Final Project Report

Document information	
Project Title	Surveillance ground system enhancements for ADS-B
Project Number	15.4.5a
Project Manager	EUROCONTROL
Deliverable Name	Final Project Report
Deliverable ID	Del D22
Edition	00.01.04
Template Version	03.00.00
Task contributors	
EUROCONTROL, ENAIRE, INDRA, NORACON, SELEX, THALES	

Abstract

ADS-B is a Surveillance technique which enables Ground & Airborne Surveillance applications thus providing associated operational and performance improvements (safety, cost efficiency, flight efficiency, spectrum efficiency etc.). Enhancements are required to the Ground Surveillance system, in order to make it compliant with the new applications and other emerging requirements such as security. The goal of SESAR project 15.4.5a was to develop Specifications and support the validation of pre-industrial prototypes of the Surveillance ADS-B ground system enhancements. The ground system addressed by the Project consists of the ADS-B Ground station and the Surveillance Data Processing and Distribution (SDPD) system. For its validation support exercises, the project used the three ADS-B Ground stations and the SDPD prototype delivered by the partner project 15.04.05b, on the basis of the 15.4.5a Specifications.

Authoring & Approval

Prepared By – *Authors of the document.*		
Name & Company	Position & Title	Date
[redacted] EUROCONTROL	[redacted]	30/11/2015

Reviewed By – *Reviewers internal to the project.*		
Name & Company	Position & Title	Date
[redacted] ENAIRE	[redacted]	14/12/2015
[redacted] EUROCONTROL		14/12/2015
[redacted] EUROCONTROL		14/12/2015
[redacted] INDRA		14/12/2015
[redacted] NORACON		14/12/2015
[redacted] SELEX		14/12/2015
[redacted] THALES		14/12/2015

Reviewed By – *Other SESAR projects, Airspace Users, staff association, military, Industrial Support, other organisations.*		
Name & Company	Position & Title	Date
[redacted] NATS	[redacted]	14/12/2015

Approved for submission to the SJU By – *Representatives of the company involved in the project.*		
Name & Company	Position & Title	Date
[redacted] EUROCONTROL	[redacted]	15/12/2015
[redacted] ENAIRE		15/12/2015
[redacted] INDRA		15/12/2015
[redacted] NORACON		15/12/2015
[redacted] SELEX		15/12/2015
[redacted] THALES		15/12/2015

Rejected By – *Representatives of the company involved in the project.*		
Name & Company	Position & Title	Date
<Name / Company>	<Position / Title>	<DD/MM/YYYY>

Rational for rejection
None

Document History

Edition	Date	Status	Author	Justification
00.00.01	30/11/2015	Draft	[redacted]	New document
00.01.00	15/12/2015	Final		Approved version for upload
00.01.01	27/01/2016	Final		Include clarifications after SJU assessment
00.01.02	02/02/2016	Final		Include clarifications after SJU assessment and partner feedback

00.01.03	12/02/2016	Final	[redacted]	Include clarifications after SJU assessment
00.01.04	24/02/2016	Final		Include clarifications after SJU assessment and Closure Gate

Intellectual Property Rights (foreground)

This deliverable consists of SJU foreground.

Acronyms

Acronym	Definition
ADS-B	Automatic Dependent Surveillance – Broadcast
ADS-B APT	ADS-B for Airport Surface Surveillance
ADS-B NRA	ADS-B in Non-Radar Airspace
ADS-B RAD	ADS-B in Radar Airspace
ATM	Air Traffic Management
GS	Ground Station
SDPD	Surveillance Data Processing and Distribution
SPI IR	Surveillance Performance and Interoperability Implementing Rule
WG	Working Group

1 Project Overview

The goal of the SESAR project 15.4.5a was to develop Specifications and support the validation of pre-industrial prototypes of the Surveillance ground system enhancements for ADS-B. The ground system addressed by the project consists of the ADS-B Ground station and the Surveillance Data Processing and Distribution (SDPD) system. For its validation support exercises, the project used the three ADS-B Ground stations and the SDPD prototype delivered by the partner project 15.04.05b, on the basis of the 15.4.5a Specifications.

