EASA
European Union Aviation Safety Agency

PBN Operational Approvals Workshop

Javier Cabrera Espinós

Bangkok, 3rd to 5th of February, 2020

Your safety is our mission.

An Agency of the European Union

EU-South East Asia Aviation Partnership Project (EU-SEA APP)
This project is funded by the European Union and implemented by the European Union Aviation Safety Agency - EASA

EASA
European Union Aviation Safety Agency

Opening and Introductions

PBN Operational Approvals Workshop

An Agency of the European Union

Opening and Introductions

Personal introduction

→ Javier Cabrera Espinós

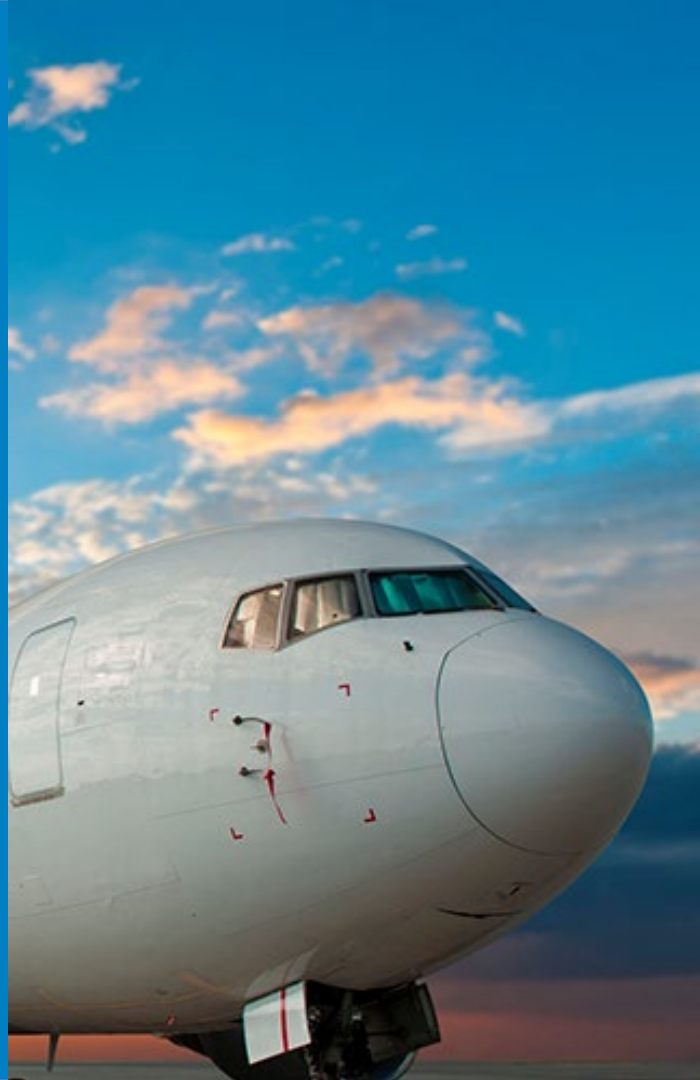
→ Aeronautical Engineer

→ Email: altair1605@hotmail.com

EASA
European Union Aviation Safety Agency

General Considerations

PBN Operational Approvals Workshop



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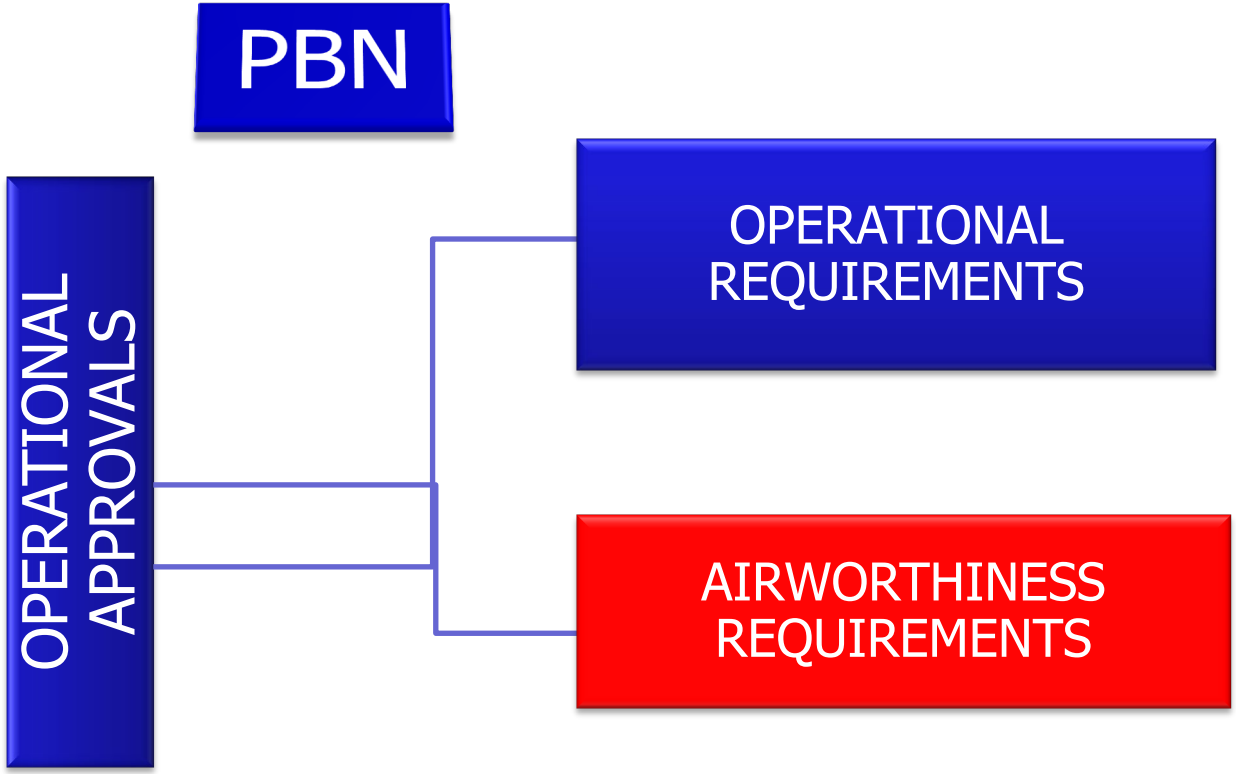
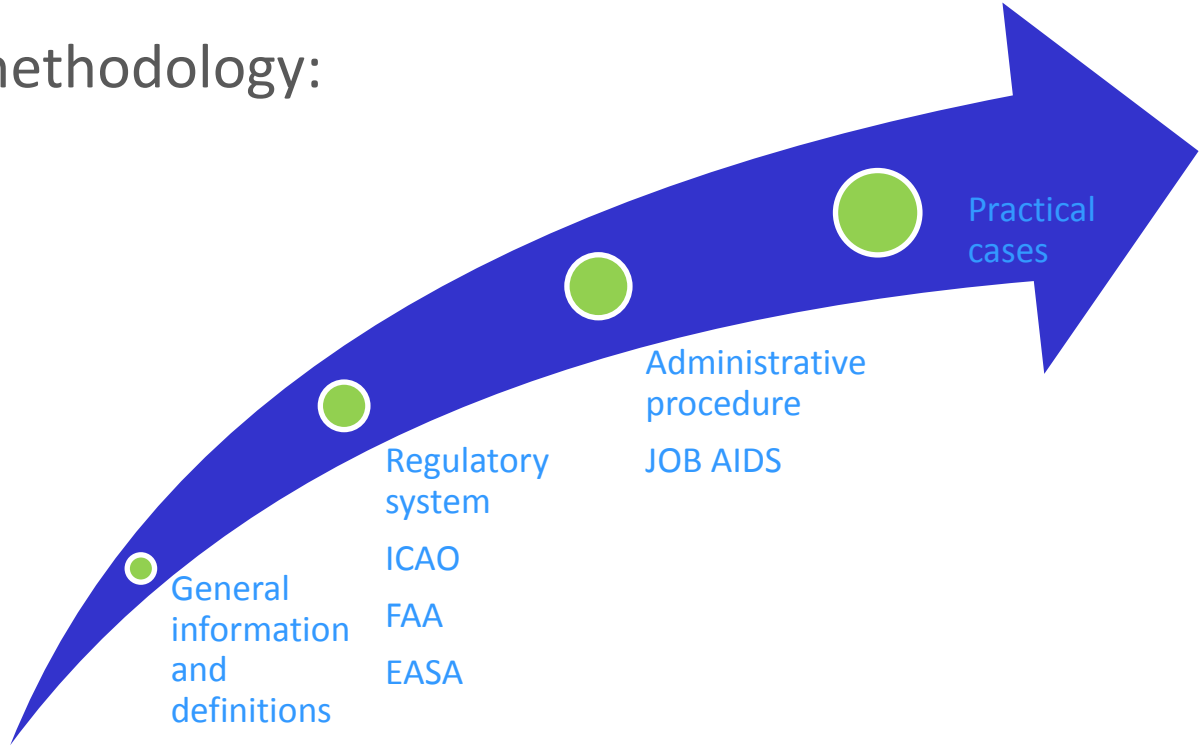
General Considerations

General Considerations



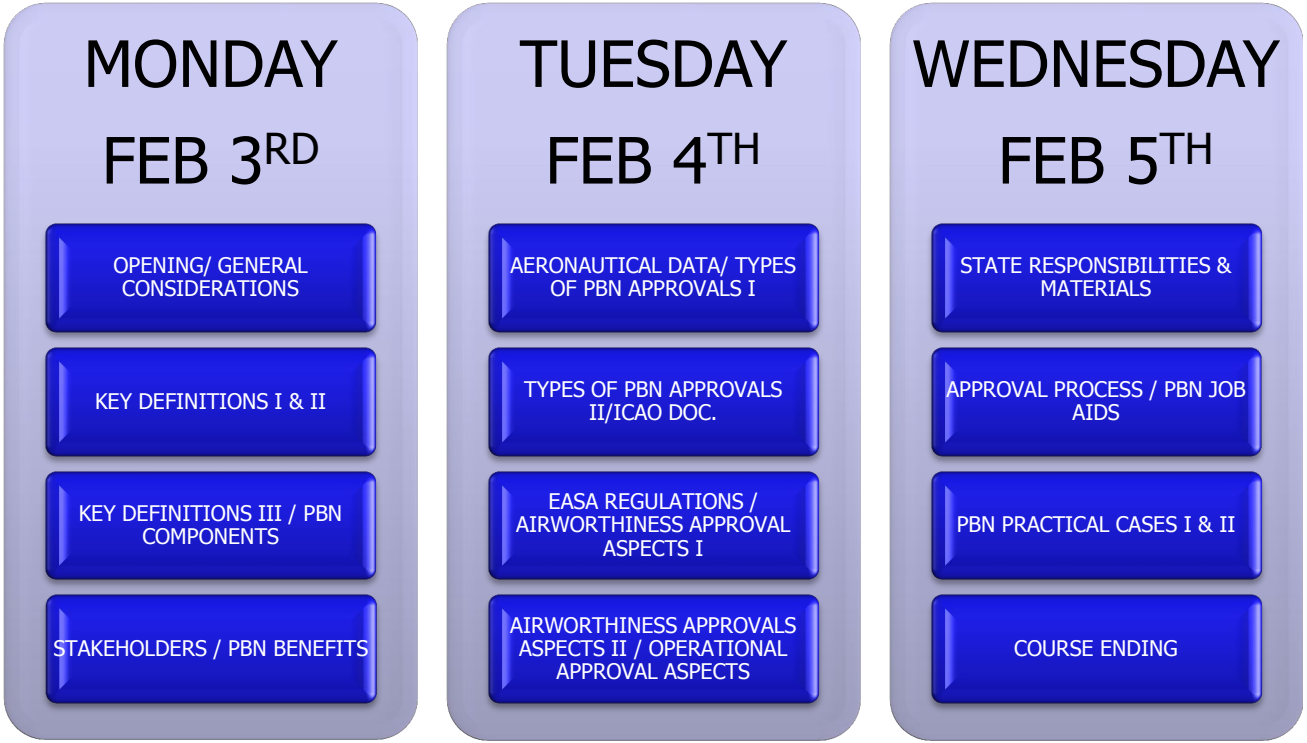
General Considerations

Delivery methodology:



General Considerations

Course schedule



General Considerations

03/02/2020 (First Day)

TIME	TITLE, SPEAKER
08:00 – 08:30	**REGISTRATION**
08:30 – 09:00	**Opening and Introductions** Instructor Mr. Javier Cabrera Espinós. EASA Expert Participant Introductions EASA EU-South East Asia Aviation Partnership Project,
09:00 – 09:30	**General Considerations** Instructor Mr. Javier Cabrera Espinós. EASA Expert
09:30 – 10:00	**GROUP PHOTO AND COFFEE BREAK**
10:00 – 10:45	**Key Definitions I** Instructor Mr. Javier Cabrera Espinós. EASA Expert
10:45 – 11:30	**Key Definitions II** Instructor Mr. Javier Cabrera Espinós. EASA Expert
11:30 – 12:30	**LUNCH BREAK**
12:30 – 13:15	**Key Definitions III** Instructor Mr. Javier Cabrera Espinós. EASA Expert
13:15 – 14:00	**PBN Components** Instructor Mr. Javier Cabrera Espinós. EASA Expert
14:00 – 14:30	**COFFEE BREAK**
14:30 – 15:00	**Stake Holder Uses of PBN** Instructor Mr. Javier Cabrera Espinós. EASA Expert
15:00 – 16:00	**PBN Benefits / Implementation Matters** Instructor Mr. Javier Cabrera Espinós. EASA Expert

General Considerations

General Considerations

Table 1: Overview of PBN specifications

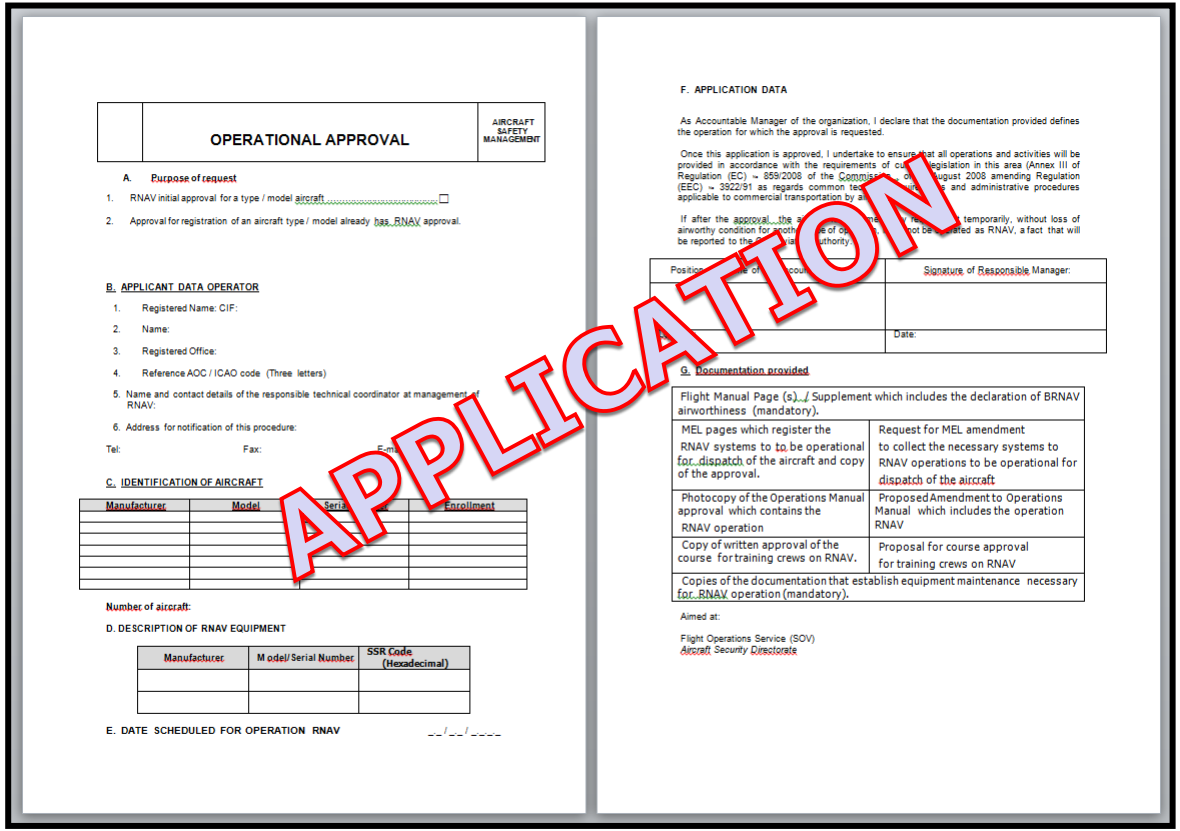
	FLIGHT PHASE							
	En-route		Arrival	Approach				Departure
	Oceanic	Continental		Initial	Intermediate	Final	Missed	
RNAV 10	10							
RNAV 5		5	5					
RNAV 2		2	2					2
RNAV 1		1	1	1	1		1	1
RNP 4	4							
RNP 2	2	2						
RNP 1			1	1	1		1	1
A-RNP	2	2 or 1	1–0.3	1–0.3	1–0.3	0.3	1–0.3	1–0.3
RNP APCH (LNAV)				1	1	0.3	1	
RNP APCH (LNAV/VNAV)				1	1	0.3	1	
RNP APCH (LP)				1	1		1	
RNP APCH (LPV)				1	1		1	
RNP AR APCH				1–0.1	1–0.1	0.3-0.1	1–0.1	
RNP 0.3 (H)		0.3	0.3	0.3	0.3		0.3	0.3

Numbers specify the accuracy level no specific approval required specific approval required

General Considerations

RNP AR APCH

RNP 0.3 (H)



OPERATIONAL APPROVAL

AIRCRAFT SAFETY MANAGEMENT

A. Purpose of request

1. RNAV initial approval for a type / model aircraft ☐
2. Approval for registration of an aircraft type / model already has RNAV approval.

B. APPLICANT DATA OPERATOR

1. Registered Name: CIF:
2. Name:
3. Registered Office:
4. Reference AOC / ICAO code (Three letters)
5. Name and contact details of the responsible technical coordinator at management of RNAV:
6. Address for notification of this procedure:

Tel: Fax: E-mail:

C. IDENTIFICATION OF AIRCRAFT

Manufacturer	Model	Serial	Enrollment

Number of aircraft:

D. DESCRIPTION OF RNAV EQUIPMENT

Manufacturer	Model/ Serial Number	SSR Code (Hexadecimal)

E. DATE SCHEDULED FOR OPERATION RNAV __/__/____

F. APPLICATION DATA

As Accountable Manager of the organization, I declare that the documentation provided defines the operation for which the approval is requested.

Once this application is approved, I undertake to ensure that all operations and activities will be provided in accordance with the requirements of civil legislation in this area (Annex III of Regulation (EC) ¬ 859/2008 of the Commission of August 2008 amending Regulation (EEC) ¬ 3922/91 as regards common technical and administrative procedures applicable to commercial transportation by air

If after the approval, the aircraft temporarily, without loss of airworthy condition for another type of operation, it will not be qualified as RNAV, a fact that will be reported to the civil authority

Position	Signature of Responsible Manager:
	Date:

G. Documentation provided

Flight Manual Page (s) / Supplement which includes the declaration of BRNAV airworthiness (mandatory).	
MEL pages which register the RNAV systems to to be operational for dispatch of the aircraft and copy of the approval.	Request for MEL amendment to collect the necessary systems to RNAV operations to be operational for dispatch of the aircraft
Photocopy of the Operations Manual approval which contains the RNAV operation	Proposed Amendment to Operations Manual which includes the operation RNAV
Copy of written approval of the course for training crews on RNAV.	Proposal for course approval for training crews on RNAV
Copies of the documentation that establish equipment maintenance necessary for RNAV operation (mandatory).	

Aimed at:

Flight Operations Service (SOV)
Aircraft Security Directorate

APPLICATION

General Considerations

"complex" PBN approval

SPA.PBN.105 PBN operational approval

Regulation (EU) 2016/1199

To obtain a PBN specific approval from the competent authority, the operator shall provide evidence that:

(a) the relevant airworthiness approval, suitable for the intended PBN operation, is stated in the AFM or other document that has been approved by the certifying authority as part of an airworthiness assessment or is based on such approval;

(b) a training programme for the flight crew members and relevant personnel involved in the flight preparation has been established;

(c) a safety assessment has been carried out;

(d) operating procedures have been established specifying:

(1) the equipment to be carried, including its operating limitations and appropriate entries in the minimum equipment list (MEL);

(2) flight crew composition, qualification and experience;

(3) normal, abnormal and contingency procedures; and

(4) electronic navigation data management;

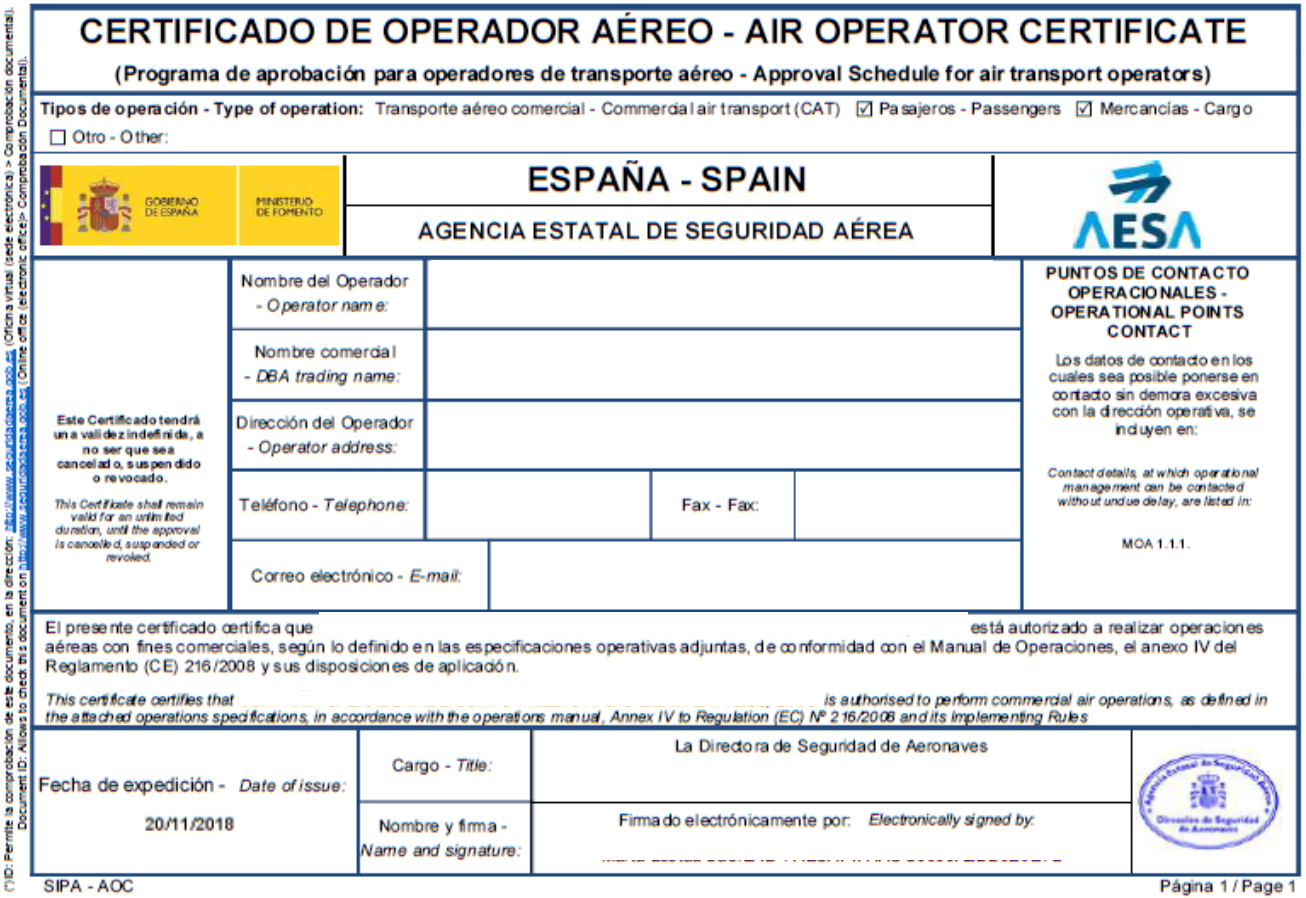
(e) a list of reportable events has been specified; and

(f) a management RNP monitoring programme has been established for RNP AR APCH operations, if applicable.

RNP AR APCH

RNP 0.3 (H)

General Considerations



CERTIFICADO DE OPERADOR AÉREO - AIR OPERATOR CERTIFICATE

(Programa de aprobación para operadores de transporte aéreo - Approval Schedule for air transport operators)

Tipos de operación - Type of operation: Transporte aéreo comercial - Commercial air transport (CAT) ☑ Pasajeros - Passengers ☑ Mercancías - Cargo

☐ Otro - Other:

GOBIERNO DE ESPAÑA — MINISTERIO DE FOMENTO

ESPAÑA - SPAIN

AGENCIA ESTATAL DE SEGURIDAD AÉREA

AESA

Este Certificado tendrá una validez indefinida, a no ser que sea cancelado, suspendido o revocado.

This Certificate shall remain valid for an unlimited duration, until the approval is cancelled, suspended or revoked.

Nombre del Operador - *Operator name:*	
Nombre comercial - *DBA trading name:*	
Dirección del Operador - *Operator address:*	
Teléfono - *Telephone:*	Fax - Fax:
Correo electrónico - *E-mail:*	

PUNTOS DE CONTACTO OPERACIONALES - OPERATIONAL POINTS CONTACT

Los datos de contacto en los cuales sea posible ponerse en contacto sin demora excesiva con la dirección operativa, se incluyen en:

Contact details, at which operational management can be contacted without undue delay, are listed in:

MOA 1.1.1.

El presente certificado certifica que está autorizado a realizar operaciones aéreas con fines comerciales, según lo definido en las especificaciones operativas adjuntas, de conformidad con el Manual de Operaciones, el anexo IV del Reglamento (CE) 216/2008 y sus disposiciones de aplicación.

This certificate certifies that is authorised to perform commercial air operations, as defined in the attached operations specifications, in accordance with the operations manual, Annex IV to Regulation (EC) Nº 216/2008 and its implementing Rules

Fecha de expedición - *Date of issue:* 20/11/2018	Cargo - *Title:*	La Directora de Seguridad de Aeronaves
	Nombre y firma - *Name and signature:*	Firmado electrónicamente por: *Electronically signed by:*

Agencia Estatal de Seguridad Aérea — Dirección de Seguridad de Aeronaves

SIPA - AOC

Página 1 / Page 1

(*) ID: Permite la comprobación de este documento, en la dirección: https://www.sedeaesa.gob.es (Oficina virtual (sede electrónica) > Comprobación documental). Document ID: Allows to check this document on https://www.sedeaesa.gob.es (Online office (electronic office)> Comprobación Documental).

General Considerations

ESPECIFICACIONES DE OPERACIONES - *OPERATIONS SPECIFICATIONS*

(Sujetas a las condiciones aprobadas en el Manual de Operaciones) - *(Subject to the approved conditions in the Operations Manual)*

Datos de contacto de la autoridad expedidora - *Issuing authority contact details*

AESA | Tel: +34 91 396 80 00 | Fax: +34 91 396 80 | E-mail: aesa@fomento.es

AOC #: ES.AOC.117 | COMPAÑIA OPERADORA DE CORTO Y MEDIO RADIO IBERIA EXPRESS, S.A.U. | Firma *Signature*: | Fecha *Date*: (*)

Especificaciones de operaciones nº - *Operations specifications*: ES.AOC.117 -313

Véase última página para Observaciones adicionales. *See last page for Additional remarks.*

Modelo de la aeronave - *Aircraft Model*: AIRBUS A320-211

Matrícula - *Registration Marks*:

El operador tiene aprobado un procedimiento para gestión interna de las matrículas operadas bajo este AOC.
The operator has an approved procedure for internal management of aircraft registration marks, operated under this AOC.

Tipos de operación - *Type of operation*: Transporte aéreo comercial - *Commercial air transport (CAT)*

☑ Pasajeros - *Passengers* ☑ Mercancías - *Cargo* ☐ Otros - *Ot*

Zona de operaciones - *Area of operation*: (*) C3 C4 C5 C7

(*) Véase última página para códigos de Zona de Operación. *See last p*

Limitaciones Especiales - *Special Limitations*:

APROBACIONES ESPECÍFICAS *SPECIFIC APPROVALS*			SI *YES*	NO	
Mercancías Peligrosas. *Dangerous goods.*			☑	☐	
Operaciones con baja visibilidad *Low visibility operations*					
Aproximación y aterrizaje. *Approach and landing.*			☑	☐	CAT I CAT II CAT IIA (DH 50 ft) (RVR 200 m)
Despegue. *Take-off.*			☐	☑	
RVSM.	N/A	☐	☑	☐	
ETOPS.	N/A	☐	☐	☑	
Especificación de navegación complejas para operaciones PBN. *Complex navigation specifications for PBN operations.*			☐	☑	
Especificación mínima de performance de navegación. *Minimum navigation performance specification.*			☐	☑	
Operaciones con helicópteros con la ayuda de sistemas de visión nocturna de imágenes. *Helicopter operations with the aid of night vision imaging systems.*			☐	☑	
Operaciones de vuelo de helicópteros con grúas de rescate. *Helicopter hoist operations.*			☐	☑	
Operaciones de servicio médico de emergencias con helicópteros. *Helicopter emergency medical service operations.*			☐	☑	
Cartera Electrónica de Vuelo (EFB) *Electronic Flight Bag (EFB)*			☑	☐	EFB Portátil. Portable EFB
Instrucción de tripulación de cabina. *Cabin crew training.*			☑	☐	
Expedición del atestados CC. *Issue of CC attestation.*			☐	☑	
Mantenimiento de la Aeronavegabilidad. *Continuing airworthiness.*			☑	☐	ES.MG.157
Otros *Other*					

(*) Firmado electrónicamente en la fecha indicada en la página 1. *(Electronically signed on date shown in page 1).*

Especificación de navegación complejas para operaciones PBN.
Complex navigation specifications for PBN operations.

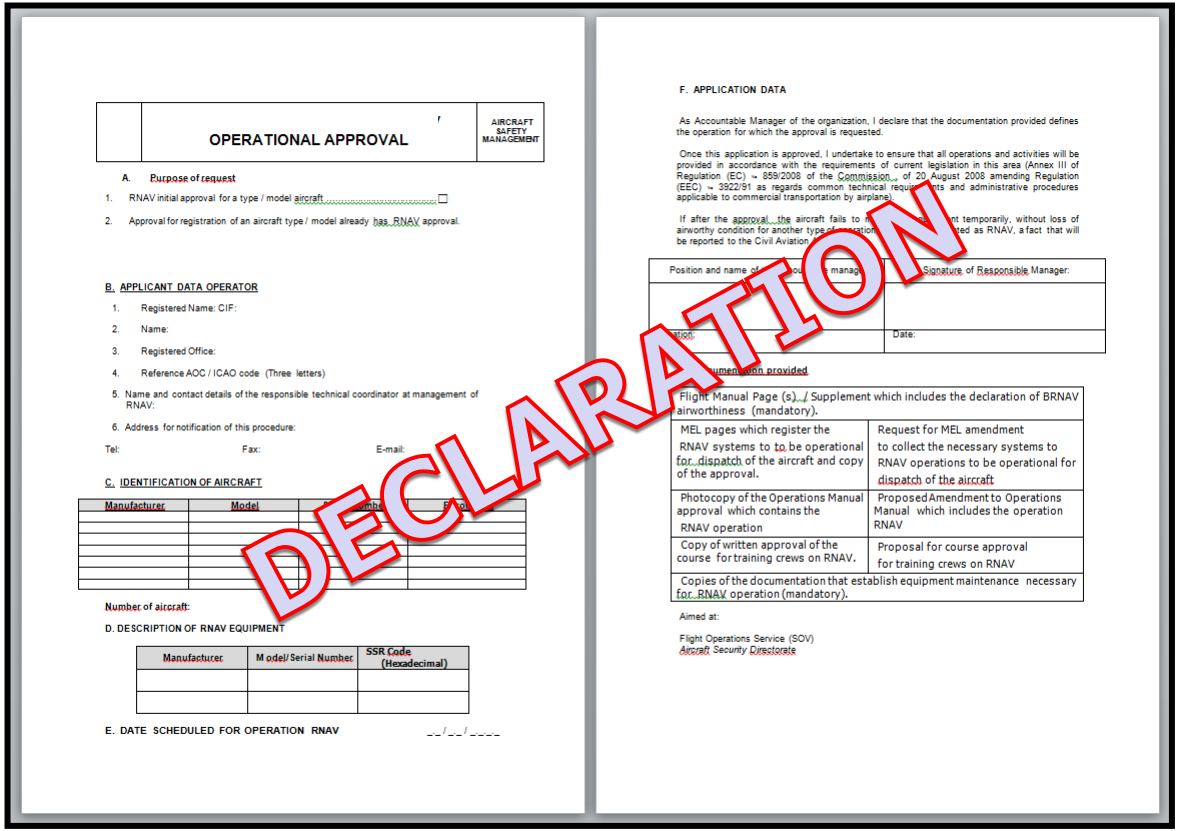
☐ ☑

RNP AR APCH

RNP 0.3 (H)

General Considerations

- RNAV 10
- RNAV 5
- RNAV 2
- RNAV 1
- RNP 4
- RNP 2
- RNP 1
- A-RNP
- RNP APCH (LNAV)
- RNP APCH (LNAV/VNAV)
- RNP APCH (LP)
- RNP APCH (LPV)



OPERATIONAL APPROVAL

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3. Registered Office:
4. Reference AOC / ICAO code (Three letters)
5. Name and contact details of the responsible technical coordinator at management of RNAV:
6. Address for notification of this procedure:

Tel: Fax: E-mail:

C. IDENTIFICATION OF AIRCRAFT

Manufacturer	Model		

Number of aircraft:

D. DESCRIPTION OF RNAV EQUIPMENT

Manufacturer	Model/Serial Number	SSR Code (Hexadecimal)

E. DATE SCHEDULED FOR OPERATION RNAV __/__/____

F. APPLICATION DATA

As Accountable Manager of the organization, I declare that the documentation provided defines the operation for which the approval is requested.

Once this application is approved, I undertake to ensure that all operations and activities will be provided in accordance with the requirements of current legislation in this area (Annex III of Regulation (EC) ¬ 859/2008 of the Commission , of 20 August 2008 amending Regulation (EEC) ¬ 3922/91 as regards common technical requirements and administrative procedures applicable to commercial transportation by airplane).

If after the approval the aircraft fails to [illegible] temporarily, without loss of airworthy condition for another type of operation [illegible] as RNAV, a fact that will be reported to the Civil Aviation

Position and name of [illegible] manager:	Signature of Responsible Manager:
[illegible]:	Date:

[illegible] provided

Flight Manual Page (s) / Supplement which includes the declaration of BRNAV airworthiness (mandatory).	
MEL pages which register the RNAV systems to to be operational for dispatch of the aircraft and copy of the approval.	Request for MEL amendment to collect the necessary systems to RNAV operations to be operational for dispatch of the aircraft
Photocopy of the Operations Manual approval which contains the RNAV operation	Proposed Amendment to Operations Manual which includes the operation RNAV
Copy of written approval of the course for training crews on RNAV.	Proposal for course approval for training crews on RNAV
Copies of the documentation that establish equipment maintenance necessary for RNAV operation (mandatory).	

