Agenda Item 5: Documentation Issues

ICAO EUR Doc 001

(Presented by the Secretariat)

SUMMARY

THIS PAPER PRESENTS ICAO EUR DOC 001 IN SUPPORT OF THE PBN TF DISCUSSIONS
INTERNATIONAL CIVIL AVIATION ORGANIZATION

EUROPEAN REGION AREA NAVIGATION

(RNAV)

GUIDANCE MATERIAL

FIFTH EDITION

PREPARED BY THE EUROPEAN AND NORTH ATLANTIC OFFICE OF ICAO

SEPTEMBER 2003
The role of the European Organisation for the Safety of Air Navigation (EUROCONTROL) in the development of the material contained in this document is acknowledged with appreciation.
**RECORD OF AMENDMENTS**

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<tbody>
<tr>
<td>ABAS</td>
<td>Aircraft Based Augmentation System</td>
</tr>
<tr>
<td>ADF</td>
<td>Automatic Direction Finding</td>
</tr>
<tr>
<td>AFM</td>
<td>Aircraft Flight Manual</td>
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<tr>
<td>AIP</td>
<td>Aeronautical Information Publication</td>
</tr>
<tr>
<td>AIRAC</td>
<td>Aeronautical Information Regulation and Control</td>
</tr>
<tr>
<td>AIS</td>
<td>Aeronautical Information Service</td>
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<tr>
<td>ATC</td>
<td>Air Traffic Control</td>
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<tr>
<td>ATCC</td>
<td>Air Traffic Control Centre</td>
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<tr>
<td>B-RNAV</td>
<td>Basic RNAV</td>
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<tr>
<td>CDI</td>
<td>Course Deviation Indicator</td>
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<tr>
<td>CF</td>
<td>COURSE to a FIX</td>
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<tr>
<td>CNF</td>
<td>Computer Navigation Fix</td>
</tr>
<tr>
<td>DF</td>
<td>DIRECT to a FIX</td>
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<tr>
<td>DME</td>
<td>Distance Measuring Equipment</td>
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<tr>
<td>DTK</td>
<td>Desired Track</td>
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<tr>
<td>EGNOS</td>
<td>European Geo-Stationary Navigation Overlay System</td>
</tr>
<tr>
<td>(E) HSI</td>
<td>(Electronic) Horizontal Situation Indicator</td>
</tr>
<tr>
<td>FA</td>
<td>Course from a FIX to an ALTITUDE</td>
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<tr>
<td>FA CF</td>
<td>Final Approach Course Fix</td>
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<tr>
<td>FAWP</td>
<td>Final Approach Waypoint</td>
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<tr>
<td>FDE</td>
<td>Fault Detection and Exclusion</td>
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<td>FMS</td>
<td>Flight Management System</td>
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<td>FTE</td>
<td>Flight Technical Error</td>
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<tr>
<td>GBAS</td>
<td>Ground Based Augmentation System</td>
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<tr>
<td>GNSS</td>
<td>Global Navigation Satellite System</td>
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<tr>
<td>GPS</td>
<td>Global Positioning System</td>
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<tr>
<td>HA</td>
<td>HOLDING Pattern to an ALTITUDE</td>
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<tr>
<td>HF</td>
<td>HOLDING Pattern to a FIX</td>
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<tr>
<td>HM</td>
<td>HOLDING Pattern to a MANUAL Termination</td>
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<tr>
<td>HSI</td>
<td>Horizontal Situation Indicator</td>
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<tr>
<td>ICAO</td>
<td>International Civil Aviation Organisation</td>
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<tr>
<td>IF</td>
<td>Initial Fix</td>
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<tr>
<td>IFR</td>
<td>Instrument Flight Rules</td>
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<tr>
<td>ILS</td>
<td>Instrument Landing System</td>
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INS  Inertial Navigation System
IRS  Inertial Reference System
MASPS Minimum Aircraft System Performance Specification
MCDU Multi-Functional Control Display Unit
MEL Minimum Equipment List
MLS Microwave Landing System
LAAS Local Area Augmentation System
MMR Multi-Mode Receiver
NDB Non-Directional Beacon
NM Nautical Mile
NOTAM Notice to Airmen
P-RNAV Precision Area Navigation
RAIM Receiver Autonomous Integrity Monitoring
RF RADIUS to a FIX
RMI Radio Magnetic Indicator
RNAV Area Navigation
RNP Required Navigation Performance
RTA Required Time of Arrival
SBAS Satellite Based Augmentation System
SID Standard Instrument Departure
SRAs Special Rules Airspace
STAR Standard Instrument Arrival Route
TF TRACK between two FIXES
TMA Terminal Control Area
VOR VHF Omni Directional Range
WAAS Wide Area Augmentation System
WGS World Geodetic System
DEFINITIONS & EXPLANATION OF TERMS

The following definitions are key terms in the context of area navigation. For the future application of P-RNAV, the definitions used are those that appear in JAA TGL No. 10 [4] and have been adapted from those given in the corresponding ICAO, EUROCAE and RTCA documents.

**Area Navigation.** A method of navigation which permits aircraft operation on any desired flight path.

**Accuracy.** The degree of conformance between the estimated, measured, or desired position and/or the velocity of a platform at a given time, and its true position or velocity. Navigation performance accuracy is usually presented as a statistical measure of system error and is specified as predictable, repeatable and relative.

**Availability.** An indication of the ability of the system to provide usable service within the specified coverage area and is defined as the portion of time during which the system is to be used for navigation during which reliable navigation information is presented to the crew, automatic pilot, or other system managing the flight of the aircraft.

**Continuity of Function.** The capability of the total system (comprising all elements necessary to maintain aircraft position within the defined airspace) to perform its function without non-scheduled interruptions during the intended operation.

**Integrity.** The ability of a system to provide timely warnings to users when the system should not be used for navigation.

**Receiver Autonomous Integrity Monitoring (RAIM).** A technique whereby a GNSS receiver/processor determines the integrity of the GNSS navigation signals using only GNSS signals or GNSS signals augmented with altitude. This determination is achieved by a consistency check among redundant pseudo-range measurements. At least one satellite in addition to those required for navigation must be in view for the receiver to perform the RAIM function (FAA AC 20-138 [16], AC 90-94) [17].

**Vertical Navigation.** A method of navigation which permits aircraft operation on a vertical flight profile using altimetry sources, external flight path references, or a combination of these.
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EXECUTIVE SUMMARY

The purpose of this document is to provide Guidance Material to States, Aviation Authorities, and the Aviation Community on all aspects of the evolutionary implementation of RNAV operations in the EUR Region in accordance with agreed time-scales. It has been developed on the basis of existing material and also taking into account all present and planned developments related to RNAV applications up to the year 2010. The document replaces ICAO Doc 001 (4th Edition) - Strategy for the Implementation of Area Navigation (RNAV) for the EUR Region - which is now obsolete.

The objective of the Guidance Material is to provide a comprehensive, self contained, reference document on all aspects of the application of RNAV and RNP, in the EUR Region, within the above defined timeframe. To achieve this objective it has been necessary to use material from other documents. In order to avoid multiple amendments whenever the text of the authoritative source document on a particular issue is changed, this document provides a summary of the of content and purpose of the material in question.

The Guidance material addresses:

- The planned time-scales for the progressive implementation of RNAV in the EUR Region;
- RNAV Concepts (RNP, B-RNAV, P-RNAV, RNP-RNAV);
- RNAV Applications – En-Route
- RNAV Applications – TMA
- Airspace and Procedure Design
- ATM RNAV Procedures
- Navigation Infrastructure;
- Aircraft Navigation Systems;
- Flight Crew Procedures and Training;
- Approval for RNAV Operations.
1. INTRODUCTION

1.1 Background

1.1.1 Prior to 1998, the system of navigation in European continental airspace was based on the use of fixed ATS routes that were anchored to the location of VOR/DME facilities. As the navigation capability of the aircraft population became more and more accurate and sophisticated, this system became increasingly uneconomical, inflexible, and inefficient in the utilisation of both the available airspace and the aircraft navigation capability.

1.1.2 In the late 1970’s, as traffic continued to grow and delays and congestion in the ICAO European (EUR) Region became a major concern, it was recognised that there was urgent need to increase the ATS system capacity. One method of achieving this objective was to make better use of the new generation of navigation systems carried by aircraft for the en-route phase of flight. These systems were capable of very accurate navigation between any two points without dependence upon the location of the ground facilities. This capability was known as Area Navigation (RNAV) and by the early 1980s the aircraft avionics technology had developed to such an extent that it was acknowledged that RNAV would form the basis of the future navigation system in the Region.

1.1.3 In 1983 the ICAO European Air Navigation Planning Group (EANPG) established a Working Group to develop RNAV Operating Criteria. This Group, the Navigation Aids and Area Navigation Working Group (NARG) produced the Guidance Material on the Application of Area Navigation (RNAV) in the EUR Region (EUR Doc 001) – First Edition.[1]


1.1.5 The Seventh European Regional Air Navigation Meeting (EUR/7 RAN, Malaga 1985), and subsequent action by the ICAO Council, confirmed that RNAV capability should constitute the basis of the future air navigation system in Europe.

1.1.6 In 1990 the Transport Ministers of the ECAC Member States directed that the carriage and use of on-board RNAV equipment would be mandatory by 1998 in the ECAC airspace. Subsequently the Navigation Strategies of the Special Committee on Future Air Navigation Systems (FANS), the Future European Air Traffic Management System (FEATS), and the European Civil Aviation Conference (ECAC) confirmed that RNAV offered improvements to airspace system capacity and efficiency. Thus the Transport Ministers directive evolved into the mandate for Basic RNAV (B-RNAV) that was implemented in EUR en-route airspace from 23 Apr 1998. The introduction of B-RNAV was seen as the first evolutionary step towards a total RNAV environment that would cover all phases of flight, based on a navigation performance that called for high levels of accuracy and functionality.

1.1.7 Within this same timeframe the ICAO RGCSP expanded the concept of Required Navigation Performance (RNP) that had been adopted initially by the ICAO FANS Committee. Whilst the precise definitions appear at more appropriate places within this document, it is important to emphasise, from the outset, the difference between the RNP Concept and RNAV.

1.1.8 RNP is intended to characterise an airspace through a statement of the navigation performance accuracy (RNP type) necessary for operations within that airspace. RNP therefore affects, and places requirements upon both the aircraft in terms of navigation equipment, and on the airspace in terms of the provision of the navigation infrastructure necessary to support the specified RNP type. The RNP types
are identified by a single accuracy value (expressed in NMs) as envisaged by ICAO Future Air Navigation Systems (FANS) Committee.

1.1.9 RNAV is a method of navigation that permits aircraft operation on any desired flight path within the coverage of station-referenced navigation aids or within the limits of the capability of self-contained aids, or a combination of these.

1.1.10 The primary means of achieving a prescribed RNP is expected to be through the use of RNAV equipment.

1.2 The Navigation Strategy for ECAC

1.2.1 The EUROCONTROL Document NAV.ET.ST16-01 -The Navigation Strategy for ECAC – Edition 2.[14] was published in March 1999. The main objective of the strategy was to provide a harmonised and integrated common framework that would allow a cost-effective, customer oriented evolution of the European Air Navigation Systems during the period 2000-2015. This document is currently under revision.

1.2.2 The Road Map of the Strategic Actions that are detailed in the revised Strategy is copied in Figure 1 below:

![Roadmap for Strategic Actions](image)

**Figure 1 - Road Map of Strategic Action**
Figure 1 shows how the time horizon of the Navigation Strategy has been split into four phases: short-term (2003-2005), medium-term (2005-2010) and (2010-2015) and long term (beyond 2015, and it provides an indication of the anticipated time-scale for the development of the main streams of the Navigation Strategy.

1.3 Implementation of the Navigation Strategy in ECAC


1.3.2 In so far as the development and use of RNAV and the introduction of the RNP Concept is concerned, TPINS established ten “Implementation Actions”. These Implementation Actions are shown below in the anticipated sequence of implementation.

1. Continue to Support Operations of Aircraft with Lower Navigation Capability
2. Provision and Maintenance of Conventional and RNAV SIDs, STARs, and Holding Procedures
3. Implementation of B-RNAV at all En-Route Flight Levels
5. Implementation of Free Routes Airspace Concept (FRAC)
6. Provision of Runway Guidance
7. Mandate of RNP1 RNAV Operations
8. Implementation of 4D RNAV Operations
10. Support for Advanced Surface Movement Guidance and Control Systems (ASMGCS) at Airports

1.4 Purpose and Scope of the Document

1.4.1 The purpose of this document is to provide Guidance Material to States, Aviation Authorities, and the Aviation Community on all aspects of the evolutionary implementation of RNAV operations in the EUR Region in accordance with agreed time-scales. The document replaces ICAO Doc 001 (4th Edition) - Strategy for the Implementation of Area Navigation (RNAV) for the EUR Region which is now obsolete.

1.4.2 The Guidance Material has been developed on the basis of existing material and also taking into account all present and planned developments related to RNAV applications up to the year 2015. This includes work already carried out (for example: EUR Doc 001-RNAV/4, EUROCONTROL CMTP, FEATS, ARN activities, the ECAC Airspace and Navigation Strategies and Transition Plans) and developments in progress at world-wide level (for example: within ICAO through FANS, GNSSP, SASP (previously RGCSP), and OCP).

1.4.3 To the extent possible, this document provides a comprehensive, self contained, reference document on all aspects of the application of RNAV and RNP, in the EUR Region, within the above defined timeframe. In seeking to provide a comprehensive reference document it has been necessary to use material from many sources. In order to avoid multiple amendments whenever the text of the authoritative source document on a particular issue is changed, this document provides a summary of the content and purpose of the material in question. Thus, for example, whilst an Operator intending to obtain a State Approval for RNAV Operations would find relevant information in this document, the authoritative JAA Temporary
Guidance Leaflets Nos. 2 [3] and 10 [4] would have to be consulted for detailed guidance. However it is intended that the material should be updated at regular intervals to maintain currency.

1.4.4 The Guidance Material addresses

- The planned time-scale for the progressive implementation of RNAV in the EUR Region;
- RNAV Concepts (RNP, B-RNAV, P-RNAV, RNP-RNAV);
- RNAV Applications – En-Route (Route Spacing, RNAV Routes)
- RNAV Applications - TMA
- Airspace and Procedure Design.
- ATM RNAV Procedures
- Navigation Infrastructure
- Aircraft Navigation Systems;
- Flight Crew Procedures and Training;
- Approval for RNAV Operations.

2. RNP AND RNAV CONCEPTS

This Section outlines the relationship between the RNP concept and RNAV and describes the different types of RNP as foreseen by the ICAO RGCSP (now the SASP). It also provides a summary of the Accuracy, Availability and Integrity, Functionality, and Continuity requirements for the types of RNAV operations applicable to European Airspace, supported by extracts from, and/or cross references to, the relevant authoritative JAA (or similar) documentation.

2.1 Required Navigation Performance (RNP)

General

2.1.1 The ICAO Review of the General Concept of Separation Panel (RGCSP) developed RNP as a concept that applies to aircraft navigation performance within a defined airspace and it therefore affects, and places requirements upon, both the aircraft and the airspace. RNP is intended to characterise an airspace by means of a statement of the navigation performance (RNP type) necessary for operations within that airspace. RNP types are identified by a single accuracy value as envisaged by the ICAO Future Air Navigation Systems (FANS) Committee.

2.1.2 From the aircraft perspective, the accuracy value is based on the combination of the navigation sensor error, airborne receiver error, display error and, for the lateral navigation element, flight technical error (FTE). The total system error (TSE) allowed in the individual lateral and longitudinal dimensions must be better than the specified RNP value for 95 per cent of the flight time of any single flight.

2.1.3 From the airspace perspective, the achievement of the navigation performance accuracy value (RNP type), within a defined airspace, requires the provision of a supporting navigation infrastructure. The RNP types can be used by airspace planners to determine airspace utilisation potential and as an input in defining route widths and traffic separation requirements, although RNP by itself is not sufficient basis for setting a separation standard. In practice, an aircraft with a navigation performance which is less accurate than that specified for operations in a particular RNP type airspace would normally be excluded from that airspace or, alternatively, it could be allocated an increased separation minimum.

2.1.4 An aircraft with a level of navigation performance more accurate than that specified for a particular RNP type of airspace can normally fly in the airspace concerned (e.g. RNP 1 certified aircraft can operate in RNP 4 airspace). However there may be occasions, when this does not apply. For example when an aircraft’s level of navigation performance accuracy is dependent upon the availability of a particular
navigation aid (Navaid) infrastructure. That aircraft might not meet the requirements of a less stringent RNP airspace that did not provide coverage of the appropriate Navaids. A practical example would be an aircraft with an RNP 1 capability, based on Dual Distance Measuring Equipment (DDME), that did not possess the appropriate long-range aids required for operations in an RNP 12.6 airspace such as the North Atlantic (NAT) Minimum Navigation Performance Specification (MNPS) Airspace.

2.1.5 Detailed guidance material on the concept and provisions of RNP, how RNP affects the system providers and system users, and advice to Regional Planning Groups concerning the development of documents, procedures and programmes to introduce RNP into the airspace, is provided in ICAO Document 9613 [2]. This document supercedes the ICAO Manual of Area Navigation (RNAV) Operations (Doc 9573) and contains all relevant material from that document.

2.1.6 Whilst ICAO Document 9613 primarily addresses the use of the RNP Concept in the En-Route phase of flight, in ICAO Document 9650 [5] the RNP Concept is applied to the approach, landing and departure phases of flight. ICAO Document 9650 provides the definition of RNP as “A statement of the navigation performance accuracy, integrity, continuity and availability necessary for the operation within a defined airspace.

RNP Types

2.1.7 ICAO Document 9613 [2] Section 3.3 specifies five types of RNP for general application to en-route operations. These are RNP 1; RNP 4; RNP 10; RNP 12.6; and RNP 20, in each instance the numerical value indicates the required 95% lateral and longitudinal position accuracy. The foreseen applications of each RNP type are as follows:

RNP 1

This is envisaged as the RNP type necessary for the most accurate and efficient ATS route operations. It will also provide the most effective support of operations, procedures and airspace management for transition to and from the TMA and the required ATS route. The navigation accuracy achieved by P-RNAV equipped aircraft in EUR airspace equates to RNP 1 but lacks the advanced functionality (e.g. fixed radius transitions, parallel off-sets (recommended only in P-RNAV) and containment integrity).

RNP4

This RNP type will support ATS routes and Airspace Design that are dependent upon the distance between Navaids (VOR/DME). It is the RNP type associated with operations in continental airspace.

ICAO Document 9613 [2] allows the use in some States of RNP 5, for an interim period, to permit the continued operation of present navigation equipment without the modification of existing route structures. In Europe, the lateral navigation accuracy of aircraft approved for operations on the existing B-RNAV Route Structure, or of those aircraft without an RNAV capability operating on the remaining conventional routes defined by VOR or VOR/DME (where the VOR facilities are less than 100 NM apart), equates to the lateral navigation accuracy associated with RNP 5.

RNP 10/ RNP 12.6/ RNP 20

These types of RNP support lateral and longitudinal separation minima in oceanic airspace and remote areas with limited navigation aids. RNP 20 is the minimum navigation performance considered acceptable to support ATS route operations. This minimum level of performance is expected to be met by any aircraft in any airspace at any time. At the present time no application of these RNP types is foreseen in EUR.
FUTURE USE OF RNP ≤1

It is anticipated that a navigation performance of RNP ≤1 will be required for the future TMA Operations described in Sub-Paragraph 4.

