No. 17

CASAS ADVISORY PAMPHLET

Subject: **Introduction to Area Navigation (RNAV) and Required Navigation Performance (RNP)**

Date: **02/01/2006**

I. ABBREVIATIONS

ABAS	Aircraft Based Augmentation System
ADF	Automatic Direction Finding
AFM	Aircraft Flight Manual
AIP	Aeronautical Information Publication
AIRAC	Aeronautical Information Regulation and Control
AIS	Aeronautical Information Service
ATC	Air Traffic Control
ATCC	Air Traffic Control Centre
B-RNAV	Basic RNAV
CDI	Course Deviation Indicator
CF	COURSE to a FIX
CNF	Computer Navigation Fix
DF	DIRECT to a FIX
DME	Distance Measuring Equipment
DTK	Desired Track
EFIS	Electronic Flight Instrument System
EGNOS	European Geo-Stationary Navigation Overlay System
(E) HIS	(Electronic) Horizontal Situation Indicator

FA	Course from a FIX to an ALTITUDE
FACF	Final Approach Course Fix
FAF	Final Approach Fix
FAWP	Final Approach Waypoint
FDE	Fault Detection and Exclusion
FMS	Flight Management System
FTE	Flight Technical Error
GBAS	Ground Based Augmentation System
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HA	HOLDING Pattern to an ALTITUDE
HF	HOLDING Pattern to a FIX
HM	HOLDING Pattern to a MANUAL Termination
HSI	Horizontal Situation Indicator
ICAO	International Civil Aviation Organization
IF	Initial Fix
IFR	Instrument Flight Rules
ILS	Instrument Landing System
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
SATCOM	Satellite Communications
SBAS	Satellite Based Augmentation System

SID	Standard Instrument Departure
SRAs	Special Rules Airspace
STAR	Standard Instrument Arrival Route
TACAN	Tactical Air Navigation Aid
TF	TRACK between two FIXES
TMA	Terminal Control Area
VHF	Very High Frequency
VNAV	Vertical Navigation
VOR	VHF Omni Directional Range
WAAS	Wide Area Augmentation System
WGS	World Geodetic System

II. 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.

III. Area Navigation (RNAV)

a. General. 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. In the future, there will be an increased dependence on the use of RNAV in lieu of routes defined by ground-based navigation aids.

RNAV systems were originally used within the en route environment as a tool for flying conventional ground-based routes including departure procedures (DPs) and standard terminal arrivals (STARs). RNAV terminal procedures are being designed with RNAV systems in mind. There are several potential advantages to this including:

1. Routings which save both time and fuel,
2. Reduced dependence on radar vectoring, altitude, and speed assignments allowing a reduction in required ATC radio transmissions, and
3. More efficient use of airspace.

b. RNAV Operations. RNAV procedures, such as DPs and STARs, demand strict pilot awareness and maintenance of the RNAV procedure course centerline. Pilots should possess a working knowledge of their aircraft navigation system to ensure RNAV procedures are flown in an appropriate manner. Additionally, pilots should have an understanding of the various waypoint and leg types used in RNAV procedures, these are discussed in more detail below.

1. **Waypoints.** A waypoint is a predetermined geographical position that is defined in terms of latitude/longitude coordinates. Waypoints may be a simple named point in space or associated with existing navaids, intersections, or fixes. A waypoint is most often used to indicate a change in direction, speed, or altitude along the desired path. RNAV procedures make use of both fly-over and fly-by waypoints.

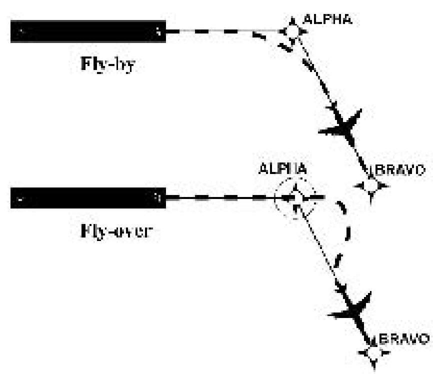
   (a) Fly-by waypoints. Fly-by waypoints are used when an aircraft should begin a turn to the next course prior to reaching the waypoint separating the two route segments. This is known as turn anticipation.

   (b) Fly-over waypoints. Fly-over waypoints are used when the aircraft must fly over the point prior to starting a turn.

   NOTE
   FIG 1-2-1 illustrates several differences between a fly-by and a fly-over waypoint.

FIG 1-2-1

Fly-by and Fly-over Waypoints



IV. **RNAV Leg Types.** A leg type describes the desired path proceeding, following, or between waypoints on an RNAV procedure. Leg types are identified by a two-letter code that describes the path (e.g., heading, course, track, etc.) and the termination point (e.g., the path terminates at an altitude, distance, fix, etc.). Leg types used for procedure design are included in the aircraft navigation database, but not normally provided on the procedure chart. The narrative depiction of the RNAV chart describes how a procedure is flown. The "path and terminator concept" defines that every leg of a procedure has a termination point and some kind of path into that termination point. Some of the available leg types are described below.

