Validation Support Activities Report

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Abstract

This document is the Validation Support Activities Report of Project 15.4.5a. The project has supported these activities using the four prototypes specified by 15.4.5a and developed by Project 15.4.5b. These include three ADS-B Ground stations (by INDRA, SELEX and THALES) as well as the SDPD prototype ARTAS (by EUROCONTROL).

Regarding the SELEX ADS-B Ground station, in Iterations 1 and 2, support to project 6.3.2 was provided, using the Malpensa Industrial Based platform. The Iteration 3 functionality was integrated in the ADS-B prototype available at SELEX-ES facility, in order to facilitate the testing.

The ADS-B Ground stations from INDRA, THALES and the ARTAS system were integrated in the ADS-B Validation Platform (AVT) of the EUROCONTROL Experimental Centre (Bretigny). In this case, the Project 15.4.5a itself has performed validation related work.

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Executive summary

This document is the report of the Validation support activities performed in the context of the SESAR Project 15.04.05a. It describes the preparation, execution and results of these activities. The project has supported these activities using the four prototypes specified by 15.4.5a and developed by Project 15.4.5b. These include three ADS-B Ground stations (by INDRA, SELEX and THALES) as well as the SDPD prototype ARTAS (by EUROCONTROL).

Regarding the SELEX ADS-B Ground station, in Iterations 1 and 2, support to SESAR project 6.3.2 was provided, using the Malpensa Industrial Based platform (IBP). The validation of the ADS-B prototype was performed with two exercises and took a relatively small subset of the overall activities of Project 6.3.2 due to the fact that these exercises hosted a wide variety of prototypes. For both validation exercises, the opportunity traffic available in the surrounding area of Malpensa Airport was exploited, and the prototypes were validated through a shadow mode approach to minimize the impact on the operational systems. The ADS-B GS was fed with real traffic data, and the CWPs were provided with both ADS-B and SDPD tracks.

The Iteration 3 functionality was integrated in the ADS-B prototype available at SELEX-ES facility, in order to facilitate the testing.

The ADS-B related validation objectives in support of the Malpensa Airport exercises of Project 6.3.2 as well as in the evaluation at the SELEX ES premises were successfully addressed.

The ADS-B Ground stations from INDRA, THALES and the ARTAS system were integrated in the ADS-B Validation Platform (AVT) of the EUROCONTROL Experimental Centre (Bretigny). The validation exercise at EEC was not originally planned as part of the project 15.4.5a work, because an external validation project had been assumed. However, as no matching SESAR operational validation project was found to be supported with these prototypes, the Project 15.4.5a itself has performed validation related work.

The aim of the validation work at the EEC was to assess and evaluate the feasibility and acceptability of the use of surveillance data provided by the 15.4.5a&b prototype Ground Stations and SDPD in a multisensor environment in TMA and en-route airspace, for different traffic loads. It was performed using operational experts (air traffic controller) as well as technical experts. Two exercises were executed for nominal and non-nominal mode respectively, containing 3 scenarios each, i.e. En-route, TMA high density and TMA medium traffic density. In addition, assessment of the Ground station performance and SDPD features with an operational perspective were performed. This included security mitigation functionality.

It should be noted that for the exercises at EEC, the used platform was not a fully comprehensive IBP, the task was an ad-hoc replacement of support to external operational validation project(s), therefore assumptions were made during the preparation phase to mitigate for the constraints.

At a generic level, considering the available scenarios, environment and traffic samples, the data provided by the ADS-B prototypes in a multisensor TMA and en-route environment can be considered as meeting the requirements for the operational services envisaged. The use of the system contributes to an improved situational awareness and does not normally increase the associated controller workload. The system also improves security by successfully mitigating the associated threats. A few cases demonstrated the need for further investigations.

It is recommended that the validation of the system should be continued in the transition towards industrialisation and deployment. This should include a detailed assessment of the performance of the overall system and its components w.r.t. associated emerging standards (e.g. EUROCAE) and Specifications as well as validation exercises of the applications to be implemented and reachable benefits at generic and local levels. The security mitigation functionality is of particular importance in this context. Any specific recommendations from the project should be taken into account. Standardisation activities should take into account the results of the projects.

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1 Introduction

1.1 Purpose of the document

This document is the Validation Support Activities Report of Project 15.4.5a. The project has supported these activities using the four prototypes specified by 15.4.5a and developed by Project 15.4.5b. These include three ADS-B Ground stations as well as the SDPD prototype.

1.2 Intended readership

The audience of this document includes:

- Projects 15.4.5a and b
- Project 6.3.2
- Any other SJU projects that may require ADS-B Validation systems for their validation activities

1.3 Structure of the document

Chapter 1 is the Introduction of the document

Chapter 2 presents the Context of the Validation support activities

Chapter 3 summarises the conduct of these activities

Chapter 4 provides the results

Chapter 5 includes the Conclusions and Recommendations

Chapter 6 presents the details of the exercises supported

Chapter 7 lists the References.

1.4 Glossary of terms

N/A

1.5 Acronyms and Terminology

To be completed if needed

Term	Definition
ADD	Architecture Definition Document
ADS-B	Automatic Dependent Surveillance - Broadcast
AMAN	Arrival Manager
A-SMGCS	Advanced Surface Movement Guidance and Control System
ASTX	Asterix
ATCO	Air Traffic Controller
ATM	Air Traffic Management

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Term	Definition
ATS	Air Traffic Services
ATS	Air Traffic data Simulator
AVT	ADS-B Validation Testbed
CS-CNS	Certification Specifications – Airborne CNS
CWP	Controller Working Position
CTW	Control Tower
DMAN	Departure Manager
E-ATMS	European Air Traffic Management System
EEC	EUROCONTROL Experimental Centre
FPL	Flight Plan
GS	Ground Station
HMI	Human Machine Interface
IBP	Industrial Based Platform
INTEROP	Interoperability Requirements
MLAT	Multilateration
MSF	Multi Sensor Fusion
OFA	Operational Focus Areas
PD	Probability of Detection
PDA	Probability of Detection Analysis
PI	Performance Indicator
RAI	Range through Active Interrogation
RTD	Round Trip Delay
RWY	Runway
SMAN	Surface Manager
SDPD	Surveillance Data Processing and Distribution
SESAR	Single European Sky ATM Research Programme

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Term	Definition
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.
SPR	Safety and Performance Requirements
TDOA	Time Difference of Arrival
TS	Technical Specification
TWY	Taxiway
WAM	Wide Area Multilateration

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2 Context of the Validation

The Validation related activities of Project 15.4.5a took place in two different environments: The first set was in support of Project 6.3.2 using the Malpensa Industrial Based Platform (IBP) and included one of the ADS-B ground stations (SELEX). The second set of activities was performed at the EUROCONTROL Experimental Centre (EEC), Bretigny, Paris and included the other two other ADS-B Ground station prototypes (INDRA, THALES) as well as the Surveillance Data Processing and Distribution system (ARTAS).

The Malpensa Industrial Based Platform (IBP) has been exploited to support the SELEX ADS-B Ground station first iteration and second iteration verification activities, foreseen in the P15.04.05b. The SELEX-ES ADS-B GS validation activities in the Malpensa IBP have been conducted in the context of EXE-06.03.02-VP-065 and EXE-06.03.02-VP-0652. In particular, the first iteration prototype was tested within the frame of EXE-06.03.02-VP-065 and the second iteration prototype within the EXE-06.03.02-VP-0652.

Validation exercise EXE-06.03.02-VP-065 aimed at validating the integration of Enhanced Surface Safety Nets, Enhanced Surface Guidance, Integrated Tower Working Position, Departure Management and Surface Management integrated, Airport Safety Nets for Controllers, D-TAXI Service and validation of Surveillance ground system enhancements for ADS-B. Therefore the ADS-B enhancements are one of the features validated within the frame of the EXE65.

During the EXE 06.03.02–VP-65 the new feature of "WAM validation" was tested whilst the "TDOA" and the "Extended WAM Validation" technique were verified within the EXE-06.03.02-VP-0652.

EXE-06.03.02-VP-652 aims a validating the integration of different Safety Nets concepts which can have a positive impact on safety providing relevant alarms to controllers within ad-hoc scenarios simulated with real time simulation technique using SELEX-ES Prototypes 12.3.2 (server part) and 12.5.2 (HMI part). Within the frame of the exercise 652 the verification of the ADS-B enhancements which have an impact on both the ground and airborne Surveillance systems in terms of safety and human performance took place. Since the second prototype differs from the first prototype only because of new software features, it was not necessary to upgrade the hardware of the first prototype that was kept untouched from the EXE 652. The validation exercise was performed exploiting the opportunity traffic available at Malpensa airport and surrounding area. As for the EXE-06.03.02-VP-65, due to safety reason and to reduce the impact of the exercise on the ATC operation, the verification of the ADS-B ground station second iteration was performed in shadow mode.

Regarding the validation at EEC Bretigny the addition of ADS-B surveillance data by the ADS-B Ground Surveillance system is to support, and in some cases enhance, Air Traffic Services through the use of a cost beneficial surveillance data source. It applies to the En-Route and terminal airspace in classes A to D in support of:

- Air Traffic Control Service:
  - Area Control Service
  - Approach Control Service

Surveillance infrastructure costs are expected to be reduced by replacing radars at the end of their operational life with ADS-B stations which are less expensive to install and to maintain. Furthermore, spectrum rationalisation will be achieved due to the fact that ADS-B is a passive Surveillance technology, thus supporting the longevity of the 1030/1090 MHz datalink and the associated stakeholder investments. Another key benefit is security by the development of relevant mitigation techniques.

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Only the requirements for the provision of an ATS in airspace classes A to D have been defined. Class E, F and G airspace are not concerned, as it is assumed that the services applied in classes A to D derive the most demanding requirements.

There are multiple variations of environments (En-route, Terminal Areas, high density or medium density) and consequently, implementations of multiple combinations are possible. Minimum airborne and ground requirements have been established by considering the most demanding environments (e.g. ADS-B RAD, EASA CS-ACNS).

There are no changes expected in the roles and responsibilities of the flight crew and controllers with regard to separation provision and no changes in the phraseology. Procedures applied by air traffic controllers and flight crews are the ICAO PANS-ATM procedures relating to surveillance-based services and the ICAO-PANS-OPS procedures, respectively.

However the introduction of the ADS-B Ground Surveillance system requires the assessment of the usefulness and acceptability by controllers. The necessity and corresponding level of operational validation depends on the impact of the new surveillance system implementation in the local environment.

The objective of the generic validation activities is to support the stakeholders in acquiring evidence to prove:

- the operational acceptability and technical feasibility of these systems
- the impact of these systems in terms of safety, capacity, efficiency and security

2.1 Concept Overview

The following Table summarises the validation supported within SESAR project 6.3.2:

Validation Exercise ID and Title	EXE-06.03.02: Validation of Airport Safety Nets and Enhanced ADS-B
Leading organization	ENAV
Validation exercise objectives	Safety improvements by surveillance data quality, reliability and accuracy augmentation by means of enhanced ADS-B application. Situational awareness and safety improvements by providing alerts related to: • Non-conformance to ATC procedures • Non-conformance to ATC instructions • Conflicting ATC clearances.
Rationale	The exercise will experiment the airport safety nets alarms both in terms of functionalities and of HMI aspects. The exercise is aimed to validate the benefits from controller point of view. It takes also the opportunity to validate an improved enhanced ADS-B application.
Supporting DOD / Operational Scenario / Use Case	Airport DOD Step 1-D07/Surface-In and Surface-Out
OFA addressed	• OFA01.02.01 Airport Safety Nets • OFA01.02.02 Enhanced Situational awareness

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	• OFA06.01.01 CWP Airport
OI steps addressed	• AO-0104-A (partially) • AO-0201-A (partially) • AO-0208-A (partially)
Enablers addressed	• AERODROME-ATC-06 • AERODROME-ATC-07 • A/C 48a • HUM-AO-0104 • CTE-S5a • CTE-S9a • CTE-S12b
Applicable Operational Context	Airport execution phase
Expected results per KPA	Safety Human Performance (Transversal Area)
Validation Technique	Real Time Simulation and Shadow mode
Dependent Validation Exercises	Joint analysis with EXE-06.03.02-VP-614 Close coordination with P6.9.2

Table 1: Concept Overview for Malpensa validation support

Validation Exercise ID and Title	EXE-15.04.05a: ADS-B in En-Route and TMA
Leading organization	EUROCONTROL
Validation exercise objectives	Verify that the behaviour of the developed system in real environment is in accordance with the operational assumptions
Rationale	Inclusion of ADS-B as a source of surveillance data; development of several technical solutions (prototype), security enhancements
Supporting DOD / Operational Scenario / Use Case	ADS-B RAD Safety, Performance and Interoperability specification document ED161
OFA addressed	OFA 03.03.01 Ground based separation provision in En-route OFA 03.03.02 Ground based separation provision in the TMA
OI steps addressed	CM-0203 Automated flight conformance monitoring

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Enablers addressed	CTE-S03a – ADS-B station for NRA Surveillance CTE-S03b – ADS-B station for RAD and APT Surveillance
Applicable Operational Context	En-Route high capacity needs En-Route medium capacity needs En-Route low capacity needs Network
Expected results per KPA	Safety Efficiency Security
Validation Technique	Shadow mode with live & simulated traffic data feed
Dependent Validation Exercises	N/A

Table 2: Concept Overview for EEC validation

2.2 Summary of Validation Exercises

2.2.1 Summary of Expected Exercise outcomes

The use of an integrated platform tools in Project 6.3.2 (Malpensa IBP) leads to several advantages:

- Safety enhancements in terms of situational awareness increase, workload reduction, surveillance data quality augmentation.
- Capacity enhancements in terms of delays reduction.
- Predictability enhancements, in terms of situational awareness increase.
- Efficiency enhancements in terms of data accuracy augmentation.
- Environmental sustainability in terms of potential fuel burn consumption and C02 emission reduction.

Validation exercise EXE-06.03.02-VP-065 aimed at validating the integration of Enhanced Surface Safety Nets, Enhanced Surface Guidance, Integrated Tower Working Position, Departure Management and Surface Management integrated, Airport Safety Nets for Controllers, D-TAXI Service and validation of Surveillance ground system enhancements for ADS-B. Therefore the ADS-B enhancements are one of the features validated within the frame of the EXE65.

Concerning the ADS-B prototype, the validation exercise EXE-06.03.02-VP-065 demonstrates the requirements foreseen in the iteration 1, and more in particular, it aims at:

- Confirming that the situation in which the tools are integrated has an added value compared to a situation where each system gives information separately and it is for the controller to choose which one has to be used
- Showing to air traffic controllers and validating with them that the integration of systems brings an additional value compared to a situation where the systems are not integrated

EXE-06.03.02-VP-652 aims a validating the integration of different Safety Nets concepts which can have a positive impact on safety providing the following alarms to controllers within ad-hoc scenarios simulated with real time simulation technique using SELEX-ES Prototypes 12.3.2 (server part) and 12.5.2 (HMI part).

For the ADS-B GS the validation exercise was mainly tailored to verify the new features integrated in the ADS-B ground station second iteration. In particular the Enhanced ADS-B ground station - Selex ES Prototype 15.4.5b iteration two, incorporates the following validations checks:

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- The functionality (TDOA validation and Enhanced ADS-B target report validation via WAM integration) to check the validity of the ADS-B derived data and to discard possible spoofing messages as well as messages transmitted by not accurate ADS-B transponders, guaranteeing an improvement of the surveillance in terms of security and safety.
- Rationalization of Surveillance infrastructure through a stronger integration of the ADS-B system into a WAM system. This integration offers the advantage of infrastructure sharing between the two surveillance systems, providing a more flexible and cost effective solution, and also the potential for substantial improvement of the 1090ES detection capability (and hence performance robustness of ADS-B reception) by taking into account multilateration derived data during the squitter decoding process.

Regarding the Validation related activities at the EEC, the high-level Validation Objectives, related to the validation of a surveillance system were as follows:

- To assess the feasibility (technical integration) of the surveillance data use in terms of system (e.g. ADS-B OUT equipment and ground equipment) and required performances,
- To assess the operational acceptability of the use of surveillance data both in terms of procedures and (mainly ground) system functionalities, HMI, etc
- To assess the impact of the use of enhanced surveillance data in terms of safety, security, and efficiency of the ATM system,

At the operational level, for maximum benefits, it is essential that the proposed procedures are operationally acceptable and accepted, and the system functionalities are usable and used to support the human in their tasks and missions in their local environment.

Therefore, at the *operational acceptability* level, the high-level objectives considered were the following:

- To assess the acceptability and acceptance of the proposed procedures and human machine interface for the controllers;
- To assess the usability and usage of the ground system prototypes;
- To assess the impact on the controller's behaviour and performance.

In terms *of impact on the ATM system*, the high-level objectives considered were the following:

- To assess the impact of the use of the enhanced ground surveillance system in a considered airspace;
- To assess the impact of the use of the enhanced ground surveillance system on the ATM system efficiency, in a considered airspace from an ANSP perspective;
- To assess the impact of the use of an enhanced surveillance system on the safety and security of Air Traffic Services in the considered airspace

These high-level Validation Objectives are not independent. There is a relationship between some objectives within the same validation aim and also with some objectives from other validation aims. For instance, the assessment of the proposed HMI usability and usage is closely linked, among others, with the assessment of the procedure acceptability and acceptance.

In addition, assessment of the Ground station performance and SDPD features with an operational perspective were performed

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2.2.2 Benefit mechanisms investigated

The Validation objectives of the project are directly or indirectly linked with the following ICAO KPAs (used as part of the Performance Framework of SESAR):

- Safety
- Capacity
- Efficiency
- Interoperability
- Environmental Sustainability
- Security

2.2.3 Summary of Validation Objectives and success criteria

The validation objectives addressed by these exercises, together with the associated success criteria are summarised hereafter.

2.2.3.1 List of Validation Objectives

The validation objectives related with ADS-B in Project 6.3.2 are as follows:

OBJ Identifier	Validation Objective Hypothesis	Metric/Indicator	Data Collection methods	Scenario ID
OBJ-06.03.02-VALP-0065.0006	Safety increases due to better surveillance information on final approach surveillance	Number of ghost tracks Controllers' perceived surveillance data quality.	Over the shoulders observation Debriefing	SCN-06.03.02-VALP-O065.0007

OBJ ID	Validation Objective Hypothesis	Metric/Indicator	Data Collection methods	Scenario ID
OBJ-06.03.02-VALP-0652.0002	Safety increases due to better surveillance information	Controllers' perceived surveillance data quality Controllers' perceived situational awareness % of validation not executed/valid/not valid tracks respect to the total number of tracks Number and type	Over the shoulders observations Debriefing System logs	SCN-06.03.02-VALP-00652.0001 SCN-06.03.02-VALP-00652.0004

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Table 3: Validation Objectives supported in Project 6.3.2 and associated scenarios

Both Validation objectives address the KPA of Safety and the area of Surveillance Data quality.

The Validation Objectives of the EEC exercise are provided hereafter. For all these validation objectives, the metrics/indicators are the controller's perceived surveillance data quality and the controller's perceived situational awareness. The data collection methods are over the shoulders observation, debriefing and system logs.

OBJ ID	Validation Objective	Scenario ID
OBJ-15.04.05a-VALP001.0001	Verify that the ground system function receives, decodes, packages and time-stamps the data, and sends corresponding surveillance reports to the ATC processing system	SCN-15.04.05a-VALP 001.0001 SCN-15.04.05a -VALP 001.0002 SCN-15.04.05a-VALP 001.0003
OBJ15.04.05a-VALP-001.0002	Verify that the ground system function provides the following minimum data set to the ATC processing system: ▪ Aircraft Horizontal Position – Latitude and Longitude ▪ Pressure altitude ▪ Quality Indications of Horizontal Position ▪ Aircraft Identity ▪ Emergency Indicators (when selected by the flight crew) ▪ Special Position Identification (SPI) (when selected by the flight crew) ▪ Time of Applicability Ground velocity and relevant quality indicator if required by the local implementation	SCN-15.04.05a-VALP 001.0001 SCN-15.04.05a -VALP 001.0002 SCN-15.04.05a-VALP 001.0003
OBJ-15.04.05a-VALP-001.0003	Verify that when direct recognition procedures are used by the controller for identification, the ground system contains a function to ensure the aircraft identity data that is broadcast is retained and correctly associated with the position information for display	SCN-15.04.05a-VALP 001.0001 SCN-15.04.05a -VALP 001.0002 SCN-15.04.05a-VALP 001.0003

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OBJ ID	Validation Objective	Scenario ID
OBJ-15.04.05a-VALP-001.0007	Verify that the processing function enables the switching between the surveillance sources (e.g. as a backup during a failure) without requiring the ATCO to perform a: ▪ Re-verification of altitude data Re-identification of aircraft identity	SCN-15.04.05a-VALP 001.0001 SCN-15.04.05a -VALP 001.0002 SCN-15.04.05a-VALP 001.0003
OBJ15.04.05a-VALP-001.0008	Verify that the minimum performance requirements for the accuracy are satisfied	SCN-15.04.05a-VALP 001.0001 SCN-15.04.05a -VALP 001.0002 SCN-15.04.05a-VALP 001.0003
OBJ15.04.05a-VALP-001.0009	Verify that the minimum performance requirements for the update rate are satisfied	SCN-15.04.05a-VALP 001.0001 SCN-15.04.05a -VALP 001.0002 SCN-15.04.05a-VALP 001.0003
OBJ-15.04.05a-VALP-001.0010	Verify that the minimum performance requirements for the latency are satisfied	SCN-15.04.05a-VALP 001.0001 SCN-15.04.05a -VALP 001.0002 SCN-15.04.05a-VALP 001.0003
OBJ15.04.05a-VALP-001.0011	Verify that the minimum performance requirements for the inconsistency and duplicate identity check are satisfied	SCN-15.04.05a-VALP 001.0004 SCN-15.04.05a -VALP 001.0005 SCN-15.04.05a-VALP 001.0006
OBJ-15.04.05a-VALP-001.0012	Verify that the minimum performance requirements for the horizontal and vertical position error detection are satisfied	SCN-15.04.05a-VALP 001.0004 SCN-15.04.05a -VALP 001.0005 SCN-15.04.05a-VALP 001.0006

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OBJ ID	Validation Objective	Scenario ID
OBJ-15.04.05a-VALP-001.0013	Verify that the minimum performance requirements for the emergency code detection are satisfied	SCN-15.04.05a-VALP 001.0004 SCN-15.04.05a -VALP 001.0005 SCN-15.04.05a-VALP 001.0006
OBJ15.04.05a-VALP-001.0017	Assess and investigate the acceptability and acceptance of the data used, by the controller, with the same separation minima as currently applied	SCN-15.04.05a-VALP 001.0001 SCN-15.04.05a -VALP 001.0002 SCN-15.04.05a-VALP 001.0003
OBJ-15.04.05a-VALP-001.0018	Assess and investigate the acceptability and acceptance of the data used, by the controller, in Terminal airspace	SCN-15.04.05a-VALP 001.0001 SCN-15.04.05a -VALP 001.0002 SCN-15.04.05a-VALP 001.0003
OBJ-15.04.05a-VALP-001.0019	Assess and investigate the acceptability and acceptance of the data used, by the controller, in En-Route airspace	SCN-15.04.05a-VALP 001.0001 SCN-15.04.05a -VALP 001.0002 SCN-15.04.05a-VALP 001.0003
OBJ-15.04.05a-VALP-001.0023	Assess and investigate the acceptability and acceptance of the data used, by the controller in case of temporary one surveillance source data loss or detected corruption for one aircraft	SCN-15.04.05a-VALP 001.0004 SCN-15.04.05a -VALP 001.0005 SCN-15.04.05a-VALP 001.0006
OBJ-15.04.05a-VALP-001.0024	Assess and investigate the acceptability and acceptance of the data used, by the controller in case of permanent one surveillance source data loss or detected corruption for one aircraft	SCN-15.04.05a-VALP 001.0004 SCN-15.04.05a -VALP 001.0005 SCN-15.04.05a-VALP 001.0006

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OBJ ID	Validation Objective	Scenario ID
OBJ-**15.04.05a-**VALP-001.0025	Assess and investigate the acceptability and acceptance of the data used, by the controller in case of temporary one surveillance source data loss or detected corruption for all aircraft	SCN-15.04.05a-VALP 001.0004 SCN-15.04.05a -VALP 001.0005 SCN-15.04.05a-VALP 001.0006
OBJ-15.04.05a-VALP-001.0026	Assess and investigate the acceptability and acceptance of the data used, by the controller in case of permanent one surveillance source data loss or detected corruption for all aircraft	SCN-15.04.05a-VALP 001.0004 SCN-15.04.05a -VALP 001.0005 SCN-15.04.05a-VALP 001.0006
OBJ-15.04.05a-VALP-001.0027	Verify the usability and usage of the display providing multiple surveillance data information to the controllers: ▪ Aircraft position and altitude ▪ Identity ▪ Emergency and SPI Indicators ▪ Ground Velocity Surveillance track presentation	SCN-15.04.05a-VALP 001.0001 SCN-15.04.05a -VALP 001.0002 SCN-15.04.05a-VALP 001.0003
OBJ-15.04.05a-VALP-001.0028	Assess and investigate which additional skills and training are required for controllers	SCN-15.04.05a-VALP 001.0001 SCN-15.04.05a -VALP 001.0002 SCN-15.04.05a-VALP 001.0003
OBJ-15.04.05a-VALP-001.0029	Assess and investigate the impact of data source presentation on the overall controller workload	SCN-15.04.05a-VALP 001.0001 SCN-15.04.05a -VALP 001.0002 SCN-15.04.05a-VALP 001.0003

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OBJ ID	Validation Objective	Scenario ID
OBJ-15.04.05a-VALP-001.0030	Assess and investigate if workload is reduced/increased following the introduction of new surveillance data	SCN-15.04.05a-VALP 001.0001 SCN-15.04.05a -VALP 001.0002 SCN-15.04.05a-VALP 001.0003
OBJ-15.04.05a-VALP-001.0031	Assess and investigate if the workload is increased in non-nominal conditions compared with current environment (due to losses or corrupted one surveillance source data)	SCN-15.04.05a-VALP 001.0004 SCN-15.04.05a -VALP 001.0005 SCN-15.04.05a-VALP 001.0006
OBJ-15.04.05a-VALP-001.0032	Verify that the use of new surveillance data introduces minor changes to controller and flight crew tasks in comparison with current procedures	SCN-15.04.05a-VALP 001.0001 SCN-15.04.05a -VALP 001.0002 SCN-15.04.05a-VALP 001.0003

Table 4: Validation Objectives considered in the EEC exercise and associated scenarios

2.2.3.2 List of Success Criteria

The main focus of the validation exercises was on controller acceptability of the provided information, performance of the data and assessment of the emergency information provided. The table below lists the success criteria and their associated validation objectives.

