



# Final Project Report

## Document information

Project Title	Future Mobile Data Link System Definition
Project Number	15.02.04
Project Manager	EUROCONTROL
Deliverable Name	Final Project Report
Deliverable ID	D01
Edition	00.01.01
Template Version	03.00.04

## Task contributors

[EUROCONTROL](#),

## Abstract

P15.02.04 focused on the Aeronautical Telecommunication Network (ATN) Internet Protocol Suite (IPS) for mobile networking and air/ground data links supporting the Future Telecommunications Infrastructure (FCI).

A promising technical solution has been identified as worthy of further detailed investigation for the two main functions of the FCI, i.e. mobility and multiple data link (multilink or "multihoming") management. This solution, called Ground-Based LISP, reduces complexity on board the aircraft. LISP - Locator Identifier Separation Protocol - also has the advantage of being based on an Internet proposed standard. Studies on the complexity on the ground side and optimisation required to the LISP Internet specification have been performed: initial verification has been carried out and shall be continued in other projects, notably SESAR 2020.

The project also carried out spectral compatibility testing for LDACS-1, the L-Band Digital Aeronautical Communication System, a proposed future terrestrial air/ground data link.

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Rational for rejection

None.

## Document History

Edition	Date	Status	Author	Justification
00.00.01	01/04/2016	Draft	Eurocontrol	Document creation Review by partners
00.01.00	29/07/2016	Final	Project Team	Final review Submission to SJU
00.01.01	4/10/2016	Final	Project Team	Address Gate Comments

## Intellectual Property Rights (foreground)

This deliverable consists of SJU foreground.

## Acronyms

Acronym	Definition
ADS-C	Automatic Dependent Surveillance - Contract
AeroMACS	Aeronautical Mobile Airport Communication System
AIS/AIM	Aeronautical Information Service / Management
AOC	Airline Operational Communications
ATM	Air Traffic Management
ATN	Aeronautical Telecommunications Network
COM	(Tele)communications
CPDLC	Controller Pilot Data Link Communications
CTE	COM technical enabler (Master Plan)
E-OCVM	European Operational Concept Validation Methodology
FCI	Future Communications Infrastructure
FOC/WOC	Flight / Wing Operations Centre - also called AOC
IETF	Internet Engineering Task Force
IPS	Internet Protocol Suite
LDACS	L-Band Digital Aeronautical Communications System
LISP	Locator Identifier Separation Protocol
MET	Meteo
QoS	Quality of Service
RFC	Request For Comments (Internet Standardisation document)
RPAS	Remotely Piloted Aircraft Systems (formerly called UAS)
TRL	Technical Readiness Level
UAS	Unmanned Aircraft Systems
Vn	Level in the E-OCVM model (e.g. V2)

# 1 Project Overview

The objective of P15.02.04 was twofold:

- The specification of the new general elements (data link technology independent) of the Future Communication Infrastructure (FCI), an umbrella communication system comprising new data links (developed in different projects in SESAR), convergence for legacy data links, and ATN/IPS network components (e.g. air/ground routers), addressing verification activities as well.

- The support to specification of the Future (Terrestrial) Mobile Data Link System (LDACS: L-Band Digital Aeronautical Communication System), which is one of the three new data links developed in the SESAR programme (the other links are developed in the SESAR Projects P15.02.06 for the new Satellite Link, and in P15.02.07 for the new airport surface link, AeroMACS). It includes limited radio compatibility testing for one proposal for the L-band Digital Aeronautical Communication System, LDACS1.

## 1.1 Project progress and contribution to the Master Plan

As part of the Communication, Navigation and Surveillance (CNS) enabling infrastructure within the ATM Master Plan, the project focused on the mobile networking and air/ground data link aspects. It also acted as the project coordinating the SESAR Communication (COM) architecture and compiling all aspects for the communication technical domain.

The project initiated studies in support of the development of the operational concept for the Future Communication Infrastructure, focusing on aspects of multiple data link (multilink) management, Quality of Service requirements, Security, Civil-Military coordination and Remotely Piloted Aircraft System integration. Coherence with other project requirements was addressed, in particular with the Future Mobile Satellite Communication project and its Mission Requirements Document, given the similar timescale and also addressing another future data link component of the FCI.

The project then proposed a functional architecture for the FCI that could accommodate the operational requirements. Technical requirements on the FCI were then derived, followed by physical architecture guidelines for the airborne and ground sides.

