Final Project Report

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Abstract

Overall project P15.02.07 together with project P9.16 focused on the Aeronautical Mobile Airport Communication System (AeroMACS), the new generation airport surface data link. The two projects supported the development and validation of the system specifications and contributed to the global harmonization of the developments in ICAO and other interested parties such as FAA and Japan. The outcome of the activities of the two projects supported the standardization of AeroMACS in various groups such as ICAO, EUROCAE, RTCA, AEEC and WiMAX Forum.

In particular, the project P15.02.07 partners performed analysis, simulations, prototype developments and coordinated globally with interested partners to define and verify the AeroMACS specifications achieving global harmonisation and international standardisation for AeroMACS.

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Intellectual Property Rights (foreground)

This deliverable consists of SJU foreground.

Acronyms

Acronym	Definition
A/G	Air / Ground
AEEC	Airlines Electronic Engineering Committee
AeroMACS	Aeronautical Mobile Airport Communications System
ANSP	Air Navigation Service Provider
APIM	AEEC Project Initiation/Modification Activity
ATC	Air Traffic Control
ATM	Air Traffic Management
ATS	Air Traffic Services
AWG	Aviation Working Group, WiMAX Forum Group
CRSL	Certification Requirement Status List, WiMAX Forum Document
E-OCVM	European Operational Concept Validation Methodology
EUROCAE	European Organization for Civil Aviation Equipment
ICAO	International Civil Aviation Organization
IP	Internet Protocol
FAA	Federal Aviation Administration
FCI	Future Communications Infrastructure
FFF	Form Fit and Function
IATA	International Air Transport Association
ITU	International Telecommunication Union
MASPS	Minimum Aviation System Performance Specification
MOPS	Minimum Operational Performance Standards
PICS	Protocol implementation conformance statement
QoS	Quality of Service
RTCA	Radio Technical Commission for Aeronautics
SARPS	Standards and Recommended Practices

SAI	Systems Architecture and Interfaces
SESAR	Single European Sky ATM Research Programme
SJU	SESAR Joint Undertaking
VLD	Very Large Scale Demonstrations
WiMAX	Worldwide Interoperability for Microwave Access

1 Project Overview

Project P15.02.07 supported the development and validation of AeroMACS (Aeronautical Mobile Airport Communications System), a new datalink to support the communication exchanges among mobile and fixed users in the surface of the airport environment. AeroMACS is one of the three new A/G datalinks components considered in the Future Communications Infrastructure (FCI), as envisaged within the European ATM Master Plan to support Terrestrial Oceanic and Airport operations (with the other two datalinks being a new SATCOM datalink and LDACS).

SESAR project P15.02.07, in strong collaboration with SESAR project P9.16, supported the definition and verification of a technical profile and architecture for a new generation airport surface data link system.

The SESAR activities resulted in the specification, development, integration and testing of the AeroMACS system and the completion or initiation of AeroMACS standardization activities in various groups such as ICAO, EUROCAE, RTCA, AEEC and WiMAX Forum. The project partners performed analysis, simulations, prototype developments and coordinated globally with interested partners (such as FAA, JCAB and ICAO) to define and verify the AeroMACS specifications.

SESAR Project 15.02.07 lead the activities covering the overall AeroMACS system aspects and additionally covered the aspects specific to the ground component, whilst SESAR Project 9.16 contributed to the overall AeroMACS system activities, and focused on the airborne component of the AeroMACS System.

1.1 Project progress and contribution to the Master Plan

AeroMACS provides an IP-based broadband mobile datalink that is foreseen to support both safety of life and regularity of flight operations, capable to support services demanding high performance, stringent QoS, Security, Broadcast, Multicast and Mobility capabilities. AeroMACS can support mobile services (airport service vehicles and aircrafts) as well as fixed services:

