





# Terminal Navigation Specifications

## RNAV 2, RNAV 1 and Basic-RNP 1

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## Overview

- Background
- ANSP Considerations
- Aircraft Requirements
- Operational Procedures
- Pilot Knowledge and Training
- Operator Approval Process
- Example RNAV 1 Implementation
- Lessons Learned
- Summary

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## Learning Objectives

At the end of this presentation, you should:

- Understand the differences between RNAV 2, RNAV 1 and Basic-RNP 1
- Understand the required (ground) navigation infrastructure and (airborne) navigation performance
- Understand the flight crew operating procedures for RNAV 2, RNAV 1 and Basic-RNP 1
- Know the aircraft and operator eligibility requirements for RNAV 2, RNAV 1 and Basic-RNP 1 approval

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## Application of Navigation Specification by Flight Phase

PBN Manual Vol II

*Table 1-1: Application of Navigation Specification by Flight Phase*

NAVIGATION SPECIFICATION	En Route OCEANIC /REMOTE	En Route Continental	ARR	FLIGHT PHASE				DEP
				APPROACH			MSSED	
				Initial	Interm.	Final		
RNAV 10	10							
RNAV 5		5	5					
RNAV 2		2	2					2
RNAV 1		1	1	1	1		1 <sup>b</sup>	1
RNP 4		4						
Basic-RNP 1			1 <sup>a,c</sup>	1 <sup>a</sup>	1 <sup>a</sup>		1 <sup>a</sup>	1 <sup>a,c</sup>
RNP APCH				1	1	0.3	1	
RNP AR APCH				1-0.1	1-0.1	0.3-0.1	1-0.1	

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## Differences Between RNAV 2 and RNAV 1

- RNAV 2 is intended for en route application
- Application of RNAV 2 allows longer IRU coasting time (and reduced DME infrastructure)

**Overall, the navigation specifications for RNAV 2 and RNAV 1 have similar requirements and identical approval process.**

**For brevity, the term “RNAV 1” will be used during this discussion and will encompass RNAV 2 and RNAV 1 operations.**



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## Differences Between RNAV 1 and Basic-RNP 1

- RNAV 1
  - Primarily intended for use where radar surveillance is applied
    - For Instrument Departures, radar coverage expected prior to first RNAV course change
  - Accommodates a larger fleet of aircraft
    - Does not require on-board performance monitoring and alerting
    - GNSS, DME/DME or DME/DME/IRU allowed
- Basic-RNP 1
  - Primarily intended where radar surveillance is not available
  - Requires on-board performance monitoring and alerting
  - Requires GNSS (may be used in areas with limited ground navigation aid infrastructure)
  - Primarily intended for use within 30 NM of departure or arrival airport

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**Why Basic-RNP 1?**

- RNP Study Group:
  - Recognized need for arrival and departure capability where radar does not exist
  - Incorporated GNSS-based RNP operations
  - Also recognized future need for new functional capabilities
    - Curved paths, vertical navigation, use outside of 30 NM from aerodrome, etc.
    - These capabilities will be addressed in future update to the PBN Manual

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**ANSP Considerations**

(PBN Manual Volume II, Parts B and C, section 3.2.1)

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**Navigation Infrastructure: ANSP Considerations**

- Infrastructure:
  - Assess navigation performance with available infrastructure, including reversionary modes
- If GNSS:
  - Ensure operators have means of predicting availability of fault-detection using ABAS (e.g. RAIM)
    - Predicted, continuous loss of ABAS fault detection of more than 5 minutes should be identified
- If DME/DME or DME/DME/IRU:
  - Use DME facilities in State AIP which comply with Annex 10 requirements
  - DME signals assumed to meet signal in space accuracy tolerances everywhere signals are received
  - DME signal used by aircraft in proper geometry

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**DME/DME (D/D) Include Angle**

- For DME/DME systems using DME facility pairs, geometry solutions require two DMEs to be  $\geq 30^\circ$  and  $\leq 150^\circ$

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**Example: Atlanta (USA) RNAV 1 STAR (Assessed for DME/DME Only)**

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**Atlanta RNAV 1 STAR (DME/DME/IRU addresses DME "gaps")**

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**Other ANSP Considerations**

- Communication and ATS Surveillance
- Additional considerations
- Publication (PBN Manual Vol II, part B or C, para 3.2.5)
- Controller training: Core training; nav spec specific
- Status monitoring: Monitor and maintain supporting infrastructure; notify users of changes (NOTAM)
- ATS System monitoring: Know why deviations occur

PBN, Vol II, Parts B and C, Sections 3.2.2 → 3.2.8  
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**Key Elements**