A gap analysis of ICAO standard for ATN/IPS, Doc. 9896, was also performed, which may lead to future proposals for document amendment to develop the FCI aspects.

A verification test bed was built to carry out initial testing on a number of the functions derived previously. To support P15.02.04 verification activities, a verification exercise (given the SESAR number EXE-15.02.04-VP843) was declared in the Verification & Validation (V&V) SESAR roadmap, integrating system components from P15.02.04 and P15.02.06 partners into the P15.02.04 ATN/IPS ground infrastructure platform.

Furthermore, P15.02.04 supported the evolution of the COM part of the Data Set description as part of the Master Plan updates that took place in the timespan of the project. COM technical enablers (CTE), not only limited to air-ground data link, were reviewed and updated as part of this work in collaboration with Work Packages B and C.

The following table addresses the level of status of the COM enablers addressed by the current project. The project contributed to the Master Plan's "Future communication infrastructure-ATN/IPS and multilink" and "New A/G datalink using ATN/IPS over L-band" COM Technical Enablers (CTE).

In relation to CTE-C04 below, the previously mentioned VP843 was declared as V2 (for ground ATN/IPS verification), corresponding to TRL3/4 considering that the airborne side was not fully addressed in the verification. It can be argued that the ground side has itself been developed to TRL4.

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In relation to CTE-C02e below, deliverables D21 and D22 document measurement campaigns that have raised the TRL to 3.

As a result of this project, emerging solutions for the ATN/IPS and the future L-Band data link are being identified and progressed, that will be further considered in SESAR2020 activities

Code	Name	WP contribution	Maturity at WP start	Maturity at WP end
CTE-C02e	New A/G datalink using ATN/IPS over L-band	Development of specification to be used as input to standardisation	TRL 1	TRL 3
CTE-C04	Future Communication Infrastructure - ATN/IPS and Multilink	Development of specifications to be used as input to standardisation	TRL 1	TRL 3/4

## 1.2 Project achievements

The project produced the following main results, documented in the deliverables listed below:

- an agreed long term operational concept supported by new air/ground datalink communication systems and the FCI, and a proposed datalink roadmap
- an agreed quality of service framework for future operational requirements on the FCI, which should be used for the future Safety and Performance Requirements of ATN Baseline 3 (the "long term")
- an agreed set of security requirements on the FCI, which has been developed with the support of WP16
- a proposed technical architecture supporting the main functions of the FCI: mobility, multilink management, routing and forwarding, security, Quality of Service management, and network management
- an initial assessment of a promising solution for the main functions above, i.e. mobility and multilink management, based on an internet standard called LISP (Locator Identifier Separation Protocol). This solution has the strong advantage of minimizing airborne complexity. It is also based on an existing Internet experimental specification - RFC 6830 - that is commercially available in some products; in line with recommendations found in D18, the LISP convergence times could be reduced with further optimization of the standard LISP. Alternatively, optimization of the LISP Mapping Resolver/Mapping Server could be an option to the same goal.
- a gap analysis that may lead to proposal for amendments of the relevant ICAO standard, Doc. 9896.
- a test bed used for a verification of a number of requirements derived previously. As mentioned above, a verification exercise (EXE-15.02.04-VP843) was declared in the V&V roadmap, integrating system components from P15.02.04 and P15.02.06 partners into the test platform. General conclusions of the Verification Exercises results are given in Deliverable 18: considering the overall results obtained during the verification tests, it can be concluded that the Indra FCI Verification Platform (multilink management solution based on LISP) addressed the feasibility of the Multilink Operational Concept through tests and simulations in a laboratory environment, and has achieved V2 (TRL 3/4) maturity level.
- the impact of LDACS1 signals onto DME/TACAN receivers has been measured within the performed laboratory testing of the project. The measurement campaign has been very comprehensive and important insight on robustness and sensitivity of DME/TACAN receivers has been obtained.



