E.02.34-D08 ERAINT Project Closeout Report

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Abstract

The final report of the ERAINT project provides a publishable summary of the results. In addition it lists all deliverables, dissemination activities, eligible costs, deviations, bills and lessons learned.

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This deliverable consists of SJU foreground.

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Publishable Summary

This document describes the results attained during the three step validation activities for civil RPAS integration in non-segregated IFR airspace under the ERAINT WP-E project E.02.34. It outlines the exercises implemented to validate that RPAS mission-oriented operation is feasible assuming a variety of traffic scenarios and available equipment.

ERAINT performed an extensive set of real-time simulations with both an RPAS and ATC controllers operating in a realistic environment. The generated scenarios were employed to analyse specific aspects related to the insertion of civil RPAS in non-segregated airspace and the impact of their automated remote operation from an ATM perspective, also supported by automation. All activities and results developed within the project have attempted to converge into a proposed concept of operation that should provide significant guidance on the way civil RPAS may be operated in the future SESAR airspace, and adherence to the European Commission Roadmap for the safe integration of civil RPAS into the European aviation system.

ERAINT specifically addressed separation provision, response to RPAS contingencies, lost link procedures, and the modification of the RPAS reference trajectory while in execution, due to mission requirements. Also, combined with the introduction of additional automation technology, the research was investigating the active interaction of the PiC (the legal responsible of the flight) and the ATC through the extensive use of automation and information exchange. We intended to find how automation (i.e. systems that support the RPAS pilot while he keeps the final decision) may help the RPAS to satisfy the operational and safety requirements; and how information could be shared between the RPAS and ATC in a proactive way through upcoming data-links.

The RPAS flight intent, defined as an on-board generated predicted trajectory, is employed as one of the main technological enablers. Flight intent, potentially implemented on top of the current ADS-C data-link standards, is employed both tactically and strategically to positively impact the ATC situational awareness during mission operations and contingency management.

ERAINT addressed the key RPAS integration requirements that were identified from various sources; namely: the existing technological and procedural gaps indicated in the Annex 2 of the Roadmap for the Integration of civil Remotely-Piloted Aircraft Systems into the European Aviation System [1] recently published by the European Commission; the SESAR roadmap [2]; as well as ERAINT-specific requirements.

The high fidelity evaluation of RPAS operations was reproduced through the usage of the RAISE-eDEP integration RPAS simulation environment. Realistic traffic and airspace structure was also extracted from EUROCONTROL’s DDR2 database [5]. Eight different ATC controllers from four different nationalities participated in the exercises, all of them in active duty and with experience in both enroute and TMA sectors. Some of them were even qualified for the sectors under evaluation.

Overall, 100 fully successful simulations were carried out, covering more than 90 hours of simulation time, of which, almost 47 hours correspond to flight time in which the simulated RPAS was under active control by a human ATC in one of the active sectors selected for the simulation exercise under consideration.

RPAS operations were reproduced through a comprehensive airspace access process. Coherent RPAS missions were designed for two types of RPAS, a HALE (High Altitude Long Endurance) RQ-4A and a MALE (Medium Altitude Long Endurance) MQ-9, submitted to ATC experts for evaluation and negotiation, executed in a highly monitored real-time environment, and evaluated under viability, safety, workload and performance metrics. Equivalent scenarios were also created to be analysed under fast-time simulation tools. ERAINT Actively collaboration with EEC’s BADA team leading to the development of the first set of RPAS’s performance models implemented under BADA3 and publicly released under the corresponding license.

ERAINT Step A addressed: Gap EC 1.1 *Short-term validation: current ATM* and Gap EC 1.2 *Long-term validation methodology: future ATM environment* [1] with respect the “Separation Provision” as the ability for RPAS to respond to mandatory ATC instructions intended to achieve prescribed separation from other aircraft; and "Traffic Avoidance" as the participation of the RPAS pilot to the separation with possibility for the ATC to delegate separation to the RPAS pilot.

