Final Project Report

Document information	
Project Title	Navigation Infrastructure RationalisationI
Project Number	15.03.02
Project Manager	THALES
Deliverable Name	Final Project Report
Deliverable ID	D08
Edition	00.01.01
Template Version	03.00.04
Task contributors	
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Abstract

The project aims to address issues associated with the decommissioning of conventional terrestrial navigation aids, find solutions to minimize the associated risk, and develop a European-wide navigation infrastructure optimisation methodology, in following the guidance given in the SESAR definition phase.

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Rational for rejection
None.

Document History

Edition	Date	Status	Author	Justification
00.00.01	30/10/2015	First Draft	[redacted]	New document
00.00.02	06/04/2016	Mature Draft		Updated document
00.00.03	08/04/2016	Updated Draft		Final document
00.00.04	11/04/2016	Final Draft		Final document including updates in the standardisation section
00.01.00	12/04/2016	Final Version		Final version

00.01.01	04/05/2016	Revised Version	[redacted]	Revised document following SJU comments

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This deliverable consists of SJU foreground.

Acronyms

Acronym	Definition
AIP	Aeronautical Information Publication
ANC	Air Navigation Conference (ICAO)
ANSP	Air Navigation Service Provider
A-PNT	Alternative Positioning Navigation and Timing
ATM	Air Traffic Management
AU	Airspace Users
CAA	Civil Aviation Authority
DEMETER	PBN Infrastructure Assessment Tool (Eurocontrol)
DME	Distance Measuring Equipment
E-ATMS	European Air Traffic Management System
ECAC	European Civil Aviation Conference (Member States)
FAA	Federal Aviation Administration
GBAS	Ground Based Augmentation System
ICAO	International Civil Aviation Organization
NDB	Non Directional Beacon
NSG	Navigation Steering Group (Eurocontrol)
NSP	Navigation Systems Panel (ICAO)
PBN	Performance Based Navigation
PCP-IR	Pilot Common Project- Implementing Rule
SESAR	Single European Sky ATM Research Programme
SESAR Programme	The programme which defines the Research and Development activities and Projects for the SJU.
SJU	SESAR Joint Undertaking (Agency of the European Commission)
SJU Work Programme	The programme which addresses all activities of the SESAR Joint Undertaking Agency.
TACAN	Tactical Air Navigation

VOR	VHF Omnidirectional Range

1 Project Overview

Project 15.03.02 addressed issues associated with the decommissioning of conventional terrestrial navigation aids, found solutions to minimize the associated risk, and developed a European-wide navigation infrastructure optimisation methodology, in following the guidance given in the SESAR definition phase. The project addressed also topics related to Alternate Positioning Navigation and Timing (A-PNT) which explores the evolution of terrestrial infrastructure using elements from all areas of CNS.

1.1 Project progress and contribution to the Master Plan

Project 15.03.02 successfully undertook studies related to the conventional ground navigation system that addressed issues associated with the optimisation of the navaids deployment over Europe considering a specific set of technical requirements defined at the beginning of the studies. These technical requirements were derived from a set of operational requirements defined and collected by project 15.03.01 “Navigation Technologies Specifications” for the En-route and TMA, and Approach and Landing phases of flight. Once the requirements were defined and the tools and methodologies for the different infrastructure assessments were agreed, the project performed a number of studies in order to identify the rationalisation potential of the navigation facilities, and also identify the infrastructure required to better support PBN operations, in particular through the identification of the current terrestrial-based RNAV coverage as well as the coverage optimisations which could be achieved with the modification of some facilities’ configurations. These studies run at a first step for all ECAC member states separately, and then at ECAC-wide level, estimated the rationalisation and optimisation potential in the ECAC area for the time period extending until approximatively year 2030. At a second step, the study of the rationalisation of the conventional navigation infrastructure was pursued but mainly to refine the analysis for a number of TMAs/Airport designated in the PCP-IR [21] as candidates for PBN implementation. Results of the rationalisation and optimisation studies can be linked to the following enablers defined in the Integrated Roadmap Dataset DS15 [20], listed in the table below.

For the A-PNT enabler, in addition to the infrastructure optimisation activities, specific analysis was performed by the project in order to assess the possible requirements that could apply to short and long term A-PNT solutions, and identify the possible CNS options that may be considered worldwide in order to provide a complementary capability to GNSS to support PBN and other reversionary navigation applications.

