PBN and GNSS Theory Course

WAIKATO AVIATION ACADEMY

Performance Based Navigation and Global Navigation Satellite System

Part 1 - PBN Concepts

- History
- Conventional area navigation systems and augmentation
- Satellite based area navigation systems and augmentation
- PBN and the Airspace Concept
- PBN monitoring,

  PBN specifications and functions

History and Development of PBN

OMEGA

Aircraft Capability

Airspace Requirement

Introduction of MNPS for oceanic operations
1977

1983
FANS committee established and developed **RNPC** concept focus on containment

RGCSP recognised the importance of the airspace requirement over aircraft capability. The concept evolved to **RNP**
1990

Edition 2 of the RNP manual published

ICAO established the RNPSORSG
2003

2008
First edition of **PBN** manual Published
8 Nav Specs.

Second edition of PBN manual Published
3 new Nav Specs
2013

PBN IFR timeframe

Third edition of PBN manual published

1970 **1980** **1990** **2000** **2010** **2020** **2030**

Sensor Based Navigation

What can the sensors deliver

Performance Based Navigation

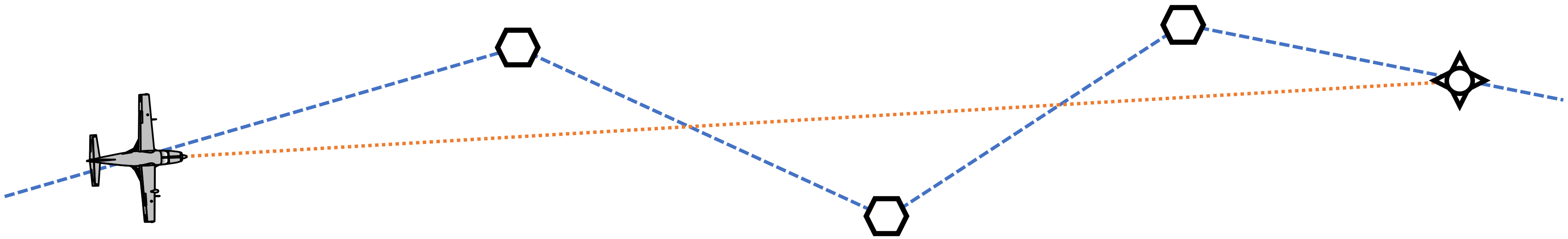
What is the performance specification for safe and efficient operations

Important

Definition of Area Nav (RNAV)

An RNAV system is "A navigation system which permits aircraft operation on any desired flight path within the coverage of station-referenced ground or space based navigation aids or within the limits of the capability of self-contained aids, or a combination of these. An RNAV system may be included as part of a flight management system (FMS)." (ICAO Doc 9613)

Put differently, area navigation permits point-to-point navigation without forcing the route to or from ground-based navigation aids



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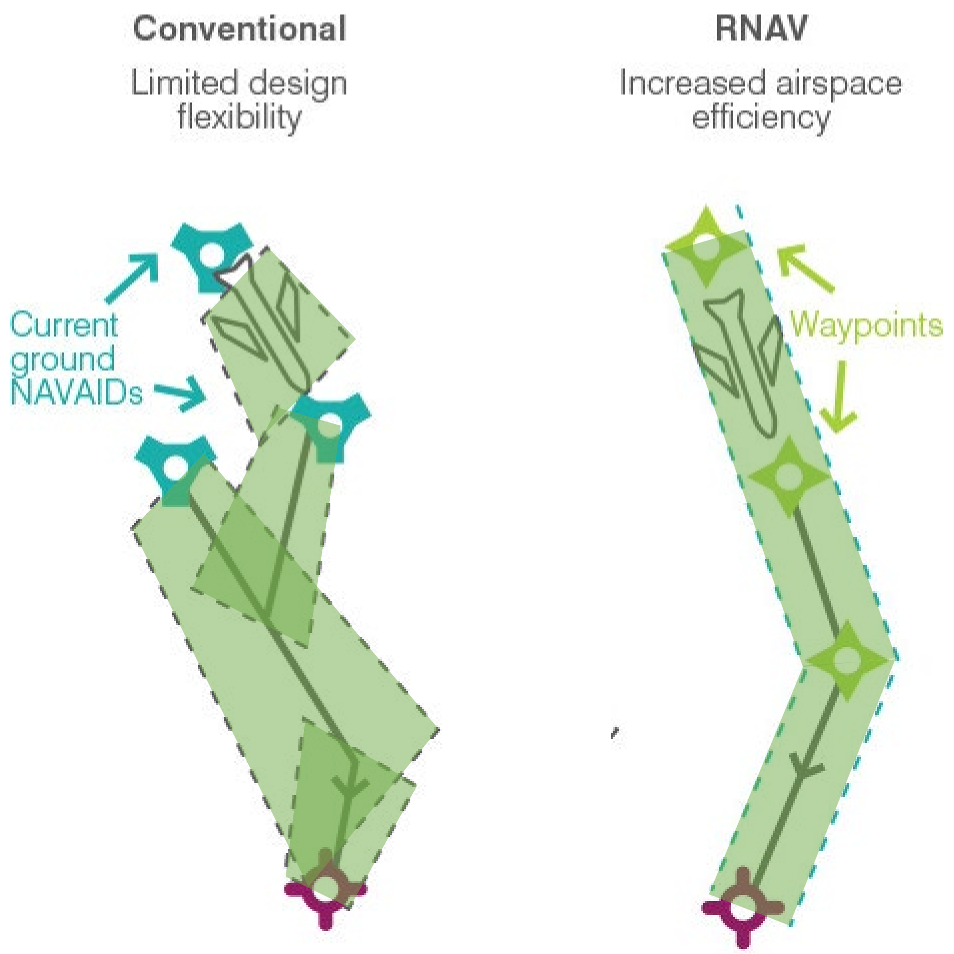
The Development of PBN

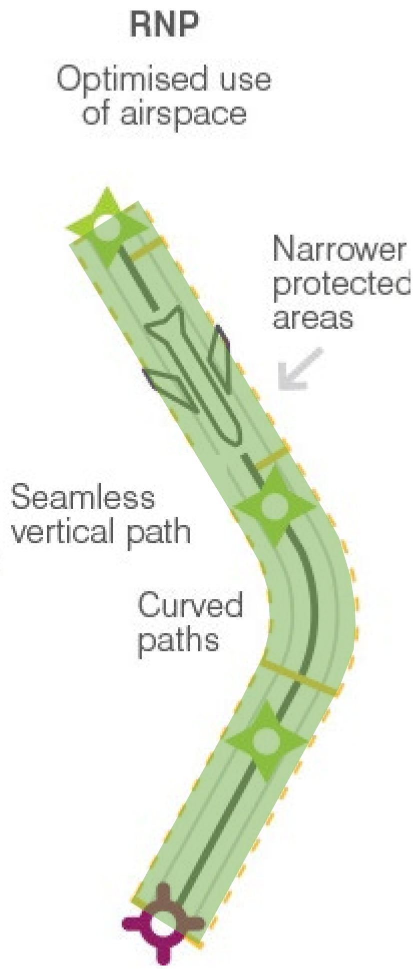


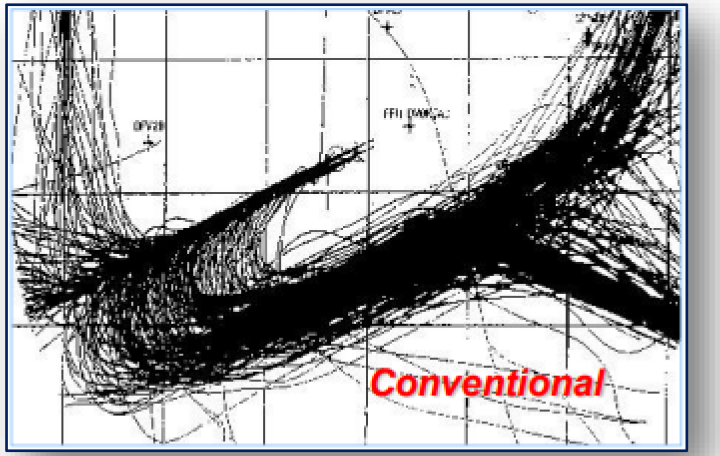
Shortfalls

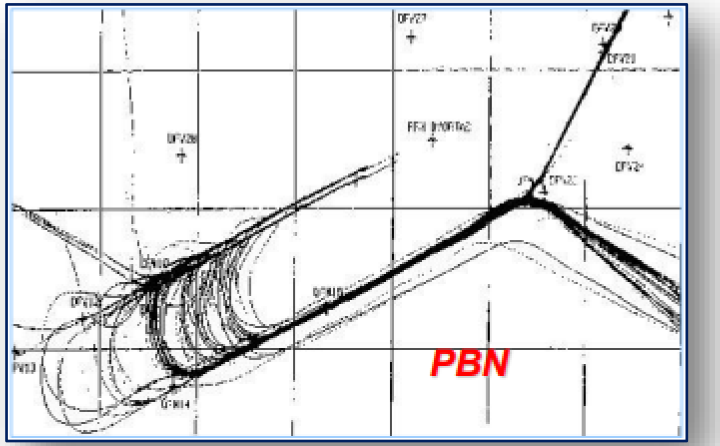
- Only technology based
- No specification between states
- No guidance on ac requirements, ops procedures, training requirements.
- Problems with inoperability

This led to a proliferation of

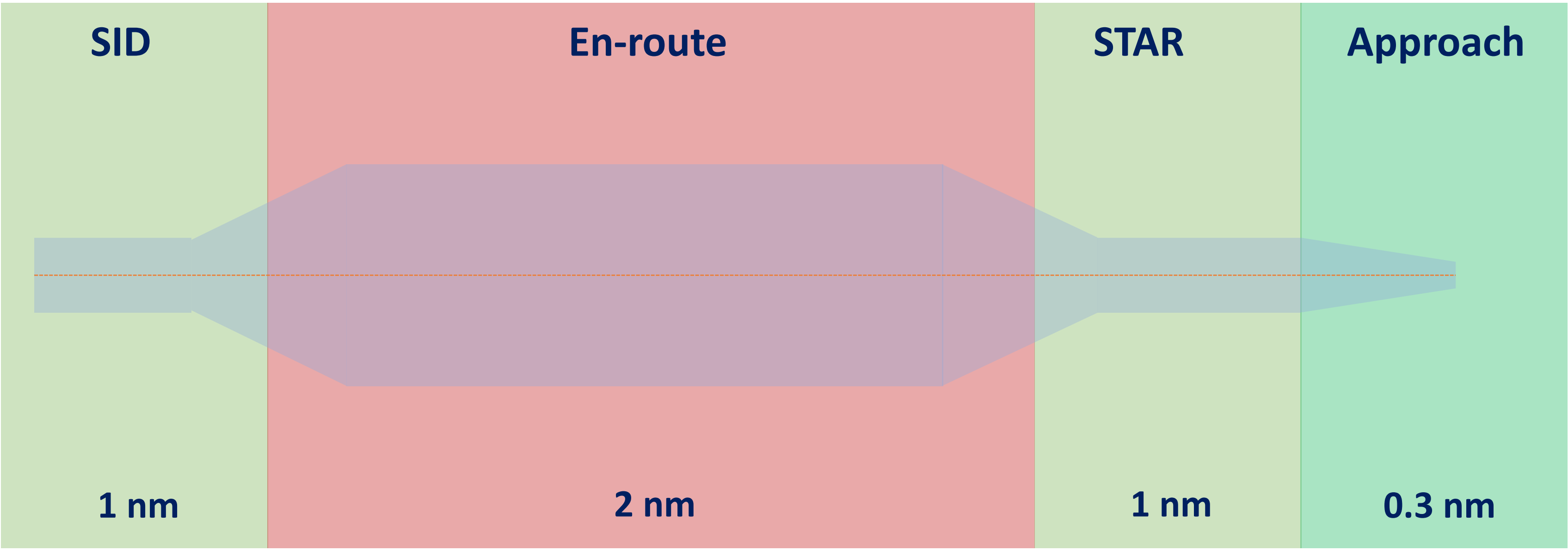
- National standards
- Variety of functional requirements
- Differing crew requirements
- Different industry concept of RNP (on board monitoring and alerting)


RNP
Optimised use
of airspace
Narrower
protected
areas
Seamless
vertical path
Curved
paths


Conventional


PBN

The accuracy requirement for area navigation



Development of sensor based area navigation capability

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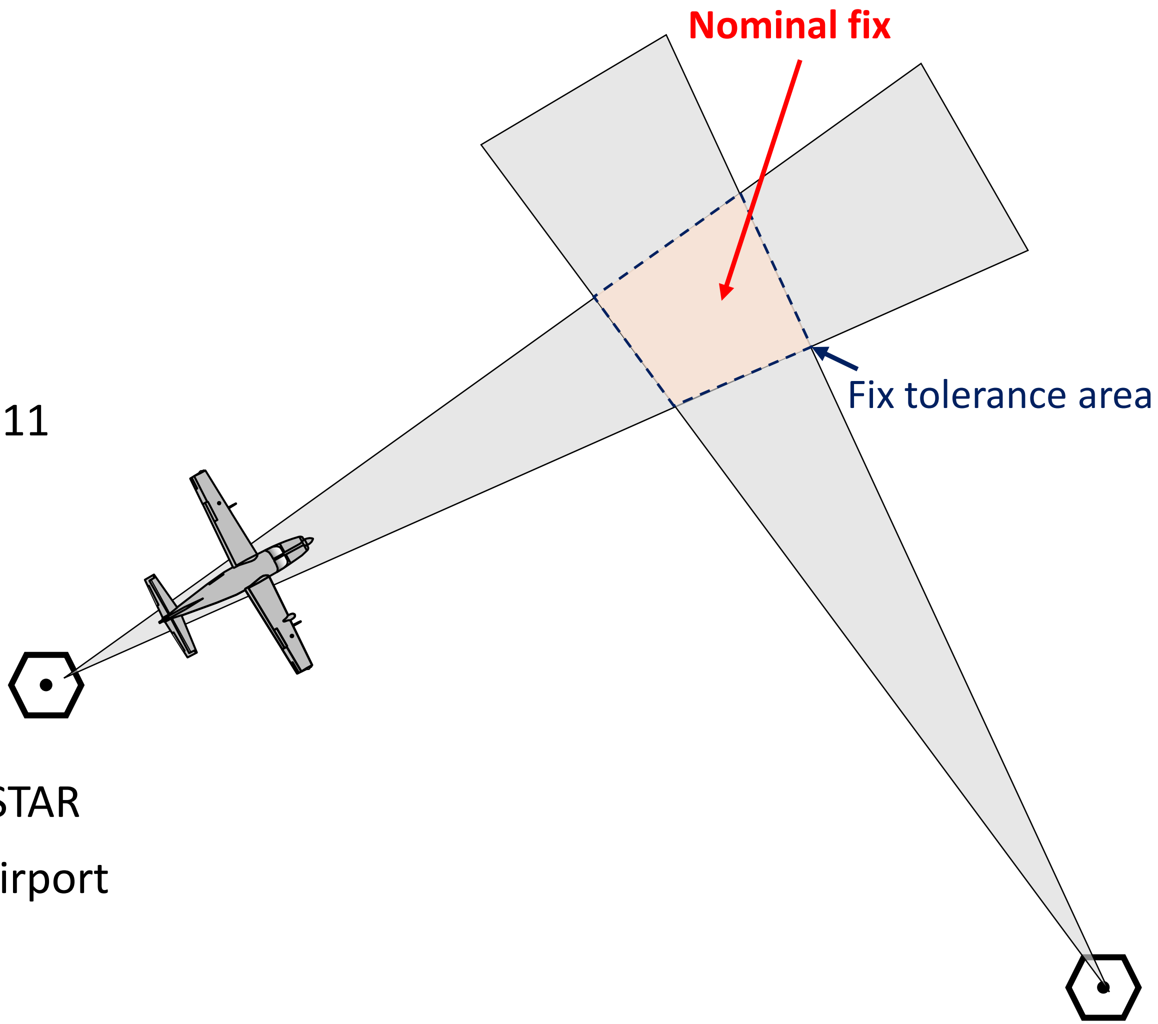
VOR

VOR use is limited due to angular error

- Increases with distance
- RNAV 5 routes only



Originally called Basic RNAV (B-RNAV) in EU

- Support first generation digital avionics, L1011

En-route operations only

- Not approved for Terminal Ops, i.e. no SID/STAR
- Except permitted on a STAR to 30nm from airport
- Operations below MSA not permitted

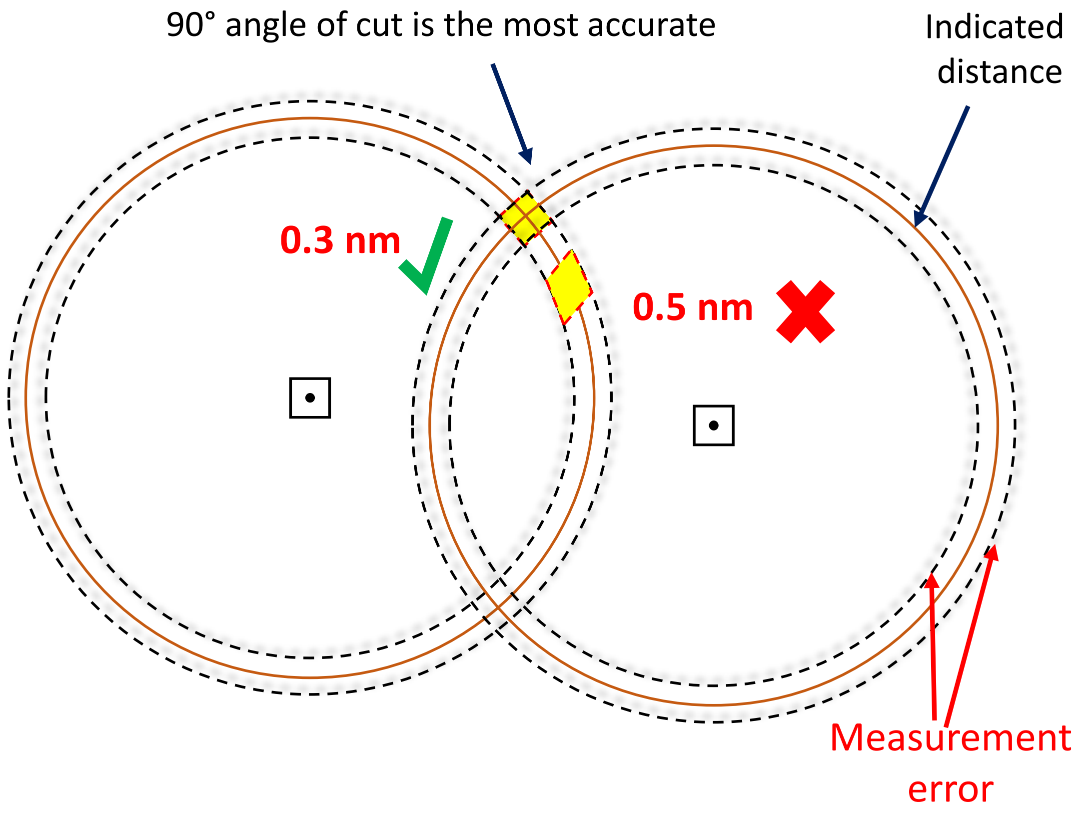
DME/DME

DME/DME position fixes have an accuracy of 0.3 nm at 90⁰ cut reducing to 0.5 nm when outside of 30-150⁰ intercept.

DME/DME is useful in updating INS position for Area Navigation.

RNAV 1 using DME/DME was developed when a higher track accuracy was required to support area navigation operations close to terrain in continental en-route operations.

RNAV 2 like RNAV 1 preceded the PBN concept and was adopted in the US to support en-route navigation in areas where there was limited DME/DME coverage.



Inertia Navigation

- Provides navigational guidance without external signals
- Provides both position and attitude reference
- Requires accurate alignment before flight and then with en-route updates
- Accuracy degradation is 1-2 nm per hour
- Updated by ground or space based systems DME/DME or GNSS
- Provides internal reference and redundancy in high specification applications e.g. RNP AR APCH

Satellite Navigation

Current:

- GPS (US) ~ 31
- GLONASS (Russia) ~27
- Galileo (European) ~ 24 > 30
- BeiDou (Chinese) ~24 > 35

Accuracy depends on multiple signals

No failure flag, therefore the system requires augmentation for safety critical activities

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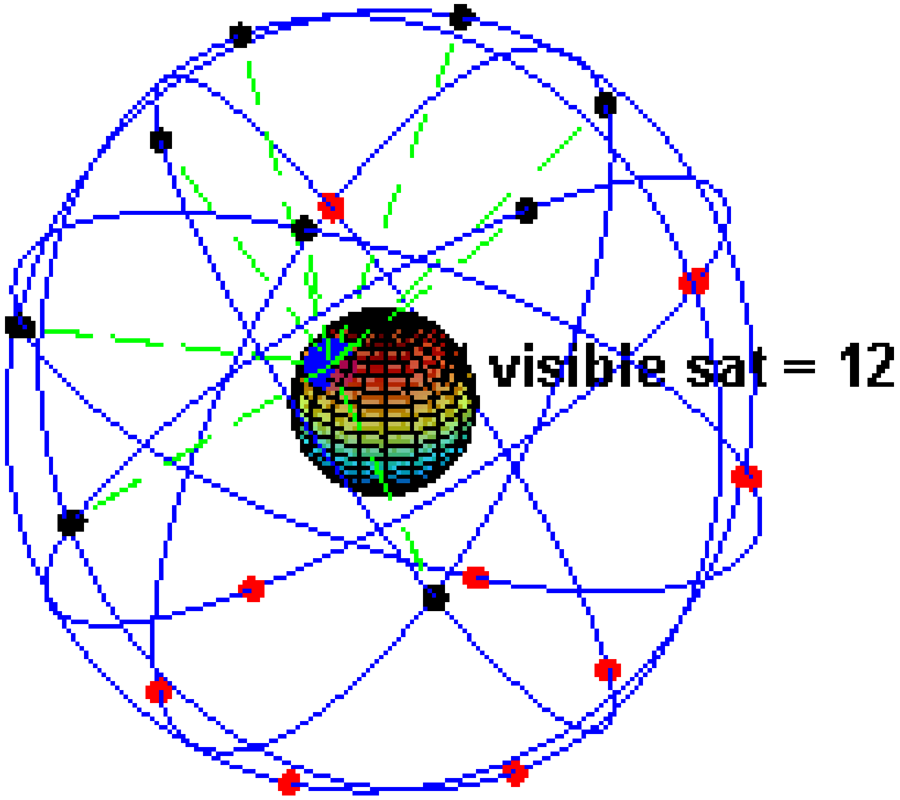
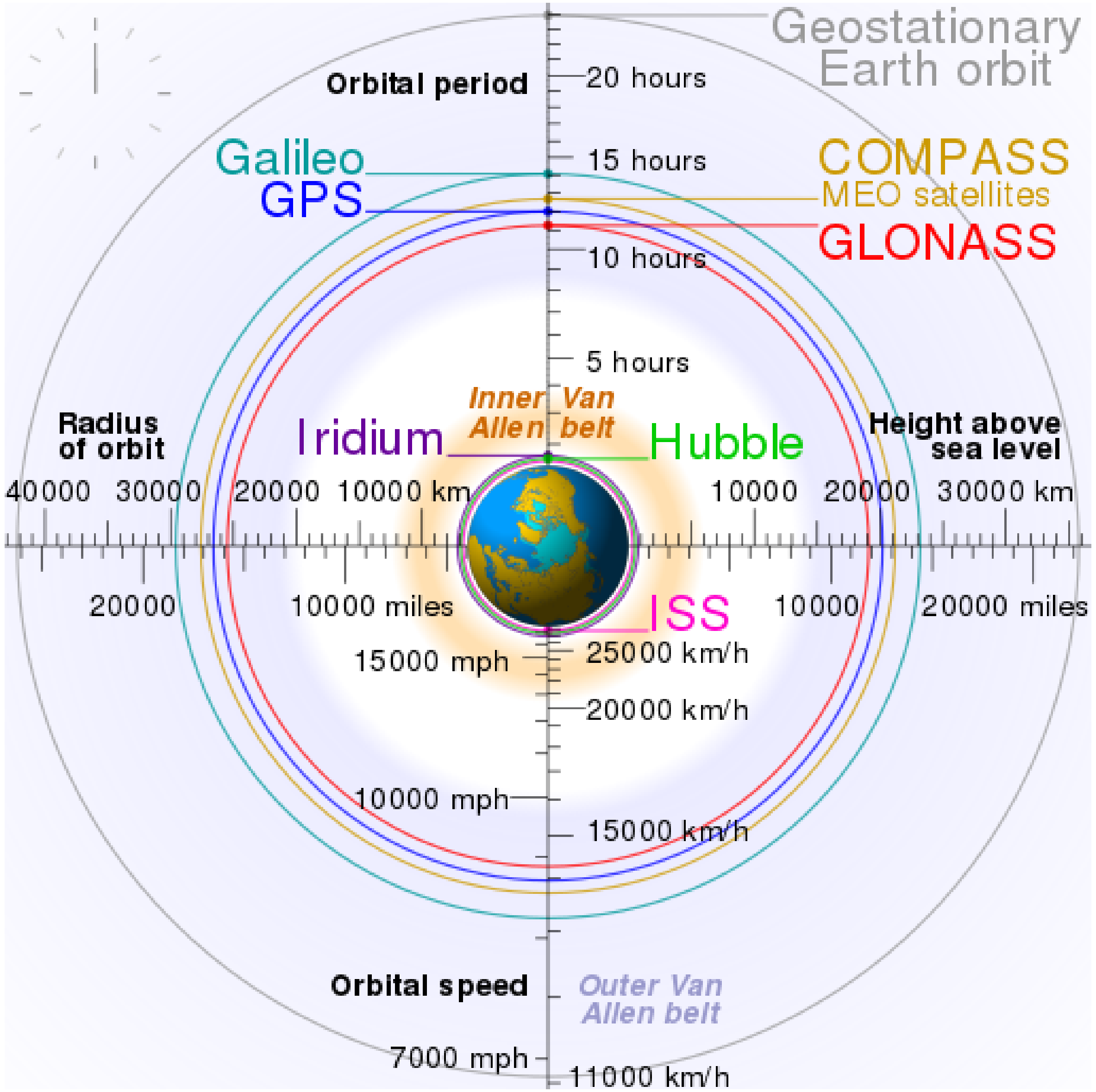
GPS Refresher



GPS Navstar (US) Satellite constellation

- 32 but requires 24 operational
- 6 planes of orbit
- Inclined at 55°
- 20,200 km altitude
- Period about 12hrs
- Minimum of 4 satellites always in view (in theory!)



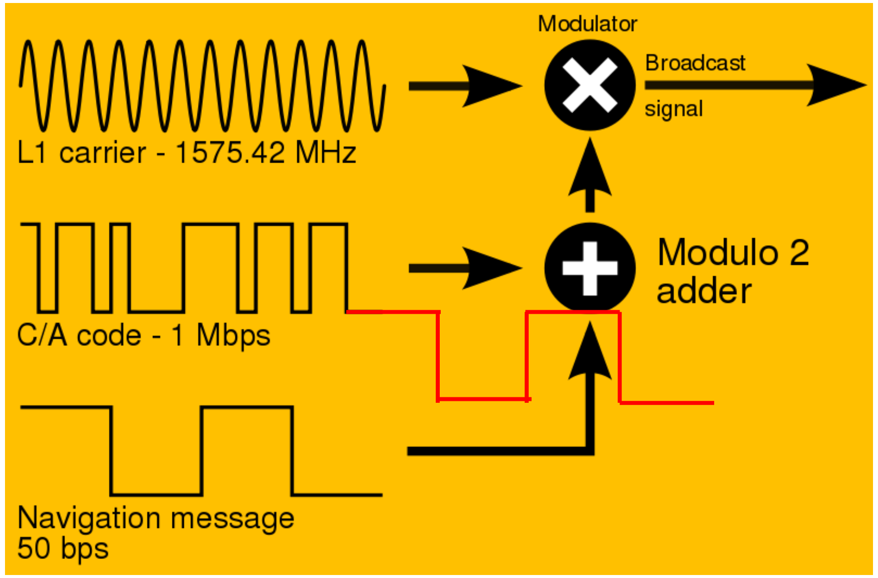
https://upload.wikimedia.org/wikipedia/commons/b/b4/Comparison_satellite_navigation_orbits.svg

GNSS components

Three segments

- Control
  - Monitoring stations
  - Master Control Station
- Space
  - 24-32 satellites
  - Atomic clocks
- User
  - Military / Civil

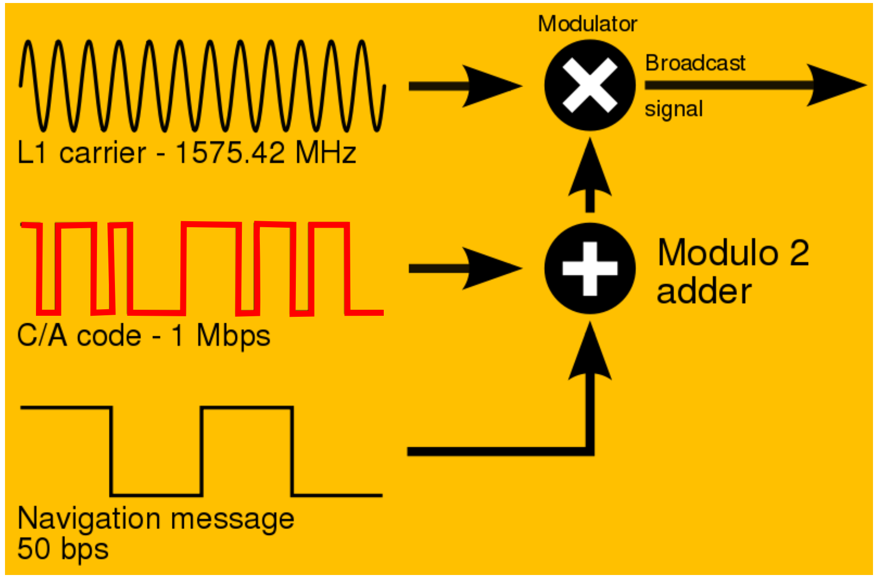
GPS components



Navigation message

- Accurate GPS time is sent first in the navigation message
- GPS → UTC conversion
- **Ephemeris**
  - provides accurate location of the individual satellite at a specific moment, specifying the satellites path. Valid for 30 minutes and transmitted every 30 seconds
- **Almanac**
  - provides orbital parameters for all satellites every 12.5 min but is not as precise as the Ephemeris and can be up to two months old. Also provides info on the state (health) of the entire satellite constellation!