1.1 Project progress and contribution to the Master Plan

The SESAR ADS-B Ground Surveillance system addressed by the project 15.4.5a consists of the following components:

- ADS-B ground station(s)
- SDPD system, which processes input data received from sensors e.g. radars, Wide Area Multilateration (WAM), ADS-B Ground Stations and distributes its output to the Users.

Due to the long duration of the project and the need for early prototype availability for verification and validation activities, the project sub-divided the tasks into three Iterations.

The Specifications developed by the project ensured compliance with the latest ADS-B applications and technology standards. They also included a set of security risk mitigation techniques.

The list of ADS-B enhancements which were matured in the project are listed hereafter:

- Compliance with the latest 1090 MHz datalink Extended Squitter technology
  - ADS-B v2 (EUROCAE ED102A/RTCA DO260B)
- Compliance with ADS-B applications
  - ADS-B in Radar Airspace (ADS-B RAD)
  - ADS-B for Airport Surface Surveillance (ADS-B APT)
- Security related mitigation techniques
  - Integration of ADS-B with WAM
  - Angle of arrival measurement
  - Position versus velocity check
  - Power measurements and range correlation
  - Time of Arrival versus Distance Validation
  - Enhanced ADS-B target report validation via WAM integration
  - Behavioural Analysis of Targets
  - Time Differential of Arrival
  - Range measurement from active interrogation
  - Multi-sensor data fusion consistency checks (SDPD system)
- Automatic system mitigation means
  - Output bandwidth optimisation

For each Iteration, the project 15.4.5a developed Specifications for the overall Ground Surveillance system, the ADS-B Ground Station, the SDPD, the Interfaces as well as for the Ground station Tests.

For the validation support exercises, the project 15.4.5a used the prototypes developed and verified by the partner project 15.4.5b on the basis of the 15.4.5a Specifications. These included three field-proven ADS-B ground systems, developed separately by the industrial providers INDRA, SELEX and THALES, and one SDPD system (ARTAS) by EUROCONTROL.

Regarding the SELEX ADS-B Ground station, in Iterations 1 and 2, validation support to project 6.3.2 was provided, using the Industrial Based platform of the Malpensa Airport. 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 focusing on the En-Route and TMA environments.

The list of Operational Improvements related with project 15.4.5a are listed hereafter:

OI Code	OI Title	Project 15.04.05a Activities/Contribution
CM-0203	Automated Flight Conformance Monitoring	Provision of ADS-B data, ensuring interoperability with the latest ADS-B standards & applications. This includes compliance with the latest 1090 MHz Extended Squitter technology (ADS-B v2), the ADS-B RAD and ADS-B APT applications as well as security related mitigation techniques. The project developed Specifications for the Ground Station, the Surveillance Data Processing and Distribution system as well as the relevant Interfaces. These Specifications were used by Project 15.04.05b to develop and verify prototypes, which Project 15.04.05a has then used to support validation activities. The above have contributed to increase the maturity of these systems and the confidence to the associated improvements.
CM-0207-A	Advanced Automated Ground Based Flight Conformance Monitoring in En-Route	Provision of ADS-B data, ensuring interoperability with the latest ADS-B standards & applications. This includes compliance with the latest 1090 MHz Extended Squitter technology (ADS-B v2), the ADS-B RAD application as well as security related mitigation techniques. The project developed Specifications for the Ground Station, the Surveillance Data Processing and Distribution system as well as the relevant Interfaces These Specifications were used by Project 15.04.05b to develop and verify prototypes, which Project 15.04.05a has then used to support validation activities. The above have contributed to increase the maturity of these systems and the confidence to the associated improvements.