(a) **Track to Fix.** A Track to Fix (TF) leg is intercepted and acquired as the flight track to the following waypoint. Track to a Fix legs are sometimes called point-to-point legs for this reason ***Narrative:*** *"via 087° track to CHEZZ WP."* See FIG 1-2-2.

(b) **Direct to Fix.** A Direct to Fix (DF) leg is a path described by an aircraft's track from an initial area direct to the next waypoint. ***Narrative:*** *"left turn direct BARGN WP."* See FIG 1-2-3.

FIG 1-2-2

Track to Fix Leg Type

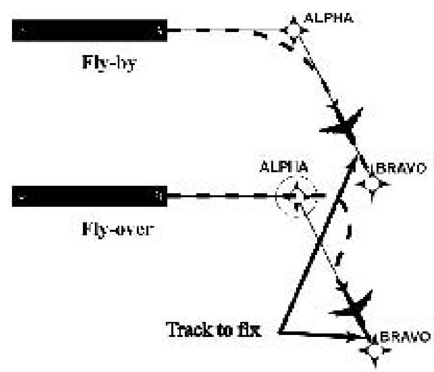
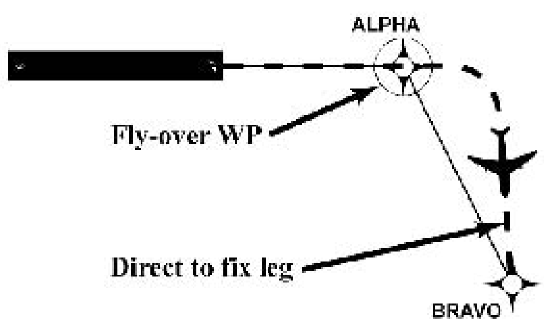


FIG 1-2-3

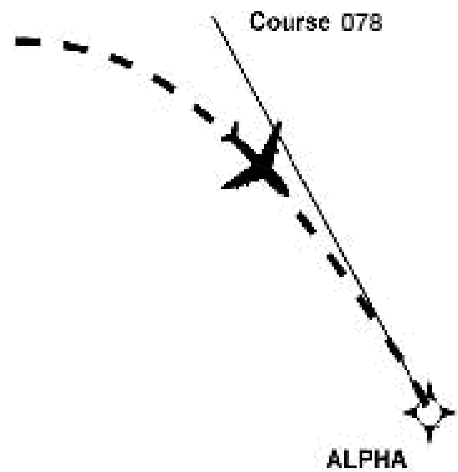
Direct to Fix Leg Type



(c) Course to Fix. A Course to Fix (CF) leg is a path that terminates at a fix with a specified course at that fix. ***Narrative:*** *"via 078° course to Alpha."*
See FIG 1-2-4.

FIG 1-2-4

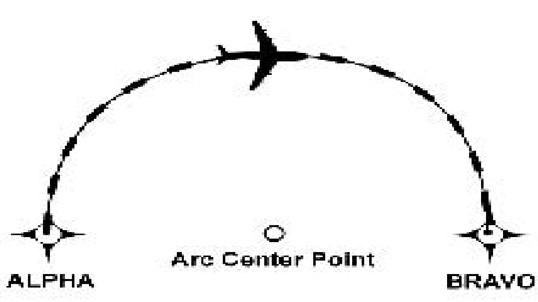
Course to Fix Leg Type



(d) Radius to Fix. A Radius to Fix (RF) leg is defined as a constant radius circular path around a defined turn center that terminates at a fix. See FIG 1-2-5.

FIG 1-2-5

Radius to Fix Leg Type



(e) Heading. A Heading leg may be defined as, but not limited to, a Heading to Altitude (VA), Heading to DME range (VD), and Heading to Manual Termination, i.e., Vector (VM). **Narrative:** "climb runway heading to 1500"; "heading 265°, at 9 DME west of PXR VORTAC, right turn heading 360°"; expect radar vectors to DRYHT INT."

V. Navigation Issues.

Navigation Issues. Pilots should be aware of their navigation system inputs, alerts, and annunciations in order to make better-informed decisions. In addition, the availability and suitability of particular sensors/systems should be considered.

(a) GPS. Operators using TSO-C129 systems should ensure departure and arrival airports are entered to ensure proper RAIM availability and CDI sensitivity.

(b) DME/DME. Operators should be aware that DME/DME position updating is dependent on FMS logic and DME facility proximity, availability, and signal masking.
The available number and geometry of facilities influences DME/DME performance.

(c) VOR/DME. Unique VOR characteristics may result in less accurate values from VOR/DME position updating than from GPS or DME/DME position updating.

(d) Inertial Navigation. Inertial reference units and inertial navigation systems are often coupled with other types of navigation inputs, e.g., DME/DME or GPS, to improve overall navigation system performance.

NOTE-
Specific inertial position updating requirements may apply.

VI. Flight Management System (FMS).

Flight Management System (FMS). A flight management system is an integrated system consisting of airborne sensors, receivers, computers, and a navigation database. These systems may also provide performance and RNAV guidance to displays and automatic flight control systems.