For the Validation Support to Project 6.3.2:

Success Criterion ID	Success Criteria	Validation Objective ID
CRT-06.03.02 - VALP-065	Data quality increases with regards to the current surveillance system by means of ADS-B application	OBJ-06.03.02 - VALP-065.0006
CRT-06.03.02 - VALP-0652.0201	Data quality increases with regards to the current surveillance system by means of ADS-B application	OBJ-06.03.02 - VALP-0652.0002
CRT-06.03.02 - VALP-0652.0202	Controller situational awareness is improved	

Table 5: Success Criteria for Project 6.3.2 Validation objectives

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For the Validation exercises at EEC:

Identifier	Success Criteria	Validation Objective ID
CRT15.04.05a-VALP-001.0101	Positive data correlation between different surveillance sources	OBJ-15.04.05a-VALP001.0001
CRT-15.04.05a-VALP-001.0202	Corresponding data is correctly displayed on the CWP	OBJ15.04.05a-VALP-001.0002
CRT-15.04.05a-VALP-001.0303	Positive correlation between the ID information from ADS-B, Mode S, Mode A, FPL	OBJ-15.04.05a-VALP-001.0003
CRT-15.04.05a-VALP-001.0707	Successful commutation between different surveillance sources while maintaining identification and position data	OBJ-15.04.05a-VALP-001.0007
CRT-15.04.05a-VALP-001.0808	Positive validation of the data accuracy through direct observation	OBJ15.04.05a-VALP-001.0008
CRT-15.04.05a-VALP-001.0909	Data refresh at CWP level is satisfactory	OBJ15.04.05a-VALP-001.0009
CRT-15.04.05a-VALP-001.1010	Data latency (display lag) is satisfactory at the CWP level	OBJ-15.04.05a-VALP-001.0010
CRT-15.04.05a-VALP-001.1111	Positive identification and notification of duplicate identity at CWP level	OBJ15.04.05a-VALP-001.0011
CRT-15.04.05a-VALP-001.1212	Positive identification and notification for positional information error at CWP level	OBJ-15.04.05a-VALP-001.0012
CRT-15.04.05a-VALP-001.1313	Positive identification and timely notification of emergency code at CWP level	OBJ-15.04.05a-VALP-001.0013
CRT-15.04.05a-VALP-001.1717 CRT-15.04.05a-VALP-001.2317 CRT-15.04.05a-VALP-001.2417 CRT-15.04.05a-VALP-001.2517 CRT-15.04.05a-VALP-001.2617 CRT-15.04.05a-VALP-001.2717	ATC operational acceptance	OBJ15.04.05a-VALP-001.0017 OBJ-15.04.05a-VALP-001.0023 OBJ-15.04.05a-VALP-001.0024 OBJ-15.04.05a-VALP-001.0025 OBJ-15.04.05a-VALP-001.0026 OBJ-15.04.05a-VALP-001.0027

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Identifier	Success Criteria	Validation Objective ID
CRT-15.04.05a-VALP-001.1818	Terminal ATC operational acceptance	OBJ-15.04.05a-VALP-001.0018
CRT-15.04.05a-VALP-001.1919	En-route ATC operational acceptance	OBJ-15.04.05a-VALP-001.0019
CRT-15.04.05a-VALP-001.2820	ATC operational assessment	OBJ-15.04.05a-VALP-001.0028
CRT-15.04.05a-VALP-001.2921 CRT-15.04.05a-VALP-001.3022	ATC workload subjective assessment	OBJ-15.04.05a-VALP-001.0029 OBJ-15.04.05a-VALP-001.0030
CRT-15.04.05a-VALP-001.3123	ATC workload subjective assessment in contingency situations	OBJ-15.04.05a-VALP-001.0031
CRT-15.04.05a-VALP-001.3224	ATC task assessment	OBJ-15.04.05a-VALP-001.0032

Table 6: Success Criteria for EEC Validation objectives

2.2.3.3 Choice of metrics and indicators

The metrics and indicators were presented in Section 2.2.3.1 above.

2.2.4 Summary of Validation Scenarios

In Project 6.3.2 validation scenario 7 was used for Exercise 65:

<u>Scenario 7 – ADS-B</u>: In order to validate ADS-B Ground Station Prototype, one scenario was experimented through shadow mode. The Enhanced ADS-B Ground Station was fed with real traffic data, and the CWPs were provided with both ADS-B and MSF tracks. The Enhanced ADS-B Ground Station improvement was tested comparing the MSF tracks against the ADS-B stand-alone tracks.

Furthermore, scenarios 1, 4 were used in Exercise 652:

<u>Scenario 1 – Reference</u>: The *Reference scenario* for live traffic run executed in order to compare it against the Enhanced ADS-B functionalities in scenario 4. This scenario has been simulated by means of shadow mode simulation and relevant data opportunely recorded.

<u>Scenario 4 – ADS-B</u>: In order to validate ADS-B Ground Station Prototype, one additional scenario was experimented through shadow mode. The Enhanced ADS-B Ground Station was fed with real traffic data, and the CWPs were provided with both ADS-B and MSF tracks. The Enhanced ADS-B Ground Station improvement was tested comparing the MSF tracks (including MLAT and WAM sensors and exploiting the enhanced ADS-B validation algorithm) against the ADS-B stand-alone tracks.

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Regarding the validation related activities at EEC, the two sets of exercises are based on the objectives to be validated. If in the first case the nominal situation was addressed and real traffic data was used both for medium and high traffic levels in different airspaces. The second exercise contained manipulated data to allow the assessment of emergency and non-nominal situations evaluation by subject experts. However in this second case the traffic sample used was also based on real traffic data recorded at an earlier date (i.e. before the validation took place). In addition, assessment of the Ground station performance and SDPD features with an operational perspective were performed.

The complete set of scenarios used during the exercises at EEC is provided below:

- SCN-**15.04.05a**-VALP 001.0001 will assess whether the behaviour of the developed system standard in real environment is in accordance with the corresponding requirements. This will be done in an en-route environment using real traffic data.
- SCN-**15.04.05a**-VALP 001.0002 will assess whether the behaviour of the developed system standard in real environment is in accordance with the corresponding requirements. This will be done in a TMA medium traffic density environment using real traffic data.
- SCN-**15.04.05a**-VALP 001.0003 will assess whether the behaviour of the developed system standard in real environment is in accordance with the corresponding requirements. This will be done in a TMA high traffic density environment using real traffic data
- SCN-**15.04.05a**-VALP 001.0004 will assess whether the behaviour of the developed system in non-nominal conditions. This will be done in an En-Route high traffic density environment using real and simulated traffic data.
- SCN-**15.04.05a**-VALP 001.0005 will assess whether the behaviour of the developed system in non-nominal conditions. This will be done in a TMA medium traffic density environment using real and simulated traffic data.
- SCN-**15.04.05a**-VALP 001.0006 will assess whether the behaviour of the developed system in non-nominal conditions. This will be done in a TMA high traffic density environment using real and simulated traffic data

2.2.5 Summary of Assumptions

The validation exercises at EEC included a number of assumptions described in the Table hereafter.

Identifier	Title	Type of Assumption	Description	Justification	Flight Phase	Note	Impact on Assessment
ASM **15.04.05a** VP001.001	Data availability	technology	Radar data from both SSR and Mode S radars is available in the simulation	Essential in the assessment of the different sources of surveillance	In flight		High

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Identifier	Title	Type of Assumption	Description	Justification	Flight Phase	Note	Impact on Assessment
ASM **15.04.05a** VP001.002	Data availability	technology	ADS-B data is available from certified aircraft	Essential in the assessment of the different sources of surveillance	In flight		High
ASM **15.04.05a** VP001.003	Data availability	technology	WAM data is available	Essential in the assessment of the different sources of surveillance	In flight	WAMdata source was not available	Medium
ASM **15.04.05a** VP001.004	System availability	Ground tools	CWP is available and the HMI is defined with required functionalities	Essential in the assessment of the different sources of surveillance	In flight	HMI did not provide the complete set of functions	Medium
ASM **15.04.05a** VP001.005	Data availability	technology	Simulated tracks are available from different surveillance sources	Essential in the assessment of the different sources of surveillance and in non nominal situations	In flight		High
ASM **15.04.05a** VP001.006	System availability	Ground tools	Simulated tracks can be manoeuvred	Essential in the assessment of the different sources of surveillance and in non nominal situations	In flight	No manoeuvrering possibilities were available	Medium
ASM **15.04.05a** VP001.007	Data availability	technology	The system shall be able to receive data coming from different surveillance sources	Essential in the assessment of the different sources of surveillance	In flight		High

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Identifier	Title	Type of Assumption	Description	Justification	Flight Phase	Note	Impact on Assessment
ASM **15.04.05a** VP001.008	System capability	technology	The system shall be able to fuse data coming from different surveillance sources	Essential in the assessment of the different sources of surveillance	In flight		High
ASM **15.04.05a** VP001.009	System capability	technology	The system shall be able to correlate data coming from different surveillance sources	Essential in the assessment of the different sources of surveillance	In flight		High

Table 7: EEC Validation Assumptions overview

2.2.6 Choice of methods and techniques

2.2.6.1 Validation Support to Project 6.3.2 (Malpensa)

The following Figurew represents the Test-Bed architecture for EXE-06.03.02-VP-065 and EXE-06.03.02-VP-0652.

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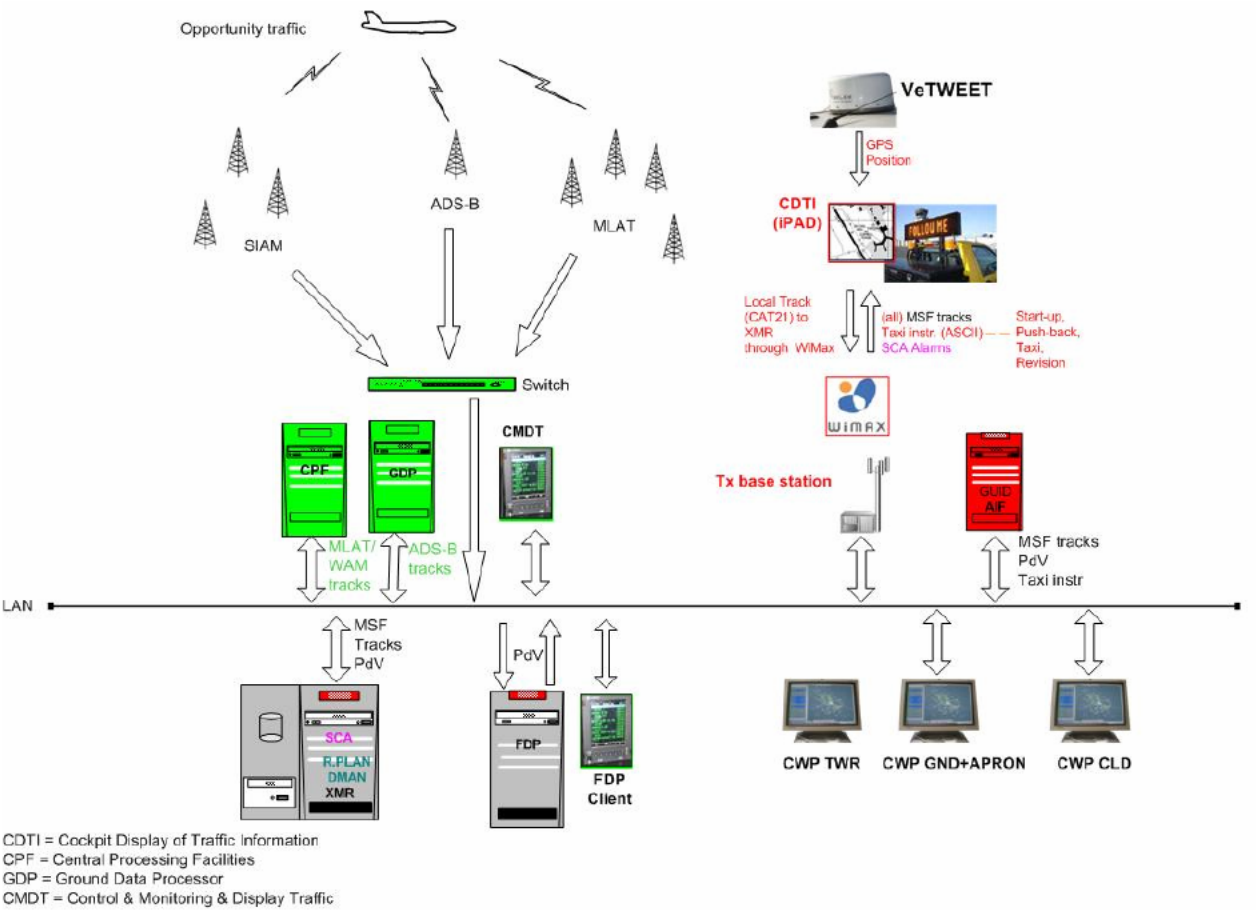

Figure 1: Test-Bed Architecture at Malpensa

The following prototypes are included in the test-bed:

System Name	Type
ADS-B Ground Station Prototype (15.04.05)	Prototype
First prototype of Surface Safety Nets Server (12.03.02)	Prototype
Surface Guidance (12.03.04)	Prototype
Tower Icwp Prototype (12.05.04)	Prototype
First prototype of integrated DMAN and SMAN platform (12.04.04)	Prototype
First prototype of Surface Alert HMI (12.05.02)	Prototype

Table 8: List of prototypes included in the Malpensa testbed

The first iteration ADS-B prototype has been integrated into IBP available at Milano Malpensa Airport. The overall integration has been done minimizing the conflict with operational system, therefore special attention has been given to the integration process (separate network, server replication, etc).

The following Figure shows the logical scheme of the ADS-B architecture deployed in Malpensa IBP. Marked with red boxes are the components verified within the exercise 65.

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The testbed's system architecture employed in the EXE-06.03.02-VP-0652 is the same of the one exploited in the EXE-06.03.02-VP-065. Nevertheless, even if there is not any hardware modification, several software modifications were introduced in the ADS-B ground station prototype to accommodate the new validation checks.

In particular referring to the Figure hereafter, the new features foreseen in the 15.4.5a, TDOA and WAM check, have been integrated into the Selex-ES Multi Sensor Fusion (MRT) CSCI.

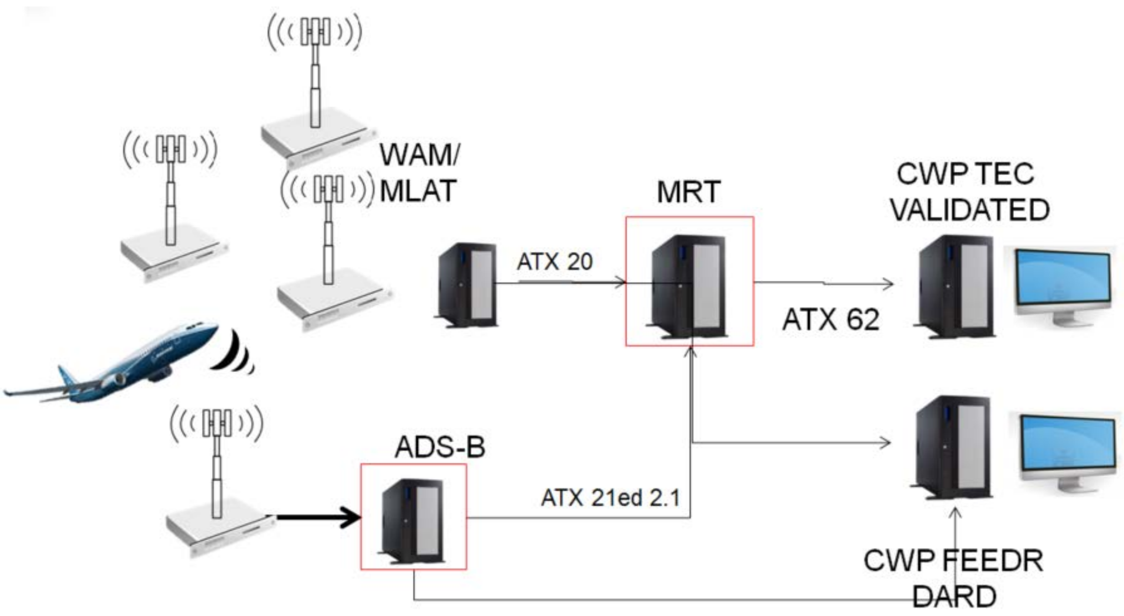

Figure 2: Project 6.3.2 ADS-B GS – architectural scheme

2.2.6.2 Validation at EEC

The system used for validating the proposed objectives consisted of several components.

AVT is an ATC surveillance platform that is designed to conform to the relevant functional and physical architecture and system, component, and interface specifications. It is designed to provide a platform enabling verification of components, interfaces, and validation tools. Its architecture, which is presented in the figure below represents the full end-to-end surveillance system chain from the aircraft to the ATC system, including:

- ground ADS-B stations receiving ADS-B data from suitably equipped aircraft,
- ADS-B data distribution facilities (ADS-B server) to filter and distribute received data to client systems,
- a surveillance data processing system capable of tracking and fusing ADS-B data with data from other surveillance sensors (e.g. SSR, Mode-S etc.),
- interfacing facilities to ATC surveillance client systems (e.g. Air Traffic Control Centre systems/simulators),
- air traffic generation simulators capable of injecting ADS-B equipped air traffic in the AVT system
- aircraft cockpit simulators to enable the use of piloted simulated ADS-B aircraft and test airborne surveillance applications

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- datalink error simulators to render the behaviour of simulated ADS-B aircraft more realistic

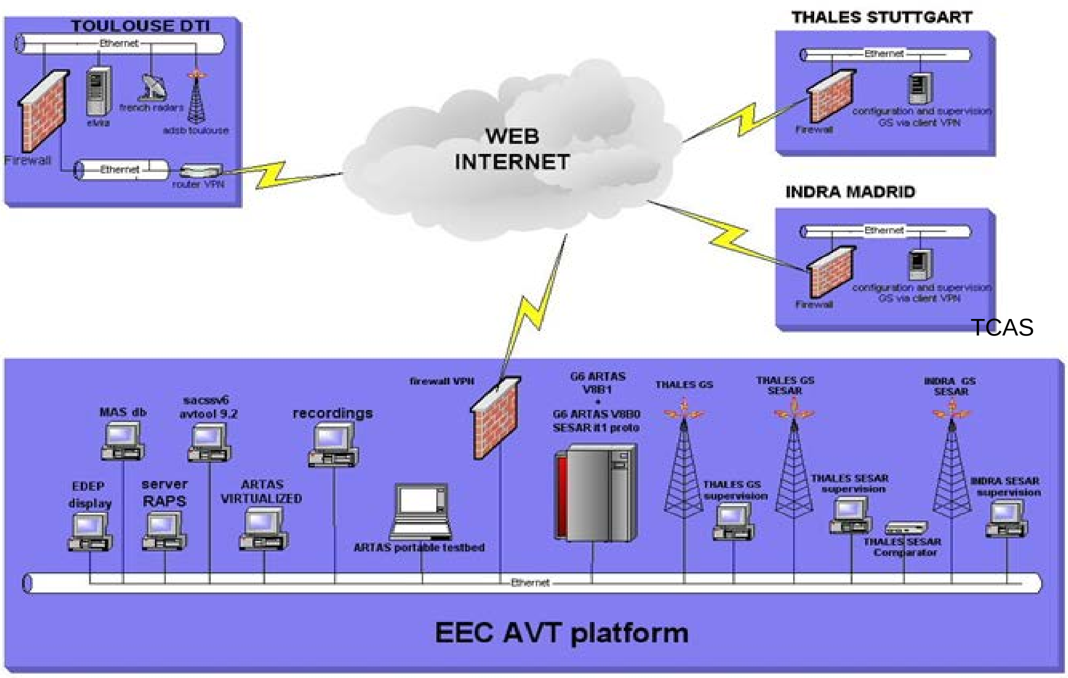

Figure 3 ADS-B Validation Testbed platform at EEC

Given the set of validation objectives considered by the validation plan, and taking into account the limitations of the available platform, interactivity with the traffic sample and the time constraints the following methodologies were used:

- Direct observation – used by subject matter expert to assess and identify any issues in the presentation of the required data, performance, update rate and accuracy
- Analysis of the data logs – to assess and evaluate the accuracy of the data decoding and fusing and it's presentation to the CWP
- Analysis of the comparison between the calculated/interpolated data from the tracker and the information received from an ADS-B source of surveillance information – to establish the accuracy of the data displayed and identify the potential display errors and their notification to the operator
- Analysis of the data logs for specific flights – to understand the decoding and correlation functions between multiple sources of surveillance data in case of non-nominal situations (e.g. emergency indicators, SPI etc.)

A set of data logs was prepared before the exercise to allow the subject matter expert to streamline the observations. The data logs were also used as a means to record the issues observed that required further investigation.

2.2.7 Validation Exercises List and dependencies

N/A

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3 Conduct of Validation Exercises

3.1 Exercises Preparation

Preparation steps for the Malpensa validation exercise were:

- High level definition of exercise including selection of functionalities available in the prototype, traffic samples, validation scenarios, special events, etc.
- Updating of the V&V platform
- Prototype testing/acceptance
- Writing of the availability notes document
- Preparation of the exercise. This activity includes, amongst other:
    - Definition of physical scenario
    - Adaptation of the traffic
    - Definition of the data gathering methods that have been used including questionnaires, structured interviews, data log, etc.
- Preparation of the training material including presentations and user manual
- Selection/invitation of ATCOs and pseudo-pilots to be involved as experimental subjects
- Preparation of the site and room hosting the exercise.

The preparation phase of the EEC validation exercises covers all activities before the actual execution of the validation like the, requirements for the evaluation platform and development of the required interfaces and functionalities and the preparation (recording) of the traffic samples. The execution phase starts with the actual exercise and also covers also the data analysis and documentation. The following main steps have been performed during the preparation phase:

- Analysis of the available sources of surveillance data on the EEC platform
- Analysis of the availability of system infrastructure
- Set up the ground infrastructure (according to the architecture presented in the chapter above)
- Set up of the required functionalities (CWP display, access to the data logs, etc.)
- Records of the traffic sample (real life traffic recorded through busy days of 2014 for the airspace considered)
- Assessment of the validity of the traffic sample recorded with respect to the validation objectives

3.2 Exercises Execution

The execution of the first exercise by Project 6.3.2 was performed from 19th to 30th November 2012 and on 17th December 2012. The second exercise took place from 25th to 29th of November 2013.

The evaluation at EEC has been conducted on 28-29th January 2015, in one cycle, covering both exercises planned and the six scenarios.

3.3 Deviations from the planned activities

No deviation from the planned Validation activities in Malpensa was reported.

During the preparation of the validation exercises at EEC minor deviations to the planned activities in the Validation Plan were necessary as not all technical and operational capabilities were available in

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the platform used. It should be noted that the task was an ad-hoc replacement of the originally planned support to external operational validation project(s) and that consequently the used platform was not a fully comprehensive IBP. Following limitations and constraints were recorded:

- Environment and Airspace: The validation exercises focused on the entire Paris TMA area and the area above this TMA normally handled by ACC sectors in DSNA. This upper airspace was considered as a unique en-route sector.
- Exercise Scenarios: The scenarios used within the validation used a recorded life traffic sample from a busy day of 2014 in the considered airspace. Parts of this scenario were used to evaluate the different traffic loads required in the exercise without having a specific traffic sample associated with the traffic load. The traffic charge was evaluated subjectively by the subject matter expert without a reference to the actual limits set in the real ATC system.
- Exercise set-up functionalities: Due to the lack of the availability of a fully comprehensive ATC platform some of the functionalities normally available on a CWP were not present (e.g. simultaneous display of the ground speed for all flights).
- Simulated flights: No simulated flights could be inserted to test the capability of the system. However, means to interact with the data provided for the recorded flight was possible, hence some of the non-nominal situations planned were evaluated

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4 Exercises Results

4.1 Summary of Exercises Results

The results of the validation related activities are summarized in the Tables below. The results are assessed with the following indications:

- OK: Validation Objective achieves the expectations (exercise results achieve success criteria)
- NOK: Validation Objective does not achieve the expectations (exercise results do not achieve success criteria)
- OPEN ISSUE: Issue to be further investigated (e.g. no clear results are obtained)
- N/A: Success criterion associated to the Validation Objective was not addressed

Due to the limitations of the available validation platform some objectives (or part of them) were only partially evaluated. The table below will include the mention of partially evaluated in the "Validation Objective Status" column

The summary results of the ADS-B related Validation exercise supported in Project 6.3.2 are provided in the Table hereafter.

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Validation Objective ID	Validation Objective Title	Success Criterion ID	Success Criterion	Exercise Results	Validation Objective Status
OBJ-06.03.02-VALP-0065.0006	Confirm that better surveillance information is available on final approach surveillance	CRT-**06.03.02** -VALP-065	Data quality increases with regards to the current surveillance system by means of ADS-B application	100% of positive feedback provided by involved controllers	OK
OBJ-06.03.02-VALP-00652-0002	Confirm that better surveillance information is available	CRT-06.03.02-VALP-0652.0201	Data quality increases with regards to the current surveillance system by means of ADS-B application.	Success criterion achieved. Since scenario reference 1 and solution 4 were compared, ATCOs effectively noticed a data quality increase by means of enhanced ADS-B application with regards to the current surveillance system. Confronting the type of data regarding the state of validation (i.e. valid, not valid, validation not executed) it has been possible to demonstrate that not valid data were excluded from the system improving data quality.	OK
		CRT-06.03.02-VALP-0652.0202	Controller situational awareness is improved	Success criterion achieved. ATCOs asserted ADS-B is useful to improve their situational awareness especially in low visibility conditions.	OK

Table 9: Project 6.3.2 ADS-B Exercise Results

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The summary of the Validation results at the EEC are provided in the Table hereafter:

Validation Objective ID	Validation Objective Title	Success Criterion ID	Success Criterion	Exercise Results	Validation Objective Status
OBJ-15.04.05a-VALP001.0001	Verify that the ground system function receives, decodes, packages and time-stamps the data, and sends corresponding surveillance reports to the ATC processing system	CRT**15.04.05a-**VALP-001.0101	Positive data correlation between different surveillance sources	Decoding is performed correctly – differences were observed at the level of the altitude for flights in vertical movement due to the difference in the update rate between pure ADS-B data and SDPD fused tracks. However this is not considered to be an issue.	OK
OBJ**15.04.05a-**VALP-001.0002	Verify that the ground system function provides the following minimum data set to the ATC processing system: Aircraft Horizontal Position – Latitude and Longitude Pressure altitude Quality Indications of Horizontal Position Aircraft Identity Emergency Indicators (when selected by the	CRT-**15.04.05a-**VALP-001.0202	Corresponding data is correctly displayed on the CWP	Generally data set is available for display to CWP. A few issues were identified.	OK (partially evaluated)

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Validation Objective ID	Validation Objective Title	Success Criterion ID	Success Criterion	Exercise Results	Validation Objective Status
	flight crew) Special Position Identification (SPI) (when selected by the flight crew) Time of Applicability Ground velocity and relevant quality indicator if required by the local implementation				
OBJ-**15.04.05a-**VALP-001.0003	Verify that when direct recognition procedures are used by the controller for identification, the ground system contains a function to ensure the aircraft identity data that is broadcast is retained and correctly associated with the position information for display	CRT-**15.04.05a-**VALP-001.0303	Positive correlation between the ID information from ADS-B, Mode S, Mode A, FPL	Generally successful. Issues with correlation between several surveillance sources at the edge of the coverage area were identified.	OK
OBJ-**15.04.05a-**VALP-001.0007	Verify that the processing function enables the switching between the surveillance sources (e.g. as a backup during a failure) without requiring the ATCO to perform a: ▪ Re-verification of altitude data	CRT-**15.04.05a-**VALP-001.0707	Successful commutation between different surveillance sources while maintaining identification and position data	Function verified and found to be according to specifications.	OK

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Validation Objective ID	Validation Objective Title	Success Criterion ID	Success Criterion	Exercise Results	Validation Objective Status
	▪ Re-identification of aircraft identity				
OBJ**15.04.05a-**VALP-001.0008	Verify that the minimum performance requirements for the accuracy are satisfied	CRT-**15.04.05a-**VALP-001.0808	Positive validation of the data accuracy through direct observation	Positional accuracy proves to be consistent with the operational requirements for both environments considered	OK
OBJ**15.04.05a-**VALP-001.0009	Verify that the minimum performance requirements for the update rate are satisfied	CRT-**15.04.05a-**VALP-001.0909	Data refresh at CWP level is satisfactory	A one second update rate was used for ADS-B only source which was proven to be more convenient for the TMA environment, especially to cover for flights changing their flight direction	OK
OBJ-**15.04.05a-**VALP-001.0010	Verify that the minimum performance requirements for the latency are satisfied	CRT-**15.04.05a-**VALP-001.1010	Data latency (display lag) is satisfactory at the CWP level	The difference in positional accuracy due to data latency could not be observed.	N/A
OBJ**15.04.05a-**VALP-001.0011	Verify that the minimum performance requirements for the inconsistency and duplicate identity check are satisfied	CRT-**15.04.05a-**VALP-001.1111	Positive identification and notification of duplicate identity at CWP level	Generally successful. Issues were detected at the edge of the coverage. These will need further investigation both at the level of the display (CWP) as well as at the level of the tracker.	Open Issue
OBJ-**15.04.05a-**VALP-001.0012	Verify that the minimum performance requirements for the horizontal and vertical position error detection are satisfied	CRT-**15.04.05a-**VALP-001.1212	Positive identification and notification for positional information error at CWP level	Limitation of the traffic sample and the platform did not allow for this objective to be assessed	N/A
OBJ-**15.04.05a-**VALP-	Verify that the minimum performance requirements for the emergency code	CRT-**15.04.05a-**VALP-001.1313	Positive identification and timely notification of emergency code at CWP	Simulated emergency codes were introduced in the exercises. The direct observation of the display did not produce	Open Issue

