ARIADNA Demonstration Report

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Abstract

This document constitutes the Demonstration Report containing the description of the exercises preparation and execution, analysis of results and conclusions and recommendations of the ARIADNA project, whose main objectives were to demonstrate the feasibility and usefulness as enablers of RPAS integration into the ATM system of an SBAS-based approach procedure for rotary wing RPAS as well as concepts for a "ground based" situational awareness system (GBSAS) with the use of ADS-B and ATC radar data to increase the remote pilot situational awareness of the surrounding traffic.

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This deliverable consists of SJU foreground.

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Executive summary

This document constitutes the Demonstration Report of the ARIADNA project, containing the description of the exercises preparation and execution, analysis of results, and conclusions and recommendations of the ARIADNA project.

The main objectives of the ARIADNA project are grouped in two exercises:

- Exercise #1: Validation of the use of an SBAS-based approach procedure for rotary wing RPAS, including the demonstration of:
  - The feasibility of designing a safe approach and landing procedure for a rotary wing RPAS based on SBAS.
  - Acceptable values for accuracy of the RPAS following the procedure, as well for the availability, integrity and continuity of the GPS (GNSS) +SBAS signal for the operation.
- Exercise #2: Validation of concepts for a “ground based” situational awareness system (GBSAS) with the use of ADS-B and ATC radar data to increase the remote pilot situational awareness of the surrounding traffic. Besides, it will be demonstrated that even very small RPAS can be equipped with ADS-B technology and therefore be “seen” by other manned and unmanned aircraft.

This project was performed by a consortium including Indra (coordinator, RPAS industry, and RPAS operator for the demonstration), ENAIRE (ANSP), CRIDA (ATM R&D) and FADA-CATEC (RPAS R&D and RPAS operator for the demonstration).

Flight demonstrations were performed in ATLAS experimental test centre using three different types of aircraft: Logo - rotary wing (RW) RPA (<25kg), Viewer - fixed wing (FW) RPA (15kg) and a MRI - general aviation (GA) manned aircraft (P2006T aircraft modified for Indra for surveillance missions).

During Exercise#1 the RW RPA was used to fly the SBAS-based procedure; in Exercise#2 Viewer and MRI fly together in order to validate the GBSAS concept. During Exercise#2, an ATCo participated in the whole exercise receiving ADS-B data at the control tower; both RPAS and GA aircraft received ADS-B information during the flights.

Based on the experience gained during the project and the results obtained, it was concluded that:

- Coordination between civil-military aviation authorities is a key aspect to reduce RPAS industry and operators’ efforts, as well as to facilitate the maturation of the regulatory framework
- It is urgent to implement a decision on specific dedicated RPAS C2 bands, especially considering the SWaP constraints of the “not large” RPAS segment
- A civil Flight Crew Licensing scheme for RPAS above “small” (>25 Kg) is necessary and should be established at EU level
- ADS-B has shown the potential to increase safety of RPAS operations. Further R&D on ADS-B, especially for Light RPAS is recommended. Miniaturization will make possible to equip even the smallest RPA

1 Introduction

1.1 Purpose of the document

This document provides the Demonstration report for the **ARIADNA** (***A****ctivities on* ***R****PAS* ***I****ntegration* ***A****ssistance and* ***D****emonstration for operations in* ***N****on-segregated* ***A****irspace*) project. It describes the results of demonstration exercises defined in *ARIADNA Demonstration Plan, 01.00.00* and how they have been conducted.

All ARIADNA consortium members have contributed to the analysis and review of the demonstration results.

1.2 Intended readership

The ARIADNA Demonstration Report is intended mainly for the following audience:

- SESAR Joint Undertaking, since this document provides the results of the project, useful conclusions and recommendations to go further with the research for the integration of RPAS in non-segregated airspace. The results of this program are expected to be a valuable input for SESAR2020 activities;
- Other RPAS Demo projects, as the results of this project might complement any of the other eight projects.
- Other SESAR members, as this project intends to demonstrate aspects relevant to the integration of RPAS in the ATM system defined by SESAR, and therefore it may be of interest to other SESAR projects / work packages / OFAs to supplement their work with the specific aspects of these new airspace users.
- Other RPAS relevant stakeholders, in particular those most relevant European stakeholders involved in the RPAS integration into the aviation system, like those member of the European RPAS Steering Group (ERSG).

1.3 Structure of the document

The document is structured in four parts described below:

- The first part (§1) aims at introducing the document;
- The second part (§2 and §3) gives an overview of the demonstration context and the organisation of the project;
- The third part (§4) presents how the demonstration activities were performed from its preparation to its execution;
- The next section (§5) analyses the main results obtained from the preparation and execution of the demonstration activities and provides a set of joint conclusions and recommendations based on the previous results analysis;
- The last part of the document (§5 and §7) gives a summary of the communication activities and a summary of conclusions and recommendations.

1.4 Glossary of terms

Term	Definition
Command and control link (C2)	The data link between the remotely piloted aircraft and the remote pilot station for the purposes of managing the flight (ref.[6])

Term	Definition
Detect and Avoid (D&A)	The capability to see, sense or detect conflicting traffic or other hazards and take the appropriate action (ref.[6])
External Pilot	Pilot in Command of the RPA by means of a RC link in order to ensure safety during the flights
Ground Based Situational Awareness System (GBSAS)	Ground Based Situational Awareness System, a system to provide increased situational awareness of the surrounding traffic to the remote pilots / flight crews of RPAS. It is a step towards full Detect and Avoid based on current technologies and infrastructure.
Operator	A person, organization or enterprise engaged in or offering to engage in an aircraft operation. Note. *In the context of remotely piloted aircraft, an aircraft operation includes the remotely piloted aircraft system* (ref.[6])
Remote (internal) pilot	A person charged by the operator with duties essential to the operation of a remotely piloted aircraft (RPA) from the ground control station and who manipulates the flight controls, as appropriate, during flight time (ref.[6])
Remote Pilot Station (RPS)	The component of the remotely piloted aircraft system containing the equipment used to pilot the remotely piloted aircraft (ref.[6])
Remotely Piloted Aircraft (RPA)	An unmanned aircraft which is piloted from a remote pilot station (ref.[6])
Remotely Piloted Aircraft System (RPAS)	A remotely piloted aircraft, its associated remote pilot station(s), the required command and control links and any other components as specified in the type design. (ref.[6])
Visual Line-Of Sight (VLOS) operation	An operation in which the remote pilot or RPA observer maintains direct unaided visual contact with the remotely piloted aircraft (ref.[6])

1.5 Acronyms and Terminology

Term	Definition
ATM	Air Traffic Management
DOD	Detailed Operational Description
E-ATMS	European Air Traffic Management System
E-OCVM	European Operational Concept Validation Methodology
OFA	Operational Focus Areas
SESAR	Single European Sky ATM Research Programme
SESAR Programme	The programme which defines the Research and Development activities and Projects for the SJU.
SJU	SESAR Joint Undertaking (Agency of the European Commission)
SJU Work Programme	The programme which addresses all activities of the SESAR Joint Undertaking Agency.

Term	Definition
Term	Definition

2 Context of the Demonstrations

2.1 Scope of the demonstration and complementarity with the SESAR Programme

As indicated in the RPAS Roadmap developed by the European RPAS Steering Group (ERSG), the overall approach towards the integration of RPAS into the aviation system and, in particular, into the ATM system is that *RPAS will have to fit into the ATM system and not that the ATM system needs to significantly adapt to enable the safe integration of RPAS*. Furthermore, *RPAS will have to prove to be as safe as current manned operations, or safer*; and *RPAS behaviour in operations will also have to be equivalent to manned aviation, in particular for the air traffic control (ATC), as it will not be possible for the ATC to effectively handle many different types of RPAS with different contingency procedures*. From this overall approach, the ERSG defined the following High Level Operational Requirements:

- The integration of RPAS shall not imply a significant impact on the current users of the airspace;
- RPAS shall comply with existing and future regulations and procedures;
- RPAS integration shall not compromise existing aviation safety levels, nor increase risk: the way RPAS operations are conducted shall be equivalent to manned aircraft, as much as possible;
- RPAS shall comply with the SESAR trajectory management process;
- All RPAS shall be able to comply with air traffic control rules/procedures;
- RPAS shall comply with the capability requirements applicable to the airspace within which they are intended to operate.

ARIADNA demonstration objectives were defined taking into consideration abovementioned high level operational requirements as well as the following topics of interest among those included in the SJU call:

- Safety: Ensure safe execution of a RPAS flight using a **Detect & Avoid (D&A) system** compatible with **existing safety nets and operating procedures**;
- Capacity and efficiency: **Address** alternative **RPAS** specific but interoperable surveillance, communications and **navigation solutions**.
- Airport integration & airspace throughput: Demonstrate take-off and **landing capability without impacting airport throughput**.
- Establish the **regulatory, operational and technical infrastructure** which enables the performance of RPAS flight tests in a mixed environment.

These topics were addressed in the following main areas that define the **scope for the demonstration**:

- **SBAS-based approach and landing procedures applicable to rotary wing RPAS**.
- **Concepts for a "ground-based" situational awareness system (GBSAS) that can be integrated in a RPAS**.

Each of these areas was associated with an exercise, thus two exercises were defined and summarized further below. A more in-depth description of the demonstration approach and the exercises' results is provided in sections 4 and 5, respectively.

Since ARIADNA executed the exercises in the airport environment and its associated ATZ airspace, the main connection of ARIADNA with SESAR projects was with operational WP5 – 'Terminal

Operations' and WP6 – 'Airport Operations'. Nevertheless it must be noted that, in the case of the "concepts for a ground-based situational awareness system (GBSAS)" such concepts are not limited to an aerodrome environment but to any phase and area of the RPAS flight where the required surveillance data can be obtained.

The exercises defined by ARIADNA covered two concepts that to some extent are being addressed by two OFAs in SESAR, although ARIADNA addresses them from a different perspective taking into account that the aircraft being considered are RPAS and the enhancement of situational awareness aims at the remote pilots.

The following tables summarises the exercises covered by ARIADNA:

Demonstration Exercise ID and Title	**EXE-RPAS.09-D-01: SBAS-based approach and landing procedures applicable to rotary wing RPAS**
Leading organization	INDRA
Demonstration exercise objectives	Validation of the use of an SBAS-based approach procedure for rotary wing RPAS: • Feasibility of designing a safe approach and landing procedure for a rotary wing RPAS based on SBAS. • Acceptable values for accuracy of the RPAS following the procedure, as well for the availability, integrity and continuity of the GPS+SBAS signal for the operation.
OFA addressed	SESAR WP5 – Terminal Operations OFA02.02.04 - Approach Procedures with Vertical Guidance
Applicable Operational Context	Airports and TMAs of low to medium density and complexity
Demonstration Technique	Flight Trial
Number of trials	6

Table 2.1-1 Exercise 1 overview

Demonstration Exercise ID and Title	**EXE-RPAS.09-D-02: Concepts for a ground-based situational awareness system (GBSAS) that can be integrated in a RPAS**
Leading organization	INDRA
Demonstration exercise objectives	Validation of concepts for a "ground based" situational awareness system (GBSAS) with the use of ADS-B and radar data to increase the remote pilot situational awareness of the surrounding traffic. Besides, it will be proved that even very small RPAS can be equipped with ADS-B technology and therefore be "seen" by other manned and unmanned aircraft.
OFA addressed	SESAR WP6 – Airport Operations OFA01.02.02 - Enhanced situational awareness

Applicable Operational Context	Airports and TMAs of low to medium density and complexity. It can be extended to any phase and area of flight (as long as ATC radar data is available).
Demonstration Technique	Flight Trial
Number of trials	15

Table 2.1-2: Exercise 2 overview

3 Programme management

3.1 Organisation

In order to achieve the goals of this project, the following consortium has been setup in combination of RPAS-related Industry, RPAS Operator, Air Navigation Service Provider (ANSP) and ATM and RPAS related R&D Organizations.

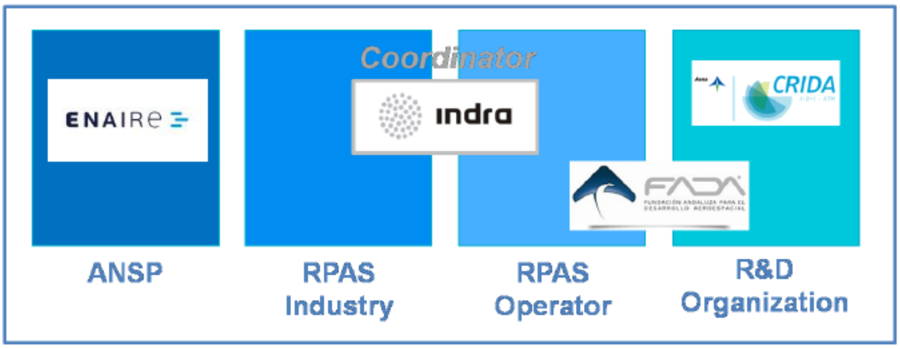


Figure 3.1-1 ARIADNA Consortium Members

The consortium consisted of a wide range of respected and highly-experienced companies each of whom plays a key role in its area of reference.

Indra was the Project Leader of the Consortium, acting as Project Manager and Coordinator, Quality Manager and also responsible for External Interfaces and Communications. The consortium organization and rules were described in the corresponding Consortium Agreement.

ENAIRE, CRIDA and CATEC acted as Project Members and performed complementary roles within the different working activities and tasks described in the WBS (Sec.3.2).

3.1.1 Roles and Responsibilities

The following roles were part of the execution of the project.

3.1.1.1 Project Manager (Project Coordinator)

The Project Manager was responsible for the day-to-day co-ordination of the project and responsible for the internal administration of the project.

The Project Coordinator was also the formal interface between the Consortium and the SJU, especially regarding reporting, financial issues and deliverables.

In the role of coordinator, he consolidated the project planning, progress reporting, financial issues, etc. using inputs from other partners. He also coordinated communication between the partners. The Project Coordinator, as leader of the Task 0, was also responsible for the preparation and delivery of all project management documentation.

As chairperson of the Project Coordination Committee meetings, the Project Coordinator as responsible for convening and organizing those meetings, preparing the agenda and afterwards the meeting minutes.

3.1.1.2 Task Leader

Each Work Package (WP) was made-up of several Tasks. The Task Leader was responsible for the execution of the task, supported by the collaborating members.

3.1.1.3 Each Member's Point of Contact (PoC) or Project Representative

Each member's PoC or project representative was the management interface of each of the partners for the ARIADNA project.

He/she was responsible to:

- Ensure the company provides adequate resources and logistic support.
- Report administrative information to the Project Coordinator.

3.2 Work Breakdown Structure

The Work Breakdown Structure (WBS) of the tasks undertaken by the project is as follows:

- **Task 0 – Project Management**
  - T0.1 – Technical Coordination
  - T0.2 – Administrative & Financial Coordination
- **Task 1 – Safety requirements for RPAS Operations**
  - Task 1.1 – Airworthiness and Flight Crew requirements
  - Task 1.2 – Safety of Operations requirements
  - Task 1.3 – Authorizations / Approvals
- **Task 2 – Operational Concept**
  - Task 2.1 – OCD for "SBAS-based approach and landing procedures for rotary wing RPAS"
  - Task 2.2 – OCD for "Ground-based situational awareness system (GBSAS)"
- **Task 3 - Technical Specification**
  - Task 3.1 – Technical Specification of the RPAS and manned aircraft
  - Task 3.2 – Technical Specification of the ground infrastructure
- **Task 4 - Verification and Validation**
  - Task 4.1 – Verification
    - T4.1.1-1 – Verification Planning for "SBAS-based approach and landing procedures for rotary wing RPAS"
    - T4.1.1-2 – Verification Planning for "Ground-based situational awareness system (GBSAS)"
    - T4.1.2-1 – Verification Execution for "SBAS-based approach and landing procedures for rotary wing RPAS"
    - T4.1.2-1 – Verification Execution for "Ground-based situational awareness system (GBSAS)"
  - Task 4.2 – Validation
    - T4.2.1-1 – Validation Strategy and Plan for "SBAS-based approach and landing procedures for rotary wing RPAS"
    - T4.2.1-2 – Validation Strategy and Plan for "Ground-based situational awareness system (GBSAS)"
- **Task 5 - Infrastructure Production**
  - T5.1 – Infrastructure Production for "SBAS-based approach and landing procedures for rotary wing RPAS"

  - T5.2 – Infrastructure Production for "Ground-based situational awareness system (GBSAS)"
- **Task 6 - Demonstration Trials (Flight Campaign)**
  - Flight tests for "SBAS-based approach and landing procedures for rotary wing RPAS"
  - Flight tests for "Ground-based situational awareness system (GBSAS)"
- **Task 7 - Demonstration Analysis and Report**
  - Task 7.1 – Results Analysis of "SBAS-based approach and landing procedures for rotary wing RPAS"
  - Task 7.2 – Results Analysis of "Ground-based situational awareness system (GBSAS)"
- **Task 8 - Dissemination**

3.3 Deliverables

3.3.1 Formal deliverables

The following are the formal deliverables to the SJU:

- ARIADNA D01 – Demonstration Plan
- ARIADNA D02 – Demonstration Report

3.3.2 Internal deliverables

The following were the internal deliverables developed during the project:

- ARIADNA I01 – Authorizations / Approvals and aviation safety aspects
- ARIADNA I02 – Operational Concept Document (OCD)
- ARIADNA I03 – Technical Specification
- ARIADNA I04 – Verification Plan and Procedures
- ARIADNA I05 – Verification Report Factory
- ARIADNA I06 – Verification Report Site
- ARIADNA I07 – Validation Strategy and Plan

3.4 Risk Management

The following risks became issues and/or corrective actions during the project (a complete list of expected risks was included in the Demonstration Plan:

Risk description	Probability assessment (Low / Medium / High / Very high)	Severity assessment (Low / Medium / High / Very high)	Issue / Corrective Actions	Owner
Risk 01: Project scope creep may cause that some activities are extended, which may result in potential delays, increase in	Low	Medium	Project extension was obtained due to change in the RW RPAS and difficulties to get authorizations.	Indra

costs, or a reduction in coverage depth for some areas.				
Risk 02: Not all required authorizations from the aviation authorities are granted, causing that some or all demonstration exercises cannot be performed.	Medium	High	Delay in authorizations induced a project delay (Risk 01). Location was changed to ATLAS were the used RW RPAS has been already authorized. Both exercises were performed properly.	Indra, FADA-CATEC
Risk 03: Any of the committed aircraft (manned and RPAS) and related equipment and operations personnel are not available, which may cause that some or all the demonstration flights cannot be performed.	Medium	High	A smaller RW RPAS was selected to fly the SBAS based procedure ensuring availability of the platform and its associated authorizations.	Indra, FADA-CATEC
Risk 04: The selected aerodrome and associated airspace is not available for the execution of the demonstration flight trials.	Low	High	San Javier (LELC) aerodrome (military base open to civil traffics) was replaced by the ATLAS experimental flight test centre (only for RPAS).	Indra
Risk 07: ADS-B equipment is not available for the three aircraft (manned and RPAS) at least for the execution of the corresponding GBSAS exercise.	Low	High	Due to the excessive delay in the certification process related to the software upgrade for the GA aircraft (MRI) flight instruments suite required to enable ADS-B Out operation in that aircraft type, the same ADS-B transponder used by the RPAS was integrated in the GA aircraft (MRI).	Indra, FADA-CATEC
Risk 08: ATC radar data from SACTA (ENAIRE) is not available for the Pelicano RPAS.	Low	Medium	No SACTA ATC radar data available at ATLAS centre. But integrated primary radar and ADS-B data was available. This SQUAWK code can also be received with and ADS-B receiver as it is in our operation	Indra, ENAIRE

Table 0-1 Risks that became issues / corrective actions

4 Execution of Demonstration Exercises

4.1 Exercises Preparation

4.1.1 Exercise 1

4.1.1.1 Flight tests

The first phase of the development consisted on the integration of all the systems, both hardware and software components of the RPA and RPS. For that purpose, some flight experimentation was performed in an airfield close to CATEC facilities, with an unpaved runway.

Figure 4.1-1 Development phase and flight tests of the rotary wing RPAS LOGO

The flight tests were performed always in VLOS conditions, as stated in authorization documentation (next section). These conditions comprise a maximum height of 400 ft AGL and maximum distance from external pilot of 500 m. Apart from that, the flight tests were done only in VMC conditions, without rain or ice.

For the last phase of the trajectory, there was expected for the flight demonstration an VFR phase where the external pilot would take control of the RPA. For that purpose, a camera was installed onboard so the images could be transmitted to the RPS, and the external pilot could be aware of the location of the runway from its perspective.

Figure 4.1-2 Validation of video communication among external pilot and RPA

4.1.1.2 Flight authorization

Since 2014 July 5th, AESA has established a new regulation for flights of unmanned aerial vehicles for civil purposes, as a basis and transition for future legislation. AESA is the Spanish Aviation Safety and Security Agency, which purpose is to ensure that aviation standards are followed in aeronautical activities and to impose penalties for breaches of civil aviation standards. This new regulation sets the procedure required to fly this kind of aircrafts, according to weight, mission, payload, etc. So, it is required to follow AESA procedures to perform the flights with the RPAS.
Flight tests were done in VLOS conditions with this RPA which is lighter than 25 kg. Apart from that, these flight trials were part of a research project, which reduces and simplifies the procedure to obtain the permission. The documentation required for these conditions were:

- a detailed description and characterization of the RPA, payload, communication link, GCS and any additional system required for the flights.
- a detailed description of the operation: runway, meteorological conditions, flight plan, staff, etc.
- an aeronautical safety assessment which will include possible risks of the operation, mitigation measures, residual risks, safety procedures, etc.

Apart from that, the RPAS pilots must prove certain requirements. They can be allowed to fly RPAS by means of one of the next three circumstances:

- Having any pilot license (including ultralight aircrafts), or have had in the last five years, or,
- Demonstrate irrefutable evidence of theoretical knowledge for obtaining any pilot license, or,
- For RPAS<25 Kg, having a basic certificate for piloting RPAS, emitted by an ATO, with theoretical knowledge about aeronautical law, generic and specific knowledge of aircrafts, aircraft performances, meteorology, aerial navigation and maps interpretation, operational procedures, communications and human factors for RPAS, adding knowledge of air traffic and advanced communications in case of BVLOS flights.

In addition, the RPAS pilots must have a medical certificate in according to LAPL requirements and be over 18 years old.

Once this documentation has been sent to AESA, the Agency communicated the operator, in this case FADA-CATEC, the acknowledgment of receipt and then the flights will be authorized according to the specified conditions.

4.1.1.3 Configuration of GPS receiver

The GPS receiver integrated in the rotary wing RPAS was the U-blox LEA-6T-0. This GPS receiver allows access to raw data from the GPS information, which is essential for the subsequent analysis of SBAS performance. This GPS receiver is not certified for IFR flights, but due to project milestones and limitations, it was the selected one for the operation, The main characteristics of this GPS module are:

Parameter	Specification	
Receiver type	50 Channels GPS L1 frequency, C/A Code GALILEO Open Service capable GLONASS FDMA SBAS: WAAS, EGNOS, MSAS	
Time-To-First-Fix		LEA-6H/LEA-6S/ LEA-6T-0/LEA-6T-1
	Cold Start (without aiding)	26 s
	Warm Start (without aiding)	26 s
	Hot Start (without aiding)	1 s
	Aided Starts	1 s
Sensitivity		LEA-6H/LEA-6S/ LEA-6T-0/LEA-6T-1
	Tracking & Navigation	-162 dBm
	Reacquisition	-160 dBm
	Cold Start (without aiding)	-148 dBm
Max. Navigation update rate		LEA-6A/ LEA-6S/ LEA-6T-0 5 Hz
Horizontal position accuracy	Without aiding	2.5 m
	SBAS	2.0 m
Configurable Timepulse frequency range		LEA-6H/ LEA-6S/ LEA-6A/ LEA-6R 0.25 Hz to 1 kHz
Accuracy for Timepulse signal	RMS	30 ns
	99%	<60 ns
	Compensated	15 ns
Velocity accuracy		0.1 m/s
Heading accuracy		0.5 degrees
Operational Limits	Dynamics	≤ 4 g
	Altitude	50,000 m
	Velocity	500 m/s

Figure 4.1-3 GPS receiver module

U-center is the free software owned by U-blox used for evaluation and configuration of GPS / GNSS U-blox modules. It is a powerful tool for analysis, recording and monitoring of GNSS data. The U-blox GPS receiver can be configured with this software. A proper configuration was essential for the goal of the project. Next figure shows the graphical interface of this software.