2.2 Area Navigation (RNAV)

Introduction

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

2.2.2 In general terms, RNAV equipment operates by automatically determining aircraft position, establishing the desired flight-path, and providing path guidance to the next waypoint. The aircraft position is derived from one, or a combination of, input(s) from the following navigation systems (which are described in Sub-Paragraph 8.4)

- INS* or IRS*
- VOR/DME
- DME/DME
- LORAN C*
- GNSS (GPS)

Note: *These systems have limitations on their use in support of B-RNAV Operations (See Sub-Para, 8.4)

2.2.3 The terms Basic and Precision RNAV were developed by the ICAO EANPG in the initial Guidance Material on the Application of Area Navigation (RNAV) [1] prior to the development of the RNP concept. In terms of lateral navigation accuracy, Basic RNAV equates to RNP5 and Precision RNAV equates to RNP1, however in each case the functionality requirements are less demanding than those necessary for RNP operations.

Basic RNAV (B-RNAV) Operations

GENERAL

2.2.4 B-RNAV was introduced in the EUR airspace as a result of the 1990 directive of the Transport Ministers of the ECAC Member States. A Basic RNAV (B-RNAV) capability is currently (2003) required for en-route operations in the majority of the airspace of the EUR Region. It is intended that during the period 2003 to 2005, this requirement will be expanded to the entire ATS Route Network of the EUR Region for all operations above FL 095.

2.2.5 Detailed Guidance Material on Airworthiness Approval and Operational Criteria for the use of Navigation Systems in European Airspace Designated for Basic RNAV Operations is provided in JAA ACJ20X4JAA (previously TGL No. 2(rev 1) – AMJ 20-X2 [3]). However compliance with the JAA Guidance does not constitute the required Operational Approval/Authorisation to conduct B-RNAV Operations. Aircraft Operators intending to operate in designated B-RNAV airspace must first obtain a specific approval/authorisation for such operations from their State Authority. The following material provides a summary of the content of the JAA guidance.
ACCURACY

2.2.6 The navigation performance of aircraft approved for Basic RNAV operations within European airspace requires a lateral navigation and along track position fixing accuracy equal to, or better than, 4.6km (2.5NM) for 1 standard deviation and the realisation of a 95% containment value of ± 9.26km (± 5 NM). This value includes signal source error, airborne receiver error, display system error and flight technical error.

2.2.7 This navigation performance assumes that the necessary coverage provided by satellite or ground based navigation aids is available for the intended route to be flown.

AVAILABILITY AND INTEGRITY

2.2.8 The minimum level of availability and integrity required for Basic RNAV systems for use in designated European airspace can be met by a single installed system comprising one or more sensors, RNAV computer, control display unit and navigation display(s) (e.g. ND, HSI or CDI). This is acceptable provided that the system is monitored by the flight crew and that in the event of a system failure the aircraft retains the capability to navigate relative to ground based navigation aids (e.g. VOR, DME, NDB).

REQUIRED FUNCTIONS

2.2.9 The following system functions are the minimum required to conduct Basic RNAV operations.

   a) Continuous indication of aircraft position relative to track to be displayed to the pilot flying on a navigation display situated in his primary field of view. In addition where the minimum flight crew is two pilots, indication of aircraft position relative to track to be displayed to the pilot not flying on a navigation display situated in his primary field of view;
   b) Display of distance and bearing to the active (To) waypoint;
   c) Display of ground speed or time to the active (To) waypoint;
   d) Storage of waypoints; minimum of 4; and
   e) Appropriate failure indication of the RNAV system, including the sensors.

RECOMMENDED FUNCTIONS

2.2.10 In addition to the foregoing, the following system functions and equipment characteristics are recommended:

   a) Autopilot and/or Flight Director coupling
   b) Present position in terms of latitude and longitude
   c) “Direct To" function
   d) Indication of navigation accuracy (e.g. quality factor)
   e) Automatic channel selection of radio navigation aids
   f) Navigation database
   g) Automatic leg sequencing and associated turn anticipation

Note: It is recommended that B-RNAV systems should provide a capture to the next track in such a manner as to minimise any overshoot. The turn anticipation should be such as to not commence the capture manoeuvre until the aircraft is within 5NM of the centre line of the new track.
AIRCRAFT FLIGHT MANUAL – MMEL (MASTER MINIMUM EQUIPMENT LIST)

2.2.11 The basis for certification should be stated in the Aircraft Flight Manual (AFM), together with any RNAV systems limitations. The AFM may also provide the appropriate RNAV system operating and abnormal procedures applicable to the equipment installed, including, where applicable, reference to required modes and systems configuration necessary to support an RNP capability.

B-RNAV SYSTEMS – ACCEPTABLE MEANS OF COMPLIANCE

2.2.12 Navigation systems which are installed on aircraft in accordance with the advisory material contained within FAA AC 90-45A, AC 20-130(), AC 20-138 or AC 25-15, are acceptable for Basic RNAV operations. Where reference is made in the AFM to either the above advisory material or the specific levels of available navigation performance (RNP), no further compliance statements will be required.

2.2.13 Compliance may be based also on the lateral navigation standards defined in JTSO-2C115, TSO-2115(), TSO-2129(), ED-27/28, ED-39/40, DO-187/ED-58 or DO-180(). However, qualification of the equipment to these standards, in itself, is not considered as sufficient for the airworthiness approval.

LIMITATIONS ON THE USE OF NAVIGATION SYSTEMS

2.2.14 The following Navigation Systems have limitations on their use in support of B-RNAV Operations;

- INS/IRS
- Loran C*
- GPS

*Currently LORAN C is not acceptable for use in the European Region (see Sub-para 8.4)

Precision RNAV (P-RNAV) Operations

GENERAL

2.2.15 As a further development of the concept of area navigation within the European region, Precision Area Navigation (P-RNAV) is being developed for implementation in terminal airspace, to optimise TMA design and to obtain increased operating capacity together with environmental benefits arising from route flexibility. However, and in accordance with the EUROCONTROL Navigation Strategy [14], the initial carriage and use of RNAV equipment capable of P-RNAV operations will be optional. This will enable the application of P-RNAV in terminal airspace for suitably equipped aircraft.

2.2.16 The P-RNAV application addresses a navigation performance for track keeping accuracy that equates to RNP1. However it does not satisfy all of the functional aspects of the Required Navigation Performance (RNP) concept promulgated in ICAO Documents 9613 [2] and 9650 [5]. P-RNAV is expected to be progressively replaced by RNP-RNAV operations during the period 2005 to 2010.

2.2.17 The authoritative Guidance Material on the Airworthiness and Operational Approval for Precision RNAV (P-RNAV) Operations in Designated European Airspace is provided in JAA Administrative & Guidance Material, Section 1, General Part 3: Temporary Guidance Leaflet No. 10 [4]. Compliance with the Guidance in TGL No. 10 does not, in itself, constitute the required Operational Approval/Authorisation to conduct P-RNAV Operations. Aircraft Operators must apply to their State Authority for such approval/authorisation. It must be emphasised that the Guidance Material in TGL No. 10
is based upon the assumption that the infrastructure necessary to support and safeguard P-RNAV Operations/Procedures, as detailed in Chapter 7 has been provided by the appropriate State Authority.

2.2.18 The technical specifications required for P-RNAV operations that are contained in the following Sub-Paragraph and in Appendix A have been taken from JAA TGL No. 10.

SYSTEMS DESCRIPTION

2.2.19 P-RNAV equipment enables the aircraft to be navigated along a path defined by waypoints held in an on-board navigation database, within the P-RNAV system’s required accuracy performance limits. Vertical navigation performance is not part of the P-RNAV criteria.

2.2.20 P-RNAV operations are based upon the use of P-RNAV equipment that automatically determines aircraft position in the horizontal plane using inputs from the following types of positioning sensor (in no specific order of priority):

   a) Distance Measuring Equipment giving automatically updated measurements from two or more ground stations (DME/DME).

   b) VHF Omni-directional Radio range with a co-located DME (VOR/DME) where the facility is identified as meeting the requirements of a specified procedure.

   c) Global Navigation Satellite System (GNSS).

   d) Inertial Navigation System (INS) or Inertial Reference System (IRS), with automatic updating from suitable radio based navigation equipment.

Notes:

i) LORAN-C is not an acceptable navigation sensor for terminal airspace operations.

ii) TACAN beacons may be included in the on-board navigation database and used to supplement DME provided they meet ICAO Annex 10 Standards and are listed in the AIP.

iii) The term GNSS refers to the US Department of Defence Global Positioning System (GPS) with Receiver Autonomous Integrity Monitoring (RAIM), or to a GPS with Aircraft Based Augmentation System (ABAS), or Space Based Augmentation System (SBAS), e.g. EGNOS.

iv) Limitations on the use of inertial data, as the means of determining aircraft position during short periods of loss of radio updating, are discussed in further detail in Sub-Paragraph 8.4.11 of this document.

2.2.21 Navigation parameters, such as distance and bearing to a waypoint, are computed from the aircraft position and the location of the waypoint. Steering guidance, referenced to the path between two waypoints, is then output to navigation displays and guidance systems to enable the desired path to be followed.

ACCURACY

2.2.22 A Precision RNAV (P-RNAV) system must have a lateral navigation and along track position fixing accuracy equal to, or better than, 0.93km (0.5NM) for 1 standard deviation and shall provide a 95% containment value of ± 1.85km (± 1NM).
Notes:

i) The track keeping accuracy is dependent on the navigation system error (a combination of path definition error, position estimation error and display error) and Flight Technical Error (FTE). It corresponds to the accuracy component of RNP1 and RNP1RNAV. Further explanation may be found in document ED75A/DO236A [7].

ii) For the purposes of obstacle clearance, a FTE of ±0.5NM is assumed for the departure (except at the departure end of the runway where, in accordance with PANS-OPS Doc 8168 [18], Volume II, Part II, 7.3.2 and 8.1, a value of ±0.1NM is assumed), ±1NM for the initial and intermediate segments, and 2NM for en-route.

iii) The objective behind this chosen level of performance is to enable RNAV systems based on DME/DME, as currently installed in many aircraft, to be used in terminal airspace on P-RNAV procedures designed according to the published criteria without further evaluation of system accuracy.

iv) Provided that the assumption in respect of typical DME performance (listed in Sub-Paragraph 8.4.2 of this document) has been shown to be valid, then, for RNAV systems that have been declared (e.g. in the Aircraft Flight Manual) to be compliant with the 2D navigation accuracy criteria of FAA AC 90-45A, AC 20-130, FAA TSO-C115, or JAA JTSo-2C115, the intent of this paragraph is considered to be satisfied and no further accuracy demonstration is required. However, such a Flight Manual statement, by itself, does not constitute an airworthiness approval for P-RNAV and compliance with all other criteria of JAA TGL No 10 [4] will need to be shown.

INTEGRITY

2.2.23 With respect to the airborne system, the probability of displaying hazardously misleading navigational or positional information simultaneously to both pilots shall be Remote.

- In the context of P-RNAV operations in the terminal area, hazardous should be interpreted as involving misleading information without a timely warning and which, in the absence of other cues, is unlikely to be detected by the flight crew.

- An airborne safety objective of Remote is an alleviation to the current guidelines of paragraph 4.a. (3)(viii) of AMJ 25-[22], which specifies Extremely Remote for the departure, arrival and approach phases of flight. This alleviation recognises that the PANS-OPS procedure design, and PANS ATM air traffic separation criteria, account for and accommodate these types of aircraft and their system integrity in current airspace. Furthermore, conservative safety margins are used in the design of P-RNAV procedures such that the risks are not increased above those currently experienced.

- A safety objective of Extremely Remote will continue to be applicable to a precision approach on the final segment i.e. from the Final Approach Waypoint (FAWP) down to the runway.

- Systems approved for RNP operations have capabilities exceeding that required for P-RNAV operations. These systems provide higher navigation integrity through implementation of containment and by giving the flight crew better awareness of accuracy through the availability of estimated position uncertainty.

- Probability terms are defined in JAA AMJ 25.1309. RNP-RNAV-[22].
CONTINUITY OF FUNCTION

2.2.24 With respect to the airborne systems, it shall be shown that:

a) The probability of loss of all navigation information is Remote.

b) The probability of non-restorable loss of all navigation and communication functions is “Extremely improbable”.

Notes:

i) In addition to the equipment required by JAR-OPS 1, Sub-part L for IFR flight (or equivalent national requirements), at least one area navigation system is required.

ii) Probability terms are defined in JAA AMJ 25.11309-[22]

REQUIRED FUNCTIONS

2.2.25 The minimum system functions required for P-RNAV Operations are detailed in Appendix A1, and the recommended functions for P-RNAV Operations are at Appendix A 2.

RNP-RNAV

2.2.26 The concept of RNP-RNAV is introduced in the Minimum Aviation System Performance Standards (MASPS) for Required Navigation Performance for Area Navigation (RNP-RNAV), RTCA DO 236A / EUROCAE ED 75 RNP-RNAV [7]. RNP-RNAV combines the accuracy standards set out in the ICAO RNP Manual (Doc 9613) [2] with specific containment integrity and containment continuity requirements, as well as functional and performance standards for the RNAV system, to achieve a system that can meet future ATM requirements. The functional criteria for RNP-RNAV address the need for the flight paths of participating aircraft to be both predictable and repeatable to the declared levels of accuracy.

2.2.27 The ICAO Obstacle Clearance Panel (OCP) is developing instrument procedure design criteria for RNP-RNAV, and the ICAO Safety and Separation Panel (SASP, previously RGCSP), is considering the spacing criteria for RNP-RNAV. To date, instrument procedure design criteria are only available for RNP 0.3 and route spacing criteria have only been established for RNP4 and higher.

2.2.28 In addition, when the ICAO All Weather Operations Panel (AWOP) considered the application of RNP concepts to approach procedures, and to precision approaches in particular, it was decided that vertical navigational accuracy had to be addressed as well as horizontal accuracy. As a result, a range of RNP types were defined from RNP 1 to RNP 0.003/z, where z reflects the requirement for vertical guidance. The GNSSP subsequently proposed a set of values that could be supported by Space Based Augmentation Systems (SBAS) and Ground Based Augmentation Systems (GBAS). These values are still under review.

2.2.29 The RNP types that are currently in use, or are being considered for use, in European Airspace are detailed in Table 2 below:
<table>
<thead>
<tr>
<th>RNP Type</th>
<th>Required Accuracy (95% Containment)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.003/z</td>
<td>± 0.003 NM [± z ft]</td>
<td>Planned for CAT III Precision Approach and Landing including touchdown, landing roll and take-off roll requirements. (ILS, MLS and GBAS)</td>
</tr>
<tr>
<td>0.01/15</td>
<td>± 0.01 NM [± 15 ft]</td>
<td>Proposed for CAT II Precision Approach to 100 ft DH (ILS, MLS and GBAS)</td>
</tr>
<tr>
<td>0.02/40</td>
<td>± 0.02 NM [± 40 ft]</td>
<td>Proposed for CAT I Precision Approach to 200ft DH (ILS, MLS, GBAS and SBAS).</td>
</tr>
<tr>
<td>0.03/50</td>
<td>± 0.03 NM [± 50 ft]</td>
<td>Proposed for RNAV/VNAV Approaches using SBAS.</td>
</tr>
<tr>
<td>0.3/125</td>
<td>± 0.3 NM [± 125 ft]</td>
<td>Proposed for RNAV/VNAV Approaches using Barometric inputs or SBAS.</td>
</tr>
<tr>
<td>0.3</td>
<td>± 0.3 NM</td>
<td>Supports Initial/Intermediate Approach, 2D RNAV Approach, and Departure. Expected to be the most common application.</td>
</tr>
<tr>
<td>0.5</td>
<td>± 0.5 NM</td>
<td>Supports Initial/Intermediate Approach and Departure. Only expected to be used where RNP 0.3 cannot be achieved (poor Navaid infrastructure) and RNP 1 is unacceptable (obstacle rich environment)</td>
</tr>
<tr>
<td>1</td>
<td>± 1.0 NM</td>
<td>Supports Arrival, Initial Intermediate Approach and Departure; also envisaged as supporting the most efficient ATS route operations. Equates to P-RNAV.</td>
</tr>
<tr>
<td>4</td>
<td>± 4.0 NM</td>
<td>Supports ATS routes and airspace based upon limited distances between Navaids. Normally associated with continental airspace but may be used as part of some terminal procedures.</td>
</tr>
<tr>
<td>5</td>
<td>± 5.0 NM</td>
<td>An interim type implemented in ECAC airspace to permit the continued operation of existing navigation equipment. Equates to B-RNAV.</td>
</tr>
</tbody>
</table>

Table 2 - RNP Types
2.2.30 At present there is no JAA guidance material to cover the application of RNP-RNAV. It is anticipated that a TGL for RNP-RNAV 0.3 Approach Operations will be produced during 2003 as many of the commercial passenger aircraft that have been delivered since 1998 are expected to meet RNP-RNAV requirements to a level of 0.03 or better.

2.2.31 Whilst the Navigation Strategy foresees RNP-RNAV being mandated by 2015, few RNP-RNAV procedures are expected to be introduced before 2010.

3. RNAV APPLICATIONS – EN ROUTE

3.1 Airspace Planning

Basic RNAV Route Spacing

INTRODUCTION

3.1.1 This Chapter describes the determination of the minimum allowable spacing between the centre lines of parallel Basic RNAV routes in ECAC airspace. The material is based on ICAO Annex 11, Attachment B §2.3 [11] that details the spacing between parallel routes (RNAV/RNAV and RNAV/Conventional), and on material and additional studies performed by EUROCONTROL in the framework of EATCHIP and EATMP.

3.1.2 The EUROCONTROL safety studies into RNAV route spacing minima included theoretical collision risk assessments based solely on the navigation capability of the aircraft, as well as studies in which an ATC intervention capability and related theoretical radar controller intervention rates were calculated.

ICAO AIRSPACE PLANNING MANUAL

3.1.3 ICAO Document - Airspace Planning Methodology for Determining Separation Minima [12] (also called the Airspace Planning Manual) provides guidance on those aspects that influence the safety of route spacing and separation minima, and on how they should be taken into account. The document does not include separation or route spacing minima, which would be applicable world-wide, although examples of safety assessments have been included. Consequently, the Manual is considered to be a valuable overview of methods that have been applied for air traffic separation safety assessments throughout the world, and is a basis for safety assessments for application in particular air traffic environments.

3.1.4 As many of the safety assessment aspects provided in the above Manual were derived from European (and EUROCONTROL/EATCHIP) activities, the methods applied within European safety assessments are compatible with the contents of the Airspace Planning Manual.

ECAC STRATEGY

3.1.5 As reflected in the ECAC strategy, ECAC Airspace can be regarded as a radar environment, in which radar ATC service (i.e. some form of radar monitoring service) is provided.

ROUTE SPACING

3.1.6 ICAO Annex 11 [11] Attachment B §2.3. refers to VOR parallel route spacing as being applicable also to RNAV parallel route spacing. Attachment A states that the VOR route spacing values should only be applied after study of the underlying safety assessment and assumptions. For application in ECAC airspace the said study was completed by the EUROCONTROL Agency.
3.1.7 The study, which included a theoretical risk assessment as well as an operational appreciation of assumptions and applications, concluded that the following parallel route spacing is applicable in ECAC Basic RNAV airspace, without any additional ATC workload due to correcting aircraft deviations as a result of inaccuracies of the navigation system or Operational Errors.

