



Final Project Report

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Task contributors

Thales

Abstract

The overall objectives of the SESAR Project 15.02.06 "Future mobile satellite communication" was to define the mission and external interfaces requirements for the future ATM aeronautical satellite communication system, to perform the complementary activities of verification in line with the European Operational Concept Validation Methodology (E-OCVM) and to support the standardization of the new satellite link.

Authoring & Approval

Prepared By - Authors of the document.		
Name & Company	Position & Title	Date
██████████ TAS-I	██████████	26/07/2016
██████████ TAS-I	██████████	26/07/2016

Reviewed By - Reviewers internal to the project.		
Name & Company	Position & Title	Date
██████████ TAS-I	██████████	26/07/2016
██████████ /ENAIRE		26/07/2016
██████████ /Airbus		26/07/2016
██████████ /INDRA		26/07/2016
██████████ /Alenia Consortium		26/07/2016
██████████ /NORACON		26/07/2016
██████████ /EUROCONTROL		26/07/2016

Reviewed By - Other SESAR projects, Airspace Users, staff association, military, Industrial Support, other organisations.		
Name & Company	Position & Title	Date
██████████ /EUROCONTROL	██████████	26/07/2016
██████████ /EUROCONTROL		26/07/2016

Approved for submission to the SJU By - Representatives of the company involved in the project.		
Name & Company	Position & Title	Date
██████████ TAS-I	██████████	26/07/2016
██████████ /ENAIRE		26/07/2016
██████████ /Airbus		26/07/2016
██████████ /INDRA		26/07/2016
██████████ Alenia Consortium		26/07/2016
██████████ /NORACON		26/07/2016
██████████ /EUROCONTROL		26/07/2016

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

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Acronyms

Acronym	Definition
ACP	Aeronautical Communications Panel
ADS-C	Automatic Dependent Surveillance - Contract
AEEC	Airlines Electronic Engineering Committee
A/G	Air-Ground
AGDL	Air-Ground Data Link
AIS-MET	Aeronautical Information Services (AIS) and Meteorological (MET) Data Link Service
ANS	Air Navigation Services
AeroMACS	Aeronautical Mobile Airport Communication System
ATC	Air Traffic Control
ATM	Air Traffic Management
ATN	Aeronautical Telecommunications Network
ATN-IPS	Aeronautical Telecommunications Network (ATN) using the Internet Protocol Suite (IPS)
ATN-OSI	Aeronautical Telecommunication Network (ATN) using Open Systems Interconnection (OSI) Standards
ATS	Air Traffic Services
CNS	Communication Navigation Surveillance
CoS	Class of Service
COCR	Communications Operating Concept and
CONOPS	Concept of Operations
CP	Communication Protocol
CPDLC	Controller-Pilot Data Link Communications
CSP	Communication Service Provider
DL	Data Link
EASA	European Aviation Safety Agency

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E-OCVM	European Operational Concept Validation Methodology
ESA	European Space Agency
EUROCAE	EUROpean Organisation for Civil Aviation Equipment
FCI	Future Communications Infrastructure
ICAO	International Civil Aviation Organisation
ICD	Interface Control Document
I/F	Interface
IP(S)	Internet Protocol (Suite)
IRD	Interface Requirement Document
ITU	International Telecommunication Union
JU	Joint Undertaking
LDACS	L-band Digital Aeronautical Communication System
MASPS	Minimum Aviation System Performance Standards
MET	METeorological
ML	Multi-Link
MLOC	Multi-Link Operational Concept
MOPS	Minimum Operational Performance
MRD	Mission Requirement Document
OSI	Open Systems Interconnection
PENS	pan-European network service
QoS	Quality of Service
RTCA	Radio Technical Commission for Aeronautics
SARPs	Standard And Recommended Practices
SES	Single European Sky
SESAR	Single European Sky ATM Research
SESAR Programme	The programme which defines the Research and Development activities and Projects for the SJU
SJU	SESAR Joint Undertaking
SJU Work Programme	The programme which addresses all activities of the SESAR Joint

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	Undertaking Agency
SWIM	System Wide Information Management
TMA	Terminal Manoeuvring Area airspace domain
US	United States
VTB	Verification Test Bed
WA	Work Activity
WG	Working Group

1 Project Overview

SATCOM communications is an important component of the current aeronautical communications, supporting in particular the operations in oceanic airspace. In addition, SATCOM is expected to become a necessary component of the Future Aeronautical Communications Infrastructure (FCI) to support the future ATM concepts requiring efficient datalink capabilities and an integral part of the future multilink datalink environment (FCI).