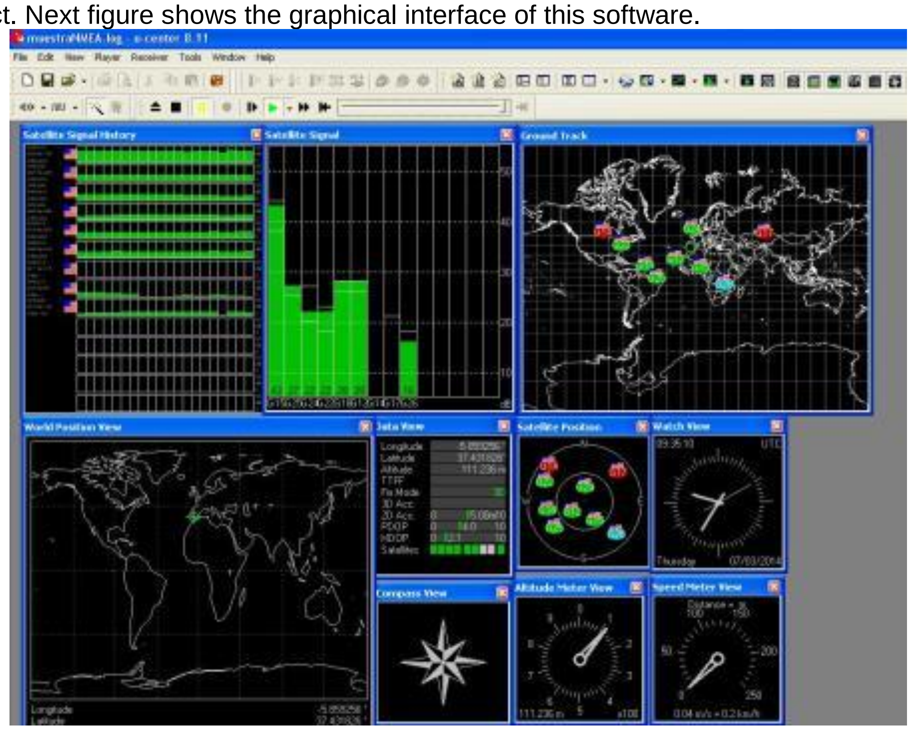


Figure 4.1-4 U-Center software graphical interface

The GPS receiver needs to be configured in such a way that accepts EGNOS information.

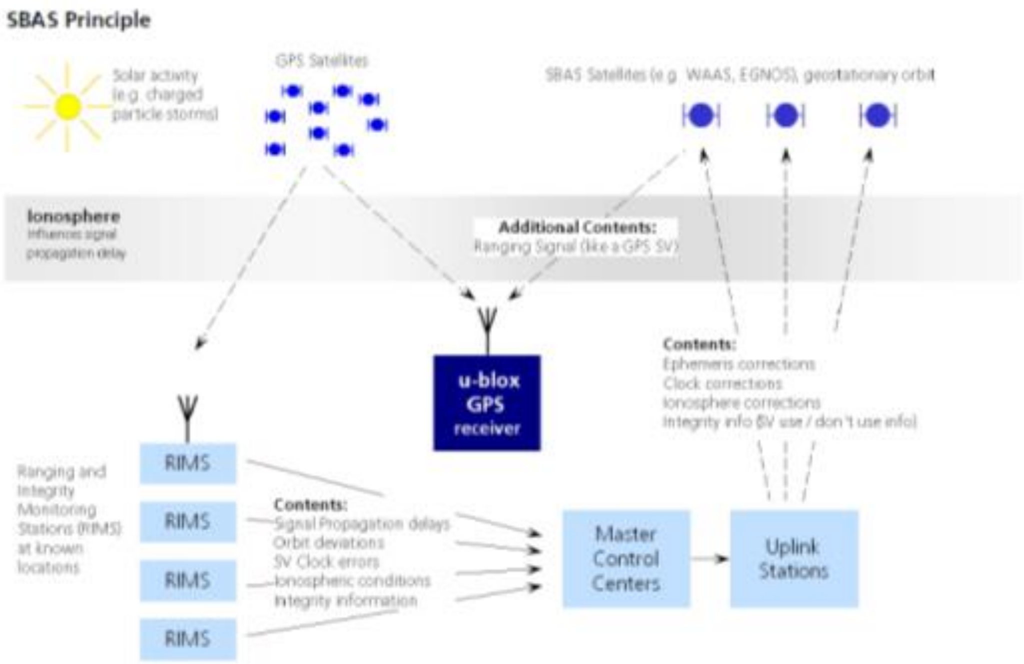


Figure 4.1-5 SBAS principle for u-blox GPS receiver

Next figure shows the configuration recommended by ENAIRE for EGNOS reception in our GPS receiver. The parameters are explained next:

- *Mode – SBAS Subsystem*: enable the SBAS subsystem
- *Mode – Allow test mode usage*: disallow SBAS usage from satellites in Test Mode (Msg 0)
- *Services/Usage – Ranging:* use SBAS satellites for navigation
- *Services/Usage – Apply SBAS correction data:* enable fast-, long- term and ionosphere corrections
- *Services/Usage – Apply integrity information:* use integrity data
- *Number of tracking antennas*: 3 channels reserved for SBAS tracking
- *PRN Mask*: allows enabling SBAS satellites, for example, restrict SBAS usage to EGNOS-only. The PRN codes of EGNOS satellites are 120, 126 and 136.

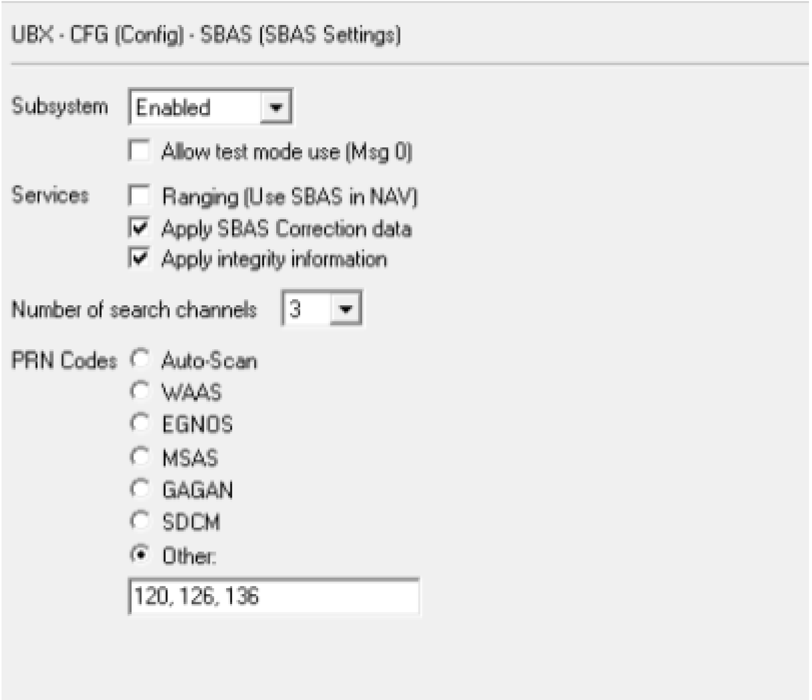


Figure 4.1-6 GPS receiver configuration for EGNOS reception*

**Note: PRNs 120, 136 and 126 (this latter under test) are those currently used for EGNOS applications. Selecting either "EGNOS" or specifying these PRNs one by one should result the same. In this case, provided that PRNs for EGNOS change over time, selecting the specific current PRNs was just a way to reinforce the assurance that the receiver was using the proper current EGNOS Geo satellites*

Different samples were taken in CATEC facilities to check the configuration of the GPS receiver. The GPS receiver was connected to an onboard PC where the GPS receiver data is recorded. Different files are saved, depending on the stored data:

- *almanach.log*: it contains information about satellite status and current date and time.
- *ephemeris.log*: it contains information about location of the satellites at any time.
- *rawData.log:* raw data which is essential for the RINEX file extraction
- *rinex.obs:* file with GPS observables (pseudorange, carrier phase, Doppler effect of satellite signals and the received noise level of the signal)
- *sbas.log:* file with correction SBAS data

4.1.1.4 Validation approach

The validation approach of this exercise was based mainly on the analysis of telemetry from the RPAS in order to assess its compliance with the designed procedure, but will also rely on the perception of the RPAS team members.

Initially it was defined a validation approach at high level through the following steps:

- Flyability of the SBAS procedure based on flight performance analysis and remote pilots´ feedback.
- Operational feasibility of the adapted PinS procedure to the low performance RW RPAS and airspace limitations, including the alternative procedure proposed to the visual segment which involves visual contact of an RPAS crew member with the RW RPAS at a defined point.
- Successful values for accuracy, availability, integrity and continuity of the GPS+SBAS signal.
- Acceptability from ATCOs of the execution and occupancy times required.

Finally this exercise was executed without ATC services, so unfortunately it wasn´t possible to analyse the acceptability of the procedure by controllers.

The technical approach to validate the accuracy of the SBAS signal is described below.

4.1.1.5 SBAS validation process

As previously indicated, the purpose of the exercise was to demonstrate the feasibility of performing a safe approach and landing using a SBAS based procedure.

GPS and EGNOS performances in the demo site were analysed by the ENAIRE Satellite Navigation experts, in order to assess its adequacy for an RNP approach down to LPV minima.

ENAIRE GNSS has its own network of GNSS stations (RECNET) distributed throughout the Spanish geography. The network of GPS and EGNOS receivers store data 24h/7d which is then processed with a SBAS performance assessment tool (Eclayr) and EUROCONTROL PEGASUS tool, and analysed by GNSS performance experts. Those tools are also used by the ESSP SAS (European Satellite Services Provider) and ESA (European Space Agency) for the evaluation of the EGNOS signal performance.

The analysis for ARIADNA covered a period of six months from April to September 2015, both included, and considering the data stored by three stations closer to the demo site.

Also information about the GPS constellation health during this reporting period, contained in the NANU messages (Notice Advisory for Navstar Users) was gathered, and a set of statistics derived from the analysis of this information were generated. These NANU messages are available in the US Coast Guard Navigation Center web.

Results from the GNSS signal for the selected environment showed that:

- GPS SPS (Standard Positioning System) performance in the selected site is adequate for RNP LNAV approach, in terms of accuracy, availability and satellite visibility (RAIM).
- EGNOS accuracy, integrity, availability and continuity were adequate for RNP APCH to LPV minima in the selected site.

4.1.1.6 PinS procedure design

The approach procedure for this exercise, developed within an 8km radius circle around the ATLAS aerodrome ARP, hence simulating an operation inside an ATZ.

Flight procedure design for this exercise has taken, as a starting point, the design criteria and principles set in the PANS-OPS (ICAO Doc. 8168) for rotorcraft PinS RNP LPV approaches. From this principles, design criteria have been adapted to the dimensions and performance of the RPAS aircraft, as typical RPAS size and performance lay out of the range of manned rotorcraft (aircraft category H), for which PANS-OPS parameters are devoted. This adaptation has always taken a conservative approach:

- For the flight procedure in this particular demo, a design maximum IAS of 30kt for the whole manoeuver has been considered (while PANS-OPS consider a design maximum IAS of 90kt just for final approach by a manned rotorcraft). This 30kt design value was deemed adequate and sufficiently conservative, taking into account the performances and normal flight speeds of the rotary wind RPAS involved in the exercise.
- Consequently, applying PANS-OPS design principles with this reduced design speed, minimum distances to be considered between waypoints where shorter compared to those resulting in a standard Cat. H PinS design.
- Also High Loss (HL) parameter in the final approach, which accounts for altimetry error and speed during the initiation of a missed approach, was also adapted (reduced) from PANS-OPS values, in accordance to this reduced design speed limit.
- At the same time, the dimensions of the obstacle protection areas used for obstacle assessment were adapted for this design, taking also into account the RPAS dimensions in

order to extrapolate PANS-OPS parameters (4m spam, compared to the 30m Cat.H spam considered in the PANS-OPS):

- Regarding terrain and obstacle information for the manoeuver design, several sources were used:
  - ATLAS aerodrome technical specifications
  - Local topographic assessment
  - Cartographical information of the involved area from the “Instituto Cartografico Nacional”
  - AIP Spain data regarding “Obstacles higher that 100m”, ENR5.4

Chart representing the procedure design is depicted in the next figure:

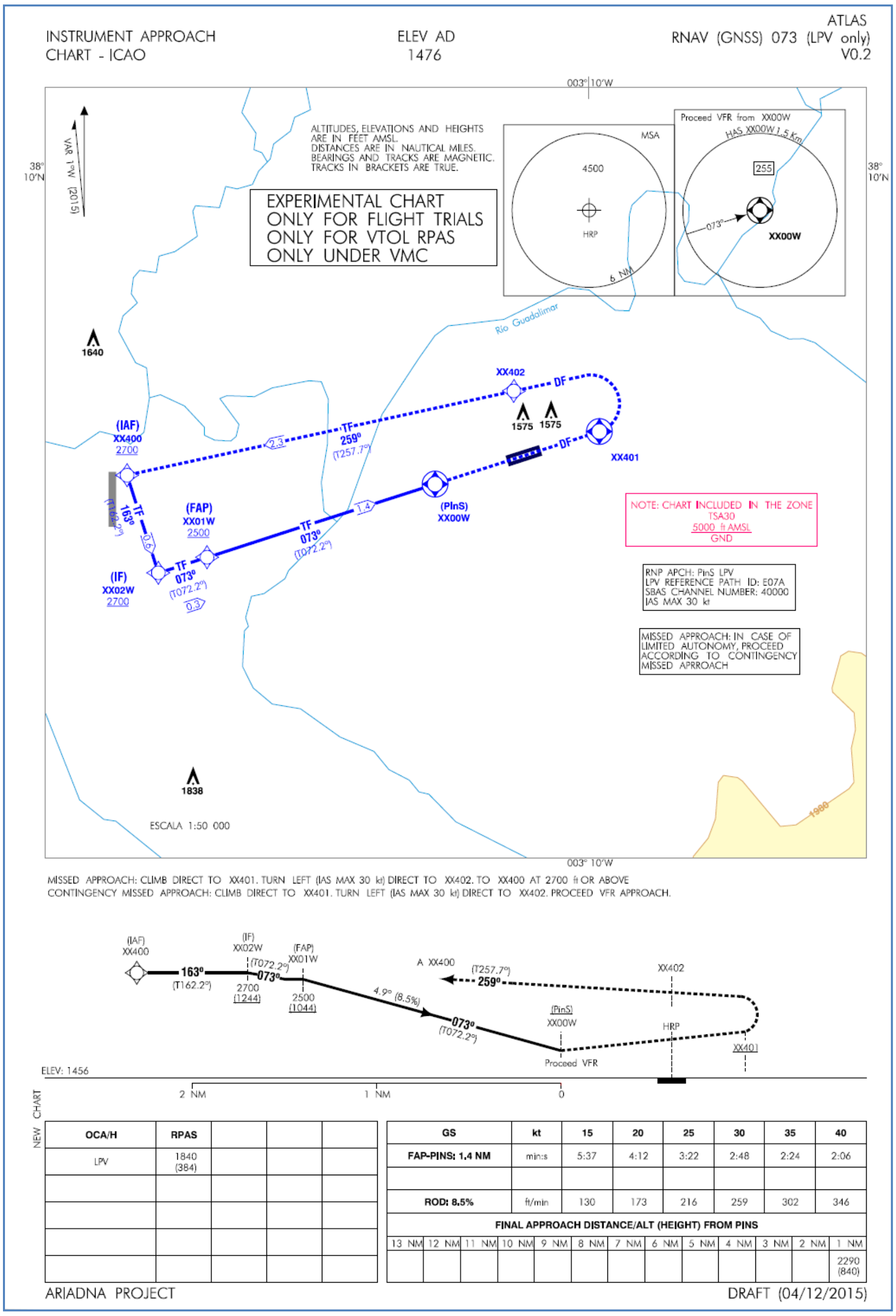


Figure 4.1-7 SBAS procedure chart

4.1.2 Exercise 2

4.1.2.1.1 FW RPAS Preparation Activities

4.1.2.1.1.1 Integration of the transponder in the RPA

The transponder installed in the RPA is a VT01-UAV-PRO, from GarrechtAvionik GmbH. This transponder is a Mode A/C and Mode S unit, specially designed for autonomous use in remotely piloted aircrafts. The manufacturer has certification base ETSO for its transponders for manned aircrafts, but this version for RPAS is still pending ETSO approval, although the process is ongoing.

Figure 4.1-8 ADS-B VT01-UAV-PRO from Garrecht Avionics

The transponder is fixed to the airframe so this cannot move during the flight. It is connected to the autopilot with a serial RS-232 cable, to provide GPS and height data via NMEA messages (GPRMC and GPGGA). An internal pressure sensor supplies data for sending coded altimeter data in the required format. No external coding altimeter or alticoder is required.
The transponder is powered by an external battery, independent from RPA avionics or motor batteries, to keep safety levels in case of device failure and not affecting the endurance of the operation.
The antenna is located on the tail boom, keeping at last 90 cm from other RF sources to avoid interferences in any system.
All configurations to the transponder device will be done on ground, using the VT-01UAV Control PC software, supplied by the manufacturer, as the system does not provide human machine interface.

Figure 4.1-9 Integration of transponder in the RPA Viewer

4.1.2.1.1.2 Transponder configuration

There is software, provided by the supplier (GARRECHT), which allows the configuration of basic parameters for the transponder. Using a serial cable, it is possible to connect to the transponder with a PC in which the software is installed. Next figure shows the software to configure the transponder:

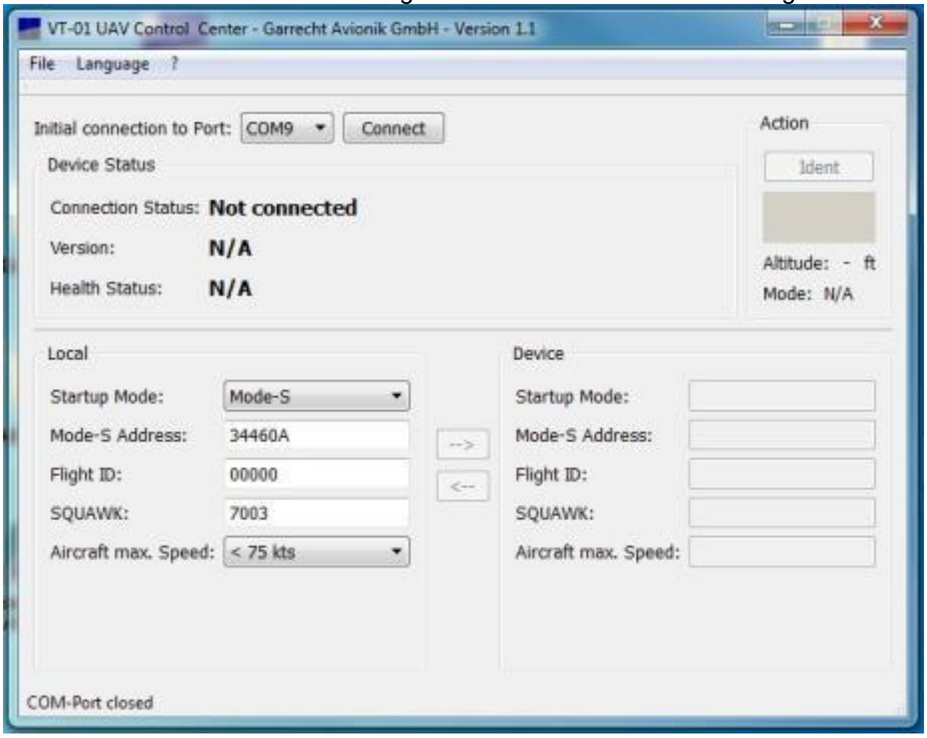


Figure 4.1-10 VT-01 UAV_Control Software configuration for the transponder

The parameters to introduce are:

- Mode S Address: code (in hexadecimal) given by ENAIRE
- Flight ID: identification code for your flight
- SQUAWK: this parameter must be given by ATC

4.1.2.1.1.3 Ground tests

Some tests have been made with a tester, TelInstruments T47G. The antenna of the transponder is directly connected to the tester (shown below) so we can check in the tester the information that sends the transponder.

Figure 4.1-11 T47G Tester for the transponder

A switch has been integrated in the transponder to change between Standby Mode (the transponder does not send information) and On Mode (the transponder sends information)
The autopilot installed in the Viewer RPAS allows the simulation of aircraft performance in flight. With this simulation, it is possible to check the ADS-B performance. ATC is contacted to ask for a SQUAWK code, which is given for ground tests.

4.1.2.1.1.4 Flight tests

4.1.2.1.1.4.1 Flight authorization

As stated in section 4.1.1.2, on 2014 July 5th, AESA established a new regulation for RPAS flights for civil purposes. Since the RPAS involved in this exercise has also a MTOW lower than 25 kg, the permission procedure is the same as explained in section 4.1.1.2

4.1.2.1.1.4.2 Preflight

During the preflight, all systems are getting ready and tested. In this phase, ATC (Air Traffic Control) will be contacted to communicate the flight operation and to ask for the SQUAWK code for the ADS-B transponder during the flight. This is a 4-digit code with which the transponder will response to a secondary surveillance radar interrogation signal or an ADS-B receiver and will uniquely identify an aircraft.
There are special codes that are assigned when there is an emergency or a communication failure. For our purpose, there is also a specific code which is assigned for VFR traffic with no flight plan (according to ICAO) and is 7000.

4.1.2.1.1.4.3 During the flight

The flight tests are performed always in VLOS conditions, as stated in authorization documentation. These conditions comprise a maximum height of 400 ft AGL and maximum distance from external pilot of 500 m. Apart from that, the flight tests are done only in VMC conditions, without rain or ice.

Figure 4.1-12 RPAS Viewer used in the flight

The flight consists of a simple flight plan with a route of waypoints, in which height can vary to check the information sent from the ADS-B using an ADS-B receiver on ground (see section 7). The GCS shows flight telemetry: position, velocity, height, etc., which can be compared to the information sent from the onboard ADS-B transponder.
Two different locations are chosen for the flight tests. First, an unpaved runway near CATEC facilities since the flexibility and structure of the RPAS Viewer makes it suitable for landing over its belly in this kind of surfaces. This test site was used for initial tests, as its location was more convenient for first flight tests.

Figure 4.1-13 Flight area in Oran facilities

Other flight area is ATLAS center in Jaen, which is a test flight center for RPAS.

Figure 4.1-14 ATLAS test centre (up); Flight area in ATLAS (down)

4.1.2.1.1.4.4 Post flight

It is important to switch the transponder off once the RPAS has landed. The main reason is to avoid cluttering up air traffic control radar.