GPS components



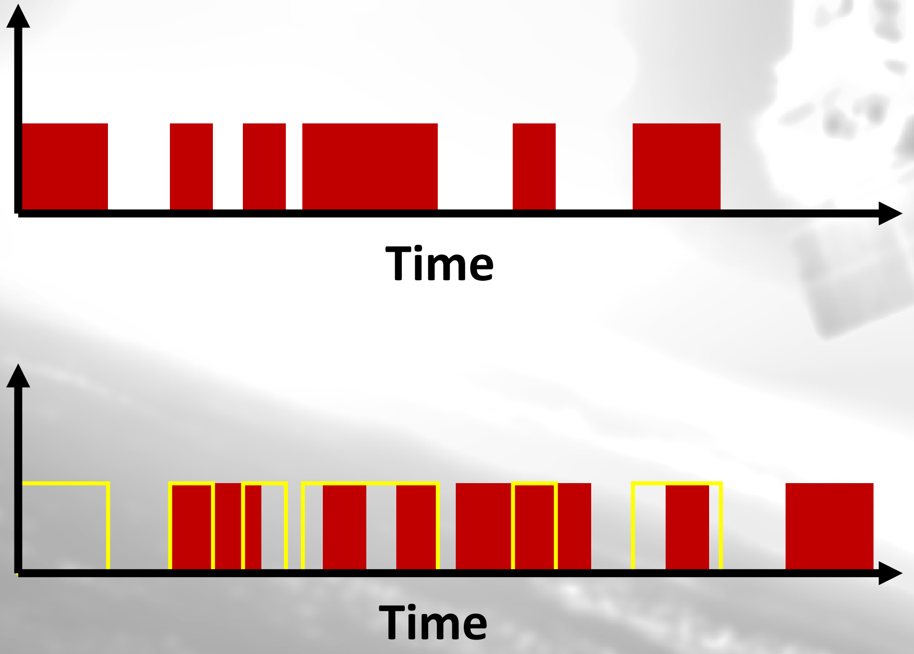
C/A code

- Satellite identification
- Pseudo-Random Noise (PRN) code
- Up to 32 PRN codes
- Each code very unique – no interference

P(Y) code

- Faster, more accurate

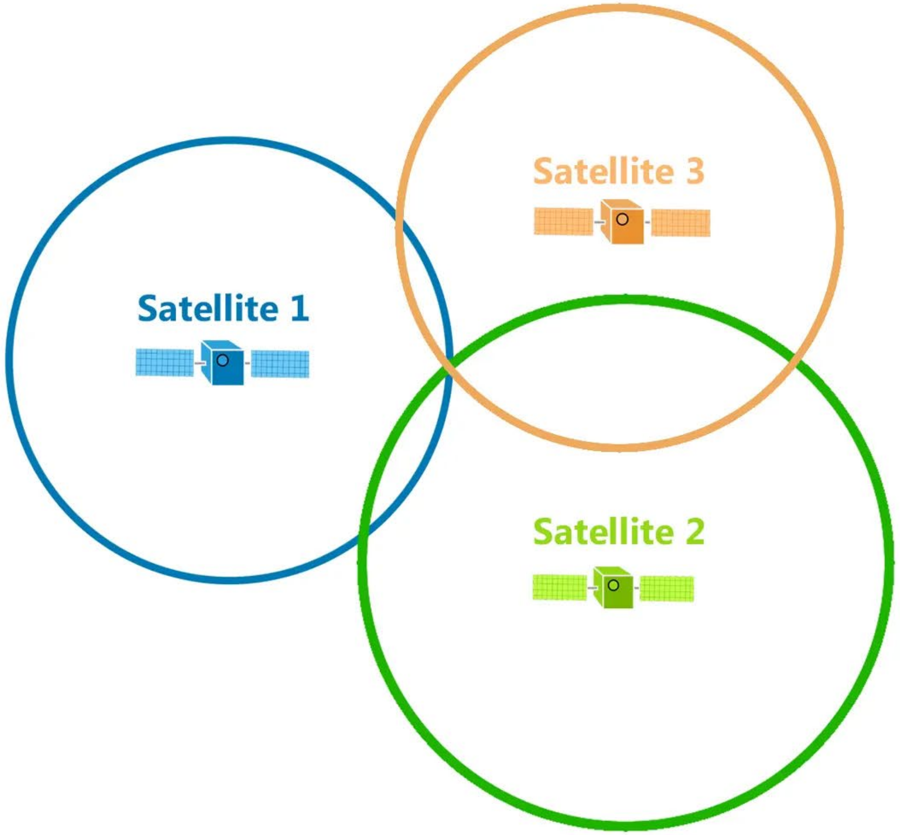
Principles of position fixing



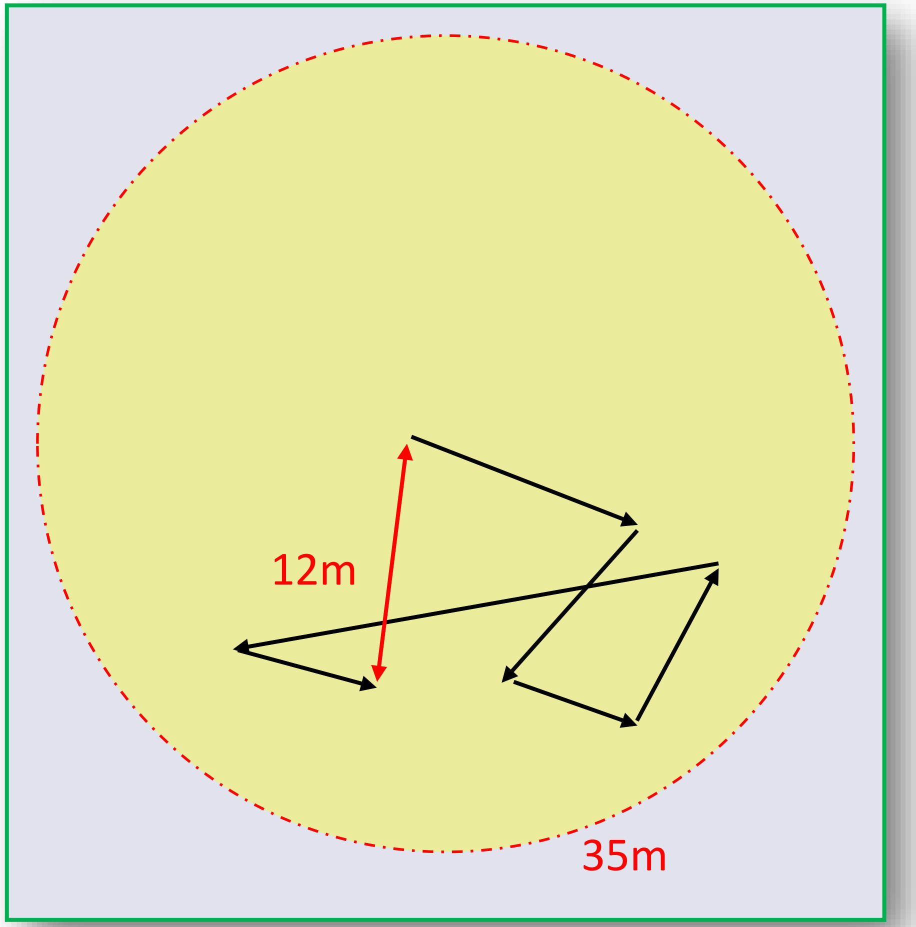
- Satellite transmits
- Some time later signal arrives at receiver
- Receiver compares code with version in memory
- Receiver calculates time difference
- Calculation repeated for each satellite in view

150 nanoseconds: pseudo range = 45,000km

Principles of position fixing



Timing errors



3-D navigation + time, requires four satellites

- But timing still very difficult to measure
- Note common sources of error

GPS accurate to **±35m, 95%** of time

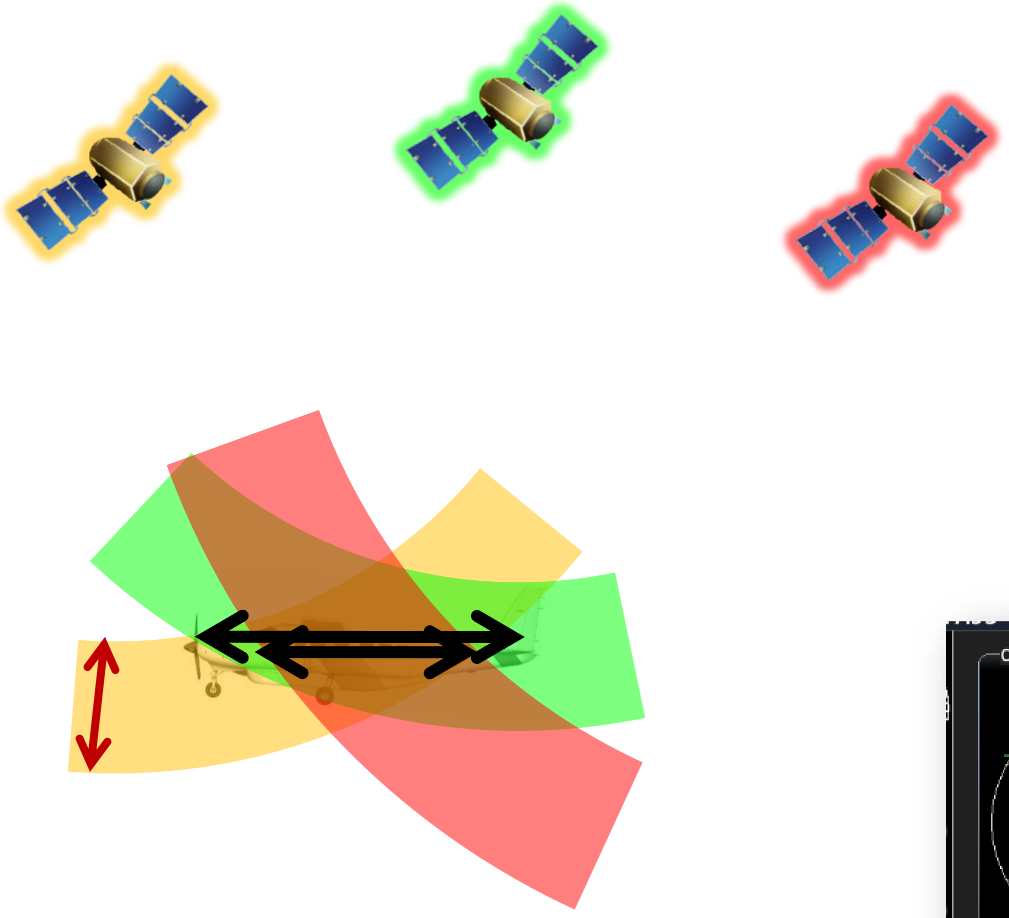
With SBAS, some of these errors are reduced

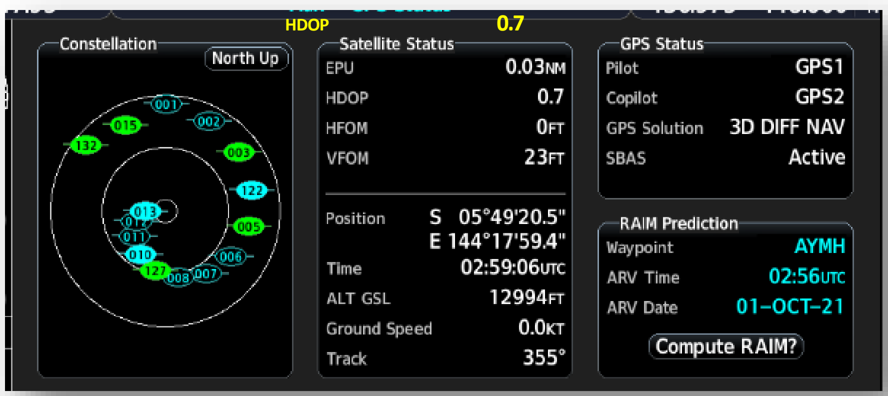
- Satellite clock
- Ephemeris
- Ionospheric error

Geometry errors

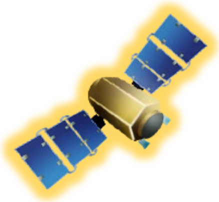
Dilution of Precision (DOP)

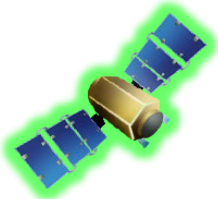
- Error due satellite geometry
- Total error / Range error
- Note range error unchanged, but wider spacing of satellites means lesser total error, or DOP...
- DOP<3 – approach ok





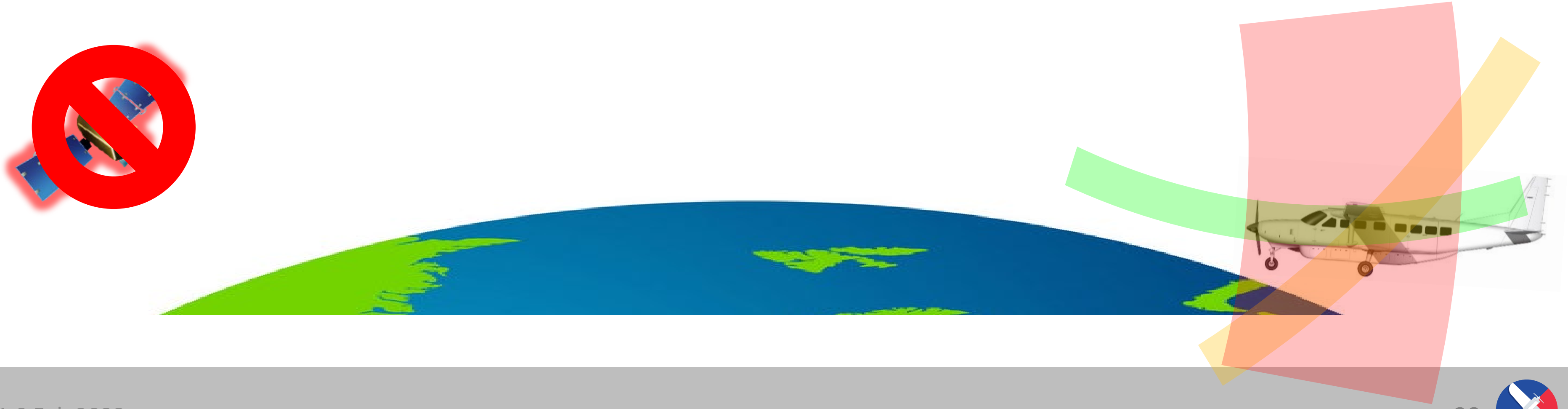
Masking





Satellites at low elevation

- Potential error due distortion through ionosphere
- Satellites close to horizon excluded by software
- Terrain / aircraft structure etc may also mask or cause multipath error
- Typically satellites at an angle of less than to $15\text{-}20^{o}$ to the horizon will be automatically removed from the calculation.



GNSS Radio Frequency Interference (RFI)

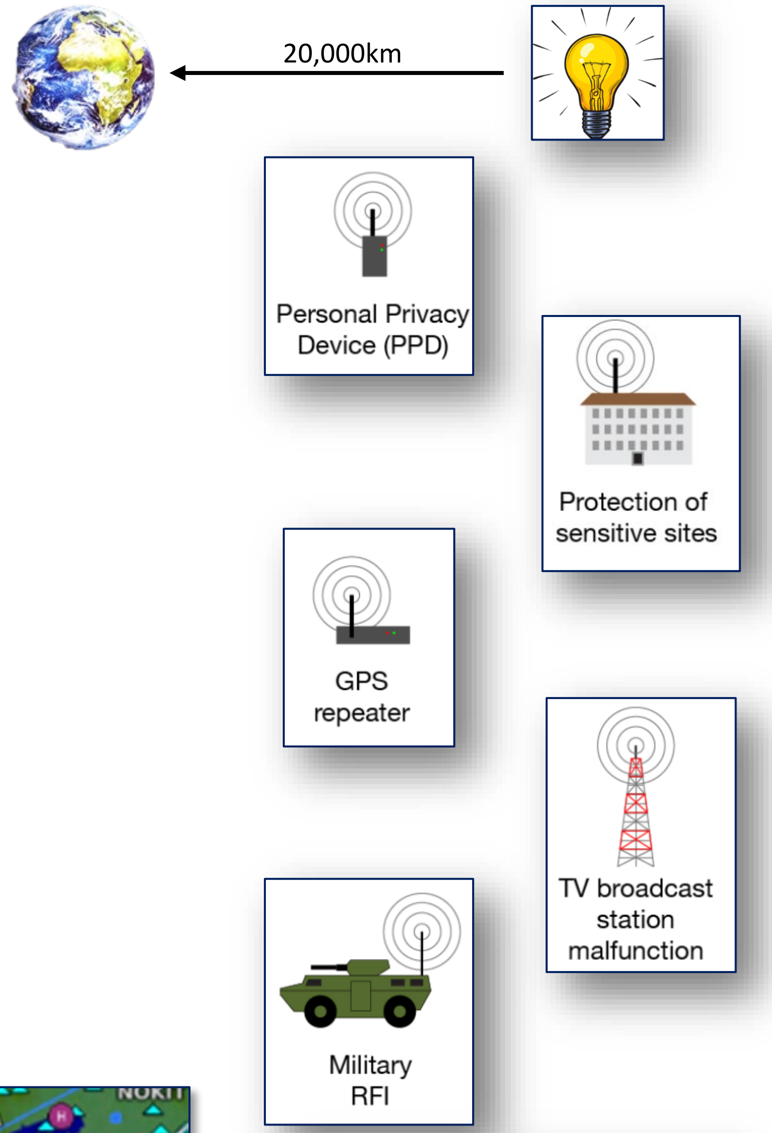
PPDs Jam signals to avoid tracking. Problem around airports

GNSS RFI may in place for security reasons. Aircraft operating in these areas may be affected

GPS repeaters used to strengthen signals can cause interference if not properly managed

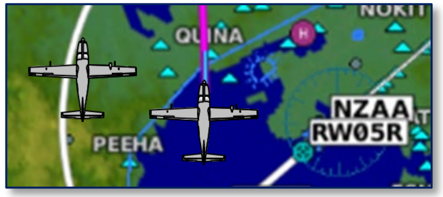
TV broadcast station malfunctions can interfere with GNSS signals

GPS RFI in military areas can cause GNSS signal interference.



GPS NAV LOST – Loss of GPS navigation. GPS fail.

LOI



APR DWNGRADE – Approach downgraded.

WGS84

Ellipsoid datum reference for determining Longitude and Latitude coordinates

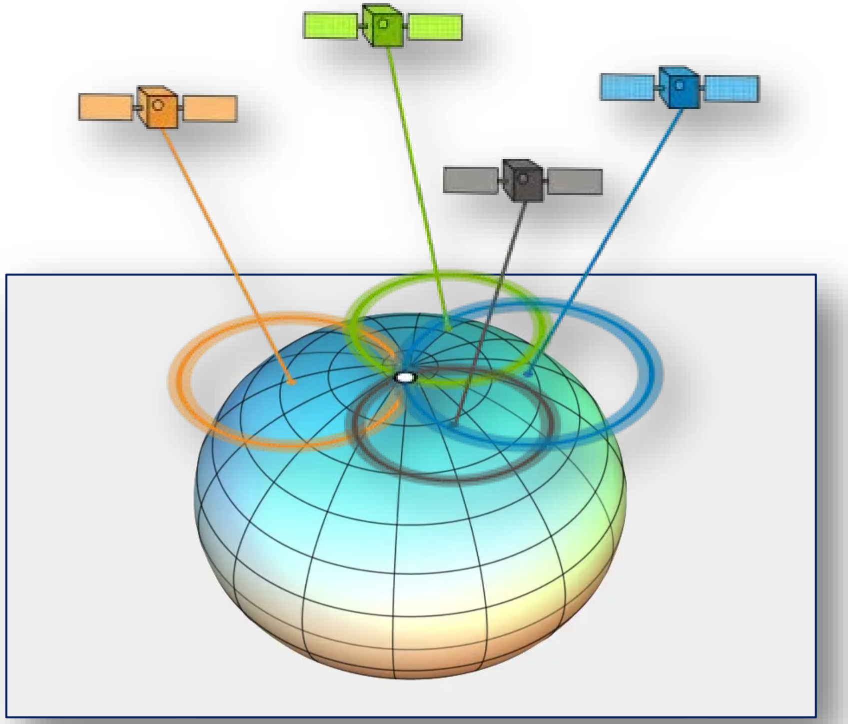
Accuracy to within 1-2 cm but this changes and needs to be updates with tectonic movement.

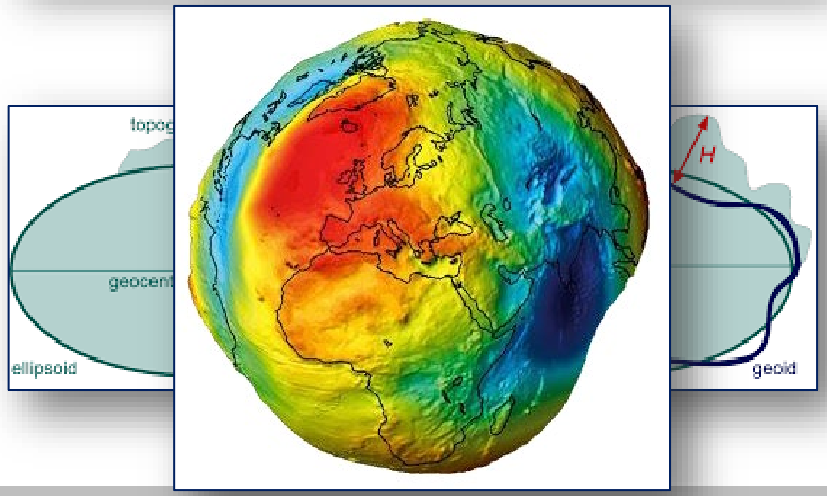
Enhanced accuracy by GNSS measurements

More difficult to measure elevation due to the irregularity of the earth's shape

For terminal and en-route – barometric altitude is used

For approach, with SBAS vertical guidance, GNSS altitude is used due to level of augmentation

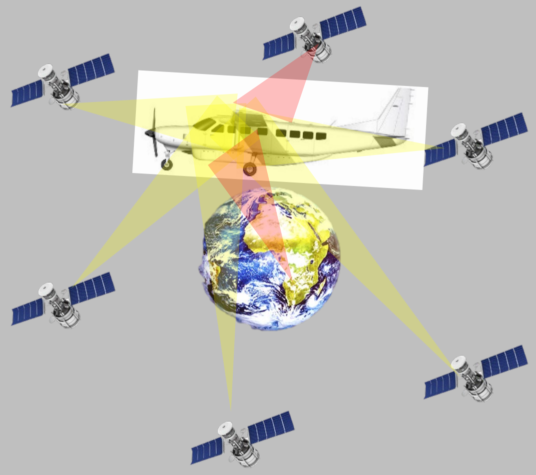




GNSS Augmentation

Important

GNSS
GPS,GLONASS, Galileo, Beidou



Space Based SBAS	ABAS	Ground Based GBAS
EGNOS (EU) WAAS (US) MSAS (Japan) GAGAN (India) SDCM (Russia)	RAIM, AAIM	GBAS (EU) LAAS (US) SCAT (Norway) PALS
• Continental wide area • Series of corrections for each satellite • Improves accuracy and provides integrity • Supports down to LPV Cat 1	• Integrity monitoring only	• Local area (23 nm radius) • Single time correction per satellite • Improves accuracy and provides integrity • Supports Precision Approach

Ground Based Augmentation System (GBAS

Single ground station

Normally airport location

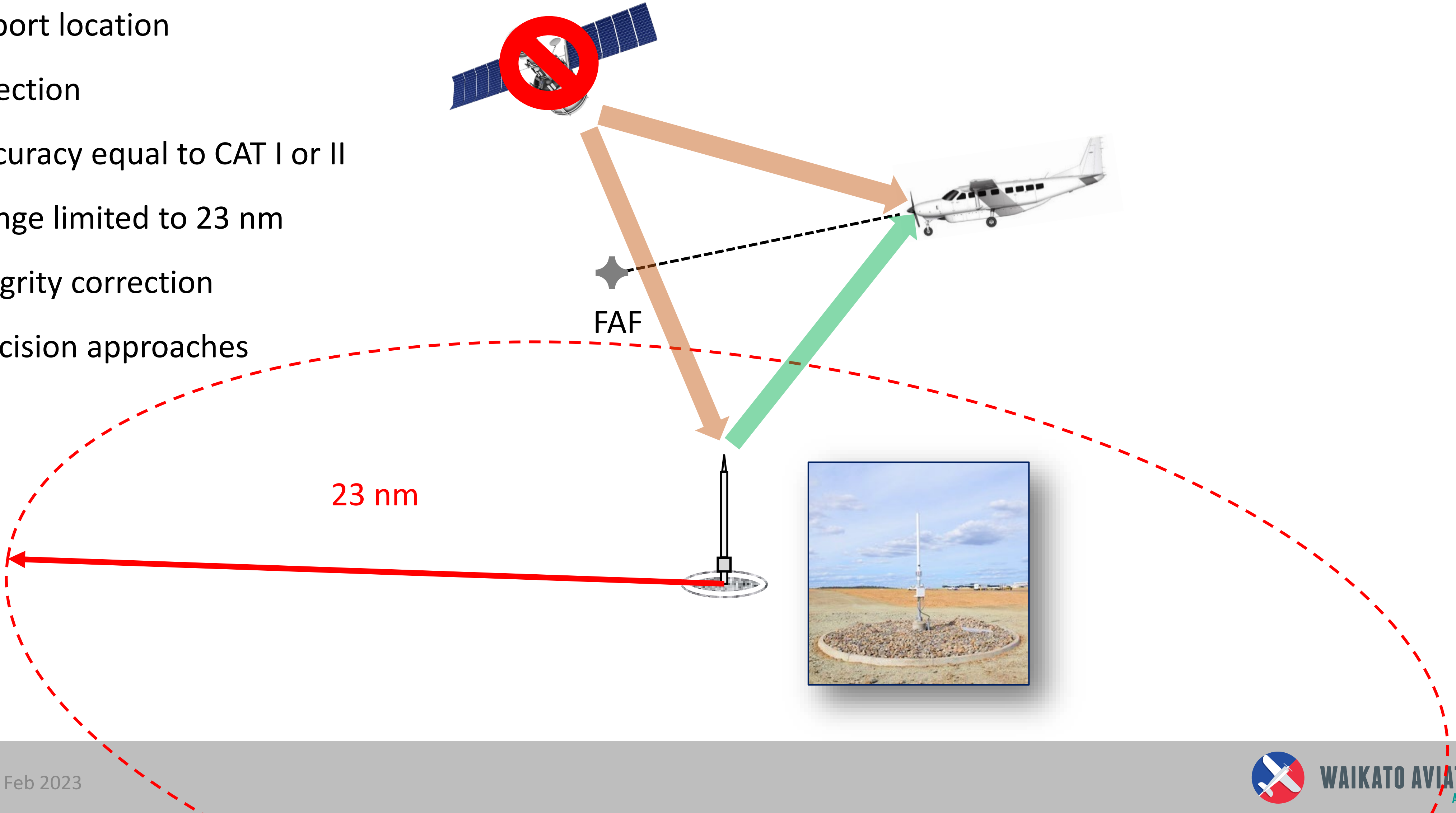
Ranging correction

Approach accuracy equal to CAT I or II

Operating range limited to 23 nm

Provides integrity correction

Supports precision approaches



Aircraft Based Augmentation System (ABAS)

Aircraft Autonomous Integrity Monitoring (AAIM)

Compares GNSS position with other sensors e.g. Inertia Reference System (IRS) and Barometric altimeter to develop integrity control.

AAIM does not correct the accuracy of the position, **it only provides integrity monitoring**

Integrity monitors GNSS during short periods of time during

- manoeuvres that might block satellites
- masking by antennas
- masking in terrain

ABAS

Receiver Autonomous Integrity Monitoring (RAIM)

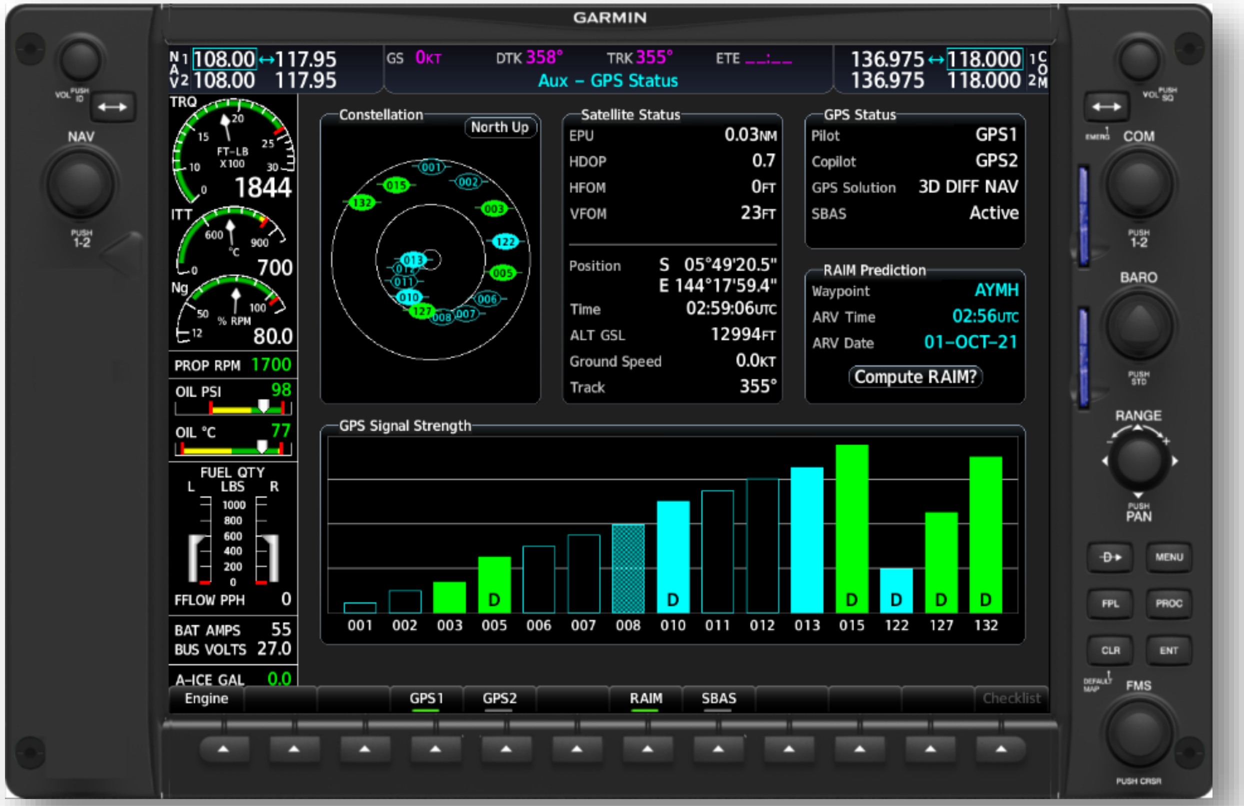
Uses additional satellites to check the validity of the aircrafts position.