Inputs can be accepted from multiple sources such as the GPS, DME, VOR, LOC and IRU. These inputs may be applied to a navigation solution one at a time or in combination. Some FMSs provide for the detection and isolation of faulty navigation information.

When appropriate navigation signals are available, FMSs will normally rely on GPS and/or DME/DME for position updates. Other inputs may be incorporated based on FMS system architecture and navigation source geometry.

VII. Required Navigation Performance (RNP)

a. General. RNP is intended to provide a single performance standard for aircraft manufacturers, airspace designers, pilots, controllers, and international aviation authorities. Some RNP procedures will take advantage of improved navigation capabilities and will result in increased flight path predictability and repeatability.

Typically, various sensor inputs are processed by an RNAV system to arrive at a position estimate having a high-statistical degree of accuracy and confidence. When RNP is specified, a combination of systems may be used, provided the aircraft can achieve the required navigation performance.

While it has been a goal for RNP to be sensor-generic, this goal is unachievable as long as the aircraft capability is in any way dependent on external signals. The aircraft navigation system always consists of specific sensors or sensor combinations and the navigation infrastructure consists of specific systems.

The RNP capability of an aircraft will vary depending upon the aircraft equipment and the navigation infrastructure. For example, an aircraft may be equipped and certified for RNP 1.0, but may not be capable of RNP 1.0 operations due to limited navaid coverage.

b. RNP Operations

1. RNP Levels. An RNP "level" or "type" is applicable to a selected airspace, route, or procedure. ICAO has defined RNP values for the four typical navigation phases of flight: oceanic, en route, terminal, and approach. As defined in the Pilot/Controller Glossary, the RNP Level or Type is a value typically expressed as a distance in nautical miles from the intended centerline of a procedure, route, or path. RNP applications also account for potential errors at some multiple of RNP level (e.g., twice the RNP level).

(a) Standard RNP Levels. U.S. standard values supporting typical RNP airspace are as specified in TBL 1-2-1 below. Other RNP levels as identified by ICAO, other states and the FAA may also be used.

TBL 1-2-1
U.S. Standard RNP Levels

RNP Level	Typical Application	Primary Route Width (NM) - Centerline to Boundary
0.3	Approach	0.3
1	Terminal	1.0
2	Terminal and En Route	2.0

NOTE

1. *The "performance" of the navigation equipment in RNP refers not only to the level of accuracy of a particular sensor or aircraft navigation system, but also to the degree of precision with which the aircraft will be flown.*

2. *Specific required flight procedures may vary for different RNP levels.*

(b) Application of Standard RNP Levels. U.S. standard levels of RNP typically used for various routes and procedures supporting RNAV operations may be based on use of a specific navigational system or sensor such as GPS, or on multi-sensor RNAV systems having suitable performance.

(c) Depiction of Standard RNP Levels. The applicable RNP level will be depicted on affected charts and procedures. For example, an RNAV departure procedure may contain a notation referring to eligible aircraft by equipment suffix and a phrase "or RNP-1.0." A typical RNAV approach procedure may include a notation referring to eligible aircraft by specific navigation sensor(s), equipment suffix, and a phrase "or RNP-0.3." Specific guidelines for the depiction of RNP levels will be provided through chart bulletins and accompany affected charting changes.

c. Other RNP Applications Outside the U.S. The FAA and ICAO member states have led initiatives in implementing the RNP concept to oceanic operations. For example, RNP-10 routes have been established in the northern Pacific (NOPAC) which has increased capacity and efficiency by reducing the distance between tracks to 50 NM. Additionally, the FAA has assisted those U.S. air carriers operating in Europe where the routes have been designated as RNP-5. TBL 1-2-2 below, shows examples of current and future RNP levels of airspace.

d. Aircraft and Airborne Equipment Eligibility for RNP Operations. Aircraft meeting RNP criteria will have an appropriate entry including special conditions and limitations in its Aircraft Flight Manual (AFM), or supplement. RNAV installations with AFM-RNP certification based on GPS or systems integrating GPS are considered to meet U.S. standard RNP levels for all phases of flight. Aircraft with AFM-RNP certification without GPS may be limited to certain RNP levels, or phases of flight. For example, RNP based on DME/ DME without other augmentation may not be appropriate for phases of flight outside the certified DME service volume. Operators of aircraft not having specific AFM-RNP certification may be issued operational approval including special conditions and limitations for specific RNP levels. Aircraft navigation systems eligible for RNP airspace will be indicated on charts or announced through other FAA media such as NOTAMs and chart bulletins.

NOTE-

Some airborne systems use Estimated Position Uncertainty (EPU) as a measure of the current estimated navigational performance. EPU may also be referred to as Actual Navigation Performance (ANP) or Estimated Position Error (EPE).

TBL 1-2-2

RNP Levels Supported for International Operations

RNP Level	Typical Application
1	European Precision RNAV (P-RNAV)
4	Projected for oceanic/remote areas where 30 NM horizontal separation is applied
5	European Basic RNAV (B-RNAV)
10	Oceanic/remote areas where 50 NM lateral separation is applied

NOTE-

Specific operational and equipment performance requirements apply for P-RNAV and B-RNAV.