Final Project Report

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Abstract

This document enfolds the final closeout report of project 15.04.03.
The project provided a technical system on the ground, which enables reception and analysis of ACAS Resolution Advisory information.
Main project objectives were the creation of a high-level system specification and the development and provision of an ACAS ground monitoring system prototype.
The project installed an up-to-date pre-industrial ACAS ground monitoring system to collect and evaluate RA information within the German Airspace.
The extensive RA data processing of the project allowed a very detailed evaluation and classification of RA information. Based on the analysis results, the project performed an ACAS Monitoring Integration and Feasibility study. The project realized several long-term tests to prove the selected technical solution and verify the system performance.

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00.01.02	09/02/2015	FINAL UPDATE	THALES	Update of deliverable D11. Align related reference.

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This deliverable consists of SJU foreground.

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1 Publishable Summary

Contribution to the roadmap for deployment activities as defined in the ATM Master Plan

The ATM Master Plan defines in OI[1] CM-0802[2] that in Step 2 controllers are automatically informed when ACAS (Airborne Collision Avoidance System) generates an RA (Resolution Advisory). This improvement is intended to complement the voice report by the pilot. The objective is to inform controllers of an RA event faster, more reliably and in a structured way, and hence increase controller's situational awareness in critical situations.

Whilst this OI is realised in related operational Ground-Airborne Safety Net Compatibility P04.08.01[3], the ACAS Monitoring P15.04.03 provides an essential enabler in the form of a novel ACAS ground monitoring concept as well as its integration into ATC surveillance systems.

This P15.04.03 analysed the operational requirements defined in P04.08.01 and defined new technical solutions to satisfy the operational requirements.

In this context, the project developed system requirements, defined technical solutions, developed an ACAS Monitoring evaluation prototype platform, validated the technical solutions, verified the system performance and performed integration and feasibility studies.

The project also used the ACAS Monitoring evaluation prototype platform to collect RA data. The RA data was subject of detailed offline technical analysis and provided to P04.08.01 for complementary operational analysis.

Project achievements

The project successfully validated the ACAS Monitoring evaluation prototype platform that meets all operational requirements. The platform covers the entire German airspace at least above FL100 and has been used for offline monitoring during a period of more than three years, thus providing further confidence in the technical ACAS ground monitoring concept.

The platform consists of:

- Modified ADS-B ground stations
- A centralised ACAS server
- A comprehensive set of recording, replay and analysis tools

Key deliverables

- System Specification Document
- Integration Study report
- Feasibility Study report

Contribution to the development of new Standards

The project developed a change proposal for EUROCONTROL ASTERIX CAT 004 (Safety Net Messages).

Recommendations

From the project point of view, the system is already mature and field-proven for standalone offline ACAS ground monitoring. Deployment within an operational environment will require validation of the operational system interface to external ATC surveillance systems, including a Safety and Security assessment.

[1] Operational Improvement
[2] ACAS Resolution Advisory Downlink
[3] Evolution of Ground Based Safety Nets

2 Final Project Report

2.1 Project Progress and Contribution

The activities addressed by project 15.04.03 contributed to the following system enabler as captured in the ATM Master Plan.

EN Code	EN Title	Project 15.04.03 Activities/Contribution	Maturity before Project	Maturity after Project
AC-48a	Air broadcast of aircraft position/vector (ADS-B) compliant with DO260B	The ACAS ground sensor and ACAS server are able to receive, decode and process the relevant Mode-S 1090 & 1030 MHz information compliant to D0260B.	V2	V3
CTE-S03a	ADS-B station for NRA surveillance (ED-102)	ADS-B station for provision of Non Radar Airspace Surveillance, compliant with EUROCAE ED-129 and receiving ED-102 squitter format.	DB	
CTE-S03b	ADS-B station for RAD and APT surveillance (ED-102A)	ADS-B station for provision of Radar and Airport surveillance, compliant with EUROCAE ED-129A and receiving ED-102A squitter format.	V2	V3

Table 1 – List of System Enablers

The project defined, developed and installed the necessary infrastructure on the ground to receive, process, distribute and analyse related submitted 1090 & 1030 MHz Mode-S aircraft messages.