Two algorithms

- Satellite geometry
- Satellite health

GNSS sensor prediction relies on **Almanac** broadcast by satellites

RAIM prediction is based on a specific phase of flight and RNP requirement. RAIM not available for APCH may become available in the missed approach



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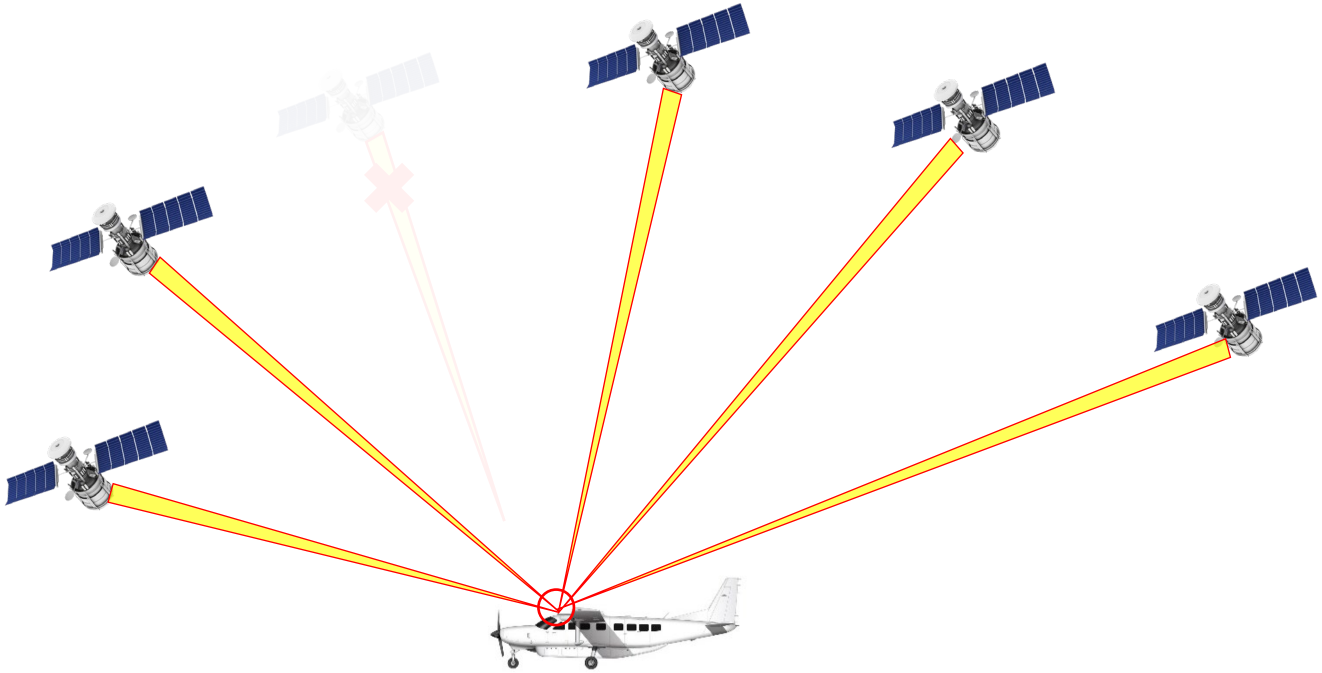
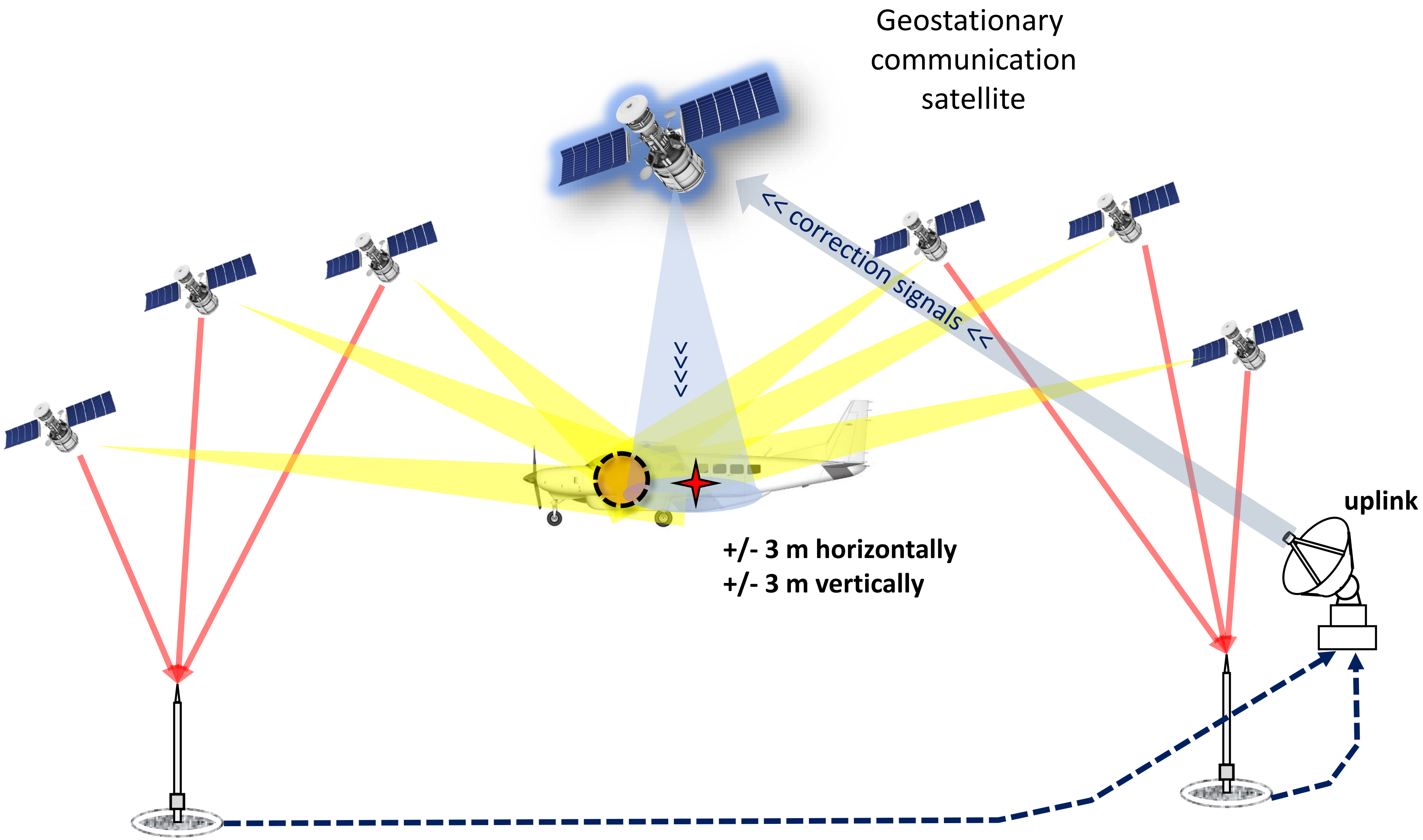
ABAS

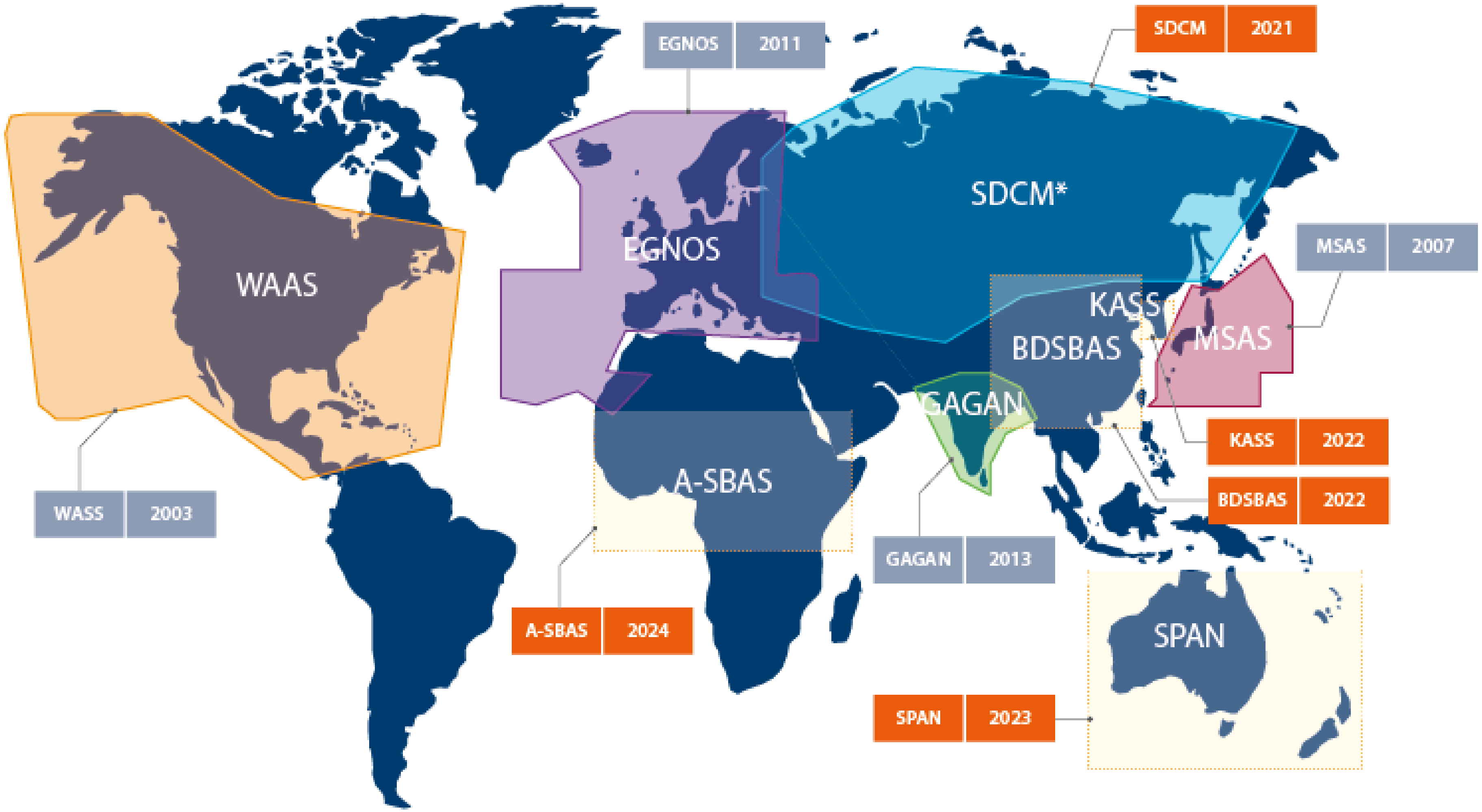
Receiver Autonomous Integrity Monitoring RAIM



Integrity monitoring only

Space Based Augmentation System (SBAS)





Operational/certified for civil aviation

Planning

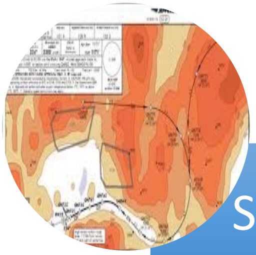
Under development/definition
*System not yet certified for civil aviation

Important

Performance Base Navigation

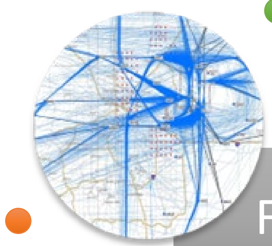
What's driving PBN?

Inter-operability



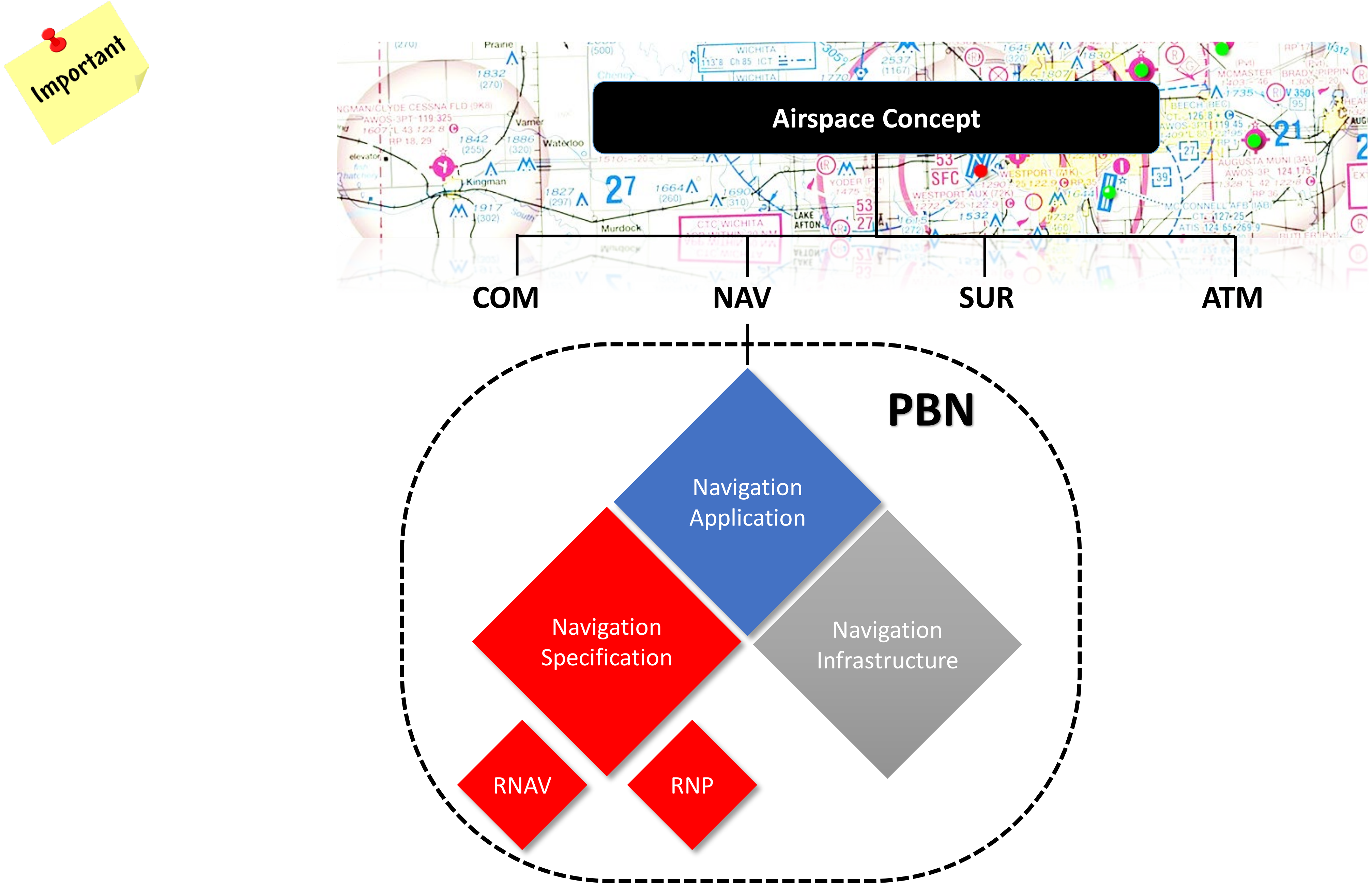
Safety

Environment

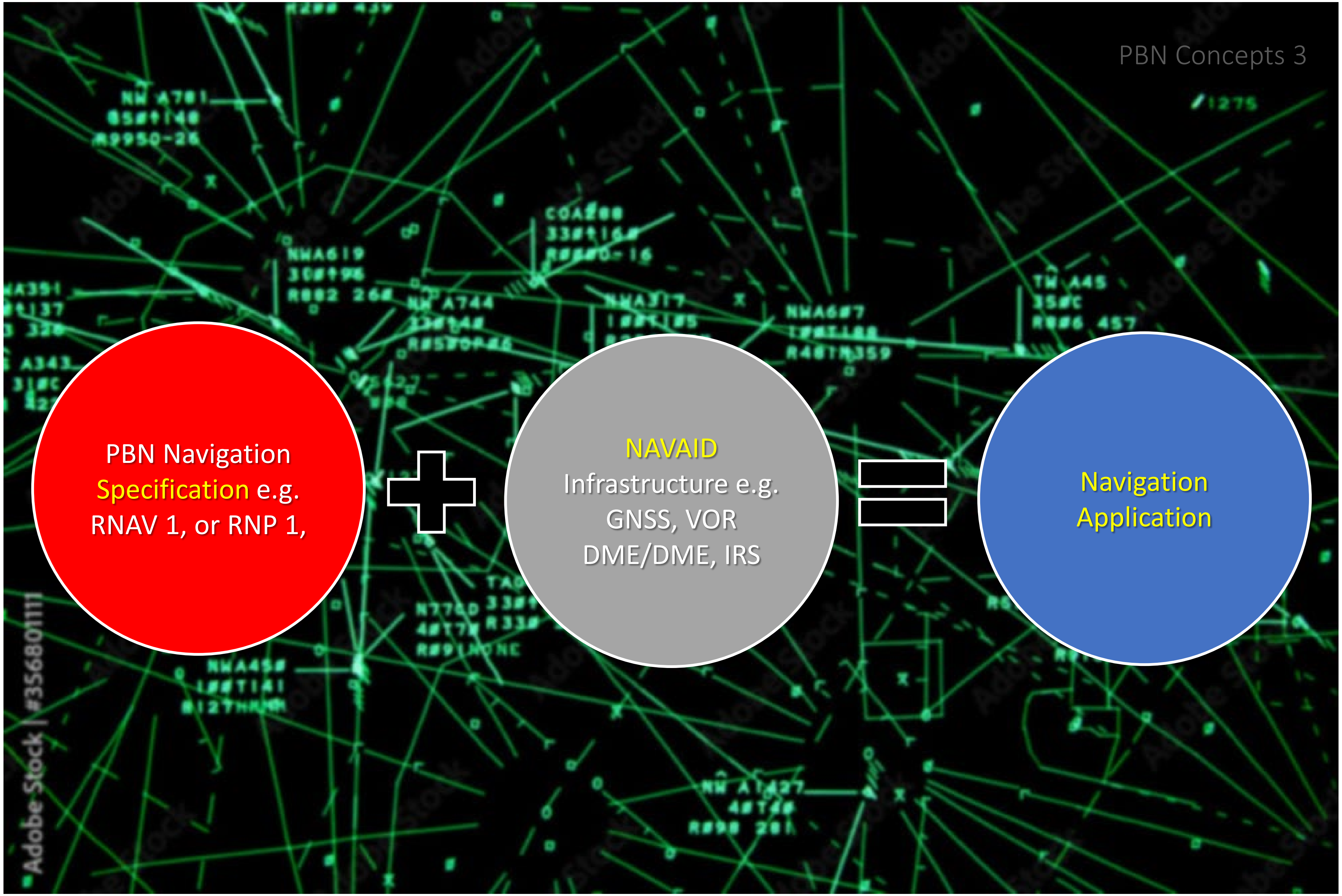


Fuel efficiency

Congestion

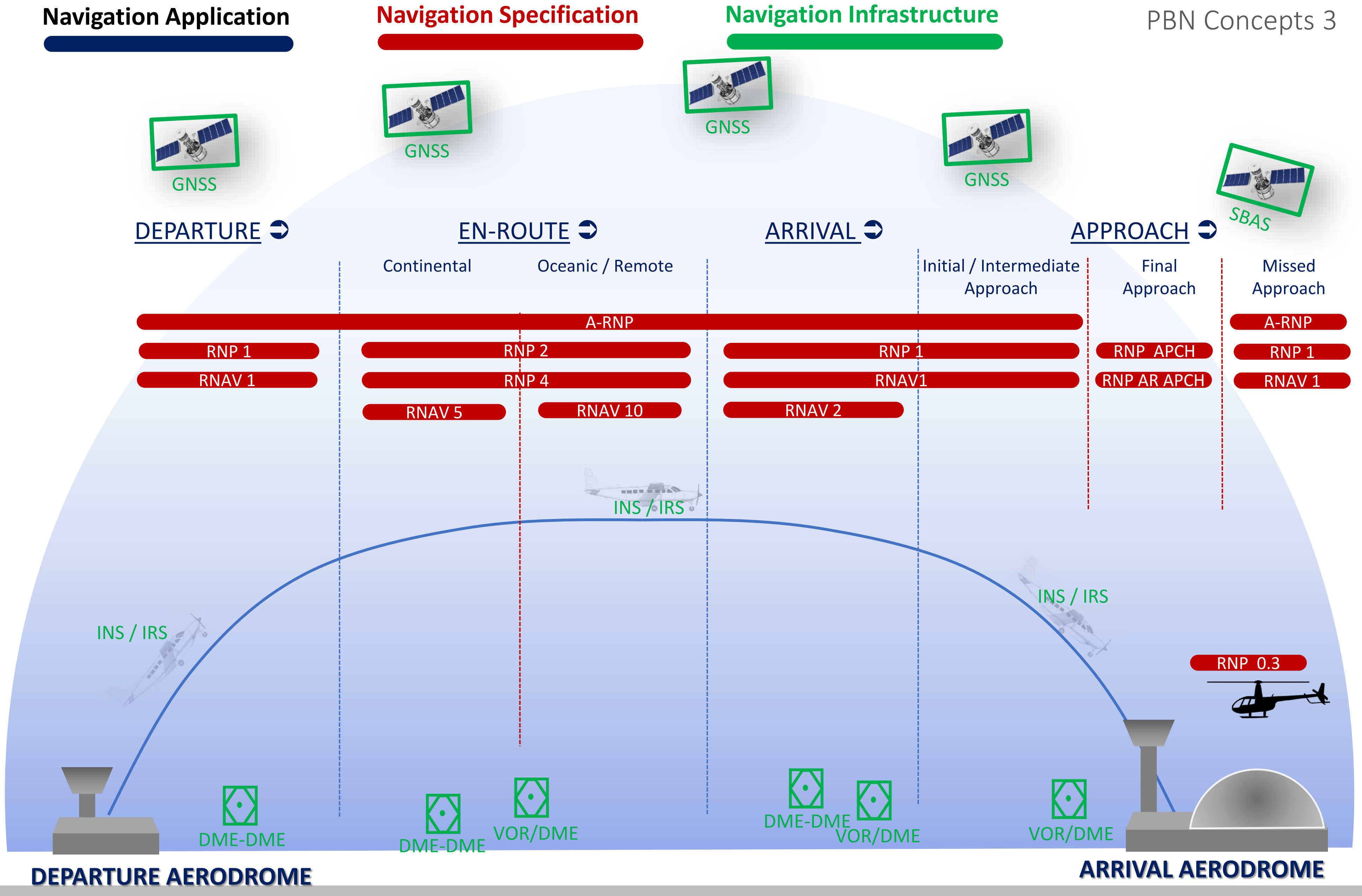

Important
Airspace Concept
COM
NAV
SUR
ATM
PBN
Navigation Application
Navigation Specification
Navigation Infrastructure
RNAV
RNP

PBN Concepts 3



Important

PBN Concepts 3



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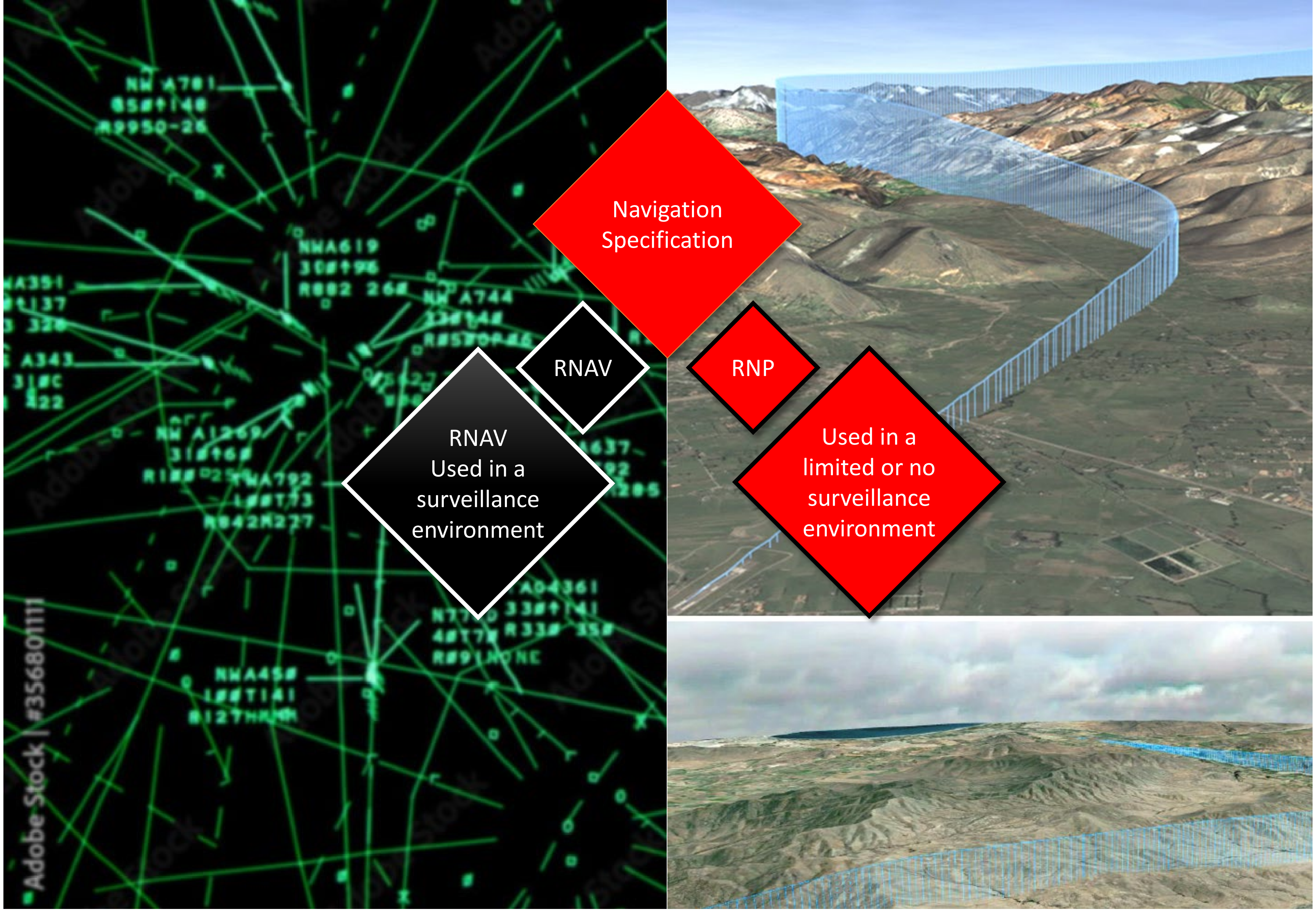

Navigation Specification
RNAV
RNAV Used in a surveillance environment
RNP
Used in a limited or no surveillance environment

Performance Specifications

Start by defining what the requirements

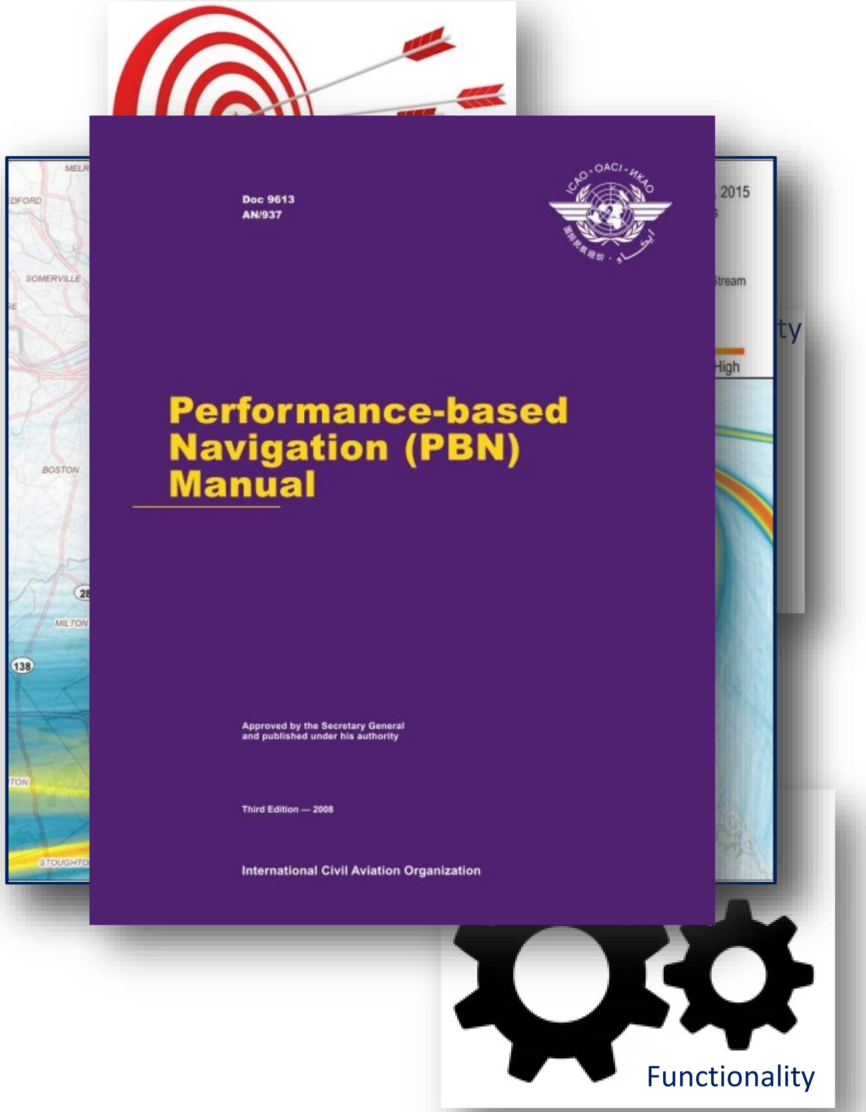
are in terms of

- **Accuracy**
- **Integrity**
- **Continuity**
- **Functionality**

and determines how these can be met

This is the opposite of RNAV which looked at what was possible with the technology

PBN offers improved efficiency, reduced costs and better standardisation



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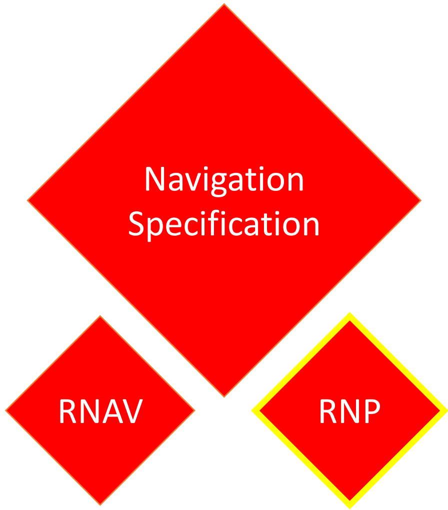
RNAV and RNP Definitions

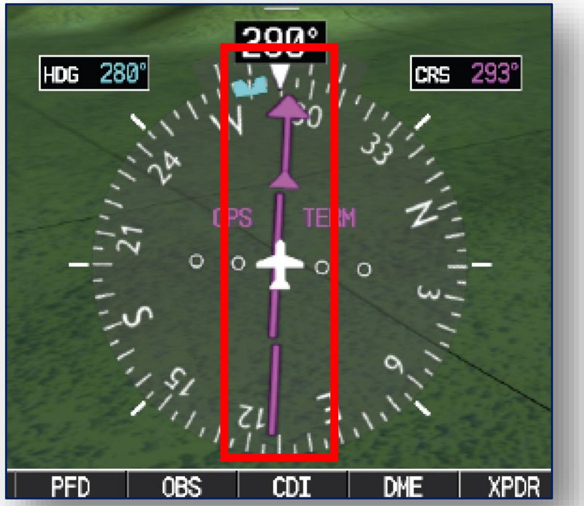
RNAV and RNP are types of PBN navigation specifications

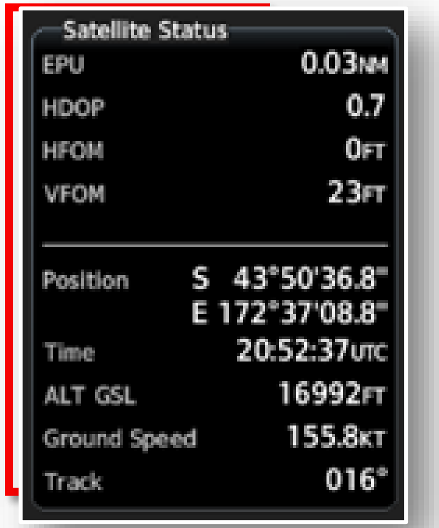


RNP requires on board **performance monitoring** and **alerting (OBPMA),** whereas RNAV does not.

