Introduction to Navigation Specifications

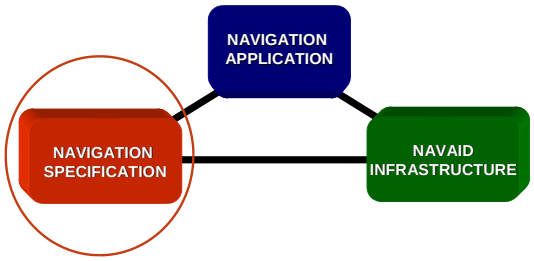
Learning Objectives

- **To review the organisation of PBN Manual Vol II**
- **To explain Vol II Part A, General**
  - PBN concept review
  - Navigation performance
    - System performance error components
    - Role and application of on-board performance monitoring and alerting
- **To describe the use and scope of navigation specifications**
- **To review the relationship with existing criteria**
- **To explain the structure and content of Vol II Parts B and C: the navigation specifications**
- **Summary**

Organisation of PBN Manual, Volume II

- **Part A: General**
- **Part B: Implementing RNAV applications *(including RNAV Specifications)***
- **Part C: Implementing RNP applications *(including RNP Specifications)***
- **Attachment A: Barometric VNAV**

PBN Concept Review (1)



PBN Concept Review (2)

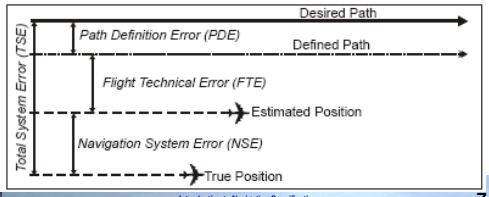
- **Requirements placed on the RNAV system**
  - Performance required for accuracy, integrity, continuity and availability
  - Functionalities necessary to achieve required performance
  - Navigation sensors to achieve required performance
  - Flight crew procedures to achieve required performance
- **RNP specifications require on-board performance monitoring and alerting…RNAV specifications do not**

Navigation Performance

- **System performance error components**
  - Lateral navigation errors
  - Longitudinal navigation errors
- **On-board performance monitoring and alerting**
  - Role
  - Application

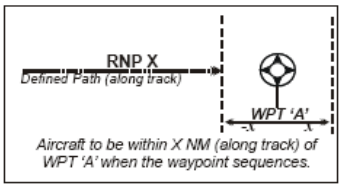
System Performance Error Components (1)

- **Lateral navigation errors (95%)**
  - Characterized by the Total System Error: TSE
  - TSE is the Root Sum Square (RSS) of 3 errors: PDE, NSE and FTE



System Performance Error Components (2)

- **Longitudinal navigation errors (95%)**
  - The TSE is characterized by the along-track navigation errors (NSE)
  - No FTE in longitudinal dimension
  - No current navigation specifications require 4-D control (time)



Role of On-board Performance Monitoring and Alerting (1)

- **To monitor TSE and alert if TSE budget is exceeded at aircraft level.**
- **The PBN concept uses "on-board performance monitoring and alerting" instead of "containment"**
- **Containment was used previously in different context and led to confusion: e.g. *containment area, contained airspace, containment value, containment distance, obstacle clearance containment***
- **Decision was to replace the containment value or the containment distance by the TSE value characterizing the *navigation accuracy***

Role of On-board Performance Monitoring and Alerting (2)

- **On-board performance monitoring and alerting:**
  - Allows the flight crew to determine whether the RNP system satisfies the navigation performance required in the navigation specification
    - Dependent on system architecture
  - Relates to both lateral and longitudinal navigation performance

Role of On-board Performance Monitoring and Alerting (3)

- **"On-board" means the performance monitoring and alerting is on-board the aircraft**
- **"Monitoring" relates to NSE and FTE**
  - PDE is constrained through database integrity and functional requirements on the defined path
  - "Monitoring" refers to the monitoring of the aircraft's performance; ability to determine positioning error (NSE) and/or to follow the desired path (PDE)
- **"Alerting" is related to monitoring**
  - Flight crew alerted if navigation system not performing to requirement

Application of On-board Performance Monitoring and Alerting (1)

- **A performance monitoring function**
  - Aircraft (or aircraft and pilot in combination)
  - Required to monitor TSE
  - Provides an alert if :
    - TSE requirement is not met
    - or if
    - probability that TSE exceeds 2x accuracy value is larger than 10^{-5}
- **Net effect of RNP navigation specifications is to bound TSE distribution**
  - PDE negligible (navigation data base integrity process)
  - FTE is known (manual flight or coupled flight)
  - NSE dynamically varies (propagation, geometry..)

