D02 - TEMPAERIS Final Report

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Abstract

This document is the Demonstration Report of TEMPAERIS RPAS Demo Project. It focuses on the analysis of the results of the flight trial campaign and the simulation campaign. Emergency procedures have been developed specifically for the project. The aim is to assess these procedures during RPAS integration in a mid-size airport. Results had proven that procedures developed in the scope of this project are accepted by ATCOs and that the main concerns regarding RPAS integration are the low speed of existing RPAS and the time lag of radio transmissions.

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Rational for rejection
None.

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00.00.04	25/07/2015	Intermediate version		Version to take into account external comments
00.00.05	18/08/2015	Intermediate version		Adding results for OBJ-RPAS05-220
01.00.00	22/09/2015	Final version		Insertion of preliminary remarks of the SJU
01.01.00	07/10/2015	Final version		Insertion of SJU remarks

Intellectual Property Rights (foreground)

This deliverable consists of SJU foreground.

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Executive summary

This demonstration report has been written by the members of the TEMPAERIS consortium for the SESAR Joint Undertaking. The objective of the project was to investigate the impact of Remotely Piloted Air Systems (RPAS) integration into non segregated airspace in a mid-traffic density environment. The project proposed and demonstrated procedures to achieve a safe integration of RPAS and manned flights in a same airspace. The impact on the traffic safety and regularity as well as on controller workload was assessed. In the same way the project highlighted ATM constraints to be taken into by RPAS systems. The project was based on trials of simulation and real flights.

Real flights have been carried out at the Bordeaux-Mérignac airport. In 2012, Bordeaux airport handled 4.38 million of passengers and approximatively 70,000 aircraft movement. It is a regional airport and it is not part of a broader airport system. Peak hours are around 25 movements per hour. Average traffic is around 10/12 movements an hour. Our real flights campaign dealt with the Approach part of air traffic control services. Focus was placed on:

- assessing, in terms of safety and regularity, the impact of inserting slow flying RPAS (between 70 and 90 kt) into a non-homogeneous traffic, as both civil and military aircraft types may be found at Bordeaux with approach speeds between 90 and 250kt,
- assessing the impact of RPAS non nominal modes (communication failure, command and control failure) on ATC performance.

Few technical problems were encountered anyway, as flights were conducted in the first week of February 2015, the cold and cloudy weather forced the RPAS to fly at an altitude below the initially planned 3000 ft. This triggered some problems on the command control link which was sometimes lost on the farthest segment of the trajectory.

Real Time Simulation (RTS) were conducted on TMA/lower en Route airspace, in order to address a broader spectrum of situations. RTS included a reference scenario with no RPAS and two RPAS scenarios: a “nominal RPAS” scenario and another one with non-nominal situations (Return Home).

These scenarios consisted in simulations lasting approximately 40mn and RPAS scenarios displayed 3 to 4 RPAS flights, of different RPAS “generic” types. These RPAS had different approach speeds and some of them were considered as using SATCOM, thus showing some lag in their behaviour.

TEMPAERIS results have proven that procedures developed in the scope of this project are accepted by ATCOs and that the main concerns regarding RPAS integration are the low speed of existing RPAS and the time lag of radio transmissions.

It appeared that all objectives defined in the Demonstration Plan [1] were fully satisfied except for the following one:

- Predictability of the RPAS trajectory: Few ATCOs considered that RPAS instructions were executed with a slight delay compared to the manned aircrafts
- Runway Capacity: Due to the low speed of the RPAS, ATCOs had to make the RPAS leave the SID earlier not to interfere with the other traffics.
- ATCO Workload: The RPAS operation generates more message exchange than the situation without RPAS.

Finally the most important lessons learned were that:

- RPAS behaviour was not perceived as different from the one of a small general aviation aircraft,

- ATCOs considered that small RPAS shall not be integrated on airports where traffic is more than 20 movements per hour,
- The following contingency procedures: radio failure, C1/C2 Loss, GPS failure, emergency landing, will have to be standardized in order to be made homogeneous at the ICAO level. However these procedures might adapted to each airport approach
- Flight plan format shall be adapted to RPAS specificity,
- Proper C2 Link technology shall be developed, using the bands available for Aeronautical Mobile Service.

1 Introduction

1.1 Purpose of the document

This document provides the Demonstration report for RPAS.05 – TEMPAERIS Demo Project It describes the results of demonstration exercises defined in D01 – TEMPAERIS Demonstration Plan 01.01.00 released on the 20/02/2014 and how they have been conducted.

Sopra Steria is the Demonstration Report Task Leader.

Airbus Defence & Space delivers input from the EXE-RPAS.05-100 results.

DSNA delivers input from the EXE-RPAS.05-200 results and to the regulation/standardization topics.

ENAC provides operational expertise on RPAS integration.

Airbus Prosky delivers input to the small RPAS integration recommendations.

1.2 Intended readership

Though other readers might be welcome, this document is mostly intended for the following audience:

- **RPAS Industry:** RPAS industry should be aware of new failure procedures of RPAS.
- **RPAS Operators:** The results of this demonstration project should concern RPAS operators as new business cases can be imagined if MALE RPAS are authorised to fly in non-segregated airspaces.
- **ANSPs:** ANSPs are concerned about Safety and new operational procedure.
- **National Authority:** National Authorities should be aware of the impact of RPAS integration on Human Performance and Safety.

1.3 Structure of the document

This document uses the JU proposed demonstration plan:

- **Chapter 1** (the present section) provides general information about the document.
- **Chapter 2** situates the project in the SESAR global frame.
- **Chapter 3** describes the project management. It deals with planning, resources and risk management.
- **Chapter 4** gives a global picture of demonstration activities.
- **Chapter 5** focusses on the demonstration exercises results.
- **Chapter 6** describes in details the demonstrations exercises.
- **Chapter 7** describes the communication activities.
- **Chapter 8** provides consortium view on RPAS integration.
- **Chapter 9** lists documentation references.

1.4 Glossary of terms

Term	Definition
ACO	Air Coordination Order (ATFM function for military RPAS)

Term	Definition
ATO	Air Task Order (daily mission list)
BRLOS	Beyond Radio Line Of Sight
BVLOS	Beyond Visual Line Of Sight
GCS	Ground Control Station
EVLOS	Extended Visual Line Of Sight
MIDCAS	Mid Air Collision Avoidance System
RLOS	Radio Line Of Sight
SATCOM	Satellite Communications
SITAC	Tactical Situation
VLOS	Visual Line Of Sight

1.5 Acronyms and Terminology

Term	Definition
APP	Approach
ATC	Air Traffic Control
ATM	Air Traffic Management
C2L	Command and Control Link
C2Loss	Command and Control link Loss
CWP	Controller's Working Position
DIRCAM	French Military Air Traffic Control Directorate
DOD	Detailed Operational Description
E-ATMS	European Air Traffic Management System
E-OCVM	European Operational Concept Validation Methodology
EC	European Commission
EO/IR	Electro Optical/ Infra Red
ESM	Electronic Surveillance Module
FPPS	Flight Plan Processing System
ICAO	International Civil Aviation Organization

Term	Definition
IFR	Instrument Flight Rules
NA	National Authority
NSA	National Safety Authority
Pseudo-pilot	Person that acts as a pilot (of RPAS or of other planes) in the simulation sessions.
OFA	Operational Focus Areas
OPV	Optionally Piloted Vehicle (A RPA which has a “back-up” pilot on board).
RPA	Remotely Piloted Aircraft
RPAS	Remotely Piloted Aircraft System
RPS	Remote Pilot Station
RT	Real Time
RTS	Real Time Simulations
SESAR	Single European Sky ATM Research Programme
SESAR Programme	The programme which defines the Research and Development activities and Projects for the SJU
SID	Standard Initial Departure
SJU	SESAR Joint Undertaking (Agency of the European Commission)
SJU Work Programme	The programme which addresses all activities of the SESAR Joint Undertaking Agency
STANAG	NATO Standardization Agreement
STAR	Standard Arrival Route
TWR	Control Tower
UAS	Unmanned Aircraft System

2 Context of the Demonstrations

TEMPAERIS consortium brought together a significant expertise in the sectors of ATM and RPAS building and operation:

- RPAS system design, integration, airworthiness and flight operations
- European R&D projects and studies in the scope of FP4-FP7 as well as SESAR and MIDCAS study, and related to technologies, concept of operations and procedures,
- Adequate management of regulatory aspects for insertion of RPAS in non-segregated airspace through their contribution to European funded initiatives and/or to regulatory bodies and standardization working groups. DSNA has very close relationship with the DSAC (French authority for certification and surveillance),
- Participation to Standardization organizations (ICAO/UASSG, EUROCAE WG73 and so forth)

2.1 Scope of the demonstration and complementarity with the SESAR Programme

The TEMPAERIS project investigated the following aspects of RPAS insertion in civilian air traffic in accordance with SESAR concepts:

- Definition and validation of procedures in aerodrome circulation, and during SID/STAR phase of flight around the same airport
- Filing of an IFR-like flight plan for RPAS
- Capability to insert in the aerodrome circulation of a middle sized commercial airport
- Capability to follow SID/STAR from/to a middle sized commercial airport
- Evaluation of the acceptance by ATC of the procedures used in the case of the occurrence of non-nominal (abnormal) situations

For that purpose, the project carried on real flights and ATC simulations:

- Real Flights: the main objectives in the in-flight demonstrations were twofold:
    - demonstrate that RPAS can be interfaced with standard civil ATC and be processed as other commercial aircraft by civil operator
    - test the acceptance by ATC of current RPAS procedures during some non-nominal situations such as communication loss or command and control loss,
- Simulations: the objectives of the ATC simulations were to evaluate whether current ATC operational procedures are applicable to RPAS in a representative controlled traffic environment, both in nominal and non-nominal modes.

The following exercises have been executed:

Demonstration Exercise ID and Title	**EXE-RPAS05-100 : Real Flights**
Leading organization	Airbus Defence & Space
Demonstration exercise objectives	• To maintain the current safety of the air traffic during real flights. • To maintain the current regularity of the TMA traffic during real flights. • To assess the level of simultaneous RPAS and piloted aircraft operations acceptable on an airport without impacting traffic flow. • To assess the efficiency of predefined emergency procedures during real flights. • To assess, during real flights, the level of trajectory predictability of the RPAS. • To check whether RPAS handover procedures between TWR and APP preserve safety. • To assess the impact of RPAS on runway capacity
High-level description of the Concept of Operations	Insertion of a slow flying aircraft into the traffic of a mid-sized airport. Failure cases has been tested (Voice communication loss, C2Loss and positioning loss)
Applicable Operational Context	Mid-traffic density TMA and airport.
Expected results per KPA	Safety and capacity maintained, at least at the same level as today. Acceptance of emergency procedures by ATC.
Number of flight trials	9 flights
Related projects in the SESAR Programme	**WP5 – Terminal Operations** **SWP05.05 TMA Trajectory Management Framework** Define and validate RPAS trajectories for the arrival and departure phases of flight, i.e. from top of descent to landing and from take-off to top of climb Validate activities including the assessment of operability, safety and performance at all levels Demonstrate the operational feasibility of the TMA Operations concepts in a complete ATM environment (including systems) **WP6 – Airport Operations** **SWP06.09 Tower management & CWP** P06.09.02 Advanced integrated CWP (A-iCWP) Refine and validate the Airport Operations concept definition, as well as the preparation and coordination of its operational validation process Airport throughput in all-weather conditions Minimize the risk of runway incursions and provide safety nets to prevent collisions on runways, taxiways and aprons.
OFA addressed	• 03.01.01 Trajectory Management Framework • 03.01.08 System Interoperability with air and ground data sharing

Table 1: Exercise EXE-RPAS.05-100 overview

Demonstration Exercise ID and Title	**EXE-RPAS05-200 : ATC simulations**
Leading organization	DSNA
Demonstration exercise objectives	• To maintain perceived safety at least at the equivalent level in the ATC simulation. • To assess, during ATC simulations, the level of trajectory predictability of an RPAS showing a significant level of time lag (5 to 10 seconds) in the communication link. • To define a safe standard "Return Home" procedure through ATC simulations. • To assess the impact on TMA capacity.
High-level description of the Concept of Operations	Simulation of RPAS operations in a mid-traffic density airspace. Failure cases has been tested (Voice communication loss, C2Loss and positioning loss) as well as mission change.
Applicable Operational Context	Mid-traffic density TMA and lower en Route airspace.
Expected results per KPA	Safety and capacity maintained, at least at the same level as today. Acceptance of emergency procedures by ATC. Evaluation of RPAS trajectory predictability.
Number of simulation trials	15 simulation sessions on 5 days.
Related projects in the SESAR Programme	**WP5 – Terminal Operations** **SWP05.05 TMA Trajectory Management Framework** Define and validate RPAS trajectories for the arrival and departure phases of flight, i.e. from top of descent to landing and from take-off to top of climb Validate activities including the assessment of operability, safety and performance at all levels Demonstrate the operational feasibility of the TMA Operations concepts in a complete ATM environment (including systems) **WP6 – Airport Operations** **SWP06.09 Tower management & CWP** P06.09.02 Advanced integrated CWP (A-iCWP) Refine and validate the Airport Operations concept definition, as well as the preparation and coordination of its operational validation process Airport throughput in all-weather conditions Minimize the risk of runway incursions and provide safety nets to prevent collisions on runways, taxiways and aprons.
OFA addressed	• 03.03.03–Ground Based Conflict Detection & Support Tools in TMA • 06.02.01 iCWP En route and TMA.

Table 2: Exercise EXE-RPAS.05-200 overview

3 Programme management

3.1 Organisation

The consortium consists in 5 partners:

- **AirbusProsky**: Airbus ProSky provided expertise on small RPAS integration.
- **Airbus Defence & Space**: Airbus Defence & Space prepared, executed and provided results of real flight exercise,
- **DSNA**: the French ANSP, provided trained ATCO personal, as well as airport/ airspace access, prepared, executed and provided results of simulation exercise. DSNA proposed updated procedures and recommendations.
- **ENAC**: the French University of Civil Aviation brought a RPAS expertise.
- **Sopra Steria**: Sopra Steria managed the validation methodology applied during the project.

DSNA was in charge of consortium management and of the interface with the SJU.

A consortium agreement has been signed by all parties. Its purpose is to define the rights and obligations of the Consortium Members against each other, including, but not limited to, their internal liability.

Consortium governance is described in a short document specifically written for this purpose.

The following administrative changes occurred during the timeframe of the project:

- Airbus Defence & Space new organization name due to a restructuration within Airbus Group
- Airbus Prosky changed the team involved in the project
- Sopra Steria new organization name due to the merger of Sopra Group and Steria

3.2 Work Breakdown Structure

3.1.1 WP100 PROJECT MANAGEMENT

This work package was under the responsibility of DSNA

Objectives
This task sets up the project so that work can start in a controlled manner. It develops both initial project management plans and configuration management plans. It also establishes the internal procedures and technical infrastructure that allows activities to be shared efficiently between the project members. Moreover this task ensures that the activities are managed in a correct, consistent, accurate and timely manner during the entire life of the project.

3.1.2 WP200 INITIAL PROCEDURES DEFINITION

This work package was under the responsibility of ENAC

Objectives
The objective of this work package is to provide a consolidated reference framework for the demonstration activities. In particular, it defines ATC/RPAS operational and emergency concepts (procedures and requirements) based on today infrastructures and technology to integrate RPAS in ATC with minimal impacts. Procedures designed in this WP may be slightly modified in WP300 and 400 to adapt for last

minute constraints (such as weather, real traffic load,…).
At the end of the project, consolidation of the results will be done in order to propose updated procedures and recommendations.

3.1.3 WP300 REAL FLIGHTS

This work package was under the responsibility of Airbus Defence & Space

Objectives
To test during flight trials the following critical points of RPAS integration into non segregated airport:

- Capability to fly SID/ STARs,
- Communication failure,
- Navigation failure.

3.1.4 WP400 ATC SIMULATION

This work package was under the responsibility of DSNA

Objectives
To provide a realistic platform for Real Time Simulations (RTS) ATC Simulations.
Concepts developed in this project are validated for operational acceptability. It is necessary for controllers to run real-time simulations that reflect the reality. For these simulations, high-fidelity "research prototypes" are used whose behavior (from the point of view of the User) is a good emulation of the target system.

3.1.5 WP500 VALIDATION

This work package was under the responsibility of Sopra Steria

Objectives

The objective of this work package is to define a validation process to assess concepts and assumptions of the procedures in real flight and simulation trials. The experimental runs, result analysis and report are in the scope of this work package.

3.2 Deliverables

Deliverable name	Date
Demonstration Plan (D01)	Jan., 2014
Final Report (D02)	Sep.30th, 2015

Table 3: Deliverables

3.3 Risk Management

Here are the risks identified during the preparation of the project and their actual impact.