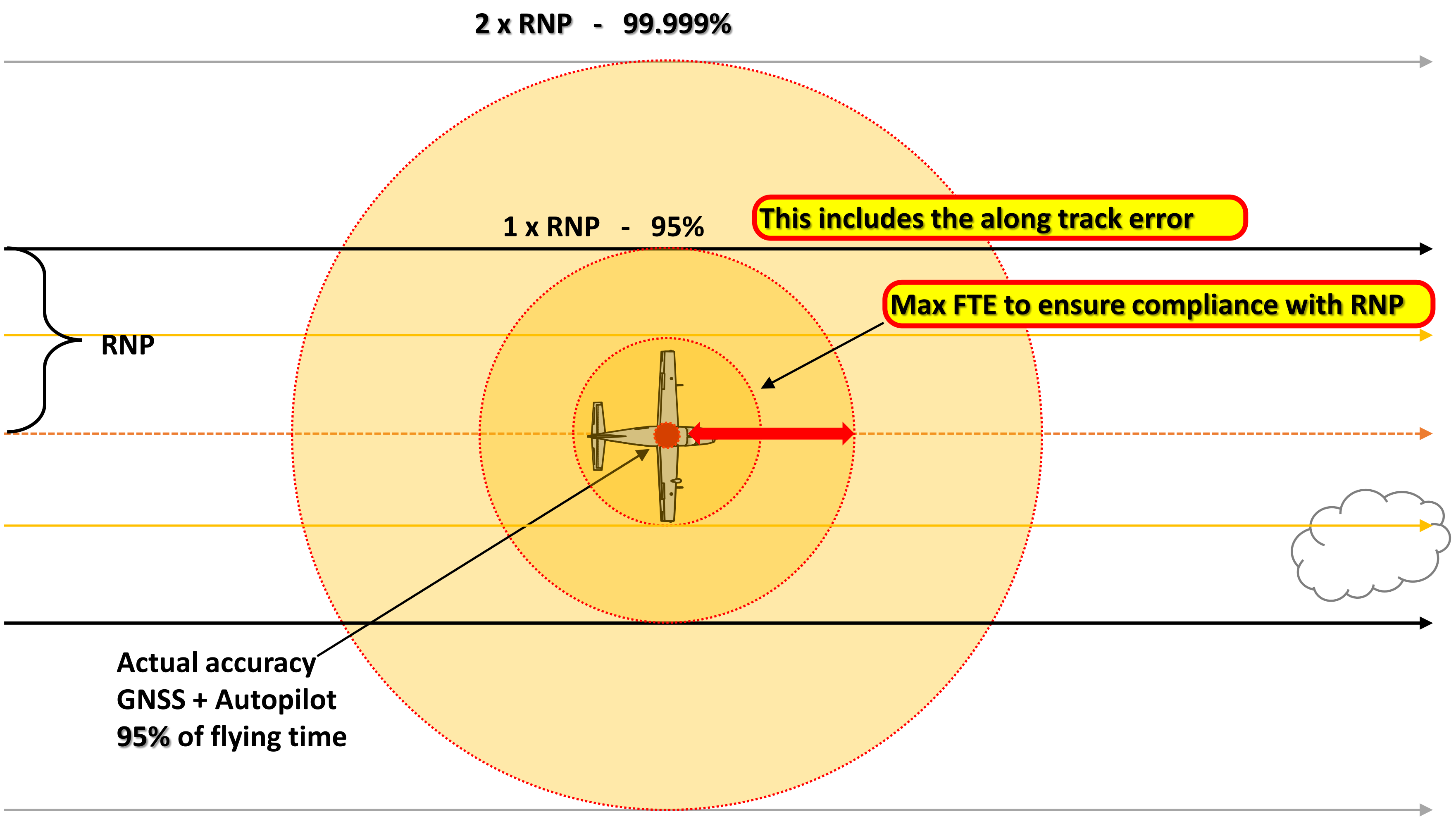
Monitoring

1. Flight Path accuracy via the CDI
2. Automatic monitoring of the navigation systems integrity through AAIM or RAIM





Flight Navigation Accuracy



Integrity Monitoring

Integrity is defined as the measure of **trust** that can be placed in the correctness of the information supplied by the total system. Integrity includes the ability of a system to provide timely and valid warnings to the user (alerts).

Conventional instruments

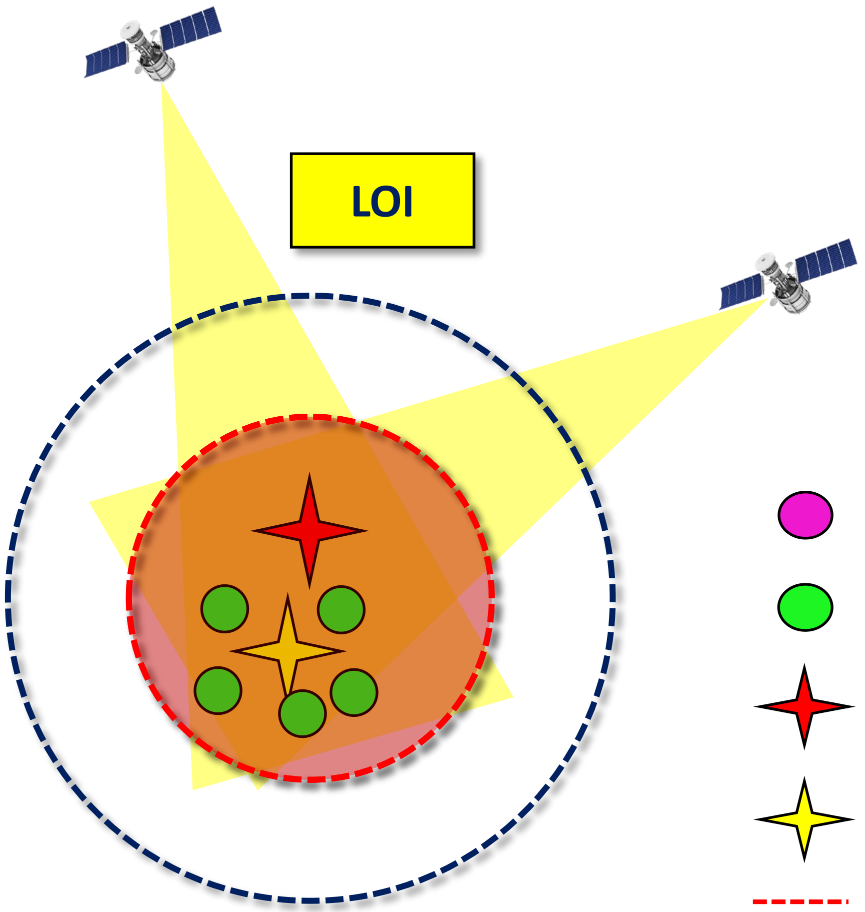
- Cross checks
- Failure flags

GNSS

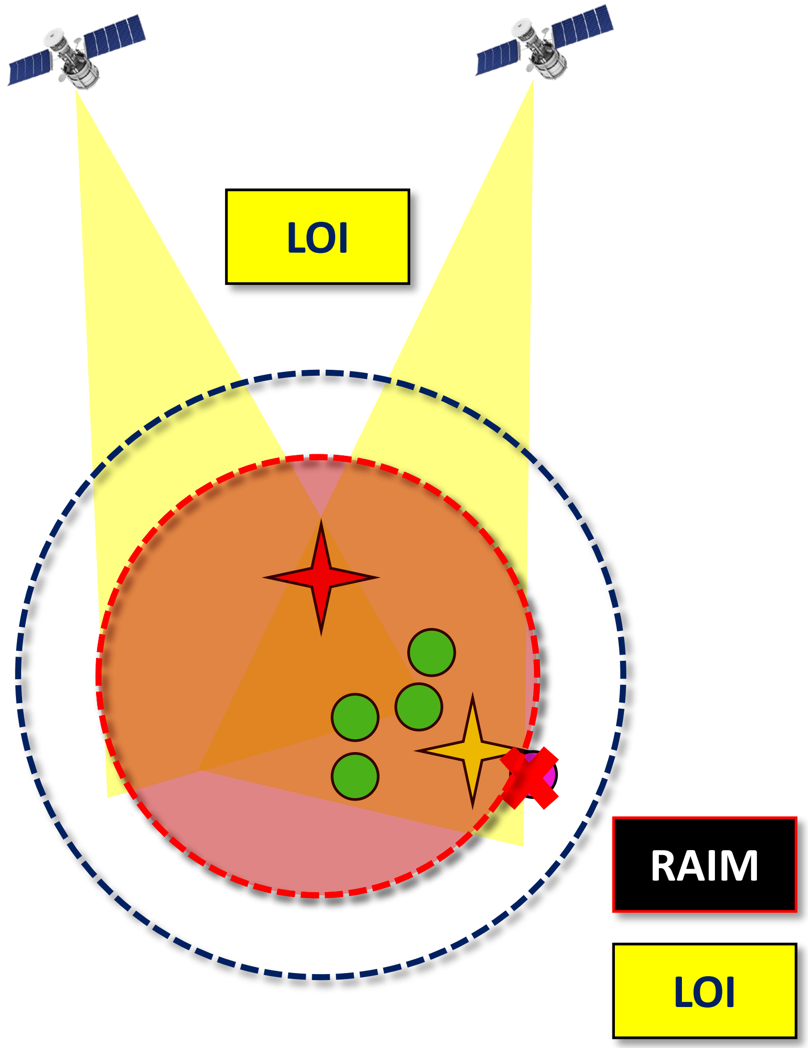
- No built in failure message
- Augmentation provides the required integrity monitoring

Integrity Monitoring

On-Board Performance Monitoring and Alerting (OBPMA)



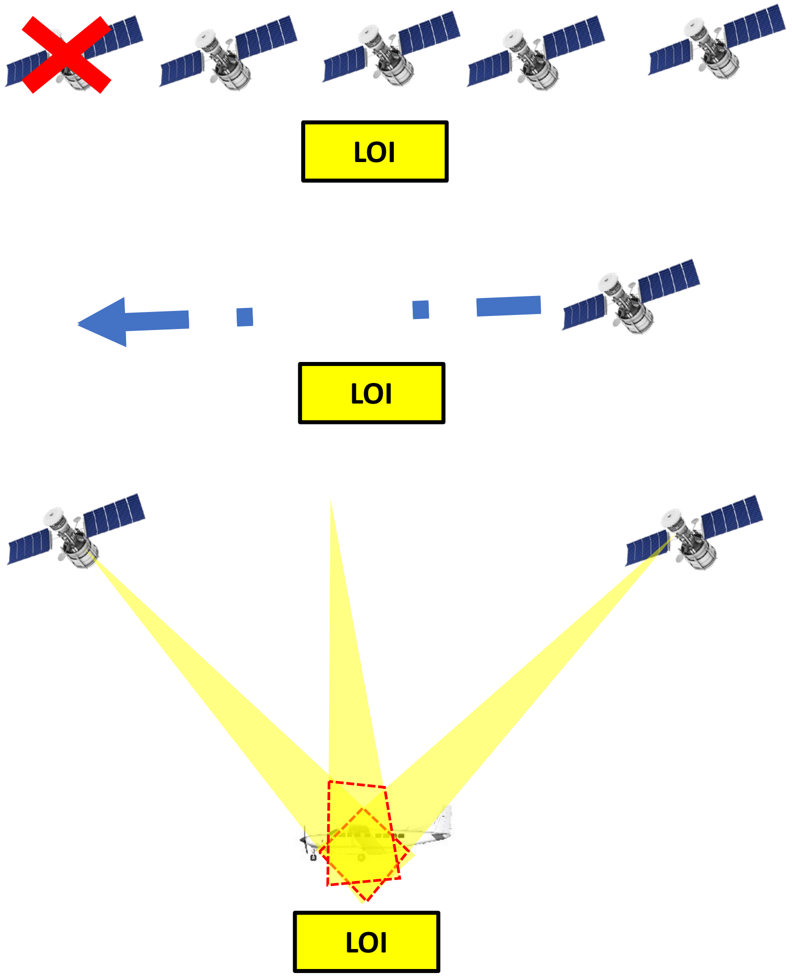
- Faulty SV
- GPS position
- True position
- Calculated position
- Horizontal Protection Limit
- Horizontal Alert Limit = RNP



Loss of Integrity - LOI

LOI triggered by

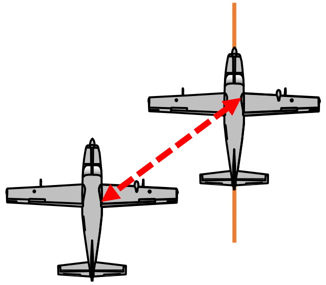
- Loss of RAIM
- The detection of a fault in satellite signals **which** compromises position accuracy
- Unfavourable satellite geometry and dilution of precision



Important

Four Main Performance Criteria

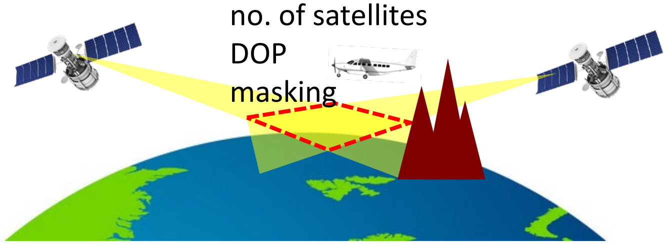
1. **Accuracy** is the conformance of the true position and the required position



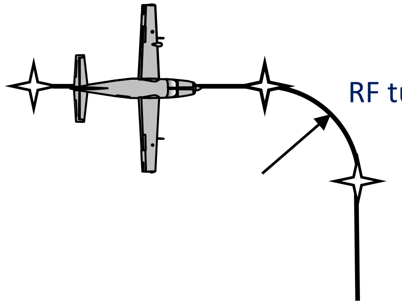
2. **Integrity** is a measure of the trust that can be placed in the correctness of the information supplied by the total system including the ability of the system to provide timely and valid alerts to the user

LOI

3. **Continuity** is the capability of the system to perform its function without unscheduled interruptions during the intended operation.



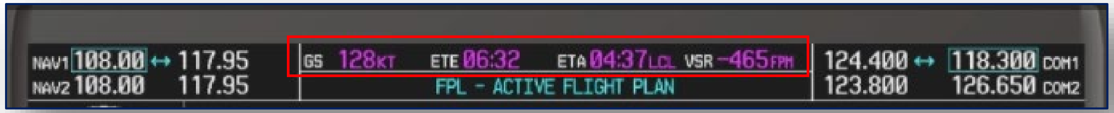
4. **Functionality** is the detailed capability of the navigation system e.g. leg transitions, parallel offset, radius turns required to meet the airspace concept



Basic Functionality

Common to all specifications

1. Display of lateral deviation
2. Distance/Bearing to active waypoint
3. Time or groundspeed to active waypoint
4. Failure indication
5. Navigation data storage function



WAIKATO AVIATION ACADEMY

Nav Spec – Additional Functionalities

Navigation Specification	Additional Functionalities					
	RF	FRT	VNAV	Parallel Offset	Hold	TOAC
RNAV 10						
RNAV 5						
RNAV 2						
RNAV 1						
RNP 4		O		R		
RNP 2		O				
RNP 1	O	O		O		
AR – RNP	R	O		R	R	O
RNP APCH	O		O			
RNP AR APCH	R		R			
RNP 0.3	O					

RF Radius to Fix – constant radius Arc leg defining a constant radius turn between two data base fixes

FRT Fixed radius transition. Higher altitude fixed radius turns only on RNP ATS routes

TOAC – time of arrival control enables aircraft to reach a waypoint within X number of seconds

VNAV computes vertical navigation based on either barometric pressure or SBAS (final segment only)

Parallel Offset – no functional requirements except for RNP 2 and A - RNP

R = Required **O = Optional**

GNSS Sensor Specification

Sensors can be divided into non-SBAS and SBAS capable

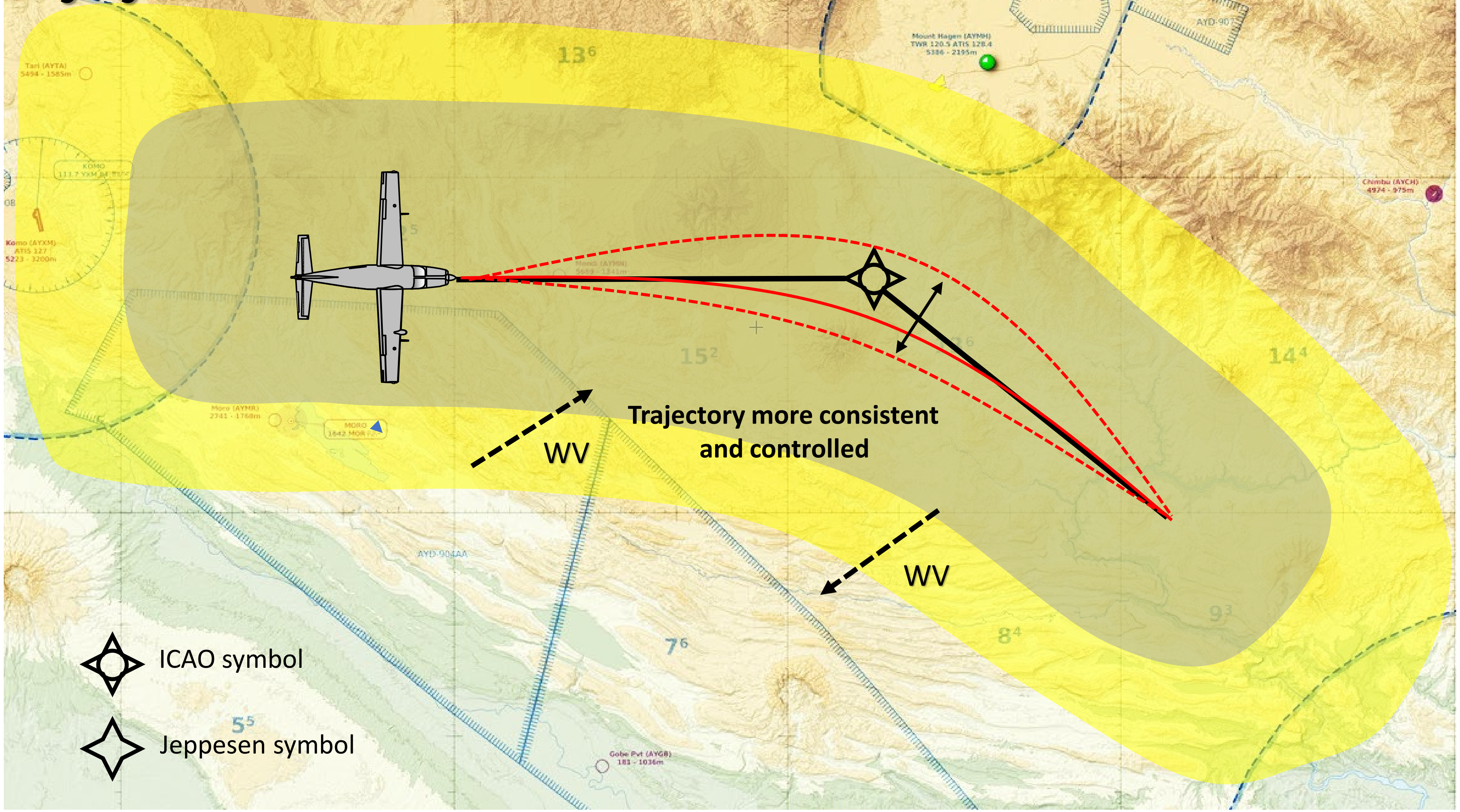
TSO-C129() **(non SBAS)**	TSO-C145/146() (SBAS)
Certification standard for first generation panel mounted IFR GNSS units dates back to 1996	Certification standard for SBAS capable panel mounted units published in 2002
Examples: GNS430, GNS530 early G1000	**Examples**: GNS430W, GNS530W early G1000W, GTN650/750
Features: Most units support database overlay and non precision RNAV Instrument Approaches Typically slow moving map refresh rate (1 per sec) Require RAIM prediction Do not provide guidance or roll-steer commands for holds, procedure turns etc Only LNAV approaches annunciate APR	**Features:** Support database overlay of LNAV and APV approaches Fast moving map refresh rate of (5 per sec) RAIM not required for SBAS coverage area Provides guidance or roll steer commands for holds, procedure turns etc All approaches, sensitivity increases

The GNNS sensor can only be used for RNP (RNAV) approaches (and other PBN operations) in accordance with the approvals in the AFM

Important

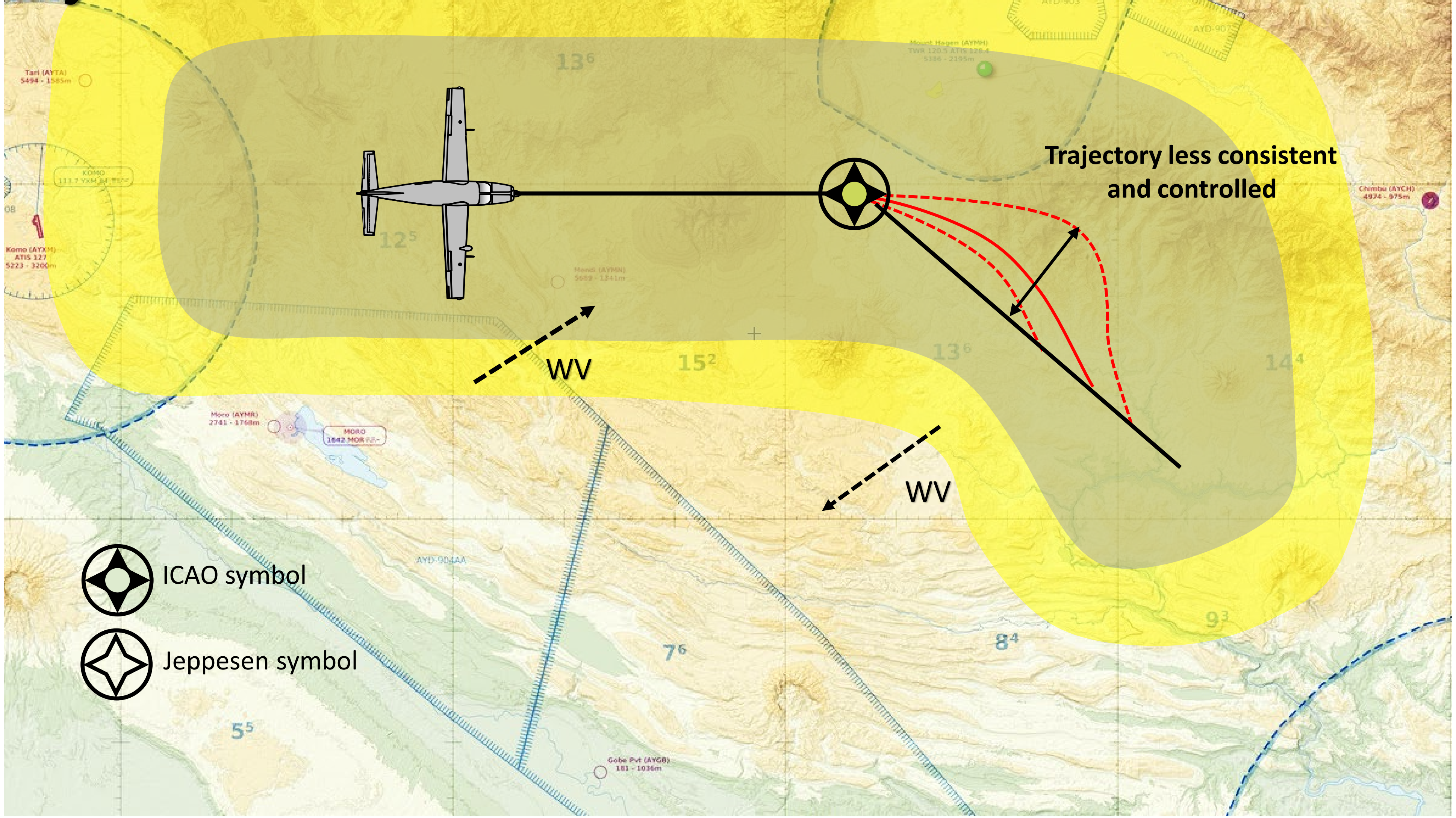
Two types of Waypoint

Flyby

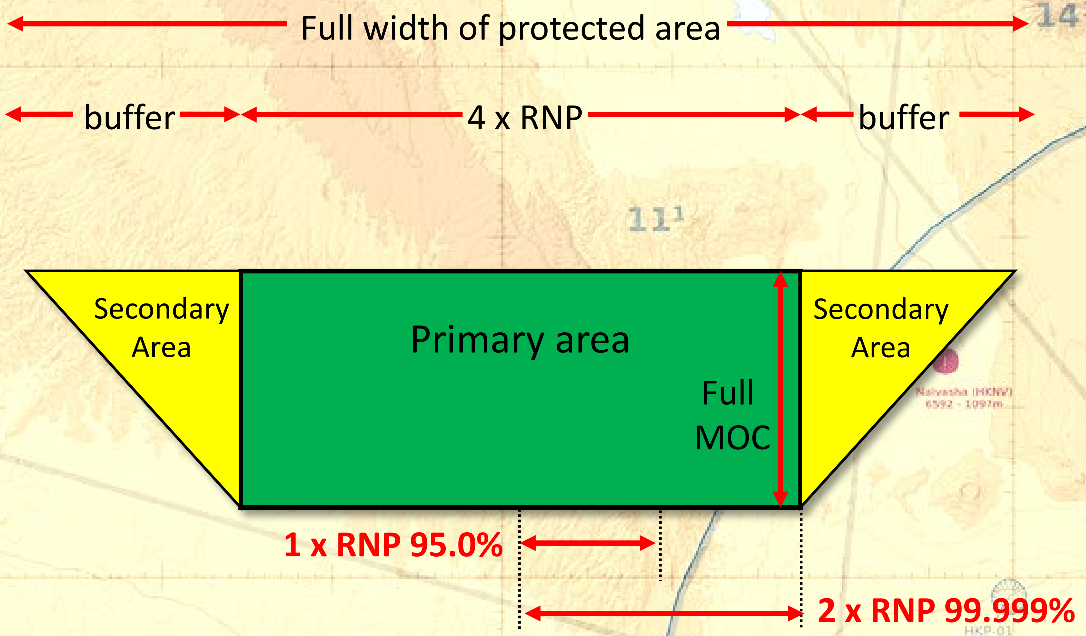


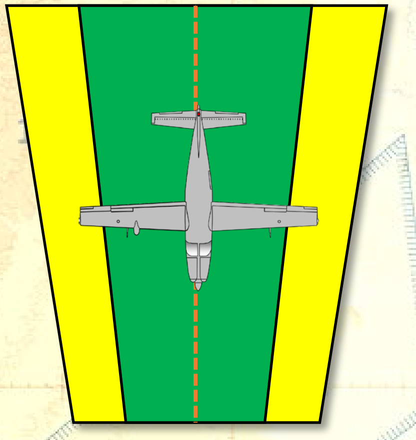
Two types of Waypoint

Flyover



Protected Areas - RNP APCH





Width of Buffer depends on

1. The leg type
2. On final approach, type of approach

RNP AR APCH

1. There is no buffer (secondary) area required on an RNP AR Approach

Protected Area for RNP APCH

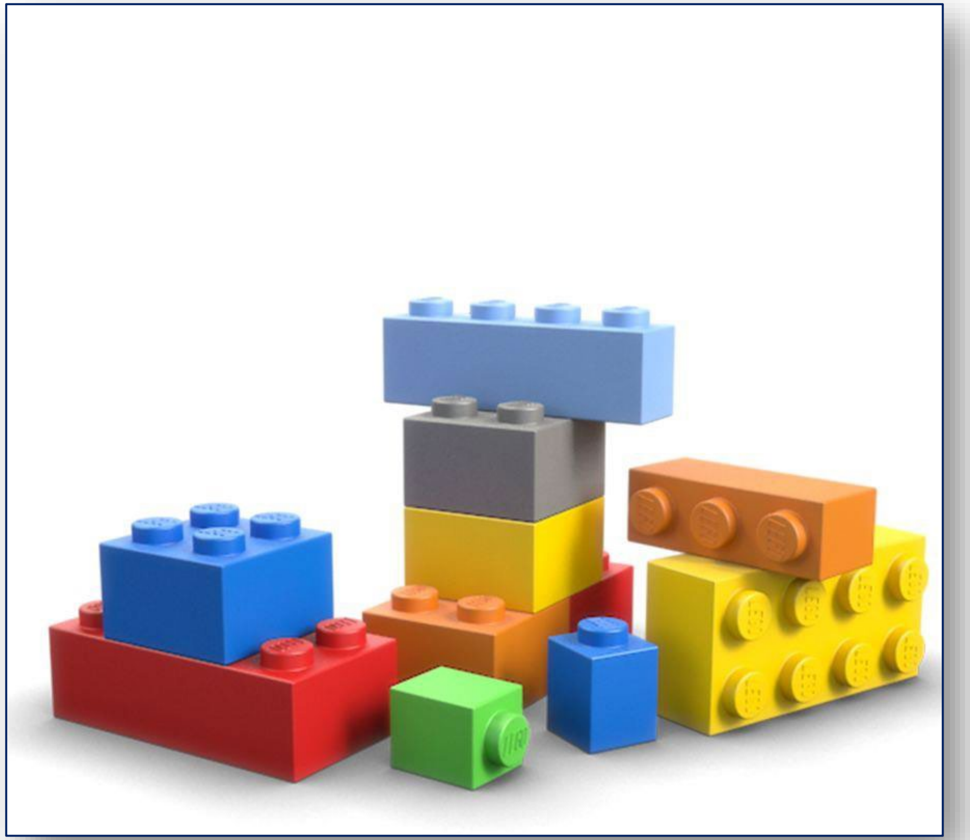
Segment	Navigation Tolerance	Buffer Value	Lateral Protection (either side of track)
Initial/Intermediate	1.0	1.0	2.5
FAF	0.3	1.0	1.45
Final to (Mapt)	0.3	0.5	0.95
Missed Approach	1.0	0.5	2.0