- 18 NM for opposite direction routes,
- 16.5 NM for same direction routes, and
- 15 NM if the aircraft on adjacent (opposite direction) routes are not assigned the same flight levels, and the percentage of climbing and descending traffic is 40% or less.

**POTENTIAL FOR REDUCTION OF BASIC RNAV ROUTE SPACING**

3.1.8 Reductions of the B-RNAV Route spacing minimum, to somewhere in the order of 10 – 15 NM, are expected to be possible in ECAC Basic RNAV airspace by placing higher reliance on the ATC Radar Monitoring and intervention capabilities. The circumstances in which such a reduction of route spacing is applied, will need to be assessed on a case by case basis. An example study is outlined in Sub-Paragraph 3.2.

3.1.9 When a reduction of the B-RNAV Route spacing is to be considered, the acceptable level of the increase in ATC workload is of primary importance. This will depend largely on local ATC conditions, procedures and systems, and these should be subject to a local appreciation and assessment which takes full account of existing operations and implicit responsibilities. In this context reference is made to the material in ICAO Doc 4444 (PANS-ATM) [14], Chapter 8 - Radar Services, especially to §8.7 - “Use of Radar in The Air Traffic Control Service”.

3.1.10 The studies to assess the minimum acceptable Basic RNAV parallel route spacing in ECAC airspace are presented in Appendix B - Theoretical ATC Intervention Rates. The results of these studies should be seen in the light of the assumptions made, namely that:

a) the actual navigation performance in ECAC Basic RNAV airspace can be expected to be much better than the required B-RNAV performance, and that this factor will significantly reduce the required controller intervention rate;

b) the number of required interventions will be reduced if the aircraft on adjacent (opposite direction) routes are not assigned the same flight levels; and

c) many of the theoretical ATC interventions, assumed in the study, may not be required due to the early anticipation by ATC of the development of undesirable traffic situations, and to the interaction between ATC and Operator which is an implicit requirement of normal radar supported ATM.

3.1.11 Nevertheless, the results of this study clearly indicate that when, in a Basic RNAV environment, the route spacing is reduced towards 10 NM, the number of required interventions increase significantly. Thus, when such a reduction is being considered, States may consider the application of ATC Support Tools, (e.g. deviation alerts) to optimise the ATC intervention capability and to minimise any increase in ATC workload.
RNAV OPERATIONAL ERRORS

3.1.12 A key assumption in the initial development of the requirements for Basic RNAV was that the achieved navigation performance would be the same as, or better than, that currently achieved on the then existing VOR/DME defined routes. Consequently a lateral track keeping accuracy of 5NM (95%) was established for Basic RNAV operations in ECAC airspace. In practice, however, the navigation accuracy of the aircraft approved for Basic RNAV operations is expected to be better than this.

3.1.13 On the other hand however, it has been recognised that navigation solely through the use of RNAV equipment might result in a type of navigation error that did not occur when navigating to/from the facilities that define VOR/DME routes. These navigation errors are essentially operational errors (e.g. incorrect insertion of waypoint co-ordinates) related to the use of the on-board RNAV equipment that result in the aircraft flying very accurately to the wrong place. The safety assessment work undertaken by EUROCONTROL has indicated that the collision risk associated with closely spaced parallel routes is very sensitive to the frequency of occurrence, and the size (which could be large), of these types of errors, and to the efficiency with which ATC is able to detect and correct them. Currently not enough information on these errors is available.

SUMMARY OF CONCLUSIONS

a) The following route spacing minima is applicable in ECAC Basic RNAV airspace, without any additional ATC workload;
   • 18 NM for opposite direction routes,
   • 16.5 NM for same direction routes, and
   • 15 NM if the aircraft on adjacent (opposite direction) routes are not assigned the same flight levels, and the percentage of climbing and descending traffic is 40% or less.

b) A reduction in the Route Spacing minima, to 10 - 15 NM, is expected to be possible in ECAC Basic RNAV airspace by placing increased reliance on the ATC Radar Monitoring and intervention capabilities, as detailed above; and

c) Where the application of the reduced route spacing is being considered, it will be necessary to obtain data on the achieved RNAV performance on B-RNAV Routes.

Precision RNAV Route Spacing

3.1.14 Work is still underway to define the route spacing in a P-RNAV/RNP 1 environment. The main issues that will determine the acceptable value include:

a) Navigation Equipment Failure modes – specifically the rate at which a navigation error build up can occur

b) Surveillance and Communications – the ability to detect and correct navigation failures

c) Deviation and/or collision alerting – the ability to inform ATC of the failure

d) Radar separation standards

e) Acceptable controller workload

f) Expected peak traffic
3.1.15 The minimum allowable aircraft separation, for en-route operations, is normally 5 NM, and this provides a finite limitation to any attempt to achieve a reduction in route spacing. Furthermore, given that RNP 1 performance means that for up to 5% of the flight time aircraft may be more than 1 NM from their defined track, it is not expected that a route spacing of below 7 NM will be possible.

3.2 Study to Determine RNP for a Procedural 10 NM Route Spacing

3.2.1 It can be seen from sub-paragraph 3.1 above that the potential for any reduction in route spacing lies somewhere in the range between the 15NM –18NM for B-RNAV (RNP 4/5) operations, and the minimum value of 7NM for P-RNAV (RNP 1). A worked example of the type of studies, identified by Annex 11 [11], that would need to be undertaken to confirm the safety of the implementation of a procedural P-RNAV route spacing of 10 NM is provided at Appendix C1.

3.3 En-Route RNAV Operations

Types of RNAV Routes

3.3.1 RNAV is applicable to operations in areas with both high and low traffic density. Whilst, within the ECAC area, it can be assumed that some form of radar surveillance will normally be available, in some areas where traffic complexity and density do not justify the provision of radar or automatic dependent surveillance (ADS), RNAV routes can be established outside radar coverage or without ADS.

3.3.2 The use of RNAV equipment will be required for navigation along ATS RNAV routes and for TMA RNAV Operations. The types of RNAV routes may be:

FIXED RNAV ROUTES;

3.3.3 Fixed RNAV routes are published ATS routes that can be flight-planned for use by aircraft with appropriate RNAV capability. Restrictions in the times of availability and flight levels are not precluded. Fixed RNAV routes should begin and end at promulgated reporting points, not necessarily defined by ground facilities. RNAV routes are defined by waypoints that may coincide with navigation aids or reporting points.

3.3.4 All ATS routes above FL245, and many ATS routes above FL095, in the following States in the EUR Region require a B-RNAV capability:

+Armenia, Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, FYROM, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Moldova, Netherlands, Norway, Poland, Portugal, Romania, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey and United Kingdom.

3.3.5 In future, States may introduce fixed RNAV routes that require a P-RNAV capability.

CONTINGENCY RNAV ROUTES;

3.3.6 Contingency RNAV routes are published ATS routes which can be flight-planned and which can be made available to aircraft with appropriate RNAV capability during specific, limited time periods (hours, days, seasons). They may also be established to meet unusual, temporary requirements arising at short notice, e.g. where a radio navigation aid is out of service and would otherwise require closure of a segment of that route to all traffic due to insufficient navigational guidance. The establishment of a contingency RNAV route in these circumstances would allow suitably equipped aircraft to continue to use the affected route segment.
RANDOM RNAV ROUTES (FREE ROUTE AIRSPACE)

3.3.7 Random RNAV routings are unpublished tracks which may be flight-planned within designated and published Free Route Airspace which are defined as follows:

a) in specified FIR/UIRs or in areas laterally defined by geographical co-ordinates; and
b) during specified periods; and/or
c) within specified flight level bands; and
d) with approval of the ATC authority.

3.3.8 Free Route airspace should have adequate air/ground communications and, depending on traffic density, ATS surveillance capability. It is envisaged that surveillance will be required in most Free Route Airspace. It can, however, be foreseen that, in some areas where traffic complexity and density do not justify the provision of radar, Free Route airspace might be established outside radar coverage or without ADS.

RNAV Applications

GENERAL

3.3.9 The RNAV applications described below are examples of methods whereby RNAV may be used by ATC. The values in each example, e.g. time, flight levels, distances, are included as general guidance and in order to present a sense of continuity to the text. They should not be construed as being the only value possible. States implementing RNAV operations are urged however to co-ordinate applicable flight levels and times with neighbouring States in order to harmonise the network at an international level.

USE OF PARALLEL OFFSET TECHNIQUES

3.3.10 The RNAV Parallel Offset function is not required in a B-RNAV certification and is only a recommended function in a P-RNAV certification. It follows that an RNAV capable aircraft may not be able to comply with an ATC request to use parallel offsets. In the future, when RNP-RNAV is introduced, it is anticipated that all aircraft will be required to have this capability.

3.3.11 One use of the Parallel Offset function is to segregate climbing/descending traffic from traffic in level flight for the time period of this manoeuvre. The main requirement will therefore apply in peak traffic periods and it is anticipated that there will be an ATC requirement for this capability to be available before the introduction of RNP-RNAV.

3.3.12 The offset distance from the assigned route will be dependent upon ATC tactical requirements.

AD-HOC RNAV APPLICATIONS (E.G. “DIRECT TO” RNAV WAYPOINTS).

3.3.13 Tactical applications of this type are considered to be a first step towards Random RNAV applications. Within the present ground environment, where ATC Support Tools may be limited, these applications may only be possible during periods of low traffic density. For B-RNAV aircraft the “DIRECT TO” capability is a recommended function, for P-RNAV/RNP1 approvals the equipment will be capable of executing “DIRECT TO” to any significant point or LAT/LONG fix.
OVERLAYING RNAV APPLICATIONS.

3.3.14 This application is designed to employ RNAV systems on procedures that can also be flown by conventional navigation systems (VOR/DME Routes). It is intended as an interim step that allows RNAV and non-RNAV traffic to follow the same routes, thereby reducing the ATS workload. It is important to realise that a route designed for conventional flying may not be flyable using an RNAV system. This is particularly the case in the Terminal Area where judicious use of power and flap settings is sometimes necessary to follow some conventional procedures. Whenever an RNAV overlay is being considered, the route should be re-designed to meet both the RNAV and the conventional requirements. This should result in an RNAV procedure being published with a conventional ‘underlay’ procedure which is clearly annotated as being ‘NOT FOR USE IN AIRBORNE NAVIGATION DATABASES’. The general layout of these routes should be such that they will not create any additional workload for ATC, i.e. so that the routes continue to be acceptable during peak periods.

ATS ROUTE NETWORK (ARN)

3.3.15 This network differs in a marked way from the VOR/DME defined ATS route structure. Within the present ground environment it is not feasible to have two different networks within a given airspace without increasing ATC workload and thereby reducing ATC capacity. The ARN is therefore only applied above a specified altitude where most aircraft are at least B-RNAV certified. Currently, the ARN applies above FL245 in the EUR, although in many States it is applied above FL095.

4. RNAV APPLICATIONS – TMA

4.1 Implementation of RNAV in the TMA.

4.1.1 When State or Airport Authorities are considering whether or not to introduce RNAV procedures into the TMA of an airport or airports within their area of responsibility, the following factors should form part of the preliminary discussions.

- Definition of Operational Requirement including:
  - Definition of the main drivers for the proposed change
  - Identification of the Operational Benefits and Penalties applicable to the User and Provider community.
- Preparation of Safety Case.
- Determination of Technical Requirements (Upgrades to Aircraft Equipment)
- Review of measures necessary to support non-compliant Civil and State Aircraft.
- Consideration of whether additions or changes are necessary to the Navigation Infrastructure.
- Consideration of impact on affected ATC and ATM Procedures.
- Consultation with other relevant Aviation Authorities, User Organisations, Local Organisations (Environmental Issues), ICAO and EUROCONTROL.
4.2 Operational Requirement

4.2.1 An operational requirement for RNAV in the TMA may be based on one or more of a number of drivers:

- Environmental pressures to modify routes in the TMA
- Changes to the en-route structure which lead to changes in the connections to the SIDs and STARs.
- Commercial pressure from operators to provide more direct and fuel-efficient routes.
- Changes to the airspace structure to improve capacity.

4.2.2 RNAV procedures can be designed to support SID, STAR, Holding and Approach operations. RNAV SIDs and STARs can be flown by aircraft with a P-RNAV approval, while RNAV approaches require a separate approval. Aircraft with only B-RNAV approvals are not authorised to fly on any RNAV procedure that includes a segment below MSA/MRVA/MFA; that contains more than 4 waypoints per 100NM (i.e. the distance between waypoints must be 25nms or more), or that is not designed in accordance with RNP 5 en-route criteria.

4.2.3 RNAV SIDs provide the opportunity to route traffic clear of environmentally sensitive areas and provide direct connections to the en-route structure. RNAV STARs allow a direct connection from the en-route structure and may also be used to route traffic in a structured way onto downwind legs or direct to the FAF, overlaying the existing pattern of radar vectors.

4.2.4 RNAV STARs that connect directly to an approach procedure, such as an RNAV approach or an ILS approach can improve situational awareness and allow more efficient vertical profiles to be flown. However, unless the ATS provider has access to comprehensive sequencing tools, it is inevitable, in order to maintain capacity in heavy traffic conditions, that some, or all, of the arriving traffic will have to be given radar vectors and the benefits from the RNAV procedure will be lost.

4.2.5 The benefits that may accrue from the introduction of RNAV procedures must be viewed against the cost that will be incurred by the operators and the ATS provider. The former must have aircraft that are appropriately certified, crews that are suitably trained and regulatory approval to conduct the operation. The latter must have automated display systems that have been modified to display individual aircraft equipage (as reported in the FPL). ATC training material should include practical and operationally significant aspects of RNAV in the TMA.

4.3 Safety Case

4.3.1 EUROCONTROL has developed a Safety Argument for the application of P-RNAV. This identifies a number of standards that have to be met and actions that have to be performed if the operation is to be considered to meet the necessary safety levels. A similar Safety Argument is being prepared for RNAV Approaches. States intending to introduce RNAV procedures should use the Safety Argument as a basis of the relevant Safety Case to demonstrate that they have met the standards, and completed all the actions, before approving and publishing the procedures. A P-RNAV implementation methodology, based upon the
P-RNAV safety argument, is provided at Appendix C1. This methodology has been accepted by EUROCONTROL member States as a common basis for P-RNAV implementation.

4.4 Technical Requirements

4.4.1 The technical requirements for airspace and procedure design are laid down in ICAO PANS-OPS Doc 8168 [18], and are further explained and expanded in EUROCONTROL Document NAV.ET1.ST10 [23]. The technical requirements for P-RNAV approval are laid down in JAA TGL 10.[4]

4.5 Non-compliant and State Aircraft

4.5.1 Until such time as P-RNAV or RNP-RNAV is mandated, States that introduce such procedures must provide alternative procedures for non-compliant or State aircraft to arrive, approach and depart. If the majority of aircraft are compliant and are using the RNAV procedures, it is possible that non-compliant aircraft may experience some delays waiting for a non-RNAV slot to be come available.

4.6 Navigation Infrastructure

4.6.1 RNAV procedures cannot be introduced without an adequate Navigation Aid infrastructure to support normal operating procedures and also Contingency Procedures in the event of a navigation system failure. Such a failure may be limited to a single aircraft (e.g. on-board RNAV system failure) or may affect a number of aircraft (e.g. a GPS outage or the failure of one or more DME stations). A number of VOR/DME stations may need to be maintained to allow fall-back to conventional navigation in such events.

4.6.2 States wishing to implement DME based procedures can determine the coverage afforded by existing ground-based navigation aids using software tools such as the EUROCONTROL DEMETER software tool. In many cases it may be necessary to relocate existing DME stations and even install new stations in order to achieve adequate DME coverage.

4.6.3 States must also address the need for monitoring the performance of both the ground-based and space based systems. All P-RNAV systems should include processes for checking the validity of the received signals in order to identify, and where possible exclude, stations that are operating outside acceptable tolerances. States may consider that it is acceptable to rely upon the airborne systems to detect breakdowns in infrastructure coverage, backed up by radar monitoring and contingency support by the ATC. Where such monitoring and contingency support cannot be provided, direct monitoring of the total infrastructure may be necessary.

4.7 ATM Procedures

4.7.1 The introduction of RNAV SIDs, STARs and Approaches can often result in changes to airspace and ATM procedures. While necessary phraseology already exists in PANS-ATM, its application to RNAV procedures needs to be clearly documented to facilitate standard usage amongst all the controllers. This is detailed in Section 6 below.

4.7.2 EUROCONTROL is currently investigating the appropriate spacing standards for P-RNAV and will be making recommendations for changes to Annex 11. The use of 'direct to' clearances within the TMA should be addressed in ATC training and during any TMA design.

4.8 Business Case

4.8.1 States wishing to develop a business case to justify the introduction of RNAV procedures may find that many of the benefits are already being claimed by the operators through the inappropriate use of systems that, while clearly P-RNAV capable, are only approved for B-RNAV operations.
4.9 Implementation Schedule

4.9.1 Experience has shown that RNAV procedures should be introduced slowly over a period of time. The changes to ATM procedures and the need for widespread training militates against the adoption of a single regional changeover date. States should publish an implementation schedule to give carriers adequate warning and thereby allow them time to obtain the necessary approvals.

4.10 Design, Validation and Publication

4.10.1 Once an implementation schedule has been agreed, procedures should be designed in close co-operation with the affected Stakeholders, the local environmental committee and the aerodrome user committee. New designs must be independently validated to ensure that they meet the PANS-OPS criteria and then should be assessed for flyability using specialist software tools and flight simulators. All the procedures must then be flight checked to confirm the infrastructure coverage, the flyability and the obstacle assessment. Published RNAV procedures must be unambiguous and should contain clear statements about the path terminator codes required for each leg. After publication, the State should check the coding provided in the commercial databases to ensure that it accurately reflects the published procedure.

4.11 Publicity and Notification

4.11.1 The introduction of RNAV procedures has a significant impact on many participants in the aviation community. For this reason it is important to keep all the participants informed of the proposed changes. Early notification and close consultation with the different groups can do much to ensure a successful implementation.

4.11.2 While many of the EUROCONTROL Member States have already issued an AIC requiring P-RNAV approval for all aircraft using RNAV routes in terminal airspace; and a number of the major carriers are applying for, or have obtained, P-RNAV approval; it is still wise to give at least 18 months notice of the first introduction of any TMA RNAV procedures.

4.11.3 Environmental committees also need to understand that there are limits to the capabilities of P-RNAV aircraft and that overly complex routes can of themselves represent safety hazards. The new RNAV procedures can result in significant changes to ATC practices and airspace sectorisation and these need to be discussed early in the programme.

4.11.4 Finally, the AIS must ensure that the data integrity required for P-RNAV procedures and RNAV Approaches is achieved. Charts and AIPs must follow agreed standards, as laid down in ICAO Annex 4 and Annex 15, and guidance material such as ICAO PANS OPS (Doc 8168) [18] and EUROCONTROL NAV. ET1.ST10 [23]. Moreover, all published material must be thoroughly checked to ensure that it is error free.

