



International Civil Aviation Organization

CAR/SAM Regional Planning and Implementation Group (GREPECAS)

Fifth Meeting of the Air Traffic Management / Communications, Navigation and Surveillance Subgroup (ATM/CNS/SG/5) - ATM Committee

Lima, Peru, 13-17 November 2006

ATM/COMM/5 - WP/04

24/10/06

Agenda Item 2: Report of the ATM Task Forces
2.1 Performance based navigation (PBN)

REPORT OF THE WORKS CARRIED OUT BY THE PBN TASK FORCE

(Presented by the PBN Task Force Rapporteur)

SUMMARY

This Working Paper presents a report of the works carried out by the PBN Task Force during the AP/ATM/12 Meeting, and the CAR/SAM PBN Roadmap.

References:

- GREPECAS/13 Report
- AP/ATM/12 Report

1. Introduction

1.1 During the Fourth Meeting of the ATM/CNS Subgroup (Mexico City, 15 to 18 August, 2005), the ATM Committee agreed that, to plan and implement the performance based navigation, it was necessary to obtain detailed information about several aspects associated to the CNS infrastructure, the navigation capacity of the fleet, the airports and other related subjects.

1.2 On the other hand, GREPECAS/13 (Santiago, Chile, 14 to 19 November 2005) took note of this requirement and approved Conclusion 13/57 - RNAV and RNP Questionnaire, by means of which the Secretariat was requested to take the pertinent steps in order to compile such information.

1.3 Replies were received to the consultation made (from Argentina, Barbados, Bolivia, Brazil, Chile, Cuba, Dominican Republic, French Guiana, Panama, Suriname and COCESNA). Notwithstanding the above mentioned and using information found in the CAR/SAM Air Navigation Plan and in other appropriate sources, it was possible to obtain additional information which was used in the data compilation. The answers received can be found in the ICAO South American Regional Office web page (www.lima.icao.int).

1.4 During the AP/ATM/11 Meeting (Lima, Peru, 28 to 30 September 2005) the PBN Task Force (PBN/TF) analysed the issues related with RNAV/RNP under the new performance based navigation concept (PBN) and the strategy to be followed for en-route and terminal operations as well as IFR approaches.

1.5 At that time, it was considered that the development of a road map was a key issue to harmonize the implementation of PBN in the CAR/SAM Regions, and approved a basic content for this document. It also adopted *Decision AP/ATM/11/2 - CAR/SAM Performance Based Navigation Road Map*, where assigned experts were requested to take the pertinent measures to develop the CAR/SAM road map for PBN implementation, defining some key dates for its coordination and execution.

2. Analysis

CNS Infrastructure

2.1 **Appendices A, B and C** to this part of the report present some graphics with the current situation of the theoretical coverage of communications, navigation and surveillance in the CAR/SAM Regions obtained from the survey and from available information at the ICAO Regional Offices.

VHF Air-ground communications

2.2 It has been noted that VHF air-ground communications in the CAR/SAM Regions have greatly improved during the last years. To a great extent, VHF communications are based in extended-range facilities, in order to cover ATS routes as far as possible (**Appendix A** to this part of the report). In those airspaces where VHF coverage is not possible States use HF communications. This is especially applied in remote oceanic or continental areas.

2.3 VHF coverage in the CAR Region continental and oceanic areas, shown in the graphics is full. With regard to the continental area of the SAM Region seems to be good. However, the presence of mountains and large forests limits coverage in some specific areas and States involved have programmes addressed to solve the lack of VHF communications in a very short term.

Navigation

2.4 Conventional navigation in CAR/SAM Regions is mostly based in VOR/DME facilities. Navigation facilities foreseen in the CAR/SAM Air Navigation Plan have been totally implemented (**Appendix B** to this part of the report). Notwithstanding the above, with the own characteristics of these radio navigation aids, there are some airspace sectors that do not have good navigation coverage. In oceanic and remote areas, navigation is met through different navigation systems with RNAV capacity, including GNSS.

Surveillance

2.5 There is wide surveillance coverage in the CAR/SAM Regions (refer to **Appendix C**). In many cases, surveillance is carried out through the application of radar monopulse techniques including wide open array. Surveillance coverage in the CAR Region seems to be full. However, in the SAM Region there some specific limitations, although that situation could be considered satisfactory. There are also development plans in some States, in order to enlarge this coverage.

Fleet navigation capacity

2.6 Derived from the analysis RNAV navigation capacities of the aircraft fleet operating in the CAR/SAM Regions and based on the information collected through the RNAV/RNP survey for this purpose, the PBN/TF concluded that a great part of the same is equipped to carry out RNAV-5 operations. Also, it has been verified that those eldest aircraft could reach RNAV-5 capacity, with the STC application or Service Bulletins, at acceptable costs.

2.7 In view of the above, the Meeting agreed that the VHF communications infrastructure, navigation and surveillance, as well as the fleet navigation capacity in the CAR/SAM Regions would be adequate for the application of RNAV 5 values in selected airspaces.

Navigation specifications

2.8 Besides the CNS infrastructure and the fleet capacity, the existing Navigation Specifications that will be part of Volume 2 of the PBN Manual should be taken into consideration. These specifications are the following:

Navigation Specification	Airspace/Operation	Applicable Sensors	Operational Limitations
RNP 10	En Route - Oceanic/Remote	GNSS	No limitations
		INS/IRS	6,2 h until the first update, after 5,7 h.
RNAV 5	En Route - Continental	GNSS	No limitations
		VOR/DME	Within the radio aid coverage
		DME/DME	Within the radio aid coverage
		LORAN	Within the Loran coverage
		INS/IRS	Up to 2 hours after the take- off
RNAV 1/2	En Route – Continental	GNSS	No limitations
		DME/DME	Routes and Procedures where there be proper coverage
	TMA	DME/DME/IRU	Routes and Procedures where the faults in the DME/DME coverage are short (approximately 15 minutes)
RNP 4	En Route - Oceanic/Remote	GNSS *	No limitations
RNP 1/2	En Route – Continental	GNSS	No limitations
		DME/DME	Routes and Procedures where there be proper coverage
		TMA	DME/DME/IRU

RNP 0,3	Approach	GNSS	No limitations
RNP AR (RNP 0,3 – 0,1)	Approach	GNSS RF MASRNP	No limitations
* Additional navigation requirements under study.			

Road Map for Performance Based Navigation Implementation in the CAR/SAM Regions

2.9 The PBN Task Force, through the ATM, OPS/AIR and SAM working groups examined the draft PBN Road Map for the CAR/SAM Regions.

2.10 In this connection it was considered appropriate to eliminate every long-term implementation reference, since concepts are still under development. After fruitful discussions, the short and medium term periods were defined for years 2010 and 2015, respectively, as per the guidelines of the new Air Navigation Global Plan.

2.11 The final draft of the Road Map is shown in **Appendix D** to this working paper. This document must be analysed by the ATM Committee and the ATM/CNS Subgroup for further submission to GREPECAS through the appropriate channels.

2.12 As result of the analysis of the above, the meeting established the following implementation strategy at short- and mid-term included in the PBN Road Map.

Short Term

2.13 The meeting agreed that in short term, till 2010, the existing on board capacity of the aircraft shall be used, as well as the existing CNS infrastructure. In the chart bellow, it is possible to observe a summary of the short term implementation proposals.

Short Term (until 2010)	
Airspace	RNAV or RNP Value
Route (Oceanic o Remote)	RNP 10 Corridor EUR/SAM and Santiago/Lima/AORRA/WATRS
Route (Continental)	RNAV 5 in selected airspaces
TMA (SID – STAR)	RNAV-1 in radar environment and with adequate ground navigation infrastructure.
	RNP 1 – No radar environment and/or without appropriate DME coverage.
Approach	RNP 0,3 in most possible airports and in all international airports. RNP AR in airport where there are obvious operational benefits.
<ul style="list-style-type: none"> • Non compulsory installation of RNAV equipment on board of non equipped aircraft in TMA and APP • Mixed Operations (equipped and non equipped aircraft) in TMA and APP • Required RNAV 2 equipment at or above FL350 for flights to/from United States. 	

Medium Term

2.14 In medium term, between 2011 and 2015 it will be necessary compulsory RNAV and/or RNP equipment in some airspaces. So, in the following chart is possible to observe a summary of mid term implementation proposals.

Medium Term (2011-2015)	
Airspace	RNAV or RNP Value
Route (Oceanic or Remote)	RNP 4 in EUR/SAM Corridor and Santiago/Lima
Route (Continental)*	RNP 2 in selected airspaces
TMA (SID/STAR)	Expansion of RNAV-1 or RNP-1 application Compulsory RNAV 1 or RNP 1 approval for aircraft operating in greater air traffic density TMAs (exclusionary airspace)
Approach	Expansion of RNP 0,3 and RNP AR application Application of GLS procedures
<ul style="list-style-type: none"> • RNP2 required equipment at or above FL290 for flights to/from United States. 	

2.15 As a consequence of the above, the approval of the following draft conclusion and draft decision is suggested:

Draft

Conclusion ATM/5/XX

CAR/SAM Roadmap for PBN

That States/Territories and International Organizations adopt and apply the CAR/SAM Roadmap for PBN as shown in Appendix XX to this part of the report.

Draft

Decision ATM/5/XX

Application of the CAR/SAM Roadmap for PBN by the ATM/CNS Subgroup

That the ATM/CNS Subgroup adopt and apply the CAR/SAM Roadmap for PBN as shown in Appendix XX to this part of the report for planning of the CAR/SAM Regions air navigation infrastructure.

WGS-84 implementation

2.16 The PBN Task Force Meeting considered of utmost importance to complete WGS-84 implementation before performance based navigation implementation and particularly to attend implementation objectives of RNP 0.3 approaches and more restrictive RNP.

RNAV and RNP training requirements

2.17 The PTN/TF meeting recalled the importance of RNAV and RNP training for safety oversight. In several events, the need that States and Territories in the CAR and SAM Regions develop a methodology for the training of experts that would be directly related with the development of planning and design of airspaces and RNAV and RNP operations. It was deemed convenient that those States and international organizations having courses in matters such as airspace planning, PANS/OPS procedures design and safety assessment are offered to the other States and international organizations, and all available consultation material be incorporated into the ICAO Regional Offices websites.

2.18 The PBN/TF meeting noted a guideline of RNAV and RNP training requirements presented by Mexico in order that States, Territories and International Organizations of the CAR/SAM Regions prepare their own training programmes aiming an effective, constant and ensured training and at the same time facilitate them the transition to RNAV/RNP operational scenario in benefit to air operators and ATS providers. The meeting agreed that these guidelines be incorporated as **Appendix E** to this working paper.

2.19 The PBN/TF Meeting considered necessary to carry out courses, workshops and seminars on airspace planning, air navigation procedures construction, aircraft approval and aircraft certification, safety evaluation and airspace monitoring, with the aim of carrying out a harmonious implementation in the Region.

Status of ICAO documentation related to instrument approach procedures

2.20 The PBN meeting was informed of latest information concerning ICAO documentation related to instrument approaches. In this respect, the meeting noted that the revised version of the *Procedures for Air Navigation Services – Aircraft Operations* (PANS-OPS, Doc 8168) was finalized and would be distributed to States in August as a “Green Cover” State letter. The applicability date is in November 2006. The “Blue Cover” State letter with a new edition or replacement pages would be distributed by October 2006. Both the Green and Blue Cover State letters would contain the Spanish version of Doc 8168.

2.21 The PBN/TF recognized that several States were implementing RNAV and RNP approaches; however, there was no available guidance material on how to conduct flight inspection and validation of the associated procedures. In this context, the meeting was informed that unlike conventional approach procedures based on navigation aids, RNP approaches did not require checking of signals. One State informed the meeting that they used commercial air carriers, who were approved to use the RNP approaches, to conduct the flight checks. The meeting wondered about the regulatory implications of this method of flight checking. In this respect, the meeting was informed that ICAO document (Doc 8071) would be updated and published before the end of 2006 and would contain guidance material on flight inspection and validation of RNP approaches. Additionally, the revised

version of Doc 8168 will contain procedures for flight inspection and validation of RNP approaches and the Obstacle Clearance Panel (OCP) is developing a Quality Assurance Manual which will provide more guidance on this subject.

2.22 The meeting was reminded that the ground based augmentation systems (GBAS) category I flight procedures criteria were already contained in Doc 8168 and were applicable in November 2004.

Development of RNAV/GNSS applications and procedures promoted by IATA

2.23 IATA informed that they have encouraged the development of RNAV/GNSS applications as part of the transition towards the new ICAO ATM/CNS concept, which allows the usage of current avionics already onboard a large number of aircraft. These procedures have proven to provide benefits to the States, airports and operators, by greatly enhancing safety, improving operational efficiency and reliability, while also providing a positive environmental impact.

2.24 There are currently a large number of published GNSS procedures in the Caribbean, and IATA and several airlines are working with other States in the CAR and SAM Regions to implement these procedures at the main international airports.

2.25 On the other hand some States have also supported this IATA initiative to create an industry partnership for the implementation of these procedures at international airports. It was informed that among States that have already implemented these procedures in airports, are:

BVB: Boa Vista	NAS: Nassau	AUA: Aruba
CGB: Cuiaba	MVD: Montevideo	BGI: Barbados
CWB: Curitiba	STT: St. Thomas	GCM: Grand Cayman
MAO: Manaus	STX: St. Croix	KIN: Kingston
VCP: Campinas	SJU: San Juan	MBJ: Montego Bay
MCP: Macapa	POS: Port of Spain	PLS: Providenciales
POA: Porto Alegre	GDT: Grand Turk	PUJ: Punta Cana (Higüey)
PVH: Porto Velho	FPO: Freeport	POP: Puerto Plata
/GEO: Georgetown	BEL: Belem	SDQ: Santo Domingo
STI: Santiago de los Caballeros	CRY: Cayenne	

2.26 In addition, IATA and American Airlines have been awarded a contract from LACAC (Latin American Civil Aviation Commission), financed by the United States Trade Development Agency (USTDA), to conduct RNAV/GNSS procedures familiarization training seminars and WGS-84 Datum validation work. The meeting was informed that, up to date, seminars have been held in Bolivia, Colombia, Ecuador, Paraguay, Peru and Uruguay and it was of the opinion that States interested in implementation projects should designate a RNAV/GNSS coordinator to contact IATA to prepare an implementation plan of these procedures in its State.

PBN implementation plans in the CAR/SAM Regions

2.27 When reviewing preparatory plans of Brazil for PBN implementation in terminal areas, the PBN Task Force considered it was valuable information which served as guidance for other States of the CAR/SAM Regions. Note was also taken on the plans of COCESNA in this connection. This document is shown in **Appendix F** to this part of the report.

Aircraft Operation and Airworthiness

2.28 The PBN/TF took note of the deliberations of the OPS/AIR/WG on the RNAV/RNP process of approval and the flight crews training programme, in charge of flight operations/flight dispatchers and maintenance personnel.

2.29 In this connection, the information concerning to PBN was reviewed as regards its two categories, RNAV and RNP, and also the guides and addresses for inspectors of the AAC on the approval process of the different types of operations: RNP10, RNP4, RNAV5, RNAV2 and RNAV1. Changes proposed to this document were incorporated and are shown in **Appendix G** to this working paper.

2.30 When reviewing the operator training programme, the meeting agreed to include in such programme a series of modifications which are reflected in **Appendix H** to this working paper.

Airspace safety and monitoring

Air navigation infrastructure

2.31 The PBN/TF analysed the information provided by the States on the questionnaire approved by GREPECAS/13 related to collection of information of the available CNS infrastructure in each State of the CAR/SAM Regions, with the corresponding coverage and verified that for a better planning it should be convenient to have more concrete information regarding the infrastructure available in the Region. This includes the Nav aids and its coverage, considering that the required performance that will be the base for the planning is directly related to this available infrastructure. On the other hand, the meeting considered that the PBN/TF could decide which performance is needed to attend the operational requirements of the Region and verify which infrastructure is needed to support the proposed performance. In both cases it is extremely necessary to know the infrastructure available, as well as the capacity of the fleet. Considering the above, the group recommended that:

Draft

Conclusion ATM/5/XX

Available navigation infrastructure

That States, Territories and International Organizations make efforts to provide information on their available navigation infrastructure, considering that this information will be the base of the studies to determine the separation minima to be applied between aircrafts in a PBN environment.

Safety assessment seminars

2.32 The meeting verified that, to implement the PBN concept in a harmonized way, it will be necessary to provide safety assessments for many different portions of airspace, using different methodologies. The meeting also considered that there is today a restricted number of professionals involved in the safety assessment subject and recommended that:

Draft

Conclusion ATM/5/XX

Safety assessment seminars/methodology

That ICAO:

- a) besides the safety assessment course already scheduled, promote seminars related to safety assessments, aiming at the preparation of personnel to work in the future PBN implementation;
- b) encourage safety airspace and separation panel (SASP) to develop a common methodology for safety assessment in terminal areas.