Protected Area for En-route and Terminal

Specification	Navigation Tolerance	Buffer Value	Lateral Protection (either side of track)
RNAV 5 > 30nm ARP	2.51	2.0	5.77
En-route	4.0 (RNP 4)	2.0	8.0
En-route	2.0 (RNP 2)	2.0	5.0
RNP 1 30nm > 15nm ARP	1.0	1.0	2.5
RNP 1 15nm to ARP	1.0	0.5	2.0

½ AW (area width) = 1.5 x NT (RNP) + BV

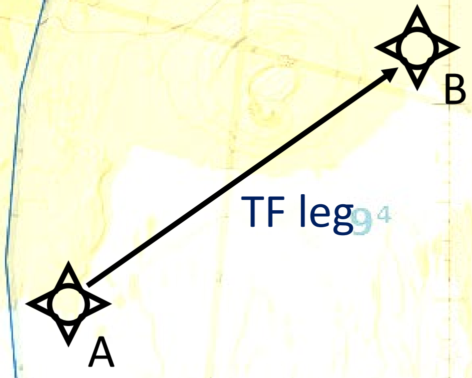
Path Terminators



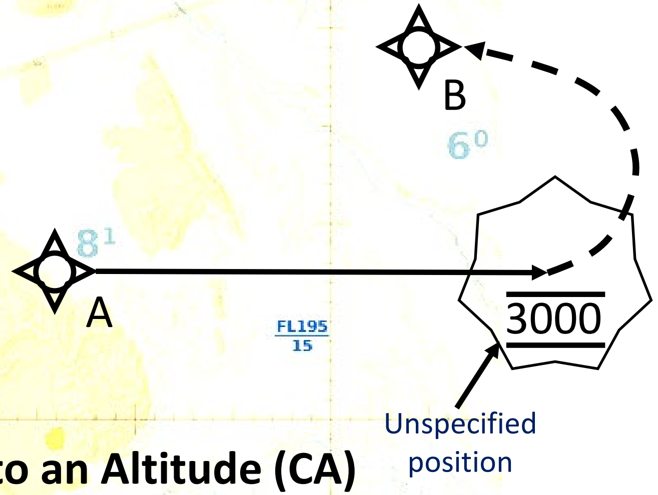
Path Terminators

Track to a Fix (TF)

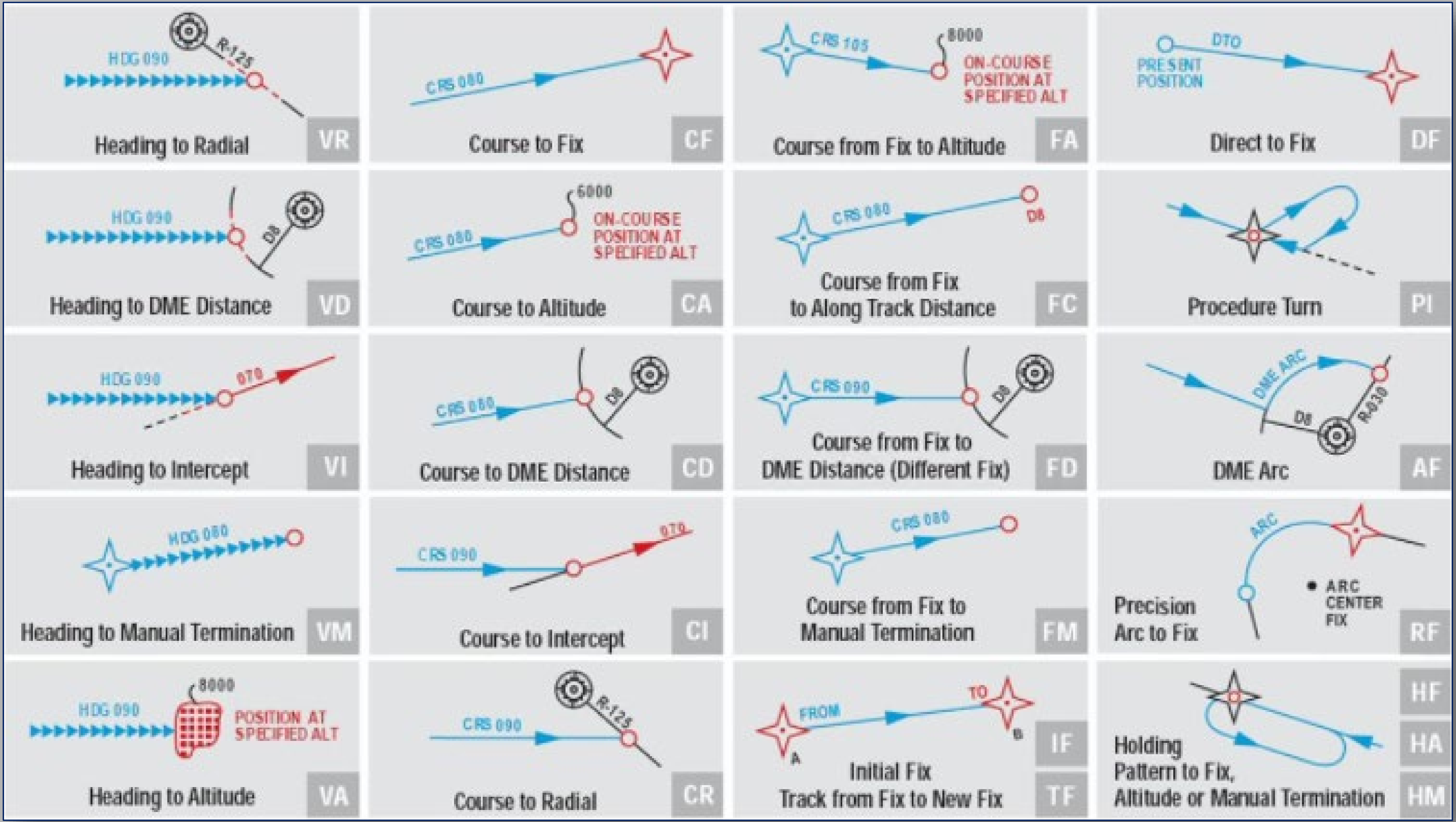
Main straight leg in PBN procedures.
Path between two way points



Course to an Altitude (CA)



A leg which defines a straight section that ends when the aircraft reaches a specified altitude e.g. Missed Approach turn



WAIKATO AVIATION ACADEMY

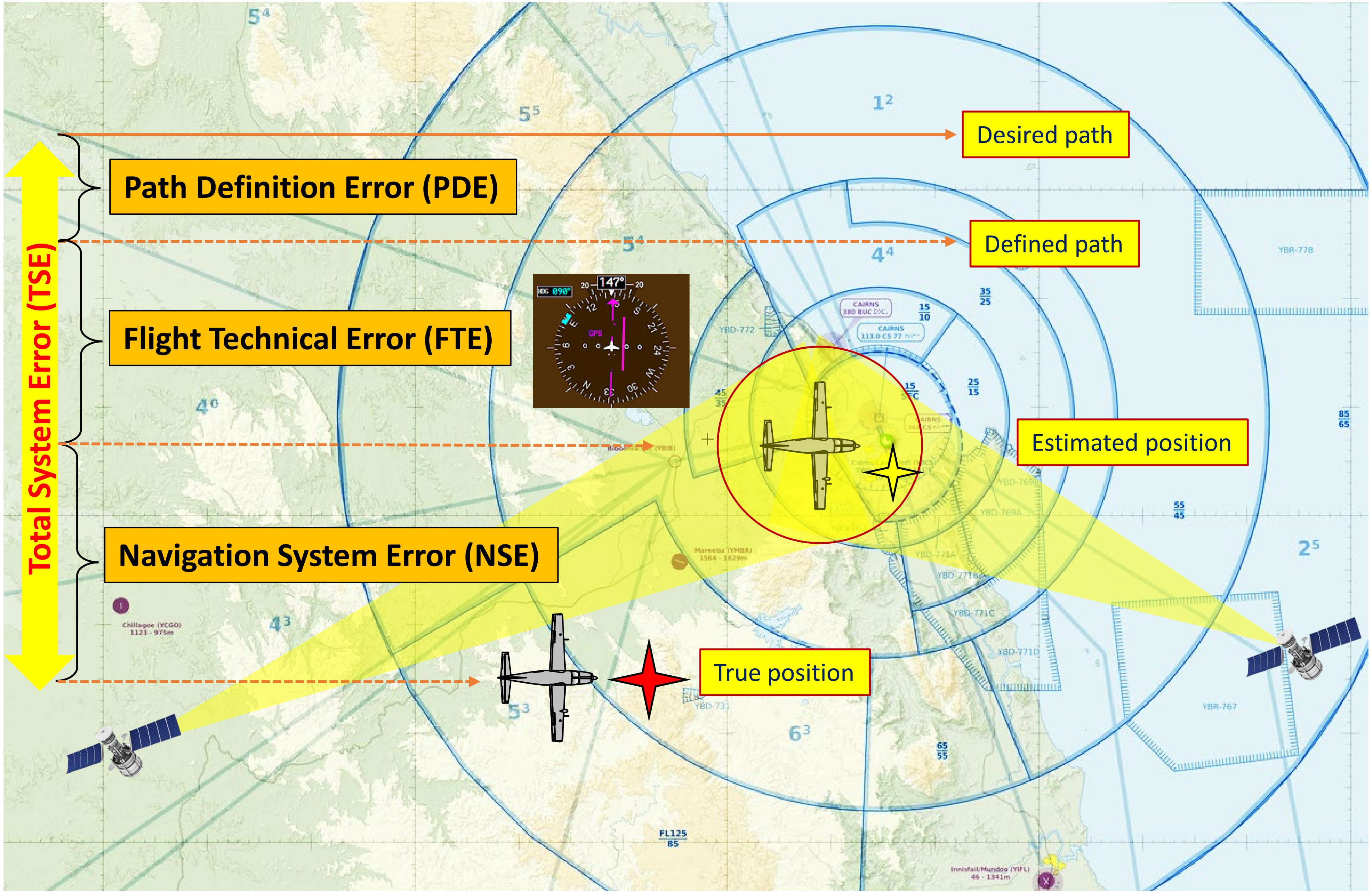
Important

The PBN Error model

We think that the position of the aircraft is in accordance with the displayed navigation system but the actual position is to within a certain degree of accuracy

True position

Calculated position



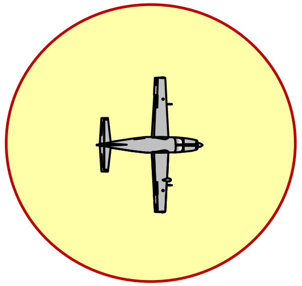
Desired path
Path Definition Error (PDE)
Defined path
Flight Technical Error (FTE)
Total System Error (TSE)
Estimated position
Navigation System Error (NSE)
True position

PBN Fundamental Requirement

Total System Error < RNP at least 95% of the time

Flight Technical Error (FTE)

(FTE) easier to monitor and SHOULD be kept to a minimum. Pilots SHOULD maintain defined centreline



Navigation System Error (NSE)

(NSE) typically small but difficult to determine

Normally, TSE is significantly smaller than the required specified accuracy BUT potentially more difficult to maintain for higher accuracy applications e.g. RNP 0.3 or 0.1 under certain conditions.

ICAO

During operations in airspace or on routes designated as RNP 1, the lateral TSE must be within +/- 1 NM for at least 95% of the total time. The along track error must also be within +/- 1 NM for at least 95 % of the total flight time. To satisfy the accuracy requirement, the 95% FTE should not exceed 0.5 NM.

Methods to minimise FTE (or cross track error)

1. Ensure that you are using approved database information and that your FPL or procedure is cross checked and accurately mirrors desired routing.

2. Ensure that your PFD and MFD screens are set up to display the required information as per standard and the CDI indication is easily observed and clear.

3. Ensure that the CDI scaling is correct under AUX page, and that for each phase of flight you are aware of the flight phase annunciation on the PFD e.g. TERM, ENR, LNAV

4. Utilise the autopilot during high and low workload phases. Ensure that the proper modes are engaged and the system is neutrally stable, i.e. aircraft is trimmed. Most reliable mode to minimise FTE is to use the APR TRK function as compared to HDG function.

5. Remain vigilant when navigation accuracy is important by maintaining a proper and regular instrument scan of the PFD and cross check navigation information so as not to solely trust one display

Part 2 – PBN Operations

Planning and Pre-Flight

Operating in PBN airspace

Procedures

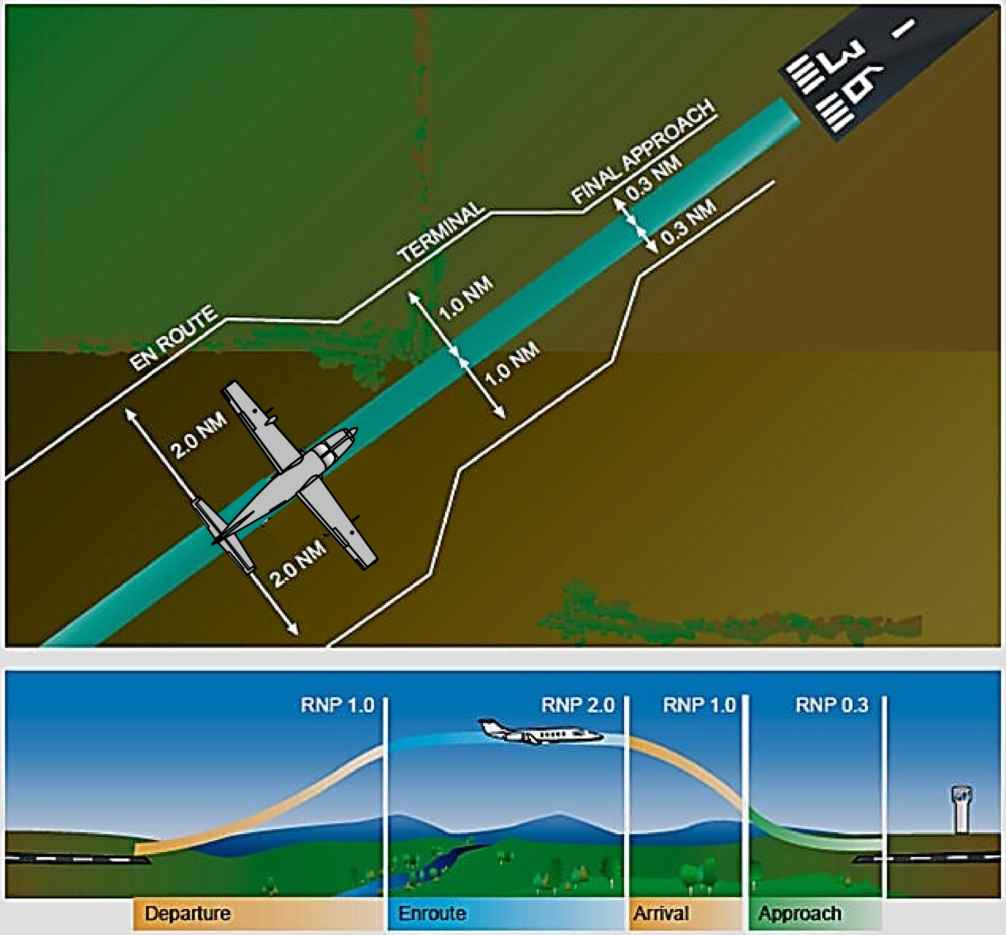
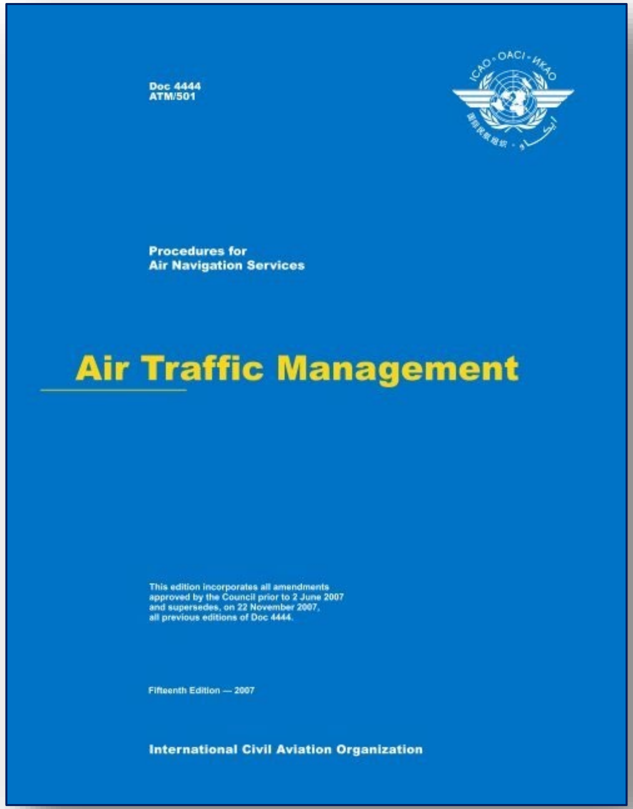


Figure 1-11. Required Navigation Performance.

Planning – Flight Plan


Doc 4444
ATM/501

Procedures for
Air Navigation Services

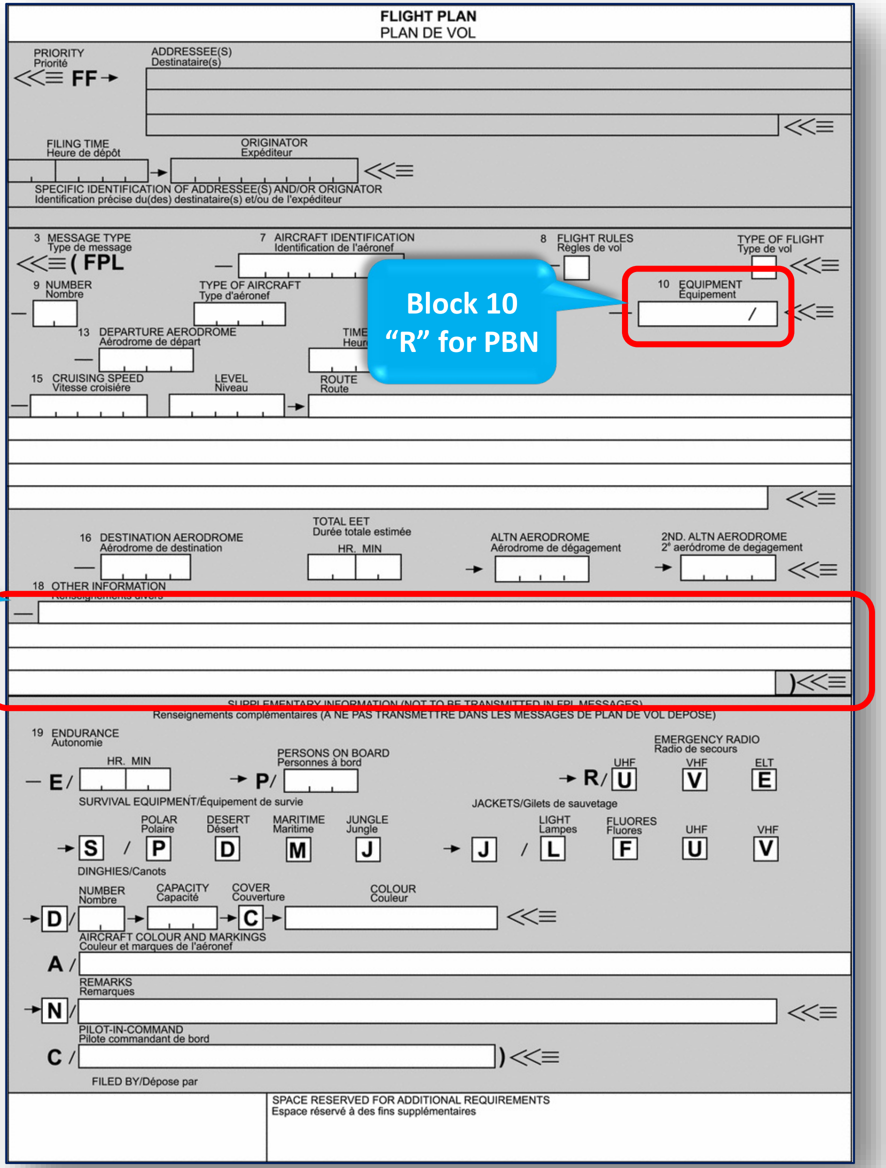
Air Traffic Management

This edition incorporates all amendments approved by the Council prior to 2 June 2007 and supersedes, on 22 November 2007, all previous editions of Doc 4444.

Fifteenth Edition — 2007

International Civil Aviation Organization

Block 18
"PBN / XX"


FLIGHT PLAN
PLAN DE VOL

PRIORITY / Priorité — <<≡ FF →
ADDRESSEE(S) / Destinataire(s) — <<≡

FILING TIME / Heure de dépôt →
ORIGINATOR / Expéditeur <<≡

SPECIFIC IDENTIFICATION OF ADDRESSEE(S) AND/OR ORIGINATOR
Identification précise du(des) destinataire(s) et/ou de l'expéditeur

3 MESSAGE TYPE / Type de message — <<≡ (FPL
7 AIRCRAFT IDENTIFICATION / Identification de l'aéronef
8 FLIGHT RULES / Règles de vol
TYPE OF FLIGHT / Type de vol <<≡

9 NUMBER / Nombre
TYPE OF AIRCRAFT / Type d'aéronef
10 EQUIPMENT / Équipement — / <<≡

13 DEPARTURE AERODROME / Aérodrome de départ
TIME / Heure

15 CRUISING SPEED / Vitesse croisière
LEVEL / Niveau
ROUTE / Route
<<≡

16 DESTINATION AERODROME / Aérodrome de destination
TOTAL EET / Durée totale estimée — HR. MIN
ALTN AERODROME / Aérodrome de dégagement
2ND. ALTN AERODROME / 2ᵉ aérodrome de degagement <<≡

18 OTHER INFORMATION / Renseignements divers
) <<≡

SUPPLEMENTARY INFORMATION (NOT TO BE TRANSMITTED IN FPL MESSAGES)
Renseignements complémentaires (À NE PAS TRANSMETTRE DANS LES MESSAGES DE PLAN DE VOL DÉPOSÉ)

19 ENDURANCE / Autonomie — HR. MIN — E /
PERSONS ON BOARD / Personnes à bord → P /
EMERGENCY RADIO / Radio de secours — UHF VHF ELT → R / U V E

SURVIVAL EQUIPMENT/Équipement de survie — POLAR / Polaire, DESERT / Désert, MARITIME / Maritime, JUNGLE / Jungle → S / P D M J
JACKETS/Gilets de sauvetage — LIGHT / Lampes, FLUORES / Fluores, UHF, VHF → J / L F U V

DINGHIES/Canots — NUMBER / Nombre, CAPACITY / Capacité, COVER / Couverture, COLOUR / Couleur → D / → → C → <<≡

AIRCRAFT COLOUR AND MARKINGS / Couleur et marques de l'aéronef — A /

REMARKS / Remarques → N / <<≡

PILOT-IN-COMMAND / Pilote commandant de bord — C /) <<≡

FILED BY/Dépose par

SPACE RESERVED FOR ADDITIONAL REQUIREMENTS
Espace réservé à des fins supplémentaires

Block 10
"R" for PBN

Important

Planning - Flight Plan

G1000 capability

	RNAV SPECIFICATIONS
A1	RNAV 10 (RNP 10)
B1	R
B2	
B3	
B4	
B5	
B6	
C1	
C2	
C3	
C4	
D1	RNAV 1 all permitted s
D2	RNAV 1 GNSS
D3	RNAV 1 DME-DME
D4	RNAV 1 DME-DME/IRU

	RNP SPECIFICATIONS
L1	RNP4
O1	Basic RNP 1 all permitted sensors
O2	Basic GNSS
O3	Basic ME-DME
O4	Basic R ME-DME/IRU
S1	RNP
S2	RNP RO-NAV
T1	RNP AR APCH with RF
T2	RNP AR APCH without RF

Question?

What coding should I fill out for the DA42 with G1000.