4.1.2.1.1.5 ADS-B receiver

Some tests have also been done with the ADS-B receiver, which shows information of air traffic around your position. The ADS-B receiver is composed of an antenna and a hardware modulus which can be connected to a PC with Ethernet cable.
Next to the RPA pilot, there is a PC connected to the ADS-B receiver which can monitor with specific software all traffic flying around. It usually shows information about position, height, aircraft identification, flight number, nationality, SQUAWK, etc.
A few ADS-B receivers have been tested to find the proper behavior and performance for the flights. The first one tested was a micro ADSB-IP BULLION2 v.4 receiver using ADSBscope software as user interface.
This receiver was rejected as the firmware filters traffic by altitude and speed, so was not possible to get data from RPA as this flies lower (400 ft) and slower (40 Kt) than commercial aircraft, for which it is intended.

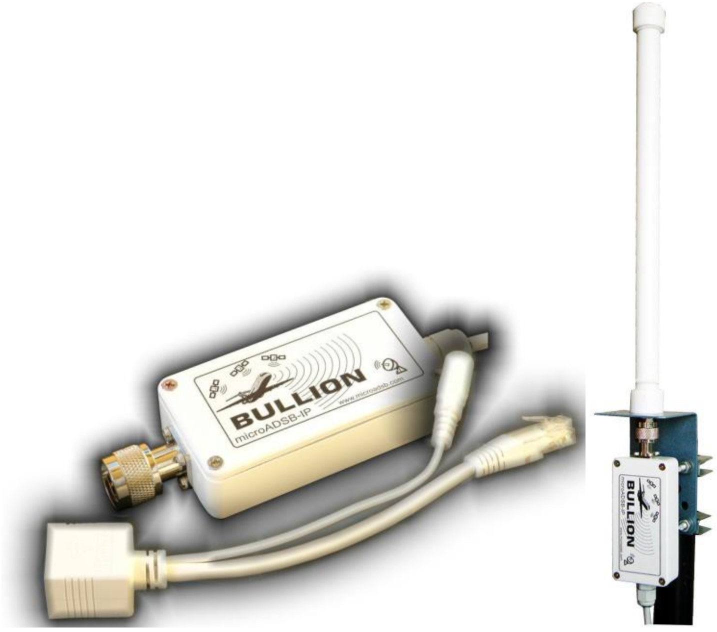


Figure 4.1-15 microADS-B BULLION2 v.4 receiver and antenna

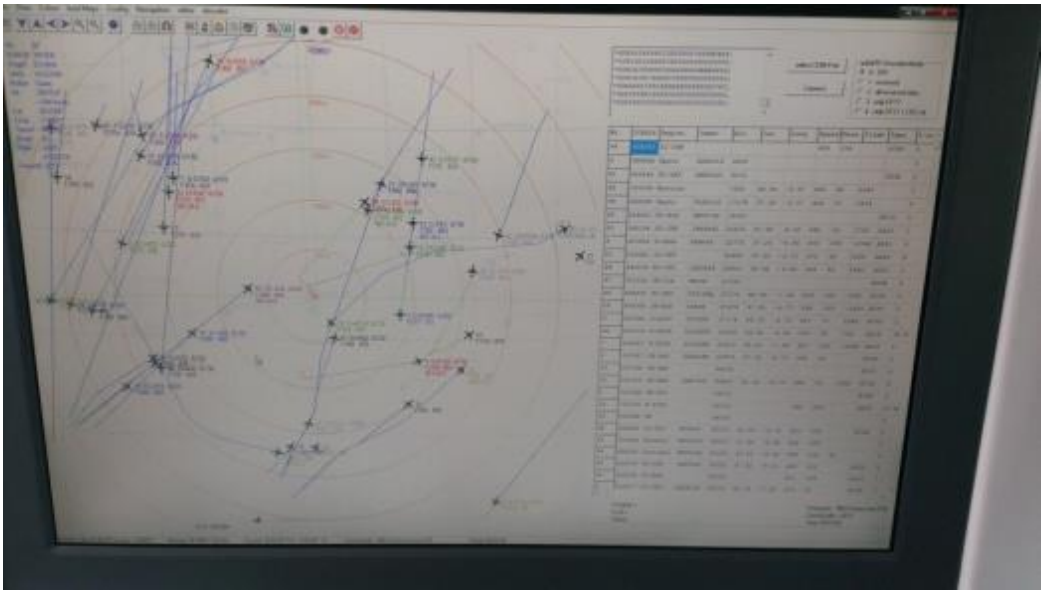


Figure 4.1-16 ADS-B scope software showing traffic flying around (only from a certain height and airspeed)

The second ADS-B receiver was a Radarcape, from Modesbeast. This device allows tracking transponder signals from ground, at any speed, and display the information directly over Google Earth.

The altitude resolution provided by the internal alticoder of the transponder is 25 ft and the configuration has to be set to transmit in Mode C+S to get proper altitude readings.
Some flight at 400 ft AGL were done to test speed and altitude correlation. Note has to be taken that RPA altitude is displayed in meters over GPS WGS84 and field altitude is at about 72 meters over that reference. Therefore 400 ft AGL corresponds to 192 meters GPS WGS84.

4.1.2.1.2 GA (manned) Aircraft Preparation Activities

4.1.2.1.2.1 Standalone verification

4.1.2.1.2.1.1 Inspection

All ADS-B equipment (OUT and IN) to be on board the MRI (GA aircraft) were inspected in accordance with Indra procedures for (COTS) elements verified at entry (see ref.[5]). The main steps were:

- Verification and registration of manufacturer certificate of conformity (CoC) for each inspected element.
- Element inspection against purchasing order requirements.
- If the inspected element is declared "in conformity" with requirements, the results registration is performed and the element is released to the purchasing department / project. Otherwise, the rejection procedure is activated.

After following the above mentioned inspection procedure the ADS-B elements were accepted.

4.1.2.1.2.1.2 Tests

The purpose of this test was to verify the correct functioning of all the required equipment functionalities to be used as ADS-B transponder. A number of tests were performed on the ADS-B transponder at a laboratory in Indra Sistemas, S.A. premises in Aranjuez. Although previous tests were performed after receiving the equipment, the one described in this report was conducted on 15/12/2014 (as results were more formally documented).

Hardware elements used were:

- Test specimen: 1x ADS-B Transponder by Garrecht Avionik with P/N VT-0102-(004)-(007)-(200)-125.
- Elements used for testing the specimen are included as follows:

Nr. of elem.	Description	Model and/or P/N	Manufacturer	Figure 4.1-18 ref. nr.
1	ADS-B receiver	TRX-1090	Garrecht Avionik	1.
1	GPS Receiver-Antenna	P/N HI-206	Haicom	2.
1	RF coupler	P/N 778D	Agilent	
1	RF load for 400W N-Type connector	P/N BN527768	SPINNER	3.
1	RF load for 5W N-Type connector			
1	RF variable attenuator with N-Type connectors	P/N 8496B	Agilent	
2	RF Adaptor from N-Type to SMA			
2	Lab electric power supply	P/N E3632A	Agilent	
2	RF cable	P/N 104/2x11SMA 451/0,5m	SUCOFLEX	
1	Test cable for power supply, RS-232 and GPS USB wire	N/A	Made by Indra for testing	4.
1	Adaptor from RS-232 DB9 to generic USB			5.
1	Black AWG24 cable to connect lab			

	power supplies (about 30 cm if both supplies are next to each other)			
1	Laptop with Windows 7 Enterprise 64bits	Elitebook 8470p	Hewlett Packard	

Table 4.1-1: Elements used at lab for ADS-B transponder testing

Besides, software tools used were:

- *VT-01 UAV Control Center* by Garrecht Avionik for ADS-B transponder configuration and control
- *TRX Tool* by Garrecht Avionik for ADS-B receiver configuration and control

The test set-up is schematized in Figure 4.1-17 and elements are shown in Figure 4.1-18 .

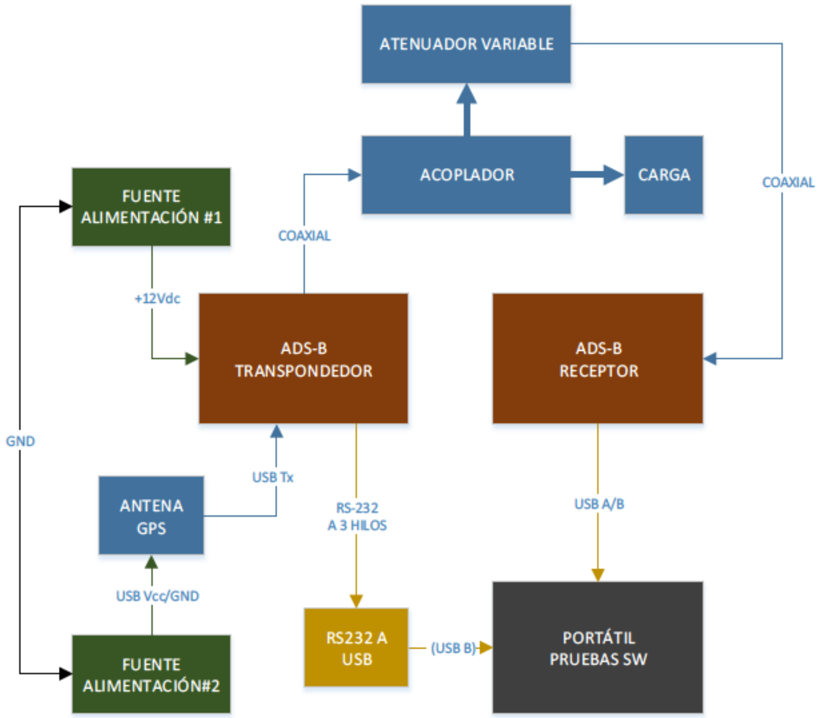


Figure 4.1-17 Scheme of ADS-B transponder test set-up

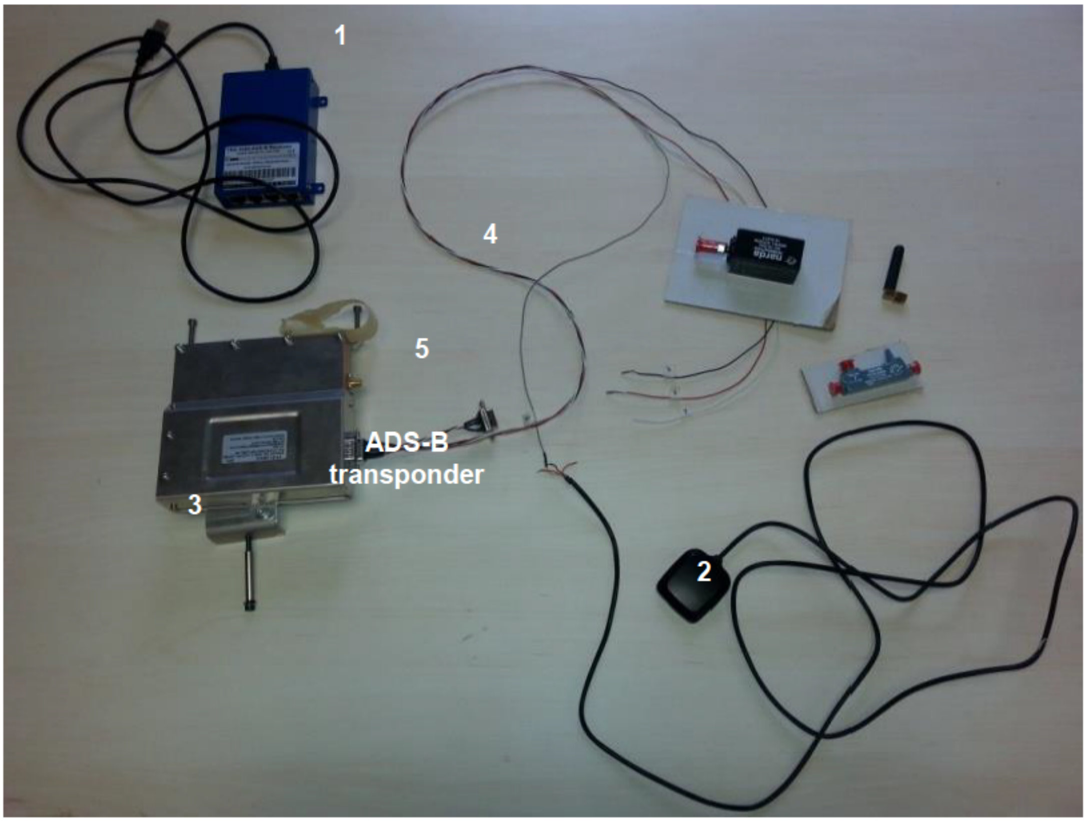


Figure 4.1-18 ADS-B transponder test set-up

Lab power supplies must be set at +12Vdc (for ADS-B transponder) and +5Vdc for GPS receiver-antenna. Output must not be activated until the set-up is completed.

The testing cable has two sets of wires:

- Power supply set:
  - three longer wires, marked as 1, 2 y 5, Nr. 1 is connected to Supply #1 Vcc (+12Vdc), nr. 5 connects with ground of Supply #1, and nr. 2 is not connected to anything.
  - three shorter wires corresponding to the GPS power supply, of which the red one is connected to Supply #2 Vcc (+5Vdc), the black one to the Supply #2 ground and the white one is not connected to anything.
- Set for adaptor from RS-232 DB9 to generic USB, which connects the ADS-B transponder to the laptop.

The ADS-B receiver is connected also to the laptop via the USB cable.

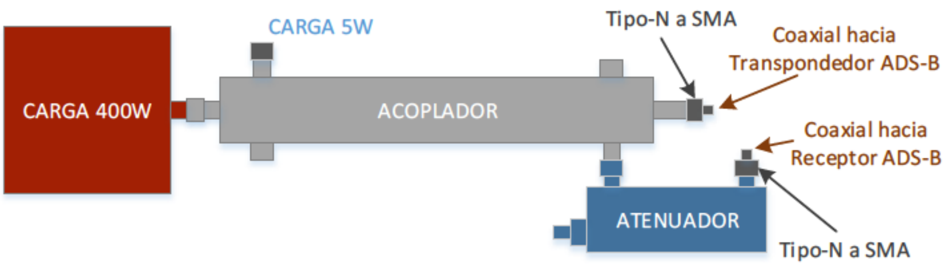


Figure 4.1-19 Scheme of the RF connections for the ADS-B transponder test set-up

NOTE: the variable attenuator must be set at -90 dBm and the GPS receiver-antenna must be placed to ensure a correct GPS signal reception.

1. **Power up**

Once MS Windows is running at the laptop and the adaptor from RS-232 DB9 to generic USB is installed correctly, the two power supply units can be activated in the marked order (first #1 and then #2). Then the setup is ready to launch the SW testing.

2. **SW Tools launch and testing**

Once the VT-01UAV Control Center and the TRX-1090 tool are launched, the following tests were performed:

1) Change modes at the VT-01UAV Control Center and watch results with the TRX-1090 tool:

- Standby: ADS-B transponder does not emit any signal. See example in Figure 4.1-20 .
- Mode-S: ADS-B transponder sends UAV (RPA) ID, position (latitude and longitude) but not altitude. See example in Figure 4.1-21 , where the red icon represent the ADS-B transponder signal shown in the ADS-B receiver.
- Mode-S + Mode-C: ADS-B transponder sends UAV (RPA) ID, position (latitude and longitude) and altitude.

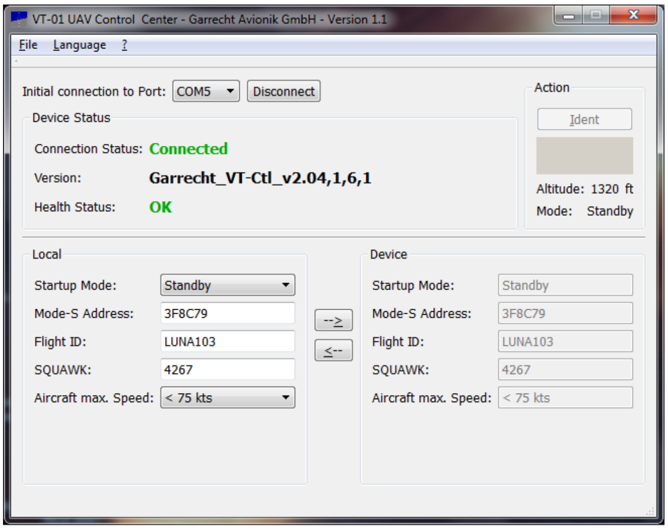
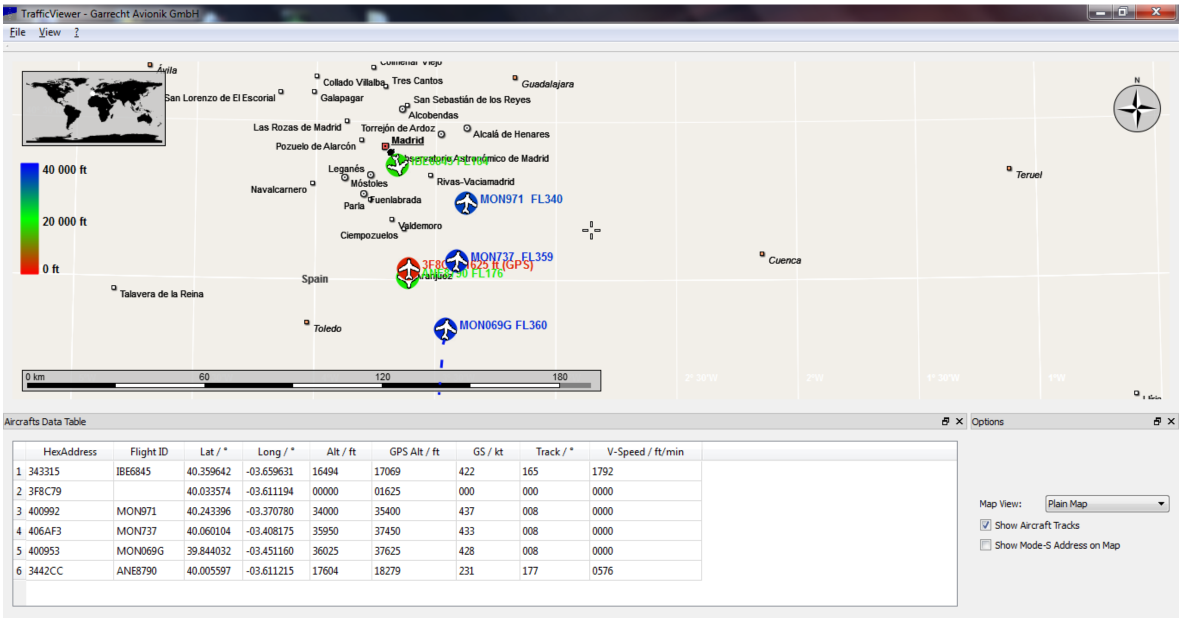


Figure 4.1-20 ADS-B Transponder configuration tool example with "stand by" mode activated



	HexAddress	Flight ID	Lat / °	Long / °	Alt / ft	GPS Alt / ft	GS / kt	Track / °	V-Speed / ft/min
1	343315	IBE6845	40.359642	-03.659631	16494	17069	422	165	1792
2	3F8C79		40.033574	-03.611194	00000	01625	000	000	0000
3	400992	MON971	40.243396	-03.370780	34000	35400	437	008	0000
4	406AF3	MON737	40.060104	-03.408175	35950	37450	433	008	0000
5	400953	MON069G	39.844032	-03.451160	36025	37625	428	008	0000
6	3442CC	ANE8790	40.005597	-03.611215	17604	18279	231	177	0576

Figure 4.1-21 ADS-B Receiver configuration tool example with "mode S" mode activated

2) The following commands were sent to the ADS-B transponder through the serial port:

- Command to enable writing (u = MU934F392632X89A<CR><LF>)
- Command to request mode (s=?<CR><LF>)
- Command to change mode (s=a<CR><LF>, s=t<CR><LF>).
- Command to request squawk (c=?<CR><LF>)
- Command to request flight ID (f=?<CR><LF>)
- Command to request max. speed (x=?<CR><LF>)
- Command to request ICAO address (h=?<CR><LF>)
- Command to request "afrmconfig" (p=?<CR><LF>)
- Command to request status (q=?<CR><LF>)
- Command to request statistic (e=?<CR><LF>)
- Command to request altitude (a=?<CR><LF>).
- Command to request sw-hw-version (z=?<CR><LF>)
- Command to request "*trigger ATCRBS id flag* " (i=?<CR><LF>)

The correct feedback was received for all commands.

The response of the ADS-B transponder unit in the above described standalone test was **satisfactory**. The ADS-B receiver and display used in the MRI were tested as part of the FAT.

4.1.2.1.2.2 Factory Acceptance Test (FAT)

The purpose of this test was to verify the suitability of the ADS-B solution (OUT and IN capabilities) in the MRI aircraft planned to be used in the Exercise 2 of ARIADNA. This FAT was performed in **Casarrubios del Monte** aerodrome (ICAO code: LEMT) on 15/12/2015.

Figure 4.1-22 Casarrubios del Monte aerodrome (ICAO code: LEMT)

The main items used were:

- Tecnam-Indra P2006T MRI aircraft (P2006T by Tecnam modified for Indra for surveillance missions)
- ADS-B OUT equipment:
  - Garrecht Avionik VT-01 UAV-x (P/N VT-0102-(004)-(007)-(200)-125)
  - RAMI AV-74 transponder antenna
  - Haicom GPS Receiver-Antenna (P/N HI-206)
- ADS-B IN equipment:
  - Garmin GDL-39 ADS-B receiver
  - Apple iPad with Garmin Pilot application

  Additionally, the following ADS-B IN equipment is also used on ground:
  - Garrecht Avionik TRX-1090 ADS-B receiver
  - Toshiba Portege Laptop R930-193 with TRX-Tool

The ADS-B transponder is installed as standalone, that is, without any integration with aircraft systems / equipment other than electric power supply and mechanical fixation, and as an experimental and not permanent integration in order to minimise impact on safety and flight authorisation, as well as to minimise effort in integration.

The ADS-B transponder was installed on a platform used for the attachment of the mission radar to the aircraft structure (radar is not installed for the use of MRI in ARIADNA).

In order to minimise impact on integration (as above mentioned):

- Even though the MRI is equipped with GNSS receiver, a simple GPS receiver-antenna was connected to the transponder and placed at the cockpit. This solution also avoids potential issues with NMEA data versions (between GNSS output at the aircraft and transponder)
- The static pressure port of the ADS-B transponder was left open and not connected to the aircraft static pressure ports. As the aircraft cabin is not pressurized, the pressure at the cabin will be taken as barometric pressure by the ADS-B transponder.
- Even though the aircraft has a transponder antenna for the GTX-33, it was deemed easier to install another antenna (also qualified for transponders)

The electric power supply is as follows:

- ADS-B transponder: from a 14 Vdc source at the aircraft.
- GPS receiver-antenna for the ADS-B transponder: a 5 Vdc battery was used for the test described in this report but another solution will be used for the demonstration campaign (e.g. voltage convertor from aircraft source or USB cable connected to PC installed in the aircraft)

Figure 4.1-23 shows the standalone integration performed for the FAT described in this report. It must be noted that the platform where the transponder is placed is covered in flight and the cable used for transponder configuration is removed once such configuration has been performed on ground.