CM-0210	Ground Based Flight Conformance Monitoring in En-Route using trajectory data	Provision of ADS-B data, ensuring interoperability with the latest ADS-B standards & applications. This includes compliance with the latest 1090 MHz Extended Squitter technology (ADS-B v2), the ADS-B RAD application as well as security related mitigation techniques. The project developed Specifications for the Ground Station, the Surveillance Data Processing and Distribution system as well as the relevant Interfaces These Specifications were used by Project 15.04.05b to develop and verify prototypes, which Project 15.04.05a has then used to support validation activities. The above have contributed to increase the maturity of these systems and the confidence to the associated improvements.
AO-0201-A	Enhanced Ground Controller Situational Awareness in all Weather Conditions for Step 1	Provision of ADS-B data, ensuring interoperability with the latest ADS-B standards & applications. This includes compliance with the latest 1090 MHz Extended Squitter technology (ADS-B v2), the ADS-B RAD application as well as security related mitigation techniques. The project developed Specifications for the Ground Station, the Surveillance Data Processing and Distribution system as well as the relevant Interfaces These Specifications were used by Project 15.04.05b to develop and verify prototypes, which Project 15.04.05a has then used to support validation activities. The above have contributed to increase the maturity of these systems and the confidence to the associated improvements.
CNS-0003-A/B/C	Rationalisation of SUR functionalities and/or technologies for CNS systems supporting cost efficiency, spectrum efficiency etc. for Step 1, 2 and 3	The Project specified and supported validation of new ADS-B functionalities enabling rationalisation (cost efficiency, spectrum efficiency etc.).In particular, the project developed Specifications for the Ground Station, the Surveillance Data Processing and Distribution system as well as the relevant Interfaces. These Specifications were used by Project 15.04.05b to develop and verify prototypes, which Project 15.04.05a has then used to support validation activities. The above have contributed to increase the maturity of these systems and the confidence to the associated improvements The ADS-B Ground Surveillance system is a key enabler for Performance Improvements, namely Surveillance infrastructure rationalisation (by improving both cost efficiency and spectrum efficiency). The associated cost is, in general, significantly lower than the one for classical means of Surveillance. The system is also fully

		interoperable with other Surveillance means and derives synergies and additional potential for performance benefits incl. security when operated in combination with multilateration. Furthermore, ADS-B is a passive Surveillance technique, i.e. it reduces the 1030/1090MHz datalink use and thus enables the longevity of the Surveillance datalink and the best use of the stakeholder investments. The relevant rationalisation process will be extended in Steps 1, 2 and 3.

Table 1 - List of OIs

The list of relevant enablers is provided hereafter:

EN Code	EN Title	Project 15.04.05a Activities/Contribution	Maturity before Project	Maturity after Project
CTE-S03a	ADS-B Station for NRA Surveillance	Baseline system. The relevant EUROCAE standard (ED-129) was the starting point for the work of project 15.4.5a. This standard was used operationally already since the start of the project (e.g. Australia, Canada) and later also in Europe (e.g. N. Atlantic). The developed prototypes meet the associated baseline Specifications.	TRL7	TRL7
CTE-S03b	ADS-B station for RAD and APT surveillance	The Project specified and supported validation of new ADS-B functionalities enabling rationalisation (cost efficiency, spectrum efficiency), security etc. The project has enabled compliance of the ADS-B Ground Surveillance system with the latest ADS-B Extended Squitter standard v2 (i.e. ED102A/DO260B), which is an enabler for the EU Regulation 1207/2011 (SPI IR). The new functionality is compliant with the ADS-B RAD and ADS-B APT standards of EUROCAE/RTCA. The specific contribution includes System Specifications, Test specifications, Interface	TRL4	TRL6

		Specifications (ASTERIX) as well as validation support. These Specifications were used by Project 15.04.05b to develop prototypes, which Project 15.04.05a has then used to support validation activities. The above have contributed to increase the maturity of these systems and the confidence to the associated improvements The project has actively supported the standardisation within EUROCAE WG51 SG4, towards publication of new Technical Specifications for the ADS-B Ground station and system.		

Table 2 - List of System Enablers

The project contributed to the SESAR proposed Technological Solution "ADS-B Ground Surveillance system".

1.2 Project achievements

The project 15.4.5a has delivered the Specifications and supported the validation of three prototype ADS-B Ground stations and the Surveillance Data Processing and Distribution (SDPD) functionality. More specifically, it has developed Specifications for the overall Ground Surveillance system, the ADS-B Ground Station, the SDPD, the Interfaces as well as for the Ground station Tests respectively. It has also produced a Report of the Validation support activities which included the prototypes developed by project 15.4.5b on the basis of the 15.4.5a project Specifications.
The baseline application was the ADS-B in Non-Radar Airspace (ADS-B NRA).