Risk description	Probability assessment	Severity assessment	Impact on project	Owner
Unavailability of demonstration vehicle	Low	High	The Airbus Defence & Space MCR4S suffered from several technical issues which delayed the real flight campaign but the reactivity of the Airbus team allowed the real flight to be conducted	Airbus Defence & Space
Impossibility to perform the flight trials due to bad weather	Medium	High	During the flight experimentation, the weather was bad on two days (Feb 4th and 6th). We managed to carry out the totality of the flight program, even if some slight modifications had to be done compared with the initial program.	All Members
Agreement of ATC at the selected location is not obtained	Low	High	ATCOs accepted willingly to carry out the experimentation.	DSNA
Personnel availability	Medium	Low	This risk did not occur.	All Members
Lack of consistency of scenario with SESAR expectations	Medium	Medium	This risk had been mitigated during the Demonstration Plan review.	DSNA, ENAC, Airbus Defence & Space

Table 4: Risk management matrix

4 Execution of Demonstration Exercises

4.1 Exercises Preparation

For detailed information about exercises execution, please refer to sections 6.1.2.1 and 6.2.2.1.

4.2 Exercises Execution

For detailed information about exercises execution, please refer to sections 6.1.2.2 and 6.2.2.2.

Exercise ID	Exercise Title	Actual Exercise execution start date	Actual Exercise execution end date	Actual Exercise start analysis date	Actual Exercise end date
EXE-RPAS05-100	Flights Trials	04/02/2015	06/02/2015	09/02/2015	15/05/2015
EXE-RPAS05-200	Simulation Trials	09/03/2015	19/03/2015	23/03/2015	15/05/2015

Table 5: Exercises execution/analysis dates

4.3 Deviations from the planned activities

Some slight deviations from the initial plan occurred.

<u>During real flight exercise:</u>

In RPAS.05-D01-TEMPAERIS Demonstration Plan, the initial timeframe to conduct real flights campaign was planned in September 2014. However due to administrative issue with the aircraft permit to fly, real flights have been postponed to November 2014.

The MCR4S has a type certificate. However the RPAS demonstrator needs a permit to fly to be operated under remote control. The permit to fly is delivered by French aviation authority (the DSAC). It usually has a validity of six months. Due to extensive reorganization of the Airbus Group the application for the permit renewal was made lately and resulted in an administrative delay.

Moreover on Oct.31st, 2014 the RPAS engine suffered from a malfunction (excessive vibration due to the failure of the propeller speed regulator), real flights had to be postponed again to February 2015.

Compared with the initially planned flights in D01 version 1.01.00 (§4.1.2, p32), the correspondence with the flights that were actually performed (called hereafter actual flights) is shown below:

- Planned flight 1: Actual flight 1,
- Planned flights 2and 3: Actual flight 2
- Planned flight 4: Actual flight 3
- Actual flight 4 did not correspond to any scenario. It was a flight test to check the range of GCS antenna,
- Planned flight 8: Actual flight 5,
- Planned flight 5: Actual flight 6,
- Planned flight 6: Actual flight 7,
- Planned flight 9: Due to bad weather and because controllers thought that being a simple combination of actual flights 6 and 7 it was decided to cancel it,
- Planned flight 7: Actual flight 8.
-

During simulation exercise:

Simulations were developed using the EASY test bench. EASY is an easily reconfigurable set of ATM simulation tools, designed to facilitate the validation of new concepts. Easy relies on a simple distributed network protocol (IVY) which enables a fast integration of specific components and a simple monitoring and information retrieval from various external application. The IVY protocol enables fast and simple data sharing between applications, can thus be used in an internet environment and does not rely on any specific programming language or operating system. So a large number of components can be connected to the EASY platform, even if they were not meant to be. . A specific development using Voice over IP technology and enabling audio latency will be used to conduct the simulations.

From the ATC point of view, the simulation framework uses the real Approach Controller Interface (IRMA). This keeps the simulation close to operational controller environment. Moreover, the traffic scenarios are built from logs of real flight, with the real aircraft performances, giving the most realistic situation. A traffic simulator is used to run in Real Time, the scenarios with the Human in the Loop (RTS-HL). A pseudo-pilot is in charge to get and manoeuvre controller clearances.

Some slight deviations from the initial program were introduced due to human resources management:

- RPAS.05-D01-TEMPAERIS Demonstration Plan, forecasted than ATCOs would participate to 3 simulations but in the end they only participated to 2 simulations run.
- In SCN-500 the RPAS1 was supposed to have C2Loss but due to operational experts who considered that C2Loss for slow RPAS was not bringing any interest to the results, the SCN-500 was recomposed.

<u>Initial SCN-500</u>

SCN-501: RPAS1: C2Loss, RPAS2: reprograms its area of operations during the mission

SCN-502: RPAS2: C2Loss, RPAS3: diverts to Bordeaux airport

SCN-503: RPAS3: C2Loss, RPAS1: reprograms its area of operations during the mission

<u>Modified SCN-500;</u>

SCN-501: RPAS2 C2Loss. RPAS1 modifies its area of surveillance during the mission

SCN-502: remains the same.

SCN-503: remains the same.

5 Exercises Results

5.1 Summary of Exercises Results

All objectives defined in the Demonstration Plan [1] were fully satisfied except for the following one:

- Predictability of the RPAS trajectory: Few ATCOs considered that RPAS instructions were executed with a slight delay compared to the manned aircrafts
- Runway Capacity: Due to the low speed of the RPAS, ATCOs had to make the RPAS leave the SID earlier not to interfere with the other traffics.
- ATCO Workload: The RPAS operation generates more message exchange than the situation without RPAS.

All results are compiled in Table 6. The evaluation of results has been done on the basis of **Table 21 p40 (KPA/KPI matrix)** on the initial **D01- Project Number RPAS05 Edition 01.01.00 TEMPAERIS Demonstration Plan** document. ***In particular, positive feedback from ATCOs was considered validated if 50% of answers were positives, except for the emergency procedures were positive answers should be at least of 70%.***

Exercise ID	Demonstration Objective Tittle	Demonstration Objective ID	Success Criterion	Exercise Results	Demonstration Objective Status
EXE-RPAS.05-100	To maintain the current safety of the air traffic during real flights.	OBJ-RPAS05-110	Zero emergency avoiding action by RPAS pilot.	Zero emergency avoiding action by RPAS pilot	OK
			No lateral trajectory deviation of more than 0.5MN	No lateral trajectory deviation of more than 0.5MN	OK
			Positive feedback from ATCOs	100% of ATCOs involved considered that safety of the traffic was not impacted	OK
	To maintain the current regularity of the flights in the TMA during RPAS real flights.	OBJ-RPAS05-120	No need for aircraft arriving to hold in holding pattern (slight delays due to vectoring are still possible)	No need for aircraft arriving to hold in holding pattern (slight delays due to vectoring are still possible)	OK
	To assess the level of simultaneous RPAS and piloted aircraft operations acceptable on an airport without impacting traffic flow.	OBJ-RPAS05-130	RPAS delay at circuit integration or before take-off under approx. 3 minutes.	2 occurrence of RPAS Delay before take-off more than 3 minutes but both due to arrival traffic.	OK
	To assess the efficiency of predefined emergency procedures during real flights.	OBJ-RPAS05-140	Acceptance of the procedure by controllers participating (more than 70% of positive answers to	100% of ATCOs who answered this question were confident with the procedures	OK

Exercise ID	Demonstration Objective Tittle	Demonstration Objective ID	Success Criterion	Exercise Results	Demonstration Objective Status
			questionnaire).		
	To assess, during real flights, the level of trajectory predictability of the RPAS. ***Remark: Execution of clearances has been done by using the radar images. Due to trajectory inertia and antenna rotation period (6 sec.), detection of clearance execution by this method overestimates actual execution time by 6 to 12 seconds.***	OBJ-RPAS05-150	Number of occurrences of clearances executed more than one minute after being issued.	No clearance executed more than one minute after being issued	OK
			Subjective evaluation by ATCO	4 out of 16 ATCOs who answered this question detected a small delay.	OK
	To check whether RPAS handover procedures between TWR and APP preserve safety.	OBJ-RPAS05-160	Number of occurrences of excessively long handovers (more than 3 minutes).	1 excessively long handovers (more than 3 minutes) but not related to RPAS operation. It was only the remote pilot who forgot to call back the approach.	OK
			Mean delay between handover clearance delivery and actual transfer less than 1 minute.	1 handover clearance delivery and actual transfer less than 1 minute. Removing the remote pilot oversight.	OK
			Subjective evaluation by ATCO	100% of ATCOs who answered this question did not considered the RPAS as different from a manned aircraft	OK
	To assess the impact of RPAS on runway capacity.	OBJ-RPAS05-170	Number of occurrences of RPAS instructed to leave SID on departing leg.	2 out of 7 flights were instructed to leave SID on departing leg	NOK
			Number of go around occurrence due to RPAS interference with other aircraft	No go around occurrence due to RPAS interference with other aircraft	OK
			Subjective evaluation by ATCOs	2 out of 16 ATCOs who answered this question considered	OK

Exercise ID	Demonstration Objective Tittle	Demonstration Objective ID	Success Criterion	Exercise Results	Demonstration Objective Status
				that the RPAS impacts the capacity	
EXE-RPAS.05-200	To maintain perceived safety at least at the equivalent level in the ATC simulation.	OBJ-RPAS05-210	Acceptable level of workload on the simulated positions compared with the baseline.	The presence of an RPAS generates more messages than the reference scenario.	NOK
			Subjective impressions by ATCOs	77.78% of ATCOs who answered this question considered that the perceived safety was not impacted by the RPAS	OK
	To assess, during ATC simulations, the level of trajectory predictability of a RPAS (especially if it is showing a significant level of time lag (5 to 10 seconds) in the communication link).	OBJ-RPAS05-220[1]	Execution of clearances in no more than 40 seconds.	Maximum clearance execution time was 27 seconds*. **They were actually executed in 9 to 27 seconds most of them well below 20 seconds.***	OK
			Comparison of the average number of messages given to this RPAS and other airplanes. Ratio (average number of messages to RPAS pseudo-pilot divided by average number of messages to aircraft pseudo-pilot) <= 1	The presence of an RPAS generates more messages than the reference scenario	NOK
	To define a safe standard "Return Home" procedure through ATC simulations.	OBJ-RPAS05-230	Implication of ATCOs in "Return Home" procedure definition and validation.	88% of ATCOs who answered this question were confident with the procedures	OK

[1] The OBJ220 has been identified, because we expected to insert in the simulation one RPAS with a 10 second lag and two with no lag. We thus intended to see whether a 10 seconds lag could be acceptable for ATCOs. As we finally, due to technical restrictions, end up with three RPAS with a 4 seconds lag each, the objective OBJ-RPAS05-220 became less meaningful. Anyway we demonstrated that a 4 seconds lag is acceptable for ATCOs on the En Route and initial Approach segment. It would not be acceptable however, closer from landing.

Because it creates an environment which is prone to message jamming, we would clearly not recommend lag to be authorized in the approach part of a fly. If it were to be done operationally, then specific measures would have to be enforced (such as ensuring that the lagged RPAS is the only aircraft working on the frequency).

Exercise ID	Demonstration Objective Tittle	Demonstration Objective ID	Success Criterion	Exercise Results	Demonstration Objective Status
			No avoiding action should be necessary once the failure has been identified and the appropriate procedure selected.	No avoiding action occurred.	OK
	To assess the impact on TMA capacity.	OBJ-RPAS05-240	Acceptable level of workload on the simulated positions compared with the baseline. Ratio (average number of instructions to RPAS pseudo-pilot divided by average number of instructions to aircraft pseudo-pilot) <= 1	The presence of RPAS seems significantly to increase the number of instructions of control	NOK
			Subjective impressions by ATCOs	77.78% of ATCOs who answered this question considered that there were no impact on TMA capacity	OK

Table 6: Summary of Demonstration Exercises Results

Remark 1: concerning the excessively long handover between flights 6 and 7 may be explained as follows:

- On Feb 5th when these flights were performed, a total of three flights was done. It was expected that the weather of the next day would be cold and misty, which proved exact. The pilot thus had some pressure the complete the three tests flights programmed on that day. At the end of flight 6, the RPAS was transferred from APP to TWR frequency. Traffic was fluid and the pilot decided to go around 2 NM from touchdown, in order to complete the flight program before dusk. After less than 2 minutes spent on the TWR frequency, he was instructed to fly direct to N point and switch back to APP frequency. He may have done it immediately, but we cannot be affirmative about it. Being cleared to N point he did not need an amended clearance, nor did the APP controller had a need to contact the RPAS for providing any separation. Anyway the RPAS pilot answered to the first message issued by the APP controller 191 seconds after transfer.

Remark 2: concerning measurement of clearance execution delay:

- For real flights we measured the time between the clearance issue and the time when the clearance execution was visible on the radar screen (which may experience between 6 and 12 sec delay as the antenna rotates at one turn every 6 seconds),
- For simulation it is the time between clearance issue and the action being taken by the pseudo pilot (i.e: the “pilot” of the simulated aircraft).

Remark 3: concerning time lag:

- it is a problem because it creates jamming. It is thus traffic dependent. Our simulation was done with a traffic sample which was quite heavy for Bordeaux and close to an airport like Orly, Nice or Geneva. We can thus say that 4 sec is acceptable. But we cannot give more hint about the highest acceptable limit. Anyway a solution could be to open a specific "LAG TRAFFIC" frequency for traffic with a certain level of lag.

5.2 Choice of metrics and indicators

Neither WP16 nor B.05 were involved in TEMPAERIS Project. Thus KPI used in this project were chosen by operational experts involved in TEMPAERIS consortium.

The following table summarize KPI used in the flight trials activities:

Principles are that data logging for data related to RPAS are under Airbus Defence & Space responsibility. Data logging for data related to ATC are under DSNA responsibility.

The following elements have been recorded rate of climb, speed, heading, delay during handover, number of conflicts with RPAS, occurrence of emergency action, conflict resolution instructions delivered to RPAS.

All RPAS flight parameters (RPAS trajectory, time, altitude, lat/long, attitude, speed,...) has been recorded by the GCS.

Other parameters (occurrences of conflict, number of conflicts,...) has been recorded by the DSNA technical team at the Bordeaux TWR/APP either by collecting paper flights strips or electronically.

Radio frequencies have been recorded by DSNA ground equipment.

Interviews of controllers have been collected on paper.

Objectives and KPA	Metrics	Data collection methods
OBJ-RPAS05-110 ***KPA: Safety***	Number of emergency avoiding action taken by pilot on board of the RPAS	Recorded by ATCO during flight
	Number of lateral trajectory deviation of more than 0.5 NM (due to RPAS navigational error)	Recorded by RPAS Ground Control Station.
	Subjective evaluation by ATCOs	Questionnaires filed
OBJ-RPAS05-120 ***KPA: Regularity***	Delays imposed to arrival aircraft (no use of holding pattern)	Recorded by ATCO on flight strips during flight. Strips will be collected.
	Subjective evaluation by ATCOs	Questionnaires filed
OBJ-RPAS05-120 ***KPA: Access and equity***	Subjective evaluation by ATCOs	Questionnaires filed
OBJ-RPAS05-130 ***KPA: Regularity***	Time spent in holding by RPAS.	Recorded by ATCO on flight strips during flight. Strips will be collected.
	Subjective evaluation by ATCOs	Questionnaires filed
OBJ-RPAS05-140 ***KPA: Participation***	Actual implication of the core team	Checking that one ATCO from the Bordeaux staff is involved in developing emergency procedures.
OBJ-RPAS05-150 ***KPA: Predictability***	Number of occurrences of clearances executed by RPAS more than one minute after being issued	Recorded by DSNA technical staff on a dedicated platform which enables to replay flights and analyse radio and radar display.
	Subjective evaluation by ATCOs	Questionnaires filed
OBJ-RPAS05-160 ***KPA: Safety***	Number of occurrences of excessively long handovers (more than 3 minutes).	Recorded by DSNA technical staff on a dedicated platform which enables to replay flights and analyse radio and radar display.
	Mean average delay between	Recorded by DSNA technical staff on a

	RPAS handover clearance delivery and actual transfer (less than 1 minute).	dedicated platform which enables to replay flights and analyse radio and radar display.
	Subjective evaluation by ATCOs	Questionnaires filed
OBJ-RPAS05-170 ***KPA: Capacity***	Number of occurrences of RPAS instructed to leave SID on departing leg	Recorded by ATCO on flight strips during flight. Strips will be collected
	Number of go around occurrence due to RPAS interference with other traffic	Recorded by ATCO on flight strips during flight. Strips will be collected
	Subjective evaluation by ATCOs	Questionnaires filed

Table 7: EXE-RPAS.05-100 KPI and data collection methods

The following table summarize KPI used in the simulation activities:

Data logging was under DSNA responsibility.

During the exercise, data has been recorded by the simulator and by human factors experts. Two types of dependent variables are collected, quantitative and qualitative data. Quantitative methods are those which focus on numbers and frequencies whereas qualitative methods are those which describe the mean to achieve a goal, as debriefing or questionnaire.

All inputs from controllers have been logged and stored in dedicated folder. All actions performed by pseudo-pilots have been logged by the simulator.

Trajectory data has been recorded for all aircraft. Radio frequency has been recorded.

Actually, all information passing through Ivy bus will be recorded.

All questionnaires were recorded via the LimeSurvey software.

