EUROPEAN ORGANISATION FOR THE SAFETY OF AIR NAVIGATION

EUROCONTROL

Navigation Sub-Group (NSG) of the ANT

NAVIGATION APPLICATION & NAVAID INFRASTRUCTURE STRATEGY FOR THE ECAC AREA UP TO 2020

Edition	:	2.0
Edition Date	:	15 May 2008
Status	:	Agreed by SCG/8
Issue Date	:	15 May 2008

EUROPEAN AIR TRAFFIC MANAGEMENT PROGRAMME

DOCUMENT CHANGE RECORD

Version	Pages Altered	Notes
Draft v 0.8	ALL	Restructuring of document presented to ANT in 2006
Draft v 0.9	ALL	Working Draft used at NSG Drafting Group
Draft v 0.11	ALL	Input received after ANT/45
Draft v 0.12	ALL	Comment Disposition from following ANT/45
Agreed by SCG-8	NONE	Document as approved by SCG/8

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DOCUMENT APPROVAL

The following table identifies all management authorities who have successively approved the present issue of this document.

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EXECUTIVE SUMMARY

In terms of both airspace and navigation, a striking evolution is envisaged from the navigation requirements serving today's fixed ATS route structure and those needed for 4D Business Trajectories identified as key requirement in the SESAR ATM Concept for 2020+. The development in navigation capability needed to realise the SESAR Concept is the final objective of the Navigation developments. However, given the considerable differences between today's Nav requirements and those of SESAR, it is not considered appropriate to implement this change in a single step. For this reason, an interim 2015 step is envisaged, and this step has been elaborated in the *2015 Airspace Concept and Strategy for the ECAC Area. The* Navigation Application and NAVAID Infrastructure Strategy addresses the provision of the navigation capability for both 2015 mid-term step and the SESAR ATM Target Concept for 2020+.

In responding to the mid-term airspace requirements of 2015, the Navigation Application and NAVAID Infrastructure Strategy aims to use navigation capability available at that time. In this way, the upgraded navigation capability in 2015 can be exploited at the same time gaining valuable experience which can be used in the realisation of the end goal of the navigation strategy, the SESAR ATM target concept of 4D Business Trajectories.

The strategy also addresses ICAO's Performance Based Navigation Strategy as agreed at the 36th ICAO Assembly in September 2007. It describes available and potential Navigation Applications and the means of supporting these applications, in terms of required performance, equipment functionality and enabling infrastructure. In identifying the NAVAID Infrastructure, the strategy takes due account of the ICAO Global CNS Concept and the EUROCONTROL GNSS Policy.

Navigation Application and NAVAID Infrastructure Strategy

The Navigation Application and NAVAID Infrastructure strategy is comprised of four Strategic Streams:

➢ **Stream 1: En route Navigation Applications** ➢ **Stream 2: Terminal Navigation Applications**	These streams envisage a phased improvement of navigation capability through a mid-term improvement of in 2015 as a step towards 4D Business Trajectories in 2020+. This mid-term navigation improvement will be embodied in the Advanced-RNP 1 specification to be incorporated in the ICAO PBN Manual. This will enable improved flight efficiency and capacity through the introduction of the Required Time of Arrival function (RTA), making it possible to meter traffic into terminal airspace. The Advanced-RNP 1 specification will also make it possible to reduce environmental impact by enabling the more precise design of routes in both the lateral and vertical planes.

➢ **Stream 3: Approach and Landing Navigation Applications**	This strategic stream will improve safety by increased use of Vertical Guidance on Approach, and the elimination of Non-Precision Approaches (NPAs) by 2016. Airport access, capacity and safety will be improved by the introduction of new technology which enables improved low visibility operations e.g. more generalised availability of Cat I/II/III precision approach through improved ILS, MLS and GBAS/GLS.

➢ **Stream 4: Evolution of NAVAID Infrastructure**	This strategic stream responds to the needs of the navigation applications. These applications, increasingly based upon RNAV principles, will be enabled primarily by the availability of GNSS with space and ground based augmentations. However, for safety and security reasons terrestrial navigation back up will remain but aids not contributing to the RNAV capability can be considered for rationalisation.

Implementation challenges, risks and issues

Realisation of the strategy is subject to various challenges, issues and risks.

The need for mandates, for example, could be challenging given the implied cost for some operators. Whilst the GNSS mandate anticipated for 2015 is needed to support ADS-B implementation, it is also needed to provide the integrity, availability and continuity for Advanced-RNP 1 (which is required to realise the Airspace changes envisaged in the 2015 Airspace Concept and Strategy). But a business case will be needed before any mandate is decided upon; this is crucial to ensuring stakeholder commitment.

If the mandate option is not exercised, e.g. for A-RNP 1 implementation, then a phased implementation is implied. This is problematic for ATC who find it difficult to manage mixed mode-operations and to maintain capacity, in the absence of adequate ATC system support, in many cases.

In NAVAID Infrastructure terms, the ability to remove NDBs when P-RNAV is widely implemented and, later, VOR's with the advent of A-RNP 1 may also prove to be an issue for service providers. As regards space-based technologies, a delay in the deployment of new GNSS constellations will impact upon the Navigation Application and NAVAID Infrastructure strategy.

Should it become impossible to defend the frequency spectrum needed to support the NAVAID Infrastructure, this will impact upon reversionary modes for some Navigation Applications which could limit or even prevent implementation of the ATM improvements set out in the Airspace Strategy.

Review

This document should be viewed as a living document, particularly in term of the availability dates identified for each of the Key Enablers. As such, it is essential that this document be reviewed every two to three years so that the strategic steps can be updated and refined.

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FOREWORD

Organisation and Contents

This document is identified as *The Navigation Application and NAVAID Infrastructure Strategy for the ECAC Area up to 2020 (Ed. 2.0 2008).* It is comprised of three Chapters and three Appendices.

The document has been structured as follows:

Chapter 1 – *Strategic Context*, places the strategy in the context of other Concepts and Strategies such as the 2015 ECAC Airspace Concept and Strategy, the Global ATM Concept and the SESAR ATM Concept for 2020+. As such, this chapter provides the framework necessary for the development of the Navigation Strategy.

Chapter 2 – *Navigation Strategy*, first describes the high level directions of the strategy and then details the Strategic Steps. At detailed level, the Navigation Strategy is comprised of two interrelated parts: *Navigation Applications* and *NAVAID Infrastructure.*

Chapter 3 – *Implementation Considerations*, is concerned with two of the options for implementing system enablers. In reviewing these two options, the knock on effect on Navigation Applications and the NAVAID Infrastructure (and their inter-relationship) is considered.

Appendix 1 – *Working Methodology,* provides a brief overview of how the Navigation Strategy was developed.

Appendix 2 – *Navigation Assumptions and Enablers of the 2015 ECAC Airspace Concept and Strategy* provides a replica of Navigation assumptions and enablers located at Appendix 2 of *The 2015 Airspace Concept and Strategy for the ECAC Area & Key Enablers*[1].

Appendix 3 – Implementation Planning, explains the various steps that have to be completed when planning for Implementation.

Document Context

This document replaces both the *EUROCONTROL Document NAV.ET1.ST16-001 Navigation Strategy for ECAC Edition 2.1 (March 1999)* and the *EUROCONTROL Document NAV.ET1.ST16-002 Edition 3.0, (24 May 2000) – Transition Plan for the Implementation Navigation Strategy in ECAC 2000-2015*, (TPINS). It updates and combines their contents.

This document is a consequence of an Airspace Strategy review and update undertaken during 2007 by the ANSO-TF[2] (Airspace and Navigation Strategies Orientation Task Force) on request of the EUROCONTROL Airspace Management and Navigation Team (ANT) as tasked by the SCG[1] (Stakeholder Consultation Group). It is also a consequence of a modified navigation 'context' that has emerged over the last few years with the development of ICAO's Performance Based Navigation concept and Strategy, the SESAR CONOPS for 2020+ and the EUROCONTROL GNSS Policy. This revised Strategy will be reflected in the ATM Master Plan and used to elaborate, as appropriate, implementation objectives for both European and Local Convergence and Implementation Plans (ECIP and LCIP)

[1] *For brevity, this document is referred to either in whole or in part as 'The 2015 Airspace Concept and Strategy' or the '2015 Airspace Concept' or 'Airspace Strategy (2008)'.*
[2] *The ANSO-TF, ANT and SCG reflect EUROCONTROL working arrangements in EATM.*

Responsible Body and Acknowledgements

This document has been developed under the auspices of the EUROCONTROL Navigation Sub-Group (NSG) of the Airspace Management and Navigation Team (ANT). The EUROCONTROL Agency wishes to acknowledge the valuable assistance received from the following stakeholders in the preparation of this document.

- Member States
- Military Representatives,
- International Council of Aircraft Owner and Pilot Associations (IAOPA),
- International Air Carriers Association (IACA),
- International Air Transport Association (IATA),
- International Civil Aviation Organisation (ICAO),
- the Association of European Airlines (AEA),
- the European Regions Airline Association (ERA), and
- the European Commission.

ASSOCIATED DOCUMENTATION

ICAO

ICAO, Annex 4 Aeronautical Charts

ICAO, Annex 6 - Operation of Aircraft, Part I – International Commercial Air Transport – Aeroplanes

ICAO, Annex 6 - Operation of Aircraft, Part II - International General Aviation - Aeroplane

ICAO, Annex 8- Airworthiness of Aircraft;

ICAO, Annex 10 – Aeronautical Telecommunications, Vol. I - Radio Navigation Aids

ICAO, Annex 11, Rules of the Air and Air Traffic Services

ICAO, Annex 15, Aeronautical Information Services

ICAO, Annex 17, Security;

ICAO, Procedures for Air Navigation Services, Air Traffic Management (PANS-ATM), Doc. 4444 ATM/501

ICAO, Global Navigation Satellite System Manual, Doc 9849

ICAO; Manual on Airspace Planning Methodology for the Determination of Separation Minima, Doc 9689

ICAO, Safety Management Manual, Doc 9859

ICAO, Procedures for Air Navigation, Aircraft Operations Volumes I & II (PANS-OPS), Doc 8168

ICAO, Manual on Testing of Radio Navigation Aids, Doc 8071

ICAO, Air Traffic Services Planning Manual, Doc 9426-AN/924

ICAO, Regional Supplementary Procedures for Air Traffic Management, Doc 7030

ICAO, Performance Based Navigation Manual, Doc 9613

ICAO, Global ATM Concept, Doc 9854

ICAO, Report of the 11th Air Navigation Conference (AN-Conf/11), Oct 2003

EUROCONTROL

EUROCONTROL, The 2015 Airspace Concept and Strategy for the ECAC Area and Key Enablers (Ed. 2.0, 2008)

Note: For brevity, this document is referred to either in whole or in part as 'The 2015 Airspace Concept and Strategy' or the '2015 Airspace Concept' or 'Airspace Strategy (2008)'..

EUROCONTROL, ATM 2000+ Strategy

EUROCONTROL, ECAC Navigation Strategy and Implementation Plan, version 6, July 2006 (Draft)

EUROCONTROL, Communication Strategy, Edition 5, 2006

EUROCONTROL, Surveillance Strategy, Edition 2.0, 2005

EUROCONTROL, ATC and Data Processing Strategy, 1999

EUROCONTROL, Guidance Material for the Design of Terminal Procedures for Area Navigation (DME/DME, B-GNSS, Baro-VNAV & RNP-RNAV), 2003

OTHER

RTCA, RNP-RNAV Minimum Aviation System Performance Standard, DO-236(B)

EUROCAE, RNP-RNAV Minimum Aviation System Performance Specifications; ED-75B

ARINC 424

RTCA, Standards for Processing Aeronautical Data, DO-200A

EUROCAE, Standards for Processing Aeronautical Data; ED-76

SESAR Concept of Operations, DLM-0612-001-02-00a - September 2007

RTCA, Minimum Operating Performance Standards for GNSS, DO-208

EUROCAE, Minimum Operational Performance Specification for airborne GPS receiving equipment used for supplemental means of navigation; ED-72A

RTCA, Standards for Aeronautical Information, DO-201(A)

EUROCAE, Standards for Aeronautical Information; ED-77

ABBREVIATIONS

ABAS Aircraft-Based Augmentation System

ADF Automatic Direction Finder

ADS-B Automated Dependent Surveillance-Broadcast

AEA Association of European Airlines

AIC Aeronautical Information Circular

AIP Aeronautical Information Publication

AMAN Arrival Manager

ANC (ICAO) Air Navigation Conference

ANSO-TF Airspace and Navigation Strategies Orientation Task Force

ANSP Air Navigation Service Provider

ANT (EUROCONTROL) Airspace Management and Navigation Team

APV Approach Procedure with Vertical guidance

ARN ATS Route Network

A-RNP1 Advanced RNP1

ASM Airspace Management

ATC Air Traffic Control

ATZ Aerodrome Traffic Zone

ATM Air Traffic Management

ATS Air Traffic Services

B-RNAV Basic RNAV

CBA Cost Benefit Analysis

CONOPS Concept of Operations

CDA Continuous Descent Approach

CDR Conditional Route

CDFA Continuous Descent Final Approach

CFIT Controlled Flight Into Terrain

CNS Communications, Navigation, Surveillance

CTA Control Area

CTR Control Zone

DMAN Departure Manager

DME Distance Measuring Equipment

DMEAN Dynamic Management of European Airspace Network

ERA European Region Airline Association

EASA European Aviation Safety Agency

EC European Commission

ECAC European Civil Aviation Conference

ECIP – European Convergence and Implementation Plan

EU European Union

EUROCAE European Organization for Civil Aviation Equipment

EUROCONTROL European Organisation for the Safety of Air Navigation

FMS Flight Management System

FOC Full Operational Capability

FOSA Flight Operational Safety Assessment

FPL Flight Plan

FRT Fixed Radius Transition

GAT General Air Traffic

GBAS Ground-based Augmentation System

GLONASS Global NAvigation SAtellite System

GLS GNSS Landing System

GNSS Global Navigation Satellite System

GPS Global Positioning System

HAZID Hazard Identification

IACA International Air Carriers association

IAOPA International Council of Aircraft Owner and Pilot Association

IAP Instrument Approach Procedure(s)

IATA International Air Transport Association

ICAO International Civil Aviation Organisation

IFR Instrument Flight Rules

ILS Instrument Landing System

INS Inertial Navigation System

IOC Initial Operational Capability

IP Implementation Package

IRS Inertial Reference System

IRU Inertial Reference Unit

LCIP Local Convergence and Implementation Plan

LNAV Lateral Navigation

LPV Localizer Performance with Vertical guidance

LVC Low Visibility Conditions

LVP Low Visibility Procedures

MLS Microwave Landing System

NATO North Atlantic Treaty Organisation

NAVAID(s) Navigation Aid(s)

NDB Non Directional Beacon

NPA Non Precision Approach

NSE Navigation System Error

OAT Operational Air Traffic

PA Precision Approach

PANS-OPS (ICAO) Procedures for Air Navigation – Aircraft Operations

PCA Prior Coordination Airspace

PBN Performance Based Navigation

P-RNAV Precision RNAV

PSR Primary Surveillance Radar

RAIM Receiver Autonomous Integrity Monitoring

RCA Reduced Coordination Airspace

RF Radius to Fix

RNAV Area Navigation

RNP Required Navigation Performance

RNP APCH RNP Approach

RNP AR APCH RNP Approach with Authorisation Required

RTA Required Time of Arrival

RTCA Radio Technical Commission on Aeronautics

RVSM Reduced Vertical Separation Minimum

R&D Research and Development

SARPS (ICAO) Standards and Recommended Practices

SBAS Satellite-based Augmentation System

SCG Stakeholder Consultation Group

SESAR Single European Sky ATM Research and Development Programme

SID Standard Instrument Departure

SSR Secondary Surveillance Radar

STAR Standard Arrival Route

TACAN – TACtical Air Navigation

TAS Terminal Airspace System

TMA Terminal Control Area

TPINS Transition Plan for the Implementation of the Navigation Strategy

TRA Temporary Restricted Area

TSA Temporary Segregated Area

UAS Unmanned Aerial Systems

VFR Visual Flight Rules

VLJ Very Light Jets

VNAV Vertical Navigation

VOR Very High Frequency Omni-directional Radio Range

xLS Any (**x**) of several PA **L**anding **S**ystems e.g. GLS, ILS, MLS

3D 3 dimensions (lateral, longitudinal and vertical)

4D 4 dimensions (lateral, longitudinal vertical and time)

GLOSSARY

Aircraft-Based Augmentation System (ABAS). An augmentation system that augments and/or integrates the information obtained from the other GNSS elements with information available on board the aircraft.