**Operational Approval**

Procedure Design Criteria

Operational Procedures and Standards

Equipment/System Standards

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**Procedure Design Criteria**

- Refer to PANS-OPS, Volume II, Part 3, Section 1
  - RNAV 1 and RNAV 2
    - Addresses GNSS
    - Addresses DME/DME
    - For both GNSS and DME/DME infrastructures, apply the greater width
  - Basic-RNP 1
    - Evaluate using basic GNSS
    - Route spacing depends on route configuration, air traffic density, and intervention capability

PBN, Vol II, Parts B and C, Section 3.2.3  
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**Key Elements**

**Operational Approval**

Procedure Design Criteria

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**Navigation Performance-Typical Systems\***

RNAV 1	Basic-RNP 1
<ul style="list-style-type: none"> <li>• GNSS               <ul style="list-style-type: none"> <li>– TSO-C129a</li> <li>– TSO-C145()</li> <li>– TSO-C146()</li> </ul> </li> <li>• DME/DME/IRU</li> <li>• DME/DME</li> </ul>	<ul style="list-style-type: none"> <li>• GNSS               <ul style="list-style-type: none"> <li>– TSO-C129a</li> <li>– TSO-C145()</li> <li>– TSO-C146()</li> </ul> </li> </ul>

\*Some systems may not qualify depending on functional capability (discussed later)

Next slides: PBN Manual Vol II, Parts B & C, Section 3.3.3

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**Navigation Performance**

**DME/DME System Criteria**

- Accuracy based on TSO-C66c performance
- Navaid infrastructure must support RNAV system performance (ANSP considerations)
  - No requirement to use VOR, NDB, LOC, IRU or AHRS
  - Reasonableness checks verify valid DME measurements
  - Aircraft required to comply with ANSP criteria:
    - Aircraft between 3-160 NM, below 40° above horizon (viewed from facility),
    - Include angle between 30°-150°,
    - Position estimation error accuracy from 0.56 NM to 1.2 NM

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## Navigation Performance

### DME/DME with Inertial Reference Unit (D/D/I)

- DME accuracy – same DME/DME criteria
- Inertial performance and limitations
  - Inertial system performance satisfies criteria of US 14 Code of Federal Regulations (CFR) Part 121, Appendix G
  - Automatic position updating capability from DME/DME is required
  - When infrastructure does not support DME/DME updating, impact of VOR radial accuracy when VOR is greater than 40 NM must not affect aircraft position accuracy
- Operational procedure (but related to aircraft): Confirm aircraft system position, within 1,000 feet (0.17NM) of a known position, at the start of the takeoff roll

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## System Performance

	RNAV 1	Basic-RNP 1
<b>Accuracy</b>	Lateral total system error $\pm 1$ NM (95%). Along track error $\pm 1$ NM (95%).	Same
<b>Integrity</b>	Malfunction of aircraft nav equipment - Major failure condition ( $10^{-5}$ / hour)	Same
<b>Continuity</b>	Loss of function – Minor failure condition if operator can revert to different nav system and proceed to suitable airport	Same
<b>Signal-in-Space</b>	If using GNSS, same as Basic-RNP 1 Not applicable for D/D RNAV or D/D/I RNAV	Aircraft GNSS equipment should alert if probability of SIS errors causing lateral position error > 2 NM exceeds $10^{-7}$ / hour

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## System Monitoring and Alerting

- Basic-RNP 1:
  - The RNP System, or the RNP System and pilot in combination, shall provide an alert if the accuracy requirement is not met, or if the probability that the lateral TSE exceeds 2 NM is greater than  $10^{-5}$
- RNAV 1:
  - No requirement

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## Functional Requirements

### (RNAV 1 and Basic-RNP 1)

- Display functions - common in modern aircraft (3.3.3.3)
- Automatically execute leg transitions and maintain tracks
  - Initial Fix (IF), Course to Fix (CF), Direct to Fix (DF), Track to Fix (TF)
  - Direct-to leg can be manually initiated
  - Heading path terminators (VA, VM, and VI) can be manually flown
  - Capability to automatically execute leg transitions consistent with CA and FM path transitions, or ability to select desired course to/from designated waypoint
  - Capability to load ATS route by route name from on board data base
- Data base integrity
  - RTCA/DO-200A / EUROCAE ED76
  - Letter of Acceptance issued by appropriate regulatory Authority

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## Data base coding, description, capability

(COWBY2.COWBY) 05076      SI-462 (FAA)      LAS VEGAS/McCARRAN INTL (LAS) LAS VEGAS, NEVADA

**COWBY TWO DEPARTURE (RNAV)**

DEPARTURE ROUTE DESCRIPTION

TAKE-OFF RUNWAY 1L: Climb via 010° course to MCDUW WP, then via 065° track to cross NAPSE WP at or below 7000, then via 092° track to COWBY WP. Thence...