Code	Name	Project contribution	Maturity at project start	Maturity at project end
CTE-N08	DME Ground Infrastructure Optimisation	DME ground infrastructure optimisation assessed for ECAC member states in support to En-Route/TMA and Approach/Landing operations. Assessment results for TMA refined for the 24 TMAs identified in the PCP-IR.	TRL7	TRL8
CTE-N11	NDB Decommissioning	NDB decommissioning assessed for ECAC member states in support to En-Route/TMA and Approach/Landing operations.	TRL7	TRL8
CTE-N12	VOR/DME MON	VOR/DME MON assessed in ECAC area in support to conventional En-Route operations.	TRL7	TRL8

CTE-N13a	A-PNT (Alternative Positioning Navigation and Timing)	Short term A-PNT solutions based on existing systems, as well as long term A-PNT alternatives introducing possible new technologies investigated.	TRL1	TRL2
CTE-N14	Gradual Rationalisation of Approach and Landing Systems	Rationalisation of Approach and Landing systems assessed for ECAC member states.	TRL7	TRL8
CTE-NGOV01	Ground Navaids Optimisation/ Rationalisation Plans	Ground Navaids Optimisation/Rationalisation Plans assessed for ECAC member states.	TRL7	TRL8

Table 1- List of Enablers related to the project

The project contributed to the two following SESAR technological solutions which are considered as important outputs to be promoted outside the SESAR 1 program: “Short term A-PNT” and “Long term A-PNT”.

1.2 Project achievements

Project 15.3.2 has worked out a reversion strategy for conventional navigation aids to evolve towards a complementary support infrastructure for PBN. This reversion strategy allows a full exploitation of PBN benefits while safeguarding continued ATM operations using a DME/DME network to support suitably equipped, while accommodating non-DME/DME equipped users with a residual VOR/DME capability.

The project delivered significant results and methodologies for all ECAC states. These results should be applicable to the time periods by 2023, and by about year 2030. The main project outcomes related to the rationalisation work can be summarized as follows

- Possibility to eliminate most NDB and a significant number of VOR (about 50%) in line with facility lifecycles (significant rationalization with coordinated efforts possible by about 2030). Optimization of DME/DME with only small investment requirements, in order to provide a robust GNSS-outage infrastructure for supporting the continuity of Air Transport operations in the large majority of ECAC, both at key airports and in all of en-route. In high infrastructure density areas, this may lead to a reduction of facilities, while in low density areas, some facilities may need to be added.

- Provision of a safe reversion network using VOR/DME for airspace users not equipped with DME/DME avionics.

- A methodology based on harmonized and validated reversion scenarios showing how to achieve this desired end-state as an integral part of PBN implementation planning.

- A detailed understanding of the limitations of terrestrial navigation aid coverage provision from a network point of view (specifically for DME/DME in overwater or mountainous areas).

Project findings on navigation infrastructure rationalisation are summarized in [8], [9], [10], [11], [13] and [14]. In relation to these results, an input from 15.3.2 was submitted to the ICAO NSP to support both the progress of the ICAO Job Card on rationalisation as well as support European implementation (NSP WGW Nov 2013 WP37, “The Need for Guidance on Navigation Facility Evolution”). The paper, titled “Strategy for Rationalization of Conventional Radio Navigation Aids and Evolution toward supporting Performance Based Navigation”, was approved by the ICAO Navigation Systems Panel for adoption in Annex 10 as new Attachment H.

In addition to the conventional navigation infrastructure rationalisation and optimisation in terms of coverage, the project addressed also A-PNT –related topics focusing on both short term and long term A-PNT.

For short term A-PNT, the project assessed the ability if current DME to support PBN operations using an RNP navigation specification. All system aspects including airborne equipment and ground facilities were considered. A system-level analysis was undertaken focusing on accuracy and integrity, and recommendations were made for the improvement of the quality of DME/DME based RNAV as a significant mitigation capability for GNSS vulnerabilities. The study concludes that DME/DME may already be offering services supporting RNP1 and lower RNP-value, and suggests a number of actions that could be undertaken to formally recognize the ability of DME to provide RNP. More details about performed studies are available in [15].

For long term A-PNT, the project assessed the initial requirements that should be supported by the A-PNT solution for both short and long term A-PNT, and investigated the different A-PNT options being discussed for the long term at European and FAA levels. The work on long term A-PNT remains relatively open and cannot fully conclude on both A-PNT requirements and on actual technologies to be selected as best candidates for GNSS outage mitigation for the long term. For this reason, proposals and initial work made by the project in [16] should be further discussed and matured in follow-on projects.