## 1.3 Project Deliverables

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

Reference	Title	Description
D25 to D37	Early Tasks	A set of deliverables produced before the Full Project was approved for initiation. All those deliverables served as a basis for further work in the full project. Deliverables D31 to D37 were studying LDACS.
D03-001	FCI Operational concept	Long term (formerly known as "step 3") operational concept supported by new air/ground datalink communication systems and the FCI. Version 001 updated to the 2015 Master Plan.
D04	QoS concept	QoS framework: this defines sets of technical parameters such as continuity, availability etc, which are required to be supported by the technical system to provide the required performance to the applications, grouped into "classes of service". Three main classes have been defined: multilink (highest performance e.g. for ADS-C and CPDLC in support of initial 4D), normal (for AIS, MET) and best effort (for AOC, now called FOC/WOC)
D05	FCI Security requirements	A security risk assessment for the FCI, together with resulting requirements.
D06	Civil/Military interoperability requirements	A set of requirements to ensure that the FCI can support military traffic.
D07	UAS FCI Integration requirements	A set of requirements to ensure that the FCI can accommodate RPAS (called UAS when the project started).
D09	Logical architecture definition	This is the logical (or functional) architecture of the FCI to support operational requirements defined above. The main functions are mobility and multilink management, QoS, security, routing and telecommunication network management. This document also includes a study of available technical solutions and their impact on the proposed architecture. A recommendation is proposed for each of the functions above.
D10	Functional requirements specification	This translates the operational requirements above into technical requirements on the functional elements of the architecture, enabling design of the physical architecture.
D11	ATN/IPS protocol specification	A study of the IPS protocols needed to support the functions and requirements above; a gap analysis that may lead to future proposals for inclusion in the ICAO standard for ATN/IPS, Doc. 9896.

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D12	Airborne Physical architecture specification	A study on a proposed physical architecture that can support the FCI on the airborne side.
D13	Ground Physical architecture specification	A set of guidelines for the physical architecture taking into account the functional architecture defined in D09.
D18	FCI verification test report	Results of the test campaign and recommendations for future work.
D21	Test plan for LDACS assessment	Testing plan focusing only on LDACS1 transmitter interference scenarios towards DME/TACAN receivers. Additional testing will be required in order to assess the impact of external DME/TACAN interference upon LDACS1 receivers, as well as the interference interactions of LDACS1 with other L-band systems.  This limited scope was introduced by SJU for PIR approval.
D22	LDACS1 transmitter test report	Report of the measurement campaign, based on the test plan (D21)

The complete deliverable list is provided in section 2.

## 1.4 Contribution to Standardisation

Deliverable D11, "ATN/IPS protocol specification" is contributing directly to standardisation.

ICAO document 9896 is the "ATN/IPS Manual", the second edition of which has been published in November 2015. D11 has performed an analysis of the document and provided a gap analysis that may lead to some amendments to be tabled for inclusion in next versions of this document.

ICAO Working Group I (Internet) is currently working on defining mobility and management solutions for the ATN. P15.02.04 has produced work and recommendations that multilink have been and will be presented at ICAO to feed the discussion towards a selection of solutions for future standardisation and deployment in support of the so-called ATN Baseline 3, based on IP.

Furthermore, Deliverable D09 (Logical Architecture) has already been presented in this ICAO working group.

The verification test results have also been presented at an AEEC meeting working with ATN/IPS in London in June 2016.

## 1.5 Project Conclusion and Recommendations

The main project conclusion are:

- an Operational Concept, Quality of Service framework and Security Requirements have been developed for the Long Term - i.e. beyond what is currently known as ATN-B2 - to be supported by the FCI;
- a promising technical solution has been identified as worthy of further detailed investigation for the two main functions of the FCI, i.e. mobility and multilink management. This solution, called Ground-Based LISP, reduces complexity on board the aircraft. Studies on the complexity on the

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ground side and optimisation required to the LISP Internet specification have been performed: initial verification has been carried out and shall be continued in other projects, notably SESAR 2020;

- compatibility measurements have been performed in support of the development of LDACS1, providing important results which require further consideration.

Recommendations for further work have been included in each deliverable, a number of them included in the current proposal for Project PJ14 part of SESAR 2020. Specifically, important recommendations for SESAR2020 are the following:

#### OPERATIONAL

- the proposed long-term operational concept and requirements were neither validated by simulations or trials, nor properly coordinated with SESAR 1 operational projects (WP4, 5, 6). Therefore, the QoS framework should be considered as an initial proposal, to be used as input for further research and coordination.
- the impact on the FCI of the accommodation of RPAS and Military aircraft needs to be further elaborated
- from an operational perspective, the role of voice in an environment where data communications has become the normal means of communications should be further studied.
- deliverable D5 shall be consulted for an extensive discussion of further studies required on the subject of FCI security, which are not repeated here for the sake of brevity. Security needs to be investigated further as it based on an end-to-end model, which could not be fully investigated at the network level defined as the scope of P15.02.04.