Objectives and KPA	Metrics	Data collection methods
OBJ-RPAS05-210 ***KPA: Safety***	Frequency occupation	Recorded and computed by EASY platform
	Subjective evaluation by ATCOs	Questionnaires filed under LimeSurvey
OBJ-RPAS05-220 ***KPA: Predictability***	***Ratio***: Number of messages to the pseudo-pilot of the RPAS with time lag/ average number of messages delivered to classical aircraft pseudo-pilots(except RPAS)	Recorded by EASY platform. Computed later on during validation.
	Number of occurrences of clearances executed by RPAS more than 40 seconds after being issued	Recorded and computed by EASY platform
	Subjective evaluation by ATCOs	Questionnaires filed under LimeSurvey
OBJ-RPAS05-230 ***KPA: Safety***	No avoiding action due to failure once the failure has been identified and the appropriate procedure selected.	Recorded by EASY platform. Computed later on during validation.
	Subjective evaluation by ATCOs	Questionnaires filed under LimeSurvey
OBJ-RPAS05-230 ***KPA: Participation***	Actual implication of the core team	Checking that one ATCO from the Bordeaux staff is involved in developing "Return Home" procedure.
OBJ-RPAS05-240 ***KPA: Capacity***	Frequency occupation	Recorded and computed by EASY platform
	Ratio: average number of instructions to RPAS pseudo-pilot divided by average number of instructions to aircraft pseudo-pilot	Recorded by EASY platform. Computed later on during validation

	Subjective evaluation by ATCOs	Questionnaires filed under LimeSurvey

Table 8: EXE-RPAS.05-200 KPI and data collection methods

5.3 Summary of Assumptions

Identifier	Title	Type of Assumption	Description	Justification	Flight Phase	KPA Impacted	Source	Value(s)	Owner	Impact on Assessment
ASM-EXE-101	Ground segment	Technical	Ground segment deployment on airfield	RPAS representativeness	Take-off & landing	All			Airbus Defence & Space	High
ASM-EXE-102	Duration	Financial	Demonstration flights campaign duration: 1 week	Funding and planning	All	All			Airbus Defence & Space	High
ASM-EXE-103	Weather	Environment	Good weather conditions	Aircraft limitation	All	All			All	High
ASM-EXE-104	ATC staff	H.R.	ATC staff availability	ATC staff involved in demonstration	All	All			DSNA	High
ASM-EXE-105	Authorization to fly	Regulatory	Authorization to fly	Experimental aircraft	All	All			Airbus Defence & Space	High
ASM-EXE-106	Frequency	Technical	Frequency assignment	Use of specific frequency, which require authorization from French administration	All	All			Airbus Defence & Space	High
ASM-001	D&A	Equipment	As far as ATC simulations are concerned (and not during real flights) RPAS will be considered to have detect and avoid equipment that will be compatible with those of classical aircraft.	No RPAS would be allowed to fly in non segregated airspace without a certified D&A equipment.	All	Safety.	TCAS is mandatory for airplanes of 19 seats or more	Fitted	DSNA	None
ASM-002	RPAS Speed	RPAS Performances	In the ATC simulation scenarios (not during real flights), RPAS speeds, will vary from slow to	RPAS performances will increase with time. Our simulations are supposed to	En route	Capacity, Efficiency,		70 to 250 kt.	DSNA	Intermediate

			moderate.	investigate a 15/20 years time horizon.		Safety, Predict ability.				
ASM-EXE-401	Percentage	Traffic sample	Percentage of RPAS in SCN400 and 500	Around 10%. Current evaluation of this factor is very difficult. We need to have enough RPAS to build a significant scenario, but not too much, as this scenario would be unrealistic.	All	Capacit y.			All	Low
ASM-EXE-402	Time horizon	Global	Time horizon in SCN 300, 400 and 500.	Around 15 years, in order to keep current aircraft types and performances.	All	Efficien cy, Predict ability.		2028	All	None
ASM-EXE-403	SATCOM	Equipment	Some RPAS in simulation will use SATCOM	SATCOM will be widely used in the future	All	Predict ability.		Yes	All	Low
ASM-EXE-404	Flight Plan Processing System	Software	Capability to transmit via data-link a precise future trajectory and visualize it on a radar scope	FPPS will be upgraded in the coming 15 years	En Route / APP	Predict ability.		Yes	DSNA	Low

Table 9: Demonstration Assumptions

5.3.1 Results per KPA

Based on the allocation of demonstration objectives to KPA defined in Demonstration Plan [1] and the Exercises Results of Table 6: Summary of Demonstration Exercises Results, here are the results per KPA:

1. **Safety:**
   - Positive or neutral impact:

     The procedures designed by the consortium were accepted by the ATCOs

   - Negative impact:

     The ATCO workload increased due to RPAS operation. The number of messages exchanged on the frequency increase had an impact on the ATCO workload but the subjective evaluation did not consider that the safety was impacted.

2. **Predictability:**
   - Positive or neutral impact:

     To be confirmed.

   - Negative impact:

     Some ATCOs considered that there was radio transmission latency during real flights. This latency impacted the time for an instruction to be followed.

3. **Capacity**
   - Positive or neutral impact:

     No impact on runway capacity was detected.

   - Negative impact:

     TMA capacity was degraded, even though ATCOs did not considered that TMA capacity was affected by RPAS operation, simulations showed that the number of messages exchanged on the frequency clearly increase.

     The ATCO workload increased due to RPAS operation. The number of messages exchanged on the frequency increase had an impact on the ATCO workload but the subjective evaluation did not consider that capacity was impacted.

5.3.2 Description of assessment methodology

Neither WP16 nor B.05 was involved in TEMPAERIS Project. Thus KPI used in this project were chosen by operational experts involved in TEMPAERIS consortium.

Statistical analysis is available in Appendix C.

5.3.3 Results impacting regulation and standardisation initiatives

The development of the specific patterns and procedures for RPAS was assessed positively. So, tailored SID/STAR procedures and abnormal/ emergency procedures could become a contribution to a standardisation process.

6 Demonstration Exercises reports

6.1 Demonstration Exercise EXE-RPAS.05-100 Report

6.1.1 Exercise Scope

The main objectives in the in-flight demonstrations were twofold:

- Demonstrate that RPAS can be interfaced with standard civil ATC and be processed as other commercial aircraft by civil operator
- Test the acceptance by ATC of current RPAS procedures during some non-nominal situations such as communication loss or command and control loss

The experimentation was conducted at Bordeaux-Mérignac airport, which is a middle sized commercial airport, with significant General Aviation traffic

- Average traffic is around 10/12 movements an hour.
- Peak hours are around 25 movements per hour.

6.1.2 Conduct of Demonstration Exercise

6.1.2.1 Exercise Preparation

An RPAS demonstrator was used for flight trials, it was composed of:

- an Air Vehicle system, based on the approved civil aircraft MCR4S. Developed as a flying test bed, the Air Vehicle is equipped to carry a variety of payloads, internal and external, such as EO/IR, ESM, maritime radar … In the frame of a previous project with the French DGA, the Air Vehicle was used as an optionally piloted vehicle (OPV). The avionics and flight control systems had been developed by Airbus D&S.
- the data-link system.
- the ground control station: based on operational ground station system, two operators are sufficient to control the Air Vehicle, the mission payloads, and the data-links. A compact mobile ground segment was used during the experimentation, allowing easier deployment, and equipment testing.

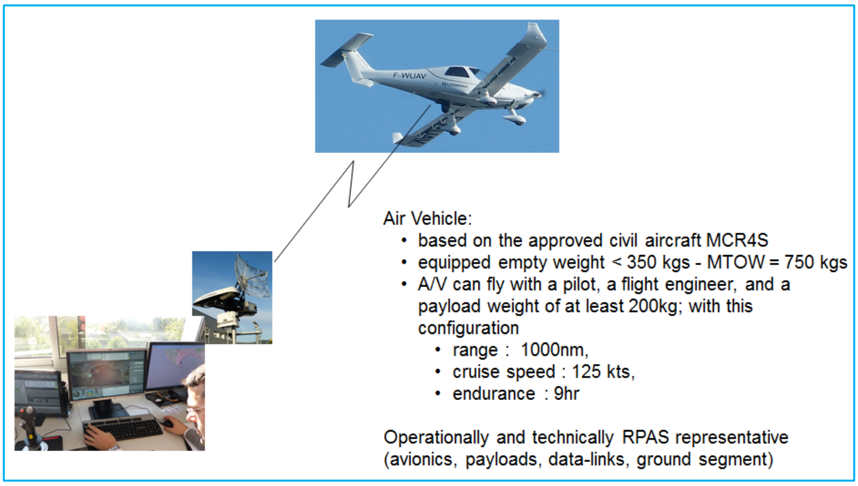

Figure 1: RPAS demonstrator

The airborne and ground systems have been adapted for the experimentation:

- installation of a radio relay to provide ground operator with ATC clearances,

- installation of a Mode S transponder on the RPAS demonstrator
- implementation of the necessary map database for the ground operator, and probably also for the backup pilot on board.

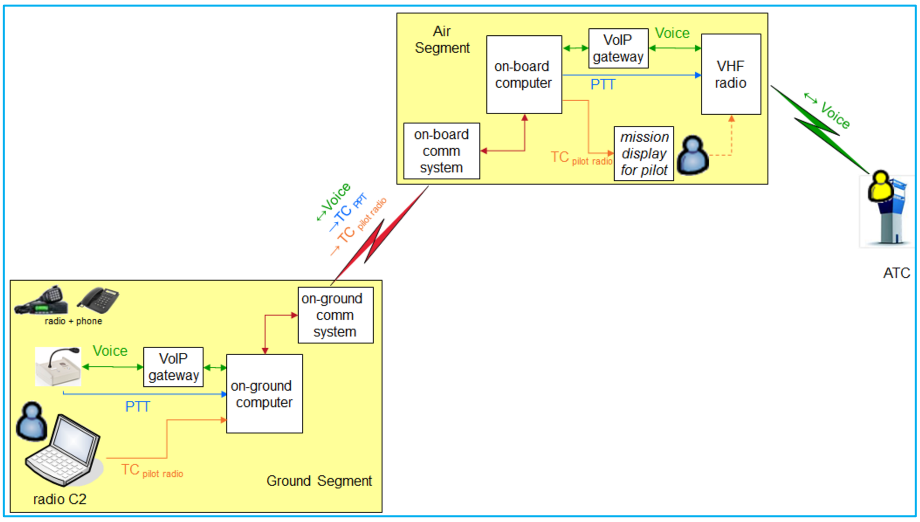

Figure 2: ATC Radio Architecture

The installation of the Ground Control Station took place at the IMA as shown on the picture below. The location for the antenna was chosen to have the best radio coverage. However as discovered during the execution phase, there were still blind spots which impacted the radio transmissions.

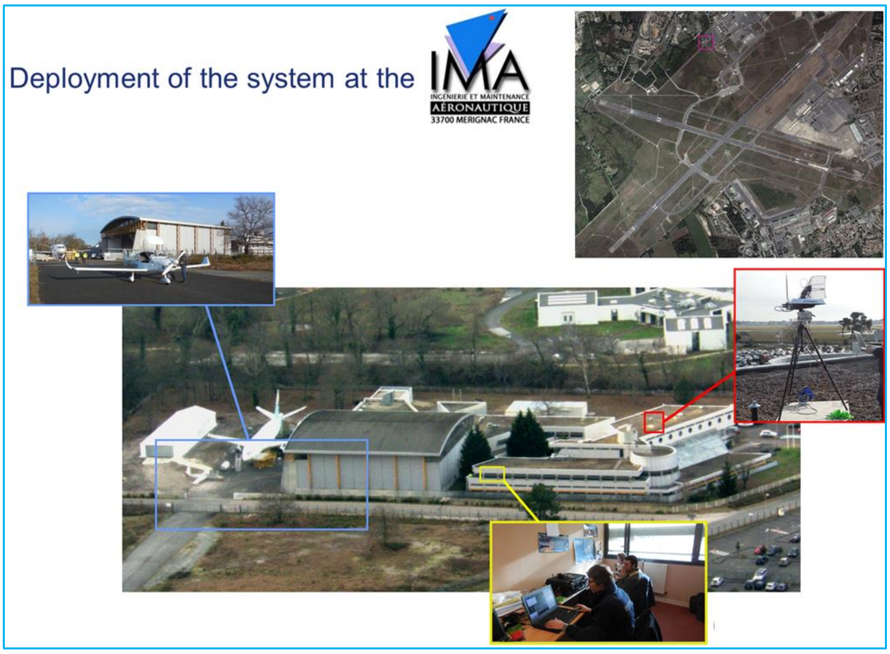

Figure 3: Deployment of the system at the IMA

Prior to the exercise execution, a first set of flight has been conducted to familiarize ATCOs with the machine's behaviour.

		Objectives	Events	Remarks
Day #1		Deployment at IMA Technical trials and flights Briefing with ATCOs		

6.1.2.2 Exercise execution

The following table describes the flights conducted for the execution of the flight trials:

		Objectives	Events	Remarks
Day #2	Actual Flight #1	Nominal SID and STAR	10:05 – 10:40 • Holding pattern: N, 3000 ft • After clearance from the ATCO, RPAS follows automatically SID and STAR procedures (RWY23)	• RPAS seen by ATCO as a small aircraft • Only some phraseology to be adapted (minor) by GCS operator (corrected in following flights)
	Actual Flight #2	Nominal STAR, API and go-around	10:38 – 12:17 • Holding pattern: N, 3000 ft • After clearance from ATCO, STAR RNAV RWY 23 • API at DA (200 ft) • Climb up to 1000 ft, turn left for go-around • Clearance from TWR for take-off • Insertion behind 2 airliners: • Leaving the holding pattern • Flying the go-around	• Insertion into traffic: no problem • API and go-around phases very rapid: automatic procedure with high level orders should be used
	Actual Flight #3	Nominal STAR, with insertion behind an IFR flight, with point merge	14:30 – 15:30 • Holding pattern: N, 3000 ft • After clearance from ATCO, • STAR RNAV RWY 23 • Behind airliner #1, ATCOs asks « direct BD408 » • RPAS joins automatically BD408 for lining up for landing • RPAS telemetry loss (3 minutes)	• During the telemetry loss, the GCS operator asked the ATCO for knowing the RPAS position. No need to command the RPAS during this telemetry loss period (relatively short), but the uplink was operational. • Telemetry regained after an onboard GPS system restart (no redundancy).
Day #3	Actual Flight #4	RWY 05/23 closed for maintenance purpose Only technical flight due to bad weather condition Optronic payload integrated; data-link and mission chain in-flight trials		
Day #4	Actual Flight #5	STAR procedure with ATC radio link loss	12:40 – 13:20 • Holding pattern: N, 2500 ft (due to weather) • After clearance from ATCO, STAR RNAV RWY 05 • ATC radio link loss between BD500 and BD501, specific	• Proposed procedure seems adapted, according to ATCO • A tag radio off “RDOF” should be associated to the transponder code

		Objectives	Events	Remarks
			transponder code activated • GCS operator call ATCO by phone to inform him about the situation • RPAS follows the STAR procedure	
	Actual Flight #6	STAR procedure with down link loss	14:50 – 15:27 • Holding pattern: NW, < 2500 ft (due to weather) • After clearance from ATCO, STAR RNAV RWY 05 • down link loss between BD500 and BD501, specific transponder code activated • GCS operator call ATCO by phone to inform him about the situation • RPAS follows the STAR procedure	• Due to bad weather conditions, new holding pattern (NW-W) at lower altitude (→some data-link loss on holding pattern) • A tag link off "LINK" should be associated to the transponder code
	Actual Flight #7	STAR procedure with up link loss	15:28 – 16:10 • Holding pattern: NW, < 2500 ft (due to weather) • After clearance from ATCO, STAR RNAV RWY 05 • Up-link loss between BD500 and BD501, specific transponder code activated • GCS operator informs ATCO about the situation. • The RPAS join a pre-defined WP for data-link regaining. • After 2 laps on the holding pattern, the RPAS follows an automatic predefined emergency landing procedure	• Due to bad weather condition, Flights #6 and 7 have been chained together, and new holding pattern (W) at lower altitude (→some data-link loss on holding pattern) • ATCO return: the more sensitive case to be carefully defined for RPAS: data-link recovery procedure has to be defined in order to ensure aircraft separation in any case, at any RPAS position. • A tag link off "LINK" should be associated to the transponder code
Day #5	Actual Flight #8	STAR procedure with GPS signal loss	Tire puncture during aircraft preparation … flight postponed to the afternoon 14:23 – 15:02 • After clearance from ATCO, STAR RNAV RWY 05 • GPS signal loss between BD500 and BD501, specific transponder code activated • GCS operator informs ATCO about the situation. • ATCO gives heading /altitude instruction, and GCS operator sends associated commands to the RPAS.	• A tag GPS off "GPOF" should be associated to the transponder code. • As soon as the GPS loss has been identified by GCS operator and ATCO, no difficulty for the ATCO to perform radar vectoring until the RPAS is on the final axis

Several sets of flights were performed during the execution:

- First set of flights (#1, #2 and #3) has been dedicated to evaluating the feasibility of radar vectoring with RPAS traffic and is considered as the reference flight
- Second set of flights (#6 and #7) was dedicated to testing emergency procedures in case of partial or total C2 loss.
- Last set of flights (#5 and #9) was programmed in order to probe emergency procedures not in C2 process, i.e: radio failure and GPS unavailability.