Note. - The most common form of ABAS is receiver autonomous integrity monitoring (RAIM)

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Airspace Concept: An Airspace Concept provides the outline and intended framework of operations within an airspace. Airspace Concepts are developed to satisfy explicit strategic objectives such as improved safety, increased air traffic capacity and mitigation of environmental impact etc. Airspace Concepts can include details of the practical organisation of the airspace and its users based on particular CNS/ATM assumptions. e.g. ATS route structure, separation minima, route spacing and obstacle clearance. *[PBN Manual, ICAO Doc 9613]*

Airspace Configurations – An Airspace Configuration refers to the pre-defined and co-ordinated organisation of ATS Routes of the ARN and/or Terminal Routes and their associated airspace structures (including temporary airspace reservations, if appropriate) and ATC sectorisation. Airspace Configurations are aimed at responding to differing strategic objectives (capacity, flight efficiency, environmental) at airspace network level. Airspace configurations result from improvements to the organisation of the airspace and Airspace Network Management.

Note: The notion of Airspace Configurations are included in the 2015 Airspace Concept and Strategy for ECAC member States,

Note: Airspace Configurations are an extension of the notion of airspace scenarios used in DMEAN. Airspace Configurations provide for a more integrated approach between airspace structures (including optimum trajectories and Terminal Airspace) and airspace network management with more flexibility in the latter. Furthermore, Airspace Configurations respond to more strategic objectives (they extend beyond demand and capacity balancing).

Airspace Structures – a generic term which includes Control Area (CTA), Terminal Control Area (TMA), Control Zone (CTR), ATS Route, Terminal Routes, ATC Sector, Conditional Route (CDR), Danger Area (D), Restricted Area (R), Prohibited Area (P), Temporary Segregated Area (TSA), Temporary Reserved Area (TRA), Cross-Border Area (CBA), Reduced Co-ordination Airspace (RCA) and Prior Coordination Airspace (PCA) *[Eurocontrol ASM Handbook]*

Approach procedure with vertical guidance (APV). An instrument procedure which utilizes lateral and vertical guidance but does not meet the requirements established for precision approach and landing operations.

ATS surveillance service. Term used to indicate a service provided directly by means of an ATS surveillance system.

ATS Routes of the ARN – ATS routes, other than standard departure and arrival routes, which are designated in accordance with the provisions of ICAO Annex 11, Appendix 1. *[The 2015 Airspace Concept and Strategy for the ECAC States (Ed. 2.0, 2008)]*

ATS surveillance system. A generic term meaning variously, ADS-B, PSR, SSR or any comparable ground-based system that enables the identification of aircraft.

Note.— A comparable ground-based system is one that has been demonstrated, by comparative assessment or other methodology, to have a level of safety and performance equal to or better than monopulse SSR.

Area navigation (RNAV). A method of navigation which permits aircraft operation on any desired flight path within the coverage of station-referenced navigation aids or within the limits of the capability of self-contained navigation aids, or a combination of these.

Note.- Area navigation includes Performance Based Navigation as well as other RNAV operations that do not meet the definition of Performance Based Navigation.

Area navigation route. An ATS route established for the use of aircraft capable of employing area navigation.

En Route Airspace – is a generic term describing airspace which is part of the airspace continuum. En route airspace encompasses ATS Routes of the ARN, ATC sectors and reserved and segregated airspaces. It includes all traffic operating within the airspace except Terminal

Airspace. *[The 2015 Airspace Concept and Strategy for the ECAC States (Ed. 2.0, 2008)]*

Note: The notions of en route and Terminal Airspace are introduced to assist the reader's understanding this strategy.

General Air Traffic (GAT) – encompasses all flights conducted in accordance with the rules and procedures of ICAO and/or the national civil aviation regulations and legislation. GAT can include military flights for which ICAO rules and procedures satisfy entirely their operational requirements.

Mission Effectiveness – a generic term related to meeting the objectives of a particular military sortie.

Mixed Navigation Environment: An environment where different navigation specifications may be applied within the same airspace (e.g. RNP 10 routes and RNP 4 routes in the same airspace) or where operations using conventional navigation are allowed together with RNAV or RNP applications. *[PBN Manual, ICAO Doc 9613]*

Navigation Aid (NAVAID) Infrastructure. NAVAID Infrastructure refers to space-based and or ground-based navigation aids available to meet the requirements in the navigation specification.

Navigation Function. The detailed capability of the navigation system (such as the execution of leg transitions, parallel offset capabilities, holding patterns, navigation data bases) required to meet the Airspace Concept.

Note: Navigational functional requirements are one of the drivers for selection of a particular Navigation Specification. Navigation functionalities (functional requirements) for each Navigation Specification can be found in Volume II, Parts B and C.

Navigation Specification. A set of aircraft and air crew requirements needed to support Performance based navigation operations within a defined airspace. There are two kinds of navigation specification: RNAV and RNP. A RNAV specification does not include requirements for on-board performance monitoring and alerting. A RNP specification includes requirements for on-board performance monitoring and alerting.

Navigation Application. The application of a navigation specification and the supporting NAVAID infrastructure, to routes, procedures, and/or defined airspace volume, in accordance with the intended Airspace Concept.

Note: The Navigation Application is one element, along with, communication, surveillance and ATM procedures meeting the strategic objectives in a defined Airspace Concept.

Operational Air Traffic (OAT) –encompasses all flights which do not comply with the provisions stated for GAT and for which rules and procedures have been specified by appropriate national authorities. OAT can include civil flights such as test-flights, which require some deviation from ICAO rules to satisfy their operational requirements.

Optimised trajectory - an ideal flight path, selected by an airspace user, which may not follow pre-defined ATS routes. *[The 2015 Airspace Concept and Strategy for the ECAC States (Ed. 2.0, 2008)]*

Performance Based Navigation. Performance Based Navigation specifies system performance requirements for aircraft operating along an ATS route, on an instrument approach procedure or in a designated airspace. Performance requirements are defined in terms of accuracy, integrity, continuity, availability and functionality needed for the proposed operation in the context of a particular Airspace Concept.

Note – Navigation Specifications such as RNAV 5, RNAV 1 etc., are defined in the PBN Manual Vol II.

Procedural control. Air traffic control service provided by using information derived from sources other than an ATS surveillance system

Receiver Autonomous Integrity Monitoring (RAIM): A form of ABAS whereby a GNSS receiver processor determines the integrity of the GNSS navigation signals using only GPS signals or GPS signals augmented with altitude (baro aiding). This determination is achieved by a consistency check among redundant pseudo-orange measurements. At least one additional satellite needs to be available with the correct geometry over and above that needed for the position estimation for the receiver to perform the RAIM function.

RNAV Operations. Aircraft operations using area navigation for RNAV applications. RNAV operations include the use of area navigation for operations which are not developed in accordance with the PBN Manual.

RNAV System: A navigation system which permits aircraft operation on any desired flight path within the coverage of station-referenced navigation aids or within the limits of the capability of self-contained aids, or a combination of these. A RNAV system may be included as part of a Flight Management System (FMS).

RNP Route: An ATS Route established for the use of aircraft adhering to a prescribed RNP Specification

RNP System: An area navigation system which supports on-board performance monitoring and alerting.

RNP Operations: Aircraft operations using a RNP System for RNP applications.

Satellite based augmentation system (SBAS). A wide coverage augmentation system in which the user receives augmentation from a satellite-based transmitter.

Standard instrument arrival (STAR). A designated instrument flight rule (IFR) arrival route linking a significant point, normally on an ATS route, with a point from which a published instrument approach procedure can be commenced.

Standard instrument departure (SID). A designated instrument flight rule (IFR) departure route linking the aerodrome or a specified runway of the aerodrome with a specified significant point, normally on a designated ATS route, at which the en route phase of a flight commences.

State Aircraft – Aircraft used in military, customs and police services.

Terminal Airspace – is a generic term describing airspace which is part of the airspace continuum. Terminal airspace surrounds an airport, and it is an airspace within which air traffic services are provided. It encompasses all the various terminologies currently used throughout the ECAC region. Such airspace predominantly contains traffic operating along Terminal Routes or, to a lesser extent, ATS Routes of the ARN. *[The 2015 Airspace Concept and Strategy for the ECAC States (Ed. 2.0, 2008)]*

[Explanatory note: The above description is aimed at including TMA, CTA, CTR, ATZ airspace classification or any other nomenclature used to describe the airspace around an airport].

Note: The notions of en route and Terminal Airspace are introduced to assist the reader's understanding this strategy.

Terminal (Arrival/Departure) Routes – is a generic term for any trajectory for arriving/departing traffic which may include STARs, SIDs and instrument approach procedures. Terminal Routes are usually designated in accordance with the provisions of Annex 11, Appendix 3 and PANS-OPS (Aircraft Operations, Doc 8168)

[EUROCONTROL Manual for Airspace Planning, Section 5: (Terminal Airspace Design Guidelines)].

CHAPTER 1
STRATEGIC CONTEXT

1.1. INTRODUCTION

The Navigation Application and NAVAID Infrastructure Strategy for the European Civil Aviation Conference (ECAC) Area described in Chapter 2 exists within the context of the ECAC operating environment and related Strategies and Concepts. Given the requirement for interoperability between ECAC and ICAO's various regions, the parent source of the strategic context is provided by ICAO. For similar (regional) reasons, strong links are forged at a Pan-European level between the Navigation Application and NAVAID Infrastructure Strategy for ECAC on the one hand and the SESAR ATM Target Concept for 2020+ on the other. Principles on which the Navigation Application and NAVAID Infrastructure Strategy for ECAC are based are derived from these various contexts.

1.2. THE ECAC ENVIRONMENT

Between 2008 and 2015, air traffic in the ECAC area is forecast to increase by over 30%. This will place more demands on the need to enhance the organisation and use of the European ATM network. Additional capacity will need to be delivered, flight efficiency improved and environmental impact reduced, while maintaining or improving safety of operations.

Managing a mix of aircraft equipage is a major ATM challenge for the ECAC Area

Air traffic diversity is expected to become more complex with the emergence of Very Light Jets (VLJs), Unmanned Aerial Systems (UAS) and the multi-task nature of military aerial missions. This will alter the aircraft performance mix of the airspace users and lead to additional diversity in the airspace user capability. The capability of the navigation system carried by this diverse user mix will also vary. At the high-end, equipment capable of providing three dimensional (3D) and some initial four dimensional (4D) control will become available in the 2015 period. Ultimately, greater 4D control will lead to the ability to undertake a fully integrated air-ground ATM with a portion of the fleet. At the same time, however, older generation aircraft included in the mix will have FMS/RNAV equipment having a more limited capability. State aircraft are also included: they need to be assured of access to airspace in cases where because of physical or mission constraints; they cannot fit the integrated navigation equipment available on the latest civil aircraft. This mix of aircraft capabilities – illustrated by the above 3D/4D discussion – applies equally to other phases of flight including approach and landing. This mix presents a challenge in providing improved ATM efficiency using the technological progress of the more advanced systems and catering for the lower capability aircraft.

Faced with these realities, the ECAC airspace will seek to maintain or improve safety levels while becoming more flexible and adaptable. At the same time, an effective balance between capacity, mission effectiveness, flight efficiency and environmental requirements will be sought whilst managing the ATM structure containing aircraft of mixed navigation capability. The role to be played by improved Navigation Applications, supported by a cost effective NAVAID Infrastructure, is vital to meeting these challenges.

Both the 2015 Airspace Concept and Strategy and the SESAR Concept of Operations address the above issues by proposing ATM changes that demand significant changes to existing navigation capability.

The existing navigation capability has been developed over a number of decades: ECAC has introduced RNAV operation en route and Terminal Airspace and significant operational benefits have been achieved. Each step has required the definition of new navigation functionality and its implementation onto the ECAC fleet. The interval between the definition of initial navigation functional requirements and their wide-spread use within the fleet can exceed 20 years. This demands that there be sufficient vision of expected future requirements and means of meeting these requirements that allow the required planning to be undertaken

Trade-Offs

Realising changes in navigation capability requires commitment from a wide range of stakeholders including aircraft operators, service providers and avionics and infrastructure manufacturers. Each stakeholder needs sufficient advance notice of requirements to ensure the timely implementation of changes. For the developments proposed for 2015 and beyond, there is an increasing interdependence of navigation capability with other developments in, for example, communication, Air Traffic Control (ATC) support tools, ATC System, meteorological information etc. Ensuring timely and synchronised availability of these components requires clear planning with sufficient lead time for the equipment developments to be achieved and the fleet to transition to the new capability in a cost effective manner.

Different user groups have diverse and sometimes conflicting needs and expectations. In order to satisfy the requirements of the entire aviation spectrum it will be necessary to make trade-offs between these conflicting requirements. Additionally, while a defined navigation capability has been identified as a requirement for achieving the desired change in ATM performance, the realisation costs will be prohibitive if a phased implementation is not possible – see Chapter 3. For this reason having sufficient lead times from the definition of requirement to the implementation will be critical to the ability to realise a cost effective transition.

1.3. RELATED CONCEPTS AND STRATEGIES

Whilst the ECAC operating environment provides the immediate operational context for the Navigation Application and NAVAID Infrastructure Strategy, the strategy needs to be aligned and rendered coherent with other concepts and strategies, some of which are broader in geographic and technical scope.

The Navigation Application & NAVAID Infrastructure Strategy for the ECAC Area has been developed to deal with these various aspects. It is also based on expressed operational requirements of a Gate-to-Gate approach. The Navigation Application and NAVAID Infrastructure Strategy also recognise the needs of the large variety of aircraft having different navigation capabilities, all seeking to achieve the optimum operational performance by exploiting the benefits of new and/or rationalised existing systems as early as possible.

1.3.1. ICAO'S GLOBAL ATM OPERATIONAL CONCEPT

The Global ATM Operational Concept, endorsed by ICAO 11th Air Navigation Conference (AN-Conf/11) and published as ICAO Doc 9854, provides the framework for the development of all regional ATM concepts. AN-Conf/11 also endorsed a number of technical recommendations affecting navigation, including the harmonization of air navigation systems between regions, frequency planning, the transition to satellite based air navigation, curved RNAV procedures, and the use of multiple GNSS signals and the rapid implementation of approaches with vertical guidance.

The ICAO Performance Based Navigation (PBN) Manual was developed in direct response to an AN-Conf/11 recommendation.

In September 2007, the ICAO 36th General Assembly issued resolutions urging States to:

- Complete PBN implementation plans by 2009;
- Implement RNAV and RNP operations (where required) for en route and terminal areas; and
- Implement approach procedures with vertical guidance (APV) (Baro-VNAV and/or augmented GNSS) for all instrument runway ends, either as the primary approach or as a back-up for precision approaches, by 2016 (with 30 per cent by 2010 and 70 per cent by 2014).

ICAO's PBN Concept provides a framework for Navigation Applications development in ECAC and ensures global interoperability

1.3.2. THE SESAR ATM TARGET CONCEPT

The ATM Target Concept proposed by the Single European Sky ATM Research Programme (SESAR) complies with the ICAO Global ATM Operational Concept. SESAR has identified three Implementation Packages (IP) to address short term improvements, the concept up to 2020 and long term goals post 2020. These IPs comprise operational improvements requiring P-RNAV in IP1, trajectory management and initial 4D in accordance with Master Plan available for operations from 2013 in IP2, and 4D trajectory contract in IP3, as well as safety and capacity improvements at aerodromes in low visibility conditions. These are supported by various navigation enablers including advanced avionics and the transition to GNSS as the primary navigation system.