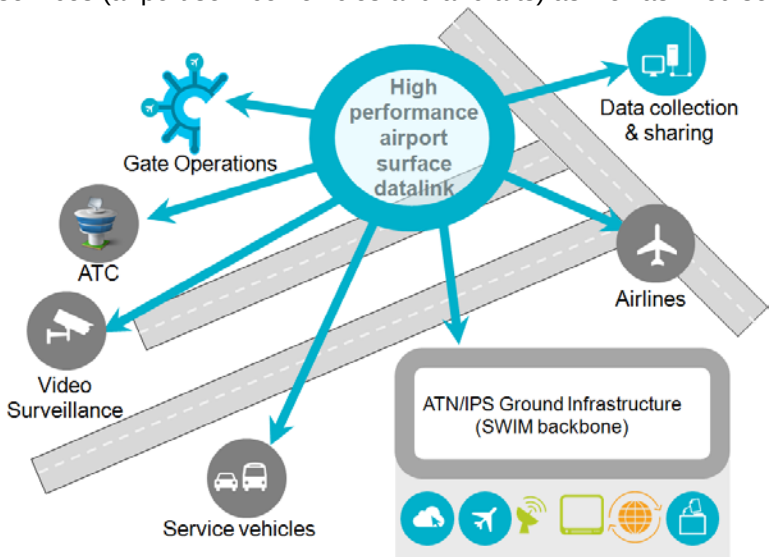

Figure 1: Potential uses of AeroMACS

Project P15.02.07 used various tools to achieve the project objectives. There has been analysis, simulations, development of two independent prototypes covering the ground and airborne equipment and testing in lab and operational environment (airports, vehicles and aircraft)

The activities addressed by P15.02.07 contributed to the following system Enablers as captured in the ATM MasterPlan:

EN Code	EN Title	P15.02.07 activities /contributions	Maturity before project	Maturity after project
CTE- C02d	New Airport Datalink technology - AEROMACS	Supported the development and standardisation of new wireless technology for the Airport Datalink, based on IEEE 802.16, as a new standard for airport surface communications (ATS, AOC and APOC) for the Aircraft and Vehicles.	V2/TRL2	V2/3 (TRL5/6)
AERODROME-ATC-21	Surface movement control workstation equipped with a system to provide alerts for vehicles	Supported the development and standardisation of technology to enable surface movement control workstations equipped with a system to provide alerts for vehicles (and to uplink alarms to those vehicles) in case of risk of collision with aircraft or area infringement.	N/A	V2/V3 (TRL5/6)

Table: List of enablers and project contributions

1.2 Project achievements

SESAR project P15.02.07 (in coordination with SESAR Project P9.16) has achieved the following:

- Definition of AeroMACS system functional and performance requirements.
- Simulations and performance analysis of the proposed specifications.
- Definition of an AeroMACS profile based on IEEE 802.16-2009.
- Specification and development of AeroMACS prototypes for testing.
- Development of Verification plans, test benches, test objectives and procedures.
- Testing in laboratory environments, including interoperability aspects (e.g., multiple manufacturers).
- Deployment and testing in real airport environment – first static, then on cars at Toulouse Airport.
- Coordination with standardization bodies (RTCA / EUROCAE / ICAO / WIMAX FORUM, ARINC AEEC) to support development of SARPS, Manual, MOPS, MASPS, Profile, etc.
- Security and safety analysis for the AeroMACS system

As a result especially of the SESAR project P15.02.07 standardisation activities and achievements , AeroMACS is a globally harmonised and interoperable standard.

In addition, the verification activities identified a few aspects related to interoperability of equipment from different manufacturers related to security and PKI aspects that are considered to be outside of the scope of the AeroMACS protocols. However these issues are relevant to the integration of any future datalink into the aviation network and therefore need to be further investigated. The security, PKI infrastructure in general as well as the AeroMACS certification aspects are currently being addressed by international standardization groups, such as WiMAX Forum and ICAO, and additional testing is planned within the WiMAX Forum

1.3 Project Deliverables

The following table presents the relevant deliverables that have been produced by the project.