Complete coding for your most accurate specification for each phase of flight Terminal / En-route / APCH

Terminal RNP 1 RNAV 1
En-route RNP2 RNAV2
Approach RNP APCH

See next slide

1

2

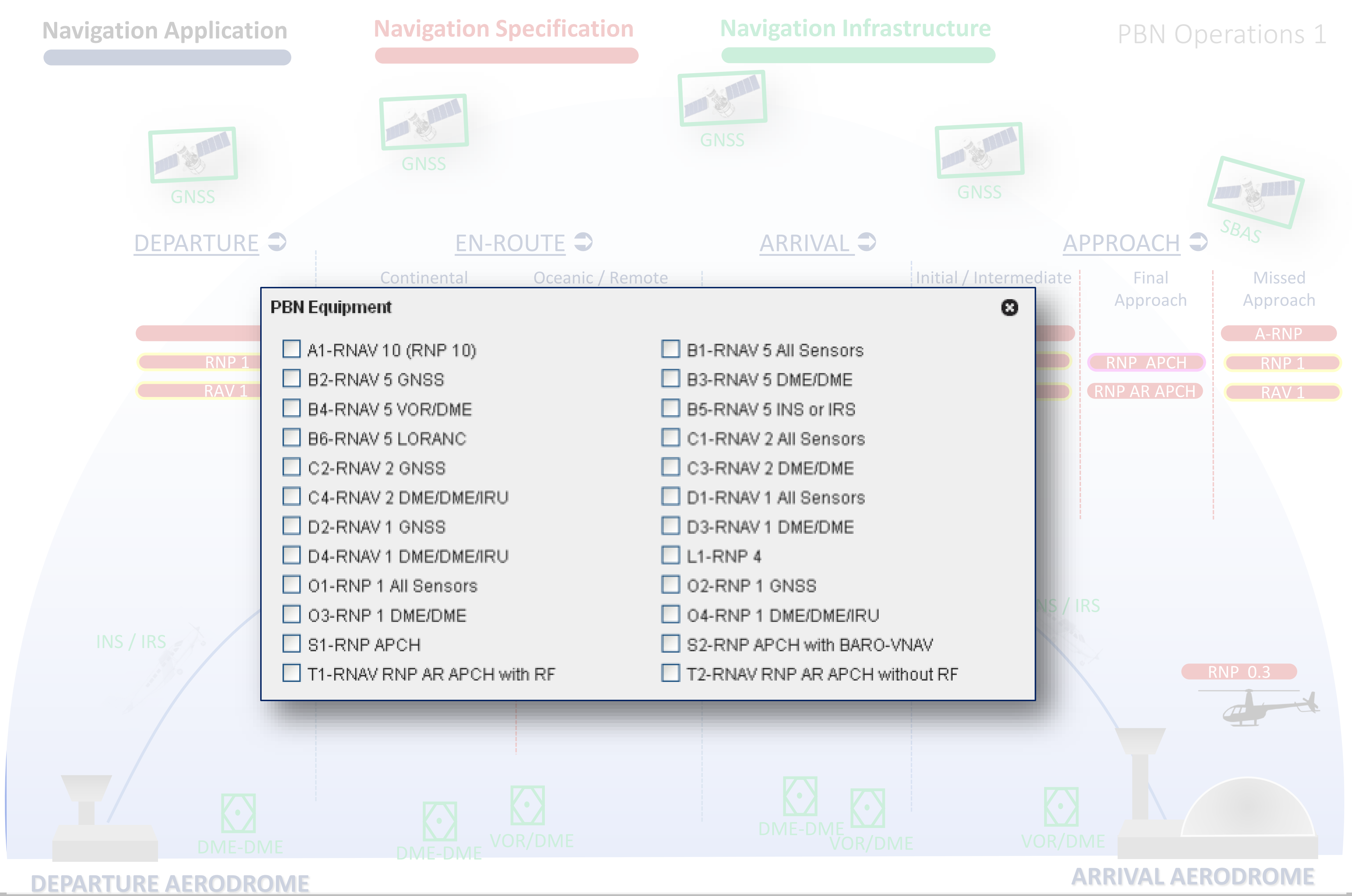
3

4

AERODROME
destination
TOTAL EET
Durée totale estimée
HR. MIN
ALTN AERODROME
Aérodrome de dégagement
2ND. ALTN AERODROME
2ᵉ aérodrome de dégagement
18 OTHER INFORMATION
Renseignements divers

PBN / C2D2O2S1

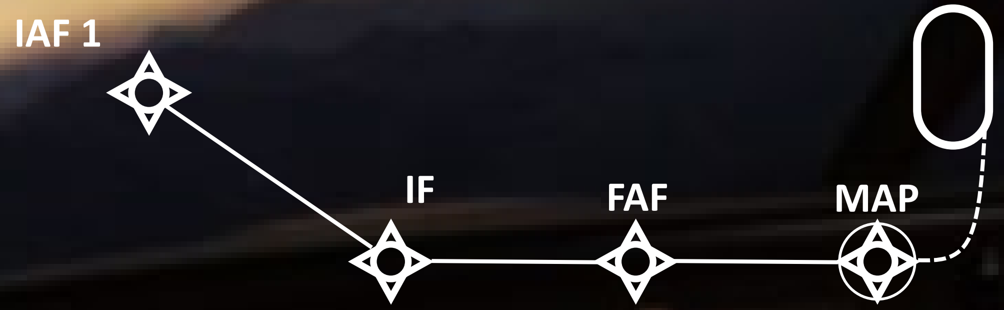
SUPPLEMENTARY INFORMATION (NOT TO BE TRANSMITTED IN FPL MESSAGES)
Renseignements complémentaires (À NE PAS TRANSMETTRE DANS LES MESSAGES DE PLAN DE VOL DÉPOSÉ)



PBN Equipment

- ☐ A1-RNAV 10 (RNP 10)
- ☐ B1-RNAV 5 All Sensors
- ☐ B2-RNAV 5 GNSS
- ☐ B3-RNAV 5 DME/DME
- ☐ B4-RNAV 5 VOR/DME
- ☐ B5-RNAV 5 INS or IRS
- ☐ B6-RNAV 5 LORANC
- ☐ C1-RNAV 2 All Sensors
- ☐ C2-RNAV 2 GNSS
- ☐ C3-RNAV 2 DME/DME
- ☐ C4-RNAV 2 DME/DME/IRU
- ☐ D1-RNAV 1 All Sensors
- ☐ D2-RNAV 1 GNSS
- ☐ D3-RNAV 1 DME/DME
- ☐ D4-RNAV 1 DME/DME/IRU
- ☐ L1-RNP 4
- ☐ O1-RNP 1 All Sensors
- ☐ O2-RNP 1 GNSS
- ☐ O3-RNP 1 DME/DME
- ☐ O4-RNP 1 DME/DME/IRU
- ☐ S1-RNP APCH
- ☐ S2-RNP APCH with BARO-VNAV
- ☐ T1-RNAV RNP AR APCH with RF
- ☐ T2-RNAV RNP AR APCH without RF

Planning - Alternates



RNP Approach with loss of RNP capability

Inadequate GNSS Integrity and Continuity

- Conventional aid redundancy to be available for approach, missed approach and alternate.

Adequate GNSS Integrity and Continuity

- GNSS ‘sole means’ permits GNSS only redundancy with some NAAs

RNP AR Approach

RNP < 0.3 RNP final segment

RNP <1.0 RNP missed approach

- Dual navigation system
- Ideally different systems GNSS/IRS

Planning RAIM Availability

GPS RAIM PREDICTIONS

NZWR (WHANGAREI)   230208 14:00 UTC
TSO-C129 (AND EQUIVALENT)
FAULT DETECTION
NO GPS RAIM FD OUTAGES FOR NPA

TSO-C146A (AND EQUIVALENT)
FAULT DETECTION
NO GPS RAIM FD OUTAGES FOR NPA

FAULT DETECTION AND EXCLUSION
02090501 TIL 02090509
02090758 TIL 02090814
02090825 TIL 02090833
02090842 TIL 02090847
02100457 TIL 02100505
02100754 TIL 02100810
02100820 TIL 02100829
02100838 TIL 02100843
02110453 TIL 02110501
02110750 TIL 02110806
02110816 TIL 02110825
02110834 TIL 02110839
GPS RAIM FDE UNAVBL FOR NPA

NZHN (HAMILTON)   230208 14:00 UTC
TSO-C129 (AND EQUIVALENT)
FAULT DETECTION
NO GPS RAIM FD OUTAGES FOR NPA

TSO-C146A (AND EQUIVALENT)
FAULT DETECTION
NO GPS RAIM FD OUTAGES FOR NPA

FAULT DETECTION AND EXCLUSION
02090502 TIL 02090507
02090533 TIL 02090540
02090759 TIL 02090814
02100457 TIL 02100503
02100529 TIL 02100536
02100755 TIL 02100810
02110453 TIL 02110459
02110525 TIL 02110532
02110751 TIL 02110806
GPS RAIM FDE UNAVBL FOR NPA

Important

Pre-Flight – Data Base Check

Aviation Data

- Waypoints ☑
- Navaids ☑
- Routes ☑
- Approaches ☑

RNAV 5 and RNAV 10
(exceptions)

AIRAC

Aviation, Information, Regulation and Control

28
day cycle of new amendments
(Thursday)

Update available 7 days before date

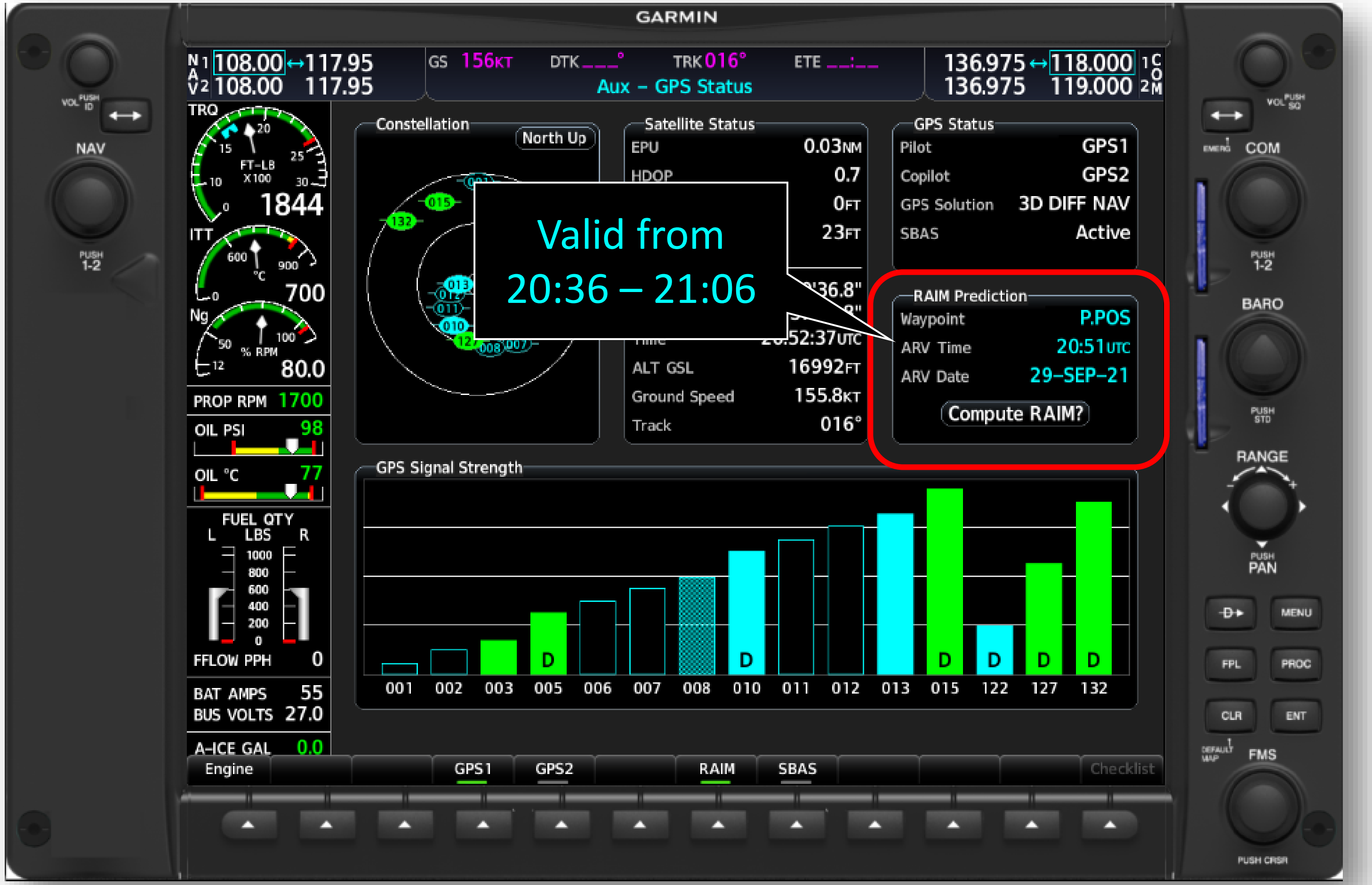
WAIKATO AVIATION ACADEMY

Pre-Flight – RAIM Prediction

RAIM outage > 5 min

re-plan

What If?



Operating in PBN airspace

Approval to operate - Aircraft

Certification of the aircraft equipment for PBN Navigation is in accordance with the following specifications;

- Accuracy
- Integrity and alerting
- Continuity
- Functionality

} Standards and functionality

CESSNA
MODEL 208 675 SHP
GARMIN G1000

SECTION 1
GENERAL

DESCRIPTIVE DATA (Continued)

NAVIGATIONAL CAPABILITIES (Continued)

4. Non-Precision Approaches:
   a. RNAV, GPS and RNP APCH to LPV minimums per AC 20-138D, AC 90-107 and AMC 20-28.
   b. RNAV, GPS and RNP APCH to LNAV or LNAV/VNAV minimums per AC 20-138D, AC 90-105A and AMC 20-27. Vertical guidance is based on GPS/SBAS when within SBAS coverage.

   Airplane Serials 20800651 and On; and 20800601 thru 20800650 incorporating CAB 34-08

   Vertical guidance is based on baro-VNAV when outside SBAS coverage, when SBAS has been disabled by pilot selection, or for approaches with "WAAS VNAV NA".

   The following non-precision approaches are approved for Airplane Serials 20800582 and On; and 20800416 and 20800500 thru 20800581 incorporating CAB-34-03

   c. RNAV, GPS and RNP APCH to LP minimums per AC 20-138D, AC 90-107 and AMC 20-28.
5. Baro-VNAV:
   a. Enroute and Terminal baro-VNAV per AC 20-138D and AMC 20-27.

   Airplane Serials 20800651 and On; and 20800601 thru 20800650 incorporating CAB 34-08

   b. Approach baro-VNAV (APV baro-VNAV) to LNAV, or LNAV/VNAV minimums per AC 20-138D and AMC 20-27. Approach vertical guidance is normally provided by GPS and SBAS, but will switch to baro-VNAV if SBAS is not available. If approach baro-VNAV is in use, the approach glidepath is always temperature compensated.

Airplane Serials 20800582 and On; and 20800416 and 20800500 thru 20800581 incorporating CAB 34-03

6. RF legs are supported for departures, arrivals, and approaches per AC 20-138D.

RNP APCH to LNAV minima (no SBAS)
RNP APCH to LNAV/VNAV minima (SBAS)
RNP APCH to Baro-VNAV minima (no SBAS)
RNP APCH to LPV minima (SBAS)

-15

Operating in PBN airspace

Approval to operate – Aircrew

Knowledge

Application

APPROVED

CERTIFIED

The pilot in command is to be approved to operate under PBN routes and procedures.

SOPs and contingency procedures to be developed and aircrew must be trained on procedures and correct use of the aircraft's systems

Most NAA's are now requiring that pilots are assessed knowledgeable in PBN theory and competent in practically applying the knowledge.

Important

PBN Contingency Procedures

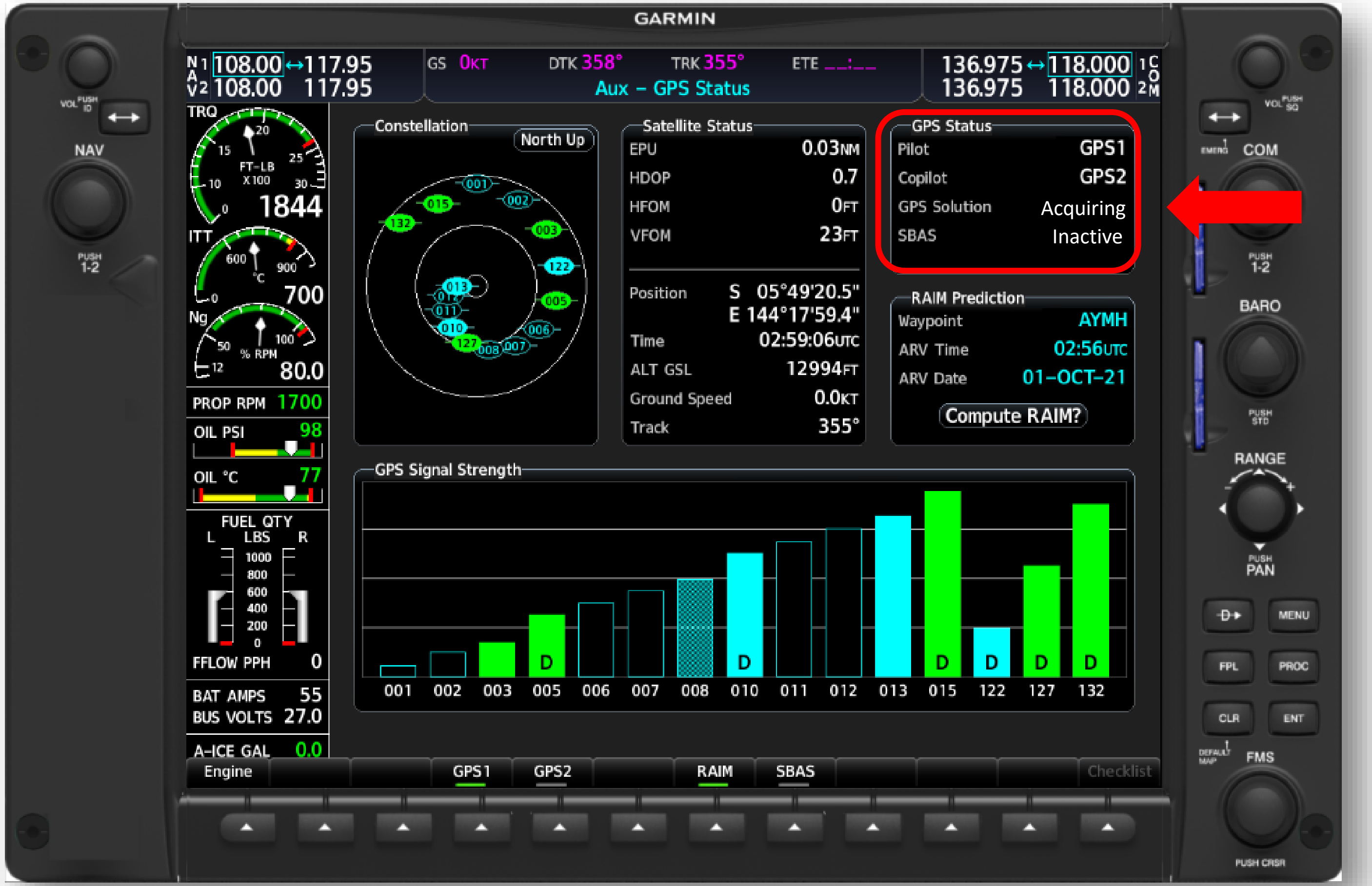
Approach - **Notify ATC** with loss of PBN capability

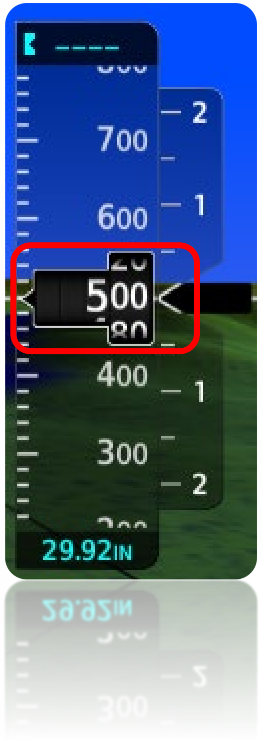
- Co-ordinate with ATC
- Revised clearance, or if no contact, carry out loss of communication protocol
- After FAF, RAIM suppressed for 5 min

En-route – Notify ATS

- RAIM loss > **10 min**
- ATS request data or provide clearance with RAIM loss
- In DR mode > **1 min**

Flight and SID Specific Requirements



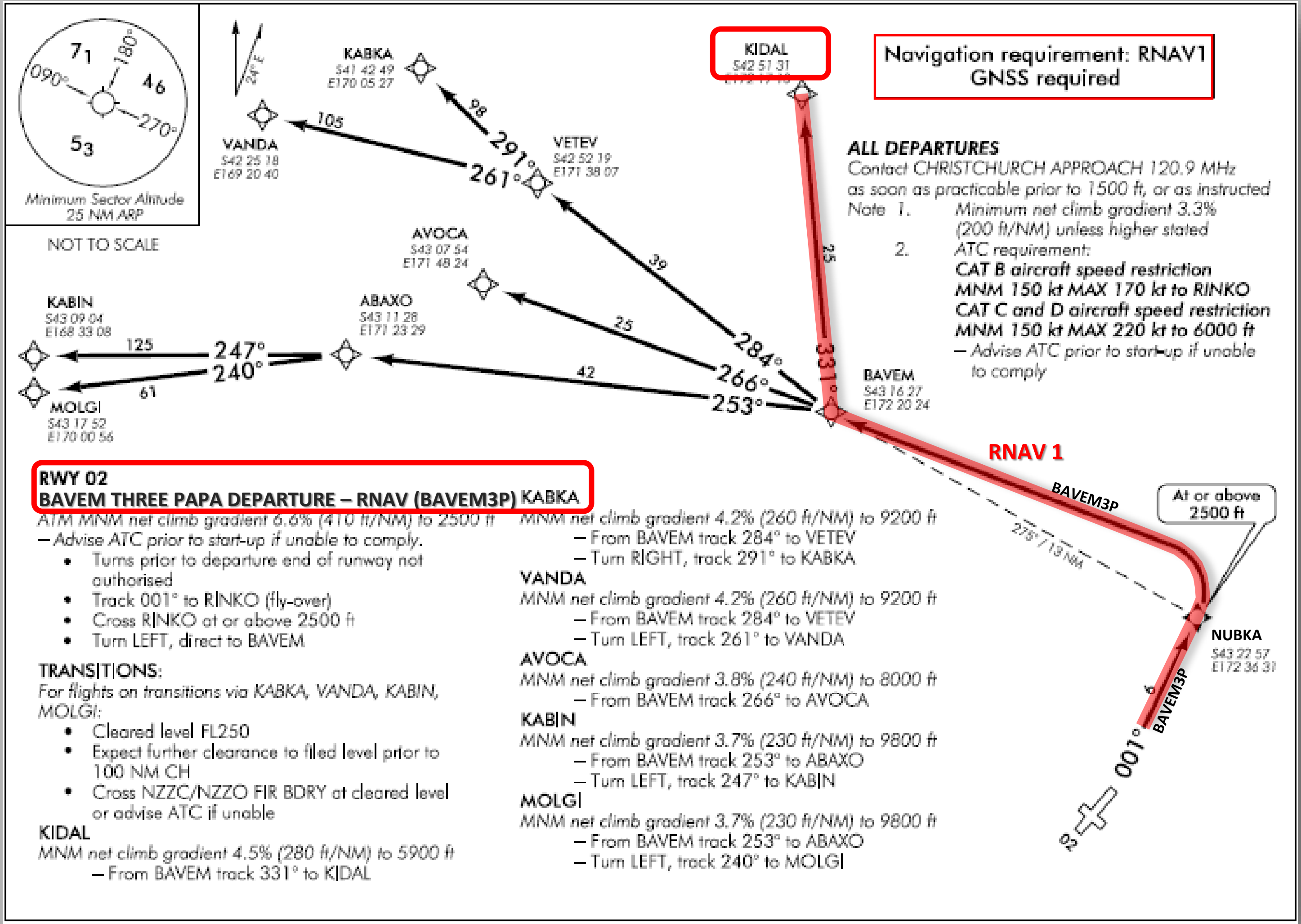


GNSS position fix before getting airborne

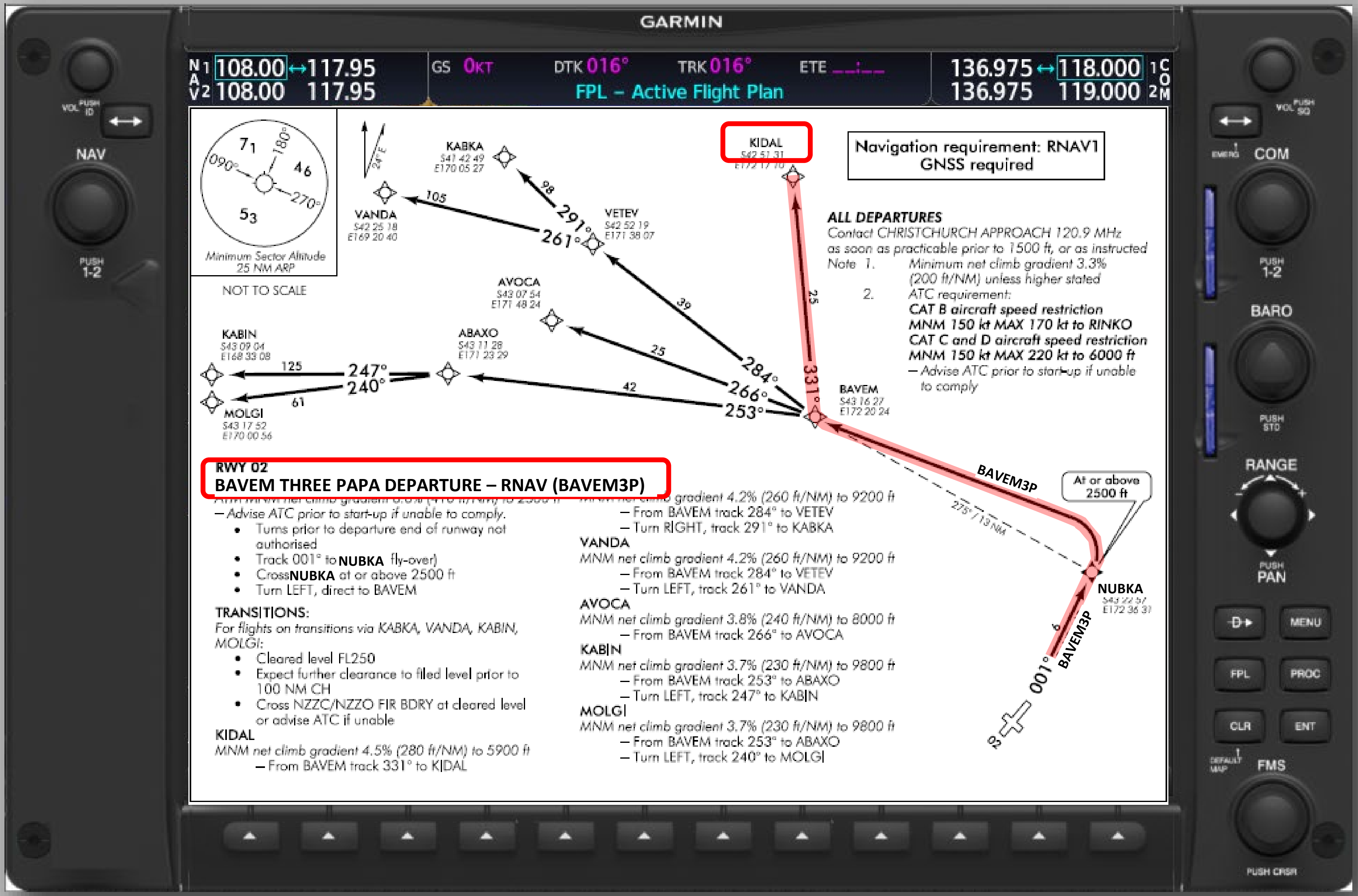
Lateral Guidance

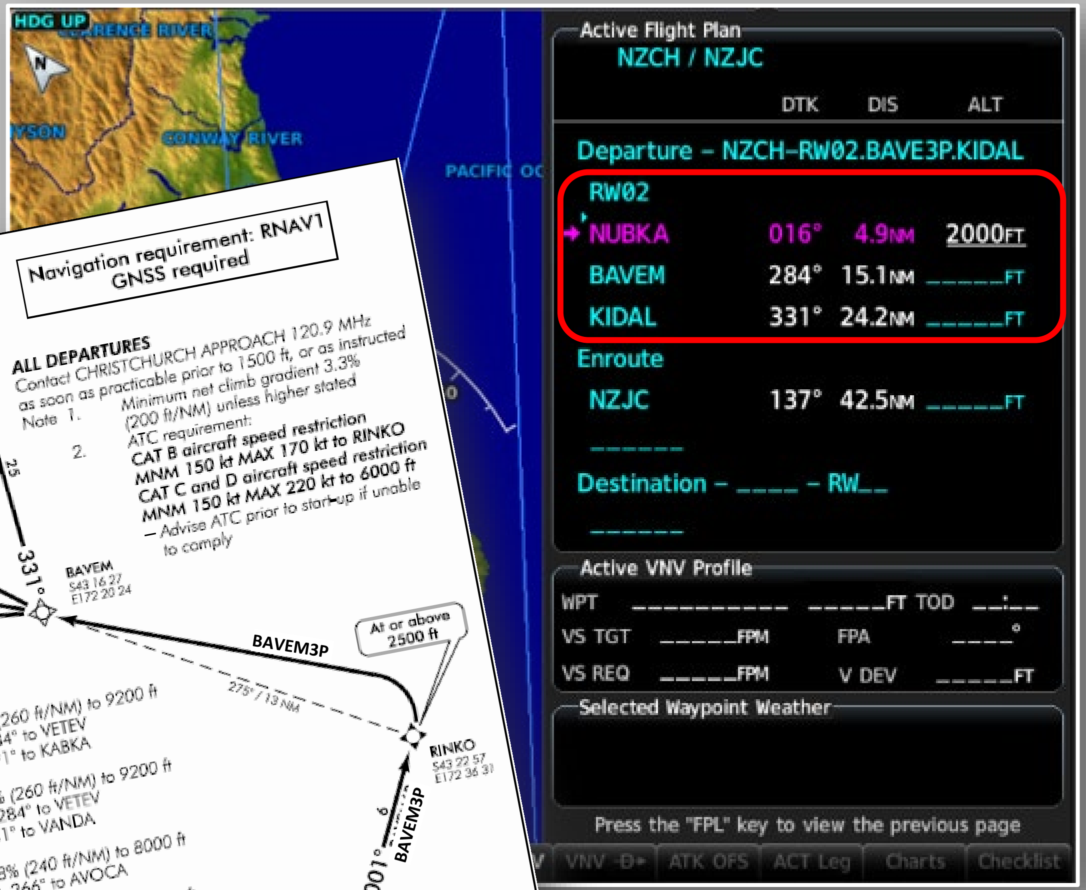
Important

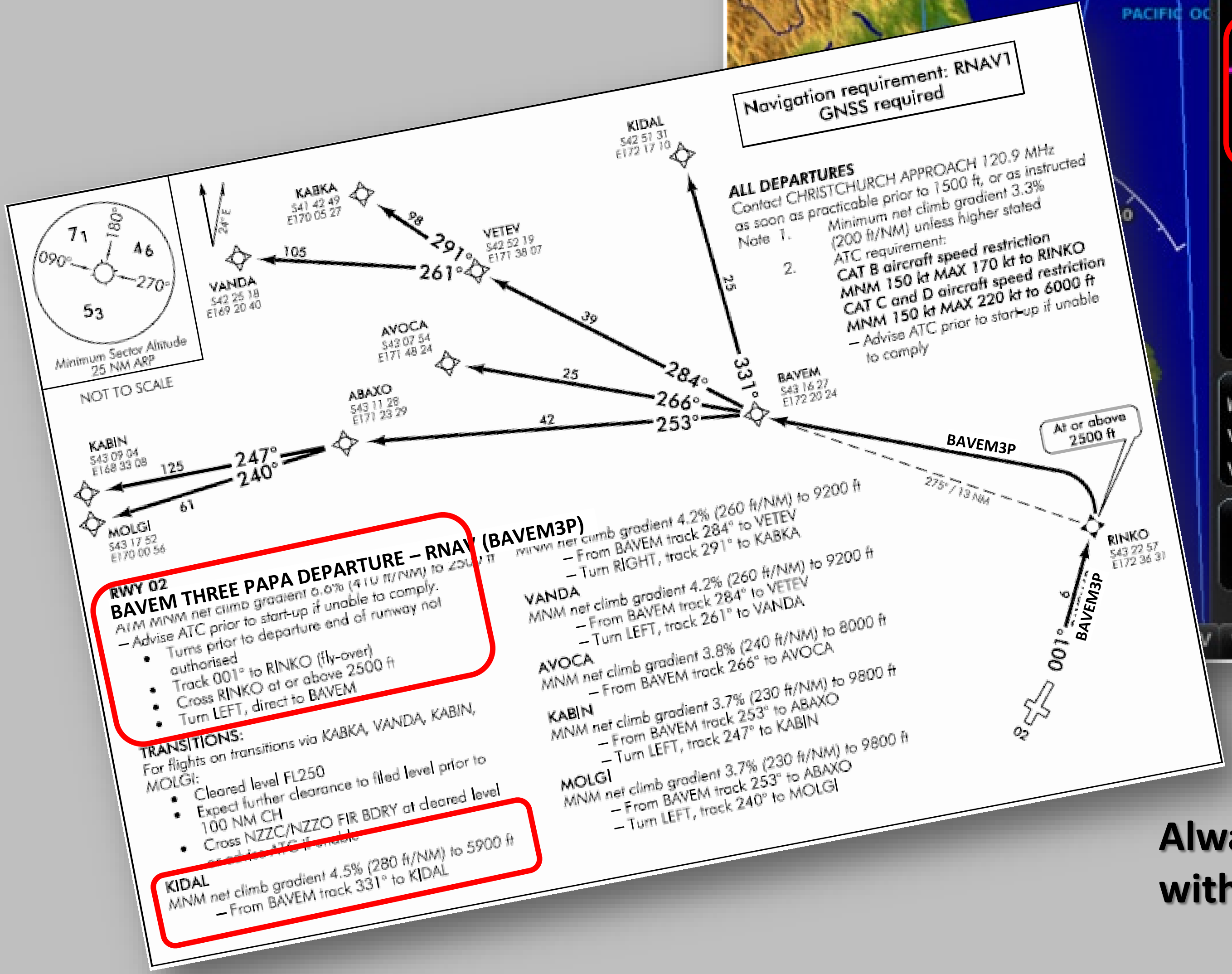
Pre-Flight (Airborne) - Selecting the Procedure