TAKE-OFF RUNWAY 1R: Climb via 010° course to PAWEK WP, then via 065° track to cross NAPSE WP at or below 7000, then via 092° track to COWBY WP. Thence...

TAKE-OFF RUNWAY 7L: Climb via 075° course to WASTE WP, then via 075° track to cross BAKRR WP at or below 7000, then via 085° track to COWBY WP. Thence...

TAKE-OFF RUNWAY 7R: Climb via 075° course to JESJI WP, then via 074° track to cross BAKRR WP at or below 7000, then via 085° track to COWBY WP. Thence...

(SOLD02.SOLD0) 05188      SI-629 (FAA)      DALLAS-FORT WORTH INTL (DFW) DALLAS-FORT WORTH, TEXAS

**SOLD0 TWO DEPARTURE (RNAV)**

DEPARTURE ROUTE DESCRIPTION

FREE AND EXPECT WAYPOINT HUBBARD DEPARTURE

JESJI

Jets requesting 17,000 feet below expect CARLAND DEPARTURE


TAKE-OFF RUNWAY 1L: Climb via 174° heading 080, then right turn direct TREXX, cross TREXX at or above 2000, then via specified route to SOLD0. Thence...

- Course
- Heading

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## Key Elements

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## Operating Procedures (RNAV 1 and Basic-RNP 1)




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## Pre-flight Planning

- Flight plan suffixes
  - Recommend filing maximum transponder and navigation capability, based upon desired services or routing
- Navigation database (based on WGS-84)
  - Aeronautical Information Regulation and Control (AIRAC) cycle
  - Supplier holding an EASA or FAA Letter of Acceptance (LOA) as described in AC 20-153
  - Stored data resolution sufficient for required track keeping accuracy
  - Database protected against pilot modification of stored data




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## Aircraft-Based Augmentation System (ABAS) Availability

- Notices to Airmen (NOTAMs)
- Prediction services (State or private)
- Guidance per operating authority
- Relevant to satellite constellation and avionics
- Assess for need to revert to alternative means of navigation




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## General Operating Procedures (1)

- Aircraft Flight Manual (AFM)
- Route checking
  - Navigation system waypoint sequence (textual and graphic)
  - Charts (paper or electronic)
  - Clearance
- Procedure retrieved by procedure name




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## General Operating Procedures (2)

- Use lateral deviation indicator, flight director, or autopilot in lateral navigation mode
- Maximum cross-track deviation limited to ½ times the navigation accuracy (e.g., 0.5 nm for RNAV 1) for normal operations on straight segments, 1 times the navigation accuracy (e.g., 1.0 nm for RNAV 1) during and after turns
- For RNP systems, ensure proper RNP (1.0) is displayed for Basic-RNP 1


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## Specific Standard Instrument Departure (SID) Requirements

- Important to verify proper runway selection, especially for parallel operations with multiple runway transitions
- Pilot must be able to follow flight guidance for lateral RNAV no later than 500 feet above airport elevation
- GNSS signal acquired before take-off roll (for operators of GNSS-equipped aircraft)
- For Basic-RNP 1, full scale sensitivity must be selected to not greater than 1 nm for SIDs extending more than 30 nm from the relevant airport (also applies to STARs)

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## Contingency Procedures


- Notify ATC of loss of navigation capability
- In event of lost communication; comply with specified, general or procedure-specific, guidance
- Where the contingency procedure requires reversion to a conventional arrival route, necessary preparation must be completed before commencing the RNAV route

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## Pilot Knowledge and Training


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## Pilot Knowledge and Training


- RNAV and RNP procedure characteristics
- Waypoint types and path terminators
- Required navigation equipment
- System-specific information
- Operating procedures including how to perform specific actions
- Operator-recommended levels of automation
- Phraseology for applications
- Contingency procedures

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## Operator Approval Process

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## Approval: Migration path to RNAV 1 and RNAV 2

Table 3-1: Additional Requirements for obtaining an RNAV 1 and RNAV 2 approval from a TOL-10 approval