Links with SESAR Implementation Packages

Almost each element of the Navigation Application and NAVAID Infrastructure Strategy paves the way for those aspects of the SESAR Target Concept that rely upon Navigation. Strong links therefore exist between the Navigation Application and NAVAID Infrastructure strategy and SESAR's Implementation Packages –

- SBAS (Satellite-Based Augmentation System) becomes available for suitably equipped aircraft to enable increased access to medium and smaller airports in the 2008-2013 time frame (see Strategic Steps 7 & 8);
- GBAS (Ground-Based Augmentation System) becomes available using GPS L1 for some users in particular operating environments in the 2008-2013 time frame (see Strategic Steps 11 & 12);
- 4D contract is foreseen for 2020+ (see Strategic Step 4);
- The requirement for Advanced-RNP 1 (A-RNP 1) with Required Time of Arrival (RTA) capability is a step towards 4D trajectory management in SESAR, even though this intermediate step is not explicitly accounted for in SESAR (see Strategic Step 3);
- Extended use of P-RNAV and RNAV for approach as a means of transitioning from permanent routes through Conditional Routes to SESAR Business/Mission Trajectories;
- Move towards GNSS becoming the prime positioning source for all phases of flight using Galileo/GPS, GBAS and SBAS is consistent with the SESAR 2009-2015 time frame;
- The continued provision of DME as a backup to GNSS is consistent with SESAR;

- Replacement of Non-Precision Approaches by approaches with vertical guidance up to 2016;

An interim step is needed between RNAV 5/ P-RNAV and SESAR's Business Trajectories

- Evolution of improved low visibility operations using GBAS to support CAT II and III operations with GPS L1 (see Strategic Step 11) then with multi constellation (see Strategic Steps 12 & 13) in the period up to 2015;
- The progressive decommissioning of VORs and NDBs made possible by the use of GNSS is aligned with SESAR time scales;
- Mandate for GNSS carriage in the 2015 time frame is fully aligned with SESAR.

A step to SESAR's Business Trajectory

The 4D Business/Mission trajectory capability defined by SESAR is the ultimate goal of the Navigation developments of the Navigation Applications and NAVAID Infrastructure Strategy. This goal needs to be viewed in light of the potential for its realisation in the proposed timescales. Experience gained with the Required Time of Arrival (RTA) capability now being introduced into the latest FMS has identified some of the limitations to existing time control methodologies. As such, developments of this RTA capability (as identified in the SESAR ATM Capability Level 2) are needed before it will be possible to realise a full 4D contract which will allow benefits to be derived by the precise planning and control of trajectories. This said, the capabilities presently being installed in aircraft will already provide benefits if correctly used. As such, it is considered inappropriate to await the availability of full 4D Contract capability before a change is made to the existing P-RNAV/RNAV 5 requirements.

Reasons for this include:

- Delays to obtaining benefits
- The change in requirements is too large to be assimilated in a single step

The developments in navigation envisaged in the SESAR Target concept and elaborated in the 2015 ECAC Airspace Concept and Strategy (see below) will need transition measures to accommodate aircraft with lower navigation capability, including State aircraft. The transition from equipment-based solutions to performance oriented options will need to enable, to the extent possible, the re-use of available avionics and existing airborne architectures.

1.3.3. THE 2015 ECAC AIRSPACE CONCEPT & STRATEGY

The ECAC Airspace Concept has been developed as an evolutionary step towards SESAR up to 2015. It describes how the 2015 ECAC Airspace Concept will be achieved using four strategic streams: Terminal Routes and Structures, ATC Sectors, ATS Routes and Other Structures, and Airspace Network Management. The key navigation enablers identified necessary to realise this Concept's Airspace Configurations are *RNAV-5, P-RNAV, Advanced-RNP 1, RNP APCH, RNP AR APCH, and LPV*. Low Visibility Approach and Landing applications are outside the scope of the 2015 Airspace Concept and Strategy for the ECAC Area, but need to be addressed in this strategy. They form part of strategic stream for approach and landing and the infrastructure requirements (e.g. ILS and DME) are detailed in the NAVAID Infrastructure implications.

The 2015 Airspace Concept and Strategy anticipates that airspace changes up to 2015 will provide the following benefits:

- **Safety** (by maintaining sector loads at reasonable level through optimised sector configurations, de-conflicting ATS routes, etc..
- **Capacity** (through the maximum exploitation of airspace resources, not constrained by national boundaries, the creation of optimised routes, reduced conflict points, optimised sector design, optimum sector configurations, etc.)
- **Flight efficiency** (by the use of optimised trajectories in specific areas or implementation of more direct routes, for example);
- **Environmental impact** (reduced through measures aiming at improving flight efficiency).

1.3.4. EUROCONTROL'S POLICY ON GNSS

The gradual transition to RNAV is the cornerstone of the ECAC Navigation Strategy from a Navigation Application perspective. The continuous enhancements of the GNSS components have the potential to allow the use of satellite navigation for the most demanding of these Navigation Applications. It will also enable the rationalisation of the conventional NAVAID Infrastructure. The EUROCONTROL policy on GNSS establishes a common vision for this transition within the aviation community taking into account operational, technical, economical, safety and security issues.

1.3.5. EUROCONTROL'S ENVIRONMENTAL POLICY & STRATEGY

The EUROCONTROL Environmental Policy and Strategy pledges to mitigate, as much as possible, the environmental impacts of all new CNS/ATM developments, as well as to launch initiatives to reduce current emissions. This includes, inter alia, more effective air traffic operations to reduce or limit the ATM-related impact of noise and gaseous emissions in the airport vicinity, as well as tools and practices to optimize flight profiles.

1.4. PRINCIPLES

It is possible to derive broad principles from the operational requirements sourced in the ECAC operating environment as well as related concepts and strategies discussed above.

Firstly, the Navigation Application and NAVAID Infrastructure Strategy are required to support the requirements detailed in the ICAO Global ATM Operational Concept, the SESAR Target Concept as well as the 2015 ECAC Airspace Concept. As such, the Navigation Strategy must lay the foundations for achieving the long term SESAR goals of User Preferred Trajectories (RNAV, 3D-RNP and 4D-RNP applications) together with improved access, safety and all weather operations through application of xLS (See Strategic Steps 9-13) ; as well as.

In accordance with the EUROCONTROL GNSS Policy, GNSS will become the primary, and potentially a sole means of navigation, to the degree that this can be demonstrated to be safe and cost effective. In addition, the strategy needs to provide optimum solutions in line with the GNSS and Environmental policies. In this context, is it necessary to coordinate the development of navigation avionics.

Secondly, given the need for Navigation to increasingly co-exist with satellite-based Surveillance and for Communication services to be critical to the implementation of the new Airspace Concept, the navigation strategy is also required to identify enablers and dependencies that will be required from the COM, SUR and ATM strategies. These include data link and ATC tools necessary to achieve the required system performance and functionality.

Thirdly, with explicit reference to supporting the 2015 ECAC Airspace Concept and Strategy as well as the SESAR ATM Target Concept, the following specific aims/principles are of relevance:

- to identify, and evolve from, the needs and priorities of both users and providers of the navigation systems and/or services;
- to provide tangible and early benefits for the users;
- to safeguard capital investments, necessary to maintain the existing NAVAID Infrastructure, in future rationalisation plans;
- to take due account of sub-regional institutional arrangements and legal regulations;
- to accommodate geographical differences in capabilities, performance requirements, and in the existing and required infrastructure;
- to enable coherent development plans to be made, both within ECAC and with adjacent regions;
- to accept the continued operations of aircraft with lower navigation capabilities for as long as operationally feasible or a mandate is implemented – see Chapter 3;
- within the context of an agreed exemption policy, to continue to provide unrestricted access to the entire ECAC airspace to Military users. To this end, it is necessary to develop procedures and maintain the supporting infrastructure to accommodate these flights, recognizing that whilst civil-military interoperability solutions will be sought, it may not be possible for GAT to comply fully with ICAO IFR or individual national aviation rules.

The evolution of Navigation systems must follow a benefit-driven approach.

In general terms –

- The Strategy must remain sensitive to the evolution of the needs and priorities of both users and providers of the navigation systems and/or services, and the consequences and benefits of the available system options, as they emerge during the period of validity of the Strategy.
- The evolution of navigation systems must follow a benefit-driven approach. European States may need to use different transition arrangements and to implement systems based on local requirements; however they will have to be developed in on-going consultation with the users and should provide tangible and early benefits. The demonstration of achievable benefits will encourage the agreement and commitment of the users. Furthermore, it will help the smooth transition to new systems and will minimise the period for which it will be necessary to support both existing and new functionalities, with consequential reduction in supporting costs.

The Navigation Application and NAVAID Infrastructure Strategy for the ECAC Area supports SESAR's Target Concept for 2020+

- Navigation systems, as well as communications and surveillance systems, rely heavily on the availability of a suitable **radio spectrum**. Competing commercial interests outside the aviation industry are acquiring increasing allocations of this valuable resource. Currently aviation interests have little influence over this allocation process as decisions are made by organisations that are not part of the aviation industry. To ensure that sufficient segments of the frequency spectrum are preserved and protected for aviation use it is essential that Navigation Applications and their requisite infrastructure are planned and the requirements fully defined, supported by the appropriate political initiatives. This need was recognised in the Report of the Eleventh Meeting of the ICAO Air Navigation Commission (AN-Conf/11 – Sep-Oct 2003).

- **Interoperability** with adjoining ICAO regions and States within those regions must be assured. As such, The RNAV/FMS functionality required for operation in ECAC will need to be coordinated with that required for operation in other areas/regions where advanced system functionality is required. This will allow cost effective implementation of navigation capability for those aircraft which operate both within and outside of the ECAC area.

1.5. BENEFITS

Given the above strategic context and the role of the Navigation Application and NAVAID Infrastructure strategy to provide consistency with other concepts and strategies, the following benefits can be identified:

- Safety (the gradual elimination of Non-Precision Approaches by 2016 will reduce the potential for Controlled Flight into Terrain)– See Strategic Step No 1f, in Chapter 2;
- Capacity (through the maximum exploitation of RNAV and RNP in en route and Terminal Airspace) – See Strategic Steps Nos 2 & 3 in Chapter 2;
- Flight efficiency (by the use of optimised trajectories enabled by RNP and 4D contract) – See Strategic Step Nos 3, 4, & 6, in Chapter 2;
- Environmental impact (reduced through the improved placement of routes using RNAV and RNP) – See Strategic Step Nos 3, 4, & 6, in Chapter 2;
- Mission effectiveness (improved through the accommodation of aircraft with lower navigation capability for as long as operationally feasible) – see Principles, above;
- Airport Access (improved operations through the more generalised availability of Cat I/II/III precision approach (e.g. improved ILS operations, MLS and GBAS/GLS) and the provision of LPV and RNP APCH giving lower minima – see Strategic Steps Nos 5-13 in Chapter 2;
- Interoperability with other ICAO regions and within the ECAC Area;

ANSPs and airspace users will also benefit from the Navigation Applications and NAVAID Infrastructure Strategy. For ANSPs, the roadmap for rationalising the ground-based NAVAID infrastructure provides the potential for investment planning and reduction of costs.

When appropriate, airspace users will be offered better flight profiles and routeing options enabled by RNAV and RNP. This will benefit the environment in terms of noise mitigation, fuel burn and emissions and enhance mission effectiveness for military users.

Where possible, the use of optimised trajectories, enabled by RNAV and RNP will permit airspace users to choose the most efficient trajectory as a means of satisfying their particular requirements.

CHAPTER 2

THE ECAC NAVIGATION STRATEGY

2.1. OBJECTIVES AND SCOPE

Within the Strategic Context described in Chapter 1, the objective of this Navigation Application & NAVAID Infrastructure Strategy is to provide a harmonised and integrated common framework that will allow a cost-effective, customer-oriented evolution of the European ATM system. This framework will support the operational improvements outlined in the 2015 ECAC Airspace Concept and Strategy as well as the SESAR Operational concept. The Strategy therefore provides the basis for:

- The development of ECAC Navigation Applications and supporting NAVAID Infrastructure;
- The rationalisation, integration and harmonisation of existing and new air navigation systems;
- The rationalisation of the NAVAID Infrastructure needed to ensure the safe and effective implementation of Navigation Applications.

The strategy addresses General Air Traffic (GAT) operations under ICAO Instrument Flight Rules (IFR) within ECAC airspace. This includes the en route, terminal area, approach and landing phases of flight together with take-off guidance.

The evolution of the ECAC NAVAID Infrastructure will be closely tied to the selection of the Navigation Applications and to the implementation of the Strategy – see Chapter 3. This evolutionary process may affect non-IFR operations, which have traditionally taken advantage of the infrastructure provided for GAT IFR operations. Consequently this strategy may impact upon non-IFR operations in the future European air navigation environment where the NAVAID Infrastructure presently supporting Visual Flight Rules (VFR) operations are no longer supported.

The Navigation Application & NAVAID Infrastructure Strategy recognise that Military users of the ECAC airspace carry out operations that may not fully meet the requirements set out in the Strategy for GAT operations. However, interoperability solutions enabling their unrestricted access to the entire airspace will continue to be addressed.

The Navigation Strategy for the ECAC Area is comprised of two inter-related parts:

- **Navigation Application**; and
- **NAVAID Infrastructure**.

The Navigation Strategy contained in this Chapter is comprised of four diagrams:

- Figure 2-1 provides the Navigation Strategy – *Generic* Roadmap aimed at conveying the intent of the four **Strategic Streams.** The vertical grid denotes the years;
- Figure 2-2 shows the Navigation Strategy – *Generic* Roadmap with its *Strategic Steps included.*
- Figure 2-3 depicts the *Detailed Roadmap* of the Navigation **Applications**
- Figure 2-4 depicts the *Detailed Roadmap* of the NAVAID **Infrastructure**

Note: Whilst Strategic Streams are equivalent to Operational Improvements in the SESAR Framework, Strategic Steps are equivalent to Operational Improvement Steps.

2.2. STRATEGIC STREAMS OF THE NAVIGATION STRATEGY

The implementation of any future concept and the achievement of associated benefits will not be possible without a significant improvement in aircraft navigation performance across the majority of the ECAC fleet. The Navigation Strategy reflects this reality with its four Strategic Streams covering the evolution of navigation developments up to 2020. Each Strategic Stream (with its associated steps) is an integral part of the total strategy.

To facilitate understanding of these Strategic Streams and their interactions, an overview of each strategic stream is provided:

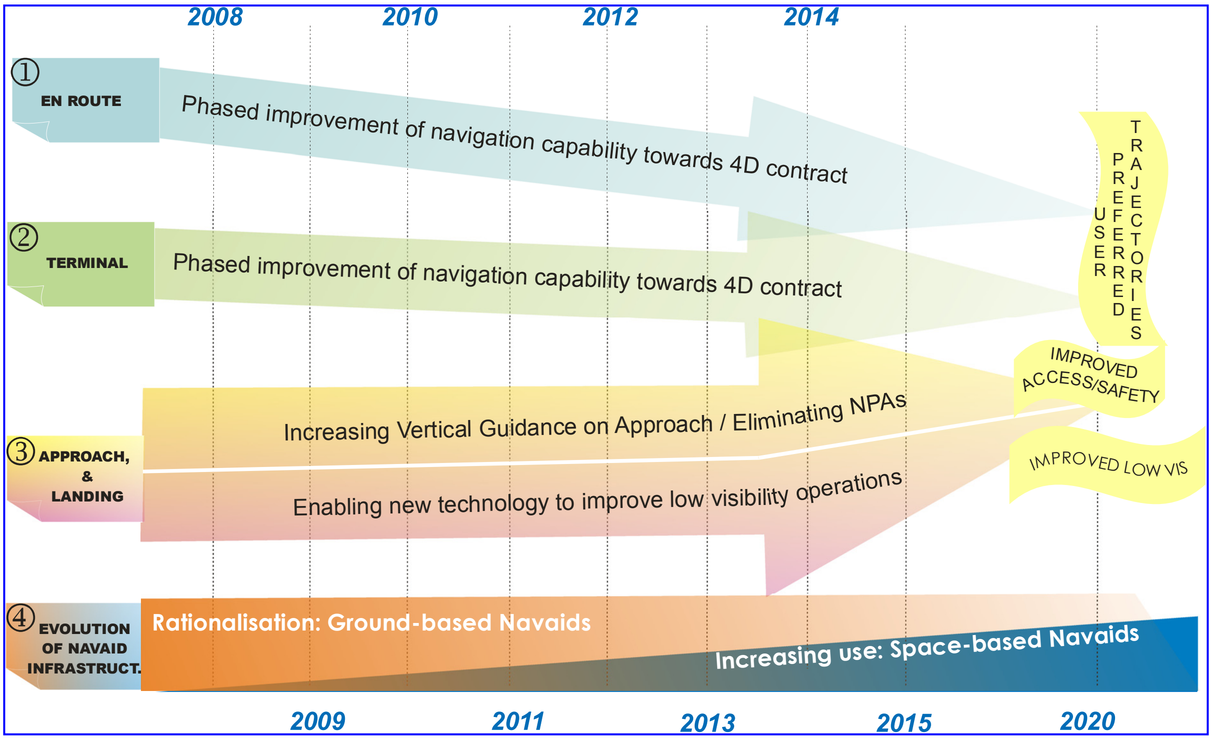

Figure 2- 1: Generic Roadmap of Navigation Strategy

2.2.1. RATIONALE FOR STRATEGIC STREAMS 1 & 2

At present the carriage of RNAV 5 (previously B-RNAV) is mandated, above a defined minimum Flight Level for en route IFR operations in ECAC. RNAV systems meeting the P-RNAV capability are needed for RNAV arrival and departure operations in terminal airspace. There is however no RNAV mandate for terminal airspace and a large proportion of published instrument flight procedures in ECAC as well as SIDs and STARs only require a conventional navigation capability supported by VOR or NDB.