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Validation Objective ID	Validation Objective Title	Success Criterion ID	Success Criterion	Exercise Results	Validation Objective Status
001.0013	detection are satisfied		level	conclusive results.	
OBJ**15.04.05a-**VALP-001.0017	Assess and investigate the acceptability and acceptance of the data used, by the controller, with the same separation minima as currently applied	CRT-**15.04.05a-**VALP-001.1717	ATC operational acceptance	Given the accuracy of the data the requirements seems to be satisfactory for the current separation minima criteria used. The issue of altitude difference display between ADS-B only source and ARTAS fused data should be further investigated.	OK (partially evaluated)
OBJ-**15.04.05a-**VALP-001.0018	Assess and investigate the acceptability and acceptance of the data used, by the controller, in Terminal airspace	CRT-**15.04.05a-**VALP-001.1818	Terminal ATC operational acceptance	Given the accuracy of the data the requirements seems to be satisfactory for the current separation minima criteria used. The issue of altitude difference display between ADS-B only source and ARTAS fused data should be further investigated.	OK (partially evaluated)
OBJ-**15.04.05a-**VALP-001.0019	Assess and investigate the acceptability and acceptance of the data used, by the controller, in En-Route airspace	CRT-**15.04.05a-**VALP-001.1919	En-route ATC operational acceptance	Given the accuracy of the data the requirements seems to be satisfactory for the current separation minima criteria used. The issue of altitude difference display between ADS-B only source and ARTAS fused data should be further investigated.	OK (partially evaluated)
OBJ-**15.04.05a-**VALP-001.0023	Assess and investigate the acceptability and acceptance of the data used, by the controller in case of temporary one surveillance source data loss or detected corruption for one aircraft	CRT-**15.04.05a-**VALP-001.2317	ATC operational acceptance	Not covered due to the platform limitations.	N/A

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Validation Objective ID	Validation Objective Title	Success Criterion ID	Success Criterion	Exercise Results	Validation Objective Status
OBJ-**15.04.05a-**VALP-001.0024	Assess and investigate the acceptability and acceptance of the data used, by the controller in case of permanent one surveillance source data loss or detected corruption for one aircraft	CRT-**15.04.05a-**VALP-001.2417	ATC operational acceptance	The positional accuracy evaluated was maintained within the requirements. Partially covered due to system limitations.	OK (partially evaluated)
OBJ-**15.04.05a-**VALP-001.0025	Assess and investigate the acceptability and acceptance of the data used, by the controller in case of temporary one surveillance source data loss or detected corruption for all aircraft	CRT-**15.04.05a-**VALP-001.2517	ATC operational acceptance	The positional accuracy evaluated was maintained within the requirements. Partially covered due to system limitations.	OK (partially evaluated)
OBJ-**15.04.05a-**VALP-001.0026	Assess and investigate the acceptability and acceptance of the data used, by the controller in case of permanent one surveillance source data loss or detected corruption for all aircraft	CRT-**15.04.05a-**VALP-001.2617	ATC operational acceptance	The positional accuracy evaluated was maintained within the requirements. Partially covered due to system limitations.	OK (partially evaluated)
OBJ-**15.04.05a-**VALP-001.0027	Verify the usability and usage of the display providing multiple surveillance data information to the controllers: ▪ Aircraft position and altitude ▪ Identity ▪ Emergency and SPI	CRT-**15.04.05a-**VALP-001.2717	ATC operational acceptance	Due to the limitation of the CWP interface available for the validation exercise, some of the data required was not displayed permanently and simultaneously for all tracks available. Only aircraft position and identity were assessed completely and proved to be acceptable for the regular use of the controller	OK (partially evaluated)

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Validation Objective ID	Validation Objective Title	Success Criterion ID	Success Criterion	Exercise Results	Validation Objective Status
	Indicators ▪ Ground Velocity Surveillance track presentation				
OBJ-**15.04.05a**-VALP-001.0028	Assess and investigate which additional skills and training are required for controllers	CRT-**15.04.05a**-VALP-001.2820	ATC operational assessment	In a mixed ADS-B only and fused surveillance environment, if different update rates are used for display controllers need to be aware of the issue. Training and experience could improve the situation	OK
OBJ-**15.04.05a**-VALP-001.0029	Assess and investigate the impact of data source presentation on the overall controller workload	CRT-**15.04.05a**-VALP-001.2921	ATC workload subjective assessment	Data source differential display was not tested in the exercise. No additional workload was identified	OK (partially evaluated)
OBJ-**15.04.05a**-VALP-001.0030	Assess and investigate if workload is reduced/increased following the introduction of new surveillance data	CRT-**15.04.05a**-VALP-001.3022	ATC workload positive subjective assessment	Data source differential display was not tested in the exercise. No additional workload was identified	OK (partially evaluated)
OBJ-**15.04.05a**-VALP-001.0031	Assess and investigate if the workload is increased in non-nominal conditions compared with current environment (due to losses or corrupted one surveillance source data)	CRT-**15.04.05a**-VALP-001.3123	ATC workload subjective assessment in contingency situations	Generally successful. Issues detected at the edge of the coverage zone should be resolved to maintain the controller workload.	OK
OBJ-**15.04.05a**-VALP-001.0032	Verify that the use of new surveillance data introduces minor changes to controller and flight crew tasks in	CRT-**15.04.05a**-VALP-001.3224	ATC task assessment	Generally successful. Correlation issues at the edge of the coverage should be resolved.	OK

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Validation Objective ID	Validation Objective Title	Success Criterion ID	Success Criterion	Exercise Results	Validation Objective Status
	comparison with current procedures				

Table 10: Summary of Validation Exercises Results at EEC

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4.1.1 Results on concept clarification

N/A

4.1.2 Results per KPA

The results have confirmed the potential of the developed ADS-B ground Surveillance system to have a positive contribution to KPAs such as safety, efficiency, interoperability, security etc.

4.1.3 Results impacting regulation and standardisation initiatives

The results have supported the inputs made to the following standards:

- EUROCAE Technical Specifications for ADS-B Ground station (ED-129A)
    - Published
- EUROCAE Technical Specifications for ADS-B Ground system (ED-129B)
    - Approaching publication
- ASTERIX Interface Specifications (for ADS-B and tracks)
    - Update ongoing

The SESAR projects have also contributed to the SDPD Specifications.

They have also developed prototypes of means of compliance with the EU Regulation 1207/2011 and its amendments.

4.2 Analysis of Exercises Results

The ADS-B related validation objectives in support of the Malpensa Airport exercises of Project 6.3.2 as well as in the evaluation at the SELEX ES premises were successfully addressed.

The use of the system contributes to an improved situational awareness and does not normally increase the associated controller workload. The system also improves security by successfully mitigating the associated threats.

While considering the main assumptions and limitations of the available validation platform at EEC the main objectives of the validation exercise have been evaluated. Subject matter expert participating in the evaluation exercise concluded that the surveillance data received and processed from an ADS-B source in TMA and en-route is within the required performance parameters for ATC services usage. A note has been recorded in the case of TMA (especially for high traffic levels) that the update rate of the ADS-B (1 second) could be beneficial if used in the position display on the CWP instead of the tracker derived one (around 5 seconds). This was found particularly useful in case of evolving traffic in lateral and vertical planes.

The traffic sample used (a recording of a day of traffic within the area considered) offered the possibility to test several cases of system behaviour in relationship with the required performance. All tests resulted in a positive conclusion.

The ATC expected performance is evaluated as not being impacted (in terms of potential workload) by the use of ADS-B alone or multiple sources of surveillance information.

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4.2.1 Unexpected Behaviours/Results

A few issues were observed and noted during the EEC exercises in relationship with the display and calculation of the actual altitude of a flight. Similarly issues were observed in relationship with the display of the emergency codes received from an ADS-B source of surveillance data. It was observed in a few cases, that though the emergency indicator was correctly received and decoded, its display on the CWP was impaired. Moreover in case of using the SPI function during an emergency code being transmitted, the emergency code is invalidated and only the SPI is decoded and sent to the CWP for display. The investigation of the issue did not produce conclusive results and therefore this issue should be investigated.

4.3 Confidence in Results of Validation Exercises

4.3.1 Quality of Validation Exercises Results

For Malpensa validation support, this is reported by 6.3.2.

For EEC, all exercises were conducted with real traffic recorded data which have an impact on the quality of the obtained results. While the traffic sample used offered the possibility of evaluating the validation objectives in a realistic scenario, the available platform and the use of simulated non-nominal events had an impact on the quality of the observations performed during the exercises and the possibility of covering fully the validation objectives considered. Also the time and the number of subject matter experts available for the validation were relatively constrained.

However, it is worth noting that the exercises provided enough data to allow the validation experts to draw conclusions and identify the few issues that may require further investigation.

4.3.2 Significance of Validation Exercises Results

For Malpensa validation, this is reported by 6.3.2.

The data which have been produced during the exercises at EEC, are strongly indicative for the demonstration of the required performance, despite the fact that due to the nature of this validation the time availability and the platform limitations these cannot be considered as statistically exhaustive.

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5 Conclusions and recommendations

5.1 Conclusions

The ADS-B related validation objectives in support of the Malpensa exercises of Project 6.3.2 were successfully addressed. Surveillance data quality improvement was demonstrated by means of ADS-B. Controllers effectively reported an enhancement of situational awareness thanks to an evident surveillance data quality improvement.

The Exercises allowed verifying the technical feasibility and the operational suitability of surface safety nets and enhanced ADS-B in an air traffic control tower environment.

Similarly for the EEC validation activities, at a generic level, considering the available scenarios, environment and traffic samples, the data provided by the ADS-B prototypes in a multisensor TMA and en-route environment can be considered as meeting the requirements for the operational services envisaged. A few cases demonstrated the need for further investigations.

The data received from an ADS-B source is integrated correctly with other surveillance data and the data is fused and combined in a single track for a flight. Comparison of the data displayed from an ADS-B source alone and a fused track for the same flight did not show differences in terms of accuracy, data stability, integrity etc.

A few issues were observed in the decoding and publication on the CWP of data related to emergency codes and SPI when used simultaneously. Correlation may become an additional issue, in the areas at the limit of the surveillance coverage.

Collected qualitative evidence suggests the use of the prototyped functionality in TMA and En-Route environment is feasible and operationally acceptable.

5.2 Recommendations

It is recommended that the few identified issues will be addressed in the future evolution of the prototypes during industrialisation and deployment.

Regarding the validation platform at EEC which was not a full IBP and in order to maximise the benefits from any possible further analysis, improvements of the CWP component of the platform with added functionalities are recommended that would allow for:

- Assessment and evaluation of all the surveillance data required for the provision of ATC simultaneously and in real time
- Data log for recording any specific issues with the transmission of the data between the tracker system and CWP
- Both numerical and graphical display of the data available to the CWP
- Possibility to inject deviation of accuracy for ADS-B traffic only in order to test the capability of the system to detect inconsistencies and their notification to the CWP

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It is recommended that the validation of the system will be continued in the transition towards industrialisation and deployment. This should include a detailed assessment of the performance of the overall system and its components w.r.t. associated emerging standards (e.g. EUROCAE) and Specifications as well as validation exercises of the applications to be implemented and reachable benefits at generic and local levels. The security mitigation functionality related results are of particular importance in this context. Any recommendations from the projects so far should be taken into account. Standardisation activities should take into account the results of the projects.

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6 Validation Exercises reports

6.1 Validation Exercise EXE-06.03.02-VP-065 Support Report

6.1.1 Exercise Scope

Validation exercise EXE-06.03.02-VP-065 aims at validating the integration of Enhanced Surface Safety Nets, Enhanced Surface Guidance, Integrated Tower Working Position, Departure Management and Surface Management, Airport Safety Nets for Controllers, D-TAXI Service as well as Surveillance ground system enhancements for ADS-B.

Concerning the ADS-B prototype, the validation exercise EXE-06.03.02-VP-065 demonstrates the requirements foreseen in the iteration 1, and more in particular, it aims at:

- Confirming that the situation in which the tools are integrated has an added value compared to a situation where each system gives information separately and it is for the controller to choose which one has to be used.
- Showing to air traffic controllers and validating with them that the integration of systems brings an additional value compared to a situation where the systems are not integrated.

The use of integrated platform tools leads to several advantages:

- Safety enhancements in terms of situational awareness increase, workload reduction, surveillance data quality augmentation.
- Capacity enhancements in terms of delays reduction.
- Predictability enhancements, in terms of situational awareness increase.
- Efficiency enhancements in terms of data accuracy augmentation.
- Environmental sustainability in terms of potential fuel burn consumption and C02 emission reduction.

Based on the integrated tools the verification has been performed in different manners i.e. using real time simulations, live trials or shadow mode. In particular, for the ADS-B ground station prototype first Iteration, the test was performed adopting a shadow mode approach and exploiting the live traffic data available in the surrounding area of Milano Malpensa Airport.

The prototypes delivered by WP12 and WP15 and integrated in the platform are reported in the following Table:

System Identifier	SUT Prototype	SUT Functionalities
15.04.05.b-D04-SELEX-ADS-B Ground Station	ADS-B Ground Station Prototype	Alignment of SELEX legacy product to ADS-B RAD standard. Integrity enhancement
12.03.02.D05-SELEX-ASN	First prototype of Surface Safety Nets Server	Surface Conflicts detection (RWY incursion, TWY conflicts, Speed Limits, Area Intrusion), Taxi Conformance Monitoring, Distribution of Alerts to Data Link

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System Identifier	SUT Prototype	SUT Functionalities
		interface
12.03.04-D06-SELEX	Surface Taxi Clearances	On Board Guidance for vehicles
12.04.04-D05-SELEX DMAN/SMAN	First prototype of integrated DMAN and SMAN platform	The prototype will integrate basic DMAN with the routing capability of A-SMGCS
12.05.02.D05-SELEX-ASN HMI	First prototype of Surface Alert HMI	Surface Conflict warnings and alerts (RWY incursion, TWY conflicts, Speed Limits, Area intrusion), Taxi Conformance monitoring (alerting on deviation from assigned route)
12.05.04-D08-SELEX-Tower iCWP	Tower CWP	HMI with: - Runway management tools - Improved surveillance for surface management - Enhanced sequencing tools - Airport safety nets - Air/Ground Data Link

Table 11: EXE65 integrated prototypes

The ADS-B GS first iteration includes a set of software upgrades necessary to adhere to the ADS-B RAD standard Moreover it includes an ADS-B position validation mechanism based on an independent surveillance source. Hence within the context of the EXE-06.03.02-VP-065, the above mentioned upgrade and validation mechanism based on comparing ADS-B position against WAM position have been verified.
The WAM validation feature represents the first step towards a set of improvements foreseen by the 15.4.5a project to make the ADS-B more robust against spoofing and integrity issues. More details about the WAM validation mechanism will be given in the next paragraphs.

The validation exercise EXE-06.03.02-VP-065 aims at demonstrating the ADS-B WAM validation features foreseen in the iteration 1.

The relevant validation objective of EXE-06.03.02-VP-065 is given in the Table hereafter together with their associated success criteria.

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OBJ	KPA	Area	Hypothesis	Metric/Indicator	Data Collection methods
OBJ-06.03.02-VALP-0065.0006	**Safety**	**Surveillance data quality**	Safety increases due to better surveillance information on final approach surveillance.	Number of ghost tracks Controllers' perceived surveillance data quality.	Over the shoulders observation Debriefing

Table 12: EXE 65 ADS-B objective

6.1.1.1 Malpensa Airport overview

Milano Malpensa airport is located about 48 km north-west from Milan. It has two parallel runways, oriented at 349° or 169° depending on the direction of use:

- RWY 35R/17L
- RWY 35L/17R

Both runways have a length of 3 920 meters and a width of 60 meters and are used for arrivals and departures. Runways 17L, 35L and 35R have ILS and all runways have the PAPI system.

The distance between the two runways is about 800m, so it is not possible to have independent and parallel approaches on them.

Milano Malpensa airport has two aprons:

- Apron West is located on the West of the runways 35R/17L and 35L/17R and it is the main one, used by scheduled domestic flights, international ones and intercontinental ones;
- Apron North 2 is located on the North of the runway 17L/R and it is mainly used by air traffic charter and low-cost airlines.

A taxiway preferential use has been defined in order to indicate the taxiway to be used to reach the apron (TWY IN) or to leave the apron (TWY OUT) as it follows:

- Apron West:
  - TWY W used as TWY IN,
  - TWY K and Apron TWY Y used as TWY OUT;
- Apron North:
  - Apron TWY A used as TWY IN,
  - Apron TWY B used as TWY IN,
  - Apron TWY C used as TWY OUT.

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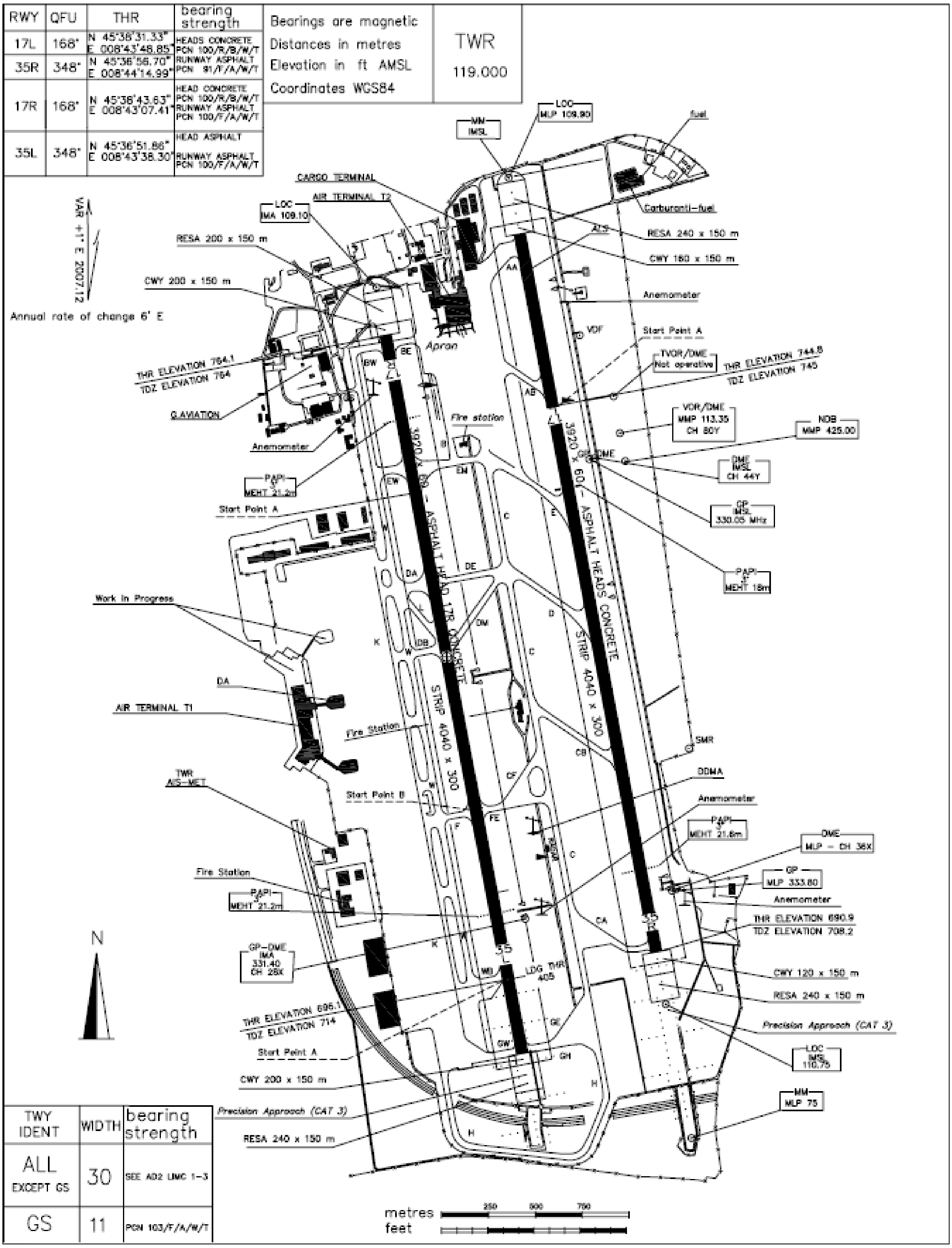

Figure 4: Milano Malpensa Aerodrome Chart ICAO

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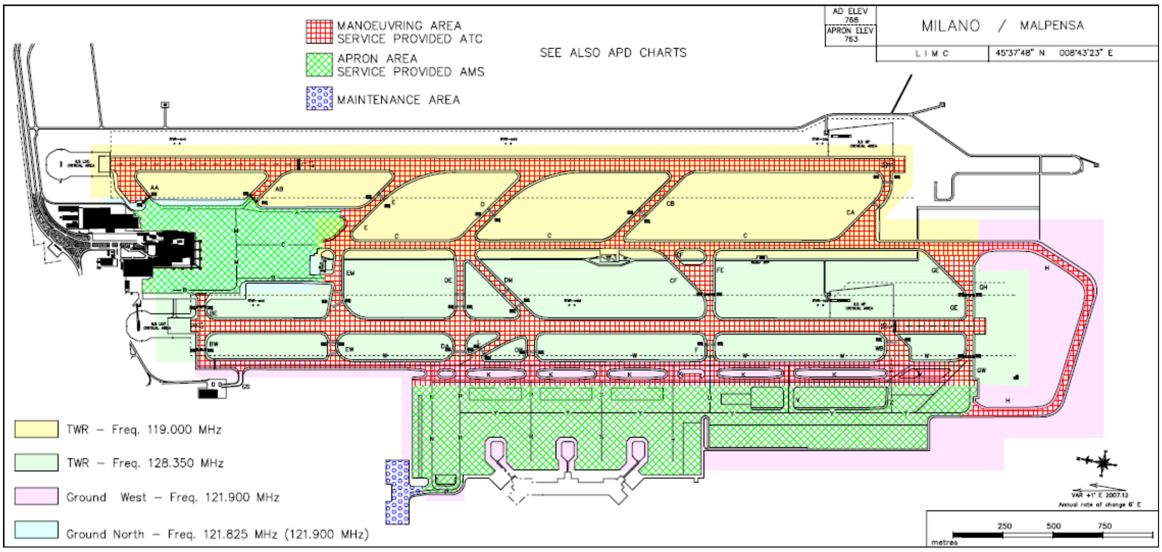

Figure 5: Milano Malpensa Aerodrome Ground Movement Chart ICAO

Figure **6** presents Link Routes and Standard Arrival Routes, currently flown by arrivals to Milano Malpensa airport.

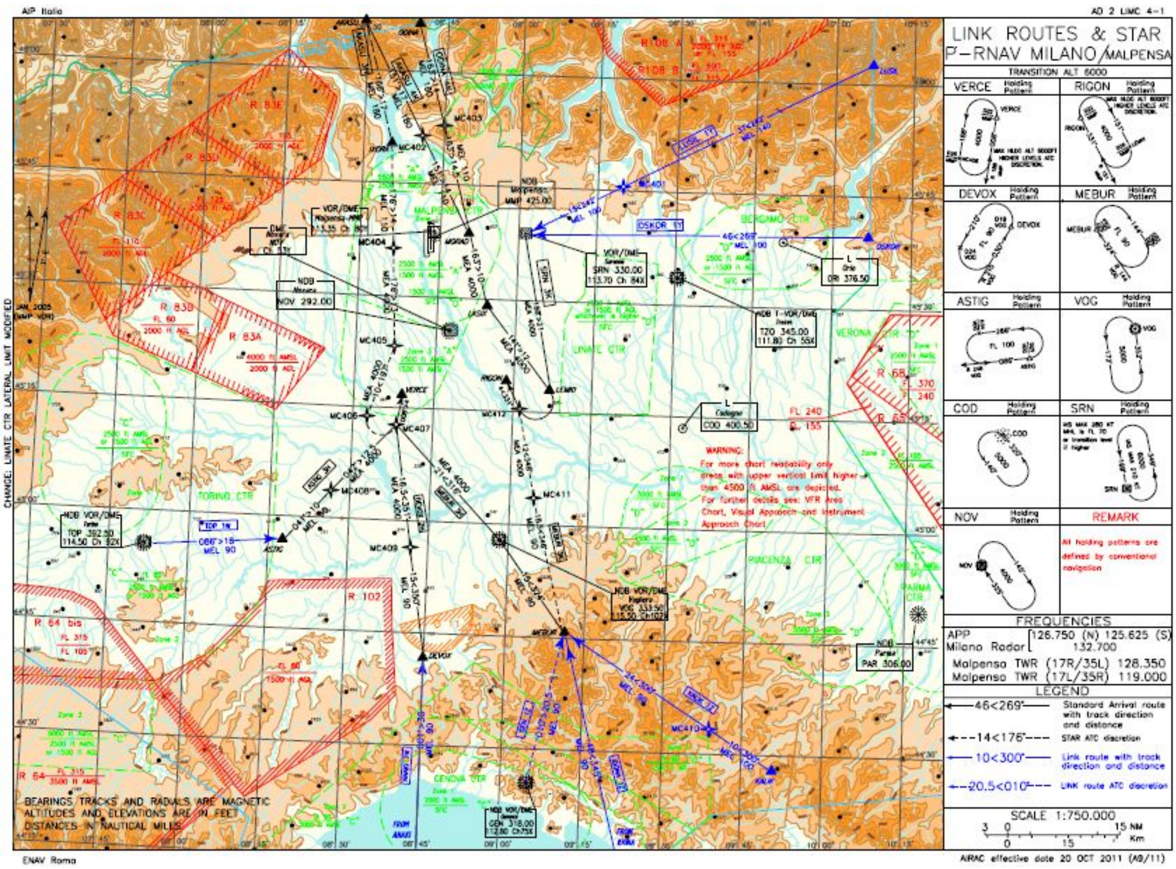

Figure 6: Milano Malpensa LINK Routes and STARS

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The traffic volume in the different scenarios may vary between:

- High traffic volume (100%): maximum current capacity in Milano Malpensa Airport.
- Medium traffic volume: between 50% and 75% of the high traffic volume.

6.1.1.2 Validation exercise system architecture

The following diagram represents the Test-Bed architecture for EXE-06.03.02-VP-065 (and EXE-06.03.02-VP-0652).

The

Figure 7 shows the overall system architecture of the IBP Milano Malpensa airport.

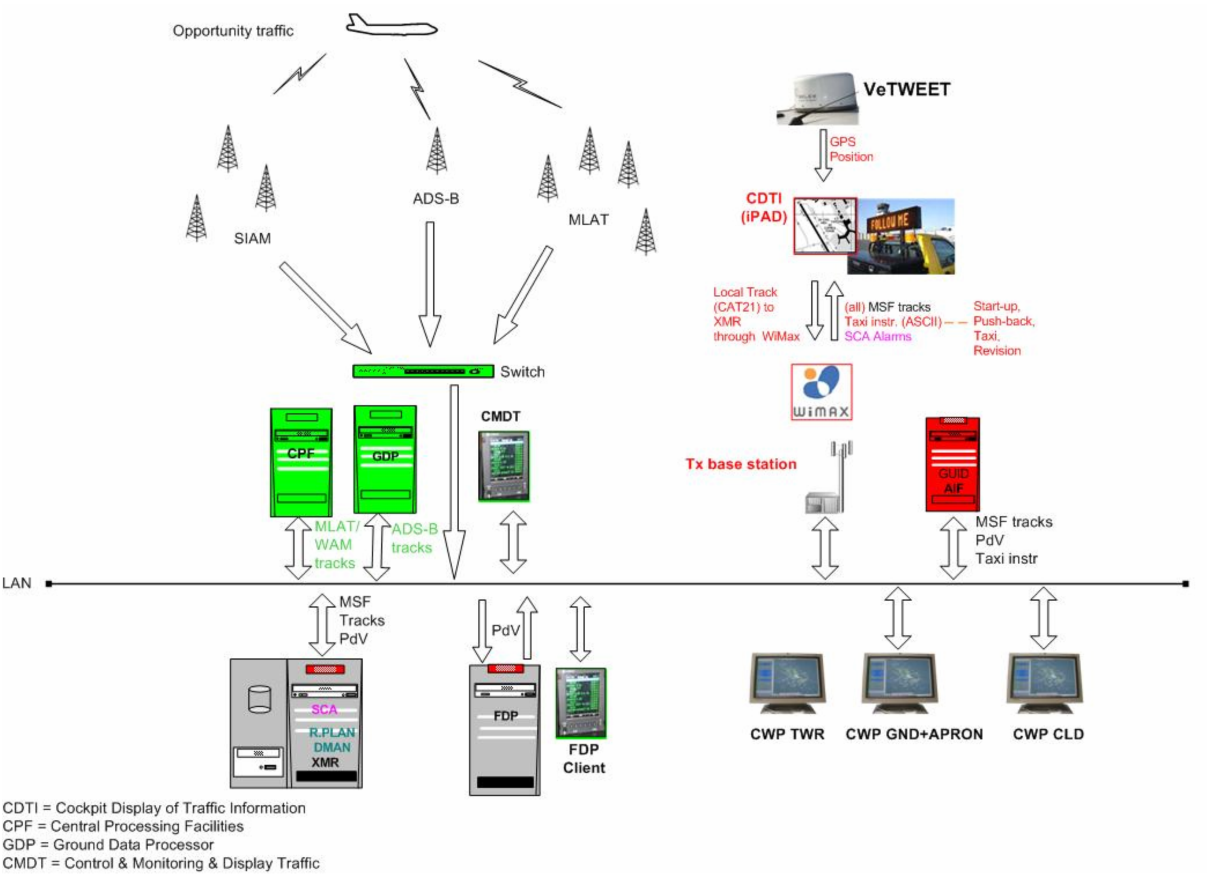

Figure 7: EXE065 Test-Bed Architecture

The following prototypes are included in the test-bed:

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System Name	Type
ADS-B Ground Station Prototype (15.04.05)	Prototype
First prototype of Surface Safety Nets Server (12.03.02)	Prototype
Surface Guidance (12.03.04)	Prototype
Tower iCWP Prototype (12.05.04)	Prototype
First prototype of integrated DMAN and SMAN platform (12.04.04)	Prototype
First prototype of Surface Alert HMI (12.05.02)	Prototype

Table 13: List of prototypes included in the Testbed

The overall integration has been done minimizing the conflict with operational system, therefore special attention has been given to the integration process (separate network, server replication, etc). The Figure hereafter shows the logical scheme of the ADS-B architecture deployed in Malpensa IBP. Marked with red boxes the components verified within the exercise 65. The Multi Radar Tracking (MRT) integrates the CSCI which is in charge of verifying the validity of the ADS-B plot. It is fed with two streams of data i.e. ASTX20 coming from the WAM system and the ASTX21 from the ADS-B GS prototype. Thus the MRT performs the position validity check comparing the position provided by WAM system against the ADS-B position. The fused system tracks as well as the sensor bypass tracks are sent and displayed to the CWPs station installed in the back-up operational room.