The Step-A evaluation has taken into account, in general terms, the basic RPAS factors that affect the execution of separation manoeuvres: basic performance factors that limit the RPAS's capabilities to perform vertical and horizontal manoeuvres, the complexity and specificities of the RPAS surveillance operations, the impact of communication latency between the pilot, the RPAS and the ATC; etc.

Two different scenarios of increasing operational complexity (ferry mission and a surveillance mission within a busy TMA) were employed to determine which concepts facilitate the RPAS integration by keeping the ATC workload increase up to reasonable levels.

Recorded taskload values show that the direct RPAS impact never exceeds beyond a 5 over 100 factor, while the overall taskload may increase with values around 10 over 100 in the most complex cases. However, all workload values maintaining an average of Low with some High peaks in those sporadic situations in which multiple traffics converge in the TMA area and the RPAS is in operation.

With respect to separation provision, no major difficulty appeared in the ferry operation while more complex separation encounters occurred in the TMA area. The RPAS performance and the communication delay condition the ATC decision to move the commercial traffics instead of the RPAS in the majority of situations. The time required for avoid conflicts by vectoring the RPAS alone is a function of speed ratio/difference and conflict geometry and that in the vast majority of cases still needs to be evaluated whether it is possible within the timeframes of tactical control.

As a conclusion, it may seem not practical to give separation intended ATC instructions to the RPAS as a common procedure unless provided much in advance (like blocking the RPAS transit from one sector to another within an ATC coordination due to peak traffic conditions). In general, it may be more reliable and safe to give separation instructions to commercial traffic in order to separate them from a RPAS, which in consequence may reduce sector capacity due to the additional workload involved. However, very clearly it is difficult to justify that as a common rule that airliners with large number of passengers and huge costs for airlines are radar vectored to avoid RPAS. Thus, a contradiction exists that needs to be further investigated.

Methods to quantify, mitigate and compensate for that ATM system performance reduction need to be investigated once we can identify which types of RPAS operations will lead to performance reductions beyond those levels that could be accepted; i.e. the same ones than those added by standard operations may introduce.

RPAS flight intent has shown itself as a highly valuable mechanism to facilitate the integration of RPAS in non-segregated airspace. During the ferry mission, flight intent reconfirmed an uneventful operation, without any separation issue and limited amount of impact with surrounding aircraft.

During the TMA surveillance mission the benefits were much higher, especially in those periods of time in which the RPAS needed to divert its initial flight plan to perform scan-area or scan-point operations. Flight intent permitted the RPAS a more clear communication of its intentions, thus letting the ATC controller to provide a higher level of non-segregation in the area where the RPAS performed its mission pattern. Given that level of non-segregation, other traffic could cross the surveillance area (at different or even the same flight level than the RPAS is operating).

Even though flight intent provides clear indications that it is the way to go in terms of RPAS integration, a number of elements need to be evaluated and consolidated before further evaluations can be performed. Two are the main aspects that require analysis. First, clarify the full concept of operation behind the usage of flight intent. In particular a clear differentiation is necessary to understand the role of the reference trajectory, and how flight intent is a valid mechanism to negotiate trajectory modifications, both permanent and temporary; but also to keep track of the RPAS trajectory while a temporary trajectory change is being executed. Second, identify how each type of flight intent should be implemented in order to maximize the benefit to the ATC. In particular there is a large difference between immediate flight intent information and flight intent designed to negotiate trajectory changes. Flight intent designed for trajectory negotiation may need to cover wider portions of the flight operation, so that the ATC can properly understand the mid- and long-term implications of the trajectory change.

ERAINT Step-B addressed Gap EC5 *Safe automated monitoring, support to decision making and predictability of behaviour*, from the Roadmap for the integration of civil RPAS – Annex 2; and in particular the technology gaps Gap EC5.1 *Safe and standard recovery procedures for contingencies and emergency*, and Gap EC 5.3 *On-board real-time smart processing*.