Operator has TOL-10	Needs to confirm these performance capabilities to ICAO RNAV 1 and RNAV 2	Note
If approval includes use of DME/VOR. (DME/VOR may only be used as the only positioning input where this is explicitly allowed.)	RNAV 1 does not accommodate any routes based on DME/VOR RNAV.	RNAV system performance must be based on GNSS, DME/DME or DME/DME/RU. However, DME/VOR inputs do not have to be inhibited or deselected.
If approval includes use of DME/DME	No action required if RNAV system performance meets specific navigation service criteria in this Chapter 3.3.3.3.2 (DME/DME only) or 3.3.3.3.3 (DME/DME/RU).	Operator can ask manufacturer or check FAA website for list of compliant systems - see Note below this table.
RNAV SID Requirement with DME/DME Aircraft	Specific RNAV guidance available no later than 500m AFE on AC 90-100 Type B procedure.	Operator should add these operational procedures.
If approval includes use of GNSS	No action required	

Note:  
[http://www.faa.gov/about/office\\_org/headquarters\\_offices/avs/offices/afsa/afsa400/afsa410/policy\\_guidance/](http://www.faa.gov/about/office_org/headquarters_offices/avs/offices/afsa/afsa400/afsa410/policy_guidance/)

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## Approval: Migration path to RNAV 1 and RNAV 2

Table 3-2: Additional Requirements for obtaining RNAV 1 and RNAV 2 approval from an AC 90-100 approval

Operator has AC 90-100	Needs to confirm these performance capabilities to ICAO RNAV 1 and RNAV 2	Note
If approval based on GNSS (TSO-C129)	GPS pseudorange step detector and GPS health word checking is required in accordance with TSO C129a/TSO C129a.	Operator should check if pseudorange step detector and health word checking is supported by the installed GPS receiver or check if GPS receiver is approved in accordance with TSO C129a/TSO C129a.
No navigation database updating process required under AC 90-100.	Data supplier and avionics data supplier must have letter of assurance (LOA) in accordance with this chapter, paragraph 3.3.3.4.m.	Operator should ask data supplier for status for the RNAV equipment.

**Current: If operator has AC 90-100A approval, then RNAV 1 compliant.**

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**Approval: Basic-RNP 1**

- Guidance material currently in development by FAA and EASA
- Material is included for future applications

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**Example  
RNAV 1 Implementation**

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**US RNAV departures at Atlanta (USA)**

**BEFORE**

Significant track dispersion

Four departure fixes

**AFTER**

After RNAV Departures

Six departure fixes

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**Lessons Learned (1)**

- Coordination with stakeholders is critical to success
  - Manufacturers
  - Operators
  - Air Traffic Control
  - Other user groups
- TSO marking does not guarantee required functionality
  - Advisory material (e.g., AC/AMC) defines full installation criteria
- Ensure procedure coding is useable by desired population

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**Lessons Learned (2)  
Procedure Complexity**

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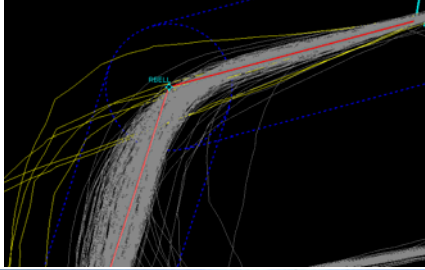
**Lessons Learned (3)  
Reduced Chart Clutter**

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**Lessons Learned (4)**

**Turn Anticipation:**  
variable for ambient conditions, altitude, angle of turn, phase of flight, avionics, and aircraft



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**Lessons Learned (5)**

- Use of simulator and flight trials
  - Highly encouraged
  - Use to identify any changes necessary prior to public implementation
- Public implementation
  - Delay initial procedure implementation following database and chart release
  - Be ready for path deviations
  - Conformance and overall operator participation will improve over time

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**Lessons Learned (6)**

- Controller expectations for flight path conformance must be realistic
  - Should allow for normal variations
  - Not be limited to depictions of the nominal path, flyability or simulation results alone
- Provide controllers with clear guidance on the interpretation of chart narratives, altitude, and speed information

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**Summary**

- RNAV 1 and Basic-RNP 1 differences:
  - RNAV 1 routes primarily developed for RNAV operations in a radar environment
  - May be used in non-radar environment if State assures system safety
  - Basic-RNP 1 intended for similar operations outside radar coverage (ATS surveillance limited or not available)
- Required navigation infrastructure and performance:
  - RNAV 1 uses DME/DME, DME/DME/IRU, or GNSS
  - Basic-RNP 1 primarily designed for GNSS
  - Functional performance requirements just as important as accuracy
- Flight crew operating procedures include certain requirements for RNAV system engagement as well as adherence to track
- Aircraft and operator eligibility requirements are listed in PBN Manual
  - PBN Manual provides standardized guidance, but not a stand-alone certification document
- Coordination among Operator, Regulator, and ANSP is crucial for success

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**Audience Response System Questions**

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**Backup Slides**

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## BACKUP: DME Receiver Labeled Performance

