Performance Based Navigation

Operations Standard & Training

Prepared & Presented By:

Capt. Ariarso Mahdi H.

Training Courses

Course divide into 3 sections :

1 Performance Based Navigation

Introduction to Performance Based Navigation

Area Navigation

RNAV Routes, SIDs, STARs and IFPs

2 Flight Crew Procedures

Preflight, Before Start, Take Off, Departure, Descent & Arrival, Contingency

Radio Phraseology

3 Specific Aircraft Equipment

Introduction to Performance Based Navigation

Background

The continuing growth of aviation increase demands on airspace capacity therefore emphasizing the need for optimum utilization of available airspace and Improved operational efficiency.

Nowdays the name implies of PBN (Performance Based Navigation) is basically the improvement of the conventional navigation RNAV (Area Navigation) with RNP (Required Navigation Performance), as we are seiing the old days ground based navigation such as VOR , VOR-DME has transition to sattelite based navigation.

Background

These factors, along with the accuracy of modern aviation navigation systems and the requirement for increased operational efficiency in terms of direct routings and track-keeping accuracy, have resulted in the concept of Performance Based Navigations derived from the application of Area Navigation (RNAV) techniques.

Approval Requirement

To comply with Area Navigation operation, Air Operator need to obtain :

1 **Airworthiness Approval**

Assures that each item of the RNAV equipment installed is of a type and design appropriate to its intended function and that the installation functions properly under foreseeable operating conditions:

- ✓ Approval of RNAV systems for RNAV operations
- ✓ Approval of RNP systems for RNP operations

This approval includes:

- Airworthiness Compliance Statement
- Operation Specification (OpsSpec)
- Navigation Database
- MEL Update based on specific aircraft type
- Equipment (Installation and Functions)

Approval Requirement

2 Operational Approval

The aircraft must be equipped with an RNAV system enabling the flight crew to navigate in accordance with operational criteria as defined in the navigation specification.

✓ Flight operation approval by the Director of DGCA

- Operational procedures (pre-departure, departure, en-route, arrival & contingency)
- Flight Crew Training
- Operations manuals, Checklist and Chart.
- MEL, identify the minimum equipment for Navigations
- Navigation database management

Move from RNAV/RNP Concept to PBN Concept

Operators have already experience the benefits of Area Navigation (RNAV) and Required Navigation performance (RNP). These benefits include safer, more efficient operations; greater capacity; and improved access.

However,

- The RNAV/RNP concepts, definitions, and naming conventions, are inconsistent in various regions of the world.
- The implementation of RNAV and RNP applications is different.
- The result has been confusion among operators, manufacturers, regulators, and air navigation service providers (such as the FAA, NATS, and NavCanada)

Performance Based Navigation (PBN)

- is the result of recent collaboration between industry, states, regulators, and service providers to understand the issues leading to this confusion, and
- to clarify and update the definitions and explanatory material about RNAV and RNP concepts and applications.
- To ensure harmonization and consistency, this effort was applied to all areas of flight, from oceanic/remote to terminal area and approach.

PBN Terminology

Performance Based Navigation Terminology

Two fundamentals aspect of any PBN operation are the requirements set out in the appropriate :

1. Navigation Specification
2. Navigation Aid Infrastructure

A Navigation specification is set for :

Aircraft
Aircrrew

A Navigation specification is defines as the performance required by the RNAV systems as well as many functional requirements such the ability to conduct curved ath procedures or to fly offset routes. As the Result of the development of aircraft technology on mid 1990 for RNAV flying the aircraft manufactured is designed with onbard performance system which able to : Monitoring and Alerting

Advantage Of PBN

The Advantages for the design of PBN to enhance :

I. The Utilization of Aircraft departure and arrival from specific aerodrome
II. The Noise Abaitement Procedure implemented on that airport
III. Saving the Fuel and Economic Value of Airline Operation
IV. Increase Safety not only reliance on VOR/ADF only
V. Reduce Communication between the Pilot and Controller
VI. Increase safety between the aircraft and terrain avoidance as part of CFIT (Controlled Flight Into Terrain) ALAR Program.

Definition RNAV and RNP

RNAV (Area Navigation)

Area limts and methods of navigation which guarantee the aircraft operation on desired flight path within the coverage of station –referenced navigation aids or within the limits of the capability of self contained aids,or combination of these, specific navigation acuracy for route or departure/approach within specific limit without the aircraft having onboard navigation performance of monitoring and alerting system.

Definition RNAV and RNP

RNP (Required Navigation Performance)

A Navigation specification which is required to have on board navigation for monitoring and alerting is refered to the RNP specification.
Because specific performance requirements are difined for ech navigation specification , an aircraft approved for RNP specification is not automatically approved for all RNAV specifications.Similarly, an aircrfat approved for an RNP or RNAV specification having strictly accuracy requirements.

The Aircraft than measured the airplane position in NM unit as we determine this as ANP (Actual Navigaton) , when the ANP is exceed of RNPthan the crew alered will be mentioned. When the ANP exceed the RNP ,rhe airplane is not tracking the accuracy of the route segment.

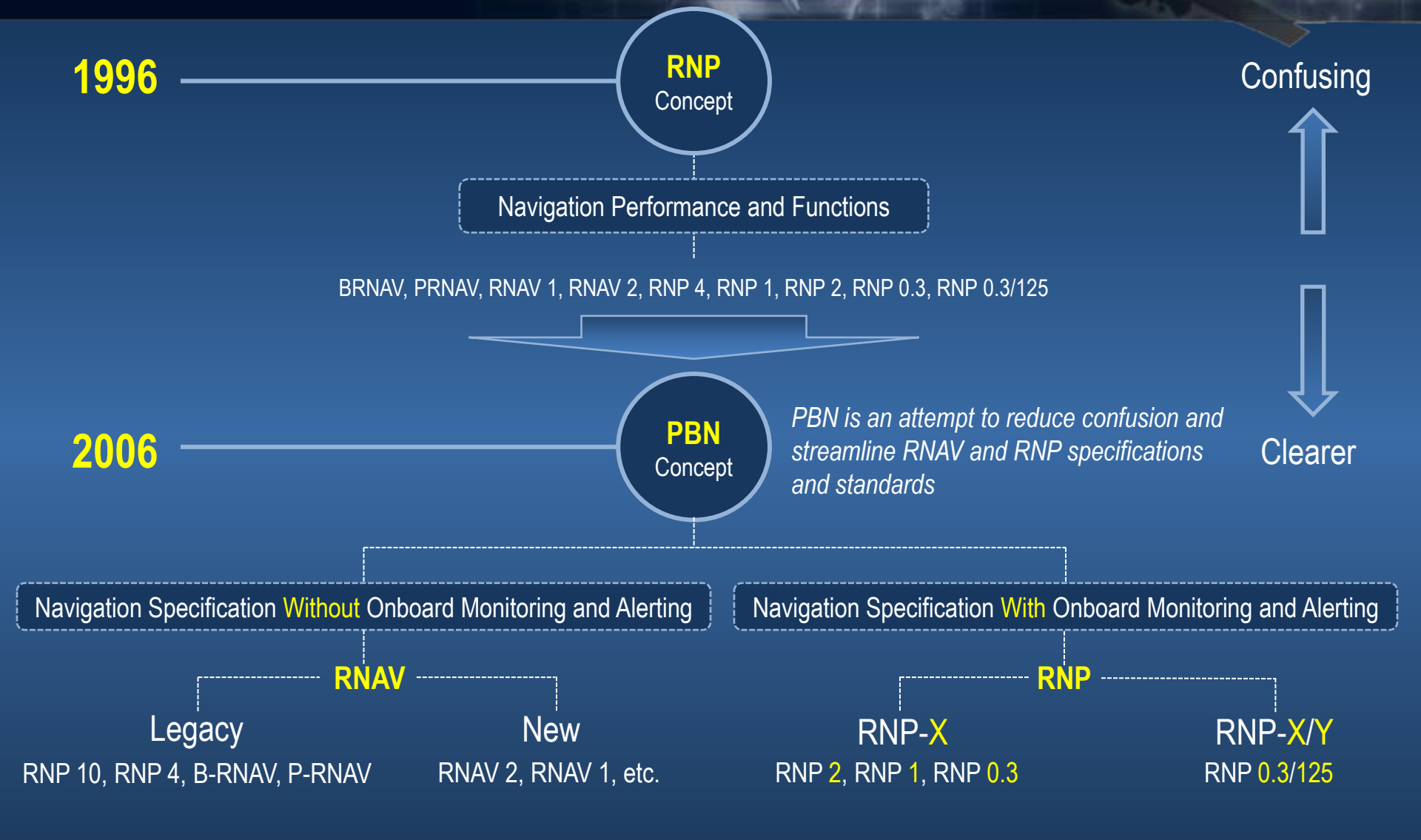
For both RNP and RNAV designation fro example (RNAV-1 or RNP-10 refers to the lateral navigation accuracy in nautical miles , which is expressed to be achieved at least 95% of the flight time the population of aircraft oerating within the airspace , route or procedure.

Definition RNAV and RNP

There are No RNAV ARR , the terms for RNP during approach is **RNP AR APCH** or **RNP APCH**

Note : AN RNAV 1 designation refers to an RNAV specification which include a requirement for 1 NM navigation accuracy among many other performance requirements.

Evolution of PBN Concept



Performance Based Navigation overview

ICAO **performance-based navigation** (PBN) represents a shift from sensor-based (NavAid to NavAid) to Performance Based Navigation system.

1. PBN is a **new concept** based on the use of Area Navigation system

2. A move from a limited statement of required performance accuracy to more extensive statements of required performance in term of **accuracy**, **integrity**, **continuity**, and **availability**, together with descriptions of how this performance is to be achieved in terms of aircraft and crew requirements.

3. The **RNP concept** has been **replace** by the **PBN concept**. Therefore a lot of RNP terminology has been replace by PBN terminology.

4. The ICAO PBN Manual **replaces** the ICAO RNP Manual

PBN Standardization benefit

1. Global Definitions of terms are provided that aimed at removing any previous regional differences

2. Compatibility, A set of globally compatible Navigations Specification is also provided. These are to be used as a basis for local or regional Navigation Applications in the en-route, terminal and approach environments.

3. Applications, increasingly, the Navigation element of Airspace Concept will be based on PBN

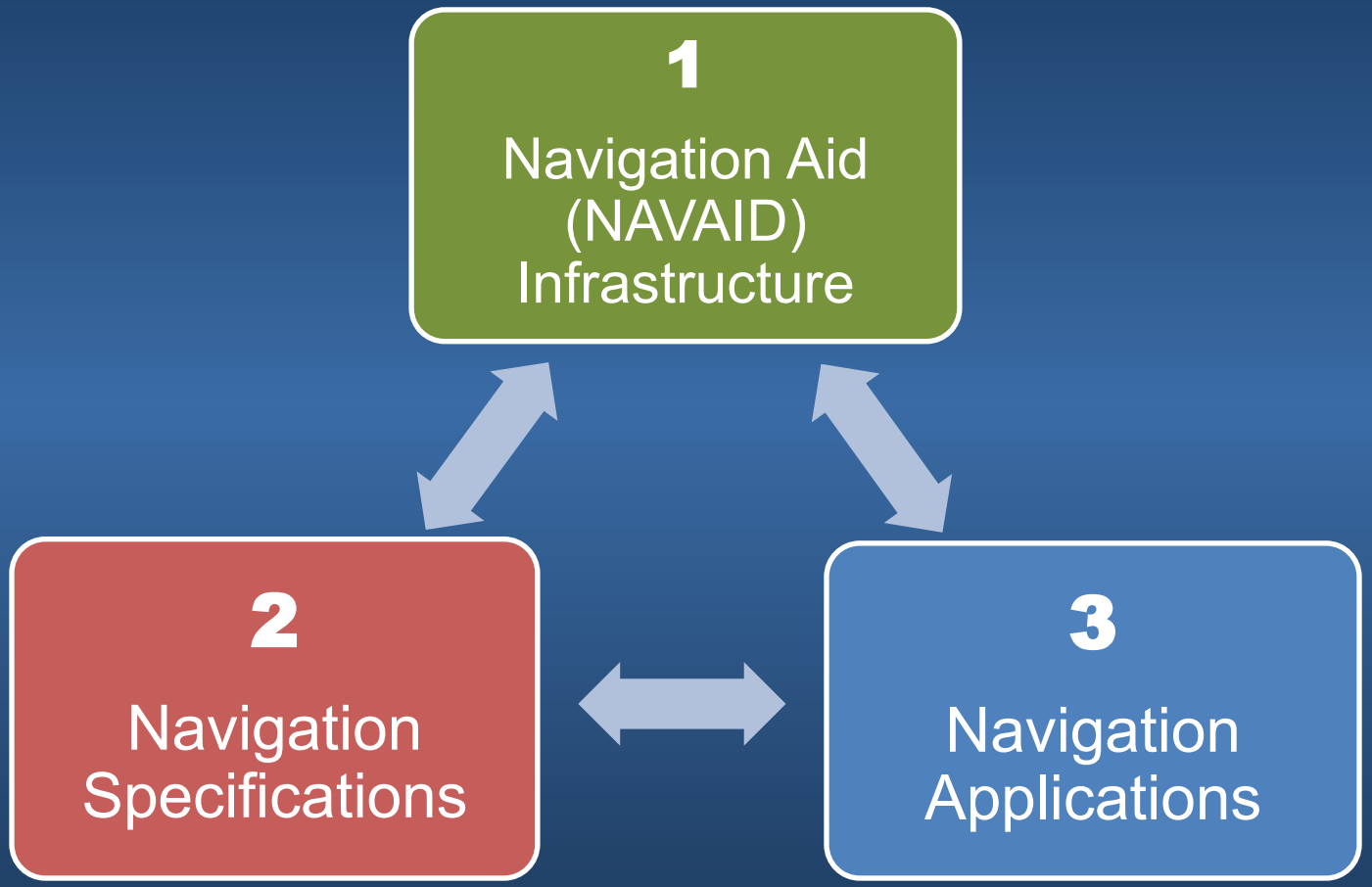
PBN Concept

PBN is not a Standalone Concept

PBN is one element that supports The Strategic Objective of :

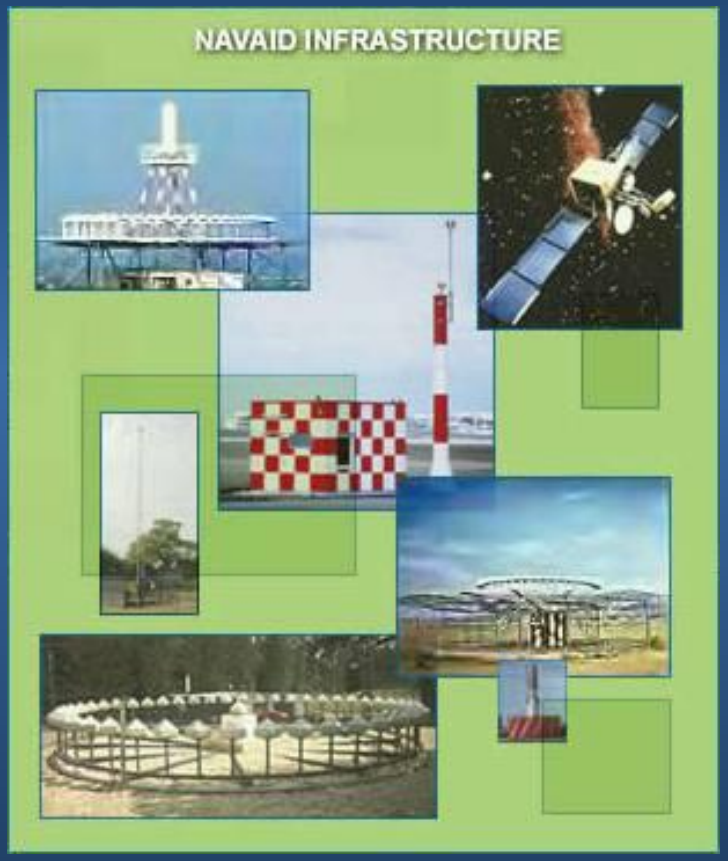
PBN Elements

There are 3 elements of PBN within an Airspace context.