SESAR Project 15.02.06 dealt with the SATCOM data link definition able to support the enhanced performance required by the FCI and multilink concept implementation. The overall objectives of the SESAR Project 15.02.06 "Future mobile satellite communication" was to define the requirements for the future ATM aeronautical satellite communication system, to perform the complementary activities of verification and to support the standardization of the new satellite link, that will be part of the Future Communication Infrastructure (FCI).

1.1 Project progress and contribution to the Master Plan

Project 15.02.06 has provided contribution to the Master Plan for the topics related to the SATCOM service definition aimed at supporting the ATM management. Several topics addressed in the ATM Master Plan have been considered in the definition of the SATCOM Service, such as:

- Service interoperability
- System capacity growth
- Safety and Security aspects
- Enhancement of the overall productivity of Air Navigation Services (ANS)
- Life cycle
- Standardization, Certification and Regulatory

These topics, together with others specifically identified for the SATCOM Service definition, have been addressed in the different P 15.02.06 working areas in order to improve their maturity level.

P15.02.06 has focused its verification activities on SATCOM Class A feasibility check. To meet this objective, specific tools have been used and a dedicated test campaign has been performed. The tools used are the Verification Test Bed, developed by the ESA Iris Programme in the frame of the ANTARES Project led by Thales Alenia Space, and the integrated Traffic Generator tool, developed within SESAR P 15.02.04.

The Operational Improvements related to project 15.02.06 are listed hereafter:

Code	Name	Project contribution	Maturity at project start	Maturity at project end
CTE-C02h	Future Satcom for ATM: Long term Satcom/IRIS (Class A Satcom)	P15.02.06 has addressed the definition of the future satellite data link, following the FCI CONOPS, defined by P 15.02.04. The project has also defined the main features and how the new satellite service will perform and operate in the frame of the FCI. The project has provided the definition of a Mission Requirements Document (MRD) and Validation Requirements	TRL 1	TRL 4

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		complementing the ESA Iris work on technology specifications. The project has also verified the satellite service solution by means of the ANTARES Verification Test Bed (VTB) provided by ESA Iris Programme and modified ad hoc in the frame of the P15.02.06 Verification activity.		
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1.2 Project achievements

The main SESAR P15.02.06 results can be divided in the three major activities area as described in the following:

- SATCOM Mission: P 15.02.06 has defined the “SATCOM Class A Mission Requirement Document” (MRD) [5]. This document is the main outcome of this activity and it aims to define the mission requirements for the future SATCOM Service able to support the Full 4D. The document takes into account the inputs coming from
 - SESAR P 15.02.04 for the multilink definition and performance assignment to the FCI
 - The ATM Master Plan as reported in the Integrated Roadmap dataset (Edition 2015)
 - The user needs, that have been collected in several steps during the overall project durations (such as: expert groups, airspace users workshops, airspace users questioners, etc)
 - The identified stakeholder (in particular ESA Iris Programme)

An important achievement for future evolution of the SESAR and Iris Programme activities on the SATCOM Class A definition and development, is that MRD provides a preliminary apportionment of the multilink performances to the SATCOM data link and its behave in a multilink environment.

- SATCOM External Interfaces: P 15.02.06 has defined the “SATCOM Class A External Interface requirement”. This activity has clearly identified the SATCOM system boundaries and its external interfaces, including aspects related to ATN/IPS and ATN/OSI (for legacy) [11]. The external interfaces definition has took into account the inputs coming from P15.02.04, for the multilink and FCI definition, and from P 15.02.05 for the Iris Precursor interfaces. This external interfaces definition activity has provided useful references for the apportionment of the A/G and G/G data link performances [8]. In addition the interactions between the SATCOM Class A solution with SWIM and PENS have been addressed [7].
- SATCOM Verification and Validation: P 15.02.06 has defined the the verification and validation approach for E-OCVM V2 and V3 maturity check of the defined SATCOM Class A solution ([12] and [16]). This activity has also included the execution of a preliminary verification test campaign aimed at checking the feasibility of the SATCOM service, using the Verification Test Bed, provided by Iris Programme/ ANTARES and the Traffic Generator tool, developed within SESAR P 15.02.04 [15] by Indra and used also for the P15.02.04 ATN/IPS tests. The activity has provided guidelines for future verification infrastructure definition ([13] and [14]).