The proposed scenarios for the nominal conditions were:

- For SID procedure testing:
  - take-off, following one of the SIDs (depending on runway in use) up to a pre-defined altitude then fly to the predefined WPs
- For STAR procedure testing:
  - Fly to holding pattern. After ATC clearance, follow the cat. A STAR from holding pattern to the runway in use, and execute a landing.
  - After a missed approach, execute a go around and an aerodrome circuit.
  - Insert behind an arrival IFR, thanks to holding and/or speed adjusting. Execute a landing.
  - Insert behind an arrival IFR, thanks to radar vectoring. Execute a landing.

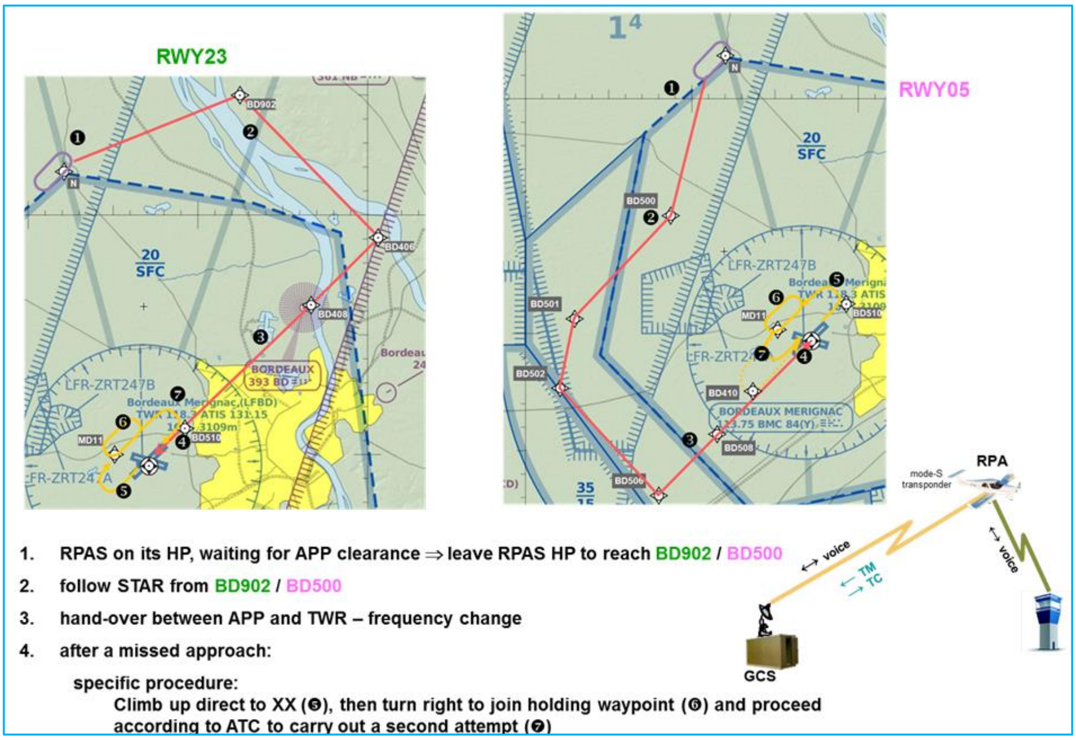

Figure 4: STAR procedure with a missed approach, in nominal condition

For non-nominal condition (during STAR procedure), the proposed scenarios were:

Flying at the holding pattern, and after ATC clearance, following the cat. A STAR from holding pattern to the runway in use

- Downlink loss :
  - GCS operator receives no TM from A/V, but can command it in order to execute ATCO's instructions (clearance for STAR procedure)

    - Specific transponder code automatically used
- Uplink loss : GCS operator receives TM from A/V, but cannot command it
- Total C2 link: GCS operator has no possibility to command and control the RPAS
    - A/V automatically flying to a Holding Waypoint for data-link re-gaining, with specific transponder code
    - After data-link regaining, the RPAS follows a nominal STAR procedure
    - GCS operator informs the ATCO about the situation and about the A/V behaviour.
- Radio loss:
    - GCS operator and ATCO use phone as back-up solution
- GPS loss:
    - STAR procedure, thanks to radar vectoring and heading instructions from the ATCO

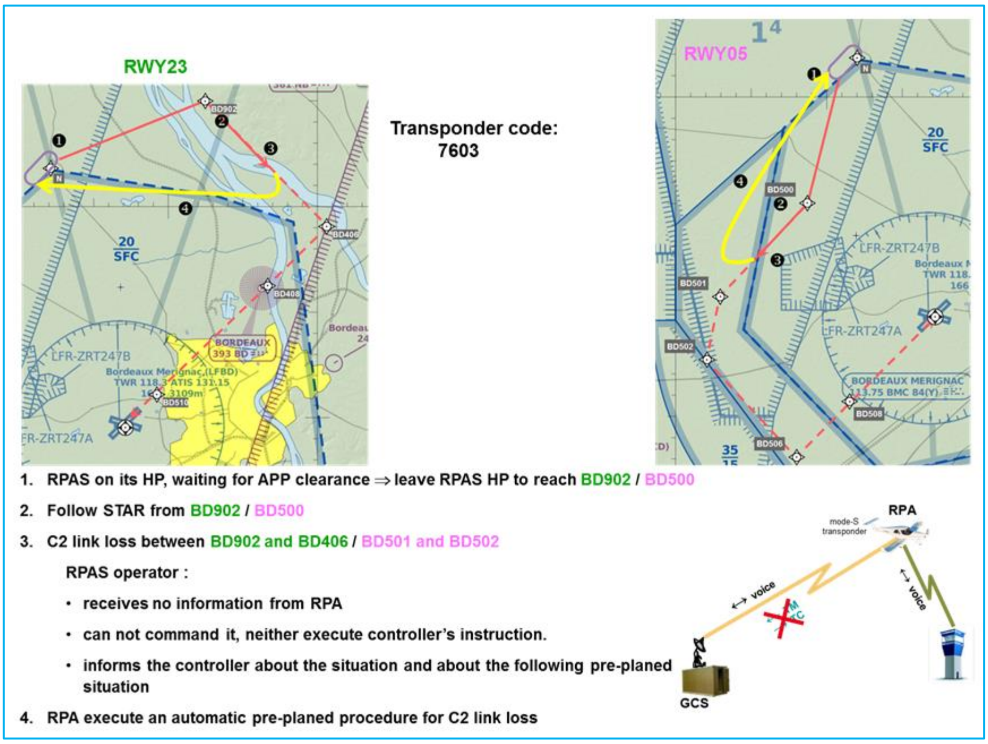

Figure 5: STAR procedure with C2 link loss - non nominal condition

6.1.2.3 Deviation from the planned activities

Some slight deviations from the initial plan occurred.

In RPAS.05-D01-TEMPAERIS Demonstration Plan, the initial timeframe to conduct real flights campaign was planned in September 2014. However due to administrative issue with the aircraft authorization to fly, real flights have been postponed to November 2014. Moreover in November 2014 the RPAS engine was out of order, real flights were postponed to February 2015.

Because of operational constraints and due to adverse weather on Feb 4th an 6th planned flight 9 has been cancelled. However the ATCOs felt that the results obtained during actual flights 6 and 7 made it redundant.

6.1.3 Exercise Results

6.1.3.1 Summary of Exercise Results

Due to the low amount of flights ran, the summary mainly focuses on qualitative feedbacks.

The main remarks from ATCOs are:

- Noticeable (but acceptable) latency in communications and RPAS answer to ATCO instruction
- Speed differences between RPAS and airliners manageable by ATCOs, with the experienced traffic
    - Only one airliner left on a holding pattern during RPAS landing
    - RPAS radar vectoring and radio link loss: not problematic
- RPAS C2 link: this situation is manageable by ATCOs only if
    - RPAS behaviour known in advance by ATCOs
    - Data-link re-gaining way-points be defined in order to ensure adequate separation between aircrafts: several DL regaining WPs could be defined in order to cover all potential situations.

From RPAS operator side, the main remark is:

- Some data-link loss occurred in some geographical areas (masking due to relief, too low altitude, or specific electronic environment?). The adverse weather (low ceiling) has probably been a factor of the data link loss because flight altitude has been sometimes limited to 2300/2500 ft instead of 3000 as it was requested in the initial flight plan.
    - Ground antenna position, and RPAS holding patterns, data link re-gaining waypoints and trajectories should be defined carefully.

6.1.3.1.1 Results per KPA

Please refer to 5.3.1

6.1.3.1.2 Results impacting regulation and standardisation initiatives

The following remarks have been gathered during flight debriefing and not specifically resulting from exercise execution.

The main remarks from ATCOs impacting regulation and standardisation are:

- RPAS should not follow all the RNAV trajectories, but should intercept them in order to reduce their flight time in approach phase. This issue was raised due to the RPAS low speed.
- According to the SID/STAR phase, the RPAS should automatically join an adequate and pre-defined WP

From RPAS operators, the main remarks impacting regulation and standardisation are:

- Insertion into air traffic require a trained operator
    - PPL-like certificate seems a minimum.
- Not experienced during trials, but discussed during preparation phase:
    - Some commands are not defined in STANAG 4586: necessary to implement a new message

Remark: During the test of emergency procedures, we used different transponder codes for each type of failure. This is different from what is being done with manned aviation. We think that a Clink or C2Link failure is different from any type of emergency situation encountered in manned aviation and that it would be of some help, for the ATCOs to get a simple method for identifying failures. Also the RPAS behaviour during a radio failure is different from a “regular” 7600. The idea was rather welcomed and we think that it would be wise to think about the opportunity of defining:

- A specific radio off code for RPAS,
- A specific C1 Uplink/ C2 Link code,
- A specific C1 Downlink/ GPS loss code.
- Engine loss or other type of gross emergency can be covered by the regular 7700 code.

6.1.3.1.3 Unexpected Behaviours/Results

NA

6.1.3.1.4 Quality of Demonstration Results

The small number of experimental flights makes it impossible to provide with statistical analysis. Anyway the participants to the experimentation showed a relatively unanimous opinion and considered the insertion of a small RPAS in the Bordeaux traffic as feasible.

Moreover a complete replay of all the flights, with radar display and synchronized radio recording was done in order to detect possible tense situations and none of them appeared to be. Which clearly tend to show that the experimental flights inserted seamlessly in the Bordeaux traffic.

6.1.3.1.5 Significance of Demonstration Results

The real flights campaign was composed of 8 flights; therefore it is impossible to produce a statistical analysis.

However the exercise provides operational significance due to the traffic used during the RPAS integration. Exercise was conducted in an environment which reflects the current situation at Bordeaux-Mérignac airport.

6.1.4 Conclusions and recommendations

6.1.4.1 Conclusions

The main feedback form ATCOs is the aircraft speed which is slow, some controllers considered that with an RPAS which could be able to have a 180 kts during the approach, the integration could be easier.

6.1.4.2 Recommendations

In order to fit in the SESAR Programme, next RPAS activities should strongly rely on B.05 KPI catalogue.

As we can consider that no RPAS will be integrated in a high density / high complexity TMA for a horizon of 15 years, focus should be put on medium size airport as done during TEMPAERIS exercises.

The need for Regulation and Standardisation is mentioned in 6.1.3.1.2.

6.2 Demonstration Exercise EXE-RPAS.05-200 Report

6.2.1 Exercise Scope

The objective of the simulations described in this section is to show the impact of the integration of RPAS in the air traffic of a civil airport. We must determine the consequences of the presence of RPAS performing SID (*Standard Instrument Departures*) - STAR (*Standard Arrival Routes*) and on the emergency procedures in the event of loss the orders of the RPAS, the communications with the RPAS or with the remote pilot.

We have appealed to TWR & TMA controllers of Bordeaux Merignac to control simulated traffic with the presence of RPAS carrying out missions in the areas close to the SID-STAR.

During the integration of RPAS in the approach traffic, we issued working hypothesis that we should observe:

- an increase in the occupation of the frequency
- an extension of the flight trajectories
- overlapping of messages time lag (radio operator frequency of the RPAS with other flights)
- a delay of commercial flights, in particular in case of radio operator breakdown of the RPAS.

6.2.2 Conduct of Demonstration Exercise

6.2.2.1 Exercise Preparation

6.2.2.1.1 Technical Environment

The environment of simulation must be closest to the operational tools used by the controllers of tower and approach. Thus, it was placed at the disposal:

- French approach radar HMI IRMA
- second IRMA HMI for an assistant
- strips printer
- strips table
- phone

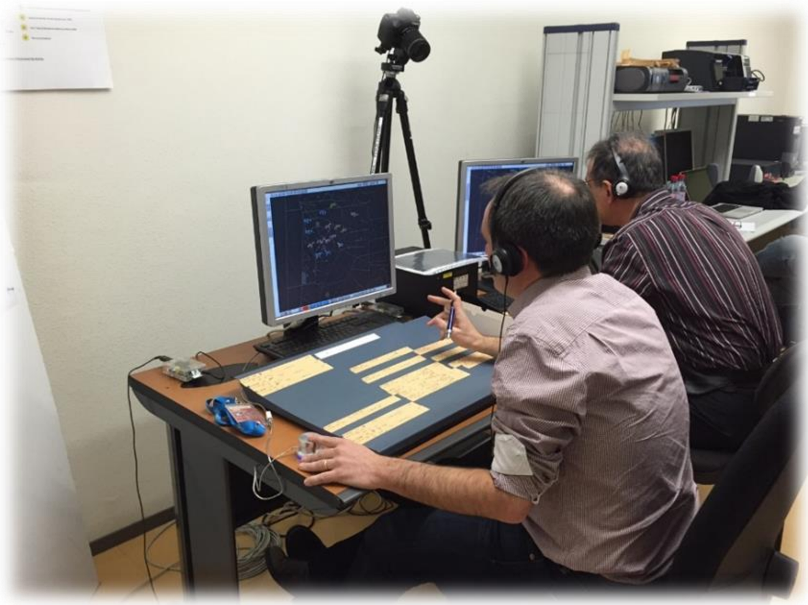

Figure 6: Control Position simulation platform

A foot alternat for the frequency is not proposed, but a solution “Power mate” (pushbutton on the left hand of the controller on Figure 6) is put in replacement. The exchange on the frequency with the pseudo-pilot is carried out with a headphone with a microphone.

On the side of the pseudo-pilots, we have two positions enables to send out the orders of piloting of the flights of simulation.

Figure 7: Pseudo-pilots simulation platforms

The reactivity of pseudo-piloting, by the respect of the phraseology and the technical platform used, takes part in the realism of simulations.

The whole of this context brings us closer to the operational situation and makes it possible to place the simulations played under good test conditions. In addition, this environment is used by scenarios as real traffics whose load however is increased to compensate the simulation effect and to keep the controller in permanent attention. Compared to a nominal traffic, the load is multiplied by two. We have approximately 1 flight per minute. Many departures are programmed to keep high load and to test RPAS flights.

6.2.2.1.2 Traffic preparation

The organization of simulations is built in order to submit the controllers to a workload on the arrivals with several flows.

- Traffic in arrival by ROYAN, CNA, LMG, MIRBA, ENSAC, CHALA, …
- Radar and standard approach procedure on runway 23 of Bordeaux-Merignac
- Minimal rate is 3 minutes between each flight.

Many departures were programmed with the idea to overload, on frequency and charge of traffic, the controller. The conflicts on departures were minimized, because the objective is not to make the activity of control complex but only to make denser it in order to accentuate the problems of integration of the RPAS.

- Traffic on departure from ROYAN, CNA, SAU, AGN, ENSAC,…
- Departures starting from CAZAUX,COGNAC
- Transits.