Reference	Title	Description
D01	Overall IEEE 802.16e/aero System Analysis & Design	D01 covers IEEE 802.16e/aero system requirements, IEEE 802.16e/aero system & certification profile analysis, IEEE 802.16e/aero architecture definition and spectrum investigations.
D02	Channel models and propagation analysis	D02 contains the study and characterization of the traffic model in the airport, the channel models and propagation analysis.
D03	IEEE 802.16e/aero Profile	D03 provides the System and Certification profile definition, the System and Certification profile evaluation and validation process, and a Report on Modelling & Performance simulations.
D04	Deployment & Integration Analysis	D04 contains the deployment and integration analysis including interference and interoperability analysis
D05	AeroMACS Prototypes Description and Verification Strategy	Deliverable D05 is comprised of two parts: Part 1 describes the AeroMACS Ground Prototypes used during tests. In particular, it details: • -IEEE 802.16e/aero standard as framework to indicate the prototype features. • -Prototype installation and setup. Part 2 describes the overall AeroMACS Verification Strategy. A multi-variable classification is described, including: testing scenarios, time of testing, projects or programmes doing the integration. It details the individual Verification Objectives that served as input to the 15.02.07 Verification Plan.
D06	Verification Plan & Report - Phase 1	Deliverable D06 covers the Phase 1 Verification Objectives, described in the Verification Strategy document. It includes the Verification Plan and Verification Report of the Phase 1 testing campaign.
D07-002	Standardization and Global Interoperability - Final report	Deliverable D07-002 describes the standardisation activities and contributions to the SESAR projects to the various standardisation groups: ICAO, EUROCAE/RTCA, AEEC and WiMAX Forum.
D08	AeroMACS Safety and Security Analysis	Deliverable D08 is the Safety and Security analysis performed in the context of the project activities
D10	AeroMACS Verification Plan & Report - Phase 2	Deliverable D10 covers the Phase 2 Verification Objectives, described in the Verification Strategy document. It includes the Verification Plan and Verification Report of the Phase 2 testing campaign

D13	AeroMACS support to Multilink concept analysis	Deliverable D13 describes the ENAIRE's contribution to project P15.02.04 (Future Mobile data Link system definition document) that were delivered by ENAIRE in the context of the SESAR Project P15.02.07 "Airport Surface Data Link" as part of task T14 "AeroMACS support to 15.02.04 (multilink concept)".

In summary the SESAR project P15.02.07 deliverables supported the following achievements:

D01 to D04: Definition and Validation (via simulations) of AeroMACS profile and features

D05: Development of BS and MS AeroMACS prototypes

D06, and D10: Integration, testing in laboratories and deployment at real airport environment and verification exercises for AeroMACS equipment

D08: Security and safety analysis for AeroMACS

All project deliverables and as reported in D07-02: International harmonisation and standardization supporting global interoperability

1.4 Contribution to Standardisation

With regard to standardization, project P15.02.07 has been a key contributor to the international AeroMACS standardization activities. The project partners provided decisive inputs and contributions to the various groups, include key contributions to the following documents:

- AeroMACS SARPs (ICAO CP WGS)
- AeroMACS Technical Manual (ICAO CP WGS)
- ED-222 Aeronautical Mobile Airport Communication System (AeroMACS) Profile (EUROCAE WG-82/RTCA SC-223)
- ED-223 Minimum Operational Performance Standards (MOPS) for the Aeronautical Mobile Airport Communication System (EUROCAE WG-82/RTCA SC-223)
- Minimum Aviation System Performance Standards (MASPS) for the Aeronautical Mobile Airport Communication System (EUROCAE WG-82)
- WiMAX Forum® AeroMACS Protocol Implementation Conformance Statement (PICS) Proforma (WiMAX Forum)
- WiMAX Forum® AeroMACS Certification Requirement Status List (CRSL)" (WiMAX Forum)
- AeroMACS Avionics Standard (ARINC AEEC)

Standardization activities are ongoing in ICAO (Manual), EUROCAE (MASPS) and AEEC (ARINC standard) and project partners (EUROCONTROL and SELEX in particular) aim to continue contributions as appropriate. An action is proposed to be agreed at the closing gate to enable the continuation of the support to standardisation activities until the end of SESAR1 activities and hopefully the initiation of the SESAR202o activities (PJ14.02.06).