WAIKATO AVIATION ACADEMY


GARMIN
108.00 ↔ 117.95
108.00 117.95
GS 0KT
DTK 016°
TRK 016°
ETE __:__
FPL – Active Flight Plan
136.975 ↔ 118.000
136.975 119.000
NAV
COM
BARO
RANGE
PAN
MENU
FPL
PROC
CLR
ENT
FMS
Minimum Sector Altitude 25 NM ARP
NOT TO SCALE
KABKA
VANDA
VETEV
AVOCA
ABAXO
KABIN
MOLGI
KIDAL
BAVEM
NUBKA
Navigation requirement: RNAV1
GNSS required
ALL DEPARTURES
Contact CHRISTCHURCH APPROACH 120.9 MHz as soon as practicable prior to 1500 ft, or as instructed
Note 1. Minimum net climb gradient 3.3% (200 ft/NM) unless higher stated
2. ATC requirement:
CAT B aircraft speed restriction
MNM 150 kt MAX 170 kt to RINKO
CAT C and D aircraft speed restriction
MNM 150 kt MAX 220 kt to 6000 ft
– Advise ATC prior to start-up if unable to comply
BAVEM3P
At or above 2500 ft
RWY 02
BAVEM THREE PAPA DEPARTURE – RNAV (BAVEM3P)
– Advise ATC prior to start-up if unable to comply.
• Turns prior to departure end of runway not authorised
• Track 001° to NUBKA fly-over)
• Cross NUBKA at or above 2500 ft
• Turn LEFT, direct to BAVEM
TRANSITIONS:
For flights on transitions via KABKA, VANDA, KABIN, MOLGI:
• Cleared level FL250
• Expect further clearance to filed level prior to 100 NM CH
• Cross NZZC/NZZO FIR BDRY at cleared level or advise ATC if unable
KIDAL
MNM net climb gradient 4.5% (280 ft/NM) to 5900 ft
– From BAVEM track 331° to KIDAL
gradient 4.2% (260 ft/NM) to 9200 ft
– From BAVEM track 284° to VETEV
– Turn RIGHT, track 291° to KABKA
VANDA
MNM net climb gradient 4.2% (260 ft/NM) to 9200 ft
– From BAVEM track 284° to VETEV
– Turn LEFT, track 261° to VANDA
AVOCA
MNM net climb gradient 3.8% (240 ft/NM) to 8000 ft
– From BAVEM track 266° to AVOCA
KABIN
MNM net climb gradient 3.7% (230 ft/NM) to 9800 ft
– From BAVEM track 253° to ABAXO
– Turn LEFT, track 247° to KABIN
MOLGI
MNM net climb gradient 3.7% (230 ft/NM) to 9800 ft
– From BAVEM track 253° to ABAXO
– Turn LEFT, track 240° to MOLGI

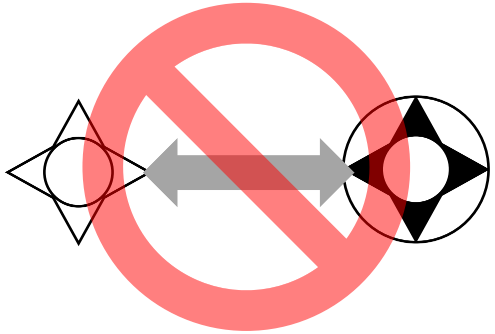




Always confirm that you are able to comply with the climb gradient.

DA42 = 333 ft/min

Amending a Procedure

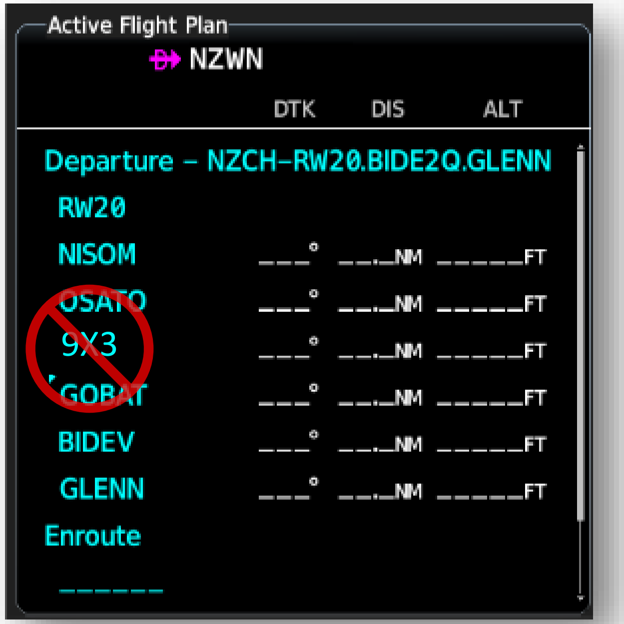


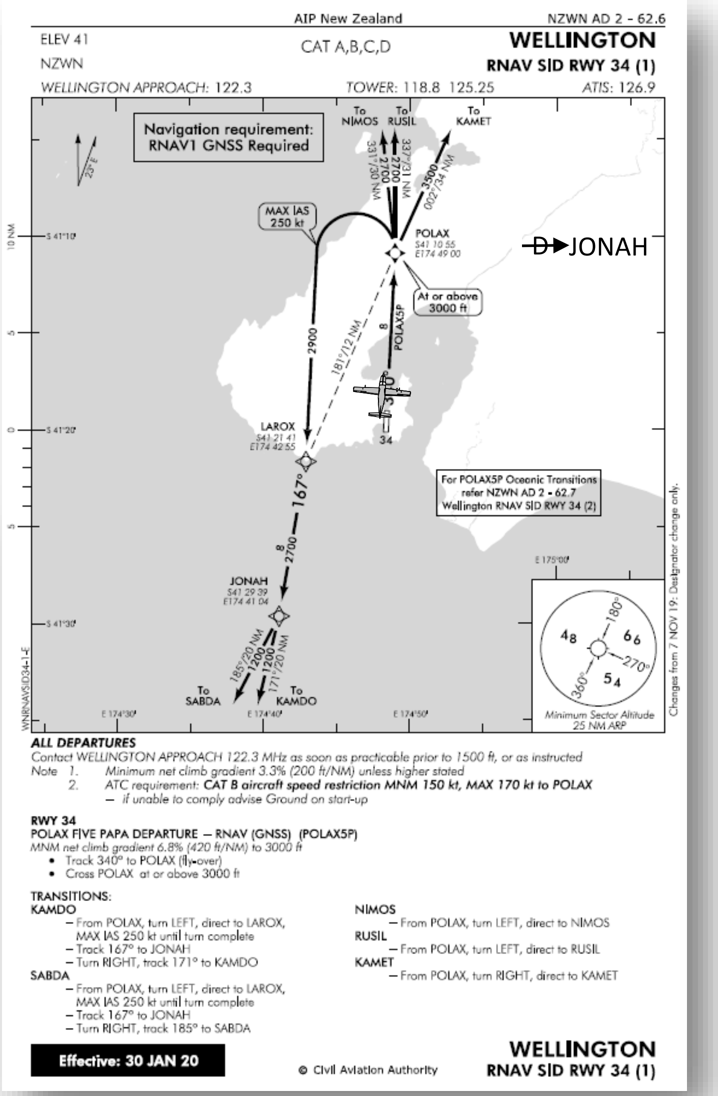
Do not swap flyby for flyover

Do not insert user waypoints

ATC may permit a direct to clearance either to another procedure point to a transition point

Direct routings normally minimalised as PBN routing is already effective





WAIKATO AVIATION ACADEMY

Computer Navigation Fix (CNF)

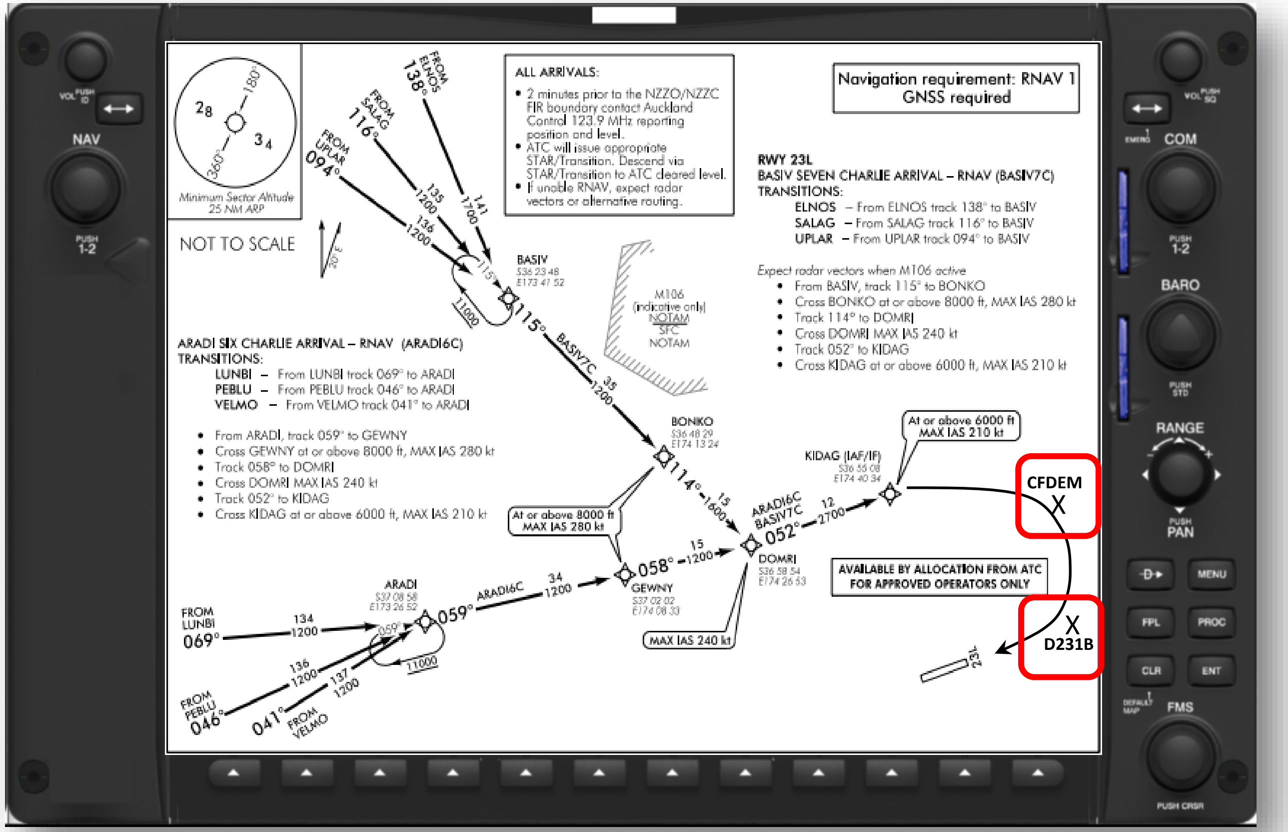
Used for overlay APCH

Not recognised by ATC

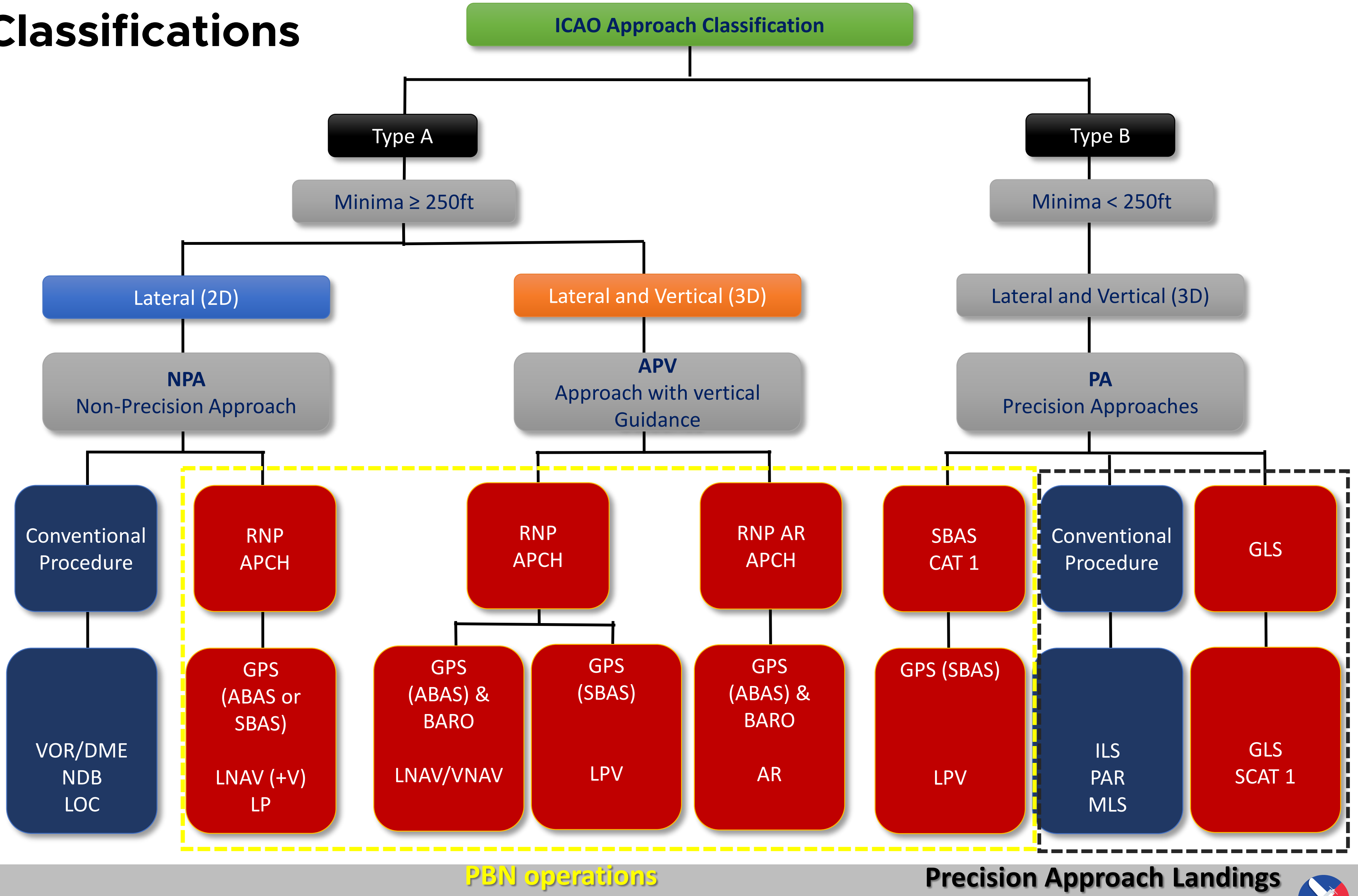
Not to be used for

- Direct to
- Filing a flight plan
- ATC communication

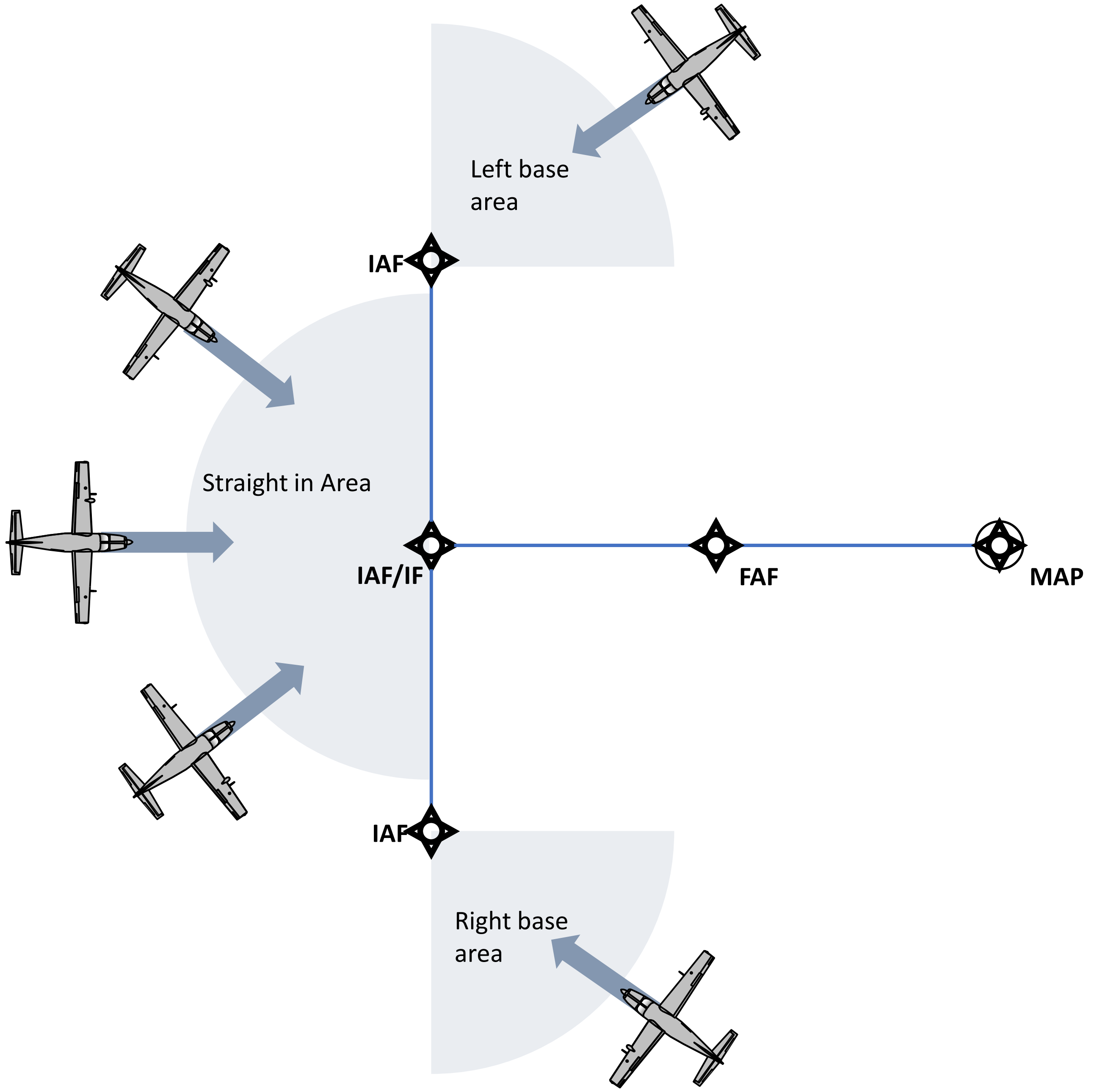
Will be identified by CFXXX



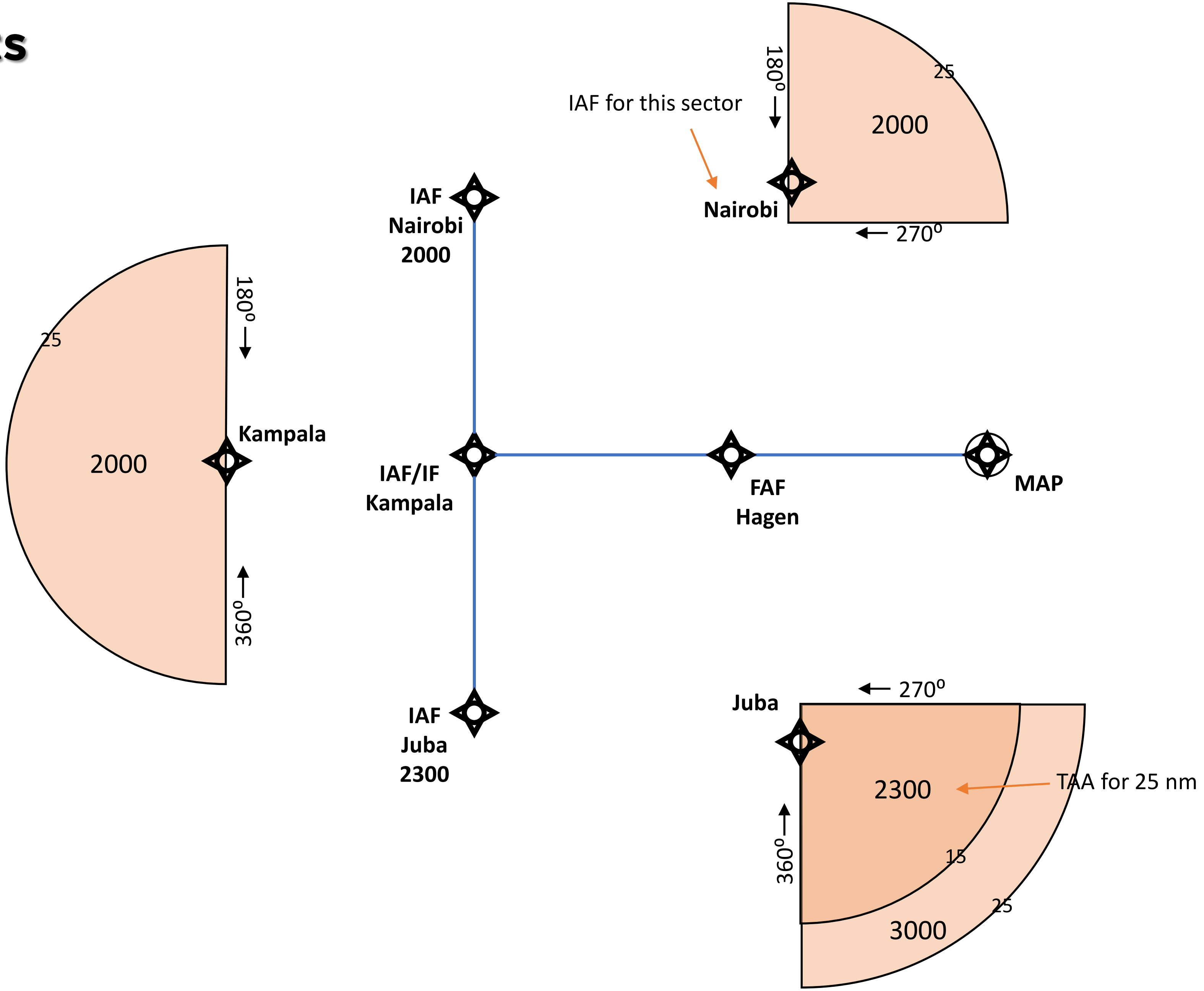
Approach Classifications



RNP Approach - Segments



RNP Approach - Segments

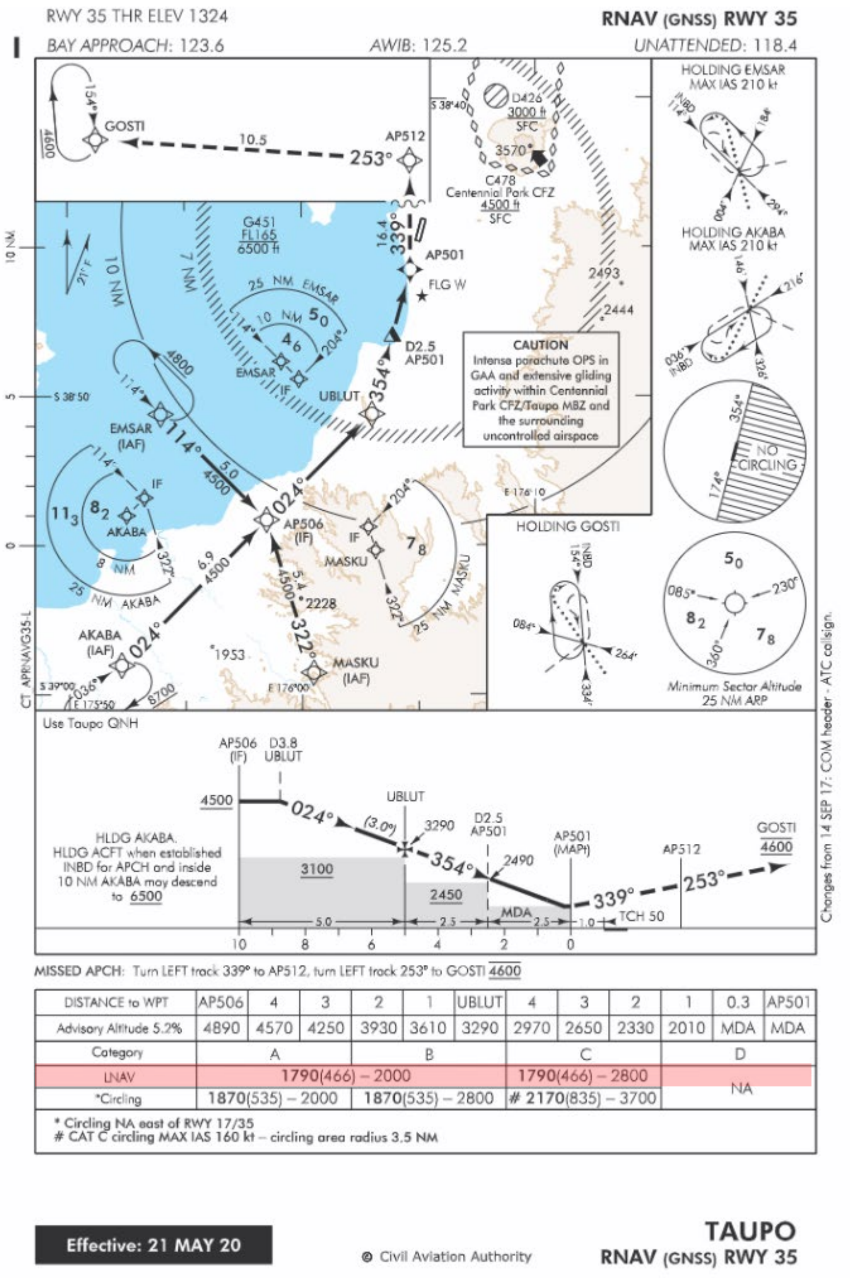


TAA = Terminal Arrival Area

RNP APCHs

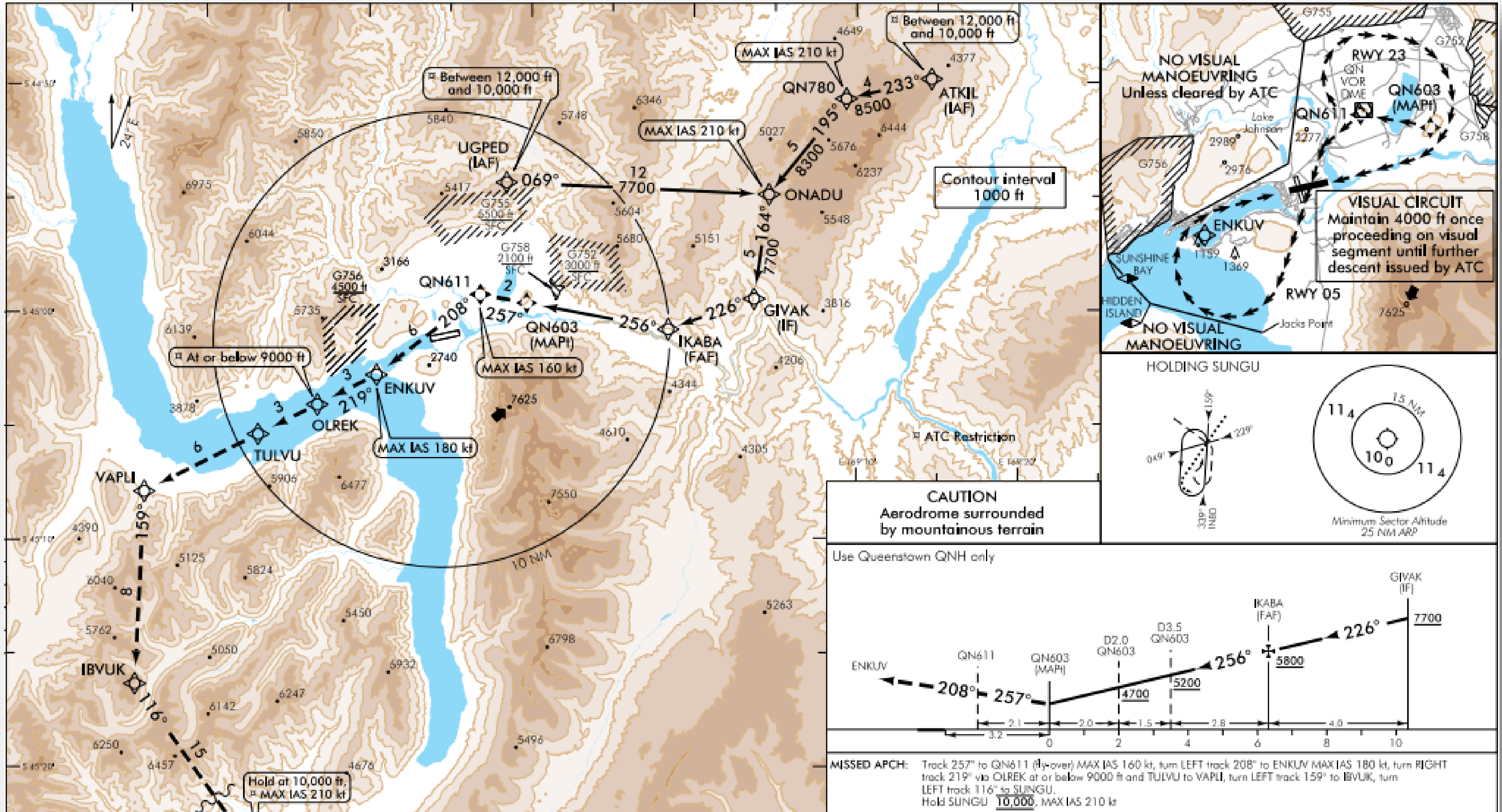
Note: Under PBN, all approaches are RNP approaches therefore require OBPMA