1 Navigation Aid (NAVAID) Infrastructure

Ground, Space or On-board NAVAIDs which support or provide positioning capability.

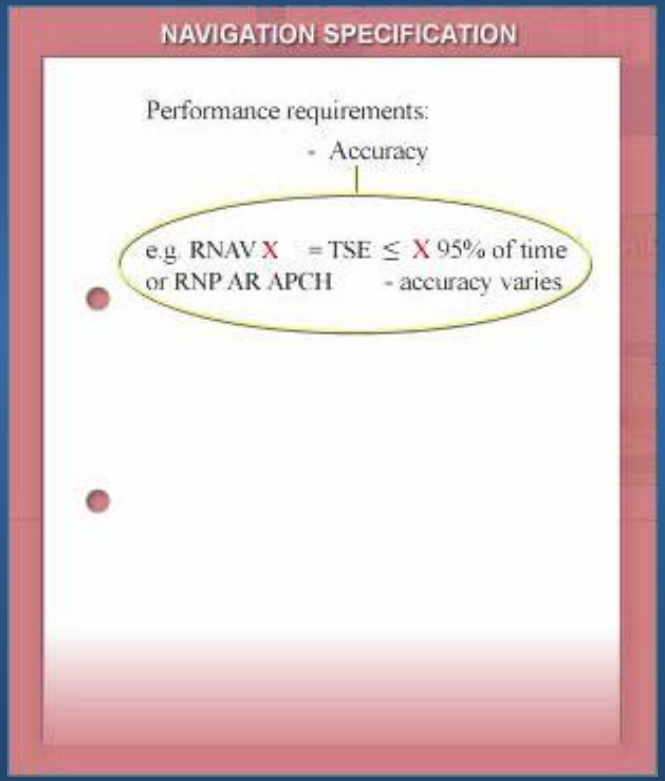


Examples of NAVAIDS:

- **Ground :**
  Very High Frequency Omni-Range (VOR), Distance Measuring Equipment (DME)
- **Space :**
  Global Navigation Satellite System (GNSS), GPS, GLONASS, WASS, EGNOS
- **On-board:**
  Inertial Reference Units (IRU).

2 Navigation Specifications

Details the Aircraft and Aircrew requirements needed to support PBN operations

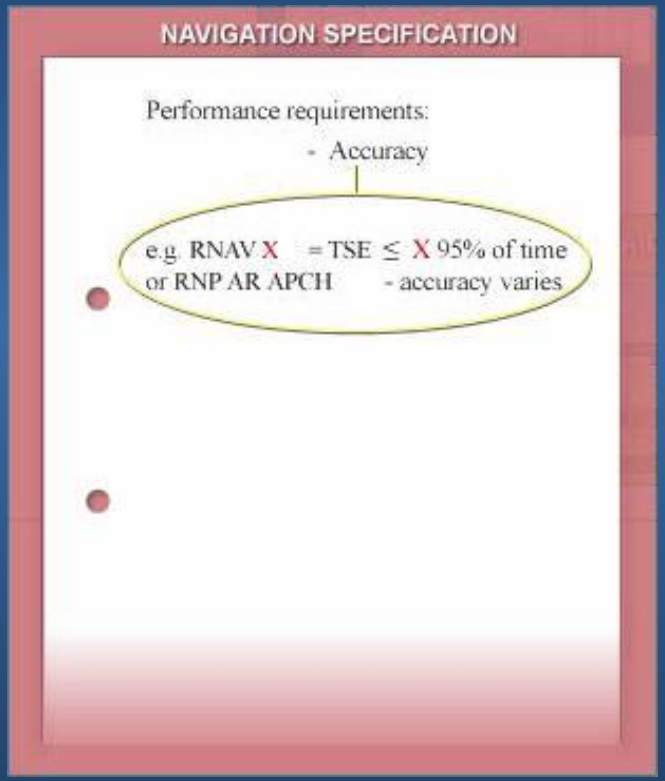


- **Navigation Specifications:**
  - ✓ **"RNAV"** Specifications
  - ✓ **"RNP"** Specifications
- **RNP Specifications:**

  Include a requirement for on-board self-containment performance monitoring and alerting While a RNAV specification does not.

2 Navigation Specification cont'd

Performance Level Requirements



- Each Navigation Specification has a **designator**. e.g. RNAV **5**, RNP **1**, RNP **APCH**, RNP **AR APCH**.
- Number in the designator represent the **minimum Lateral Navigations accuracy in nautical miles** (nm) that must be maintained for at least **95%** of the flight time.
- Combined error is known as **"Total System Error"**

2 Navigation Specification cont'd

Explanation of **Total System Error** and associated errors

Desired Path – path over ground that the aircraft expected to fly

Defined Path – reference path computed by Flight Plan Management function in the RNAV system

Estimate Position – provide by NAV function of the RNAV system

PDE
- difference between desired and defined paths
- reflects error in navigation database, computational errors in the RNAV system and display errors (usually very small)

NSE
- difference between true and estimated position
- NSE is otherwise known as Position Estimation Error (PEE)

FTE
- difference between estimated position and defined position
- Relates to crew or autopilot's ability to fly along defined path
- FTE is otherwise known as Path Steering Errors (PSE)

TSE=$\sqrt{PDE^2+FTE^2+NSE^2}$ (= approximately the difference between true position and desired path)
– used for PBN operations

2 Navigation Specification cont'd

Required Performance

- ✓ **Positioning accuracy :** is the difference between the actual and estimated position in fault free conditions (NSE),
- ✓ **Track-keeping accuracy :** is the total navigation system error (TSE) arising from NSE, flight technical error (FTE) and path definition error (PDE)
- ✓ **Integrity :** The degree of confidence that can be placed on the RNAV system's position estimations,
- ✓ **Continuity :** The ability of the navigation system to provide its service without interruption during an operation,
- ✓ **Availability :** The ability of the total system to perform its function at the initiation of the intended operation.

2 Navigation Specification cont'd

Other requirements to achieve desired Performance levels:

Each Navigation Specification also details other requirements needed to achieve the specified performance level:

- ✓ Navigation functionalities of the RNAV system; the detailed capability of the navigation system (such as the execution of leg transitions, parallel offset capabilities, holding patterns, navigational databases),
- ✓ Choice of navigation sensors that may be used, and
- ✓ Aircrew knowledge and training requirements.

Monitoring and Alerting Requirements:

- There are 'RNAV' and 'RNP' Specifications:
- 'RNP' signifies a requirement for on-board performance monitoring and alerting. 'RNAV' signifies no such requirement.

Different between States

Navigation Specification with the same designator may vary between States as they depend on the State's NAVAIDs infrastructure

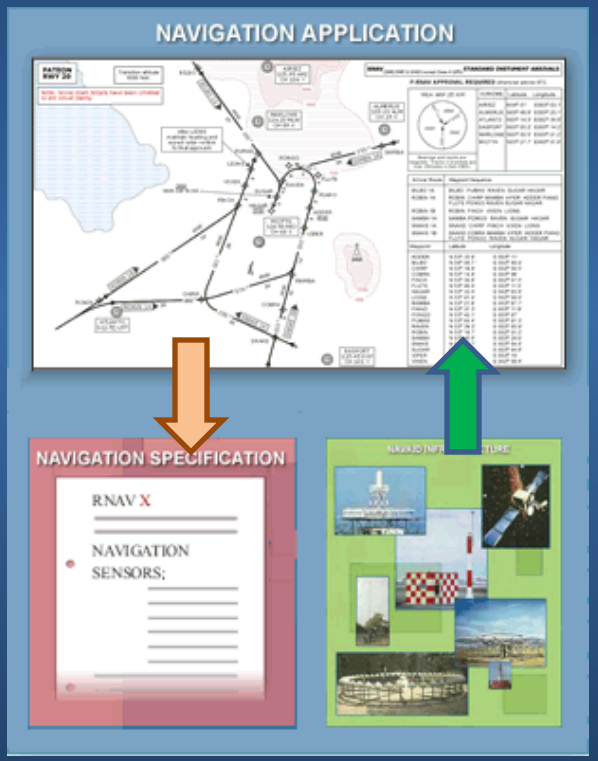
TO FLY THE ROUTE

Must be equipped with:
DME/DME & GNSS

The Aircraft & Crew Must comply with both Navigation Specifications

3 Navigation Applications

Application of a Navigation Specification and the supporting NAVAID Infrastructure to specific routes or procedures, or in an defined airspace volumes.



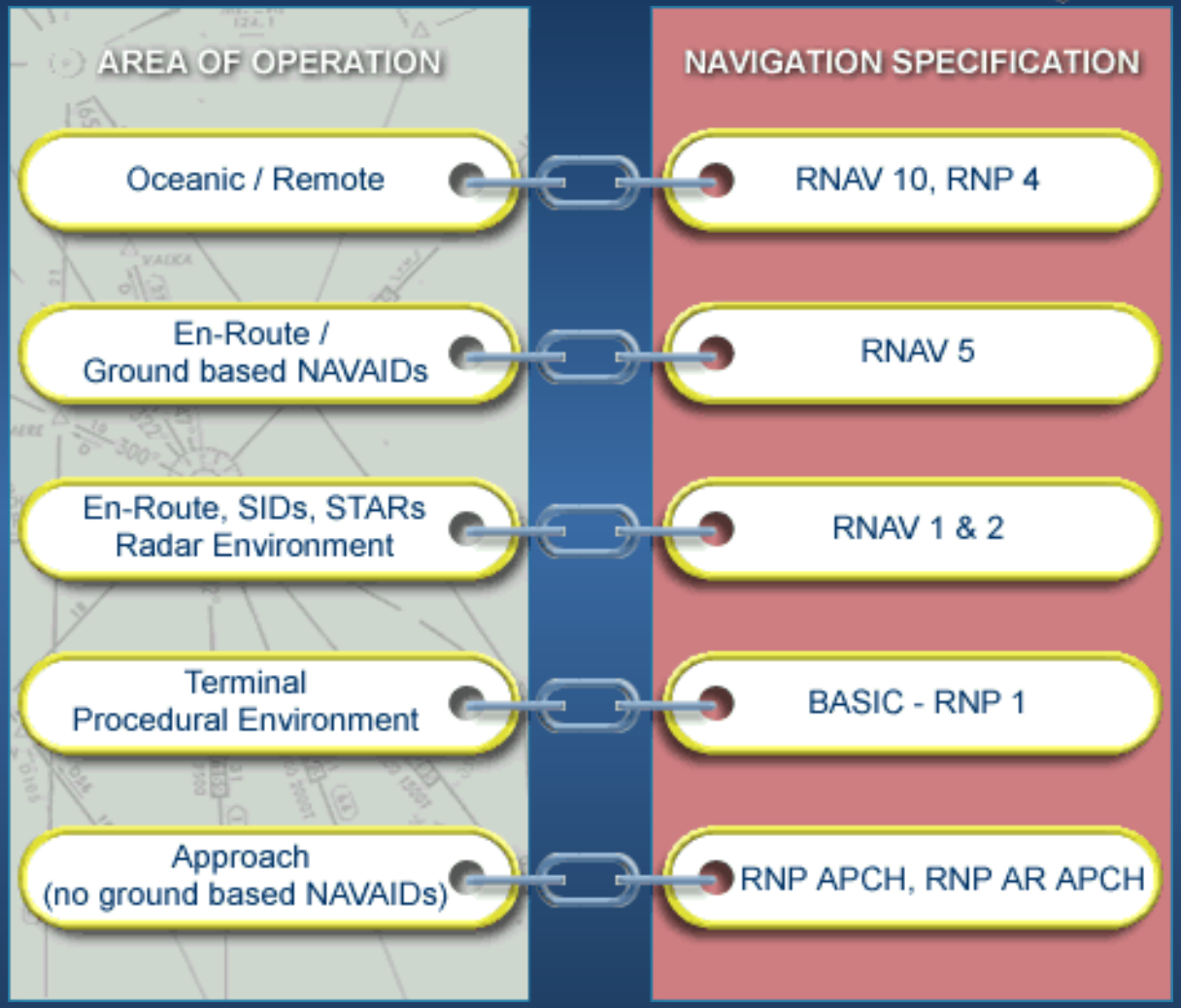
The designator of a Navigation Application matches the corresponding Navigation Specification.