The percentage of aircraft operating in ECAC approved for P-RNAV is increasing, reaching 80-90% in many terminal airspaces. This enables States and airport operators to publish P-RNAV arrival and departure procedures and to reconfigure the terminal airspace to provide more efficient operations. This process will continue in the period to 2015 and might involve the requirement for P-RNAV approval in certain airspace. This could result in a significant reduction, or even the removal, of the ability to operate in some terminal airspaces without the P-RNAV approval.

In the post 2015 period the introduction of more demanding airspace systems will be the catalyst for the next step in RNAV applications. The need for closely spaced parallel route together with the parallel offset capability with spacing maintained during the turn will demand new RNAV/FMS functionality. The degree of reliance upon RNAV is expected to reach a level where Advanced RNP capability will be required for both arrival and departures (i.e. A-RNP 1).

The long term SESAR Target Operations for 2020+ calls for 4D Business Trajectories. While 4D contracts are foreseen only beyond the 2020 timeframe, FMSs are already being delivered with a Required Time of Arrival capability. The 2015 Airspace Concept and Strategy identifies the need to use RTA in the en route to support the revised airspace system post 2015. The present RTA accuracy is somewhat limited in the descent although new software versions being released by the FMS manufacturers are gradually overcoming these limitations. Application of the enhanced RTA functionality as a step towards a full 4D capability is expected to bring operational benefits in 2015-2020 timescale.

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2.2.2. RATIONALE FOR STRATEGIC STREAM 3

Strategic Stream 3 has two parts; the first aims at enabling different types of approaches based on RNAV; the second addresses precision approach and landing operations based on alternatives to the current standardised Instrument landing System (ILS).

2.2.2.1. RNAV APPROACH CAPABILITY

The RNAV approach operations are directed towards extending the application of Streams 1 and 2 (which provide an RNAV capability from en route and TMA down to the Final Approach Fix (FAF)) to RNAV operations with vertical guidance to decision height, replacing conventional non-precision approach. These will be enabled by increased use of satellite navigation in line with the GNSS policy whilst providing:

- Better access to airports enabled by lower operating minima than conventional Non Precision Approach (NPA) Procedures;
- Increased safety by the provision of vertical guidance for the final approach;
- Greater flexibility for route design;
- Increased capacity at airports;
- Improved airport access

Precision approaches are the safest and practically all aircraft are equipped with ILS. However, it is not economically viable or even practically possible to install ILS equipment at all runway ends. There are also many occasions when ILS systems are out of service due to maintenance or airport works requiring alternative approach procedures to be available. Conventional NPA usually provide this backup solution, but this usually degrades airport accessibility due to significantly higher minima. Implementing RNAV approaches with vertical guidance would provide an improvement compared to conventional NPA procedures, both in terms of safety and in terms of airport accessibility. LPV procedures (Localizer Performance with Vertical Guidance), providing ILS localiser lateral precision, and RNP AR APCH may also serve to enable independent parallel approaches during ILS outage where this would not be possible when NPA procedures are employed to replace ILS. The US version of SBAS has demonstrated performance and has a monitoring environment sufficient to enable LPV implementation with a 200 ft decision height. Once experience has been gained with EGNOS operations, it is expected that the achieved performance will allow similar operations.

(a) Lateral guidance

Greater flexibility and typically improved lateral accuracy make RNAV approaches favourable for a more complex airport environment, where either obstacle issues or environmental constraints limit the application of conventional procedures.

In addition, RNAV approaches can easily be implemented at all runway ends on an airport at low cost from the Air Navigation Service Providers (ANSP) point of view and provide safe approach capability to runways ends which have no instrument approach published today.

(b) Vertical guidance

The primary benefit of RNAV Approaches is increased safety because continuous descent guidance is provided to the aircrew. This makes the approach easier to fly and reduces chances of controlled flight into terrain (CFIT), by avoiding dive and drive approaches.

Continuous descent final approaches (CDFAs) also offer environmental benefits compared

to 'step-down' descents, in terms of reduced noise and fuel use.

Reductions in minima with respect to conventional NPA procedures may also be achievable, in particular through APV with geometric vertical guidance, which can allow successful approaches in conditions that would otherwise cause a disruption event (delay, diversion or cancellation).

ICAO Assembly Resolution

It is well recognised throughout the community that the introduction of RNAV approaches with vertical guidance provides safety benefits. ICAO issued a resolution at the 36th Assembly meeting held in September 2007 encouraging States to implement approach procedures with vertical guidance at all runway ends. Any of the APV types of approach (APV-Baro/VNAV or SBAS APV) can be implemented to conform to this recommendation.

2.2.2.2. Landing (Precision Approach) Capability

Instrument Landing Systems (ILS): ILS systems currently provide a very efficient service today for precision approach and landing operations globally. As such, it is recognised that there will not be a rapid transition from ILS to GBAS and that an ILS network will be maintained for the foreseeable future. However, ILS systems are facing some problems in terms of multi path effects, dimension of the sensitive areas and radio spectrum constraints that are becoming progressively more critical. This is particularly the case in ECAC where airport infrastructure expansion is rapid and the requirement and density of Cat II/III operations is the highest in the world. In these cases, GBAS and MLS are potential replacement candidates.

Microwave Landing System (MLS): Where the levels of service of ILS Cat III cannot be maintained, MLS is considered a candidate to replace ILS Cat III in the timeframe 2008-2015 and therefore provide early low visibility capacity benefits.

Ground-Based Augmentation System (GBAS): GBAS has the capability to provide increased capacity by supporting more advanced operations such as:

- Allowing for enhanced flexible approaches in a seamless way, such as high performance RNP approaches and multiple approaches to a single runway (linked to advanced controller aids).
- Increasing flexibility of airport runways by enabling precision approach at all runway ends of an airport simultaneously.
- Maintaining airport throughput during low visibility operations.
- Increasing closely spaced parallel approach availability

The implementation of GBAS will not see a rapid replacement of ILS but can be economically viable and operationally acceptable on a local basis for an increasing number of airports and airspace users based on the progressive developments over the next few years.

GBAS Cat I stations are considered to be an interim step towards the development of GBAS Cat II/III stations. It is expected that GBAS standards and developments will ultimately support Cat II/III operations based on the combined use of signals coming from different constellations (i.e. GPS, Galileo and GLONASS). Current developments at technical and standardisation level are aimed at achieving Cat II/III capabilities based on GPS with only one frequency (L1) augmented by additional airborne and ground capability. In this case, provisions to allow the transition from current developments to a multi-constellation scheme should be made as it will enable a more generalised achievement of Cat II/III capability.

Airborne related cost is one of the key drivers in the transition from ILS to GBAS. To limit that cost to the airlines, the “standard fit" avionics package will have to include GBAS. This will be especially efficient if GBAS is to enable non ILS look alike operations (e.g. RNP). It was initially expected that just a few aircraft would be retrofitted with GBAS equipment but the number of retrofit will largely depend on the retrofit avionic package definition and the associated cost. Where forward fit has occurred GBAS cost have been relatively low; it is expected that this will be maintained once all commercial aircraft manufacturers offer GBAS capability as standard equipment.

It is expected that there will be an increasing but, in the timescale of this strategy, still limited application of Enhanced Vision Systems (EVS) and Synthetic Vision Systems (SVS) to provide increased operational capability.

2.2.3. RATIONALE FOR STRATEGIC STREAM 4

Note – This Strategic Stream effectively enables Strategic Streams 1-3 whilst simultaneously reflecting the impact on the NAVAID Infrastructure, on Strategic Streams 1-3 (for a discussion on the relationship between Navigation Applications and NAVAID Infrastructure, see Chapter 3).

GNSS offers the basis for a source of positioning information capable of being to be used for all phase of flight. The EUROCONTROL policy on GNSS envisages a gradual reliance on Satellite navigation towards its use as a sole navigation service, provided that this can be shown to be the most cost beneficial ATM solution and that safety and security requirements are met.

The vision for implementing this policy is based on the combined use of signals coming from at least two constellations each with diverse radio frequencies. User receivers will process signals from different GNSS constellations in combination with augmentations (e.g. ABAS, SBAS depending on individual business cases, mission requirements and the phase of flight).

The positioning accuracy provided by basic GNSS (GPS) exceeds that of any terrestrial navigation signal used for area navigation and provides this capability globally. Nevertheless GPS does have limitations to its use primarily caused by risks associated with continuity of service . In addition whilst its susceptibility to jamming is no worse, and in some aspects less than that of terrestrial systems, the impact of such jamming could be greater. Space and ground based augmentations will enhance accuracy and availability but will not remove the susceptibility to jamming whether from deliberate actions or solar events.

A single-constellation single-frequency (ie GPS) signal, results in potential for common mode failures which could affect large parts of airspace. This limits the reliance that can be placed upon GNSS as a sole service application. The modernisation of GPS and GLONASS and the expected availability of Galileo from around 2015 would overcome many of the fundamental limitations of today’s GPS.

The expected availability of nearly 60 satellites (from GPS and GALILEO), transmitting on two frequencies (with potentially more than 80 if GLONASS becomes fully operational) will provide a very robust system with high redundancy and accuracy and with full time availability of internal airborne integrity validation. A multi-constellation and multi-frequency GNSS environment will address most of the concerns related to common mode failure, reduce the risk of accidental jamming and improve ionosphere characterisation at receiver level.

The impact of GNSS Signal in Space failures upon ATM is more critical than the impact of failures of individual terrestrial Navaids due to the size of the airspace that could be affected. Studies show that intentional interference (i.e. jamming) and the effect of the solar activity on the GNSS signals are two major obstacles for the achievement of sole–service concept. Whilst initial simulations have demonstrated that ATM mitigation methods can be applied successfully, it remains to be proved that these measures can be universally applied.

The extensive use of Aircraft Based Augmentation Systems (ABAS) including inertial systems will mitigate the consequences of GNSS failures, in particular for en route and terminal operations. A trade-off based on safety, security, economic, operational aspects and the effectiveness of the mitigation measures, and ATC workload in the event of a GNSS services failure will define the best balance between the ATM required level of GNSS robustness and the size of backup ground-based backup network (e.g. number of DMEs and ILSs) that would be needed in the long term considering also the ATC workload in the event of a GNSS services failure.

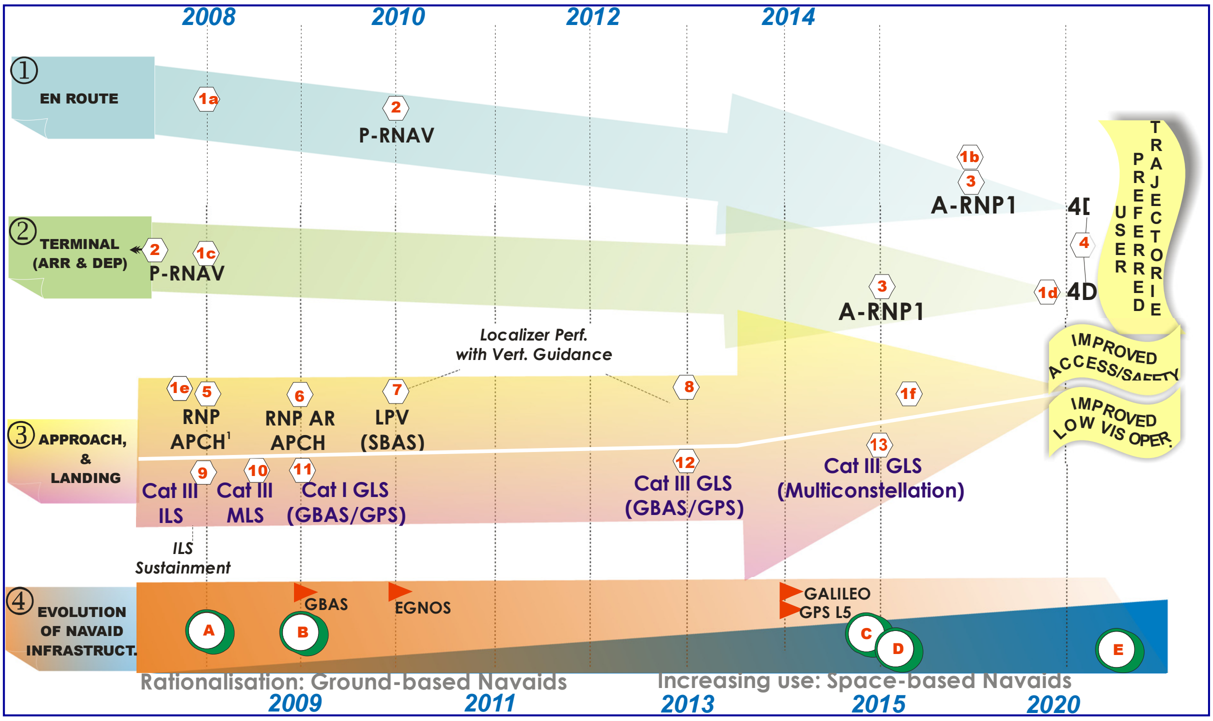
Whilst initial risk analysis and mitigation evaluation have identified that the impact of GNSS failures over a wide area can be effectively managed by ATM, operational experience will be needed as part of the process of confirming these results before any move can be made to a total GNSS environment

2.3. STRATEGIC STEPS OF THE NAVIGATION STRATEGY

The Navigation Apploication and NAVAID Infrastructure strategy is made up of 18 strategic steps: 13 of these are related to navigation applications, whilst the remaining five steps pertain to the NAVAID Infrastructure.

These steps are illustrated in Figure 2-2 on the next page.

Figure 2- 2: Generic Roadmap of Navigation Strategy with Strategic Steps



Note: With the exception of Steps 1b/1d/1f and Steps 2 & 3, all dates related to above Steps are for initial operations (IO).

Reading the Tables at paragraphs 2.3.1 & 2.3.2 and 2.4 (following pages)

S/ Stream	S/ Step	w.e.f / By	Explanation of Strategic Step Enabler & Associated NAVAID Infrastructure, where applicable)
③	6	2008	**Sustainability of Precision Approach Operations based on ILS Cat III** *Enabler: ILS*

Strategic Stream 3 = Approach & Landing

Number of Strategic Step (matches Steps in Figure 2-2)

With Effect From *i.e. Date of initial implementation*
By *i.e. Date of withdrawal of capability.*

Explanation of Strategic Step, Enabler & Associated NAVAID Infrastructure, where applicable.

Note – The implication of w.e.f depends on the implementation concept. In the case of a mandate, the w.e.f date is the date on which the mandate becomes applicable. Alternatively, if implementation is phased, then the w.e.f is the date by which sufficient aircraft equipped for operation to be viable; this corresponds with the Airspace Strategy's "Implementation From" Date identified on that Strategy's detailed Roadmap – See Chapter 2 of The 2015 Airspace Concept and Strategy for the ECAC Area & Key Enablers (Ed. 2.0, 2008).