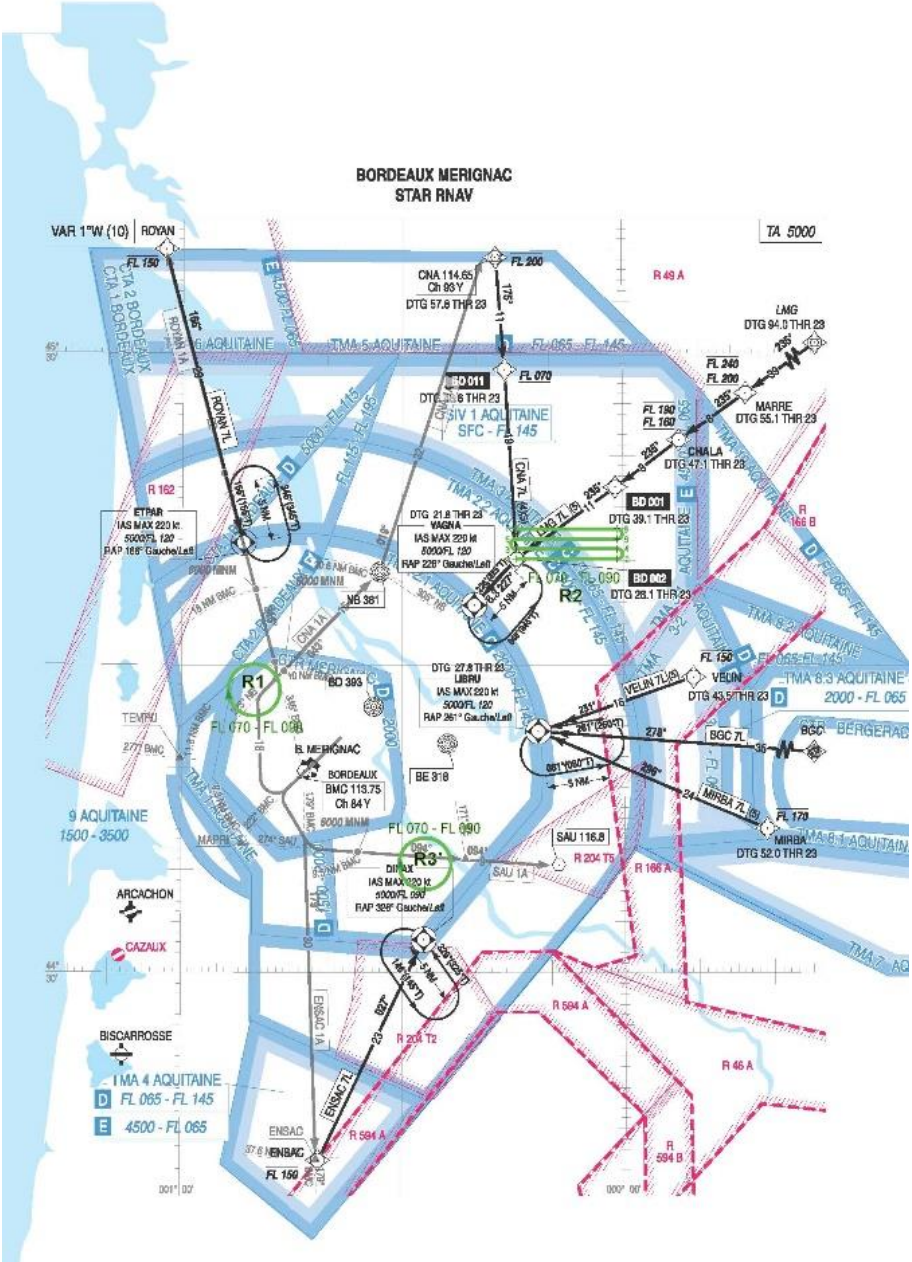

Figure 8: Arrival and departure flow in Bordeaux-Merignac approach

6.2.2.1.3 Data collection methodology

A systematic observation of the working session of each participant is carried out. We must notice the reactions of the controllers, to note down the big events. The course of simulations is entirely recorded, which makes it possible thereafter to visualize the controlled traffic. The frequency is also saved.

The whole of these data provides measures used to the analysis:

- of number of clearances
- of the trajectory of the flights (commercial flights and RPAS)
- of time of occupation of the frequency

A questionnaire is proposed at the end of the working session, after the second simulation. The questions concern mainly the feeling about the integration of the RPAS in the traffic and in particular the impact on the workload and the security. He is also asked an opinion on the emergency procedure suggested in simulations with the RPAS.

6.2.2.2 Exercise execution

Simulations ran on the site of Bordeaux Merignac took place in rooms close to the tower of control. Beforehand, the controllers were invited to be registered on a planning to run the experiments. The period was extended over 2weeks (from March 2nd to March 5th and from March 9th to March 13th). An availability of 2 hours was required to be able to carry out 2 simulations of 45 minutes corresponding respectively to a reference traffic (without RPAS and with RPAS in nominal situation) and a traffic of test with RPAS in situation of breakdown. 2 simulations were carried out one following the other.

Ctrl01	SIM01-02 Ref300UAV502
Ctrl02	SIM05-06 Ref400UAV503
Ctrl03	SIM03-04 Ref400UAV502
Ctrl04	SIM07-08 Ref300UAV501
Ctrl05	SIM09-20 Ref300UAV502
Ctrl06	SIM10-11 Ref400UAV501
Ctrl07	SIM12-13 Ref300UAV502
Ctrl08	SIM16-17 Ref300UAV503
Ctrl09	SIM14-15 Ref400UAV502
Ctrl10	SIM18-19 Ref300UAV501
Ctrl11	SIM21-22 Ref400UAV501
Ctrl12	SIM23-24 Ref400UAV503
Ctrl13	SIM25-26 Ref300UAV503
Ctrl14	SIM27-28 Ref400UAV503
Ctrl15	SIM29-30 Ref400UAV502
Ctrl16	SIM31-32 Ref300UAV502
Ctrl17	SIM33-34 Ref300UAV501
Ctrl18	SIM35-36 Ref400UAV501

Figure 9: RTS Planning

On whole, 18 controllers took part in this simulation campaign, accompanied by 5 other controllers who occupied the role of assistant. The 5 assistants were assigned by chance to various simulations. The instruction for each one was to coordinate with the pseudo-pilots and to carry out tasks of support (preparation of strips, regulation of speed of the flights at the entry of TMA). It was indicated like instructions to avoid helping to anticipate strategies or informing the eminence of a breakdown. However the assistant was authorized to announce, to recall, as it must do it in the operational, the situations to be supervised (catch up after take-off), information traffic to be taken into account (clearance level, coordination…).

Before each session, a briefing presents the objective of simulation and the organization of the platform. The instructions are given on the type of traffic to control, the starting situation and the course of the flights (levels of approach, speed, trajectory…), and in particular of the RPAS (missions, phraseology, breakdown procedure…).

At the end of each session, according to the availability time of the controller, a debriefing on the last exercise is carried out.

6.2.2.2.1 Simulation scenarios

5 scenarios of simulations have been run:

- One reference scenario **(REF300)**
  - No RPAS flights
- One scenario with RPAS (UAV400)

- 3 RPAS flights under "nominal" operation
  - UAV1L - "slow" type – on mission on turns of 360° at the point (R1) in the northern axis of the departures
  - UAV2M - "middle speed moving" type - on mission starting from VAGNA on Eastern-Western tracks
  - UAV42 – fast moving type – transits on Southern/Northern axes
- Three scenarios with RPAS on radio failure, changing area or alternate aerodrome
  - **UAV501** >> Scenario UAV400 with:
    - UAV2M on radio failure
    - UAV1L changes zone for its mission (R1')
  - **UAV502** >> Scenario UAV400 with:
    - UAV2M on radio failure
    - UAV42 in diversion and radar vectoring
  - **UAV503** >> Scenario UAV400 with:
    - UAV42 on radio failure
    - UAV1L changing area for its mission (R1')

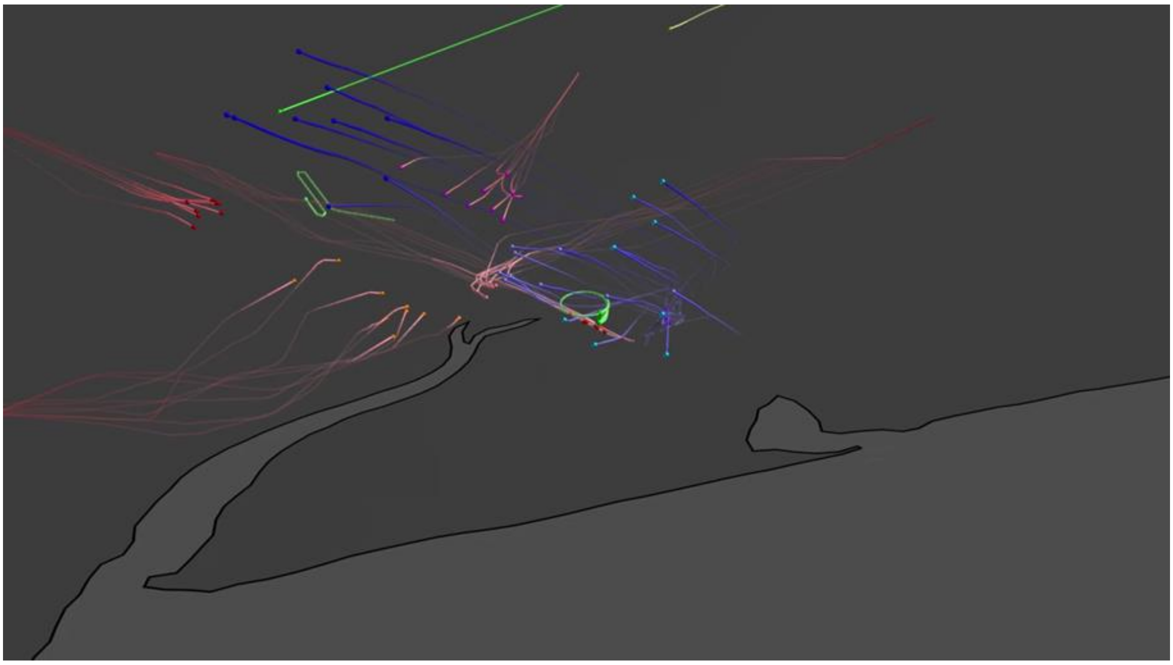

Figure 10: Different missions and trajectories of RPAS during simulations (in green)

Traffic is identical for all simulation runs, except that RPAS are not displayed in SCN300. The goal of the protocol is to put in situation of comparison various simulations between them and, in particular those without RPAS with those with RPAS, the change being defined only by the presence or not of RPAS.

6.2.2.2.2 Breakdown procedures for the RPAS

In the case of simulation of a connection breakdown with RPAS UAV2M and UAV42 a preset procedure is setting up. The RPAS then carries out a return towards the airport, after 1minute on its heading, starting from its last assigned level. It must then start a descent to 5000 feet into direct on beacon VAGNA. At this beacon, it performs a holding of integration of approximately 2 minutes at the altitude of 5000 feet. Then, it descents in final procedure at 3000ft and continues until the landing. We consider that the RPAS vacates quickly the runway.

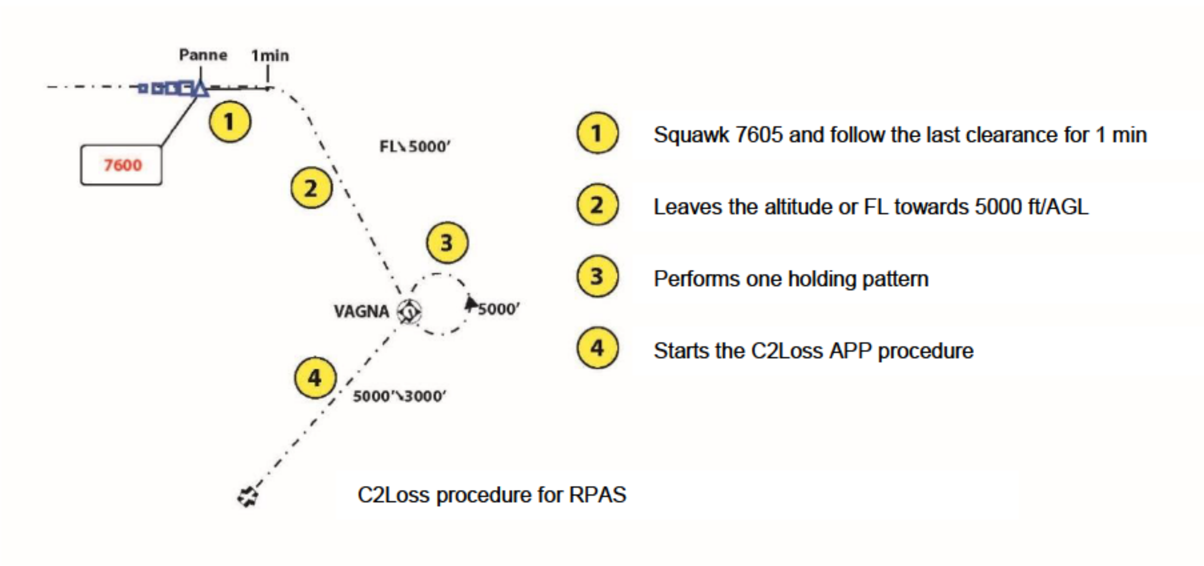

Figure 11: Briefing picture about approach RPAS radio failure procedure

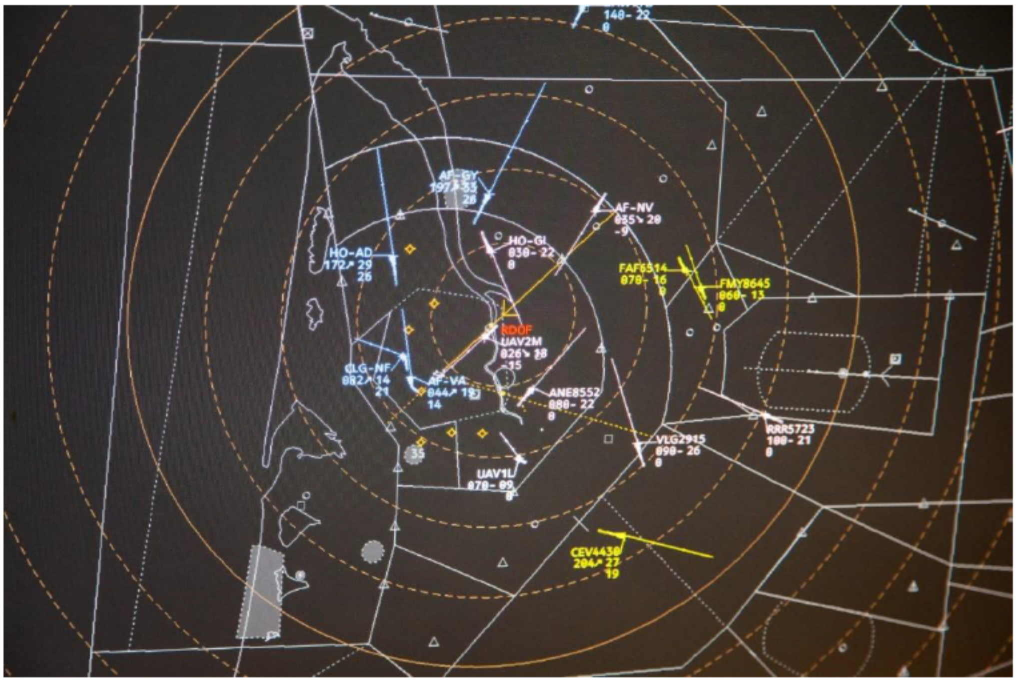

Figure 12: View of IRMA HMI at Bordeaux-Merignac approach

The radar HMI Figure 12 illustrates a traffic condition during a simulation with a failure program on RPAS (REF502). In particular, we can distinguish the RPAS UAV2M on radio failure, which is in final landing phase. A RDOF alarm (Radio OFF) is displayed on the label. We can also identify UAV1L in its circular area R1 in south of the airport. Still in the south, is displayed CEV4430 departing from CAZAUX. To the east, in yellow, two transit flights pass each other (FAF6514 and FMY8645).

6.2.2.3 Deviation from the planned activities

In RPAS.05-D01-TEMPAERIS Demonstration Plan, ATCOs were supposed to participate to 3 simulations but due to human resources management, each ATCO participated to 2 simulations run.

In SCN-500 the RPAS1 was supposed to have C2Loss but due to operational experts who considered that C2Loss for slow RPAS was not bringing any interest to the results, the SCN-500 was recomposed.

Initial SCN-500

SCN-501: RPAS1: C2Loss, RPAS2: reprograms its area of operations during the mission

SCN-502: RPAS2: C2Loss, RPAS3: diverts to Bordeaux airport

SCN-503: RPAS3: C2Loss, RPAS1: reprograms its area of operations during the mission

Modified SCN-500;

SCN501: RPAS2 C2Loss. RPAS1 modifies its area of surveillance during the mission

SCN502: remains the same.

SCN503: remains the same.

6.2.3 Exercise Results

6.2.3.1 Summary of Exercise Results

The measurements recorded during simulations, that it is on the counting of the given instructions of control and the type of instructions, on the distance from the trajectories of the flights, on the radio messages, reveal significant differences between the conditions of traffic "without RPAS" (REF300) and the conditions of traffic with integration of RPAS (UAV…). The presence of RPAS in particular impacted the frequency with an increase of the messages and more overlaps. Even if the commercial flights were not penalized on their trajectories of approach, we note some waits in holding pattern when RPAS have got breakdowns (radio failure of the UAV2M around VAGNA).

It is not about a general impact and certain simulations with RPAS (UAV503) appeared not very different from REF300. For reminder, during UAV503 simulations, the controllers were confronted with a radio breakdown of the UAV42 whose trajectory as flight of transit did not seem too constraining. The procedure suggested was appreciated and generally well suited to the traffic in progress. The change of area for UAV1L never really posed problem insofar as the departures were systematically limited compared to the level of the RPAS and that this change of area was carried out on a level of flight made safe above aerodrome of approach. Moreover, it is a situation which is not unfamiliar to the controllers and this has never been a problem because it is occasionally the same situation encountered during photo or observations missions… Indeed, these missions already today are sometimes programmed not far from the approach area of Bordeaux-Merignac.

In fact, which we must retain is:

- problems undergone by flows in departure,
- the combination of situation of breakdowns (radio and diversion, the UAV502),
- the time lag on frequency which increases the number of message because of overlaps of frequencies.