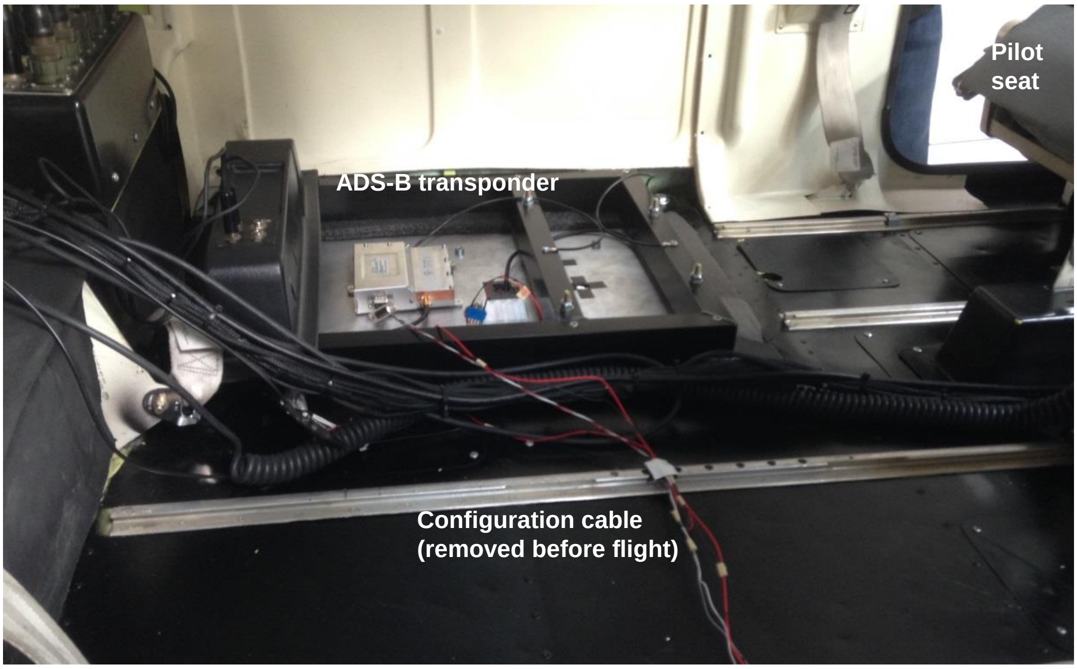


Figure 4.1-23 ADS-B Transponder (VT-01 UAV-X) standalone integration in MRI

With regard to the ADS-B receiver and display, both are portable elements (as described in I03, ref.[4]) and were placed as illustrated in Figure 4.1-24 .

Figure 4.1-24 ADS-B IN equipment in the MRI

The procedure for testing the ADS-B equipment on board the MRI was simple and as follows:

- The equipment is automatically switched on once the MRI electrical system is started and feeds the ADS-B equipment. As the ADS-B transponder is set to an active mode, in particular "mode S + C", it transmits from the moment it is switched on.
- The ADS-B signal is checked on ground with the Garrecht ADS-B receiver.
- The ADS-B signal is also checked on ground with the Garmin ADS-B receiver (to be used on board the aircraft), which is not capable of detecting MRI ADS-B signals on ground.
- Then the MRI performs aerodrome pattern several times and the ADS-B signal is checked on ground with the Garrecht ADS-B receiver, while the MRI pilot checks traffics and own position with the on board (Garmin) ADS-B receiver.
- Even though there are flights restrictions affecting the associated airspace (Madrid TMA is class A), at least one flight must cover a distance longer than the expected ones to be covered at the project demonstration site. Likewise, both checks on ground and on board must be performed with the respective ADS-B receivers.

A flight was performed on 15 December 2015 to perform abovementioned procedure. **Results were satisfactory** as ADS-B data was received properly, as illustrated on the following figures.

Figure 4.1-25 MRI starts up and ADS-B transponder becomes active

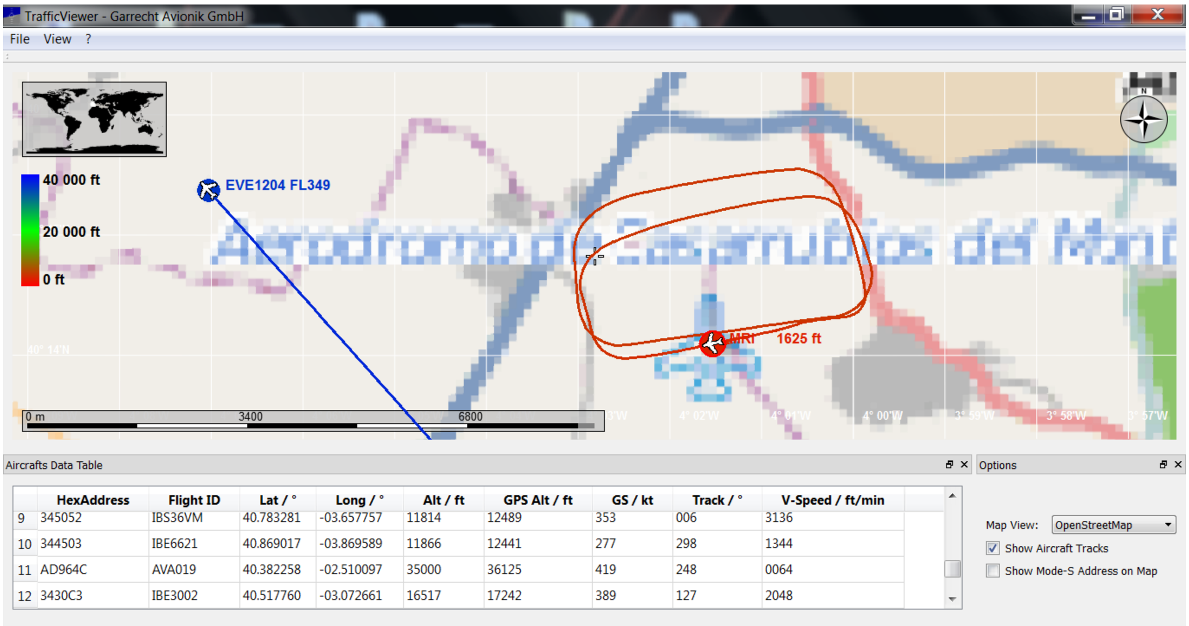


Figure 4.1-26 MRI ADS-B signal check from Garrecht receiver on ground

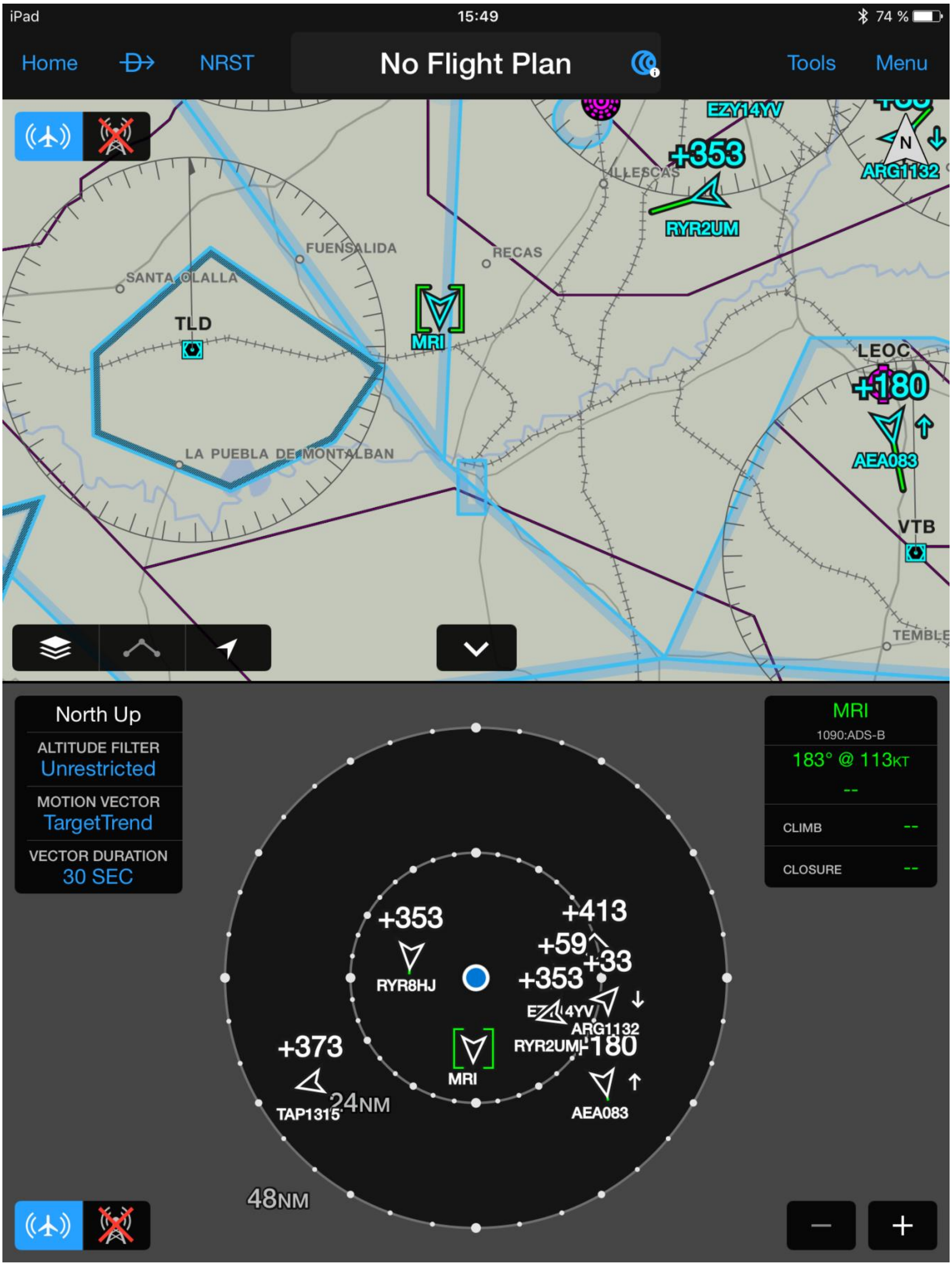
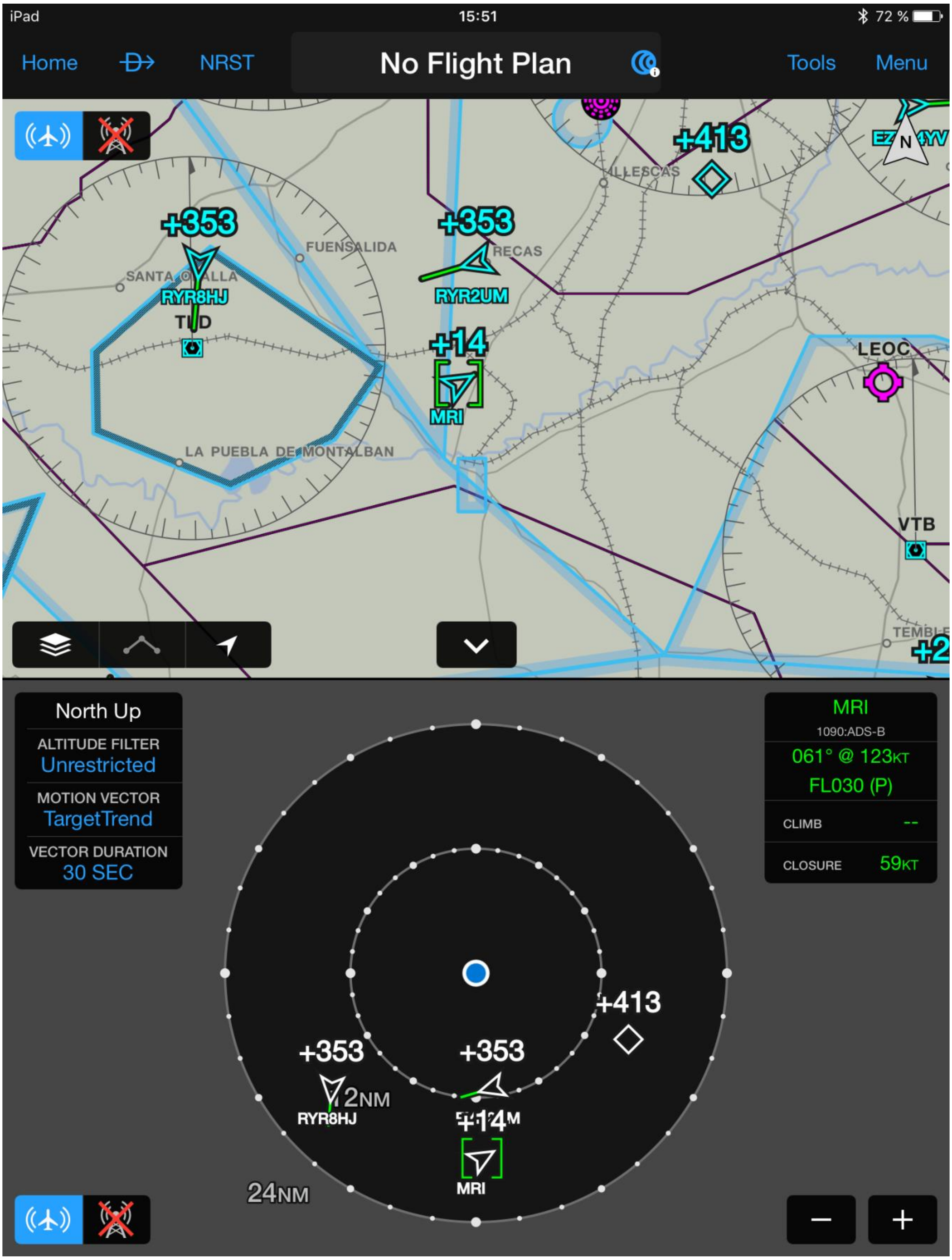
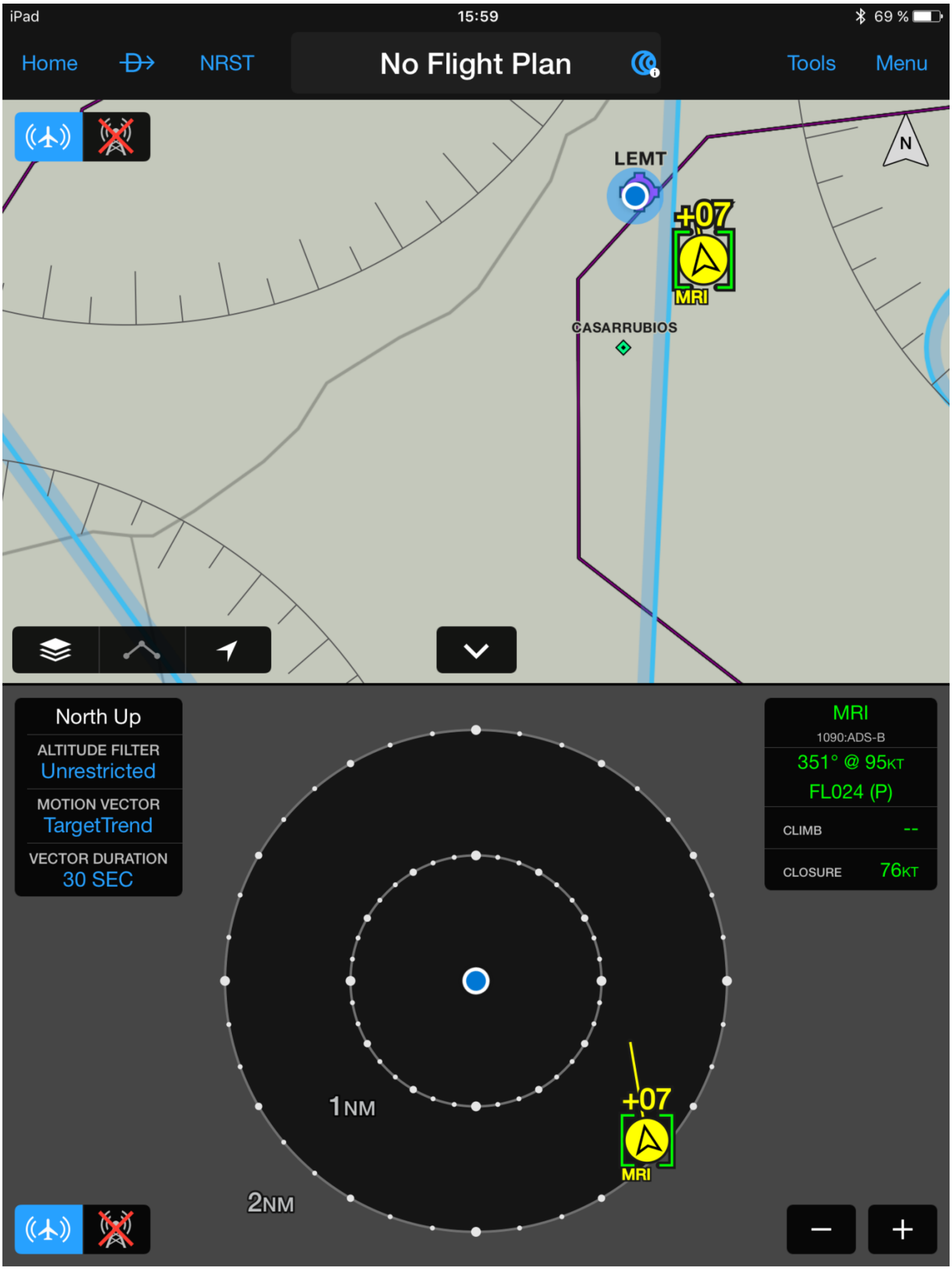


Figure 4.1-27 MRI ADS-B signal check from Garmin receiver on ground



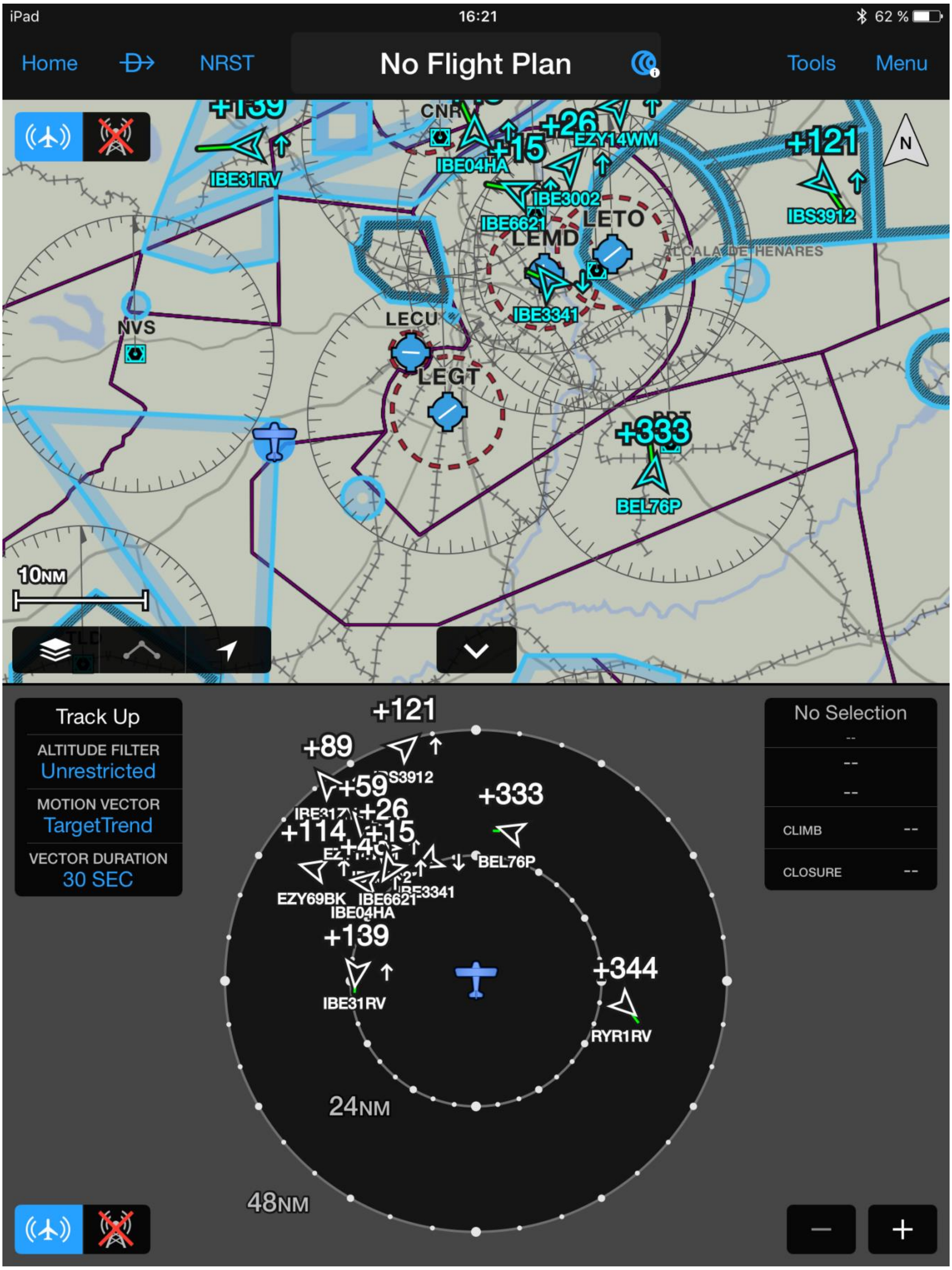
NOTE: MRI was turning back at about 18 NM from the aerodrome (where the receiver was) and was between 3000 and 3400 ft MSL approximately (LEMT elevation is 2050 ft). Due to the low flight altitude, signal was weak at that distance.

Figure 4.1-28 MRI ADS-B signal check from Garmin receiver on ground



NOTE: As MRI was approaching the aerodrome at a 700 ft or less above the Garmin receiver (on ground), the symbol changes to yellow to warn (Traffic Advisory) that the traffic is too close.

Figure 4.1-29 MRI ADS-B signal check from Garmin receiver on ground



NOTE: MRI position is depicted with a "blue aircraft" symbol on both (upper and bottom) part of the display (which reflects the fact that the receiver is on board).

Figure 4.1-30 MRI ADS-B signal check from Garmin receiver on ground

4.1.2.1.3 Design of GBSAS scenarios

The general conditions for all scenarios were defined with the following conditions:

- METEO:
  - Daytime
  - VMC
  - No precipitation (rain / snow)
- Airspace use limitation for RPAS:
  - ZOTER: ATLAS TSA 30
  - ZOUAS: Circular cylinder with vertical axis through the ARP, 8 km radius and vertical limits from SFC to 4000 ft (1000 ft below TSA 30 limit as safety buffer)
- The ATCO involved in the operations provide the "simulated instructions / clearances" to be followed by the participating aircraft ("simulated" means no actual responsibility for the ATCO in terms of provision of air navigation services)
- The same integrated radar (PSR) data and ADS-B data to be used by the control tower and the RPAS. ADS-B data will be used in the manned aircraft (when participating) from its on-board equipment. All participating flight crews in a scenario monitor the other participating aircraft, using either ADS-B data (manned aircraft) or ADS-B+PSR data (RPAS) during the whole scenario.

4.1.2.1.3.1 Scenario SCN-RPAS09-003

In this scenario, a separation of a manned aircraft (GA aircraft) and a RPAS (small FW RPAS) by ATC is emulated in flight.

Some basic aspects and parameters for the separation scenarios are described below.

- DA: Direct Angle
- VMD: Vertical Miss Distance (+ host above / - host below)
- HMD: Horizontal Miss Distance
- CPA: Closest Point of Approach
- TrV: Traffic Avoidance Volume

These parameters are illustrated in Figure 4.1-31 .