Aimed at:

Flight Operations Service (SOV)
Aircraft Security Directorate

DECLARATION

General Considerations

"non-complex" PBN approval

AMC1 CAT.OP.MPA.126 Performance-based navigation

ED Decision 2016/015/R

PBN OPERATIONS

For operations where a navigation specification for performance-based navigation (PBN) has been prescribed and no specific approval is required in accordance with SPA.PBN.100, the operator should:

(a) establish operating procedures specifying:

(1) normal, abnormal and contingency procedures;

(2) electronic navigation database management; and

(3) relevant entries in the minimum equipment list (MEL);

(b) specify the flight crew qualification and proficiency constraints and ensure that the training programme for relevant personnel is consistent with the intended operation; and

(c) ensure continued airworthiness of the area navigation system.

General Considerations

EQUIPMENT LEVEL APPROVAL

NAVIGATOR BOX
e.g. GPS of type ABC

- GPS could be a sensor in multi-sensor system or a self-contained and stand-alone navigator;

AIRCRAFT LEVEL APPROVAL

- Installation approval on aircraft against an EASA AMC or FAA AC which includes an operational context e.g. RNAV 5;

OPERATOR LEVEL APPROVAL

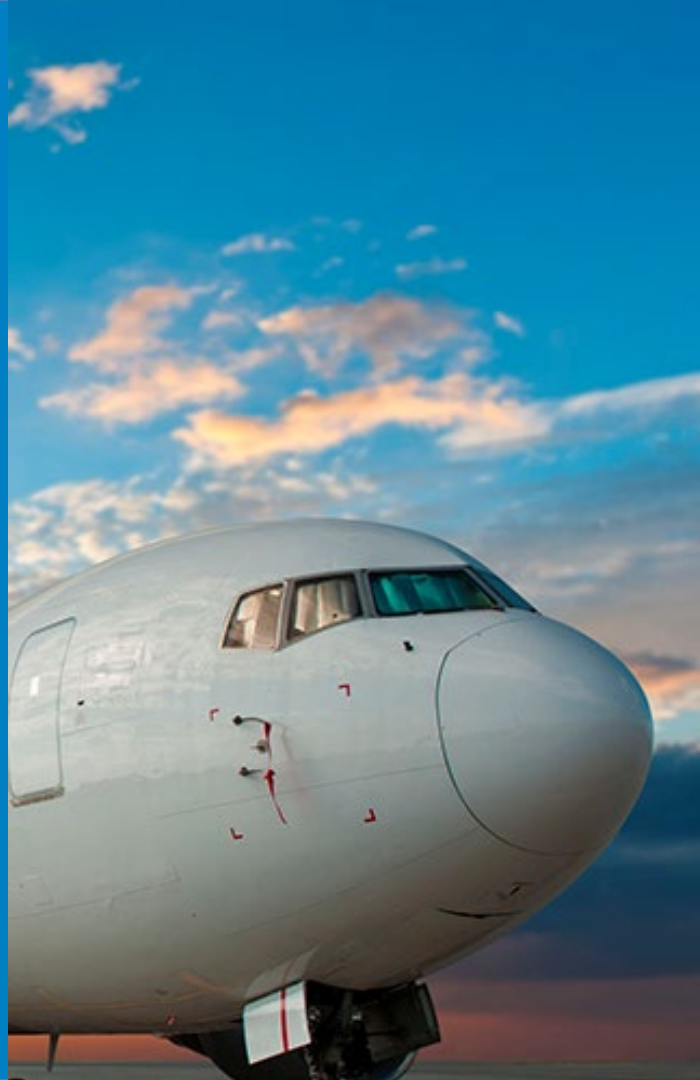
+

- For the aircraft installation to be used by pilot, operational approval needed.
- Operational Approval is concerned with training, flight crew procedures, quality, database management, etc.

EASA
European Union Aviation Safety Agency

Key Definitions I

PBN Operational Approvals Workshop



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Key Definitions I

Performance Based Navigation

Key Definitions I

There are two kinds of **navigation specifications**:

→ **RNAV** area navigation and

→ **RNP** required navigation performance.

Main objective: reduce lateral spacing between routes

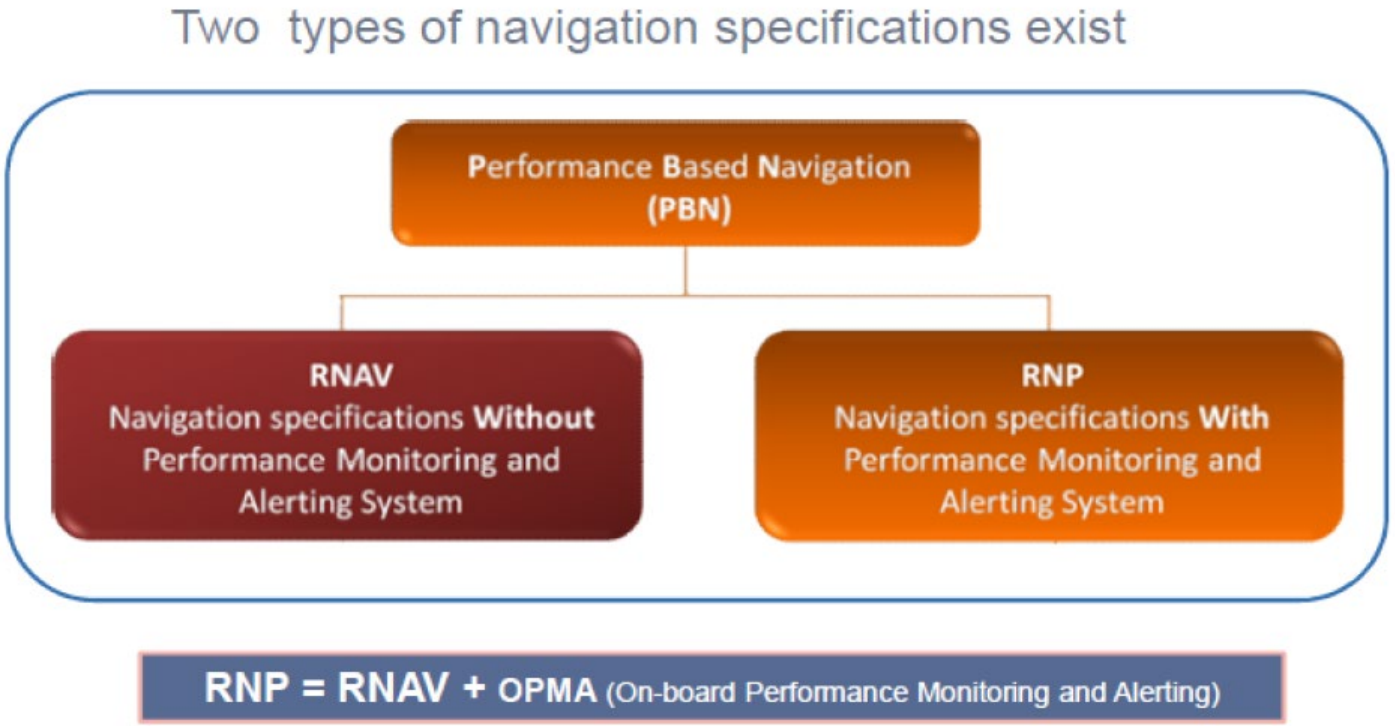
Key Definitions I

These specifications are similar. The key difference is:

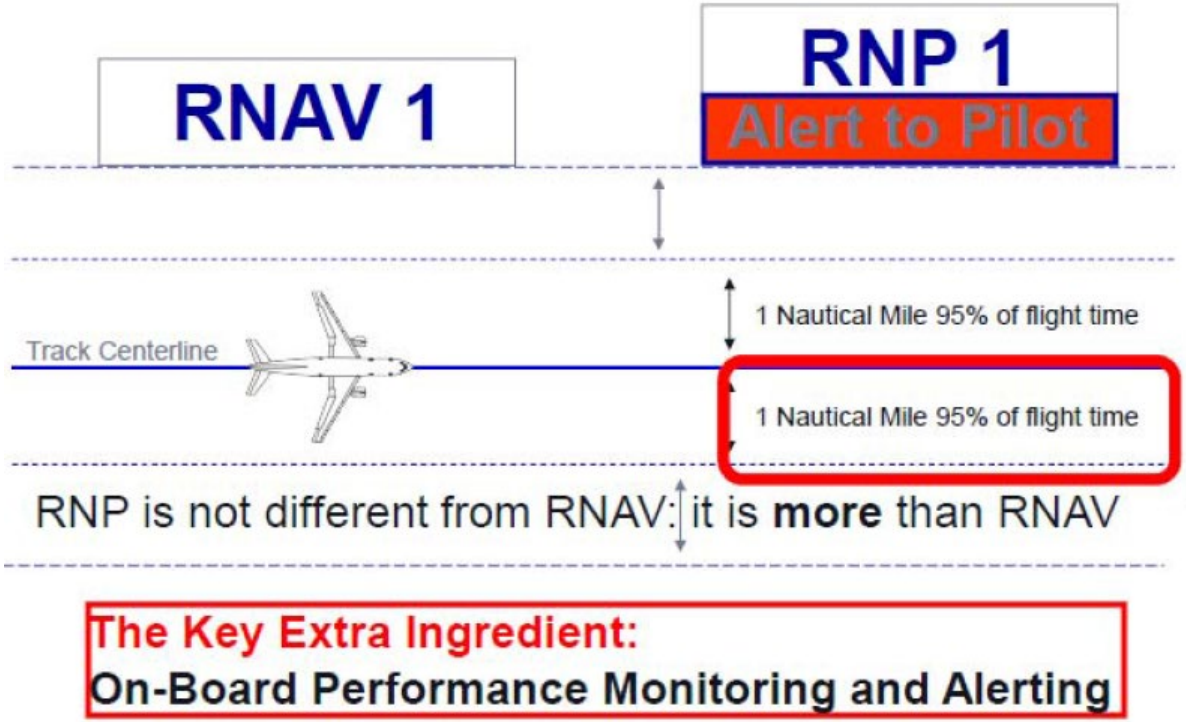
→ **RNP specification**: a navigation specification that includes a requirement to have an **on-board performance monitoring and alerting system**

→ A **RNAV specification** does not have such a requirement.

Key Definitions I

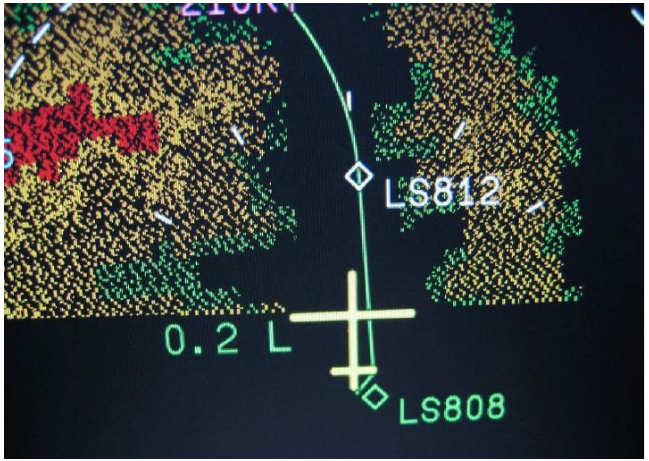


Key Definitions I



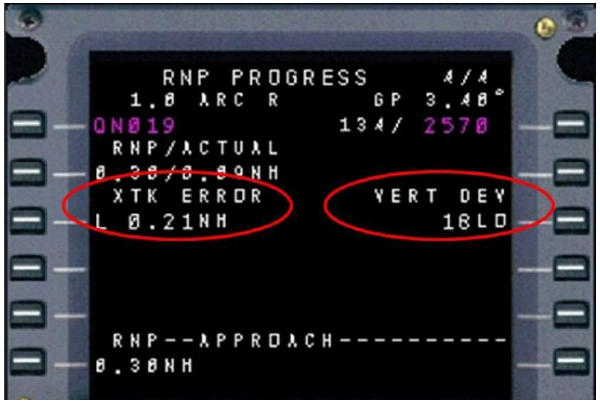
Key Definitions I

Monitoring and alert systems



Example of cross-track deviation display in 1/10th NM

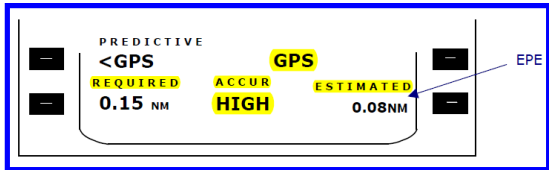
Alert annunciated on Boeing 737NG navigation display

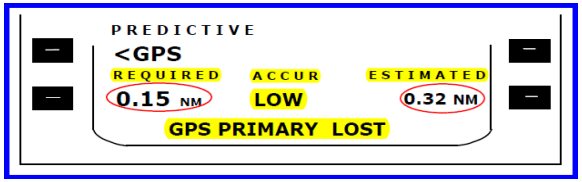


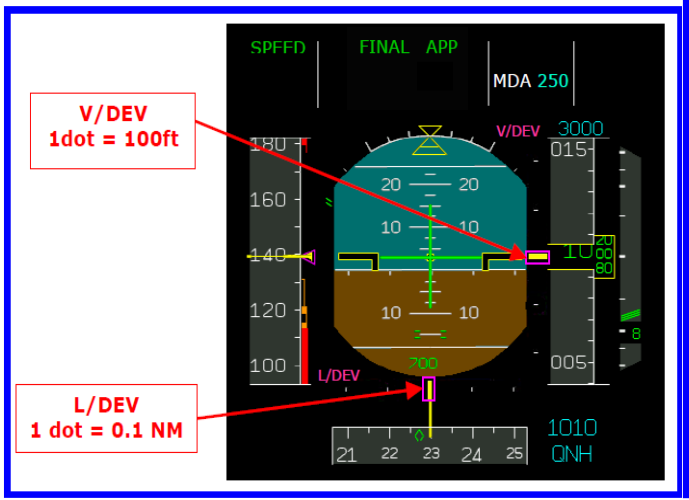
Cross-track and Vertical Deviations shown on Control and Display Unit

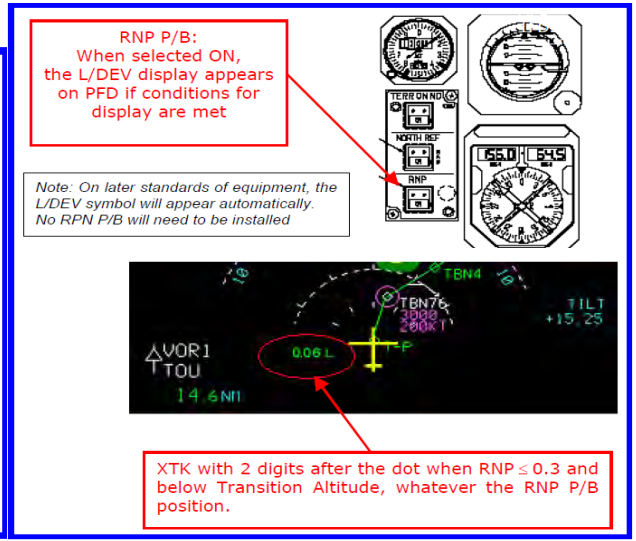
Key Definitions I

Monitoring and alert systems









Key Definitions I

- The performance-monitoring and alerting system provides some automated assurance functions to the flight crew.
- These functions monitor the performance of the systems and alert the flight crew when the RNP parameters are not met, or cannot be guaranteed with a sufficient level of integrity.

Key Definitions I

RNP and RNAV specifications

ANOTHER DIFFERENCES?

Key Definitions I

RNAV

→ Traditionally, the "required navigation performance" was ensured by the **mandatory use of certain equipment** on board.

→ The development of new equipment and technologies made it impracticable to continue with this laborious method of selection.

Key Definitions I

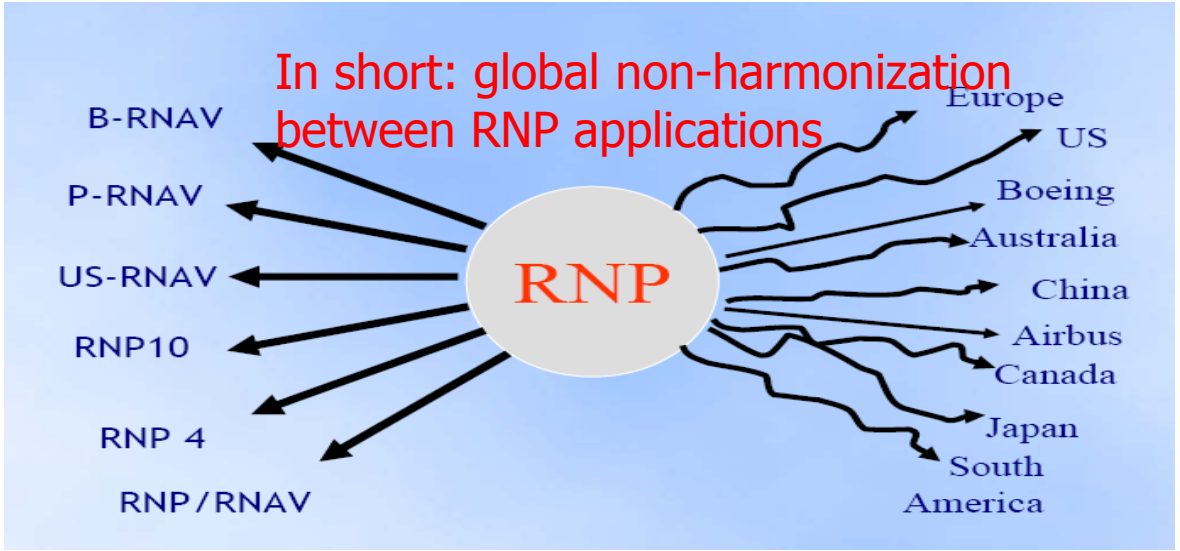
RNP

→ Instead of equipment, it is focused on Functional Requirements

→ Each "TYPE" RNP defines the navigation performance for all users of a given airspace and has a correspondence with the navigation capability available in that airspace

Key Definitions I

Wide variety of Functional Requirements



Variety of Sensors Required for Navigation

Different requirements for crews

Key Definitions I

PBN specifies that the performance requirements of the aircraft RNAV or RNP system must be defined in terms of

→ Accuracy

→ Integrity

→ Availability

→ Continuity

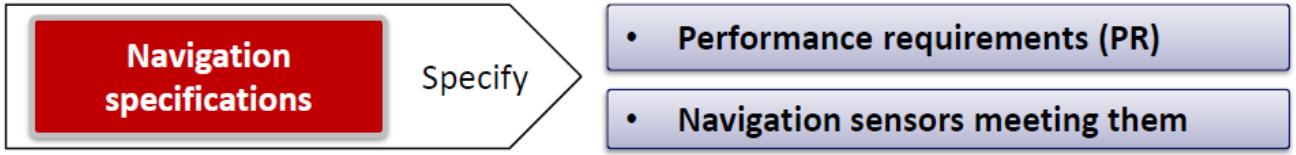
→ Functionality

required for proposed operations in the **context of a particular airspace**

Key Definitions I

Unlike conventional navigation, PBN is not sensor-specific

The **PBN concept** represents a shift from sensor-based to PBN



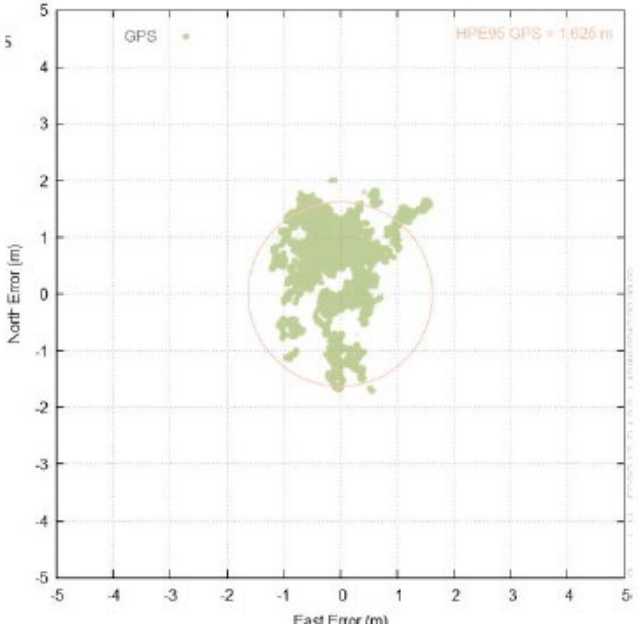
A certain set of PRs may be met by more than one sensor.

Key Definitions I

Performance based navigation

ACCURACY

(04) Definition "*conformance of the true position and the required position*"



Example of GPS static measurements

Key Definitions I

Performance based navigation

Availability

(09) Definition “percentage of time (annually) that the services of the system are usable by the navigator”

(Alt: proportion of time during which reliable navigation information is presented to the crew, autopilot, or other system managing the flight of the aircraft)

The availability of a system (or service) establishes the percentage of time during when the operation (for example a final approach) can be started.

Key Definitions I

Performance based navigation

Continuity

(05) Definition “capability of the system to perform its function without unscheduled interruptions during the intended operation”

(Alt from ICAO SARPS: It relates to the capability of the navigation system to provide a navigation output with the specified accuracy and integrity during the approach, assuming that it was available at the start of the operation)

The continuity of the system guarantees that once an operation (for example a final approach) is initiated, it will not be interrupted.

Key Definitions I

Performance based navigation

Integrity

(06) Definition “a measure of the trust that can be placed in the correctness of the information supplied”

The system must have the ability to provide timely and valid alerts to the user

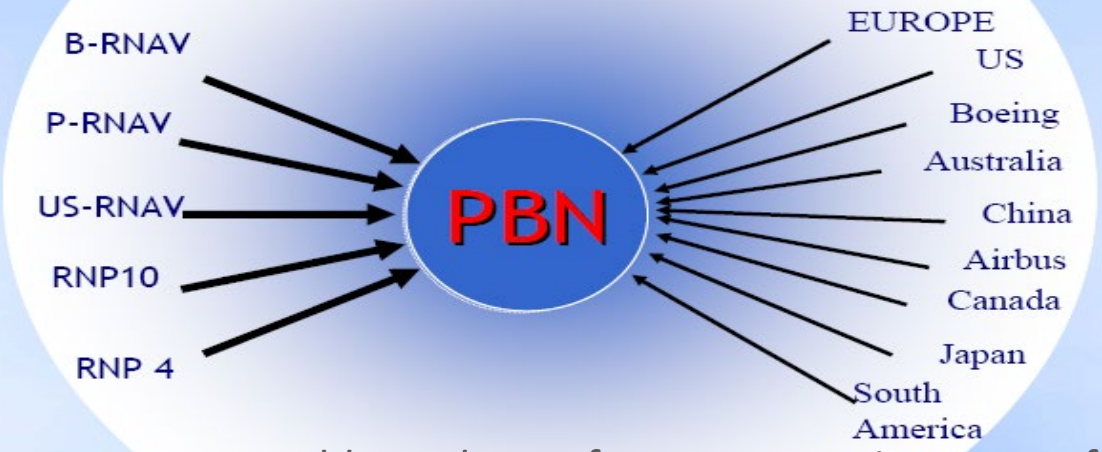
Loss of Integrity Alert for a Garmin G1000 (source: Garmin)

The integrity of the system (or service) establishes to which degree the navigation source can be trusted during the flight.

Key Definitions I

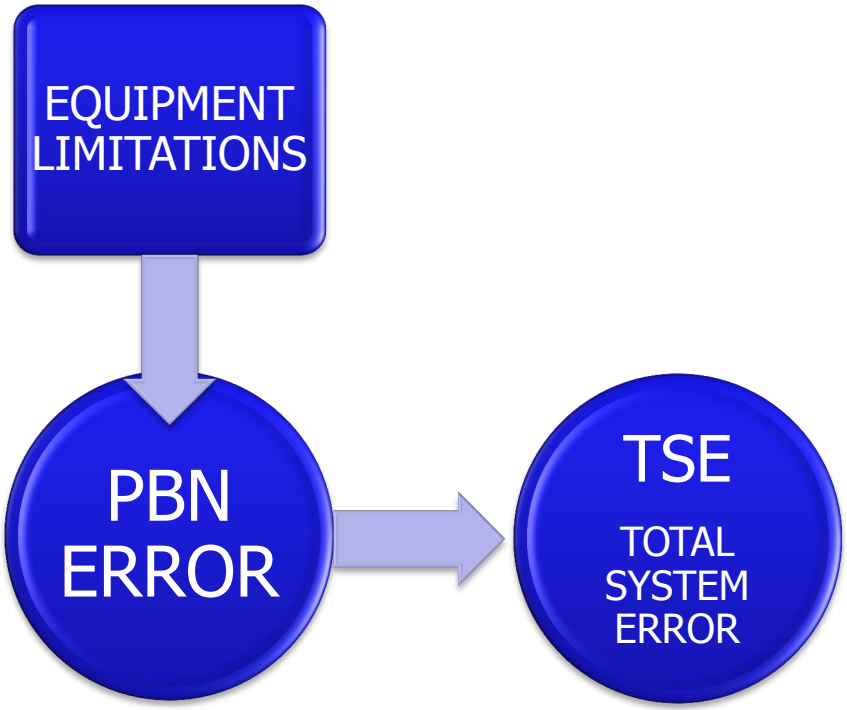
Provide a uniform and harmonized interpretation of the RNP and RNAV specifications.

PBN Objectives



Address the performance requirements of navigation of new RNP specifications applied to airspace of terminal area and approach.

Key Definitions I

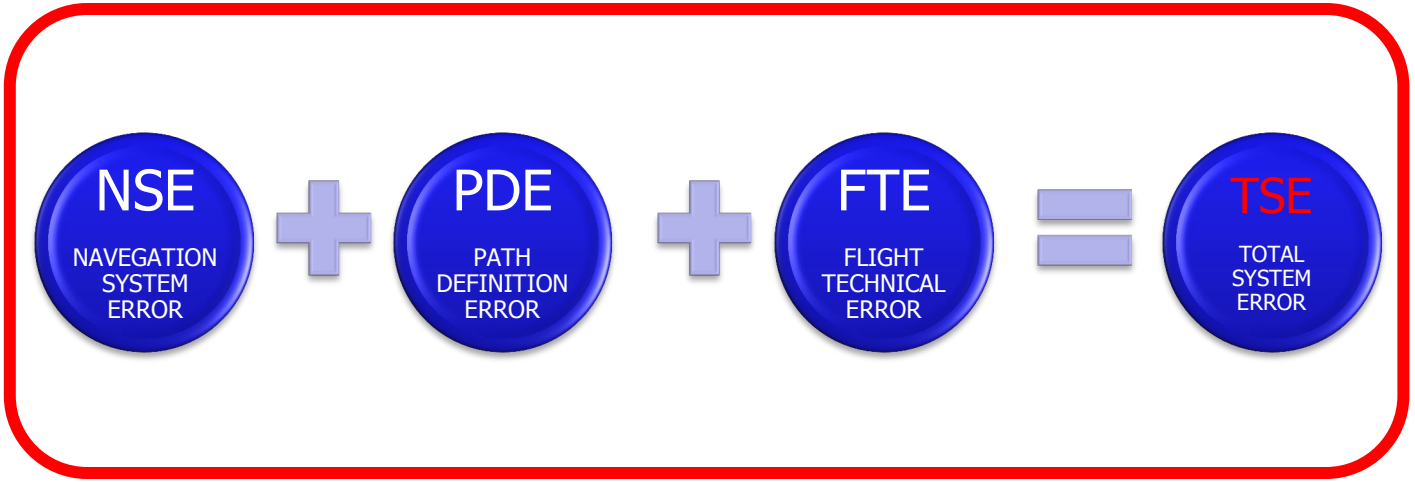


Key Definitions I

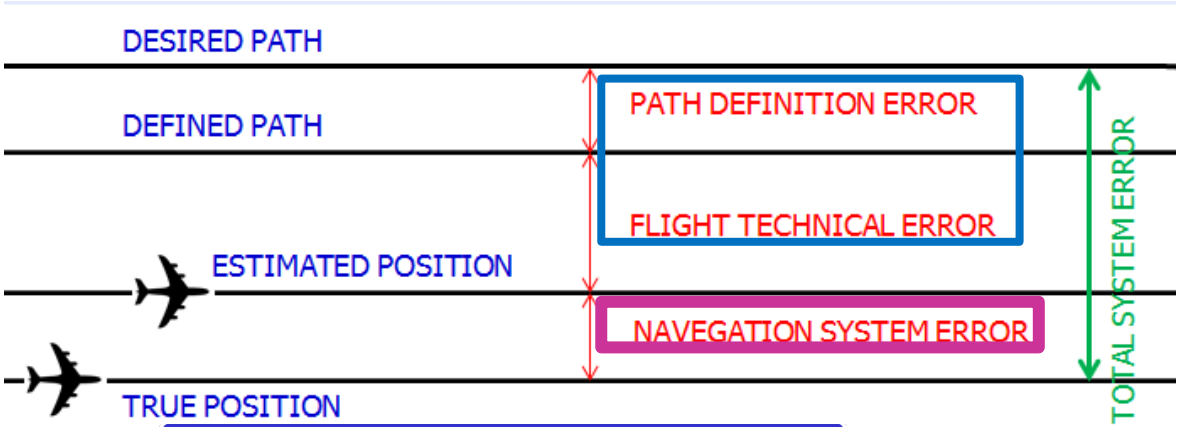
TSE: Is the deviation from the nominal or desired position and the aircraft's true position, measured in nautical miles.

It should remain equal to or less than the required accuracy expected to be achieved at least 95 % of the flight time by the population of aircraft operating within the airspace, route or procedure.

Key Definitions I



Key Definitions I



NSE: Navigation System Error

- Refers to the difference between the aircraft's estimated position and actual position.

PDE: Path Definition Error

- Occurs when the path defined in the RNAV system does not correspond to the desired path, i.e. the path expected to be flown over the ground (because wind vector may not be repeatable, or because target altitude is dependent on engine thrust and aircraft weight).

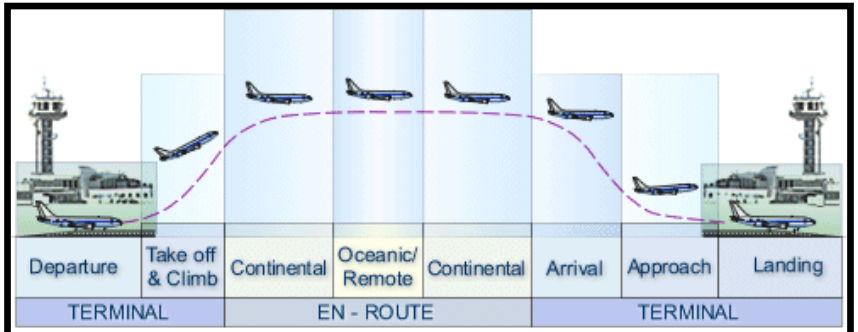
FTE: Flight Technical Error

- Relates to the air crew or autopilot's ability to follow the defined path or track, including any display error (e.g. course deviation indicator (CDI) centring error)

Key Definitions I

PBN

Flight Phases



	Flight Phase	Navigation Specification	Required Accuracy (TSE)	Enabling System
EN-ROUTE	Oceanic /Remote	RNAV 10	± 10 NM (95%)	GPS/INS
		RNP4	± 4 NM (95%)	GPS
	Continental	RNAV 5	± 5 NM (95%)	VOR/DME /GPS/INS
		RNAV 2	± 2 NM (95%)	
		RNAV 1	± 1 NM (95%)	
TERMINAL	Arrival/ Departure	RNAV 2	± 2 NM (95%)	DME/GPS
		RNAV 1	± 1 NM (95%)	DME/GPS
		Basic - RNP 1	± 1 NM (95%)	GPS
	Approach /Landing	RNP APCH	Down to 0.3 NM in final approach phase (95%)	GPS
		RNP AR APCH	Down to 0.1NM in final approach phase (95%)	GPS

Navigation Specification

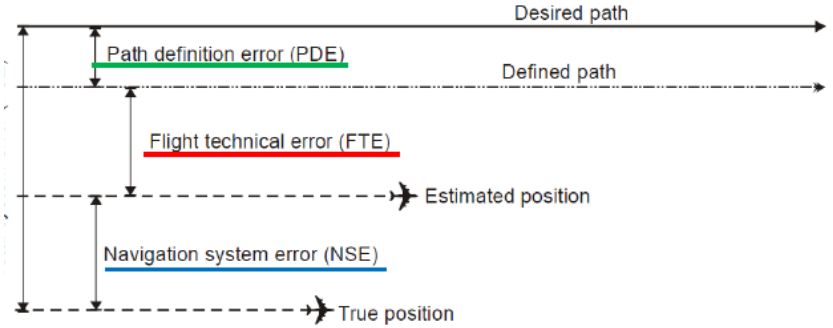
Key Definitions I

There are 3 main independent lateral errors in the context of on-board performance monitoring and alerting. Together they account for the **Total System Error (TSE), which forms the basis for performance estimation and monitoring**

(01) ***Path Definition Error (PDE)****: occurs when the path defined in the RNAV system (database) does not correspond to the desired path, i.e. the path expected to be flown over the ground*

(02) ***Flight Technical Error (FTE)****: relates to the air crew or autopilot's ability to follow the prescribed path or track, including any display error (e.g. CDI centering error). Sometimes, if adding display error, referred as PSE (Path Steering Error)*

(03) ***Navigation System Error (NSE)****: refers to the difference between the aircraft's estimated position and actual position. The accuracy of a navigation system may be referred to as* ***EPE (Estimated Position Error)****.*



CE **(04) Total System Error (TSE):** Root Sum of PDE, FTE and NSE

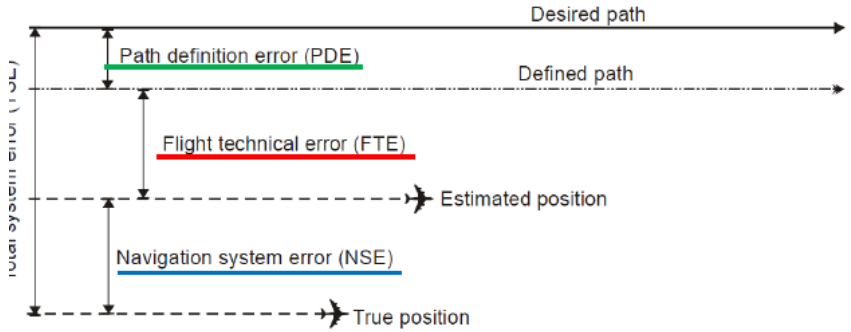
(05) The navigation accuracy depends on the TSE

With SBAS, expect: NSE << FTE

Key Definitions I

This function allows the air crew to detect whether or not the RNP system satisfies the navigation performance required (requirements based on TSE) in the navigation specification

- **On-board** means that the performance monitoring and alerting is effected on board the aircraft and not elsewhere
- **Monitoring** refers to the monitoring of the aircraft's performance as regards its ability to determine positioning error and/or to follow the desired path
- **Alerting** relates to monitoring: if the aircraft's navigation system does not perform well enough, this will be alerted to the air crew



- ***Path Definition Error (PDE)**: cannot be monitored or controlled but generally is sufficiently small that it can be ignored.*
- ***Flight Technical Error (FTE)**: FTE can be controlled by the flight crew and should be minimized.*
- ***Navigation System Error (NSE)**: cannot be controlled by the flight crew but should be monitored to ensure that it remains within acceptable limits. **That is why it is characterized by the ANP (Actual Navigation Performance)***

Key Definitions I

REMINDER!
RNAV specifications do not require monitoring and alerting functions!