The aim of the Step-B validation activities was to ensure that RPAS contingency management concepts are operationally usable, that the resulting RPAS-ATC interaction and workload remained within manageable levels, but also that the RPAS retained enough flexibility to perform all the required recovery operations that guarantee the survival of the platform. Benefit factors to alleviate the RPAS insertion penalty will include the exploitation of ADS-B, RPAS-ATC data links, and automated supporting tools to facilitate the management of the contingencies.

Two different scenarios of different operational complexity (the MALE TMA surveillance, and a long range HALE north of the MUAC area) validated the management of RPAS contingencies while keeping the ATC workload increase up to reasonable levels. The RPAS contingency management has been implemented under a number of principles:

1. Contingency routes were pre-planned for all portions of the mission, being negotiated with the ATM authority, and known with certain level of detail by the actual ATC controllers.
2. The RPAS will have the capability to execute most/all the contingency procedures in a fully automated manner, under the PiC supervision when possible.
3. Flight intentions and strategic trajectory negotiation took place between the RPAS and the ATC during engine failure contingencies; and along the RPAS mission, prior to potential lost-link contingencies.
4. Decision tools were available to the PiC to select the most advantageous contingency response.
5. The RPAS never executed separation manoeuvres autonomously, unless commanded by the PiC due to a direct ATC request.

This Step-B evaluation has taken into account, in general terms, the basic RPAS factors that affect the execution of contingencies, specifically to manage engine failure and lost-link contingencies: basic performance factors that limit the RPAS's capabilities, the complexity and specificities of the RPAS surveillance operations, the impact of communication latency between the pilot, the RPAS and the ATC; etc.

The development of contingency RPAS operations individually managed is viable and resulting into limited ATC workload impact when implemented under a reasonable concept of operation (values never exceeded Low values with some Fair peaks during the RPAS contingency). Further investigation is required to evaluate coupled or chained contingencies, especially those related to the loss of the command and control link. Flight intent has demonstrated as a key mechanism to improve the understanding of the ATC with respect the way the RPAS will respond to the flight contingency.

Finally, Step-C validation activities focused on the modification of the RPAS reference trajectory while in execution, due to mission requirements that justify such a change. The trajectory modification will be requested, negotiated and executed under the SESAR concept of operation, assuming a variety of traffic scenarios and available equipment.

The aim of the validation activities was to ensure that the concept of operation for RPAS reference trajectory modification during execution is operationally usable; that the resulting RPAS-ATC interaction and workload remains within manageable levels, but also that the RPAS retains enough capacity to perform all the required recovery operations that guarantee the survival of the platform. Benefit factors to alleviate the RPAS insertion penalty included the exploitation of ADS-B, RPAS-ATC data links, and automated supporting tools to facilitate the management of the trajectory negotiation and update process. Moreover, it has been investigated how this trajectory change can be implemented under the SESAR concept of operation and the procedural and technological elements that come with it.

Further investigation is necessary before RPAS can be integrated in a broader sense. The experience gathered in the ERAINT project raised a better understanding of the factors that should be considered, beyond the basic integration of a single vehicle, namely:

- Extend the evaluation of the RPAS insertion impact to analyse the impact and feasibility of larger fleets of RPAS operating simultaneously over an extensive area.
- The impact on surrounding traffic flight inefficiency needs to be understood in order to clarify whether there is a substantial economic penalty that may result to airlines from a large scale

RPAS operation. The reduced performance of RPAS when compared with most airliners is an important factor, but not less relevant than the actual RPAS mission itself.