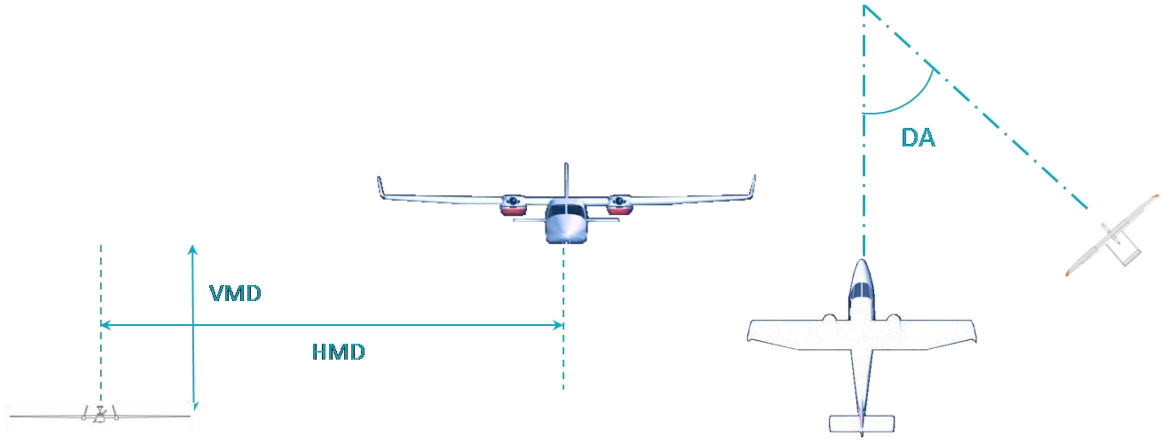


Figure 4.1-31 Parameters used in Scenario 1 of Exercise 2

The main characteristics of this scenario are:

- VMD: +500ft (MRI above)
- HMD: 0

- DA: 90º
- Viewer Altitude: 300ft AGL
- MRI Altitude: 800ft AGL
- Viewer speed: 40 KIAS
- MRI speed: 100 KIAS
- Flight conditions: VMC
- TWR: Test Coordinator (TC) (Indra) + ATCO (ENAIRE).

The design of the "encounter" trajectories for separation is depicted in Figure 4.1-32 .

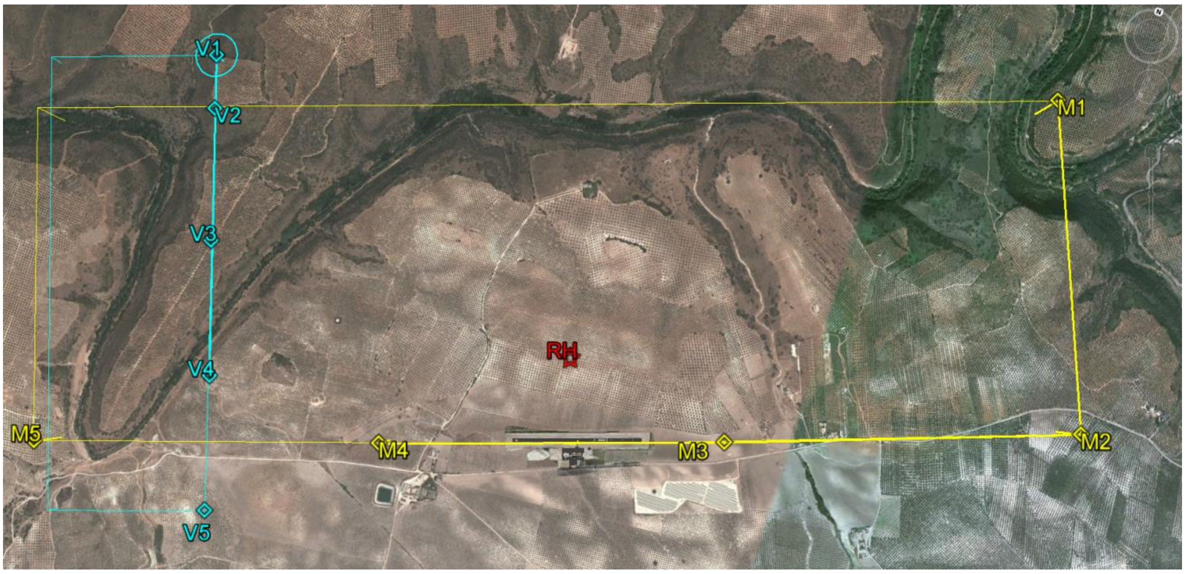


Figure 4.1-32 Design of Scenario 1 trajectories

Where:

- General Aviation (GA) aircraft is authorised to perform an aerodrome pattern (without intention to perform landing) (yellow track with waypoints M1 to M5). Headwind and tailwind segments are 2.5 NM long, and the other two segments are one third the latter.
- Small FW RPAS crosses headwind segment of GA aircraft (blue track with waypoints V1 to V5.
- Separation between waypoints of each trajectory is set so that they are separated 30 s at the nominal speed of each aircraft (see above). Hence: M2-M5 ~ 2.5 NM; M1M2 ~ M2M3 = M3M4 =M4M5 ~ 0.83 NM (2.5/3); V2V3 = V3V4 = V4V5 ~ 617 m
- RH is the "Return Home" or emergency point in case of any RPAS emergency (if the RPA is able to continue flight after failure it will automatically fly and hold at the RH point to be manually-RC recovered)

Test coordinator indicates scenario start once each aircraft is holding at point #1 (M1, V1)

ATCO gives separation instruction between points #2 (M2, V2) and #4 (M4, V4)

Pilots of both aircraft use ADS-B to track each other. RPAS pilot and ATCO also use a display with integrated radar/ADS-B data.

4.1.2.1.3.2 Scenario SCN-RPAS09-004

In this scenario, a separation of a manned aircraft (GA aircraft) and a RPAS (small FW RPAS) by ATC is emulated in flight.

The main characteristics of this scenario are:

- VMD: +500ft (MRI above)
- HMD: 0
- Viewer Altitude: 300ft AGL
- MRI Altitude: 800ft AGL
- Viewer speed: 40 KIAS
- MRI speed: 100 KIAS
- Flight conditions: VMC
- TWR: Test Coordinator (TC) (Indra) + ATCO (ENAIRE).

Two sub-scenarios were defined:

- 2A: Both aircraft (GA aircraft and RPAS) perform aerodrome patterns, with opposite directions ("head on encounter" at the runway segment). GA aircraft performs its patterns without intention to land whereas the RPAS is authorised to land.
- 2B: The same as above but both aircraft performing patterns with the same direction ("overtaking encounter" at the runway segment)

The design of the "encounter" trajectories for separation is depicted in Figure 4.1-33 and Figure 4.1-34.

Figure 4.1-33 Design of Scenario 2A ("head on") trajectories

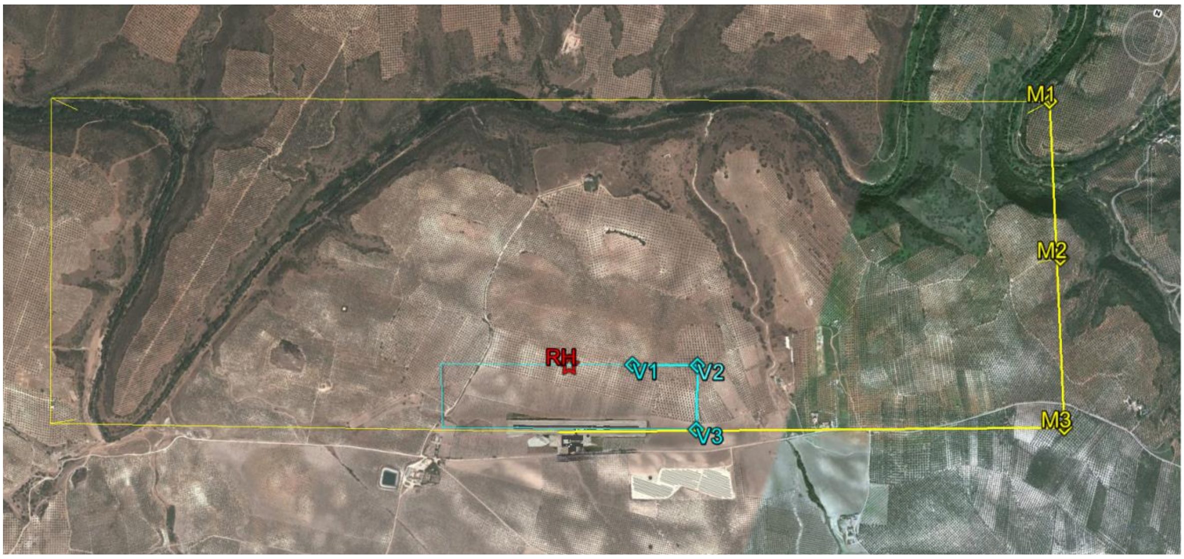


Figure 4.1-34 Design of Scenario 2B ("Overtaking") trajectories

Where:

- RPA performs an aerodrome pattern (blue track) where: V1V2 = V2V3 (base segment) ~ 300 m
- GA aircraft performs an aerodrome pattern (yellow track) where: M2M2 = M2M3 ~ 0.42 NM (2.5 NM /6)
- RH is the "Return Home" or emergency point in case of any RPAS emergency (if the RPA is able to continue flight after failure it will automatically fly and hold at the RH point to be manually-RC recovered)

Test coordinator indicates scenario start once each aircraft is holding at point #1 (M1, V1)

ATCO gives separation instruction between points #2 (M2, V2) and #3 (M3, V3)

Pilots of both aircraft are using ADS-B to track each other. RPAS pilot and ATCO also use a display with integrated radar/ADS-B data.

4.1.2.1.3.3 Scenario SCN-RPAS09-005

In this scenario a "runway incursion" conflict is emulated using two RPAS. One of the RPAS is performing an aerodrome pattern with authorisation to land but there is another RPAS on the runway. Both RPA have their ADS-B transponder on, so the airborne RPA can detect the one on the runway. After the authorisation to land to the airborne RPA, either the ATCO or the RPAS pilot "detects" the encounter (the latter detects it using the ADS-B and or ADS-B & radar data and informs the ATCO) and the ATCO gives the miss approach instruction.

4.1.2.2 Validation approach

The validation approach of this second exercise relied on the twofold methodology defined for the scope of these activities, however it was more based on qualitative results to assess the impact of the concept to be proved in the different human actors involved in the exercise, air traffic controllers, remote pilots and manned aircraft pilot.

The high level validation approach defined for the demonstration of GBSAS in the context of ARIADNA comprised the following set of activities, all of them taking place during the execution of the flights:

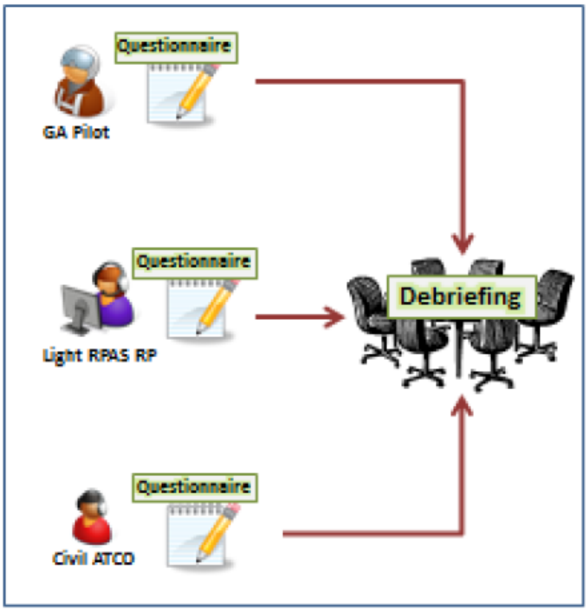
- The correctness of ADS-B signal detection by each of the aircraft, whose flight crew has to be able to track the other aircraft.

- The adequacy of radar data from SACTA to provide the RWRPAS remote flight crew with information on the surrounding traffic.
- The differences that might appear between the ADS-B signal and the radar data from SACTA (ATC system)
- The performance of the simulated conflict resolution by the involved aircraft.
- The situational awareness and workload indicators of remote pilots (in particular of RW RPAS) and ATCOs.
- The adequacy of voice communications between ATC and remote pilots.

Finally, the new aerodrome selected for the trials didn´t have ATC services, so SACTA information couldn´t be used to improve the situational awareness of the remote pilots.

In addition, the RPAS used to conduct these exercises was fixed wing RPAS instead of a rotary wing one.

For this exercise, ARIADNA consortium prepared ad-hoc questionnaires for controllers and pilots and conducted de-briefings with all the actors, following the standard human factor approach.



It has been also important the trajectory analysis to understand the evolution of the separation between both aircraft during the execution of the conflict resolution manoeuvers. For this assessment it was needed to adapt the trajectory analysis tool to the data provided by ADS-B system and by the telemetry of this particular RPAS.

4.2 Exercises Execution

The two ARIADNA demonstration exercises were performed in ATLAS experimental test centre on the dates according to the following table (deviations from the planned activities are presented in Sec.4.3):

Exercise ID	Exercise Title	Actual Exercise execution start date	Actual Exercise execution end date	Actual Exercise start analysis date	Actual Exercise end date
EXE-RPAS.09-D-01	SBAS-based approach and landing procedures applicable to rotary	22/02/2016	26/02/2016	29/02/2016	04/03/2016

Exercise ID	Exercise Title	Actual Exercise execution start date	Actual Exercise execution end date	Actual Exercise start analysis date	Actual Exercise end date
	wing RPAS				
EXE-RPAS.09-D-02	Concepts for a ground-based situational awareness system (GBSAS) that can be integrated in a RPAS	18/01/2016	22/01/2016	25/01/2016	29/01/2016

Table 4.2-1: Exercises execution/analysis dates

In **Exercise 1**, the design procedure was flown as planned following the nominal trajectory and following a missed approach (3 repetitions each) at approx. 20-25KIAS.

Figure 4.2-1 Location of GCS during Exercise 1 demonstration

Figure 4.2-2 Commanded flight plan during Exercise 1 demonstration

In **Exercise 2**, three scenarios (with several repetitions each) were performed as planned: midair encounter crossing, midair encounter head-on/overtaking, and runway incursion.

Figure 4.2-3 Visual detection of manned aircraft from ATC position

Figure 4.2-4 Overtaking scenario

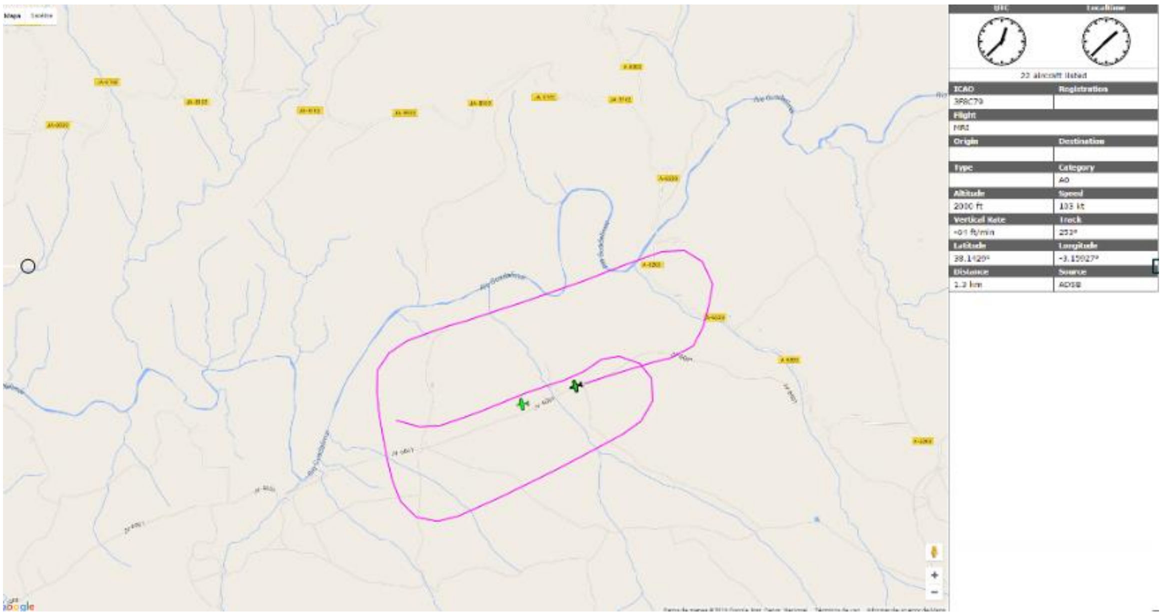


Figure 4.2-5 Detection of aircraft on ADS-B screen during overtaking scenario

Figure 4.2-6 Head-on scenario

Figure 4.2-7 Deployment of FW RPAS for midair encounters (left) and runway incursions (right).

4.3 Deviations from the planned activities

The following were deviations during the actual demonstration with respect to the planned activities:

- Demonstration flights were performed in **ATLAS centre** (under civil authority) instead of San Javier airport (under military authority) due to the delays associated with permissions.
- The demonstration flights were performed with a **RW RPAS (Logo)** provided by the consortium partner FADA_CATEC. No impact on the overall budget but the transfer of the corresponding activities requires some redistribution of the effort. This RW RPAS had the advantage of being already authorised to fly in the ATLAS aerodrome, eliminating therefore the risks associated to the authorisation process and the subsequent delay.
- Exercise 1 did not finally have the **support of ATCO** but it was considered that the related objectives were fully covered by Exercise 2.
- For Exercise 1, specific assessment for **visual segment of the PinS procedure** was implemented by confirming mutual visual contact between external pilot – helicopter, and internal pilot (using pilot camera) – external pilot.
- Due to the excessive delay in the certification process related to the software upgrade for the GA aircraft (MRI) flight instruments suite required to enable ADS-B Out operation in that aircraft type, **the same ADS-B transponder used by the RPAS was integrated in the GA aircraft (MRI)** even though this equipment is designed for RPAS (derived from a version for manned aviation, but the one for RPAS does not have HMI for on board pilot control) and

does not fully comply with all requirements (mainly those related with equipment qualification). A positive aspect of this final solution regarding verification was that results of the related activities performed for the MRI reinforce those conducted for RPAS, as the latter use the same transponder.

- **SACTA** ATC radar was not available at ATLAS, so it was replaced by integrated primary radar and ADS-B data, achieving, with other means, the **full demonstration objectives**

5 Exercises Results

5.1 Summary of Exercises Results

This section summarises the results obtained and the status of the validation objectives.

Exercise ID	Demonstration Objective Tittle	Demonstration Objective ID	Success Criterion	Exercise Results	Demo Objective Status
EXE-RPAS.09-D-01	Validate the feasibility of a "PinS"-like approach procedure based on SBAS (EGNOS) to be used by a rotary wing RPAS.	OBJ-RPAS09-001	The RPAS can fly the designed procedure with acceptable performances from a safety and airport/airspace capacity viewpoint	The RPAS is able to follow the PinS-like approach procedure without deviations	OK
EXE-RPAS.09-D-01	Assess the impact that the performance of SBAS approaches by RPAS has on runway throughput and airport operations	OBJ-RPAS09-002	The time required by a rotary wing RPA to perform the approach and landing manoeuvres does not negatively affect the aerodrome operations.	The low performances in terms of speed and rate of descend would be the main factor impacting other operations in the airport but it would be manageable in low density and complexity airports.	OK
EXE-RPAS.09-D-02	Assess the flight crew's situational awareness and related safety impact due to the use of ADS-B (for RPAS and manned aircraft)	OBJ-RPAS09-003	Pilots of all aircraft involved in the demonstration exercise (RPAS and manned aircraft) can effectively track with ADS-B the other involved aircraft.	The manned aircraft pilot and the remote pilot found the ADS-B display very useful to locate other surrounding traffics but at the same time and with the current RPAS crew distribution, the remote pilot considered that it could be a distraction.	OK
EXE-RPAS.09-D-02	Assess ATCO's situational awareness and related safety	OBJ-RPAS09-004	No unexpected trajectory or performance deviations of	Controllers´ situational awareness was maintained	OK

Exercise ID	Demonstration Objective Tittle	Demonstration Objective ID	Success Criterion	Exercise Results	Demo Objective Status
	impact in scenarios where RPAS must follow ATC instructions for conflict resolution		RPAS with respect to those requested by the ATC.	although they dedicated more time to the RPAS than usually to other aircraft	
EXE-RPAS.09-D-02	Assess the safety impact associated to the communications between the RPAS flight crews and ATCOs	OBJ-RPAS09-005	No R/T communication issues are reported by RPAS flight crews or ATCOs that can derive in a safety hazard.	Mistakes and errors in ATC communications were few and did not impact on safety.	OK
EXE-RPAS.09-D-02	Demonstrate that RPAS operations at aerodromes and associated airspace of low to medium density and complexity (with ATZ segregation during the RPAS operations) do not cause excessive stress of ATCOs and remote pilots	OBJ-RPAS09-006	The perceived stress by flight crews and ATCOs is within safe levels as qualitatively reported (see NOTE-1 below) during de-briefing sessions and post-exercise questionnaires.	The stress of all the actors, pilots and controllers, increased compared to their current basis. This increment is manageable as far as it is done in a segregated environment similar in complexity to this.	OK

Table 5.1-1: Summary of Demonstration Exercises Results

5.2 Choice of metrics and indicators

Due to the nature and regulatory limitations of the project, ARIADNA has focused on the technical and operational feasibility of integrating RPAS in airport operations and how this would impact on human factors. Bearing the scope of the project in mind, it can be understood that ARIADNA has not addressed any of the Key Performance Indicators defined by SESAR, which are those performance indicators with a target set.

On the other hand, Human Performance has been defined as a Performance Focus Area by B04.01 in the Performance Framework for SESAR2020 program although there is no SESAR Performance Ambition directly associated to it.

There have been defined four areas to be undertaken in a human performance assessment with performance indicators associated to them, some of which have been covered by ARIADNA. The following table presents these areas, the indicators defined and those that have been analysed by ARIADNA.

HP area	Performance indicator	ARIADNA coverage	ARIADNA indicator

Roles, responsibilities, operating methods and human tasks	Task descriptions (HP1.1)	NO	N/A
	Workload (HP1.2)	YES	Stress
	Human error (HP1.3)	YES	Errors in communications and compliance of ATC instructions
Technical support systems and Human-Machine interface	Trust in Automation (HP2.1)	NO	N/A
	Timeliness of system responses (HP2.2)	NO	N/A
	User interface acceptability (HP2.3)	YES	Operational acceptability
Team structures and team communication	Impact of team changes (HP3.1)	NO	N/A
	Task balance within team (HP3.2)	YES	Task distribution
	Communication burden and Situational Awareness (HP3.3)	YES	Number of R/T and perceived situational awareness
HP related transition factors	Technology acceptance (HP4.1)	YES	Acceptability to integrate RPAS in non-segregated airspace
	Change in competence requirements (HP4.2)	YES	Knowledge
	Changes in recruitment and selection requirements (HP4.3)	NO	N/A
	Training costs (HP4.4)	YES	Need for more training
	Head count costs (HP4.5)	NO	N/A

Table 5.2-1: SESAR HP indicators studied by ARIADNA

Although the indicators defined are mainly oriented to ATCOs, ARIADNA has studied the impact also on RPAS and manned aircraft pilots with current competences and tasks.

5.3 Summary of Assumptions

The following table presents the assumptions that were modified along the project evolution to adapt the change of scope of the project.

Identifier	Title	Type of Assumption	Description	Justification	Flight Phase	KPA Impacted	Source	Value(s)	Owner	Impact on Assessment

ASS-RPAS09-007	Radar data from SACTA is available	Ground Technology	The ATC radar data from SACTA (ENAIRE) was not available and only ADS-B information was used by RPAS crew.	GBSAS related exercise was executed (all scenarios) with ADS-B information.	Flight within ATZ	Safety	N/A	N/A	FADA INDRA	In principle, radar data from SACTA will be available at the selected location (DeSIRE RPAS demo recently performed at the same location with SACTA data)

Table 5.3-1: Demonstration Assumptions

It is worth noting that the deviations described in Sec.4.3 did not affect the rest of assumptions defined in the Demonstration Plan.