	RNAV specification	RNP specifications	
		RNP X specification not requiring RF or FRT	RNP X specification requiring RF or FRT
NSE (monitoring and alerting)	Requires no alerting on position error or pilot cross-check of NSE.	Alerting on position accuracy and integrity.	
FTE (monitoring)	Managed by on-board system or crew procedure.	Managed by on-board system or crew procedure. More specific display scaling.	
PDE (monitoring)	Assumed to be zero; the desired path is not defined on turns.		Assumed to be zero; path defined on RF and FRT.
NET EFFECT ON TSE	TSE distribution not bounded. In addition, the wide variation in turn performance results in need for extra protection on turns.	TSE distribution bounded, but extra protection needed on turns;	TSE distribution bounded; no extra protection needed if turns defined by RF or FRT.

CE

(01) *On board performance monitoring and alerting of FTE is managed by on board systems or crew procedures*

Example: RAIM or FDE algorithm + CDI crew monitoring

CE

(02) *On board performance monitoring and alerting of NSE is a requirement of on-board equipment for RNP*

Example: RAIM or FDE algorithm

CE

(06) *On board performance monitoring and alerting of PDE are managed by gross reasonableness of navigation data*

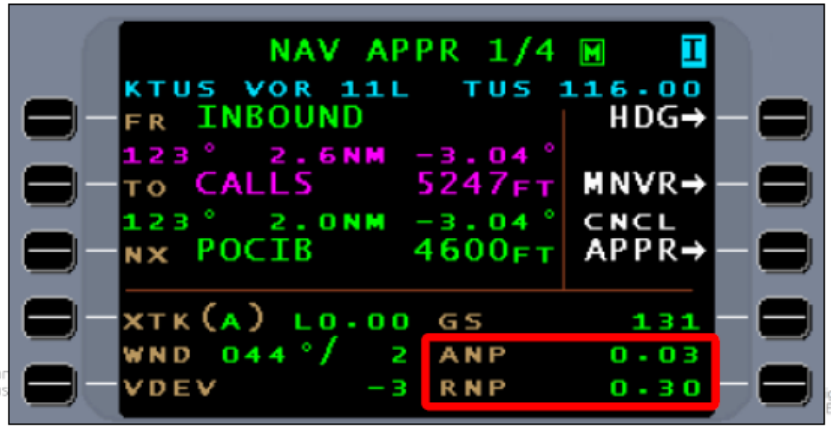
Key Definitions I

- On-board performance monitoring **shall not be regarded as error monitoring**
- Alerts are issued when the system cannot guarantee with sufficient integrity that the position meets the accuracy requirement
- When an alert is issued, the probable reason is the loss of capability to validate the position data (insufficient satellites being a potential reason in the case of GNSS)

In other words, even if the position was able to meet the accuracy requirement, since the system is unable to prove it, an alert would be issued.

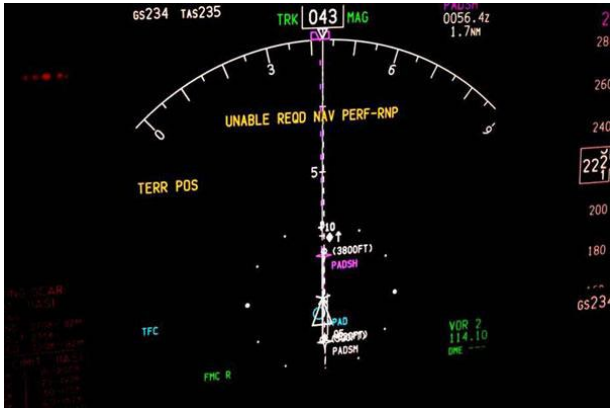
Key Definitions I

Depending on the navigation sensor, ANP is compared with the RNP:



Key Definitions I

Depending on the navigation sensor, ANP is compared with the RNP:



Boeing

When ANP exceeds RNP, an UNABLE RNP message is displayed to the flight crew. This indicates that the FMS position does not meet the required accuracy, so the procedure (such as an approach) must be aborted.

Key Definitions I

❖ CE 965/2012

Table 1: Overview of PBN specifications

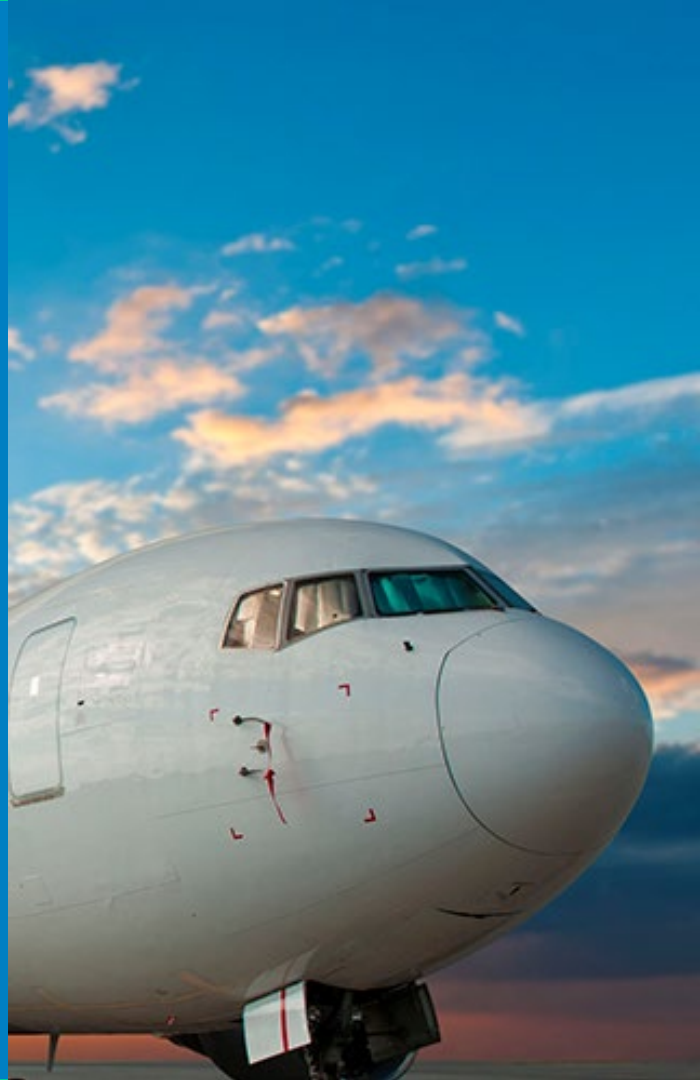
	FLIGHT PHASE							
	En-route		Arrival	Approach				Departure
	Oceanic	Continental		Initial	Intermediate	Final	Missed	
RNAV 10	10							
RNAV 5		5	5					
RNAV 2		2	2					2
RNAV 1		1	1	1	1		1	1
RNP 4	4							
RNP 2	2	2						
RNP 1			1	1	1		1	1
A-RNP	2	2 or 1	1–0.3	1–0.3	1–0.3	0.3	1–0.3	1–0.3
RNP APCH (LNAV)				1	1	0.3	1	
RNP APCH (LNAV/VNAV)				1	1	0.3	1	
RNP APCH (LP)				1	1		1	
RNP APCH (LPV)				1	1		1	
RNP AR APCH				1–0.1	1–0.1	0.3-0.1	1–0.1	
RNP 0.3 (H)		0.3	0.3	0.3	0.3		0.3	0.3

Numbers specify the accuracy level no specific approval required specific approval required

EASA
European Union Aviation Safety Agency

Key Definitions II

PBN Operational Approvals Workshop



An Agency of the European Union

Key Definitions II

Study case:

Basic random area navigation

Key Definitions II

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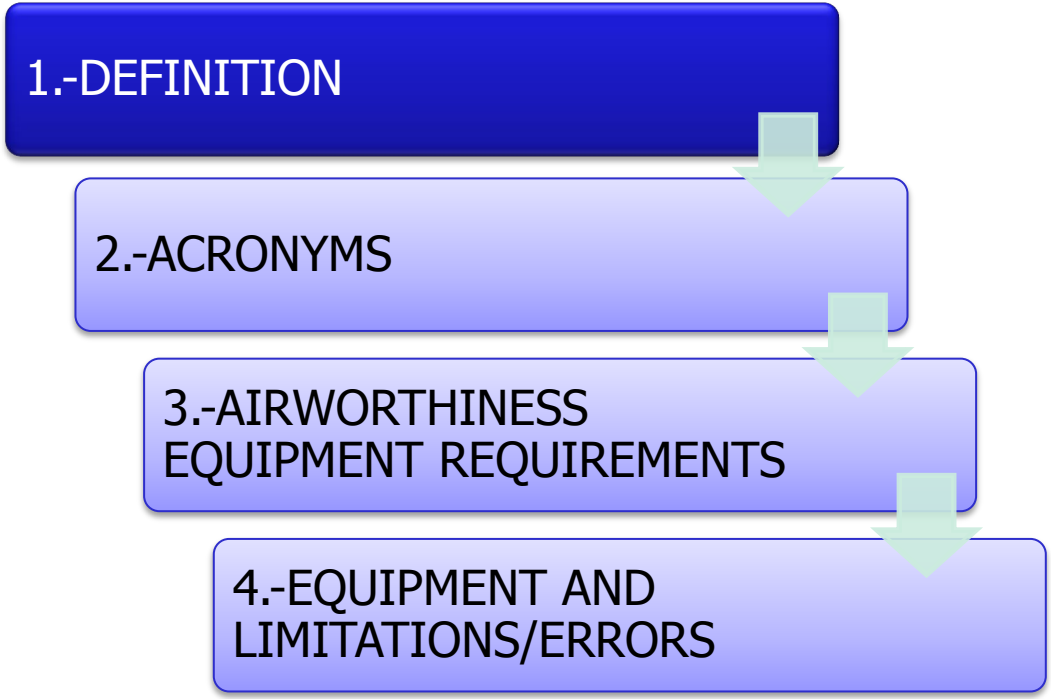
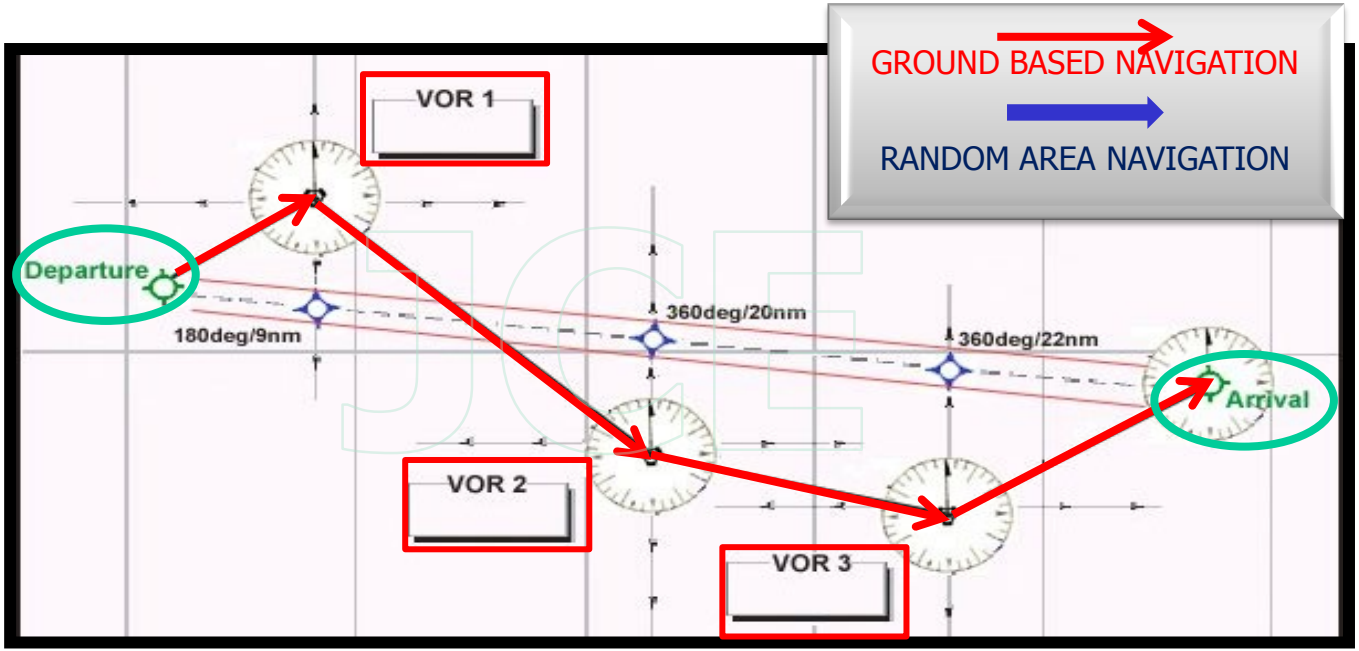


Key Definitions II

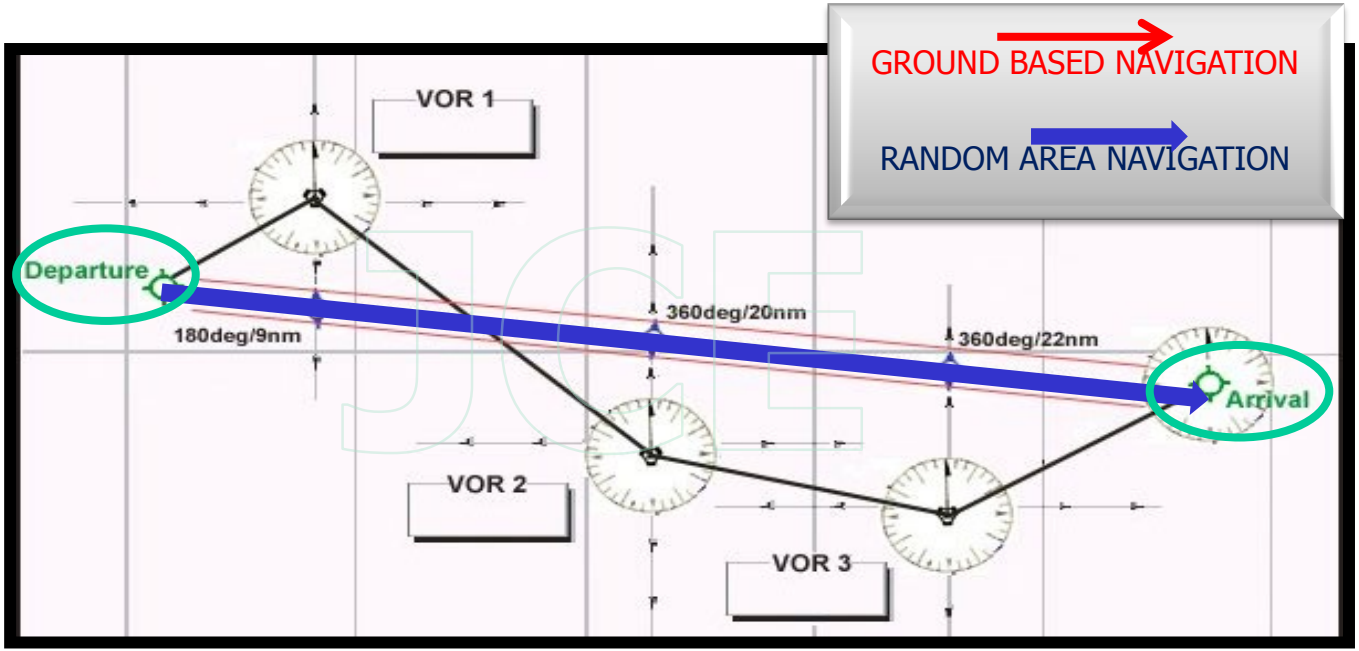
Random area navigation (RNAV) ‼️

→ Method of navigation that permits aircraft operation on any desired course within the coverage of station-referenced navigation signals or within the limits of a self-contained system capability.

Key Definitions II

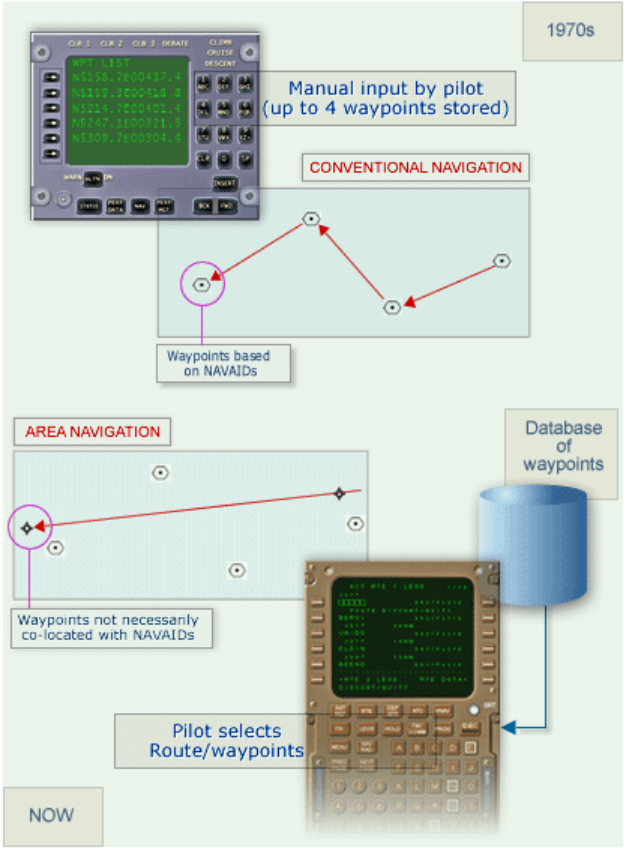


Key Definitions II

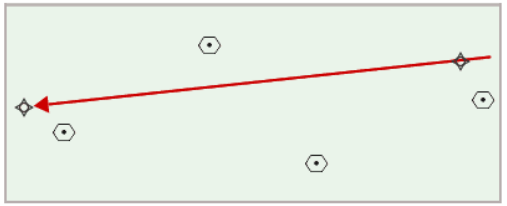


Key Definitions II

From "Conventional" to Area Navigation



Key Definitions II



Aircraft fly desired path

Area Navigation

- The International Civil Aviation Organization (ICAO) Definition:
  - A method of navigation which permits aircraft operation on any desired flight path within the coverage of ground-based or space-based navigation aids or within the limits of self-contained aids, or a combination of these.
- Area Navigation is the key enabler for Performance Based Navigation (PBN).
  - Area navigation enables the aircraft to fly a path, or "leg", between points, called "waypoints", which are not necessarily co-located with ground-based navigational aids.

Key Definitions II

Summary

- → Conventional navigation involved defining routes structures between ground–based NAVAIDs.
- → Area Navigation, which defines routes as any desired path, is a key enabler for PBN.
- → In Terminal Airspace aircraft fly between either flyover, or fly-by waypoints.
- → Only aircraft with an on-board navigation computer (RNAV system) can perform Area Navigation.
- → An aircraft's position is calculated by the RNAV system using inputs from ground-based, space-based NAVAIDS or on-board self-contained systems.

Key Definitions II

How an aircraft flies a route

RNAV System receiving information from different navigation sensors.

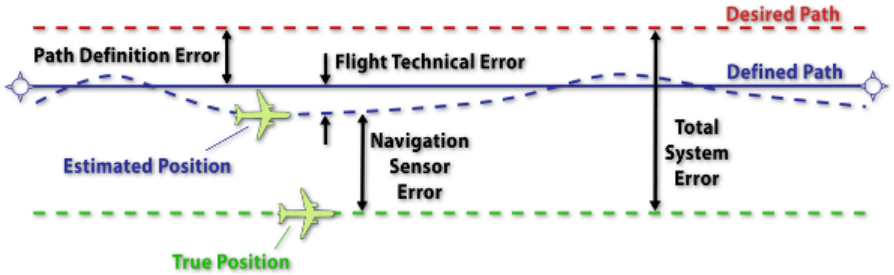
Key Definitions II

RNAV system functionality

Navigation Display (ND) & Flight Management System (FMS)

Key Definitions II

Total System Error (TSE)



TSE and associated errors.

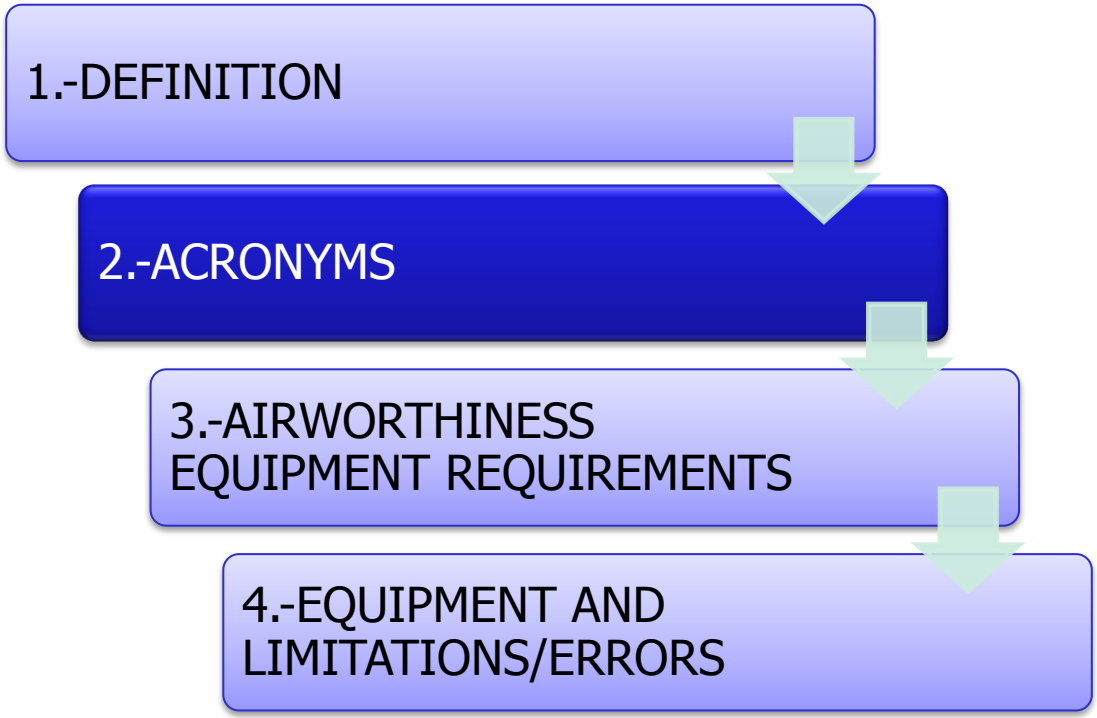
When an aircraft is certified, it has been demonstrated that all of the errors combined, the aircraft is able to fly within the required performance 95% of the flight time.

Key Definitions II

Summary

- RNAV Systems provide Navigation, Flight Plan Management using waypoints, guidance and control together with Display and System Controls.
- Navigation computers are not all the same, they may be simple or complex and may or may not have a database which is aircraft operator (AO) specific.
- The navigation computer defines and displays the path using waypoints that are inputted by the pilot or called up from the database.
- The aircraft's position is calculated by the RNAV system using inputs from ground-based, space-based NAVAIDS, or on-board sensors. This position is then compared to the defined path to provide path steering.
- Accuracy and consistency to fly the desired path depends on the aircraft capabilities and functionalities.
- Navigation accuracy requirements in PBN are based on the Total System Error, which is the error between the true position of the aircraft and the desired path the airspace designer wants the aircraft to fly.

Key Definitions II



Key Definitions II

List of acronyms

RNAV
Area Navigation

RNP
Required Navigation Performance

VOR
VHF (Very High Frequency) Omni-directional Radio- range

DME
Distance Measuring Equipment

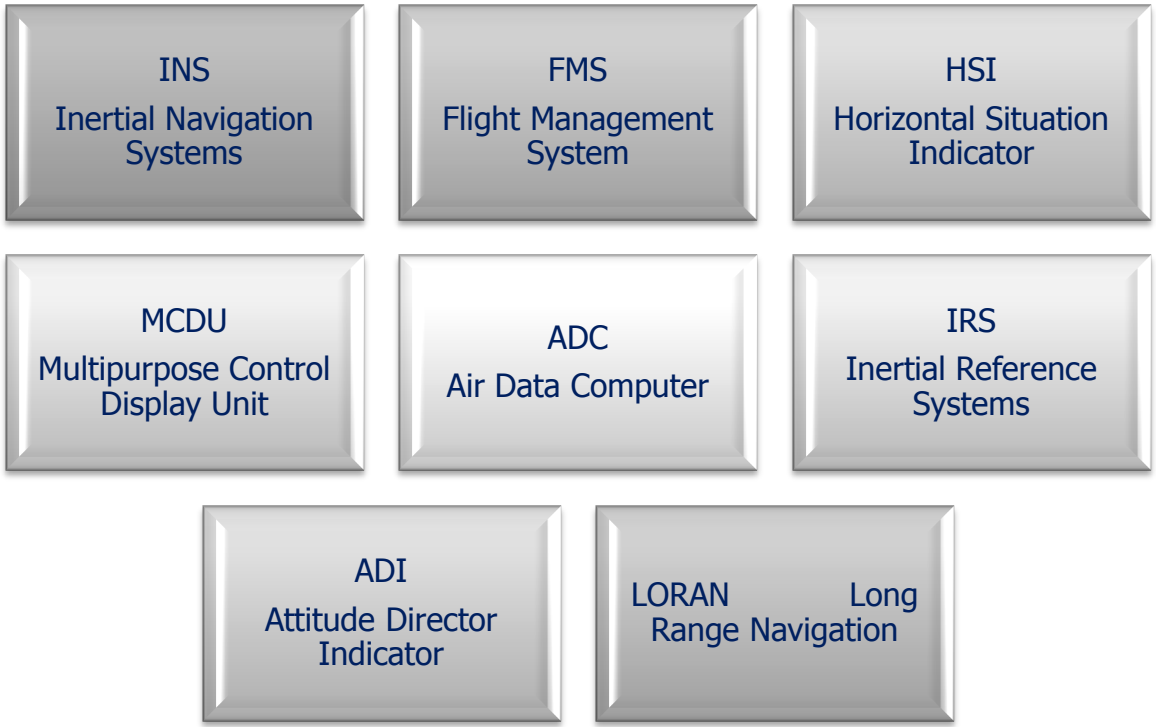
GNSS
Global Navigation Satellite System

SBAS
Satellite-Based Augmentation System

EGNOS
European Geostationary Navigation Overlay Service

Key Definitions II

List of acronyms



Key Definitions II

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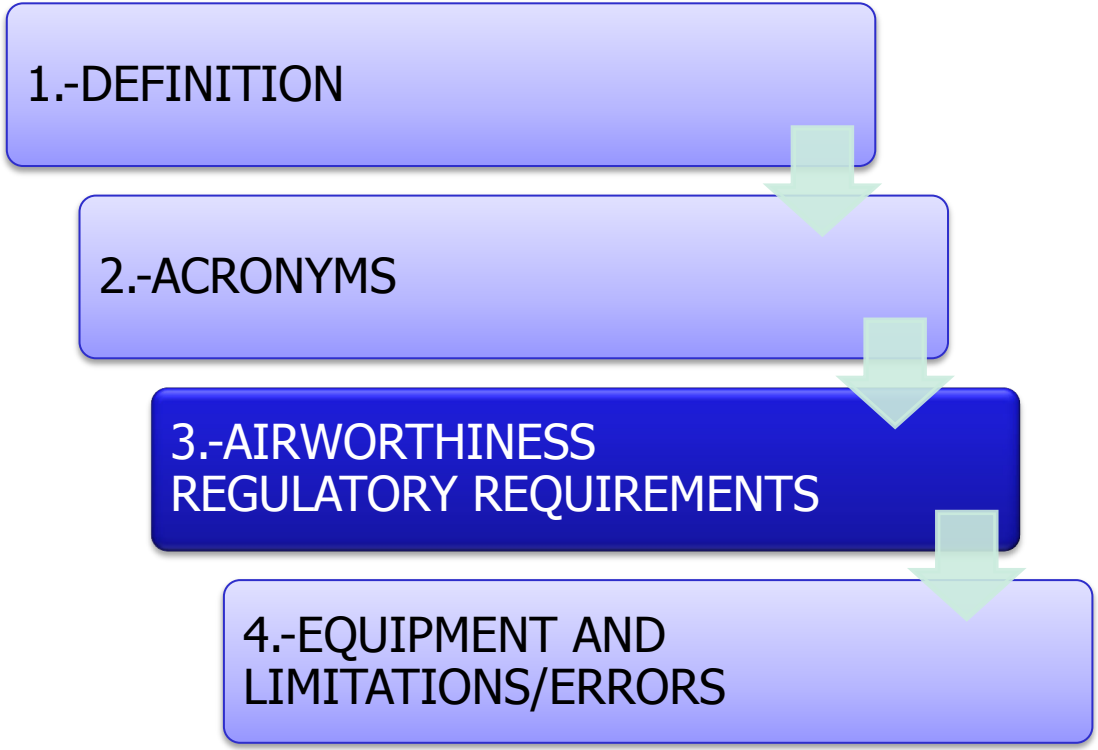
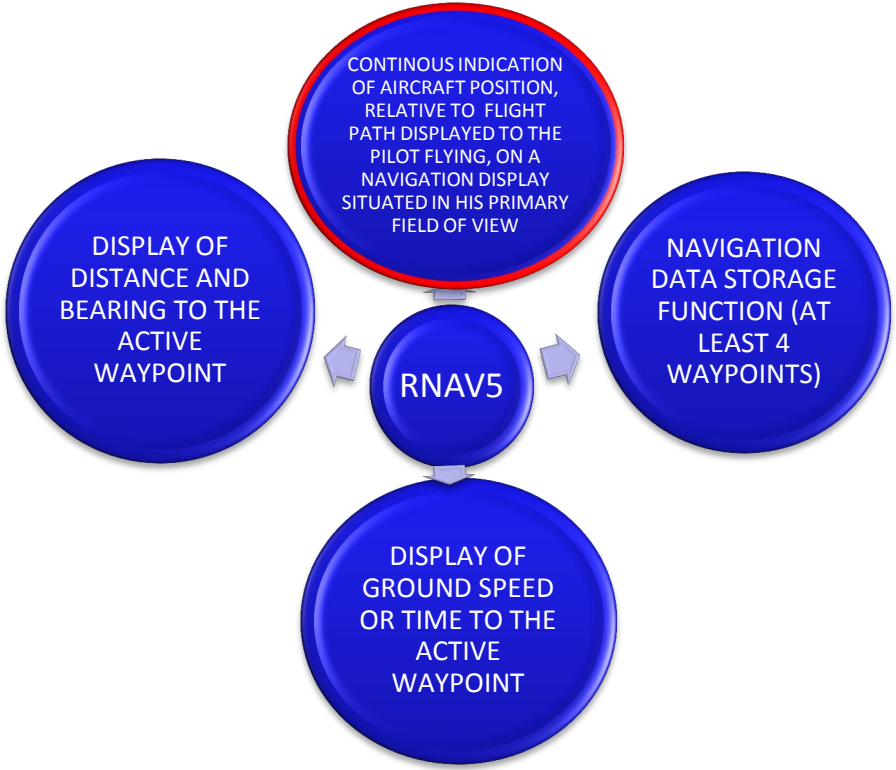


Key Definitions II

Airworthiness regulation requirements



Key Definitions II

RNAV and RNP specifications include requirements for certain navigation functionalities. At the basic level, these functional requirements may include:

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;

b) display of **distance and bearing to the active** (To) waypoint;

c) display of **ground speed or time to the active** (To) waypoint;

d) navigation data storage function; and

e) appropriate **failure indication** of the RNAV or RNP system, including the sensors.

Example: Garmin GNS 430W

Key Definitions II

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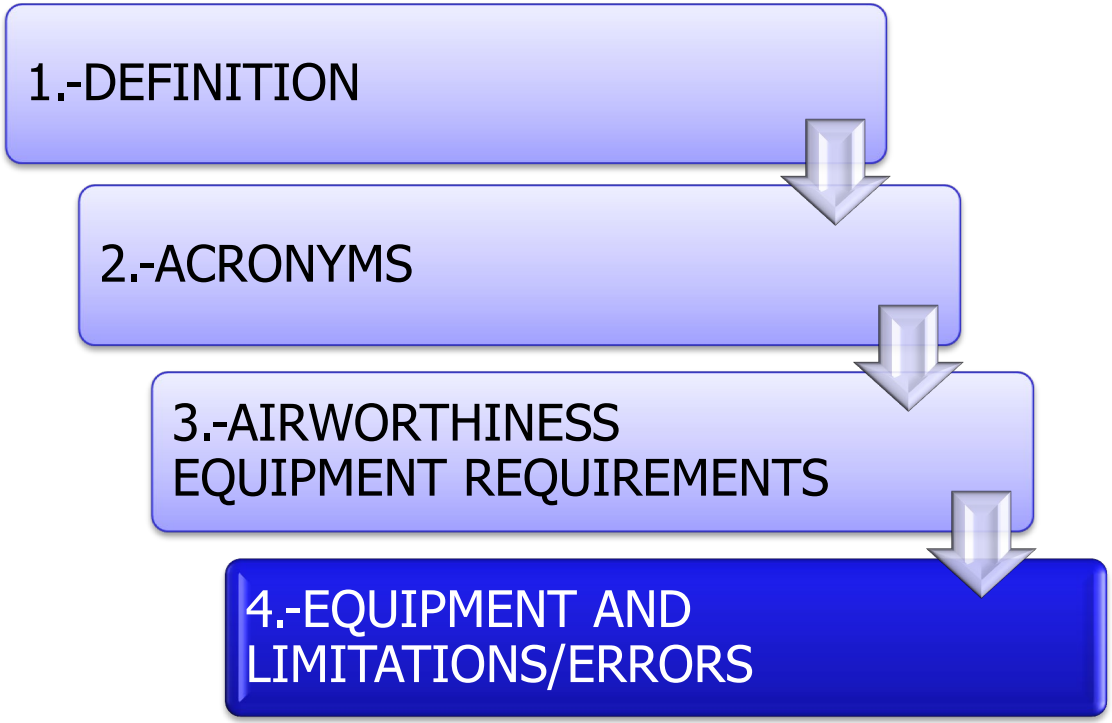
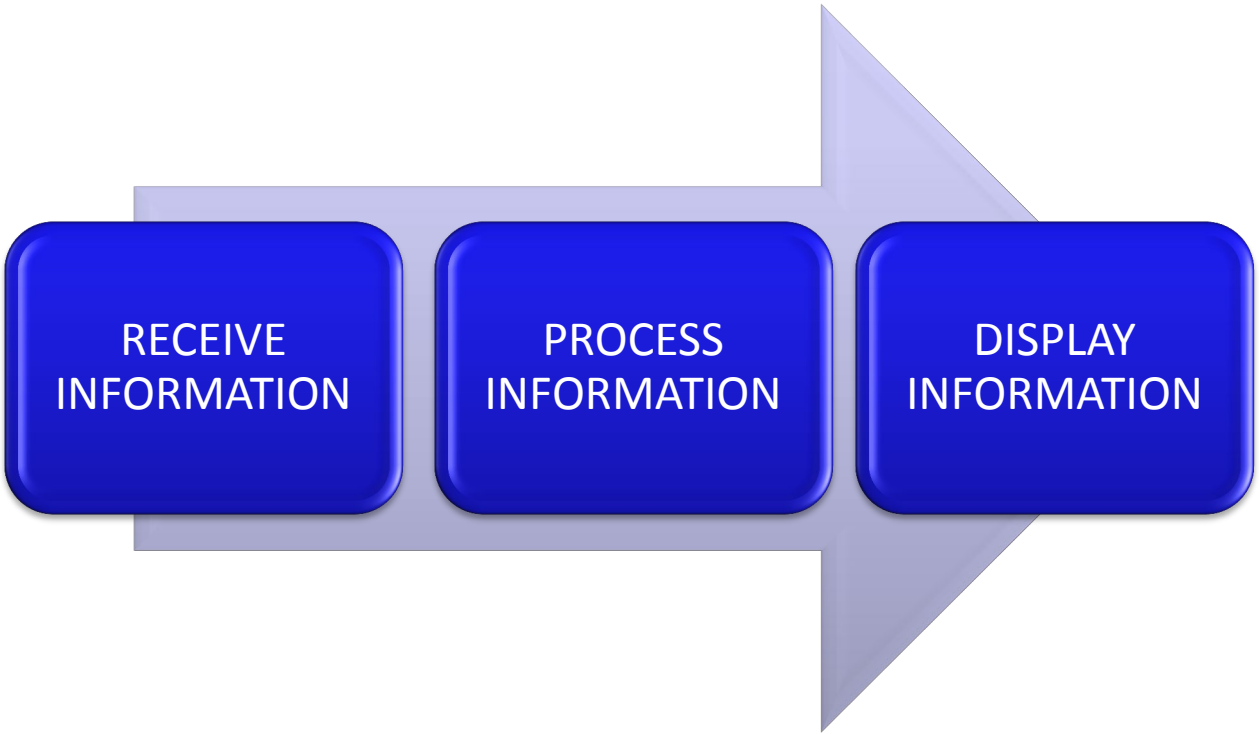


Key Definitions II

Equipment



Key Definitions II

RECEIVE INFORMATION

GPS Transceiver

RECEIVE INFORMATION

RECEIVE INFORMATION

Key Definitions II

GPS Transceiver

VOR Transceiver

DME Transceiver

PROCESS INFORMATION

FLIGHT MANAGEMENT SYSTEM

MULTIFUNCTION DISPLAY UNIT

Key Definitions II

FLIGHT MANAGEMENT SYSTEM

MULTIFUNCTION DISPLAY UNIT

DISPLAY INFORMATION

EXTERNAL ANNUNCIATOR

MD41-1468A

MD41-1408A

Vertical View

Key Definitions II

Equipment

RECEIVE INFORMATION

RECEIVE INFORMATION

RECEIVE INFORMATION

PROCESS INFORMATION

FLIGHT MANAGEMENT SYSTEM

MULTIFUNCTION DYSPLAY UNIT

DISPLAY INFORMATION

Key Definitions II

Automatic determination of the aircraft's position?