The ADS-B GS sends the ADS-B tracks (in ASTERIX CAT 021) and service messages (in ASTERIX CAT 023) to the Selex-SI Multi Sensor Fusion which is part of the SESAR test-bed. The CSCI Multi Sensor Fusion is in charge of managing the ADS-B information and all the enhancements of the ADS-B GS developed in project.15.04.05.

In order to perform the WAM validation, an additional WAM server has been installed in the equipment room (3rd floor). This WAM server is in charge of receiving raw data from the existent MLAT sensors plus three additional sensors (SIAM) located outside the airport with the aim of increasing the surveillance coverage of the current operative MLAT system.

The WAM server will output ASTERIX Cat. 20 tracks, which will be received by the Enhanced ADS-B prototype, in order to perform the ADS-B validation algorithms.

Furthermore the SESAR CWP prototypes have been developed and improved in order to fulfil the requirement of each project participating to the EXE-06.03.02-VP-065.

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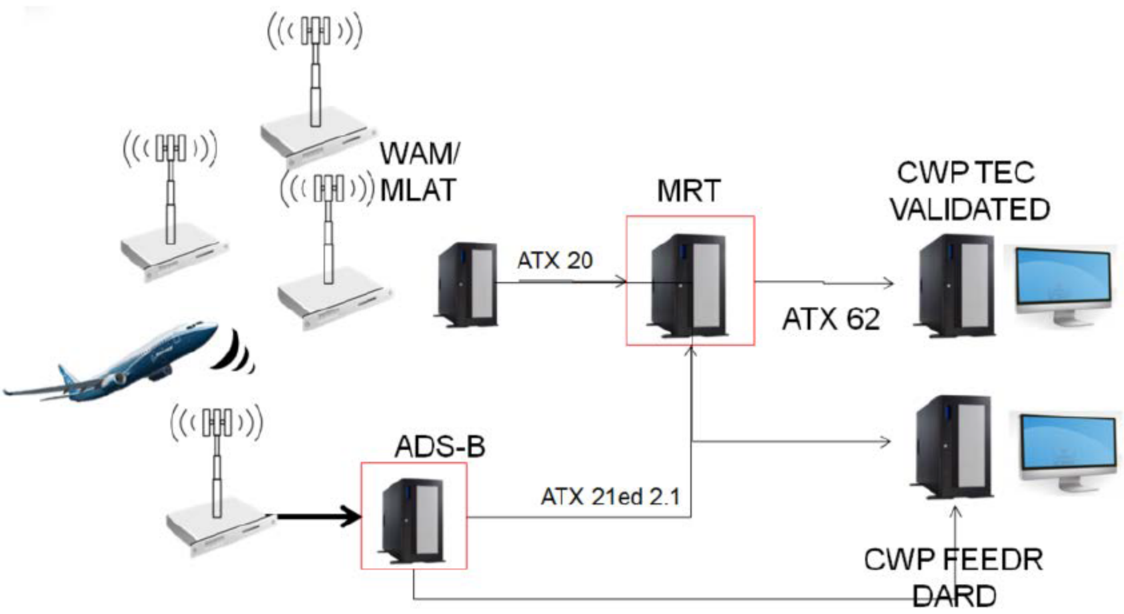

Figure 8 ADS-B GS Iteration 1 – architectural scheme

The ADS-B GS server is installed into a dedicated rack placed on the 3rd floor of the tower control. The Antenna is installed on the roof of the control tower and both displays are installed one next to another in the backup operation room on the 10th floor of the control tower. A fibre-optic connection is in place for data communication between the two floors. The SESAR racks are installed in the equipment room (3rd floor). The ADS-B prototype's server is shown in the following Figure 9.

Figure 9: P15.04.05 SELEX ADS-B GS Prototype rack

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The Control and Monitoring work station is installed on a desk located in the same equipment room (

Figure **10**).

Figure 10 SELEX ADS-B GS Control and Monitoring workstation installation

The ADS-B sensor is installed in the equipment room at the 8th floor and the 1090 MHz antenna on the roof of the CTW (Figure 11).

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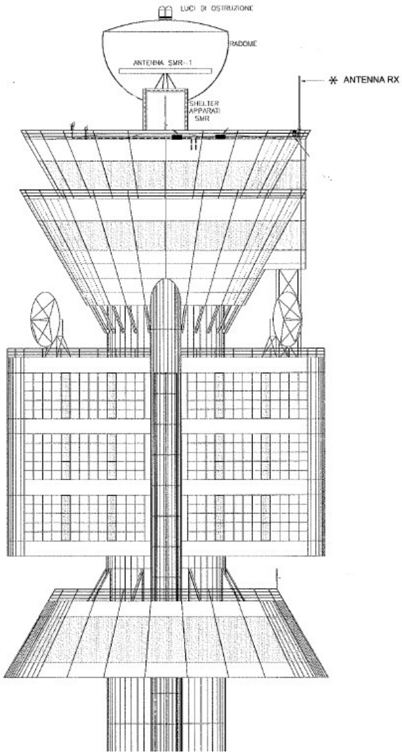

Figure 11 SELEX ADS-B GS 1090 MHz antenna installation

The following Figure 12 shows the positions reserved for the validation exercise in the backup operational room of MXP Control Tower.

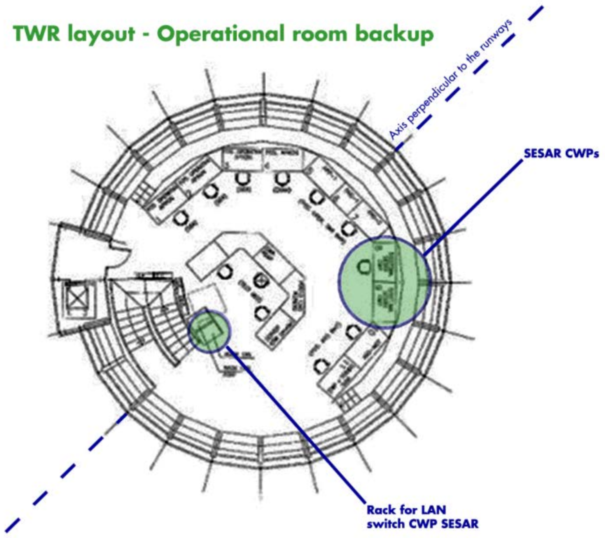

Figure 12 CWPs installation details

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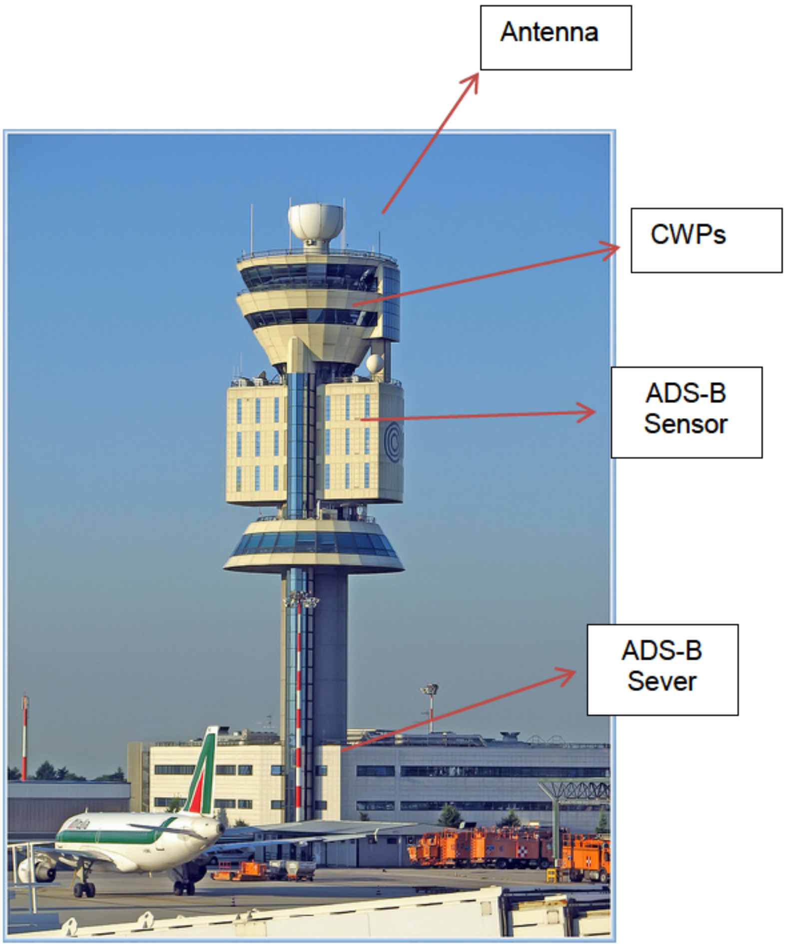

Figure 13 Milano Malpensa Control Tower

6.1.1.3 SELEX ADS-B GS prototype first iteration

The following subsection includes a description of the validation component introduced in the first iteration and therefore subjected to the verification process defined by the EXE 65.

6.1.1.3.1 ADS-B GS first iteration - WAM Validation

ADS-B is an ATC surveillance technology, which enables cost-efficient Gate-to-Gate Ground based Surveillance and Airborne Surveillance. The future SESAR ATM Services include ADS-B applications (such as "ADS-B out" and ASAS) which have an impact on both the ground and airborne Surveillance system in terms of safety, performance, interoperability, security. Enhancements are thus required to the ground Surveillance system to make it compliant and capable to support the SESAR development and validation activities, as well as the timely and efficient transition to industrialization and operational deployment.

The simplicity to fabricate a fake ADS-B signals generator with output which is indistinguishable from the real one and the security issue generated by wrong position transmitted by an erratic XPDR pose

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challenges. Therefore opportune countermeasures have been identified to get rid of these security issues.

15.5.4b Project has received ADS-B ground system enhancement specifications and test specifications from Project 15.4.5a as input to develop and verify ADS-B 1090 Extended Squitter ground station and Surveillance Data Processing and Distribution (SDPD) prototypes to support SESAR ATM Services.

The majority of currently deployed ADS-B 1090 ES systems are integrated to WAM system. Such integration offers not only the advantage of infrastructure sharing between the two surveillance systems but also the potential for substantial improvement of the 1090ES detection capability (and hence performance robustness of ADS-B reception) by taking into account multilateration derived data during the squitter decoding process. This is related mainly with target acquisition, handling of duplicate Mode S addresses, protection against spoofing, as well as integrity and continuity enhancements.

The ADS-B GS first iteration includes a validation of received ADS-B positions with an independent surveillance source, the WAM system.

The WAM validation method relies on an external source (WAM position report) to validate the ADS-B received position. The received ADS-B position is validated and marked as VALID if the received position match the position received from the WAM system The acceptance criteria requires that “the distance between the two positions shall be less than a predefined threshold”, thus if the distance exceed the threshold the track is marked as validated and NOT VALID. In case that the WAM data is not available the track is marker as NOT VALIDATED.

In the context of the EXE 65 the verification has been performed looking for erratic XPDR, and for security issue without employing any fake transponders.

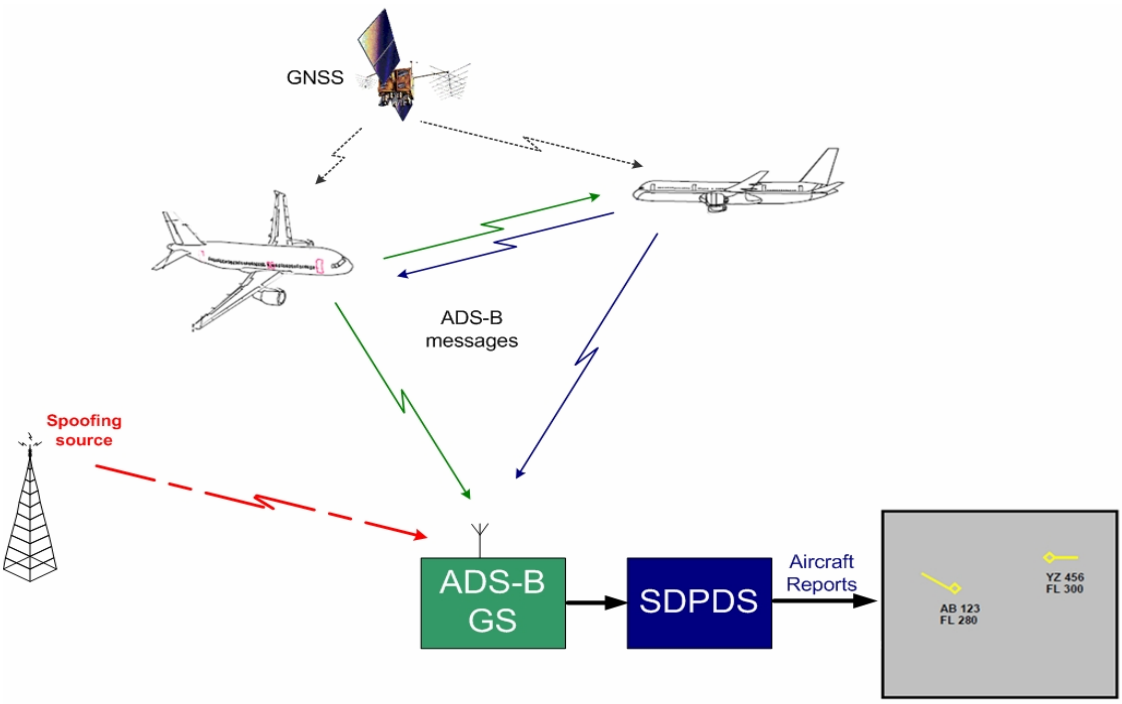

Figure 14: ADS-B –spoofing scenario

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The presence of erratic XPDR, is not a unlikely event, in fact was possible to record the data of the aircraft with call sign IBE3637 ICAO address 34138C, where the difference between the ADS-B track and MLAT track is evident (Figure hereafter). The ADS-B track has a considerable bias probably due to the use of a navigation source different from GPS. In this case the WAM validation algorithm marks the ADS-B data as “not valid”.

Figure 15: Erratic XDPR- misplaced airplane position

The assessment of compliance of the SELEX ADS-B GS to the corresponding Specifications was performed in the SELEX-ES facility using a specific testbed and was not part of the EXE 65.

6.1.2 Conduct of Validation Exercise

6.1.2.1 Exercise Preparation

The main preparatory activities are described below:

- High level definition of the exercise, including selection of functionalities available in the prototype, the traffic, validation scenarios, special events, etc..
- Updating of the platform
- Prototype testing/acceptance
- Writing of the availability notes document
- Preparation of the needed
- Definition of the data exercise: this activity includes, amongst other:
- Physical scenario

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- Adaptations of the traffic gathering methods that will be used including questionnaires, structured interviews, data log, etc.
- Preparation of the training material including presentations, user manual (if needed).
- Selection/invitation of ATCOs and pseudo-pilots to be involved as experimental subjects
- Preparation of the site and room hosting the exercise

6.1.2.2 Exercise execution

The execution of the exercise includes training and runs sessions. The exercise was performed in the period from 19th to 30th of November 2012 and on 17th of December where an additional session took place.

The main execution activities are indicated hereafter:

- Run execution according to the predefined scenarios
- Data collection according to the methods selected during the preparatory phase including data record, debriefing, questionnaires, etc.

In order to satisfy the scope of the exercise, several simulation scenarios were tested, in particular one scenario was prepared and execute to cope with the validation of the ADS-B GS prototype. A description of the ADS-B GS scenario is provided hereafter:

Scenario 7 – ADS-B**:** In order to validate ADS-B Ground Station Prototype, one scenario was experimented through shadow mode. The Enhanced ADS-B Ground Station was fed with real traffic data, and the CWPs were provided with both ADS-B and MSF tracks. The Enhanced ADS-B Ground Station improvement was tested comparing the MSF tracks against the ADS-B stand-alone tracks.

The above scenario was executed during the validation sessions as reported below in the Figure below.

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DATE	RUN 1	RUN 2	RUN 3	RUN 4	RUN 5
19/11/2012	TA00 demo by Exercise Technical Coordinator	TA01 Blue/Yellow/Red	TA02 Orange/Green/Blue Green/Blue/Orange Blue/Orange/Green	TD01 Orange/Blue/Green	
20/11/2012	TA03 Orange/Red/Yellow	TD02 Blue/Green/Orange	TD03 Blue/Red/Yellow	TD03_bis Blue/Red/Yellow	
21/11/2012	TD04 Orange/Yellow/Red	TD03_tris Blue/Red/Yellow			
22/11/2012	TD05 Blue/Green/Orange Green/Orange/Blue	TD00 Demo by Exercise Technical Coordinator	MA01 Green/Yellow/Red	MA02 Green/Blue/Orange	MA03 Blue/Orange/Green
23/11/2012	MA04 Orange/Green/Blue	MU01 Green/Blue/Orange	MU02 Green/Red/Yellow	MU03 Blue/Yellow/Red	
26/11/2012	MA05 Orange/Red/Yellow	MB01 Blue/Yellow/Red	MB02 Orange/Red/Yellow		
27/11/2012	TB01 refresh Safety nets	MB03 Green/Blue/Orange	TC01 refresh D-TAXI	TC02 refresh D-TAXI	MC01 Orange/Blue/Green
28/11/2012	MC02 Green/Orange/Blue	MC03 Orange/Red/Yellow	MC04 Green/Yellow/Red	MC05 Blue/Green/Orange	
29/11/2012	MD01 Orange/Red/Yellow	VD01 show	VD02 show	MD02 Orange/Blue/Green	
30/11/2012	MD03 Blue/Green/Orange	MD04 Green/Yellow/Red	MD05 OPL/Orange/Blue		
17/12/2012	ME01	ME02	MF01		

Figure 16 Exercise 65 execution

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- The green box MF01 corresponds to the ADS-B run.
-
-

Each measured run, characterised by a traffic density of 50 a/c per hour, lasted about 70 minutes in order to collect consistent data in order to address both qualitative and quantitative measurements.

Five controllers participated to the experiment; each of them was identified with a colour code as reported the following Table. The controllers not coming from Milano Malpensa participated to other exercise within WP6, in which Milano Malpensa was the simulated operational environment.

Controller	Colour	Current occupation	Previous experience in SESAR Validation activities
ATCo1	Blue	Rome Fiumicino Tower Controller	Participated to EXE-06.07.03-VP090a, EXE-06.07.03-VP09b, EXE-06.08.04-VP298
ATCo2	Orange	Napoli Capodichino Tower and Approach Controller	Participated to EXE-06.07.03-VP090a, EXE-06.07.03-VP09b, EXE-06.08.04-VP298
ATCo3	Green	Bologna Tower Controller	Participated to EXE-06.07.03-VP090a, EXE-06.07.03-VP09b, EXE-06.08.04-VP298
ATCo4	Red	Milano Malpensa Tower Control	none
ATCo5	Yellow	Milano Malpensa Tower Control	none

Table 14: Exercise 65 Air Traffic Controllers

After each measured run, the controllers were interviewed by Human Factors and Safety Experts according to structured interviews in order to collect feedback related to workload and situational awareness inherent to the specific run and each controller position.

Debriefing sessions involving controllers, validation experts and Exercise Technical Coordinator were organized in case of need for clarification due to unexpected behavior of the system, to analyze an unusual event or to share specific feedback and discuss about it.

During each measured run, system data were recorded in order to address quantitative analysis especially in relation to Efficiency, Predictability and Environmental Sustainability Key Performance Area.

6.1.2.3 Deviation from the planned activities

No deviation was reported.

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6.1.3 Exercise Results

6.1.3.1 Summary of Exercise Results

Controllers had the chance to appreciate the reachable benefits of the ADS-B WAM validation feature, however due to fact that the scenario was fed with opportunity traffic there were not enough conditions to stimulate all the different behaviors (VALIDATED and NOT VALID, VALIDATED AND VALID, NOT VALIDATED).

6.1.3.1.1 Results on concept clarification

N/A

6.1.3.1.2 Results per KPA

The results have confirmed the potential of the developed ADS-B ground Surveillance system to have a positive contribution to KPAs such as safety and security.

6.1.3.1.3 Results impacting regulation and standardisation initiatives

The exercises have used prototypes which are means of compliance with the EU Regulation 1207/2011 and its amendments.

The results have supported the inputs made to the following standards:

- EUROCAE Technical Specifications for ADS-B Ground station (ED-129A)
  - Published
- EUROCAE Technical Specifications for ADS-B Ground system (ED-129B)
  - Approaching publication
- ASTERIX Interface Specifications (for ADS-B and tracks)
  - Update ongoing

6.1.3.2 Analysis of Exercise Results

The exercise results are very positive. The assessment of surveillance data improvement in the considered scenario has received a 100% of positive feedback by the ATCOs which participated in the exercise. The summary is presented in the Table hereafter.

Objective ID	Scenario ID	Scenario Title	PI ID	Measure Value
OBJ-06.03.02-VALP-0065.0006	SCN-06.03.02-VALP-0065.0007	ADS-B	ATCOs' subject assessment of surveillance data improvement	100% of positive feedback provided by involved controllers.

Table 15: Performance Indicators

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6.1.3.2.1 Unexpected Behaviours/Results

None reported.

6.1.3.3 Confidence in Results of Validation Exercise

N/A (reported by Project 6.3.2)

6.1.4 Conclusions and recommendations

6.1.4.1 Conclusions

The table below summarizes the conclusion received from the controllers (related with ADS-B part of the exercise):

Operational concept	Main results
ADS-B **AO-0205**: Automated Assistance to Controller for Surface Movement Planning and Routing	Surveillance data quality improvement was demonstrated by means of ADS-B.

Table 16: EXE 65 Conclusions

6.1.4.2 Recommendations

It is recommended to perform further experimentation on the associated reachable benefits.

6.2 Validation Exercise EXE-06.03.02-VP-652 Support Report

6.2.1 Exercise Scope

EXE-06.03.02-VP-652 aims a validating the integration of different Safety Nets concepts which can have a positive impact on safety providing alarms to controllers. It used ad-hoc scenarios simulated with real time simulation technique using SELEX-ES Prototypes 12.3.2 (server part) and 12.5.2 (HMI part). The exercise took place also in Malpensa airport.

Within the frame of the exercise 652 the verification of the ADS-B enhancements which have an impact on the Surveillance system in terms of safety and human performance took place. The validation exercise was performed exploiting the opportunity traffic available at Malpensa airport and surrounding area. As for the EXE-06.03.02-VP-65, due to safety reason and to reduce the impact of the exercise on the ATC operation, the verification of the ADS-B ground station second iteration was performed in shadow mode.

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For the ADS-B GS counterpart the validation exercise was mainly tailored to verify the new features integrated in the ADS-B ground station second iteration. In particular the Enhanced ADS-B ground station - Selex ES Prototype 15.4.5b iteration two, incorporates the following functionality:

- The functionality (TDOA validation and Enhanced ADS-B target report validation via WAM integration) to check the validity of the ADS-B derived data and to discard possible spoofing messages as well as messages transmitted by not accurate ADS-B transponders, enabling an improvement of the surveillance in terms of security and safety.
- Stronger integration of the ADS-B system into a WAM system, supporting amongst others infrastructure rationalisation. This integration offers the advantage of infrastructure sharing between the two surveillance systems, providing a more flexible and cost effective solution, and also the potential for substantial improvement of the 1090ES detection capability (and hence performance robustness of ADS-B reception) by taking into account multilateration derived data during the squitter decoding process.

The validation exercise EXE-06.03.02-VP-0652 demonstrates the ADS-B validation features foreseen in the iteration 2, and more in particular, aims at:

- Confirming that the situation in which the tools are integrated has an added value compared to a situation where each system gives information separately and it is for the controller to choose which one has to be used.
- Showing to air traffic controllers and validating with them that the integration of systems brings an additional value compared to a situation where the systems are not integrated.

The validation objective, limited to the ADS-B GS, identified for EXE-06.03.02-VP-065 is given in the following Table, together with the associated success criteria.

OBJ	KPA	Area	Hypothesis	Metric/Indicator	Data Collection methods
OBJ-06.03.02-VALP-0652.0002	Safety	Surveillance data quality	Safety increases due to better surveillance information.	• Controllers' perceived surveillance data quality. • Controllers' perceived situational awareness • % of validation not executed/valid/not valid tracks respect to the total number of tracks • Number and type of notifications	Over the shoulders observations Debriefing System logs

Table 17: EXE 652 Validation Objectives

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As already mentioned the ADS-B ground station prototypes is one of prototypes that were verified within the EXE65, the full list of the prototypes integrated into the IBP Milano Malpensa platform originates from:

- **12.03.02** - Enhanced Surface Safety Nets;
- **12.05.02** - Airport Safety Nets and wind-shear;
- **15.04.05b** - ADS-B ground station enhancements (Prototype).

6.2.1.1 Validation exercise system architecture

The testbed system architecture employed in the EXE-06.03.02-VP-0652 is the same of the one exploited in the EXE-06.03.02-VP-065, described above. Nevertheless, even if there is not any hardware modification, several software modifications were introduced in the ADS-B ground station prototype to accommodate the new validation checks.

In particular referring to the following

Figure **17**, the new features foreseen in the 15.4.5a (TDOA and WAM check), have been integrated into the Selex-ES Multi Sensor Fusion (MRT) CSCI.

TDOA validation check allows the ADS-B position validation using data derived from at least two ADS-B receivers. To assess the validity and integrity of the ADS-B position, this method compares the transmitted ADS-B position against the locus of estimated position derived from a spatial equation defined by the means of the two ADS-B receivers.

The enhanced WAM validation checks represents an extension of the WAM validation check already introduced in the EXE 65. Whereas in the first iteration the WAM validation mechanism exploits the WAM position to validate the ADS-B plot, for the second iteration the WAM validation has been extended adding others checks such as the velocity check, altitude check and Mode-S Data check. Thus for the second iteration, the WAM validation is executed comparing the received ADS-B data (velocity, position, altitude, etc.) against a set of WAM data. If any of those checks fails the plot is declared validated and NOT VALID. If all the checks pass, the plot is marked as validated and VALID. In case that the WAM data is not available the ADS-B plot is declared NOT VALIDATED.