2.33 The PBN/TF meeting considered the industry activities in developing minimum aviation system performance standards (MASPS) for RNP that addressed aspects of implementation including system performance criteria, operational considerations, system qualification, navigation data, and navigation databases. These discussions resulted in new standards that represented fundamental change in a number of areas:

- a) system requirements that reflected the distribution of safety responsibility across the stakeholders (i.e. pilot, system, operational procedure, procedure and airspace design, airworthiness approval and operational approval),
- b) setting specific conditions and criteria for the system and procedure design,
- c) performance standards intended to support obstacle clearance or separation,
- d) specification of changes necessary to assure the reliability, repeatability and predictability of the navigation system for flight guidance and flight management,
- e) specification of data management and control processes necessary for navigation databases containing the RNP procedures,
- f) specification of data requirements along with the rigor and processes to assure correct, accurate and usable navigation source data.

2.34 It was remarked that RNAV/RNP approach procedures, whether AR or basic public procedures (regardless of RNP), have not seen jet transport accidents due to crew error or other causes. In large part, this is due to the greater assurance of the aircraft capability, crew training and procedures, and in the procedure design.

2.35 The operational safety has also been significantly enhanced through:

- a) Simplicity of flying the approaches relative to the traditional VOR/ADF. Fix to fix navigation using LNAV in conjunction with a MAP display is vastly simpler for crews than monitoring primitive VOR course or ADF bearing information while trying to combine this with DME information, crossing radials/bearings, etc.
- b) Constant angle barometric path definition and the ability to fly this path automatically means that multiple crew errors must be made to result in a CFIT accident, as opposed to traditional "dive and drive" methods which only require one crew error to cause a fatal accident. The potential for multiple errors is removed by the capabilities and improvements in the flight systems.
- c) The constant angle path also easily provides the crew a low-workload stabilized approach method to avoid landing accidents.

2.36 Considering the information provided it is evident that with RNP, there is tight coupling between the procedure and airspace design criteria for en-route and terminal operations and the assurance that only performance qualified aircraft and systems, and operators are allowed to conduct the operations. Together all requirements of the aircraft qualification and operator approval constitute specific aspects of the safety of the operation that must be addressed and approved. In light of this the meeting adopted Decision AP/ATM12/05 - Points to be considered by the SAM and OPS/AIR WG, indicating that the SAM and OPS/AIR WG consider the guidance and criteria provided for operational considerations observed in **Appendix I** to this working paper, when developing requirements for the risk analysis of the operations, as well as when developing national regulations for the aircraft and operators approval for the operations with the use of the PBN concept.

2.37 Consequently, the following is suggested to the meeting:

Draft

Conclusion AP/ATM/12/06

Importance of operational errors

States, Territories and International Organizations analyze the importance of operational errors in an environment with PBN and invest all possible resources in the training of air traffic controllers and pilots aiming the reduction of these errors considering the future implementation of this concept in the CAR/SAM Regions.

Terms of reference and work programme of the performance-based navigation task force

2.38 The meeting recalled that during GREPECAS/13 Meeting, among other matters, the RNAV/RNP implementation strategy within the performance-based navigation concept (PBN). In view of this analysis, the meeting considered that the strategy shall be the RNAV/RNP implementation by en-routing areas in CAR/SAM scenarios, as per their own operational needs, which could involve a group of States/Territories and International Organizations.

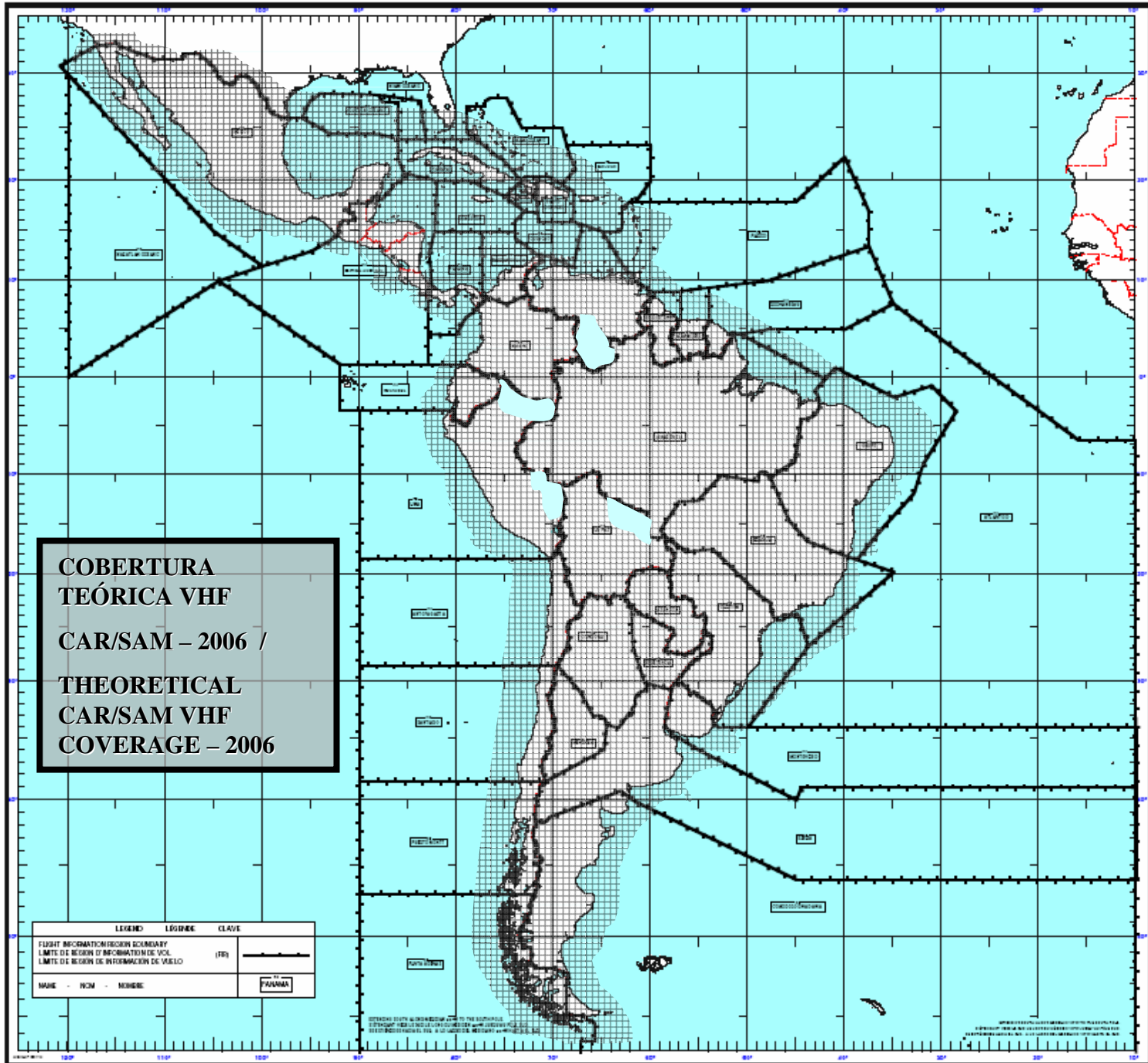
2.39 The meeting considered that regional planning should continue developing through the GREPECAS ATM/CNS Subgroup ATM Committee Performance Based Navigation Task Force.

2.40 Consequently, the meeting analyzed the terms of reference of the PBN/TF and in view of the tasks executed so far by the ATM, OPS/AIR and SAM working groups, proposed some changes to its work programme, which shall be presented under agenda item 6.

3. Suggested action

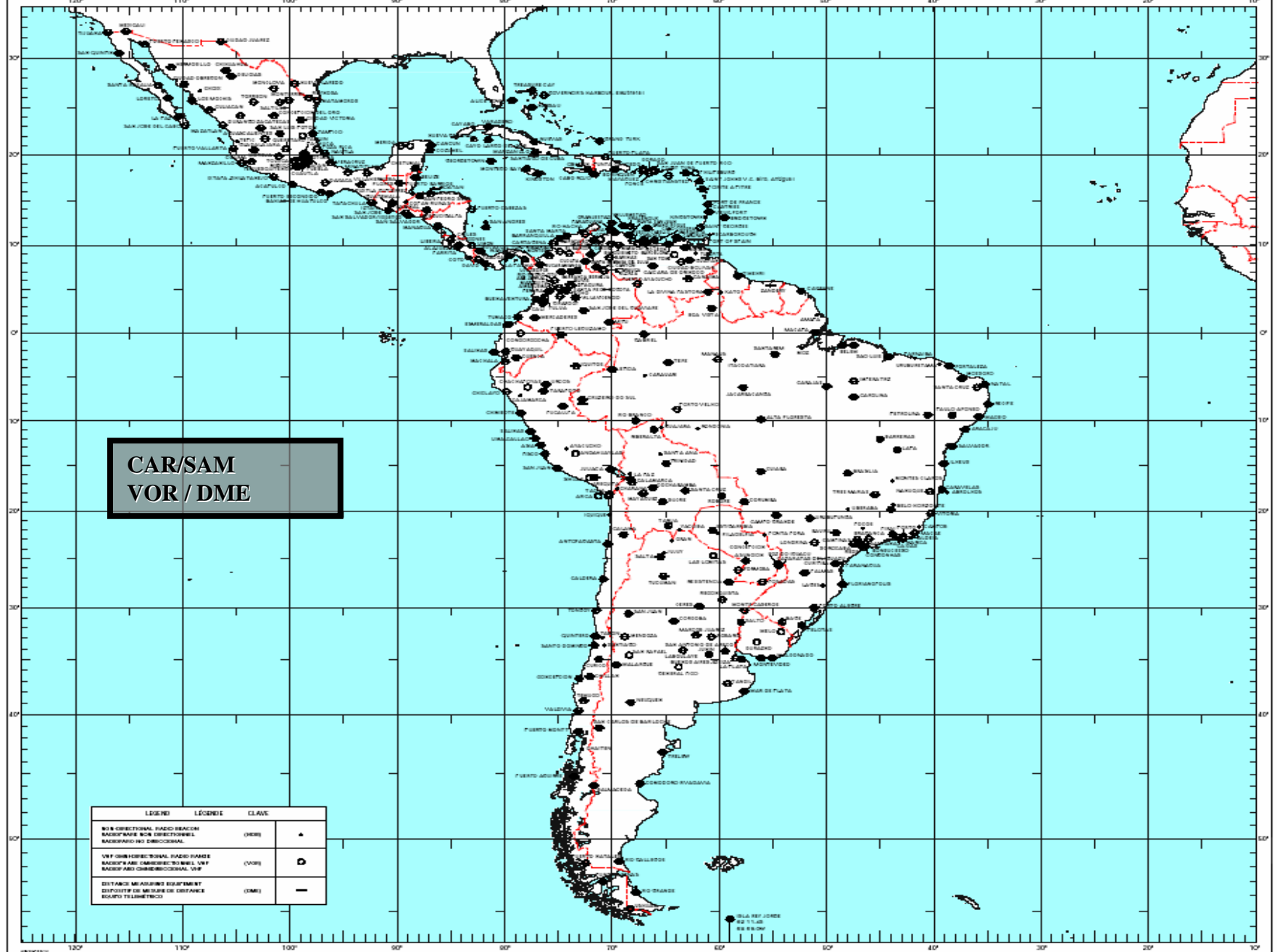
3.1 The meeting is invited to:

- a) Take note of the information presented in this working paper, and
- b) Analyse the CAR/SAM Roadmap for PBN, propose changes deemed pertinent and approve the draft conclusions/decision shown in paragraphs 2.15, 2.31, 2.32 and 2.37 of this working paper.



**COBERTURA
TEÓRICA VHF
CAR/SAM - 2006 /
THEORETICAL
CAR/SAM VHF
COVERAGE - 2006**

LEGEND	LEGÈNDE	CLAVE
FLIGHT INFORMATION REGION BOUNDARY	LIMITES DE REGION D'INFORMATION DE VOL	(FR)
NAME - NOM - NOMBRE		PANAMA

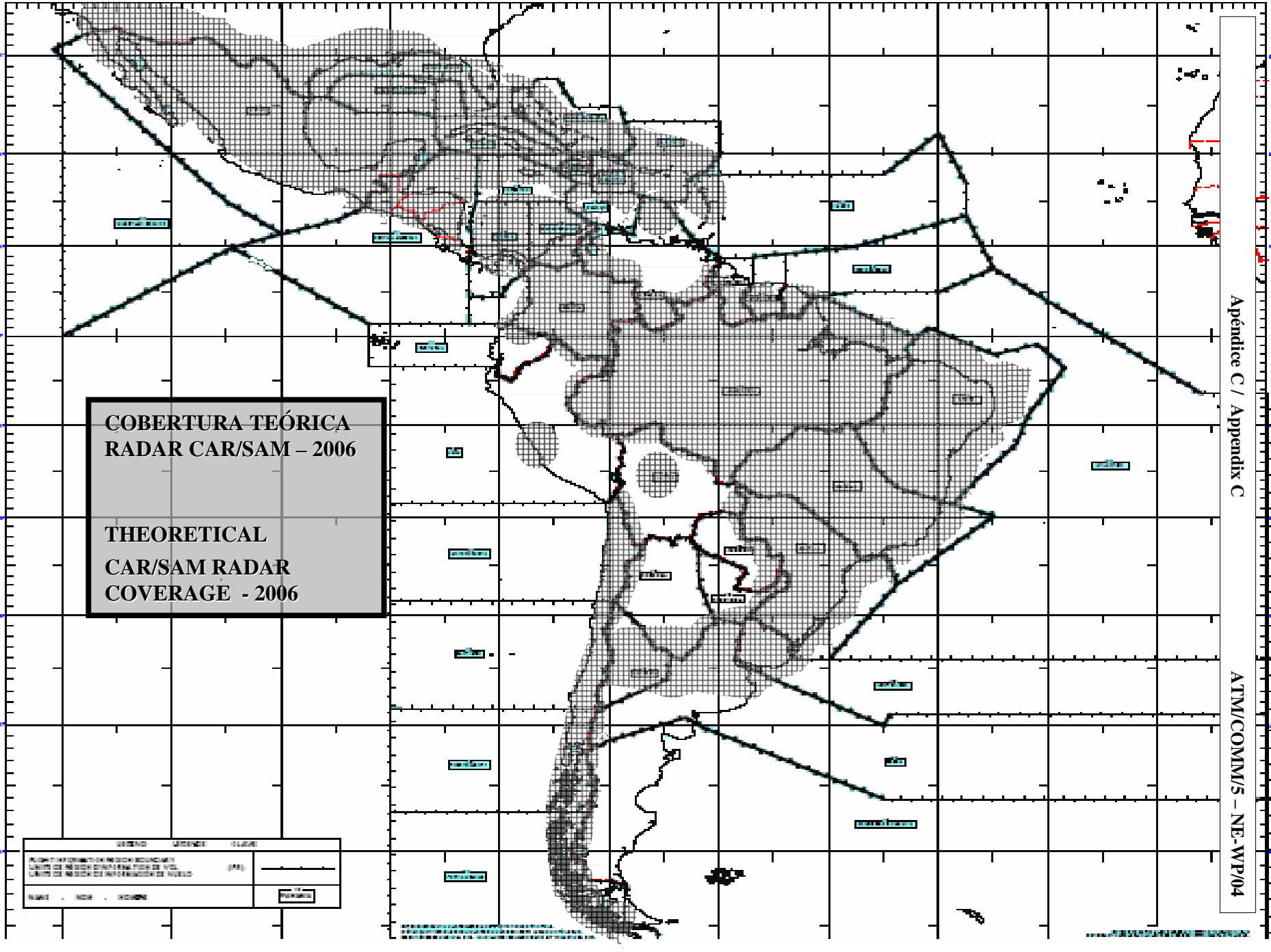
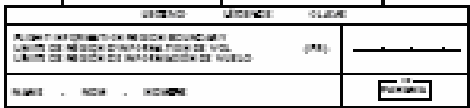


**CAR/SAM
VOR / DME**

LEGEND	LEGENDE	CLAVE
NON-DIRECTIONAL RADIO BEACON RADIOFARE NON DIRECTIONNEL RADIOFARE NO DIRECTIONAL	(NDB)	▲
VOR/DME VOR/DME RADIOFARE OMNIDIRECTIONNEL VOR RADIOFARE OMNIDIRECTIONNEL VOR	(VOR)	●
DISTANCE MEASURING EQUIPMENT EQUIPEMENT DE MESURE DE DISTANCE EQUIPE TILIMETRICO	(DME)	

**COBERTURA TEÓRICA
RADAR CAR/SAM - 2006**

**THEORETICAL
CAR/SAM RADAR
COVERAGE - 2006**



APPENDIX D

PBNRM



INTERNATIONAL CIVIL AVIATION ORGANIZATION

**North American, Central American and Caribbean (NACC)
Regional Office**

South American (SAM) Regional Office

CAR/SAM ROADMAP FOR PERFORMANCE-BASED NAVIGATION

(Lima, November 2006)

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1. EXECUTIVE SUMMARY

1.1. Following RVSM implementation on 20 January 2005, the main tool for optimising the airspace structure is the implementation of performance-based navigation (PBN), which will foster the necessary conditions for the utilisation of RNAV and RNP capabilities by a significant portion of airspace users in the CAR/SAM Regions.