Key Definitions II

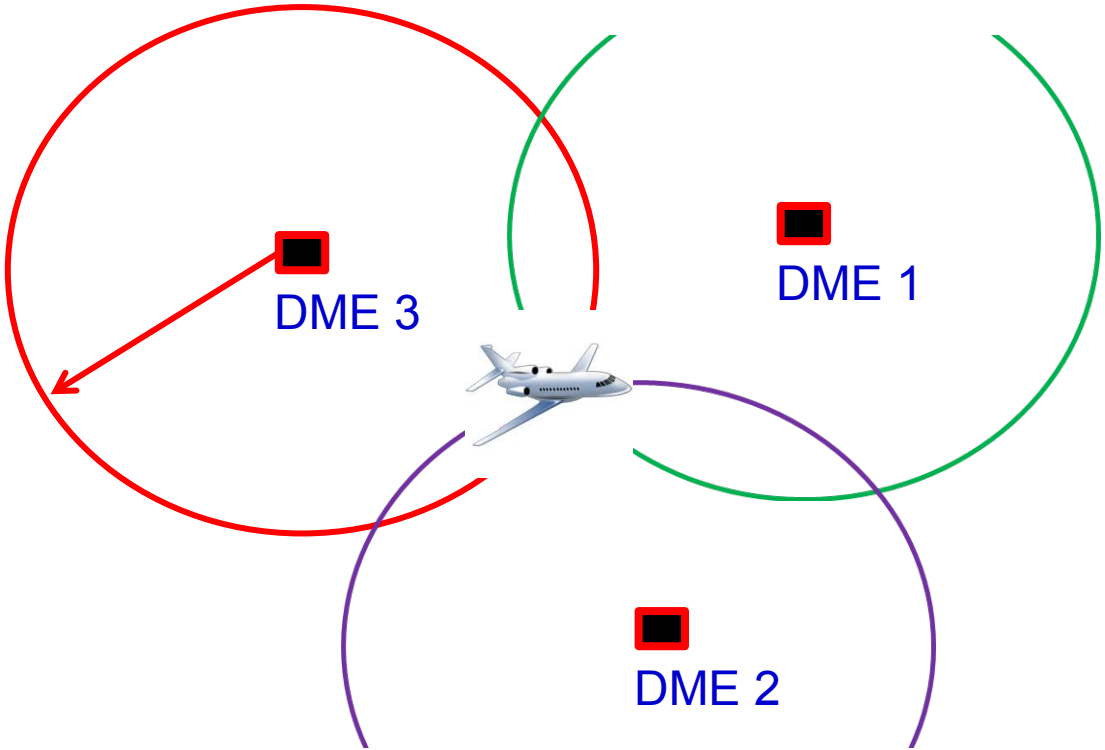
Made from Flight Management Systems and data obtained from one or a combination of the following sensors:

- → **DME/DME** Distance measurement equipment
- → **DME/VOR** Very High Frequency Omni-directional Radio- range
- → **INS** Inertial Navigation System or **IRS** Inertial Reference Systems
- → **GPS** Global Positioning System
- → **LORAN** Long Range Navigation

Key Definitions II

RNAV 5 (B RNAV)

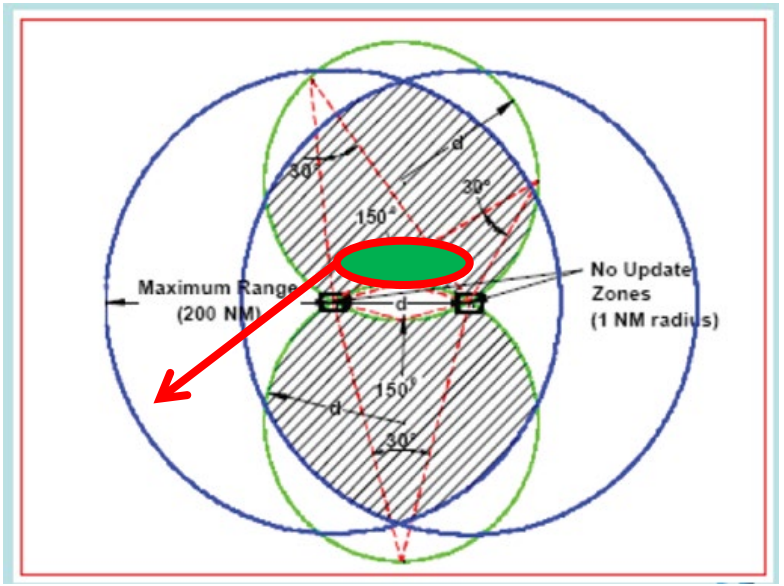
DME/DME



Key Definitions II

RNAV 5 (B RNAV)

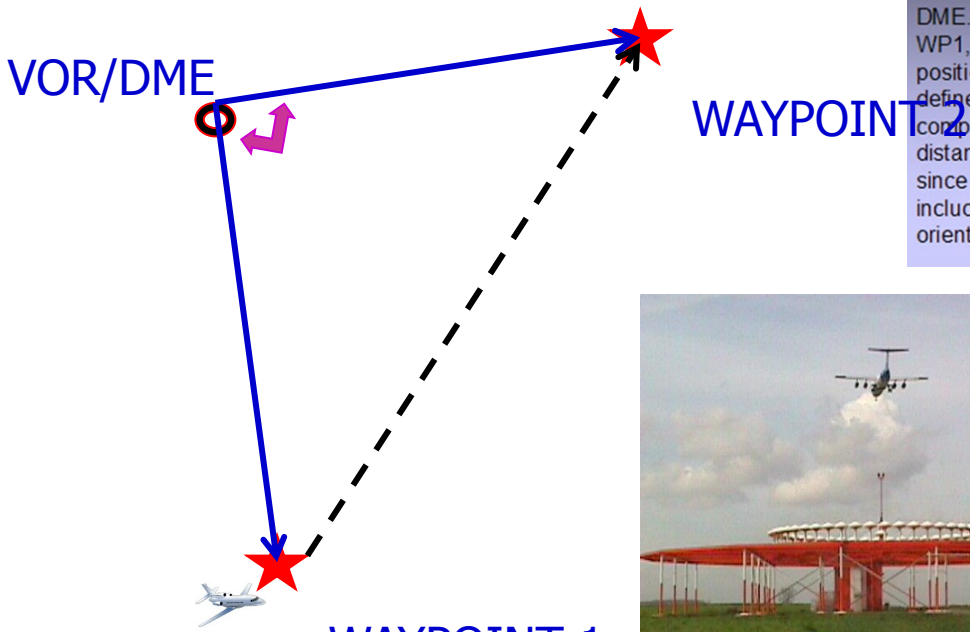
- → DME (disadvantages):
  - → Coverage limitation: 200 NM radius
  - → No update zones: 1NM radius



Key Definitions II

RNAV 5 (B RNAV)

VOR/DME



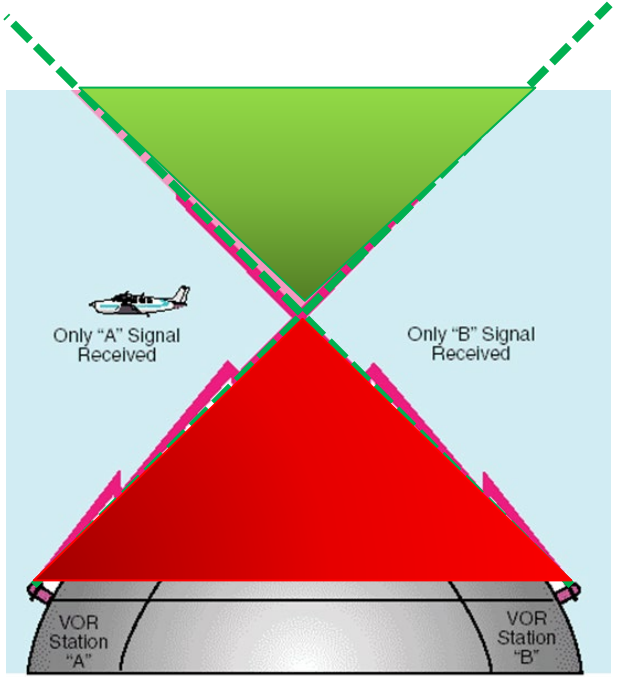
WP1 is defined by DTY VOR/ DME. When aircraft arrives WP1, system will measure WP1 positions relate to POL (station defines WP2). Then system can computes the course and distance from WP1 to WP2 since it has two sides and included angle and the orientation of magnetic north.

Key Definitions II

RNAV 5 (B RNAV)

→ VOR (disadvantages):

- → VOR ground stations transmit within a VHF frequency band of 108.0 – 117.95 MHz.
- → The signals transmitted are subject to line-of-sight restrictions. Therefore, its range varies in direct proportion to the altitude of receiving equipment.



re 10: VHF transmissions follow a line-of-sight course.

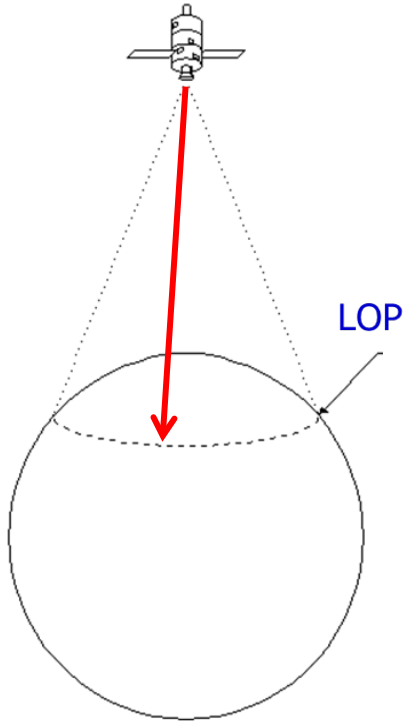
Key Definitions II

RNAV 5 (B RNAV)

GPS

→ Global Positioning System

- → Is a satellite based navigation system. It uses a digital signal from each satellite to send data to the receiver.
- → The receiver can establish a line of position (LOP) on the Earth



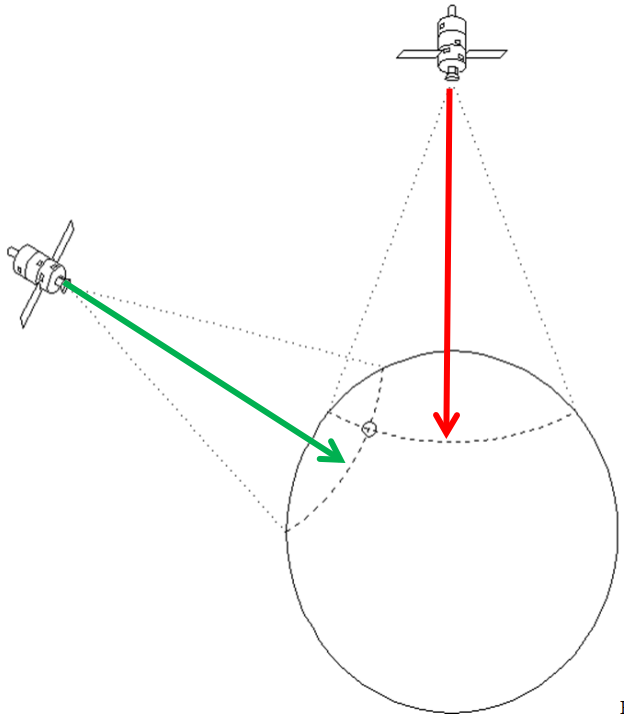
Key Definitions II

RNAV 5 (B RNAV)

GPS

→ Global Positioning System

→ A second LOP will provide two possible locations



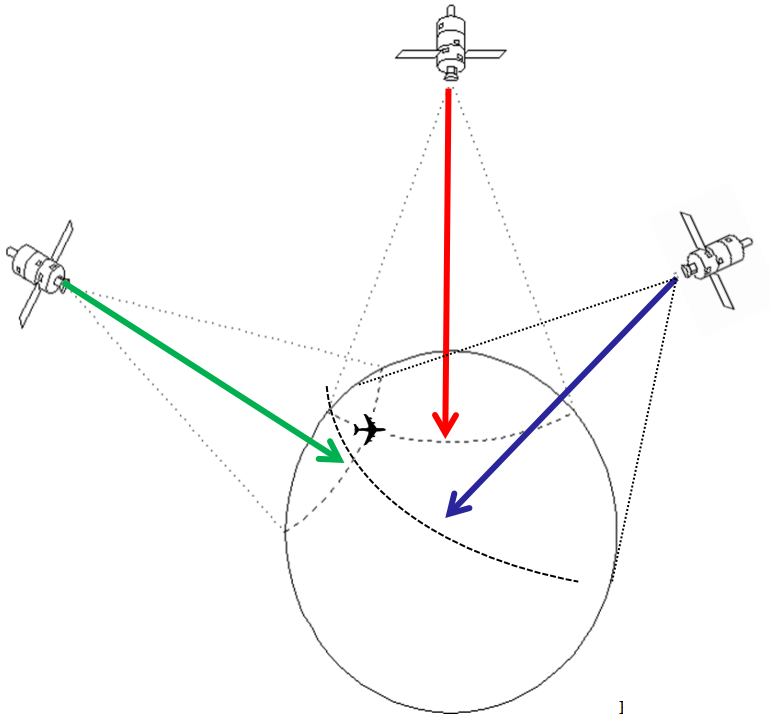
Key Definitions II

RNAV 5 (B RNAV)

GPS

→ Global Positioning System

→ A third LOP will resolve that to a single position.

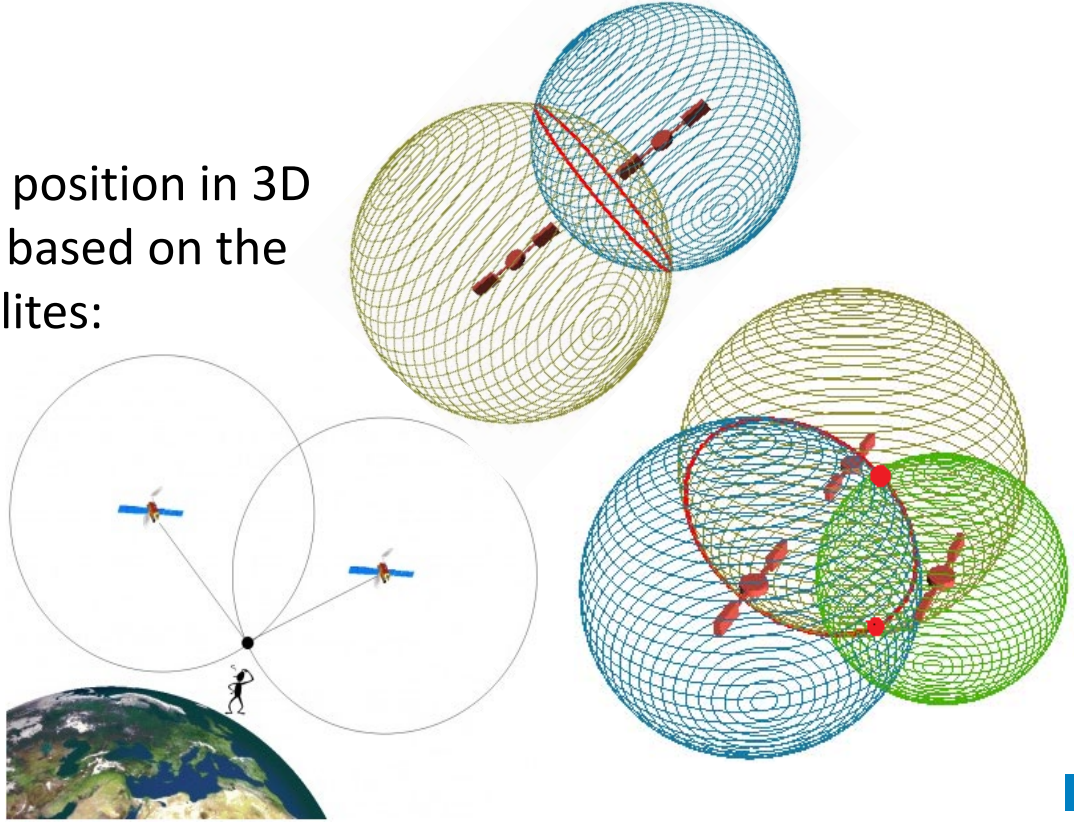


Key Definitions II

RNAV 5 (B RNAV)

GPS (Disadvantages)

→ A receiver calculates its position in 3D (X/Y/Z) and GNSS-time, based on the signals of multiple satellites:



Key Definitions II

RNAV 5 (B RNAV)

GPS (Disadvantages)

→ Calculating principle (FYI):

A receiver calculates a position in 3D (X/Y/Z) and time, based on the following matrix of formulae:

$$(X1 - \mathbf{X})^2 + (Y1 - Y)^2 + (Z1 - Z)^2 = (t1.c - CB.c)^2$$
$$(X2 - X)^2 + (Y2 - \mathbf{Y})^2 + (Z2 - Z)^2 = (t2.c - CB.c)^2$$
$$(X3 - X)^2 + (Y3 - Y)^2 + (Z3 - \mathbf{Z})^2 = (t2.c - CB.c)^2$$
$$(X4 - X)^2 + (Y4 - Y)^2 + (Z4 - Z)^2 = (t2.c - \mathbf{CB}.c)^2$$

With: X1, Y1, Z1 = 3D coordinates of satellite 1 when its signal was emitted

t1 = Time when the signal was emitted by satellite 1

X, Y, Z = Position of (and calculated by) the receiver (= 3 unknown factors)

CB = Clock Bias = Time error of receiver with respect to the "GNSS time" (= 4th unknown factor in the equation, as "receiver time" is very inaccurate)

c = Speed of the signal = Speed of light (300.000 km/hour, or 300.000.000 m/s)

Key Definitions II

RNAV 5 (B RNAV)

GPS (Disadvantages)

- → Clock bias
  - → Each minor difference (CB) between the satellite's emission time of the signal ("GNSS-time") and the receivers' own "time" at that moment, is MULTIPLIED BY 300.000.000 and may lead to 100's meters of position error…
  - → Receivers are regarded as "the weak link" in the GNSS set-up, as they don't have atomic clocks (with extreme high accuracy)
  - → The time delay (CB) between GNSS-time in the satellites and receivers, is incorporated as a 4th unknown in the equations to determine receiver position and is solved mathematically
  - → This explains the need of a 4th satellite for exact 3D-positioning, to help solve the 4th unknown factor: CB

Key Definitions II

- Ephemeris error
  - This is a fancy name for the difference between the predicted orbit (as expressed in the almanac data) and the satellite's real orbit. There are several sources of this error; one is variation in the earth's gravitational field.
- Clock drift
  - Each satellite has a precise Cesium beam atomic clock. They drift slowly (fractions of second per year), but they do drift.
- Ionospheric and tropospheric distortion
  - This is error sustained by the satellite signals passing through the earth's atmosphere.

Key Definitions II

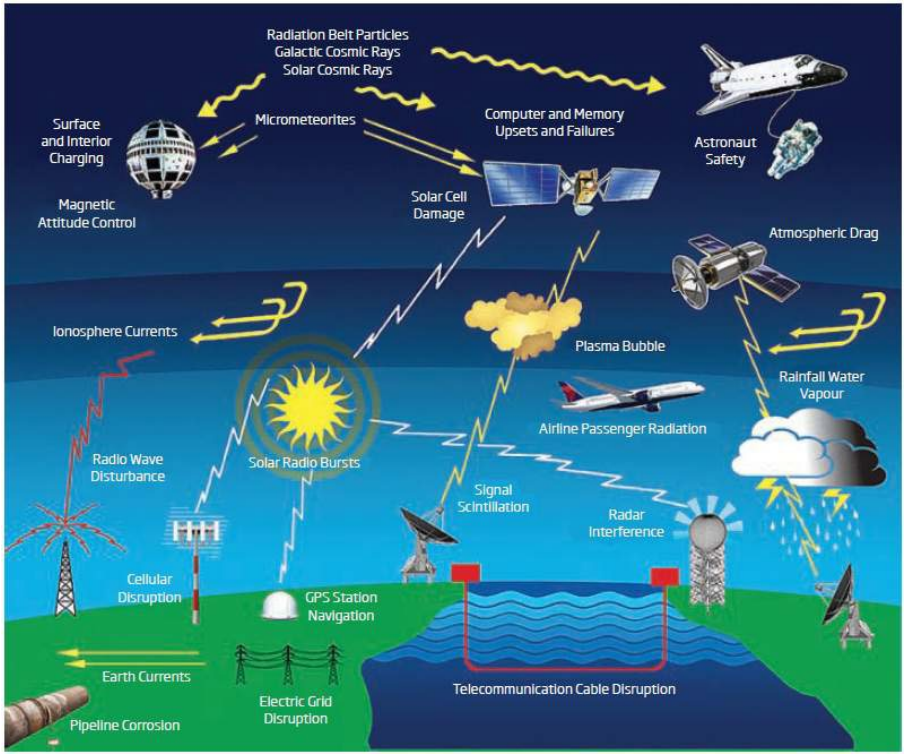
Effects of Space Weather on Aviation:

→ Communication

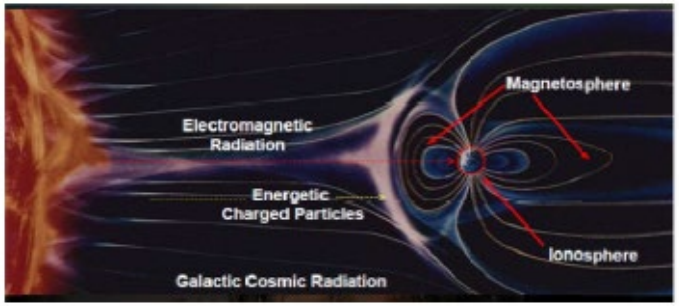
→ Navigation

→ Avionics

→ Radiation



Key Definitions II



EASA Safety Information Bulletin

SIB No.: 2012-09
Issued: 23 May 2012

Subject: Effects of Space Weather on Aviation

Ref. Publication:
1. EU OPS 1.390 Cosmic Radiation;
2. SIB 2012-10 Single Event Effects (SEE) on Aircraft Systems Caused By Cosmic Rays;
3. Appendix 1 contains a list of useful web-site and identify those that provide information or prediction on actual space weather.

Applicability: All aircraft and their operations, all ATM/ANS (Air Traffic Management/Air Navigation Services) systems and their operations, all aerodromes and their operations.

Description: This SIB informs aircraft operators, aircraft manufacturers, avionics systems designers, electronic equipment and component manufacturers, ATM/ANS service providers, aerodrome operators and competent authorities of the effects of space weather on electronic devices, communication, navigation and surveillance services and human beings and should be read in conjunction with SIB 2012-10 for on-board systems.

Space weather is a generic term which refers to the environmental conditions in the space around the Earth extended up to the Sun. The major drivers for the space weather are flows of energetic charged particles and electromagnetic radiation. Both of which penetrate and interact with the Earth's atmosphere and magnetic field. The main contributors to space weather can be further separated into Solar and Galactic radiation.

The figure below is a graphical, not to scale, representation of solar and galactic radiation and their interaction with the Earth magnetosphere and ionosphere (from NOAA: National Oceanic and Atmospheric Administration (USA)). The sun activity is the main contributor.

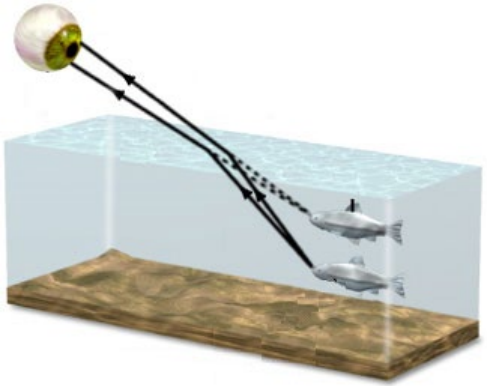
Key Definitions II

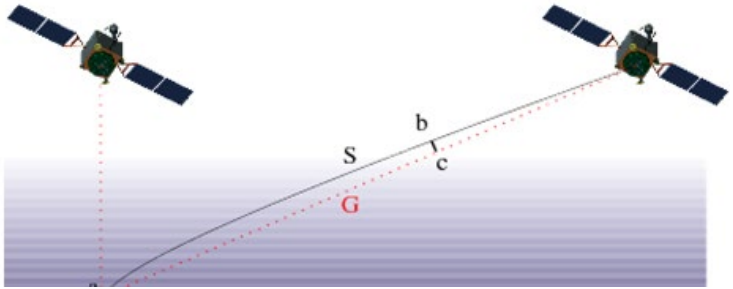
Space Weather Report (SWR)

Key Definitions II

Tropospheric Interference:

→ the signals originate from outer space (vacuum, no matter) and travel through the atmosphere, that becomes more dense closer to the Earth => “Bending” or Refraction of the signal (that travel in a curved pattern, not in a straight line!), when encountering denser medium



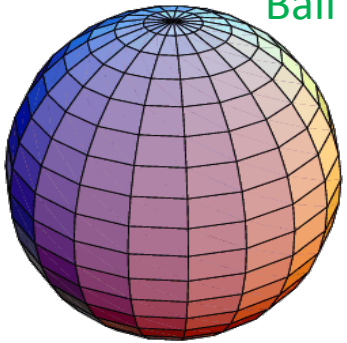


Key Definitions II

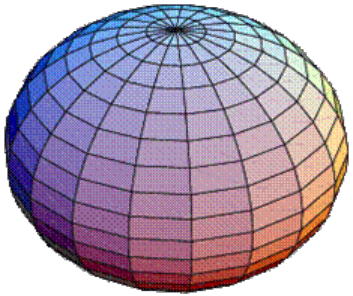
The Earth is more of a “sphere” than a ball, in shape

- → GPS and Galileo use WGS-84 as reference, for the Earth: it considers the Earth’s circumvent as a perfect sphere
- → Unfortunately the Earth still is a “Rock” in the Universe that is gently forming into a sphere, even after millions of years…
- → This explains why altimetry is difficult using GNSS-technology!

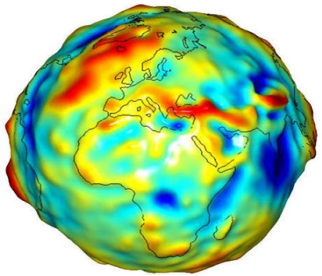
Ball



WGS-84 *(sphere)*



Real Earth *(rock)*



Key Definitions II

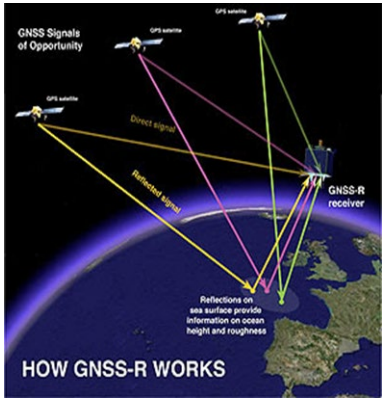
RNAV 5 (B RNAV)
GNSS Augmentation

Augmentation of a global navigation satellite system (GNSS) is a method of improving the navigation system's attributes, through the integration of external information into the calculation process.

Some systems transmit additional information about sources of error (such as clock drift, ephemeris, or ionospheric delay)

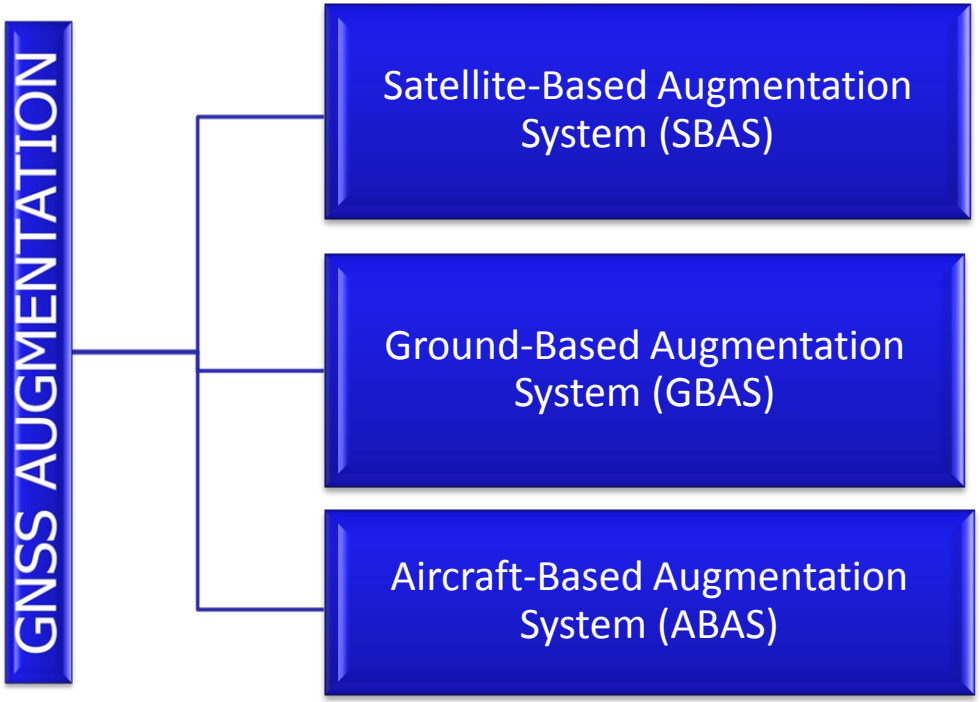
A third group provide additional vehicle information to be integrated in the calculation process.

Others provide direct measurements of how much the signal was off in the past



GNSS Augmentation

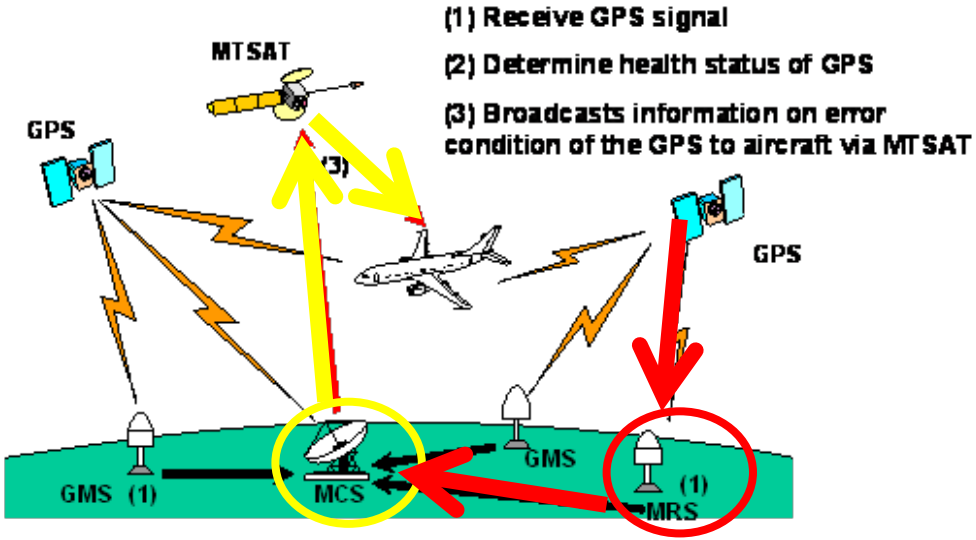
Key Definitions II



Key Definitions II

Satellite-Based Augmentation System (SBAS)

→ System that supports wide-area augmentation through the use of additional satellite-broadcast messages.