#### TECHNICAL

- multi-homing options (also called multilink in this project) cannot be addressed independently from mobility solutions. The description of ground-based LISP provided in the deliverables addresses this aspect and must be further expanded: any other considered mobility solution will have to be studied along the same lines. If further analysis shows that Ground-based LISP has some critical limitations, it should be further studied since this protocol is currently in development. On the other hand, if new IP-based solutions are implemented in the future, they could be also further studied. Whatever the solution (LISP or other), it should be pushed for standardisation at ICAO and the IETF.
- Network management needs to be performed as system configuration, system monitoring, maintenance, security and administration are highly inter-dependent.
- Multicast routing for end-to-end air-ground communications were addressed since this could be used for AIS/MET services. However, its use should be further developed.
- Several generic service provision models should be defined so as to identify specific technical requirements under specific conditions of deployment/service provision.

#### VERIFICATION

- The FCI test bed developed in this project provided useful results documented in D18. Further verification is mandatory to address items listed above and in the deliverables.

#### LDACS1

- Further investigations of LDACS1 are necessary, particularly:
  - Investigate interference from LDACS1 to other legacy systems in the L-band, e.g. GNSS (Global Navigation Satellite Service), etc
  - Evaluate resulting interference situations for realistic environments;
  - Investigate interference from legacy systems to LDACS1.
  - Identify possible deployment scenarios and develop deployment criteria.
  - In-flight tests shall be carried out to test real LDACS1 interference.
  - Develop a complete LDACS1 access network, including the definition of the access network entities and functions as well as the specifications for the A/G subnetwork, the interface

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between the LDACS1 entities (e.g. interface specification to the airborne and A/G router) and the interfaces to the mobile subnetwork and the ground ATN/IPS Internetwork

Additional details for all these recommendations are found in the Deliverables.

## 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] Deliverable D1 - Final Project Report - Edition 00.01.00
- [5] Deliverable D2 - WA1 Periodic report - Edition 00.01.00
- [6] Deliverable D3 - FCI Operational Concept - Edition 00.01.00
- [7] Deliverable D3-001 - Update of D03: FCI Operational Concept - Edition 00.01.01
- [8] Deliverable D4 - QoS Concept - Edition 00.01.00
- [9] Deliverable D5 - FCI Security Requirements - Edition 00.01.00
- [10] Deliverable D6 - Civil/Military Interoperability Requirements - Edition 00.01.00
- [11] Deliverable D7 - UAS FCI Integration requirements- Edition 00.01.00
- [12] Deliverable D8 - WA2 Periodic Report - Edition 00.01.00
- [13] Deliverable D9 - Logical Architecture Definition - Edition 00.01.00
- [14] Deliverable D10 - Functional Requirements Specification - Edition 00.01.00
- [15] Deliverable D11 - ATN/IPS Protocol Specification - Edition 00.01.00
- [16] Deliverable D12 - Airborne Physical Architecture Specification - Edition 00.01.00
- [17] Deliverable D13 - Ground Physical Architecture Specification - Edition 00.01.00
- [18] Deliverable D14 - WA3 Periodic report - Edition 00.01.00
- [19] Deliverable D15 - WA3 2 FCI Verification Test Plan - Edition 00.01.00
- [20] Deliverable D16 - WA3 3 FCI Verification Test Bed Requirement Specification - Edition 00.01.00
- [21] Deliverable D17 - WA3 4 FCI Verification Test Bed Design/Integration/Acceptance Definition - Edition 00.01.00
- [22] Deliverable D18 - WA3 5 FCI Verification Test Report - Edition 00.01.00
- [23] Deliverable D19 - WA3 6 FCI Support to Operational Validation Projects Plan - Edition 00.01.00
- [24] Deliverable D20 - WA4 Periodic Report - Edition 00.01.00
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- [26] Deliverable D22 - LDACS1 transmitter test report - Edition 00.01.00
- [27] Deliverable D23 - WA5: COM technical architecture description as support to SESAR PB.4.3 - Edition 00.01.00
- [28] Deliverables D25 to D37: Early Task documents, produced before P15.02.4 project start
- [29] ICAO Document 9896, Edition 2, Nov. 2015 "Manual on the Aeronautical Telecommunication Network (ATN) using Internet Protocol Suite (IPS) Standards and Protocol"
- [30] Deliverable D128 - Project B.4.3 - "Architecture Description Document SESAR 1 edition"
- [31] Integrated Roadmap Data Set DS16—13 July 2016

**-END OF DOCUMENT-**

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