1.2. In view of the need for detailed navigation planning, it was deemed advisable to prepare a PBN Roadmap to provide proper guidance to air navigation service providers, airspace operators and users, regulating agencies, and international organisations, on the evolution of navigation, as one of the key systems supporting air traffic management, which describes the RNAV and RNP navigation applications that should be implemented in the short, medium and long term in the CAR/SAM Regions.

1.3. The CAR/SAM PBN Roadmap was developed by the CAR/SAM States and International Organizations, together with the international organizations concerned (IATA, IFALPA, IFATCA), and is intended to assist the main stakeholders of the aviation community plan the future transition and their investment strategies.

1.4. The CAR/SAM PBN Roadmap will be the basic material for the development of a broader CAR/SAM navigation strategy, which will serve as guidance for regional projects for the implementation of air navigation infrastructure, such as SBAS, GBAS, etc., as well as for the development of national implementation plans.

1.5. This document begins with a brief description of the need for a roadmap, the strategic objectives of the document, and the principles on which the implementation will be based. It should be noted that, during the transition period, conventional air navigation procedures would continue to be applied in order to safeguard the operations of users that are not RNAV- and/or RNP-equipped.

1.6. It then explains the PBN implementation strategy for both en-route and terminal area operations. It also analyses briefly the PBN concept, and lists the benefits of implementing this concept.

1.7. A review is made of data concerning the regular traffic of passengers on CAR/SAM airlines during the 1994-2004 period, CAR/SAM traffic forecasts, and traffic trends up to the year 2015.

1.8. It furthermore defines the implementation of performance-based navigation in the short, medium, and long term with respect to en-route operations, TMA operations (SIDs and STARs), and IFR approaches, broadly establishing the requirements and specifications for each stage.

1.9. A description is made of RNAV/RNP approval, which will encompass two types of approvals: airworthiness, exclusively relating to the approval of aircraft; and operational, dealing with the operational aspects of the operator. RNAV/RNP approval will be granted to operators that comply with these two types of approvals.

1.10. The implementation of the performance based navigation forecast significant safety-related changes in the airspace structure as well as to the ATC system. The ICAO requirement for new operations introduced post 2000 is that the risk of collision has to be less than 5 than 5×10^{-9} per dimension.

1.11. After the implementation of PBN applications and the airspace concept, the total system needs to be monitored to ensure that the safety of the system is maintained. A System Safety Assessment is conducted after implementation and evidence collected to ensure that the safety of the system is assured.

2. EXPLANATION OF TERMS

2.1 The drafting and explanation of this document is based on the understanding of some particular terms and expressions that are described below:

CAR/SAM PBN Roadmap. Document offering appropriate guidance for air navigation service providers, airspace operators and users, regulating agencies, and international organizations, on the evolution of navigation, as one of the key systems supporting air traffic management, which describes the RNAV and RNP navigation applications that should be implemented in the short, medium and long term in the CAR/SAM Regions.

Performance Based Navigation. Performance based navigation specifies RNAV system performance requirements for aircraft operating along an ATS route, on an instrument approach procedure or in an airspace.

Performance requirements. 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. Performance requirements are identified in navigation specifications which also identify which navigation sensors and equipment may be used to meet the performance requirement.

3. ACRONYMS

3.1 Lista de Acrónimos/ List of Acronyms

ADS/B	Vigilancia dependiente automática-radiodifusión Automatic dependent surveillance-broadcasting
ADS/C	Vigilancia dependiente automática-contrato Automatic dependent surveillance-contract
ANS	Servicios de navegación aérea Air navigation services
ANSP	Proveedores de Servicios de Navegación Aérea/Air Navigation Service Providers
ASM	Gestión del espacio aéreo/ Airspace Management
ATC	Control de tránsito aéreo/ Air Traffic Control
ATFM	Gestión de afluencia del tránsito aéreo/ Air Traffic Flow Management
ATM	Gestión del tránsito aéreo/ Air Traffic Management
ATN	Red de telecomunicaciones aeronáuticas/ Aeronautical Telecommunication Network
ATS	Servicio de tránsito aéreo/ Air Traffic Services
CAR/SAM	Regiones Caribe y Sudamérica/Caribbean/South American Regions
CNS/ATM	Comunicaciones, navegación y vigilancia/Gestión del tránsito aéreo/ Communications, Navigation and Surveillance/Air Traffic Management
CPDLC	Comunicaciones por enlace de datos controlador-piloto /Controller-Pilot Data Link Communications
CTA	Area de control /Control Area
DME	Equipo Radiotelemetrico/Distance-Measuring Equipment
FAR	Regulación federal de aviación/Federal Aviation Regulation
FANS-1/A	Sistemas de navegación aérea del futuro – Aviónica/ Future Air Navigation Systems - Avionics
FDE	Detección y eliminación de fallas / Fault Detection and Exclusion
FIR	Región de información de vuelo /Flight Information Region
FMS	Sistema de gestión de vuelo /Flight Management System
GBAS	Sistema de Aumentación con Base en Tierra/Ground-Based Augmentation System
GLS	Sistema de aterrizaje GBAS / GBAS Landing System
GNE	Error de navegación grave / Gross Navigation Error
GNSS	Sistema mundial de navegación por satélite / Global Navigation Satellite System
GPMS	Sistema de monitoreo de la performance del GPS / GPS Performance Monitoring System
GREPECAS	Grupo Regional de Planificación y Ejecución CAR/SAM/ CAR/SAM Regional Planning and Implementation Group
GRAS	Sistema de Aumentación Terrestre Regional / Ground Regional Augmentation System
HF	Alta frecuencia/ High Frequency
IATA	Asociación del Transporte Aéreo Internacional/ International Air Transport Association
ICD	Documento de control de interfaz / Interface Control Document
IFALPA	Federación Internacional de Asociaciones de Pilotos de Líneas Aéreas/International Federation of Air Line Pilots' Associations
IFATCA	Federación Internacional de Asociaciones de Controladores de Tránsito Aéreo/International Federation of Air Traffic Controllers' Associations
IRU/INS	Unidad de referencia inercial/Sistema de navegación inercial/ Inertial Reference Unit/Inertial Navigation System
JAA	Autoridades Conjuntas de Aviación Civil/Joint Aviation Authorities

JAR	Regulaciones Conjuntas de Aviación Civil/Joint Aviation Regulations
NAT	Atlántico septentrional /North Atlantic
NDB	Radiofaro no direccional /Non-Directional Beacon
NOTAM	Aviso al Personal Encargado de las Operaciones de Vuelo/Notice to Airmen
PBN	Navegación Basada en la Performance /Performance-Based Navigation
RNAV	Navegación de área/Area Navigation - RNAV Route: Ruta de navegación de área/Area navigation route
RNP	Performance de navegación requerida /Required Navigation Performance
RNP AR	Requerimiento de aprobación para la performance de navegación requerida/ Required Navigation Performance Approval Required
RNPC	Capacidad de la performance requerida de navegación/Required navigation performance capacity
RNPSORSG	Grupo de Estudio sobre RNP y Requerimientos Operacionales Especiales/RNP and Special Operational Requirements Study Group
SARPS	Normas y métodos recomendados (ICAO)/ Standards and Recommended Practices (ICAO)
SATCOM	Comunicaciones por satélite/Satellite Communications
SBAS	Sistema de Aumentación de Base Satelital/Satellite-based Augmentation System
SID	Salida Normalizada por Instrumentos/Standard Instrument Departure
SSR	Radar secundario de vigilancia/Secondary Surveillance Radar
STAR	Llegada Normalizada por Instrumentos/Standard Instrument Arrival
TLS	Nivel de seguridad deseado/Target Level of Safety
TMA	Area Terminal/Terminal Area
VHF	Muy alta frecuencia /Very High Frequency
VDL	Enlace de datos en VHF/ VHF Data Link
VOR/DME	Radiofaro omnidireccional VHF/Equipo radiotelemétrico/Very High Frequency Omnidirectional Radio Range/Distance-Measuring Equipment

4. INTRODUCTION

Need for a roadmap

4.1 Following RVSM implementation on 20 January 2005, the main tool for optimising the airspace structure is the implementation of performance-based navigation (PBN), which will foster the necessary conditions for the utilisation of RNAV and RNP capabilities by a significant portion of airspace users in the CAR/SAM Regions.

4.2 Current planning by the Regional Planning and Implementation Groups is based on the Air Navigation Plans and the Regional CNS/ATM Plans. Currently, these plans are mostly made up by tables that do not contain the necessary details for the implementation of each of the CNS and ATM elements.

4.3 In view of the need for detailed navigation planning, it was deemed advisable to prepare a PBN Roadmap to provide proper guidance to air navigation service providers, airspace operators and users, regulating agencies, and international organisations, on the evolution of navigation, as one of the key systems supporting air traffic management, which describes the RNAV and RNP navigation applications that should be implemented in the short and medium term in the CAR/SAM Regions.

4.4 Furthermore, the CAR/SAM PBN Roadmap will be the basic material for the development of a broader CAR/SAM navigation strategy, which will serve as guidance for regional projects for the implementation of air navigation infrastructure, such as SBAS, GBAS, etc., as well as for the development of national implementation plans.

Objectives

4.5 The CAR/SAM PBN roadmap has the following strategic objectives:

- a) To ensure that the implementation of the navigation item of the CNS/ATM system is based on clearly established operational requirements.
- b) To avoid unnecessarily imposing the mandate for multiple equipment on board or multiple systems on ground.
- c) To avoid the need for multiple airworthiness and operational approvals for intra- and inter-regional operations.
- d) To prevent commercial interests from outdoing ATM operational requirements, generating unnecessary costs for CAR/SAM States and International Organizations, as well as for airspace users.
- e) To explain in detail the contents of the CAR/SAM Air Navigation Plan and of the CAR/SAM CNS/ATM Plan, describing potential navigation applications.

4.6 Furthermore, the CAR/SAM PBN Roadmap will provide a high-level strategy for the evolution of the navigation applications to be implemented in the CAR/SAM Regions in the short term (2006-2010), medium term (2011-2015). This strategy is based on the concepts of Area Navigation (RNAV) and Required Navigation Performance (RNP), which will be applied to aircraft operations involving instrument approaches, standard departure (SID) routes, standard arrival (STAR) routes, and ATS routes in oceanic and continental areas.

4.7 The CAR/SAM PBN Roadmap was developed by the CAR/SAM States and International Organizations together with the international organizations concerned (IATA, IFALPA, IFATCA), and is intended to assist the main stakeholders of the aviation community plan a gradual transition to the RNAV and RNP concepts. The main stakeholders of the aviation community that benefit from this roadmap are:

- Airspace operators and users.
- Air navigation service providers.
- Regulating agencies.
- International organizations.

4.8 This roadmap is intended to assist the main stakeholders of the aviation community plan the future transition and their investment strategies. For example, airlines and operators can use this roadmap to plan future equipage and additional navigation capability investments; air navigation service providers can plan a gradual transition for the evolving ground infrastructure. Regulating agencies will be able to anticipate and plan for the criteria that will be needed the future.

Principles

4.9 The implementation of PBN in the CAR/SAM Regions shall be based on the following principles:

- a) Conduction of cost-benefit analyses to justify the implementation of the RNAV and/or RNP concepts in each particular airspace;
- b) Conduction of pre- and post-implementation safety assessments to ensure the application and maintenance of the established target levels of safety;
- c) Development of airspace concepts, applying airspace modelling tools as well as real-time and accelerated simulations, which identify the navigation applications that are compatible with the aforementioned concept.
- d) Continued application of conventional air navigation procedures during the transition period, to guarantee the operations by users that are not RNAV- and/or RNP-equipped.

PBN implementation strategy

En-route operations

4.10 It is impossible to include the whole CAR/SAM airspace in a single Implementation Plan for En-Route Operations, since the restructuring of the CAR/SAM airspace for PBN application would become an extremely complicated task.

4.11 Likewise, the establishment of a single RNAV or RNP value for the CAR/SAM Regions is unlikely, bearing in mind the differences in air traffic complexity and movement, as well as the differences in CNS infrastructure, which will probably lead to the application of different airspace concepts in the CAR/SAM Regions.

4.12 Thus, the most appropriate strategy is the implementation of PBN by routing areas in CAR and SAM scenarios, according to their own airspace concepts and infrastructure characteristics, which may involve a group of States/Territories and International Organizations. This implementation strategy will be applied by the States/Territories/International Organizations themselves and will permit the establishment of the RNAV or RNP values for the various areas that will be harmonised within the scope of GREPECAS.

TMA operations

4.13 TMA operations have their own characteristics, taking into account the applicable separation minima between aircraft and between aircraft and obstacles. It also involves the diversity of aircraft, including low-performance aircraft flying in the lower airspace and conducting arrival and departure procedures on the same path or close to the paths of high-performance aircraft.

4.14 In this sense, the States/Territories and International Organizations shall develop their own national plans for the implementation of PBN in TMAs, based on the CAR/SAM PBN Roadmap, seeking the harmonisation of the applicable RNAV and/or RNP criteria to avoid the need for multiple operational approvals for intra- and inter-regional operations, and the applicable aircraft separation criteria that will be soon published by ICAO Headquarters.

5. **PBN CONCEPTS**

5.1 Performance based navigation specifies RNAV system performance requirements for aircraft operating along an ATS route, on an instrument approach procedure or in an airspace.

5.2 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. Performance requirements are identified in navigation specifications which also identify which navigation sensors and equipment may be used to meet the performance requirement.

5.3 There are both RNP specifications and RNAV specifications. A RNP specification includes a requirement for onboard performance monitoring and alerting and is designated as a RNP X. A RNAV specification does not have such requirements and is designated as RNAV X.

5.4 Performance based navigation therefore depends on:

- the RNAV system and installation on the aircraft being approved to meet the performance and functional requirements of the navigation specification prescribed for RNAV operations in an airspace; and
- Air crew satisfying the operating requirements set out by the regulator for RNAV operations; and
- A defined airspace concept which includes RNAV operations; and
- an available Navaid infrastructure;

Note: Additional information may be obtained in the Manual XXXX – Performance based navigation.

6. **BENEFITS OF PERFORMANCE-BASED NAVIGATION**

Performance Based Navigation

6.1 Air traffic growth in the CAR/SAM Regions is foreseen at mid term, at the same time that the economical activity. A growth of 6.2, 5.5 y 5.6, % of regular passenger air traffic of CAR/SAM Regions airlines is foreseen in 2005/2006/2007, respectively, as compared to global growth forecast of 7.6, 6.5 and 6.2%, respectively. At long term, airlines passengers air traffic in the Region is expected to grow at an average of 4.0% until year 2015. This growth may lead to air traffic congestion periods which may guide to ATM lack of efficiency.

6.2 In order to ensure ATM efficiency and avoid unnecessary restrictions to airspace users, specifications should be avoided as to who to satisfy navigation requirements indicating only which is the performance and navigation functionality required from the RNAV system. Under the PBN concept, the generic navigation requirements are defined based on operational requirements. Thus, users may evaluate the available options as regards technology and air navigation services which could permit to satisfy these requirements. The solution elected should be the most cost-effective

6.3 The development of the Performance Based Navigation Concept recognizes that advanced aircraft RNAV systems are achieving a predictable level of navigation performance accuracy which, together with an appropriate level of functionality, allows a more efficient use of available airspace to be realized. It also takes account of the fact that RNAV systems have developed over a 40 year period and as a result there are a large variety of implementations. Identifying navigation requirements rather than on the means of meeting the requirements will allow use of all RNAV systems meeting these requirements irrespective of the means by which these are met.

6.4 The main benefits derived from the implementation of PBN are:

- a) Increased airspace safety through the implementation of continuous and stabilised descent procedures that avoid controlled flight into terrain (CFIT);
- b) Reduced aircraft flight time due to the implementation of optimal flight paths, with the resulting savings in fuel and environmental protection.
- c) Use of the RNAV and/or RNP capabilities that already exist in a significant percentage of the aircraft fleet flying in CAR/SAM airspace.
- d) Improved airport and airspace arrival paths in all weather conditions, and the possibility of meeting critical obstacle clearance and environmental requirements through the application of optimised RNAV or RNP paths.
- e) Implementation of more precise approach, departure, and arrival paths that will reduce dispersion and will foster smoother traffic flows.
- f) Reduced delays in high-density airspaces and airports through the implementation of new parallel routes and new arrival and departure points in TMAs.
- g) Possible reduction of spacing between parallel routes to accommodate more traffic in the same flow.
- h) Reduced workload for air traffic controllers and pilots due to reduced communications time.

7. IMPLEMENTATION OF PERFORMANCE-BASED NAVIGATION

7.1 ATM operational requirements

7.1.1 The ATM World Plan makes necessary to adopt an airspace concept able to provide and operational scenery that includes Routes Network, Minimum separation, Assessment of obstacles clearance, and CNS infrastructure that satisfies safety specific strategic objectives, capacity, efficiency, environment and technology addressed to the implementation of performance/based navigation.