- **RNAV Applications** are supported by RNAV Specifications.
- **RNP Applications** are supported by RNP Specifications.
- Navigation Applications will be detailed in charts and in the **Aeronautical Information Publications** (AIPs).

PBN within different Airspace Concepts

You will see that there is a strong link between an area of operation and the Navigation Specification.

This is because they were originally designed for specific Areas of Operation.



Benefits of PBN

SAFETY	CAPACITY	EFFICIENCY	ACCESS	ENVIRONTMENT
Reduced Control Flight into Terrain Lateral and Vertical Track-keeping more accurate & reliable	Increase Parallel Route to reduce Delays and Congestion Accommodate Traffic Growth	Enhanced reliability, repeatability, &predictability increased air traffic throughput smoother traffic flow	Improved Airport and Airspace access Obstacle clearance and contraints optimise by PBN tracks	Flying defined flight path means less throttle activity and better avoidance of noise-sensitive areas
RNP approach replaces circling approach	Parallel RNAV 2 ATS routes between cities	RNAV 1 SID continuous Climb to Enroute	RNP approach allowing lower Minima	RNP (AR) approach with guided curved Missed Approach

Its about time..

… Let’s take a break ….

Next : Area Navigation….

KALSTAR AVIATION

Area Navigation

Area Navigation (RNAV)

The International Civil Aviation Organization (ICAO) definition:

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

- **RNAV system** uses **NAVAIDs** to determine the aircraft's **position**
- **Air Traffic Services (ATS)** route established for the use of aircraft capable Area Navigation
- **Waypoints** which are defined by **coordinate**
- When values are specified (e.g. RNAV 5), they indicate the required performance level for the operation and accuracy must be maintain for at least **95%** of flight time .Only Aircraft equipped with RNAV system can navigate effectively to these waypoints
- Aircraft position is **calculated by the RNAV system** using inputs from one of the following:
  - DME/DME, VOR/DME, GNSS, Self-contained navigational aids (IRS)

RNAV Principle Applications

RNAV was developed to provide more lateral freedom and thus more complete use of available airspace.

This method of navigation has three principal applications:

1. A route structure can be organized between any given departure and arrival point to reduce flight distance and traffic separation;
2. Aircraft can be flown into terminal areas on varied pre-programmed arrival and departure paths to expedite traffic flow; and
3. Instrument approaches can be developed and certified at certain airports, without local instrument landing aids at that airport.

Required Navigation Performance (RNP)

Required navigation performance (RNP) is **RNAV with the addition** functional enhancements, including **onboard performance monitoring** and **alerting** capability.

A defining characteristic of RNP operations is the ability of the airplane navigation system to provide improved **performance information**, monitor the **navigation performance** and **inform the crew** if the requirement is not met during an operation.

This onboard monitoring and alerting capability **enhances the pilot's situational awareness** and can enable **reduced obstacle clearance** or **closer route spacing** without intervention by air traffic control.

When **values are specified** (e.g. RNP 5), they indicate the **required performance level** for the operation and accuracy must be maintain for at least **95%** of flight time .

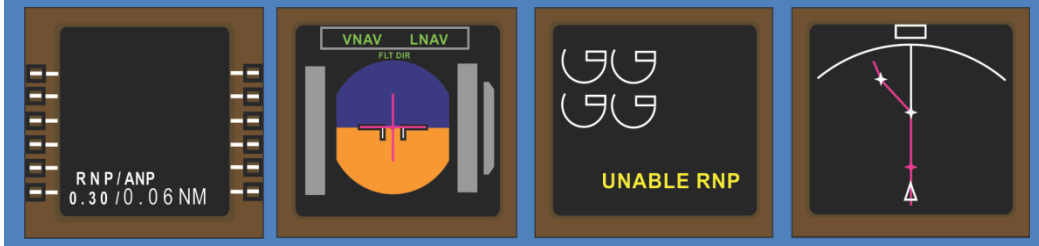
RNP also adds the ability to do **curved path segments.**

Required Navigation Performance (RNP)

RNAV

Provides flight crews with an enhanced new interface designed to minimize manual insertion and control errors.

MONITORING & ALERTING



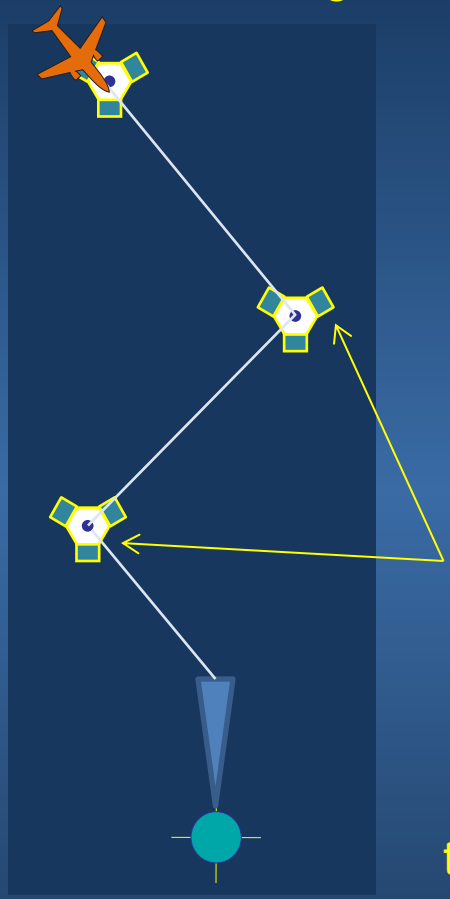
INCREASED OPERATIONAL SAFETY

RNP
Capable

Enhanced situation awareness, better monitoring and alerting, and improved indication of equipment failure

Area Navigation Evolution

Conventional Navigation



Limited Design Flexibility

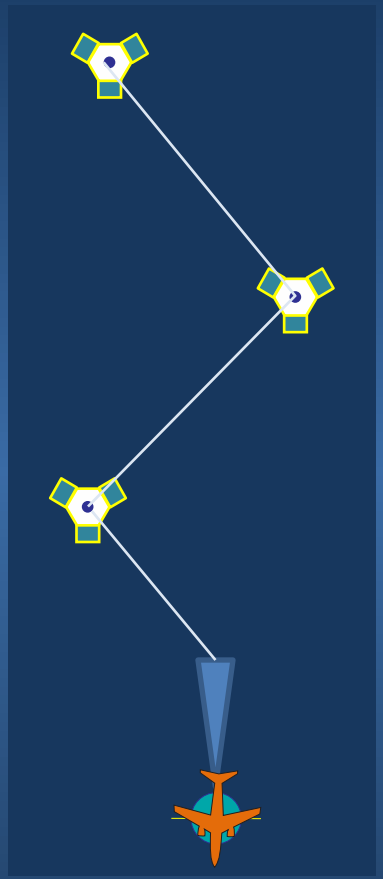
- Traditionally route structures were developed between the NAVAIDs
- NAVAIDs used include Non-Directional Beacons (NDBs) and Very High Frequency Omni-directional Ranges (VORs).
- Routes are defined by the geographical positions of NAVAIDs or fixes based on the intersection of radials from two NAVAIDs or a distance and a bearing from one.
- Aircraft are required to overfly these NAVAIDs and fixes

Current Ground NAVAIDs

Obviously,
this is not optimum routing

Area Navigation Evolution

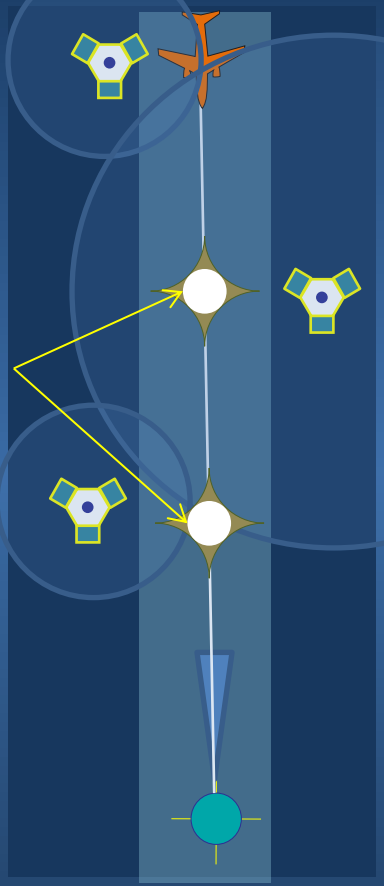
Conventional Navigation



Limited Design Flexibility

WAPOINTS

RNAV



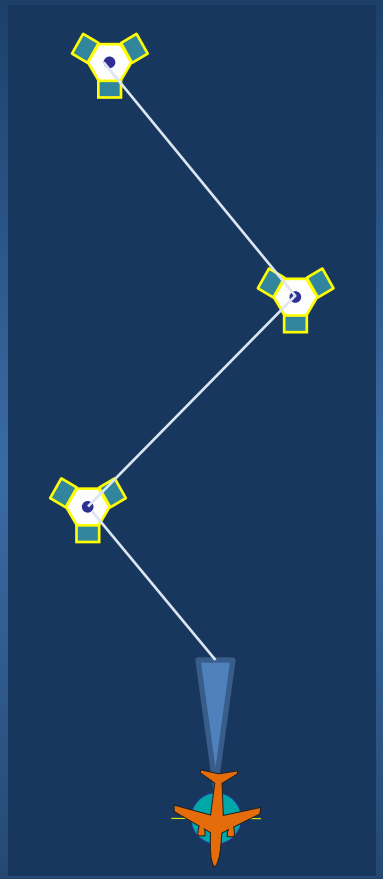
Increase Airspace Efficiency

- RNAV system uses NAVAIDs to determine the aircraft's position
- Waypoints which are defined by coordinate
- Only aircraft equipped with an RNAV system can navigate effectively to these waypoints
- Aircraft position is calculated by the RNAV system using inputs from one of the following :

  DME/DME, VOR/DME, GNSS, IRS

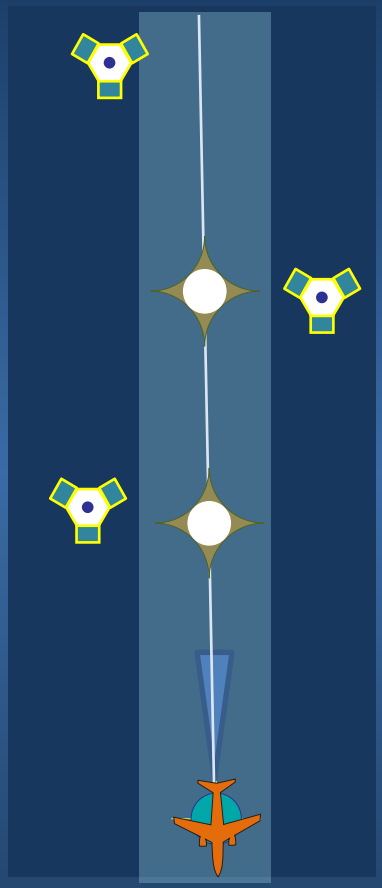
Area Navigation Evolution

Conventional Navigation



Limited Design Flexibility

RNAV



Increase Airspace Efficiency

RNP

Optimize use of Airspace

RNAV System

RNAV system integrates information received from sensors, inputs from its internal database and crew entered data to provide:

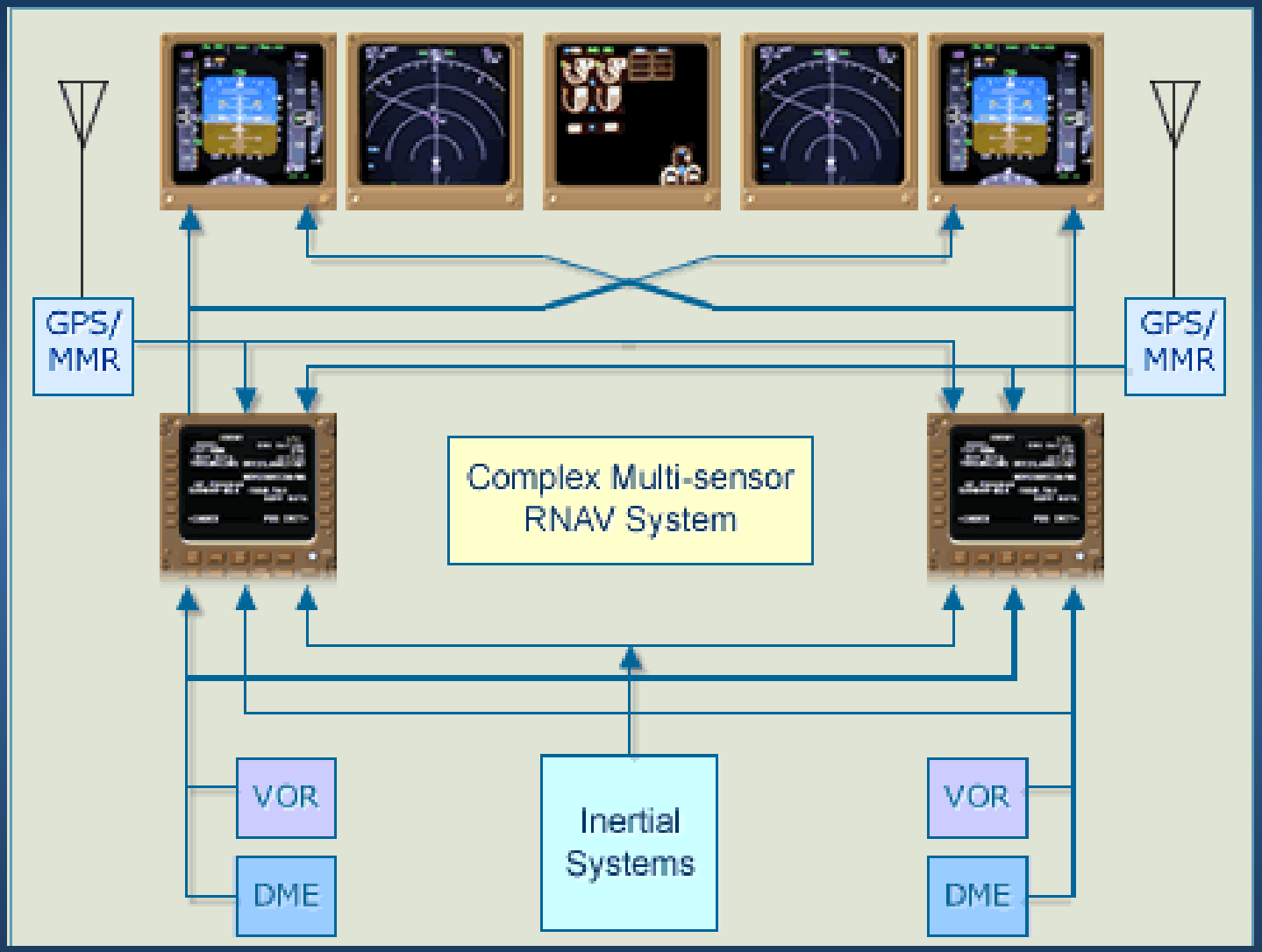
- Navigation
- Flight Plan Management (referencing waypoints, not ground-based NAVAIDs)
- Guidance & Control
- Display & System Control

RNAV system is designed and certified to provide a particular level of navigation accuracy with repeatable and predictable path definition.