The project 15.4.5a added functionality enabling ADS-B in Radar Airspace (ADS-B RAD) and ADS-B for Airport Surveillance (ADS-B APT).

The ADS-B Ground Surveillance system addressed by the project 15.4.5a was made compliant with the latest version of ADS-B avionics standard (ADS-B v2, i.e. EUROCAE 102A/RTCA DO260B). This standard is a means of compliance with the relevant EU Regulation 1207/2011 (Surveillance Performance and Interoperability Implementing Rule SPI IR).

Another key improvement enabled by the project is the security related functionality. This functionality includes multiple techniques which mitigate security risks for ADS-B as sole means of Surveillance as well as for ADS-B in a multisensor environment, thus addressing the associated challenges.

The ADS-B Ground Surveillance system of project 15.4.5a enables the operational improvements attributed to Surveillance such as Flight Conformance monitoring and Enhanced Ground Controller Situational Awareness in all Weather Conditions. These contribute to improved safety, capacity and flight efficiency. Moreover, it is a key enabler for Performance Improvements, namely Surveillance infrastructure rationalisation (by improving both cost efficiency and spectrum efficiency). The associated cost is, in general, significantly lower than the one for classical means of Surveillance. The ADS-B Ground Surveillance system addressed by the Project is also fully interoperable with other Surveillance means and derives synergies and additional potential for performance benefits incl. security when operated in combination with multilateration. Furthermore, ADS-B is a passive

Surveillance technique, i.e. it reduces the 1030/1090MHz datalink use and thus enables the longevity of the Surveillance datalink and the best use of the stakeholder investments.

The project has provided significant contribution to standardisation activities including EUROCAE and ASTERIX, as well as to the SDPD Specifications work by the relevant stakeholder groups (such as EUROCAE WG51/SG4, ARTAS User Group, ASTERIX Maintenance Group). More specifically, it has contributed to the associated EUROCAE Technical Specifications for ADS-B Ground station ED129A and ED129B. The inputs provided by the project covered both the system Specifications and the Test Specifications of the Ground Stations. Moreover, the 15.4.5a project Specifications and Validation support activities Report are inputs also to the SDPD stakeholder and ASTERIX stakeholder groups, supporting their decisions on the further use of the new functionalities, as necessary.

The project 15.4.5a paved the way to other SESAR projects, namely 15.4.2, 15.4.6 and, in the future SESAR 2020, as well as to the transition towards industrialisation and implementation.

1.3 Project Deliverables

The following table presents the relevant main deliverables that have been produced by the project. Some of the deliverables for Iteration 3 include the content of Iterations 1 and 2, i.e. they are incremental. In these cases, the deliverables for iterations 1 and 2 respectively are not listed.

Reference	Title	Description
D18	First iteration of ADS-B Surveillance System Specifications	Overall Surveillance system Specifications for Iteration 1, including compliance with ADS-B v2 (ED102A/DO260B), ADS-B RAD application as well as a first set of security risk mitigation techniques.
D19	Second iteration of ADS-B Surveillance System Specifications	Overall Surveillance system Specifications for Iteration 2, including compliance with ADS-B APT application as well as a second set of security risk mitigation techniques.
D20	Third iteration of ADS-B Surveillance System Specifications	Overall Surveillance system Specifications for Iteration 3, including the third set of security risk mitigation techniques. Note: D18 and D19 contain the respective Iteration 1 and 2 Surveillance System Specifications
D13	Third iteration of ADS-B Ground Station Specifications (for Trajectory Based Operations)	Specifications of the ADS-B Ground Station for Iterations 1, 2 and 3, including the compliance with ADS-