2.3.1. STRATEGIC STEPS: NAVIGATION APPLICATIONS

S/ Stream	S/ Step	w.e.f	Explanation of Strategic Step Supporting Systems & Cross-Reference to associated NAVAID Infrastructure, where applicable
①	1a	2008	**Gradual Elimination of remaining Conventional Routes, replaced by RNAV or RNP routes** *Enabler: RNAV 5; P-RNAV, A- RNP 1*
In the existing B`-RNAV environment in ECAC, the retention of conventional routes/navigation aids is necessary to provide a reversionary capability for those aircraft equipped with a single RNAV system. In the future, the progressive implementation of P-RNAV and A-RNP1 operations will require that all aircraft carry dual RNAV systems as conventional navigation aids will be unable to satisfy the navigation performance requirements. Consequently the conventional route structure will be gradually withdrawn.			
S/ Stream	S/ Step	By	Explanation of Strategic Step Supporting Systems & Cross-Reference to associated NAVAID Infrastructure, where applicable
①	1b	2017	**All Conventional Routes discontinued** *Enabler: P-RNAV A- RNP 1 & dual systems; S/Step A*
When all aircraft are equipped with dual RNAV systems and are operating in a P-RNAV, or better, environment, it will be possible to withdraw all of the conventional route structure.			
S/ Stream	S/ Step	w.e.f	Explanation of Strategic Step Supporting Systems & Cross-Reference to associated NAVAID Infrastructure, where applicable
②	1c	2008	**Gradual Elimination of Conventional arrival and departure Procedures, replaced by RNAV or RNP procedures.** *Enabler: P-RNAV; S/Step A*
See the rationale in Strategic Step 1a above.			
S/ Stream	S/ Step	By	Explanation of Strategic Step Supporting Systems & Cross-Reference to associated NAVAID Infrastructure, where applicable
②	1d	2020	**All Conventional arrival and departure Procedures discontinued** *Enabler: A- RNP 1 & dual systems; RNP APCH/RNP AR APCH.*
See the rationale in Strategic Step 1b above.			
S/ Stream	S/ Step	w.e.f	Explanation of Strategic Step Supporting Systems & Cross-Reference to associated NAVAID Infrastructure, where applicable
③	1e	2008	**Gradual Elimination of NPA, replaced by RNP Procedures and APV.** *Enabler: RNP APCH/RNP AR APCH/LPV*
See the rationale in Strategic Step 1a above.			
S/ Stream	S/ Step	By	Explanation of Strategic Step Supporting Systems & Cross-Reference to associated NAVAID Infrastructure, where applicable
③	1f	2016	**All NPAs discontinued** *Enabler: RNP APCH/RNP AR APCH/LPV & GPS (L1+L5) & GALILEO (and/or other constellations that become available in the same time scales);*
See rationale in strategic step 1b, above.			

S/ Stream	S/ Step	w.e.f	Explanation of Strategic Step Enabler & Associated NAVAID Infrastructure, where applicable)
①	2	2010	**Application of Precision RNAV in Terminal & En Route Airspace for ATS routes, arrival and departure procedures.** *Enabler: P-RNAV; DME/DME; INS/IRS update; GPS including EGNOS after 2009;*
②		<2008	

P-RNAV will support enhancements of route structure, in both en route and terminal airspace and enable the use of optimised trajectories in certain areas. It offers the ability to use RNAV functionality for the departure, en route and arrival phase of flight except final approach and missed approach. In terminal airspace, P-RNAV allows the arrival and departure routes to be placed in a manner that best meet the needs of the airport, the air traffic controller and the pilot. This often means shorter, more direct routes with simple connections to the en route structure. However, where environmental issues play a major role, arrival or departure routes can be designed to take best advantage of the airspace available and, where possible, by-pass densely populated areas. Careful design can also result in appropriately segregated arrival and departure streams, thereby reducing the need for radar vectors and workload for both the pilot and the controller. P-RNAV will also allow for closer route spacing in the en route environment.

S/ Stream	S/ Step	w.e.f	Explanation of Strategic Step Enabler & Associated NAVAID Infrastructure, where applicable)
①	3	2018	**Application of Advanced-RNP 1 in Terminal & En Route Airspace for ATS routes, arrival and departure procedures.** *Enabler: A-RNP1; DME/DME; INS/IRS update; GPS, including EGNOS after 2009; Data Link (4Dlink)*
②		2015	

With the introduction of A-RNP 1, the advantages gained from P-RNAV will be further enhanced by onboard performance monitoring and alerting and the execution of more predictable aircraft behaviour in the en route and terminal Airspace. A-RNP 1 will enable the design of closely spaced parallel ATS routes as well as departure and arrival procedures including the turns (fixed radius turns). The consistency in design and execution of procedures will allow for more optimum use of airspace and alleviation of environmental constraints. Consistent use of onboard systems will enhance flight efficiency in both terminal and en route airspace (e.g. where optimised trajectories are used). This will contribute to Safety due to increased situational awareness on the flight deck. A-RNP 1 will support enhancements of route structure, in both en route and terminal airspace, that are capable of providing increased airspace capacity, operational efficiency and economic benefits.

The 2015 ECAC Airspace Concept and Strategy has identified requirements for certain functionalities (to be incorporated in the A-RNP 1 specification, still to be developed) for the 2015 time frame. In context, the following navigation Enablers/functionalities have been identified:

- RF (Radius to Fix)
- FRT (Fixed Radius Transition)
- RNAV Holding *(this refers to aircraft having on-board holding functionality)*
- 3D Management
- Parallel Offset
  Note: the exact nature of the operational requirement associated with this functionality needs to be further defined so that the functionality can be accurately described.
- RTA (Required Time of Arrival) in en route mode only
  Note 1: RTA en route functionality is one means of achieving metering into Terminal Airspace
  Note 2: The RTA function may need to be improved to allow operations in the en route descent phase of flight. This will allow for improved profile predictability.
  Note 3: the use of data link for the exchange of 4D related information (meteo data, RTA etc) will need to be coordinated with appropriate projects (e.g. 4DLink)

For a full listing of Navigation Assumptions & Enablers of the 2015 ECAC Airspace Concept and Strategy see Appendix 2.

S/ Stream	S/ Step	wef	*Explanation of Strategic Step* *Enabler &* *Associated NAVAID Infrastructure, where applicable)*
① ②	4	2020+	**Application of 4D Operations (4D Contract)** *Enabler: 4D RNP; AMAN; ATC SUPPORT TOOLS; Data link*
While initial local applications of some 4D Navigation functions will be implemented earlier, this step represents the broad implementation of 4D navigation using trajectory based operations as defined in SESAR. This will permit an optimal integration of user-preferred trajectories into the ATM system, minimizing fuel cost while increasing schedule reliability even in high density traffic environments. Implementation of this step will require advanced harmonized avionics capabilities, integrated ATC ground support tools and data links (weather data, time and speed control parameters). While positioning accuracy of current GNSS is sufficient for these operations, advanced GNSS (including time synchronization) is most likely required in order to achieve the necessary safety levels.			

S/ Stream	S/ Step	w.e.f	*Explanation of Strategic Step* *Enabler &* *Associated NAVAID Infrastructure, where applicable)*
③	5	2008	**Implementation of RNP APCH with/without Baro VNAV** *Enabler: RNP APCH; GPS*
RNP APCH procedures without vertical guidance are flown to LNAV minima. The goal is to replace conventional (Non-Precision Approaches) with laterally guided RNAV procedures primarily based on the use GPS. RNP APCH with vertical guidance provided is a vertically guided approach that can be flown by modern aircraft with VNAV functionality using barometric inputs. Most Boeing and Airbus aircraft already have this capability meaning that a large part of the fleet is already equipped. However, there are very few published procedures.			

S/ Stream	S/ Step	w.e.f	*Explanation of Strategic Step* *Enabler &* *Associated NAVAID Infrastructure, where applicable)*
③	6	2009	**Implementation of RNP AR APCH** *Enabler: RNP AR APCH; GPS*
RNP AR approaches introduced to make use of the capabilities of certain modern aircraft to provide better access to runways with terrain or environmental constraints, where needed. They use specific obstacle clearance criteria and require a particular RNP approval and flight operational safety assessment (FOSA) for implementation.			

S/ Stream	S/ Step	w.e.f	*Explanation of Strategic Step* *Enabler &* *Associated NAVAID Infrastructure, where applicable)*
③	7	2010	**Implementation of Localizer Performance with Vertical Guidance (LPV) Approaches using SBAS** *Enabler: LPV; GPS & EGNOS*
The improved lateral and vertical performance of augmented GNSS allows LPV procedures to be implemented providing 3D guidance on a geometric lateral and vertical path. LPV is a procedure supported by SBAS systems such as WAAS in the US and EGNOS in Europe to provide lateral and vertical guidance. The term LPV stands for localizer performance with vertical guidance. The lateral performance is equivalent to an ILS localizer and the vertical guidance is provided against a geometric path in space rather than a barometric altitude. LPV is of particular interest to a category of users with aircraft that do not have sophisticated FMS based avionics that can perform			

Baro/VNAV. LPV also provides geometrically based approach profiles; this has the potential to enable reduced decision heights compared with barometric VNAV where the decision height has to take account of the limitations of barometric VNAV.

S/ Stream	S/ Step	w.e.f	Explanation of Strategic Step Enabler & Associated NAVAID Infrastructure, where applicable)
③	8	2013	**Implementation of LPV procedures with minima equivalent to ILS Cat-I.** *Enabler: LPV; GPS & EGNOS*

Experience gained with LPV operations is expected to demonstrate that the achieved performance using SBAS/GNSS can support approaches with minima equal to that provided today by ILS Cat-I.

S/ Stream	S/ Step	w.e.f	Explanation of Strategic Step Enabler & Associated NAVAID Infrastructure, where applicable)
③	9	2008	**Sustainability of Precision Approach Operations based on ILS Cat III** *Enabler: ILS*

This step aims to sustain ILS operations until such time as MLS/GBAS can be cost effectively used to replace ILS. The sustainment considered is very restricted in scope and limited to the ground systems, due to the need to remain compatible with installed aircraft ILS receivers. Consequently, more fundamental operational improvements are not envisaged, as these will be addressed by GBAS or MLS.

S/ Stream	S/ Step	w.e.f	Explanation of Strategic Step Enabler & Associated NAVAID Infrastructure, where applicable)
③	10	2008	**Precision Approach Operations based on MLS Cat III** *Enabler: MLS*

This step supports implementation of MLS as an alternative to ILS in support of short term improvements in runway throughput during Low Visibility operations.

S/ Stream	S/ Step	w.e.f	Explanation of Strategic Step Enabler & Associated NAVAID Infrastructure, where applicable)
③	11	2009	**CAT I GLS operations using GBAS** *Enabler: GBAS (GPS)*

This step is to enable an alternative system to ILS CAT I operations based on local augmentation of the GNSS signal (CAT I GBAS). This step is an interim, but required Step towards Step 12 & 13.

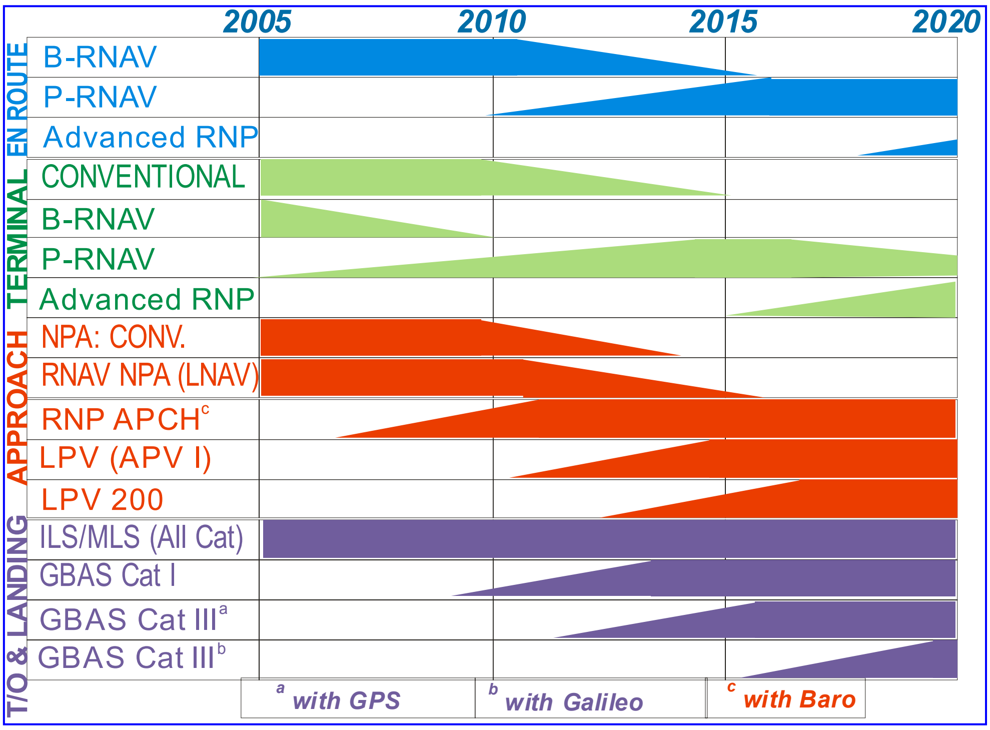
GBAS (Ground Based Augmentation System) as ICAO augmentation to satellite navigation is recognised as the long term precision approach system to support all weather operations, both by the ICAO Air Navigation Conference and also within SESAR, as it will offer same benefits over ILS as MLS, reduce installation and maintenance costs of ground infrastructure and ensure optimisation of new operational concepts based on GNSS.

S/ Stream	S/ Step	w.e.f	Explanation of Strategic Step Enabler & Associated NAVAID Infrastructure, where applicable)
③	12	2013	**CAT III GLS Operations with GBAS/GPS** *Enabler: GBAS (GPS)*
This Step is the logical consequence from the ICAO and SESAR orientation to quickly move towards GNSS-based systems for all phases of flight. As a follow-on of Step 8 this enables GBAS use for CAT II/III operations. Due to the implementation schedules for GALILEO and the GPS Upgrade Programme, initially this capability is planned to use GPS only. This will allow operators to operate under low visibility and get early benefits with GBAS.			

S/ Stream	S/ Step	w.e.f	Explanation of Strategic Step Enabler & Associated NAVAID Infrastructure, where applicable)
③	13	2015	**CAT III GLS Operations with Multi-constellation** *Enabler: GBAS (GPS L5 / Galileo)*
This step is the generalisation of GBAS capability providing GLS CAT II/III operations for all autoland aircraft. It is based on providing local integrity information for signals from multiple satellite constellations on multiple frequencies. This is the final step of the approach stream regarding precision approach systems. With GALILEO and/or improved GPS in operation, GBAS CAT II/III ILS look-alike service robustness will be increased and its use may be generalised to all auto-land aircraft.			

The Strategic Steps depicted in the Generic Roadmap (see Figure 2-2) and detailed above do not accurately reflect the phased implementation of certain Navigation Applications and phased discontinuation of others. In order to appreciate this reality, the Navigation Applications Roadmap is provided on the next page.

Figure 2- 3 - ECAC Roadmap of Navigation Applications



In the above Figure, some applications progressively disappear. The necessary mandates for the elimination for these applications will need to be supported by the appropriate business and safety cases.

2.3.2. STRATEGIC STEPS: NAVAID INFRASTRUCTURE

The Strategic Steps related to the NAVAID Infrastructure respond to the requirements for the implementation of Strategic Steps related to the Navigation Applications, above.