'Navigation function' computes data that includes aircraft position, velocity, track angle, etc. This data is displayed on the Navigation Display (ND) or a Course Deviation Indicator (CDI) and may be displayed on the Flight Director (FD) and fed to the Auto Pilot.

'Flight Plan Management' function uses the internal database to compute the reference path (defined path)

Complex Multi-sensor RNAV System



RNAV System

RNAV system provides lateral guidance by comparing the aircraft's position, estimated by the Navigation function, with the defined lateral path to generate steering commands.

Number of factors:

- the defined path may not exactly match the desired path,
- the aircraft's actual position may not coincide with its estimated position.

Required navigation accuracy of an aircraft must take into account all of the errors. This is referred to as **the Total System Error** (TSE).

Waypoints

ICAO defines Waypoint as :

A specified geographical location used to define an area navigation route or the flight path of an aircraft employing area navigation.

Terminal operations waypoints:

- **Fly-by :** A waypoint which requires turn anticipation to allow tangential interception of the next segment of a route or procedure, or
- **Flyover :** A waypoint at which a turn is initiated in order to join the next segment of a route or procedure.

For en-route operations most waypoints are treated as 'fly-by' although some navigation specifications may allow the option of flying over the point.

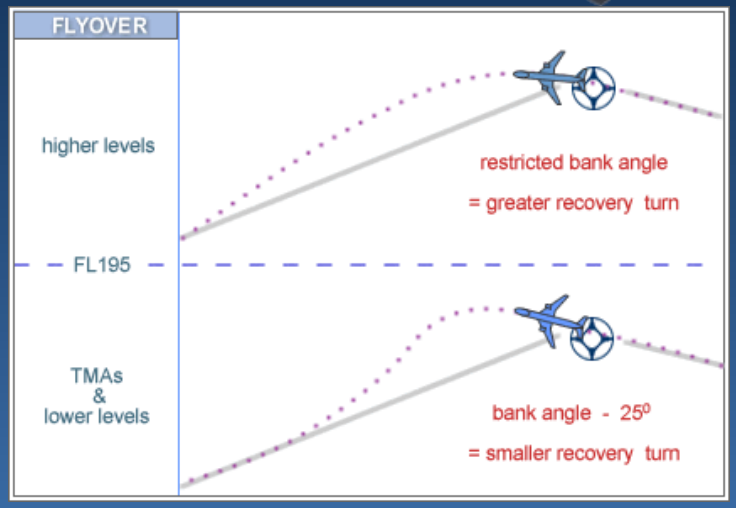
A waypoint is defined as a geographic coordinate and is identified by:

- 5 letter unique name code, e.g. GAPRI,
- if located with a ground based NAVAID by the 3 letter ICAO identifier for that station, e.g. IMU
- **Terminal Airspace** only by an alphanumeric name code, e.g. DF410.

Waypoints and turn performance functionality

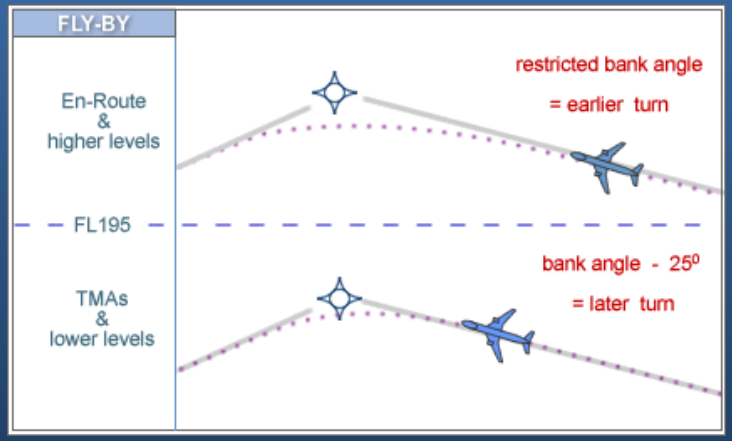
Flyover:

- All aircraft capable of area navigation
- **Disadvantage;** The aircraft must over-fly the waypoint and then recover to the next desired track.
- Recovery back on to the intended path after the turn initiation may not be consistent due to different aircraft performance.



Fly-by:

- **Majority** of aircraft capable of area navigation have this functionality.
- Aircraft's RNAV system anticipates the turn. The turn starts at some distance before the waypoint to allow tangential interception of the next segment of a route or procedure.
- Turn initiation will be dependent upon the aircraft's maximum bank angle and speed.
- All turns are affected by **True Air Speed (TAS)** and wind velocity.

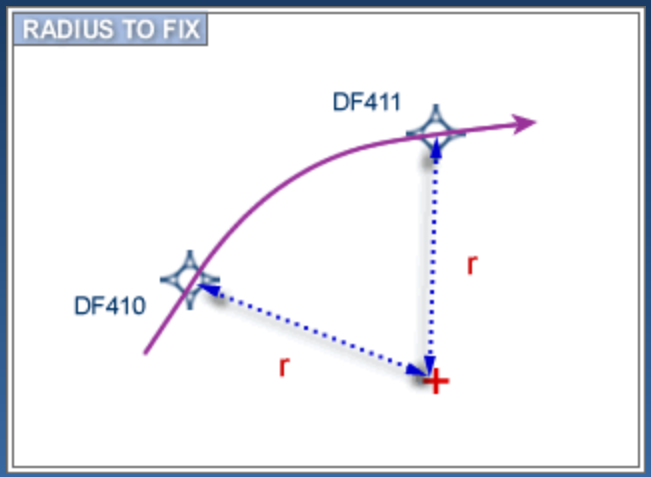


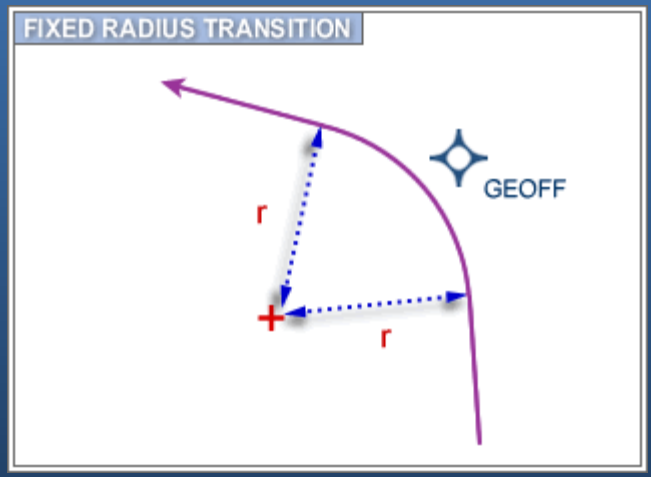
Waypoints and turn performance functionality

- **Fixed radius turns** are used to ensure predictable and consistent track keeping in the turn.
- The aircraft commences the turn at a defined point and then automatically adjusts the **Angle of Bank** (AOB) to maintain a constant radius from a specified point.

Fixed radius performance is achieved in one of two ways.

1. **Radius to Fix (RF):**
   - For Standard Instrument Departures (SIDs), Standard Arrival Routes (STARs). And Instrument Approached
2. **Fixed Radius Transitions:**
   - Other **Air Traffic Services** (ATS) routes, usually at higher altitudes.
   - Fixed Radius Transitions (FRTs), used in the en-route phase of flight, will have a defined turn radius which may be fixed by waypoint, altitude or by airspace.





LEG

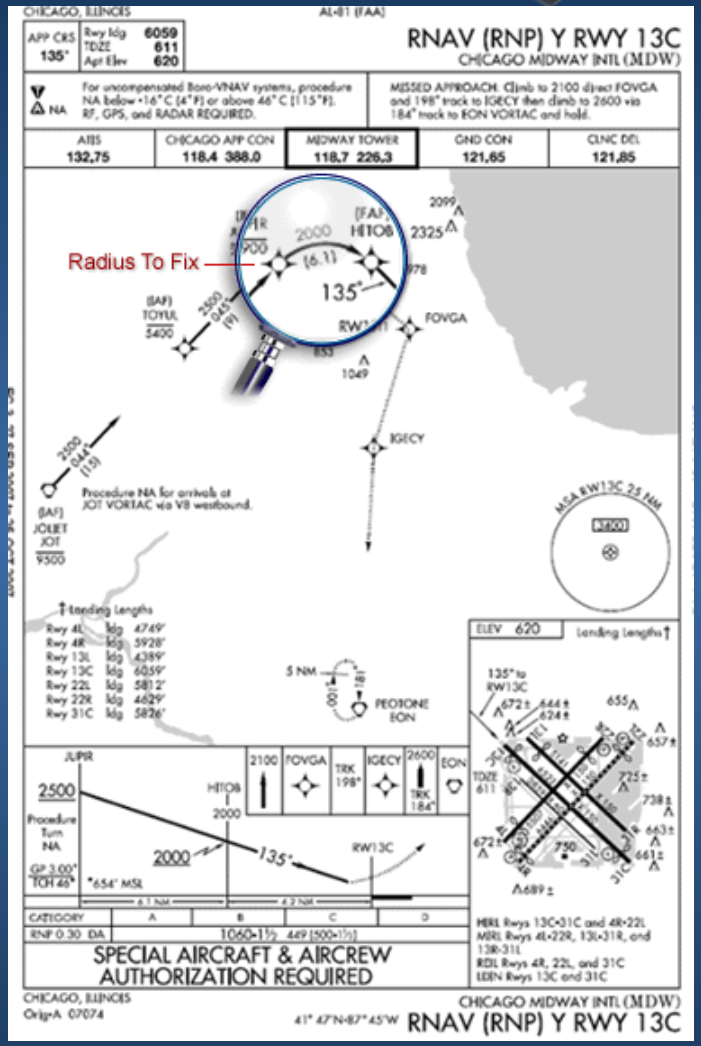
Desirable to define how an aircraft will fly between waypoints

Leg : The path between two waypoints

ATS routes :
Aircraft will fly the ‘leg’ to the next waypoint in sequence, performing a fly-by turn where capable.

SIDs, STARs and Approaches :
Each 'leg' is associated with a 'Path Terminator', which defines how the path will be flown and how the ‘leg’ will be terminated.

Radius to Fix (RF),
used for SIDs, STARs and Approaches , is an example of a 'leg' whose path is a fixed radius turn terminating at the next fix (which is a waypoint).



Aircraft RNAV system and Database

Using the Data

- RNAV system **with** a database : the pilot will select the company or waypoint in turn from the database to create a route.
  Pilot is unable to change the data in the database to avoid risk of data corruption
- RNAV system **without** a database: the pilot is required to manually insert the waypoints
- The databases are updated and validated in accordance with the ICAO AIRAC cycle.

Flying the Path

- The aircraft uses one or more sensors to estimate its position and the RNAV system calculates the deviation from the ‘defined path’ and adjusts accordingly to maintain that path.
- How well the **'actual'** and **'desired'** paths coincide, and especially the ability to follow fixed path turns, depends on:
  - Coding of the database,
  - Navigation sensors,
  - Capabilities and functionalities of the RNAV system
  - Manual/Flight Director/autopilot control of the aircraft.

Navigation Sensors: Lateral Navigation (LNAV)

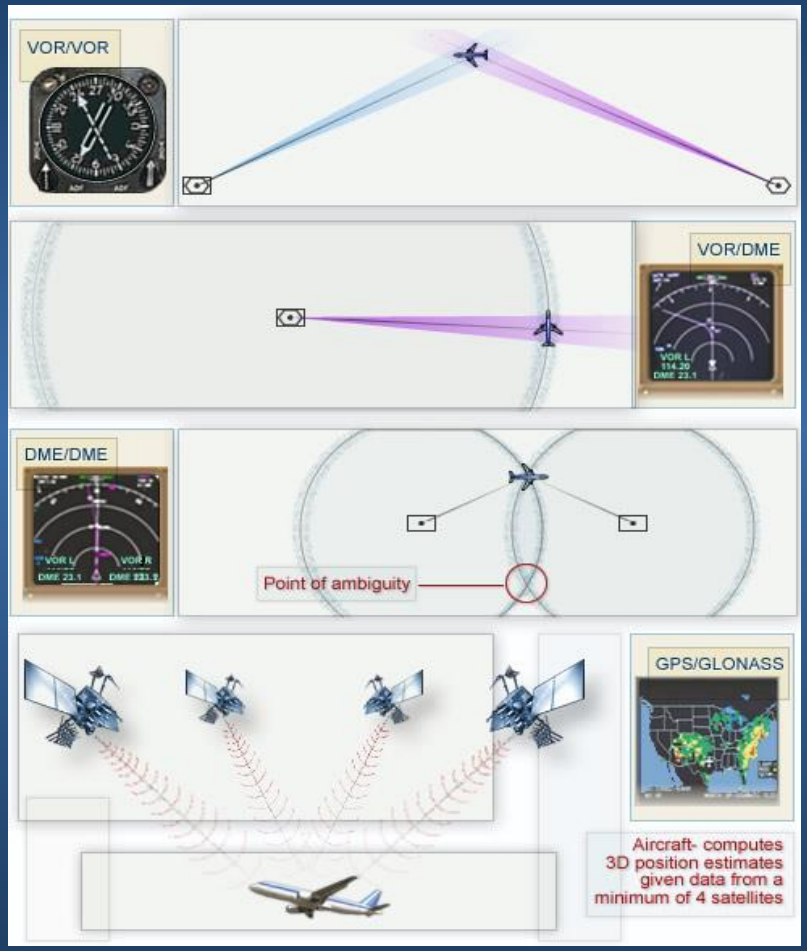
Primary sensors used for Area Navigation Ground-based:

VOR/VOR (Bearing/Bearing):
Requires 2 stations to estimate a position, however poor accuracy means that this is not used by RNAV systems.