- Better metrics need to be developed to measure the ATC's workload and taskload increase factors resulting from managing one or more RPAS. Those factors will have direct impact on a sector capacity while RPAS operate within.
- More complex contingency scenarios need to be investigated. In particular those scenarios that combine multiple types of RPAS failures occurring at the same time or in a ripple effect.
- Data-link technologies have demonstrated to be a key contributing factor that facilitates integration by raising awareness. The technological viability and cost of a generalized utilization on-board RPAS, but also within the ATC centres needs extensive evaluation.

ERAINT's conclusion can be summarized in a single sentence: *individual mission oriented RPAS can be integrated in complex IFR airspace safely, but with a cost in terms of ATC workload and airliners flight inefficiency*. Data link technology will ease that integration, raising ATC awareness, but will not reduce ATC workload in a significant way. The level of induced flight inefficiency will greatly depend on the RPAS's mission and the complexity of the airspace; thus the impact can be limited by carefully designing the location and timing of missions in highly complex airspace. The scalability and reasonable limits of those impact factors will require further investigation.

1 Introduction

1.1 Purpose of the document

The purpose of this document is to:

- Summarise the technical results and conclusions of the ERAINT project in a Publishable Summary;
- Provide a complete overview of all project deliverables;
- Provide a complete overview of all dissemination activities (past and in progress). Where appropriate, provide feedback from presentations. We will also describe future exploitation plans.
- Provide a complete overview of the billing status, eligible costs, planned and actual effort (incl. an explanation of the discrepancies).
- Analyse the lessons learnt at project level.

1.2 Intended readership

This document is intended for projects that investigate the insertion of RPAS in non-segregated IFR airspace. It describes in three Steps A – B - C the validation process followed to investigate (A) basic integration and separation management, (B) contingency management, and (C) its basic impact on the SESAR concept of operation; but also investigates the use of data-link technologies to improve the RPAS integration across the explored phases of operation. The findings may be of interest to those projects evaluating future RPAS integration.

1.3 Inputs from other projects

N/A

1.4 Glossary of terms

2 Technical Project Deliverables

Number	Title	Short Description	Approval status
D0.1	Project Plan	Project Plan including dissemination plan	Approved
D1.1	Experimental plan and metrics to evaluate separation management	Experimental plan and metrics including workload to evaluate separation management	Approved
D2.1	Strategies for RPAS separation management and selected evaluation scenarios	Strategies for RPAS insertion in non-segregated airspace with special focus on separation management	Approved
D3.1	Mission design to validate the RPAS separation ConOps	Mission design to validate the RPAS specific strategies for separation management	Approved
D4.1	Validation report of results of the RPAS separation experiments	Validation report of results of the RPAS separation experiments including operational and workload metrics	Approved
D1.2	Experimental plan and metrics to evaluate contingency management	Experimental plan and metrics including workload to evaluate contingency management	Approved
D2.2	Strategies for RPAS contingency management and selected evaluation scenarios	Strategies for RPAS insertion in non-segregated airspace with special focus on contingency management	Approved
D3.2	Mission design to validate the RPAS contingency ConOps	Mission design to validate the RPAS specific strategies for contingency management	Approved
D4.2	Validation report of results of the RPAS contingency experiments	Validation report of results of the RPAS contingency experiments including operational and workload metrics	Approved
D1.3	Definition of the experimental plan and metrics to evaluate low impact flight plans	Definition of the experimental plan and metrics including workload to evaluate low impact flight plans	Approved
D2.3	Strategies for RPAS low airspace impact and selected evaluation scenarios	Strategies for RPAS insertion in non-segregated airspace with special focus on low airspace impact	Pending
D3.3	Mission design to validate the RPAS airspace impact ConOps	Mission design to validate the RPAS specific strategies for airspace impact minimization	Approved
D4.3	Validation report of results of the RPAS airspace impact experiments	Validation report including operational and workload metrics	Pending

Table 1 - List of Project Deliverables

3 Dissemination Activities

The ERAINT consortium tried to actively contact with all RPAS-related stakeholders, in Europe and worldwide, that could be interested in the technology and results attained along the project development. The most successful collaboration has been the relationship with the BADA unit at EEC, triggering the open development of RPAS performance models. The results achieved in this specific activity have been also disseminated within NASA, which also developed RPAS performance models a few years ago.