The project mainly concentrated on the processing of ACAS related information parts, whereby also ADS-B parts used as Surveillance sensor input (please see also Figure 2). Due to the fact that ACAS incidents are very rare, the project invested significant efforts in Tools to record and replay RA data.

The ACAS ground sensor prototype functionality is based on hardware and software capabilities of the WP 15.04.05b ADS-B ground stations. In principle, the project extended the ADS-B ground stations by a 1030 MHz receiver unit to cover the entire ACAS communication. These multi-purpose ground senor are capable to perform ADS-B and ACAS functions in parallel compliant the standard DO260, DO260A and DO260B. The project paid especially attention to the reception and processing of ground sensor Mode-S telegram formats enclosing resolution advisory information (Appendix A).

The ACAS monitoring of project 15.04.03 is a custom-made technical system solution on the ground to identify initiated airborne events in which the ACAS system has generated Resolution Advisories (RA).

Currently, air traffic controllers rely on pilots to report RAs by radio as they occur. These reports are sometimes late, incomplete or absent.

The first project objective was to define, implement and install an ACAS ground monitoring system prototype to record these critical situations in the airspace for incident investigations as well as for offline analysis with aim to improve safety or airspace design. The second project objective was to make RA data available to the controller as the events take place to enhance her/his situational awareness and to prevent them from issuing instructions to the aircraft receiving RAs.

To achieve these objectives, project 15.04.03 activities have been sub-divided into the following tasks:

- **Sensor Siting and Integration**

  One of the first project goals was to commence collection and evaluation of received ACAS RA data as soon as possible. Therefore, the project re-used the already installed experimental monitoring system in Germany (DFS AMOR) and extended it by installing two additional SESAR ACAS ground sensors (background system). The background system covered the entire German Airspace at least down to FL100. All connected ACAS sensors sent their received ACAS RA data via dedicated network lines to the ACAS server in Frankfurt-Langen.

  The background system was an important and useful first project milestone that enabled rapid system prototype development and refinement of the system specification. Furthermore, the background system provided the basic infrastructure to start initial offline data collection and evaluation exercises.

- **System Specification**

  The project formulated high level technical requirements for an ACAS ground monitoring system. The project took into account the operational requirements received from the operational counter-part project 4.8.3[4] and considered also the results of the initial data collection and evaluation exercises. The system specification defines the ACAS ground monitoring system functions, the system architecture and describes all system components and interfaces.

  Key system functions are the collection and storage of RA information into a database, the fusion of multiple ACAS ground sensor data and surveillance sensor data, as well as the classification and dispatch of validated RA information to external ATM systems.

  The system specification constituted the baseline for the ACAS monitoring system prototype development and used afterwards also as reference document for the final prototype verification.

- **Prototype Development and Improvement**

  In order to make the background system compliant with the system specification the project developed:

  - An upgrade of the ground sensor software
  - New ACAS server application software
  - New ACAS control and monitoring system application software
  - New ACAS RA data recording and replay tools

[4] Ground-Airborne Safety Net Compatibility, now incorporated in project 4.8.1

- Upgrade of InCAS[5] simulator software

All prototypes and tools have been subject to internal testing and verification before being integrated into the background system.

The project then evaluated the experience gained in the initial data collection and evaluation exercises to feed a prototype improvement process. The project selected only those findings and enhancements, which could be implemented economically within the tight project time line.

- **Initial and Final Data Collection and Evaluation**

Main objective of the project was to collect, store and evaluate offline the received RA data. Because of the limited system functionality at the project start, the RA data collection and analysis were subdivided into two separate working phases (Initial and Final).

During the Initial phase the project relied on the installed background system and subsequently on the available prototype system. The project paid particular attention at the beginning to the RA data collection and offline evaluation. With the introduction of the prototype system components (ACAS server and Recording & Replay Tools) the project gradually evaluated the system performance, operational online system processing as well as RA data distribution to external ATC systems.

Within the Final RA data collection and analysis phase the project considered onto the prototype system improvements. In this connection, the project mainly concentrates on the verification of the prototype improvements effectiveness.