S/ Step	w.e.f	*Explanation of Strategic Step* *Supporting Systems &* *Associated NAVAID Infrastructure/Step, where applicable)*
A	2008	**Optimisation of DME coverage to improve quality of service and support to RNAV operations** *Supporting Systems: P-RNAV, A-RNP 1, DME*

S/ Step	w.e.f	*Explanation of Strategic Step* *Supporting Systems &* *Associated NAVAID Infrastructure/Step, where applicable)*
B	2009	**Reduce redundancy of VOR/NDB** *Supporting Systems: P-RNAV, RNP APCH, LPV; VOR, NDB, GNSS, radar/multilateration based surveillance services; S/Step 1a.*

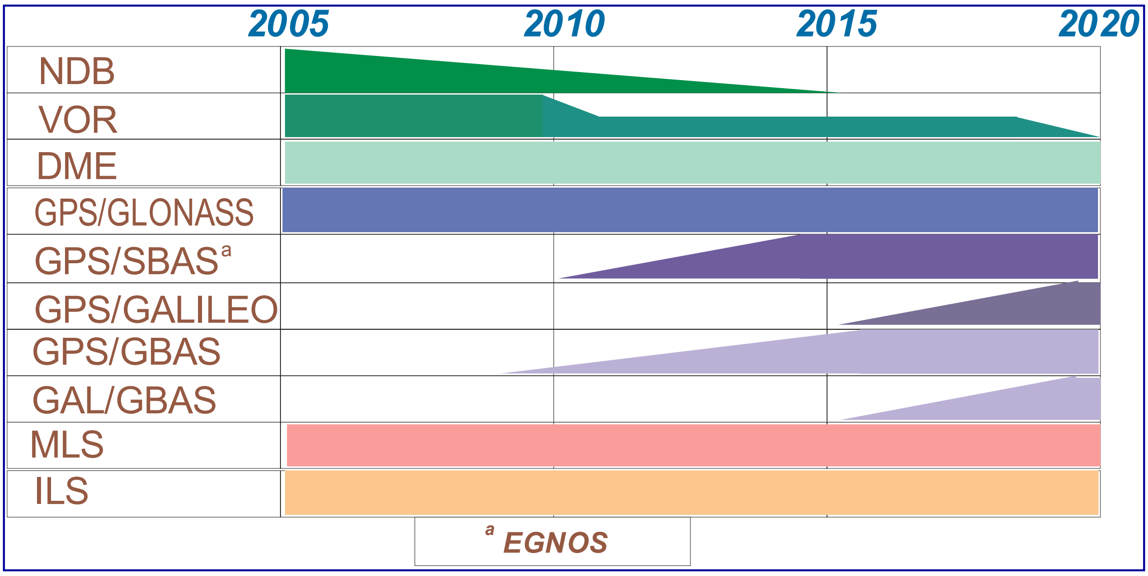
S/ Step	w.e.f	*Explanation of Strategic Step* *Supporting Systems &* *Associated NAVAID Infrastructure/Step, where applicable)*
C	2015	**Reduce Number of VORs, & NDBs and rationalise number and placement of DME** *Supporting Systems: dual RNAV systems (P-RNAV, A-RNP 1), RNP APCH, LPV; VOR, NDB, GNSS, radar/multilateration based surveillance services*

S/ Step	w.e.f	*Explanation of Strategic Step* *Supporting Systems &* *Associated NAVAID Infrastructure/Step, where applicable)*
D	2015	**Anticipated mandatory Carriage of GNSS (GPS/Galileo)** *Supporting Systems: GPS; Galileo; Dual RNAV; Business case for A-RNP 1; S/Step E;* *Dependency: ADS-B*
Mandatory carriage of GNSS is needed to enable the implementation of A-RNP 1 (S/Step 3) to meet the Airspace requirements. It's timing is predicated on the requirements of the Airspace Strategy but would need Galileo to be available in order to avoid unnecessary expense for operators equipping initially with GPS and later with Galileo.		

S/ Step	w.e.f	*Explanation of Strategic Step* *Enabler &* *Associated NAVAID Infrastructure, where applicable)*
E	2020+	**Decommissioning of VOR and NDB** *Enabler: GBAS/Galileo/GPS L5 & Dual A-RNP 1*

The Strategic Steps depicted in the Generic Roadmap (see Figure 2-2) and detailed above do not accurately reflect the phasing in and out of certain components of the NAVAID Infrastructure. This reality is depicted in the NAVAID Infrastructure Roadmap, below.

Figure 2- 4 - ECAC Roadmap of NAVAID Infrastructure



2.3.2.1. NAVAID INFRASTRUCTURE STEPS SUPPORTING THE NAVIGATION APPLICATIONS

The NAVAID Infrastructure requirements address both RNAV operations for all phases of flight from take off to final approach and also the precision approach and landing.

En route and TMA (Supporting Strategic Streams 1 & 2)

a) 2008-2015

- The transition to a total RNAV environment, defined in the Application Streams 1 and 2, will require enhancing DME coverage (Strategic Step A at para. 2.3.2) to improve the quality of service for en route and terminal operations. This will be achieved mainly by deploying additional DMEs, and in some cases by repositioning some of the existing facilities, as enabled by some decommissioning of VOR. In areas of radio spectrum congestion, the DME coverage optimisation may depend on VOR reduction. DME coverage redundancy may be enhanced by the availability of TACANS, provided these are maintained and operated to meet the ICAO SARPS requirements. Most of the air transport and business aviation fleet is already equipped with DME based RNAV systems, whereas fleet equipage with GNSS receivers is not expected to be sufficient to support the RNAV requirements both en route and in terminal airspace before 2015.
- A limited reduction of NDB and VOR may take place (Strategic Step B) due to a progressive reduction of conventional routes and procedures (Strategic Step 1a and 1c), while leaving a sufficient backbone of NAVAIDS to continue supporting a reducing non-RNAV GAT route structure at lower flight levels, supporting remaining conventional SIDs, STARs, NPAs and missed approaches, and enable ATC to re-route aircraft in the event of individual aircraft RNAV failure. The progressive reduction of this type of NAVAIDS will increase ANSPs cost efficiency.
- The required capability of the resulting environment will depend mainly upon the local operational environment. This includes the expected traffic density, route

spacing and potential for ATM and aircraft systems to provide support for continued operation of all aircraft in the event of GNSS outage.

b) 2015-2020

- The transition to a total RNAV environment will require use of GNSS to address those areas where suitable DME coverage cannot be achieved, such as low flight levels in terrain constrained areas. This and the move towards increased use of GNSS for operational benefits implies the need to mandate the carriage of GNSS equipment in all aircraft (Strategic Step D). The mandate for the carriage of GNSS equipment is in line with the overall strategic context defined by the ICAO CNS/ATM concept, the EUROCONTROL GNSS policy and SESAR. Dual RNAV with DME/DME and GNSS sensors will be required for all Commercial Air Transport operations in order to meet the operational requirements in respect of the risk of loss of navigation capability on Air Transport operations.
- GALILEO and enhanced GPS will start to become available in the 2015-20 period allowing increased reliance on GNSS once dual constellation dual frequency equipment is installed in aircraft and experience is built up on Galileo operation.
- The low-end General Aviation and Air work aircraft with only GNSS equipment will be allowed, but it is expected that that most of this fleet will be progressively equipped with dual equipment. For aircraft where DME based RNAV is not fitted, the lack of backup to GNSS based RNAV will result in need for an alternative reversion, in case of GNSS failure. ATC workload and safety case considerations will probably result in a need to retain some VORs. However, the primary reversion is likely to be ATC surveillance and the reversionary modes for these GA aircraft will need to be considered within the context of overall safety and business case studies.
- Military aviation is expected to be able to meet advanced civil navigation requirements mainly based on GNSS. However, tactical aircraft with airborne architecture constraints might have to be handled by accepting the equivalence of military systems performances. Such military systems might include TACAN, GPS PPS, GALILEO PRS, Multimode receivers (MMR), Inertial and Military Mission Systems.

c) Post 2020

- In this time frame, it is expected to have a multi-constellation and multi frequency GNSS environment that will provide an adequate level of GNSS service in terms of robustness and performance. These GNSS enhancements will reduce significantly the probability of having a GNSS failure and would reduce the extent of an alternative reversion, allowing for a reduced DME network to support the back-up requirement. The existence of a total RNAV environment will allow further removal of VOR and NDB (Strategic Step E), thus increasing ANSPs' cost efficiency. In this time frame, a significant percentage of the General Aviation fleet is expected to have dual equipment (GNSS supported by inertial or DME/DME). For those remaining aircraft with single equipment (e.g. low end General Aviation, legacy lower capability State aircraft), the lack of RNAV backup will result in need for a reversion support that can be managed by ATC. Consideration of available mitigations will have to be addressed including the surveillance environment, ATC workload, operation below Minimum Radar Altitude and lost communication requirements. For State aircraft, the ability to revert to TACAN and on-board aiding is expected to provide alternative backups.

Approach and Landing (supporting Stream 3)

a) 2008-2015

- Aircraft ILS equipage is universal and most airports needing instrument approaches have ILS ground equipment. ILS will remain the prime source of guidance for approaches and Cat I landings in ECAC and will continue to support all categories of airspace users. Cat I GLS (GBAS/GPS) will become available. ILS will remain the only means for Cat II/III operations, however, toward the end of the period, depending on Research and Development results , there may be a limited availability of Cat II/III GLS capability (using a GPS/GBAS capability augmented by on-board systems) at runways with Cat II/III lighting. This might increase the rate of take up of GBAS based landing as a back up to ILS to cater for maintenance/system failures. To these ends, the interoperability with military differential GPS will need to be studied.
- The gradual elimination of NPAs (both conventional and RNAV) in accordance with the decisions of the 36th ICAO Assembly to be replaced by Approaches with Vertical Guidance (APV) either based on SBAS or Baro-VNAV. This is expected to be completed early in the period 2015-2020 with the provision of APV to all IFR runway ends.
- Runways presently not equipped with Precision Approach and Landing system may consider SBAS (e.g. LPV 200) or Cat I GLS (GBAS/GPS) systems with airport lighting system upgrades as needed. Some CAT I ILSs may be replaced by SBAS APV or CAT I GLS. Business case for such changes will depend upon nature of traffic and availability of aircraft with certified GNSS based approach and landing systems.
- Where necessary and once agreed by ICAO, ILS modified to overcome multipath problems will be available to maintain Cat II/III capability at some runway ends.
- Where a business case can be made (e.g. improved capacity for Low visibility procedures (LVP) or where the ILS modifications (above) cannot overcome multipath) MLS CAT III may be equipped as a alternative or replacement to ILS.

b) 2015-2020

- ILS remains the prime source of guidance for approaches and landings in ECAC. Where necessary and once agreed by ICAO, ILS modified to overcome multipath problems will be available to maintain Cat II/III capability at some runway ends.
- MLS, Cat I GLS and LPV 200 will continue to be introduced where required.
- Cat II/III GLS (GBAS/Multi-constellation Dual Frequency) available. With the increased equipage of airports with GBAS ground station and aircraft with GLS capability, GLS procedures will be increasingly used
- Consideration of need to require carriage of RNP APCH/LPV approach system to allow the removal of all conventional NPA procedures and the decommissioning of associated NAVAIDs.
- RNP AR APCH will have increasing application where RNP operations cannot be undertaken with RNP APCH procedures.
- Where necessary and once agreed by ICAO, ILS modified to overcome multipath problems to maintain Cat II/III capability

c) BEYOND 2020

- ILS remains a significant source of guidance for approaches and landings. Where necessary, ILS will be modified to overcome multipath problems to maintain Cat II/III capability
- MLS, Cat I GLS and LPV 200 will continue to be introduced where required.
- Increased equipage of GLS aircraft capability together with the provision of GLS GBAS procedures (Cat I/II/III) at more airports. This is expected to be accompanied by the decommissioning of ILS CAT I systems, where the Business and Safety Case can be established. ILS Cat II/III will be retained to provide backup to GLS to address GLS availability issues (deliberate jamming and solar activity).
- Requirement for RNP APCH/LPV/GBAS for RNAV approach if ILS not available.
- Increased equipage of aircraft with combined GPS/GALILEO/SBAS reception will lead to the introduction of LPV procedures at most runway ends.
- RNP AR APCH will continue to have increasing application where RNP operations cannot be undertaken with RNP APCH procedures.

CHAPTER 3

IMPLEMENTATION CONSIDERATIONS

3.1. INTRODUCTION

The 2015 Airspace Concept and Strategy for the ECAC Area and Key Enablers (Edition 2.0) and the SESAR Concept of Operations for 2020+ call for an increased reliance on Area Navigation for the En Route, Terminal and Approach phases of flight. From an infrastructure perspective, there will be increased dependency on GNSS providing a positioning service, allowing for rationalisation of conventional ground based navigation aids with back-up provided through DME coverage and ATM surveillance services. In seeking to achieve the targets of the 2015 Airspace Concept and Strategy, the timely availability of ground and airborne Enablers is crucial.

This chapter considers implementation in the context of the 2015 ECAC Airspace Concept and the mid-term SESAR targets. To this end, enablers are discussed first, then two implementation options are identified using a worked example of Advanced-RNP 1 (A-RNP 1). This is followed by a discussion on how these implementation options would affect and impact upon Navigation Applications and the NAVAID Infrastructure evolution.

3.2. ENABLERS

The 2015 ECAC Airspace Concept and Strategy distinguishes between General and Specific enablers.

General enablers include the clear and unambiguous political commitment necessary to ensure the realisation of the 2015 Airspace Concept, for example; action plans and work programmes to direct the course of work and working arrangements to detail the development and achievement of the Concept.

Specific enablers include human, procedural or institutional and System enablers such as those included in the Navigation Application and NAVAID Infrastructure Strategy in Chapter 2 and identified in the Airspace Strategy and replicated in Appendix 2 of this document.

System enablers can be broadly clustered into two groups: ground and airborne. Despite their different roles, it is clear that many airborne and ground enablers will need to be integrated if the benefits of the 2015 Airspace Concept are to be realised. The interdependence of these enablers will necessitate synchronised implementation, if the desired benefits are to be achieved.

3.3. IMPLEMENTATION OPTIONS

Two Implementation Options have been identified in Chapter 3 of *The 2015 Airspace Concept and Strategy for ECAC and Key Enablers:* This section considers these two options in the context of Navigation Enablers. To this end, the relationship between Navigation Applications and the NAVAID Infrastructure are discussed using a worked example of a mix between P-RNAV and Advanced RNP-1 (**see** Strategic Step 3 of the Navigation Strategy in Chapter 2) called for in the Airspace Strategy. The A-RNP 1 specification includes requirements for various functionalities i.e. RF (Radius to Fix); FRT (Fixed Radius Transition); RNAV Holding; RTA for en route (Required Time of Arrival); 3D Management function – see paragraph 3.4 below.

The discussion is rounded off in paragraph 3.4 with General Considerations.

Note . – Whilst Advanced-RNP 1 is used to focus the discussion on implementation options and associated considerations, many of the issues apply equally to RNAV and RNP applications in the Approach phase of flight (Strategic Stream 3)

3.3.1. OPTION 1: PHASED IMPLEMENTATION LEADING TO MIXED OPERATIONS.

Option 1 envisages a phased implementation of A-RNP 1, using the worked example. Of necessity, this option involves providing the support necessary to permit ATC to handle mixed traffic of A-RNP 1 and, for example, P-RNAV. For this option, the following would need to be in place:

- Available ATC system support to allow the controller to know the capability of the aircraft (this involves the Flight Data Processor being able to extract the relevant information from Item 18 of the ICAO ATC FPL); ***and***
- Available ATC system support that permits handling the traffic according to their navigation capability; ***and***.
- Guidance material on handling mixed traffic is provided to ANSPs. Such material would include airspace design considerations, allocation of the appropriate clearances, the factors to be considered in determining the percentage number of approved aircraft needed etc.; ***and***
- Safety and Business cases; ***and***
- Implementation Plans.

Considerations for Phased Implementation

If a phased implementation were undertaken for Advanced RNP 1, such a decision would probably be considered as being cost effective (in that retrofits would not be required); politically acceptable and more appropriate a choice for Terminal Airspaces which grow at different rates, have different levels of complexity, different operational requirements and varied fleet mixes. Nevertheless, this option involves an investment from the ANSP (with an extended notice period) and lead to a requirement for modifications to the Flight Data Processor for some ATC systems (to allow a mix of traffic to be effectively handled). The mixed traffic resulting from this option may lead to a reduction in capacity and the option may not be appropriate in a congested airspace environment, and flight efficiency could also be affected. If lessons are learned from the P-RNAV experience, that the uptake of A-RNP 1 would be slow as ANSPs wait for 90% of the aircraft to be equipped before publishing A-RNP 1 procedures.

> ***Phased Implementation is a more popular solution with airspace users but currently very difficult for ATC to manage effectively***

A phased implementation of A-RNP 1 would also affect the NAVAID Infrastructure evolution. To support the combination of P-RNAV and A-RNP 1 traffic in the same airspace, it would be necessary to maintain the current NAVAID Infrastructure. This would effectively question the need for Strategic Step D and prevent implementation of the Airspace Concept. An additional consequence would be a delay in transitioning towards GNSS as per the ICAO Global ATM Concept. Furthermore, harmonisation would not be achieved.

3.3.2. OPTION 2: MANDATE AIRBORNE NAVIGATION ENABLER

Option 2 envisages a mandate of A-RNP 1 in an airspace, using the worked example. This solution would be appropriate if, for example, the ATC system support is not available or is not sufficiently effective to allow the required capacity gains to be realised (this is the case today). In such a case, the following considerations should be included:

- Business case; ***and***
- The lead-time to be given to airspace users and, depending on the nature of the mandate, various service providers such as ANSPs; ***and***
- The extent of the mandate (local, regional or ECAC-wide) ; ***and***
- Safety cases; ***and***
- Implementation Plans. This option involves an investment for the airspace user (including a 7 year lead time) with less costs being incurred by the ANSPs. This option will ensure that capacity is maintained or increased. However, this option may result in slowing the pace of change (to more advanced navigation capability) if the lowest common denominator is selected as a mandate for the airborne navigation enabler.·

Considerations for a Mandate

If a mandate of airborne equipment were to be considered for A-RNP 1, such a decision means that less costs are incurred by the ANSPs but that an investment is needed from some the airspace users. As such, a mandate decision would have to be based on a cost benefit analysis (CBA) and seven years advanced notice to operators would be required. This is usually why the political acceptance of a mandate can be difficult to achieve.