5. AIRSPACE AND PROCEDURE DESIGN

5.1 Terminal Airspace

5.1.1 The introduction of RNAV provides the opportunity for ATS Providers to optimise route placement and, in turn, optimise airspace structures. As routes are no longer constrained to Navaid locations, they can be laid out to provide the most logical connections and more efficient traffic flows. In Terminal Airspace for example, the application of RNAV makes it possible to:

a) Use existing radar vectoring patterns as a basis for the design of RNAV SIDs and STARS which, in many cases results in reduced track mileage and reduced fuel burn;

b) Design instrument approaches procedures with little or no requirement for turn reversals;
c) Segregate RNAV SIDs and STARs and rationalise the number of Terminal Airspace entry/exit points;

d) Stagger or prevent the merging of STARs and/or increase the options for the divergence of SIDs;

e) Improve the placement of holding areas; and

f) Avoid areas sensitive to noise pollution;

5.2 Environmental Considerations

5.2.1 Whilst the increased flexibility and higher standard of track keeping accuracy associated with RNAV provide the potential for new routes and procedures to be introduced in the Terminal Area, the environmental impact of the introduction of any changes must be taken into account.

5.2.2 RNAV Procedures that allow aircraft to climb efficiently, facilitate direct routings, reduce holding times and allow more widespread use of continuous descent and/or low power/low drag approaches may well have positive environmental impacts. However, when considering the introduction of new RNAV procedures the following should be taken into consideration, always mindful of an individual State’s legislation and requirements:

a) Potential environmental impacts and possible mitigation must be considered from the earliest possible stage of planning, designing and revising procedures with the necessary consultation taking place.

b) After consultation changes should only be implemented where it is clear that an overall environmental benefit will accrue or where airspace management considerations and the overriding need for safety allow for no practical alternative.

c) Concentrate aircraft taking off along the least possible number of specified routes consistent with airspace management considerations and the overriding need for safety.

d) Noise Preferential Routes may pre-determine where any RNAV routes may go.

e) Local circumstances (terrain, inner city airports etc.) may make it impossible to concentrate traffic over less populated areas.

f) Recognise the long-term stability of the route structure in the vicinity of airports and preserve that route structure as far as possible. New routes should be planned to minimise flight populated areas.

g) Proposed changes may have a significant effect on the level and distribution of noise in the vicinity of an aerodrome. The consultation process should therefore include assessments of the effect on:

- The size and shape of the standard daytime noise contours
- Noise footprints of the noisiest aircraft operating there at night.

based on the existing and forecast traffic levels. The forecast levels should include any possible growth in traffic as a consequence of the proposed changes and/or any growth that has already been planned.
h) Proposals for changes to procedures should include careful consideration of the impact on areas beneath the new tracks as they may contain a legacy of noise sensitive developments.

i) In addition to noise, similar consideration should be given to the control of pollution and the maintenance of air quality in the vicinity of airports, in particular those in or near built up areas.

j) Departure procedures should be designed to enable aircraft to climb efficiently and not be inhibited by conflicts with other traffic, including holding patterns, taking into account the overriding need for safety.

k) Consideration should be taken of the fact that, while environmental benefits can often be clearly demonstrated and are generally welcomed by the community, there is a danger that, once it becomes apparent that the noise contours have been reduced, new buildings may encroach on the airport thereby reducing future flexibility.

l) If RNAV procedures are to be flown accurately they must be designed to take account of the performance characteristics of the user aircraft population.

m) Negative environmental impacts may be justified, according to the policy of individual states, when all sustainable development objectives are taken into account.

5.3 RNAV Procedure Design

5.3.1 The actual design of the route/procedure is enabled by criteria that are detailed in ICAO Doc 8168 Vol. II PANS-OPS [18]. In general, RNAV routes and procedures are designed according to the following principles:

a) The natural flows of traffic, as determined by demand, existing radar vectoring patterns and connection points to the en-route ATS route network are identified first as well as the runways to be serviced.

b) The intended purpose of the new procedure together with the operators and aircraft types expected to use the procedure are identified. Procedures should be developed to support all users but there may often be merit in developing particular routes for regional aircraft or aircraft of a specific performance capability.

c) Different factors can influence the final design:

i) Available Navaid coverage: DME based procedures require continuous coverage from at least two DME stations with a subtended angle of between 30 and 150 degrees. Availability requirements may mean that coverage from a minimum of three DMEs is necessary. GNSS coverage may be affected at lower altitudes through terrain masking (mainly in mountain valleys) or local electromagnetic interference.

ii) Environmental impact: If P-RNAV or better is being used, the accuracy and repeatability of RNAV track-keeping is often so much better than conventional navigation that it is possible to ensure that, wherever feasible, the planned route does not pass over residential areas at low levels.

iii) Terrain and Airspace Reservations.
5.3.2 The procedure is then designed formally using the PANS-OPS criteria and a detailed obstacle assessment is carried out. ARINC 424 Path Terminator coding requirements are defined at this stage.

5.3.3 Once the design process is complete, the procedure must be evaluated and validated using appropriate software tools, simulators and flight checks.

5.3.4 Finally the procedure should be published, using standard symbols and terminology, and including details of any speed or altitude constraints as well as the path terminators used in the procedure.

5.4 Waypoint Naming

Note: The following material was presented to the Thirteenth Meeting of the ICAO Obstacle Clearance Panel (ICAO OCP/13 (28 October – 8 November 2002)) in the form of a proposed amendment to ICAO Doc 8168 Vol. II PANS-OPS [18]. It is still (September 2003) under discussion.

5.4.1 All RNAV waypoints must have an identifier. A globally unique 5 Letter name code should be provided for all waypoints which are determined by the ATSP as requiring globally unique identifiers. This will include waypoints in the en-route structure, waypoints used common to more than one TMA or more than one airport in a single TMA, waypoints used as activation points for ATSP computer software and any other waypoints required by the ATSP. All other waypoints involved in terminal RNAV procedures, including, where necessary, optional waypoints to allow path stretching or reduction (Tactical Waypoints) may be designated by a combination of alphabetic and numeric data (alphanumerics).

5.4.2 The naming rules set out in the following table should be applied:

<table>
<thead>
<tr>
<th>Rule</th>
<th>Area of Application</th>
<th>General Usage</th>
<th>Name Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>En-route waypoints</td>
<td>En-route environment</td>
<td>5 letter globally unique pronounceable ICAO Namecode</td>
</tr>
<tr>
<td>2</td>
<td>Final waypoint SID</td>
<td>TMA procedures and transition to en-route</td>
<td>5 letter globally unique pronounceable ICAO Namecode</td>
</tr>
<tr>
<td>3</td>
<td>Initial waypoint STAR</td>
<td>TMA procedures and transition from en-route</td>
<td>5 letter globally unique pronounceable ICAO Namecode</td>
</tr>
<tr>
<td>4</td>
<td>Waypoints common to more than one TMA or used in a procedure common to more than one airport in a single TMA which are not used for en-route</td>
<td>TMA procedures</td>
<td>5 letter globally unique pronounceable ICAO Namecode</td>
</tr>
<tr>
<td>5</td>
<td>Waypoints unique to an aerodrome, without a properly assigned 4 letter location indicator (ICAO Doc 7910), used for TMA procedures.</td>
<td>TMA procedures</td>
<td>5 letter globally unique pronounceable ICAO Namecode</td>
</tr>
<tr>
<td>6</td>
<td>Tactical TMA Waypoints</td>
<td>TMA procedures</td>
<td>5 Alphanumeric Namecode specific to the TMA.</td>
</tr>
<tr>
<td>Rule</td>
<td>Area of Application</td>
<td>General Usage</td>
<td>Name Type</td>
</tr>
<tr>
<td>------</td>
<td>---------------------</td>
<td>---------------</td>
<td>-----------</td>
</tr>
</tbody>
</table>
| 7    | Strategic TMA Waypoints  
Waypoints unique to an aerodrome, used for TMA procedures, and designated by the ATS provider as requiring prominent display or as having the function of an activation point. 
Based upon ATC preferences, these are usually waypoints that are very regularly used in ATC communication. | TMA procedures | 5 letter globally unique pronounceable ICAO Namecode |
| 8    | Waypoints unique to an aerodrome, where Rule 6 cannot be applied due to the non-availability of a particular block, or blocks, of numbers, used for TMA procedures. 
This should be restricted to domestic aerodromes or aerodromes with a low traffic density. | TMA procedures | 5 letter globally unique pronounceable ICAO Namecode |

5.4.3 The following criteria should be applied to when alphanumeric name-codes are to be used:

a) The alphanumeric namecode convention that is adopted should be applicable to all airports within the State.

b) The alphanumeric namecode should consist of no more than 3 numbers with the alphabetic characters being taken from the airport designator.

c) The convention and the rules of application should be published in the States AIP.

d) As global uniqueness cannot be assured without centralised data management, consideration should be given to providing a centralised database to enable blocks of numbers to be allocated to specific aerodromes.

e) Consideration should be given to restricting the number allocation to numbers between 361 and 999 and to avoid numbers ending in 5 or 0 in order to avoid any potential misunderstanding in ATC to pilot communication.

f) As global uniqueness cannot be assured for waypoints containing alphanumericics, to avoid any potential mis-selection of following ATC re-routing, ATC should not use waypoints identified by alphanumericics in any re-routing from the en-route structure into a terminal procedure.

g) Until such time as alphanumeric namecodes are approved by ICAO for use in RTF transmissions, States should validate the concept prior to implementation.
6. ATM RNAV PROCEDURES

6.1 Introduction

6.1.1 ICAO Provisions related to the application of B-RNAV are published in the ICAO Doc 7030 [19]. ATC Procedures for P-RNAV, are, at the time of printing, the subject of the ICAO approval process and will be included in a subsequent edition of this document.

6.1.2 The categories of ATM procedures which are expected to be published by ICAO are:

   a) Flight Planning provisions for P-RNAV;
   b) Additional RTF phraseology related to RNAV;
   c) Amplified contingency procedures for RNAV; and
   d) Co-ordination phraseology specific to RNAV.

6.2 Flight Planning

ICAO FPL Item 10 (a), RNAV Equipment Information

6.2.1 The implementation of RNAV for en-route applications requires the mandatory carriage of B-RNAV for IFR operations. However, inasmuch as the ECAC-agreed concept for the RNAV implementation will allow for three types of terminal area procedures, with respect to the minimum airborne NAV equipment fit required, namely:

   • P-RNAV,
   • B-RNAV, or
   • Non-RNAV.

6.2.2 It is a fundamental requirement for ATC to be able to distinguish, systematically, between the various levels of RNAV equipment fit, such that the assignment of SIDs/STARs can be accomplished in a systematic, efficient and unambiguous manner, without the creation of undue additional controller workload.

6.2.3 The FPL is therefore seen as the means whereby this fundamental requirement must be supported. The automated processing of the FPL Item 10 information will be fundamental to enabling the systematic display, to all relevant ATC control positions, of the individual aircraft RNAV level of equipage.

6.2.4 Flight Planning provisions, in respect of ECAC RNAV equipment carriage requirements, were developed with the following considerations:

   a) Consistency with the ICAO RNP concept.

   b) Consistency with the conclusions reached by ICAO in respect of filing of information with respect to B-RNAV, namely:

      • that B-RNAV equipment shall form part of the standard equipment fit and shall therefore be indicated through the use of the Letter S in item 10,
      • the requirement for the Letter R to also be inserted in Item 10, in conjunction with the letter S, filed in respect of B-RNAV,
6.2.5 As a means of enabling the ability of local FDPSs to properly identify and display to ATC the level of RNAV equipment of aircraft intending to operate in a future ECAC RNAV environment, appropriate instructions to operators, with respect to the filing of Item 10 RNAV information Letters S and R for B-RNAV, as well as the filing of a dedicated Letter/Designator for P-RNAV equipage, is necessary.

6.2.6 The following provisions for the filing of RNAV equipment information for flights operating within ECAC, are applicable:

<table>
<thead>
<tr>
<th>Item 10</th>
<th>Item 18</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aircraft not equipped with RNAV (State a/c)</td>
<td>--</td>
</tr>
<tr>
<td>Aircraft equipped with B-RNAV</td>
<td>SR</td>
</tr>
<tr>
<td>Aircraft equipped with P-RNAV</td>
<td>SR *</td>
</tr>
</tbody>
</table>

Note: At the time of writing (September 2003), a proposal for the amendment of ICAO Doc. 7030/4 EUR Regional Supplementary Procedures [19], on the subject of P-RNAV, was under consideration by ICAO. The proposal included a provision for the use of the letter P in the FPL Item 10(a) to indicate State Approval for P-RNAV operations. It will be necessary to consult the current documentation to establish the validity of this proposal. If so approved, the entry in FPL Item 10(a) to indicate a State Approval for P-RNAV operations will be the letters SRP.

6.3 RNAV Phraseology

6.3.1 The RTF phraseology for use by State aircraft, not equipped with RNAV, should be understood in the context of the mandatory nature of the B-RNAV equipment. As such, State aircraft, not equipped for B-RNAV operations, but having a navigation accuracy meeting RNP5, do require special handling by ATC, and therefore all include the following phrase whenever initial contact on an ATC frequency is established:

(aircraft callsign) **NEGATIVE-RNAV**

6.3.2 The RTF, associated with a failure or degradation of an aircraft's (civil or military) B-RNAV system, detected before or after departure, is as follows:

(aircraft callsign) **UNABLE RNAV DUE EQUIPMENT**
6.3.3 Given the mixed mode of RNAV operations which exists, a set of RTF phraseologies has been formulated which would enable the resolution of inconsistencies between:

- a terminal area procedure, assigned by ATC, and
- the actual aircraft's type of RNAV certification, which could preclude the pilot from accepting the assigned procedure.

6.3.4 Given the safety-related issues, associated with the avoidance of terrain, for aircraft operating on terminal area procedures for which the corresponding and appropriate aircraft certification does not exist, the harmonisation of RTF related to the mitigation of such risk within ECAC, was the basis for the formulation of the following RTF Phraseology.

6.3.5 If a RNAV arrival or departure procedure, which has been assigned cannot be accepted by the pilot, for reasons of either the RNAV equipment or circumstances associated with its operational use, the pilot shall inform ATC immediately by use of the phrase:

**UNABLE (designator) DEPARTURE [or ARRIVAL] DUE RNAV TYPE**

6.3.6 If for any other reason, the pilot is unable to comply with an assigned terminal area procedure, the pilot shall inform ATC immediately by use of the phrase:

**UNABLE (designator) DEPARTURE [or ARRIVAL] (reasons)**

6.3.7 If ATC is unable to assign a RNAV arrival or departure procedure requested by a pilot, for reasons associated with the type of on-board RNAV equipment indicated in the FPL/CPL, ATC shall inform the pilot by use of the phrase:

**UNABLE TO ISSUE (designator) DEPARTURE [or ARRIVAL] DUE RNAV TYPE**

6.3.8 If for any other reason, ATC is unable to assign an arrival or departure procedure requested by the pilot, ATC shall inform the pilot by use of the phrase:

**UNABLE TO ISSUE (designator) DEPARTURE [or ARRIVAL] (reasons)**

6.3.9 As a means for ATC to confirm the ability of a pilot to accept a specific RNAV arrival or departure procedure, ATC shall use the phrase:

**ADVISE IF ABLE (designator) DEPARTURE [or ARRIVAL]**

6.4 ATC Contingency Procedures.

6.4.1 The operators of aircraft where a failure or degradation of the B-RNAV system is detected before departure shall not insert the designators "S" or "R" in Item 10 of the flight plan. Since such flights require special handling by ATC, Item 18 of the flight plan shall contain STS/RNAVINOP. Subsequently, for a flight for which a flight plan has been submitted, an appropriate new flight plan shall be submitted and the old flight plan cancelled. For a flight operating based on a repetitive flight plan (RPL), the RPL shall be cancelled, and an appropriate new flight plan shall be submitted.

6.4.2 In respect of a contingency related to the degradation of an aircraft's P-RNAV system, to a level of B-RNAV, prior to departure, the provisions of B-RNAV apply. For this specific category of RNAV system degradation (i.e. where the RNAV system is still able to meet the requirements of B-RNAV), the FPL shall include the letters “S” and “R” indicating compliance with B-RNAV requirements. In this respect, such degradation, prior to departure, need not be seen as a contingency event, since P-RNAV is not mandatory.
6.4.3 The operators of aircraft where a failure or degradation, resulting in the aircraft being unable to meet of P-RNAV as well as the functionality and RNP 5 accuracy requirements of B-RNAV, is detected before departure, shall not insert the designators "S", "R" in Item 10 of the FPL. Subsequently, for a flight for which a flight plan has been submitted, an appropriate new flight plan shall be submitted and the old flight plan cancelled. For a flight operating based on a repetitive flight plan (RPL), the RPL shall be cancelled, and an appropriate new flight plan shall be submitted.

6.4.4 Finally, with respect to the specific category of failures or degradations of P-RNAV systems, in flight, to levels of performance consistent with B-RNAV requirements, the following considerations are relevant:

- An increase in the complexity of ATC training and awareness issues, associated with an RNAV TMA environment which could already be characterised by a complex mix of RNAV equipment, under even normal circumstances,
- P-RNAV failures representing total RNAV failures (i.e.: these are identical to the existing situation with respect to a B-RNAV failure), and
- the very infrequent rate of occurrence of those particular instances of P-RNAV degradations to B-RNAV performance levels.

6.4.5 No particular or distinct contingency procedures, dedicated specifically to P-RNAV degradations to B-RNAV performance levels while in-flight, exist or are deemed necessary. That is to say that, a P-RNAV system degradation, occurring whilst operating on a RNAV TMA procedure requiring P-RNAV, would equate, in an operational sense, to a complete RNAV system failure, for which existing RNAV contingency procedures would apply.

6.4.6 The operational impact of considering a P-RNAV system that degrades in flight to B-RNAV, as a RNAV failure, is of some significance for a limited sub-set of such occurrences, represented by aircraft operating on P-RNAV standard instrument departures (SIDs). In such cases, a P-RNAV equipped aircraft, whose RNAV system were to degrade to B-RNAV performance levels, would be declared as being a non-RNAV contingency, with the result that it could not be assigned to an ATS route requiring the use of B-RNAV.

6.4.7 Given the very limited number of such situations that can be expected to occur, the advantages associated with minimising both the ATC and pilot workload in the event of this type of RNAV contingency, far outweigh the disadvantages of not being able to assign a B-RNAV route. Furthermore, if a P-RNAV system did degrade to the level of B-RNAV, it could also be susceptible to further degradation(s) as the flight progresses.

6.4.8 The RNAV contingency procedures related to the carriage and operation of B-RNAV equipment, is equally applied to the failure and degradations, in flight, of P-RNAV systems. The following provisions refer:

"When an aircraft cannot meet the requirements for either P-RNAV or B-RNAV, as required by the RNAV ATS route or procedure, as a result of a failure or degradation of the RNAV system, a revised clearance shall be requested by the pilot."

6.4.9 In summary, for RNAV contingencies occurring in flight:

i) Aircraft, certified for B-RNAV, operating on the enroute ATS route network will comply with the contingency procedures associated with the use of B-RNAV,

ii) Aircraft, certified for P-RNAV, operating on the enroute ATS route network will comply with the existing contingency procedures associated with the use of B-RNAV,
iii) Aircraft, certified for B-RNAV, operating on terminal area procedures requiring the use of B-RNAV systems will comply with the existing contingency procedures associated with the use of B-RNAV,

iv) Aircraft, certified for P-RNAV, operating on terminal area procedures requiring the use of B-RNAV systems will comply with the existing contingency procedures associated with the use of B-RNAV,

v) Aircraft, certified for P-RNAV, operating on terminal area procedures requiring the use of P-RNAV would comply with the provisions as described for the use of B-RNAV.