The results of both RA data collection phases proved the compliance of the ACAS Monitoring system to the requirements, both phases are accompanied by related evaluation reports [12][15].

- **System Integration and Feasibility**

The project assessed the integration of an ACAS ground monitoring system into an overall ATM system. The integration study [16] looked into potential ways of how the intercepted RA data could be used on the ground and provided a description how that information could be used on- and off-line. The study has shown that the ACAS Monitoring system has proven its value during a long period of off-line monitoring. The project supported in a comprehensive way the preparation of validation exercises in SESAR project 4.8.3 (now merged into 4.8.1). The ACAS Monitoring system has not yet been proven for real-time use, pending on the execution of the validation exercises in SESAR project 4.8.1.

The project conducts as well the feasibility of implementation and deployment of the ACAS ground monitoring system into the overall ATM system [17]. Existing architectural and technical solutions for ACAS monitoring are Mode S radar and ADS-B ground stations. The ACAS Monitoring project developed another solution (ACAS ground sensor(s), plus available Surveillance sensor(s), and ACAS server - Figure 2) that can be used stand-alone or in combination with the existing solutions. ACAS monitoring using Mode S radar provides sufficient information about encounters but the rotating antenna introduces latency. The project solution eliminates the latency by using an omnidirectional antenna but provides insufficient information about encounters, unless the transponder in compliant the RTCA DO-260B standard. The ACAS Monitoring project improved the ADS-B solution by receiving additional information about encounters.

The project feasibility investigations revealed that the optimum solution for ACAS monitoring is to combine the Mode S radar and the ACAS Monitoring project solutions. The project developed an ACAS Server which performs combination of all available information and

[5] Interactive Collision Avoidance Simulator

transmission of the encounter information to the ATM system. The Data evaluation studies demonstrated that the data quality and integrity are sufficient.

- **System Verification and System Evaluation**

  The Technical System Specification of project 15.04.03 constitutes the fundamental input for the preparation of the related necessary system tests, and it is used as base reference for the prototype verification. Main objective was to test the entire system on the ground, which permits the collection and storage of RA information in a database, as well as the fusion, classification and the dispatch of validated RA information to external connected ATM systems. The verification tests were executed successfully by the project team in several working sessions on the ACAS test-bed in Langen/DFS.

  At the project end, the project summarized and noted down the results and conclusions of the system evaluation and the verification tests [9]. The evaluation concerned the inspection of the entire prototype system.