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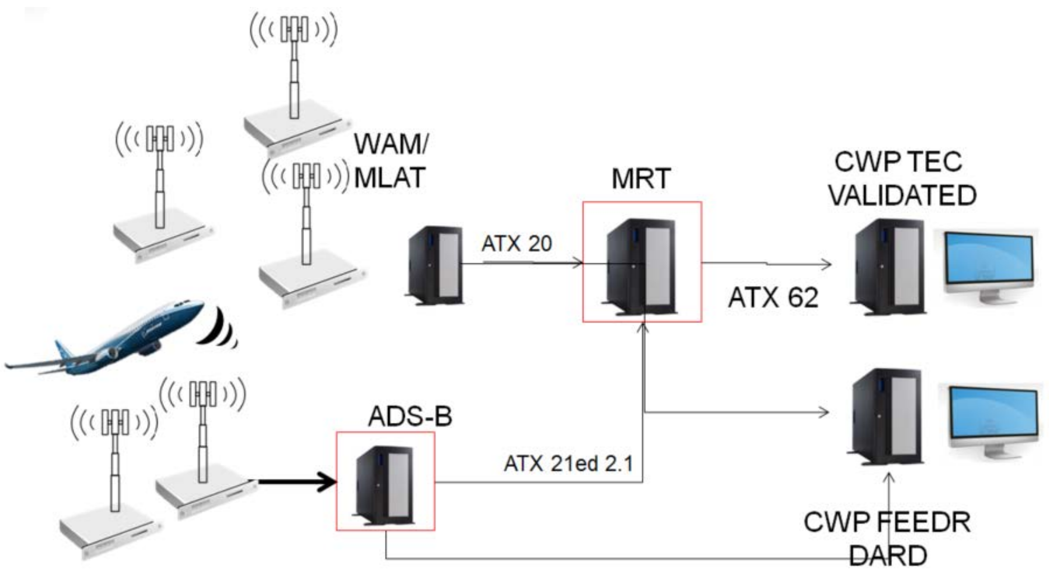

Figure 17: ADS-B GS second iteration

6.2.1.1.1 SELEX ADS-B GS prototype second iteration

The following subsections include a description about the validation mechanisms introduced in the ADS-B ground station second iteration and subjected to the verification process defined by the EXE 652.

6.2.1.1.2 Extended WAM Validation check ADS-B GS prototype Second Iteration

The goal of the ADS-B validation mechanisms is to determine the coherence of the received ADS-B position data with respect to other available information. In general the validation mechanisms are classified in two categories:

- Validation algorithms based on external inputs
- Validation algorithm based on signal attributes

The Extended WAM validation Mechanism lies into the first category, in fact in this case the validation process relies on the WAM data. Within the context of the exercise 652 the WAM validation mechanism has been extended in order to accommodate new features that were not available for the EXE 65.

In particular were added:

- Velocity validation
- Altitude validation
- Mode S Data validation

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The WAM position validation mechanism was available from the EXE 65.

The WAM validation is performed only if there is data available over ASTX Cat 20, in case the ASTX Cat 20 is not available the output of the validation block is NOT VALIDATED. The output of the four validation blocks feed an XOR block, so that if any of the validation check fails the plot is marked as Validated and NOT VALID. The plot is marked as Validated and VALID if all the validation checks pass.

Each validation block (position, velocity, altitude) has its own configuration parameters that allow setting the acceptance threshold.

In the context of the EXE 652, the Mode-S data validation check was not verified due to unavailability of Mode-S interrogator necessary to extract the BDS.

6.2.1.1.3 TDOA validation check ADS-B GS prototype second iteration

The goal of the ADS-B validation mechanisms is to determine the coherence of the received ADS-B position data with respect to other available information. The validation checks are classified in two categories:

- Validation algorithms based on external inputs
- Validation algorithm based on signal attributes

The TDOA validation Mechanism lies into the second category, in fact in this case the validation process exploits the Times Of Arrival measured by two distinct GSs. This validation check requires that at least two distinct ground stations receives the same 1090 ES reply. Each of the two ground stations will provide the Time Of arrival of the message, thus those information will be exploited to calculate first the TDOA and then to calculate the locus of possible emitter locations. The ADS-B plot is declared VALID if the minimum distance between the ads-b position and the TDOA contour is below or equal to a predefined threshold, NOT VALID in the contrary. The ADS-B plot is declared NOT VALIDATED if the 1090 ES is received by a single receiver. The Figure hereafter shows the generic principle of the TDOA validation check.

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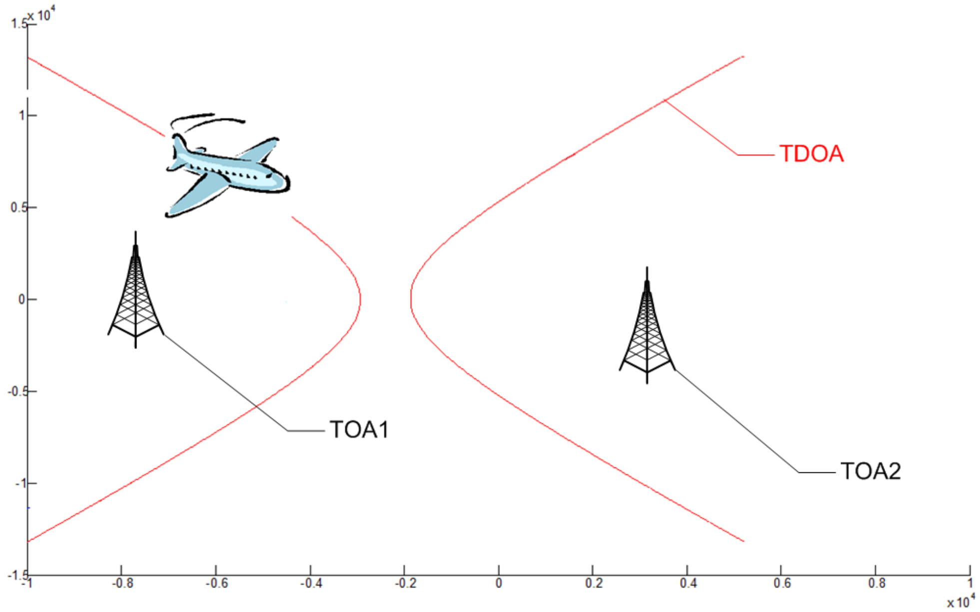

Figure 18: TDOA Validation

6.2.2 Conduct of Validation Exercise

6.2.2.1 Exercise Preparation

The preparation steps for the Exercise 652 validation exercise are as follows:

- High level definition of exercise including selection of functionalities available in the prototype, traffic samples, validation scenarios, special events, etc.
- Updating of the V&V platform
- Prototype testing/acceptance
- Writing of the availability notes document
- Preparation of the exercise. This activity includes, amongst other:
    - Definition of physical scenario
    - Adaptation of the traffic
    - Definition of the data gathering methods that have been used including questionnaires, structured interviews, data log, etc.
- Preparation of the training material including presentations and user manual
- Selection/invitation of ATCOs and pseudo-pilots to be involved as experimental subjects
- Preparation of the site and room hosting the exercise.

6.2.2.2 Exercise execution

The execution of the exercise was performed from 25th to 29th of November 2013.

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The main execution activities are described below:

- Run execution
- Data collection according to the methods selected during the preparatory phase including data record, debriefing, questionnaires, etc.

The execution of the exercise was performed from 26th to 27th of November 2013. In order to satisfy the scope of the exercise, several simulation scenarios were tested, and in particular two scenarios were prepared and executed to cope the validation of the ADS-B GS prototype.

A description of the ADS-B GS scenario is reported hereafter:

- Scenario 1 – Reference. The Reference scenario for live traffic run executed in order to compare it against the Enhanced ADS-B functionalities in scenario 4. This scenario has been simulated by means of shadow mode simulation and relevant data opportunely recorded.
- Scenario 4 – ADS-B. In order to validate ADS-B Ground Station Prototype, one additional scenario was experimented through shadow mode. The Enhanced ADS-B Ground Station was fed with real traffic data, and the CWPs were provided with both ADS-B and MSF tracks. The Enhanced ADS-B Ground Station improvement was tested comparing the MSF tracks (including MLAT and WAM sensors and exploiting the enhanced ADS-B validation algorithm) against the ADS-B stand-alone tracks.

The above scenarios were executed during the validation sessions as reported below in the Figure 19below.

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Figure 19: EXERCISE 652 agenda

	TRAINING
	REFERENCE SCENARIO
	SAFETY NETS SCENARIO
	ENHANCED ADS-B SCENARIO
	POST RUN QUESTIONNAIRE AND POST SIMULATION QUESTIONNAIRE
	DEBRIEFING

Figure 20: Exercise 652 run ID coding

6.2.2.3 Deviation from the planned activities

None reported.

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6.2.3 Exercise Results

6.2.3.1 Summary of Exercise Results

To obtain the status of exercise results both qualitative and quantitative data have been taken into account. The Table hereafter provides an overview.

Validation Objective ID	Validation Objective Title	Success Criterion ID	Success Criterion	Exercise Results	Validation Objective Status
OBJ-06.03.02-VALP-0652.0002	ADS-B	CRT-06.03.02-VALP-0652.0201	Data quality increases with regards to the current surveillance system by means of ADS-B application.	**Success criterion achieved** Since scenario reference 1 and solution 4 were compared, ATCOs effectively noticed a data quality increase by means of enhanced ADS-B application with regards to the current surveillance system. Confronting the type of data regarding the state of validation (i.e. valid, not valid, validation not executed) it has been possible to demonstrate that not valid data were excluded from the system improving data quality.	OK
		CRT-06.03.02-VALP-0652.0202	Controller situational awareness is improved.	**Success criterion achieved** ATCOs asserted ADS-B is useful to improve their situational awareness especially in case of low visibility conditions.	

The positive impact on safety was experimented also by means of the enhanced level of surveillance data quality using Enhanced ADS-B functionality. In order to validate the ADS-B Ground Station prototype, one additional scenario was simulated through shadow mode using real traffic. In order to

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point out the data quality enhancement and so, enhancing the quality of Situational awareness, improve the level of safety, two CWPs fed with real traffic data were compared one with the Enhanced ADS-B Ground Station and another with both ADS-B and MSF tracks. In particular, three different colour tracks were displayed:

- green for validated data (displayed on both monitors)
- red for excluded data
- yellow for data under evaluations

Since red data were excluded from Enhanced ADS-B algorithm and not presented on the CWP, controllers had the opportunity to notice that data quality was really improved.

The figure below expresses some controllers' feedback regarding the use of Enhanced ADS-B.

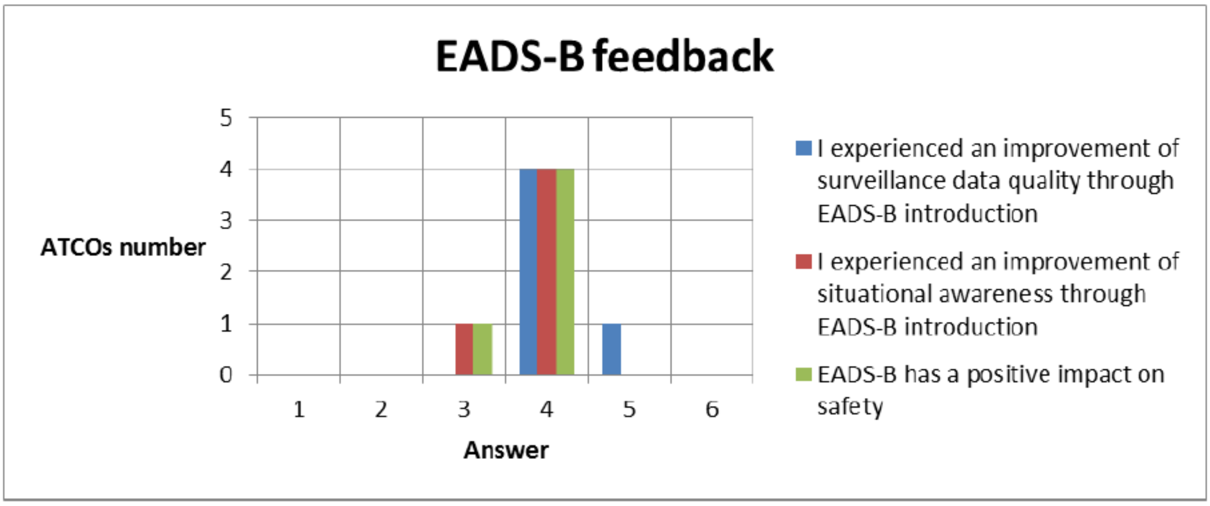

Figure 21: ATCO feedback about the use of EADS-B

Considering that 5 controllers participated in the shadow mode simulation giving a possible answer from 1 to 6 according to Figure 21, for each question proposed for PRQ and PSQ questionnaires, it is possible to note that they had the chance to appreciate the reachable benefits of this function since 4 ATCOs gave a positive answer with a value of 4: considering the enhancement of data quality and situational awareness so, the level of safety evidently increases.

Moreover, their qualitative judgment has been supported also with quantitative assessment of ADS-B data recorded during a prefixed time.

Table 11 shows a particular set of samples recorded in Milano Malpensa airport. Comparing the type of data, it is possible to demonstrate that each target, captured by radar stamp for a number of times, was considered valid, not valid and not executed data by the system.

ICAO_ADDRESS	#VALID	#NOT VALID	#VALIDATION NOT EXECUTED
5023677	0	0	55
4198619	619	0	1

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3958607	1725	82	83
3416456	825	0	2
4220518	2869	7	31
5023632	97	0	32
9003790	40	0	54
655398	3035	41	88
3953736	29	0	0
4220526	1682	10	48
5024238	1109	0	107
4197091	1662	0	18
5276104	262	1521	685
5023985	1691	44	6
4695996	1888	6	14
5023983	307	0	2
4220225	1321	0	8
5023237	414	0	0
9003785	2861	55	17
4763040	545	0	5
5024355	40	0	15
4197442	1560	0	15
5023952	1270	0	6
5024316	368	0	0
3813921	48	0	0
4198140	1129	0	111
3958386	740	0	80
3950666	987	0	39
4197772	2263	29	17

Table 18: Enhanced ADS-B recorded data

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For example, the target “5276104” was considered 262 times valid, 1521 not valid and 685 times not executed. Where the target was not valid it was excluded from the visualization making more accurate the system. The Figure 22 below, linked to data in

Table 18 expresses the frequency of type of data for each target (legend on the right of figure).

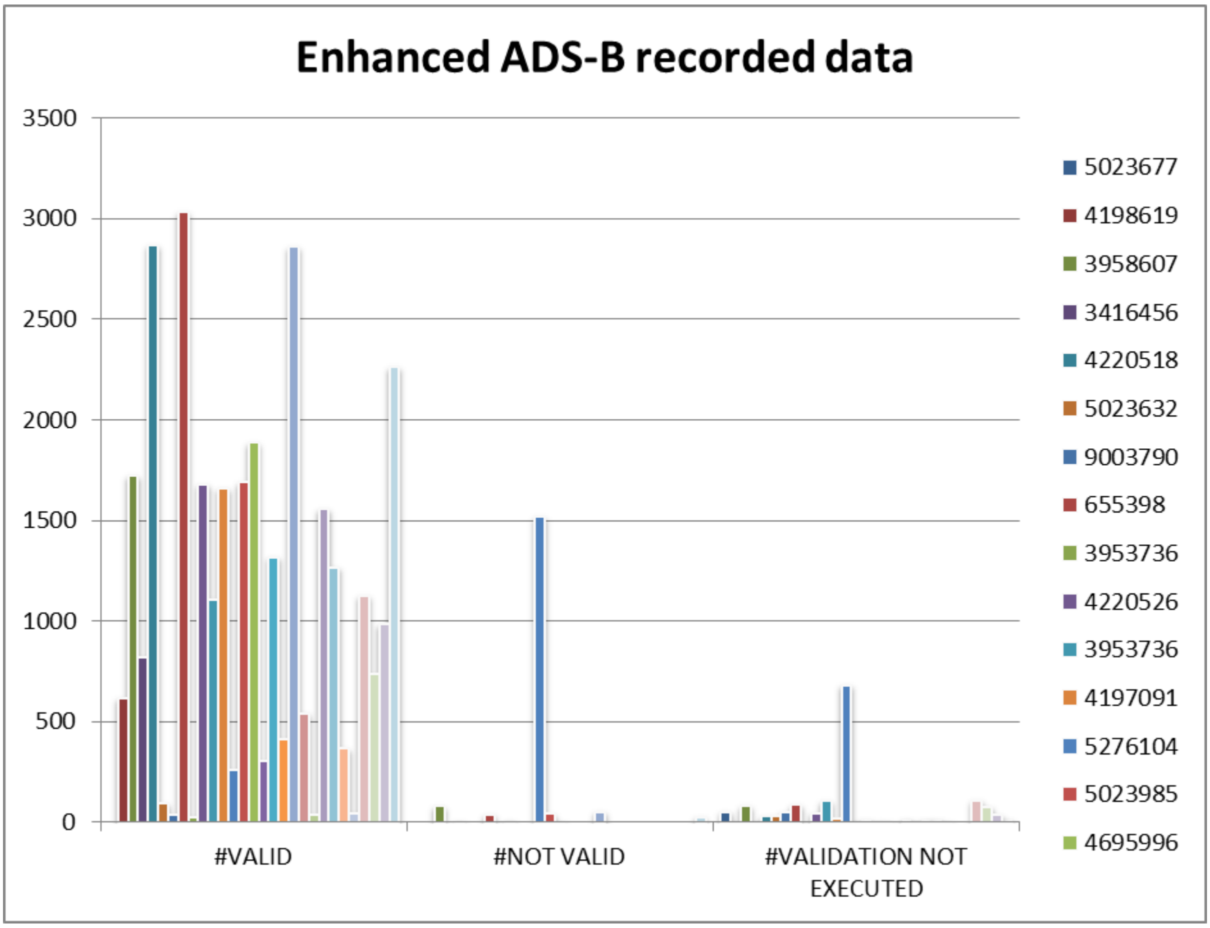

Figure 22: Histogram of enhanced ADS-B recorded data

Objective and subjective data collected during the exercise are the main source of information, which give the initial start to the whole results analysis.

To analyse data collected during the simulation by questionnaires, debriefings, over the shoulder observations and systems logs, the following steps have been followed:

- raw data (objective and subjective) grouped
- raw data synopsis in order to underline the significant aspects concerning both objective and subjective collected data
- Information integration of quantitative and qualitative data
- Final conclusion in relation to specific exercise objectives.

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6.2.3.1.1 Results on concept clarification

N/A

6.2.3.1.2 Results per KPA

The results have confirmed the potential of the developed ADS-B ground Surveillance system to have a positive contribution to KPAs such as safety and security.

6.2.3.1.3 Results impacting regulation and standardisation initiatives

The exercises have used prototypes which are means of compliance with the EU Regulation 1207/2011 and its amendments.

The results have supported the inputs made to the following standards:

- EUROCAE Technical Specifications for ADS-B Ground station (ED-129A)
  - Published
- EUROCAE Technical Specifications for ADS-B Ground system (ED-129B)
  - Approaching publication
- ASTERIX Interface Specifications (for ADS-B and tracks)
  - Update ongoing

6.2.3.2 Analysis of Exercise Results

Objective	Scenario ID	Scenario Title	PI ID	Meassure Values
OBJ-06.03.02-VALP-00652-0002	SCN-06.03.02-VALP-00652.0001	Reference	ATCOs' subject assessment of decreased surveillance data quality with respect to ADS-B scenario.	80% of controllers had the chance to appreciate the reachable benefits of Enhanced ADS-B function.
OBJ-06.03.02-VALP-00652-0002	SCN-06.03.02-VALP-00652.0004	ADS-B	ATCOs' subject assessment of increased surveillance data quality with respect to reference scenario.	80% of controllers had the chance to appreciate the reachable benefits of Enhanced ADS-B function.
OBJ-06.03.02-VALP-00652-0002	SCN-06.03.02-VALP-00652.0001	Reference	ATCOs' subject assessment of decreased situational awareness with	80% of controllers had the chance to appreciate the reachable benefits of Enhanced ADS-B

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			respect to ADS-B scenario.	function.
OBJ-06.03.02-VALP-00652-0002	SCN-06.03.02-VALP-00652.0004	ADS-B	ATCOs' subject assessment of increased situational awareness with respect to reference scenario.	80% of controllers had the chance to appreciate the reachable benefits of Enhanced ADS-B function.
OBJ-06.03.02-VALP-00652-0002	SCN-06.03.02-VALP-00652.0004	ADS-B	% number of validation not executed/valid/ not valid tracks with respect to the total number of tracks.	Recorded ADS-B data of opportunity traffic (present at time of registration), collecting executed/valid/not valid tracks, shows that valid are those filtered with enhanced ADS-B algorithm.

Table 19: Performance Indicators

6.2.3.2.1 Unexpected Behaviours/Results

None reported.

6.2.3.3 Confidence in Results of Validation Exercise

N/A. Reported by Project 6.3.2.

6.2.4 Conclusions and recommendations

6.2.4.1 Conclusions

Exercise 652 allowed verifying the technical feasibility and the operational suitability of surface safety nets and enhanced ADS-B in an air traffic control tower environment. Final conclusions, based on both quantitative and qualitative data collection methods, are presented in the

Table 20 below.

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Operational concept	Main results
ADS-B AO-0201-A: Enhanced Ground Controller Situational Awareness in all Weather Conditions for Step 1	Controllers effectively experimented an enhancement of situational awareness thanks to an evident surveillance data quality improvement by means of enhanced ADS-B algorithm.

Table 20: EXE652 – ADS-B results

6.2.4.2 Recommendations

On the basis of the exercise, it is recommended to further investigate the data security. Furthermore, new standardisation initiatives should be considered.

6.3 SELEX ADS-B GS Third Iteration Validation Report

This section gives a brief description about the validation mechanisms introduced in the ADS-B ground station third iteration and the followed validation approach. Contrary to the first and second iteration, which have been matched with an exercise, the third iteration did not follow the same approach, indeed there was not a validation exercise performed in the Milano APT for the third iteration.

During the execution of the exercise 65 and exercise 652, the question was raised about the difficulty to have valid conditions, leveraging the opportunity traffic, to allow a solid verification of the 3rd iteration validation exercise itself. In fact the validation exercise requires the availability of erratic transponder and this condition cannot be predicted in advance. Therefore a long campaign of observation, data recording and data analysis is necessary to fully assess the prototype. Obviously this activity would have a considerable impact on time and project cost.

Those aspects and the fact that the Range through Active Interrogation (RAI) functionality can be fully tested in the laboratory, without diminishing the consistency of the verification itself, SELEX-ES decided to verify the RAI feature in a laboratory rather than in a real scenario such as Malpensa IBP.

The third iteration verification activities are performed in the SELEX-ES facility of Rome, where an appropriate test bench has been opportunely arranged in advance.

The third iteration ADS-B GS prototype includes the "Range through Active Interrogation" (RAI) feature. The RAI is a validation mechanism designed to verify that a given aircraft, transmitting ADS-B messages, lies inside a *computed volume* that corresponds to its reported position within the decoded messages. The above mentioned *volume* is calculated by interrogating selectively the ADS-B target using UF5 and calculating the round trip delay (RTD) defined as the difference between the interrogation timestamp and the timestamp in which the elicited reply is received. Therefore the ADS-B GS will calculate the Aircraft Range as follow:

$$Aircraft\ Range = C * \frac{RTD}{2}$$

where C is speed of light.

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The RTD validation mechanism determines if the interrogated aircraft has a measured range which lies on the sphere within a user definable threshold of the measured range. If this is the case, the RTD test returns a **validated and valid** result, reported within the Range from Active Interrogation or RAI field in the fifth extension of ASTERIX CAT 21 data item I21/40 Target Report Descriptor in the ADS-B target report. If the measured range exceeds the user threshold then the RAI field is set of **validated and not valid** within I21/40 data item in the ADS-B target report. This is shown schematically in Figure below:

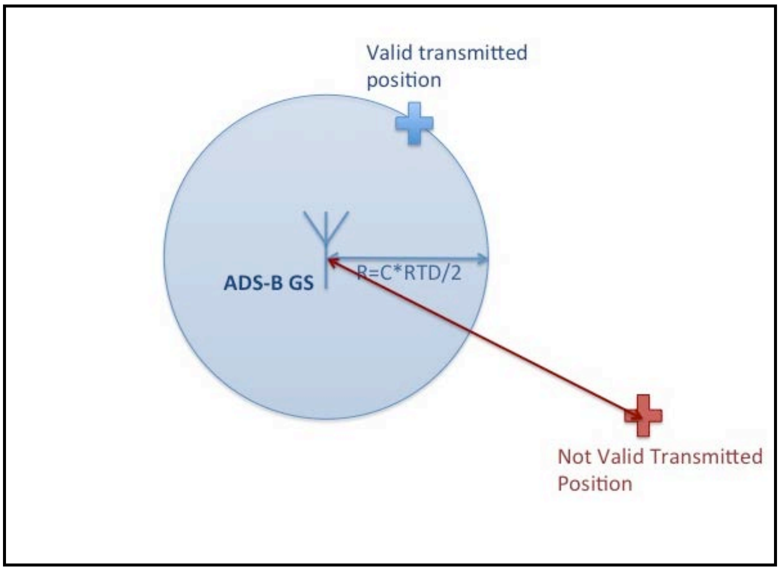

Figure 23: Schematic of RTD measurement process within the RAI test

If the test is not performed because the aircraft is in excessive range for valid interrogation by the enhanced ADS-B GS, then the RAI bit in I21/40 is set to **not validated** in the output ADS-B target report.

If the ADS-B report does not return an associated RTD, it is specified in the D20 document to set the RAI bit to **not validated** in I21/40 data item. This has significant impact for the operation of the security enhancement in the presence of false ADS-B messages.

To verify the RAI mechanism SELEX-ES exploited the tool Air Traffic data Simulator (ATS). ATS is a legacy software that runs on LINUX OS. It has been developed by SELEX-ES to support the internal verification of the ADS-B GS prototypes. ATS is capable to generate scenarios with multiple ADS-B targets, where for each target, it transmits all the Mode S messages foreseen in any predefined MLAT, WAM or ADS-B scenario. Likewise, the tool is able to generate the message associated to XPDR replies (UF) elicited by 1030 MHz Interrogation. In this particular case, the 1030Mhz interrogation will be scheduled, triggered and executed by the ADS-B GS software layer, consequently the ATS will reply to the elicited interrogation. The overall sensor functionalities of signal processing, decoding and time stamping are emulated by the ATS that generates directly the payload

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to be fed into the ADS-B ground station's software layer. Therefore the ATS emulates the XPDRs, the ground station sensor and the 1030 interrogator.

The ground station's software layer and the ATS tool exchange messages using a legacy protocol that runs over TC/IP. The ATS's data stream fed the ground station's software layer through the sensor LAN port, once the ground station's Software layer finishes the data processing, the decoded message and validation message are dispatched through the operative LAN in ASTERIX format. The ATS tool has been configured to execute the verification test as defined into the D20 Third Iteration Tailoring Test Specification.

6.4 EEC Validation Exercise Report

6.4.1 Exercise Scope

The scope of the validation exercises at EEC was to evaluate from an operational perspective the use of ADS-B data in a multi-sensor surveillance environment.

6.4.2 Conduct of Validation Exercise

6.4.2.1 Exercise Preparation

The validation exercise was conducted on 28-29th January 2015 using an evaluation platform and real traffic recorded.

The environment targeted by the evaluation covered both TMA and en-route airspace with traffic levels from medium to high. Subject matter experts provided observations and evaluation of the validation objectives by direct interaction with the traffic samples.

Non-nominal situations were inducted through the manipulation of the data received from the ADS-B source.

The exercise preparation covered the selection of the used airspace and traffic sample as well as the testing of the available platform and its functions.

The airspace used in the validation exercises consisted of Paris TMA (to evaluate the approach control related requirements) and the region above the Paris TMA in order to evaluate the requirements corresponding to an en-route environment.

The traffic sample used for the investigation a real traffic recorded during a day in 2014. In order to increase the relevance of the evaluation the recorded traffic of a high traffic load day was used. No additional traffic was simulated in the evaluation; however some of the data was manipulated to cover for the non-nominal situations to be validated.

The system architecture of the validation platform is presented in the figure below.