The table below summarizes the different contributions to standardization bodies:

Standardization body	Description	Key achievements, outcome and future work
ICAO	CP-1 ACP WGS CP WGS	• Project was active contributor to the development of AeroMACS documents

		• Active support and representation of the European side at ICAO WGS meetings • Key milestone was the contribution to the SARPS Validation that ended with the SARPS approval in December 2015. • Ongoing work in CP/WGS is the support to the development of the AeroMACS Technical Manual (planned for completion in Q3 2016)
EUROCAE RTCA	EUROCAE WG-82 RTCA SC-223	• Active support and representation of the European side at EUROCAE/RTCA meetings • Key milestones achieved were the development of: o ED-222 Aeronautical Mobile Airport Communication System (AeroMACS) Profile o ED-223 Minimum Operational Performance Standards (MOPS) for the Aeronautical Mobile Airport Communication System
EUROCAE	EUROCAE WG-82	• Active contribution of P15.02.07 in EUROCAE WG-82 • Key milestone was the support for the development of of the Minimum Aviation System Performance Standards (MASPS) for the Aeronautical Mobile Airport Communication System • Ongoing work is the support to the publication of the MASPS planned for Q2/Q3 2016
WiMAX Forum	AeroMACS AWG (Aviation Working Group) and AWG subgroups (Certification and PKI)	• Representation of the European side at WiMAX Forum, including active support in AeroMACS related events and dissemination of results into the WiMAX community **Error! Reference source not found.** • Support to AWG group discussions • PICS and CRSL documents were developed with support of SESAR AeroMACS projects • Ongoing work includes further support to AWG: o AeroMACS Certification o Network Reference Model o AeroMACS PKI
ARINC	AEEC SAI	• Submission of the AeroMACS APIM and launch of the AEEC SAI AeroMACS subgroup in 2014. • Active participation in SAI meetings and dissemination of AeroMACS results **Error! Reference source not found.** • Ongoing work includes the support to the

		development of AeroMACS ARINC standard, which is the avionics standard covering the Form Fit and Function (FFF) requirements.

Table – Summary of Contribution to Standardization Groups

1.5 Project Conclusion and Recommendations

Simulations, prototypes development and intensive verification activities and support to standards development performed in SESAR project P15.02.07 demonstrate that AeroMACS is able to support airport ground communications for fixed and mobile users covering Airline Operational Communications (AOC), Air Traffic Control (ATC) and Airport Authority Communications. Trials conducted on airport surface even show that it supports bandwidth demanding services in mobility such as video or VoIP, opening the way to consider new airport applications.

P15.02.07 testing activities covered a set of Verification Objectives as described in the AeroMACS Verification Plan, including both laboratory tests and airport tests at Toulouse Airport. P15.02.07 testing activities also contributed to the ICAO SARPS validation. In general terms, the analysis of the extensive number of tests executed during the P15.02.07 test campaign shows positive results and outcome, demonstrating the suitability of AeroMACS as a good candidate technology to cover the airport surface domain for its proven performance and maturity.

The AeroMACS verification campaign has enabled the project to reach a number of conclusions and recommendations. In terms of performance, it can be concluded from the extensive number of tests performed and reported in Deliverables D06 and D11, that AeroMACS is suitable from the technical perspective to support operational services at airport surface.

The verification activities also identified a few aspects related to interoperability of equipment from different manufacturers related to security and PKI aspects that are considered to be outside of the scope of the P15.02.07 and the AeroMACS protocols. However these issues are relevant to the integration of any future datalink into the aviation network and therefore need to be further investigated. The security, PKI infrastructure and AeroMACS certification aspects are currently being addressed by international standardization groups, such as WiMAX Forum and ICAO, and additional testing is planned within the WiMAX Forum.