Key Definitions II

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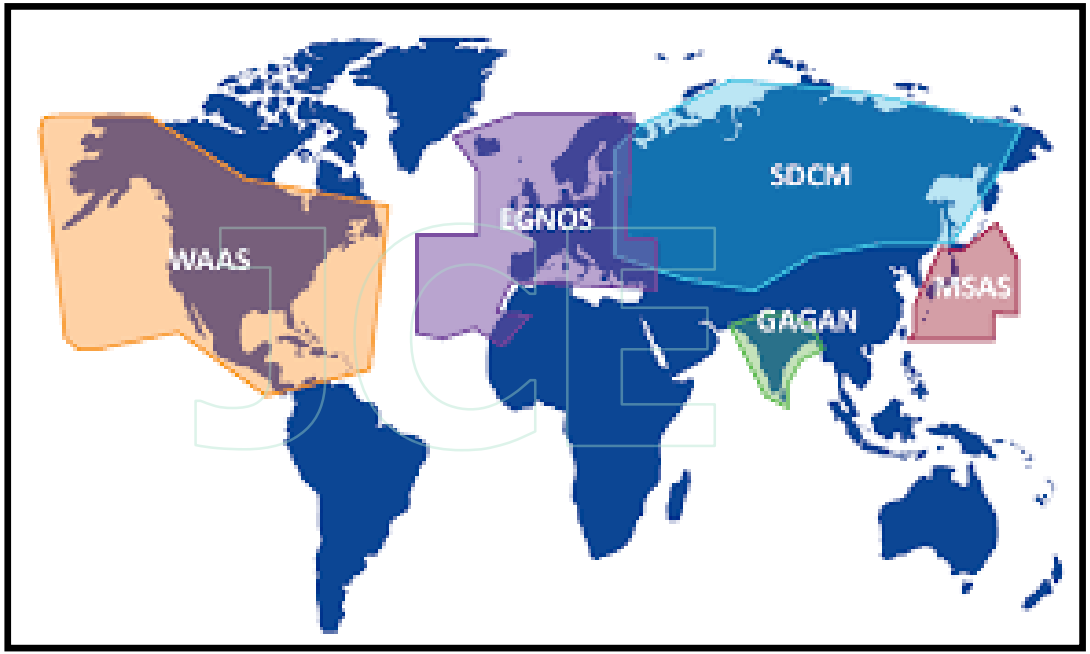
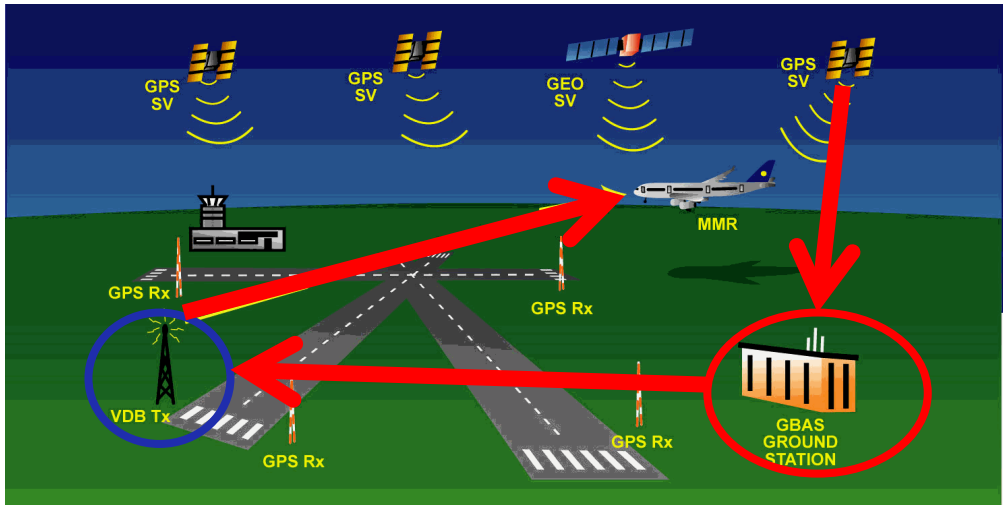


(*GPS Aided Geo Augmented Navigation*)

Key Definitions II

Ground-Based Augmentation System (GBAS)

→ System that supports augmentation through the use of terrestrial radio messages. Composed of one or more accurately surveyed ground stations, which take measurements concerning the GNSS, and one or more radio transmitters, which transmit the information directly to the end user



Key Definitions II

Aircraft-Based Augmentation System (ABAS)

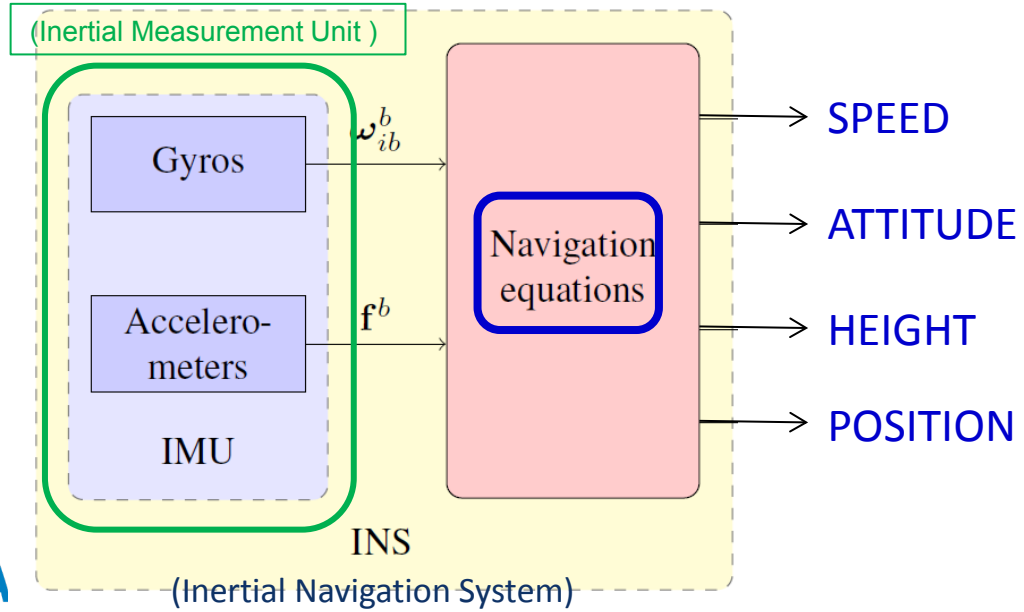
- On board the aircraft, the augmentation take the form of additional information being blended into the position calculation. Many times the additional avionics operate via separate principles than the GNSS and are not necessarily subject to the same sources of error or interference.

- RAIM is Receiver Autonomous Integrity Monitoring for aviation GPS applications.
- In order for a GPS receiver to perform a RAIM or Fault Detection function, a minimum of 5 satellites with satisfactory geometry must be visible to the GPS receiver.

Key Definitions II

Inertial Navigation System (INS)

→ A block diagram of an inertial measurement unit (IMU) combined with navigation equations to form an inertial navigation system (INS).

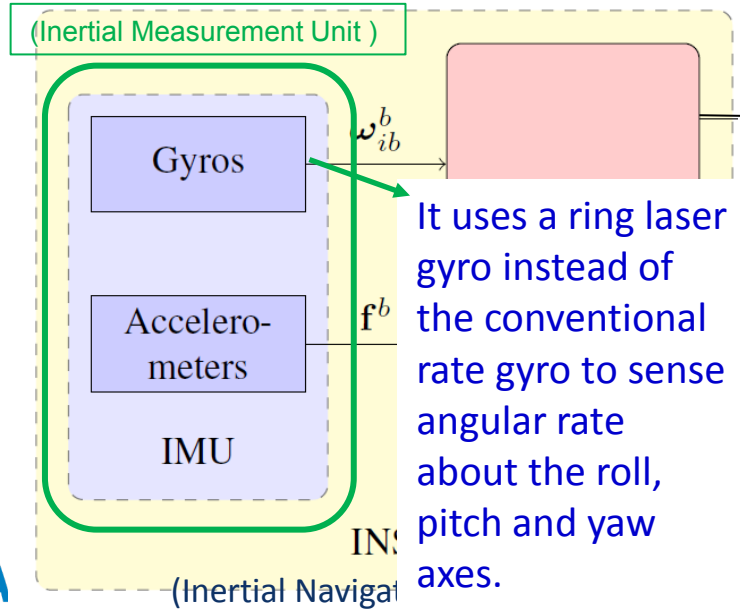


RNAV 5 (B RNAV)
INERTIAL NAVIGATION
SYSTEM (INS)

Key Definitions II

Inertial Reference System (IRS)

→ A block diagram of an inertial measurement unit (IMU) combined with navigation equations to form an inertial navigation system (IRS).



It uses a ring laser gyro instead of the conventional rate gyro to sense angular rate about the roll, pitch and yaw axes.

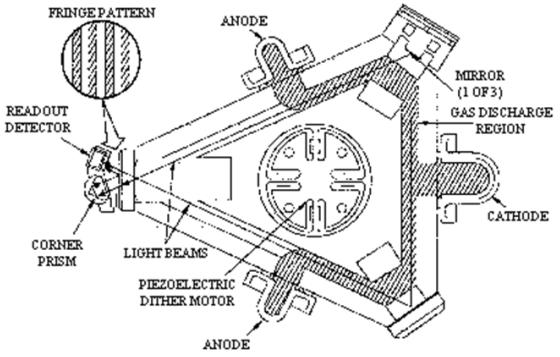
→ SPEED

→ ATTITUDE

→ HEIGHT

→ POSITION

RNAV 5 (B RNAV)
INERTIAL REFERENCE
SYSTEM (IRS)

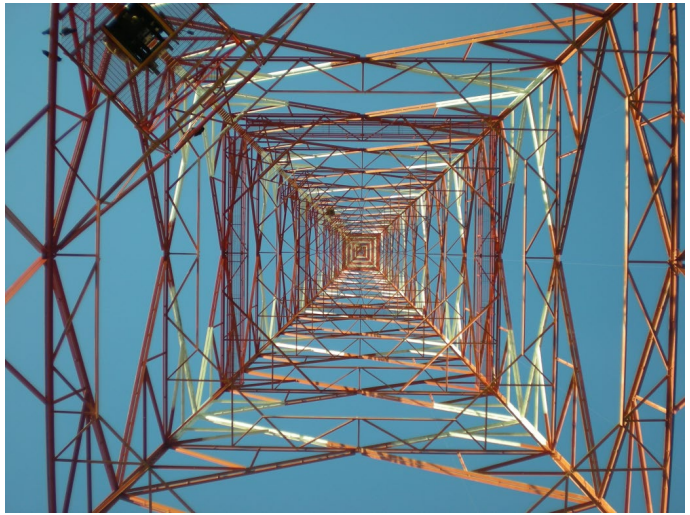


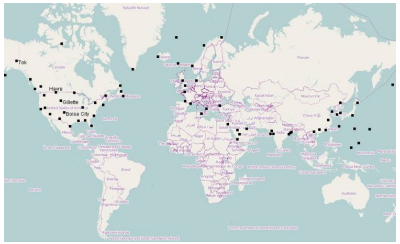
Key Definitions II

RNAV 5 (B RNAV)

Long Range Navigation (LORAN)

→ Is a hyperbolic radionavigation system where broadcasting stations transmit a precisely timed signal.



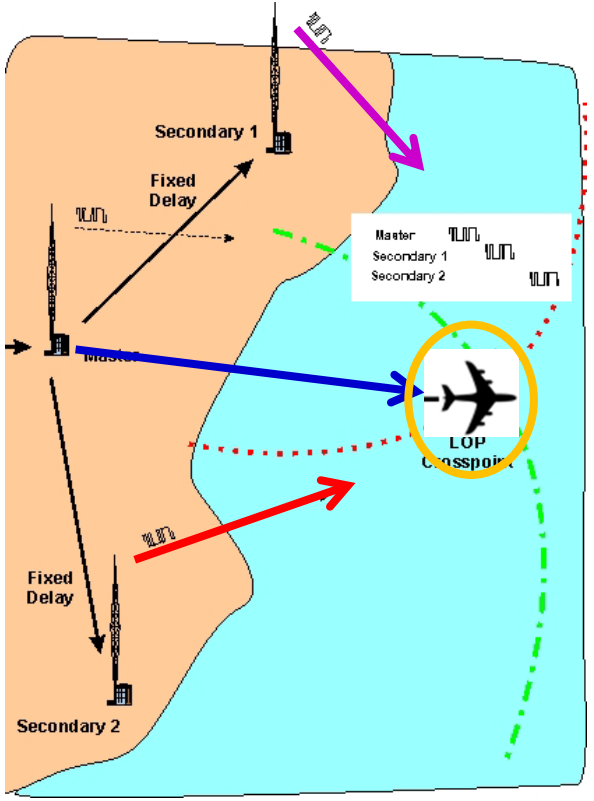


Key Definitions II

RNAV 5 (B RNAV)

Long Range Navigation (LORAN)

→ The receiver calculates the time difference between each of the pulse sequence to determine the distance from each transmitter to create a hyperbolic line of position (LOP). The location is defined by the intersection of both LOPs.



Key Definitions II

- **Ionospheric disturbances**
  - Solar storms affect Loran, yielding periods - ranging from minutes to hours - of unavailability.
- **Solar events**
  - A common cause failure that can disrupt both Loran and GPS. The good news is that while both GPS and Loran are affected by solar storms, the degradation occurs at different times. Loran is affected by ionospheric changes which occur soon after the solar storm occurrence; GPS is affected some days later when Loran has fully recovered.
- **Power line carriers**
  - A lot of equipments use the electrical transmission lines to communicate data which may cause interferences to Loran receivers

Key Definitions II

→ **Altimetry System Error**

Difference between the altitude indicated by the altimeter display, assuming a correct altimeter barometric setting, and the pressure altitude corresponding to the undisturbed ambient pressure. (ICAO doc 9574)

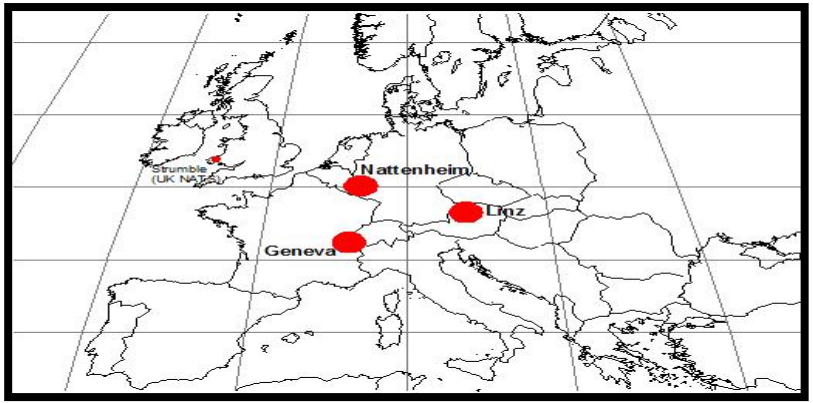
→ Put more simply, ASE is the difference between the altitude that the pilot, ground controller and aircraft systems believe the aircraft to be at, and the actual altitude. To be compliant with international standards the ASE of an aircraft must be less than 245 ft.)

Key Definitions II

→ Height Monitoring Systems (HMU)

Height Monitoring Units in Europe.

- → They determine the geometric height and position of an aircraft by comparing the time of reception of the SSR transponder signals at different receiver locations.
- → When completed, the monitoring produces the ASE readings for each aircraft.



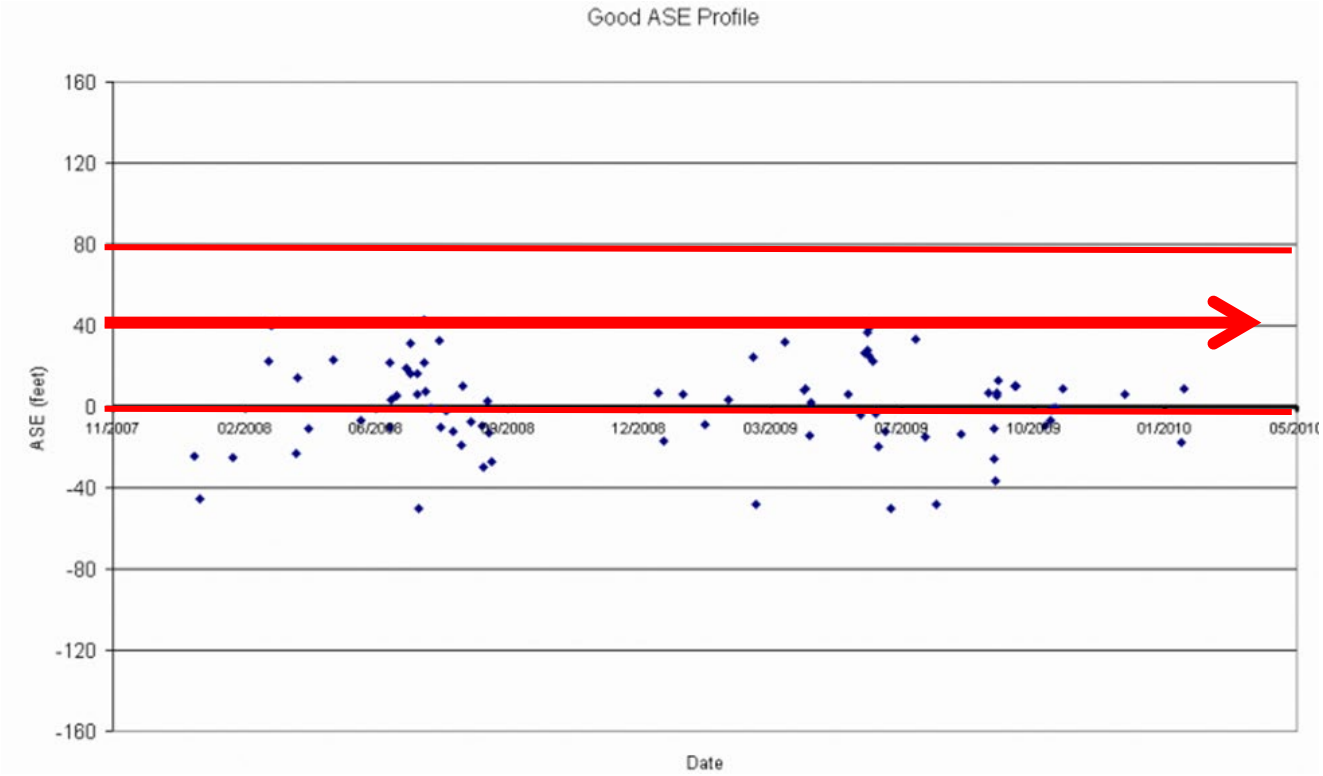
EUR Region HMU Locations

Key Definitions II

- **GPS Monitoring Unit (GMU)**
  - Portable carry on device used to estimate the ASE of a single flight for one aircraft.
- **ADS-B Height Monitoring System**
  - New method of Height monitoring which utilizes the geometric height data transmitted in the aircraft's ADS-B broadcasts.

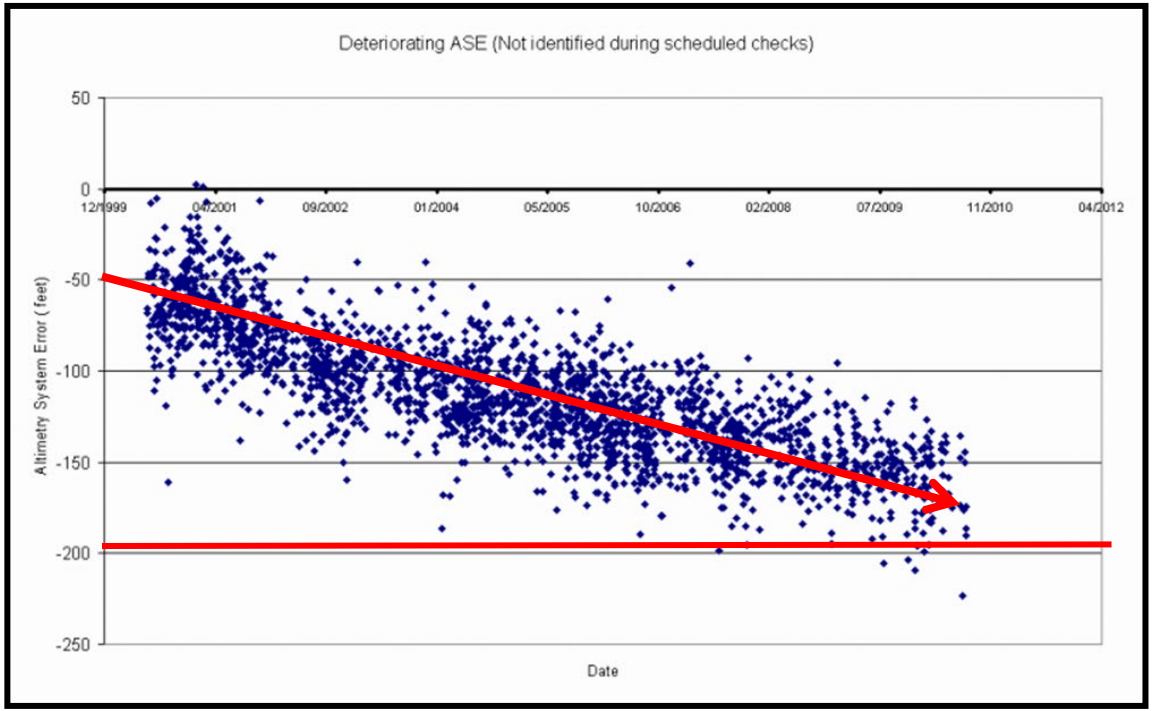
Key Definitions II

Aircraft ASE profile that has a low ASE and is also stable over time



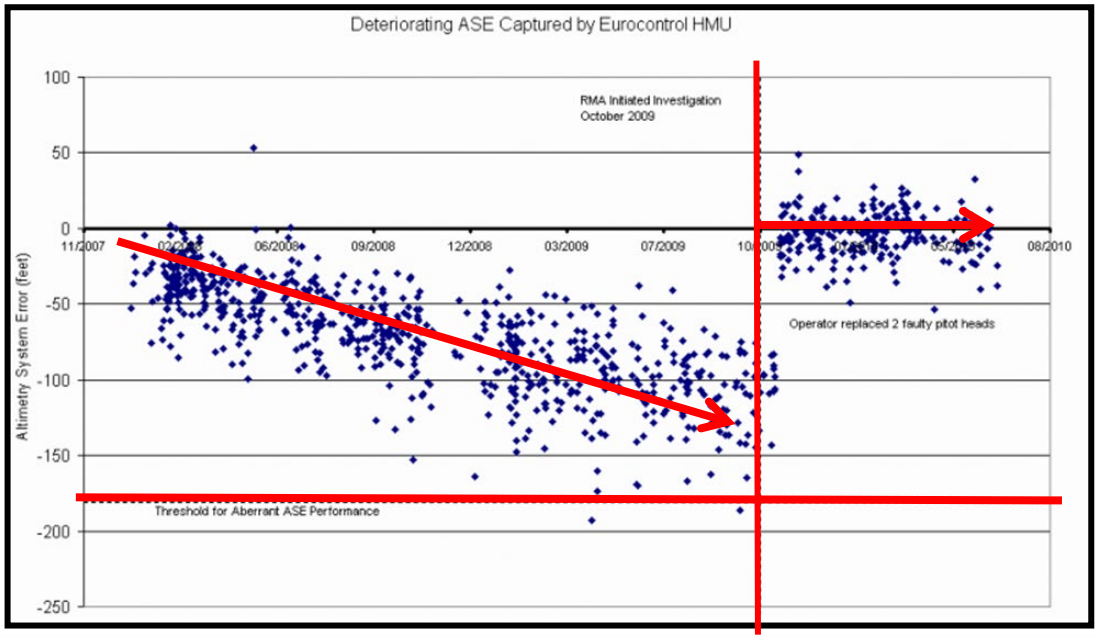
Key Definitions II

In contrast, the next example shows the long term ASE curve for an individual aircraft where deteriorating ASE has not been identified during scheduled checks.



Key Definitions II

The graph below shows the ASE curve for an individual airframe showing an increase of ASE from approximately -50 feet to over -150 feet in 1 year. The vertical line illustrates when this aircraft came to the attention of the EUR RMA and took action. Improvement in performance after the operator changed faulty pitot heads is clear to see.



Key Definitions II

Aberrant ASE

- An RMA may recommend a State or operator to investigate the performance of an aircraft which is aberrant if the typical performance is over a pre-set limit (typically 200 ft.) or if the ASE characteristic indicates a significant trend towards non-compliance.

- The ASE of any individual airframe shall be less than ±245 ft.


EUR Doc 034

GUIDANCE MATERIAL FOR THE CONTINUED SAFETY MONITORING OF THE EUROPEAN RVSM AIRSPACE

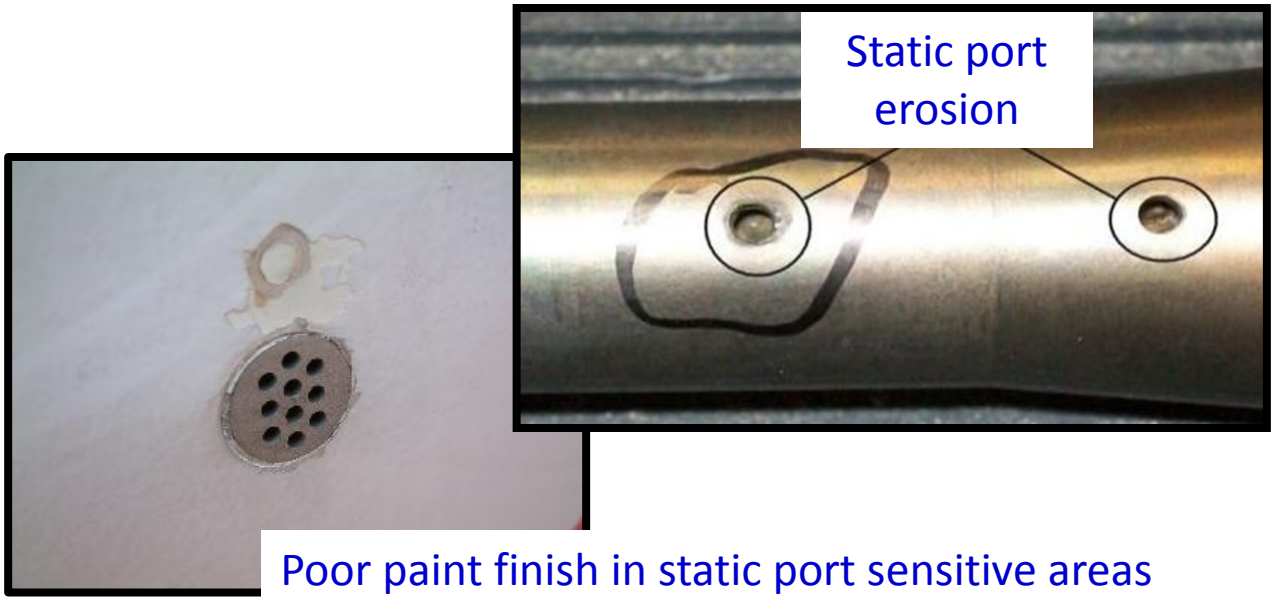
Version 1.0

November 2015

Prepared by the ICAO European and North Atlantic Office on behalf of the European Air Navigation Planning Group (EANPG)

Key Definitions II

Damage to static ports and pitot tubes



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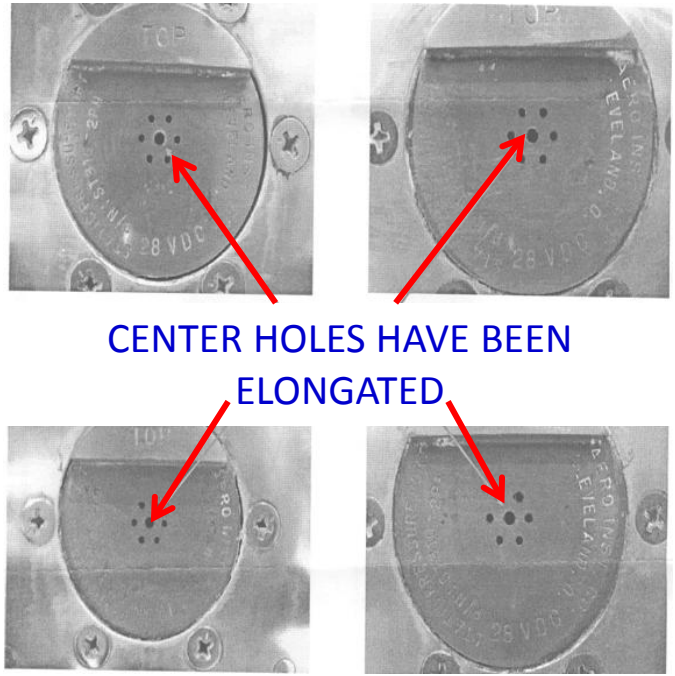
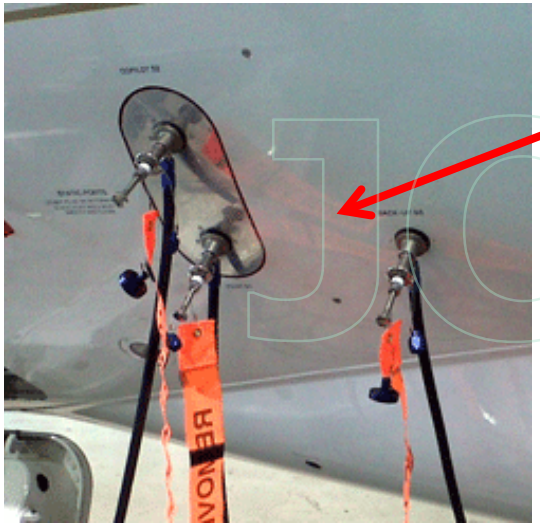
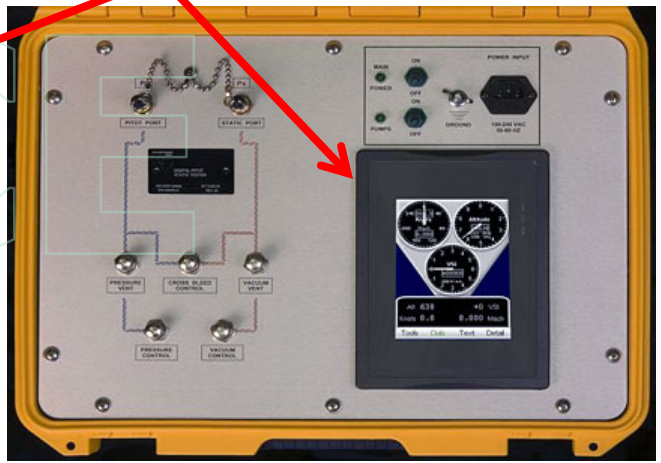


Key Definitions II

Adequacy RVSM inspection procedures



RVSM Maintenance Tests



Key Definitions II

QUESTIONS

Key Definitions II

1. (RNP):
   a) Designed to reduce the standard vertical separation between aircrafts flying between FL290 and FL410.
   b) It´s an application of the Traffic Alert and Collision Avoidance System (TCAS).
   c) Method of navigation that permits aircraft operation on any desired course within the coverage of station-referenced navigation signals or within the limits of a self-contained system capability, or a combination of these.
   d) Special training procedures for using the weather radar system.

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Key Definitions II

2. Related to Aircraft-Based Augmentation System, the RAIM function stands for:
   a) Reduced Antenna Integration and Maintenance for ILS applications.
   b) Receiver Autonomous Integrity Monitoring for aviation GPS applications.
   c) Range Antenna Indicator Malfunction for TCAS applications.
   d) Receiver Autonomous Integrity Monitoring for aviation weather radar applications.

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Key Definitions II

3. Which of the following options are related to cause Global Positioning System (GPS) errors
   a) Ephemeris error, Clock drift, Ionospheric and tropospheric distortion.
   b) Hysteresis error, Compression error and static distortion.
   c) Pressure variation caused by skin waviness effects.
   d) Poor paint finish in static port sensitive areas.

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Key Definitions II

4. The purpose of Static Source Error Correction (SSEC) is
   a) To produce a minimum residual static system error.
   b) To minimize ionospheric distortion.
   c) To generate guidance beams at microwave frequencies for guiding aircraft to landings.
   d) To improve the Runway Visual Range (RVR) at landing.