5.3.1 Results per KPA

Taking into account the kind of activities executed by ARIADNA and all the limitations that applied to the flights, the main objectives of ARIADNA were to demonstrate the operational feasibility of small rotary wing RPAS to execute adapted standard SBAS procedures and the improvement on of remote and manned aircraft pilots situational awareness by presenting them with surrounding traffic information based on ADS-B technology.

It must be noted **that no enhancement on the level of current KPAs can be expected** by the proposed concept addressed in the exercises, since there are no RPAS currently operating in civil (or open to civil operations) aerodromes / TMAs, and therefore the introduction of RPAS only can be expected to rather have a negative impact in terms of KPAs considered in the current ATM system. Therefore, the goal was to **minimize the degrading of current levels of KPAs related to the ARIADNA exercises**. Due to the changes in the scope of the exercises and basically the change of location, has prevented to obtain more representative results.

Below are depicted some conclusions on Safety and Capacity:

- Safety: Finally the exercises have been performed in a dedicated aerodrome, only used by the RPAS, with the manned aircraft using only the surrounding airspace. Under these conditions, the different operations didn´t impact on the safety of airport / TMA operations.

  The presentation of surrounding traffic information to the manned aircraft pilot replaced the difficulty to track the RPAS visually due to its small size and it was very welcomed.

- Capacity (airport and airspace): Since finally the GBSAS exercise was executed with a fixed wing RPAS, it operated directly from the edge of the runway requiring the invasion of the runway by RPAS staff for preparation and recovery, what would clearly impact on other operations. For this reason, the conclusions of these trials cannot be considered to assess any impact on capacity. The current airport / TMA capacity is not affected (or not significantly) by the introduction of these new stakeholders. In the case of the SBAS-based approach procedure, the required space and time is minimized, thus minimizing also impact on aerodrome operations (it must be noted that probably in short-medium term operations – RPAS operations will take place in segregated airspace activated in “free” windows between manned aircraft operations).

- Human Factors: although a proper human factor assessment according to the guidelines of SESAR has not been performed, ARIADNA has analysed some of the indicators identified in the new version of the Performance Framework and how the results of ARIADNA impact on them. This is highlighted below with the following colour code:

- Worsen 🔴
- Improve 🟢
- Maintain ○

It must be noted that the indicators defined in the performance framework of SESAR were born without thinking on remote pilots but ARIADNA has considered them.

	Remote Pilot 	GA pilot 	ATCOs 
Workload (HP1.2)	🔴 It was identified an increase in the workload due to the interaction with ATC and other aircraft and to the time to locate other aircraft in the ADS-B display.	🔴 Identifying and monitoring the RPAS visually was more demanding than with other aircraft due to the small size.	🔴 Errors in the communications, take-off and landing procedures different to standard ones and the small size of the RPAS that made difficult to track it visually increased the effort of the controllers and could change the working method to rely more on radar.
Human error (HP1.3)	🔴 The interaction with ATC, in particular the communications, increased the possibility to make an error. Remote pilots recognised that disregarded other important tasks.	○ N/A	○ N/A
User interface acceptability (HP2.3)	🟢 ADS-B information was found very useful and easy to understand with a low effort demand.	🟢	N/A
Task balance within team (HP3.2)	🔴 All the tasks, communications with ATC and external pilot together with piloting duties, were gathered on the same person.	○ N/A	○ N/A
Communication burden and Situational Awareness (HP3.3)	🔴 Communication burden increased due to the interaction with ATC. On the other hand, ADS-B display was	🟢 Situational awareness was increased thanks to ADS-B information provided in the cockpit.	○ Situational awareness was maintained although they dedicated more time to the RPAS than usually

	useful to locate other surrounding traffics although at the same time and with the current RPAS task balance within team, the remote pilot considered that it could be a distraction.		to other aircraft, however communications were more demanding due to the lack of background of the remote pilot.
Technology acceptance (HP4.1)	All the actors accepted the introduction of RPAS in ATC environments although all of them demanded more training and clear regulation as a necessary previous step.		
Change in competence requirements (HP4.2)	To ensure a safe integration in non-segregated airspace it has been proved that a higher knowledge on ATC procedures and communications is required.	N/A	ARIADNA has demonstrated that controllers need to have a background on RPAS performances and specific emergency and take-off/landing procedures.
Training costs (HP4.4)	It has been concluded that the training on ATC procedures and communications need to be increased.	Although not a key issue, to include RPAS performance notions in the training would be desirable.	More training on RPAs performances, operating methods (take-off, landing, loitering or mission) and specific emergency procedures is highly required.

Table 5.3-2: Human Performance results obtained by ARIADNA

5.3.2 Impact on Safety, Capacity and Human Factors

As mentioned before in the document, current regulatory framework forced to select a different aerodrome, thus reducing the representativeness of the results, especially for capacity. ARIADNA has mainly focused on its assessment on safety and human factor aspects, drafting very interesting conclusions.

Safety

- Increase pilots´ Situational Awareness: ARIADNA has proved that a Ground Based Situational Awareness System (GBSAS) based on ADS-B is feasible, operational and technical, to be integrated in RPAS of small size as well as in manned aircraft. It has demonstrated to increase the situational awareness of remote and manned aircraft pilots, providing them with own and surrounding traffic information, with a low impact on their workload.
- Task balance within RPAS team (HP3.2): Concentrating RPAS piloting tasks and ATC interaction in the same person may have a negative impact on safety since the remote pilot could miss some important duties. The VIEWER RPAS staff configuration, something common in many RPAS, is one remote pilot and the external pilot (safety pilot), who can take control of the RPA in VLOS conditions and distance (airfield operation). They have an internal

radio to exchange information battery level, airspeed, height, course, and so on. In these exercises, the remote pilot was in charge of the communications with ATC but the external pilot wasn´t in that frequency, what could reduce the number of internal communications between remote and external pilots.

- Integrate, homogenize and publish RPAS take-off and landing procedures: the coexistence of RPAS take-off and landing procedures different to manned aircraft ones is a challenge for controllers and pilots. If it is more constraining to follow standard procedures, RPAS designed procedures should be integrated, homogenized and published with standard procedures.
- Publish and increase knowledge of RPAS specific emergency procedures: An RPAS has several procedures in case of certain emergencies such as communication loss, GPS loss, battery low, etc., which are very specific of its operation and are not known by manned aircraft pilots and controllers. For these exercises, these procedures were explained to ATCOs and manned aircraft pilot, so they could predict the RPAS behaviour in case of these emergencies.

Since safety is tightly linked with capacity, (if something impacts negatively on safety, usually capacity is decreased to maintain safety levels) the conclusions pointed above can serve as potential indicators for capacity.

Human Factors

- Increase knowledge of controllers´ on RPAS performances: currently controllers are not familiar with the performances of the RPAS and the introduction of these aircraft in airport environments may change their working method. For instance, controllers stated the difficulty to follow visually the RPAS compared to manned aircraft, this may imply to change how they work to rely more on radar or other support tools than in looking out of the window.
- Intensify the background of remote pilots on ATC procedures and communications: currently the regulation to train remote pilots only includes a short introduction to communications and ATC procedures, but having seen the errors made it would be suggested to increase the training on these subjects, in line with commercial pilots, to ensure a safe integration of RPAS in more complex environments.

5.3.3 Description of assessment methodology

The validation approach defined in ARIADNA will rely on two main pillars:

- The human factor assessment of the tasks performed by flight crews (of both manned aircraft and RPAS) and ATCOs;
- The assessment of navigation procedure adaptation to RPAS flight performances and airspace limitations based on trajectory analysis.

Both aspects will be part of the validation of the feasibility of this RPAS to follow standard procedures.

For validating this, ARIADNA has obtained qualitative and quantitative results from the following sources:

- Qualitative data has been collected from RPs, ATCOs and manned aircraft pilot after the flight campaign by means of:
    - Debriefing sessions that were conducted after the trials to capture the feedback from the different actors;
    - Individual ad-hoc questionnaires. Different questionnaires were developed for each actor. Since the controller was dedicated to the exercise with no more flights under its responsibility it was disregarded to assess workload or situational awareness with standard questionnaires.
- Quantitative data has been obtained by comparing the following sources of flight racks:
    - Flight tracks from ADS-B and PSR. The system merges both sources of data in the same interface;

  - VIEWER telemetry.

5.3.4 Results impacting regulation and standardisation initiatives

The following lessons learnt can be derived from the experience gained during the project, as indicated in ref. [2]:

- The development of a civil regulatory framework for RPAS is fortunately increasing pace in Spain (and globally). A (interim) **regulation for the civil use of RPAS** in Spain was issued in July 2014, which fully impacted the ARIADNA project.
- However, the **current civil focus is on small RPAS** (< 25 Kg) (particularly in VLOS → easier integration) whereas for **larger ones** (> 25 Kg) experience is being built on a **"case by case basis"**.
- **ARIADNA** has been a good opportunity for Spanish **CAA to increase their experience** beyond the small RPAS (where CAA has been gaining a significantly more extensive experience). Unfortunately this **process took significantly longer** than initially expected.
- **RPAS segment between "small"** (< 25 Kg) and **"large"** (e.g. MALE category) can be considered, in relative terms, the **most difficult one** to address from the **airworthiness certification** and **operations approval** standpoints, partly due to the **reduced size, weight and power (SWaP)** and **lack of suitable aeronautically qualified equipment**.
- **Frequencies use authorisation is major issue**. Despite WRC-12 conclusions, there is **no implementation** (at least in Spain) of **dedicated RPAS C2 bands**. Besides, for the WRC "allocated" 5030–5091 MHz band there is a lack of available data links suitable for not large RPAS.
- **Qualification of civil remote pilots,** above "small" RPAS, is still **not well defined** in Spain. On the **military** side, **licensing** is **only for the military**.
- Regarding **operation authorisations**:
  - Authorisations are to operate in VLOS (only civil) or in **segregated airspace**. The latter is the **only choice** for an operation of interest with RPAS above "small".
  - But **segregation is a very limited resource**. Fortunately some (few) new test ranges with segregable airspace have been approved or are under way.
  - However, to **operate in an aerodrome** (of interest for an ATM project) currently forces to select a **military air base** (at least in Spain) → **Complex authorisations process** → **taking significantly longer** than initially planned (it would be out of civil scope of the project).
- Even though the demo campaign has not been yet performed, internal testing has already shown the potential of **ADS-B to increase safety of RPAS operations**:
  - It **can be used even by "small" RPAS** (Viewer in ARIADNA is also equipped with ADS-B and already successfully tested) → not only increases situational awareness of remote pilots but **makes "small" RPA "visible" to manned aircraft pilots.**
  - ADS-B not only provides a **situational awareness** of flight crews (both in manned A/C and RPAS) of the **surrounding traffic** (equipped with transponder) ... but it also a useful tool for remote pilots to have **basic data information in case telemetry is lost** (as long as the RPA is within the range of the ADS-B receiver)

From above lessons learnt, and as indicated in ref. [2], the following main recommendations are derived:

- Projects like these RPAS demos are definitely essential for the **increase of stakeholders' familiarization**, especially **Aviation Authorities**. Thus, it is advisable to **continue this kind of activities**.

- **Coordination among civil and military aviation authorities** is a key aspect to easy RPAS industry and operators efforts, as well as to facilitate the maturation of the **regulatory framework.**
- It is urgent that **authorities address properly the "difficult segment" of RPAS above "small"** (up MALE?).
- It is urgent to **implement decision on dedicated RPAS C2 bands** ... but also considering the **SWaP constraints** of the "not large" RPAS segment (e.g. the 5030–5091 MHz may not be suitable for airborne terminals for that segment)
- A **civil flight crew licensing (FCL) scheme for RPAS** above "small" (<25 Kg) is required and should be established **at EU level**.
- **Further R&D on ADS-B**, especially for Light RPAS (and in particular for "small" RPAS) is recommended: miniaturization will make possible to equip even the smallest RPA and make them "visible" to any other airspace user.
- Even if **radar data from an ATC system** (like SACTA) is not expected to be shared with all operators, it could be an **important current tool for specific operators** (e.g. State flights) with RPS at an aerodrome (to be fed by ATC radar data), while for the rest of operators at a **dedicated flight field surveillance data radar** (e.g. from a PSR like that equipping the ATLAS centre) might definitely become a **fundamental tool to ensure safe operations** within segregated airspace (to ensure RPAS are tracked and enable situational awareness to activate flight termination in case of risk of the RPA flying away the airspace limits). Then, the use of these radar solutions coupled with ADS-B data can lead to **short-term ground-based situational awareness systems**.

5.4 Analysis of Exercises Results

OBJ-RPAS09-001 Validate the feasibility of a "PinS"-like approach procedure based on SBAS (EGNOS) to be used by a rotary wing RPAS.

The RPAS can fly the designed procedure with acceptable performances from a safety and airport/airspace capacity viewpoint.

ARIADNA has demonstrated that rotary wing RPAS can follow Point in Space (PinS) standard procedures adapted to the performances of the RPAS using SBAS (EGNOS) for this phase of flight.

It must be noted that the RPAS used in this exercise will probably not be integrated in aerodromes with commercial traffic, however it was a good test bench to demonstrate the feasibility of these new users to execute standard procedures adapted to lower performances. Taking into account the feasibility of this particular RPAS to comply with this procedure, larger rotary wing RPAS, likely candidates to operate from civil aerodromes, will surely be able to execute PinS-like approach procedures.

RPAS pilots are not used to standard airport approach procedures, so they design particular approach trajectories depending on the mission and weather conditions. However, RPAS pilots seemed to be comfortable with the operation and the RPAS could follow the trajectories quite well, so the implementation of this approach procedure for rotary wing RPAS was seen feasible by RPAS crew. Nevertheless, it would be of great importance to design more specific PinS approaches for RPAS according to their performances. Hence, more specific PinS approach procedures depending on RPAS performances could be developed for different RPAS weights and sizes.

ARIADNA consortium has represented ADS-B data to assess the compliance of the RPAS with the designed procedure. Here below, snapshots of the horizontal and vertical profiles of the procedure, as designed in the navigation chart, are depicted.

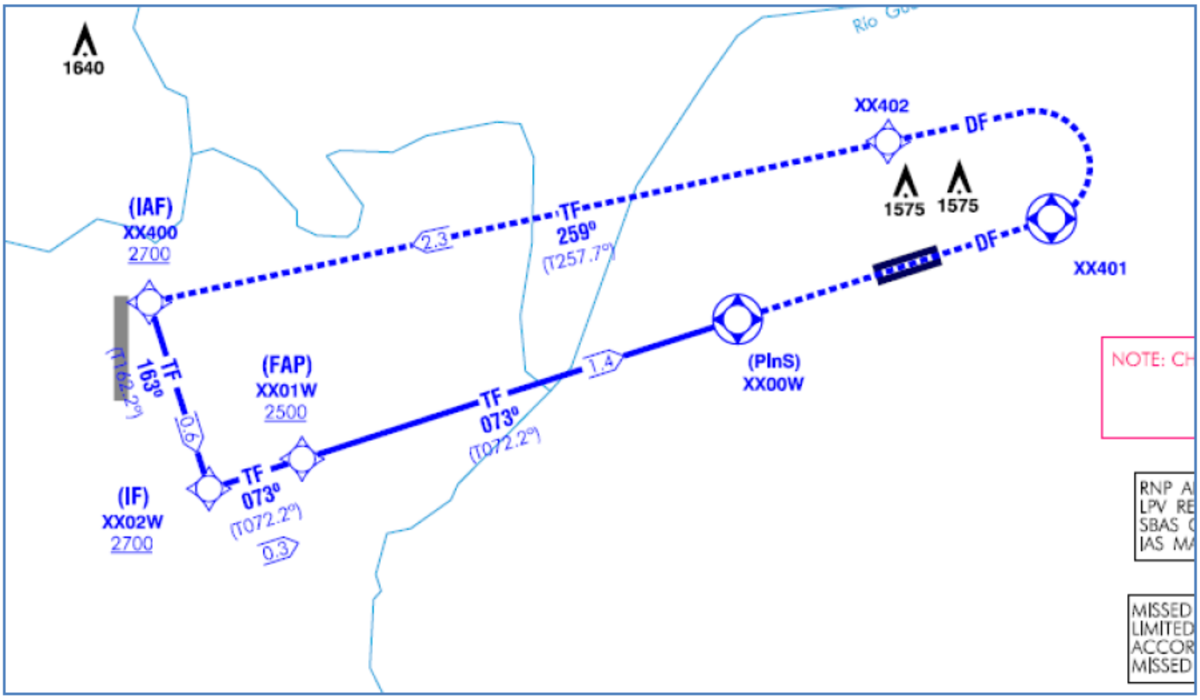


Figure 5.4-1 Nominal horizontal profile of the PinS procedure

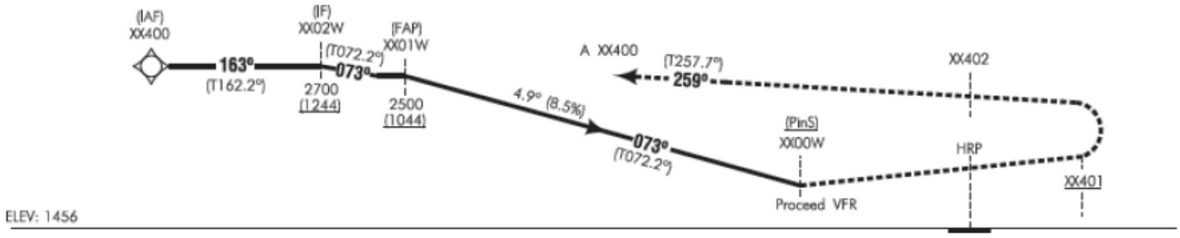


Figure 5.4-2 Nominal vertical profile of the PinS procedure

Comparing the nominal procedure with ADS-B information, it can be concluded that **the RPAS is able to follow the PinS-like approach procedure without deviations** as it can be appreciated in the figures below.

First figure represents on 3D an example of the nominal PinS approach procedure and the waypoints defined in the navigation chart. It can be seen that the aircraft followed the procedure correctly laterally and also vertically.

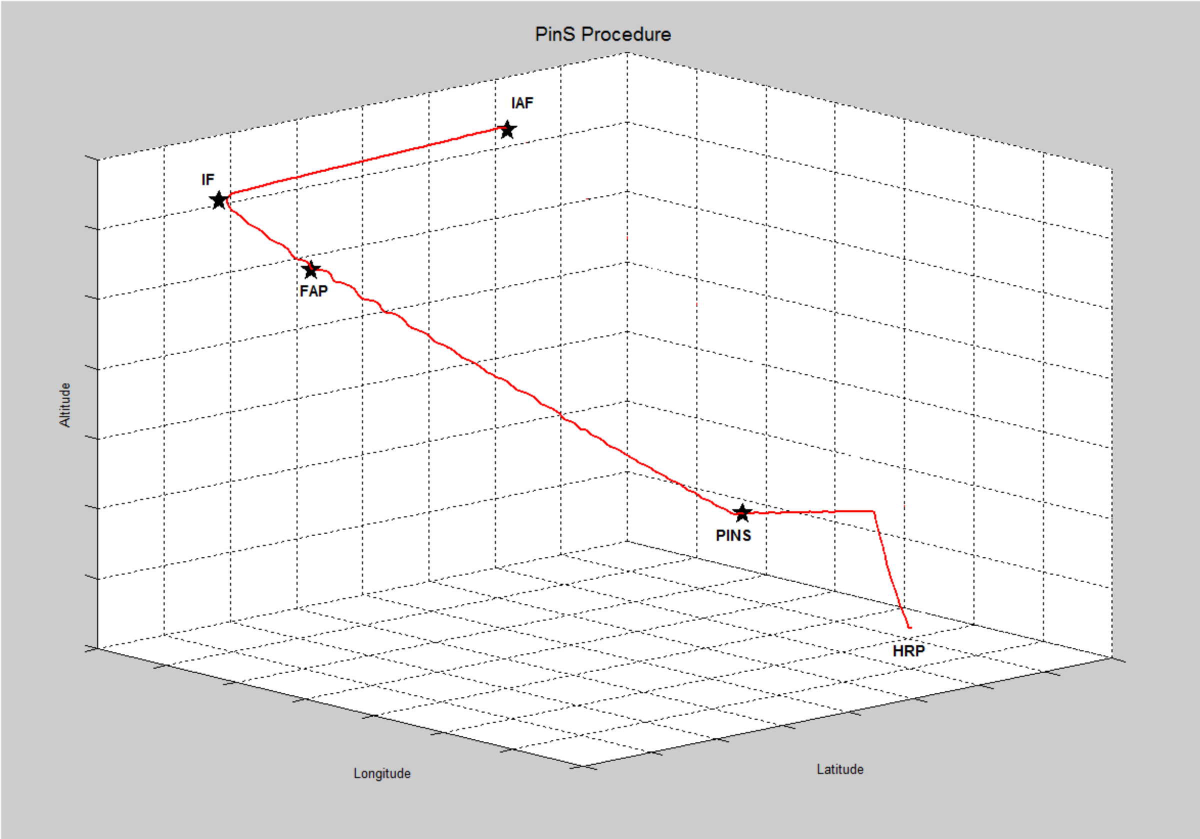


Figure 5.4-3 - Trajectory executed for the nominal PinS procedure

The execution of the missed approach scenario, illustrated in the following figure, was equally successfully since after the PinS waypoint the RPAS followed correctly the procedure back to the IAF point.

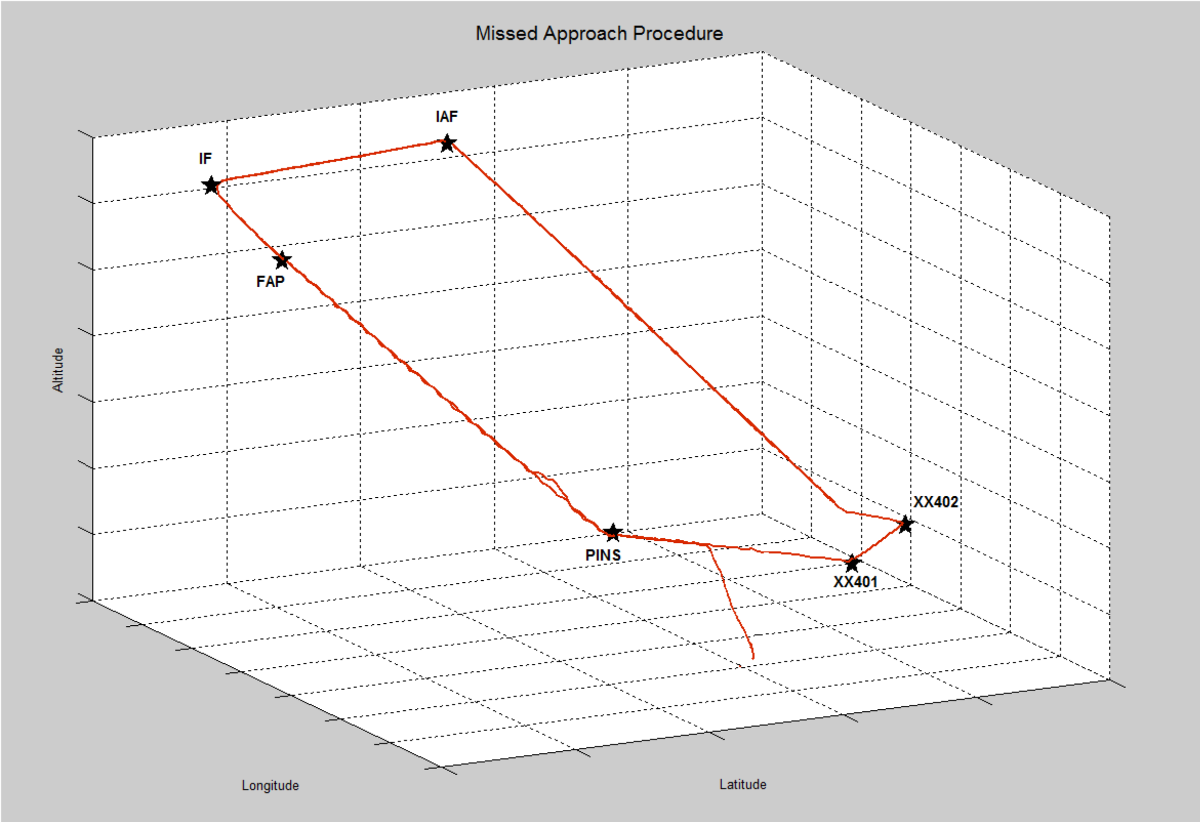


Figure 5.4-4 Trajectory executed for the missed approach PinS procedure

The ability of the RPAS to follow the designed manoeuver, above depicted from the ADS-B information, is also confirmed by the analysis of the data registered by the GNSS receiver during the series of flights in the context of Exercise 1. Navigation System Error (NSE) values kept within boundaries according to ICAO prescriptions for the whole series. Also Flight Technical Error FTE was acceptable for all phases of the procedure, keeping the aircraft within the margins of linear scale deflection during “ILS look-alike” angular guidance for the final approach.

