-link system called controller-pilot datalink communications (CPDLC) has been currently starting to connect pilots and controllers to routine communications using Data link messages [16]. The objective of this system is to automate those routine massages in the communications so that pilots and ATCos can concentrate in other tasks. CPDLC represents the base for some services developed in the future controlled airspace (MAS) of SESAR (for example, the 4D trajectory concept is closely related with CPDLC implementation). The RPAS should be compatible with CPDLC (this could be a subsystem on board the RPA or in the RPS).

Depending on the airspace class, the ATC is responsible for granting the clearance to enter in airspace and to manage the separation between aircraft commanding orders to the pilot. To perform this communication, the pilot is linked to ATC through a voice (or data link) channel. This link is split into several sub-

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channels, one for each ATC airspace region (responsible for the flight overflying that region).

The requirements and issues about aeronautical communications have been described and analyzed in different works [17], which divide the problem into two scenarios: communication in short and medium/long endurance missions.

Currently, for RPAS low endurance missions (RLOS operations) the solution to be in contact with traffic controller is simple, as it can be established from RPS by direct link with ATC through ground infrastructure or by using a radio channel frequency shared with ATC. This is not a challenge because it is an external system which does not require any kind of communication with the RPA.

More complex is the situation where RPA crosses different sectors and RP has to contact with different ATC units. In this case, the possibility of lost link between the RPS and the RPA forces the RPA to have a certain level of autonomy, in order to maintain minimum separation distances from other traffic and avoid conflicts. The level of autonomy should also cover the contingency of excessive signal delay between RPA and RPS during the execution of a command to avoid conflicts.

According to [6] the communication between ATC and RP could be implemented using the RPA as a communications relay. Table III shows the possible ways of establishing RPAS - ATC communication depending on the distance of operation of the RPA (distance of the RPA from its controlling station RPS).

TABLE III. RPAS COMMUNICATIONS WITH ATC

| RPAS Communications with ATC | |
|---|---|
| **RPS – ATC Direct Link** *(Based on ground-to-ground architecture or radio (UHF, C band). New ATS infrastructure required).* | **RPS – ATC using RPA as relay** *(Based on HF or SATCOM (INMSARSAT, Iridium) for transoceanic operations).* |
| *RPA in RLOS (Short range missions: Direct communication between ATC-RP).* | |
| *RPA in BRLOS (Long range missions: RPA as a relay of communications).* | |
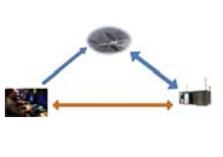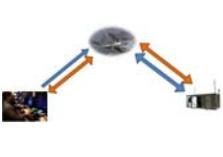
*Operation distance between RPS and RPA*

As mentioned before, the communication link could be done directly from the RPS to ATC (and this link could be used as the main link or as a redundant emergency link). In this case, Remote Pilots will act as pilots of manned aircraft do, and they will be responsible for selecting the correct subchannel ordered from ATC unit to communicate.

In the other case, the communication is done using the RPA as relay. In this case, the RPA should be constantly communicated with the ATC, the ATC orders should be redirected to the RPS through RPA or satellite communications (SATCOM). Since the RPA is not able to change the ATC channel by its own, autonomous mechanisms and messages to perform the communication should be implemented into the RPA, adding complexity to the system.

The communications made using the RPA as relay should have an acceptable level of delay (latency), so that ATC instructions are executed in the required time comparable to manned aircraft (longer delay in response from RPS implies an increase of operational risk). Some delay is introduced as a consequence of resending the data from the RPA to RPS. Furthermore, depending on the distance between the RPS and the RPA, the communication will not always be a direct one, and could be made through Satellite (this will be the case of RPAs with long endurance flights and covering large distances). The satellite communications could produce delay between the order given by ATC and its execution (readback is needed within 2 seconds [18]). RPS tools should support the monitoring of the communication delay and signal quality in order to switch to the best possible communication link. Moreover, the communication link between the RPS and the RPA is a weakness due to the risk of signal jamming and spoofing. RPAS system should be protected from this possibility.

All ATC communication need to have a required communications performance (RCP) appropriate to the ATS provided in the airspace concerned. RP must have not only a C2 data link with the aircraft, but also a voice and/or data link between the RPS and the relevant ATS unit. The C2 RCP Type parameters are: communication transaction time; continuity; availability and; integrity.

Approval to operate in any given airspace would have to consider whether the RPAS communication architecture meets the needs of the ATS provider. Information exchange between ATC and the remote pilot will likely require the same levels of reliability, continuity and integrity, as manned aviation, referred to as 'Quality of Service' (QoS).

• If the ATC (voice or data) communication is relayed via the C2 link, the link must support the requirements of the most demanding RCP.

• If ATC voice communication is relayed though a ground data link that link must also meet the required RCP.

*2) RPA - external users interface: the DAA system*

The ICAO rules for operation in airspace [1][7] make that the RPA, independently of the type of airspace (MAS/UMAS) must be aware of the flight conditions (VMC or IMC), its relative position regarding other airspace users, and its position with respect to the terrain (DAA capability). This capability can be achieved with enhanced with sensors or the ACAS system (automatic exchange of information between aircraft) [19] allowing the RPA to behave as if there was a pilot on board, at least in terms of conflict detection and resolution, assuring the maintenance of the minimum separation distances.