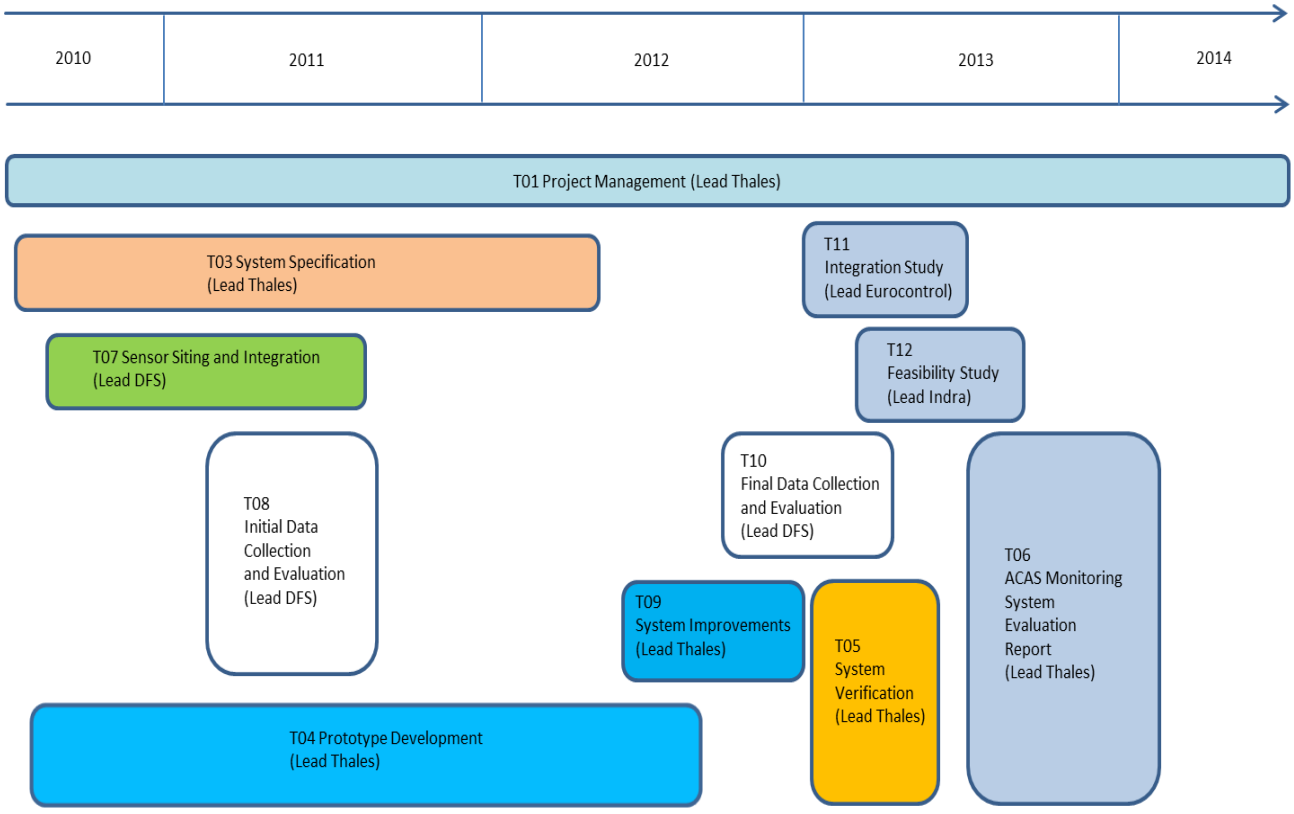

Figure 1 Project 15.04.03 – Tasks Domains

Concluding, project 15.04.03 results offered results to other SESAR projects and external working groups. However, the missing validation of the system and the operational system interface (Figure 2) to an external ATC surveillance system in a real operational environment is still an open issue. These missing activities might need to be further investigated and solved before entering into a future operational employment.

The SESAR 15.04.03 project team was composed by one ANSP – DFS, EUROCONTROL and two industry partners (INDRA and Thales Stuttgart (Lead)).

2.2 Project Achievements

A summary of the project achievements is presented below:

- The project defined a high-level ACAS ground monitoring system specification, which can be used by a standardisation group as base reference input for the preparation of a minimum technical system specification.
- The project performed long-term RA data collection and evaluation of airborne incidents within the German airspace, allowing afterwards the offline data analysis and the evaluation of the system performance.
- The project presented a robust verified solution on the ground to record, replay and analyse RA data. The ACAS ground monitoring system is ready for validation and deployment (offline monitoring).
- The project has proven that the system is able to process and distribute valid RA events to external ATM systems (controllers) as requested within two seconds. Main concern was at the project beginning the time duration between the indication of an RA event in the cockpit, and the distribution of the event over the network to the ATM system. The project team evaluated several times varied tests and analyzed the system's latency.
- The project prototype have inspected and verified very detailed the system capabilities to detect and filter-out false RAs.
- The project shown that the fusion and the utilization of Surveillance sensor data (Mode-S radar, WAM, MLAT and ADS-B) with ACAS ground sensor RA data are very beneficial and practicable.
- The project demonstrated that ACAS monitoring on the ground is feasible and could be integrated into an overall ATM system.