VOR/DME (Bearing/Range):
Angular error from the VOR limits the maximum range for some navigation applications.

DME/DME (Range/Range):
Requires a minimum of 2 DMEs plus ambiguity resolution to estimate a position,

Space-Based:
Global Navigation Satellite Systems (GNSS) support 3D position solution is calculated by estimating the range from 4 satellites.



Navigation Sensors: Vertical Navigation (VNAV)

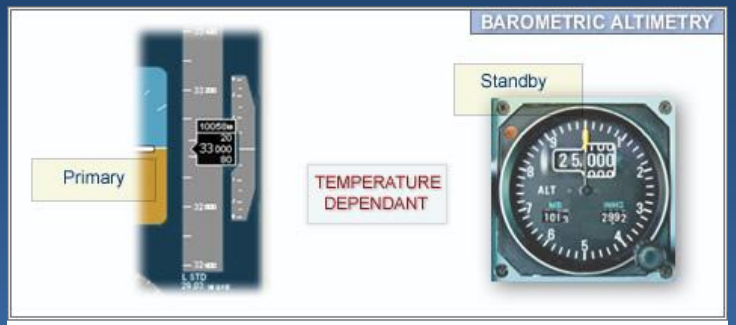
Two System to Support Vertical Navigation

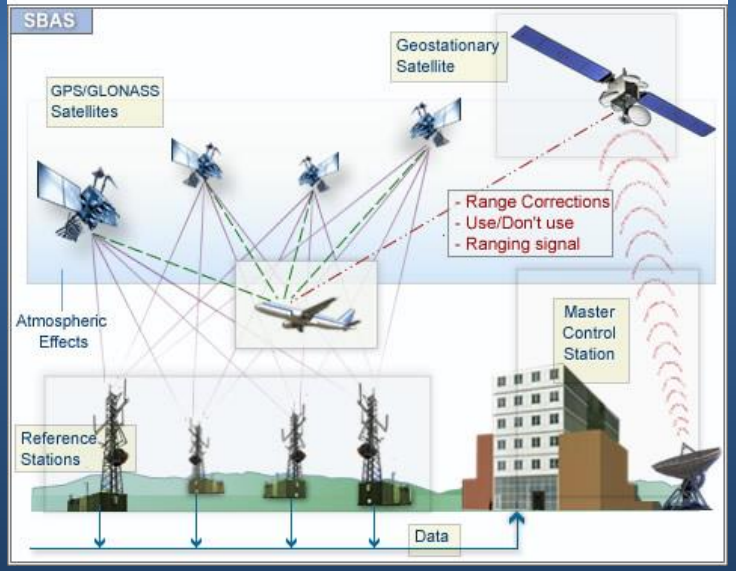
1. **Barometric Altimetry**
   BARO NAV provides reading based on atmospheric pressure
2. **Geometric Altimetry**

   Space Based Augmentation System (SBAS)

   Vertical accuracy is provided by SBAS, of which there are $ system covering different part of the world

   1. WAAS – United States
   2. EGNOS – Europe
   3. MSAS – Japan
   4. GAGAN - India



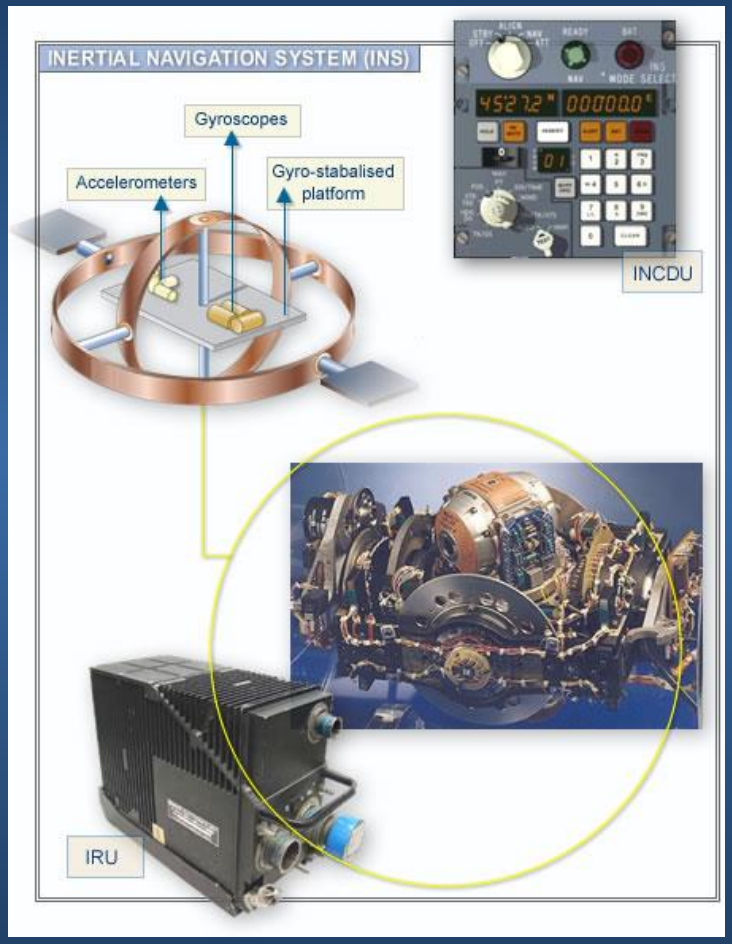


Navigation Sensors: on-Board

Inertial Reference System (IRS)

- Operate autonomously, without reference to any external systems.
- IRS can provide **short term accurate information** that can be used with ground or space based navigation systems to enhance the position estimate
- Limits on the their time of use are prescribed in the Navigation Specification (i.e. RNAV 5)

  An Inertial platform can be used for 2 hours with no updating, but for an RNP AR approaches this maybe limited as little as 40 seconds.
- An Inertial Navigation System (INS) is a standalone independent system.



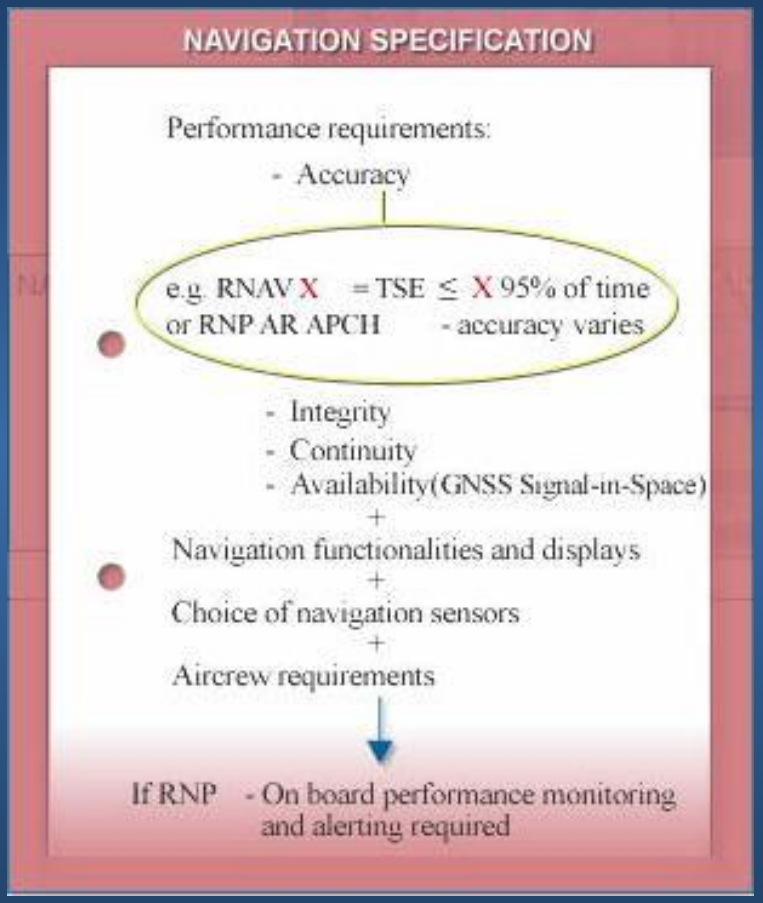
Implications for PBN

Implications for PBN

PBN operations require (lateral) accuracy, integrity and continuity of aircraft systems together with particular RNAV computer functionalities to meet specific requirements.

Positioning Accuracy

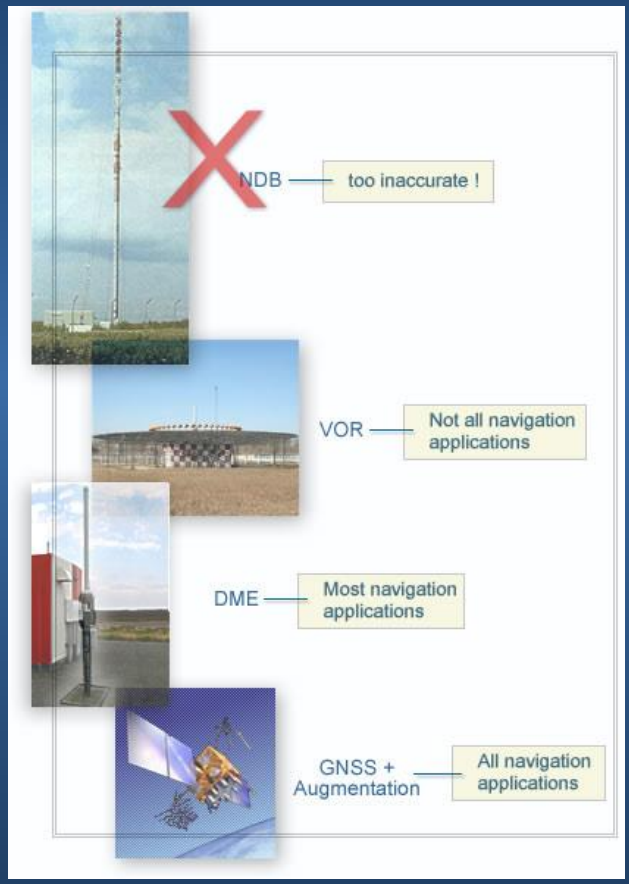
- Lateral track accuracy is defined by:
  - Path that has been defined by the RNAV system
  - Navigation sensor used to estimate the position
  - Ability of the pilot and system to fly the defined path.
- Flight Technical Error (FTE).



NAVAIDs Accuracy

Some sensors are better suited to PBN operations than others:

- **NDB :** is not an input to RNAV systems as it is not accurate enough for position estimation.
- **VOR :** at long range is the least accurate of the ground-based NavAids used in Area Navigation,it is too inaccurate for the more demanding lateral track accuracy requirements.
- **DME :** providing there are sufficient stations with appropriate geometry, supports most Navigation Applications up to a simple approach. the accuracy of a DME/DME position estimation is too poor when the DOP of the signals from a pair of stations subtend less than 30° and more than 150°.
- **GNSS :** GPS and possibly other constellations has the least error, with augmentation (integrity checking),



Integrity

Integrity is the **degree of confidence** that can be placed on the position estimation by the RNAV system.

- Failure to meet the integrity requirement should result in an alert to the pilot. This is also true for some RNAV systems including all those using GPS.
- GPS constellation does not have an acceptable alerting system for civil aviation.
- AAIM: Integrity monitoring is provided on the flight deck by linking the GPS receiver with either an Inertial system or a Barometric altimeter.

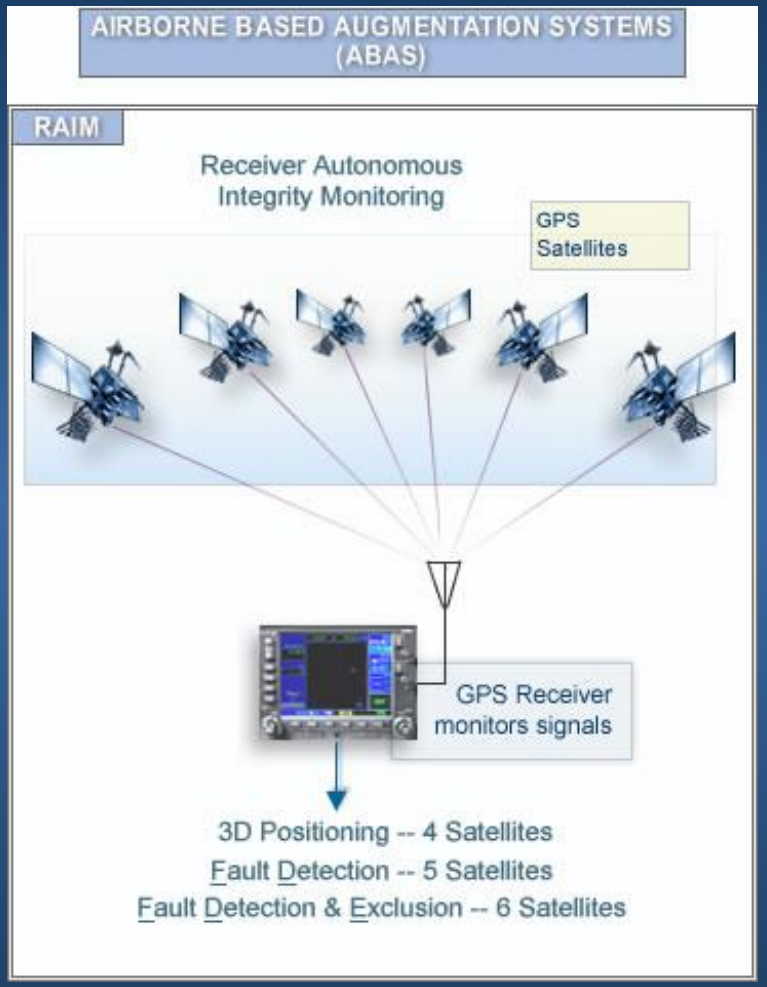
GPS RAIM

RAIM is the most common form of integrity monitoring. It is an algorithm integrated in the GPS receiver which compares a series of position estimations for internal consistency.