1.3 Project Deliverables

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

Reference	Title	Description
D10 [13]	D2.2.Navaids Requirements in support of Performance Based Navigation (PBN) and Rationalisation	The main objective of D10 is to collect the operational navigation performance requirements allocated to GNSS, Navaids and On-board navigation systems for step 1 and step 2 (up to approx. year 2023/ 2030) from SESAR project 15.03.01 “Navigation Technologies Specifications” and to allocate these requirements at the conventional navigation ground system level by defining the technical specifications required from the conventional navaids so that they are able to achieve signal-in-space requirements corresponding to the supported navigation application. D10 is built on the work performed in the first phase of project 15.03.02 and aims to update and consolidate D03 that analysed and validated the navigation requirements for 2013-2023 timeframe, submitted at the beginning of the project.
D04 [8]	D1.3.Simulation Tools for Phase 1	The main purpose of the document is the definition of simulation and evaluation tools/means and processes to be used for the assessment of the navigation infrastructure and of potential rationalization and optimization solutions at state and ECAC-wide level.
D05 [9]	D1.4.A.Infrastructure Assessment of individual ECAC states	This document presents the results of the Navaid Infrastructure assessment in the individual ECAC member States. The main objective of the assessment was to identify possible solutions for the rationalization and optimization of ground navigation aids network in step 1 timeline (up to approx. year 2023) for each assessed state, taking into consideration the foreseen evolution of the

		navigation applications.
D06 [10]	D1.4.B.ECAC-Wide Navigation Infrastructure Assessment	This Deliverable provides a summation of the individual State Reports prepared in 15.3.2 Deliverable D05 and its Annexes to provide an ECAC Wide assessment of the current and rationalised VOR and optimised DME infrastructures to support Performance Based Navigation operations throughout ECAC.
D07 [11]	D1.5.Guidelines for Transition towards an Optimized Conventional Navigation Infrastructure	This deliverable provides guidance for the stakeholders to proceed with rationalisation. It aims at defining a generic rationalisation methodology and identifying the main issues related to the rationalisation process. A numbers of conclusions are highlighted in the document in addition to some identified key issues that require further consideration.
D11 [14]	D2.3.Rationalisation Planning for ECAC	The main objective of this deliverable is to provide an estimation on the evolution of the ground navaids network in the timeframe of SESAR Step 1 & 2 (up to year 2030) based on the envisaged operational requirements. The assessments performed aimed mainly at refining the results described in D05 state reports. The following studies were performed and are part of this deliverable as individual appendices: - Detailed DME/DME coverage assessments in the TMAs included in the scope of the PCP-IR - Analysis of potential solutions for improving the DME/DME performance or optimizing the ground network in particular environments - Refinement of the VOR/DME MON analysis.
D12 [15]	D2.4.A.A-PNT/DME Enhancement Analysis	This report assesses the suitability of DME as a near term A-PNT capability to provide a navigation reversion capability to mitigate potential GNSS service interruptions. It considers all system aspects including airborne equipment, ground facilities and in-service operations issues. A very significant capability is demonstrated for a significant part of fielded equipment both in terms of accuracy and integrity. The report should serve as a baseline for further developments of both short and long term A-PNT equipment and services.
D13 [16]	D2.4.B.A-PNT/Alternate Technology Options	The report investigates the long term A-PNT options that may be required to mitigate against localised GNSS failures and residual lack of equipage level on certain aircraft. It includes an initial assessment of A-PNT requirements, and an assessment of the various technologies being discussed at FAA and European levels.

Table 2- List of Deliverables

1.4 Contribution to Standardisation

As a direct output of the project efforts, a “Strategy for Rationalization of Conventional Radio Navigation Aids and Evolution toward supporting Performance Based Navigation” was agreed by ICAO Navigation Systems Panel, for inclusion in Annex 10 [18]. It is being published as attachment H to volume 1 [19] with an applicability date of 10 November 2016. Annex 10 [18] was chosen with the aim to reach ANSP Engineering in charge of navigation aid operation and renewal. It may be appropriate to ensure awareness of the material in other communities (such as introducing references in the next update of the ICAO Global Air Navigation Plan).

It should be further assessed if some aspects relating to the use of DME/DME and VOR/DME, both in the context of PBN-use (RNAV and RNP Specifications) and as a reversion capability, should lead to further updates of the ICAO PBN Manual, Doc 9613 [17].