6.5 Contingency RTF Phraseology

6.5.1 The RNAV contingency RTF Phraseology is as follows:

**UNABLE RNAV DUE EQUIPMENT**

6.6 ATC Actions

6.6.1 With respect to the degradation/failure in flight of a B-RNAV system, while the aircraft is operating on an ATS route requiring the use of B-RNAV, the following ATC actions apply:

a) aircraft should be routed via VOR/DME defined ATS routes; or

b) if no such routes are available, aircraft should be routed via conventional navigation aids, i.e. VOR/DME; or

c) when the above procedures are not feasible, the ATC unit should, where practicable, provide the aircraft with radar vectors until the aircraft is capable of resuming its own navigation.

*Note: Aircraft routed in accordance with a) or b) may, where practicable, require continuous radar monitoring by the ATC unit concerned.*

6.6.2 With respect to the degradation/failure in flight of an RNAV system, while the aircraft is operating on a terminal area procedure requiring the use of RNAV, the following applies:

a) The aircraft should be provided with radar vectors, until the aircraft is capable of resuming its own navigation; or

b) The aircraft should be routed by conventional navigation aids, i.e.: VOR/DME.

6.6.3 The use of radar vectors is considered as a means best suited to resolve such issues in a tactical TMA environment.

6.7 Terrain Clearance

6.7.1 The use of RNAV does not affect existing ICAO provisions describing responsibilities with respect to avoidance of terrain. Specifically, unless an IFR aircraft is receiving navigation guidance in the form of radar vectors from ATC, the pilot remains responsible for avoidance of terrain.

*Note: Consistent with such responsibilities, pilots executing ATC instructions to proceed "direct to waypoints", are responsible for avoidance of terrain. ATC level clearances, associated with such direct-to instructions, shall be in accordance with established minimum flight altitudes.*
6.8 Direct-to-instructions

6.8.1 Pilots operating in accordance with an ATC instruction to proceed "DIRECT (significant point)", where such significant point is an element of a terminal area procedure, which the aircraft has been cleared to follow, shall comply with both speed restrictions and, only to the extent the cleared level makes possible, level restrictions published at such significant point, unless such restrictions are explicitly cancelled by ATC.

6.8.2 Such an instruction by ATC to proceed “DIRECT (significant point)” does not represent the specification of a change to the aircraft’s previously specified clearance limit. As a consequence, an aircraft having been cleared to “PROCEED DIRECT (significant point), where such significant point is an integral element of a terminal area procedure, shall continue with the terminal area procedure, after reaching the significant point.

6.8.3 Additionally, an aircraft cleared to “PROCEED DIRECT (significant point)”, where the significant point is not an integral element of a terminal area procedure, must be provided with additional instructions from ATC as to the route of flight to be flown after reaching such significant point.

6.9 Vertical Profile/Level Clearance

Relationship of Terminal Area Procedure Assignment to Vertical and Lateral Navigation of Aircraft.

6.9.1 With respect to aircraft navigation, Terminal Area Procedures can be of the following categories, each category being associated with an explicit statement of the specific authorisation which the Terminal Area Procedure represents, with respect to lateral and vertical navigation:

   a) Terminal area procedure does not contain a published level in the form of "CLIMB TO (level)" or "DESCEND TO (level)", and does not include published level restrictions at significant points within the terminal area procedure.

      Clearance to follow such a terminal area procedure represents authorisation with respect to lateral navigation only. Authorisation with respect to vertical navigation will be, or will have been, issued by ATC, in the form of explicit level clearances.

   b) Terminal area procedure does not contain a published level, in the form of "CLIMB TO (level)" or "DESCEND TO (level)", but does contain published level restrictions at significant points within the terminal area procedure.

      Clearance to follow such a terminal area procedure represents authorisation with respect to lateral navigation only. Authorisation with respect to vertical navigation will be, or will have been, issued by ATC, in the form of explicit level clearances. Level restrictions published as integral elements of the terminal area procedure, shall be complied with only to the extent the cleared level makes possible.

   c) Terminal area procedure does contain a published level, in the form of "CLIMB TO (level)" or "DESCEND TO (level)", and does not contain published level restrictions at significant points within the terminal area procedure.

      Clearance to follow such a terminal area procedure represents authorisation with respect to lateral and vertical navigation. Explicit level clearances subsequently issued by ATC shall override the published level.
d) Terminal area procedure does contain a published level, in the form of "CLIMB TO (level)" or "DESCEND TO (level)", and does contain published level restrictions at significant points within the terminal area procedure.

Clearance to follow such a terminal area procedure represents authorisation with respect to lateral and vertical navigation. Explicit level clearances subsequently issued by ATC shall override the published level. Level restrictions published as integral elements of the terminal area procedure, shall be complied with only to the extent the cleared level makes possible.

7. NAVIGATION INFRASTRUCTURE

7.1 State Responsibilities

General

7.1.1 The high level statement which addresses the responsibilities of the State with regard to provision of navigation facilities is set out in ICAO Document 7300/8 – Convention on International Civil Aviation (Eighth Edition - 2000), Article 28 [20]:

“Each Contracting State undertakes, in so far as it may be practicable, to: Provide, in its territory, airports, radio services, meteorological services and other navigation facilities to facilitate international air navigation, in accordance with the standards and practices recommended or established from time to time, pursuant to the Convention.”

This statement is amplified in Chapters 2 and 3 of ICAO Annex 10 (Volume 1) – Radio Navigation Aids [21], which describe the General Provisions and Specifications for Radio Navigation Aids.

Provision of Navigation Infrastructure.

7.1.2 The term “Navigation Infrastructure” has been defined by the ICAO Obstacle Clearance Panel (OCP) as the “Ground and/or Space-borne equipment available for use within a designated airspace, together with the airborne equipment that is required to be carried within that airspace”. As shown in Sub-Paragraph 7.1.1 above, the responsibility for the provision and/or availability of the navigation facilities that constitute the ground and/or space-borne element of the navigation infrastructure rests with the relevant State Authority. The carriage of the appropriate airborne equipment is the responsibility of the aircraft operator. However, whilst the airborne equipment required for operations in a particular airspace is specified in the appropriate JAA TGL, little guidance is currently available to States to assist in the provision of adequate facilities to support RNAV operations.

7.1.3 One of the features of the introduction of B-RNAV in the airspace of the ECAC Member States in 1998 was that it would make minimal impact on the provision of navigation facilities by States. The initial development of B-RNAV was based on the prerequisite that the existing conventional VOR/DME navigation infrastructure would be adequate. This will not be the case as the progression towards a P-RNAV, RNP1-RNAV environment, as envisaged in the Navigation Strategy [14] and the Transition Plan for ECAC [15], takes place.

7.1.4 During this evolutionary process, and during the transition to GNSS, it is expected that the ECAC ground navigation infrastructure will rely on Dual DME/DME coverage. The adequacy of the coverage of the DME/DME infrastructure can be assessed using a software tool such as the EUROCONTROL DEMETER programme that incorporates a terrain database. The programme can also be used to identify key DME facilities and to assist in the determination of the optimum location of additional facilities.
7.1.5  Whilst It is expected that some rationalisation/withdrawal of ground navigation aids will be possible during the transition to GNSS, it will remain necessary for States to continue to provide the supporting navigation infrastructure for each phase of flight. The ECAC Transition Plan [15]. anticipates that “the rate of technological development of the system [GNSS] and the time needed for the resolution of institutional limitations will result in the need for a ground based back-up system for GNSS for the foreseeable future.

**Rationalisation of Navigation Aids**

7.1.6  The following material relating to the planning considerations for the rationalisation of the navigation aids, has been taken from the ECAC Navigation Strategy [14] and the Transition Plan for ECAC [15].

7.1.7  The Navigation Strategy [14] aims to increase the cost efficiency of flight operations through a judicious deployment and use of supporting infrastructure for all phases of flight. However any reduction in the ground-based navigation infrastructure through decommissioning plans and/or its replacement with new technology has implications in aircraft systems, which need to be assessed with priority. Today aircraft operating in European airspace are equipped with a large variation of system mixes, with different levels of capabilities, and different, even contradictory, operational interests.

7.1.8  Furthermore, frequency spectrum availability becomes a significant limiting factor. Frequency allocation cannot be achieved by a simple transfer and, in addition, several systems (DME, VOR, ILS, MLS, GNSS with all its augmentations) need to be supported at the same time.

7.1.9  During the rationalisation phase the decision to withdraw, relocate or add a particular facility will be the responsibility of the Provider State and/or Airport Authority in consultation with Users and Military Authorities. The factors which will need to be addressed, should include:

- A review of the operational impact of the planned change with respect to the ability to meet the existing requirements and the availability of, and coverage provided by, other existing navigation systems (VOR, VOR/DME, DME, DME/DME, or GNSS);

- Cost/Benefit Assessment in terms of the cost savings (maintenance and refurbishing) resulting from the withdrawal of a facility, or the enhanced operational effectiveness of relocated or additional facilities, against the possible costs to Users (e.g. additional aircraft equipment, increased User Charges).

7.1.10 The following general trends are foreseen in the rationalisation of ground navigation aids:

**NDBs.**

There will be a rationalisation of NDB facilities in the period up to 2005, with complete withdrawal from service expected by 2010.

**VORs.**

Some withdrawal of VORs may take place in the period 2005 – 2010, but it is considered unlikely to be completed before 2015.

**DMEs.**

It is not anticipated that any DMEs will be withdrawn before 2015. However some facilities may have to be re-sited, or additional ones introduced, to support:
a) The rationalisation of NDBs/VORs;

b) The use of B-RNAV at all Flight Levels, and

c) The extended use of P-RNAV and/or RNP 1 RNAV.

**Satellite Navigation Systems.**

7.1.11 The Navigation Strategy [14] incorporated the emergence of satellite technology and its future role in the global navigation environment. However, it was expected (based on then current knowledge) that the rate of technological development of the system, and the time needed for the resolution of institutional limitations, would result in the need for a ground-based back-up navigation aid for GNSS, for the foreseeable future, for all phases of flight.

7.1.12 Currently GNSS is approved, in conjunction with the ground based navigation infrastructure, to support B RNAV operations in European Airspace in accordance with the requirements set out in JAA ACJ20X4 -TGL No.2 [3]. Furthermore, Airworthiness and Operational Approval Material for GPS to support P-RNAV Operations is published in TGL No 10 [4]. The JAA has also published ACJ20X5 (previously TGL No.3 Rev 1) which provides general guidance for the use of GPS in various flight phases. This leaflet should not be used independently but rather in conjunction with specific guidance material produced for each phase of flight.

7.1.13 The Satellite Based Augmentation System (SBAS) EGNOS (European Geo-stationary Navigation Overlay System) is expected, subject to the provision of the appropriate EUROCAE MASPS and MOPS, ICAO SARPS and JAA Documentation, to be operational around 2004. EGNOS will eventually meet the navigation performance requirements for all phases of flight down to Approach with Vertical Guidance II (APV-II) or possibly CAT I.

7.1.14 Ground Based Augmentation Systems (GBAS), subject to similar provisions as detailed above, are likely to be available to support Category I operations around 2004, with Category II and III capability in the 2008 timeframe.

**Provision and Publication of Navigation Data**

7.1.15 RNAV procedures that are published in the State AIPs are subsequently extracted and coded into databases by commercial navigation database providers. These companies supply the data to the avionics manufacturers who repack it for use in the respective RNAV systems. At each stage in the data chain there are opportunities for data to be altered through corruption or, more often, as the result of deliberate or inadvertent human inputs.

7.1.16 The RTCA and EUROCAE have produced a common document 'Standards for Processing Aeronautical Data' (DO-200A/ED 76) [8] which provides a recommended minimum standard for the processing of aeronautical data. The JAA have recognised this standard in TGL 9 and is considering draft guidance material covering the application of JAR 21 Subpart G with respect to production and release of navigation databases. They are also expected to issue additional guidance to assist the companies to obtain production approval.

7.1.17 The application of such standards will not necessarily of itself guarantee the integrity of the data. EUROCONTROL is developing a standard for data origination and publication which should be available in late 2003. It is intended that States will have some assurance that the data integrity is maintained, from the point of origination until publication, if this standard is applied. The standard will detail the quality management process that is required. It will provide clear guidance to data originators, such as surveyors and procedure designers, on requirements for training, data sources, verification, validation, publication and qualification of software tools; and finally, it will specify applicable publication and data distribution standards. A specification for a software tool to support the data validation and transfer will also be
published and the introduction into service of the **European AIS Database (EAD)** will be anticipated. This data origination standard is expected to apply to all organisations involved in the generation and publication of aeronautical data in the State AIP, including surveyors, procedure designers, airspace designers, ANSPs and ATSPs.

7.1.18 In the meantime, States should publish supplementary information in the form of radials/bearings and DME distances associated with selected RNAV waypoints to enable the flight crew to verify the RNAV performance during the procedure. Furthermore, Carriers and avionics manufacturers (or a nominated third party) should carry out end-user checks to ensure that the only changes in the database at each AIRAC update are those that were intended by the AIS.

**Common Geodetic Reference System (WGS 84)**

7.1.19 Historically almost all countries used to base their national Maps/Charts on a reference frame with a specific set of datum parameters that provided accurate position data over the area of interest. This resulted in the situation where, when close to a border between two countries with different reference frames, an aircraft could be seen by the Radar installations in the two countries as having different positions. The size of the discrepancies in the two positions ranged from metres to kilometres. From a navigation perspective, for as long as the primary means of continental en-route navigation was based on the use VOR/DME, these differences did not have any significant effect since the aircraft followed the radial tracks to or from the beacon, regardless of the published co-ordinates.

7.1.20 This situation began to change with the introduction of INS, for unlike the national ground-derived co-ordinates, INS derived co-ordinates are Earth-centred. This is due to the fact that INS uses accelerometers on a gyro or laser ring stabilised platform to sense movement and determine aircraft position. The alignment of the platform relates to the Earth's centre of mass and rotation resulting in INS-generated co-ordinates that are referenced to the Earth's centre. Consequently the published co-ordinates as referenced to a local geodetic datum will not compare, directly, with INS-generated co-ordinates. However because of the initial alignment of INS with local co-ordinates before take-off, the system is most accurate within the area defined by the local datum. To-date, international “Inter-Datum” long distance flights, have not been affected by the "co-ordinate shift" which is small when compared with the hourly drift of the INS.

7.1.21 Similarly the co-ordinates derived by the aircraft Global Navigation Satellite System (GNSS), from signals received from satellites, are also Earth-centred because the GNSS satellites operate with an Earth-centred reference model, WGS 84. The value of the high accuracy of the GNSS co-ordinates is considerably degraded when compared with ground position co-ordinates based on a local geodetic datum.

7.1.22 When operating in a B-RNAV en-route environment, these differences are not significant. However in the approach and landing phases of flight, or where reduced aircraft lateral separation is implemented, i.e. in the future P-RNAV or RNP-RNAV environment with high accuracy and integrity requirements, these discrepancies cannot be tolerated and demand the introduction of a common geodetic reference system.

7.1.23 This problem was identified in the early 1980s and in March 1989, the Council of the International Civil Aviation Organisation (ICAO) accepted the following Recommendation from its Special Committee on Future Air Navigation Systems (FANS/4):

"**RECOMMENDATION 3.2/1 - ADOPTION OF WGS 84**

That ICAO adopt, as a standard, the geodetic reference system WGS 84 and develop appropriate ICAO material, particularly in respect of Annexes 4 and 15, in order to ensure a rapid and comprehensive implementation of the WGS 84 geodetic system.”
7.1.24 The introduction of WGS 84 in the ECAC area was undertaken by the EUROCONTROL Agency and was successfully implemented on 1 January 1998.

Note: WGS84 implementation has been formally completed for the horizontal component only. The implementation of the vertical component was required only at specified locations. The requirements for the vertical component for future operations are under investigation within EUROCONTROL.

8. AIRCRAFT NAVIGATION SYSTEMS

8.1 General

8.1.1 Sub-paragraph 2.2 provides a summary of the performance requirements of aircraft navigation equipment for B-RNAV and P-RNAV Operations. This section provides a brief description of the Navigation Systems/Aids that provide inputs of navigation data to the RNAV equipment.

8.1.2 There are many different types of RNAV equipment currently available, covering a wide range of capability and sophistication. At the bottom end of the scale are the simple RNAV computer systems that can only accept VOR/DME inputs and the GPS stand-alone TSOc129a [6] receiver. Such equipment, if installed and operated in accordance with approved procedures, will be capable of meeting at least the Basic level of RNAV accuracy envisaged for standard continental airspace. Then there are the more complex types of RNAV equipment using inputs such as INS or Loran-C, which are approved for operations in the North Atlantic Minimum Navigation Performance Specification (NAT MNPS) airspace. INS systems may also be considered for approval for use for B-RNAV Operations in European continental airspace provided that special operating procedures or additional navigation fixes are applied to ensure that the required navigational accuracy is maintained. At the top end of the scale there is an increasing number of aircraft fitted with advanced RNP-RNAV systems meeting the requirements of ED 75A. [7]. and the RNAV facility incorporated in Flight Management Systems (FMS) (see Paragraph 8.2).

8.1.3 RNAV systems can accept inputs from a variety of navigation aids. These include:

- Short-range coverage systems such as VOR/DME and DME/DME
- coverage systems such as Loran-C (Not acceptable for EUR B-RNAV operations).
- Self contained systems such as Inertial Navigation Systems (INS) and Inertial Reference Systems (IRS).
- World-wide coverage systems such as Global Navigation Satellite Systems

This Chapter provides an explanation of the requirements, characteristics and limitations of the various RNAV Systems that may be approved for use in an RNAV environment.

8.2 Flight Management Systems (FMS)

8.2.1 Most of the current generation of Public Transport Aircraft are equipped with a Flight Management System (FMS). An FMS is an integrated system that provides for the management of both the Aircraft Performance and the Navigation functions.

8.2.2 The Aircraft Performance capability makes it possible to obtain the optimum efficiency and economy in the operation of the aircraft, whilst the navigation function in most FMS equipment meets the requirements of B-RNAV and is expected to satisfy the more demanding requirements of P-RNAV operations and even RNP-RNAV operations. This document is only concerned with the navigation function of FMS equipment.
8.3 RNAV System Requirements

8.3.1 In addition to the navigation functions that are required by aircraft operators, there are additional functions that are required by ATS Providers to enable them to be able to fully exploit the capabilities of RNAV equipment. Different levels of functionality, integrity, availability and continuity are required for B-RNAV, P-RNAV, RNP-RNAV and RNAV Approaches. The requirements for B-RNAV and P-RNAV were developed in conjunction with the Joint Aviation Authorities (JAA) and include specifications regarding navigation accuracy, displays, data bases, route planning and updating, navigation aid solution, tracking functions, holding, automatic outputs, flight crew alerts and system monitoring. They are published in the JAA ACJ20X4 [3], for B-RNAV, and in TGL 10 [4], for P-RNAV, and are summarised in Paragraph 2.2. A TGL for RNAV Approaches is currently being drafted and it is expected that it will be published by the end of 2003.