3.1 Presentations/publications at ATM conferences/journals

Pérez-Batlle, M., Cuadrado R., Barrado C., Royo P., Pastor E. Real-time Simulations to Evaluate RPAS Contingencies in Shared Airspace, 5th SESAR Innovation Days, 1-3 December 2015, Università di Bologna Bologna, Italy.

Pastor, E., Perez-Batlle, M., Royo, P., Cuadrado, R. & Barrado, C. 2014 (Oct). Real-time Simulations to Evaluate the RPAS Integration in Shared Airspace. In Proceedings of the 4th SESAR Innovation Days (SIDs2014). EUROCONTROL, Madrid, Spain.

Pastor, E., Perez-Batlle, M., Royo, P., Cuadrado, R. & Barrado, C. 2013 (Nov). Preparing for an Unmanned Future in SESAR Real-time Simulation of RPAS Missions. In SESAR Innovation Days (SID2013). Eurocontrol, Stokholm, (Swedeen).

Pastor, E., Royo, P., Cuadrado, R., Barrado, C. & Pérez-Batlle, M. 2013 (Nov). Eraint - Evaluation of the RPAS-ATM interaction in non-segregated airspace. In SESAR Innovation Days (SID2013). Eurocontrol, Stokholm, (Swedeen).

Perez-Batlle, M., Pastor, E., Prats, X., Royo, P. & Cuadrado, R. 2013 (Jun). Maintaining separation between airliners and RPAS in non-segregated airspace. In Proceedings of the 10th USA/Europe Air Traffic Management Research and Development Seminar (ATM2013). Eurocontrol/FAA, Chicago, IL (USA). Best paper in track award.

Royo, P., Barrado, C. & Pastor, E. 2013 (Nov). ISIS+: A Software-in-the-Loop Unmanned Aircraft System Simulator for Nonsegregated Airspace. AIAA Journal of Aerospace Information Systems. Vol. 10 (11) pp. 530-544.

HALA! SUMMER UNIVERSITY: Integration of Remotely Piloted Aerial Systems IN ATM Operations, 14th - 17th July 2014 Place: La Granja de San Ildefonso (Spain). Including presentations:

- RPAS Integration RPAS flight performance envelope and separation problem.
- Separation approaches as a function of TAS/Mach ratio.
- RPAS Concept of Integrated Operations.
- RPAS Mission Area - airspace analysis, using NEST.
- Introduction RPAS real-time simulation and analysis.

3.2 Presentations/publications at other conferences/journals

Pastor, E., RPAS ATM Integration Concept – the ERAINT Project. ART Workshop ‘RPAS and their Impact on ATM’ on 24th September, Vilnius (Lithuania).

Pérez-Batlle M., Tadeo C., Pastor E., 2015 (Sep) A Methodology for Measuring the Impact on Flight Inefficiency of Future RPAS Operations, Proceedings of the 34th Digital Avionics Systems Conference. IEEE/AIAA, Prague, Czech Republic

Pérez-Batlle, M. BADA-based RPAS dynamic models for enabling their integration in shared airspace. BADA User Group Meeting, 9-10th September, Washington DC (USA).

Pérez-Batlle, M. Requirements and use of BADA models in support to RPAS. BADA User Group Meeting, 9-10th September, Washington DC (USA).

E. Pastor, P. Royo, R. Cuadrado, M. Pérez-Batlle and C. Barrado, ISIS+: A Realistic ATM-UAS Simulation Environment, Proceedings of the AUVSI Unmanned Systems 2013.