7.1.2 In this regard, the following programmes will be developed in different areas:

- a) traffic and cost benefit studies
- b) automation necessary update
- c) operations simulation in different sceneries
- d) ATC personnel training
- e) FPL processing
- f) AIS support
- g) WGS 84 implementation when necessary
- h) uniform classification of adjacent and regional airspaces
- i) RNAV/RNP application in SIDs and STARs
- j) RNAV routes implementation and coordination

7.2 RNAV/RNP approval will cover to types of approvals: airworthiness, which will exclusively deal with aircrafts approval, and operations, which will take care of the operational aspects of air transport operators. The fulfilment of these types of approvals will permit operators to obtain RNAV/RNP approval.

7.3 **Short term (up to 2010)**

7.3.1 En-route operations

7.3.1.1 Taking into account air traffic low density in oceanic airspaces, no significant changes are expected in the present airspace structure that will demand changes in applied RNAV values. The only exception will be RNP-10 application in the WATRS Region, which will demand a significant change in the CAR Region airspace structure. In airspaces where RNP-10 is applied (EUR/SAM Corridor, Lima-Santiago de Chile Routes and South Atlantic Random Routes System), no short-term changes are expected.

7.3.1.2 In the continental airspace, RNAV-5 implementation in selected airspaces is expected, where possible to obtain operational benefits and available CNS infrastructure is able to support it.

7.3.2 TMA operations (SIDs and STARs)

7.3.2.1 The application of RNAV-1 in State-selected TMAs, in radar environments, with ground navigation infrastructure is expected, which permits DME/DME and DME/DME/INS operations. In this phase mixed operations (equipped and non-equipped) will be admitted, and RNAV-1 operations shall be initiated when an adequate percentage of air operations are approved.

7.3.2.2 In non-radar environments and/or in environments that do not count with adequate ground navigation infrastructure, the application of RNP-1 is expected in State-selected TMAs with exclusive application of GNSS, whenever an adequate percentage of air operations are approved. In this TMA will also be admitted approved and non-approved aircrafts. The application of overlay procedures or exclusive RNP procedures will depend on air traffic complexity and density.

7.3.3 IFR approaches

7.3.3.1 The application of RNP 0,3 approach procedures (basic GNSS) is expected in the maximum possible of State-selected airports, principally in international airports, maintaining conventional approach procedures for non-equipped aircraft.

7.3.3.2 The application of RNP AR approach procedures is expected in State-selected airports, where obvious operational benefits can be obtained, based on the existence of significant obstacles.

Short Term (until 2010)	
Airspace	RNAV or RNP Value
Route (Oceanic o Remote)	RNP 10 Corridor EUR/SAM and Santiago/Lima/AORRA/WATRS
Route (Continental)	RNAV 5 in selected airspaces
TMA	RNAV-1 in radar environment and with adequate ground navigation infrastructure.
	RNP 1 – No radar environment and/or without appropriate DME coverage.
Approach	RNP 0,3 in most possible airports and in all international airports. RNP AR in airport where there are obvious operational benefits.
<ul style="list-style-type: none"> • Non compulsory installation of RNAV equipment on board of non equipped aircraft in TMA and APP • Mixed Operations (equipped and non equipped aircraft) in TMA and APP • Required RNAV 2 equipment above FL350 for flights to/from United States. 	

7.4 Medium term

7.4.1 En-route operations

7.4.1.1 The application of RNP 4 in the oceanic airspace in EUR/SAM corridor is expected, with utilization of ADS/CPDLC, in order to permit the use of lateral and longitudinal separation of 30 NM. This application will depend on the evolution of the aircraft fleet flying in the airspace.

7.4.1.2 In this phase, the application of RNP-2 is expected in selected areas of the continental airspace, with high air traffic density and exclusive application of GNSS, depending on the analysis of ground infrastructure, which will indicate whether it is possible to use RNAV applications. The establishment of a backup system will be necessary as well as the development of contingency procedures in the event of GNSS failure. The application of RNP-2 will facilitate the PBN application in non surveillance airspace. With the exclusive application of GNSS more control of the GNSS signal is needed, through GPS Monitoring Systems that include NOTAM, FDE, etc.

7.4.2 TMA operations

7.4.2.1 In this phase, it is expected to extend the application of RNAV (RNP) 2/1 in State-selected TMAs, depending of ground infrastructure and of aircrafts navigation capacity. In TMAs of high air traffic complexity and movement (excluding airspaces), the use of RNAV or RNP 1 equipments will be mandatory. In TMAs of less air traffic complexity, mixed operations will be admitted (equipped or non-equipped).

7.4.3 IFR approaches

7.4.3.1 In this phase the extended application of procedures RNP 0.3 and RNP AR in selected airports is expected. Also, the initiation of application of GLS procedure is expected to guarantee a smooth transition between TMA phase and the approximation phase, basically using GNSS for the two phases.

Medium Term (2011-2015)	
Airspace	RNAV or RNP Value
Route (Oceanic or Remote)	RNP 4 in EUR/SAM Corridor and Santiago/Lima
Route (Continental)	RNP 2 in selected airspaces
TMA (SID/STAR)	Expansion of RNAV-1 or RNP-1 application Compulsory RNAV 1 or RNP 1 approval for aircraft operating in greater air traffic density TMAs (exclusionary airspace)
Approach	Expansion of RNP 0,3 and RNP AR application Application of GLS procedures
<ul style="list-style-type: none"> • RNP2 required equipment over FL290 for flights to/from United States. 	

8. SAFETY ASSESSMENT

8.1 The implementation of the performance based navigation forecast significant safety-related changes in the airspace structure as well as to the ATC system, including the implementation of reduced separation minima or new procedures that only shall be applied after a safety assessment has demonstrated that an acceptable level of safety will be met.

8.2 To demonstrate that the system is safe it will be necessary to execute a safety assessment of the proposed operation. This will take two forms:

- 1) A collision risk assessment for the proposed RNAV system specification;
- 2) A safety case for the operation.

8.3 After the PBN applications implementation, all the system should be monitored in order to ensure to maintain operational safety. In case of unforeseen events, dependency in charge of monitoring should propose and coordinate with all interested parts the implementation of mitigating measures as soon as possible.

A-1
APPENDIX X1

Reference documentation for developing operational and airworthiness approvals

Organisation	Code	Title
ICAO	Doc (under development by the RNPSORSG)	Performance-based navigation (PBN)
ICAO	Doc 8168 – OPS/611	Aircraft operations
ICAO	Doc 4444	Procedures for air navigation services – Air traffic management
ICAO	Doc 8733	CAR/SAM air navigation plan
ICAO	Doc 7030/4	SAM Regional supplementary procedures (SUPPS)
FAA	Order 8400.10	Required navigation performance 10 (RNP 10) operational approval
FAA	AC 90-96	Approval of US operators and aircraft to operate under instrument flight rules (IFR) in European airspace designated for basic area navigation (BRNAV/RNP 5)
FAA	AC 90-100	US Terminal and en route area navigation
FAA	AC 90-101	Approval guidance for RNP procedures with SAAAR
FAA	Order 8260.52	United States standards for required navigation performance (RNP) approach procedures with special aircraft and aircrew authorization required (SAAAR)
JAA	Leaflet No. 2 (TGL 2) Rev 1	Guidance material on airworthiness approval an operational criteria for the use of navigation systems in European airspace designated for basic RNAV operations
JAA	Leaflet No. 3 (TGL 3) Rev 1	Interim guidance material on airworthiness approval and operational criteria for the use of the NAVSTAR Global Positioning System (GPS)
JAA	Leaflet No. 10 (TGL 10)	Airworthiness an operational approval for precision RNAV operations in designated European airspace
EUROCONTROL	Doc 003-93	Area navigation equipment: operational requirements and functional requirements
RTCA	Do-236B	Minimum aviation system performance standards: Required navigation performance for area navigation
RTCA	Do-238A	Minimum operational performance standards for required navigation performance for area navigation

Documentation availability

The documentation described in paragraph 1 of this document may be obtained at the following websites:

- a) Copies of EUROCONTROL documents may be requested from EUROCONTROL, Documentation Centre, GS4, Rue de la Fusee, 96, B-1130 Brussels, Belgium; (Fax: 32 2729 9109). Website: <http://www.ecacnav.com>.
- b) Copies of EUROCAE documents may be purchased from EUROCAE, 17 rue Hamelin, 75783 Paris Cedex 16, France (Fax: 33 1 4505 7230). Web site: <http://www.eurocae.org>.
- c) Copies of FAA documents may be obtained from the Superintendent of Documents, Government Printing Office, Washington, DC 20402-9325, USA. Website: <http://www.faa.gov/certification/aircraft/> (Regulation and guidance library).
- d) Copies of RTCA documents may be obtained from RTCA Inc., 1140 Connecticut Avenue, N.W., Suite 1020, Washington, DC 20036-4001, USA, (Tel: 1 202 833 9339). Website: www.rtca.org.
- e) Copies of ARINC documents may be obtained from Aeronautical Radio Inc., 2551 Riva Road, Annapolis, Maryland 24101-7465, U.S.A. Website: <http://www.arinc.com>.
- f) Copies of JAA documents are available from the JAA's Publisher Information Handling Services (IHS). Information on prices, where and how to order is available in the JAA website: <http://www.jaa.nl> and in the IHS websites: <http://www.global.his.com> and <http://www.avdataworks.com>.
- g) Copies of EASA documents may be obtained from EASA (European Aviation Safety Agency), 101253, D-50452 Koln, Germany.
- h) Copies of ICAO documents may be purchased from the Document Sales Unit, International Civil Aviation Organization, 999 University Street, Montreal, Québec, Canada H3C 5H7, Fax: 1 514 954 6769, or at: sales_unit@icao.org, or through national agencies.

APPENDIX E

RNAV RNP TRAINING REQUIREMENTS

ATC training for RNAV-RNP

- Develop training program for RNAV-RNP, in accordance with ICAO guidelines.
- Selection and training of ATC instructors to provide RNAV-RNP training.
- Assessment of program and timelines for RNAV-RNP training.
- Carry out RNAV-RNP training and assessment.

Content of theory training:

- Definitions.
- Evolution of RNAV
- Evolution of RNP concept.
- Performance based navigation concept (BRNAV, PRNAV, CRNAV, TRNAV, etc.)
- RNAV-RNP equipment on aircraft (sensors VOR, DME, IRU, INS, GPS, FMS, etc.) and limitations.
- Requirements for RNAV- RNP operations (containment and integrity)
- Type of RNAV-RNP operations (RNAV values / RNP precision)
- Warnings and aircraft equipment failure on board.
- ATC warnings for aircraft equipment failure on board.
- Contingency procedures.
- Aeronautical phraseology.
- Routes design on RNAV-RNP, SID/ STAR/ RNAV-RNP E IAP/ RNAV-RNP.
- Correct writing of Item 10, 15, y 18 of flight plan
- RNAV-RNP application for better use of airspace.

Content of practice training::

Scenario of medium or high density traffic operations.

- Simulation of offset flights, fly over, fly by turns, etc.
- Simulation of RNAV-RNP en route flights, SID, STAR, IAP.
- Simulation of separation between aircrafts with different type of navigation (RNAV-RNP and VOR/ DME)
- Simulation of separation between aircrafts with same type of navigation (RNAV-RNP)
- Vectors simulation for aircrafts to waypoint, track, arc, route segment or RNAV-RNP instrument procedure.
- Simulation with conventional RNAV-RNP flights.
- Simulation with entire RNAV-RNP scenario.
- Simulation of data from items 10 and 18 of flight plan.
- Simulation of longitudinal and lateral offset automatic warning.
- Simulation of ATC workload.
- Simulation of contingency procedures

APPENDIX F

PBN Implementation Project in Brazil Terminal Areas

1. Introduction

1.1. The Fourth Meeting of the ATM/CNS Subgroup (Mexico City, 15th to 18th August, 2005) considered that operations in TMAs have peculiar characteristics, taking into account the separation minima applicable between aircraft and between aircraft and obstacles and also the aircraft diversity which involves low performance aircraft that fly within the inferior airspace and that develop arrival and departure procedures in the same path or near the paths of high performance aircraft.

1.2. In this sense, the meeting also considered that the States/Territories and International Organizations should develop RNAV/RNP Implementation National Plans in TMAs, based on the RNAV/RNP Operational Concepts of CARSAM Regions, to be developed by the RNAV/RNP Task Group to harmonize the applicable RNAV/RNP criteria, mainly to avoid the need of multiple operational approvals to flight within the CAR/SAM Regions; the applicable separation criteria between aircraft will soon be published by ICAO Headquarters.

1.3. The GREPECAS/13 (Santiago, 14th to 19th November, 2006) took note of this proposal and approved Conclusion 13/56 **Models of RNAV/RNP Implementation Action Plans for En-Route and Terminal Area Operations**, as a consequence the States/Territories and International Organizations as well as RNAV/RNP Implementation Groups were requested to use the models of RNAV/RNP Implementation Action Plans – En Route and Terminal Area Operations, developed by PBN Task Group.

2. Analysis

2.1. Based on Conclusion 13/56 of GREPECAS/13, Brazil has developed a PBN Implementation Plan in the main country TMAs, composed by a total of 12 phases, between 2006 and 2012. The entire Project is attached to this working paper as Appendix "A".

2.2. The first six phases of the project have the objective of establishing a complete implementation process, covering the following tasks:

- a) Real Time Simulation
- b) Fast-Time Simulation
- c) Cost-Benefit Analysis
- d) Safety Evaluation
- e) Impact on the ATC Systems
- f) Operators and Aircraft Approval
- g) Standards y Procedures
- h) Air Traffic Controllers and Pilots Training
- i) Post-Implementation System Performance Monitoring

2.3. At the end of project's sixth phase, with the PBN implementation in Brasilia and Recife TMAs, it is expected the establishment of a complete PBN implementation process which will allow implementation in Brazil's main TMAs.

2.4. At the end of the Project, it is expected that PBN be implemented in the following TMAs:

TMA	DATE
Brasília	March 2008
Recife	March 2008
São Paulo	August 2009
Belo Horizonte	August 2009
Rio de Janeiro	January 2011
Porto Alegre	January 2011
Salvador	August 2012
Curitiba	August 2012

TMA PBN Implementation Planning - Brazil			
	Start	Finish	Responsible
1. Phase 1	8-Feb-06	30-Jun-06	
1.1 Theoretical Model	8-Feb-06	30-Jun-06	SDOP-ATM
1.1.1 Update of PBN TMA Simulation Proposal with the conclusions of RNPSORSG/7 (13 to 17/02/2006)	20-Feb-06	24-Feb-06	SDOP-ATM
1.1.2 Analysis of PBN Draft Manual	1-Mar-06	30-Jun-06	SDOP-ATM
1.1.3 Analysis of Implementation Experience of others States	1-Mar-06	30-Jun-06	SDOP-ATM
1.1.4 Development of PBN Airspace Structure Proposal for the Brasília and Recife TMA, including the development of Approach, Departure and STAR Draft Procedures.	1-Mar-06	30-Jun-06	SDOP-ATM
1.1.5 Collect traffic data to identify the main traffic flow	1-Mar-06	30-Jun-06	SDOP-ATM
1.1.6 Analysis of fleet navigation capacity that operates in the Brasília and Recife TMA.	1-Mar-06	30-Jun-06	SDOP-ATM
1.1.7 Inclusion of Standard Procedures of Scenario 1	1-Mar-06	30-Jun-06	SDOP-ATM
1.1.8 Update of Theoretical Model with the conclusions of AP/ATM/12 (15 to 19/04/2006)	10-Apr-06	30-Jun-06	SDOP-ATM
1.1.9 Update of Theoretical Model with the conclusions of RNPSORSG/8 (05 to 09/06/2006)	12-Jun-06	30-Jun-06	SDOP-ATM
1.2 Real Time Simulation	8-Feb-06	30-Jun-06	CINDACTA I/III
1.2.1 Definition of Database Team	8-Feb-06	24-Feb-06	CINDACTA I/III
1.2.2 Data Collection Scenario 1	13-Feb-06	24-Feb-06	CINDACTA I/III
1.2.3 Database Generation Scenario 1	1-Mar-06	28-Apr-06	CINDACTA I/III
1.2.4 Insertion and adjustment of Database Scenario	2-May-06	30-Jun-06	CINDACTA I/III
1.3 Fast Time Simulation	8-Feb-06	30-Jun-06	ICEA