Some of the activities carried on in the frame of P 15.02.06 need to be consolidated in the frame of SESAR 2020, in particular the ones related to the FCI and multilink (including consolidation of the mission requirements and external interface requirements).

1.3 Project Deliverables

The following table presents the relevant deliverables that have been produced by Project 15.02.06

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Reference	Title	Description
D104	SATCOM Mission Requirement Document	<p>This document is the SATCOM Mission Requirement Document.</p> <p>The document identifies the mission requirements for the satellite communication system provided as input to the ESA Iris Programme.</p> <p>The defined requirements represent a comprehensive set of user requirements that must be applied to SATCOM aimed at becoming an integral part of the FCI. The requirements address a number of key areas, and in particular aim at achieving a balance between performance and safety requirements and low user costs [5].</p>
D106	SATCOM System EATMN and SWIM Services Interface Definition	<p>This document first analyses the requirements imposed by the System-Wide Information Management (SWIM) architecture on the satellite-based communications component (SATCOM System) of the SESAR Future Communications Infrastructure. Based on this analysis, the external interfaces of the SATCOM System are identified for the user, control and management planes. Special attention is dedicated to external interfaces related to mobility management and multilink functionalities. More details on the external interfaces of the SATCOM System are given in the SATCOM External Interface Requirements Document (D111) of P15.02.06 [7].</p>
D108	Technical Performance Allocation (A/G and G/G Links)	<p>The main objective of this task is to provide the apportionment of technical performance parameters between Air-Ground link and Ground-Ground link, in terms of delay and availability requirements, and from the ATM satellite subsystem point of view.</p> <p>The D108 rationale is three folds :</p> <ol style="list-style-type: none"> 1.Survey analysis of WP15.02.04 and other SESAR activities results with regard to the major assumptions to be considered :Air-Ground and Ground-Ground domains boundaries, CoS to QoS mapping, QoS model 2.Performance analysis of the A/G part 3.Performance analysis of the G/G part <p>An apportionment between the Air-Ground and Ground-Ground links performances is then proposed [8].</p>

D111	SATCOM External Interface Requirement Document	<p>This document aims at providing support to the Iris programme, defining the SATCOM interfaces from gateways to the SESAR infrastructure in order to ensure successful message exchanges between all nodes of the ATM system and providing a link between SATCOM system and the whole aeronautical communications network.</p> <p>The issues of ATN/IPS and ATN/OSI will be investigated comprising their integration in the overall SATCOM ground-network [11].</p>
D115	Verification Test Procedures Definition and Test Execution for E-OCVM V2	<p>The document aims to define the Test Procedures for the E-OCVM V2 test campaign.</p> <p>For each identified test cases (source Task 116), test procedures are defined, in order to conduct verification testing.</p> <p>The test procedures are written in conformance with the test specification and specify the following information, as a minimum:</p> <ol style="list-style-type: none"> 1) Objective of the test including identification of the MRD requirements to be verified; 2) Identification and configuration of each test, including deviation from system requirement or equipment reference; 3) Test set-up identification, including test facility and data handling, equipment/instrumentations and manuals, 4) Test conditions including test levels and duration, tolerances, data acquisition and reduction. 5) Instructions for operation, including test preparation, test performance, pass-fail criteria, and past test activities (relationships). 6) Safety and security instructions. 7) Responsibilities. <p>The document aims also to report the result of the verification tests campaign defined in order to assess the V2 maturity level of the SATCOM service defined in the SATCOM MRD D104 [15].</p>