Key Definitions II

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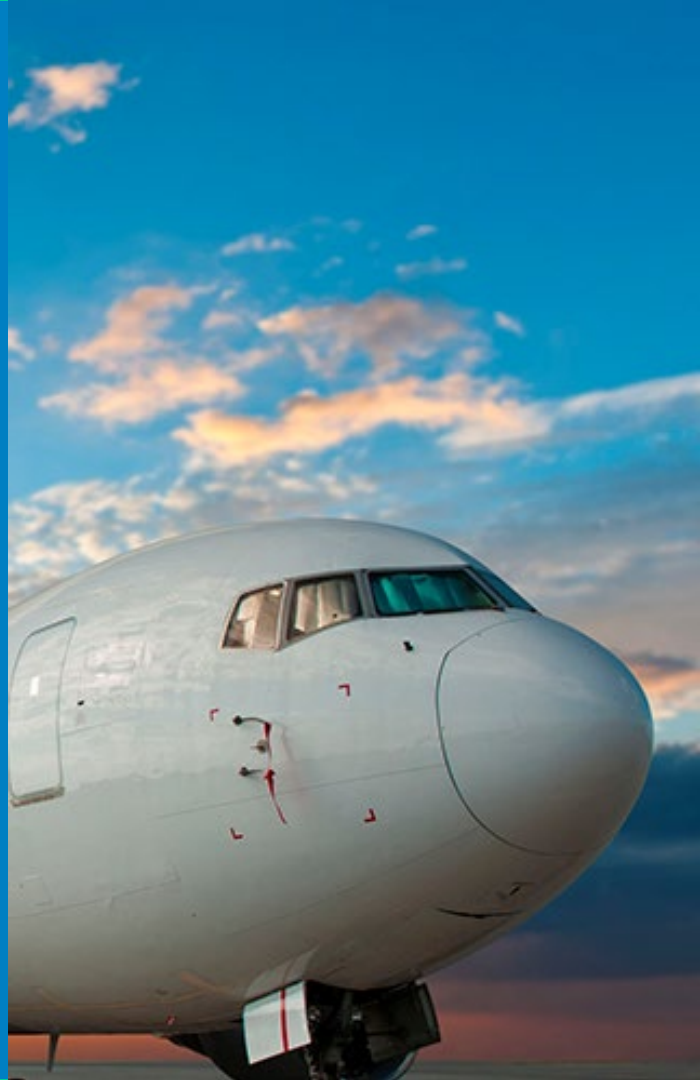
EASA
European Union Aviation Safety Agency

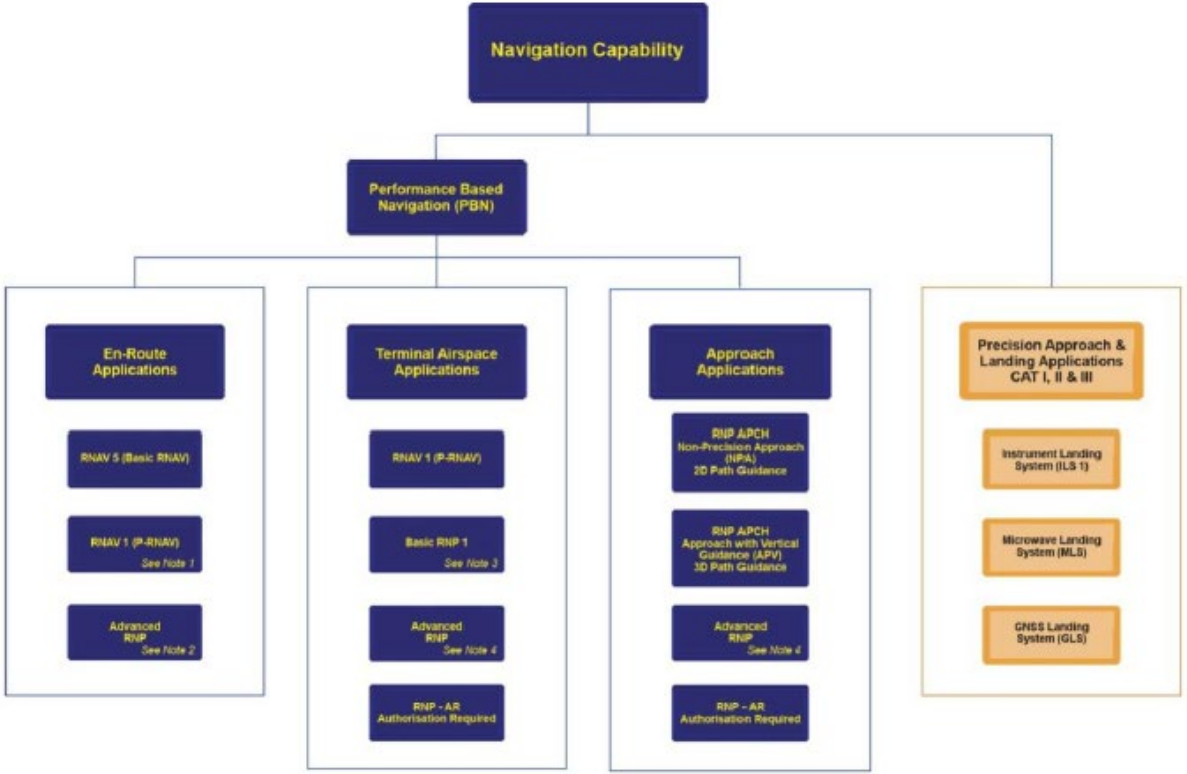
Key Definitions III

PBN Operational Approvals Workshop



An Agency of the European Union

Key Definitions III



Note 1 *Application of RNAV 1 Performance aspects, not terminal airspace functionality*

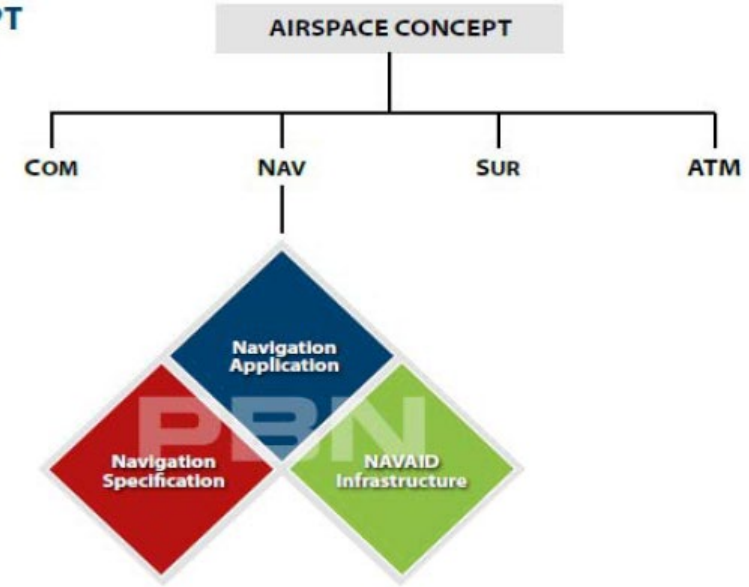
Note 2 *Including Fixed Radius Transition (FRT)*

Note 3 *Equivalent to RNAV 1 + GNSS, typically associated with Radius to Fix (RF)*

Note 4 *Including Radius to Fix (RF)*

Key Definitions III

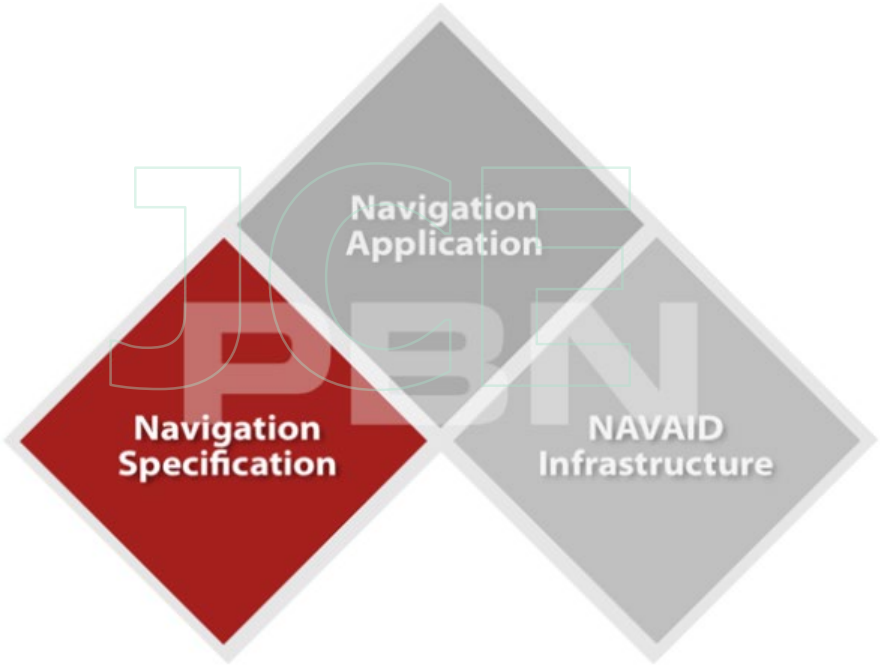
AIRSPACE CONCEPT



The PBN Manual introduces the *Airspace Concept* as a formal way to set out and respond to airspace requirements. As such, the development of the Airspace Concept is a key step in PBN implementation.

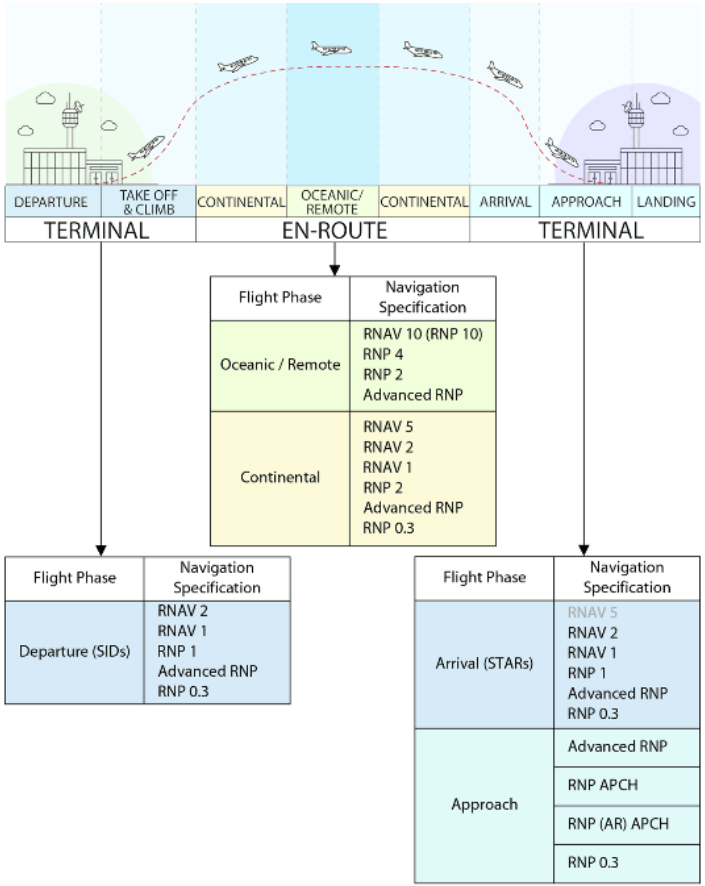
Key Definitions III

Navigation Specifications



Key Definitions III

Navigation Specifications



Key Definitions III

Navigation Specifications

→ In terms of PBN the required performance can be considered as the following:

» ***Accuracy***

Positioning accuracy is the difference between the actual and estimated position in fault free conditions (NSE).

Track-keeping accuracy is the difference between the actual and desired position in fault free conditions (TSE).

» ***Continuity***

The ability of the navigation system to provide its service without interruption during an operation, provided it was available at the start of that operation.

» ***Functionality***

The aircraft capabilities in terms of the avionics of the navigation computer and airframe.

As a subset PBN considers the availability of the GNSS signal in space (SIS).

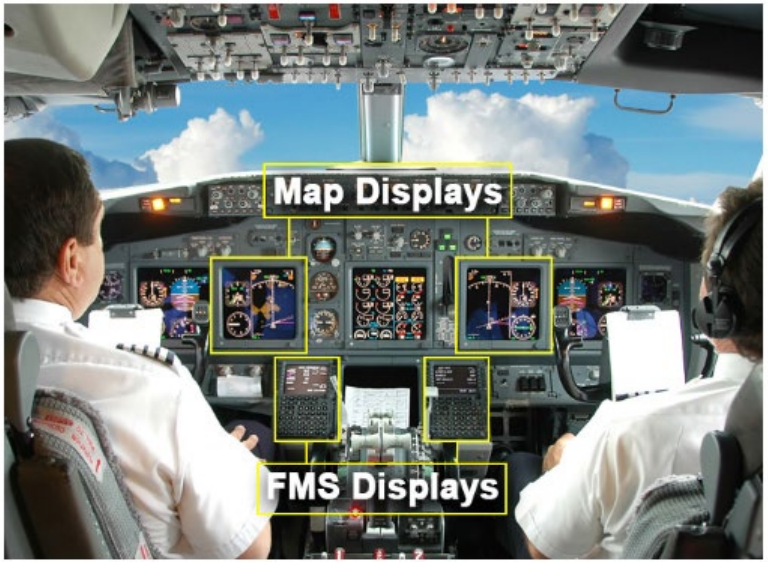
» ***Availability***

The ability of the total system to perform its function at the initiation of the intended operation.

In PBN, availability is limited to the GNSS Signal–In–Space (SIS).

Key Definitions III

Other requirements to achieve desired performance levels



Navigation Displays

Key Definitions III

Navigation Specifications

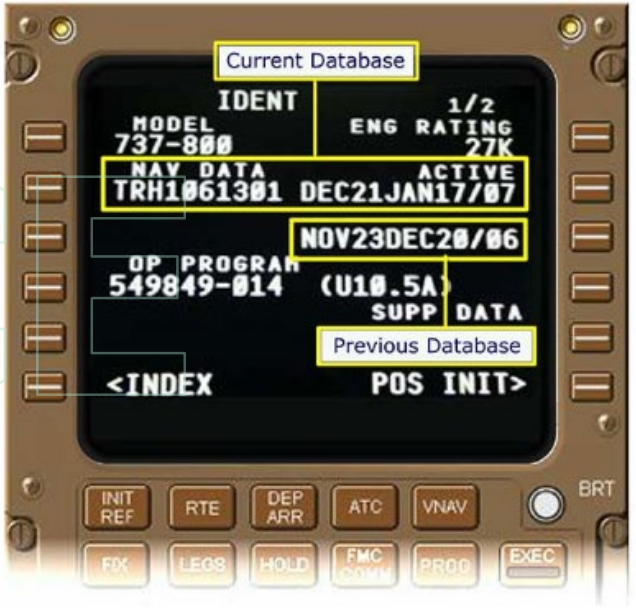
Aircraft position relative to track.

Distance and bearing to active (TO) waypoint.

Key Definitions III

Navigation Specifications

Ground speed to active (TO) waypoint.



Navigation data storage.

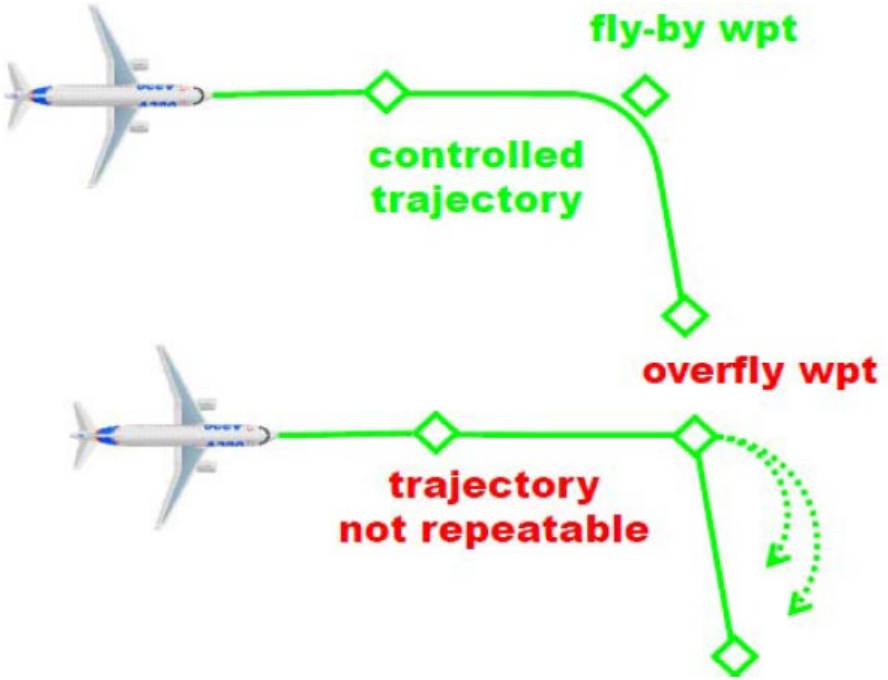
Key Definitions III

Navigation Specifications

Navigation performance alert.

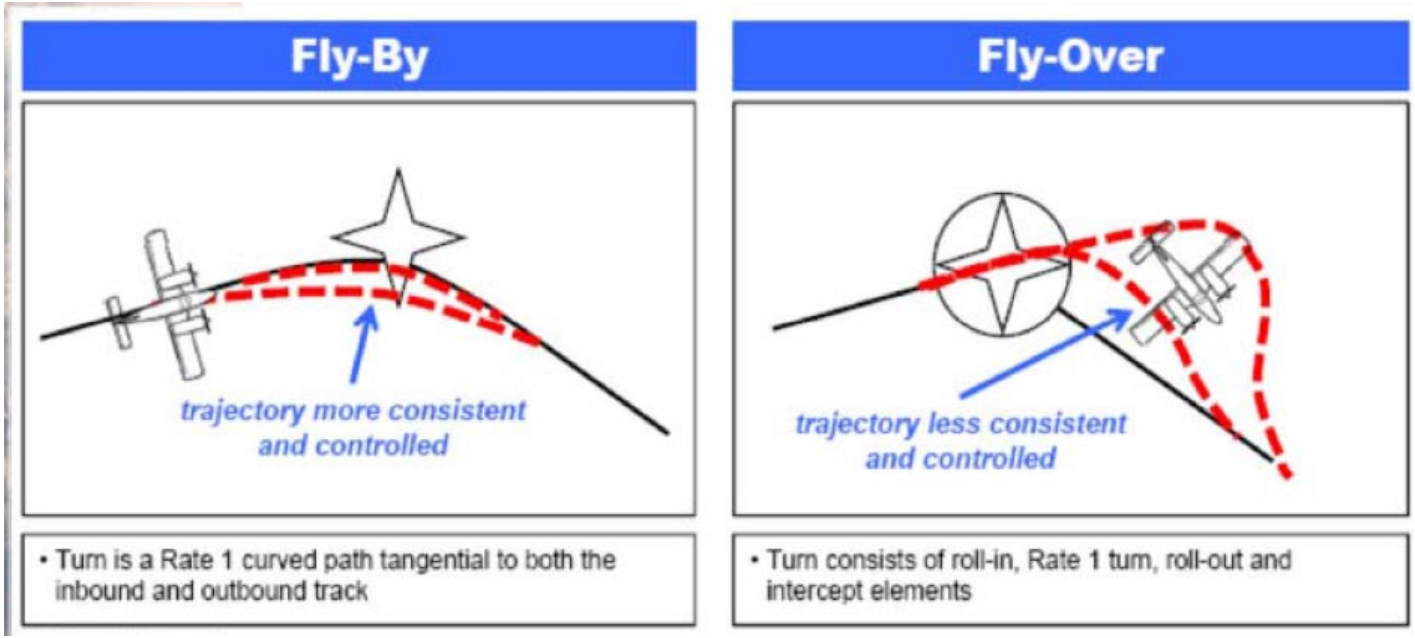
Key Definitions III

Waypoints

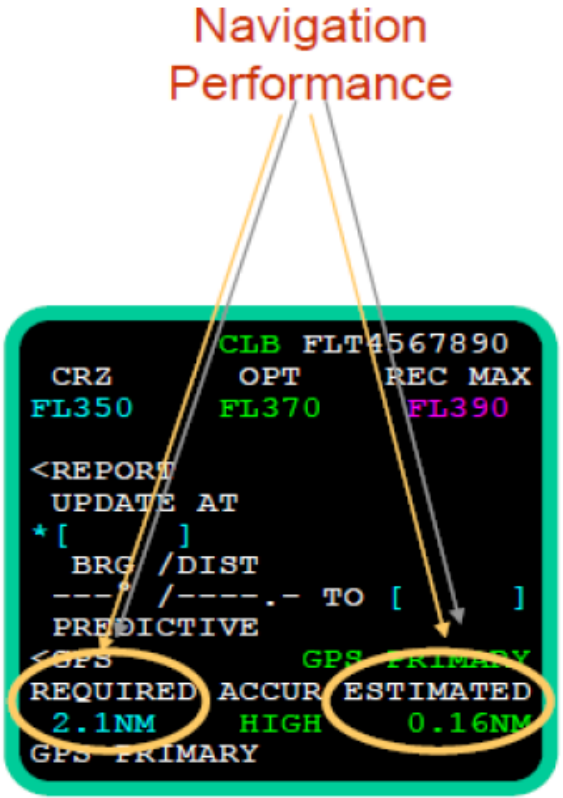


Key Definitions III

Waypoints

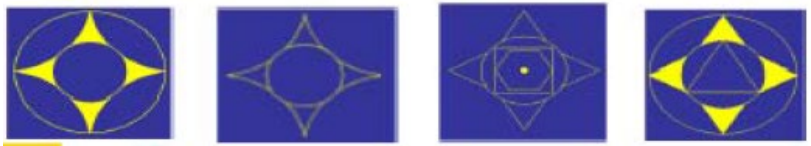


Key Definitions III



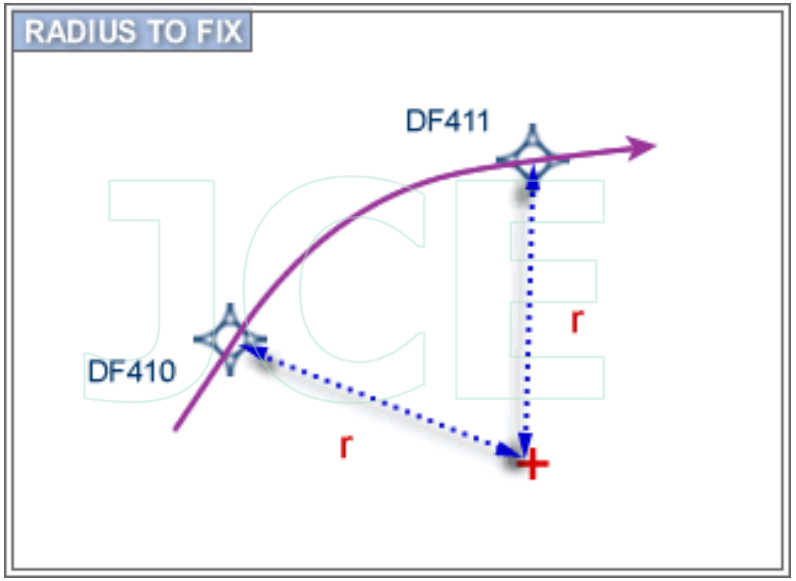
Key Definitions III

Fly-by Waypoint	
Fly-over Waypoint	
Fly-by Waypoint coincident with Significant Point (Compulsory Reporting Point)	
Fly-over Waypoint coincident with VOR/DME	
Fly-by Waypoint coincident with NDB	



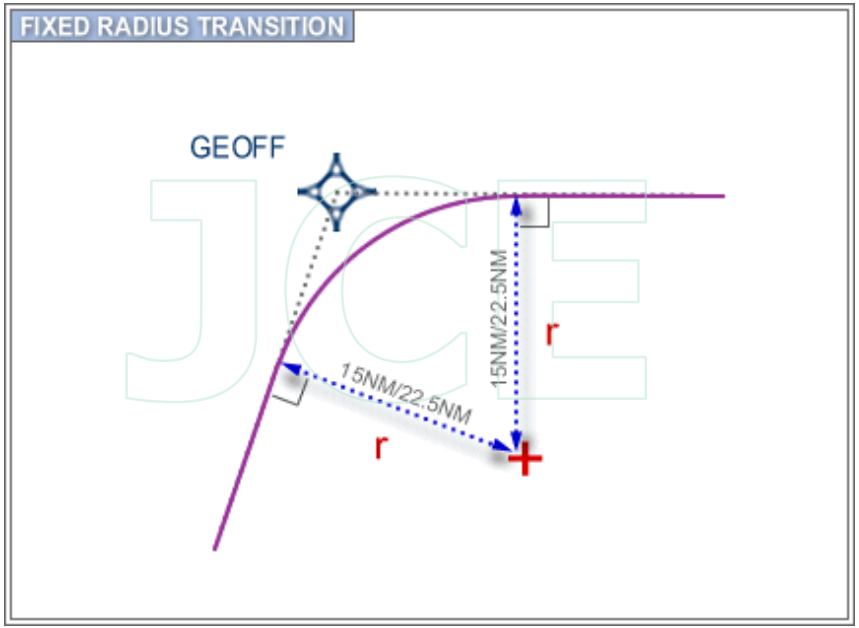
Key Definitions III

Radius to Fix (RF)



Key Definitions III

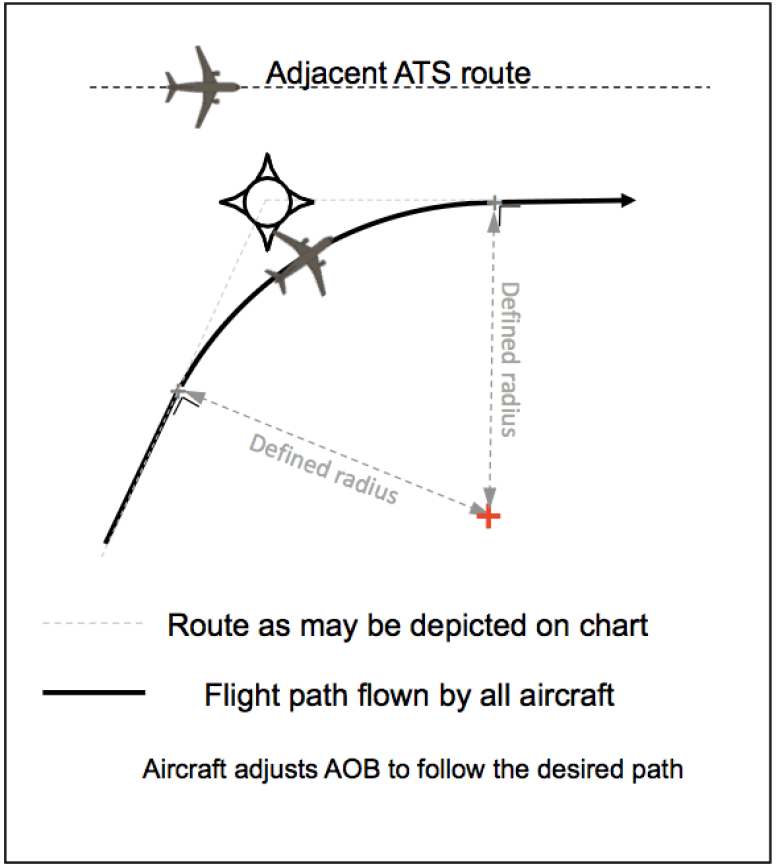
Fixed Radius Transition (FRT)



Key Definitions III

Description of a 'LEG' and how an aircraft flies it

En-Route and Terminal



Key Definitions III

Aircraft RNAV system and Database

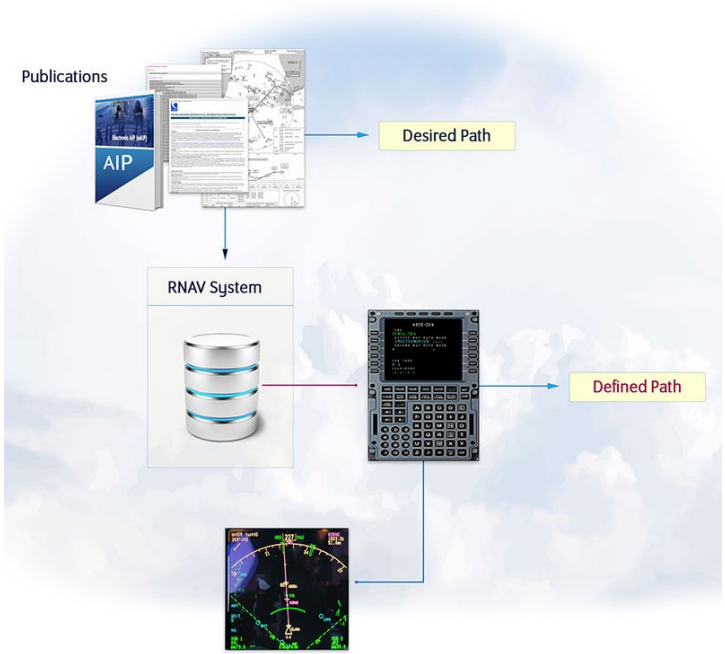
Key Definitions III

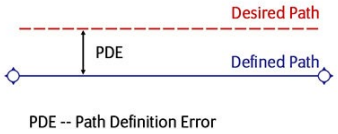
Using the data

Arrival Route	Waypoint Sequence
SNAKE 1A	SNAKE CHIRP FINCH VIXEN LIONS
SNAKE 1B	SNAKE COBRA MAMBA VIPER ADDER PIANO FLUTE PONGO RAVEN SUGAR HAGAR

Key Definitions III

Creating the Path

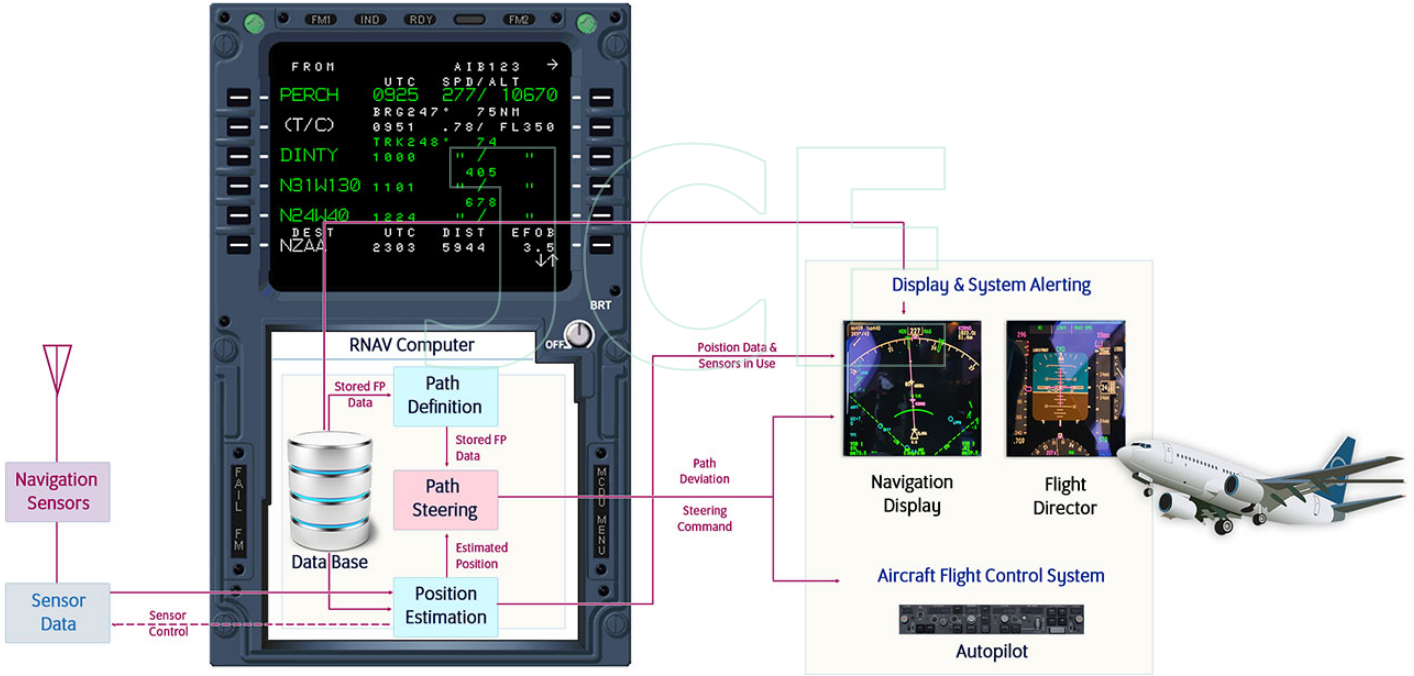




PDE -- Path Definition Error

Key Definitions III

Flying the Path



Key Definitions III

Implications of cross Specification qualification

Key Definitions III

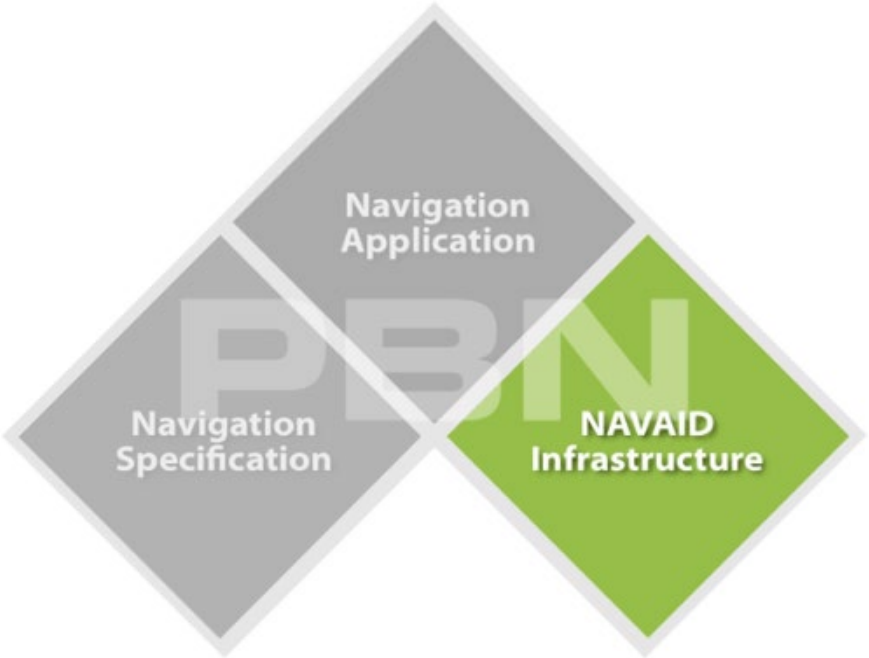
Advanced – RNP (A-RNP)

A-RNP is a Navigation Specification that was specifically developed to cover all phases of flight under a single certification and operational approval.

Note: High continuity is required for oceanic/remote continental operations.

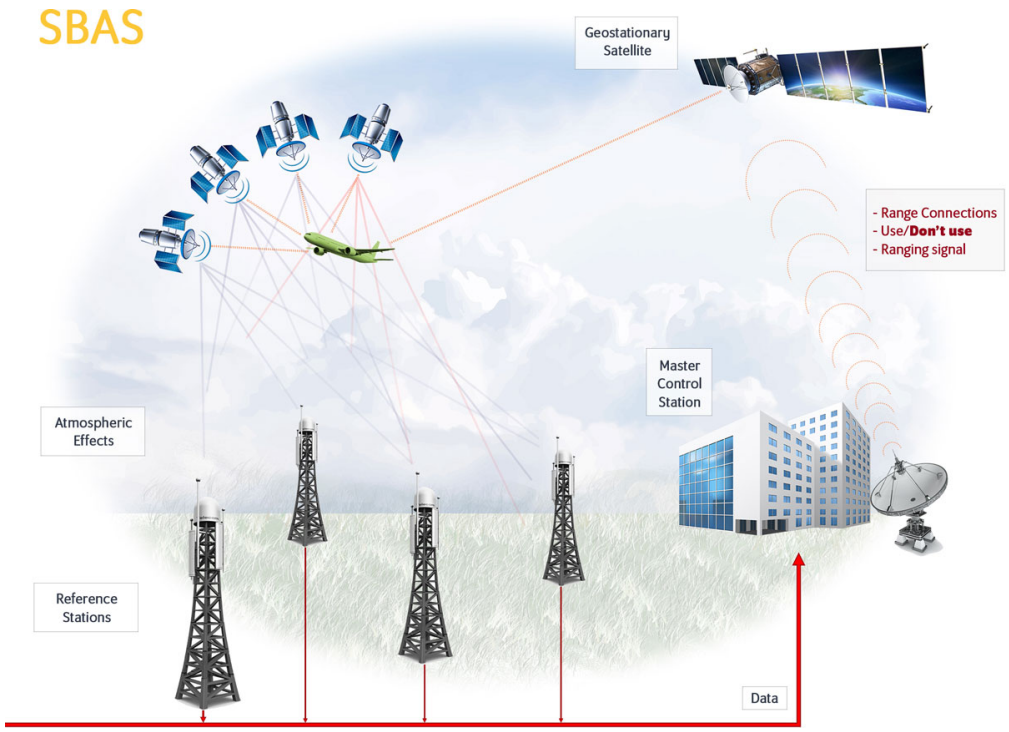
Key Definitions III

Navigation aid infrastructure



Key Definitions III

Space Based Augmentation Systems (SBAS)



Key Definitions III

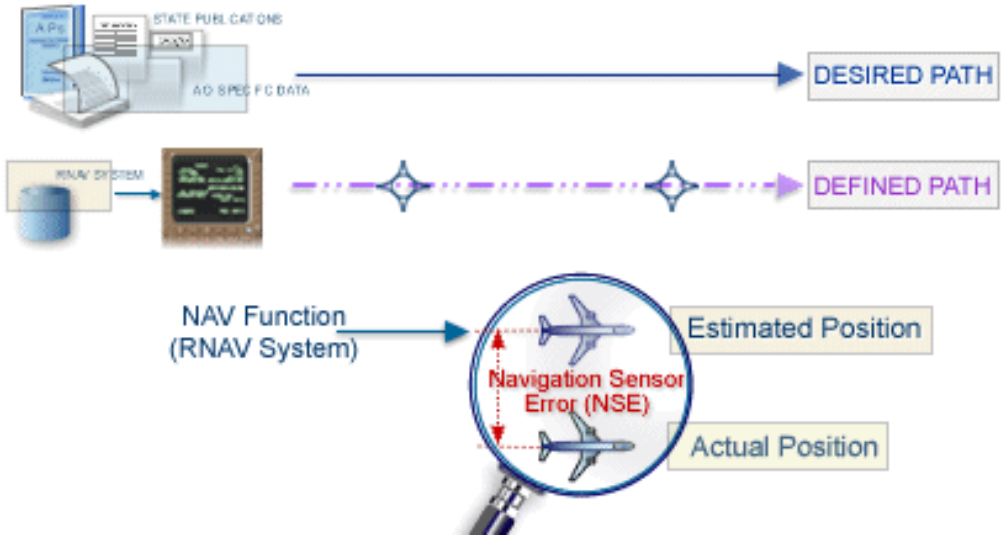
Ground Based Augmentation Systems (GBAS)

Supports precision approaches down to CAT I today. GBAS corrections could also be used by suitably equipped RNAV systems.