- RAIM is based on the availability of additional satellites in view.
- RAIM algorithm should detect a faulty satellite; this is known as Fault Detection (FD). If the receiver has extra functionality it may be able to perform Fault Detection and Exclusion (FDE).

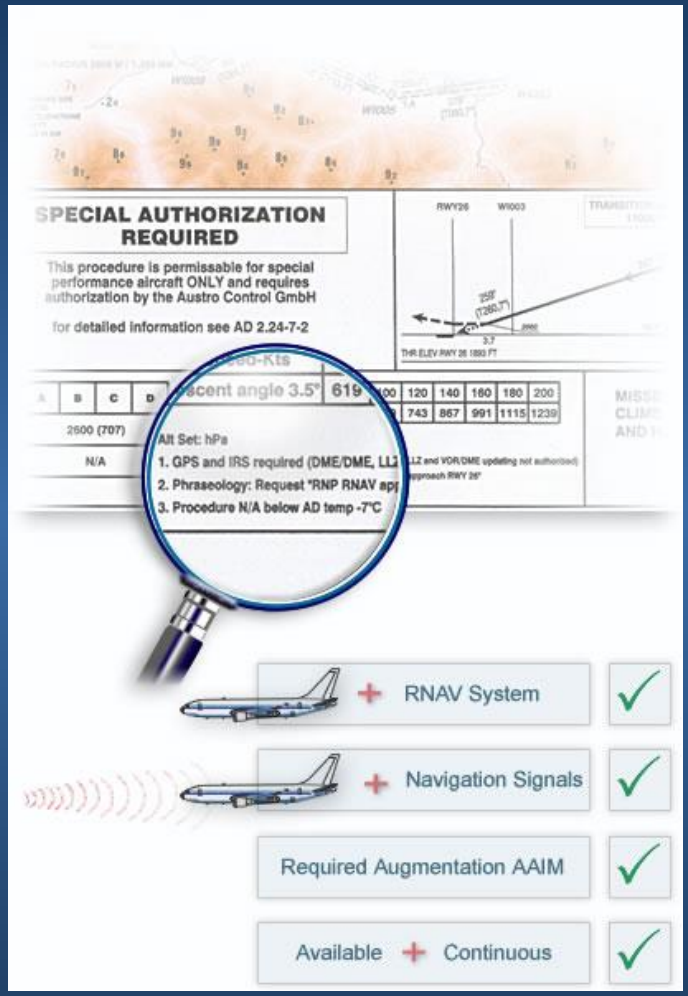
Fault Detection (FD) requires 5 satellites:
If the estimated positions start to spread out and exceed a preset value, then a fault is declared.

Fault Detection and Exclusion (FDE) requires 6 satellites:
Receiver can detect which satellite is faulty and exclude any positional data received from it.



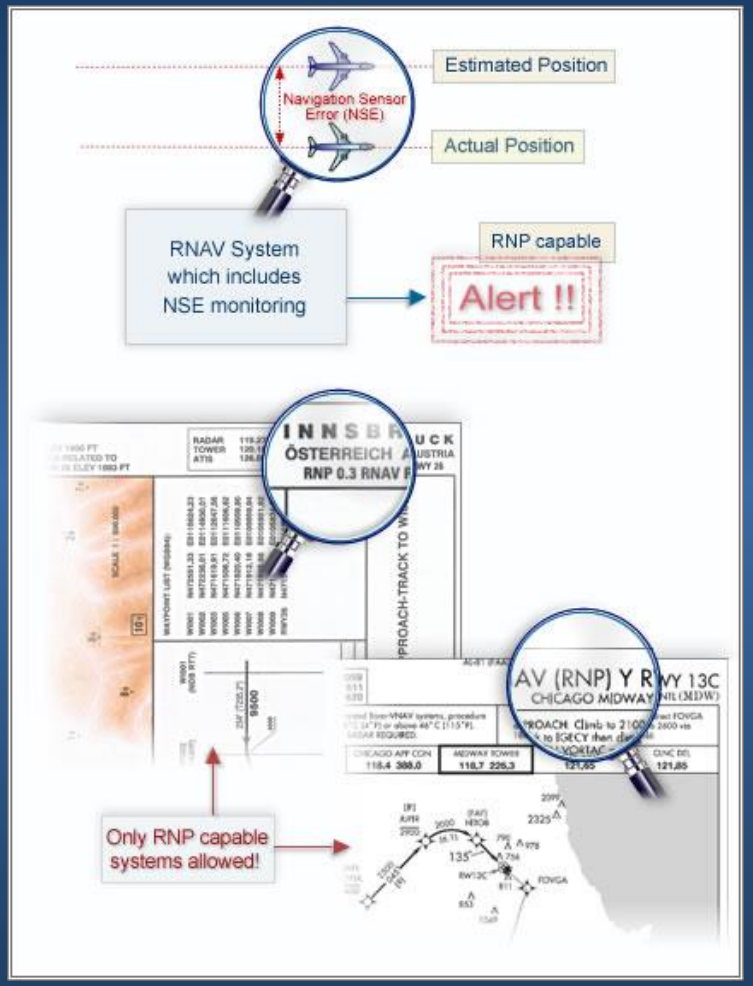
Availability and continuity

- Both the signals-in-space and the aircraft systems must meet the required accuracy, integrity and continuity for that operation.
- Should be able to perform for the whole of the defined operation
- Should also be available for the required operation and once the particular phase of flight has begun, continue to function for the period of that operation.



On-board Performance Monitoring and Alerting

- **Aircraft RNAV systems** do not necessarily provide the pilot with a warning when the required lateral accuracy limits have been exceeded.
- However, some RNAV systems do have extra functionality to monitor the Navigation Sensor Error (NSE) and issue alerts.
- Those RNAV systems with this extra functionality (on-board monitoring and alerting) are RNP capable.
- Some navigation applications will require **RNP capable** systems for their operations.



KALSTAR AVIATION

RNAV Routes, SIDs, STARs and IFPs

Phases of Flight and PBN:

PBN Navigation Specifications which relate to the different phases of flight.

The table shows :

EN-ROUTE:

Oceanic/Remote Continental

Continental

TERMINAL AIRSPACE:

Arrival/Departures

Approach/Landing

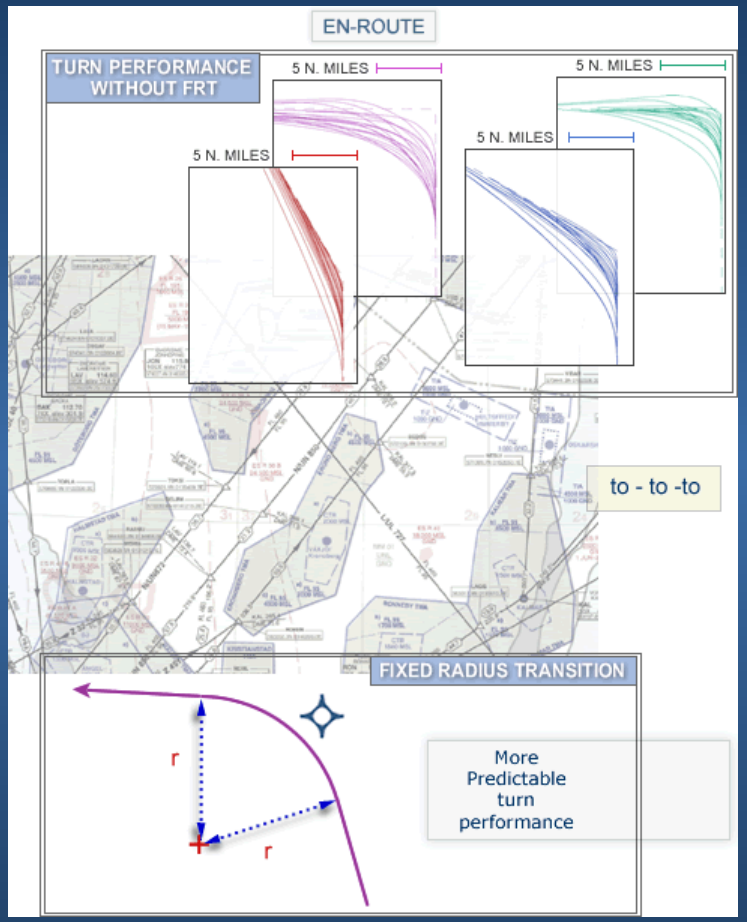
Standard (RNP APCH) with or without vertical guidance, which everyone can fly, or

Demanding (RNP AR APCH) requiring specific approval, functionality and training.

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

En-route navigation/Segments

- Area Navigation is based on paths between waypoints
- Turn performance varies depending on wind and speed.
- Fixed Radius Transition (FRT) capability (not a required functionality in the Navigation Specifications) will have better turn performance.

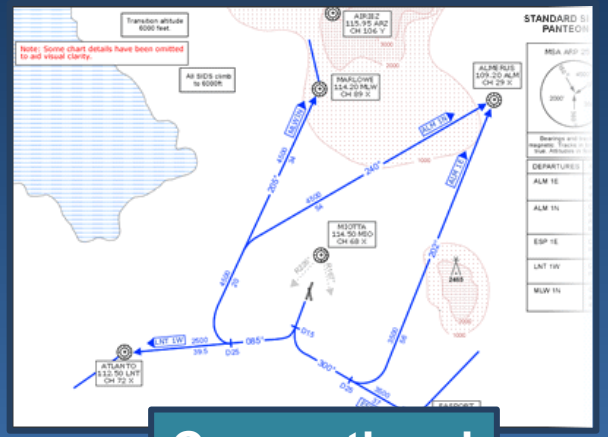


En-route segments:

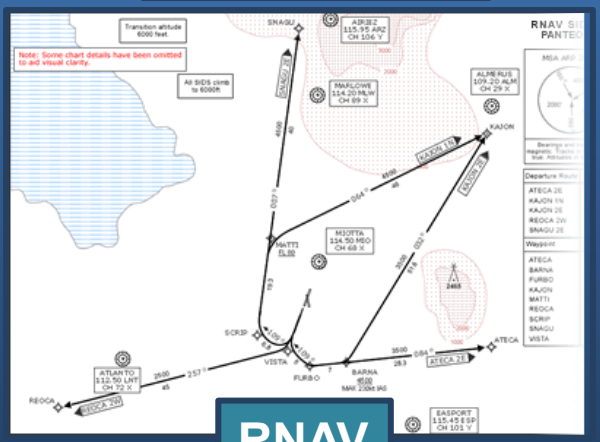
- Aircraft fly from waypoint to waypoint
- Turn performance of the aircraft is determined by the waypoint definition
- To guarantee predictable paths when turning, FRTs can be used..

Terminal Airspace : SIDs

- Prior to take-off, if the aircraft has only has only DME/DME positioning, and sufficient DMEs are not in view, position updating is not possible.
- Aircraft's position can be fixed at the end of the runway before the take-off roll (e.g. use of TOGA button)
- Lateral position relative to the runway centerline is dependent upon any cross-wind on initial climb.



Conventional



RNAV

Terminal Airspace : STARs

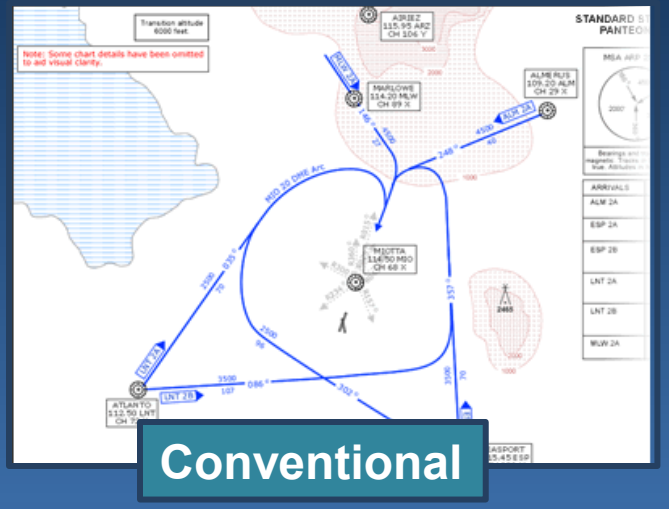
Two methods used to terminate RNAV STARs

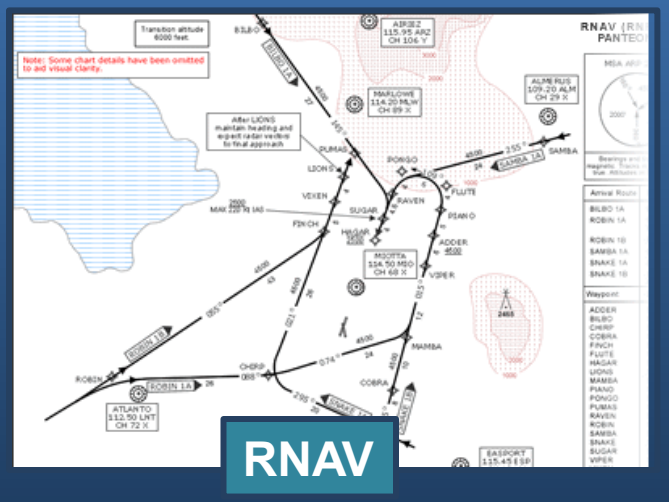
Closed STARs

Publication of an uninterrupted RNAV track to the final approach segment of the relevant instrument approach.