Cuadrado, R., Royo, P., Barrado, C., Pérez-Batlle, M. & Pastor, E. 2013 (Nov). Architecture issues and challenges for the integration of RPAS in non-segregated airspace. In Proceedings of the IEEE 32nd Digital Avionics Systems Conference. IEEE/AIAA, Syracuse, NY (USA).

Royo, P., Cuadrado, R., Barrado, C., Salamí, E., Pérez-Batlle, M. & Pastor, E. 2013 (Nov). Towards the automation of the UAS mission management. In Proceedings of the IEEE 32nd Digital Avionics Systems Conference. IEEE/AIAA, Syracuse, NY (USA).

3.3 Web presence

A number of actions has been planned to take regarding the web presence of the project. On one hand, a YouTube channel, where videos depicting part of the simulation exercises have been created, produced and uploaded, was created. On the other, as planned in the proposal, will be to make available the extensive collection of simulation results developed in ERAINT. This objective requires further analysis in order to generate a scalable and useful database that can be the seed for adding future RPAS-related information related to ATM integration.

3.4 Demonstrations

5th SESAR Innovation Days (SIDs2015), Dec 2015. EUROCONTROL, Bologna, (Italy).

Multi-day demonstration carried out at the SESAR Innovation Days for the researchers attending the conference. The demonstration intended to disseminate the RPAS insertion problem, increasing the awareness among the ATM community.

10th USA/Europe Air Traffic Management Research and Development Seminar (ATM2015). Jun 2015. EUROCONTROL/FAA, Lisbon, (Portugal)

Multi-day demonstration carried out at the ATM Seminar for the researchers attending the conference. The demonstration intended to disseminate the RPAS research carried out by the ERAINT project to the NASA delegation attending that conference. Initial contacts were made as well as discussions with respect the strategies to carry out when evaluating the ATM insertion in non-segregated airspace.

4th SESAR Innovation Days (SIDs2014). Dec 2014. EUROCONTROL, Madrid, Spain.

Multi-day demonstration carried out at the SESAR Innovation Days for the researchers attending the conference. The demonstration intended to disseminate the RPAS insertion problem, increasing the awareness among the ATM community.

3rd SESAR Innovation Days (SIDs2013). Dec 2013. EUROCONTROL, Stockholm, (Sweden).

Multi-day demonstration carried out at the SESAR Innovation Days for the researchers attending the conference. The demonstration intended to disseminate the RPAS insertion problem, increasing the awareness among the ATM community.

The drone night. COSMOCAIXA Museum. Oct 2015 Barcelona (Spain)

Multi-day demonstration carried out at COSMOCAIXA museum. The demonstration intended to disseminate the RPAS integration problem to the Spanish general public.

3.5 Future plans

The results and experience attained within the ERAINT project should trigger further research aspects that have been identified as important. Those research aspects refer to the generalized impact of RPAS once fleets of vehicles operate in non-segregate airspace as well as the development of the adequate metrics to measure that impact. Within that general objective in mind, the exploitation plans foreseen from ERAINT are the following:

- Extend the evaluation of the RPAS insertion impact to analyse the effect of larger fleets of RPAS operating simultaneously over an extensive area. That investigation is crucial to determine the integration impact beyond a single aircraft operation, and to determine up to which limit the European airspace can absorb an increase in IFR RPAS operations.
- Interaction with EUROCONTROL to refine the airspace impact metrics (taskload and flight inefficiency) taking into account the specific characteristic of RPAS. The experience gathered in the project should lead to the development of further research and proposal in that area.
- RPAS contingency scenarios go beyond individual failures. Hence, scenarios that combine multiple types of RPAS failures occurring at the same time or in a ripple effect need to be investigated, with special emphasis on the potential impact of communication latencies during critical portions of the flight.
- Data-link technologies have demonstrated to be a key contributing factor that facilitates integration by raising awareness. Viability of the concepts developed in ERAINT within current and future standards will need to be investigated.
- Development of RPAS performance models to be used in the ATM domain, in particular for the implementation of BADA3 and BADA4 models for selected RPAS of which certain performance data is available. Those models will be critical to validate that 4D trajectory prediction strategies foreseen in SESAR.
- Collection of the trajectory data will lead to the development of a data base of RPAS trajectories, which should be made available to the research community in order to promote ATM research in the area.
- The additional knowledge gathered about the operation of the eDEP simulation environment has led to the extension of the simulation capabilities with the objective to develop further investigation in the SID, STAR and airport domain. Given that the existing simulation environment already covers the arrival-departure environment, we will extend it to include the RPAS take-off/landing and taxi operations.