1.3.1 Definition of Database Team	8-Feb-06	24-Feb-06	ICEA
1.3.2 Development of Data Model	8-Feb-06	28-Apr-06	ICEA
1.3.3 Database Generation Scenario 1	1-Mar-06	28-Apr-06	ICEA
1.3.4 Data Model Validation	1-Mar-06	28-Apr-06	ICEA
1.3.5 adjustment of Database Scenario 1	8-May-06	16-Jun-06	ICEA / SDOP-ATM
1.3.6 adjustment of Database Scenario 2	8-May-06	16-Jun-06	ICEA / SDOP-ATM
1.3.7 Development of Scenario 1 Reports (baseline)	19-Jun-06	30-Jun-06	ICEA
2. Phase 2	3-Jul-06	30-Nov-06	
2.1 Theoretical Model	3-Jul-06	30-Nov-06	SDOP-ATM
2.1.1 Metrics Definition	3-Jul-06	12-Jul-06	SDOP-ATM
TMA PBN Implementation Planning - Brazil			
	Start	Finish	Responsible
2.1.2 Development of Data Collection sheet	3-Jul-06	12-Jul-06	SDOP-ATM
2.1.3 Conclusion of Scenario 2	3-Jul-06	16-Aug-06	SDOP-ATM
2.1.4 Development of Standard Procedures Scenario 2	1-Aug-06	30-Nov-06	SDOP-ATM
2.2 Real Time Simulation	3-Jul-06	29-Nov-06	CINDACTA I/III
2.2.1 First measurement Scenario 1 (baseline) - Recife TMA	17-Jul-06	21-Jul-06	CINDACTA III
2.2.2 Database Generation and video-map scenario 2 - Recife TMA	20-Jul-06	25-Jul-06	CINDACTA III
2.2.3 Insertion and adjustment Database and Video-map scenario 2 - Recife TMA	26-Jul-06	28-Jul-06	CINDACTA III
2.2.4 First Measurement scenario 1 (baseline) - TMA Brasília	14-Aug-06	18-Aug-06	CINDACTA I
2.2.5 Database Generation and video-map scenario 2 - Brasilia TMA	17-Aug-06	22-Aug-06	CINDACTA I
2.2.6 Insertion and adjustment Database and Video-map scenario 2 - Brasilia TMA	23-Aug-06	25-Aug-06	CINDACTA I
2.2.7 Insertion and adjustment Database and Video-map scenario 1 and 2 - TMA Recife (ICEA)	25-Sep-06	6-Oct-06	CINDACTA III
2.2.8 Database Generation and video-map scenario 1 and 2 - TMA Brasília (ICEA)	9-Oct-06	20-Oct-06	CINDACTA I
2.2.9 Coordination Meeting Air Traffic Controllers APP and ACC - Recife	13-Nov-06	14-Nov-06	SDOP-ATM
2.2.10 Coordination Meeting Air Traffic Controllers APP and ACC - Brasília	28-Nov-06	29-Nov-06	SDOP-ATM
2.3 Fast Time Simulation	3-Jul-06	31-Oct-06	ICEA

2.3.1 Final Adjustment of Database and Video-Map Scenario 2	3-Jul-06	29-Sep-06	ICEA
2.3.2 Preliminary Reports Scenario	14-Aug-06	6-Oct-06	ICEA
2.3.3 Final Reports Scenario 2	14-Aug-06	31-Oct-06	ICEA
3. Phase 3	4-Dec-07	30-Mar-07	
3.1 Theoretical Model	4-Dec-07	30-Mar-07	SDOP-ATM
3.1.1 Data Collection and Analysis	4-Dec-07	30-Mar-07	SDOP-ATM
3.1.2 Partial Report PBN Simulation	10-Mar-07	20-Mar-07	SDOP-ATM
TMA PBN Implementation Planning - Brazil			
	Start	Finish	Responsible
3.2 Real Time Simulation	4-Dec-07	30-Mar-07	
3.2.1 Run Real Time Simulation	4-Dec-07	30-Mar-07	SDOP-ATM/CINDACTA I/III
3.3 Fast Time Simulation	4-Dec-07	30-Mar-07	
3.3.1 Reports Scenario 2 and Comparative Reports Scenario 1/2	4-Dec-07	30-Mar-07	SDOP-ATM/ICEA
4. Phase 4	2-Apr-07	31-Jul-07	
4.1 Theoretical Model	2-Apr-07	31-Jul-07	SDOP-ATM
4.1.1 Scenario 3 Finalization	2-Apr-07	13-Apr-07	SDOP-ATM
4.1.2 Development of Standard Procedures Scenario 3	16-Apr-07	31-Jul-07	SDOP-ATM
4.2 Real Time Simulation	30-Apr-07	31-Jul-07	CINDACTA I/III
4.2.1 Insertion and adjustment of scenario Scenario 3	30-Apr-07	22-Jun-07	CINDACTA I/III
4.2.2 First Measurement Scenario 3 - TMA Recife	9-Jul-07	13-Jul-07	CINDACTA III
4.2.3 First Measurement Scenario - TMA Brasília	23-Jul-07	27-Jul-07	CINDACTA I
4.3 Fast Time Simulation	16-Apr-07	29-Jun-07	ICEA
4.3.1 Insertion and adjustment of scenario Scenario 3	16-Apr-07	15-Jun-07	ICEA
4.3.2 Preliminary Reports Scenario 3	18-Jun-07	29-Jun-07	ICEA

5. Phase 5	1-Aug-07	21-Dec-07	
5.1 Theoretical Model	1-Aug-07	21-Dec-07	
5.1.1 Data Recollection and Analysis	1-Aug-07	30-Oct-07	SDOP-ATM
5.1.2 Revision and Edition of Theoretical Model PBN simulation	1-Nov-07	21-Dec-07	SDOP-ATM /ICEA / CINDACTAI/III
5.2 Real Time Simulation	1-Aug-07	30-Oct-07	
5.2.1 Database Generation and video-map scenario Scenarios 1 e 2 - TMA Recife (ICEA)	1-Aug-07	30-Oct-07	CINDACTA III
5.2.2 Database Generation and video-map scenarios 1 e 2 - TMA Brasília (ICEA)	1-Aug-07	30-Oct-07	CINDACTA I
5.2.3 Coordination Meeting with Air Traffic Controllers APP e ACC - Recife	1-Aug-07	30-Oct-07	SDOP-ATM
5.2.4 Coordination Meeting with Air Traffic Controllers APP e ACC - Brasília	1-Aug-07	30-Oct-07	SDOP-ATM
5.2.5 Run Real Time Simulation - ICEA	1-Aug-07	30-Oct-07	SDOP-ATM / CINDACTA I/III
TMA PBN Implementation Planning – Brazil			
	Start	Finish	Responsible
5.3 Fast Time Simulation	1-Aug-07	30-Oct-07	
5.3.1 Report Scenario 3 and Comparative Reports Scenarios 1/3 and 2/3	1-Aug-07	30-Oct-07	SDOP-ATM/ICEA
6. Phase 6	1-Mar-06	21-Mar-08	
6.1 Cost-Benefit Analysis	30-Nov-06	21-Dec-07	SDOP-ATM
6.1.1 Preliminary Cost-Benefit Analysis	30-Nov-06	20-Dec-06	SDOP-ATM
6.1.2 Final Cost-Benefit Analysis	15-Jul-07	21-Dec-07	SDOP-ATM
6.2 Safety Assessment	1-Mar-06	21-Feb-08	SDOP-ATM
6.2.1 Development of Safety Assessment Model for TMA	15-Apr-06	31-Jan-07	SDOP-ATM
6.2.2 Development of Data Collection Program to the Safety Assessment	2-May-06	30-Jun-06	SDOP-ATM
6.2.3 Development of Final Safety Assessment	1-Feb-07	21-Feb-08	SDOP-ATM
6.3 Evaluation of ATC Automatic System Impact	1-Jul-06	21-Feb-08	SDOP-ATM/SDTI-SIC/CISCEA
6.3.1 Evaluate impact of PBN implementation in the ATC automatic systems	1-Jul-06	21-Feb-07	SDOP-ATM/SDTI-SIC
6.3.2 Implement the necessary changes in the ATC automatic systems	21-Feb-07	21-Feb-08	CISCEA

6.4 Aircraft and Operators Approval	13-Mar-06	21-Feb-08	DAC
6.4.1 Analyze of the available Navigation Specification, taking into consideration the actual and planned CNS infrastructure (RNAV-1/FAA AC 90-100)	13-Mar-06	21-Feb-07	DAC
6.4.2 Develop and Publish the Operational Approval Process	13-Mar-06	21-Feb-07	DAC
6.4.3 Establish the Readiness Target	8-Jan-07	30-Mar-07	SDOP-ATM
6.4.4 Evaluate the Approved Aircraft Percentage	1-Mar-07	21-Feb-08	CARSAMMA
6.5 Rules and Procedures	13-Mar-06	21-Feb-08	SDOP-ATM
6.5.1 Update the GNSS Application Rules	13-Mar-06	21-Feb-07	SDOP-ATM
6.5.2 Develop and publish AIC, informing the PBN implementation planning in Brasilia and Recife TMA	30-Nov-06	21-Feb-07	SDOP-ATM
6.5.3 Publish AIP Supplement containing applicable rules and procedures, including suspension possibility	1-Aug-07	AIRAC NOV 2007	SDOP-ATM
6.5.4 Revise Standard Procedures of Brasília and Recife APP	1-Aug-07	21-Jan-08	CINDACTA I/III
6.5.5 Development/Review/Flight Inspection/Charting/Publication of Approach, Departure and STAR Procedures	1-Aug-07	AIRAC NOV 2007	SDOP-ATM
6.5.6 Finalize Letter of Agreement changes	1-Aug-07	21-Jan-08	CINDACTA I/III
TMA PBN Implementation Planning – Brazil			
	Start	Finish	Responsible
6.6 Training	3-Apr-06	14-Mar-08	SDOP-ATM / CINDACTAI/III
6.6.1 Develop Training Documentation for Pilots	3-Apr-06	21-Feb-07	DAC
6.6.2 Develop Training Documentation for ATCO	1-Aug-07	14-Nov-07	SDOP-ATM / CINDACTAI/III
6.6.3 Run ATCO Training	20-Nov-07	14-Mar-08	CINDACTA I/III
6.6.4 Internal Seminar	5-Nov-07	7-Mar-08	
6.6.5 External Seminar	21-Jan-08	7-Mar-08	
6.8 Final Implementation Decision	NA	21-Feb-08	SDOP-ATM
6.8.1 Complete ATS Documentation	NA	21-Feb-08	SDOP-ATM
6.8.2 Complete Operational Readiness Assessment	NA	21-Feb-08	CARSAMMA

6.8.3 Complete Safety Assessment	NA	21-Feb-08	SDOP-ATM
6.8.4 "trigger" NOTAM Publication	NA	14-Feb-08	SDOP-ATM
6.9 System Performance Monitoring	1-Aug-07	21-Mar-09	SDOP-ATM
6.9.1 Develop a Pos-Implementation Monitoring Program	1-Aug-07	21-Feb-08	SDOP-ATM
6.9.2 Run a Pos-Implementation Monitoring Program	21-Mar-08	21-Mar-09	SDOP-ATM
Phase 7 PBN Implementation São Paulo TMA	Feb-08	Jun-08	SDOP-ATM
7.1 Collect traffic data to identify the main traffic flow	Feb-08	Apr-08	
7.2 Analysis of fleet navigation capacity that operates in the TMA	Feb-08	Apr-08	SDOP-ATM
7.3 Development of PBN Airspace Structure Proposal for the TMA, including the development of Approach, Departure and STAR Draft Procedures.	Feb-08	Jul-08	SDOP-ATM
7.4 Fast Time Simulation	Feb-08	Mar-09	SDOP-ATM
7.5 Real Time Simulation	Feb-08	Mar-09	SDOP-ATM
7.6 Safety Assessment	Feb-08	Mar-09	SDOP-ATM
7.7 Cost-Benefit Analysis	Feb-08	Mar-09	SDOP-ATM
7.8 PBN Implementation in the TMA SP	NA	Aug-09	SDOP-ATM
TMA PBN Implementation Planning - Brazil			
	Start	Finish	Responsible
Phase 8 PBN Implementation Belo Horizonte TMA	Feb-08	Jun-08	SDOP-ATM
8.1 Collect traffic data to identify the main traffic flow	Feb-08	Apr-08	
8.2 Analysis of fleet navigation capacity that operates in the TMA	Feb-08	Apr-08	SDOP-ATM
8.3 Development of PBN Airspace Structure Proposal for the TMA, including the development of Approach, Departure and STAR Draft Procedures.	Feb-08	Jul-08	SDOP-ATM
8.4 Fast Time Simulation	Feb-08	Mar-09	SDOP-ATM
8.5 Real Time Simulation	Feb-08	Mar-09	SDOP-ATM
8.6 Safety Assessment	Feb-08	Mar-09	SDOP-ATM
8.7 Cost-Benefit Analysis	Feb-08	Mar-09	SDOP-ATM
8.8 PBN Implementation in the TMA BH	NA	Aug-09	SDOP-ATM
Phase 9 PBN Implementation Rio de Janeiro TMA	Sep-09	Jan-10	SDOP-ATM
9.1 Collect traffic data to identify the main traffic flow	Sep-09	Nov-09	

9.2 Analysis of fleet navigation capacity that operates in the TMA	Sep-09	Nov-09	SDOP-ATM
9.3 Development of PBN Airspace Structure Proposal for the TMA, including the development of Approach, Departure and STAR Draft Procedures.	Sep-09	Dec-09	SDOP-ATM
9.4 Fast Time Simulation	Feb-09	Aug-10	SDOP-ATM
9.5 Real Time Simulation	Feb-09	Aug-10	SDOP-ATM
9.6 Safety Assessment	Feb-09	Aug-10	SDOP-ATM
9.7 Cost-Benefit Analysis	Feb-09	Aug-10	SDOP-ATM
9.8 PBN Implementation in the TMA RJ	NA	Jan-11	SDOP-ATM
Phase 10 PBN Implementation Porto Alegre TMA	Sep-09	Jan-10	SDOP-ATM
10.1 Collect traffic data to identify the main traffic flow	Sep-09	Nov-09	
10.2 Analysis of fleet navigation capacity that operates in the TMA	Sep-09	Nov-09	SDOP-ATM
10.3 Development of PBN Airspace Structure Proposal for the TMA, including the development of Approach, Departure and STAR Draft Procedures.	Sep-09	Dec-09	SDOP-ATM
10.4 Fast Time Simulation	Feb-09	Aug-10	SDOP-ATM
TMA PBN Implementation Planning - Brazil			
	Start	Finish	Responsible
10.5 Real Time Simulation	Feb-09	Aug-10	SDOP-ATM
10.6 Safety Assessment	Feb-09	Aug-10	SDOP-ATM
10.7 Cost-Benefit Analysis	Feb-09	Aug-10	SDOP-ATM
10.8 PBN Implementation in the TMA PA	NA	Jan-11	SDOP-ATM
Phase 11 PBN Implementation Curitiba TMA	Feb-11	Jun-11	SDOP-ATM
11.1 Collect traffic data to identify the main traffic flow	Feb-11	Apr-11	
11.2 Analysis of fleet navigation capacity that operates in the TMA	Feb-11	Apr-11	SDOP-ATM
11.3 Development of PBN Airspace Structure Proposal for the TMA, including the development of Approach, Departure and STAR Draft Procedures.	Feb-11	Jul-11	SDOP-ATM
11.4 Fast Time Simulation	Feb-11	Mar-12	SDOP-ATM
11.5 Real Time Simulation	Feb-11	Mar-12	SDOP-ATM
11.6 Safety Assessment	Feb-11	Mar-12	SDOP-ATM
11.7 Cost-Benefit Analysis	Feb-11	Mar-12	SDOP-ATM
11.8 PBN Implementation in the TMA CT	NA	Aug-12	SDOP-ATM

Phase 12 PBN Implementation Salvador TMA	Feb-11	Jun-11	SDOP-ATM
12.1 Collect traffic data to identify the main traffic flow	Feb-11	Apr-11	
12.2 Analysis of fleet navigation capacity that operates in the TMA	Feb-11	Apr-11	SDOP-ATM
12.3 Development of PBN Airspace Structure Proposal for the TMA, including the development of Approach, Departure and STAR Draft Procedures.	Feb-11	Jul-11	SDOP-ATM
12.4 Fast Time Simulation	Feb-11	Mar-12	SDOP-ATM
12.5 Real Time Simulation	Feb-11	Mar-12	SDOP-ATM
12.6 Safety Assessment	Feb-11	Mar-12	SDOP-ATM
12.7 Cost-Benefit Analysis	Feb-11	Mar-12	SDOP-ATM
12.8 PBN Implementation in the TMA SV	NA	Aug-12	SDOP-ATM

(Available only in Spanish)

Proyecto de Implantación total del WGS-84 y Desarrollo de Procedimientos RNAV/RNP de Centroamérica

1. Introducción

1.1 Desde los inicios de las recomendaciones emanadas por la Organización de Aviación Civil Internacional OACI, con la finalidad de considerar el uso de los equipos de nueva generación a bordo de las aeronaves modernas, La Corporación Centroamericana de Servicios de Navegación Aérea COCESNA, le ha dado seguimiento al desarrollo de las aplicaciones RNAV comprendidas dentro de los conceptos CNS/ATM.

1.2 La necesidad de establecer procedimientos RNAV dentro de la Región Centroamericana, ha sido un tema debidamente analizado por los Especialistas ATM en diferentes Foros, Seminarios y Reuniones, lo que ha generado algunos proyectos de decisión o conclusiones para impulsar estos procedimientos en concordancia con lo que demanda el modernismo de las flotas de las Líneas Aéreas, así como la seguridad operacional.