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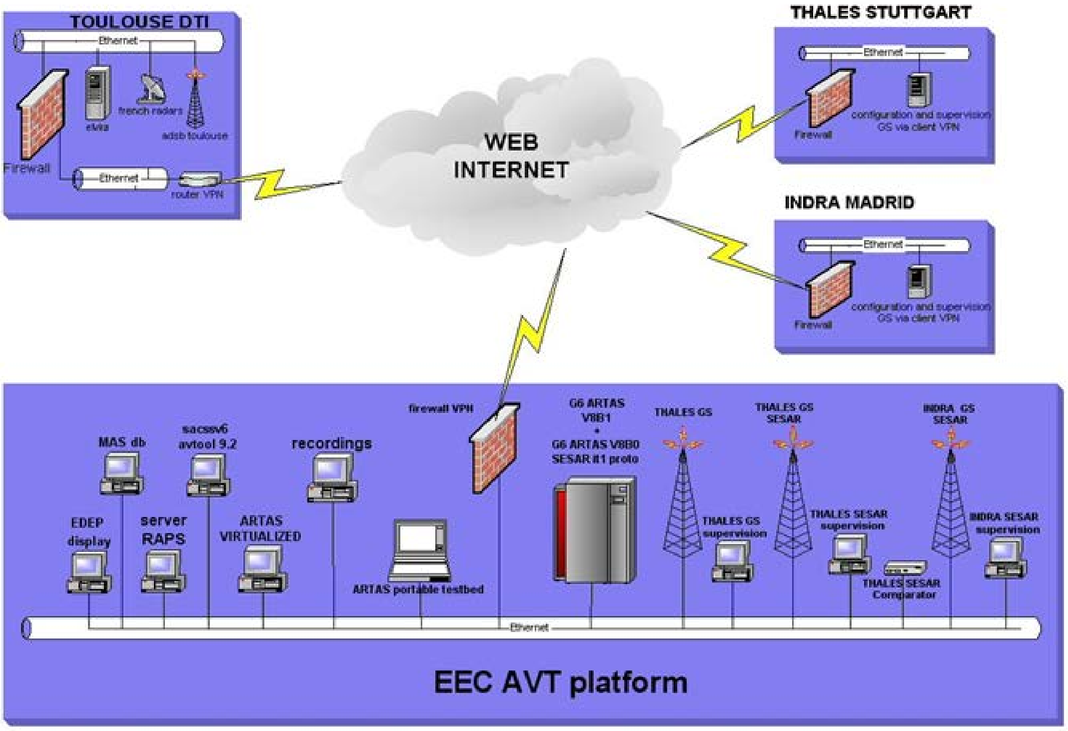

Table 21: ADS-B Validation Testbed at EEC

To support the exercise execution a set of check lists were prepared in advance, providing a full list of the validation objectives mapped to specific exercises and environments. For each validation objective the check list indicated the method of evaluation and associated assumptions.

Subject matter experts were required to fill in in real time the check lists and make any supplementary observations if deemed necessary.

The interface provided to the subject matter experts for the evaluation consisted on a CWP mock-up based on the eDep platform. The data presented in real time consisted of:

- Aircraft horizontal position
- Position symbol
- Aircraft position from selected surveillance source (on demand)
- Aircraft identification (as a result of Mode S and/or ADS-B data received)
- Aircraft altitude
- Aircraft altitude from a selected surveillance source (on demand)
- Aircraft track vector
- Aircraft track history
- Environment data (TMA boundary, runways of major airports, waypoints, state boundaries)

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Also the platform allowed for the display for selected aircraft of a complete set of data received from the surveillance source. This data included (on demand):

- Aircraft speed
  - Calculated
  - Received from ADS-B
- Aircraft heading/track
  - Calculated
  - Received from ADS-B
- Emergency indicator
- SPI
- Quality indicator in case of ADS-B data
- Surveillance sensors considered in the calculation of the track

It worth noting that the CWP interface did not allow the simultaneously display of several parameters (for all aircraft/tracks) therefore some of the validation objective were covered only partially.

In parallel to the CWP the system allowed the visualisation of aircraft position and data on the ARTAS display. This allowed during the evaluation the assessment, for individual aircraft, of the data received from different surveillance sources, their use in the determination of the track, etc.

6.4.2.2 Exercise execution

The evaluation of the ADS-B Ground station prototypes from two manufacturers as well as of the Surveillance Data processing and Distribution system (ARTAS) took place at the EEC premises, Bretigny, France over a long period of time in the course of the project.

Furthermore, the validation exercise took place on January 28th and 29th 2015 at the EUROCONTROL premises in Bretigny (EEC), France.

One ATCO, one engineer as well as an observer representative from an ANSP participated in the validation exercise.

The exercise took place as a shadow mode of current operations. Due to simulation set-up constraints the exercise required a merging of the three different environment scenarios.

6.4.2.3 Deviation from the planned activities

The limitations of the user interface for the CWP was not entirely suitable for the validation of all the elements considered. The evaluation of data corruption was performed at technical level and not during the operational evaluation.

6.4.3 Exercise Results

6.4.3.1 Summary of Exercise Results

In the following chapters the results of the evaluation exercises will be presented based on each validation objective considered.

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Tables are included providing each validation objective, the validation means used during the evaluation and associated observations as recorded during the run. When needed, the observation column will mention the environment associated with the comment. Notes and special issues discussions are included at the end of each sub-chapter.

Note: Depending on their importance, some validation objectives were covered by both exercises. The results provided by the evaluation were included in both exercises results regardless of their originating observation.

6.4.3.1.1 Exercise #01

The exercise was based on the following scenarios:

- SCN-15.04.05a-VALP 001.0001 - assess whether the behaviour of the developed system standard in real environment is in accordance with the corresponding requirements. This will be done in an en-route environment using real traffic data
- SCN-15.04.05a-VALP 001.0002 - assess whether the behaviour of the developed system standard in real environment is in accordance with the corresponding requirements. This will be done in a TMA medium traffic density environment using real traffic data
- SCN-15.04.05a-VALP 001.0003 - assess whether the behaviour of the developed system standard in real environment is in accordance with the corresponding requirements. This will be done in a TMA high traffic density environment using real traffic data

Objective	Validation Means	Observations
OBJ-15.04.05a-VALP-001.0001 - Verify that the ground system function receives, decodes, packages and time-stamps the data, and sends corresponding surveillance reports to the ATC processing system	Observe and evaluate that data is displayed and correlated with other surveillance sources	Decoding of the data received is performed correctly. An issue was observed at the level of the calculated/displayed altitude for flights in vertical movement in a few cases. When ADS-B data only was presented in comparison with the fused track data, due to the difference in the update rate between the two a difference in the displayed altitude was observed. This was not considered to be an issue for the use of the information for ATC services in the en-route environment. For the TMA environment a more regular data update was considered to bring operational benefits.
OBJ-15.04.05a-VALP-001.0002 - Verify that the ground system function provides the following minimum data set to the ATC processing system: - Aircraft Horizontal	Observe if displayed data is complete for each aircraft	Position: the considered update rates (for display) influence the horizontal position of the aircraft when comparing an ADS-B only position with a fused track. In the En-route environment this is not an issue as the distances in question are not large compared with the scale of the sectors and the horizontal expected evolution of the flights.

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Objective	Validation Means	Observations
Position – Latitude and Longitude - Pressure altitude - Quality Indications of Horizontal Position - Aircraft Identity - Emergency Indicators (when selected by the flight crew) - Special Position Identification (SPI) (when selected by the flight crew) - Time of Applicability - Ground velocity and relevant quality indicator if required by the local implementation		However in the TMA environment, when frequent changes of direction occur, the update rate of the ADS-B only data seems to provide enhanced operational benefits. Note that the validation system was updating the displayed horizontal position for the fused track at a rate of 5 seconds. Aircraft identity: A correct display of the identity was observed in the considered types of airspace. Quality indicators: Quality indicators were available for display in a case by case basis for selected flights. This allowed an evaluation of the use of the data by the tracker depending on the reported quality of the ADS-B data and correlated to the considered environment. It was concluded that the algorithm is correctly assessing the quality of the data received and filters out data not meeting the requirements from the fused track and in relationship with the geographical filter imposed (e.g. for TMA area) Ground velocity: Due to the limitations of the CWP system ground speed was not fully assessed during the evaluation. However the track vector (based on the ground speed calculation and aircraft track) was evaluated as conforming with the requirements. In the TMA environment, when comparing an ADS-B data only track vector with the one associated with the fused track, it was evaluated that the update rate of the ADS-B data would provide operational benefits especially for flights executing turns. Altitude: the data presented was evaluated to be according to the requirements. Minor deviations were observed when comparing an ADS-B only altitude data and a fused track data due to the update rate differences. On few occasions a significant discrepancy was detected between the ADS-B reported altitude and the fused track altitude. The recommendation was that further investigation should be performed. Flight IDs were logged and the issue was recorded.

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Objective	Validation Means	Observations
OBJ-15.04.05a-VALP-001.0003 - Verify that when direct recognition procedures are used by the controller for identification, the ground system contains a function to ensure the aircraft identity data that is broadcast is retained and correctly associated with the position information for display	Correct flight ID is decoded and displayed. The flight ID is maintained and lost ID correlation is not an issue from an operational point of view	During the entire scenario no instances were detected/observed when a de-correlation occurred in the normal working environment (i.e. core area considered for the scenario). An issue with the correlation of the track with the aircraft ID was observed in few occasions at the edge of the surveillance coverage area. In practice it was recommended that the correlation in these areas is further investigated.
OBJ-15.04.05a-VALP-001.0007 - Verify that the ADS-B and radar processing function enables the switching between the surveillance sources (e.g. as a backup during a failure) without requiring the ATCO to perform a: - Re-verification of altitude data - Re-identification of aircraft identity	Observe any issues related to altitude and ID data displayed to ATC when switching between ADS-B and other surveillance	The available platform allowed the switch between different sources of surveillance. The CWP also allowed for the simultaneous display of data received and processed from several surveillance sources (through colour coded symbols). When surveillance source switch was performed, the track data was observed to be stable enough not requiring re-identification or supplementary altitude check. A difference in the displayed altitude was detected for vertical moving traffic between ADS-B source alone and ARTAS mainly due to the update rate for display. However this difference was acceptable from an operational point of view and not requiring re-verification of the altitude.

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Objective	Validation Means	Observations
OBJ-15.04.05a-VALP-001.0008 - Verify that the minimum performance requirements for the accuracy are satisfied	Observe any issues regarding the position accuracy and continuity of the displayed flight positions (e.g eventual jumps, target loss, etc) Technical assessment on the fusion of multiple data sources.	Positional accuracy observed was considered to be consistent with the operational requirements for the corresponding environments. It was observed when comparing an ADS-B only position with the fused track, due to the different update rates, occasionally, the difference between the displayed positions is less than ¼ of a NM. It was considered that this difference is acceptable.
OBJ-15.04.05a-VALP-001.0009 - Verify that the minimum performance requirements for the update rate are satisfied	Observe any issues regarding the position continuity of the displayed flight positions (e.g eventual jumps, target loss, etc) Technical assessment on the fusion of multiple data sources.	A one second update rate was used for the data received from an ADS-B source alone. This was observed to be more convenient for a TMA environment (especially in case of high traffic loads), especially for flights in vertical evolution and performing heading changes. For the heading/track display, the fused track with 5 sec display update rate provided a difference, compared with the ADS-B only data, in some cases. This was considered acceptable.

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Objective	Validation Means	Observations
OBJ-15.04.05a-VALP-001.0010 - Verify that the minimum performance requirements for the latency are satisfied	Observe any issues related to the position data latency (eventually by switching between ADS-B data source and another available source and identify if there are any jumps in positions) Technical assessment on the fusion of multiple data sources.	Due to the limitations in the available validation platform, eventual differences in positional accuracy due to data latency could not be observed. The visual comparison between the ADS-B 1/sec displayed tracks and the updated ARTAS fused position was satisfactory from an operational point of view
OBJ-15.04.05a-VALP-001.0017 - Assess and investigate the acceptability and acceptance of the data used, by the controller, with the same separation minima as currently applied OBJ-15.04.05a-VALP-001.0018 - Assess and investigate the acceptability and acceptance of the data used, by the controller, in Terminal airspace OBJ-15.04.05a-VALP-001.0019 - Assess and investigate the acceptability and acceptance of the data used, by the controller, in En-Route airspace	Observe the accuracy and reliability of the data displayed	Through direct observation it was concluded that the accuracy of the data provided at the CWP is satisfactory for the current separation minima criteria used (i.e. for both considered environments).

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Objective	Validation Means	Observations
OBJ-15.04.05a-VALP-001.0027 - Verify the usability and usage of the display providing ADS-B/WAM surveillance data information to the controllers: - Aircraft position and altitude - Identity - Emergency and SPI Indicators - Ground Velocity - Surveillance track presentation	Observe the reliability of the considered HMI	Through direct observations it was concluded that position and altitude data presented were suitable for the scope of the ATC service considered. An issue was detected for aircraft ID correlation at the edge of the surveillance coverage area. The SPI indicator was tested (by simulating an SPI indication for one of the flights) and found to be correctly decoded. While the CWP interface was not allowing a direct observation of an eventual SPI indication, a few flights were modified to transmit SPI and the reception was observed in the data block associated with the flights. The SPI was decoded correctly on both ADS-B only tracks as well as on the fused tracks. Position and altitude data presented were considered suitable for the scope of the service considered. It was noted that due to the limitations of the CWP functionalities, some of the data that would be required for permanent simultaneous display (e.g. ground speed) was not available. It was recommended that a more realistic CWP interface with all the required functionalities should be used in the future.
OBJ-15.04.05a-VALP-001.0028 - Assess and investigate which additional skills and training are required for controllers	Observe and identify any issues related to mixed data source displayed to ATC	It was concluded that if the working environment considers presenting the end user with a mixed ADS-B only and fused surveillance positional data (e.g. in transition areas), and if in this case different update rates are used for display, controllers will need to be aware of the issue and specific training and procedures will be needed. It was noted that training and experience with such a system could improve the situation in time.

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Objective	Validation Means	Observations
OBJ-15.04.05a-VALP-001.0029 - Assess and investigate the impact of data source presentation on the overall controller workload OBJ-15.04.05a-VALP-001.0030 - Assess and investigate if workload is reduced/increased following the introduction of new surveillance data	Observe and identify any issues that may contribute negatively to the controller workload (e.g. loss of ID, requirement to re-identify a flight etc) Subjective assessment of the potential workload related to the use of ADS-B data	Due to the limitation in the validation system data source differential display could not be thoroughly tested in the exercise. A difference in the track symbol depending on the surveillance data source was not available for display (i.e. the data source was completely transparent in the nominal mode for the end user at the level of the CWP) It was assessed that no additional workload would be induced by the availability of the new surveillance source in the presented track.
OBJ-15.04.05a-VALP-001.0032 - Verify that the use of new surveillance data introduces minor changes to controller and flight crew tasks in comparison with current procedures	Observe and evaluate new eventual requirements for ATC tasks in the new environment	It was assessed that in nominal conditions, for the considered environment it is unlikely that additional tasks will be required for ATC in providing the service. Potentially, if coverage and correlation issues are maintained in a local environment, procedures and additional controller training may need to be put in place to deal with the issue.

Table 22: EXE #01 results

6.4.3.1.2 Exercise #02

The exercise was based on the following scenarios:

- SCN-**15.04.05a**-VALP 001.0004 - assess whether the behaviour of the developed system standard in real environment is in accordance with the corresponding requirements during non-nominal situations. This will be done in an en-route environment using real and simulated traffic data.

- SCN-**15.04.05a**-VALP 001.0005 - assess whether the behaviour of the developed system standard in real environment is in accordance with the corresponding requirements during non-nominal situations. This will be done in a TMA medium traffic density environment using real and simulated traffic data.

- SCN-**15.04.05a**-VALP 001.0006 - assess whether the behaviour of the developed system standard in real environment is in accordance with the corresponding requirements during non-

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nominal situations. This will be done in a TMA high traffic density environment using real and simulated traffic data

Objective	Validation Means	Observations
OBJ-15.04.05a-VALP-001.0001 - Verify that the ground system function receives, decodes, packages and time-stamps the data, and sends corresponding surveillance reports to the ATC processing system	Data is displayed and correlated with other surveillance sources	Decoding of the data received is performed correctly. An issue was observed at the level of the calculated/displayed altitude for flights in vertical movement in a few cases. When ADS-B data only was presented in comparison with the fused track data, due to the difference in the update rate between the two, a difference in the displayed altitude was observed. This was not considered to be an issue for the use of the information for ATC services in the en-route environment. For the TMA environment a more regular data update was considered to bring operational benefits.

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Objective	Validation Means	Observations
OBJ-15.04.05a-VALP-001.0002 - Verify that the ground system function provides the following minimum data set to the ATC processing system: - Aircraft Horizontal Position – Latitude and Longitude - Pressure altitude - Quality Indications of Horizontal Position - Aircraft Identity - Emergency Indicators (when selected by the flight crew) - Special Position Identification (SPI) (when selected by the flight crew) - Time of Applicability - Ground velocity and relevant quality indicator if required by the local implementation	Displayed data is complete for each aircraft	Position: the considered update rates (for display) influence the horizontal position of the aircraft when comparing an ADS-B only position with a fused track. In the En-route environment this is not an issue as the distances in question are not large compared with the scale of the sectors and the horizontal expected evolution of the flights. However in the TMA environment, when frequent changes of direction occur, the update rate of the ADS-B only data seems to provide enhanced operational benefits. Note that the validation system was updating the displayed horizontal position for the fused track at a rate of 5 seconds. Aircraft identity: A correct display of the identity was observed. Also it worth noting that it was difficult throughout the scenario to identify cases in which only Mode A SSR targets were available to allow the participants to better evaluate the correlation mechanism. Quality indicators: Quality indicators were available for display in a case by case basis for selected flights. This allowed an evaluation of the use of the data by the tracker depending on the reported quality of the ADS-B data and correlated to the considered environment. It was concluded that the algorithm is correctly assessing the quality of the data received and filters out data not meeting the requirements from the fused track and in relationship with the geographical filter imposed (e.g. for TMA area) Ground velocity: Due to the limitations of the CWP system ground speed was not fully assessed during the evaluation. However the track vector (based on the ground speed calculation and aircraft track) was evaluated as conforming with the requirements. In the TMA environment, when comparing an ADS-B data only track vector with the one associated with the fused track, it was evaluated that the update rate of the ADS-B data would provide operational benefits especially for flights executing turns. Altitude: the data presented was evaluated to be according to the requirements. Minor deviations were observed when comparing an ADS-B only altitude data and a fused track data due to the

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Objective	Validation Means	Observations
		update rate differences. On few occasions a discrepancy was detected between the ADS-B reported altitude and the one of the fused track. The recommendation was that further investigation is needed to understand the reason for such discrepancies. Flights IDs were logged and an action was recorded to investigate the issue

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Objective	Validation Means	Observations
OBJ- 15.04.05a-VALP-001.0011 - Verify that the minimum performance requirements for the inconsistency and duplicate identity check are satisfied	Observation of the correct flight ID decoded and displayed. In case of duplication of flight ID transmitted/decoded the system provides a clear indication	Generally successful. An issue was detected at the limit of the surveillance coverage area in a few cases. They were related to the capability of the system to correlate data received from multiple sources of surveillance for the same aircraft. It was concluded that these issues will need further investigation both at the level of the display (CWP) as well as at the level of the tracker.
OBJ-15.04.05a-VALP-001.0012 - Verify that the minimum performance requirements for the horizontal and vertical position error detection are satisfied	Check if the system filters out any data does not meet the requirements	Due to the limitations of both traffic sample (real life data recording without possibility of simulated/altered tracks to be inserted in the evaluation) and the platform constraints (lack of complete set of functionalities for the CWP), this objective was not assessed during the operational validation exercise. This was addressed using technical verification of the security mitigation techniques.
OBJ-15.04.05a-VALP-001.0013 - Verify that the minimum performance requirements for the emergency code detection are satisfied	Observe and evaluate the timely detection and display of an emergency code	During the evaluation, simulated emergency codes were introduced in the exercises. Specific flights were chosen in which the recorded data was modified so as to simulate the transmission of an emergency code. The direct observation of the CWP display for these specific flights, did not produce conclusive result in terms of performance requirements for the display of the emergency situations. It was concluded that further investigation is required.

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Objective	Validation Means	Observations
OBJ-15.04.05a-VALP-001.0014 - Verify the methodology used for validating the received ADS-B data.	Technical validation of the data received from multiple sources	Objective was not covered during the operational validation exercise but with the security mitigation functionality tests.
OBJ-15.04.05a-VALP-001.0021 - Assess and investigate the acceptability and acceptance of the data used, by the controller, for the provision of Alerting Service	Observe and evaluate the data available/displayed in case of an emergency	As explained in OBJ-15.04.05a-VALP-001.0013 evaluation, the emergency codes simulated were available in the data provided by the ADS-B source. This data, presented to the controller was considered to be acceptable for the scope of the alerting service. It was recommended that if ADS-B emergency related data is received at the required quality (ADS-B v3) it is preferred that the indication provided to the controller is decoded into the corresponding emergency indicator (e.g. emergency status 3 – low fuel, emergency status 5 – unlawful interference, etc).
OBJ-15.04.05a-VALP-001.0023 - Assess and investigate the acceptability and acceptance of the data used, by the controller in case of temporary ADS-B/WAM data loss or detected corruption for one aircraft	Observe the accuracy and reliability of the data displayed, in case of ADS-B data loss: e.g. correct traffic symbols, no positional jumps, etc Observe and evaluate the system reverting to full data availability.	Due to the available system limitations this objective was not covered in the evaluation.

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Objective	Validation Means	Observations
OBJ-15.04.05a-VALP-001.0024 - Assess and investigate the acceptability and acceptance of the data used, by the controller in case of permanent ADS-B/WAM data loss or detected corruption for one aircraft OBJ-15.04.05a-VALP-001.0025 - Assess and investigate the acceptability and acceptance of the data used, by the controller in case of temporary ADS-B/WAM data loss or detected corruption for all aircraft OBJ-15.04.05a-VALP-001.0026 - Assess and investigate the acceptability and acceptance of the data used, by the controller in case of permanent ADS-B/WAM data loss or detected corruption for all aircraft	Observe the accuracy and reliability of the data displayed, in case of ADS-B data loss: e.g. correct traffic symbols, no positional jumps, etc	This objective was assessed by turning off the ADS-B feed into the tracker. No visible jumps were observed in the position of the displayed aircraft. It should be noted that the CWP interface available did not make any difference in the track position symbol depending on the surveillance source used, therefore the loss in this case is transparent for the controller.

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Objective	Validation Means	Observations
OBJ-15.04.05a-VALP-001.0027 - Verify the usability and usage of the display providing ADS-B/WAM surveillance data information to the controllers: - Aircraft position and altitude - Identity - Emergency and SPI Indicators - Ground Velocity - Surveillance track presentation	Observation and evaluation of the proposed HMI in case of emergency and non-nominal situations	Through direct observations it was concluded that position and altitude data presented were suitable for the scope of the ATC service considered However, as mentioned in the previous validation objectives evaluation few issues were detected for aircraft ID correlation at the edge of the surveillance coverage area. The SPI indicator was tested (by simulating an SPI indication for one of the flights) and found to be correctly decoded. While the CWP interface was not allowing a direct observation of an eventual SPI indication, a few flights were modified to transmit SPI and the reception was observed in the data block associated with the flights. The SPI was decoded correctly on both ADS-B only tracks as well as on the fused tracks Position and altitude data presented were considered suitable for the scope of the service considered It was noted that due to the limitations of the CWP functionalities, some of the data that would be required for permanent simultaneously display (e.g. ground speed) was not available. It was recommended that further evaluation exercises are performed using a more realistic CWP interface with all the required functionalities. Additional potential issues describing the interference between emergency codes and the use of SPI are described in the following chapters.
OBJ-15.04.05a-VALP-001.0031 - Assess and investigate if the workload is increased in non-nominal conditions compared with current environment (due to losses or corrupted ADS-B/WAM data)	Subjective assessment of the potential workload associated with the use of multiple surveillance sources	Generally successful. Issues detected at the edge of the coverage zone should be resolved to maintain the controller workload.

Table 23: EXE #02 results

6.4.3.1.3 Results on concept clarification

N/A

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6.4.3.1.4 Results per KPA

The results have confirmed the potential of the developed ADS-B ground Surveillance system to have a positive contribution to KPAs such as safety, efficiency, interoperability, security etc.

6.4.3.1.5 Results impacting regulation and standardisation initiatives

The results have supported the inputs made to the following standards:

- EUROCAE Technical Specifications for ADS-B Ground station (ED-129A)
    - Published
- EUROCAE Technical Specifications for ADS-B Ground system (ED-129B)
    - Approaching publication
- ASTERIX Interface Specifications (for ADS-B and tracks)
    - Update ongoing

The SESAR projects have also contributed to the SDPD Specifications.

They have also developed prototypes of means of compliance with the EU Regulation 1207/2011 and its amendments.

6.4.3.2 Analysis of Exercise Results

The use of the ADS-B Ground Surveillance system contributes to an improved situational awareness and does not normally increase the associated controller workload. The system also improves security by successfully mitigating the associated threats.

Subject matter expert participating in the evaluation exercise concluded that the surveillance data received and processed from an ADS-B source in TMA and en-route is within the required performance parameters for ATC services usage. A note has been recorded in the case of TMA (especially for high traffic levels) that the update rate of the ADS-B (1 second) could be beneficial if used in the position display on the CWP instead of the tracker derived one (around 5 seconds). This was found particularly useful in case of evolving traffic in lateral and vertical planes.

The traffic sample used (a recording of a day of traffic within the area considered) offered the possibility to test several cases of system behaviour in relationship with the required performance. All tests resulted in a positive conclusion.

The ATC expected performance is evaluated as not being impacted (in terms of potential workload) by the use of ADS-B alone or multiple sources of surveillance information.

6.4.3.2.1 Unexpected Behaviours/Results

6.4.3.3 Confidence in Results of Validation Exercise

While considering the main assumptions and limitations of the available validation platform at EEC the main objectives of the validation exercise have been evaluated.

6.4.3.3.1 Quality of Validation Exercise Results

All exercises were conducted with real traffic recorded data which have an impact on the quality of the obtained results. While the traffic sample used offered the possibility of evaluating the validation

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objectives in a realistic scenario, the available platform and the use of simulated non-nominal events had an impact on the quality of the observations performed during the exercises and the possibility of covering fully the validation objectives considered. Also the time and the number of subject matter experts available for the validation were relatively limited.

However, the exercises provided enough data to allow the validation experts to draw conclusions and identify the few issues that may require further investigation.

6.4.3.3.2 Significance of Validation Exercise Results

The data which have been produced during the exercises at EEC, are strongly indicative for the demonstration of the required performance, despite the fact that due to the nature of this validation the time availability and the platform limitations these cannot be considered as exhaustive.

6.4.4 Conclusions and recommendations

6.4.4.1 Conclusions

The aim of the validation work at the EEC was to assess and evaluate the feasibility and acceptability of the use of surveillance data provided by the 15.4.5a prototype Ground Stations and SDPD in a multisensor environment in TMA and en-route airspace, for different traffic loads. It was performed using operational experts (air traffic controller) as well as technical experts. Two exercises were executed for nominal and non-nominal mode respectively, containing 3 scenarios each, i.e. En-route, TMA high density and TMA medium traffic density. In addition, assessment of the Ground station performance and SDPD features with an operational perspective were performed.

It should be noted that for the exercises at EEC, the used platform was not a fully comprehensive IBP, the task was an ad-hoc replacement of support to external operational validation project(s), therefore assumptions were made during the preparation phase to mitigate for the constraints.

At a generic level, considering the available scenarios, environment and traffic samples, the data provided by the ADS-B prototypes in a multisensor TMA and en-route environment can be considered as meeting the requirements for the operational services envisaged. The use of the system contributes to an improved situational awareness and does not normally increase the associated controller workload. A few cases demonstrated the need for further investigations. Associated recommendations for further work are also made.

6.4.4.2 Recommendations

It is recommended that the few identified issues will be addressed in the future evolution of the prototypes

Regarding the validation platform at EEC which was not a full IBP and in order to maximise the benefits from any possible further analysis, improvements of the CWP component with added functionalities are recommended that would allow for:

- Assessment and evaluation of all the surveillance data required for the provision of ATC simultaneously and in real time
- Data log for recording any specific issues with the transmission of the data between the tracker system and CWP

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- o Both numerical and graphical display of the data available to the CWP
- o Possibility to inject deviation of accuracy for ADS-B traffic only in order to test the capability of the system to detect inconsistencies and their notification to the CWP

It is recommended that the validation of the system will be continued in the transition towards industrialisation and deployment. This should include a detailed assessment of the performance of the overall system and its components w.r.t. associated emerging standards (e.g. EUROCAE) and Specifications as well as validation exercises of the applications to be implemented at generic and local levels. Any recommendations from the projects so far should be taken into account.

6.5 ADS-B Ground station evaluation at EEC

6.5.1 Probability of detection analysis

Probability of Detection Analysis (PDA) is aimed for measuring the message detection performance of the ADS-B Ground Station. It measures the PD for a given 3D volume, either given per individual 3D cell, for the range/azimuth/altitude range or for the entire operational volume (coverage). This section describes the PDA performed for the ADS-B GS installed at EEC Brétigny at various times, particularly after installation and major changes to the hardware/software configuration.

6.5.1.1 PDA with data from 8 February 2012

PDA is performed in order to establish the detection performance of the ADS-B_GS_A with data from 8 February 2012. Figure 24 below gives the detection performance of the ADS-B_GS_A.