8.4 Characteristics of RNAV Systems

VOR/DME

8.4.1 Within this category there is a considerable variation in capability. Possibly the least complex of this type of equipment - all of which must be capable of meeting the Basic RNAV level of track keeping accuracy - are systems using a VOR/DME station moving facility. In effect this type of RNAV system electronically offsets a selected VOR/DME facility (by a range and bearing calculated and set by the operator) to the position of the next waypoint and the aircraft is then provided with apparent VOR steering guidance to that waypoint. The equipment is of course still subject to the designated operational coverage and reception limitations of the selected facility which must be at a range of 93 km (50NM) or less from the aircraft in order to meet the specified level of performance accuracy. Other types of systems with automatic position update are less constrained but, in general, systems that have multiple navigation inputs do not use the VOR/DME input unless it is required by a procedure or it is the only Navaid available.

DME/DME

8.4.2 One of the most accurate, currently available, means of updating RNAV and Flight Management Systems (FMS) equipment, within European continental airspace, is by reference to multiple DMEs, with a minimum of two suitably positioned facilities being needed to provide a position fix. The quality of the positional information will be dependent on the relative geometry of the DMEs and their range from the aircraft, and therefore the system will have a fall-back routine whereby other combinations of aids, e.g. VOR/DME, may be utilised. An accuracy equal to or better than 0.93 km (0.5NM) (one SD) is expected for en-route operations where adequate DME/DME coverage is available.

LORAN C

8.4.3 Loran-C is a radio navigation system, which uses synchronised time signals from ground transmitting stations spaced several hundred miles apart. The stations are configured in chains of three to five stations that transmit with the same group repetition interval (GRI). Within each chain, one station is designated as master and the remainder as secondaries; the master has unique pulse and phase transmission characteristics to distinguish it from the secondaries. Aircraft position is derived by measuring the difference in arrival time of Loran-C pulses from three or more ground stations.

8.4.4 Loran-C equipment may be ‘stand-alone’, but modern systems are more usually integrated with a navigation computer in order to provide a range of positional and associated information, and coupled to the autopilot.

8.4.5 The Loran-C ground wave is used for navigation and adequate signal coverage is normally in the region of about 900 NM. However, the usable coverage area may be affected by ground conductivity, atmospheric and man-made interference with the signal reception. System status is available through the NOTAM system.
8.4.6 There are a number of disadvantages to the Loran-C system:

- the signals are subject to local interference from such sources as LF transmitters and power line emissions;
- a failure of one transmitter can leave a major area without coverage;
- approval of Loran-C for RNAV operations will be limited to the geographical area of good ground wave signal reception. It should be noted that acceptable Loran coverage is very limited in the European Region; and
- LORAN C is only capable of achieving B-RNAV accuracy

8.4.7 Currently LORAN C is not acceptable for use in the EUR B-RNAV airspace.


8.4.8 The Inertial Navigation System (INS) is a totally self-contained aircraft system. It is basically a gyro-stabilised platform which employs accelerometers and integrators to first detect aircraft accelerations in the horizontal plane, and then, by double-integration to convert the accelerations into a displacement of the aircraft position, in nautical miles, along and across track. These displacements are applied to the aircraft position which is set, to a high degree of accuracy, prior to departure from the aircraft stand. Output functions of the system include accurate present position information, and other computed navigation data. Steering commands and angular pitch, roll and heading information may also be available. Most aircraft fitted with INS have either duplicate systems, or triple-mix systems which continuously compare/average the outputs of the three systems. If one of the three systems disagrees significantly with the other two, its data can be excluded from the averaging process.

8.4.9 The Inertial Reference System (IRS) uses laser-gyro accelerometers giving constant inputs to the Navigation Computer/FMS, which calculates all the navigation data, based as for INS, on an accurate, stabilised initial reference position. The normal operating practice is to align the systems (INS or IRS/FMS) with the aircraft’s stand position and to then define the planned route by pre-setting a series of waypoints. The system will then navigate the aircraft along the predetermined track. In the event of a change of route new waypoints can be inserted at any time.

8.4.10 INS accuracy, although very high following the initial alignment on the stand, decays with time. A linear decay, per hour, of 2.8 to 3.7 kilometres (1.5 to 2 nautical miles) must be allowed, although much lower figures are often achieved in practice. Thus INS can be expected to guide an aircraft within the normal tolerances (± 5 nautical miles) of a VOR-defined route system for something in excess of 1,850 kilometres (1,000 nautical miles) following the initial alignment. At this stage, some older INS equipment that require manual updating (an imprecise process – see below) will be unable to maintain the accuracy required for B-RNAV operations.

8.4.11 This does not apply to the newer INS and FMS equipment which have an automatic position updating capability using accurate navigation data (e.g. simultaneous double DME inputs). Furthermore, for aircraft originating within Europe, equipped with a triple-mix INS, it is rarely necessary to update the position in flight. However aircraft equipped with an older, more basic, dual INS without a function for an automatic radio updating would not be sufficiently accurate for European RNAV routes after two hours of flight as detailed in JAA TGL No.2 [3] Sub-Paragraph 4.4.2 1

Global Navigation Satellite System (GNSS)

8.4.12 GNSS is the key element of the ICAO CNS Concept and, as the name implies, is a worldwide position and time determination system. At present GNSS consists of two independent satellite based navigation systems, the US Global Positioning System (GPS) and the Russian GLONASS. Each system
incorporates system integrity monitoring. Specific system augmentations are developed as necessary to ensure provision of high integrity, highly accurate navigation service to support the RNP for a particular airspace or specific phase of flight, (en-route, TMA, and NPA).

8.4.13 The principle of operation relies upon the measurement of the range of the receiver from one or more satellites. The range is computed by multiplying the transit time of a signal from a satellite to the receiver by the speed of light. The time defined at the satellites is synchronised and thus any time difference at the receiver will result in an error that is constant in the measurement of range from all Satellites. Consequently measurements from four satellites are necessary, three are required to resolve the three-dimensional co-ordinates (x, y, z) of the receiver and the fourth resolves the time difference at the receiver.

GPS

8.4.14 The GPS satellite constellation consists of 24 satellites in six orbital planes inclined at 55 degrees at an altitude of 20,200 Km (approximately 12,600 miles). The satellites are designed with double or triple redundancy to provide an expected operational life of five years.

8.4.15 The use of GPS to perform Basic RNAV operations is limited to equipment approved to TSO C129 [6] in accordance with JAA TGL No.2 [3] Sub-Paragraph 4.4.2.3. Traditional navigation equipment (e.g. VOR, DME, and ADF) will need to be installed and be serviceable, so as to provide alternative means of navigation.

8.4.16 Differential GPS (DGPS) can be used to augment and enhance the integrity and accuracy of stand alone GPS. There are two types of DGPS, Local Area DGPS (LADGPS) and Wide Area DGPS (WADGPS). These are described below in the material on “Augmentation Systems”.

GLONASS

8.4.17 The GLONASS constellation consists of 24 satellites in 3 orbital planes at 19,100 Km (approximately 11,900 miles) above the surface of the earth. Only 21 of the satellites are active and these provide continuous five satellite coverage over 86% of the globe. Four satellite coverage, which is sufficient for most navigation purposes, is available over 90% of the globe.

8.4.18 The Russian MOD is the owner and prime user of the system. Whilst the military retains ultimate control of GLONASS, the use for civil purposes is the responsibility of the Russian Space Agency (RSA).

GALILEO

8.4.19 Galileo will be the future European contribution to the Global Navigation Satellite System (GNSS). It is based on the same technological principles as the American GPS and the Russian GLONASS systems. Galileo is being designed as an independent satellite navigation system but, at the same time, this design is optimised for use with other systems, notably GPS.

8.4.20 The core of the Galileo system will be a global constellation of 30 satellites in three Medium Earth orbital planes inclined at 56° to the equator at about 23,000 km altitude. Ten satellites will be spread evenly around each plane with each taking about 14 hours to orbit the Earth. Each plane will have one active spare able to cover for any failed satellite in that plane. An inter-connected ground infrastructure will complete the system. The Ground infrastructure will mainly consist of 2 Galileo Control Centres, 5 Monitoring and Control Stations and 5 Mission data up-link Stations which will allow a global coverage without interruption. Regional components will independently provide the integrity of the Galileo services by means of additional facilities. Regional service providers using authorised integrity uplink channels provided by Galileo will disseminate regional integrity data. Local components will enhance the above with local data distribution by means of terrestrial radio links or existing communication networks in order to provide additional accuracy, availability and integrity for critical applications.
8.4.21 The Galileo infrastructure will be implemented in three phases. During the Development and Validation phase (2002-2005), the mission requirements will be consolidated, the satellites and ground-based components developed and the system validated in orbit. During the Deployment phase (2006-2007), the construction and launch of the remaining satellites will occur and the complete ground segment will be installed. The final, Operations, phase is expected to begin in 2008.

AUGMENTATION SYSTEMS

8.4.22 Standalone GNSS does not satisfy the integrity requirements for some safety critical applications. Three means of augmenting GNSS have been defined in order to provide the necessary integrity:

- Aircraft Based Augmentation Systems (ABAS)
- Space Based Augmentation Systems (SBAS)
- Ground Based Augmentation Systems (GBAS)

ABAS

8.4.23 The use of on-board augmentation involves procedures that increase the integrity of GNSS without the need for any additional ground or space based infrastructure. There are two types of ABAS:

- Receiver Autonomous Integrity Monitoring (RAIM)

RAIM involves the self-monitoring of the tasks conducted by the receiver. To carry out this function there must be a minimum of five satellites in view. Four satellites are required for the determination of aircraft position and time, and one redundant satellite to check the consistency of all of the measurements and to detect any possible problems. A further satellite (total six) would be necessary to detect and isolate the problem. If an input from a barometric altimeter is used, the receiver can conduct the RAIM function with four satellites only.

- Aircraft Autonomous Integrity Monitoring

AAIM is achieved through the integration and use of the output of other navigation sensors or data sources, such as IRS/INS. These are used to monitor the consistency of the measurements obtained from the satellites.

SBAS

8.4.24 There are several different types of Space Based Augmentation Systems (SBAS) under development. These apply the principles of WADGPS (Wide Area Differential GPS) through the acquisition of differential corrections from geo-stationary satellite systems (described below). However as the coverage area is very large the satellites in view for all of the potential users are not the same and there can be no common correlation of biases. Thus WADGPS is organised in a different way to LADGPS (described below). Instead of one ground reference station, WADGPS uses a network of reference stations, located at selected sites, to provide vectored differential corrections. The definition of a particular vector is dependent upon the position of the receiver within the coverage area.

- European Geo-stationary Navigation Overlay Service (EGNOS). It is expected that EGNOS will achieve technical Advanced Operational Coverage (AOC) by 2004 with operational certification in 2005. AOC will support Primary Means for navigation down to Approach with Vertical Guidance II (APV II).
• US Wide Area Augmentation System (WAAS). This is being developed by the FAA in parallel with EGNOS. The FAA plan to have the system capable of supporting Approach with Vertical Guidance I (APV I) in 2003 and CAT I in 2010 to 2012.

• Japanese MT Satellite Augmentation System (MSAS). MSAS was delayed by a launch failure in 1999. A replacement satellite will be launched in 2002 with replacements every 5 years.

8.4.25 The ICAO Interoperability Working Group (IWG) is currently developing the concept of the interoperability of these systems. The Group is addressing the Technical, Operational and Legal aspects.

8.4.26 All SBAS incorporate a ground network of GNSS receivers at precisely defined locations. These receivers continuously monitor all GNSS satellites in view and send raw GNSS measurements to redundant Master Control Stations (MCS) that process the observations to determine four corrections for each GNSS satellite, one relates to Satellite time and the other three to satellite position. The MCS also estimate corrections for ionospheric delays. If any of the corrections cannot be determined with sufficient confidence the MCS will issue a “Do not use” flag against the satellite in question. The MCS send all of the data to the geo-stationary satellites that broadcast three information streams to airborne users.

• The integrity data that describes the health (usability) of the GNSS satellites.

• The correction data that improves the accuracy of the GNSS measurements made by the aircraft receivers.

• Ranging data that augments the existing GNSS constellation.

GBAS

8.4.27 Ground Based Augmentation System (GBAS) is used to provide additional data, applicable locally or within a small area, to enhance the integrity, availability, and accuracy of GNSS to support TMA operations, Precision Approaches, and ASMGCS. Local Area Differential GPS (LADGPS) is a type of GBAS.

8.4.28 LADGPS employs a reference receiver at a precisely defined location. The receiver determines its position from the GPS satellites in view and, by comparing this position with its known location, calculates any biases in the measurements from the satellites. The receiver then transmits these biases in the form of differential corrections to all users within the local area where the same satellites signals are being received. Position errors of less than 10 metres are typical of LADGPS.

8.5 Limitations of RNAV Systems

8.5.1 In an RNAV system a computer is employed to convert navigation data inputs into aircraft position, to calculate track and distance, and to provide steering guidance to the next waypoint. One disadvantage of this system is that the computer cannot identify a blunder or other erroneous inputs. Furthermore, while the computer is designed so that calculation errors are minimal and do not significantly affect the accuracy of the output, the actual computed position will contain the errors inherent in the navigation data inputs.

8.5.2 The four major causes of navigation errors have been identified as:

a) inappropriate selection of Navaids;

b) manual data inputs into the RNAV system;
c) errors in the source material provided by States; and

d) errors in the navigation data base as delivered to operators.

8.5.3 The occurrence of Errors (a) and (b) will be minimised through adherence to, and training in, Flight Crew Operating Procedures. These issues are addressed in Chapter 9.

8.5.4 There are a number of ongoing activities aimed at reducing the incidence of errors (c) and (d) for if the original source data is incorrect, then the entire process is incorrect. EUROCAE and RTCA have published a document that provides a recommended minimum standard for the processing of aeronautical data that is applicable to all phases of the aeronautical data process, from origination through acceptance and application by the end-user. This document, EUROCAE ED 76 / RTCA DO 200A - Standards for Processing Aeronautical Data [8] is intended to be used by organisations seeking approval of the method(s) they use to process or manipulate data. ED 76/RTCA DO 200A is identified in JAA TGL 9 [9] as a means of demonstrating that the processes applied to aeronautical data, intended for use in navigation or other databases, preserve a level of quality of the data commensurate with its intended use. TGL 10 [4] requires that the navigation database updating process complies with ED 76 [8] or equivalent approved procedures and all the commercial database providers have indicated that they will be ready for certification by 2002. Many States are introducing quality assurance systems based upon ISO 9000 [10] and some are also applying the principles laid down in ED 76 [8]. Studies are also being carried out to determine the current integrity of commercial databases, to identify any potential misidentification of Navaids and to resolve inconsistencies in the State AIPs.

8.6 Database Updating

8.6.1 It is the responsibility of the Operators to determine the scope of the database used in an RNAV system and to ensure that it is provided by a supplier that meets the requirements of TGL 9 [9] and ED 76 [8]. While the level of accuracy and thoroughness of the source material (AIP, etc.) on which databases rely is the responsibility of States, the commercial database providers have a responsibility to ensure that they accurately reproduce the source material as provided by States and have the procedures in place to rapidly respond to database error reports from their clients. States that publish RNAV Approach procedures must ensure that the integrity of the waypoint co-ordinates is maintained from the point of origination to the point of publication.

8.6.2 Another source of error may occur when the updating of the database cannot be carried out, thereby leading to differences between the actual navaids, waypoints, runway thresholds and instrument procedures and the loaded database on board the aircraft. The updating process is a major workload for providers and operators. For this reason, changes cannot be initiated in periods other than those corresponding to normal AIRAC dates. In case of temporary changes such as displacement of a VOR/DME, the beginning and the end of such an operation should conform to AIRAC dates. If the modification cannot be carried out in due time, the frequency of the Navaid should be changed, if at all possible.

9. FLIGHT CREW PROCEDURES AND TRAINING

Note: The Flight Crew Procedures and Training requirements detailed in this document have been taken from JAA ACJ20X4 [3] and JAA TGL No. 10 [4]. The material is provided for information only and should not be used for any operational purpose. The referenced JAA Documents provide the authoritative material on Flight Crew Procedures and Training for B-RNAV and P-RNAV Operations in ECAC airspace. In addition the attention of Flight Crews should be drawn to the ATC Procedures set out in Chapters 5 and 6 of this document.
9.1 Flight Crew Procedures

Normal Operations

PRE-FLIGHT PLANNING

9.1.1 During the pre-flight planning phase, the availability of the navigation infrastructure, required for the intended operation, including any non-RNAV contingencies, must be confirmed for the period of intended operation. Availability of the onboard navigation equipment necessary for the route to be flown must be confirmed. The onboard navigation database must be appropriate for the region of intended operation and must include the navigation aids, waypoints, and coded terminal airspace procedures for the departure, arrival and alternate airfields.

9.1.2 Where the responsible airspace authority has specified in the AIP that dual P-RNAV Systems are required for specific terminal procedures, the availability of these systems must be confirmed. This typically will apply where procedures are effective below the applicable minimum obstacle clearance altitude or where radar coverage is inadequate for the purposes of supporting P-RNAV. This will also take into account the particular hazards of a terminal area and the feasibility of contingency procedures following loss of P-RNAV capability.

9.1.3 If a stand-alone GPS is to be used for P-RNAV, the availability of RAIM must be confirmed with account taken of the latest information from the US Coastguard giving details of satellite non-availability.

Note: (1) RAIM prediction may be a function of the equipment provided that satellite non-availability data can be entered. In the absence of such a function, an airspace service provider may offer an approved RAIM availability service to users.

(2) A EUROCONTROL GPS Predictive RAIM tool can be accessed at – www.ECACnav.com. However a RAIM check is not required for EUR B-RNAV operations.

DEPARTURE

9.1.4 At system initialisation, the Flight Crew must confirm that the navigation database is current and verify that the aircraft position has been entered correctly. The active flight plan should be checked by comparing the charts, SID or other applicable documents, with the map display (if applicable) and the MCDU. This includes confirmation of the waypoint sequence, reasonableness of track angles and distances, any altitude or speed constraints, and, where possible, which waypoints are fly-by and which are fly-over. If required by a procedure, a check will need to be made to confirm that updating will use a specific navigation aid(s), or to confirm exclusion of a specific navigation aid. A procedure shall not be used if doubt exists as to the validity of the procedure in the navigation database.

Note: As a minimum, the departure checks could be a simple inspection of a suitable map display that achieves the objectives of this paragraph.

9.1.5 The creation of new waypoints by manual entry into the RNAV system by the Flight Crew is not permitted, as it would invalidate the affected P-RNAV procedure. Route modifications in the terminal area may take the form of radar headings or ‘direct to’ clearances and the flight crew must be capable of reacting in a timely fashion. This may include the insertion in the flight plan of waypoints loaded from the database.

9.1.6 Prior to commencing take off, the flight crew must verify that the RNAV system is available and operating correctly and, where applicable, the correct airport and runway data have been loaded.
9.1.7 Unless automatic updating of the actual departure point is provided, the Flight Crew must ensure initialisation on the runway either by means of a manual runway threshold or intersection update, as applicable. This is to preclude any inappropriate or inadvertent position shift after take-off. Where GNSS is used, the signal must be acquired before the take-off roll commences and GNSS position may be used in place of the runway update.