1.3 Por las razones antes indicadas, COCESNA está llevando a cabo el Proyecto Implantación total del WGS-84 y desarrollo de procedimientos RNAV/RNP de Centroamérica, el cual contempla dentro del contenido de sus objetivos y fases de ejecución contar con todos los elementos necesarios que faciliten la provisión de los servicios de navegación aérea y permitan optimizar las ventajas de operación con que cuentan actualmente las Líneas Aéreas.

2. Objetivos del proyecto

2.1 Los objetivos seleccionados para el cumplimiento del Proyecto Implantación total del WGS-84 y desarrollo de procedimientos RNAV/RNP de Centroamérica, se resumen a continuación:

- Implantación total del WGS-84 en Centroamérica;
- Lograr una aplicación regional del uso del concepto RNAV conforme a los criterios de la OACI;
- Mejorar la seguridad de la navegación aérea;
- Mejorar la distribución y ordenamiento del espacio aéreo;
- Obtener mayor eficiencia en la operación de las aeronaves;
- Reducir los tiempos por demoras en las llegadas y salidas de las aeronaves; y

3. Fases del proyecto

3.1 FASE 1 : Implantación Total del WGS-84

3.1.1 El propósito de esta primera fase ha tenido sus avances en la mayoría de los Estados Centroamericanos, teniéndose información recibida en COCESNA acerca de la finalización del levantamiento de obstáculos en los aeropuertos internacionales de San Salvador MSLP, Tegucigalpa MHTG, San Pedro Sula MHLM, La Ceiba MHLC, Roatán MHRO y la actualización del convenio de cooperación entre la Autoridad de Aeronáutica Civil y el Instituto Nacional de Estudios Territoriales de Nicaragua.

3.2 FASE 2 : Capacitación

3.2.1 La capacitación incluida dentro de este proyecto contempla la preparación del personal técnico siguiente:

- El personal técnico especialista en procedimientos de aproximación por instrumentos;
- El personal de tripulación de vuelo de la aeronave de COCESNA que verifica los procedimientos; y
- El personal de las Administraciones de Aeronáutica/Aviación Civil que requieren conocer sobre la certificación, aprobación, autorización, aplicación y publicación oficial de los procedimientos RNP RNAV.

3.2.2 Hasta la fecha, mediante este proyecto, la tripulación de vuelo de la aeronave de inspección de radioayudas de COCESNA ha participado en varios eventos relacionados al tema, entre ellos el Tercer Seminario CAR/SAM RNAV/RNP, realizado en la Ciudad de Lima, Perú, en septiembre de 2005.

3.2.3 Adicionalmente, dentro del proceso de instrucción de la tripulación de COCESNA, se tiene contemplado su capacitación específica en lo relacionado a la inspección y certificación de los procedimientos RNAV/RNP que serán implantados en Centroamérica, como parte del mencionado dentro del proyecto.

3.2.4 Más recientemente, con la colaboración de la IATA, el Instituto Centroamericano de Capacitación Aeronáutica ICCAE de COCESNA realizó el seminario GNSS RNAV RNP en la ciudad de San Salvador, contando con la participación de Especialistas de los Estados de Belice, Costa Rica, El Salvador, Guatemala, Honduras y Nicaragua, así como la de los Tripulantes y Especialistas del Grupo TACA, COPA y los especialistas de COCESNA.

3.2.5 Dentro del tema de capacitación también está contemplada la preparación del personal de las Administraciones de Aeronáutica/Aviación Civil de Centroamérica y de COCESNA en el diseño de procedimientos RNAV.

3.3 FASE 3 : Diseño de Procedimientos

3.3.1 Con esta fase se pretende que, una vez formado el personal especialista en el diseño de procedimientos de los Estados, cada Administración Aeronáutica estará en la capacidad de elaborar sus propios procedimientos RNAV, de acuerdo a las necesidades locales y en cumplimiento de la normativa de la OACI.

3.4 FASE 4 : Verificación y Certificación de Procedimientos

3.4.1 En esta fase el proyecto contempla que se requiere el aporte correspondiente de los diseños elaborados en cada Estado para ser verificados en vuelo. Es entendido que la oficialización de la certificación de los procedimientos como paso previo a su publicación es responsabilidad de cada Estado Centroamericano.

APPENDIX G

RNAV/RNP APPROVAL GUIDELINES

1. General

1.1 As the implementation of the PBN concept grows throughout the world, it is expected that an aircraft will pass through different airspaces and routes with different types of RNAV and/or RNP between the time it takes off and lands, which will require multiple authorisations for a single aircraft and operator, thus increasing the workloads for both operators and the CAA. In order to reduce this workload, it is necessary to design a generic approval process that will allow RNAV/RNP authorisations to be issued under a single criterion.

1.2 These guidelines contain information about the new performance-based navigation (PBN) concept and its two application categories defined as: area navigation (RNAV) operations and required navigation performance (RNP) operations. It also gives CAA inspectors directions and guidance about the approval process for the following types of operations: RNP 10, RNP 4, RNAV 5, RNAV 2 and RNAV 1.

2. RNAV/RNP approval

2.1 RNAV/RNP approval will cover two types of approvals: airworthiness approval that will deal exclusively with aircraft approval, and operational approval, which will deal with the operational aspects of the operator. Compliance with these two types of approvals will permit operators to obtain RNAV/RNP approval.

2.1.1 Airworthiness approval.-

- a) Any aircraft an operator intends to use in RNAV/RNP airspace must obtain an airworthiness approval from its CAA before an operating approval can be issued to it;
- b) Approval will be granted to an aircraft that meets the requirements of the airworthiness approval documents of each State, which must be based on the requirements of the PBN manual (being prepared at this time by the RNPSORSG working group).

2.1.2 Operational approval.-

- a) The State of the Operator will be the authority responsible for approval of flight operations in the airspace in which a type of RNAV/RNP is prescribed. The approval authority will make sure that the aircraft is equipped with the necessary systems for conducting operations of the RNAV/RNP type for which operational approval is required.

3. RNAV/RNP approval process

3.1 The RNAV/RNP approval process consists of five phases as described below:

- a) Phase one: Pre-application;
- b) Phase two: Formal application;
- c) Phase three: Analysis of the documentation;
- d) Phase four: Inspection and demonstration;
- e) Phase five: Approval.

4. Phase one – Pre-application

4.1 Phase one may be started by the operator, when it determines and expresses its intention to the CAA to operate in RNAV/RNP airspace, or by the CAA, when it requires that operators obtain an RNAV/RNP approval.

4.2 On learning the intention of the operator or of the CAA, the Head of the inspection and certification body will appoint the certification team, one of whose members will be the designated HCT. In that case, the POI may be appointed as such.

4.3 The CAA team appointed to carry out the applicant's approval process must become familiar with all aspects of the proposed or required operation, in order to give the operator guidance and advice during the pre-application meeting and throughout the entire process. The inspectors must accordingly:

- a) become familiar with the existing CAA policy and with the requirements established for RNAV/RNP approval;
- b) become familiar with the appropriate RNAV/RNP technical material;
- c) become familiar with aircraft requirements for each type of RNAV/RNP;
- d) become familiar with the methods used to determine aircraft admissibility;
- e) make a precise evaluation of the nature and scope of the proposal;
- f) determine whether validation tests or flights are required;
- g) determine the need for coordination requirements;
- h) make sure that the operator or applicant clearly understands the minimum requirements for an acceptable application; and
- i) determine the date on which the operator intends to start RNAV/RNP operations.

4.4 The newly appointed head of the certification team (HCT) will call the operator to a pre-application meeting.

4.5 The CAA team will take up the following issues in the course of the pre-application meeting:

- a) Phases of the approval process, pointing out the responsibilities of each party during those phases;
- b) existing RNAV/RNP regulatory requirements and approval documents;

- c) reference documents (for example, the ICAO performance-based navigation manual and this document);
- d) elements of the airworthiness data package;
- e) airworthiness and operations documents, manuals and programmes that the operator must present, together with the application for RNAV/RNP approval in Phase two;
- f) operating and maintenance procedures to be carried out by the operator;
- g) aircraft requirements for each type of RNAV/RNP;
- h) methods for determining aircraft admissibility;
- i) coordination procedures between the CAA and the operator;
- j) the need for the applicant to form a working team for the approval operation;
- k) timetable of events;
- l) grounds for rejecting the documentation;
- m) validation flight or test requirements;
- n) validation test or flight plan (if required);
- o) acceptable standards or rules for the submission of documents;
- p) training programmes for flight crews, FOO/AD and maintenance personnel;
- q) paragraph or paragraphs of the OpSpecs to be implemented;
- r) grounds for suspension or revocation of RNAV/RNP approval.

4.6 During this phase, the CAA and the operator will reach a common understanding about the RNAV/RNP approval.

4.7 This phase concludes when the CAA is satisfied that the operator has gained a thorough knowledge of all the aspects involved in the RNAV/RNP approval process.

5. Phase two – Formal application

5.1 Phase two starts when the operator sends the formal application, together with the following documentation. Figure 2-1 – *Example of a formal application*, describes an example of its contents.

- a) Airworthiness documents, that make it possible to determine aircraft admissibility, such as:
 - 1) For aircraft under production (or new aircraft): AFM, AFM supplement, and/or TCDS;
 - 2) For aircraft that have achieved their service capacity: as applicable, SB; Aircraft service change; Service letter; STC, including certification data package, and document confirming fulfilment of the modification and/or inspection (e.g. FAA/JAA Form 337).

- b) Maintenance documents, as applicable:
 - 1) For aircrafts that have demonstrated their capacity in its manufacturing process; all maintenance documents and manual presently in force and applicable to operation (for example: MM, SRM, IPC, WDM, etc); Maintenance manuals;
 - 2) For aircrafts that have achieved their capacity in service: all updated maintenance documents and manual (all supplements to affected manual, for example: supplement to AFM, MM, etc.);
 - 3) Revised operator maintenance control manual , which should contain description of aircraft equipment, giving a detail of its relevant components to carry out the requested RNAV/RNP operation.
 - 4) Revised maintenance programme
- c) Description of navigation equipment integration;
- d) In the case of RNP 10 and/or RNP 4 operations, the time limits for requested operation with INS or with IRU in oceanic or remote areas. The time limit proposed by the applicant for RNP 10 and/or RNP 4 operations should be stated in relation to the specified INS or IRU. The applicant should keep in mind the effect of headwinds in the area where RNP 10 and/or RNP 4 operations are to be carried out.
- e) Description of updating procedures, if used;
- f) RNAV/RNP training programmes (initial and periodic):
 - 1) Flight crew;
 - 2) FOO/AD; and
 - 3) Maintenance personnel.
- g) Revised operations manual: policies, operational practices, and procedures.
 - 1) Flight planning;
 - 2) Pre-flight procedures;
 - 3) En-route procedures;
 - 4) Updating procedures and repercussions of the update on the navigation solution (if the update is planned and whether it is only for aircraft with inertial systems);
 - 5) Flight crew knowledge; and
 - 6) In-flight contingency procedures according to ICAO Doc 7030 *Regional supplementary procedures*.
- h) MEL
- i) Procedure for validation of navigation database and authorization letters of suppliers of said data.
- j) Aircraft operating manual (AOM) and checklists;
- k) Performance history (previous performance);
- l) Validation test or flight plan.

5.2 This phase does not include a thorough evaluation, nor the analysis of the documentation presented; however, the documentation must be examined in enough detail to determine its completeness.

5.3 If the proposal is unsatisfactory, it should be returned to the operator with a written explanation of the reasons for its rejection.

5.4 If the proposal is satisfactory, the CAA HCT will decide to continue with the following phase of the process.

6. Phase three – Analysis of the documentation

6.1 In phase three, the CAA team must make a detailed analysis of all the documentation presented with the formal application.

6.2 The CAA team will determine the admissibility of the aircraft or group of aircraft by using one of the following three methods:

- a) Aircraft that have an RNAV/RNP airworthiness statement in the AFM;
- b) Aircraft that do not have an RNAV/RNP airworthiness statement in the AFM, to which approval is granted by virtue of other rules or previous rules (*e.g.* Appendix 30 to the OPS LARs, Part I, or Appendix G to 14 CFR, Part 121); and
- c) Collection of data, using the following methods:
 - sequential; or
 - periodic.

6.3 There are two possibilities as a result of phase three:

- a) When the results of the detailed analysis of the documentation are satisfactory, the process proceeds to phase four. Otherwise, the application will be returned to the operator, together with the documentation and a written explanation of the reasons for its rejection.

7. Phase four – Inspection and demonstration

7.1 Once the documentation has been approved, the following activities will be carried out in phase four:

- a) RNAV/RNP training for flight crews, FOO/AD and maintenance personnel, which will be verified by the CAA; and
- b) Validation tests or flights, which will follow the guidelines of Chapter 13 – *Validation tests*, of Volume II, Part II of the MIO and the corresponding chapter of the MIA.

7.2 The regulations of the States do not prohibit the commercial transportation of passengers during validation tests. The CAA team may authorise the applicant to transport passengers on board a validation flight when the proposed operation is similar to those included in the applicant's previous experience.

7.3 This phase ends when the training and validation test requirements have been successfully completed. If the applicant fails the validation tests or flights, the operator must take corrective measures and then reschedule those tests or flights, and send in a new validation test or flight plan.

8. Phase five – Approval

8.1 Once the operator has completed the airworthiness, continued airworthiness, and operational requirements, the CAA will issue the RNAV/RNP approval through paragraphs B034, B035 or B036 of the OpSpecs, as applicable.

9. Work aid

9.1 Figure 2-2 – *Work aid for RNAV/RNP approval* describes the specific steps to be followed during the RNAV/RNP approval process.

10. Documentation availability

14.1 The documentation described in paragraph 1 of this document may be obtained at the following electronic addresses:

- a) Copies of EUROCONTROL documents may be requested from EUROCONTROL, Documentation Centre, GS4, Rue de la Fusee, 96, B-1130 Brussels, Belgium; (Fax: 32 2729 9109). Web site: <http://www.ecacnav.com>.
- b) Copies of EUROCAE documents may be purchased from EUROCAE, 17 rue Hamelin, 75783 Paris Cedex 16, France (Fax: 33 1 4505 7230). Web site: <http://www.eurocae.org>.
- c) Copies of FAA documents may be obtained from the Superintendent of Documents, Government Printing Office, Washington, DC 20402-9325, USA. Web site: <http://www.faa.gov/certification/aircraft/> (Regulation and guidance library).
- d) Copies of RTCA documents may be obtained from RTCA Inc., 1140 Connecticut Avenue, N.W., Suite 1020, Washington, DC 20036-4001, USA, (Tel: 1 202 833 9339). Web site: www.rtca.org.
- e) Copies of ARINC documents may be obtained from Aeronautical Radio Inc., 2551 Riva Road, Annapolis, Maryland 24101-7465, USA. Web site: <http://www.arinc.com>.
- f) Copies of JAA documents are available from the JAA's Publisher Information Handling Services (IHS). Information about prices and where and how to order is available at the JAA website: <http://www.jaa.nl> and IHS websites: <http://www.global.his.com> and <http://www.avdataworks.com>.
- g) Copies of EASA documents may be obtained from EASA (European Aviation Safety Agency), 101253, D-50452 Koln, Germany.
- h) Copies of ICAO documents may be purchased from the Document sales unit, International Civil Aviation Organization, 999 University Street, Montreal, Québec, Canada H3C 5H7, (Fax: 1 514 954 6769, or by e-mail: sales_unit@icao.org) or through national agencies.

Figure 2-1 – Example of a formal application

Mr. Jorge Medrano
 Head of the certification and inspection body
 Chiclayo 857
 Miraflores

Dear sir:

I am writing you, in your capacity as Head of the CAA certification and inspection body, to ask you to issue an approval of the ORION Company's OpSpecs to carry out RNP 10 (4) and/ RNAV 1 (2, 5) operations, *for 6.2 hours between updates on the designated routes (for RNP 10 and RNP 4 operations only).*

The following aircraft meet the requirements and capabilities specified in (*specify the order or AC according to which the aircraft will be approved, e.g. AC 90-100/TGL 2, etc.*).