Key Definitions III

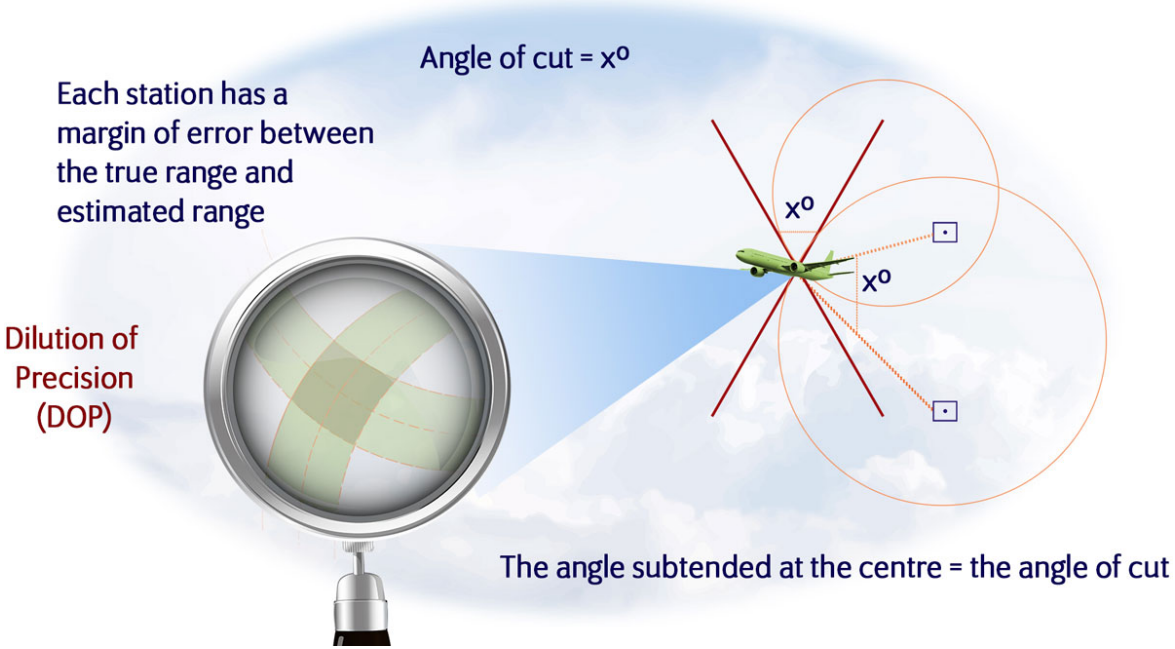
Implications for PBN

Positioning Accuracy



Key Definitions III

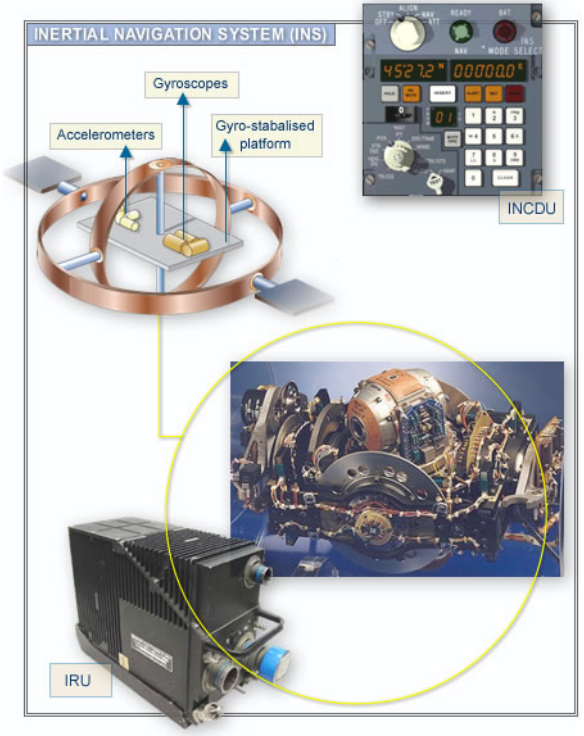
Positioning Accuracy



Key Definitions III

On-board autonomous navigation capability

Inertial Reference Systems (IRS):

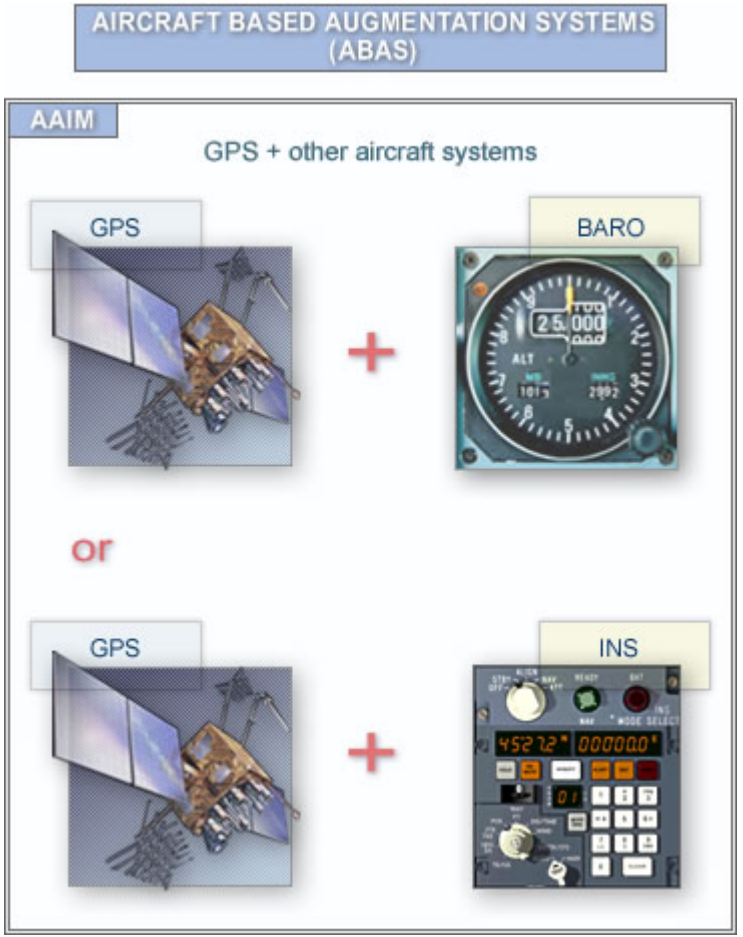


Key Definitions III

Integrity

AAIM:

Integrity monitoring is provided on the flight deck by linking the GPS receiver with either an Inertial system or a Barometric altimeter



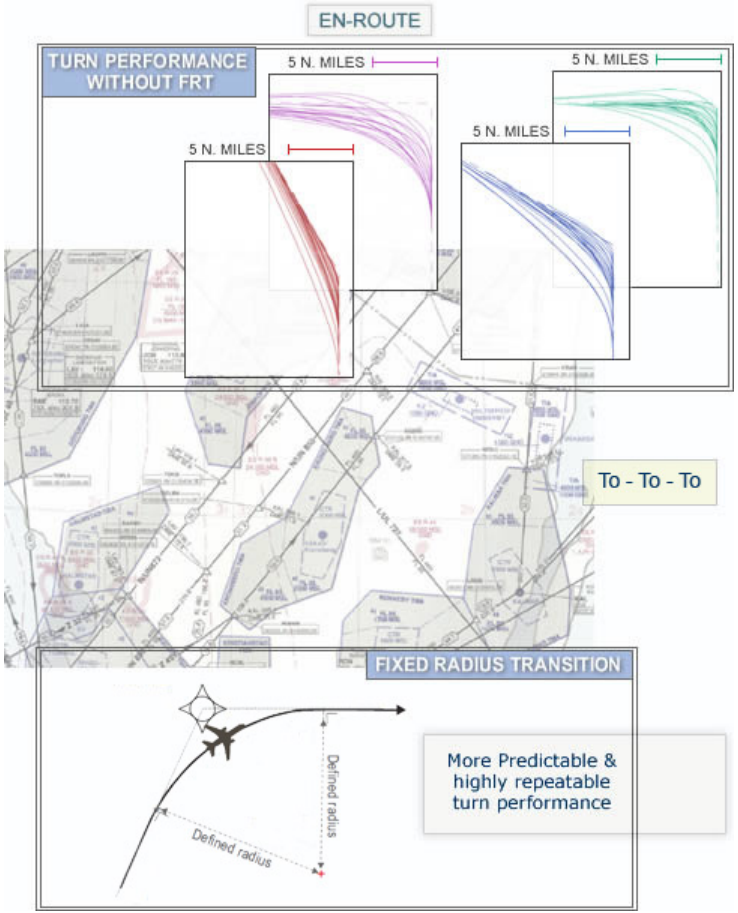
Key Definitions III

Navigation Applications

Key Definitions III

En-route navigation

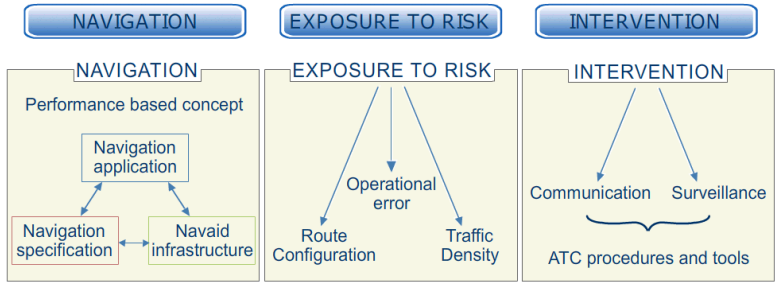
En-route segments



Key Definitions III

En-route navigation

Benefits of PBN



✓ *Relevant*
✗ *Largely irrelevant*

		NAVIGATION	EXPOSURE TO RISK	INTERVENTION
SEPARATION MINIMA	(1) (for tactical use) without ATC Surveillance	✓	✓ *(2)*	✗
	(1) (for tactical use) with ATC Surveillance	✗	✗ *(2) and (3)*	✓
ROUTE SPACING	without ATC Surveillance	✓	✓	✗
	with ATC Surveillance	✓	✓	✓

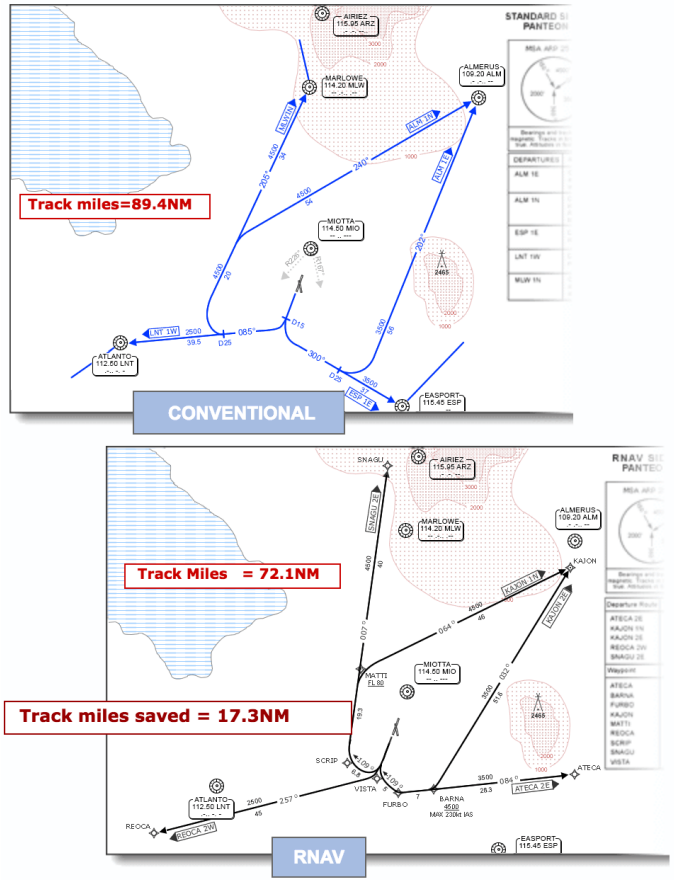
(1) In context, separation minima based on navaid or navigation sensor or PBN
(2) Traffic density = single aircraft pair
(3) Separation minima determined as a function of performance of ATC surveillance system

Key Definitions III

Terminal Airspace Navigation

SIDs

The following image shows an example of a departure. It demonstrates that, when RNAV is used, as there is no need to overfly NAVAIDs, shorter track miles can be provided. This will result in more efficient use of airspace and fuel.

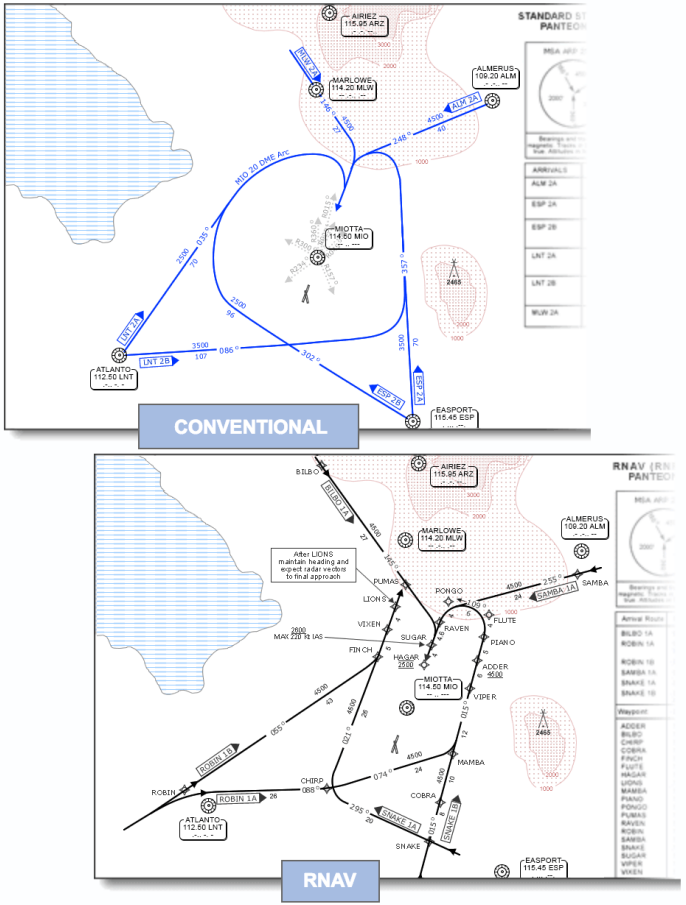


Key Definitions III

Terminal Airspace Navigation

STARs

These STAR charts highlight the fact that RNAV operations can be used to provide highly repeatable routes for better separation and sequencing, and to reduce track miles, as there is no requirement to route via the NAVAID.



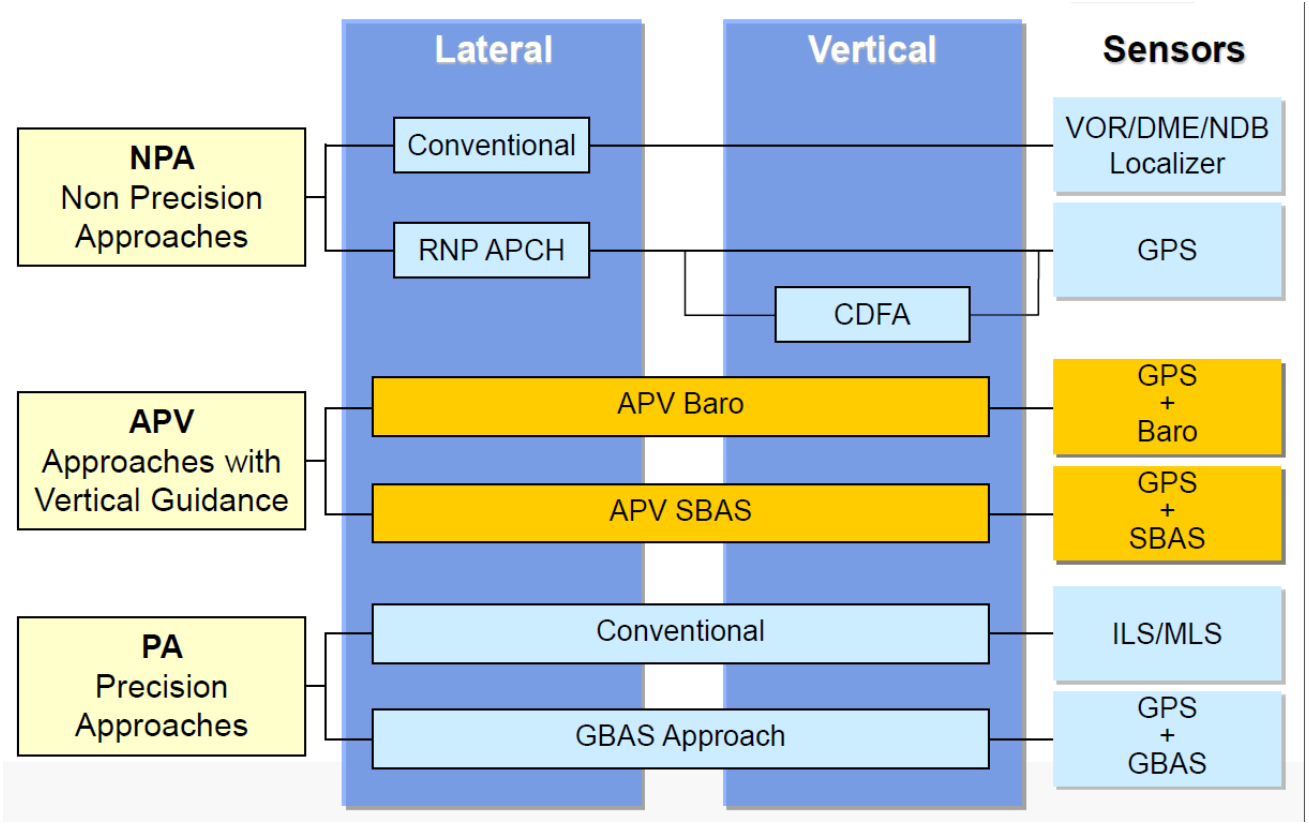
Key Definitions III

Terminal Airspace Navigation

Closed STARs

Open STARs:

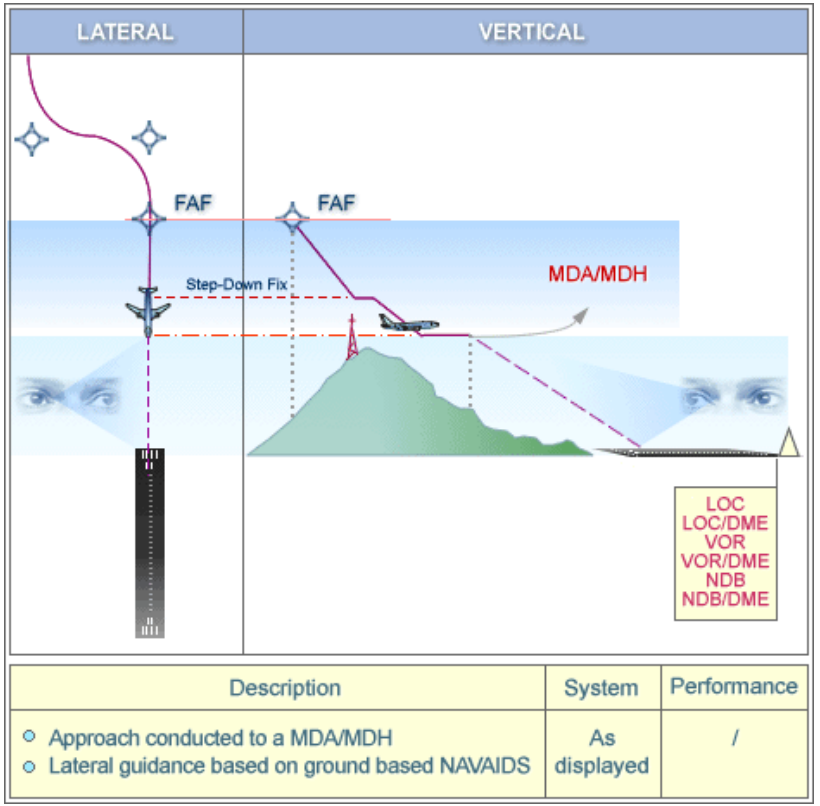
Key Definitions III



Key Definitions III

Terminal Airspace Navigation

Approach



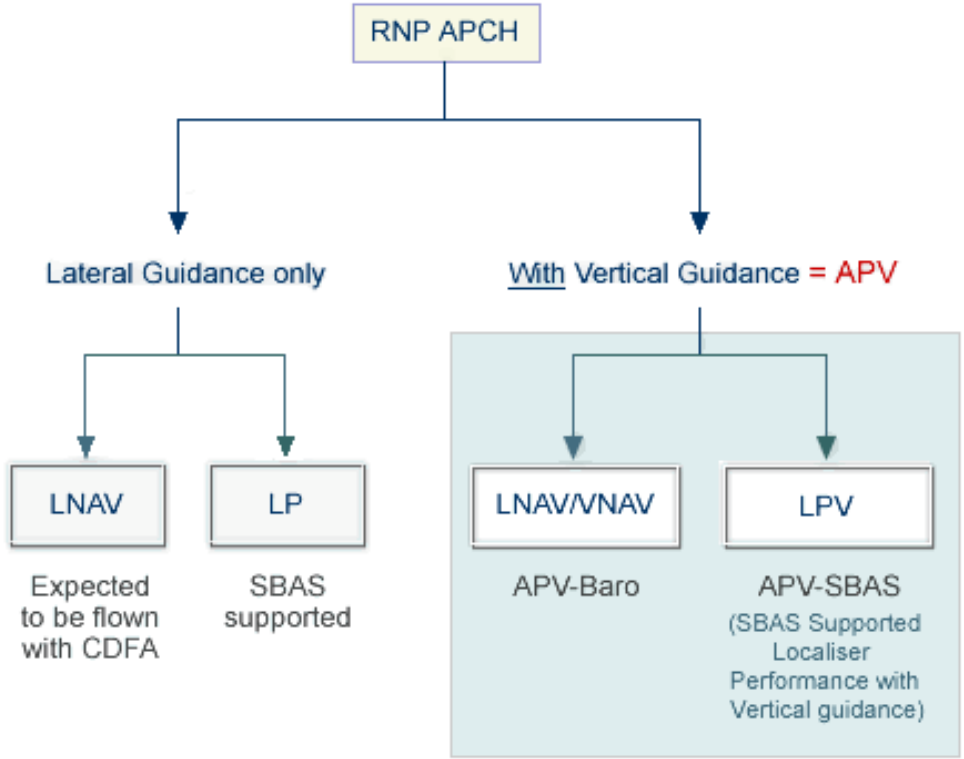
Description	System	Performance
○ Approach conducted to a MDA/MDH ○ Lateral guidance based on ground based NAVAIDS	As displayed	/

Key Definitions III

Terminal Airspace Navigation

Approach

RNP APCH



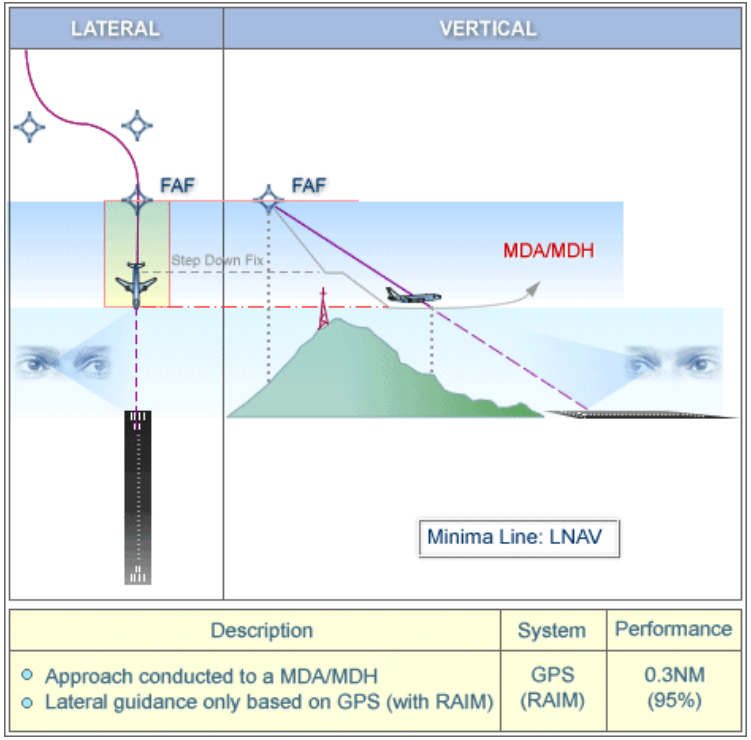
Key Definitions III

Terminal Airspace Navigation

Approach

RNP APCH

If the pilots can't see the runway as they approach the minimum altitude they will initiate the missed approach procedure.

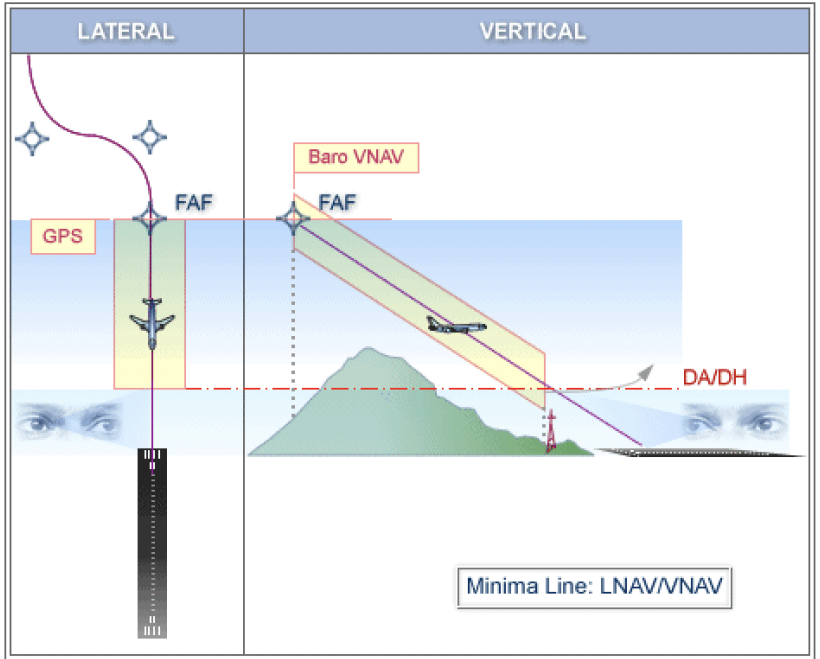


Key Definitions III

Terminal Airspace Navigation

Approach

RNP APCH with Vertical guidance (APV)



Description	System	Performance
○ Approach conducted to a Decision Altitude/Height ○ Lateral guidance only based on GPS (with RAIM) and vertical guidance based on Baro	GPS (RAIM) + Barometric altimetry	0.3NM(95%)

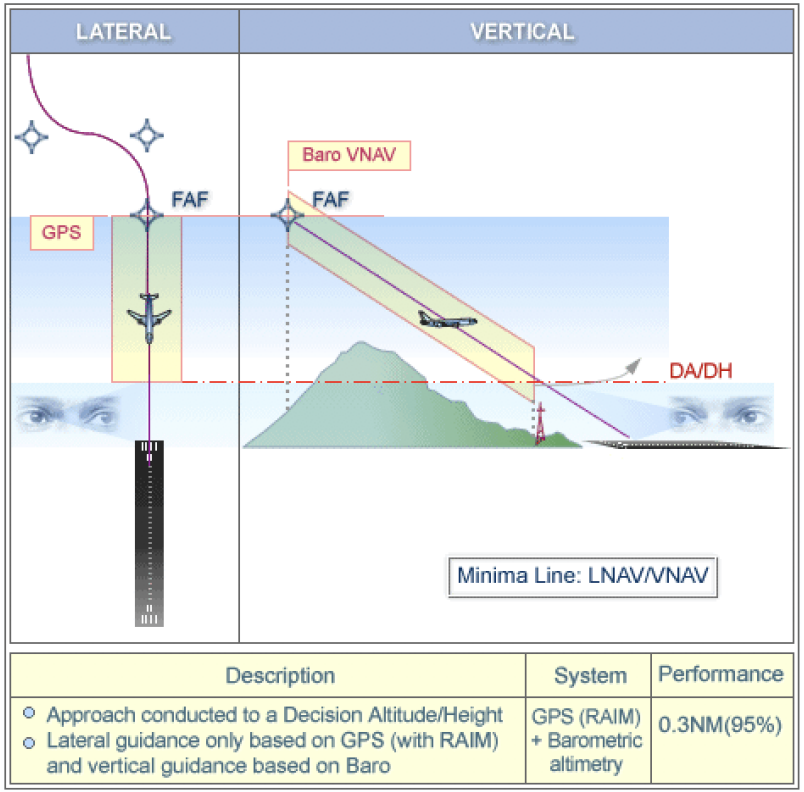
Key Definitions III

Terminal Airspace Navigation

Approach

RNP APCH with Vertical guidance (APV)

APV BARO VNAV



Description	System	Performance
○ Approach conducted to a Decision Altitude/Height ○ Lateral guidance only based on GPS (with RAIM) and vertical guidance based on Baro	GPS (RAIM) + Barometric altimetry	0.3NM(95%)

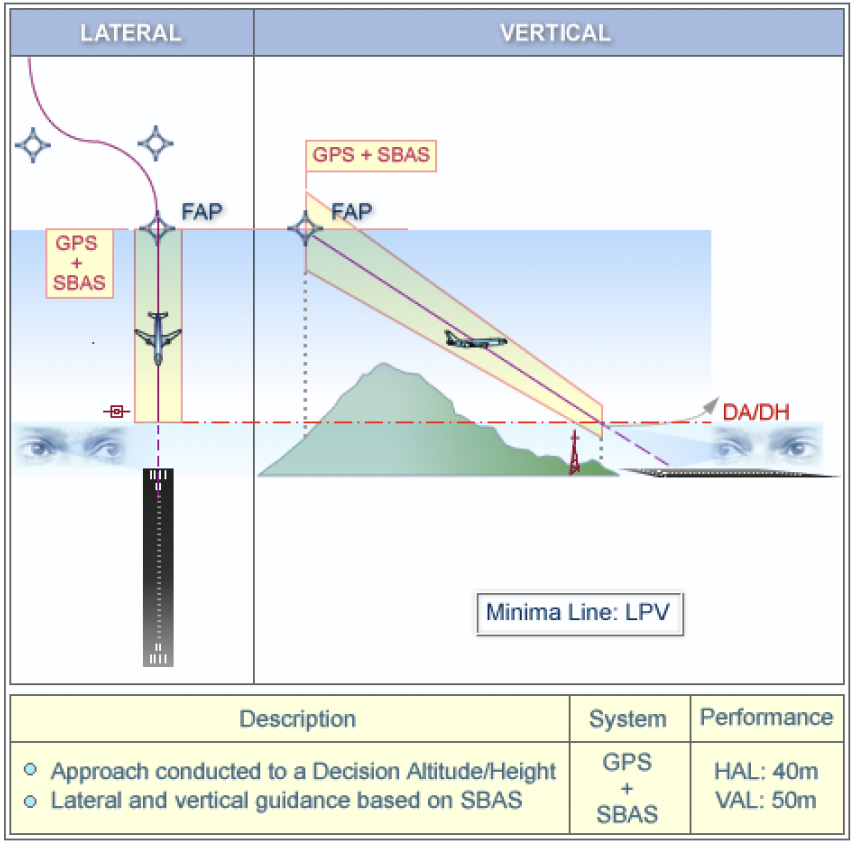
Key Definitions III

Terminal Airspace Navigation

Approach

RNP APCH with Vertical guidance (APV)

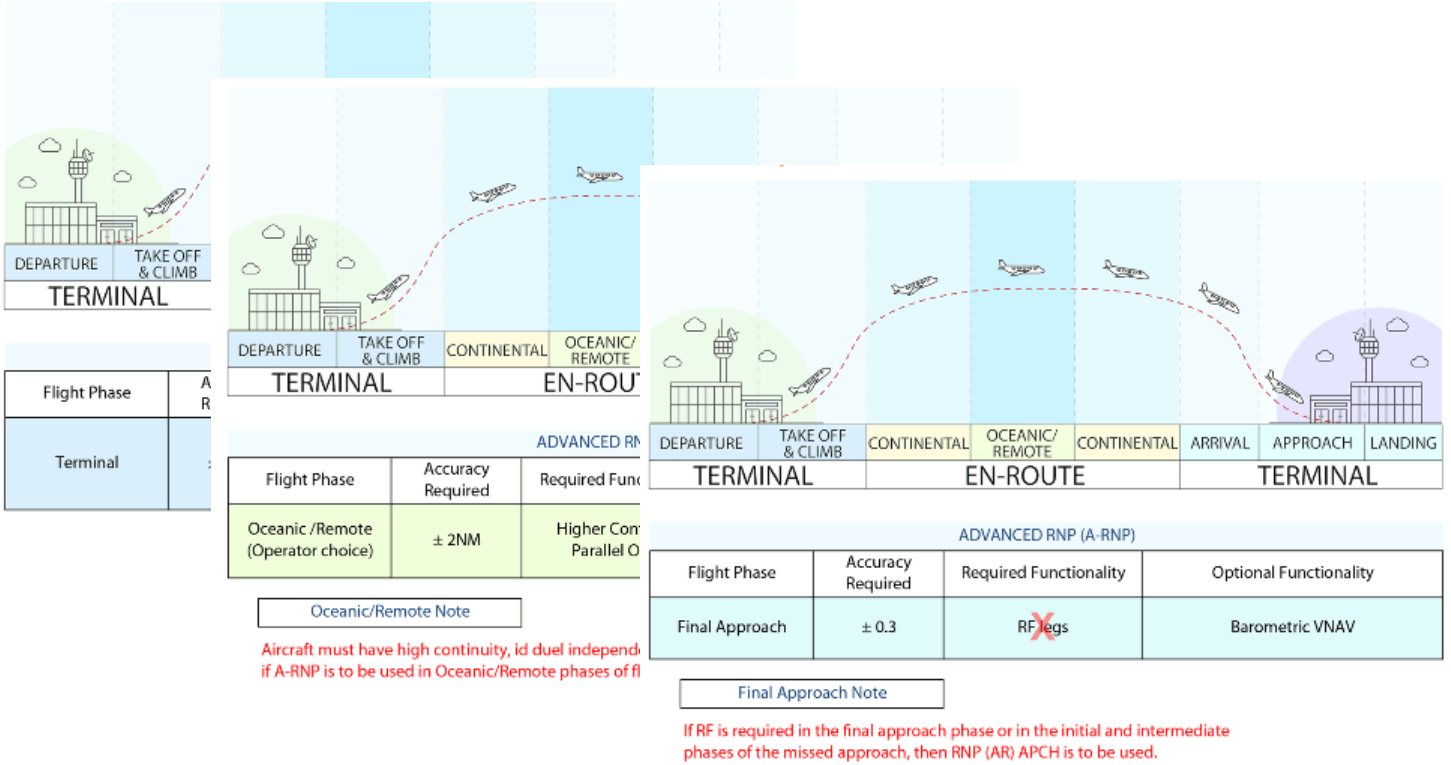
APV SBAS



Description	System	Performance
○ Approach conducted to a Decision Altitude/Height ○ Lateral and vertical guidance based on SBAS	GPS + SBAS	HAL: 40m VAL: 50m