Mandates of Airborne equipment are the favoured option for efficient ATM ... but can be costly for airspace users (if the mandate is too demanding).

It has been shown that the demonstration of a cost benefit for a mandate can be difficult, particularly when a substantial number of retrofits are required. The longer one waits for a mandate allowing for a more 'natural' change in fleet equipage, the less expensive the mandate becomes. Additionally, in order for the mandate to succeed and for the operational benefit to be achieved (this can be a difficult balance to attain) it is important not to set the bar too high in terms of functionality otherwise retrofit costs could be incurred by even 'well' equipped aircraft – thus affecting the CBA.

To date in ECAC, navigation mandates have been ECAC wide e.g. RVSM and RNAV 5. This has shown that capacity is increased – but that the pace of change may be slowed (to more advanced navigation capability) if the lowest common denominator is selected as a mandate for the airborne navigation enabler. This can be illustrated by the two navigation mandates above where RNAV 5 compatible equipment was first installed on aircraft in 1970 and the mandate became effective in 1998. For RVSM, the first moves towards its implementation was in 1964 and this was only actually implemented in 2002.

One of the disadvantages of mandates for Terminal Airspace (for A-RNP 1 or RNP APCH, for example) is that the operational requirement for such a mandate may not exist in all Terminal Airspaces. This therefore adversely affects the cost benefit analysis for that particular TMA. It is possible that when it comes to future mandates, a different perspective should be considered such as looking at mandates for particular Terminal Airspaces only or for a particular block of sectors in a particular geographic area. Such an approach would have several advantages, amongst which would be that requirements for ECAC-wide retrofits could be mitigated and that the cost-benefit analysis easier to achieve if the mandate 'region' chosen already had a high percentage of equipped aircraft.

The nature of an A-RNP 1 mandate would affect the NAVAID Infrastructure evolution. If, for example, the A-RNP 1 specification required dual systems and GPS L5, VORs could be decommissioned. Alternatively, if the mandated A-RNP 1 specification decided on a single system, VOR's would be needed as a backup.

3.4. GENERAL CONSIDERATIONS RELATED TO OPTIONS 1 & 2

There are a number of general points that need to be considered with respect to Options 1 and 2. These have a bearing on implementation, and can influence the pace of change. These points have been derived from past navigation implementations and hold true for future evolutions. What can be concluded is that each situation may attract its own implementation strategy and that no one size option fits all, be that for En route, Terminal or Approach flight phases or for dense verses less dense airspace. As mentioned in paragraph 1.5 of The *2015 Airspace Concept and Strategy for ECAC and Key Enablers*, trade-offs may need to be made between capacity, flight efficiency and environmental mitigation before deciding on an implementation strategy for a given airspace configuration.

3.4.1. RELATIONSHIP BETWEEN NAVIGATION APPLICATIONS & NAVAID INFRASTRUCTURE

The inter-relationship between Navigation Application and NAVAID Infrastructure can be viewed from both sides:

- With an increased reliance on RNAV, the introduction of a new Navigation Application facilitates rationalisation of conventional ground based infrastructure. Removal of VOR and NDB facilities and alignment of DME to provide a backbone architecture can lead to cost savings for the ANSP. However, with a phased implementation, such rationalisation will be limited.

> ***Navigation Applications and the NAVAID Infrastructure are two sides of the same coin.***

Alternatively,

- Introduction of infrastructure technology e.g., Galileo, GPS L5, EGNOS and GBAS can in themselves open opportunities for the development of new Navigation Applications e.g., in the approach phase, which in itself might lead to decommissioning of approach aids.

Both are therefore general considerations in the implementation planning.

Another driver for the ANSP is the renewal/replacement costs associated with ground based navigation aids. Particularly in the case for VOR, if the implementation of a navigation enabler (application) and infrastructure rationalisation can be timed to coincide, opportunities exist for significant cost savings. Conversely, if the NAVAID infrastructure is relatively young, there will not be the same motivation for removal. The NAVAID lifecycle costs therefore become a general consideration in any implementation planning and can significantly influence the pace of change, especially over the short term.

The Navigation Strategy recognises both of these considerations in the inter-relationship between navigation application and NAVAID Infrastructure and looks out to beyond 2015 to a 2020 target situation. By 2020, it is foreseen that the major infrastructure initiatives will have come on line and Navigation Applications for each flight phase evolved. From an implementation perspective, the challenge is managing the transition to the 2020 target situation.

3.4.2. DIFFERENCES BETWEEN STRATEGIC STREAMS

Implementation across Strategic Stream 1 (En route), 2 (Terminal) and 3 (Approach and Landing) will move at a different pace and under different conditions and consequently have different effects on Strategic Stream 4 (as discussed above).

The *En route* is typically the starting point for implementation as it affects the majority of airspace users. The Navigation Applications have traditionally been less demanding in terms of required navigation performance and functionality. This is foreseen to remain the case.

Phased Implementation is the 'favoured' option for Terminal Airspaces because they are all so different ….. but logjams occur as insufficient aircraft equip and ATC has difficulty in handling mixed traffic.

The introduction of Basic RNAV across ECAC in 1998 highlighted a number of issues. Any En route implementation will have interactions with surrounding En route airspace and the connectivity with Terminal airspace. However, within the ATS routes network itself, accommodation of mixed traffic is severely constrained due to density of tracks and the applicable route spacing standards. It is difficult to see how RNAV 5 could have been introduced throughout ECAC without the force of a mandate. By implementing a Navigation Application above a fixed flight level, it had the effect of blocking that airspace to non RNAV 5 traffic and accelerated the transition to RNAV. Although future implementation in the En route may not be mandated across the whole of ECAC, it is envisaged that sector, multiple sector or FAB mandate might be necessary because of the shear interaction of ATS routes.

Terminal airspace implementation has been a different matter. Constrained only by the arrival and departure procedures the issue is one of access to aerodromes with operator compliance the main factor. The retention of conventional procedures in a mixed traffic environment restricts capacity growth. The Precision RNAV experience has shown that having aircraft suitably equipped and operators approved is a major factor. ANSPs also have a role in influencing change. Rather than wait for the industry to migrate to a given standard, by forcing implementation on a Terminal Airspace or Terminal Airspace System (TAS) forces equipage. This clearly does not need to occur across the whole of ECAC as a mandate, but can be introduced in those areas where implementation can bring benefits in terms of capacity, flight efficiency and environmental mitigation. It is envisaged that implementation within Terminal Airspace and TAS will remain largely independent from En route and be conditioned by availability of the Navigation Application equipment in the air transport fleet. However the P-RNAV implementation has also illustrated the problem associate with implementation without a mandate. ANSPS are reluctant to plan an implementation until it can be assured that there are sufficient aircraft equipped. On the other hand operators are reluctant to equip and train their pilots for the new operations when it is not clear that the proposed operations will be implemented. The result has been that several attempts to move to introduce P-RNAV have been repeatedly delayed to the extent that operators appear to have lost faith in the implementation occurring and as a result no change occurs. To break this log jam, once the equipment is widely available, political commitment and commercial incentives to move to this new standard may be required.

The Approach and Landing Stream has traditionally been independent of both En route and Terminal Airspace implementations. Governed more by the aerodrome facilities (NAVAID and airport infrastructure such as runway lighting), access has again been the driver. The major consideration for the core aerodromes throughout ECAC has been operational capacity under all environmental conditions with emphasis on Low Visibility Procedures (LVP). This business objective will remain and consequently ILS is envisaged to provide services supporting LVPs for foreseeable future. With RNAV and GNSS in particular, a change has been observed in this Stream with implementation of alternate methods of approach and landing. The advantage of both technologies is that it can be implemented alongside traditional instrument approach procedures with flexibility to accommodate different aircraft capabilities. The downside is that a plethora of approach types and classifications are emerging whereas previously there were just the Precision and Non-Precision categories. From an implementation perspective it means that an aerodrome operators will have to respond to customer demands and the capability of their aircraft in deciding which approach and landing facilities to offer. There will likely be differences between regional and city hubs depending on the mix of traffic and implementation will largely be driven by local demand.

Development of the Navigation Applications to meet the approach and landing technological advances, be that GNSS based (un-augmented or augmented) or RNAV solutions, will present a challenge to the international community. Ensuring full interoperability is key to seamless implementation and striving for a rational and logical hierarchy of terms and standards is fundamental.

3.4.3. Development of Navigation Applications

As mentioned in the previous section, the development of standards to ensure interoperability is key. Consideration therefore needs to given to the Navigation Application itself and the requirements it introduces in terms of navigation performance and functionality. The ICAO Performance Based Navigation Manual (Doc 9613) has been produced with harmonisation across Regions as one of its fundamental goals. Reaching agreement on the precise nature of a Navigation Specification provides the advance notice to aircraft and equipment manufacturers, operators and ANSPs of what to aim for. Implementation can then be planned around the Navigation Specification. Translation of ICAO navigation specifications into European legislation has to then be considered as part of the process towards certification. Implementation can then proceed with sufficient notice to allow for equipage. Implementation Planning for 2015 and beyond therefore has to take account of the availability of the certification guidance to allow operators to equip, train their flight crews and obtain the necessary approvals. The same consideration applies to the ICAO Standards and Recommended Practices (SARPS), and in particular ANNEX 10, where standards for approach and landing are evolving.

> ***Only the navigation functionalities included in the Airbus 380 today can reasonably expected to be available ECAC wide in 20 years time without a mandate.***

3.4.4. Aircraft Considerations

Technology is largely unconstrained (apart from cost) and tends to move ahead of implementation for a number of reasons. Getting a Navigation Application from a proof of concept or trial into the field for whatever Strategic Stream, takes considerable planning. As already mentioned, aircraft equipage is a major factor and in turn the availability of complaint equipment, either for retrofit or for inclusion in new production build, is a critical path. It is a fact that in looking ahead to 2015, most of the features of a new Navigation Application will probably have to be available today or else there will be little chance of being available on sufficient airframes for that timeframe. Designs for a new aircraft type are frozen long before Type Certification so it arguable that anything new has missed the Airbus A380 and A350 and the Boeing 787. Replacement designs for short haul aircraft (A320 and B737) are not envisaged before the second half of the next decade, which means that airspace development will be constrained with what is available on our most capable aircraft of today. The life cycle for a new Navigation Application, which requires functionality not currently available, is estimated as approximately 10 to 15 years. So for SESAR 4-D Business Trajectories we should be thinking about the detailed definition phase now.

Service life of airframes is also a major consideration. Depending on utilisation, it is not unusual to have an aircraft life of 25 to 30 years. With mid-life updates, navigation equipment design can easily become updated, but updates come at a recurring cost and operators will only choose to upgrade if the commercial dis-benefit against the competition becomes significant i.e., restricted access to airspace or procedures leads to a commercial disadvantage. What this means is that at any one time there are multiple generations of aircraft types and navigation capability operating within ECAC airspace. Mandates can unify matters, but as a compromise lead to the need to aim at one of the lower levels of available performance – see paragraph 3.3.2.

When planning implementation it is therefore important to take account of:

> ***In the future, there will be requirements for dual redundancy for RNAV Systems***

- Current aircraft capability commonly available across the whole range of stakeholders
- The service life of aircraft and navigation equipment designs
- The time taken to introduce a Navigation Application not available today

It should be noted that with both RNAV 5 and P-RNAV, the standards were written around what was already available on the majority of aircraft types or at least could be made available without significant retrofit cost. At least for the short and medium term, it is envisaged that future implementations, to remain cost effective, will continue to be based around taking what a significant number of aircraft have today and defining the Navigation Specification and its Application around that capability.

3.4.5. AIRBORNE NAVIGATION EQUIPMENT REDUNDANCY

The move towards RNAV/GNSS and away from routes and procedures predicated on conventional navigation aids, means that continuity of function becomes a consideration. Whilst reversion to either a conventional route/procedure or recovery through ATC is a contingency option today, with rationalisation of the NAVAID Infrastructure and eventual dependency on GNSS, this will not be the case in say, 2020. Large aircraft navigation sensors are typically dual redundant e.g., VOR, DME, ADF. With future reliance on RNAV equipment e.g., Flight Management Systems (FMS), there will be a regulatory requirement for dual systems – See Strategic Step 1a. Most new production aircraft will not be affected, but for a significant number of older types and airframes, the operators may have to consider outlay for dual equipment. Introduction of such a continuity requirement will be linked to the safety case supporting implementation of a Navigation Application and take account of the available infrastructure. Therefore, infrastructure rationalisation whilst making a cost saving for the ANSP, can have a direct impact on the operator. A balance has to be found with a trade-off between conventional infrastructure and airborne equipment costs. The cost benefit analysis will need to consider this as part of any implementation strategy.

3.5. CONCLUSIONS

The above considerations therefore lead to the following conclusions:

3.5.1. En Route Operations

For en route operations there seem limited possibilities for achieving the network benefits without an implementation mandate. Any implementation mandate would need to be supported by appropriate benefits analysis and be endorsed through the EATM approval processes. The analysis will need to consider the Airspace Strategy requirements against the equipage of the ECAC fleet and expected trends in equipage through planned retrofit and the purchase of new aircraft. Maximising the benefit to cost ratio might necessitate compromises between functional requirements and implementation schedules.

3.5.2. Operations in Terminal Airspace

The differences that exist between the requirements of individual Terminal Airspaces and the needs of airspace users makes it less likely that there will be a positive benefit to cost ratio of an ECAC wide mandate for RNAV functionality targeted purely at the Terminal Airspace Operation. However, it may be possible to demonstrate a positive benefit to cost ratio for a mandate for an individual Terminal Airspaces or group of such airspaces.

It should be noted, that, unlike the RNAV 5 implementation for which equipment meeting only the minimum level of functionality were not suitable for terminal airspace operation, all of the potential Navigation Specifications for future application en route in ECAC also provide a Terminal Airspace operational capability. As a result there is not expected to be a repeat of the operational problems which occurred in the RNAV 5 implementation where there was no means of linking the en route structure with the airport using only RNAV procedures. Additionally the benefits analysis for proposed en route operations may be able to take into account additional benefits derived from Terminal Airspace applications, which could impact an ECAC wide implementation plan.

3.5.3. Approach and Landing operations

Approach and Landing requirements differ between airports, and often between runways at a given airport.

- Precision Approach

  Studies have shown that maintenance of ILS capability for as long as possible is the most cost effective way of providing a precision approach and landing capability since all IFR aircraft have an ILS capability and the costs of retrofitting aircraft predominate the overall cost calculations.

  The introduction of GLS and MLS will depend upon the operational requirement at an individual airport. At present the lack of a GNSS based Cat II/III capability and an immediate need for improved operational capability with Cat II/III capability might lead to a need to equip with MLS. The increasing equipage of GBAS capability in new aircraft together with a continued capability to offer ILS Cat II/III capability, might lead an airport operator to decide to provide GBAS accepting that the generalised capability of GLS Cat II/III might be delayed until 2015 or beyond.

- RNAV approach

  The ICAO assembly decision to move from conventional NPA to Approach with Vertical guidance by 2016 will be an important driver for the adoption of RNAV approach. Airports will need to provide the required approach procedures, but no additional lighting beyond the facilities provided for NPA will be required for either LPV or APV Baro VNAV. It is expected that experience with EGNOS operation, will demonstrate the capability of EGNOS to support LPV 200. This will result in an alternative means to provide a Cat I decision height. However, whilst this will save the airport the cost of providing a precision approach guidance system for Cat I, the runway will need to be equipped with Cat I lighting and this is the major cost driver in the provision of a Cat I Precision Approach capability. Local business cases will therefore be important in determining the options to be adopted by an airport in the move from NPA to RNAV approaches

APPENDICES

Appendix 1

Working Methodology

Overview

The following diagram (Fig.2) illustrates the rationale used to derive the Navigation Strategy, having taken the following into consideration:

- aircraft operators' requirements;
- known European and Global policies, concepts and plans for Air Navigation Systems;
- the infrastructure and services in use, being introduced and/or planned for introduction.