Type of RNAV/RNP	Aircraft type and series	Navigating equipment	Communication equipment	Time limit
RNP 10 and 4 RNAV 1, 2 and 5	B 747-400	List the navigation equipment, by name, type, model and manufacturer	List the navigation equipment, by name, type, model and manufacturer	Number of hours or unlimited for RNP 10 or RNP 4
RNP 10 and 4 RNAV 1, 2 and 5	B 737-500	List the navigation equipment, by name, type, model and manufacturer	List the navigation equipment, by name, type, model and manufacturer	Number of hours or unlimited for RNP 10 or RNP 4

Sincerely yours,

César Martínez Zerpa
 Executive President of ORION

Figure 2-2 – Work aid for RNAV/RNP approval

Applicant:		
RNAV Type:	RNP Type:	
Activities	Inspectors	Date
1. Phase one - Pre-application		
a) Statement of the intention of the applicant		
b) Appointment of the CAA team that will conduct the RNAV/RNP approval of the applicant		
c) Familiarisation of the CAA team with: <ol style="list-style-type: none"> 1) The existing policy of the CAA and the requirements established for RNAV/RNP approval; 2) The appropriate RNAV/RNP technical material; 3) The aircraft requirements for each type of RNAV/RNP; 4) The methods for determining aircraft admissibility; 5) A precise evaluation of the nature and scope of the proposal; 6) Determining whether validation tests or flights are required; 7) Determining the need for coordination requirements; 8) Making sure the operator or applicant clearly understands the minimum requirements for an acceptable application; and 9) Determining the date on which the applicant intends to start RNAV/RNP operations. 		
d) Convening of the applicant to a pre-application meeting		
e) Pre-application meeting (subjects to be covered) <ol style="list-style-type: none"> 1) Phases of the approval process 2) Regulatory requirements and approval documents 		

<ol style="list-style-type: none"> 3) Reference documents 4) Airworthiness data package 5) Airworthiness and operational documents to be submitted with the formal application 6) Operating and maintenance procedures to be carried out by the applicant 7) Aircraft requirements 8) Methods for determining aircraft admissibility 9) Coordination procedures 10) Creation of a work team by the applicant 11) Timetable of events 12) Grounds for rejection of the documentation 13) Validation test or flight requirements 14) Validation test or flight plan (if required) 15) Acceptable standards for the submission of the documentation 16) Training programmes for flight crews, FOO/AD and maintenance personnel. 17) Paragraph or paragraphs of the OpSpecs to be developed 18) Grounds for suspension or revocation of RNAV/RNP approval 		
f) Opening of the approval record		
2. Phase two – Formal application		
a) Formal application letter, attaching the following documentation:		
<ol style="list-style-type: none"> 1) Airworthiness documents <ul style="list-style-type: none"> - For aircraft under production: AFM, AFM supplement and/or TC data sheet - For aircraft that have achieved their service capacity: as applicable, SB; Aircraft service change; Service letter; STC, including certification data package, and document confirming fulfilment of the modification and/or inspection (e.g. FAA/JAA Form 337) 		

<p>2) Maintenance documents</p> <ul style="list-style-type: none"> - For aircrafts that have demonstrated their capacity in its manufacturing process; all maintenance documents and manual presently in force and applicable to operation (for example: MM, SRM, IPC, WDM, etc); Maintenance manuals; - For aircrafts that have achieved their capacity in service: all updated maintenance documents and manual (all supplements to affected manual, for example: supplement to AFM, MM, etc.); - Revised operator maintenance control manual , which should contain description of aircraft equipment, giving a detail of its relevant components to carry out the requested RNAV/RNP operation. - Revised maintenance programme 		
3) Description of aircraft equipment		
4) For RNP 10 and/or RNP 4 operations, the INS/IRU time limits		
5) Description of the update procedures, if used		
6) Training programmes for flight crews, FOO/AD, and maintenance personnel		

<p>7) Revised operations manual: policies, operational practices and procedures:</p> <ul style="list-style-type: none"> - Flight planning - Pre-flight procedures - En-route procedures - Update procedures and repercussions of updates on the navigation solution - Flight crew knowledge - Contingency procedures 		
<p>8) MEL</p>		
<p>9) Procedure for validation of navigation database and authorization charts of suppliers of said data</p>		
<p>10) Aircraft operating manual (AOM) and checklists</p>		
<p>11) Performance history</p>		
<p>11) Validation test or flight plan</p>		
<p>3. Phase three – Documentation analysis</p>		
<p>a) Analysis of the documentation submitted with the formal application</p>		
<p>1) Airworthiness documents</p> <ul style="list-style-type: none"> - For aircraft under production: AFM, AFM supplement and/or TC data sheet - For aircraft that have achieved their service capacity: as applicable, SB; Aircraft service change; Service letter; STC, including certification data package, and document confirming fulfilment of the modification and/or inspection (e.g. FAA/JAA Form 337) 		
<p>2) Maintenance documents</p> <ul style="list-style-type: none"> - For aircrafts that have demonstrated their capacity in its manufacturing process; all maintenance documents and manual presently in force and applicable to operation (for example: MM, SRM, IPC, WDM, etc); Maintenance manuals; 		

<ul style="list-style-type: none"> - For aircrafts that have achieved their capacity in service: all updated maintenance documents and manual (all supplements to affected manual, for example: supplement to AFM, MM, etc.); - Revised operator maintenance control manual, which should contain description of aircraft equipment, giving a detail of its relevant components to carry out the requested RNAV/RNP operation. - Revised maintenance programme 		
3) Description of navigation equipment integration		
4) For RNP 10 and/or RNP 4 operations, INS/IRU time limits		
5) Description of update procedures, if used		
6) Training programmes for flight crews, FOO/AD, and maintenance personnel		
<p>7) Revised operations manual: policies, operational practices and procedures:</p> <ul style="list-style-type: none"> - Flight planning - Pre-flight procedures - En-route procedures - Update procedures and repercussions of updates on the navigation solution - Flight crew knowledge - Contingency procedures 		
8) MEL		
9) Procedure for validation of navigation database and authorization letters of suppliers of said data;		

10) Aircraft operating manual (AOM) and checklists		
11) Performance history		
12) Validation test or flight plan		
<p>b) Evaluation of the navigation system to determine its admissibility:</p> <ol style="list-style-type: none"> 1) Aircraft with RNAV/RNP airworthiness statement in the AFM; 2) Aircraft without RNAV/RNP airworthiness statement in the AFM, to which approval is granted by virtue of other standards or previous standards 3) Data collection (RNP 10) by the following methods: <ul style="list-style-type: none"> - sequential or periodic 		
4. Phase four – Inspection and demonstration		
<p>a) Evaluation of the training given to:</p> <ol style="list-style-type: none"> 1) Flight crews 2) FOO/AD 3) Maintenance personnel 		
b) Evaluation of validation tests or flights according to the guidelines of Chapter 13 – <i>Validation tests</i> , of Volume II, Part II of this manual		
c) Aircraft inspection		
5. Phase five – Approval		
<ol style="list-style-type: none"> a) Approval of the paragraph or paragraphs of the OpSpecs b) Presentation of the paragraph or paragraphs of the OpSpecs to the applicant c) Completion and closing of records d) Completion and closing of the general approval registry 		

APPENDIX H

1. Training, operational practices and procedures programmes

1.1 In order to guide operators through the RNAV/RNP approval process, a model will be developed of the contents of the training programmes, operational practices and procedures for flight crews, flight operations officers/flight dispatchers (EOV/DV), and maintenance personnel. In general, the training programmes, operational practices and procedures should cover the following areas:

- a) General operational topics
- b) flight planning;
- c) pre-flight procedures;
- d) procedures prior to entering RNAV/RNP airspace or route;
- e) procedures within RNAV/RNP airspace and/or route;
- f) flight crew knowledge; and
- g) in-flight contingency procedures according to ICAO Doc. 7030 *Regional supplementary procedures*.

2. General operational topics

2.1 General operational topics will include at least the following elements:

- a) Performance-based navigation (PBN) and RNAV/RNP operations concepts and definitions;
- b) RNP 10, RNAV 5, RNAV 1/2, RNP 4, RNP 1/2, RNP 0,3 and RNP navigation specifications with required authorization (RA) (RNP 0,3 – 0,1), indicating operation airspaces, applicable sensors and operational limitations;
- c) changes in aeronautical charts and documents reflecting entrance in force of RNAV/RNP operations;
- d) effects of updating navigation systems;
- e) MEL utilization;
- f) requirements for flight planning;
- g) contingency procedures for RNAV/RNP airspaces (e.i. failure of RNAV equipment);
- h) procedures for each type of applicable RNAV/RNP;
- i) procedures and personnel in charge of verifying integrity and validity of navigation database (e.i. ARINC 424);
- j) procedures for degradation and restitution of a RNAV/RNP operation; and
- k) information of Advisory circulars (AC) and ICAO PBN Manual.

3. RNP 10 and RNP 4 training programmes and operational practices and procedures

3.1 The training programme for flight crews and flight operations officers/flight dispatchers (EOV/DV), shall be reviewed and approved. At least the following areas will be included:

3.2 Flight planning.- During flight planning, the flight crew must pay particular attention to conditions that could influence operations in RNP 10/RNP 4 airspace or routes. These conditions could include the following:

- a) check to see whether the aircraft is approved for RNP 10/RNP 4 operations;
- b) check to see whether the RNP 10/RNP 4 time limit has been considered (only for aircraft equipped with INS or IRU);
- c) check to see whether the letter “R” has been entered in box 10 of the ICAO flight plan;
- d) verify GRS requirements, such as FDE, if applicable to the operation;
- e) if required for a given navigation system, take into account any operational restriction related to RNP 10/RNP 4 approval; and
- f) check the planned flight route, including diversion to any alternate aerodrome, in order to identify the types of RNAV/RNP required.

3.3 Pre-flight procedures.- The following activities must be carried out during the pre-flight stage:

- a) review the technical maintenance records (maintenance logbooks) to make sure that the equipment meets the conditions for flight in RNP 10/RNP 4 airspace or routes. Make sure that maintenance measures have been taken to correct any defects in the equipment required;
- b) during the external inspection of the aircraft, check the condition of navigation antennas and of the airframe coating near each of the antennas (a competent and authorised person other than the pilot may do this, *e.g.* a flight mechanic or a maintenance worker); and
- c) review the emergency procedures for operations in RNP 10/RNP 4 airspace or routes. These are no different from normal oceanic emergency procedures with one exception: flight crews should be capable of recognising, and the ATC should be notified, when the aircraft is no longer fit to navigate at its capacity level, according to the RNP 10/RNP 4 approval.

3.4 En-route procedures.- The following shall be observed:

- a) before the oceanic point of entry, two LRNS must be in operating condition. If that is not the case, the pilot shall consider diverting to an alternate aerodrome where that equipment is not required or diverting for repairs;
- b) before entering oceanic airspace, the position of the aircraft must be determined as accurately as possible through external navigation aids. This may require DME/DME or VOR checks to determine errors in the navigation system by comparing displayed and actual positions. If the system needs an update, appropriate procedures must be followed with the assistance of a prepared checklist;
- c) the in-flight operational exercises conducted by the operator must include mandatory cross-check procedures, in order to identify navigation errors in time to keep the aircraft from inadvertently deviating from the routes authorised by the ATC.

3.5 Contingency procedures.- Flight crews must become familiar with the following general provisions:

- a) an aircraft must not enter or continue to operate in RNP 10 designated airspace, according to the authorisation in force issued by the ATC, if its navigation system, due to failure or degradation, falls below RNP 10/RNP 4 requirements. In that case, the pilot will obtain an amended authorisation as soon as possible;
- b) according to the instructions of the ATC, operations can continue according to the authorisation in force issued by the ATC or, if that proves impossible, a revised authorisation may be requested;
- c) in any case, the flight crew shall follow the contingency procedures established for each region in which it operates and obtain ATC authorisation as soon as possible.

4. RNAV 5 training programmes

4.1 RNAV 5 training programme.- The training programme for flight crews shall be reviewed and approved by the CAA. The operator will include at least the following areas:

- a) definition of RNAV in terms of RNAV 5 requirements in CAR/SAM airspace;
- b) knowledge of the airspace where RNAV 5 is required;
- c) changes in aeronautical charts and documents that reflect the entry into effect of RNAV 5 operations;
- d) equipment required and its operation in order to be able to operate in RNAV 5 airspace, together with the limitations of such equipment;
- e) flight planning requirements;
- f) contingency procedures in RNAV 5 airspace (*e.g.* RNAV system failure);
- g) RNAV 5 en-route and terminal area procedures, when applicable;
- h) methods to reduce navigation errors through dead-reckoning navigation techniques;
- i) information cited in the ACs of each State and in this document.

5. RNAV 1 and RNAV 2 training programme

5.1 The training programme shall provide sufficient training (*e.g.* through flight training devices, flight simulators, and the aircraft) concerning the on board RNAV system. The training programme will include the following topics:

- a) information concerning this section;
- b) meaning and proper use of the suffixes of aircraft navigation equipment;
- c) characteristics of procedures as defined in chart and textual descriptions:
 - 1) description of WPT types (fly over and fly through) and of route finalizers, and of any other types used by the operator, as well as those associated with the flight routes of the aircraft; and

- 2) navigation equipment required for operation in RNAV routes, SIDs, and STARs (for example: DME/DME, DME/DME/IRU, GNSS).
- d) specific information about the RNAV system:
 - 1) levels of automation, announcement modes, changes, alerts, interactions, reversions and degradations;
 - 2) functional integration with other aircraft systems;
 - 3) meaning of en-route disconformities, as well as related flight crew procedures;
 - 4) monitoring procedures for each flight phase (*e.g.* monitoring of PROG or LEGS pages);
 - 5) types of navigation sensors (*e.g.* DME, IRU, GNSS) used by the RNAV and associated systems;
 - 6) anticipation of turns, taking into account the effects of speed and altitude;
 - 7) interpretation of electronic displays (indicators) and symbols;
- e) RNAV operating procedures, as applicable, including how to perform the following actions:
 - 1) checking the validity of the aircraft navigation data;
 - 2) checking the successful conclusion of the RNAV self-testing system;
 - 3) initialising the position of the RNAV system;
 - 4) obtaining the flight and database of a SID or STAR with the appropriate transition;
 - 5) tracking of speed and altitude restrictions associated with a SID or STAR;
 - 6) changing a runway associated with a SID or STAR;
 - 7) checking the WPT and the flight plan programming;
 - 8) conducting a manual or automatic runway update (with a change in the take-off site, if applicable);
 - 9) direct flight to a WPT;
 - 10) one-course/path flight to a WPT;
 - 11) intercepting a course/path;
 - 12) vectoring outside, and then again following, the procedure;
 - 13) determining errors perpendicular to the path and diversions;
 - 14) inserting and eliminating en-route disconformities;
 - 15) removing and reselecting navigation sensor entries;
 - 16) when so required, confirming the exclusion of a specific navigation aid or type of navigation aid;
 - 17) when so required by the CAA, executing major navigation error checks, using conventional NAVAIDs; and
 - 18) changing arrival and alternate aerodromes.
- f) automation levels recommended by the operator for each flight phase and workload, including methods for minimising error perpendicular to the path, in order to keep to the centre line of the procedure;
- g) phraseology for RNAV applications;

6. GNSS training module for operators that request to operate this system

6.1 Training programme on the GPS as primary means of navigation.- In addition, training programmes for flight crews, flight operations officers/flight dispatchers (EOV/DV), and maintenance personnel that use GPS, will include the following training curriculum:

6.1.1 GPS system components and operating principles.- Understanding of the GPS system and its operating principles:

- a) GPS system components: control segment, user segment, and space segment;
- b) on-board equipment requirements;
- c) GPS satellite signals and pseudo-random code;
- d) positioning principle;
- e) receiver clock error;
- f) masking function;
- g) performance limitations of the different types of equipment;
- h) WGS84 coordinate system;

6.1.2 Navigation system performance requirements.- Define the following terms in relation to the navigation system and evaluate the degree of compliance by the GPS system of the requirements associated with the following terms:

- a) precision;
- b) integrity;
 - 1) means to improve GPS integrity: RAIM.
- c) availability;
- d) service continuity

6.1.3 Authorisations and documentation.- Requirements applicable to pilots and navigation equipment for GPS operation:

- a) pilot training requirements;
- b) aircraft equipment requirements;
- c) AFM system certification criteria and limitations;
- d) GPS-related NOTAMs.

6.1.4 GPS system errors and limitations.- Cause and magnitude of typical GPS errors:

- a) ephemerides;
- b) clock;
- c) receiver;
- d) atmospheric/ionospheric;
- e) multi-reflection;
- f) selective availability (SA);
- g) total typical error associated to the C/A code;
- h) effect of the dilution of precision (DOP) on the position;
- i) susceptibility to interference;

- j) comparison of vertical and horizontal errors; and
- k) path-tracking precision. Collision avoidance.

6.1.5 Human factors and GPS.- Limitations on the use of GPS equipment due to human factors. Operating procedures that offer protection against navigation errors and loss of awareness of the real situation due to the following causes:

- a) mode errors;
- b) data entry errors;
- c) data checks and validation, including independent cross-checking procedures;
- d) automation-induced relaxation;
- e) lack of standardisation of GPS equipment;
- f) information processing by humans and situational awareness.

6.1.6 GPS equipment – Specific navigation procedures.- Knowledge of the appropriate operating procedures for GPS in the typical navigation tasks for each specific type of equipment in each type of aircraft that includes:

- a) selection of the appropriate operating mode;
- b) review of the different types of information contained in the navigation database;
- c) forecast of the availability of the RAIM function;
- d) procedure for entering and checking the WPT defined by the user;
- e) procedure for entering, retrieving and checking flight plan data;
- f) interpretation of the typical information shown on the GPS navigation display: LAT/LONG, distance and heading to the WPT, CDI;
- g) interception and maintenance of the GPS-defined routes;
- h) in-flight determination of ground speed (GS), estimated time of arrival (ETA), time and distance to the WPT;
- i) indication of WPT overflight;
- j) use of the “DIRECT TO” function;
- k) use of the “NEAREST AIRPORT” function;
- l) use of the GPS in GPS or DME/GPS arrival procedures.