Application of On-board Performance Monitoring and Alerting (2)

- **RNP navigation specifications provide assurance that TSE is suitable for the operation**
- **High confidence on aircraft position**
  - TSE remains ≤ required accuracy for 95% of flight time
    and
  - Probability TSE for each aircraft exceeds specified TSE (2xRNP) without annunciation is < 10^{-5}
- **Performance monitoring is not error monitoring**
  - Alert if detection of an error position or if it is not possible to determine if the position is accurate
    - An alert doesn't mean that the actual position is wrong

Application of On-board Performance Monitoring and Alerting (3)

- **Safety assessment**
  - Performance monitoring and alerting required for RNP navigation specifications (RNP 4, Basic-RNP 1 and RNP APCH) does not obviate need for safety assessments
  - Cannot assume appropriate route spacing is 4xRNP
  - Navigation database errors not covered by nav specs
- **RNP AR APCH specificities**
  - Additional requirements to more tightly control each error source
  - Aircraft requirements and/or crew procedures

Application of On-board Performance Monitoring and Alerting (4)

One possible implementation

NSE Monitoring and Alerting

Alerting Threshold: (1x accuracy) Nm
Pb missed alerting: 10-7/Fl Hr

FTE Monitoring and Alerting

Crew procedure based on display scaling
Effective threshold: ½ full scale deflection
Pb missed alerting: not quantified. Crew procedure.

PDE Monitoring and Alerting

Based on Data quality process
- LOA or equivalent
- Gross error check: Crew procedure

TSE Monitoring and Alerting

All error components monitored or controlled

Use and Scope of Navigation Specifications

- **Use and scope of navigation specifications by flight phase**
- **Relationship with existing criteria**
- **Vol II, Parts B and C organisation**
  - **Navigation specification template**

Use and Scope of Navigation Specification by Flight Phase

PBN Manual includes airworthiness, operational and training guidance

NAVIGATION SPECIFICATION	FLIGHT PHASE							
				APPROACH				
	En Route Oceanic / Remote	En Route Continental	ARR	Initial	Intermed	Final	Missed	DEP
RNAV 10 (RNP 10)	10							
RNAV 5		5	5					
RNAV 2		2	2					2
RNAV 1		1	1	1	1		1	1
RNP 4	4							
Basic-RNP 1			1	1	1		1	1
RNP APCH				1	1	0.3	1	
RNP AR APCH				1 - 0.1	1 - 0.1	0.3 - 0.1	1 - 0.1	

Use and Scope of Navigation Specifications

- **ICAO navigation specifications do not address all airspace requirements (e.g., comm, surv) necessary for operation in a particular airspace, route or area**
  - These will be listed in the AIP and ICAO Regional Supplementary Procedures
  - Incumbent upon States to undertake a safety assessment in accordance with provisions outlined in Annex 11 and PANS-ATM, Chapter 2
- **ICAO PBN Manual provides a standardized set of criteria, but is not a stand-alone certification document**
  - Examples: RNP 4, RNAV 1, RNP AR APCH

Navigation Specifications and the Approval Process

- **Navigation specifications are used by States as *basis* for aircraft certification and operational approval**
- **A navigation specification does not in itself constitute regulatory guidance material**
  - Aircraft approved by State of manufacture
  - Operators approved in accordance with their National Operating Rules
- **Compliance with one navigation specification does not guarantee compliance with another**

Relationship with Existing Criteria

- **Not re-inventing the wheel**
- **Taking existing criteria e.g., Orders, ACs, AMC, and TGL etc.**
- **A more logical structure**
- **Common format and content**
- **More complete to enable uniform implementation**