4 Total Eligible Costs

Date	Deliverables on Bill	Contribution for Effort	Contribution for Other Costs (specify)	Status
31.03.2014	D0.1 D0.2 D0.3 D1.1 D2.1 D5.1	92.931,36 €	760,0 €	Paid
25.09.2014	D3.1 D0.4 D4.1 D0.5	86.229,62 €	1.120,09 €	Paid
17.02.2015	D0.6 D0.7 D5.2 D1.2 D2.2	86.830,06 €	3.400,76 €	Paid
15.10.2015	D0.8 D0.9 D3.2 D4.2	87.604,84 €	4.224,36 €	Paid
15.01.2016	D1.3 D2.3 D5.3 D0.10 D3.3 D4.3 D5.3 D6 D0.11	174.118,52 €	4.594,8 €	To be billed
GRAND TOTAL		527.714,41 €	14.100,01 €	

Table 2 Overview of Billing

Company	Planned man-days	Actual man-days	Total Cost	Total Contribution	Reason for Deviation
UPC	675	663.16	299.435,13 €	303.976,63 €	No deviation
Levelco	182	182.06	153.062,69 €	114.760,37 €	No deviation
J. Peres Mir	286	286.13	164.178,97 €	123.077,42 €	No deviation
GRAND TOTAL	1143	1131.35	616.676,79 €	541.814,42 €	No deviation

Table 3 Overview of Effort and Costs per project participant

5 Project Lessons Learnt

What worked well?
Development of RPAS-ATC simulation environment with realistic missions and realistic traffic allowed to experiment the operational scenarios that upcoming RPAS may develop while operating under IFR conditions in non-segregated airspace.
Development of various types of RPAS flight intent through a simulated data-link worked properly and allowed to assess its positive contribution to the ATC situational awareness (nominal: 5-10 min, contingency: full trajectory, requested: for trajectory negotiation).
The efforts carried out to identify the performance of the RPAS employed during the evaluations provided a better understanding of their capabilities, but also the creation of an accurate trajectory prediction system that was critical to populate the RPAS flight intent.
Cooperation between active ATC controllers and research institution maximized the effectiveness of the project development, beyond the simple participation of ATC in simulations.
Additional ATC support provided by SESAR to complement the one available within the ERAINT consortium, permitting a large number of repetitions for each exercise, exploring different ways to addresses the same RPAS integration aspect.
Active collaboration with EEC's BADA team leading to the development of the first set of RPAS's performance models implemented under BADA3 and publicly released under the corresponding license.
What should be improved?
The ATC simulation environment (eDEP) worked well in most occasions, but its reliability was limited. In certain occasions the simulator failed due to unknown reasons and in certain cases it was extremely sensitive to the initial configuration of the data.
Taskload metrics used to capture the impact of a single RPAS operation where non-effective as the actual factors considered in that metrics (CAPAN) did not include the specific particularities of RPAS's operations.
Separation management of one RPAS at a time in a sector is considered manageable, but the impact of several RPAS acting within a sector is identified as a major recommendation for further studies. Whereas a single RPAS can be successfully handled in tactical way, to cope with multiple RPAS they need to be handled upstream in planning / strategic phase.
Full non-segregation was envisaged within the project development. However, in those situation in which RPAS impact on separation may be excessive, a mission trajectory employing a variation of a Type 2 DMA could be allocated along the RPAS mission. Only a portion of the whole DMA need to be activated each time as in a Variable Profile Area. Each subarea is activated through separated CTO at ARES and CTO at ARES exit. The consecutive activation of a sequence of DMA portions, each one of them overlapping with the next one in the proper sequence, with its corresponding time range constraints, will simplify the RPAS management.
Access to RPAS related information very difficult (related to operational mission concepts, system capabilities and vehicle performance). Active goal to develop a continuous gathering of information through contacts with operators and system developers.
Access to information and data related to main stream work packages is extremely difficult, thus limiting the opportunities to maintain the correct alignment with SESAR.