Open STARs

publication of an RNAV nominal track up to a waypoint, such as a metering Fix or a downwind waypoint, followed by ATC vectors to final approach





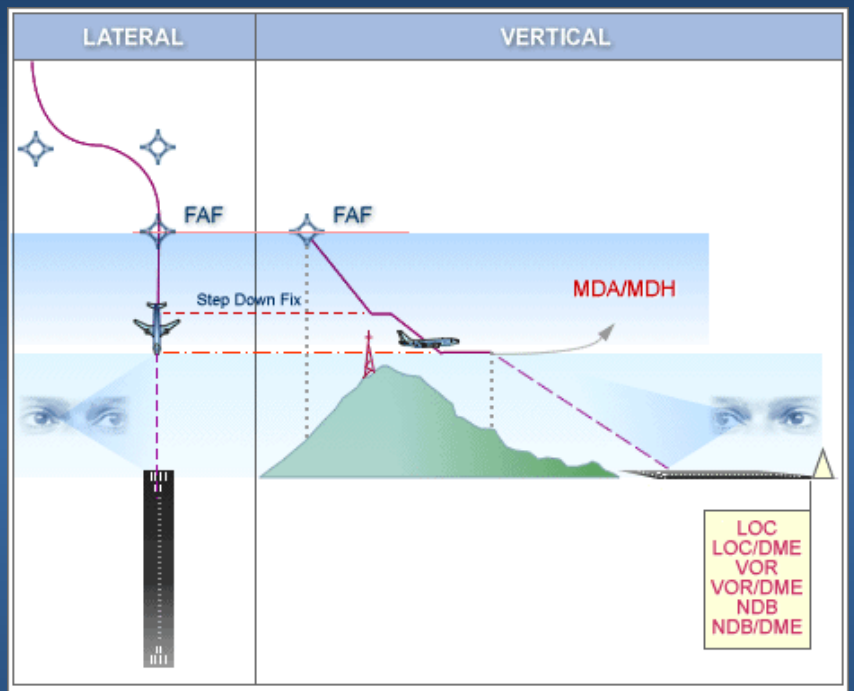
Terminal Airspace : Approach

Two types of approach:

1. **ILS based** precision approach
2. **Non-Precision Approach** (NPA), where only lateral guidance was available from a conventional NAVAID.

- Dive and Drive
- With an NPA, the pilot can lose along track situational awareness.
- As an initial step towards improving operational safety, a move away from 'Dive and Drive' to a Continuous Descent Final Approach (CDFA) is being made.
- With PBN, all approaches are RNP procedures) and can be with or without vertical guidance.

Conventional NPA

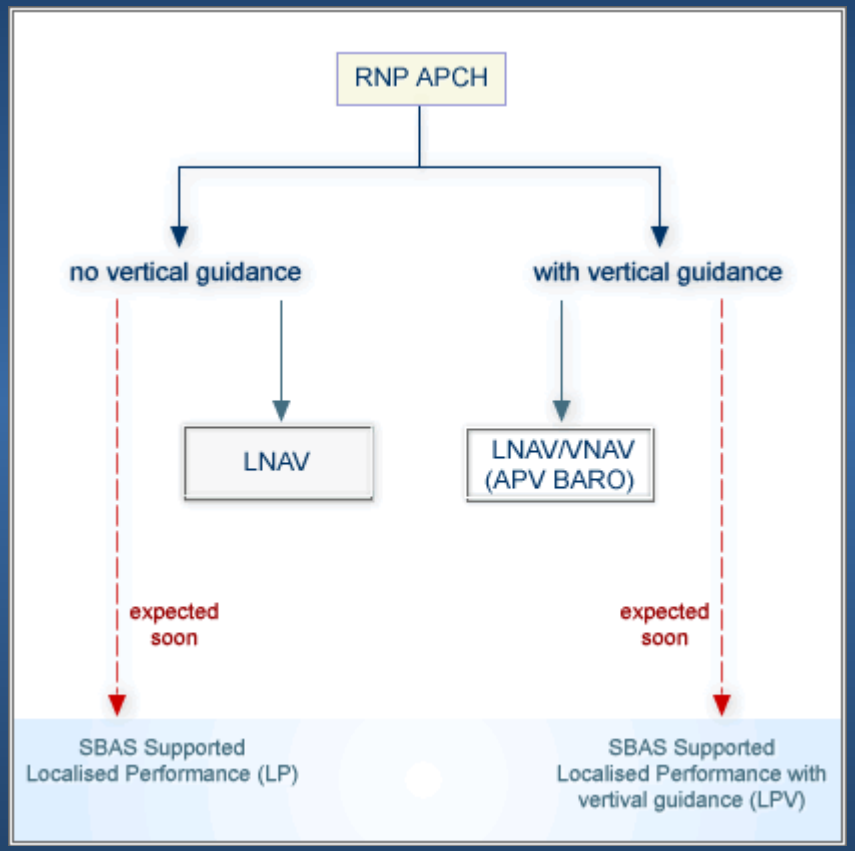


Description	System	Performance
○ Approach conducted to a MDA/MDH ○ Lateral guidance based on ground based NAVAIDS	As displayed	/

RNP APCH approach

RNP APCH

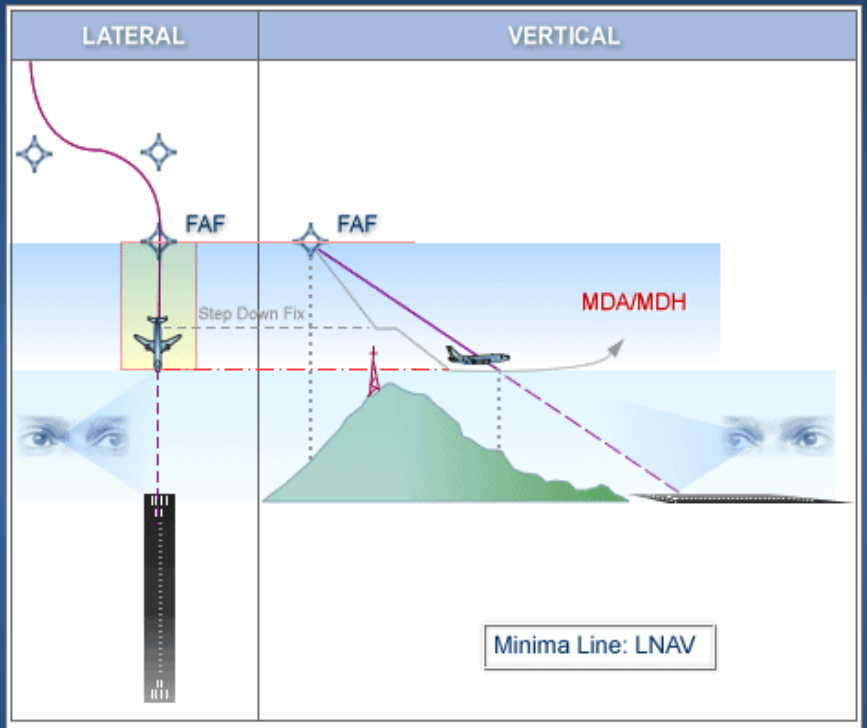
- is the standard approach specification that all aircraft can use.
- can be implemented with or without vertical guidance which may affect the minima.



RNP APCH approach cont'd

- RNP APCH is loaded from the navigation database.
- GPS with RAIM provides the lateral positioning to support **0.3** nm track accuracy on final approach.
- LNAV APCH is expected to be flown as a **Continuous Descent Final Approach** (CDFA) to a Minimum Descent Altitude/Height (MDA/MDH) .
- If pilots can't see the runway as they approach the minimum altitude they will initiate the missed approach procedure respecting the MDA/MDH.

RNP APCH with CDFA

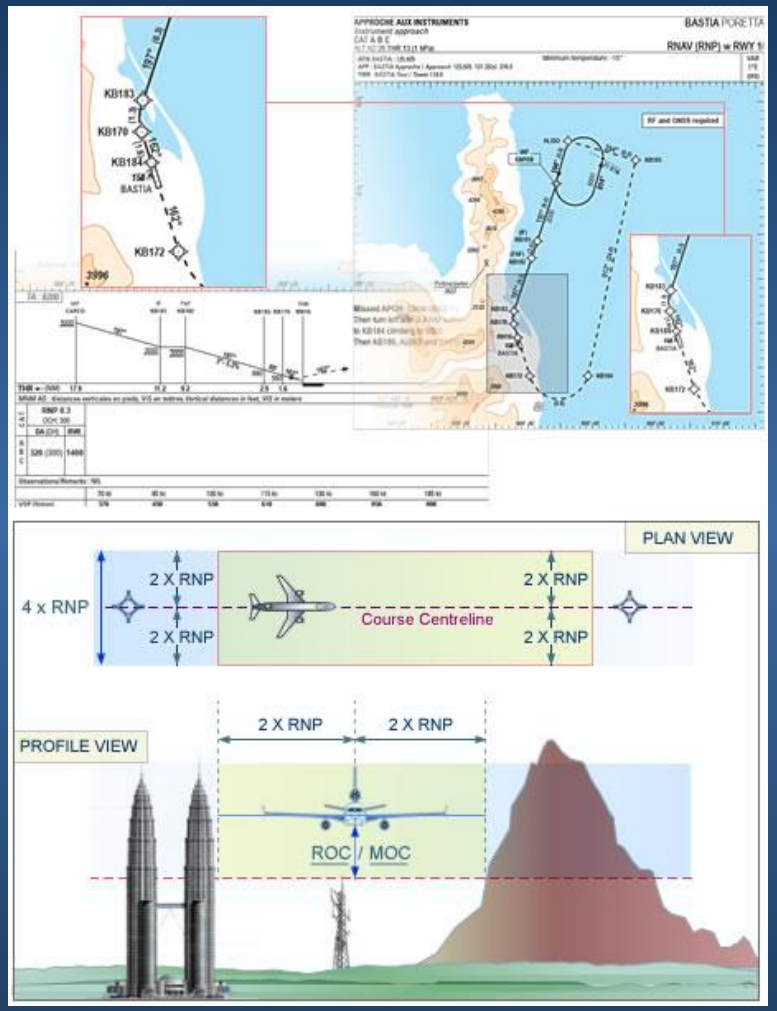


Description	System	Performance
○ Approach conducted to a MDA/MDH ○ Lateral guidance only based on GPS (with RAIM)	GPS (RAIM)	0.3NM (95%)

RNP AR APCH approach

RNP AR APCH (Approval Required)

- An RNP AR APCH is used where terrain or obstacles will not permit a normal RNP APCH to be used.
- AR procedures may also be employed for ATM purposes
- This type of approach requires specific approval from the **State's Regulator** and may necessitate additional aircraft equipage i.e. dual GNSS systems and Inertial platform, aircrew procedures and pilot training.
- Lateral track accuracy required can be as low as **0.1** nm and aircraft functionality such as RF leg capability



Finally..

… Let’s take a break ….

Next : Crew Procedures….

KALSTAR AVIATION

Flight Crew Procedures

PREFLIGHT

1. Crew must be TRAINED, QUALIFIED and CURRENT

2. FLIGHTPLAN

When the crew(s) or Aircraft is not RNAV compliance, the Flight plan must be amended by Dispatcher

3. NOTAMS

- ✓ Check any lack of availability of NavAid that might effect RNAV operation including any non-RNAV contingencies and must be confirm for the period of intended operation

4. Minimum Equipment List (MEL)

- ✓ Confirmed availability of onboard navigation equipment for the route to be flown.
- ✓ Check Area navigation equipment un-serviceability affecting RNAV operations .
- ✓ In certain areas, this may include the availability of an autopilot and/or flight director to maintain track keeping accuracy.

Before Start

1 FMC DATABASE

- ✓ Confirm the FMC database validity date, and verify that aircraft's initial position has been entered correctly.
- ✓ FMS NAV database must be current and appropriate for the intended operation this include the relevant navigation aids, waypoints, and coded Terminal area procedures for the departure, arrival and alternate airfields.

2 FMC FLIGHT PLAN

Active flight plan should be checked by comparing the charts, SID or other applicable documents with the map display and the (M)CDU.

- ✓ Confirmation of correct waypoint sequence
- ✓ Correct of track angles and distances
- ✓ Any altitude or speed constraint
- ✓ Correct identification, where possible, of waypoints as fly-by or fly-over

Before Start

2 FMC FLIGHT PLAN

Active flight plan should be checked by comparing the charts, SID or other applicable documents with the map display and the (M)CDU.

- ✓ Confirmation of correct waypoint sequence
- ✓ Correct of track angles and distances
- ✓ Any altitude or speed constraint
- ✓ Correct identification, where possible, of waypoints as fly-by or fly-over
- ✓ Aware any segment of the procedure which is below MSA.
- ✓ If required by a procedure, a check must be made to confirm that position updating is using a specific navigation aid.
- ✓ A procedure shall not be used if doubt exists as to the validity of the procedure in the navigation database

Before Start

3 FMC ROUTE MODIFICATIONS

- ✓ Route modifications in the Terminal area may take the form of radar headings or “direct to” clearances and the flight crew must react promptly
- ✓ This may include the insertion of a waypoint sequence loaded solely as part of an alternative procedure.
- ❖ The creation of new waypoints by MANUAL INSERTION into the RNAV system by the flight crew is **NOT PERMITTED** as it would invalidate the affected RNAV procedure

Take off

1 Prior to TAKE OFF

- ✓ Verify correct RNAV system operation, correct airport and runway data

2 LINE-UP

- ✓ Updating of the actual departure point must be guaranteed either by manual or automatic initialization on the runway, to avoid position shift after take-off (even with GPS active)
- ✓ B737 CL and NG have automatic position update when TOGA is pressed; pay attention to insert correct intersection “take-off shift” on (M)CDU T/O page

DEPARTURE

1 Flight plan monitoring:

- ✓ During the procedure and when feasible, flight progress should be monitored for navigational reasonableness, by crosschecks with conventional navigation aids using the primary displays in conjunction with the (M)CDU.
- ✓ Let the system auto tune useful stations for crosscheck
- ✓ If RNAV Specifications is NOT based on GPS equipment, transition to the RNAV structure shall only be made from the point where the aircraft has entered DME/DME coverage