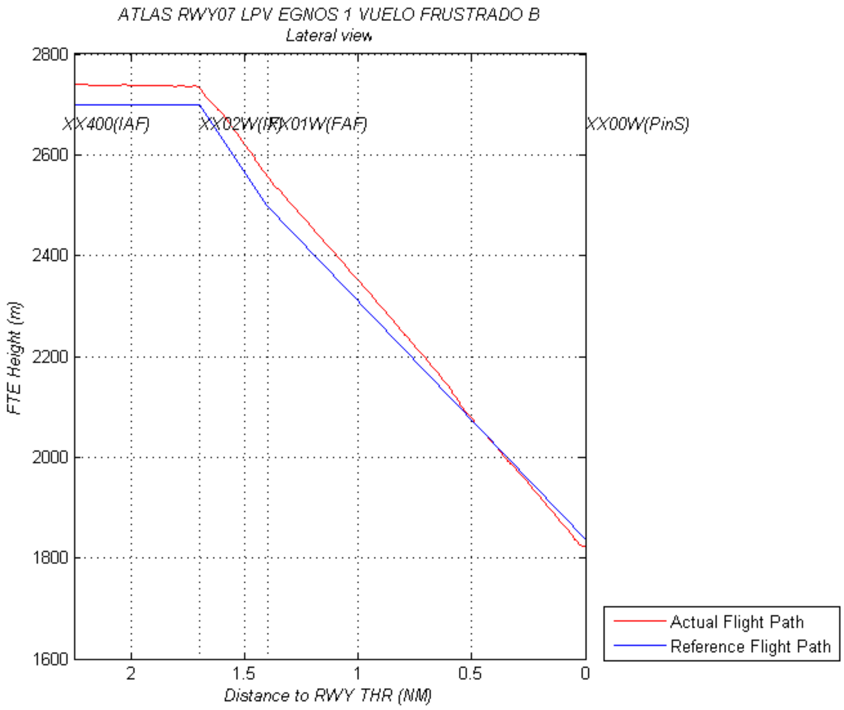


Figure 5.4-5 Vertical Profile vs Reference during Final App

It needs to be considered that the adaptation of PinS approach procedure to RPAS included a 'visual segment' from the PinS waypoint when both the RPA and the RPS are in "visual sight", meaning that the RPA is visible from ground through naked eye and the RPS is visible from the camera on board the RPA.

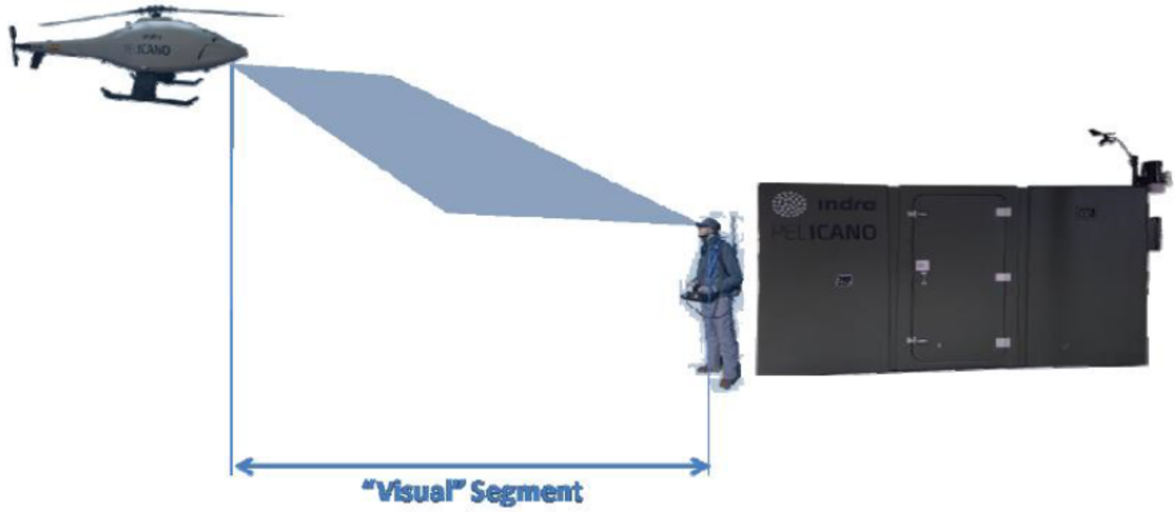


Figure 5.4-5 PinS visual segment procedure

However, the RPAS crew highlighted that it was very difficult to see the aircraft at the required point located less than 0.6 NM (1 Km) away from the aerodrome. During the different flights, the remote pilots identified the aircraft at around 800 meters from the RPS, this is 0.4 NM. Nevertheless, at this point the external pilot wasn´t able to determine the attitude of the RPAS. It was at around 500 meters, when the external pilot was able to identify the attitude of the RPAS, which is essential in case there is a need to take manual control.

On the other hand, the image from on-board electro-optic systems received in the RPS allowed identifying the runway and the RPS before arriving to the PinS waypoint. It was not the same with the external pilot, since it was not until the RPAS was at around 500 meters from the RPS when the external pilot was sharply visible.

The adapted procedure tested in ARIADNA should be reworked in the future depending on on-board electro-optic systems performances. Given the human eye capabilities demonstrated by ARIADNA, if the procedure is to be maintained with the double visual check, RPAS crew on ground should be provided with support means to identify the RPAS and its attitude.

OBJ-RPAS09-002 Assess the impact that the performance of SBAS approaches by RPAS has on runway throughput and airport operations.

The time required by a rotary wing (RW) RPA (with similar performances to the RW RPAS) to perform the approach and landing manoeuvres does not negatively affect the aerodrome operations.

In this exercise it has been proved that the time needed by this specific RPAS to execute the PinS-like approach procedure is over 11 minutes in a nominal scenario and 25 minutes when a missed approach is executed. Taking into account these values, and according to the categorization of airports established by C02 in SESAR, the aerodromes with medium and high capacity, those with more than 50 movements per hour during peak hours could be impacted by the execution of these procedures by similar RPAS. Nevertheless, low capacity airports (less than 30 operations by hour during peak hours) would be the only ones which would not be affected.

Potential	Not impact

	Impact	
Low capacity airport		x
Medium capacity airport	x	
High capacity airport	x	

Although it exist a potential risk of impact in the two last types of aerodromes, it has to be noted that the SBAS approach followed by an RPAS could be executed in those cases if they were not at their peak hours.

The low performances in terms of speed and rate of descend would be the main factor impacting other operations in the airport but it would be manageable in low density and complexity airports. It is a similar effect as when nowadays it is put a helicopter or piston aircraft among jets.

In addition, it must be understood that so far these new stakeholders, and in particular the rotary wing RPAS used in ARIADNA, need from ground staff to get into the runway with the RPAS for take-off and landing manoeuvers since it is not able to taxi on its own. This time is not considered in the analysis above, but it is a time that the runway needs to be closed in order to ensure safety of the operators.

OBJ-RPAS09-003 Assess the flight crew's situational awareness and related safety impact due to the use of ADS-B (for RPAS of different sizes and categories, and manned aircraft) and ATC radar (for an RPAS with operations in an aerodrome where such data could be available to an operator authorised to use them).

Pilots of all aircraft involved in the demonstration exercise (both RPAS and manned aircraft) can effectively track with ADS-B the other involved aircraft. In the case of manned aircraft, an increment of pilot's situational awareness is gained with respect to the current situation (pilot can effectively track RPAS of different characteristics, e.g. sizes and performances).

As mentioned before in this document, the change of location to execute the trials had also an impact on the scope of this objective. Since there was not ATC radar services in the final aerodrome used, it was not possible to provide the RPAS crew with this information, so that both pilots relayed only on ADS-B data.

The manned aircraft pilot and the remote pilot found the ADS-B display very useful to locate other surrounding traffics but at the same time and with the current RPAS crew distribution, the remote pilot considered that it could be a distraction.

It must be noted that the remote pilot had experience with the information provided by ADS-B displays, what made easier his familiarization with the system. On the other hand, the manned aircraft pilot didn´t have any expertise with similar systems.

Both pilots considered that the ADS-B system helped them to improve their situational awareness although they used other means to locate each other. Thus, while the manned aircraft pilot looked out of the window to know where the RPAS was, the remote pilot used the ATC progress reports to understand the position and attitude of the manned aircraft.

When asked by the most useful means to locate each other the answers were:

	ADS-B	Other Means
General Aviation pilot	X	
Remote pilot	X	Progress reports on frequency

Table 5.4-1: Most useful means to find other aircraft

The reason why the general aviation (GA) pilot preferred ADS-B system is that, due to the size of the RPAS used in this demonstration, it was really hard for him to find it by looking out of the window.

The answer of the remote pilot can be understood by analysing his perception of the following statements that shows the perception of having paying less attention to other tasks.

	Remote Pilot	GA pilot
I needed to much time to find the location of the other aircraft	NO	NO
I have disregarded other important tasks	YES	NO
It was difficult to monitor the evolution of other traffics	NO	NO

Table 5.4-2: Pilots perception when using ADS-B display

Although the RP considered very useful the presentation of the position of the VIEWER and the manned aircraft, he relayed mainly in the 2D location. The high workload due to the multiple tasks overtaken by the RP, and the lack of training for positioning aircraft at different altitudes in the same screen appear to be the most likely reasons for this. A wrong location of own and surrounding aircraft might lead to pilot errors.

Both pilots found useful the ADS-B system in conflict situations to execute the most efficient manoeuver and to monitor the evolution of the other aircraft.

However the main source for resolving the conflicts was the provision of information and instruction of resolution manoeuvers by controllers. While both pilots found the instructions clear, precise and on time, the remote pilot found it as a distraction for other tasks. As explained in OBJ-RPAS09-005, due to the composition of VIEWER crew, the remote pilot has to cope with piloting and communication tasks. The main differences with manned aircraft pilots are: first the RP has to manage two different radios, one with ATC and one with the external pilot, and second, piloting an RPAS imply introducing commands in a computer-like interface rather than using a yoke or a stick.

The following table serves us to understand how similar the perception of both pilots during the execution of the different resolution manoeuvers tested in the exercises is. They were asked to answer for the four manoeuvres from one to three, being 3 the answer with more importance.

	Remote Pilot				GA pilot		
	Convergence	**Head-on**	**Overtaking**	**Runway incursion**	**Convergence**	**Head-on**	**Overtaking**
Closer to the other aircraft	3	2	1	1	3	3	2
Manoeuvre more difficult	3	1	1	2	1	1	1
More useful the information of surrounding traffic	3	2	2	1	3	3	3

Table 5.4-3: Pilots perception of the execution of collision avoidance manoeuvers

It can be noted that while for the remote pilot the resolution manoeuvre in the convergence trial was the most difficult, for the manned aircraft pilot it was easy as they are used to that type of manoeuvres.

OBJ-RPAS09-004 Assess ATCO's situational awareness and related safety impact in scenarios where RPAS must follow ATC advices for conflict resolution.

No unexpected trajectory or performance deviations of RPAS with respect to those requested by the ATC.

As expected, the performances of the VIEWER RPAS were very different to what ATCOs are used to. However, this did not decrease the capacity of controllers to predict the RPAS evolution. ATCOs mentioned that it would be necessary to increase the training of the controllers on the RPAs performances.

Even if the remote pilot provided progress reports correctly and on time, controllers stated that they had requested to the RPAS more progress reports than usually to manned aircraft.

In addition, controllers considered that the radar monitoring time was higher with the RPAS than with manned aircraft, mainly due to the unfamiliarity with this type of users. Controllers also highlighted that the RPAS reaction time was slightly higher compared to manned aircraft; even if it would imply a risk they considered it could be manageable.

Nevertheless, it is important to mention, that according to ATCOs´ opinion, they don´t see neither feasible nor necessary to integrate RPAS of this low performances in airports with manned aviation. As they don´t need a proper runway to operate from, they could work outside airports. Bearing this in mind, all the conclusions regarding the performances of the RPAS used in ARIADNA need to be taken as particular to the exercise, being expected that the RPAS likely to be integrated at airports will have greater performances.

Controllers´ situational awareness was maintained although they dedicated more time to the RPAS than usually to other aircraft. For the integration of these stakeholders in a more complex environment it would be needed specific training for the ATCOs in order to maintain current level of situational awareness and safety, with the same number of movements.

Controllers did not find unexpected trajectory deviations, something that is supported by the analysis of trajectory information from radar and RPAS telemetry. In a quantitative way, it has been proved that no unexpected trajectory deviations of the RPAS with respect to those requested by the ATC by comparing the trajectories represented in the ATC tower, that one defined by the ADS-B along with the primary radar, and the trajectory represented in the RPS, that one showed by the RPAS telemetry.

For such comparison of trajectories, it has been necessary to adequate data received from different sources due to the differences in data cadence; ADS-B/radar data has one sample per second while telemetry has up to ten samples per second. Besides the number of samples, it has been homogenized in the geo-reference system used, to Cartesian coordinates.

In the next figures it has been represented in three dimensions radar tracks (red) and telemetry data (blue).

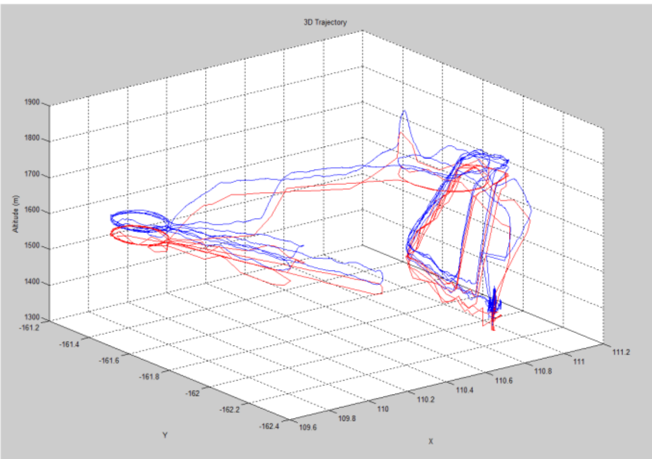


Figure 5.4-6 3D comparison of ADSB/primary radar and telemetry

Next it is presented separately the analysis of lateral and vertical profiles.

Studying in detail the evolution of the lateral divergence between both trajectories, it has been appreciated that the difference found is minimum. The following pictures illustrate the comparison in the horizontal plane of trajectories from ADS-B/radar (red) and telemetry (blue), together with the evolution of the separation between both for each flight of EXE-RPAS.09-D-02. The graph showing the evolution of the lateral difference presents not only the obtained values but also the trend line. The trend line is useful to appreciate that the difference on average is within acceptable limits, around 0.02 NM for all the scenarios.

However, controllers highlighted that they currently provide separation between aircraft visually, using radar or ADS-B information to improve situational awareness but not to separate traffic. The small size of the RPAS used in ARIADNA makes almost impossible to safely continue applying these procedures.

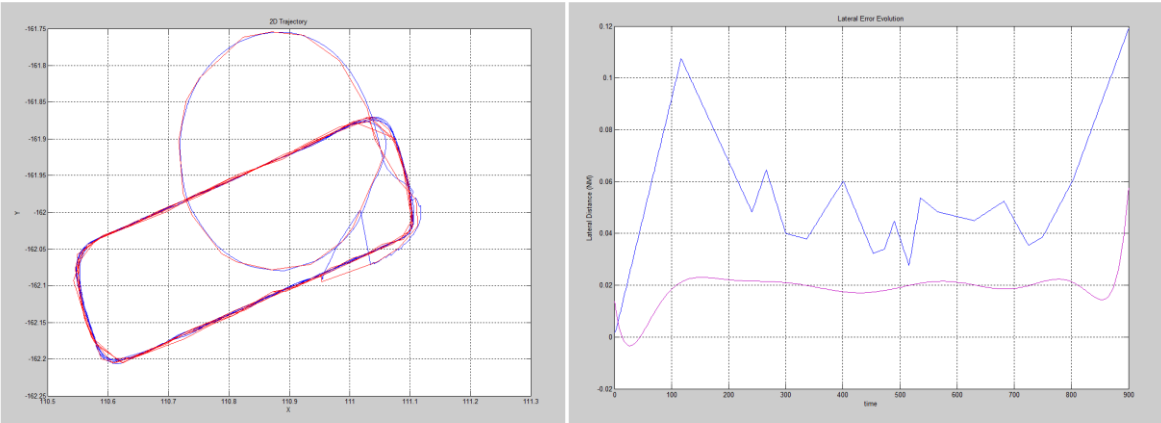


Figure 5.4-7 Trajectory comparison (RADAR/ADS-B vs. Telemetry) for runway incursion scenario

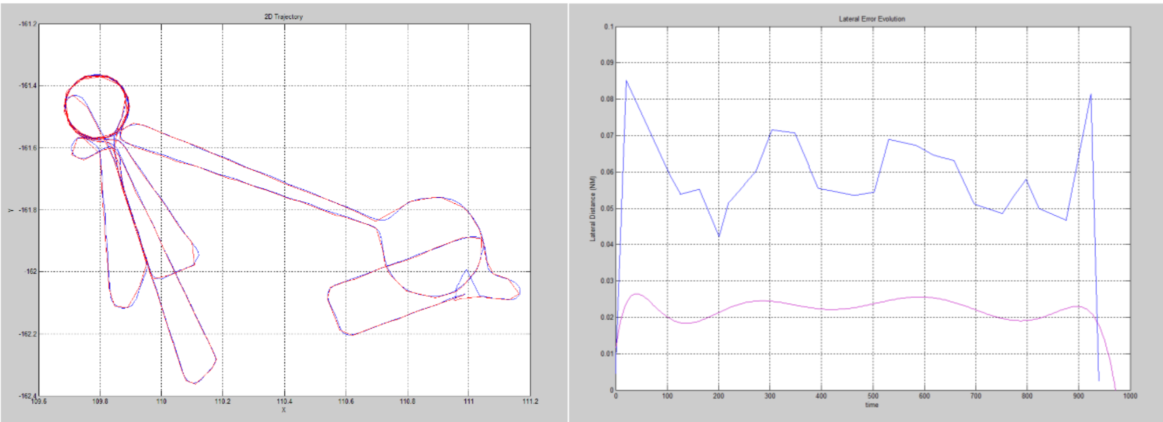


Figure 5.4-8 Lateral comparison (RADAR/ADS-B vs. Telemetry) for convergence scenario

On the vertical plane, the difference between both trajectories is studied in feet. As it can be seen from the figures below, the divergences were more significant during the highest phases where altitude changes are sufficient pronounced, coinciding usually with the end of the climb or the descend phase. ADS-B accuracy, 25 feet, is better than some secondary radar, 100 feet. However, the data cadence is lower than telemetry what makes more difficult to show those changes emphasized by the RPAS speed.

The following graphs illustrate the evolution of the difference in altitude between both trajectories, being the lowest vertical differences produced when the RPAS was level off.

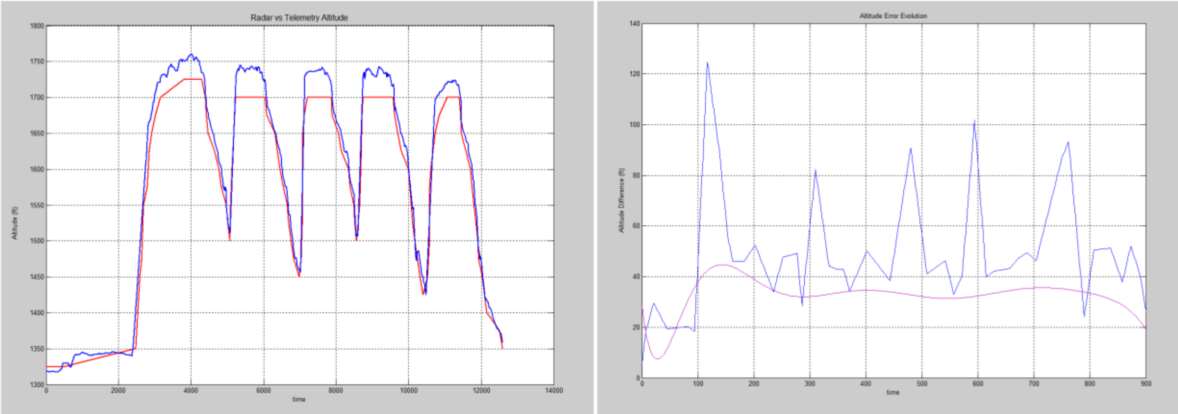


Figure 5.4-9 - Vertical comparison (RADAR/ADS-B vs. Telemetry) for runway incursion scenario

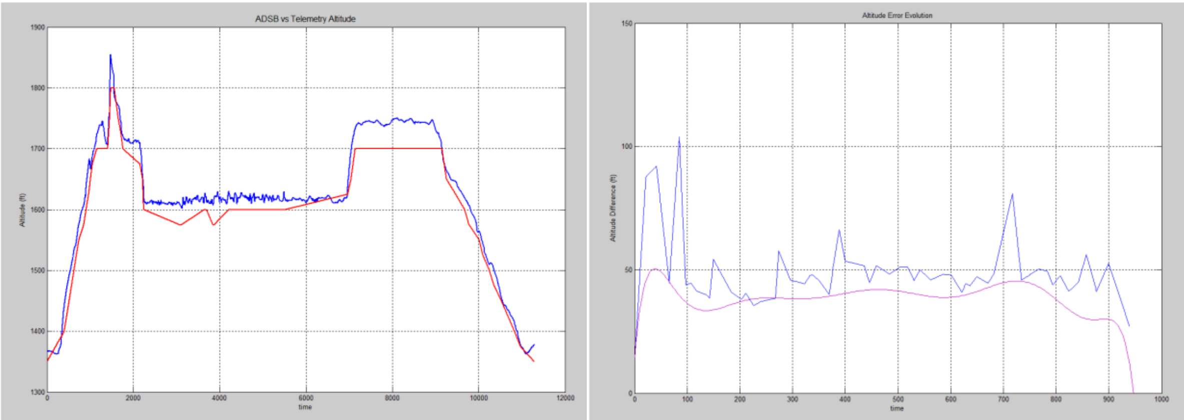


Figure 5.4-10 - Vertical comparison (RADAR/ADS-B vs. Telemetry) for convergence scenario

The vertical difference on average is 27 feet which is within limits of the error range of the manned aircraft transponders, this is +/- 100 feet. The highest value of vertical divergence is 118 feet, over 36 meters. Taking into account that the tolerance of an ATC radar screen in non RVSM airspace is +/- 300 feet, Ref [9], and the maximum discrepancy between the altimeter and the transponder is 125 ft as regulated by EASA, the difference of 27 ft found during the ARIADNA exercises is acceptable for the operation.