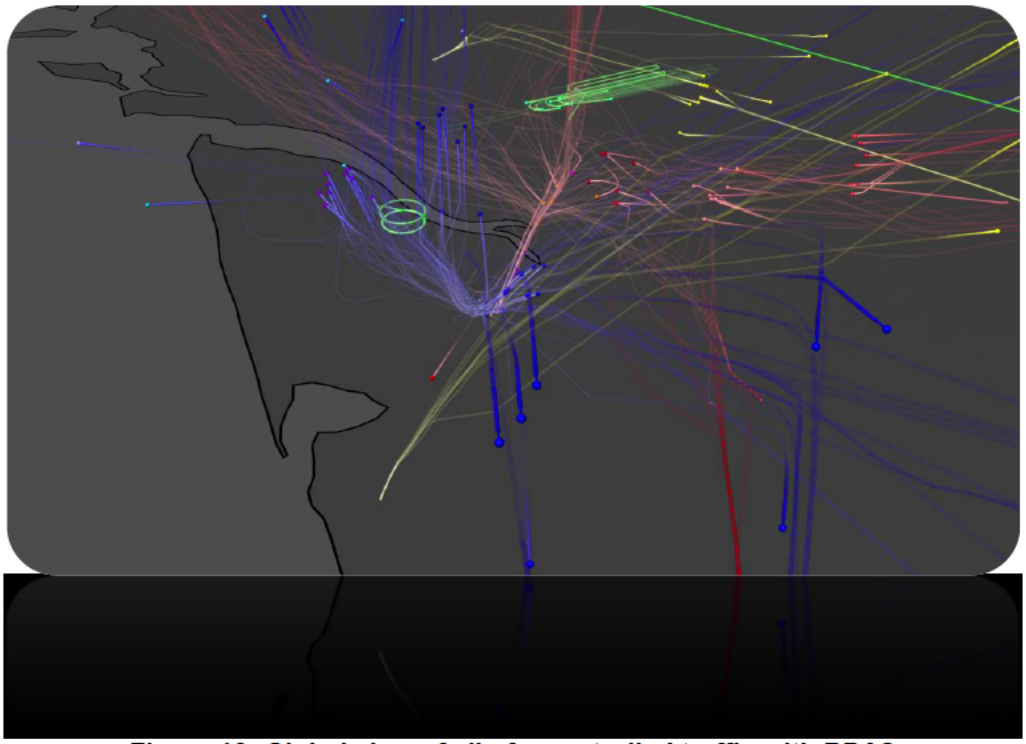

Figure 13: Global view of all of a controlled traffic with RPAS

We see well that the integration of the RPAS in the airspace of approach implies adaptations, regulations, which were correctly managed by the controllers, even without real surprised because similar to other type of traffic (VFR, parachuting, weather…). However, the management of this new traffic impacted on the flow of flows, in particular starting, and consequently increased the occupation of the frequency.

Simulations were felt very charged. It is true that the traffic was multiplied by two compared to one "normal" day, with an increased starting rate. Embarrassment created alternatively on the departures in North and the South east come to reinforce this feeling of load.

Thus, overall, the workload was accepted in this context of simulation with the idea that this conditioning is useful to make the exercises interesting for the activity of control but so necessary "to amplify the effect" in the presence of RPAS.
All the controllers did not react in the same manner. Some of them anticipated better than others or exploiting regulation appropriateness's, enabling them less to undergo the specific behaviour of RPAS.

The Figure below illustrates well some differences in strategies.

Figure 14: Trajectories of FGLOS

The situation sown corresponds to two different runs of simulation UAV502, with the radio failure on UAV2M and the diversion of UAV42. The situation corresponds to the moment when UAV2M starts its final approach. Before that, it followed the breakdown procedure with a holding of two minutes on VAGNA. At this point, the FGLOS is close. We see in this example that the choice of road is different according to the 2 controllers. One takes the choice of the standard road with waiting on VAGNA. The other deviates the flight in course towards the West to then bring back it on the extended ILS centreline.

We see that some controllers chose to use vectoring to accelerate the approach of the aircraft interfering with the RPAS which experienced radio failure. Some others were more conservative and decided not to take the risk of loosing separation. Such differences happen in many simulationsl.

6.2.3.1.1 Results per KPA

KPA	Exercise ID	Demonstration Objective Tittle	Demonstration Objective ID	Success Criterion	Exercise Results	Demonstration Objective Status
Safety	EXE-RPAS.05-200	To maintain perceived safety at least at the equivalent level in the ATC simulation.	OBJ-RPAS05-210	Acceptable level of workload on the simulated positions compared with the baseline.	The presence of an RPAS generates more messages than the reference scenario.	NOK
Safety	EXE-RPAS.05-200	To maintain perceived safety at least at the equivalent level in the ATC simulation.	OBJ-RPAS05-210	Subjective impressions by ATCOs	77.78% of ATCOs who answered this question considered that the perceived safety was not impacted by the RPAS	OK
Safety	EXE-RPAS.05-200	To define a safe standard “Return Home” procedure through ATC simulations.	OBJ-RPAS05-230	No avoiding action should be necessary once the failure has been identified and the appropriate procedure selected.	No avoiding action	OK
Predictability	EXE-RPAS.05-200	To assess, during ATC simulations, the level of trajectory predictability of a RPAS (especially if it is showing a significant level of time lag (5 to 10	OBJ-RPAS05-220[2]	Execution of clearances in no more than 40 seconds.	Clearances executed in no more than 27 seconds	OK

[2] The OBJ220 has been identified, because we expected to insert in the simulation one RPAS with a 10 second lag and two with no lag. We thus intended to see whether a 10 seconds lag could be acceptable for ATCOs. As we finally, due to technical restrictions, end up with three RPAS with a 4 seconds lag each, the objective OBJ-RPAS05-220 became less meaningful. Anyway we demonstrated that a 4 seconds lag is acceptable for ATCOs on the En Route and initial Approach segment. It would not be acceptable however, closer from landing.

		seconds) in the communication link).				
Predictability	EXE-RPAS.05-200	To assess, during ATC simulations, the level of trajectory predictability of a RPAS (especially if it is showing a significant level of time lag (5 to 10 seconds) in the communication link).	OBJ-RPAS05-220	Comparison of the average number of messages given to this RPAS and other airplanes.Ratio (average number of messages to RPAS pseudo-pilot divided by average number of messages to aircraft pseudo-pilot) <= 1	The presence of an RPAS generates more messages than the reference scenario	NOK
Participation	EXE-RPAS.05-200	To define a safe standard “Return Home” procedure through ATC simulations.	OBJ-RPAS05-230	Implication of ATCOs in “Return Home” procedure definition and validation.	88.89% of ATCOs who answered this question were confident with the procedures	OK
Capacity	EXE-RPAS.05-200	To assess the impact on TMA capacity.	OBJ-RPAS05-240	Acceptable level of workload on the simulated positions compared with the baseline. Ratio (average number of instructions to RPAS pseudo-pilot divided by average number of instructions to aircraft pseudo-pilot) <= 1	The presence of RPAS seems significantly to increase the number of instructions of control	NOK
Capacity	EXE-RPAS.05-200	To assess the impact on TMA capacity.	OBJ-RPAS05-240	Subjective impressions by ATCOs	77.78% of ATCOs who answered this question considered that there were no impact on TMA capacity	OK

6.2.3.1.2 Results impacting regulation and standardisation initiatives

Please refer to 5.3.3.

6.2.3.1.3 Unexpected Behaviours/Results

Neither unexpected behaviour nor results has been identified.

6.2.3.1.4 Quality of Demonstration Results

In this paragraph, we would like to mention limits of the environment of the simulations. Even if realism is considered to be satisfactory, it remains situations where the controllers indicated that they would not react in the same way in operational conditions.

Regarding the effect of the time lag, that is to say the messages overlapping on frequency due to the simultaneous use of the communication, realism is considered as reached. The overlapping undergone during the experiments often completely caused interference to messages. The expected consequence is that there are many repetitions of message, inaudible control instructions. However, as in reality, when messages are scrambled, few words can be enough to give sense. For example, in one of simulations, FAF6510 calls, but the fact of receiving the end of the message and the appearance of the FAF6510 on the radar screen indicates to the controller that it is this flight and as a result he answers correctly.

But, the flexibility of the environment of simulation nevertheless made it possible to give to the controllers the possibility of controlling the planes as usual. For example, there were not real constraints on the type of transmitted instructions. The controllers could regulate the trajectories into direct, headings, on particular points and even make carry out multiple orders. Prior coordination on starting levels and speeds were also negotiated in advance to respect the possibilities of the simulator and the workload of the pseudo-pilots.

Globally, the controllers found simulations charged and not very real taking into consideration what they can meet every day.

They recognize however that this situation of overload allows them to better apprehend the problems of RPAS and to be sensitive of the difficulties which the cases of breakdowns could cause. It was one of the required results.

6.2.3.1.5 Significance of Demonstration Results

Statistical analysis and results significance are described in Appendix C.

6.2.4 Conclusions and recommendations

6.2.4.1 Conclusions

The subjective approach of the questionnaires emphasizes the problems of the time lag and the consequences on the overlap of messages.

In particular, it is often indicated that the fact of having RPAS in its space of control decreases the capacity of the traffic and increases the workload.

The integration of RPAS is not without cost and resulted in adjustments of strategies of the controllers, such as the grouping of the messages, which only appeared after further statistical investigation shown in Appendix C.

6.2.4.2 Recommendations

Please refer to §8.1.

7 Summary of the Communication Activities

The following tables resume our communication program.

Action	Date	Type	Attendance	Execution
Initialization of project website	March 2014	Web site	Aviation and RPAS users communities.	Done
Communication of project initial concept definition	May 2014	Press release	Specialized aviation and RPAS media, including Internet media.	Done
Communication on the real flights demonstration program	September 2014	Press release, Invitations of journalists	Specialized aviation and RPAS media, including Internet media.	Not done, due to the postponing of real flights and the short time notice before real flight execution
Communication on the real flights demonstration results	December 2014	Press release,	Specialized aviation and RPAS media, including Internet media.	Yes. Done in March 2015, due to the late execution of flights.
Communication on the completion of the demonstrations activities	April 2015	Press release,	Specialized aviation and RPAS media, including Internet media.	Done
Communication on the publishing of project final report	September 2015	Press release,	Specialized aviation and RPAS media, including Internet media.	Forecast

Table 10: Communication Activities

Here are some press releases dealing with our project (including on SESAR Ju site):

http://www.sesarju.eu/newsroom/all-news/rpas-demonstration-capability-integrate-remote-piloted-aircraft-demonstrator
http://www.airtrafficmanagement.net/2015/02/tempaeris-demonstrates-uav-integration/
http://www.icao.int/Meetings/RPAS/RPASSymposiumPresentation/Day%201%20Session%201%20Patrick%20Gandil%20-%20The%20take-off%20of%20civil%20RPAS%20activities%20in%20France.pdf
http://rpas-regulations.com/index.php/news-blog-archive/item/187-french-consortium-demonstrates-uas-integration-into-civil-airspace

Event	Date	Responsible	Attendance	Execution
World ATM Congress 2014- Madrid	3-6 March 2014	ENAC	ANSP, ATC systems providers	Done
SJU Information Sharing Day- Brussels	To be confirmed	DSNA	ANSP, ATC systems providers, airspace users.	?
ISARRA2014 : International Society for Atmospheric Research Using Remotely Piloted Aircraft,	26-28 May 2014	ENAC	ATC systems providers, RPAS manufacturers	Done

Air & Space Academy symposium : « Présent et futur des *drones* civils »	13-14 Nov. 2014	DSNA & ENAC	Whole aviation community.	Not done due to the of the real flights being postponed
CDC 2014 : IEEE Conference on Decision and Control	15-17 December 2014	ENAC	ATC systems providers, RPAS manufacturers	Done
World ATM Congress 2015- Madrid	March 2015	DSNA & ENAC	ANSP, ATC systems providers	Done
Entretiens de Toulouse 2015- Rencontres aérospatiales.	April 2015	DSNA & ENAC	ANSP, ATC systems providers	Done
Paris Air Show 2015	June 15th-21st, 2015	DSNA	Whole aviation community.	Not done
Project final event- Toulouse.	July 8th 2015	ENAC	ANSP, ATC systems providers, airspace users.	Done

Table 11: Communication Events

8 Next Steps

TEMPAERIS project was initially intended to focus on inserting a GA aircraft sized RPAS in the traffic of a mid- sized regional airport. Due to some exceptional circumstances and because we felt the question was to be investigated, we decided to carry out a survey of the insertion of small drones in the vicinity of a regional airport. We will thus detail hereafter the next steps that we think necessary to insert both small and larger RPAS in the traffic.

8.1 Conclusions

From a general point of view, here are the conclusions gathered from this project:

- RPAS behaviour was not perceived as different from the one of a small general aviation aircraft,
- ATCOs considered that small RPAS shall not be integrated on airports where traffic is more than 20 movements per hour. This is of course an estimated value, but there is an operational support for it. Wake turbulence calls for a separation of about 6 NM for a small RPAS to land behind a mid-sized jet such as an A320 or a B737. The RPAS flying under 2 NM/ minute takes (at least!) 3 minutes to fly these 6 NM. We clearly see that landing only one slow RPAS at a place where we have 20 arrivals an hour will start creating uncompressible delays,
- There is a need for the appropriate technology (ex: HD cameras + communication architecture) to secure the use of the « line up behind and hold » procedure (and also maybe the « see and avoid »),
- The following contingency procedures: radio failure, C1/C2 Loss, GPS failure, emergency landing, will have to be standardized in order to be made homogeneous at the ICAO level. However these procedures might adapted to each airport approach
- Flight plan format shall be adapted to RPAS specificity,
- Proper C2 Link technology shall be developed, using the bands available for Aeronautical Mobile Service.

8.1.1 Insertion of smaller RPAS

The first question to solve is to define a limit between smaller and larger RPAS. Though it is now accepted that the mission of the RPAS will be an essential point, which may sometimes override any other consideration, TEMPAERIS Consortium thinks that a clear limit should be set between the drones that will be easily detectable by the human eye and those which will not be. This question obviously deals with the “see and avoid” concept, which will remain for a while a basis of GA aviation operations. The 150 kg limit might be a suitable one.

Small RPAS may also be a safety and security threat. While TEMPAERIS does not address security aspects, safety management calls for minimizing the risks of airspace infringements or collision risks with other aircraft. It is thus understandable that the TEMPAERIS Consortium wishes to identify and track even small RPAS. This is, by the way, one element of the Riga declaration.

8.1.2 Insertion of larger RPAS under IFR rules, in controlled airspace

Concerning RPAS integration under IFR rules, in controlled airspace, we propose that future studies of projects should address the following items:

Type of research	*Description of task*
Hardware/ Software	Airborne Detect and Avoid Systems supporting operations with non-cooperative intruders
Software	Airborne Collision Avoidance for Remotely Piloted Aircraft Systems -
Hardware/ Software	Surface operations by RPAS
Procedures	RPAS Integration in controlled airspace. Human factors aspects.

8.1.3 Insertion of larger RPAS under VFR rules

Concerning RPAS integration under VFR rules, the following SESAR 2020 solutions are currently defined:

Type of research	*Description of task*
Hardware/ Software	Airborne Detect and Avoid Systems supporting operations with non-cooperative intruders
Software	Airborne Collision Avoidance for Remotely Piloted Aircraft Systems -
Hardware/ Software	Surface operations by RPAS
Hardware/ Software/ Procedures	Use of TIS-B by RPAS

8.2 Recommendations

This section gives recommendations to each type of RPAS however; here are some general recommendations which should be applied for all type of RPAS integration:

- RPAS shall be included in the Trajectory Management Framework,
- ATCOs' HMI shall be able to present mission trajectory,
- Future studies or projects shall include solutions for the Small RPAS/ Very Low Level topics, especially specific CNS/ ATM and AIS solutions for this market segment,
- Initial package shall comprise: a simple and efficient navigation system, a permanent position reporting system and a geofencing capability.

8.2.1 Insertion of smaller RPAS

As it was said in section 8.1.1 we wish to permanently identify and track smaller RPAS, as Riga declaration required. We fully support this idea and every RPAS (except the toys with a C2 range of less than, say, 100 meters), should be fitted with a chip that:

- Identifies the RPAS,
- Permanently transmit its position and identification
- And maybe also records all flight data.

The type of communication band on which this data exchange would be carried out needs to be defined. ADS- B is a possibility, but there is a risk to saturate the 1090 Mhz frequency. UAT is also a possibility, as well as the use of GSM telephone frequencies.

Because they may interfere between each other and also with other airspace user (even at Very low levels) the small drones should also be constrained to declare their flights, using an approved aeronautical information site. Of course, introducing this obligation, as well as the above requirement on identification, should be compensated by a relief in the necessary administrative authorizations to fly. Typically flight declaration on an approved aeronautical site should be equivalent to filing a FPL. If FPL is accepted, you receive a FPL number and your flight may be programmed. This should be the same for RPAS.

Moreover, because their use may be very common, smaller drones should also be mandatorily fitted with a geo-fencing device that will prevent illegal airspace penetration. This device could be a database, provided by an approved aeronautical information source and updated on every AIRAC cycle that would limit RPAS operations according to:

- The airspace class,
- The RPAS equipment,
- The pilot's privilege.

A default access free airspace is thus defined; a specific authorization would be required to fly in any other part of the airspace.