		B v2 (ED102A/DO260B), ADS-B RAD and ADS-B APT applications as well as the security risk mitigation techniques.
D14	Third iteration of SDPD Specifications for Trajectory Based Operations	Specifications of the SDPD for Iterations 1, 2 and 3, including the compliance with ADS-B v2 (ED102A/DO260B), ADS-B RAD and ADS-B APT applications as well as the security risk mitigation techniques.
D15	Third iteration of Interface Specifications for Trajectory Based Operations	Specifications of the ASTERIX Interfaces for Iterations 1, 2 and 3, including compliance with ADS-B v2 (ED102A/DO260B), ADS-B RAD and ADS-B APT applications as well as the security risk mitigation techniques. These cover ASTX Cat 21, 23 and 62.
D08	First iteration of ADS-B Ground Station Test Specifications (for Time Based Operations)	Test Specifications of the ADS-B Ground Station Iteration 1, including compliance with ADS-B v2 (ED102A/DO260B), ADS-B RAD application as well as a first set of security risk mitigation techniques.
D12	Second iteration of ADS-B Ground Station Test Specifications (for Trajectory Based Operations)	Test Specifications of the ADS-B Ground Station Iteration 2, including compliance with ADS-B APT application as well as a second set of security risk mitigation techniques.
D16	Third iteration of ADS-B Ground Station Test Specifications for Trajectory Based Operations	Test Specifications of the ADS-B Ground Station Iteration 3, including the third set of security risk mitigation techniques. Note: D08 and D12 contain the respective Iteration 1 and 2 ADS-B Ground Station Test Specifications
D21	Validation Support Activities Report	Report on the validation support exercises of the project, covering both the support to Project 6.3.2 as well as the exercises at the EEC. The document includes the preparation, execution, results, conclusions and recommendations of these exercises.

Table 3 - List of Deliverables

1.4 Contribution to Standardisation

The project 15.4.5a has significantly contributed to standardisation. Its deliverables were used as inputs to the development of the following standards:

- EUROCAE Technical Specifications for ADS-B Ground station (ED-129A by WG51 SG4)
  Published
- EUROCAE Technical Specifications for ADS-B Ground system (ED-129B by WG51 SG4)
  Approaching publication
- ASTERIX Interface Specifications (ASTX Cat 21, 23 and 62 by the ASTERIX Maintenance Group)
  Update ongoing

The SESAR projects have also contributed to the SDPD Specifications.

Relevant application standards are the ADS-B in Radar Airspace, ADS-B for Airport Surveillance (both published by EUROCAE/RTCA), as well as the EUROCAE Generic Surveillance SPR (ongoing by EUROCAE WG102).

1.5 Project Conclusion and Recommendations

The project 15.4.5a has delivered significant results for the ADS-B Ground system enhancements for ADS-B, both in terms of Specifications and validation support.

The baseline application was the ADS-B in Non-Radar Airspace. The project added functionality enabling ADS-B in Radar Airspace and ADS-B for Airport Surveillance. The ADS-B Ground Surveillance system as enhanced by the Project 15.4.5a is compliant with the latest version of ADS-B avionics standard which is a means of compliance with the relevant EU Regulation 1207/2011 (Surveillance Performance and Interoperability Implementing Rule SPI IR). Another key improvement enabled by the Project is the security related functionality. This functionality mitigates security risks for ADS-B as sole means of Surveillance as well as for ADS-B in a multisensor environment, thus addressing the associated challenges.

The deliverables include Specifications for the ADS-B Ground Surveillance system, the ADS-B Ground Station, the SDPD, the ASTERIX Interfaces and the ADS-B Ground station tests. Moreover, Validation support activities were performed, indicating at a generic level, that the ADS-B Ground Surveillance system prototype can be considered as meeting the expectations. 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.

The project has provided significant contribution to standardisation activities including EUROCAE and ASTERIX, as well as to the SDPD Specifications work by the relevant stakeholder groups. It paved the way to other SESAR projects and the subsequent transition towards industrialisation and deployment through an increased maturity level for the systems and confidence to the associated improvements.

It is recommended that in the transition towards and through industrialisation and deployment, including possible Large Scale Demonstration projects, 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 exercises of the applications to be implemented and their reachable benefits at generic and local levels, should be included. The security mitigation functionality is of particular importance in this context. Any specific recommendations from the project should be taken into account. Moreover, standardisation activities should take into account the results of the projects. This includes Ground Station functionality, SDPD functionality as well as ASTERIX change proposals for Categories 21, 23 and 62 which should be considered by the relevant stakeholder groups.