D116	V&V Test Plan & Test Cases definition for V3 (including V2 Update)	<p>The deliverable aims to define the V&V activities related to the SATCOM system required to assess its V3 maturity level, in line with the methodology proposed by E-OCVM.</p> <p>The final objective of this verification & validation plan will be to achieve technical acceptance of the designed SATCOM system in front of the Mission Requirements Document (MRD), as part of Task 104, and Interface Control Document (ICD), as part of Task 111. The process will provide the validation of the logical & technical architecture with respect to the technical performance requirements identified at the Operational Context level [16].</p>
D122	European and international standardisation bodies 2014-2016	<p>This document summarises the P15.02.06 project activities in relation to supporting the SATCOM standardisation under task T122. It covers the support provided by the project partners to the NEXUS Group, the regular updates provided to ICAO and in particular the Aeronautical Communications Panel (ACP) and its working groups and its successor the Communications Panel (CP) and its working groups, the support provided to the EUROCAE Working Group 82 as well as other groups supporting the international harmonisation.</p> <p>Deliverable D122 builds upon the deliverable D121 of task 121 covering therefore all supported standardisation activities for the duration of the project [19].</p>

1.4 Contribution to Standardisation

Project 15.02.06 has contributed to the standardization activities that are related to the SATCOM Class A solution mainly in the frame of Task 121 and Task 122.

The key outcomes of the support provided to SATCOM standardisation tasks were:

- the finalisation of the NEXUS work with the submission to ICAO of a proposal for updated SATCOM SARPS, which include more stringent performance requirements (SATCOM Performance Class B),
- the inclusion in the ICAO programme of the development of SATCOM standards and an emerging agreement for the way ahead
- the initiation of the SATCOM activities in the EUROCAE Working Group 82 and the support provided
- the support to the global harmonisation in particular with US (in the context of the Coordination Plan 4.4)
- the contributions to additional groups (such as AEEC, ICNS and FCI Task Force) addressing SATCOM aspects, disseminating information about the SESAR SATCOM activities and coordinating with external stakeholders to support international harmonisation

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1.4.1 NEXUS

The NEXUS group has been established by the NEXSAT Steering Group aiming to facilitate the standardisation aspects of the future SATCOM systems.

NEXUS group proposed the establishment in the future ICAO SATCOM SARPS of 3 classes of performance (class A, B and C) for the aviation SATCOM systems (current and future) as follows:

- Class C covers the performance requirements included in the current AMS(R)S SARPs and is applicable to systems already standardized in ICAO
- Class B covers more stringent (compared to Class C) performance requirements (such as the ones required by initial 4D)
- Class A covers more stringent (compared to Class B) performance requirements (such as those required by full 4D and by the SESAR/NextGEN/CARATS future concepts)

Following the agreement in the three classes of performance and the desired structure of the updated SARPs, the NEXUS work focused on the definition of the class B performance requirements. For the definition of class B, NEXUS aligned the work with the EUROCAE and RTCA WG78 and SC214 work describing the ATN Baseline 2 (ATN/B2) services

The project P15.02.06 partners involved in the standardisation have been very active in the contributions in NEXUS and, in particular, undertook the development of specific sections of the draft material for the ICAO proposal.

1.4.2 ICAO

The SESAR partners have been supporting the international coordination on the SATCOM aspects and used the opportunities of ICAO meetings to provide updates on the European activities and in particular, the status of project P15.02.06 and the NEXUS work.

1.4.3 EUROCAE

Within EUROCAE, Working Group 82 (WG82) has been established to develop the appropriate standards related to the new air-ground data link technologies, including data links for airport surface and En-Route/TMA using terrestrial and satellite communications. WG82 addressed so far AeroMACS and in 2014 group was tasked to address also the SATCOM aspects in parallel to the AeroMACS work. WG82 decided to consider the SATCOM data link aspects in dedicated meetings separately from the meetings addressing the AeroMACS aspects.