Finally, a last question concerns the use of small RPAS in urban area. While the VLOS use of a single RPAS may be relatively feasible, as an appropriate safety perimeter may be secured, the use of non-VLOS or the use of several RPAS in an inhabited area raises a lot of concerns. As far as a RPAS is to be used over inhabited areas, a certified soft crash device should be mandatory. Another issue is the use of several RPAS over industrial areas such as harbors for example. The implementation of a RPAS traffic Management service at very low altitude, such as the NASA UTM project aims at defining it, seems to be the only solution to guarantee a safe exploitation of a RPAS fleet in such conditions. This traffic management service would provide ground based detect and avoid as well as C2 link integrity management.

We recommend that further studies or projects shall:

- In connection with EASA actions in the domain, identify a VLL (Very Low level) segment:
  - studies in order to define the type of device to be fitted on the small drones, in order to identify them provide protection against unlawful airspace infringement and, when necessary, make them cooperative with other traffic,
  - studies that will define how and when RPAS users (and especially users of small RPAS) will declare their intent to fly or file a FPL in the Flight Plan Processing System,
  - studies in order to define a VLL traffic management service in areas where low level traffic density calls for it,
  - studies to define the type of equipment that should be installed on board of the RPA and into the GCS, in order to allow non VLOS urban operations.

8.2.2 Insertion of larger RPAS under IFR rules, in controlled airspace

We strongly recommend that a specific solution dedicated with RPAS control and command link use shall be inserted in further studies or projects. The lack of such solution will simply jeopardize the feasibility to insert RPAS in non- segregated airspace.

We also advise to insert RPAS into non segregated airspace by following a step by step approach that will start by inserting RPAS into a "somewhat segregated" airspace, using the current technologies and procedures, while not impacting safety and capacity, and shall gradually remove constraints on a 15-20 year time period, according to reliable new technology introduction. The reliability of new technology shall be compatible with current safety level standards.

We also suggest to tackle the problem of transmitting HD images to the remote pilot. The resulting capabilities maybe used both by the ground segment follow line up and hold type procedures at the runway threshold, as well as, for the providing of traffic information in the flight segment.

We considered that RPAS should strongly be part of the Trajectory Management Framework as predictability is one of the key to success for RPAS integration.

8.2.3 Insertion of larger RPAS under VFR rules

We think that this topic shall be addressed in further studies or projects. We think that a solution dealing with light and cheap cooperative system for collision avoidance should be proposed in the future.

9 References

9.1 Applicable Documents

The documents mentioned in the template are examples that can be removed

[1] EUROCONTROL ATM Lexicon
https://extranet.eurocontrol.int/http://atmlexicon.eurocontrol.int/en/index.php/SESAR

9.2 Reference Documents

The following documents provide input:

[1] D01-TEMPAERIS Demonstration Plan
SESAR JU Extranet Link

[2] AATM Master Plan
https://www.atmmasterplan.eu

Appendix A KPA Results

Please refer to §5.1 and §6.2.3.1.1

Appendix B EXE-RPAS.05-100 Results Figures

N°of the flight	Ecarts de plus de 0,5NM	Frequency transfert lasting more than 1 minute	Frequency transfert lasting more than 3 minutes	Nombre of transferts considered	Clearance not executed after 1 minute	Nombre of clearances considered	Mean transfert time (sec)	Mean clearance execution time (sec)
1	0	0	0	2	0	2	27,5	35
2-3	0	0	0	2	0	2	22,5	30,5
4	0	0	0	2	0	2	26	49,5
5	0	0	0	2	0	2	15	31,5
6	0	0	0	2	0	1	20	47,5
7	0	1	1	1	0	2	191	40
9	0	0	0	2	0	6	15,5	22,5
						Average (sec)	52,92	42,75
						Average without flight 7	25,30	

Incoming IFR stacking due to RPAS	RPAS take off delay exceeding 3 mn	Other aircraft delayed by more than 3 mn due to RPAS	Avoiding action by RPAS pilot	Action due to F-WUAV	Remarks
0	0	0	0	0	
0	1	1	0	1	Flights 2 et 3 combined. RPAS holds 5 mn 09sec at holding point due to the landing of two aircraft. FWWGN then delayed by 5mn01 sec due to RPAS which is a slow machine. However F-WWGN is a teste flight and is not in a hurry to take-off.
0	1	0	0	0	RPAS holds 3 mn 53 at holding point, due to a rise in traffic. Voluntarily exits SID.
0	0	0	0	3	Radio failure test. RYR781V is asked to keep speed to land before the RPAS, HOP01GI is slowed down to insert behind RPAS.
0	0	0	0	1	Downlink failure test. ARL421 is delayed by 1 mn 43s due to RPAS.
0	0		0	1	Uplink failure test. MEDOC07 is delayed by 2 mn 08sec. RPAS pilot forgets to call APP frequency back, with no consequence.
0	0	0	0	0	GPS failure test. RPAS asks to leave SID to shortened flight time due to inclement weather.

Tableau 1: Real Flight KPI Measurements

Appendix C EXE-RPAS.05-200 Results Figures

C.1 Number of instructions

Assuming that the traffic flow management in simulation with RPAS would increase the number of instructions intended of the flights. In particular, the missions of UAV1L and UAV2M respectively on the centreline of departure towards North (or South when change of mission at R1') and starting from beacon VAGNA, or on the centreline of approach of the runway 23 are likely to produce constraints on the trajectories of the commercial flights.

We name instructions all actions on the trajectory of the flight (Level, Heading, Direct track, Speed, ILS Interception). We integrated in this analysis only the commercial flights of simulation. The 3 RPAS, of course, are not entered since they are to note the consequences of the presence the RPAS in the surrounding traffic. We included in a first analysis the whole traffic, i.e. the Arrivals and the Departures flow.

A first total result on the whole of simulations underlines light differences between the types of scenario, and in particular between simulations REF300 and simulations UAV, i.e. with RPAS. For example, one notes on means a difference in 25 instructions between the REF300 and the UAV400. Simulations with breakdowns on the RPAS are displayed with less difference. The UAV502, comprising the situation more penalizing (radio breakdown and diversion by radar vectoring), have a mean average of 22 more instructions than the REF300.

On the other hand, we noted a significant difference between REF300 and UAV400. The presence of RPAS seems to bring to different behaviours. We insist here on the fact that these two groups of simulations are carried out in first by the controllers. Also, from the point of view of the training, the two groups are positioned in a similar way.

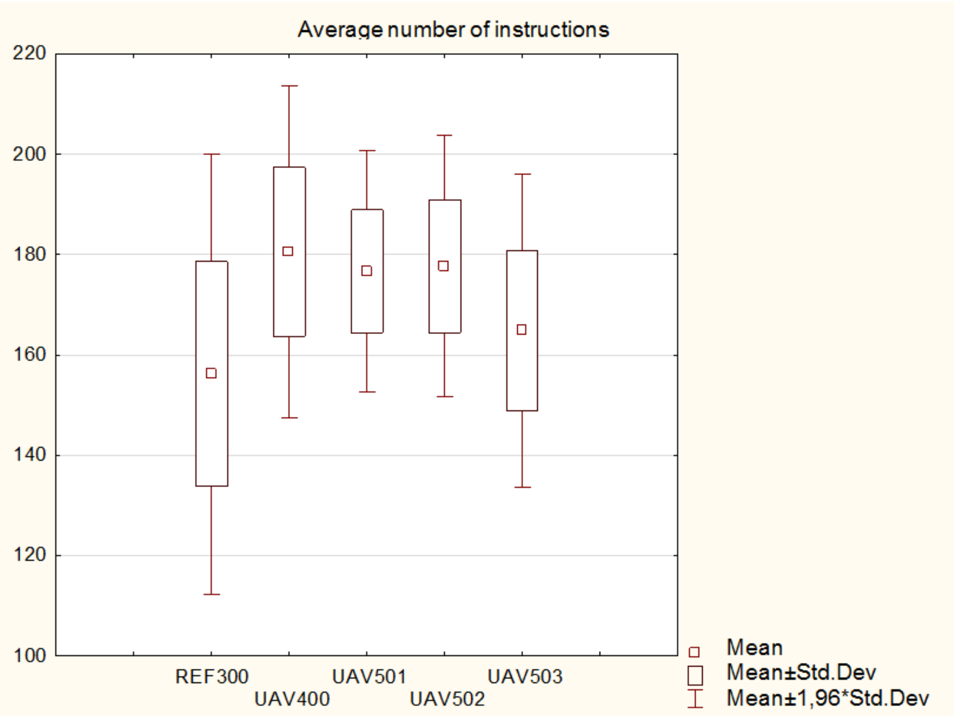

Figure 15: Graph of the test T about the number of instructions in seconds

We can thus legitimately think that this “training effect” was sufficiently high to gum the impact of the presence of the RPAS in the UAV group. It is all the more marked that we do not obtain a significant difference between the REF300 and the UAV50X while at the same time simulations UAV400 are significantly different from the REF300. The UAV50X are systematically carried out in the second position and thus we see well that the preliminary knowledge of the surrounding traffic makes it possible to anticipate behaviours of flights and thus consequently to reduce the actions of control.

We expected the consequences of this choice of protocol, and therefore it is advisable however to read the results, more on the comparison between the REF300 and UAV400 that on a comparison between the first and the second working session.

Also with this grade of analysis, which we will retain about the level of impact on the instructions of control is the significant difference between the REF300 and the UAV400 but the little of significant differences between most of simulations REF300, UAV400 and the UAV with breakdowns. The presence of RPAS thus seems significantly to increase the number of instructions of control, suggesting that there was not a difference in behaviour on the management of the surrounding traffic. But the impact proves to be less high since knowledge is established and the presence of RPAS is under control.

We point out that the previous data of analysis include the whole traffic (Arrivals and Departures). Thus let us take the choice to carry out the analysis on two different samples that wants to say that we now separate the data of the flights on Arrival and the flights on Departure. The idea is better to specify the impacts on flows, in particular to distinguish the constraints from RPAS UAV1L on the centreline of departure and the UAV2M which flies around VAGNA beacon.

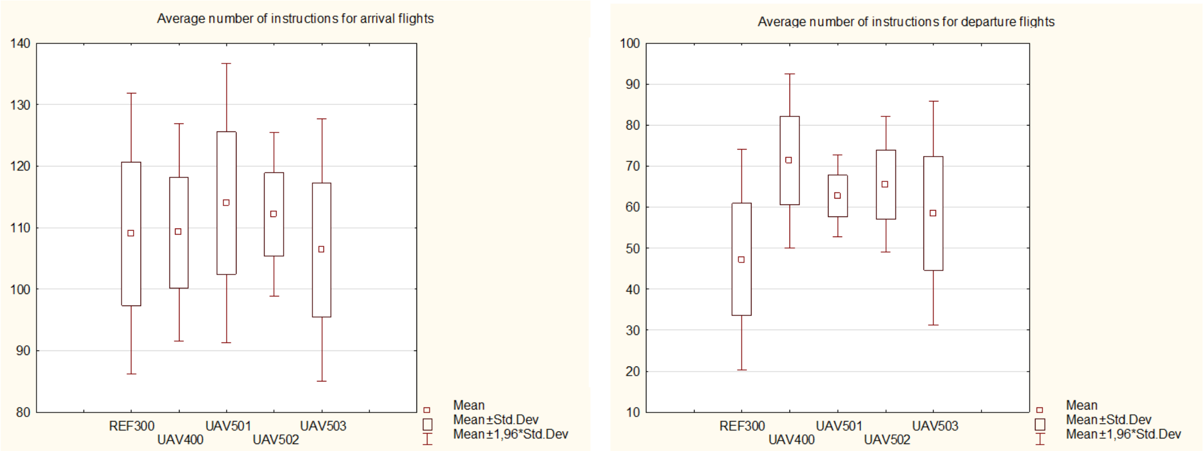

Figure 16: Graph of the test T about the number of instructions per Arriving flight (ARR) and per Departing flight (DEP)

We note immediately with the reading of Figure 16: Graph of the test T about the number of instructions per Arriving flight (ARR) and per Departing flight (DEP), for the first the flights on arrival (ARR) and for the second the flights on departure (DEP), a difference. The means of the instructions on the ARR (Arrival) appear very similar whereas the means on the DEP (Departure) seem more heterogeneous. The graph of the DEP shows a clear difference between the groups REF300 and UAV400.

What can be known as following this part of the analysis, it is that the presence of the RPAS generates more instructions of control on the unit of the traffic and especially that this difference is statistically significant on the flights on departure. In particular, the mission of the UAV1L in the departing area is particularly constraining.

C.2 Analysis of the trajectories

C.2.1 Distances flown

Knowing that the presence of RPAS in the traffic would increase the number of instructions of control, we also put forth the hypothesis that the regulation thus carried out would increase the trajectories of the flights. The rationale is related to the impact which the RPAS could have, and in particular a RPAS with a failure in the approach flow management.

On the assumption of a difference in distances between simulations, the statistical results (test T) do not reveal a significant difference. The distances flown at landing are not greater than when the traffic integrates RPAS.

But as we could identify it in the previous results, this report joined the data on the regulations carried out by the controllers, i.e. the control statements transmitted to the planes. Figure 17 presents the values of averages of the distances covered until the landing according to simulations.

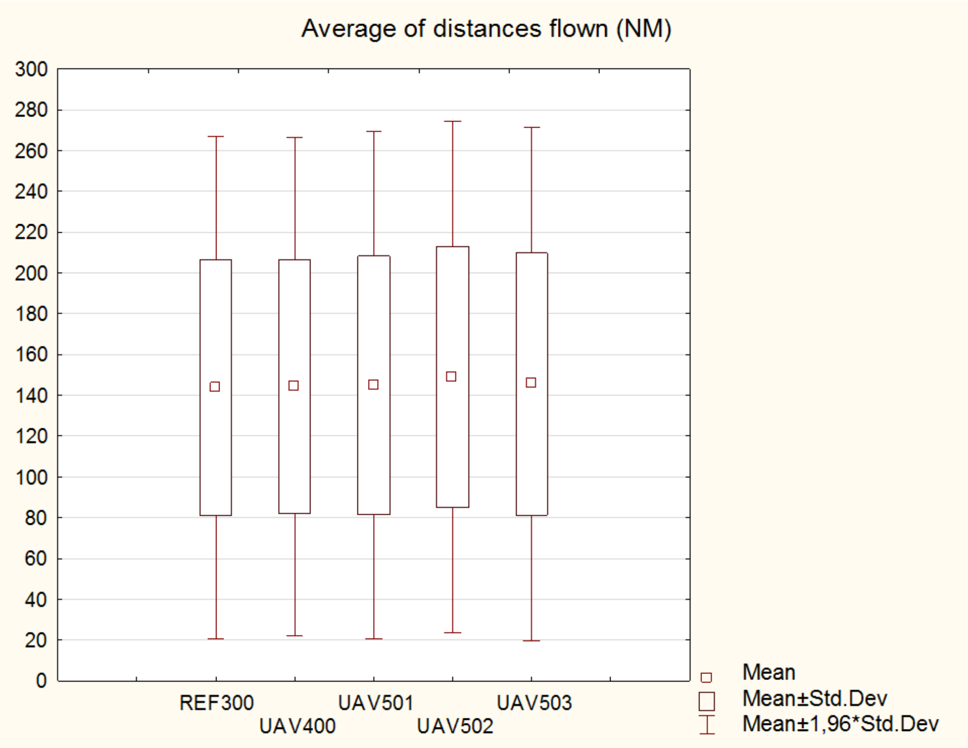

Figure 17: Graph of the test T, on distances values (in NM) of trajectories of flights up to landing

It appears clearly that the means are similar whatever the type of simulations with or without RPAS. It thus seems that the presence of RPAS in the traffic more does not affect the decisions of routes for the regulations in approach, in particular it does not lengthen (reduce) in an important or consequent way the trajectories of the other flights. At the beginning of the study, we had the contrary assumption, in particular in the case as of breakdowns. The consequences were expected on the flights finally at the time of the breakdown of the RPAS with like situation of the flights slowed down or were holding in pattern until the landing of the RPAS. But what we could observe, it is rather a strategy of the controller to make pass a maximum of flights by optimizing the trajectories of approaches. It is an explanation of the results.

C.2.2 Flight time

The distance covered from the flights is an interesting clue to identify possible impacts of the presence of the RPAS. But time is also a good indicator because it is also a means of regulation of the traffic, in particular in the management of the sequencings.

For this calculation, we took the time between the hour of beginning of simulation and the hour of landing. The comparison of run times of the flights of the sequences of traffic does not emphasize particular differences between most simulations. Only, the category of simulations UAV502 points out more important means of flight times. In spite of this light difference, the report is interesting because it seems to show the type of impact of a breakdown of the RPAS on the traffic. Here, it was about a diversion with radar vectoring (UAV24) combined with a radio breakdown of the UAV2M (R2). It is the combination of both which was penalizing.