This quantitative analysis supports the controllers´ perception that the RPAS didn´t deviate from the expected trajectories and also highlights the negligible difference between the trajectory information presented in the controller radar screen and the trajectory depicted in the Remote Pilot Station.

ARIADNA consortium has also analysed the separation between the RPAS and the manned aircraft during the execution of conflict resolution manoeuvers instructed by ATC. For instance, during the convergence scenario, it was simulated that when the manned aircraft was in final leg to land, an RPAS invaded the runway axis, so that the controller had to instruct the manned aircraft to miss the approach by turning and the same for the RPAS.

The representation of the trajectories followed in this exercise has been included below as an example of the feasibility of the RPAS to comply with ATC instructions. In red it is represented the RPAS trajectory and in blue the manned aircraft one.

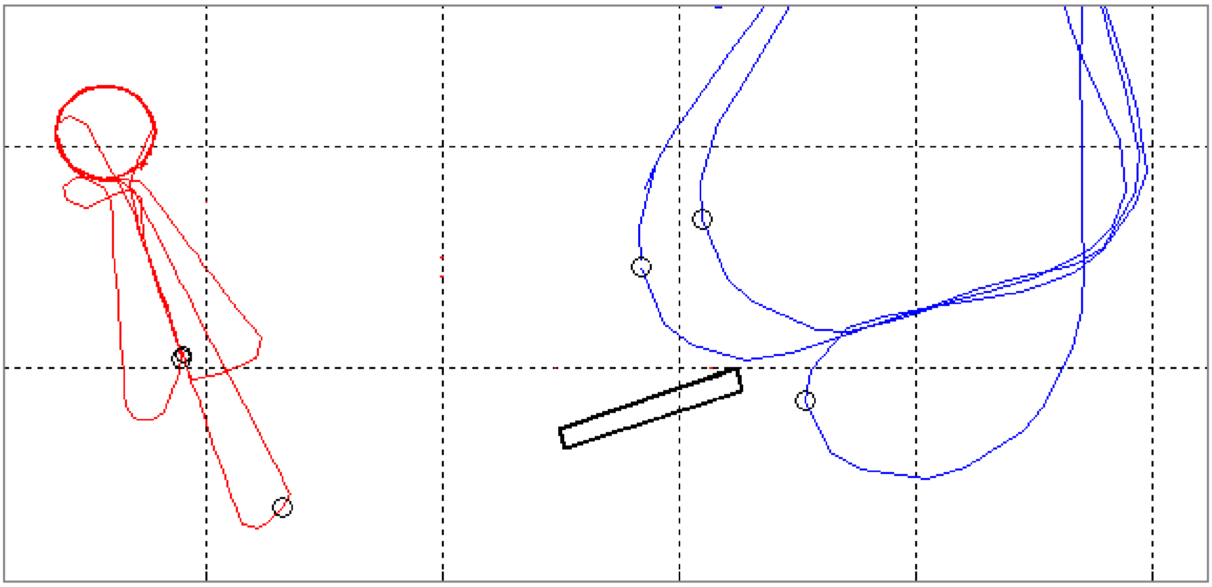


Figure 5.4-11 Aircraft trajectories during the execution of conflict resolution manoeuvers in case of convergence

As it can be observed in the figures, the RPAS executed the conflict resolution manoeuvers with the same precision as the manned aircraft, independently than the manoeuver was to one side or the other. The minimum separation found between the two aircraft is 0.9 NM; however it needs to be known that the excise was executed maintaining a safety buffer of 500 feet between the altitudes of both aircraft.

In aerodrome control, when both aircraft are on visual control by ATC, this lateral separation is found by controllers acceptable for safety of the operations.

OBJ-RPAS09-005 Assess the safety impact associated to the communications between the RPAS flight crews and ATCOs.

No R/T communication issues are reported by RPAS flight crews or ATCOs that can derive in a safety hazard.

Mistakes and errors in ATC communications were few and did not impact on safety of the operations as the environment was dedicated to these trials and so the complexity was very low. Although the RP did not have a standard pilot training, thanks to his general aviation background, communications were fluent and the phraseology mostly adhered to standards.

The most frequent errors were the lack of collation of instructions and the lack of authorisations requests.

Controllers found the communications different compared to their experience with manned aviation, although they considered it could be a manageable risk. This would be mitigated by increasing the training of the remote pilots on ATC procedures and phraseology.

Controllers found the remote pilot read-back time slightly higher compared to manned aircraft pilots.

The VIEWER crew was composed of an external pilot and a remote one. This last person considered that the workload increased during the operation compared to previous experience, since the interaction with ATC and other manned aircraft was highly demanding.

Although the remote pilot didn´t mix the two radios he operated, one for ATC and another to communicate with the external pilot, operating two frequencies at a time could be a source of errors in more complex environments were more users are using the frequency.

OBJ-RPAS09-006 Demonstrate that RPAS operations at aerodromes and associated airspace of low to medium density and complexity (with ATZ segregation during the RPAS operations) do not cause excessive stress of ATCOs and remote pilots.

The perceived stress by flight crews and ATCOs is within safe levels as qualitatively reported during de-briefing sessions and post-exercise questionnaires.

Due to the size of the RPAS and the performances of the model used in this exercise, ATCOs found difficult to monitor and predict the evolution of the RPAS in airport environment. Controllers are used to follow visually those flight phases closer to the airport, but for the RPAs used in ARIADNA, this distance is reduced quite considerably. However, this was mitigated by equipping the RPAS and the tower with ADS-B, although it would change slightly the current working method by looking out of the window.

Figure 5.4-12 Control services

Controllers also stated that carrying the RPAS lights would help them find it in the sky and monitor its progress and attitude.

On top of this, controllers highlighted that current RPAS take-off and landing procedures might be difficult to manage in a mixed environment due to the differences with the procedures for manned aircraft. The fact that for take-off and landing manoeuvers the RPAS requests part of the team to walk into the runway was a stressful factor for the controller, as at the same time the manned aircraft was flying in the area.

In addition, the controllers highlighted that some instructions were not followed correctly, for instance finding that the RCF point was so closed to the runway that orbits in downwind invaded the runway.

All these aspects made for the controllers more demanding and stressful to interact with the RPAS compared to their experience with manned aviation. However, since the aerodrome and surrounding airspace were dedicated for this exercise the stress and workload of the controllers was acceptable. It wouldn´t be the case in a more complex environment.

Contrary to the perception of the controllers, the remote pilot considered that ATC instructions were followed correctly, having found all the indications easy to perform. The fact that the aerodrome was closed for these operations was a facilitator.

The remote pilot had some difficulties with ATC communications, although he considered as a manageable risk. This might be due to the little experience on controlled environments. The communication with the controllers, the adherence to ATC instructions and the monitoring of the manned aircraft location, summed to the piloting tasks increased the level of stress of the remote pilot. It would have been difficult for one person to manage the RPAS in a more complex ATC environment.

For the manned aircraft pilot, it was also more demanding to interact with the RPAS since it was difficult to find it visually.

Summarising, **the stress of all the actors, pilots and controllers, increased compared to their current basis.** This increment is manageable as far as it is done in a segregated environment similar in complexity to this. For the complete integration in a non-segregated environment, the training of ATCOs and remote pilots should be improved in order to ensure that the interaction allows maintaining the levels of capacity.

5.4.1 Unexpected Behaviours/Results

No unexpected behaviours/results were identified during validation exercises preparation, execution and analysis.

5.5 Confidence in Results of Demonstration Exercises

5.5.1 Quality of Demonstration Exercises Results

The execution of the project in an aerodrome closed for these flights has prevented to analyse the impact of integrating RPAS in a real operational environment. However, this has been considered an excellent way to soften the familiarisation between RPAS pilots and ATCOs before a complete integration in more complex environments.

5.5.2 Significance of Demonstration Exercises Results

The change of location to execute the trials, from a low density airport to a RPAS dedicated aerodrome, has reduced the expected significance of the project. It does not imply the same level of real interaction to operate in a shared airfield than in one closed for these operations. To increase the operational realism of the flights, controlled airspace and procedures were simulated.

On the contrary, the fact to have a dedicated aerodrome for the RPAs trials made possible to increase the statistical significance since a larger number of flights were executed thanks to the possibility to have a temporary segregated area from the rest of air traffic.

5.5.3 Conclusions and recommendations

This section presents the main conclusions and recommendations found by ARIADNA. They are particular for the type of exercises and RPAS used within the project. A set of more general conclusions and recommendations aimed at supporting the investigation of key aspects in the integration of RPAS in non-segregated airspace is enclosed in section 7.

As a general comment, it must be understood that the conclusions drafted in ARIADNA project, and exposed below, are based on the experience with the specific RPAS used during the demonstration flights. It is important to remark this fact, due to the high variability in RPAS performances that exists nowadays. The conclusions and recommendations included in this section should be understood as applicable when using this concrete RPAS and only could be extrapolated to RPAS with similar performances.

Remote pilot situational awareness: ARIADNA has proved the feasibility of a Ground Based Situational Awareness System (GBSAS) solution to provide remote pilots with surrounding traffic information based on ADS-B data. This solution does not depend on other ground systems as other solutions based on radar information. The downside of this solution is that it is dependent on collaborative aircraft, since only those aircraft equipped with ADS-B out systems will be presented in the remote pilot station.

Communications: It has been demonstrated that RPAS pilots has not enough training in ATC communications and phraseology in order to ensure a safe integration in non-segregated airspace. It would be necessary to put the training of the remote pilots at a similar level than commercial pilots, especially if it is likely that they will operate in ATC environments. Hence, it would be of help to execute simulation training with ATC during the courses of RPAS pilots. This would be of much interest for those who obtain the authorization without any aviation background, which is the case of many RPAS operators in these days.

Workload balance within the RPAS team: current team structures of the RPAS used in this project and many other RPAS operators concentrate different tasks and responsibilities in one person, the remote pilot. Integrating RPAS in non-segregated airspace introduces new tasks and responsibilities, for this reason, RPAS operators need to balance the new workload among the team. In cases like the RPAS used in ARIADNA, it might be necessary to incorporate a new member to the team in order to cope with ATC interaction and piloting tasks in safe manner.

Airport working method: Controllers in airport environment relies mainly on visual monitoring, especially in the take-off and approach phases. The integration of RPAS of small size would change this, since they are very difficult to visualize. This would be more compromising in airports without radar coverage.

RPAS specific emergency procedures: The real emergency procedures established for RPAS are not familiar for aviation community and they are not designed to follow ATC instructions. In case of emergencies, the RPAS execute some manoeuvres which are predefined, so it would be of interest for further studies to include these procedures in the manned aviation knowledge with the agreement of ATC, manned aviation pilots and RPAS operators.

ATC units and references: The units and references used by remote pilots are generally different to the standards used in ATC. For instance, while in ATC altitudes are based on barometric sensors referenced to local or standard sea level pressure, and measured in feet or flight levels, most RPAS operators use GPS altitude, measured in meters. It is the same with speed or rate of climb/descend, in ATC the units used are knots or Mach numbers and feet per minute, while most of RPAS operators use meters per second.

Regulatory limitations: current regulation for civil RPAS operations in Spain was published in July 2014, when the project had already been designed. This has strongly affected the progress of the project, since the new process to obtain certifications and approvals for this kind of aircraft, affected the planning of the project and made more difficult to achieve the deadlines. For this reason, it was necessary to move to light RPAS (m<25 kg) where the regulation is more flexible.

Need to test integration of RPAS with more representativeness: The existence of ATLAS, as an airfield and associated airspace devoted to RPAS experimentation and already known by Spanish aviation authorities has facilitated the execution of the demonstrations. However, as indicated already in this document, the fact that the aerodrome was dedicated to the trials reduced the operational representativeness of the project. In the future, concepts and solutions for the integration of RPAS in non-segregated airspace should be executed in more representative environments involving standard ATC services and other traffic.

Feasibility to perform adapted standard procedures: Specific Point in Space (PinS) – like approach procedure needed to be designed ad-hoc for the airfield and for the RPAS taking into account its performances. Although this type of procedures is quite novel even for manned aviation, it was demonstrated to be feasible also for rotary wing RPAS. The image from the camera on-board the RPAS and transmitted to ground were of great help for the visualization of the runway and the RPAS external pilot, but the small size of the rotary wing RPAS made difficult to find it from the ground. At this moment, the external pilot has not only to identify the RPAS, but also to understand its orientation and attitude in order to continue with 'visual' segment of the PinS procedure.

6 Summary of the Communication Activities

The following are most relevant communication activities related to ARIADNA project:

- **Dissemination event: UNVEX 2014 04/03/2014, Madrid**
  Indra, ENAIRE, CRIDA - Specialized Audience
- **Dissemination event: RPAS Demo Projects Joint Workshop 24/02/2015, Brussels**
  Indra, ENAIRE, CRIDA, FADA CATEC - General Audience
- **Dissemination event: Aerodays 2015 20-23/10/2015, London**
  Indra - General Audience
- **Dissemination event: UNVEX 2016 24-25/05/2016, Madrid**
  Indra, ENAIRE, CRIDA - Specialized Audience

The following are web links to several ARIADNA published related information.

http://www.seguridadaerea.gob.es/media/4204942/140128_sesar_c_alves_rodrigues_madrid_final.pdf

http://www.infouas.com/seleccionan-dos-proyectos-espanoles-para-ensayar-la-entrada-de-uav-en-en-espacio-aereo-europeo/

http://www.defensa.com/frontend/defensa/europa-ultima-programa-investigacion-para-integracion-uavs-aereo-vn10639-vst241

http://www.infodefensa.com/es/2013/11/04/noticia-dos-proyectos-espanoles-ensayaran-como-introducir-uav-en-los-cielos-de-europa.html

http://www.auvsi.org/unmannedsystemseurope/program/dayone/regulatorycollaboration

http://www.hisdesat.es/esp/includes/descargar_adjunto.php?id=135

http://www.aerodays2015.com/wp-content/uploads/sites/20/6G-Daniel-Cobo-Vuilleumier.pdf

7 Next Steps

ARIADNA has demonstrated that rotary wing RPAS can follow Point in Space (PinS) standard procedures adapted to the performances of the RPAS using SBAS (EGNOS) for this flight of phase.

It must be noted that the RPAS used in this exercise will probably not be integrated in aerodromes with commercial traffic, however it was a good test bench to demonstrate the feasibility of these new users to execute standard procedures adapted to lower performances. Taking into account the feasibility of this particular RPAS to comply with this procedure, larger rotary wing RPAS, likely candidates to operate from civil aerodromes, will surely be able to execute PinS-like approach procedures.

ARIADNA has proved the feasibility of a Ground Based Situational Awareness System (GBSAS) solution to provide remote pilots with surrounding traffic information based on ADS-B data. This solution does not depend on other ground systems as other solutions based on radar information. Given the short term European mandate for implementation of ADS-B technology, this is definitely a key catalyser towards a common airspace use of manned and unmanned aircraft in Europe.

7.1 Conclusions

As a summary, ARIADNA has achieved the following conclusions:

- A Ground Based Situational Awareness System (GBSAS) solution is feasible to provide remote pilots with surrounding traffic information based on ADS-B data
- More communications and phraseology training is needed for RPAS pilots in order to ensure a safe integration in non-segregated airspace.
- Integrating RPAS in non-segregated airspace introduces new tasks and responsibilities, for this reason, RPAS operators need to balance the new workload among the team.
- Visual monitoring, especially in the take-off and approach phases should be adapted for integration of RPAS of small size.
- RPAS emergency procedures need further studies to include these procedures in the manned aviation knowledge with the agreement of ATC, manned aviation pilots and RPAS operators.
- Point in Space (PinS) – like approach procedures were demonstrated to be feasible also for rotary wing RPAS although a specific procedure should be defined and tested for the visual segment.
- Visual separation procedures used by controllers (with radar or ADS-B information to improve situational awareness but not to separate traffic) cannot be applied safely for small size RPAS, since they are very difficult to spot.

7.2 Recommendations

Apart of the recommendations discussed in Sec.5.5.3, this section is more focused on recommended R&D activities to be conducted towards a safe integration of RPAS in different environments:

- Special attention on RPAS performance while designing approach procedures. ARIADNA has demonstrated that the execution of standard procedures by RPAS is feasible although with reduced performances.

  Simultaneous non interfering approaches are flight procedures designed to allow the operation of helicopters without conflicting with fixed-wing aircraft. Specific activities would be interesting to assess the integration of these procedures in airports.
- Further consideration on the involvement of mini RPAS in the integration with manned aircraft, especially on current initiatives in the frame of SESAR2020 and the RPAS European roadmap.
- Determine the RPAS types likely to be integrated in each traffic density and complexity environment.

To ensure the maximum representativeness of the activities to be conducted in the future, especially in the case of flight trial demonstrations, it is needed to establish what types of RPAS are likely to be integrated in each operational environment based on their needs and performances.

Not all the RPAS types will need to operate from ATC controlled airports and in controlled airspace; it will depend on the mission and deployment needs of the RPAS, being the larger RPAS with higher performances and higher level of equipage, the most feasible candidates to operate in these environments.

- Analyse Human Factors in more complex environments

  As it has been mentioned several times through this report, the activities undertaken by this project have been very useful as a first step in the integration of RPAS in non-segregated airspace.

  However, as in every first step, ARIADNA and the other RPAS demo projects performed under the umbrella of SESAR have executed their activities in low complex environments what has been useful to obtain indications of the impact that the integration of RPAS in non-segregated airspace would have on roles and responsibilities.

  To increase the representativeness and reliability of the results, **Human Performance should be assessed when integrating RPAS in more complex environments**, representative of the expected operational scenario where every type of RPAS is likely to be integrated.

  To follow a proper increasing maturity approach, it is recommended that the integration of RPAS in more complex environments is first validated though other validation techniques different to flight trials. In an early phase, the impact that this integration would have on roles and responsibilities could be assessed by gaming techniques, evolving in a more mature phase to Real Time Simulations. This validation technique is perfect to execute a complete Human Performance assessment avoiding any potential impact on safety of other operations.

- Performance Assessment

  In line with the previous bullet, the lack of a representative scenario has prevented the projects to assess in detail the potential impact on the performance of the ATM system.

  ARIADNA and other RPAS demo projects have proved the low performances of RPAS compared to those of manned aviation, especially commercial aircraft, needing longer times to execute common manoeuvres. Airport operations are even more critical, depending on the RPAS, since many of them currently require from some members of the RPAS crew to incur in the runway for take-off and landing manoeuvres.

  The integration of low performance aircraft and helicopters with higher capable aircraft is always difficult to manage by controllers in high demanding traffic situations. So that, anyone could expect that the integration of RPAS may have a negative impact on the performance of the ATM system.

  To determine a progressive deployment of RPAS on different scenarios and depending on their performance, it is needed to assess the impact that they would have on all the complexity environment categories defined within SESAR. For this, it would be needed to perform a sensitivity-like analysis, with different traffic samples varying the percentage of RPAS. Fast Time and Real Time simulations would be appropriate techniques to quantify performance on the indicators defined by SESAR.

  Summarising, it is highly recommended to execute a considerable number of simulations, using environments representative of different traffic complexity and density scenarios, using traffic samples with several rates of RPAS and including a range of the most likely RPAS to be integrated in each scenario in order **to quantify the performance indicators defined by SESAR**. In a second step, this would allow estimating the impact on the whole ECAC area based on most updated traffic forecasts.

- RPAS specific Emergency procedures

Management of RPAS specific emergency procedures has not been tested in ARIADNA, but it has deeply studied during the planning phase and it is considered one of the cornerstones of the integration of RPAS in non-segregated airspace.

So far, there are established procedures for the case when aircraft have a communication failure or any other emergency. They can be broadly transmitted through specific transponder codes so that the expected behaviour of the aircraft in troubles is known by ATC community. However, there are no similar international standards for RPAS emergency procedures.

RPAS specific emergency procedures, mainly C2 link and GPS loss, are clear cases when ATM regulation needs to be adapted to RPAS requirements. RPAS could adapt to current manned aircraft emergency procedures but for those specific of RPAS, regulation and procedures need to be developed in order to ensure a safe operation in a mixed fleet environment.

It is recommended to conduct further activities to assess the impact of procedures like C2 link or GPS loss in complex environments.

- In a first step, it has to be analysed how to introduce this procedures in the flight plan to ensure that in the event of an emergency, ATC is aware of the intentions and knows how to work with it.
- It needs to be studied how to homogenize these procedures for different RPAS, so that the behaviour is the same independently of the RPAS
- In addition, it has to be validated whether it is better that the points (known as recovery points) where these procedures are executed are part of the airspace configuration and common to all RPAS operating there, which is line with controllers´ opinion, or on the other hand they are defined by the RPAS crew and broaden through the validation plan. Should these recovery points be part of the airspace configuration, it should be studied how to design and operate them. How often is it need to be defined a recovery point? What to do when the recovery point is occupied by an RPAS and another RPAS plans to operate in the same airspace? How to proceed with other traffics? What if the RPAS fails to recover the signal? These and more questions need to be answered by means of expert groups supported by simulations to provide useful inputs to regulatory bodies.
- Management of these RPAS emergency procedures in complex environments will surely have an impact on workload and stress of all the actors, mainly air traffic controllers and remote pilots, but also manned aviation pilots. To ensure the safety levels, it would be recommended to run Real Time Simulations to analyse this impact.

➢ Large demonstrations

ARIADNA has demonstrated that even in segregated environments the interaction of RPAS with ATC introduces more complexity, having detected the need to improve the training of RPAS crews in ATC procedures and communications.

Bearing this in mind, it is suggested **to conduct large demonstrations** to cover the integration of RPAS in a progressive way, **what could be useful to generalise among public opinion the operation of RPAS** in the same environment as manned aircraft.

➢ Detect & Avoid Systems

ARIADNA has demonstrated that a ground based system able to provide surrounding traffic information to remote pilots improves their situational awareness. However, we have seen that although the GBSAS system defined and used in ARIADNA is suitable for any type of RPAS, it depends on collaborative aircraft, what could be a limitation in some environments.

It is necessary to continue the **investigation of Detect & Avoid systems to equip RPAS**, as well as to continue working on regulation to guarantee that RPAS can access to airspace maintaining safety levels.

GBSAS would cover the 'Detect' part of the concept, but focused need to be placed also on the '**Avoid**' term; this could imply developing **models of ad-hoc defined resolution manoeuvres**, based on RPAS lower performances.

8 References

8.1 Applicable Documents

[1] ARIADNA D01 – Demonstration Plan

[2] ARIADNA I01 – Authorizations / Approvals and aviation safety aspects

[3] ARIADNA I02 – Operational Concept Document (OCD)

[4] ARIADNA I03 – Technical Specification

[5] ARIADNA I04 – Verification Plan and Procedures

[6] ARIADNA I05 – Verification Report Factory

[7] ARIADNA I06 – Verification Report Site

[8] ARIADNA I07 – Validation Strategy and Plan

[9] ICAO Doc. 4444 Procedures for Air Navigation Management

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