9.1.8 During the procedure and where feasible, flight progress should be monitored for navigational reasonableness, by crosschecks, with conventional navigation aids using the primary displays in conjunction with the MCDU. Where applicable and when used, the Flight Crew procedures will need to include monitoring to verify automatic updating of the inertial systems to ensure the period without updating does not exceed the permitted limit.

9.1.9 Where the initialisation (detailed above) is not achieved, the departure should be flown by conventional navigation means. A transition to the P-RNAV structure should be made at the point where the aircraft has entered DME/DME coverage and has had sufficient time to achieve an adequate input.

Note: If a procedure is designed to be started conventionally, then the latest point of transition to the P-RNAV structure will be marked on the charts. If a pilot elects to start a P-RNAV procedure using conventional methods, there will not be any indication on the charts of the transition point to the P-RNAV structure.

ARRIVAL

9.1.10 Prior to the arrival phase, the Flight Crew should verify that the correct terminal procedure has been loaded. The active flight plan should be checked by comparing the charts with the map display (if applicable) and the MCDU. This includes confirmation of the waypoint sequence, reasonableness of track angles and distances, any altitude or speed constraints, and, where possible, which waypoints are fly-by and which are fly-over. If required by a procedure, a check will need to be made to confirm that updating will exclude a particular navigation aid. A procedure shall not be used if doubt exists as to the validity of the procedure in the navigation database.

Note: As a minimum, the arrival checks could be a simple inspection of a suitable map display that achieves the objectives of this paragraph.

9.1.11 The creation of new waypoints by manual entry into the RNAV system by the Flight Crew would invalidate the P-RNAV procedure and is not permitted.

9.1.12 Where the contingency to revert to a conventional arrival procedure is required, the flight crew must make the necessary preparation.

9.1.13 During the procedure and where feasible, flight progress should be monitored for navigational reasonableness by crosschecks with conventional navigation aids using the primary displays in conjunction with the MCDU. In particular, for a VOR/DME RNAV procedure, the reference VOR/DME used for the construction of the procedure must be displayed and checked by the flight crew. For RNAV systems without GNSS updating, a navigation reasonableness check is required during the descent phase before reaching the Initial Approach Waypoint (IAWP). For GNSS based systems, absence of an integrity alarm is considered sufficient. If the check fails, a conventional procedure must then be flown.

Notes: (1) For example, where feasible, display bearing/range to a VOR/DME from the RNAV system and compare the result with the RMI read-out (selected to same VOR/DME).

(2) For some systems the accuracy may be derived from the navigation mode or accuracy mode.

(3) Where the MCDU shows only integers and is unable to display errors with sufficient resolution for P-RNAV accuracy checks, an alternative means of checking will need to be followed.
9.1.14 Route modifications in the terminal area may take the form of radar headings or ‘direct to’ clearances and the flight crew must be capable of reacting in a timely fashion. This may include the insertion of tactical waypoints loaded from the database. Manual entry or modification by the flight crew of the loaded procedure, using temporary waypoints or fixes not provided in the database, is not permitted.

9.1.15 Although a particular method is not mandated, any published altitude and speed constraints must be observed.

Contingency Procedures

9.1.16 Contingency procedures will need to be developed by the operator to address Cautions and Warnings for the following conditions:

a) Failure of the RNAV system components including those affecting flight technical error (e.g. failures of the flight director or automatic pilot);

b) Multiple system failures;

c) Failure of the navigation sensors; and

d) Coasting on inertial sensors beyond a specified time limit.

9.1.17 The flight crew must notify ATC of any problem with the RNAV system that results in the loss of the required navigation capability, together with the proposed course of action.

9.1.18 In the event of communications failure, the flight crew should continue with the RNAV procedure in accordance with the published lost communication procedure.

9.1.19 In the event of loss of P-RNAV capability, the flight crew should invoke contingency procedures and navigate using an alternative means of navigation that may include the use of an inertial system. The alternative means need not be an RNAV system.

Incident Reporting

9.1.20 Significant incidents associated with the operation of the aircraft which affect or could affect the safety of RNAV operations, need to be reported as specified in JAA TGL No. 10 [4] Section 10.4. Specific examples may include:

- Aircraft system malfunctions during P-RNAV operations which lead to:
  a) Navigation errors (e.g. map shifts) not associated with transitions from an inertial navigation mode to radio navigation mode;
  b) Significant navigation errors attributed to incorrect data or a navigation database coding error;
  c) Unexpected deviations in lateral or vertical flight path not caused by pilot input;
  d) Significant misleading information without a failure warning;
  e) Total loss or multiple navigation equipment failure.

- Problems with ground navigational facilities leading to significant navigation errors not associated with transitions from an inertial navigation mode to radio navigation mode.
9.2 Flight Crew Training

9.2.1 All Flight Crews must receive appropriate training, briefings and guidance material in the operation of RNAV-based departure and arrival procedures. This should cover the normal and contingency procedures identified in paragraphs 9.1.1 (Normal Procedures) and 9.1.16 (Contingency Procedures). Wherever practicable, standard training events (simulator checks/proficiency checks) should include departures and arrivals using the RNAV-based procedures. The operator must ensure that the Training Manual contains appropriate material to support P-RNAV operations. The minimum content of a Training Manual is detailed in JAA TGL No. 10 [4] Section 10.5, Table 3, and the topics are summarised below:

Subjects

- Theory of RNAV, including the differences between B-RNAV, P-RNAV and RNP-RNAV.
- Limitations of RNAV
- Charting, database and avionics issues including Waypoint naming concepts.
- RNAV Path terminator concepts and especially the use of the ‘CF’ path terminator and ‘TF’ path terminator.
- Fly-by and fly-over waypoints.
- Use of the RNAV equipment including, where appropriate:
  a) Retrieving a procedure from the database;
  b) Verification and sensor management;
  c) Tactically modifying the flight plan;
  d) Addressing discontinuities;
  e) Entering associated data such as:
     i) Wind;
     ii) Altitude/Speed constraints; and
     iii) Vertical Profile/Vertical Speed;
  f) Flying the procedure;
  g) Use of Lateral Navigation Mode and associated lateral control techniques;
  h) Use of Vertical Navigation Mode and associated vertical control techniques; and
  i) Use of automatic pilot, flight director and auto-throttle at different stages of the procedure.
- RT phraseology for RNAV
- The implications for RNAV operations of system malfunctions that are not RNAV related (e.g. hydraulic failure or engine failure).
10. APPROVAL FOR RNAV OPERATIONS

10.1 Responsibilities

Service Provider

10.1.1 Before publishing airspace or instrument flight procedures that require RNAV capabilities, the Service Provider is responsible for ensuring that:

a) all the agreed methodologies have been followed,

b) the appropriate standards and criteria have been applied,

c) the necessary verification, validation and flight checks have been carried out,

d) the ATS systems are capable of processing the relevant data,

e) the ATC controllers have received the relevant training; and

f) the necessary safeguards are in place to ensure that data integrity is maintained.

Aircraft Operator

10.1.2 Before commencing Operations in Airspace that has been designated and/or notified as RNAV Airspace, the Aircraft Operator is responsible for ensuring that specific approval for such operations has been obtained from the appropriate State Airworthiness Authority. The Operator will be required to demonstrate that the aircraft RNAV equipment is in compliance with specific Navigation System Performance Standards, dependant upon the Airspace requirements, and that Flight Crews have received appropriate training in RNAV Procedures.

NAVIGATION SYSTEM PERFORMANCE STANDARDS

10.1.3 The Navigation System Performance Standards are defined by the Joint Aviation Authorities (JAA). The requirements for RNP-RNAV have yet to be issued but are expected to be in conformity with the MASPS as set out in EUROCAE ED75 / RTCA DO-236 [7]. The requirements for B-RNAV Operations have been issued by the JAA in ACJ20X42 [3], and for P-RNAV Operations in TGL No. 10 [4]. These requirements have been summarised in Paragraphs 2.2.4(B-RNAV) and in 2.2.15(P-RNAV) of this document.

FLIGHT CREW PROCEDURES AND TRAINING

10.1.4 The Flight Crew Procedures and Training Requirements for B-RNAV Operations are set out in JAA TGL No.2 [3], and for P-RNAV Operations in TGL No.10 [4] and are summarised in Section 9 of this document.

10.1.5 For the Public Transport Operator, the Flight Crew Training and Operating Procedures can be demonstrated and regulated through the relevant parts of the Company Operations Manual.

10.1.6 For General Aviation and other Operators, that do not need an Operations Manual, it will be necessary for them to take such measures, as defined by their responsible State Airworthiness Authority, to satisfy the said Authority that their knowledge of, and ability to conduct, RNAV Operating Practices and Procedures is at least the equivalent of that set for AOC Holders. Guidance on RNAV Practices and Procedures and on Flight Crew Training is provided in this document. It must be emphasised that the responsibility for gaining an approval for RNAV operations rests with the Operator.
State Authority

10.1.7 The Regulatory Authority of the State of the Operator, or of the State in which the Aircraft is registered, is responsible for the issuance of RNAV Approvals to Operators who demonstrate compliance with the above requirements for operations in designated RNAV Airspace. The State Regulatory Authority is also responsible for ensuring that any Service Provider wishing to implement, or publish, RNAV operations complies with the appropriate standards and guidance material issued by ICAO, EUROCAE and EUROCONTROL.

Basis of State Legislation

10.1.8 State Legislation relating to the conduct of RNAV Operations should be based on the material in ICAO Document 7030/4 [19] EUR/RAC 23 Paragraph 18. – Procedures for Area Navigation (RNAV) Operations that sets out:

a) Application of RNAV Procedures.
   This establishes the aircraft navigation performance requirement for operations in the defined RNAV airspace.

b) Area of Applicability

c) Means of Compliance
   This establishes the responsibility of the State of Registry (of the Aircraft) or of the State of the Operator as appropriate, for the conformance to the navigation requirement.

d) RNAV Route Designation

e) Flight Planning
   This establishes the use of the letter “R” in Item 10 of the Flight Plan by Operators of aircraft fitted with RNAV having a navigation accuracy meeting RNP 5

f) Procedures for Operation on RNAV Routes
   These establish:
   i) the need for aircraft to confirm routing and navigation accuracy before joining and during operation on an RNAV Route
   ii) the aircraft and ATC procedures to be followed in the event of a failure or degradation of the aircraft navigation system.

g) ATC Procedures for State Aircraft not equipped with RNAV but having a navigation accuracy meeting RNP 5.
### APPENDIX A1 - MINIMUM SYSTEM FUNCTIONS REQUIRED FOR P-RNAV OPERATIONS

*Paragraph 2.2.25 refers*

<table>
<thead>
<tr>
<th>Item</th>
<th>Functional Description</th>
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| 1    | Display elements, e.g. CDI, (E)HSI, each with a lateral deviation display, To/From flag, and failure indicator, for use as primary flight instruments for navigation of the aircraft, for manoeuvre anticipation, and for failure/status/integrity indication, visible to the pilot and located in the primary field of view when looking forward along the flight path. The course selector of the deviation display shall be automatically slaved to the RNAV computed path. The deviation display shall have a full-scale deflection suitable for the phase of flight and based on the required track keeping accuracy. Scaling may be set automatically by default logic or to a value obtained from a navigation database. The full-scale deflection value must be known or made available for display to the flight crew. For P-RNAV operations, a value of ±1 NM is acceptable. An acceptable alternative is a navigation map display, readily visible to the flight crew, with appropriate map scales and giving equivalent functionality to the lateral deviation display, except that scaling may be set manually by the pilot.  

*Note: JAA JTSO-C129a [6], for GPS equipment, prescribes scaling values of 5.0 NM for en-route, 1.0 NM for terminal airspace, and 0.3 NM for a non-precision approach.* |
| 2    | Capability to continuously display to the pilot flying, on the primary flight instruments for navigation of the aircraft, the RNAV computed desired path (DTK) and aircraft position relative to the path. |
| 3    | Where the minimum flight crew is two pilots, means for the pilot not flying to verify the desired path and the aircraft position relative to the path. |
| 4    | A navigation database, containing current navigation data officially promulgated for civil aviation, which can be updated in accordance with the AIRAC cycle and from which terminal airspace procedures can be retrieved and loaded into the RNAV system. The resolution to which the data is stored must be sufficient to achieve the required track keeping accuracy. The database must be protected against flight crew modification of the stored data.  

*Note: When a procedure is loaded from the database, the RNAV system is required to fly it as published. This does not preclude the flight crew from having the means to modify a procedure or route already loaded into the RNAV system as permitted by Section 10. However, the procedure stored in the database must not be modified and must remain intact within the database for future use and reference.* |
<p>| 5    | Means to display the validity period of the navigation database to the flight crew. |
| 6    | Means to retrieve and display data stored in the navigation database relating to individual waypoints and navigation aids, to enable the flight crew to verify the procedure to be flown. |
| 7    | Capacity to load from the database into the RNAV system the whole terminal procedure(s) to be flown |</p>
<table>
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<tr>
<th>Item</th>
<th>Functional Description</th>
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<tbody>
<tr>
<td>8</td>
<td>Display of the active navigation sensor type, either in the pilot’s primary field of view, or on a readily accessible page on an MCDU together with a means of determining navigation system performance.</td>
</tr>
<tr>
<td>9</td>
<td>Display of the identification of the active (To) waypoint, either in the pilot’s primary field of view, or on a readily accessible page on an MCDU, readily visible to the flight crew.</td>
</tr>
<tr>
<td>10</td>
<td>Display of distance and bearing to the active (To) waypoint in the pilot’s primary field of view. Where impracticable, the data may be displayed on a readily accessible page on an MCDU, readily visible to the flight crew.</td>
</tr>
<tr>
<td>11</td>
<td>Display of ground speed or time to the active (To) waypoint, either in the pilot’s primary field of view, or on a readily accessible page on an MCDU, readily visible to the Flight Crew.</td>
</tr>
<tr>
<td>12</td>
<td>Where the MCDU is to be used to support the accuracy checks of Section 10 (of TGL 9), display of lateral deviation with a resolution of 0.1NM.</td>
</tr>
<tr>
<td>13</td>
<td>Automatic tuning of VOR and DME navigation aids used for position updating together with the capability to inhibit individual navigation aids from the automatic selection process. Note: Further guidance may be found in ED-75A/DO-236A [6], Section 3.7.3.1.</td>
</tr>
<tr>
<td>14</td>
<td>Capability for the P-RNAV system to perform automatic selection (or de-selection) of navigation sources, a reasonableness check, an integrity check, and a manual override or deselect. Further guidance may be found in ED-75A/DO-236A [6], Section 3.7.3.1.</td>
</tr>
<tr>
<td>15</td>
<td>Capability for the “Direct to” function.</td>
</tr>
<tr>
<td>16</td>
<td>Capability for automatic leg sequencing with display of sequencing to the flight crew.</td>
</tr>
<tr>
<td>17</td>
<td>Capability to execute database procedures including fly-over and fly-by turns.</td>
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| 18   | Capability to execute leg transitions and maintain tracks consistent with the following ARINC 424 path terminators, or their equivalent:  
  - Initial Fix (IF),  
  - Track between Two Fixes (TF),  
  - Course to a Fix (CF),  
  - Course from a Fix to an Altitude (FA),  
  - Direct to a Fix (DF)  
Note: Path terminators are defined in ARINC Specification 424, and their application is described in more detail in documents EUROCAE ED-75A/ RTCA DO-236A, ED-77/ DO-201A, and EUROCONTROL document NAV.ET1.ST10. |
| 19   | Indication of the RNAV system failure, including the associated sensors, in the pilot’s primary field of view. |
| 20   | For multi-sensor systems, automatic reversion to an alternate RNAV sensor if the primary RNAV sensor fails.  
*Note: This does not preclude means for manual navigation source selection.*  |
| 21   | Alternative means of displaying navigation information, sufficient to perform the checking procedures of Section 10 (of TGL 9) |

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### APPENDIX A2 – RECOMMENDED SYSTEM FUNCTIONS FOR P-RNAV OPERATIONS

<table>
<thead>
<tr>
<th>Item</th>
<th>Functional Description</th>
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| 1    | Capability to fly a path parallel to, but offset left or right from, the original active route. The system should provide for entry of an offset distance of at least 20 NM in increments of 1 NM. Operation in offset mode should be clearly indicated to the flight crew. When in offset mode, the system should provide reference parameters (e.g. cross-track deviation, distance-to-go) relative to the offset path and offset reference points. An offset should not be propagated through route discontinuities, unreasonable path geometry, or beyond the initial approach waypoint. Prior to the end of the offset path, indication should be provided to the flight crew, to allow sufficient time to return to the original active route. Once a parallel offset is activated, it should remain active for all route segments of the flight plan until either it is removed automatically, until the flight crew enter a Direct-To routing, or until flight crew (manual) cancellation.  
   **Note:** The purpose of this function is to enable offsets for tactical operations authorised by ATC (e.g. weather avoidance). It is not intended to be used for strategic offsets which will be promulgated and coded in the navigation database as separate parallel routes. |
| 2    | Coupling to the flight director and /or automatic pilot from the RNAV system with unambiguous mode indication. The coupling arrangements for the RNAV system to flight director/automatic pilot must be evaluated to show compatibility and that operating modes, including RNAV system failures modes, are clearly and unambiguously indicated to the flight crew. |
| 3    | Capability for vertical navigation based upon barometric inputs. |
| 4    | For an RNAV system using DME/DME updating, supported by IRS, means for automatic runway position update at the start of the take-off run including means to enter a distance offset for situations where the published threshold and the actual start of the take of run differ (i.e. take-off shift). |
| 5    | Display of the navigation mode in the pilot’s primary field of view. |
| 6    | Capability to execute leg transitions and maintain tracks consistent with the following ARINC 424 path terminators, or equivalent:  
   - Holding Pattern to a Manual Termination (HM)  
   - Holding Pattern to an Altitude (HA)  
   - Holding Pattern to a Fix (HF)  
   - Constant Radius to a Fix (RF).  
   **Notes:**  
   i) Path terminators are defined in ARINC Specification 424, and their application is described in more detail in documents EUROCAE ED-75A/RTCA DO-236A, ED-77/DO-201A, and EUROCONTROL document NAV.ET1.ST10.  
   ii) The RF leg type is unique to RNP-RNAV systems whereas the other types may exist in non-RNP systems. |
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APPENDIX B – THEORETICAL ATC INTERVENTION RATES

(Paragraph 3.1.10 refers)

1. This Appendix briefly outlines the results of a EUROCONTROL study into the theoretical ATC intervention rates in a Basic RNAV parallel route system. The study was performed to derive information on the effect that the reduction of route spacing may have on the required controller intervention rate.

2. The EUROCONTROL study into the theoretical intervention rate for Basic RNAV route spacing has been based on a number of assumptions. These assumptions include:

   - 100% RNP 5 performing aircraft (i.e. 5 NM, 95%)
   - The ATC sector contains a parallel route system of 100 NM in length
   - The ATC sector contains 7 flight levels
   - Aircraft are assigned the same flight levels on both (parallel) tracks
   - The traffic flow is 25 aircraft per hour per track (divided over the 7 flight levels)
   - Two intervention modes are considered:
     i) Deviation mode:
        The controller intervenes to prevent an aircraft from entering the 5 NM wide middle zone between the two route centre lines.
     ii) Conflict mode:
        The controller intervenes to prevent a pair of aircraft to come within a 5 NM distance from each other.