Navigation Specification
Common Organisation of Volume II, Parts B and C

Where "X" represents the chapter number:

- **X.1 Introduction**
- **X.2 ANSP Considerations**
- **X.3 Navigation Specification**
- **X.4 References**

Navigation Specification
Section X.2 :Air Navigation Service Provider Considerations (1)

- **Navigation infrastructure**
  - Sufficient for proposed operation, including reversionary modes
- **Communication and ATS surveillance**
  - Determine reliance on radar
- **Obstacle clearance and route spacing**
  - References PANS-OPS
- **Publication**
  - Incorporation into AIP, and reference to ICAO Annex 15

Navigation Specification
Section X.2 :Air Navigation Service Provider Considerations (2)

- **Controller**
  - Core training and training specific to the Nav Spec
- **Status monitoring**
  - Navaid infrastructure monitoring
  - Notam issuance
- **ATS System monitoring**
  - Feedback in case of navigation error (crew or ATC report)
  - Prevent re-occurrence of navigation error

Navigation Specification
Overview of Specific Navigation Services

	GNSS	IRU	D/D	D/D/IRU	D/VOR
RNAV 10	√	√			
RNAV 5	√	√	√	√	√
RNAV 2/1	√		√	√	
RNP 4	√				
Basic-RNP 1	√				
RNP APCH	√				
RNP AR APCH	√				

Navigation Specification
Section X.3

- **Background**
- **Approval process**
- **Aircraft requirements**
- **Operating procedures**
- **Pilot knowledge and training**
- **Navigation database**
- **Oversight of operators**

Navigation Specification
Section X.3 : Approval Process

- **Aircraft Eligibility**
  - Must be demonstrated
  - Can be based on Aircraft Flight Manual or supplemental information
- **Operational Approval**
  - Operating procedures
  - Flight crew training
  - Control of navigation database process, where required
- **Approval obtained in accordance with State operating rules**

Navigation Specification
Section X.3 Aircraft Requirements

- **Performance Requirements**
  - Accuracy, Integrity, Continuity, GNSS signal-in-space
  - Performance monitoring and alerting
    - Only applicable for RNP systems
- **Criteria for Specific Navigation Services**
  - Defines allowable systems and required performance
- **Functional requirements**
  - Just as important as performance
- **Navigation database requirements**
  - **When required**

Navigation Specification
Section X.3 Operating Procedures

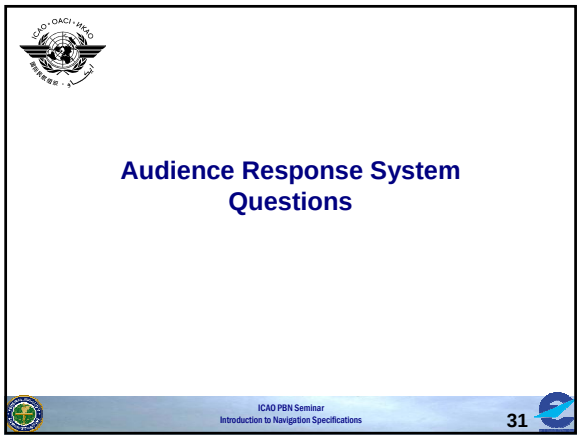
- **Pre-flight planning**
- **General operating procedures**
  - **During the flight**
- **Performance expectations (deviation from path)**
  - Pilot has critical role in performance monitoring
- **Contingency procedures**
  - **E.g. procedure In case of RNAV system failure**

Navigation Specification
Section X.3 Pilot Knowledge and Training

- **Lists training tasks considered important, which may <u>already</u> be part of operator's training program**
- **System-specific information on how navigation system functions is vital to success**

Summary

- **PBN Concept = navigation specification + navaid infrastructure + navigation application**
- **Navigation performance**
  - System performance error components
  - On board performance monitoring and alerting
- **Use and scope of navigation specifications**
  - Navigation Specification provides implementation guidance for PBN operations → not a stand-alone certification document
- **Relationship with existing criteria**
- **Common organization of Vol II Parts B and C**
  - ANSP considerations, navigation specification (aircraft requirement and operational requirements)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