2.3 Project Deliverables

A summary of the project deliverables is presented in the table below:

Deliverable Code	Deliverable Name	Description	Assessment Decision
D01	Project Closeout Report	The deliverable (this document) enfolds the final closeout report of project 15.04.03.	No Reservation
D03 [4],[18]	System Specification Document	The deliverable addresses the high level technical requirements for an ACAS ground monitoring system. The system specification will take into account the operational requirements received by partner project 4.8.3 and consider the results of the Initial Data Collection task realized by means of an already installed and used background system in the Germany Airspace.	No reservation
D04 [6]	ACAS Monitoring system prototype	The deliverable encloses the Availability/Release Note for the developed ACAS ground monitoring system prototype (Ground sensors, ACAS server and Tools).	No reservation (P)
D05 [7],[8],[9]	Verification Report	The deliverable comprises the test procedures and test results of the ACAS ground monitoring system prototype verification. The system verification was executed in parallel to the preparation of the final release of the ACAS Monitoring Evaluation report. The high-level system requirements elaborated by the team during the project were the baseline of the verification.	No reservation (P)
D06 [10]	ACAS Monitoring Evaluation Report	The deliverable constitutes the closing report of the ACAS ground monitoring prototype system evaluation. The report enlarges and completes the	2nd Round SJU Assessment No reservation

		preceding initial and final system data evaluation and system prototype verification, whereas the project team turns its main attention and considerations to the overall system, to the individual system components and its boundaries. The report summarizes the results of verification activity, so the reader can easily focus on potential system improvements or weak points.	
D07 [11]	Background System	The deliverable encloses the official Availability/Release Note of the successfully installation and integration of two new additional SESAR ground sensor sites into already existing ACAS Monitoring equipment (Background System) within the German airspace by the project partners DFS and Thales Stuttgart. Whereby, the SESAR project has taken the advantage to further ACAS Monitoring ground station sensors and equipment installed and used by the DFS AMOR project.	No reservation (P)
D08 [12]	Preliminary Data Evaluation Report	The deliverable enfolds the preliminary results of the initial data collection and evaluation of ACAS Resolution Advisory (RA) events (1st phase) in the coverage of the ACAS-Monitor background system.	No reservation (P)
D09 [13],[14]	Improved ACAS Monitoring Report	After the release of the ACAS ground monitoring system prototype the project tested and analysed the system performance. In a second step, the project introduced and verified system improvements and fault corrections. The deliverable listed the implemented and tested improvements and error corrections for the ACAS ground monitoring system prototype.	No reservation (P)
D10	Final Data Evaluation Report	The deliverable contains the results of the final data collection	No reservation

[15]		and evaluation of ACAS Resolution Advisory (RA) events (2nd and final phase) in the coverage of the enlarged ACAS-Monitor background system (on top of that developed SESAR prototype system enhancements).	
D11 [16]	Integration Study	The deliverable encloses the findings of an investigation of the integration of ACAS ground monitoring system into an overall ATM system.	No reservation (P)
D12 [17]	Feasibility Study	The deliverable aims to demonstrate that the utilization of the developed ACAS ground monitoring system is realizable.	2nd Round SJU Assessment No Reservation

Table 2 – Project Deliverables

2.4 Project Contribution

The project stated a proposal for the definition of the operational interface from the ACAS ground monitoring system to external systems, such as a connected ATC surveillance system.

After analysis of the manner and volume of the processed and to transfer RA data, the project decided to use and update an already defined standard protocol for Surveillance Data Exchange.

The project selected the ASTERIX Category 004 protocol, which describes the standard for Safety Net Messages. The project proposal affecting the main ASTERIX Category 004 definition part, as well the reserved expansion field part – appendix A. Please see and verify also the related project document [18].

Remark: The project proposal is currently under review by the Eurocontrol ASTERIX team, the proposed updates are backward compatible.

2.5 Project Conclusions and Recommendations

From the project point of view, the system is already mature and field-proven for standalone offline ACAS ground monitoring.

Prior to any deployment within an operational environment, it will require validation of the operational system interface to external ATC surveillance systems, including a Safety and Security assessment.