1.5 Project Conclusion and Recommendations

Project 15.03.02 has delivered significant results for the rationalisation of the conventional navigation infrastructure, in terms of rationalisation requirements, methodologies, proposals for optimised navigation infrastructure configurations and recommendations for the support of the transition towards a PBN environment. These achievements were not only profitable for the SESAR 1 program itself, but also for all ECAC states for which a considerable resource was made available in order to assess the state-specific aspects.

Project rationalisation activities were performed in close collaboration with other SESAR projects such as 15.03.01 “Navigation Technologies Specifications”, 15.03.04 “GNSS Baseline Study” and 9.27 “Multi-constellation GNSS Airborne Navigation Systems”, and also with different external stakeholders involving the AUs, the military, and the ECAC states’ ANSPs and CAAs. The coordination with all these stakeholders aimed at collecting the inputs required for the different studies run by the project, and also at sharing the results, findings and recommendations generated following the different assessments performed at ECAC-wide and state level, in order to gather as much feedback as possible and ensure to the possible extent a wide awareness about the project proposals and a wide acceptance of the project results.

The project objectives are considered achieved from SESAR program perspective. It is recommended that the generated results are brought outside the programme, leading to a full deployment of a rationalized and PBN-optimized ground navigation infrastructure which should most probably be driven by state- and/or regional-wide initiatives.

Furthermore, Deliverable 07 of project 15.3.2 [11] contains guidance for the implementation of navigation infrastructure rationalization and evolution. This material should be made more accessible. Inclusion as guidance in standardization documents would be helpful.

In the area of A-PNT, the project has assessed the future role of DME and proposed a solid framework from the European side for further research concerning long term A-PNT.

2 References

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[4] SESAR 15.03.02, 15.03.02-D01-D1.0.Project Management Report, D01, Edition 00.01.00, 02/12/2014

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[9] SESAR 15.03.02, 15.03.02-D05-D1.4.A.Infrastructure Assessment of individual ECAC states, D05, Edition 00.01.00, 18/12/2012

[10] SESAR 15.03.02, 15.03.02-D06-D1.4.B.ECAC-Wide Navigation Infrastructure Assessment, D06, Edition 00.01.00, 10/06/2013

[11] SESAR 15.03.02, 15.03.02-D07-D1.5.Guidelines for Transition towards an Optimized Conventional Navigation Infrastructure, D07, Edition 00.02.00, 06/02/2015

[12] SESAR 15.03.02, 15.03.02-D09-D2.1.Coordination Report (Phase 2), D09, Edition 00.01.00, 08/04/2016

[13] SESAR 15.03.02, 15.03.02-D10-D2.2.Navaids Requirements in support of Performance Based Navigation (PBN) and Rationalisation- Consolidated Deliverable with Contribution of 15.03.07, D10, Edition 00.02.00, 28/01/2016

[14] SESAR 15.03.02, 15.03.02-D11-D2.3.Rationalisation Planning for ECAC-Consolidated deliverable with Contribution of 15.03.07, Edition 00.02.00, 28/01/2016

[15] SESAR 15.03.02, 15.03.02-D12-D2.4.A.A-PNT/DME Enhancement Analysis-Consolidated Deliverable with Contribution of 15.03.07 and 15.03.01, Edition 00.01.00, 13/04/2016

[16] SESAR 15.03.02, 15.03.02-D13-D2.4.B.A-PNT/Alternate Technology Options-Consolidated Deliverable with Contribution of 15.03.07 and 15.03.01, Edition 00.01.00, 20/04/2016

[17] ICAO Doc 9613, Performance-based Navigation (PBN) Manual, Fourth Edition, 2013

[18] ICAO Annex 10, Aeronautical Telecommunications, Volume 1, Radio Navigation Aids, Sixth Edition, July 2006

[19] Attachment H, "Strategy for Rationalization of Conventional Radio Navigation Aids and Evolution towards supporting Performance Based Navigation", Adoption of Amendment 90 to ICAO Annex 10, Volume I (Enclosure A), State Letter AN 7/62.2.1-16/23, International Civil Aviation Organization, Montreal, 4 April 2016

[20] Integrated Roadmap/Master Plan Dataset DS15, December 2015

[21] European Commission IMPLEMENTING REGULATION (EU) No 716/2014 on the establishment of the Pilot Common Project supporting the implementation of the European Air Traffic Management Master Plan, 27 June 2014

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