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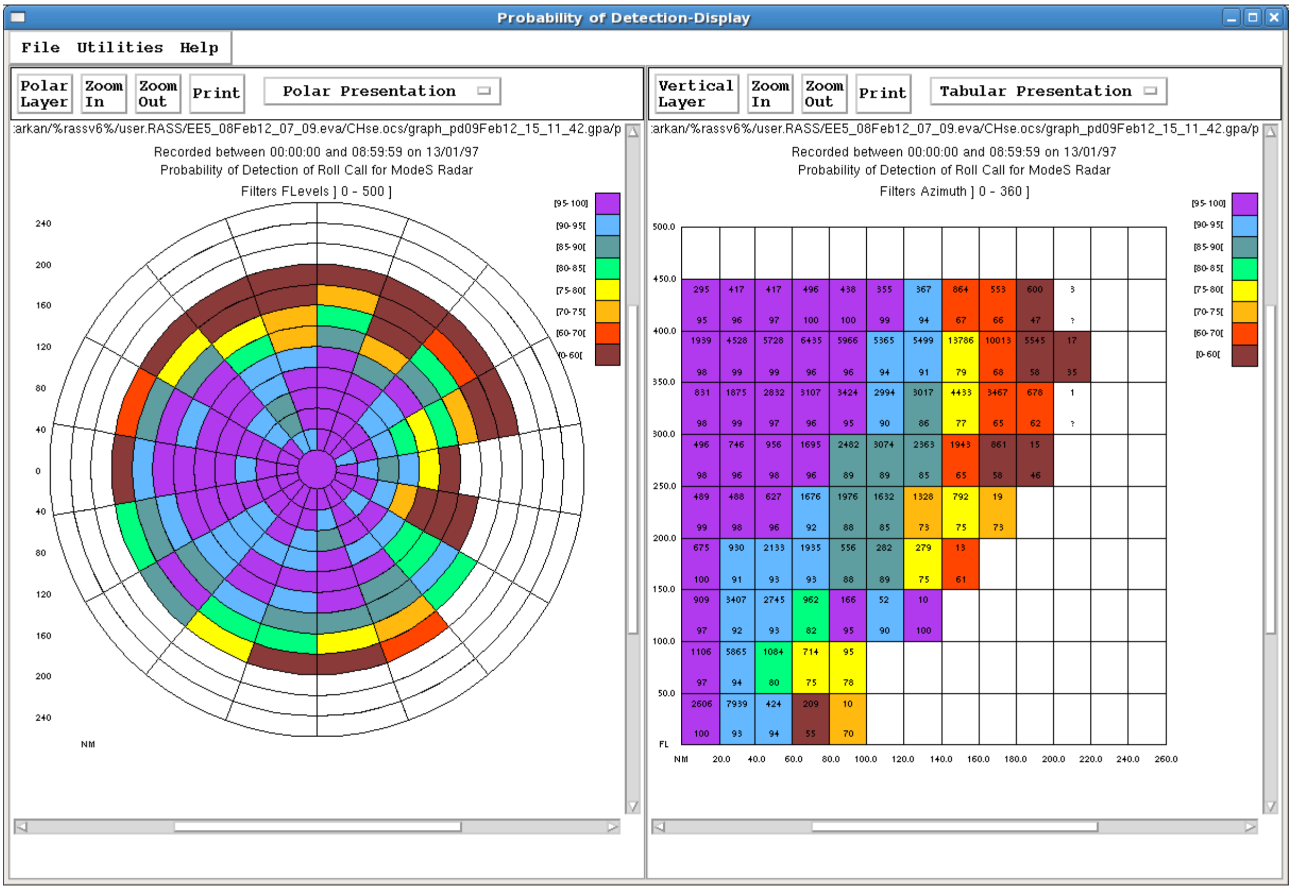

Figure 24: ADS-B_GS_A PD for 5 sec update rate for 8 February 2012 07:00-09:00

6.5.1.2 PDA with data from 28 February 2012

PDA is performed in order to compare the detection performance of the ADS-B_GS_A and ADS-B_GS_B with data from 28 February 2012. The 3D PD displays are given for three azimuth ranges separately because ADS-B_GS_A has three sector antennas. Figures below give the detection performance of the ADS-B_GS_A and ADS-B_GS_B. Figure 25 to Figure 30 show the 3D PD for ADS-B_GS_A and ADS-B_GS_B for the three azimuth ranges.

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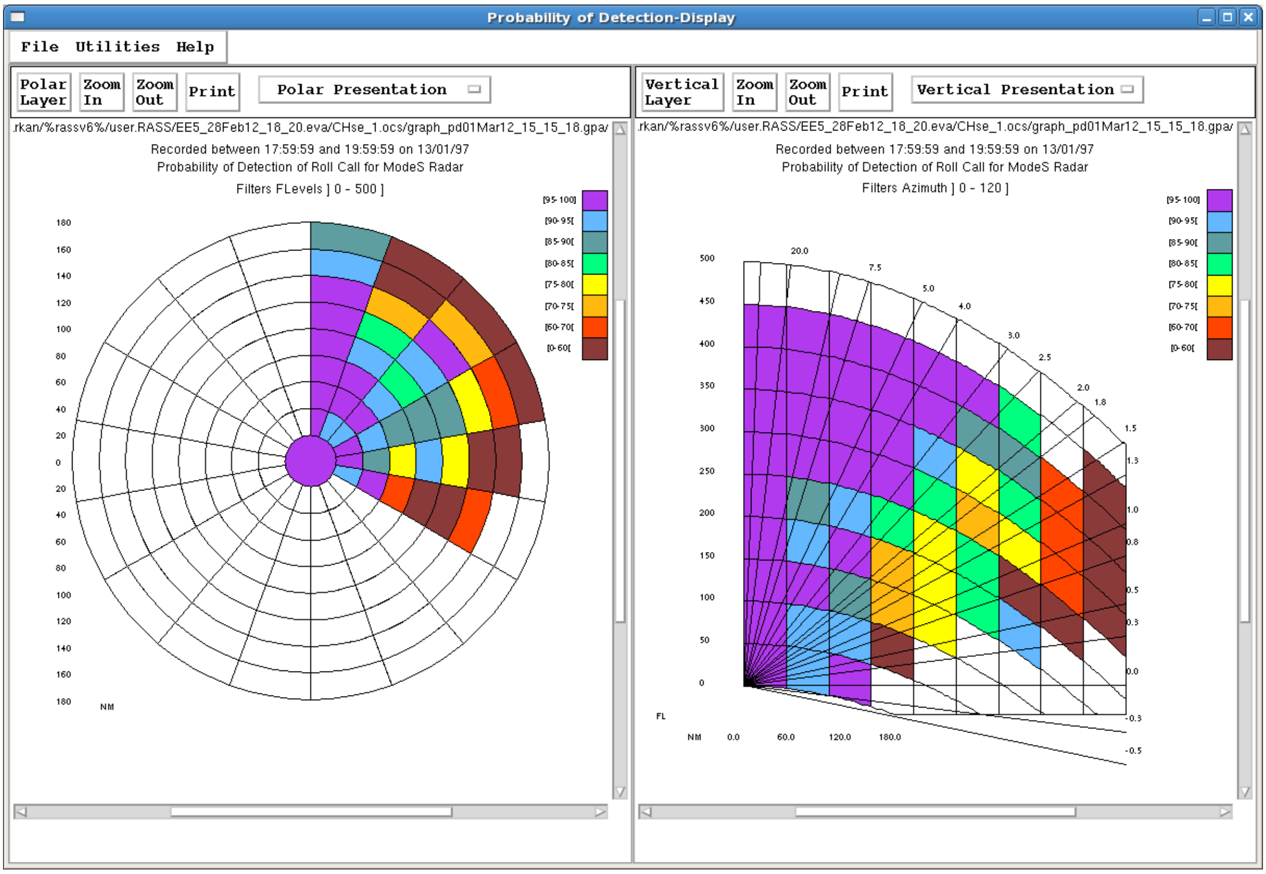

Figure 25: ADS-B_GS_A PD for 5 sec for azimuth 0-120 deg for 28 February 2012 18:00-20:00

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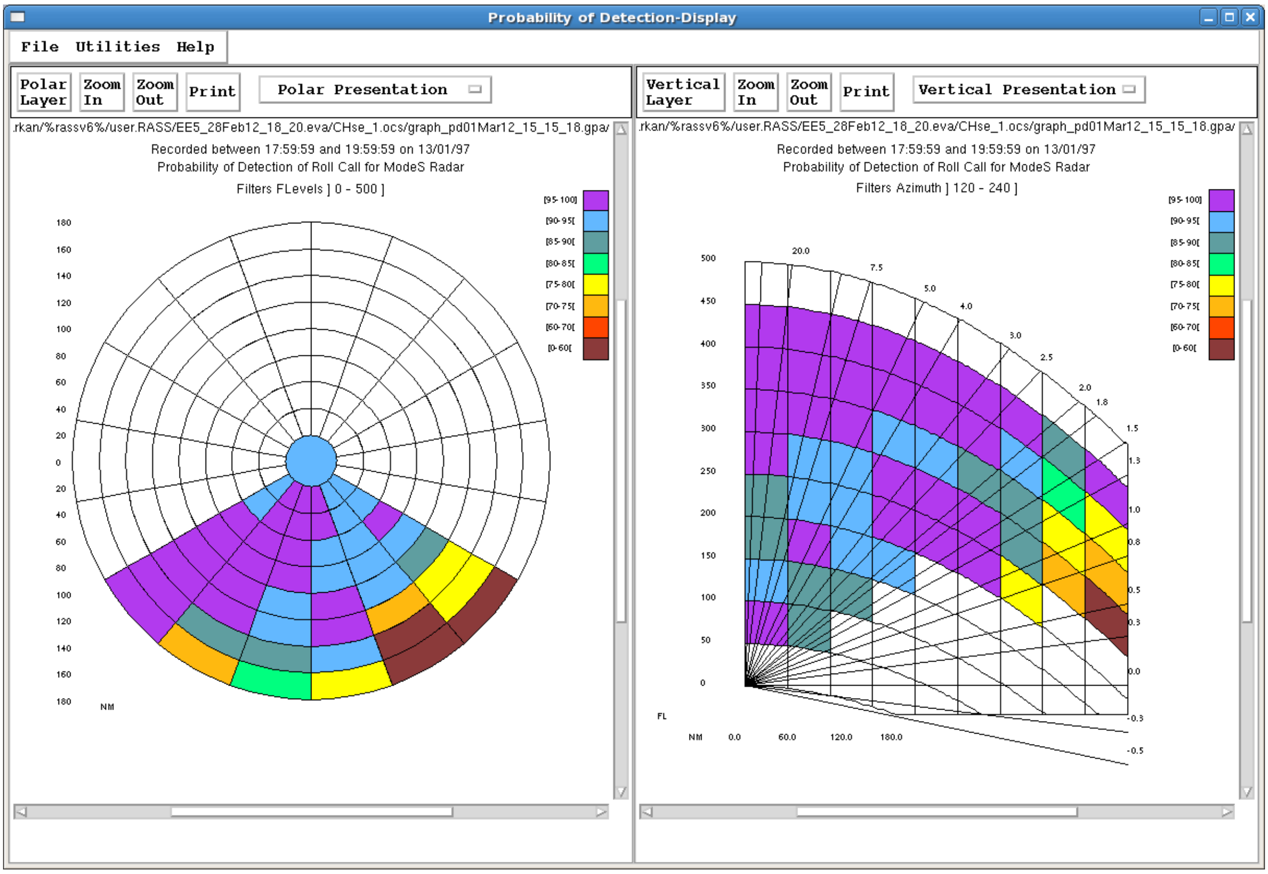

Figure 26: ADS-B_GS_A PD for 5 sec for azimuth 120-240 deg for 28 February 2012 18:00-20:00

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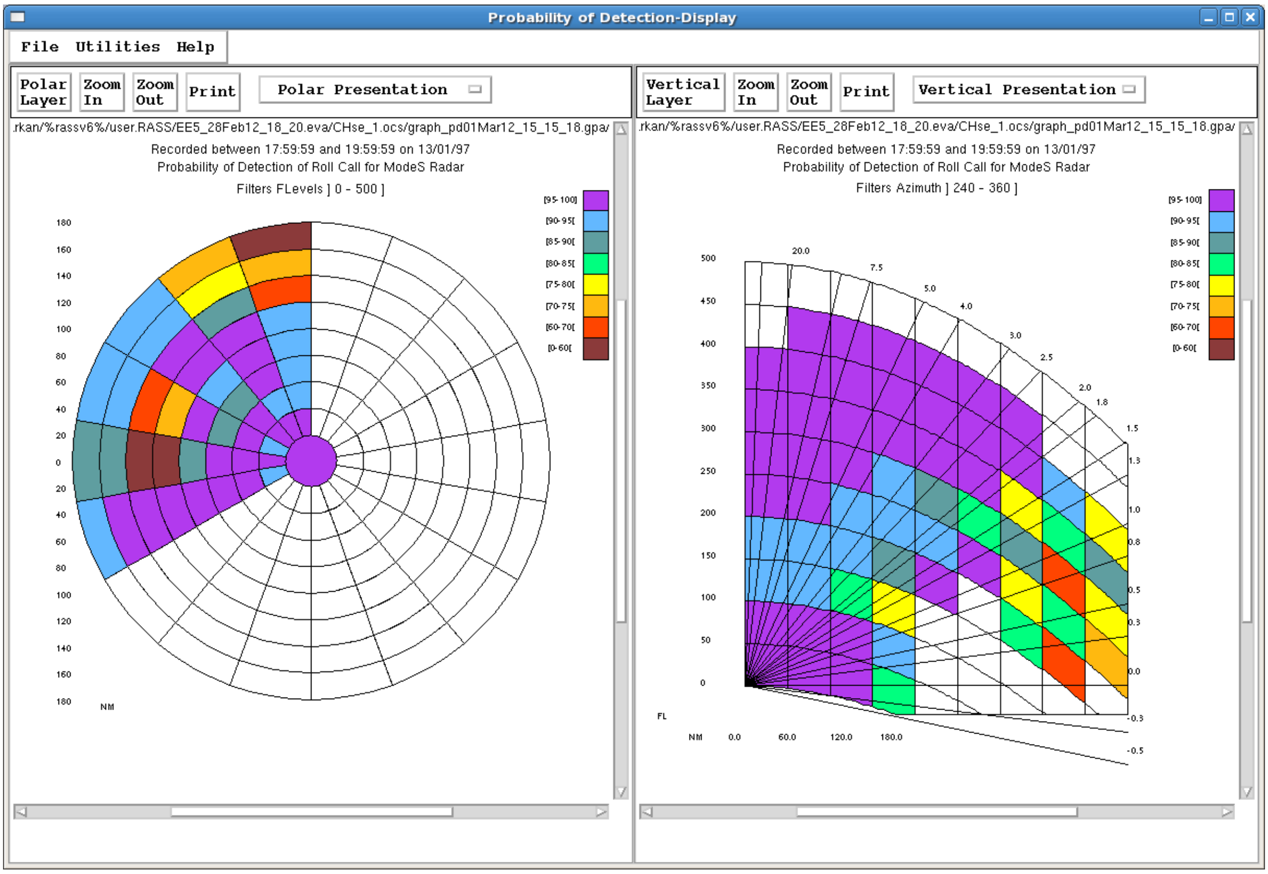

Figure 27: ADS-B_GS_A PD for 5 sec for azimuth 240-360 deg for 28 February 2012 18:00-20:00

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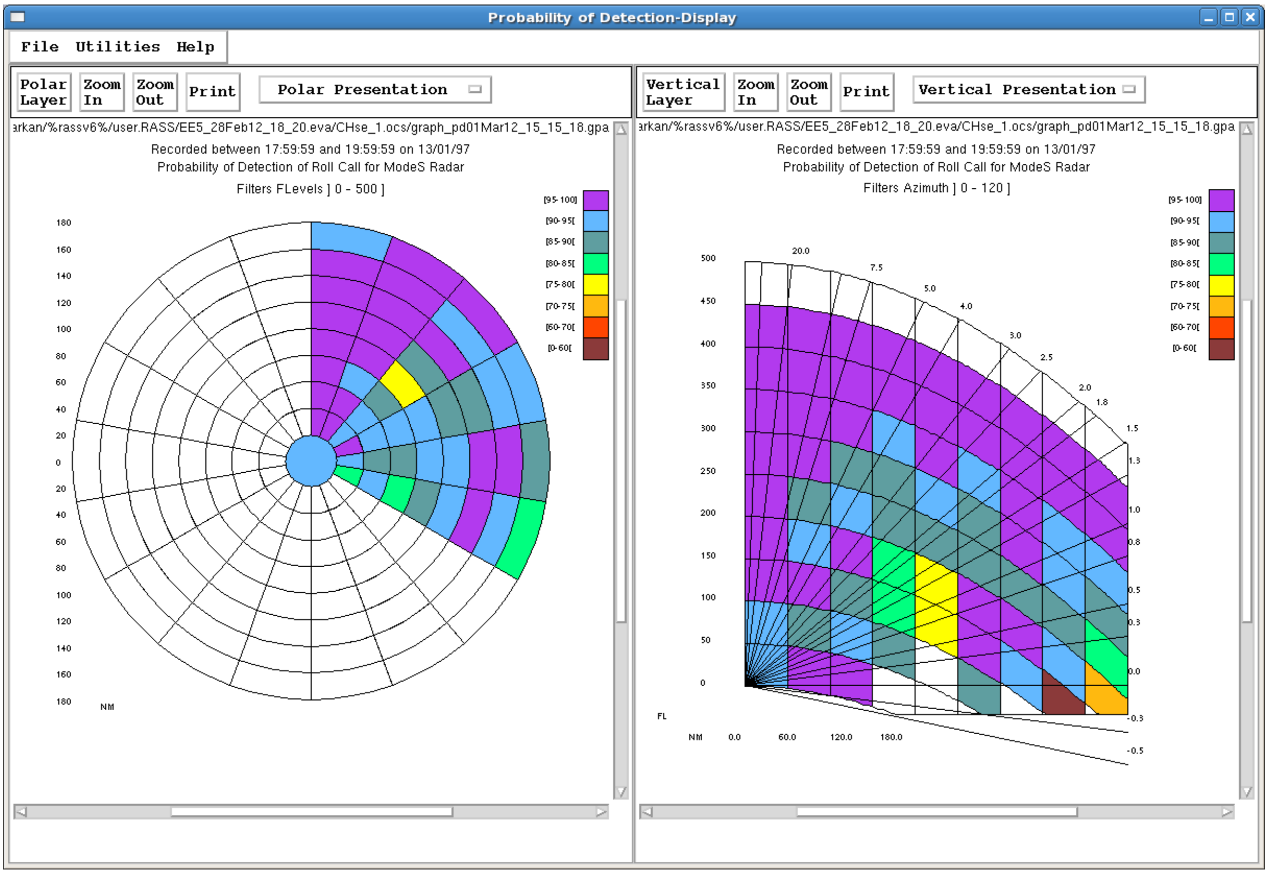

Figure 28: ADS-B_GS_B PD for 5 sec for azimuth 0-120 deg for 28 February 2012 18:00-20:00

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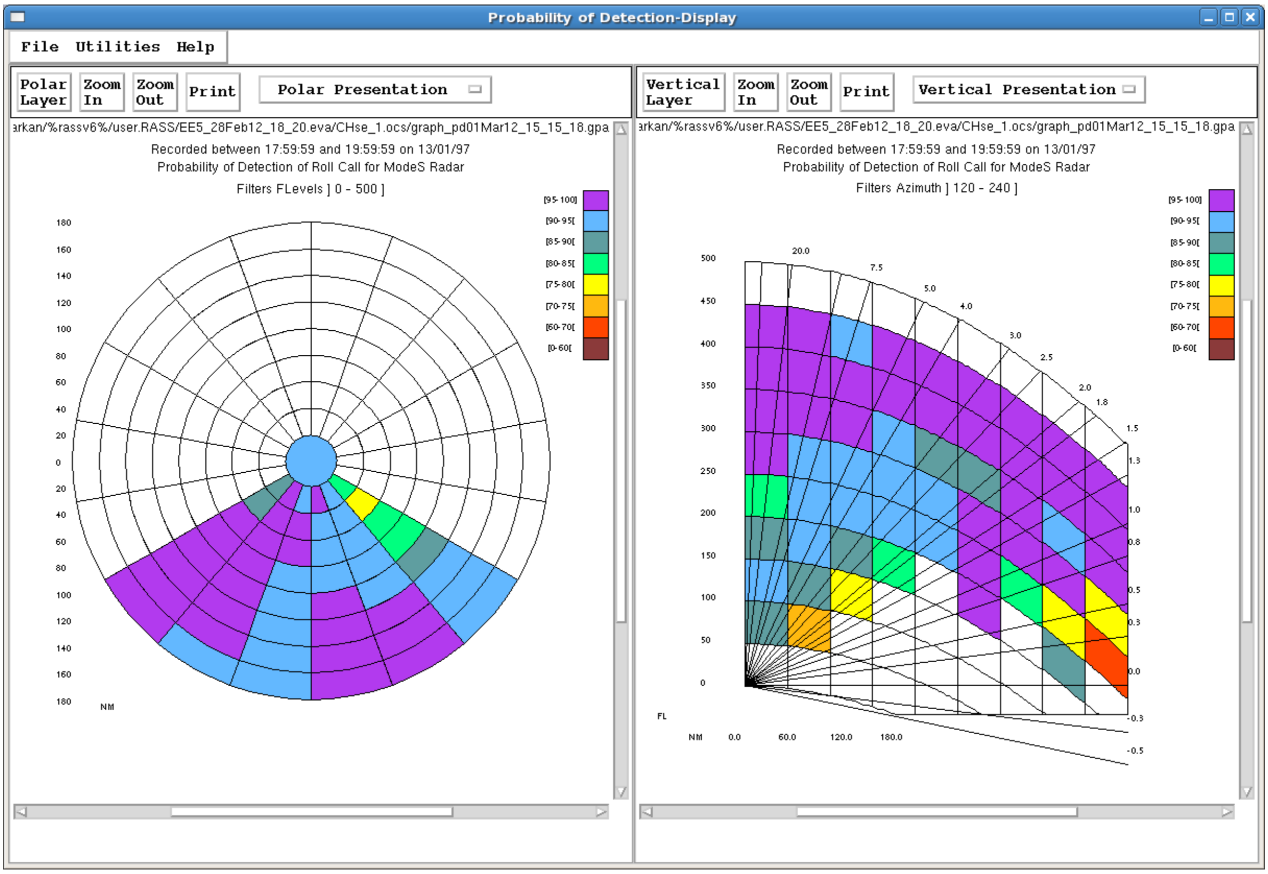

Figure 29: ADS-B_GS_B PD for 5 sec for azimuth 120-240 deg for 28 February 2012 18:00-20:00

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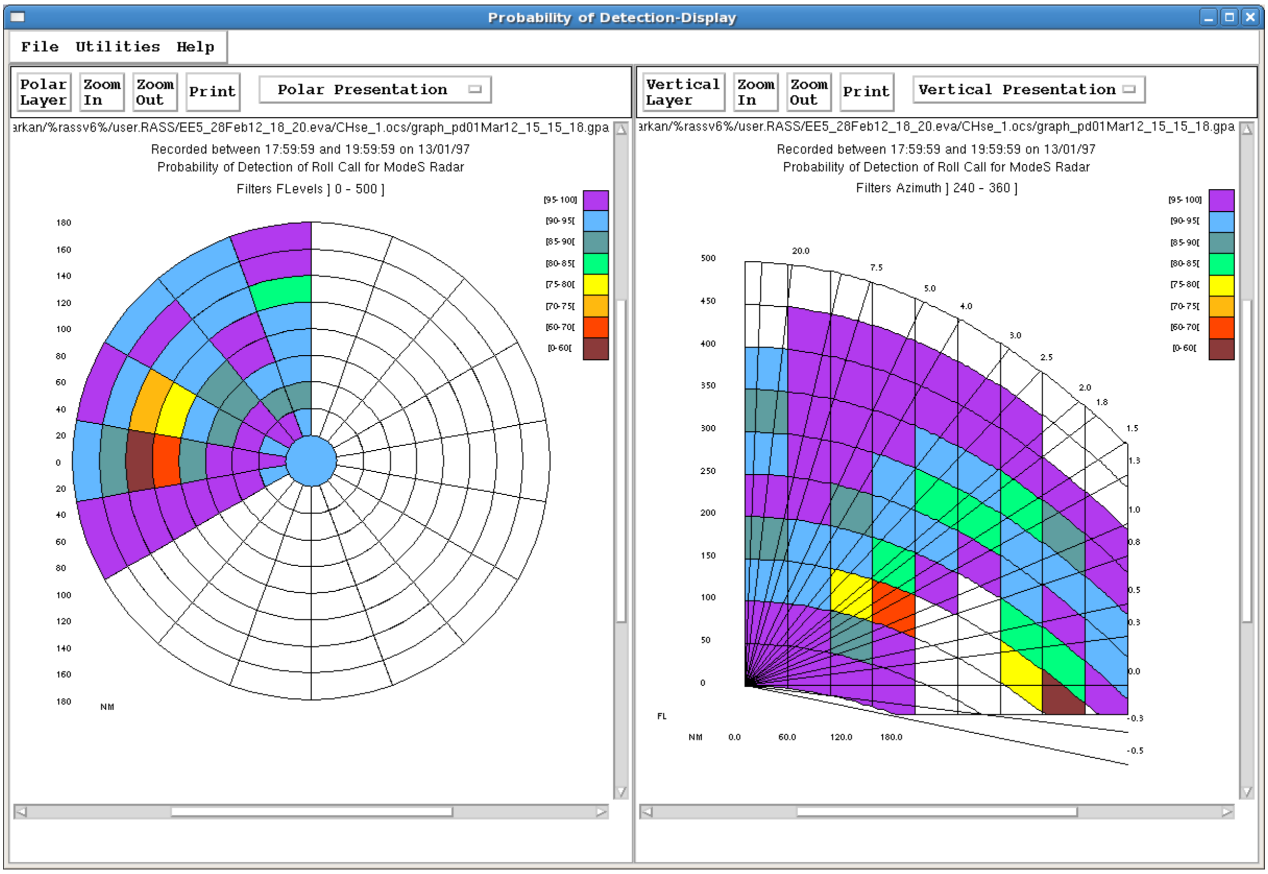

Figure 30: ADS-B_GS_B PD for 5 sec for azimuth 240-360 deg for 28 February 2012 18:00-20:00

6.5.1.3 Analysis made with data from 31 January 2013

Figure 31 and Figure 32 show the PD performance of ADS-B_GS_A and ADS-B_GS_B with data from 31 January 2013, 16:00 – 18:00. The detection performance of ADS-B_GS_B is slightly better than ADS-B_GS_A with three sector antennas. It is also likely that there is an obstacle affecting the detection performance of both stations around azimuth angle of 100 degrees as indicated by the lower detection rates at longer range.