3. The Table below contains the resulting theoretical ATC intervention rates, for route spacing of 10, 12 and 14 NM. Any change in the traffic flow or track length would produce a proportional change in intervention rates.

<table>
<thead>
<tr>
<th>Track Spacing</th>
<th>10 NM</th>
<th>12 NM</th>
<th>14 NM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conflict Mode</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Same Direction</td>
<td>0.2 to 0.3</td>
<td>0.08 to 0.1</td>
<td>0.02 to 0.03</td>
</tr>
<tr>
<td>- Opposite Direction</td>
<td>3 to 5</td>
<td>1 to 1.5</td>
<td>0.3 to 0.5</td>
</tr>
<tr>
<td>Deviation Mode</td>
<td>11 to 16</td>
<td>6 to 10</td>
<td>3 to 5</td>
</tr>
</tbody>
</table>

Table 1 Estimates of the ATC Intervention Rates (per hour) for closely spaced parallel B-RNAV/RNP5 Routes.

4. In any consideration of these results, due account should be taken of:

   i) the fact that the underlying assumptions can be regarded as a worst case scenario, and
   ii) the comments in § 4.3 of the body of the guidance material.
APPENDIX C1 – EXAMPLE STUDY OF REQUIREMENTS FOR A 10 NM P-RNAV ROUTE SPACING

(Paragraph 3.2 refers)

Safety Targets

1. The existing route spacing standards for tracks in continental airspace having surveillance coverage, were primarily developed on the basis of operational experience with only a limited application of safety analysis. Whilst reliance upon such long established practice can be used to support continued operations, the safety implications of any new or revised operation must be assessed against the generic aviation requirement to maintain or increase the existing level of safety.

2. The ICAO Standards and Recommended Practices set out a Target Level of Safety (TLS) of $5 \times 10^{-9}$ fatal accidents per flight hour for operations introduced after 1/1/2000. To assess the system safety, models were developed which estimated the achieved Level of Safety. The model that was developed initially for procedural operations takes into account:
   a) traffic density
   b) navigation performance
   c) probability of vertical overlap (how good is the height keeping performance?)
   d) dimensions of the aircraft (represented as a box that approximates to the size of the aircraft. Any overlap of two boxes equates to a collision)
   e) average aircraft speeds
   f) track spacing

3. Of the above variables, the determination of aircraft navigation accuracy provides the greatest uncertainty. Typically this can be represented by a complex function that takes into account:
   a) the standard system performance (effectively the RNP);
   b) the potential for blunder errors.

4. The latter item includes the error sources that are common to both RNAV and non-RNAV operations and also those that are unique to RNAV operations, namely errors in the compilation of the navigation data base and also route/waypoint insertion errors by the pilot. Thus whilst the core error distribution of an RNAV system meeting RNP 1 could be much smaller than the core distribution for a conventional navigation system, the tails of the distribution of an RNAV system, due to these blunders errors, could be significantly worse than those of a conventional system. For RNP 5 systems, the impact of the tails of the distribution is less pronounced than in an RNP 1 system, but it is still necessary to assess the potential error sources, their frequency, and their impact on the operation.

Assessment of Risk in a Procedural Environment

5. The model developed for this analysis (the “Reich model”) relates to the risk associated with procedural operation in so far as it takes no account of the potential for ATC or pilot intervention to avoid a collision. Thus, without additional qualification it is possible to define the spacing which allow routes to be declared independent.
6. Using the Reich model, it is possible to assess collision risk in relation to the target level of safety for a number of alternative operational scenarios including:

   a) Density of flight operations  
   b) Alternative Flight Level allocation schemes  
   c) Different values for RNAV navigation accuracy (RNP values)  
   d) Potential for non RNAV system errors (blunders)  

These scenarios that are considered in this assessment are detailed in Appendix C2.

7. The Collision Risk figures derived using assumptions based upon these scenarios are given in Tables C1 to C4 below. They assume operation on independent routes with 10 NM track spacing with 25 aircraft per hour per track distributed equally over all flight levels.

8. Whilst this traffic density per track is considered to be representative of many routes, it is an under representation of the peak traffic flows that can occur on some routes in the core area of Europe.

<table>
<thead>
<tr>
<th>Assessment of Level of Collision Risk</th>
<th>Zero Blunders</th>
<th>1 IN 10^6 Blunder Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>RNAV PERFORMANCE</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RNP 1 to existing standards</td>
<td>3.68 * 10^{-13}</td>
<td>5.98 * 10^{-7}</td>
</tr>
<tr>
<td>RNP 1 in conformance with RNAV MASPS</td>
<td>1.29 * 10^{-54}</td>
<td>5.98 * 10^{-9}</td>
</tr>
<tr>
<td>RNP 4</td>
<td>1.44 * 10^{4}</td>
<td>1.44 * 10^{4}</td>
</tr>
<tr>
<td>RNP 5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table C1  Collision Risk for 10NM Route Spacing – Opposite Direction Traffic

9. The figures shown in Table C1 reflect Scenario 1 where either a Flight Level Allocation Scheme (FLAS) cannot be applied or, where a FLAS is applied, the angular difference between tracks is small.

<table>
<thead>
<tr>
<th>Assessment of Level of Collision Risk</th>
<th>Zero Blunders</th>
<th>1 IN 10^6 Blunder Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>RNAV PERFORMANCE</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RNP 1 to existing standards</td>
<td>2.74 * 10^{-14}</td>
<td>4.45 * 10^{-10}</td>
</tr>
<tr>
<td>RNP 1 in conformance with RNAV MASPS</td>
<td>9.57 * 10^{-56}</td>
<td>4.45 * 10^{-10}</td>
</tr>
<tr>
<td>RNP 4</td>
<td>1.07 * 10^{-5}</td>
<td>1.07 * 10^{-5}</td>
</tr>
<tr>
<td>RNP 5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table C2 - Collision Risk for 10 NM Route Spacing - Same Direction Traffic
10. Table C2 reflects Scenario 2 where the application of a FLAS results in same direction only traffic being at the same flight level.

<table>
<thead>
<tr>
<th>RNAV PERFORMANCE</th>
<th>Assessment of Collision Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Zero Blunders</td>
</tr>
<tr>
<td>RNP 1 to existing standards</td>
<td>2.94 * 10^-14</td>
</tr>
<tr>
<td>RNP 1 in conformance with the RNAV MASPS</td>
<td>1.03 * 10^-35</td>
</tr>
<tr>
<td>RNP 4</td>
<td>1.15 * 10^-5</td>
</tr>
<tr>
<td>RNP 5</td>
<td></td>
</tr>
</tbody>
</table>

Table C3 - Collision Risk for 10 NM Route Spacing - Climbing/Descending Traffic

11. Table C3 reflects Scenario 3 where a dual track structure is in operation, each being a unidirectional track employing a FLAS such as the semi-circular rule. In this case the only potential lateral conflicts arising from traffic in this route structure arises from opposite direction traffic in climb and descent operating on the adjacent track with a significant reduction of the collision risk from that applicable to Table C1.

12. From Tables C1 to C3 it can be seen that:

- Current RNP 1 equipped aircraft can meet the Target Level of Safety in the absence of blunder errors. The collision risk remains below the TLS even after blunder errors rates up to 1 in 10^6 are taken into account. Such error rates are potentially achievable in normal operations but it is clear that the size and frequency of blunder errors are the key determinants in the assessment of any reduction of route spacing.

- For both RNP 4 and RNP 5 it can be seen that the blunder errors are relatively less significant since the basic accuracy of RNAV performance predominates. Application of these systems in an environment employing 10 NM route spacing will result in the TLS being exceeded by between 3 and 5 orders of magnitude.

Effect of Operations by Aircraft with differing RNAV capabilities

13. Tables C1-C3 above only cover the system performance in either a total RNP 1 environment or a total RNP 4/5 environment. However, even in 1998 when the carriage of Basic RNAV first became mandatory, over 40% of RNAV equipped aircraft were already capable of meeting RNP 1 accuracy standards. It is therefore necessary to consider the system safety given a mix of RNP 1 and RNP 4/5 capable aircraft.

14. The effect of a mixed environment is shown in Table C4. The table considers the potential collision risk for varying proportions of RNP 1 and RNP 5 aircraft operating on a route structure with 10 NM Track spacing. The tabulated collision risks correspond to a total RNP 5 environment at one extreme, ranging down to a total RNP 1 environment at the other.
**Table C4 - Collision Risk - Mixed Fleet of RNP 1/RNP5 aircraft – Opposite Direction Traffic**

15. It can be seen from Table C4 that the performance of the RNP 5 systems dominate the level of collision risk even when as much as 80% of the aircraft population are capable of RNP 1 operations. Thus the expected proportion of RNP 1 equipped aircraft will not reduce the level of Collision Risk sufficiently to satisfy the TLS \((5 \times 10^{-9})\) with a procedural route spacing of 10 NM.

**Implication of Assessment of Collision risk**

16. From the above considerations it is clear that routes accommodating aircraft with an RNP 5 or 4 capability, with a 10 NM track spacing, cannot be operated as independent routes.

17. Whilst, this does not prevent the implementation of such routes at a 10 N Mile spacing it does mean, that whilst the RNAV capability provides the potential for restructuring of the airspace, the RNAV system performance will not, in itself, be sufficient to ensure the required level of safety. Thus the total CNS/ATM environment will need to be considered in the evaluation of the system safety.

**CNS/ATM Requirements to Support a 10 NM Track Spacing**

**General**

18. For VOR routes with 50 NM or less between VORs the 95% containment value for aircraft on VOR defined routes would be +/- 4 NM (i.e. RNP 4). Attachment A to ICAO Annex 11 [11] sets out material for the establishment of ATS Routes Spacing based upon such system accuracy.

The attachment states:

“...with parallel routes systems under continuous radar control, it can be expected that a reduction to the order of 8-10 NM but probably not less than 7 NM may be possible as long as radar monitoring workload is not increased substantially by that reduction.”

19. The attachment notes that for such separations large turns are to be avoided where possible and, where not possible, profiles should be defined for turns greater than 20 degrees. The attachment also suggests that to provide such separation reductions there is a need to consider:

a) Radar coverage and the availability of an automatic alarm

b) Monitoring Continuity

c) RT. quality
d) Traffic (volume, characteristics)

e) Sector Workload

20. Annex 11 [11] does not provide guidance to the airspace planner on specific requirements for any of the above. However, the results of the EUROCONTROL studies together with the Strategies for Radar and Communications allow these requirements to be elaborated as follows.

**EUROCONTROL Study of CNS ATM Requirements**

21. The first three of the above requirements (a, b, and c) form a set of functions which together need to provide the required addition to the total system integrity for the traffic environment (volume and characteristics) assumed in the derivation of Tables 1 to 3.

22. It was shown above that the operation of B-RNAV routes at 10 NM spacing will require an enhancement of system capability of between 3 and 5 orders of magnitude above that obtainable from procedural operations. The degree of enhancement necessary will depend upon the implementation scenario and the expected traffic density.

23. The structure required to provide an enhancement to the system safety provided by the navigation capability will comprise the Surveillance, Communications and ATC systems. Assuming the need to reduce the collision risk from $5 \times 10^{-5}$ to $5 \times 10^{-9}$ these have to contribute jointly a reduction of the collision risk by approximately $10^4$ by the detection and resolution of the conflicts resulting from the navigation performance.

![Figure 2 - Augmentation of System Safety](image)

24. Figure 2 above represents a simplified breakdown of the potential contributions to the total system integrity to be derived from components independent of the navigation system. From existing EUROCONTROL Standards and ICAO SARPS, it is possible to confirm that the integrity provided by Dual Radar and Dual Communications (i.e. dual T/R, backup channel etc.) environment substantially exceeds the integrity augmentation requirements for a 10NM route spacing.

25. The remaining issue is the requirement that would be placed upon the “ATC System” to support 10 NM route spacing. At this spacing the two adjacent 95% containment surfaces of RNP 5 performances would touch whilst there would be 2 NM between the routes if RNP 4 performance was to be adopted, In these situations, it might be possible to provide an adequate degree of confidence from statistical analysis that 10 NM track spacing could be achieved by the selection of appropriate implementation
scenarios, under the condition of dual track operation with same level opposite or same direction traffic. On the other hand, Radar separation standards could be violated by aircraft that were operating in full conformance to the RNP requirements.

26. The implications of this on the acceptability of operation with 10 NM separation depends substantially on the system environment and general conclusions are not easily derived. The following Table C5 gives an indication of the ATC Intervention Rates that may be necessary in order to support such operations.

<table>
<thead>
<tr>
<th>ATC INTERVENTION RATES (Hourly)</th>
<th>Opposite Direction (Scenario No.1)</th>
<th>Same Direction (Scenario No. 2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RNP 1 to existing standards</td>
<td>0.1</td>
<td>0.002</td>
</tr>
<tr>
<td>RNP 1 in conformance with RNAV MASPS</td>
<td>0.001</td>
<td>0.0001</td>
</tr>
<tr>
<td>RNP 4</td>
<td>8.81</td>
<td>0.96</td>
</tr>
<tr>
<td>RNP 5</td>
<td>25</td>
<td>2</td>
</tr>
</tbody>
</table>

Table C5 - Intervention Rates for 10 NM Track Spacing.

27. Table C5 shows the calculated ATC Intervention Rates using the environments described in Scenarios 1 and 2 of Appendix C (i.e. opposite and same direction traffic). Clearly RNP 1 aircraft would generate little or no additional workload. However for RNP 4 and 5 aircraft the rates will vary from a low of less than 1 per hour for same direction traffic (RNP 4) to a high of 25 per hour for opposite direction traffic (RNP 5). Whilst the RNP 4 case will probably prove acceptable it is likely that a suitable medium term conflict alert or a deviation alert will be required. This will need to be verified by simulation.

Track Structure

28. To support the provision of closely spaced tracks, the EUROCONTROL Standard specifies the turn performance for P-RNAV (i.e. RNP 10 aircraft as being +/- 1 NM around the arc of a circle of defined radius).

29. Neither the EUROCONTROL Standard nor the RNAV MASPS Document require such performance of B-RNAV (RNP 4 or RNP 5) equipment. In addition the JAA B-RNAV TGL No 2 rev 1, has provided “Grandfather Rights” to equipment approved against standards such as AC 90-45() that dates back to the early 1970s. As a result, for B-RNAV systems, the turn anticipation distance can be as much as 20 NM in advance of the waypoint defining the turn. Studies performed for EUROCONTROL have shown that a 20 degree track change can result in a spread of performance of up to 2 NM and thus in adverse conditions the target track spacing (i.e. ignoring all navigation errors) could be reduced to 8 NM.

30. The spread in performance increases substantially for greater track angle changes and therefore the requirements of Annex 11 in respect of larger track changes remains applicable for B-RNAV operation.
Requirements For Application of B-RNAV Routes at 10 NM Spacing

31. Based upon the above considerations necessary to satisfy the TLS of $5 \times 10^{-9}$, the introduction of 10 NM route spacing for RNP 4 or RNP 5 operations will require:
   a) Dual Radar cover
   b) Dual Communications capability (dual radio, backup frequency)
   c) Turns should be limited to 20 degrees.
   d) To ensure acceptable controller workload, opposite direction same level traffic is to be avoided for parallel or slowly diverging tracks.

32. It is important to note that the sample Collision Risks and Intervention Rates, shown in the various tables, were based on a level of traffic that can be exceeded by a factor of two on some tracks in the core area of Europe. In these areas, and where opposite direction traffic cannot be avoided, suitable computer assistance should be provided. This requirement will need to be verified by simulation but is based upon the fact that with the proposed spacing, radar separation could be infringed whilst both aircraft are behaving in full conformance with the RNAV system standard.
APPENDIX C2 - SCENARIOS FOR COLLISION RISK CALCULATIONS IN APPENDIX C1

Introduction

1. This Appendix sets out the basis upon which the collision risks and intervention rates set out in the Tables in Appendix C1 were derived.

2. The appendix summarises:
   a) Possible Flight Level Allocation Schemes (FLAS) which provide the basis for assessing the potential for conflicts;
   b) Navigation performance which is derived from
      • RNAV system performance
      • Potential for blunder errors;

Flight Level Allocation Scheme

3. Three FLAS were considered:

Scenario No. 1 - All Flight Levels available to all aircraft. This leads to the potential for conflicts from opposite direction traffic assigned the same Flight Level. This scenario is considered to be a worst-case scenario and the least likely to occur in practice.

Scenario No. 2 - Operation with a Flight Level allocation scheme (e.g. semicircular rule) resulting only in same direction traffic at a given flight level.

Scenario No. 3 - Operation with a dual track structure, each being unidirectional employing a FLAS such as the semicircular rule. In this case the only potential lateral conflicts arise from opposite direction traffic in climb and descent operating on the adjacent track. This scenario results in opposite direction conflicts but with a reduced potential for occurrence when compared with Scenario 1. In a typical environment, studied by one of the States represented on the NSSG it was shown that, for a medium level sector, up to 80% of aircraft are in climb or descent. This environment would lead to a reduction in collision risk by a factor of approximately 0.08 when compared with scenario 1.

Navigation Performance

RNAV System Accuracy

4. The study considered:
   a) RNP4 and RNP 5 performance. The former being derived from the RNAV Minimum Aviation System Performance Specification (MASPS) being developed by RTCA and EUROCAE. The RNP 5 performance requirements were assumed to be identical except for the reduction in the required accuracy of performance.
b) Navigation accuracy of RNP 1 equipment which was expected to constitute up to 50% of all RNAV equipment in operation by 1998 and could therefore have a significant influence on the overall system performance.

Potential for Blunders

5. The RNAV MASPS is designed to ensure that, RNAV systems provide navigation accuracy in accordance with the declared RNP. The MASPS also defines requirements in terms of RNAV availability and integrity thus ensuring a low risk of the system not working or claiming to be operational when it is not conforming to the system specification.

6. The RNAV MASPS does not, and indeed cannot, cover errors that are not the direct result of deficiencies in the RNAV system. Whatever system safeguards are introduced there will remain the potential for system errors that, whilst not attributable to the navigation system itself, arise from the methods of operation involved in the application of RNAV.
These include;

   a) Navigation Data errors
   b) Mis-selection of routes
   c) ATC errors

7. Operational procedures are designed to keep these errors to a manageable level. However, they are unlikely to be maintained at much better than one failure per million. These limitations derive from a number of considerations including:

   a) Data errors meeting future standards will only need to achieve error rates of $1 \times 10^{-5}$
   b) Human error rates, even in well structured environments such as ATC, seldom achieve better than $1 \times 10^{-6}$ i.e. around one error per working life and can, under high workload or fatigue conditions become as low as $1 \times 10^{-4}$. Typical human error rates in non-structured environments are normally regarded to be around $1 \times 10^{-3}$.
ANNEX

LIST OF REFERENCE DOCUMENTS

4. JAA Administrative & Guidance Material, Section One, General Part 3: Temporary Guidance Leaflet No. 10 – Airworthiness and Operational Approval for Precision RNAV Operations in Designated European Airspace.
10. ISO 9000
11. ICAO Annex 11 - Air Traffic Services
12. ICAO Document 9689 – Manual on Airspace Planning Methodology for Determining Separation Minima” (also called the Airspace Planning Manual)
13. ICAO Document 4444 (PANS-ATM)
18. ICAO Document 8168 Vol. II PANS-OPS
22. JAA Document AMJ 25 RNP-RNAV
23. EUROCONTROL Document NAV.ET1.ST10

– END –