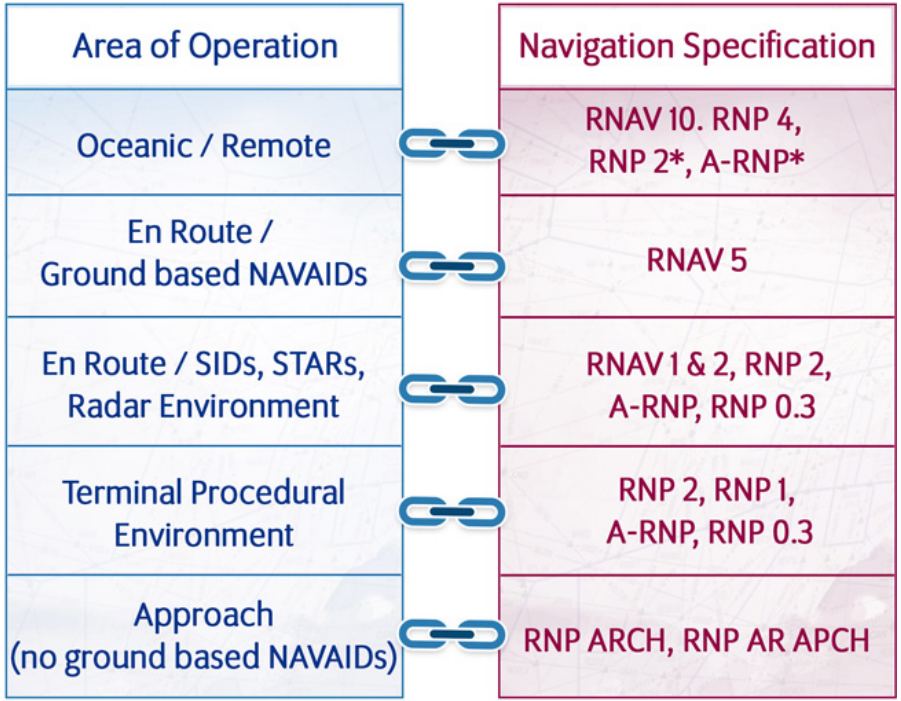
Key Definitions III

Advanced RNP (A-RNP)



Key Definitions III

Examples of Navigation Specifications in different areas of operation

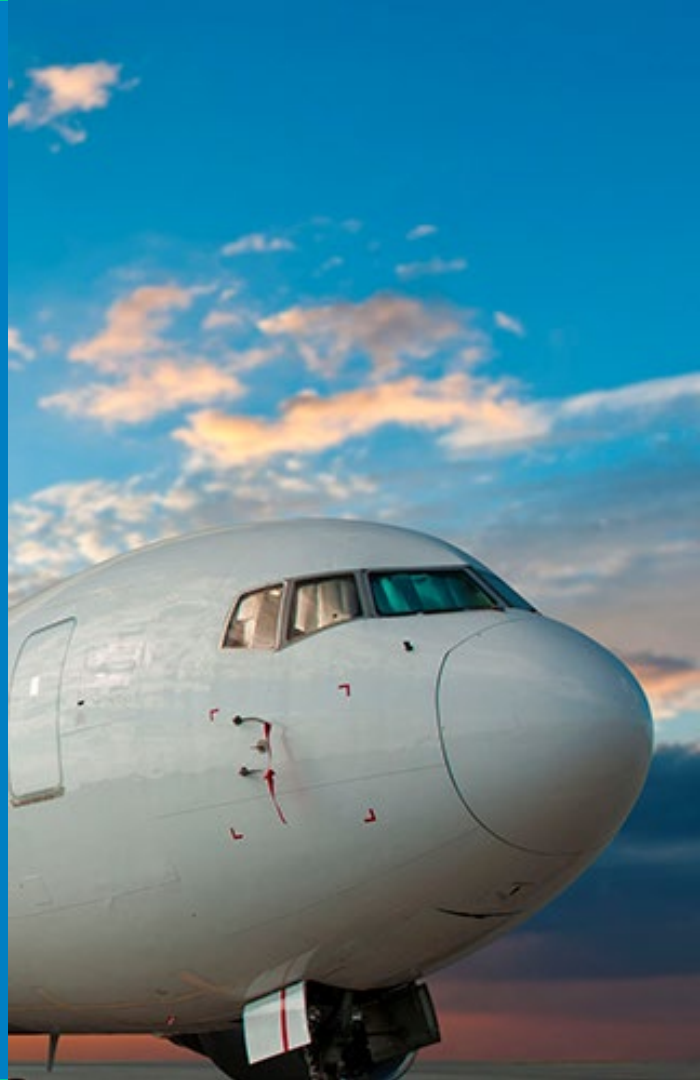


* High Continuity Required

EASA
European Union Aviation Safety Agency

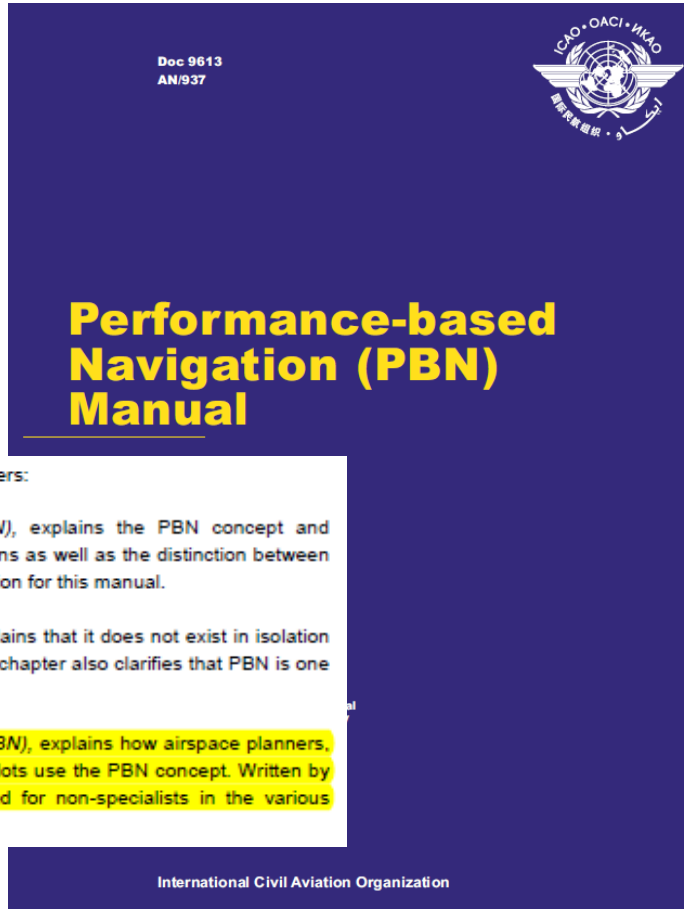
Stake Holders Uses of PBN

PBN Operational Approvals Workshop



An Agency of the European Union

Stakeholders Uses of PBN



Part A — *The Performance-Based Navigation (PBN) Concept,* contains three chapters:

Chapter 1 — *Description of Performance-based Navigation (PBN),* explains the PBN concept and specifically emphasizes the designation of navigation specifications as well as the distinction between RNAV and RNP specifications. This chapter provides the foundation for this manual.

Chapter 2 — *Airspace Concepts,* provides a context to PBN and explains that it does not exist in isolation but rather as an integral component of an airspace concept. This chapter also clarifies that PBN is one of the CNS/ATM enablers in an airspace concept.

Chapter 3 — *Stakeholder Uses of Performance-based Navigation (PBN),* explains how airspace planners, procedure designers, airworthiness authorities, controllers and pilots use the PBN concept. Written by specialists of these various disciplines, this chapter is intended for non-specialists in the various disciplines.

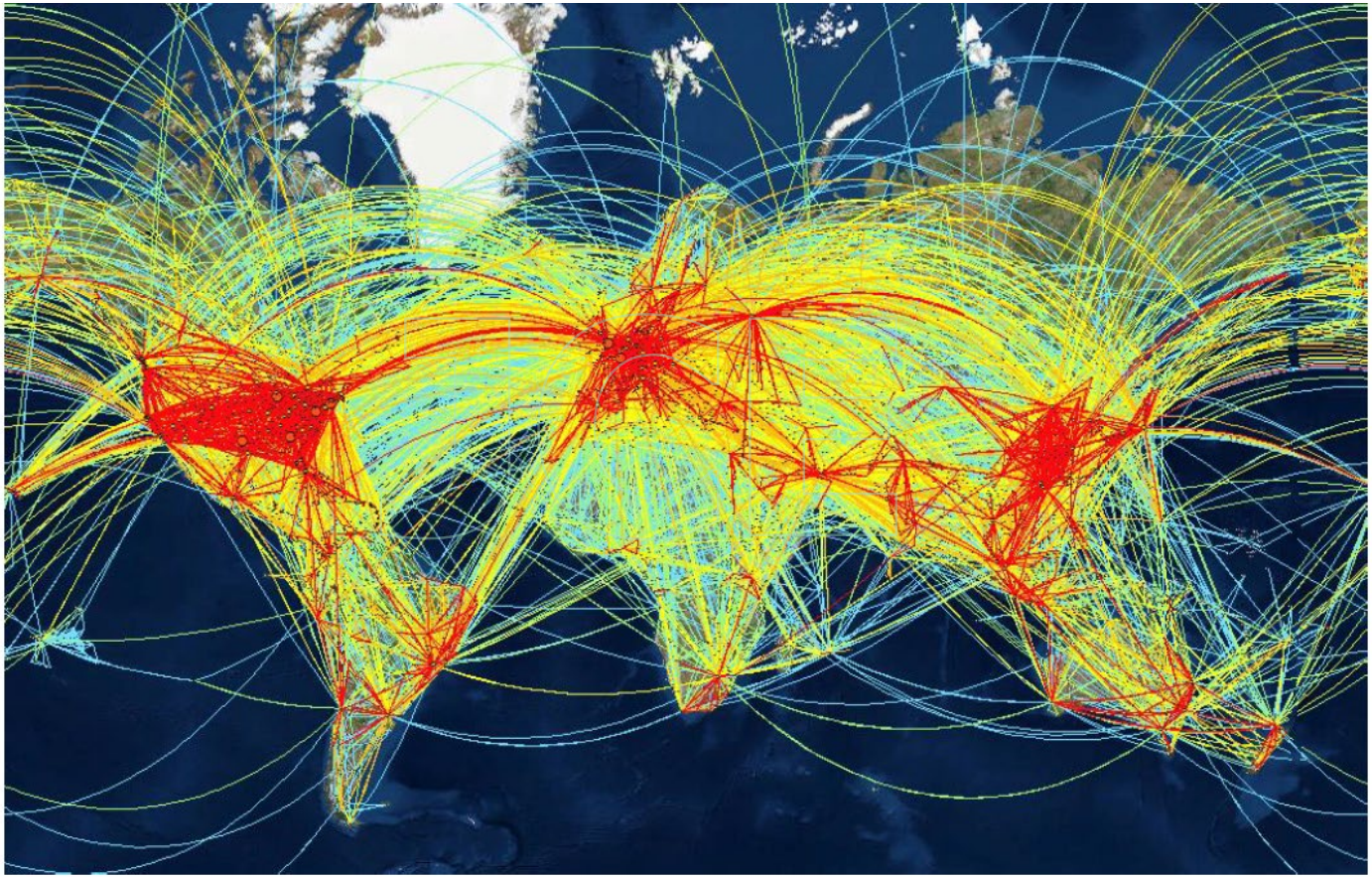
Stakeholders Uses of PBN

Stakeholders

- Airport Operators
- Aircraft Operators
- Other:
  - Industry Representatives
  - Public
  - Community Groups
  - Airport Authorities
  - Government Officials

Stakeholders Uses of PBN

Stakeholders Uses of PBN



Stakeholders Uses of PBN

Airport Operators

→ The involvement of airport operators benefits procedure design by potentially enabling the maximum achievable environmental benefits given local constraints allowing the community buy in, and aiding in the seamless implementation of FAA's NextGen Program.

Stakeholders Uses of PBN

Airport Operators Concerns

→ The concerns of airport operators related to the design of flight procedures serving their airport include efficient access of passenger and aircraft to the NAS, meeting environmental requirements for the airport, satisfying the needs of the communities proximate to the airport, maximizing airport revenue, and minimizing operational costs.

Stakeholders Uses of PBN

Airport Operators Contributions

→ Airport personnel can address these concerns by engaging in the procedure development process.

→ The airport operator is recognised as a primary stakeholder in PBN development.

Stakeholders Uses of PBN

Communities

→ Input from community representatives is valuable in helping lo ensure that the needs of the community are understood and considered in the procedure design.

Stakeholders Uses of PBN

Concerns

→ The concerns of communities proximate to airports regarding flight procedure design include the concentration of aircraft noise, increases in air traffic, local air quality, and the preeminence of air traffic.

Stakeholders Uses of PBN

Contributions

→ Communities can address these concerns by being aware of and understanding the procedure development project and having opportunities to voice their concerns. Representative bodies also offer the opportunity for education regarding PBN procedures.

Stakeholders Uses of PBN

Aircraft Operators

→ Aircraft operators are typically a project sponsor and may design their own procedures for an airport.

Stakeholders Uses of PBN

Aircraft Operators concerns

→ Aircraft operators want to ensure the usability of the published procedures. They typically want designs that they can use and that are approved by ATC. Additional concerns of aircraft operators include design for fuel and lime savings as well as providing reliable access to airspace and airports.

Stakeholders Uses of PBN

Aircraft Operators contributions

→ Aircraft operators can contribute with specific information fundamental to the procedure design including defining their normal operations, understanding of their flight planning process, the capacities of their aircraft, the typical\weights and climb profiles and the current and planned PBN.

Stakeholders Uses of PBN

Challenges

→ Planning

→ Outreach

→ Technical design

→ Utilisation

→ Process

Stakeholders Uses of PBN

Challenges

→ Planning

- → An airport master plan should consider the timing and effects of PBN implementation capacity and traffic demand, facility requirements, alternatives, noise, and implementation schedules for major capital improvements.
- → This will ensure that airport infrastructure will meet the needs of the potential increase in operations enabled by PBN.

Stakeholders Uses of PBN

Challenges

→ Planning

- → A Noise Compatibility Study should consider PBN airspace alternatives designed to avoid noise-sensitive land use areas and hereby reducing the overall impact of noise on a community.
- → Planning PBN noise abatement alternatives prior to the implementation of a metroplex or other PBN taking advantage of the resources available through the process.

Stakeholders Uses of PBN

Challenges

→ Outreach

- → Challenges in outreach include community opposition and resources. Community opposition to PBN procedures may be due to limited knowledge and understanding and can hamper the implementation of procedures.
- → Outreach lo communities prior to the procedure development process can help to obtain their understanding and approval.
- → However, this may require significant resources depending on the nature of the project and level of interest and concern of the community.

Stakeholders Uses of PBN

Challenges

→ Outreach

- → Educating the community on the benefits associated with PBN is paramount; airports typically have outreach programs and procedures in place, which can be leveraged to support PBN outreach efforts.

Stakeholders Uses of PBN

Challenges

→ Technical design

- → Challenges in technical design may include PBN procedure requirements, aircraft performance differences, and stakeholder needs.
- → Regarding procedure requirements, when coupled with local terrain and airspace constraints, it is possible that the procedures may be operationally challenging or infeasible to implement, or may have high ceiling and visibility requirements.

Stakeholders Uses of PBN

Challenges

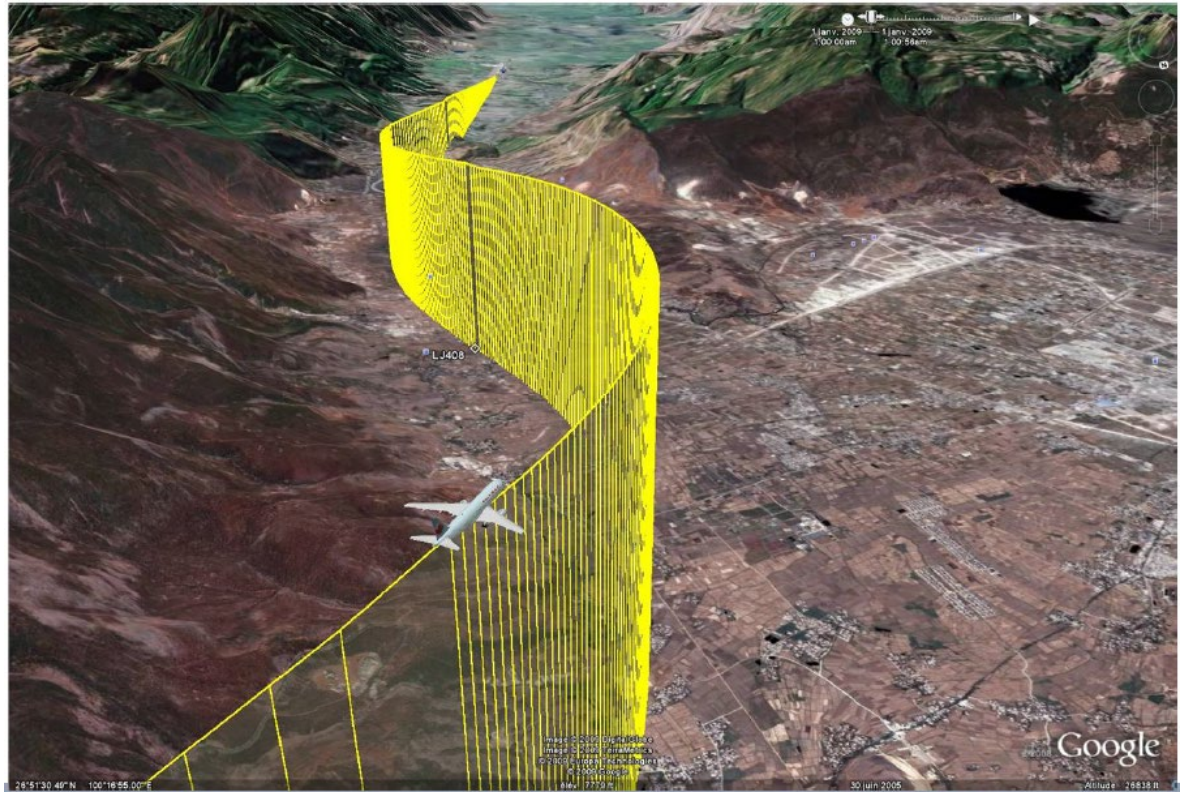
→ Technical design

- → Regarding aircraft performance, different aircraft and their FMS's can exhibit performance differences while flying the same procedure.
- → Accounting for the breadth of performance differences in the design and evaluation of the procedures can be challenging.
- → Regarding stakeholder needs, achieving the benefits at the proposed procedures, while adjusting their design to meet the needs of all the stakeholders without compromising the design objectives, can be challenging.

Stakeholders Uses of PBN

Challenges

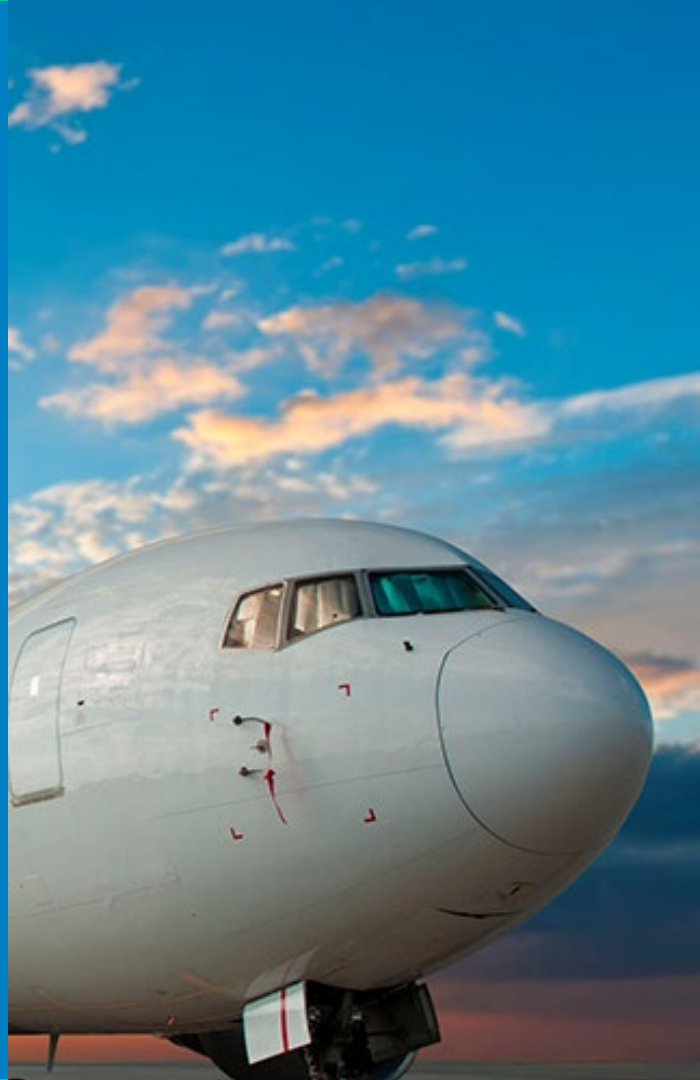
→ Technical design



EASA
European Union Aviation Safety Agency

PBN Benefits / Implementation Matters

PBN Operational Approvals Workshop



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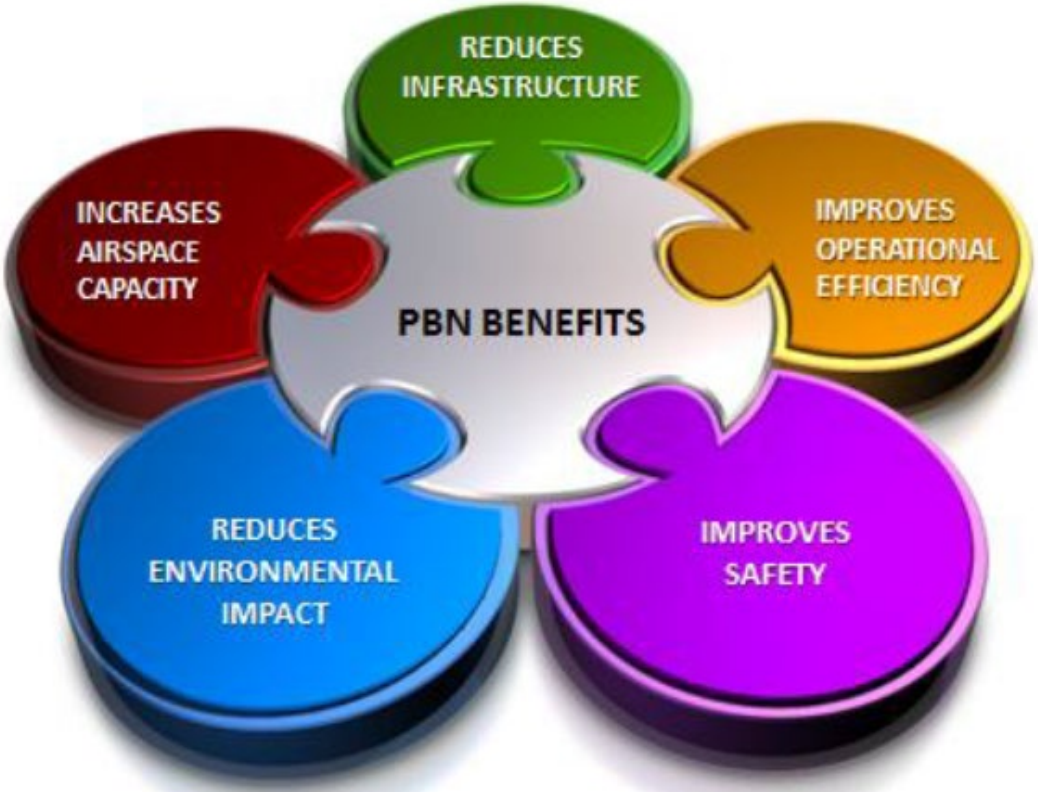
PBN Benefits / Implementation Matters



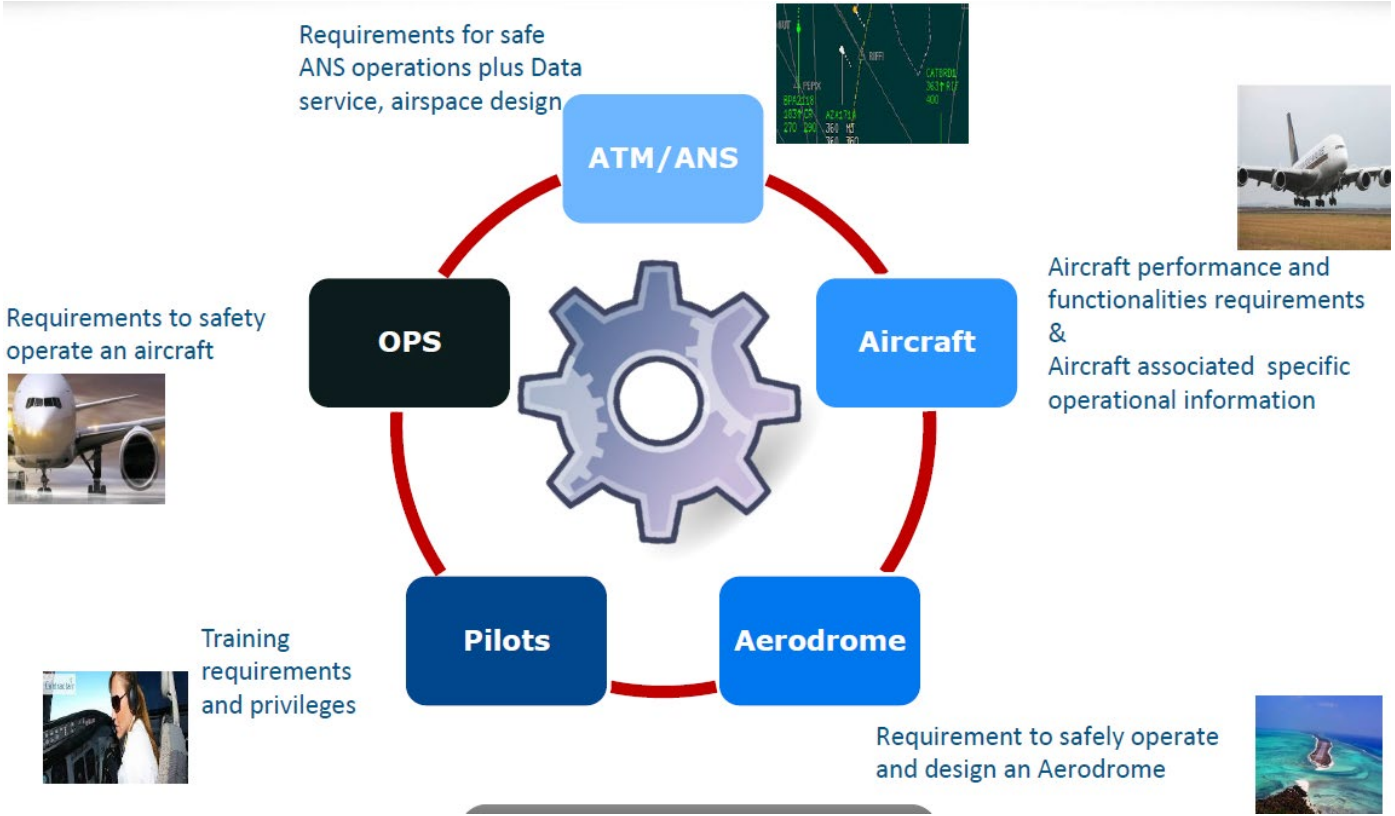
PBN Benefits / Implementation Matters

Widespread use of PBN has significant **benefits** for total system **safety, capciaty** and **environmental** impact

Operating methods based on PBN are, in general, **simpler for flight crews** than conventional navigation, and are the real-world operating methods that have been used for many years by the majority of operators

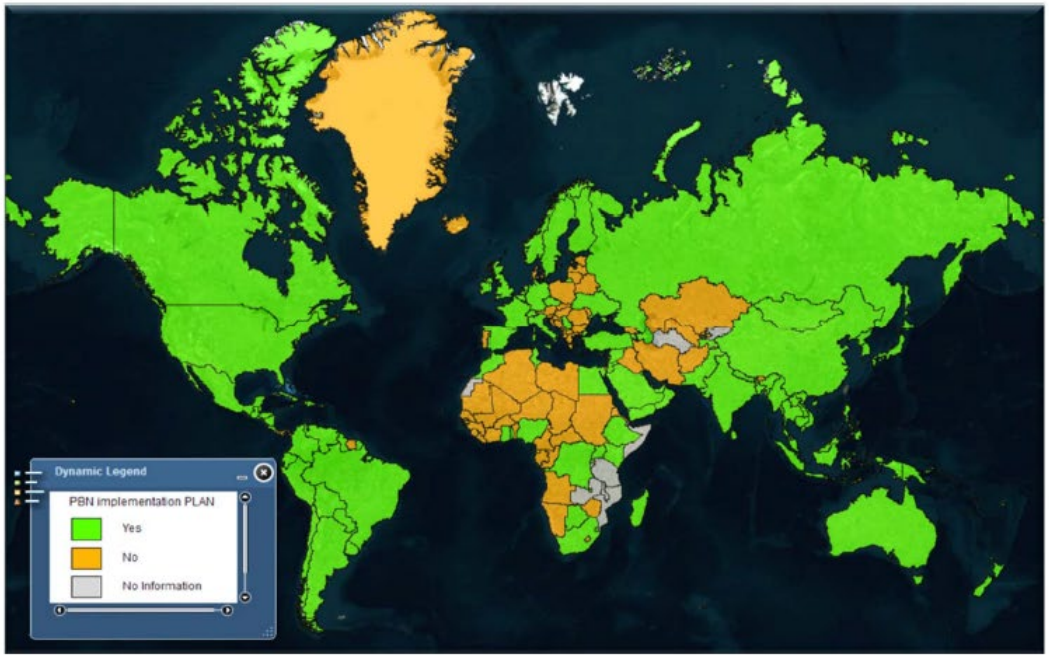
Commonality in operating methods between PBN specifications

PBN Benefits / Implementation Matters



PBN Benefits / Implementation Matters

Global Implementation Status



Only 102 States (or 53%) have a PBN Implementation Plan

PBN Benefits / Implementation Matters

PBN Benefits

→ PBN represents a fundamental shift from sensor-based to performance-based navigation and offers a number of advantages over the sensor-specific method of developing airspace and obstacle clearance criteria.

PBN Benefits / Implementation Matters

PBN Benefits

- → reduces the need to maintain sensor-specific routes and procedures, and their associated costs;
- → avoids the need for developing sensor-specific operations with each new evolution of navigation systems, which would be cost-prohibitive;
- → allows for more efficient use of airspace (route placement, fuel efficiency and noise abatement);clarifies how RNAV and RNP systems are used; and
- → facilitates the operational approval process for operators by providing a limited set of navigation specifications intended for global use.

PBN Benefits / Implementation Matters

PBN Benefits

→ PBN can potentially enable operational benefits in the areas of safety, flight efficiency and airspace capacity, as well as improved cost-efficiency and reduced environmental impact.

PBN Benefits / Implementation Matters

PBN:

- Improves Safety
  - Reduces CFIT
  - Consistent predictable flight plans
  - Stabilized approach paths
- Improves Operating Returns
  - Reduces fuel costs
  - Reduces investments in ground based systems
  - Reduces time in flight through more direct routes
- Increases airspace capacity
  - More efficient direct routes
  - Reduces airspace conflicts
- Is environmentally friendly

PBN Benefits / Implementation Matters

Benefits in terms of ATC:

- Safety culture
- Fewer radio transmissions
- Lower chance of readback/hearback errors
- Greater predictability
- Airspace containment
- Fewer go-arounds
- Less transit occupancy time in airspace
- Changing roles and responsibilities
- Best practices involving stakeholders in design

PBN Benefits / Implementation Matters

Implementation

- → Pilot Training
- → Aircraft Systems
- → Names, definitions and charts
- → Global Harmonization

PBN Benefits / Implementation Matters

Pilot Training

→ Globally, pilots do not have the same knowledge and skill level with regard to PBN. Since no worldwide standardization exists on this, the scope, length and methods of training, as well as trainer knowledge and skills, may vary considerably.

PBN Benefits / Implementation Matters

Aircraft Systems

→ Aircraft automation is becoming more precise and more complex resulting in divergent user platforms based on the operator's avionics and aircraft manufacturer requirements. The systems should preferably made upgradable, have common "look and feel" characteristics with common procedures between applications and aircraft, and be intuitive for the pilot to readily interpret the information displayed.

PBN Benefits / Implementation Matters

Names, definitions and charts

→ As with any new technology there are many definitions, names and criteria and these are still evolving. This may create confusion among pilots, airlines and regulators.

PBN Benefits / Implementation Matters

PBN Naming Convention

→ Currently, the PBN approach procedure naming convention is not standardized throughout the world and is inconsistent with the PBN navigation specifications. Examples of differing naming conventions used by States include RNAV (GPS) RWY XX, RNAV (GNSS) RWY XX, RNAV (RNP) RWY XX.

PBN Benefits / Implementation Matters

PBN Naming Convention

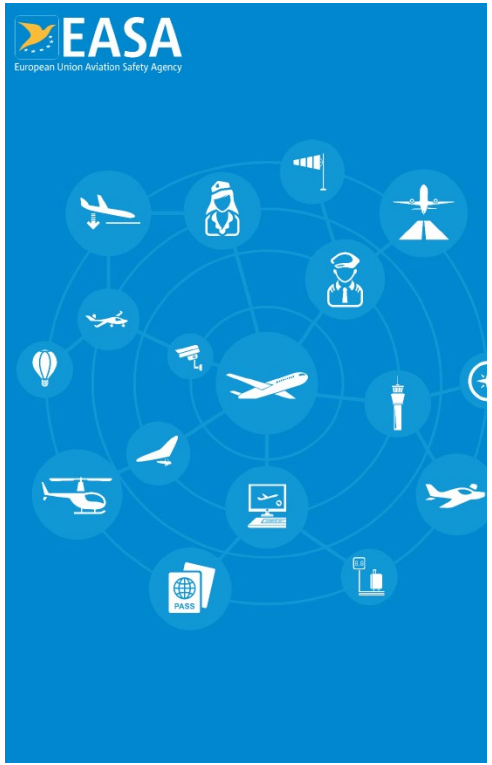
→ The ICAO Circular 336 provides guidance to assist States and other stakeholders with the transition from RNAV to RNP approach chart identification. This circular provides the necessary guidance to States on how to make that transition. From 1 December 2022, only the term RNP will be permitted, e.g. RNP RWY XX or RNP RWY XX (AR) will be acceptable while RNAV, GPS and GNSS will not be. During the transition period however, it is possible to have a considerable variation in the IAP designation policies of different countries.

PBN Benefits / Implementation Matters

Global Harmonisation

→ The lack of standard ICAO SARPs leads to different implementation approaches in different countries. For example, SESAR and NextGen (USA programme) have provided regional implementations of PBN but these are not globally harmonized. There is also a lack of harmonized state implementation of PBN phraseologies

PBN Benefits / Implementation Matters



PBN Benefits / Implementation Matters

Navigation after June 2030

Only the specified PBN applications and functionalities permitted for normal operations.

There are only two explicit exceptions

- CAT II & CAT III landing systems can remain in service unaffected
- other instrument flight procedures can be designed/kept in support of contingency modes

Use of SBAS to Support operation to CAT I minima – removal of ILS

EASA
European Union Aviation Safety Agency

End slide

PBN Operational Approvals Workshop

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