The objectives of the contributions provided to the two WG82 meetings above were mainly to:

- Raise awareness of activities performed in the scope of Iris, SESAR and NEXUS
- Coordinate with activities of other groups (ICAO, RTCA, SESAR, AEEC)
- Foster WG82 development MOPS and MASPS for current SATCOM Class B and future SATCOM Class A
- Propose technical solutions for the implementation of SATCOM
- Coordinate and steer the joint efforts in order to follow the COM Roadmap
- Emphasise the need to progress with the standardization of the future Class A SATCOM to ensure availability of compliant systems
- Show feasibility of Class A SATCOM systems, based on outcomes from P15.02.06 and ESA/Iris
- Promote development of a single global Class A SATCOM standard
- Contribute to definition of user requirements for SATCOM Class A
- Support the definition of QoS, CoS, performance requirements and global naming of SATCOM classes

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1.5 Project Conclusion and Recommendations

Project 15.02.06 has addressed the definition of the future satellite data link as a part of the future datalinks of the overall FCI to comply with the demanding performance requirements aimed at supporting the full 4D operations and the future ATM applications.

The main conclusions that can be derived from the SESAR Project 15.02.06 results are:

- The project has confirmed the important role that the long term SATCOM service shall play in the Future Communication Infrastructure (FCI) defined within P 15.02.04 and in implementing the Multilink Operational Concept
- The project has confirmed the important role that the long term SATCOM service shall play in increasing the data capacity in order to support the foreseen traffic growth
- The project has confirmed that the long term SATCOM service will be provided by a SATCOM A/G data link that is able to comply with the future QoS requirements of the CPDLC, ADS-C, AIS/MET and AOC applications
- The project has confirmed that, even if, in the long term SATCOM solution, the data link will have a predominant role, the voice service will be kept for specific cases linked to emergency or non-routine communications
- The project has identified the long term SATCOM system boundaries and it has confirmed the need of interfaces with the ground networks such as SWIM and PENS
- The project has confirmed the need of an enhanced safe and secure long term SATCOM service
- The project has confirmed that the long term SATCOM service shall be interoperable with respect to the legacy services and to other future services, as soon as the same communication protocol is applied
- The project has generated the long term SATCOM Mission Requirements that defines the future SATCOM system able to fulfil the future long term performance requirements (Class A performance requirements).
- The project has contributed actively to several A/G datalink Standardization bodies, as EUROCAE & RTCA, IACO, etc
- The project has confirmed the feasibility of the defined SATCOM service solution, by means of a dedicated test campaign execution. The SATCOM service solution makes use of the SATCOM technology designed in the frame of the ANTARES project, part of the ESA Iris Programme.

The mentioned feasibility check test campaign is the P15.02.06 Exercise with reference EXE-15.02.06-VP-844. The exercise has been carried out using as Platform the Verification Test Bed developed in the ANTARES project of the ESA Iris Programme and complemented with a Traffic Generator developed in P15.02.04 project.

In order to consolidate the long term SATCOM solution defined in SESAR Phase 1 and to continue its verification process, the following main recommendations has been derived from the SESAR P 15.02.06 activities:

- To continue the close coordination with the projects that will address, in SESAR 2020, the FCI and MLOC consolidation, to retrieve mutual benefits from the information exchanges
- To identify and to interact with SESAR 2020 projects that will have stronger relations with the possible SATCOM service solution users, in order to collect useful inputs, feedbacks and recommendations

- To continue the interaction with the ESA Iris Programme in relation with the long term SATCOM requirements.
- To support future SATCOM service definition activities with tools and testing facilities able to increase the confidence of the values/numbers that will be further defined and apportioned for the SATCOM Class A
- To consolidate the verification and validation strategy in alignment with ESA Iris Programme roadmap. In addition, in order to proficiently progress on the SATCOM service verification it will be important to consolidate the definition of the system under test and:
 - To identify the mean/s to allow the improved system verification at the increasing TRL level
 - To identify the interfaces to perform the testing activities and the exchange of data between the system under-test and testing facility
- To continue in working closely with the European and not European standardization bodies (i.e. EUROCAE, RTCA, ICAO, etc) to disseminate the SATCOM service solution analysis outcomes, to retrieve benefits from the feedbacks of expert stakeholders and to keep track or influence the standardization evolutions.

The identified recommendation should be kept into consideration in SESAR 2020 PJ.14-02-02, named "Future Satellite Communications data link". PJ.14-02-02 will be focused on the near and long satellite data link technologies for both continental and oceanic regions. It will also include digital voice as an element of the Future Communications Infrastructure (FCI).

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