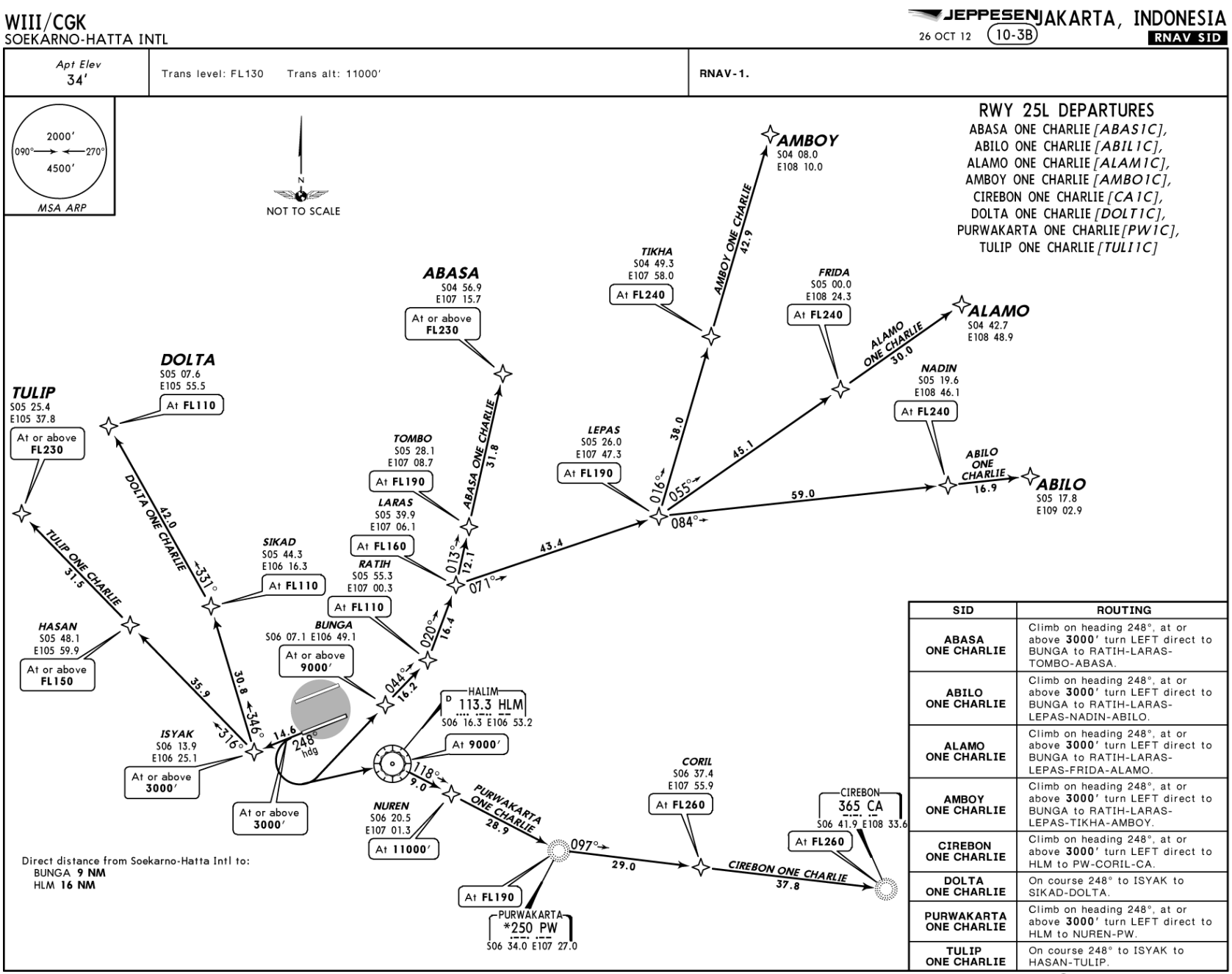
  This is valid when either the aircraft is not GPS equipped , or GPS position information is U/S

DEPARTURE

2 Track Keeping monitoring

- ✓ When using A/P and/or F/D, particular attention must be paid to the correct modes. Track keeping monitoring of a RNAV procedure below MSA will also require attention in degraded conditions such as engine failure, as both the vertical and the lateral obstacle clearance become more critical
- ✓ when F/D is available, it must be selected ON. If it is not available, the A/P must be selected ON. at least one guidance system must be available for the PF.
- ✓ With contingencies such as engine failure the quality of the lateral navigation is best obtained with use of A/P and correct rudder trim

Sample RNAV SID



SID	ROUTING
ABASA ONE CHARLIE	Climb on heading 248°, at or above **3000'** turn LEFT direct to BUNGA to RATIH-LARAS-TOMBO-ABASA.
ABILO ONE CHARLIE	Climb on heading 248°, at or above **3000'** turn LEFT direct to BUNGA to RATIH-LARAS-LEPAS-NADIN-ABILO.
ALAMO ONE CHARLIE	Climb on heading 248°, at or above **3000'** turn LEFT direct to BUNGA to RATIH-LARAS-LEPAS-FRIDA-ALAMO.
AMBOY ONE CHARLIE	Climb on heading 248°, at or above **3000'** turn LEFT direct to BUNGA to RATIH-LARAS-LEPAS-TIKHA-AMBOY.
CIREBON ONE CHARLIE	Climb on heading 248°, at or above **3000'** turn LEFT direct to HLM to PW-CORIL-CA.
DOLTA ONE CHARLIE	On course 248° to ISYAK to SIKAD-DOLTA.
PURWAKARTA ONE CHARLIE	Climb on heading 248°, at or above **3000'** turn LEFT direct to HLM to NUREN-PW.
TULIP ONE CHARLIE	On course 248° to ISYAK to HASAN-TULIP.

CHANGES: BUNGA crossing altitude revised.

DESCENT and ARRIVAL

1 Check FLIGHTPLAN

- ✓ This is performed in the same way as for departure
- ✓ Some P-RNAV procedures called “open procedures” are terminated by means of a heading segment to assist sequencing and to prevent automatic turns onto final approach
- ✓ Pay attention to particular segments of P-RNAV procedures below MSA
- ✓ If required, a check will need to be made to confirm that updating will include or exclude a particular NavAids as appropriate
- ✓ The crew briefing shall include reversion to a conventional procedure.
- ✓ As for departure, the creation of new waypoints by manual entry into the RNAV system is **NOT PERMITTED**.

DESCENT and ARRIVAL

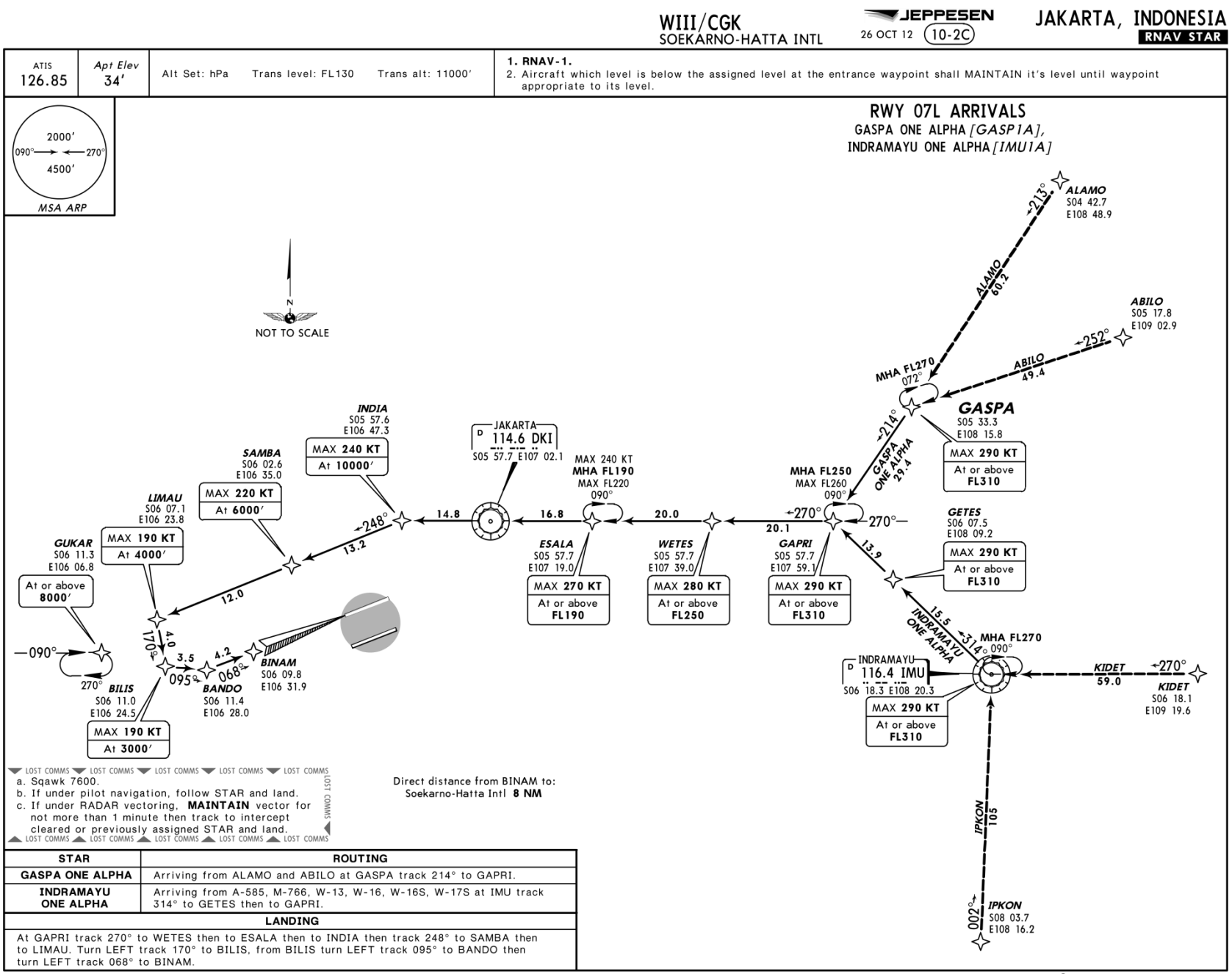
2 SYSTEM ACCURACY Check

- ✓ For RNAV systems without GPS updating, check is required during descent prior reaching the Initial Approach Fix (IAF)

3 ROUTE Modification

- ✓ Route modifications in the Terminal Area may take form of radar headings or “direct to” ATC clearances and the flight crew must be ready to react promptly. This may include the insertion in the flightplan of a waypoint sequence loaded solely from the database as part of an alternative procedure
- ✓ Manual entry or modifications by the flight crew of the loaded procedure, using temporary waypoints or fixes not provided in the database, is **NOT PERMITTED.**
- ✓ Ehen using A/P and/or F/D, particular attention must be made to the active mode.

Sample RNAV STAR



STAR	ROUTING
GASPA ONE ALPHA	Arriving from ALAMO and ABILO at GASPA track 214° to GAPRI.
INDRAMAYU ONE ALPHA	Arriving from A-585, M-766, W-13, W-16, W-16S, W-17S at IMU track 314° to GETES then to GAPRI.

LANDING

At GAPRI track 270° to WETES then to ESALA then to INDIA then track 248° to SAMBA then to LIMAU. Turn LEFT track 170° to BILIS, from BILIS turn LEFT track 095° to BANDO then turn LEFT track 068° to BINAM.

CHANGES: ESALA, GASPA, GAPRI, and IMU holding altitudes revised.

Contingency

1 Contingency procedures are developed to address Cautions and Warnings for following conditions

- ✓ Failure of the RNAV system components including those affecting flight technical error (e.g. failures of F/D or A/P)
- ✓ Multiple system failures
- ✓ Failure of navigation sensors
- ✓ Drifting on inertial sensors beyond a specified time limit

Contingency

2 ALERT Message

- ✓ If the following alert messages are displayed, check navigation accuracy with NavAid raw data, or with the GPS Monitor page (if GPS installed):
  - ➢ VERIFY POSITION
  - ➢ IRS NAV ONLY
  - ➢ (NG) GPS L (or R) INVALID
  - ➢ (NG) UNABLE REQD NAV PERF-RNP
  - ➢ (NG) VERIFY RNP
- ✓ If the accuracy check confirms that RNP-1 is lost, or if all installed FMC's failed: inform ATC and revert to conventional navigation
- ✓ If the accuracy check confirms that only one FMC position is incorrect, resume navigation with the other system.

Contingency

2 Contingency Procedure

- ✓ The flightcrew must notify ATC of any problem with the RNAV system that results in the loss of the required navigation capability, together with the proposed course of action
- ✓ Use Appropriate RNAV Radio Telephony Phraseology
- ✓ In the event of communication failure, the flightcrew should continue with the RNAV procedure in accordance with the published lost communication procedure.
- ✓ In the event of loss of RNAV capability, the flightcrew should invoke contingency procedures and navigate using an alternative means of navigation, which may include the use of an inertial system.
- ✓ The alternative means don't have to be an RNAV system.
- ✓ B737-CL and NG aircraft are capable of navigating on IRS navigation only; this is indicated by a message "IRS nav only" on the MCDU; the (M)CDU Progress page will indicate the degraded estimated navigation accuracy; navigation accuracy will then possibly degrade by IRS drift

RNAV related radiotelephony phraseology

Introduction

To avoid ambiguity about the status of aircraft and aircrew qualification a standardized set of R/T phrases has been defined

This phraseology closely matches the standard phraseology in use for RVSM operations.

Radiotelephony Phraseology

1 If a procedure cannot be accepted by the pilot for reasons of

- ✓ Either the RNAV equipment status
- ✓ Or circumstances associated with its operational use

“UNABLE (designator) **DEPARTURE (or ARRIVAL) DUE RNAV TYPE”**

Radiotelephony Phraseology

2 If for any other reason the pilot is unable to comply with an assigned Terminal Area Procedure, the pilot shall inform ATC immediately by use of the phrase:

"UNABLE (designator) **DEPARTURE** (or Arrival) **DUE** (reason)"

Example:
If the RNAV SID or STAR is not in the FMC database, the phraseology would be:

SRIWIJAYA123, UNABLE GASPA ONE ALPHA DUE TO NOT AVAILABLE IN DATABASE

Radiotelephony Phraseology

3 When the ATC FLIGHT PLAN indicates that the aircraft is not RNAV for reasons of onboard equipment , ATC shall inform the pilot by issue of following phrase:

“UNABLE TO ISSUE (designator) **DEPARTURE** (or Arrival) **DUE RNAV TYPE”**

Radiotelephony Phraseology

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

"UNABLE TO ISSUE (designator) **DEPARTURE (or ARRIVAL) (**reasons)**"**

5 ATC shall use following phrase:

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

Radiotelephony Phraseology

6 Obtaining Priority from ATC when weather deviation is required.

“WEATHER DEVIATION REQUIRED, REQUEST …. (Your Intention)”

KALSTAR AVIATION

End of Presentation

Any Questions ?