2.6 Acronyms and Terminology

Term	Definition
1090 ES	1090 MHz Mode S Extended Squitter
1090 GS	ADS-B 1090 MHz Extended Squitter Ground Station
ACAS	Airborne Collision Avoidance System
ADS	Automatic Dependent Surveillance
ADS-B	Automatic Dependent Surveillance – Broadcast
AMOR	ACAS Monitor
ANSP	Air Navigation Service Provider
ARA	Active Resolution Advisories
ASTERIX	All Purpose Structured EUROCONTROL Surveillance Information Exchange
ATC	Air Traffic Control
ATM	Air Traffic Management
BDS	Comm-B Data Selector
BITE	Built-In Test Equipment
CMS	Control and Monitoring System
Comm -A	Short Uplink Communication Message (Mode S)
Comm-B	Short Downlink Communication Message (Mode S)
Comm-C	Long Uplink Communication Message (Mode S)
Comm-D	Long Downlink Communication Message (Mode S)
CRC	Cyclic Redundancy Check
DF	Downlink Format
DFS	Deutsche Flugsicherung GmbH
E-ATMS	European Air Traffic Management System
ES	Extended Squitter
EUROCAE	European Organisation for Civil Aviation Equipment
FAA	Federal Aviation Administration

Term	Definition
FDPS	Flight Data Processing System
FMS	Flight Management System
GPS	Global Positioning System
GS	Ground Station
Hz	Hertz
I/O	Input and/or Output
ICAO	International Civil Aviation Organization
IP	Internet Protocol
LDAP	Light Weight Directory Access Protocol
LSB	Least Significant Bit
MB	Message field in Comm-B (Mode S)
MC	Message field in Comm-C (Mode S)
ME	Message Field in Extended Squitter
MHz	Megahertz
MOPS	Minimum Operational Performance Standards
MSB	Most Significant Bit
MSL	Minimum Signal Level
MTL	Minimum Trigger Level
N/A	Not applicable
NM	Nautical Mile
NTP	Network Time Protocol
PD	Probability of Detection
RA	Resolution Advisory
RADL	Resolution Advisory Downlink
RF	Radio Frequency
RTCA	Radio Technical Commission for Aeronautics
s	Seconds

Term	Definition
SAC	System Area Code of data source
SESAR	Single European Sky ATM Research Programme
SESAR Programme	The programme which defines the Research and Development activities and Projects for the SJU.
SIC	System Identification Code of data source
SJU	SESAR Joint Undertaking (Agency of the European Commission)
SJU Work Program	The program which addresses all activities of the SESAR Joint Undertaking Agency.
SNMP	Simple Network Management Protocol
SSR	Secondary Surveillance Radar
TA	Traffic Advisory
TCAS	Traffic Alert and Collision Avoidance System
TCP	Trajectory Change Point
TMA	Terminal Area
TOA	Time of Applicability
TOMR	Time of Message Reception
UDP	User Datagram Protocol (an Internet Protocol)
UF	Uplink Format
UTC	Universal Time Coordinated
WAM	Wide Area Multilateration
WGS 84	World Geodetic System 1984

3 Appendix A

The ACAS ground monitoring system prototype processes the following Mode-S telegram formats:

- Downlink Format: DF16-30
  DF17 type 28 – subtype 2 (DO260B RA)
  DF20/DF21 – RA Downlink
  DF5/DF21 – Squawk/Mode3A
  DF11, DF17 and DF18
- Uplink Format: UF16-30,31,32