Table 4 - Project Lessons Learnt

6 References

[1] Marc Pérez-Batlle. Real-time Simulations to Evaluate RPAS Contingencies in Shared Airspace, 5th SESAR Innovation Days, 1-3 December 2015, Università di Bologna Bologna, Italy.

[2] Pastor, E., Perez-Batlle, M., Royo, P., Cuadrado, R. & Barrado, C. 2014 (Oct). Real-time Simulations to Evaluate the RPAS Integration in Shared Airspace. In Proceedings of the 4th SESAR Innovation Days (SIDs2014). EUROCONTROL, Madrid, Spain.

[3] Pastor, E., Perez-Batlle, M., Royo, P., Cuadrado, R. & Barrado, C. 2013 (Nov). Preparing for an Unmanned Future in SESAR Real-time Simulation of RPAS Missions. In SESAR Innovation Days (SID2013). Eurocontrol, Stokholm, (Swedeen).

[4] Perez-Batlle, M., Pastor, E., Prats, X., Royo, P. & Cuadrado, R. 2013 (Jun). Maintaining separation between airliners and RPAS in non-segregated airspace. In Proceedings of the 10th USA/Europe Air Traffic Management Research and Development Seminar (ATM2013). Eurocontrol/FAA, Chicago, IL (USA). Best paper in track award.

[5] Pastor, E., Royo, P., Cuadrado, R., Barrado, C. & Pérez-Batlle, M. 2013 (Nov). Eraint - Evaluation of the RPAS-ATM interaction in non-segregated airspace. In SESAR Innovation Days (SID2013). Eurocontrol, Stokholm, (Swedeen).

[6] Perez-Batlle, M., Pastor, E., Prats, X., Royo, P. & Cuadrado, R. 2013 (Jun). Maintaining separation between airliners and RPAS in non-segregated airspace. In Proceedings of the 10th USA/Europe Air Traffic Management Research and Development Seminar (ATM2013). Eurocontrol/FAA, Chicago, IL (USA). Best paper in track award.

[7] Royo, P., Barrado, C. & Pastor, E. 2013 (Nov). ISIS+: A Software-in-the-Loop Unmanned Aircraft System Simulator for Non-segregated Airspace. AIAA Journal of Aerospace Information Systems. Vol. 10 (11) pp. 530-544.

[8] E. Pastor, P. Royo, R. Cuadrado, M.P. Batlle and C.Barrado, ISIS+: A Realistic ATM-UAS Simulation Environment, Proceedings of the AUVSI Unmanned Systems 2013.

[9] Cuadrado, R., Royo, P., Barrado, C., Pérez-Batlle, M. & Pastor, E. 2013 (Nov). Architecture issues and challenges for the integration of RPAS in non-segregated airspace. In Proceedings of the IEEE 32nd Digital Avionics Systems Conference. IEEE/AIAA, Syracuse, NY (USA).

[10] Royo, P., Cuadrado, R., Barrado, C., Salamí, E., Pérez-Batlle, M. & Pastor, E. 2013 (Nov). Towards the automation of the UAS mission management. In Proceedings of the IEEE 32nd Digital Avionics Systems Conference. IEEE/AIAA, Syracuse, NY (USA).