When considering the whole set of activities and results of P9.16 and 15.02.07, it is considered that future activities on AeroMACS should pay a particular attention to the following points:

- Interoperability: Once the WMF AeroMACS certification process is ready, it is highly recommended that future AeroMACS prototypes/products are invited to play the full game of the AWG WiMAX Forum certification, in order to check 1) that the certification process is manageable/efficient/reasonable and 2) to confirm that going through this process truly contributes to allow that products from different vendors are fully AeroMACS interoperable
- Airport coverage: With the experience gained through the airport trials, it is emphasized that cell planning optimization is a critical activity for an efficient deployment at the airport, in order to be fully representative of a real deployment, and this is especially critical in future AeroMACS deployment in big airport and related VLD activities. Thus it is highly recommended that for any future projects, the deployment of the Base Stations at the target Airport be accomplished following state of the art practices for the deployment of a cellular network, with notable effort brought on the Airport AeroMACS network design, with RF propagation characterization, and proper calibration of propagation parameters. This should require a deep involvement of the welcoming Airport Authority to provide necessary inputs for the RF characterization studies and for the selection of optimum location for the BS antenna location.
- Quality of the installations: moving from a prototype phase to a product phase will require to take into account a full environmental qualification process (e.g. temperature, shock,

vibration), the environmental characteristics being defined according to the context of use (airborne, vehicle, fix outdoor installation).

- Under the perspective to reach saturation of VDL2 infrastructure to support ATN B1 services as well as the emerging of new services demanding high performance, it is recommended to develop AeroMACS business case and ground infrastructure implementation plans to support planning for the future deployment of AeroMACS. This is also supported by the EASA report on VDL datalink and the recommendation on airport surface to expedite the fielding of specific technology for the airport surface (e.g., AeroMACS).
- Future European projects on AeroMACS should include studies on the strategies that could be developed in Europe to encourage the deployment of AeroMACS, and to break the chicken and egg situation that may otherwise temper the dynamic of the AeroMACS deployment. There might be two main axis of considerations for these studies: 1) identifying the applications/services that could get an immediate benefits from the use of AeroMACS and focus the first deployment of AeroMACS for these applications/services, hoping that other services will later join the group of AeroMACS users once an initial AeroMACS infrastructure has been deployed. 2) identification of incentives that could allow current users of VDL Mode 2/ Public Cellular solutions at Airports to become interested by AeroMACS.
- The previous point is also in connection with the need to clarify the business cases for the different actors, and for that to study the costs of ownership, of operation and of the services for the different ownership and business model scenarios that could be identified, and the use cases
- From the determination of solid business and use cases, should be derived the target Airborne AeroMACS system architecture and determined how (and if) the Airport AeroMACS access network will be integrated within the today (ACARS, ATN/OSI, “public” IP internetwork) and/or future (FCI) overall aeronautical communication infrastructures.
- Further work in the frame of standardization should be envisaged on AeroMACS Certification, PKI & Security, ground network connectivity and standard Airborne AeroMACS equipment architecture, considering in particular that AeroMACS will coexist with other links (multilink) sharing the network and security infrastructure.
- Integration of ATN/OSI and ATN/IPS over AeroMACS within ANSP domain for ATC services and overall integration of AeroMACS within the FCI multilink environment and consideration of complementing the VDL2 operations.
- Verification of digital voice communications (VoIP) over AeroMACS.

Hence, it is recommended to continue activities on AeroMACS in future activities/projects (SESAR2020, VLDs, etc)

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] Latest Project baseline (Edition date: 02/06/2014)

[5] P15.02.07-D01_v00.01.00 Overall IEEE 802.16e/aero System Analysis & Design

[6] P15.02.07-D02_v00.01.00 Channel models and propagation analysis

[7] P15.02.07-D03_v00.02.00 IEEE 802.16e/aero Profile

[8] P15.02.07-D04_v00.02.00 Deployment & Integration Analysis

[9] P15.02.07-D05_v00.01.00 AeroMACS Prototypes Description and Verification Strategy

[10] P15.02.07-D06_v00.01.00 Verification Plan & Report - Phase 1

[11] P15.02.07-D07-001_v00.01.00 Interim Standardization and Global Interoperability

[12] P15.02.07-D07-002_v00.01.00 Standardization and Global Interoperability

[13] P15.02.07-D08_v00.01.00 AeroMACS Safety and Security Analysis

[14] P15.02.07-D10_v00.02.00 Verification Plan & Report - Phase 2

[15] P15.02.07-D13_v00.01.00 AeroMACS support to Multilink concept analysis

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