The DAA system operates in two differentiated modes: the Collision Avoidance Mode and the Separation Mode. The Separation Mode acts in the long distance providing advisories of the potential risks of violating separation minima. In the Collision Avoidance Mode, the system acts in the short distance and it is capable of detecting conflicting traffic with the sufficient time of anticipation so as to carry out the evasive manoeuvre (considering that conflicting traffic would be that whose planned trajectory would be at a lesser distance than 500 ft from the RPAS (vertically and horizontally).

The DAA system would allow keeping the required separation distance of the RPAS with the rest of the traffic, IFR or VFR [1]. This mode acts at a longer distance from the intruder.

The requirements for the DAA system are:

- The system should be a boarded one, because otherwise it could not be autonomous;

- The system will have to be connected to its RPS so that the RP can be assisted during the flight, sending the information about possible intruders detected by its sensors and the risk they represent depending on the trajectory path and proximity;

- The DAA must be informed to the Flight Management System (FMS), in order to have precise information for a correct prediction of the risk situations (at least the position and the speed of the RPAS);

- The DAA system will have to calculate a possible evasion manoeuvre that will have to be compatible with the limitations and own actions of the RPAS and according to the current conditions of flight.

- The communication link status should be known in real time, in order to know if the controls have been lost over the RPA and the autonomous mode should be started.

- In case of detecting a loss of separation minima situation, the information should be communicated to other systems such as the FMS to calculate the required manoeuvre and also the RP to take the decision of approving or not that manoeuvre.

Following Eurocontrol specifications [20], the DAA system should send to the RPS the information of interest for the pilot (incoming traffic, calculated manoeuvre of evasion..) and it should have an Autonomous mode.

The tactical manoeuvres executed autonomously by the DAA system will modify the trajectory. The RP will also have the possibility to make time critical changes if required in the trajectory of the vehicle. Those updates in the trajectories will appear in the NOP, allowing the RPAS to adjust its trajectory (in real time).

*3)   RPS - RP interface: the Human Machine Interface*

The Human Machine Interface (HMI) design is paramount for the provision of information to the RP (communications, command and control of the RPA, communications with the ATM system,..). It is advisable that the HMI provides to the RP the relevant information, filtering the non relevant. The information should be filtered attending to the RP needs in every phase of flight. Available commands should allow the pilot to feel he is in control of the RPA.

The HMI interface between the RP and the RPS could incorporate colour displays, pull-down menus, pop-up information advisories and on-screen control commands. The interface may also include the RP to control the aircraft with a new concept that allows the user to provide instructions to the vehicle through a tactile screen (this concept is being studied for future ATCos to interact with aircraft and issue clearances via data link instead of voice communications) as in [21].

The interface design goal is to provide the RP all of the information which is pertinent to the current RPS at any time of flight and under any circumstance (nominal, contingency, and emergency operation) and allowing the RP to acknowledge ATC clearances quickly and smoothly.

CONCLUSIONS

RPAS integration in non segregated airspace would be achieved when three main challenges are solved.

The first one is to establish the standards to certify the airworthiness of the RPAS systems as a whole (RPA, on board equipment and operators qualification). The second one, the technological gap of some RPAS systems, is expected to be solved in the near future [1], and it should be accompanied with the civil aviation authorities' approval. The third one, more complex, is to assess RPAS adherence to the operational rules currently applicable in ATM (for manned aviation), and to maintain the current level of safety. This is the objective of the proposed integration.

To this aim, a technological solution should be provided to fill the gap of not having a person physically onboard the aircraft, particularly regarding the observation of the environment and the maintenance of minimum separation distances with the rest of the traffic and obstacles (conflict detection and resolution). In addition for the RPAS, this implies the maintenance of safe, reliable and continuous communications within the system (robust C2 link between RPS and RPA) and the environment (RPAS with ATM system).

The intention of the study is to avoid segregation in managed airspace as far as possible. Some segregation is unavoidable such as that needed to accommodate certain military and civil activities (due to the immediacy of the operation or the nature of the operation). For reasons of access and equity of all users, it is not proposed to segregate aircraft on the basis CNS capability or the type of separation service being provided.

Taking into account all the considerations and specifications gathered, RPAS will have to comply with the rule of not increasing the risk of operations of other airspace users.

The focus has been set on RPAS operations in the context of ATM proposed by SESAR for future operations. SESAR ATM Target Concept is likely to be affordable and economically viable to all stakeholders only under some conditions, as presented in [22]. For this purpose, a primary

mode of operation has been proposed, in which the RP is overseeing continuously the operation, and a back up mode that allows the RPA to be in autonomous flight (in case of data link loss or other contingencies/emergencies).

Regarding traffic and collision avoidance, the airspace has been divided into controlled and uncontrolled airspace. In controlled, the interfaces needed to cooperate with the rest of the users present in SESAR has been introduced, while in uncontrolled airspace (where ATC is not available to separate an RPA from other airspace users), the RP assumes this responsibility using available surveillance (SUR) information and technical assistance in the form of a DAA system. The DAA system will initiate autonomous collision avoidance in certain circumstances, and especially in case of loss link with the RPS.