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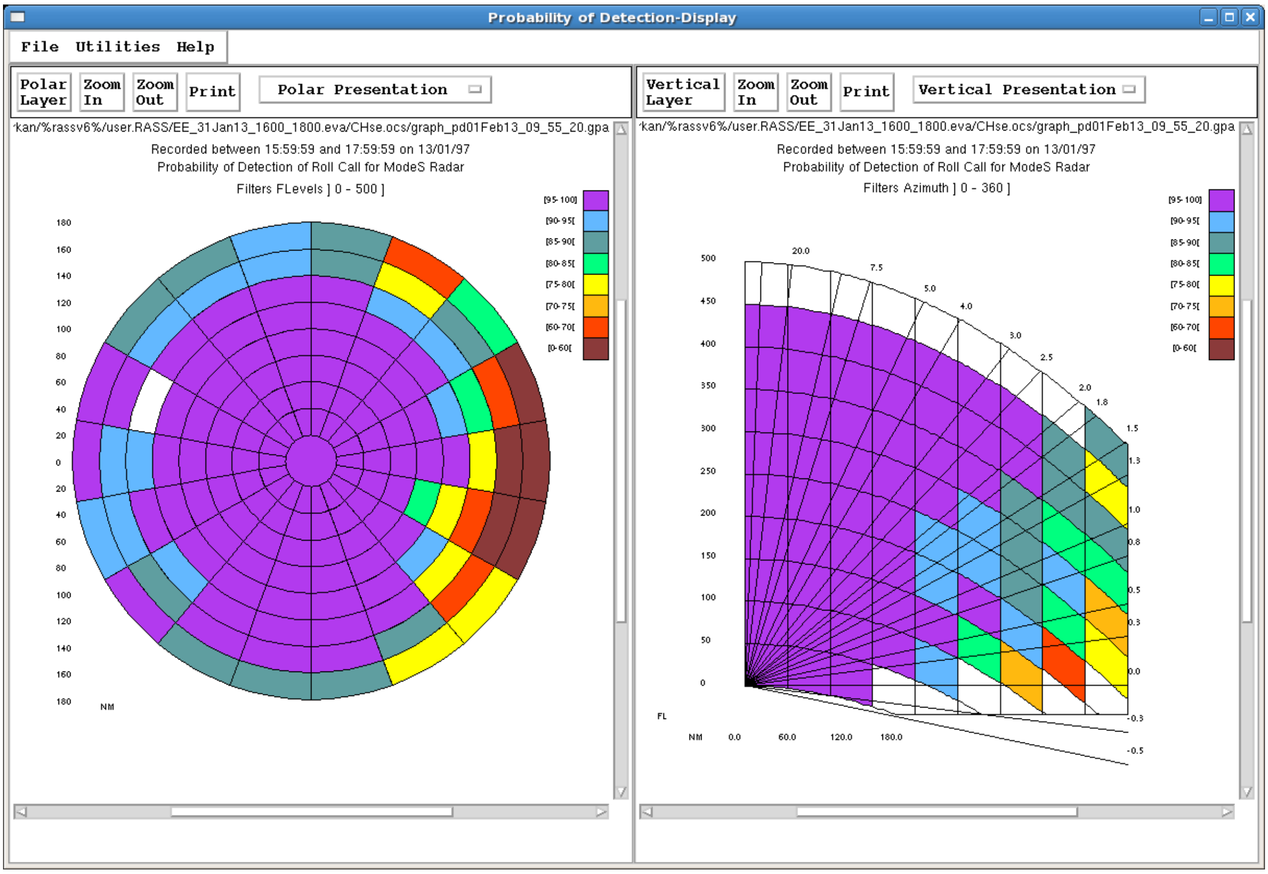

Figure 31: ADS-B_GS_A PD for 5 sec for 31 January 2013 16:00-18:00

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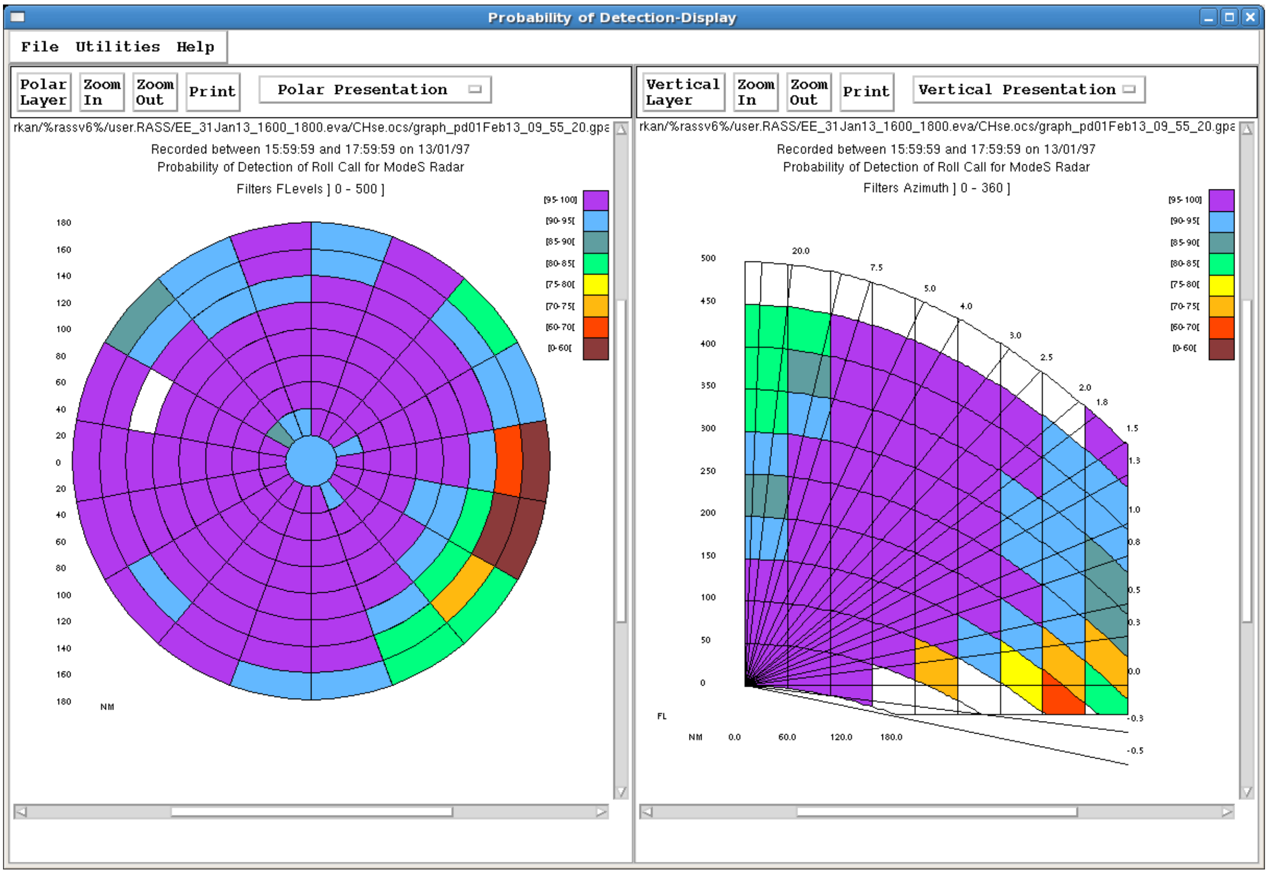

Figure 32: ADS-B_GS_B PD for 5 sec for 31 January 2013 16:00-18:00

6.5.1.4 Analysis made with data from 10 March 2013

Figure 33 show the PD performance of ADS-B_GS_A with data from 10 March 2013, 16:00 – 18:00. The detection performance of the station is similar to before the software update on 8 March 2013.

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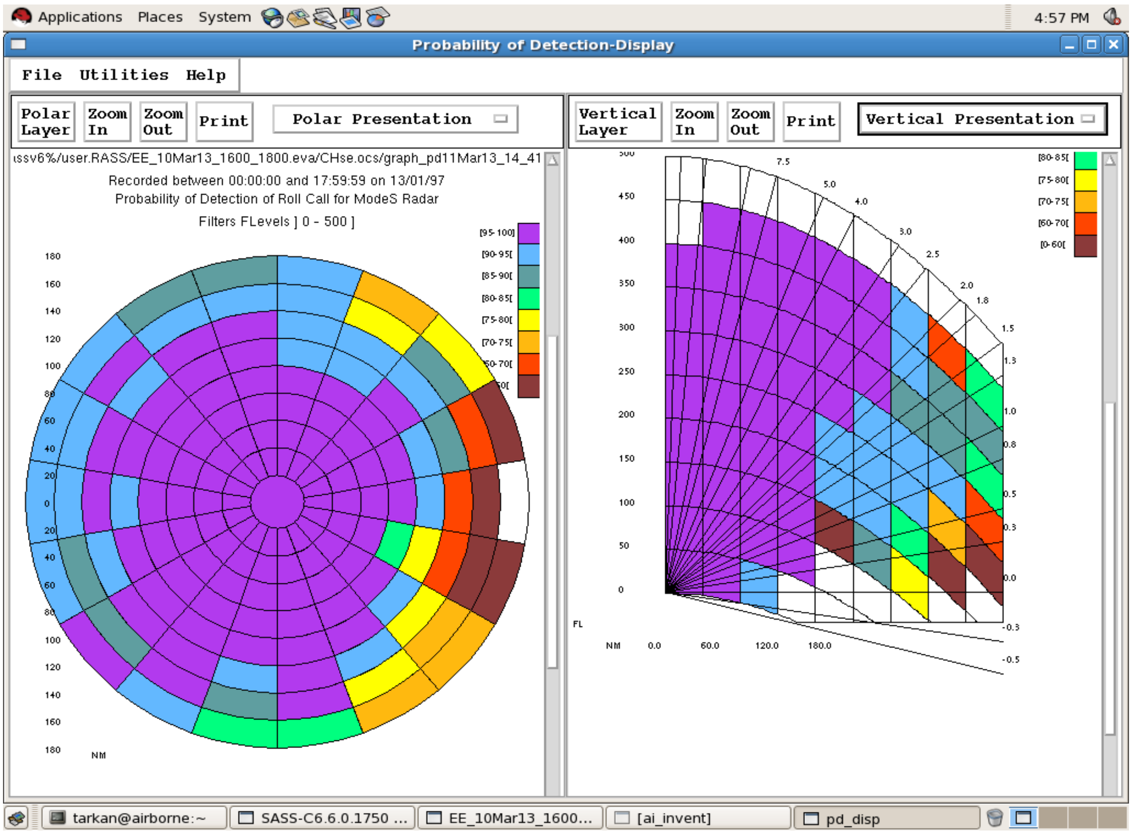

Figure 33: ADS-B_GS_A PD for 5 sec for 10 March 2013 16:00-18:00

6.5.1.5 Analysis made with data from 3 & 4 April 2013

The overall PD performance of ADS-B_GS_A and ADS-B_GS_B with data from 3 and 4 April 2013, 16:00 – 18:00 are as follows:

ADS-B GS	3 April 2013	4 April 2014
ADS-B_GS_A	94,09 %	94,76 %
ADS-B_GS_B	94,77 %	94,91 %
ADS-B_GS_B’	96,78 %	97,04 %

Table 24: Overall PD for the three ADS-B GS for 3 & 4 April 2014

The detection performance of ADS-B_GS_A is similar to ADS-B_GS_B, which are both slightly worse than ADS-B_GS_B’. Both ADS-B_GS_B share the same antenna with a splitter, but apparently there is some cable loss causing lower PD for one of the ADS-B_GS_B stations.

Analysis made with data from 18 March 2014

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Figure 35 shows the PD performance of ADS-B_GS_A and ADS-B_GS_B with data from 18 March 2014, 16:00 – 18:00. The detection performance of ADS-B_GS_B is slightly better than ADS-B_GS_A and both station's PD are similar to previous analyses.

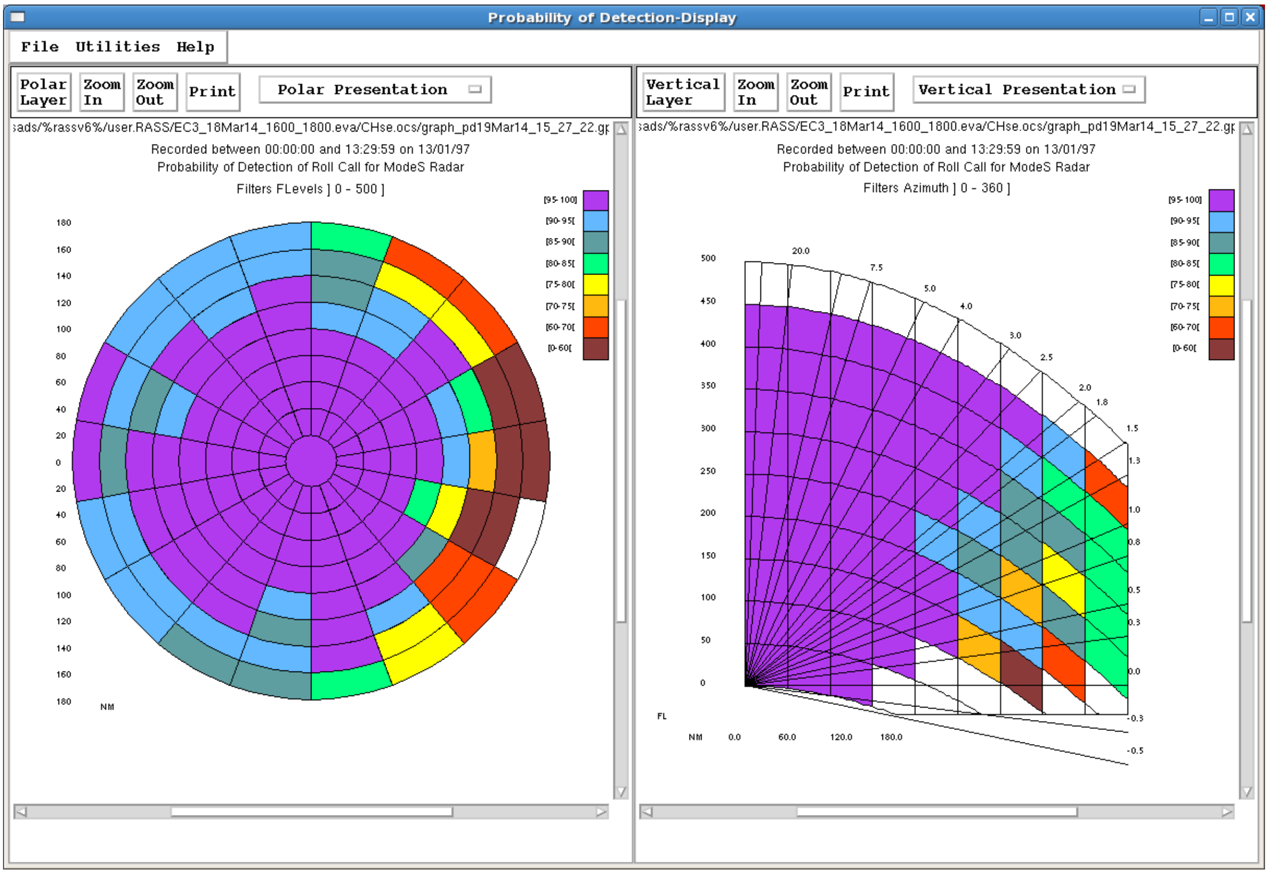

Figure 34: ADS-B_GS_A PD for 5 sec for 18 March 2014 16:00-18:00

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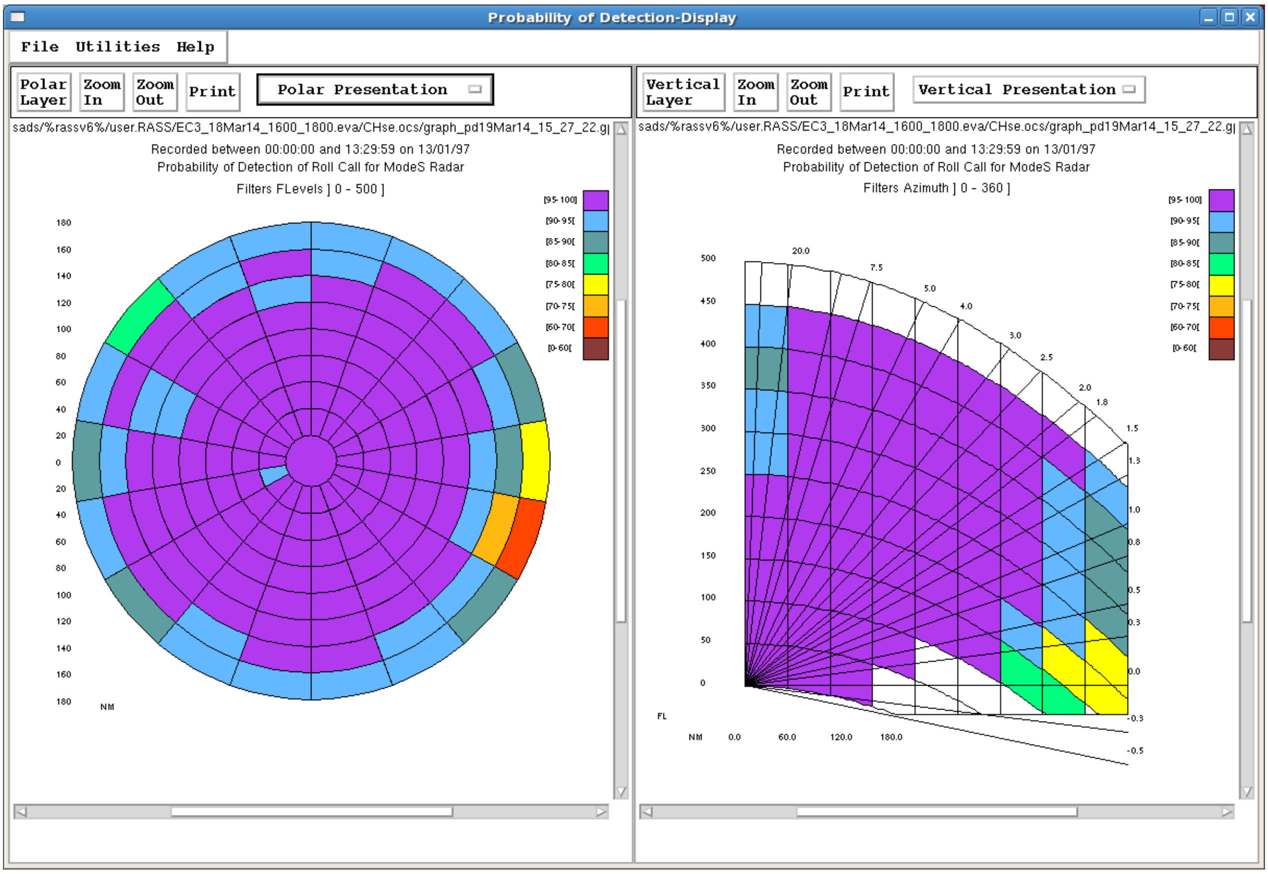

Figure 35: ADS-B_GS_B PD for 5 sec for 18 March 2014 16:00-18:00

6.5.1.6 Conclusions

In addition to the Ground Station testing that took place in the context of 15.4.5b, additional tests with a specific operational interest have been performed at the EEC within project 15.4.5a. These tests were generally successful.

6.6 Surveillance Data Processing and Distribution Evaluation at EEC

The SDPD was evaluated at EEC focussing on specific issues of operational interest.

The prototype SDPD prototype Iteration 1 processes (amongst others) the following information provided by ADS-B reports:

- Emergency indication
- SPI indication
- Mode A code information
- Position change/Velocity Validation

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- Time of Arrival Validation information
- WAM Integration Validation
- Angle of Arrival Validation
- Power/Range Validation

The following requirements, from the Prototyping DO6 Table A 1 were evaluated during the testing:

Requirement definition	SESAR reference
INCONSISTENCY EMERGENCY CODE	REQ-15.04.05.a-D06-0010.0010
ADS-B ONLY TRACK POTENTIAL SPOOFING	REQ-15.04.05.a-D06-0010.0015
SERVING ADS-B ONLY TRACK	REQ-15.04.05.a-D06-0010.0020
DO-260B COMPLIANCE	REQ-15.04.05.a-D06-0020.0010
WAM VALIDATION	REQ-15.04.05.a-D06-0030.0010

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SERVING WAM VALIDATION RESULT	REQ-15.04.05.a-D06-0030.0020
TOA/DISTANCE CONSISTENCY PROCESSING	REQ-15.04.05.a-D06-0040.0010
TOA/DISTANCE CONSISTENCY POTENTIAL SPOOFING	REQ-15.04.05.a-D06-0040.0015
TOA/DISTANCE VALIDATION RESULT	REQ-15.04.05.a-D06-0040.0020
POWER/RANGE VALIDATION PROCESSING	REQ-15.04.05.a-D06-0050.0010
POWER/RANGE POTENTIAL SPOOFING	REQ-15.04.05.a-D06-0050.0015
SERVING POWER/RANGE VALIDATION RESULT	REQ-15.04.05.a-D06-0050.0020
ANGLE OF ARRIVAL VALIDATION PROCESSING	REQ-15.04.05.a-D06-0060.0010
ANGLE OF ARRIVAL POTENTIAL SPOOFING	REQ-15.04.05.a-D06-0060.0015
SERVING ANGLE OF ARRIVAL VALIDATION RESULT	REQ-15.04.05.a-D06-0060.0020
VELOCITY VERSUS POSITION CHECK PROCESSING	REQ-15.04.05.a-D06-0070.0010
VELOCITY VERSUS POSITION SPOOFING	REQ-15.04.05.a-D06-0070.0015
SERVING VELOCITY VERSUS POSITION CHECK	REQ-15.04.05.a-D06-0070.0020

Table 25: SDPD Evaluation Iteration 1

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The SDPD prototype Iteration 2 and 3 processes (amongst others) the following information provided by ADS-B reports:

- Emergency indication
- SPI indication
- Mode A code information
- Behaviour Analysis Validation
- Time of Arrival Validation information
- WAM Integration Validation
- Time Difference of Arrival Validation
- Angle of Arrival Validation
- Power/Range Validation

The following requirements were evaluated during the testing:

Requirement definition	SESAR reference
DUPLICATE MODE 3/A CODES OR AIRCRAFT ID	REQ-15.04.05.a-D06-0010.0010
ADS-B ONLY TRACK POTENTIAL SPOOFING	REQ-15.04.05.a-D06-0010.0015
SERVING ADS-B ONLY TRACK	REQ-15.04.05.a-D06-0010.0020
DECODING ASTERIX CAT 021 2.0	REQ-15.04.05.a-D06-0020.0010
WAM VALIDATION PROCESSING	REQ-15.04.05.a-D10-0030.0010
SERVING WAM VALIDATION RESULT	REQ-15.04.05.a-D06-0030.0020
ToA/DISTANCE CONSISTENCY PROCESSING	REQ-15.04.05.a-D06-0040.0010
ToA/DISTANCE VALIDATION RESULT	REQ-15.04.05.a-D06-0040.0020
POWER/RANGE VALIDATION PROCESSING	REQ-15.04.05.a-D06-0050.0010
SERVING POWER/RANGE VALIDATION RESULT	REQ-15.04.05.a-D06-0050.0020
ANGLE OF ARRIVAL VALIDATION PROCESSING	REQ-15.04.05.a-D06-0060.0010

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SERVING ANGLE OF ARRIVAL VALIDATION RESULT	REQ-15.04.05.a-D06-0060.0020
TDOA VALIDATION PROCESSING	REQ-15.04.05.a-D10-0045.0046
SERVING TDOA VALIDATION RESULT	REQ-15.04.05.a-D10-0045.0048

Table 26: SDPD Evaluation Iteration 2&3

6.6.1 System architecture for the ARTAS testing

The figure 3 shows the overall system architecture of the EEC testbed used to test the prototype ARTAS V8B0_SJU_WP15_4_5b or V8B1_SJU_WP15_4_5b.

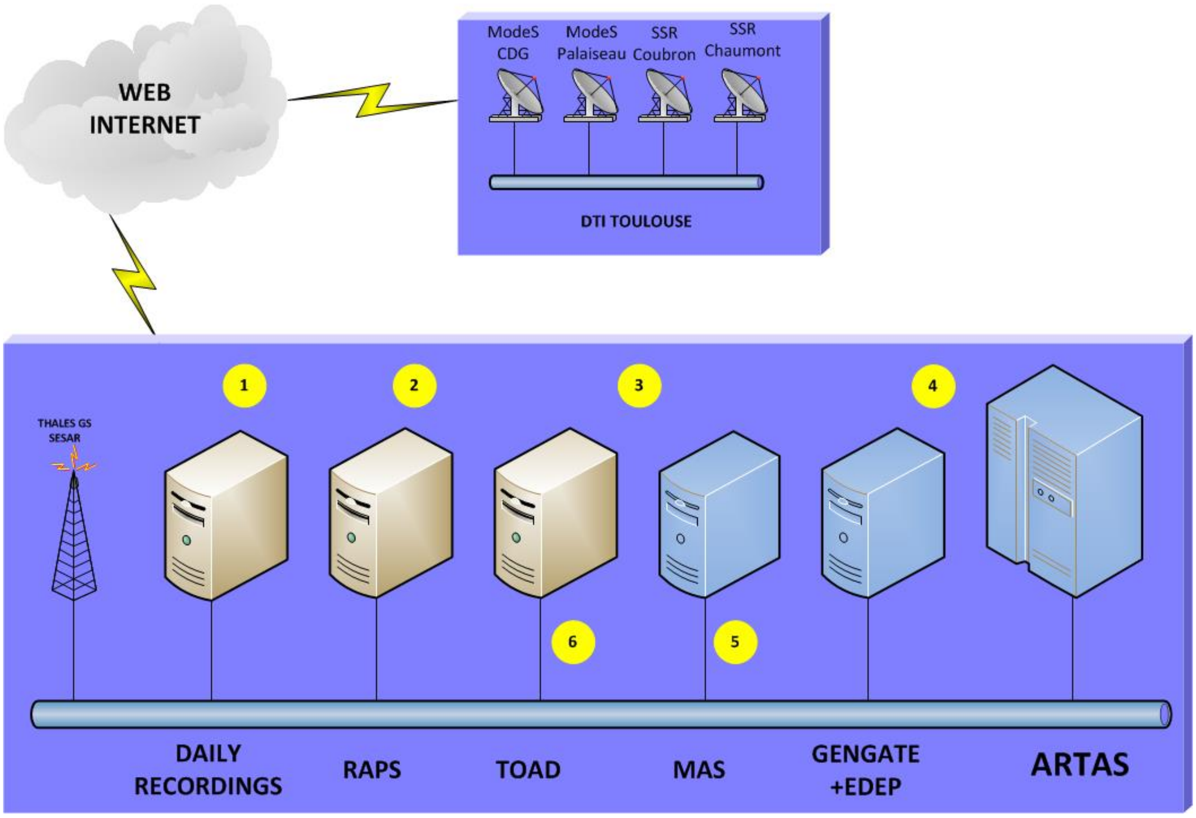

Figure 36: SDPD testbed

The ASTERIX cat21 messages coming from the SESAR Ground Station are daily recorded with GENGATE application in a final format file; The ASTERIX cat1 and cat48 messages coming respectively from 2 Secondary radars (Coubron and Chaumont) and from 2 Mode S radars (CDG

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and Palaiseau) are daily recorded with GENGATE application in a final format file; In all these daily recordings, the 15th of September 2013 is chosen as the sample of live traffic to be used for the test;

The 5 recordings of the 15/09/13 are filtered to keep only 30 minutes of traffic concerning 2 aircrafts equipped with transponders DO-260B. These aircraft have the callsigns UP210 and UPS 232 and are flying in the north of France ,from Germany, inbound to the UK airspace;

These 5 samples of traffic are then imported in the ORACLE database of the MAS application to be modified according to the tested requirement. The tables are exported to new final format files to create a new scenario.

The scenario is replayed with GENGATE, the messages are sent to ARTAS in order to be processed. The ASTERIX cat62 messages which are sent back from ARTAS, are recorded with GENGATE,ASTERIX cat21 and cat62 data can be shown on a map with Edep application;

The ASTERIX cat62 messages are then imported in the ORACLE database. The results of the test can be evaluated in querying the database.

6.6.2 Tests and results

Among the SDPD ITERATION 1 requirements, the following tests have been executed:

- For some ASTERIX cat21 messages in the scenario, the Angle of Arrival verification has been set to ”not valid”;
- For some ASTERIX cat21 messages in the scenario, the power/range evaluation and the integration WAM verifications have been set to ”not valid”;
- For some ASTERIX cat21 messages in the scenario, several validations as position change/velocity, power/range, time of arrival, WAM integration and angle of arrival, have been set to ”not valid”;
- Number of occurrences and the duration of a bad validation of an angle of arrival have been tested in ARTAS.
- Different emergency codes were introduced in the radar or ADS-B data alternatively to create discrepancies in ARTAS;
- The scenario was modified to create a flight which sends extended squitters but which is not detected by the radars sensors

Among the SDPD ITERATION 2&3 requirements, the following tests have been executed in ARTAS:

- For some ASTERIX cat21 messages in the scenario, the Angle of Arrival verification has been set to ”not valid”
- For some ASTERIX cat21 messages in the scenario, the power/range evaluation and the integration WAM verifications have been set to ”not valid”
- For some ASTERIX cat21 messages in the scenario, several validations as position change/velocity, power/range, time of arrival, WAM integration and angle of arrival, have been set to ”not valid”
- Number of occurrences and the duration of a bad validation of a time difference of arrival, have been tested in ARTAS
- Different emergency codes were introduced in the radar or ADSB data alternatively to create discrepancies in ARTAS
- The scenario was modified to create a flight which sends extended squitters but which is not detected by the radars sensors
- Different Mode A codes or callsigns were introduced in the radar or ADS-B data alternatively to create discrepancies in ARTAS

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- The same Mode A code or callsign were introduced in the radar or ADS-B data for the both flights in a common limited airspace

The results of the SDPD tests at the EEC are generally satisfactory.

6.6.3 Conclusions

In addition to the SDPD testing that took place in the context of 15.4.5b, additional tests with a specific operational interest have been performed at the EEC within project 15.4.5a Iterations 1, 2 and 3. The tests included security related functionality mitigating the associated threats.

The tests were generally successful.

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