The project recommends, in particular, that other SESAR projects should make use of 15.04.05a functionality and interface specifications.

The follow-up project 15.4.6 “ADS-B capacity and security” is one candidate for these tasks. The ADS-B ground Surveillance system addressed by Project 15.4.5a establishes a solid baseline for project 15.04.06, which looks also at the inclusion of techniques designed to further improve the security of ADS-B, in particular to guard against spoofing, as well as to support 1090 MHz datalink capacity enhancement related functionality. So, the project recommends the usage of the 15.4.5 functionality for these further developments.

The functionalities specified in project 15.4.5a (and prototyped in project 15.4.5b) are an input for the EUROCAE WG51 SG4, which is updating the Technical specifications of ADS-B & WAM systems. The output of EUROCAE WG51 is including guidance on data sharing between WAM and ADS-B systems, which are used as input in 15.4.2 project (“Integrated Surveillance sensor technologies"), so these activities should maintain a strong relationship. Due to this, the 15.04.02 is also a follow-up project from 15.04.05. New functionalities specified in 15.4.5 projects are implemented in 15.4.2 platforms.

Furthermore, solutions envisaged in SESAR 2020 are also expected to use the prototypes developed in the project.

The project 15.4.5a contributed to the SESAR proposed Technological Solution "ADS-B Ground Surveillance system".

2 References

[1] SESAR Programme Management Plan, Edition 03.00.01

[2] European ATM Master Plan

[3] Multilateral Framework Agreement ("MFA") signed between the SJU, EUROCONTROL and its 15 selected members on August 11, 2009, amended on 14 June 2010, 19 October 2010 and 2 July 2012

[4] SJU 15.04.05a ADS-B Surveillance System Specifications for first Iteration, D18, Ed. 00.01.00, 2010

[5] SJU 15.04.05a ADS-B Ground Station Specifications for first Iteration, D05, Ed. 00.01.00, 2011

[6] SJU 15.04.05a SDPD Specifications for first Iteration, D06, Ed. 00.01.00, 2011

[7] SJU 15.04.05a Interface Specifications for first Iteration, D07, Ed. 00.01.00, 2011

[8] SJU 15.04.05a ADS-B Ground Station Test Specifications for first Iteration, D08, Ed. 00.01.00, 2011

[9] SJU 15.04.05a ADS-B Surveillance System Specifications for second Iteration, D19, Ed. 00.01.00, 2011

[10] SJU 15.04.05a ADS-B Ground Station Specifications for second Iteration, D09, Ed. 00.01.00, 2011

[11] SJU 15.04.05a SDPD Specifications for second Iteration, D10, Ed. 00.01.00, 2011

[12] SJU 15.04.05a Interface Specifications for second Iteration, D11, Ed. 00.01.00, 2011

[13] SJU 15.04.05a ADS-B Ground Station Test Specifications for second Iteration, D12, Ed. 00.01.00, 2012

[14] SJU 15.04.05a ADS-B Ground Surveillance Specifications for third Iteration, D20, Ed. 00.01.00, 2012

[15] SJU 15.04.05a ADS-B Ground Station Specifications for third Iteration, D13, Ed. 00.01.00, 2012

[16] SJU 15.04.05a SDPD Specifications for third Iteration, D14, Ed. 00.01.00, 2012

[17] SJU 15.04.05a Interface Specifications for third Iteration, D15, Ed. 00.01.00, 2012

[18] SJU 15.04.05a ADS-B Ground Station Test Specifications for third Iteration, D16, Ed. 00.01.00, 2012

[19] SJU 15.04.05a Integration Report for Iteration 1, D02, Ed. 00.01.00, 2012

[20] SJU 15.04.05a Integration Report for Iteration 2, D03, Ed. 00.01.00, 2014

[21] SJU 15.04.05a Integration Report for Iteration 3, D04, Ed. 00.01.00, 2015

[22] SJU 15.04.05a Validation Support Activities Report, D21, Ed.00.01.00, 2015

-END OF DOCUMENT-