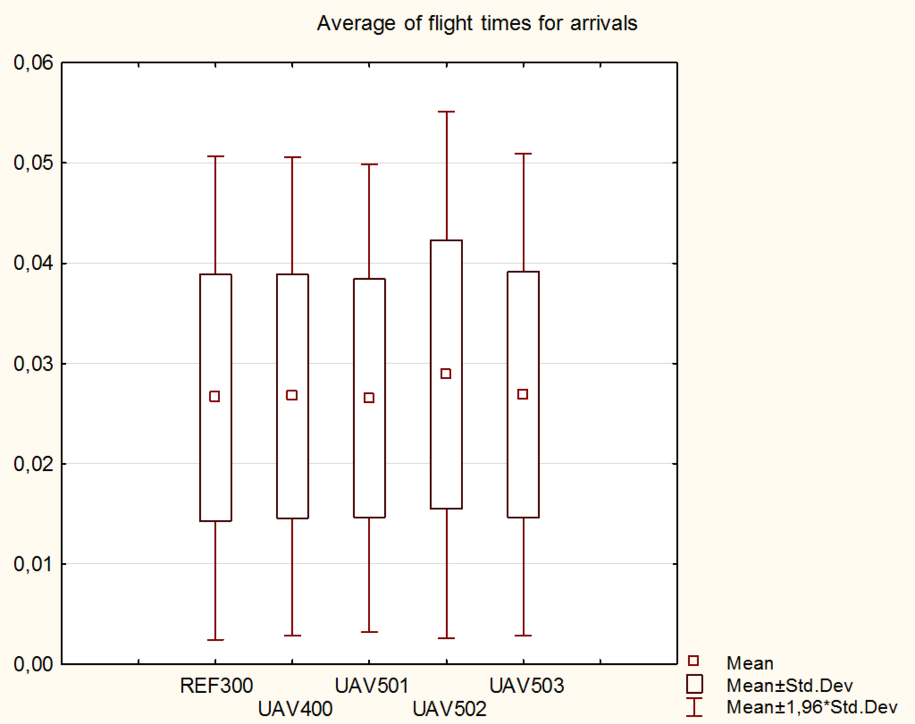

Figure 18: Graph about the flight time of the ARR traffic (Arrivals)

C2.3 Number of holding stack

To supplement the trajectory analysis, we also calculated the number of holding pattern over beacon initiated by the controller on a certain number of flights according to simulations. The graphs Figure 19 shows the result. It shows more settings in holding pattern in simulations UAV501 and UAV502. The breakdown of UAV2M in the area of VAGNA seems to be caused by the difficulty on the arrivals with in particular of holding on LIBRU for the flights coming from the East or ETPAR for the flights coming from North (ROYAN) or VAGNA for the flights in final segment (Figure 19).

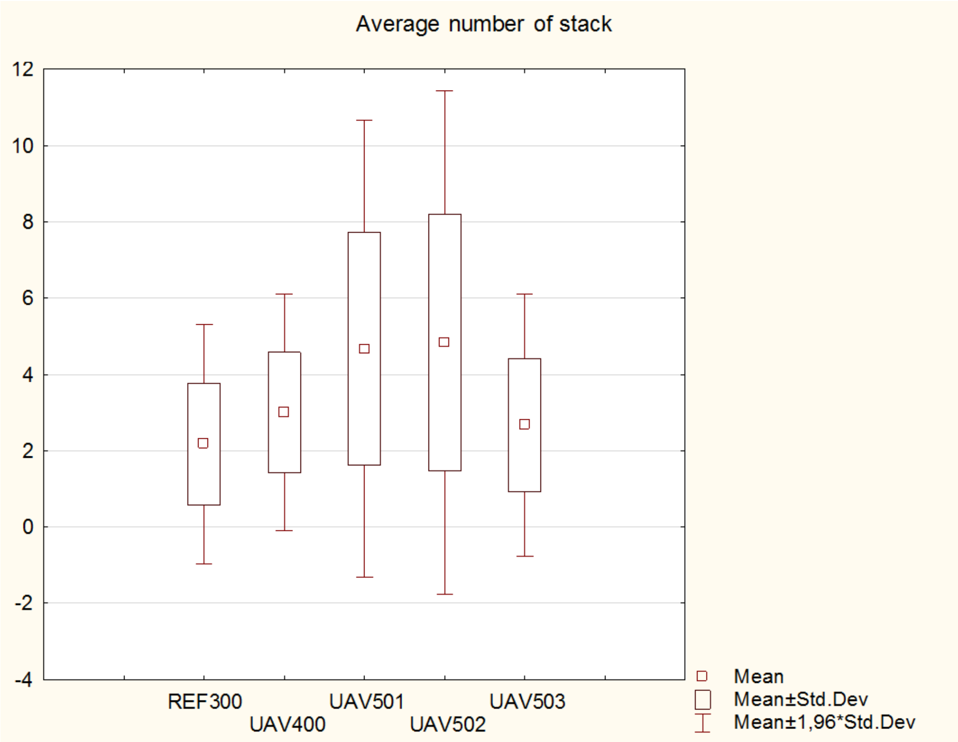

Figure 19: Number of arrival flights holding in stacks

In addition, the diversion of UAV42 in the simulations UAV502 comes to disturb the flights in approach by the setting in ILS final procedure. We detected here the direct consequences of the presence of RPAS in the trajectories of the commercial flights and the impact on the course of the traffic while at the same time this kind of RPAS reacts like an IFR flight with similar performances speed. It should however be noted that this diversion also occurred with a radio failure of UAV2M which was on mission around the beacon of approach VAGNA; emergency procedure being in addition on this particular landing axis.

C.3 Frequency occupation

Several questions arise as for the consequences, on the frequency, of the presence of RPAS in the traffic.

One of our principal assumptions relates to the radio latency, i.e. the latency time in the transmission of the communications of the RPAS. It is necessary to know the limits of them and to test the consequences of them. In simulations with RPAS, the latency was arbitrarily established with 4 seconds.

The experience feedback of the controllers on this question is generally critical. Nothing of surprising insofar as this latency in the communication can seem only one problem, because either the message is truncated or it is completely scrambled. Moreover, it is mainly what arises from the questionnaires submitted to the controllers and the remarks in debriefing.

However, the controllers say to be themselves adapted while recognizing that beyond the superposition of frequencies, the awkward effect remains the time difference between the sending of the message and its reception. The controller is confronted with the doubt of the radio message collating, and the difficulty increases when the RPAS is near the area of approach.

We studied the way in which the frequency was used and will question about the occupancy rate of the frequency, in particular in simulations with RPAS.

C.3.1 Number of messages

We proposed to check if there were more messages under a condition than in another. In other words, did the presence of RPAS, for example, increase the number of messages of control?

The graph Figure 20 shows that simulations with RPAS have the highest values, indicating that they cumulate a number of messages on radio frequency more important than simulations of reference REF300. In other words, we note by this result that the controllers have had, on average, more contacts with the flights with traffics which integrated RPAS. It is all the more true between REF300 and UAV400 and UAV502, as the "test T confirms it". This result is not surprising since it corroborates the previous analyses on the number of control instructions.

The result between REF300 and UAV400 let's suppose that the presence of the RPAS generates radio messages on the frequency. We can advance the explanation which this increase is partly due to the instructions given to the RPAS as the results show it on the number of instructions of control.

We can notice that the significant differences are not systematic with all simulations with RPAS. UAV502 seems to be the most constraining. This result is coherent with the configuration of these simulations which introduced a radio failure with UAV2M and radar vectoring with UAV42. Let us note that this UAV42 generally flies like a flight crossing the area in other simulations and generates few constraints. In radar vectoring procedure, the trouble is much more important, the more so as the diversion uses the normal ILS approach like commercial flights.

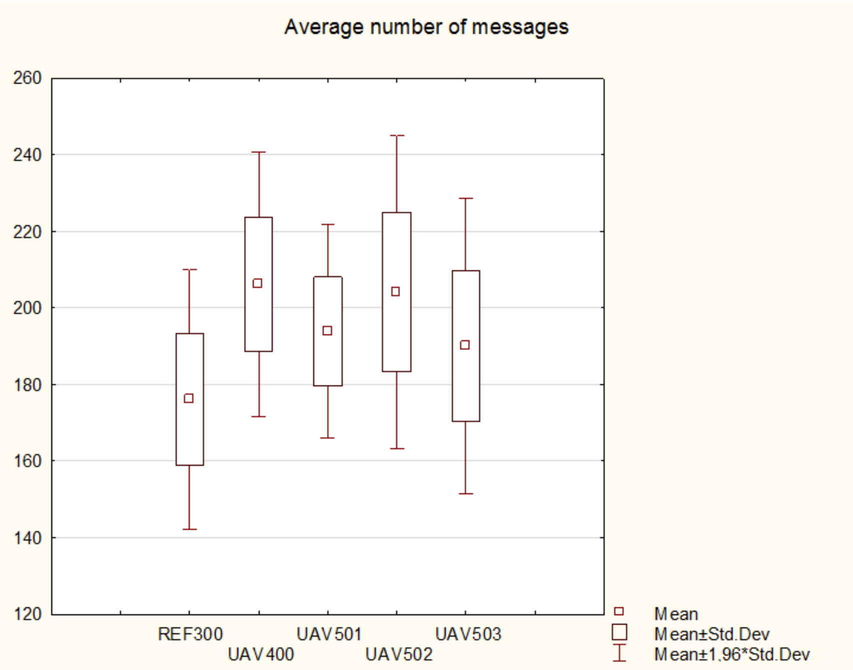

Figure 20: Average number of message exchanges graph

C.3.2 Messages duration

One of the foreseeable consequences of the presence of the RPAS in the traffic is the modification of the time of occupation of the frequency. In particular, we expected that the messages are shorter, especially that on certain controls of RPAS as UAV2M the communications is more numerous (missions of several tracks on an area). Sometimes, we can hear: "I will follow the standards as that I save the number of messages".

The results on the averages of the durations of messages according to simulations indicate a downward trend in the case of the exercises with RPAS. Sure, the difference are not significant but is not marked enough, in particular between REF300 and UAV400, not to reject the assumption of the presence of an effect.

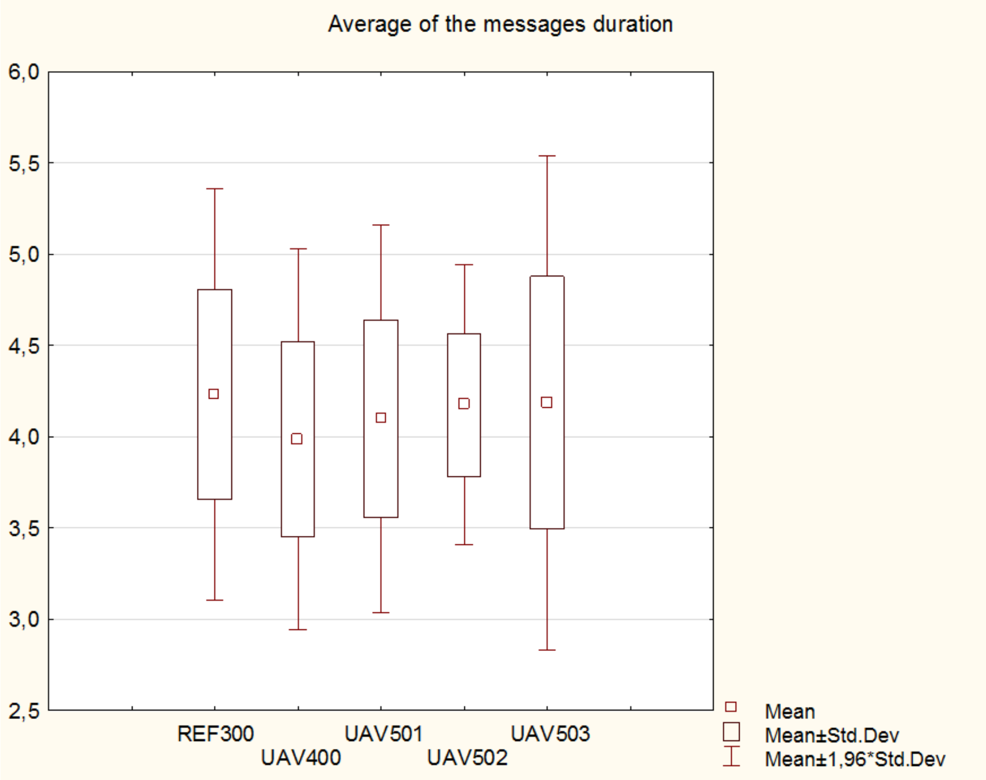

Figure 21: Average of messages duration in seconds

The controllers corroborate this effect while suggesting perhaps re-examining the phraseology for the RPAS. Being a consumer of messages, as the results show it, the document collating with the RPAS could be optimized so as not to have an exchange of message with each change of trajectory like the UAV2M. An instruction like “recall if change of mission or end of mission” would make it possible to reduce the number of messages. In addition, but it is another problem; the suppression of “LAG” would decrease the needs to too often repeat the same messages.

C3.3 Message jamming

It is not rare that the messages at the frequency are scrambled because of a simultaneous emission. This phenomenon gets worse with the “LAG” because the controller or the pilot does not control any more the moment of the reception. We thus wanted to check this assumption and to compare the number of overlapping between the categories of simulations.

The statistical test notes much significant dependence between various groups of simulations. As soon as there is presence of RPAS, the number of overlapping increases. We can think that the “LAG” is the direct cause of these overlaps. The result of the UAV502 draws however our attention (Figure 22). It is simulations with RPAS which, on average, have less overlaps and which do not appear statically different from REF 300.

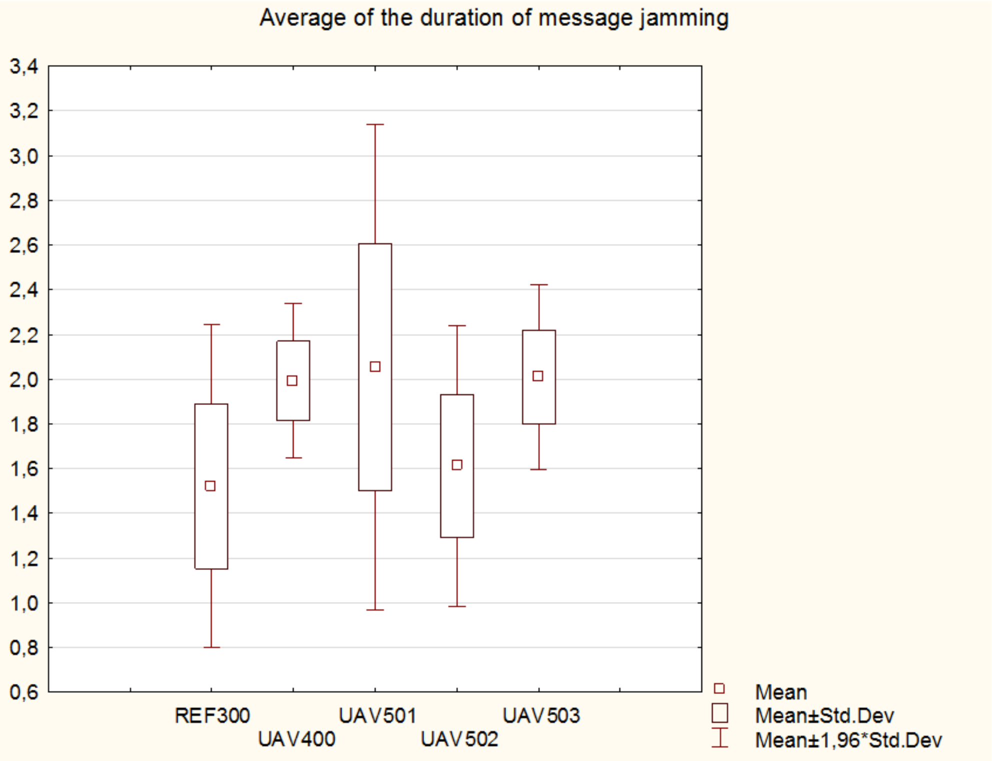

Figure 22: Average duration of message jamming

However, it is well between these two categories of simulations that we noted the most difference on the number of messages transmitted on frequency. We thus have simulations UAV502 which have the number of messages among most and the number of overlaps lowest of simulations with RPAS. Would they have had a strategy of regulations, an adaptation in the search for optimization of the time of frequency or the moment of the transmitted messages on frequency?

Appendix D ATCO Questionnaire

Date	login

1- Did you have the impression that the behaviour of the RPAS was similar to that of a light aircraft piloted with its various phases of flight?

☐ Yes ☐ No

Please write your answer here:

If your answer is “no”, which elements were different compared to the behaviour from a light plane?

Make the comment of your choice here:

2- Did you feel a latency time between the moment when you transmitted the instructions and the time when the RPAS carried out the manoeuvre?

☐ Yes ☐ No

Please write your answer here:

If your answer is “yes”, then did that involve amendments of clearance or changes of strategy compared to the expected situation?

☐ Yes ☐ No

Make the comment of your choice here:

3- Did you have difficulties to insert RPAS in the sequences of traffic of approach or aerodrome?

☐ Yes ☐ No

Please write your answer here:

If your answer is “yes”, then which elements made difficult the insertion of the RPAS?

Make the comment of your choice here:

4- Was the security of the traffic assured?

☐ Yes ☐ No

Please write your answer here:

Please write your answer here:

If your answer is “no”, which elements deteriorated the security level of the traffic?

Make the comment of your choice here:

5- Did the emergency procedures seem to you adapted?

☐ Yes ☐ No

Please write your answer here:

If your answer is “no”, which modifications would, you wish that we implement so that they are more effective?

Make the comment of your choice here:

6- If you must renew this kind of experimentation, which improvements could we bring to insert the RPAS in your airspace and on your aerodrome?

Please write your answer here:

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