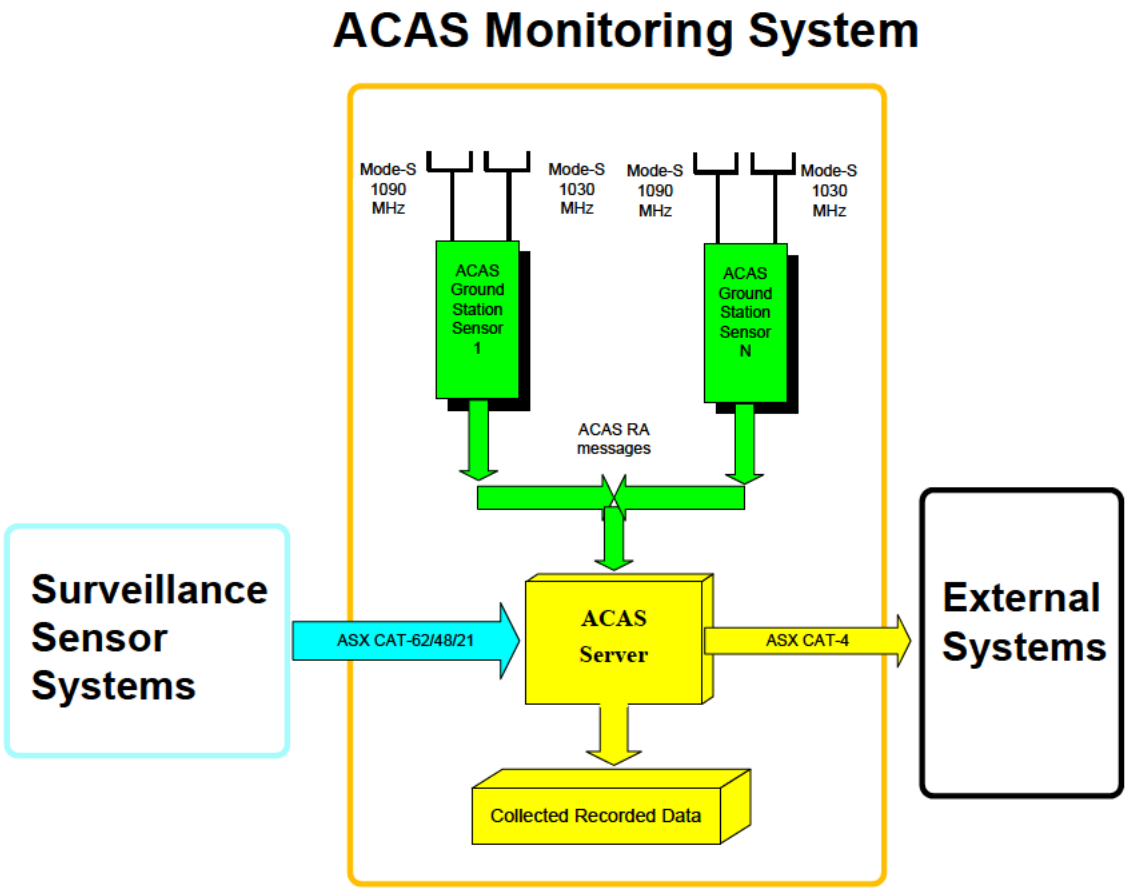

Figure 2 Scheme of ACAS ground monitoring system

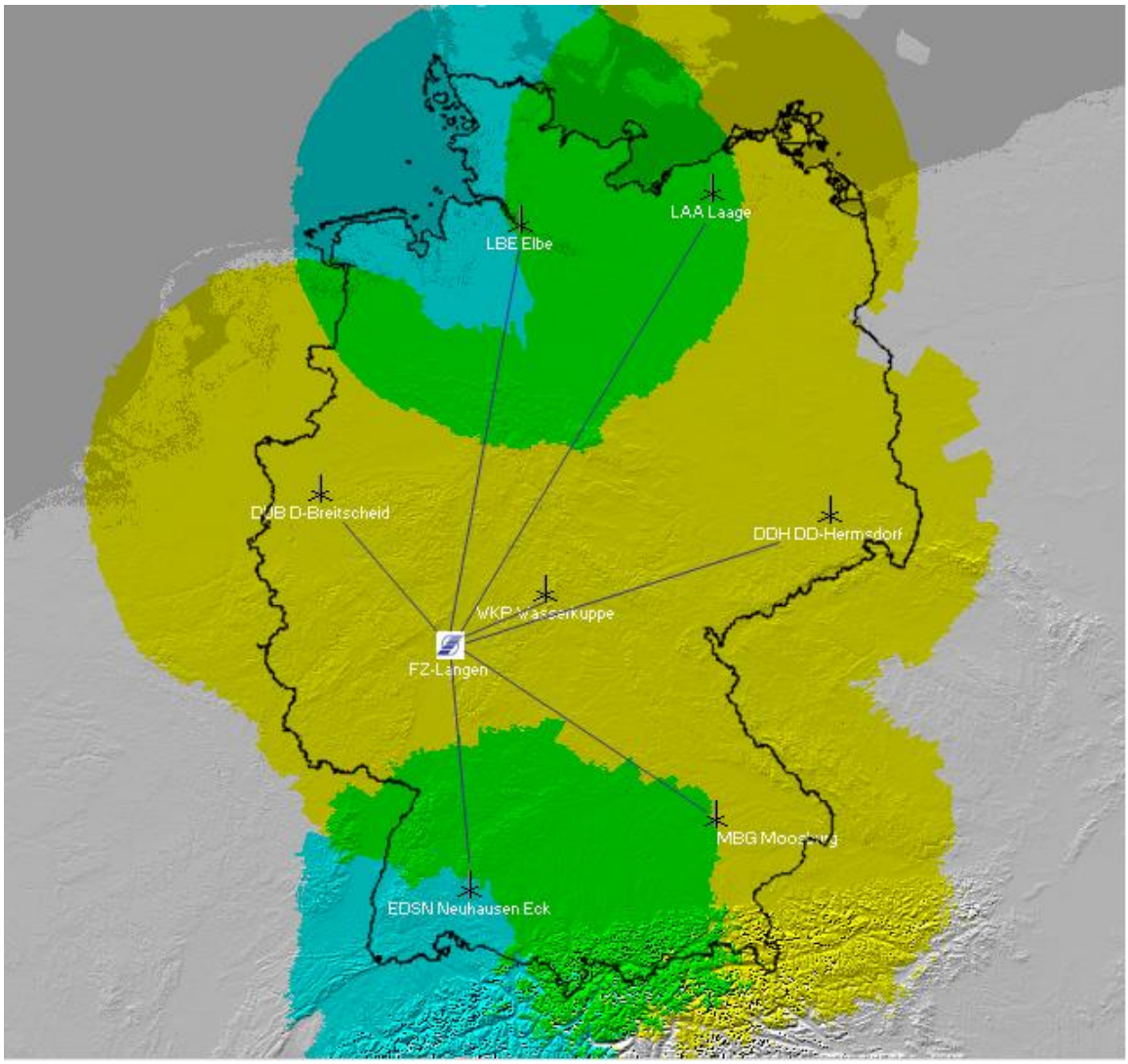

Figure 3 ACAS Monitoring System & Coverage - AMOR and SESAR sensors (blue)

4 References

[1] SESAR Programme Management Plan, Edition 03.00.01

[2] European ATM Master Plan, Edition 2

[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] Latest Project baseline please see https://extranet.sesarju.eu/WP_15/Project_15.04.03/Latest/Forms/AllItems.aspx

[5] DEL15 04 03 D03 SYSTEM SPECIFICATION DOCUMENT – Assessment Report Updates V00.01.01 Edition 00.01.01 – Date 04/Sept/2012

[6] 15 04 03 D04 ACAS Monitoring system prototype Edition 00.00.02 – Date 31/Aug/2012

[7] 15.04.03-D05-Verification-Report Edition 00.01.00 – Date 10/April/2013

[8] 15.04.03-D05-Veriication-Report-Log-Records-20120903-signed-part1 Date 08/Oct/2013

[9] 15.04.03-D05-Veriication-Report-Log-Records-20120903-signed-part2 Date 08/Oct/2013

[10]15 04 03-D06-ACAS-Monitoring-Evaluation-Report-Assessment-Updates Edition 00.03.00 – Date 06/Aug/2014

[11]15.04.03-D07-Background System Edition 00.00.03 – Date 09/June/2011

[12]15.04.03-D08-Preliminary Data Evaluation Report Edition 00.01.00 – Date 08/Aug/2011

[13]15 04 03 D09 Improved ACAS Monitoring system Edition 00.00.02 – Date 17/Dec/2012

[14]Improvement.Tests-19Dec2012-Langen-DFS Date 19/Dec/2012

[15]15.04.03-D10-Final Data Evaluation Report Assessment Report Updates v3.0 Edition 00.00.03 – Date 06/Aug/2013

[16]DEL 15 04 03 D11 INTEGRATION STUDY 00 01 02 Edition 00.01.02 - Date 04/Feb/2015

[17]15.04.03-D12-Feasibility Study-Assessment-Updates_1.04 Edition 00.01.04 – Date 19/Aug/2014

[18]ASX CAT 004-SESAR P15.04.03 – FINAL PROJECT PROPOSALS – 29July2014 l

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