6.1.7 Verification of GPS equipment.- For each type of equipment in each aircraft, the following operational and start-up checks must be conducted at the appropriate time:

- a) constellation status;
- b) RAIM functional status;
- c) dilution of precision (DOP) status;
- d) effectiveness of the instrument flight rules (IFR) database;
- e) receiver operating condition;
- f) CDI sensitivity;
- g) position indication.

6.1.8 GPS messages and warnings.- For each type of equipment in each aircraft, timely action must be recognised and taken in face of GPS messages and warnings, including the following:

- a) loss of RAIM function;
- b) 2D/3D navigation;
- c) dead-reckoning navigation mode;
- d) database not updated;
- e) loss of the database;
- f) GPS equipment failure;
- g) barometric data entry failure;
- h) power failure;
- i) prolonged parallel displacement; and satellite failure.

7. Training programme for maintenance personnel

- a) PBN concepts and definitions.
- b) Maintenance dispatch ensuring equipment requirements compliance for RNAV/RNP operations.
- c) Preflight inspection: condition of the navigation antennas and coverage of fuselage near the antennas.
- d) MEL use – dispatch restrictions
- e) Instructions about the installation of new equipment
 - 1) Approved data and TSOs compliance
 - f) Changes in the maintenance programme – ICA
 - g) FMS – DB, registries and personnel in charge of the update, etc.
 - h) Precision of sensors – certified equipment for precision assessment
 - i) Training necessary to carry out approval process of RNAV/RNP airworthiness..

APPENDIX I

PERFORMANCE-BASED NAVIGATION INFORMATION

1 Purpose

1.1 The main purpose of this document is to provide information to aid understanding of the paradigm change with Performance-based Navigation operations. To do so requires a brief review and discussion on a number of background items including the shared safety role of the airborne system, procedure and airspace design, and operator.

2 Introduction

2.1 The initial industry activities in developing minimum aviation system performance standards (MASPS) for RNP addressed aspects of implementation including system performance criteria, operational considerations, system qualification, navigation data, and navigation databases. These discussions resulted in new standards that represented fundamental change in a number of areas:

- a) system requirements that reflected the distribution of safety responsibility across the stakeholders (i.e. pilot, system, operational procedure, procedure and airspace design, airworthiness approval and operational approval)
- b) setting specific conditions and criteria for the system and procedure design,
- c) performance standards intended to support obstacle clearance or separation,
- d) specification of changes necessary to assure the reliability, repeatability and predictability of the navigation system for flight guidance and flight management,
- e) specification of data management and control processes necessary for navigation databases containing the RNP procedures,
- f) specification of data requirements along with the rigor and processes to assure correct, accurate and usable navigation source data.

3 Safety Assurance Process

3.1 From the system functional safety and airworthiness standpoint, processes were identified and defined to formalize the level and types of assessments and analyses necessary to assure intended functionality, and performance. The functional hazard analyses identify effects of functional failures and conditions in the system, along with required or recommended actions and limitations where necessary. The system safety analysis formalizes a comprehensive analyses of all aspects of the system hardware, architecture, configurations, modes and functionality to show how safety requirements are satisfied.

3.2 An associated step in the airworthiness process is system validation. Using a combination of analyses and tests on the ground, lab and aircraft, the system and its functionality are assessed for varying conditions and environments. A key aspect of this for performance-based operations is the extension of conditions and situations to address rare-normal events. The addition of rare-normal in the systems demonstration provides a fundamental alleviation for procedure design consideration of such conditions.

4 System Design Assurance

4.1 Besides the process assurance steps, key system requirements were needed and specified based upon assessment and analysis of critical aspects of the systems functions, usage, failures and errors. Specifying system and operational requirements for these has the effect of being able to exclude or minimize the risk of many failures and conditions that would result in potential deviations and increasing operational risk.

4.2 However, the opportunities for operational errors go beyond just the functions, features and performance of the airborne system. This led to additional assessment of RNP error components and the potential effects of the errors, erroneous information, etc with the equipment, infrastructure, navigation data, flight planning and human in the loop. This resulted in added guidance for operations and usage.

4.3 Altogether, the standard for navigation system performance was raised significantly to meet the needs of RNP operations, facilitate implementation, and enhance operational safety. Areas where this takes place include:

- a) Lateral performance assurance limits (containment integrity) were specified at $2xRNP$, with an associated probability of 10^{-5} of undetected excursion.
- b) Lateral performance continuity (containment continuity) was specified at 10^{-4} probability of annunciated loss of a required RNP capability.
- c) definition of reliable, predictable and repeatable lateral and vertical flight paths, using leg types with such characteristics, as well as altitude/speed constraints for geometric point to point paths and paths with vertical angles.
- d) definition of flight path data contained in the system navigation database.
- e) specification of unique factors affecting the path i.e. earth reference, magnetic variation, etc.
- f) crew situational awareness with lateral and vertical deviation information and displays and operating procedures as integral to lateral and vertical operations.
- g) operational considerations associated with RNAV e.g. RNP applicability, transitions in paths, etc.
- h) monitoring and alerting.
- i) Vertical path performance limits that bound vertical total system error and is based upon modern aircraft performance.
- j) specification of unique factors affecting the vertical path i.e. temperature effects.

- k) operational considerations associated with vertical navigation i.e. system calculated deceleration path segments

4.4 With all this attention to system functions, features and performance, a known area with significant impact required attention. This was the source navigation data, derived charts, and electronic versions contained in airborne navigation databases. The letter of authorization for navigation database suppliers and processes, based upon the industry standard DO-200A/ED-76 is a critical part in minimizing the potential for errors in procedures contained in databases. Just as important is source data quality and the need for service providers and States to meet the industry standards outlined in DO-201A/ED-77.

4.5 Collectively, all of the parts result in much more robust systems, performance and functionality than has existed previously.

5 System Safety versus Operational Safety

5.1 To start, there is no direct statistical connection between the system safety processes for the aircraft and system, and the target level of safety objective typical to the operational safety rationale.

5.2 However, the airworthiness process includes safety assurances steps described previously, which are tied to the regulations for safety from the equipment, systems and installation standpoint. Included is the determination of the system hazard classification that is one element of the safety in an operation. Other elements are the performance and design assurance in the RNP system stemming from the containment integrity and containment continuity provided.

5.3 The level for the hazard classification for the RNP system is designated “major”, which corresponds to a 10^{-5} probability of misleading navigation information per flight hour. And for RNP system performance, there is a requirement that the probability of exceeding the airspace performance requirement undetected and unannounced should be less than 10^{-5} per flight hour.

5.4 The general concern is that this aspect of system performance appears insufficient for the target level of safety, i.e. risk of accident that is 10^{-7} per operation.

5.5 One consideration is the historical accident rate for approach which is 2.6×10^{-7} per approach, for all causes. None have been associated with the undetected misleading or erroneous navigation system performance. And this is just for systems whose design assurance basis “major”, 10^{-5} as well as those meeting the MASPS performance requirements. So it is clear that while the 10^{-7} safety objective is matched to the accident rate, there is no connection between the accident rate and the system assurance level.

5.6 One set of explanations is that current airspace allocations provide a large operational safety margin, that dependence on the navigation system functions is low, that other safety nets such as surveillance and collision avoidance systems have been effective, and that operations have been largely dictated by ATC instruction.

5.7 Another explanation contains several parts.

5.7.1 One part is that with modern aircraft the manner in which flight and status information is presented to the crews have not only significantly improved safety in the conduct of flight operations, but aided the crew in the identification of anomalies that could have created some sort of operational problem. With the modern systems architectures and flight planning capabilities in the aircraft, the crew has continuous awareness of the desired flight path, the aircraft location, flight progress, and navigation performance. So when considering operational risk, the airplane navigation system has not been a causal factor in accidents or incidents.

5.7.2 Another part is that a focus solely on performance requirements will have little impact on operational safety. This is supported by accident data that shows that operational risk is dominated by other factors such as human error that are hard to quantify and correct. However, it is this area where attention and focus is required to improve safety for RNP operations such that improvements are made for situational awareness, human interface, and alerting.

5.7.3 Additionally for RNP aircraft, part of the certification demonstration is a performance and capability evaluation and analysis. This step is critical in demonstrating the aircraft provides the levels of performance, functionality, monitoring and alerting essential to the safe conduct of RNP operations.

5.7.4 It is clear that the contribution of the improvements in system functions, features and human interfaces to an operational safety cannot be quantified as they can for other elements in the traditional fault tree. Operational judgment and experience is that these features and improvements are an integral to cockpit operations and systems architecture, reducing exposure to operational errors and enhancing operational safety. Examples follow:

5.7.4.1 Situation Awareness to enhance Crew Operations and Detection

- a) Electronic map display of flight path and other map information such a geographical reference points, airports, nav aids, etc.
- b) Displays of time to go, distance to go, winds, track etc for current flight situation and progress on electronic map display
- c) Graphical displays, improved deviation scales, and numerical readouts for lateral and vertical deviation
- d) Indications of the active RNP and the current level of navigation performance

5.7.4.2 System Functions and Capabilities to Reduce the Incidence of Errors

- a) Path Definition using path terminators that are reliable, predictable and repeatable, minimal variability
- b) Path Definition including altitude constraints and vertical angles reflecting procedure requirements and charts

5.7.4.3 Improved Human Interface to Reduce the Incidence of Operational Errors

- a) Availability of route, departure, arrival, transition and approach procedures from the navigation database
- b) Format and context checking for entries of waypoints and flight data.
- c) Alerting messages:
 - o when data entry is incorrect format, range or is not allowed, i.e. an invalid entry
 - o when an attempted deletion is not allowed
 - o when SID or arrival and runway not compatible
 - o if flight plan change deletes waypoint altitude constraints defining the descent path
 - o when the end of an active route is overflow
 - o when the crew entry of an RNP exceeds the system default or database RNP value

5.7.4.4 Improved Monitoring and Alerting

- a) Monitoring and alerting when actual performance exceeds RNP
- b) Monitoring and alerting when calculated position differs between FMCs

6 Flight Operation Factors

6.1 RNP/RNAV approach procedures, whether AR or basic public procedures (regardless of RNP), have not seen jet transport accidents due to crew error or other causes. In large part, this is due to the greater assurance of the aircraft capability, crew training and procedures, and in the procedure design. The operational safety has also been significantly enhanced though:

- a) Simplicity of flying the approaches relative to the traditional VOR/ADF. Fix to fix navigation using LNAV in conjunction with a MAP display is vastly simpler for crews than monitoring primitive VOR course or ADF bearing information while trying to combine this with DME information, crossing radials/bearings, etc.

- b) Constant angle barometric path definition and the ability to fly this path automatically means that multiple crew errors must be made to result in a CFIT accident, as opposed to traditional "dive and drive" methods which only require one crew error to cause a fatal accident. The potential for multiple errors is removed by the capabilities and improvements in the flight systems.
- c) The constant angle path also easily provides the crew a low-workload stabilized approach method to avoid landing accidents.

7 Procedure Design, Aircraft Qualification and Operator Approval

7.1 While all of the preceding information has been to rationalize why the system safety for RNP operations is well thought out and addressed by design, analysis and test, it is the step in assessing aircraft and operators relative to the procedure design criteria and application that completes the safety assessment for RNP AR operations.

7.2 The key aspects of procedure design for RNP AR are:

- a) The RNP is scalable, with 0.1 NM minimum, 0.3 NM nominal for the final approach, and 1 NM nominal for initial, intermediate and missed approach.
- b) Obstacle clearance of 2xRNP with no secondary areas.
- c) Tailored and guided missed approaches
- d) Fixed radius turns, where necessary
- e) Vertical obstacle clearance based upon aircraft performance requirements, also known as the vertical error budget (VEB). It is a derivation and an extrapolation of existing obstacle clearance margins from FAA notice 8260.48, considering the added requirements for demonstrated navigation performance and aircraft operational capability.
- f) Missed approach OCS tailored to aircraft climb performance

7.3 The aircraft qualification criteria is aimed at assuring the functions, features, and performance capabilities are matched to procedure design. Some of the specific and critical elements include:

- a) the provision of on-board performance monitoring and alerting consistent with the performance requirement of the procedure, airspace, etc. There are a number of acceptable alternatives for this. For example, in a system with real-time estimation of position uncertainty and monitoring of flight technical error, this caution may be activated when the combination of position uncertainty and FTE exceeds the budgeted design limit for total system error. System compliance may also be demonstrated by allocating the performance requirements to each potential source and monitor those error sources separately. In this implementation, the caution could be activated when either the position uncertainty or FTE becomes unacceptable. Yet

another implementation is to demonstrate through test and analysis that the FTE is inherently bounded, in which case the caution would be activated when the position uncertainty exceeds the allocated design limit. Implementation is left to the equipment designers.

- b) demonstration that the aircraft is capable of meeting a 10^{-7} airspace containment, or that RNAV & Baro-VNAV performance and functionality are demonstrated to be consistent with the procedure design and operation.
- c) GNSS or IRU as the main basis of performance accuracy and continuity, with allowance for DME/DME where appropriate.
- d) Autoreversion to secondary sensor, for continuity
- e) Altimetry System Error must satisfy

$$ASE = -8.8 \cdot 10^{-8} \cdot H^2 + 6.5 \cdot 10^{-3} \cdot H + 50 \text{ feet, at } 99.7\%$$
- f) Temperature Compensation, limitations for operations if the capability is not provided and the temperature is beyond that accounted for in the procedure design.
- g) Path Definition: providing the essential predictability, repeatability and reliability with path terminators IF, RF, TF, DF, CF, FA, and VM. Considerations for fly-bys, Waypoint Resolution, Vertical Path specification, Altitude/Speeds, Database procedures & verification, Magvar, RNP changes, Leg Sequencing, altitude restrictions.
- h) Path Steering performance, through specific criteria for displays and scaling
- i) Situation Awareness, Progress information and Status for the desired path, path deviation, active waypoint, bearing/distance, Ground speed & Time, active fix, track, distance to go, baro-altitude, active sensors, and system failures
- j) Design Assurance that the level of software is consistent with the criticality/hazard of the operation.
- k) Database, must be valid, must be current, and have appropriate processes at the database supplier and operator for handling, management and control.

8

Guidance and criteria are provided for operational considerations

- a) Equipment Required & Dispatch: This ensures the system performance capability is provided and available for the intended operations
- b) Autopilot/Flight Director: This ensures that the level of performance if dependent on these is available and usable
- c) Predicted RNP Assessment: This ensures tools and processes are in place to assure infrastructure will be available to enable the required level of performance.
- d) Navaid Exclusion: Operators must ensure appropriate procedures to exclude nav aids in accordance with NOTAMs.
- e) Navigation Database Currency: Operators must ensure databases are current.
- f) Database Flight Plan & Confirmation: Operator must use the correct procedures from the database
- g) RNP Awareness & Management: Operators must ensure that the RNP is appropriate for the procedure

- h) Sensor Use & Management: The appropriate sensor must be available for use.
- i) Track Deviation Monitoring: Tracking and monitoring to RNP laterally and 75 feet vertically, consistent with the assumptions for procedure design.
- j) System Crosscheck: depending on the hazard classification of the system, additional crosschecks may be necessary.
- k) Procedures with RF Leg: considerations on the conduct of procedures with an RF and how aircraft system capabilities are a factor.
- l) Altimeter Setting: current altimeter setting for a procedure
- m) Altimeter Crosscheck: assurance that altimeters are consistent and within tolerance
- n) Non-standard climb gradient: assurance that aircraft will meet the requirement of the procedure.
- o) Engine Out: guidance and considerations
- p) Go-Around/Missed Approach with RNP 1 and < 1 and considerations with GNSS Failure & Coasting
- q) Contingency Enroute, Approach

8.1 Training must address all aspect of the operational considerations, use of the aircraft, crew procedures, etc.

8.2 RNP Monitoring Program: A process to ensure continued compliance

9 Conclusions and recommended actions

9.1 It should be evident that with RNP, there is tight coupling between the procedure and airspace design criteria for enroute and terminal operations and the assurance that only performance qualified aircraft and systems, and operators are allowed to conduct the operations. Together all requirements of the aircraft qualification and operator approval constitute specific aspects of the safety of the operation that must be addressed and approved.

9.2 The PBN SAM-WG is requested to consider these points when developing requirements for the risk analysis of the operations with the use of the PBN concept.

9.3 The PBN OPS/AIR-WG is requested to consider these points when developing standards for the aircraft and operators approval for the operations with the use of the PBN concept.

9.4 States are requested to analyze the importance of operational errors in an environment with PBN and invest all possible resources in the training of air traffic controllers aiming the reduction of these errors considering the future implementation of this concept in the CAR/SAM Regions.