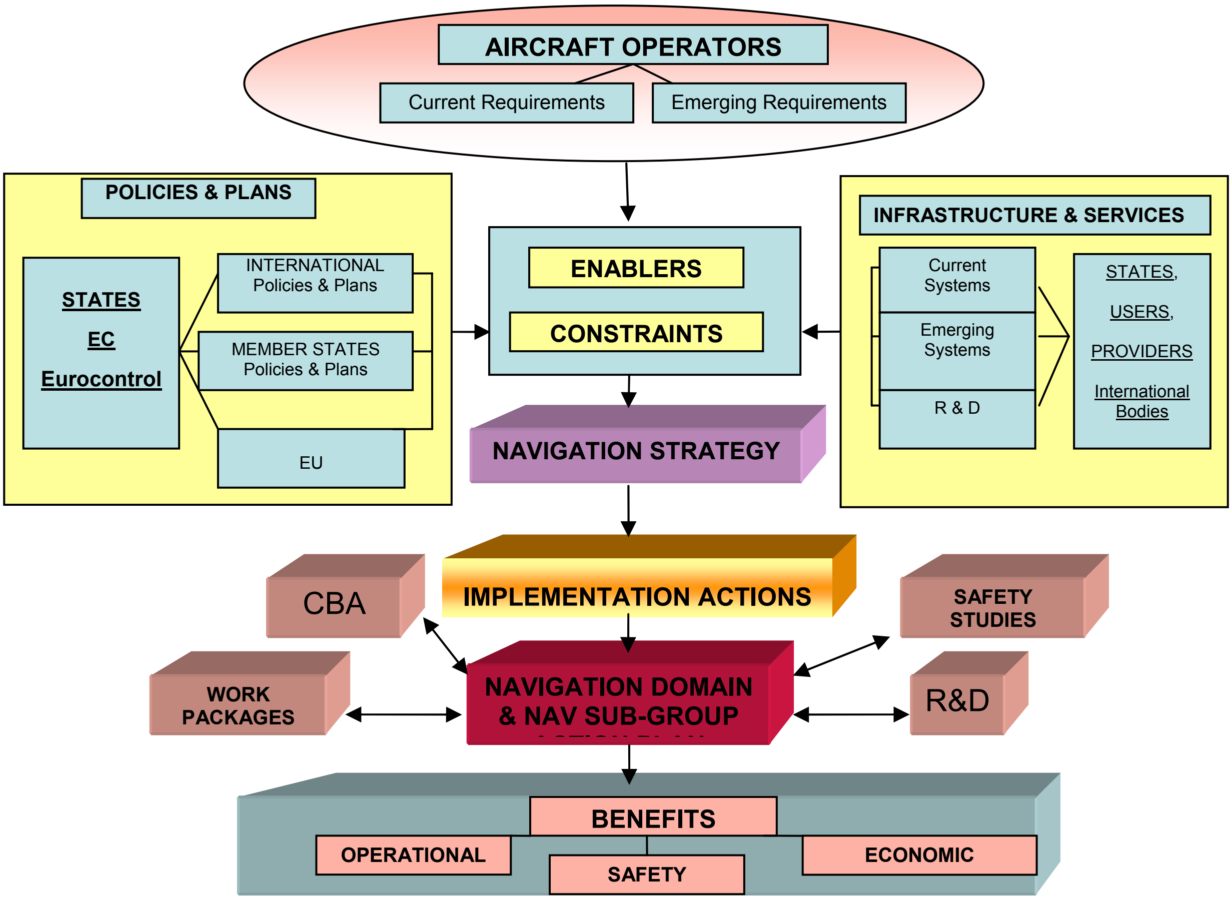


Figure A-1: Working Methodology

In order to facilitate a standardised approach to the planning implementation of the Navigation Strategy's Strategic Steps, the use of a template/check list of planning considerations, is provided at Appendix 2.

As far as possible, the definition of the different tasks includes the identification of the responsible bodies and appropriate target dates for completion. The IOC and FOC dates shown in the Navigation Strategy in Chapter 2 are preliminary estimates based on publicly available information as confirmed by the responsible bodies.

Due to the dynamic nature of the Strategic Steps, it is accepted that the Strategic Steps and a subsequent action plan would need reviewing on a regulator basis, as well as coordination with the appropriate bodies. As the EUROCONTROL Agency is responsible for the management of the EATM in ECAC, it is anticipated that the ANT would be responsible for the maintenance, managing, and monitoring of the progression of the Navigation Strategy and its Action Plan.

Of the Implementation Actions identified in the original TPINS document, the following are no longer applicable:

- The implementation of the RVSM Programme. (I.A. No 4 closed)
- The closure of Implementation Actions that now lie within the remit of other Domains (Free Routes (I.A. No 6), ASMGCS (I.A. No 11))
- The merging of two Actions (Runway Guidance (I.A. No.1 and the Provision and Maintenance of the AWO Capability I.A. No 9).
- The division of the TPINS Implementation Actions into two categories.

Finally, the document has been developed on the basis of a time horizon that has been split into three periods - Short-term (2008-2015), medium-term (2015-20) and long-term (2020 and beyond) for each of three defined phases of flight – Departure, En route and Arrival (Approach & Landing).

Appendix 2

Navigation Assumptions & Enablers from the 2015 ECAC Airspace Concept and Strategy

The Airspace concept described in Chapter 1 of the document entitled *The 2015 Airspace Concept and Strategy for the ECAC States (Ed. 2.0, 2008)* is based upon certain assumptions which are considered realistic in the 2015 time-frame. Some of the assumptions contained in Appendix 2 of that document are 'background' assumptions that are not explicitly referred to in the Airspace Concept but integral to it. **E**nablers which are needed to achieve specific steps of the Airspace Strategy detailed in Chapter 2 of *The 2015 Airspace Concept and Strategy for the ECAC States (Ed. 2.0, 2008)*, are distinguished in the text which follows by insertion of the symbol (❖ + Enabler Code) preceding the entry, where appropriate.

This appendix replicates the Navigation Assumptions and Enablers identified in Appendix 2 of *The 2015 Airspace Concept and Strategy for the ECAC States (Ed. 2.0, 2008).* The dates associated with this anticipated availability are also shown; these dates are sourced in Chapter 2 of *The 2015 Airspace Concept and Strategy for the ECAC States (Ed. 2.0, 2008)* and correspond to the Initial Operational Capability (IOC) associated with the Strategic Steps of the Navigation Strategy.

2: Navigation Assumptions: Enabler Code N

2.1 RNAV 5 will be the minimum RNAV specification used for designing ATS routes of the ARN

2.2 **(❖Nb)** Precision-RNAV (P-RNAV) specification *(Already Available)*.

2.3 **(❖Nc)** Advanced RNP 1 specification (which includes functionalities in A 2.4 to A 2.7 and 2.16) *(Available 2011)*.

2.4 **(❖Nd)** Advanced-RNP 1 with RNAV holding function. *(Available 2011)*.

Note: RNAV holding refers to aircraft having an on-board holding functionality.

2.5 **(❖Ne)** Advanced-RNP 1, including Radius to Fix (RF) and Fixed Radius Transition (FRT) functionalities are required to respond to the need for predictable and repeatable track performance along Terminal Routes for the design of noise preferential terminal routes . *(Available 2011)*.

2.6 **(❖Nf)** 3D management will be based on the use of CDAs and window constraints. VNAV functionality is one means by which this could be accomplished. The 3D management function is to be defined in the Advanced-RNP 1 specification. *(Available 2011)*.

2.7 **(❖Ng)** Advanced-RNP 1 with the RTA functionality in en route mode is required to permit the metering (in time) of traffic from the ARN into Terminal Airspace. *(Available 2011)*.

Note: RTA en route functionality is one means of achieving metering into Terminal Airspace

2.8 There will be a requirement for the application of the RNP APCH specifications (with or without vertical guidance) to enable stringent track keep performance on final approach where there is no instrument approach aid. *(Already Available)*.

2.9 **(❖Ni)** In other cases, there will be a requirement for the application of the RNP AR APCH specification to enable curved approaches or approaches through terrain rich areas. *(Already Available)*.

2.10 **(❖Nj)** The European DME infrastructure will be retained to provide reversionary possibility. *(Already Available)*.

2.11 To accommodate various instrument approach requirements, it is assumed that ILS, MLS, GBAS (GLS Cat I approaches) and SBAS (LPV approaches) are available as needed.

2.12 A minimum number of Non-precision approaches (NPA) will be retained.

2.13 Instrument Flight Procedure design criteria (ICAO PANS-OPS) will be required for the design of window constraints to enable 3D management in Terminal Airspace or use of VNAV function (see Assumption 2.6, above).

2.14 **(❖Nn)** Generic European route spacing criteria to support closer route spacing in En Route airspace using P-RNAV (for straight segments only). *(Already available)*.

2.15 **(❖No)** Improved spectrum and frequency management will be in place to ensure that sufficient spectrum is available for NAV applications in the VOR and DME bands (❖). (see Communication Assumption 1.2) *(Available 2010)*.

2.16 **(❖Np)** Advanced RNP-1 with parallel-offset functionality for tactical use in the en route phase of flight as an alternative to radar vector along a straight segment. *(Available 2011)*.

Note: the exact nature of the operational requirement associated with this functionality needs to be further defined so that the functionality can be accurately described.

2.17 **(❖Nq)** Navigation Data to be downlinked for route conformance monitoring (see **❖Cd)** *(Available 2011)*.

2.18 Sufficient database capacity to accommodate increased number of RNAV or RNP SIDs/STARs.

Note 1: The Enabler A-RNP 1 (Advanced-RNP 1)= Nc includes associated functionalities (Nd to Ng and Np). Enabling A-RNP 1 envisages several steps including development of the European Navigation Specification in cooperation with the FAA, endorsement by ICAO for inclusion in the PBN Manual, the existence of certification material, EASA approval and operational approval. In context, the enabler availability date of 2011 associated with the functionalities for Advanced RNP 1 reflects the date by which the EASA material is published.

Appendix 3

Generic Template for Implementation Planning

The following Template is provided to assist in the planning processes leading to the Implementation of new Navigation Requirements and Procedures' The various steps are not listed in a rigid chronological order, or in order of importance. They are intended to form a checklist of the activities that will need to be addressed in the development of most new projects.

1. **Review of Initial Planning Assumptions**
2. **Review of Anticipated Operational Benefits**
   - Confirm a clear operational requirement exists,
   - Initial consultation with the all affected stakeholders
   - Complete initial safety Case (including a HAZID), and an outline business case that identifies/quantifies the operational and economic benefits.

   The demonstration of these benefits should form part of the Navigation Domain Work Programme and may require the use of fast and real time simulations.

3. **Cost Benefit Analysis**
4. **Safety Case**
5. **Business Case**

   A Business Case should be developed in consultation with all affected Stakeholders. It should take due account of:
   - Operational requirements
   - Technical Requirements/Operational Capability of Aircraft
   - Supporting Ground Infrastructure;
   - Safety Case requirement;
   - Cost benefit considerations;
   - Operational benefits
   - Overall aims and direction of the future navigation plans.
   - ATM Considerations
   - Security case requirements.

6. **Support for State**

   Whenever a change to aircraft and/or airspace requirements is envisaged, it will be necessary to determine, through consultation with Military Authorities, the level of support necessary for continued operations by State Aircraft. The civil military working arrangements available at EUROCONTROL can facilitate this consultation.

7. **Dependencies**

   In order to ensure a smooth implementation of any enhanced level of operations, it will be essential to define/establish links to, and impact on, the Planning Strategies of other Domains, and to ensure coherence with the objectives of the SESAR Concept of Operations for 2020+

8. Co-ordination

All planning and implementation activities should be closely co-ordinated with all affected Stakeholders, e.g.

- Provider States
- Operators and User Organisations.
- NATO
- Aviation Industry
- External Programmes and Projects

9. Define Implementation Schedule

Implementation time-scales should be developed to ensure the realisation of the maximum operational and cost efficiency as defined by the CBA and Business Case, It will be essential to provide sufficient notice of planned changes to all Stakeholders,

CBAs are highly dependent upon close adherence to the planned implementation time-scales. Any excessive delay in implementation may change the balance of advantage and cause the CBA to be reviewed,

.

10. Notification process

The formal notification process should be commenced as soon as is operationally possible. This process will include:

- ICAO Legislation & Documentation e.g. – ICAO Document 7030 – Regional Supplementary Procedures.
- Issuance of Generic AIC to States,

  Note; It will then be the responsibility of State Authorities to issue State AICs detailing changes and specific State requirements.
- National Procedures – to be updated by State Authorities as required

11. Publicity

The maximum possible publicity should be given to implementation plans and requirements. This could include some or all of the following, dependent upon the complexity of the proposed changes:

- Bulletins/Newsletters
- Helpdesk/User Support Cell
- Education and Awareness Material (Training ***Videos, CDs etc)***
- Workshops/Seminars if required

Appendix 4

RNAV Approaches

The development of RNAV approaches has resulted in the development of complex terminology. The following provides a brief summary of the more important types of approach.

Conventional (Non-Precision Approaches) are to be replaced by laterally and, optionally vertically, guided RNAV procedures, based primarily on the use GPS.

RNP APCH Implementation of RNP APCH both with and without Baro/VNAV.

RNP APCH procedures without vertical guidance are flown to LNAV minima. Although they may be flown with continuous descent they have been designed according to basic GPS non precision approach criteria.

RNP APCH with vertical guidance provided is a vertically guided approach that can be flown by modern aircraft having Area Navigation or Flight Management Systems with VNAV functionality using barometric inputs. Most Boeing and Airbus aircraft already have this capability as well as some of the smaller regional jets. Therefore a large part of the ECAC Air Transport fleet is capable of RNP APCH although, due to the lack of EASA certification and operational approval documentation, few aircraft operating in ECAC are approved for these operations. The EASA material is expected to be available during 2008

Safety cases are being prepared that may be used by States as an input to their implementation safety case.

LPV - Implementation of LPV approaches enabled by SBAS.

The improved lateral and vertical performance of augmented GNSS allows LPV procedures to be implemented providing 3D guidance on a geometric lateral and vertical path. LPV is a procedure supported by SBAS systems such as WAAS in the US and EGNOS in Europe to provide lateral and vertical guidance. The term LPV stands for Localizer Performance with Vertical guidance. The lateral performance is equivalent to an ILS localizer and the vertical guidance is provided against a geometric path in space rather than a barometric altitude. LPV is of particular interest to a category of users with aircraft that do not have sophisticated FMS based avionics that can perform Baro/VNAV.

With EGNOS expected to be operational by the end of 2009 or early 2010, the provision of LPV procedures will become possible, encouraging those operators not able to use APV Baro VNAV to consider retrofitting appropriate equipment. EASA certification and Operational material is still in preparation but is expected to become available in 2009

Safety cases being prepared for LPV have drawn upon the RNP APCH safety case as a large degree of commonality exists between the two types of procedures. As for RNP APCH these safety cases are being prepared to support starts in the preparation of their implementation safety cases.

Through TEN-T funding the Agency will be able to support a part of the cost of a number of initial LPV implementations. The aim of this support is to provide initial implementation experience and thereby provide the data needed to develop implementation guidance material. This will be developed as an RATF deliverable to be used by all States.

LPV 200 - Implementation of LPV procedures with minima equivalent to ILS Cat-I.

The WAAS system has demonstrated performance and possesses a monitoring environment that has enabled LPV implementation with 200ft decision height. The runway requirements remain the same as those for Cat I (eg lighting) but the availability of such a capability could provide a back up to ILS during maintenance or ILS system outages.

Experience gained with EGNOS operations is expected to demonstrate that the achieved performance using SBAS/GNSS can support approaches with minima equal to that provided today by ILS Cat-I. An Ad Hoc group has been established to evaluate whether EGNOS performances can support LPV200 operation.

RNP AR

RNP AR approaches make use of advanced RNP capabilities of certain modern aircraft to provide better access to runways with terrain or environmental constraints. They use specific obstacle clearance criteria and require a particular RNP approval for the aircraft. RNP AR is designed for the latest, most sophisticated aircraft, capable of Performance Based Navigation. The AR operations are particularly demanding an equipment performance alone is not sufficient to ensure system safety. The operational requirements are an important part of the requirements and pilot training is a central part of the requirement. The operation requires a particular kind of safety assessment (FOSA) for operational approval.

Guidance Material for States to develop the required FOSA safety assessment is to be developed as a deliverable from RATF.