In the foreseeable future, RPAS will have to prove to be as safe as current manned operations, or safer. This way it is expected that RPAS should comply with the same safety requirements that are required for the manned aircraft. These requirements include the redundancy of some systems, the RP training, airworthiness of RPA and the agreed and supervised procedures, where EASA has ultimate responsibility over safety.

RPAS behaviour in operations will also have to be equivalent to manned aviation, in particular in their interaction with air traffic control (ATC), as it will not be possible for the ATC to effectively handle many different types of RPAS with different contingency procedures.

This requirement involves that the RPAS being integrated in MAS would probably have similar equipment and performances to manned aviation, so that their behaviour is expectable for the rest of the users of the airspace. For those operating in UMAS, which have more freedom and flexibility in their operations and equipment, the autonomy of the RPA and the DAA system onboard would be of main relevance, so that minimum separation distances are kept under any circumstance, without relying solely on the RP supervision.

The proposed solution for RPAS, based on SESAR CONOPS, is commonly accepted and can be assumed by several international organizations related with aeronautical operations, and that should be finally supported by ICAO and EUROCOTROL (compliance). The solution is compliant with international civil aviation regulations, and allows the RPAS to operate in the same conditions as the rest of the users, while maintaining the safety of the ATM system.

## ACKNOWLEDGMENT

## REFERENCES

[1] International Civil Aviation Organization (ICAO), "Manual on Remotely Piloted Aircraft Systems (RPAS)", Draft version, April 2012.

[2] International Civil Aviation Organization (ICAO), "Annex 2 - Rules of the Air", Tenth Edition. July 2005.

[3] SESAR Joint Undertaking, "Architecture of the Technical Systems Description Document for Step 1".

[4] SESAR Joint Undertaking, "Roadmap European ATM Master Plan". Edition 2, October 2012.

[5] U.S. Department of Transportation, "Integration of Civil Unmanned Aircraft Systems (UAS) in the National Airspace System (NAS)", Federal Aviation Administration (FAA). First Edition 2013.

[6] International Civil Aviation Organization (ICAO), "Circular 328 Unmanned Aircraft Systems (UAS)", 2011.

[7] International Civil Aviation Organization (ICAO), "Amendment 43 to the International Standards Rules of the Air (Annex 2)", March 2012.

[8] Karthik Ramalingam, Professor Roy Kalawsky and Chris Noonan, "Integration of Unmanned Aircraft System (UAS) in Non-segregated Airspace: A Complex System of Systems Problem". Loughborough University, UK.

[9] U.S. Department of Transportation, "Unmanned Aircraft Operations in the National Airspace System", Federal Aviation Administration (FAA), March 2011.

[10] SESAR Joint Undertaking, "SESAR CONOPS at a Glance", Edition 2, July 2011.

[11] Keven A. Gambold, "Unmanned Aircraft System Access To National Airspace", November 2011.

[12] International Civil Aviation Organization (ICAO), "Doc 9863 Airborne Collision Avoidance System (ACAS) Manual", First Edition. 2006.

[13] Estado Mayor (MºDefensa), "Normas Del Jefe De Estado Mayor Del Ejército Del Aire, Autoridad Competente Militar, Sobre La Operación De Sistemas Aéreos No Tripulados (Uas) Militares En Espacio Aéreo Segregado", División De Operaciones Sección De Espacio Aéreo, February 2011. (Spanish)

[14] International Civil Aviation Organization (ICAO), "Doc 9965 AN/483 Manual on Flight and Flow Information for a Collaborative Environment".

[15] EUROCONTROL, "Specification for the application of the Flexible Use of Airspace (FUA)", Edition 1.1., January 2009.

[16] International Civil Aviation Organization (ICAO), "Doc 9694 Manual Of Air Traffic Services Data Link Applications", First Edition, 1999.

[17] Institute of Communications and Navigation, German Aerospace Center (DLR), Germany, "Future Aeronautical Communications", InTech, 2011.

[18] Esa M. Rantanen, Jason S. McCarley & Xidong Xu., "Time Delays in Air Traffic Control Communication Loop: Effect on Controller Performance and Workload", The International Journal of Aviation Psychology Volume 14, Issue 4 (p. 369-394). 2004.

[19] EUROCONTROL, "Unmanned Aircraft Systems – ATM collision Avoidance Requirements", Edition No. 1.3, May 2010.

[20] EUROCONTROL, "Specifications for the use of Military Remotely Piloted Aircraft as Operational Air Traffic Outside Segregated Airspace", (MIL/MILT/UAV/06-2116 V2.0), February 2012.

[21] Nathan M. Paczan, Jeremy Cooper, Eric Zakrzewski, "Integrating Unmanned Aircraft Into Nextgen Automation Systems", The MITRE Corporation, Mclean, VA. October 2012.

[22] International Civil Aviation Organization (ICAO), "Circular 330, Civil Military Cooperation in Air Traffic Management", 2011.