This is an RNP approach to LNAV minima, but typically it is called an LNAV approach



WAIKATO AVIATION ACADEMY

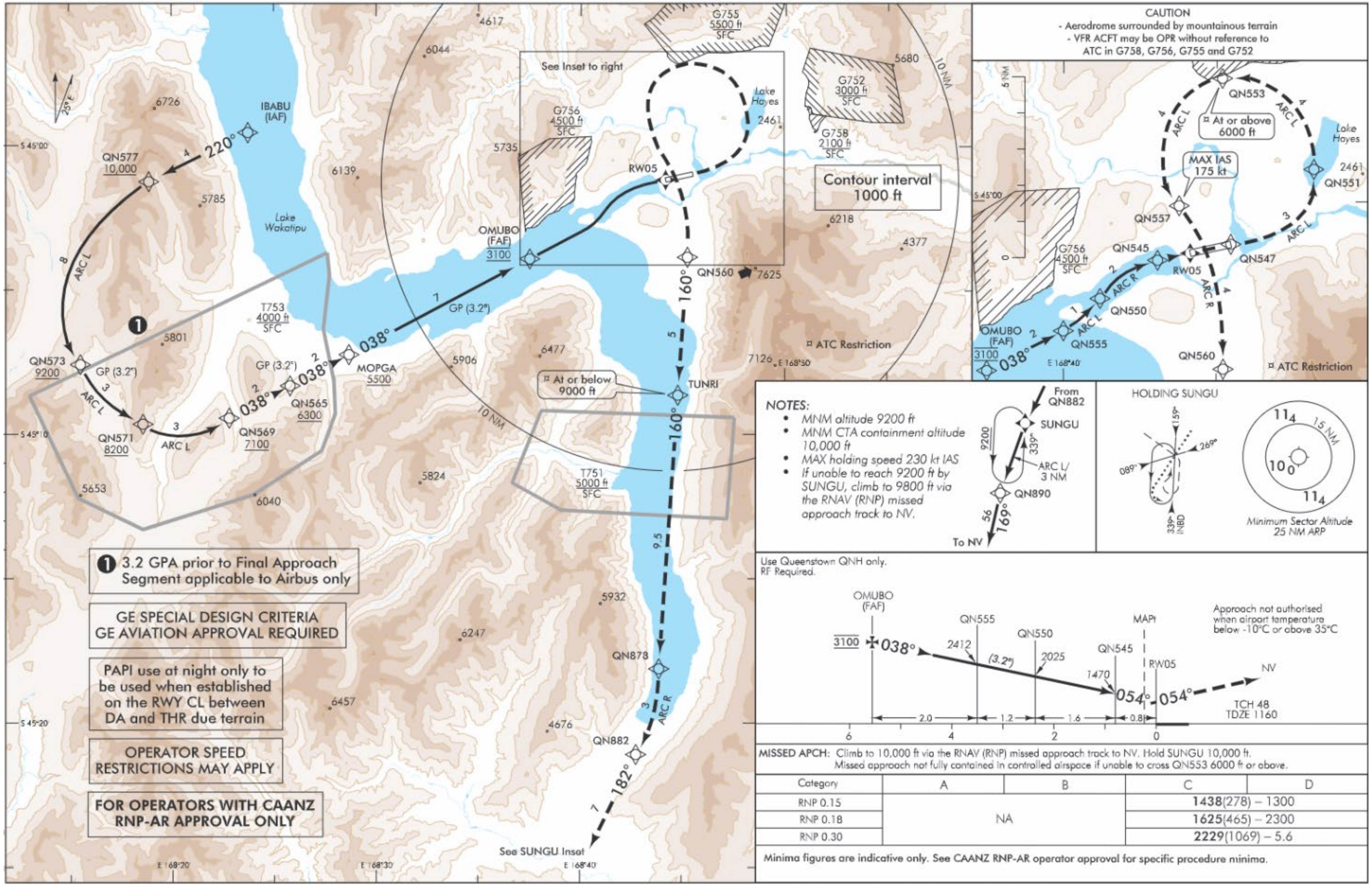
RNP APCHs



DISTANCE to WPT	QN603	1	2	3	4	5	6	IKABA	1	2	3	GIVAK
Advisory Altitude 5.8%	MDA	4450	4800	5150	5500	5850	6200	6300	6650	7000	7350	7700
Category	A			B			C			D		
Visual Circuit *	# 4100(2929) – 5									NA		

* Procedure does not meet ICAO PANS OPS circling criteria. Aircraft should expect to be cleared to join visual circuit pattern or as directed by ATC (see chart NZQN AD 2-51.3 Queenstown Aerodrome (3)). Maintain 4000 ft once proceeding on visual segment until further descent issued by ATC
# Daylight operations only

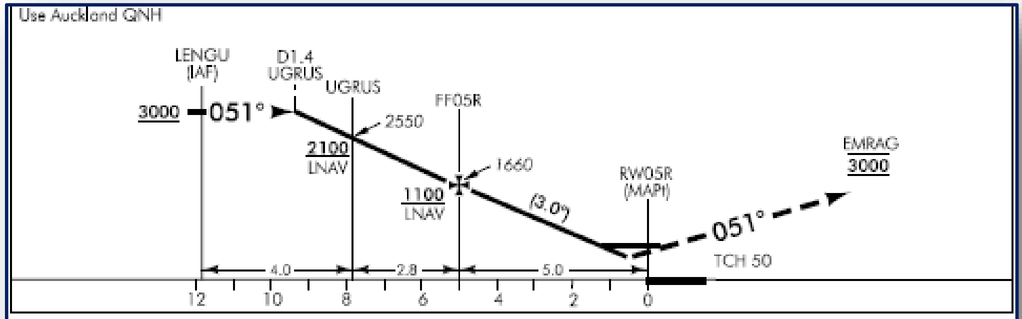
RNP AR APCHs


CAUTION
- Aerodrome surrounded by mountainous terrain
- VFR ACFT may be OPR without reference to ATC in G758, G756, G755 and G752
See Inset to right
Contour interval 1000 ft
IBABU (IAF)
220°
QN577 10,000
ARC L
QN573 9200
GP (3.2°)
QN571 8200
QN569 7100
QN565 6300
MOPGA 5500
OMUBO (FAF) 3100
038°
RW05
QN560
160°
TUNRI
At or below 9000 ft
QN878
QN882
182°
See SUNGU Inset
T753 4000 ft SFC
T751 5000 ft SFC
G755 5500 ft SFC
G752 3000 ft SFC
G756 4500 ft SFC
G758 2100 ft SFC
Lake Wakatipu
Lake Hayes
ATC Restriction
QN553
At or above 6000 ft
MAX IAS 175 kt
QN551
QN557
QN545
QN547
QN550
QN555
3.2 GPA prior to Final Approach Segment applicable to Airbus only
GE SPECIAL DESIGN CRITERIA
GE AVIATION APPROVAL REQUIRED
PAPI use at night only to be used when established on the RWY CL between DA and THR due terrain
OPERATOR SPEED RESTRICTIONS MAY APPLY
FOR OPERATORS WITH CAANZ RNP-AR APPROVAL ONLY
NOTES:
• MNM altitude 9200 ft
• MNM CTA containment altitude 10,000 ft
• MAX holding speed 230 kt IAS
• If unable to reach 9200 ft by SUNGU, climb to 9800 ft via the RNAV (RNP) missed approach track to NV.
From QN882
SUNGU
QN890
To NV
HOLDING SUNGU
Minimum Sector Altitude 25 NM ARP
Use Queenstown QNH only.
RF Required.
Approach not authorised when airport temperature below -10°C or above 35°C
MAPt
TCH 48
TDZE 1160
MISSED APCH: Climb to 10,000 ft via the RNAV (RNP) missed approach track to NV. Hold SUNGU 10,000 ft.
Missed approach not fully contained in controlled airspace if unable to cross QN553 6000 ft or above.
Category A B C D
RNP 0.15 NA 1438(278) – 1300
RNP 0.18 1625(465) – 2300
RNP 0.30 2229(1069) – 5.6
Minima figures are indicative only. See CAANZ RNP-AR operator approval for specific procedure minima.

RNP APCH Classifications

Important

2-D	3-D
Lateral guidance only	Lateral and vertical guidance
Minima expressed as MDA	Minima expressed as DA
LNAV based on GNSS	
LP based on SBAS augmented GNSS	



MISSED APCH: MAX IAS 185 kt. Climb on 051° to EMRAG 3000

DISTANCE to WPT	UGRUS	2	1	FF05R	4	3	2	1.2	0.9	RW05R
Advisory Altitude 3°	2550	2300	1980	1660	1340	1020	700	MDA	DA	MDA

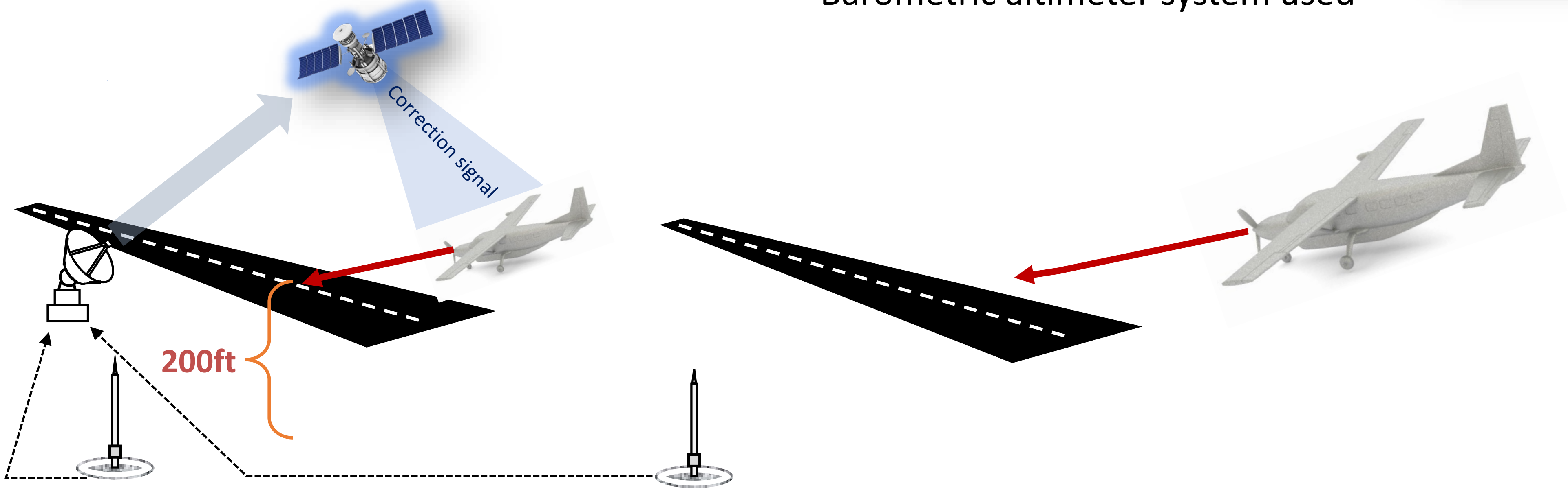
Category	A	B	C	D
LNAV/VNAV *	340(325) – 1500			
LNAV	440(425) – 1500			
Circling	560(537) – 1900	630(607) – 2800	#790(767) – 3700	#930(907) – 4600

* Valid to AD temperature -5°C. Use of remote QNH NA.
# Circling CAT C and D NA north of RWY

WAIKATO AVIATION ACADEMY

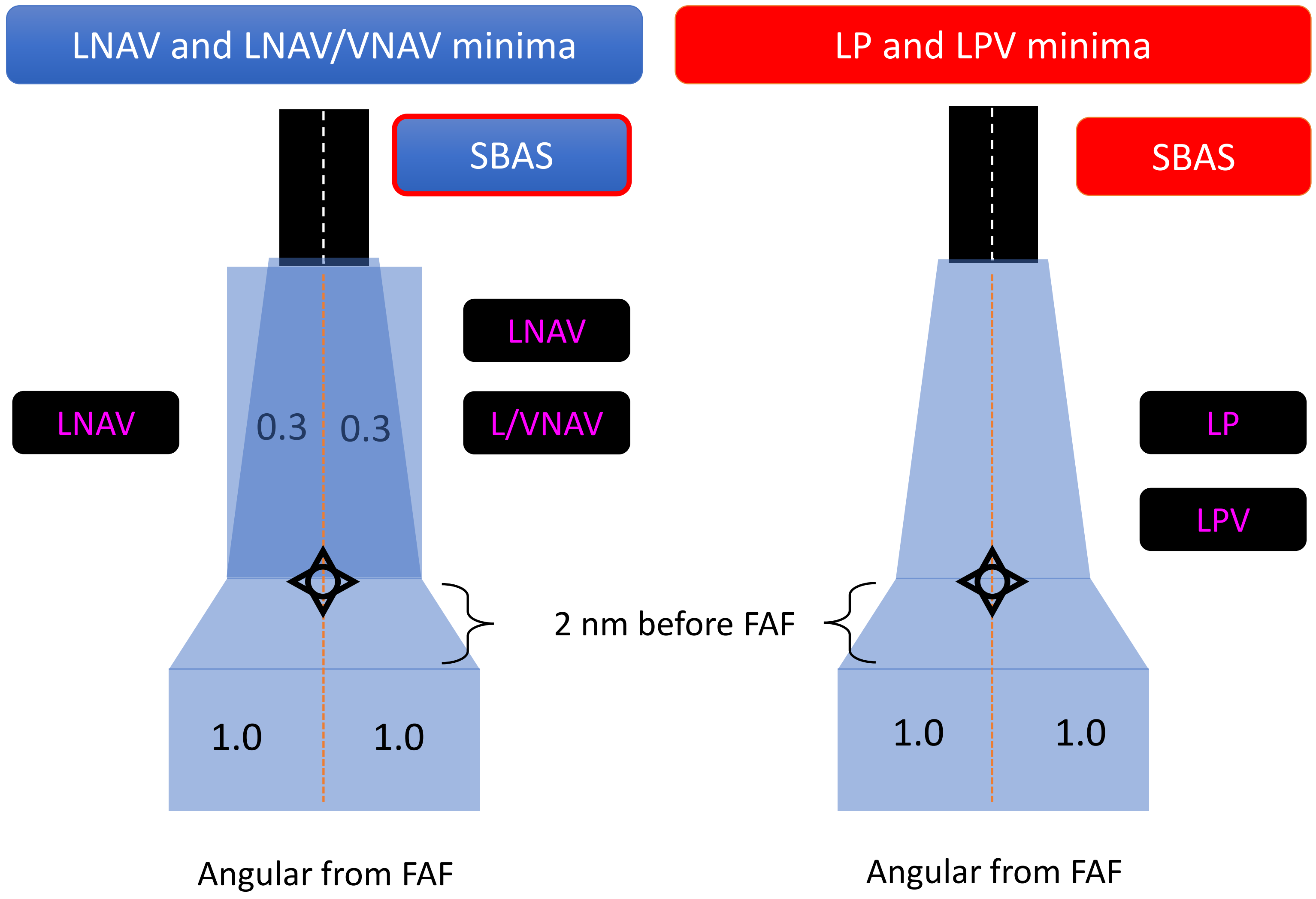
Vertical guidance on RNP APCHs (APV)

LPV Minima	LNAV/VNAV Minima
SBAS only	SBAS or Baro-VNAV
Vertical profile from SBAS signal	Baro-VNAV • Vertical profile generated • Barometric altimeter system used
ILS Cat 1 minima performance	



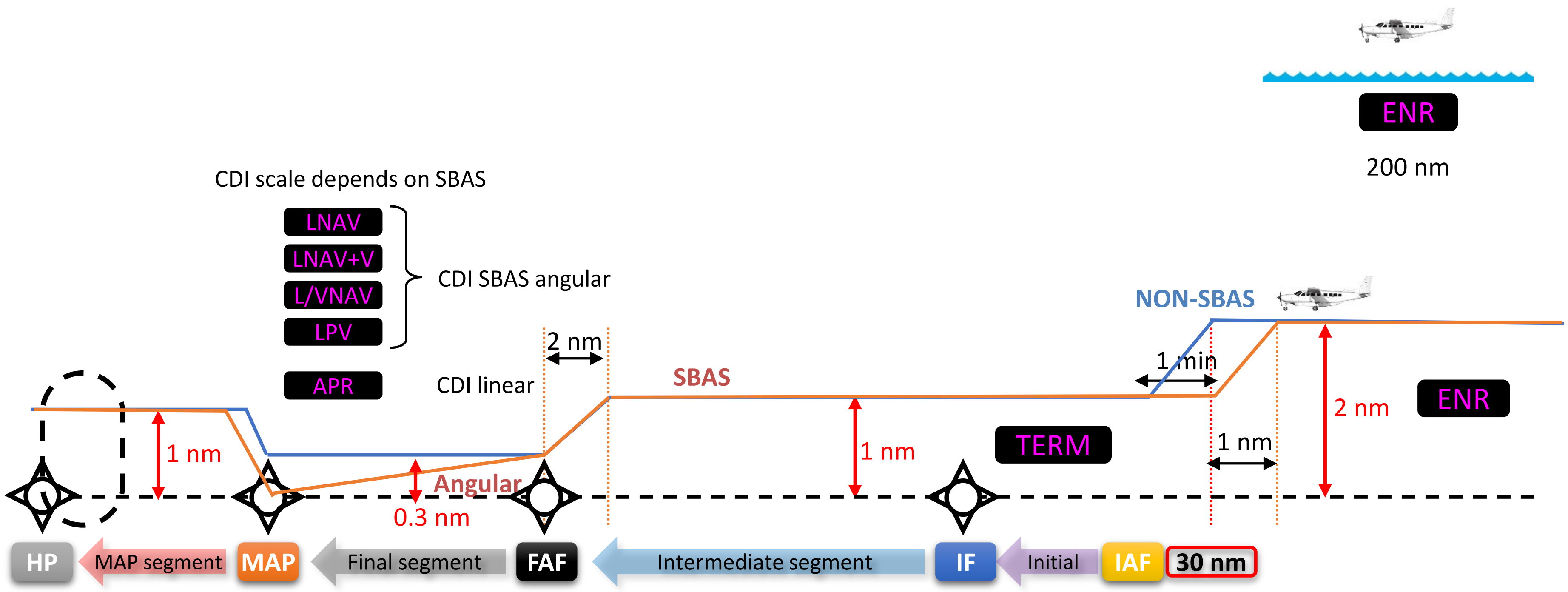
Lateral guidance on RNP APCHs

Important



CDI Scaling on APCHs

Important

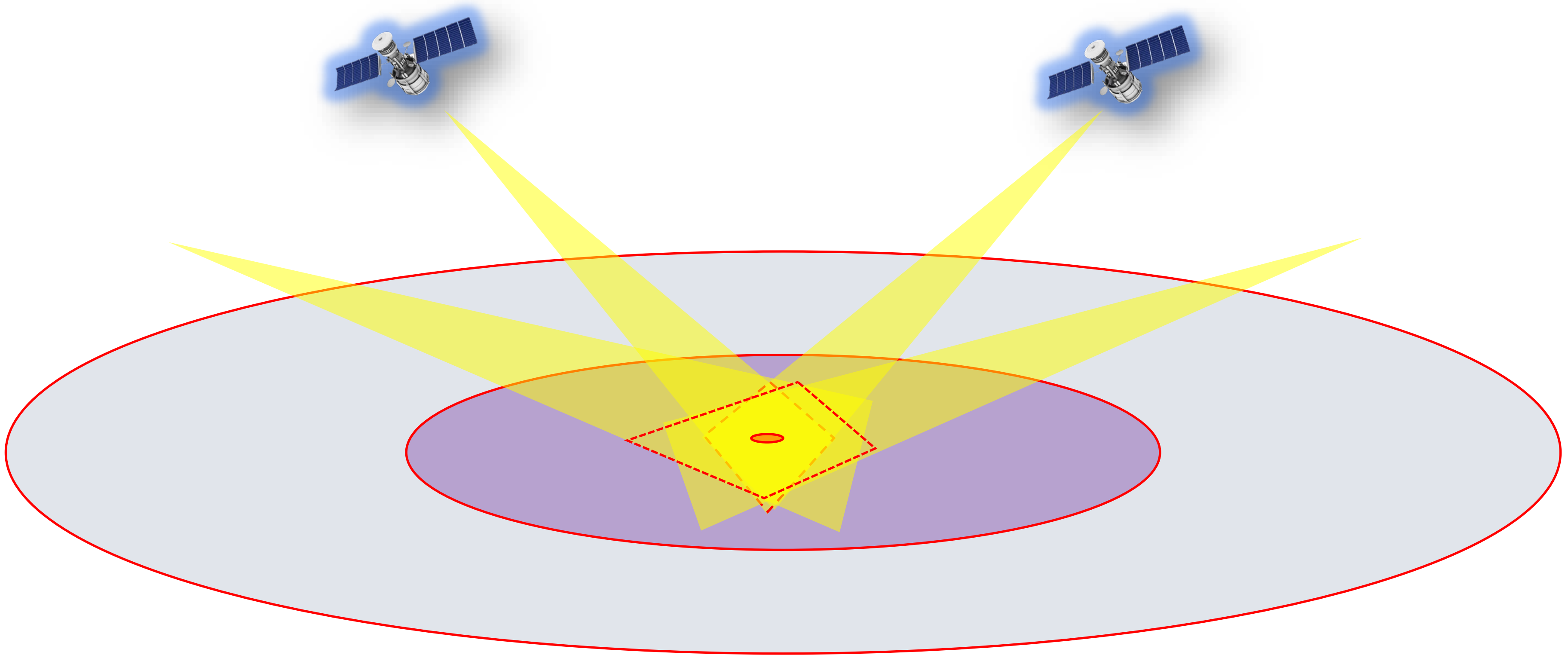


Sloping line represents continuous adjustment of CDI scale from one range to the next

When database terminal and approach procedures are active, the IFR unit automatically adjusts the CDI full-scale deflection and the RAIM position integrity alert to the limit appropriate for each phase of flight

Integrity Monitoring on APCH

Important

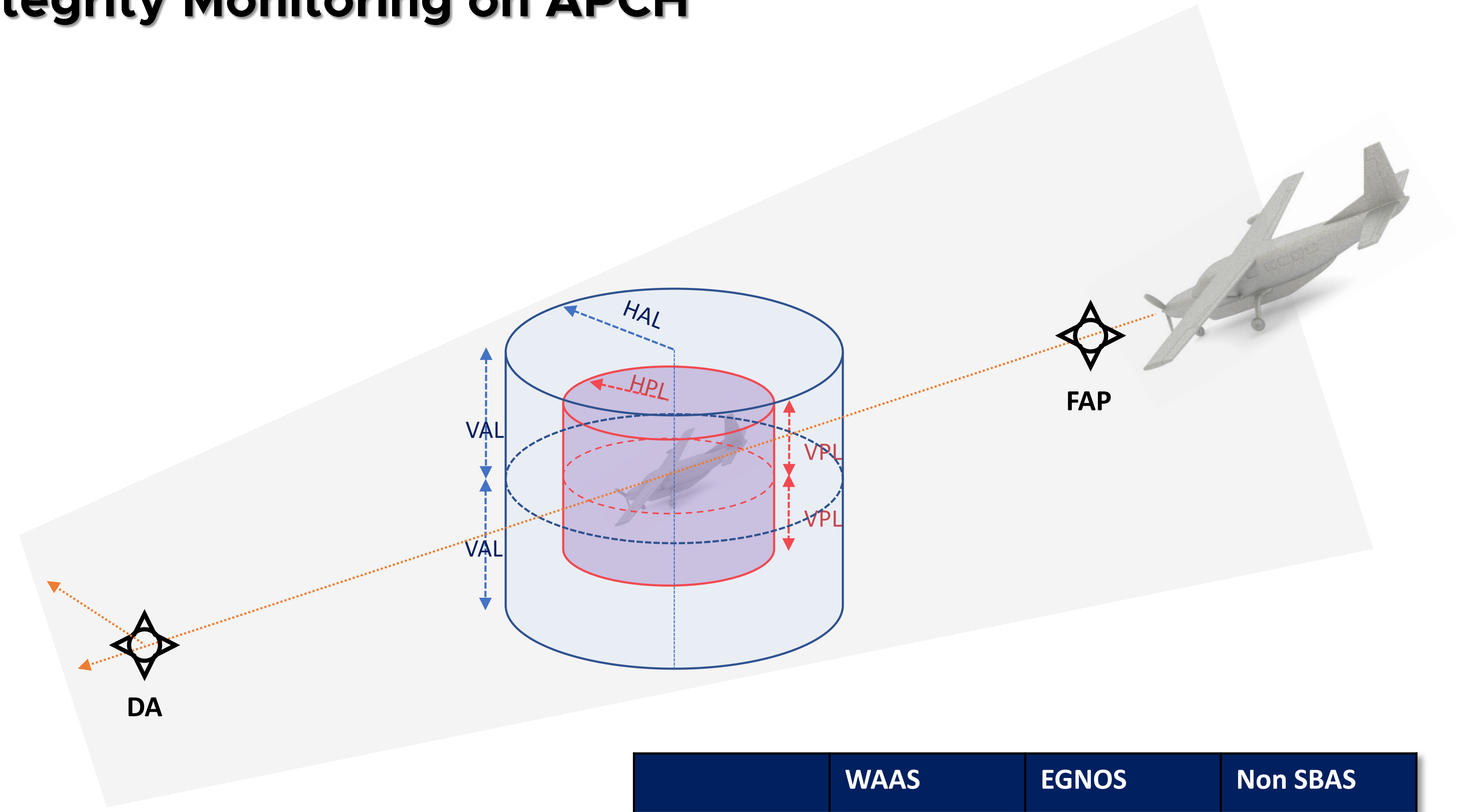


Horizontal Protection Limit **HPL**

Horizontal Alert Limit **HAL = RNP#**

LOI

Integrity Monitoring on APCH



	WAAS	EGNOS	Non SBAS
Lateral	1.0m	3.0 m	< 10.0m
Vertical	1.5 m	3.0 m	

Operating Procedures - APCHs

Confirm approach mode engaged **(LNAV)** before FAF or FAP

Confirm both lateral and vertical flight path displays (Note LNAV +V)

Establish on final approach course before FAF or FAP

Missed APCH

Use conventional aids if available

Track to MSA using safest means e.g. Ipad following Mapt tracks or DR/time based

Always check Mapt waypoints and tracks as part of the approach brief

APCH Monitoring LNAV and L/VNAV

CDI error normally limited to ½ scale deflection or ½ RNP on approach

Greater than 1 x RNP (0.3 nm), or full scale deflection, execute missed approach

Brief deviations up to 1 x RNP is acceptable during/after turns

Important

APCH Monitoring Vertical on Baro-VNAV

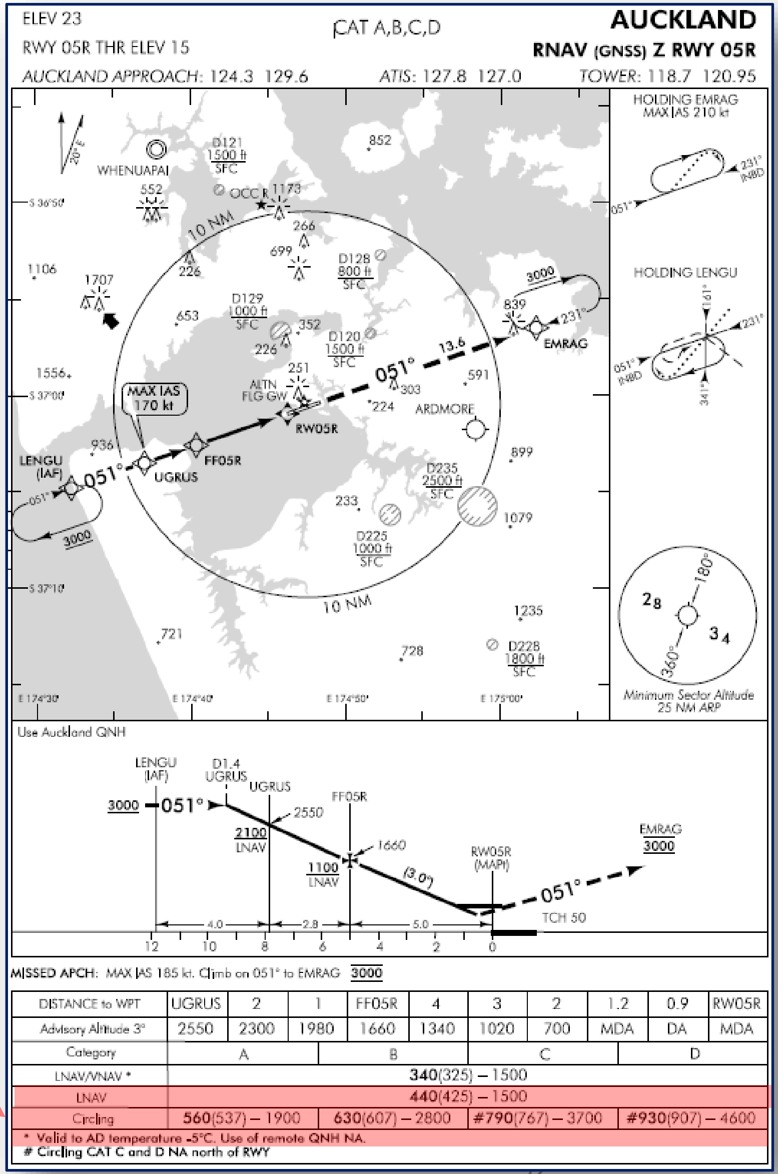
Sensitive to temp error

Min temp for approach

Below min temp, BARO-Nav not authorised except with FMS compensation

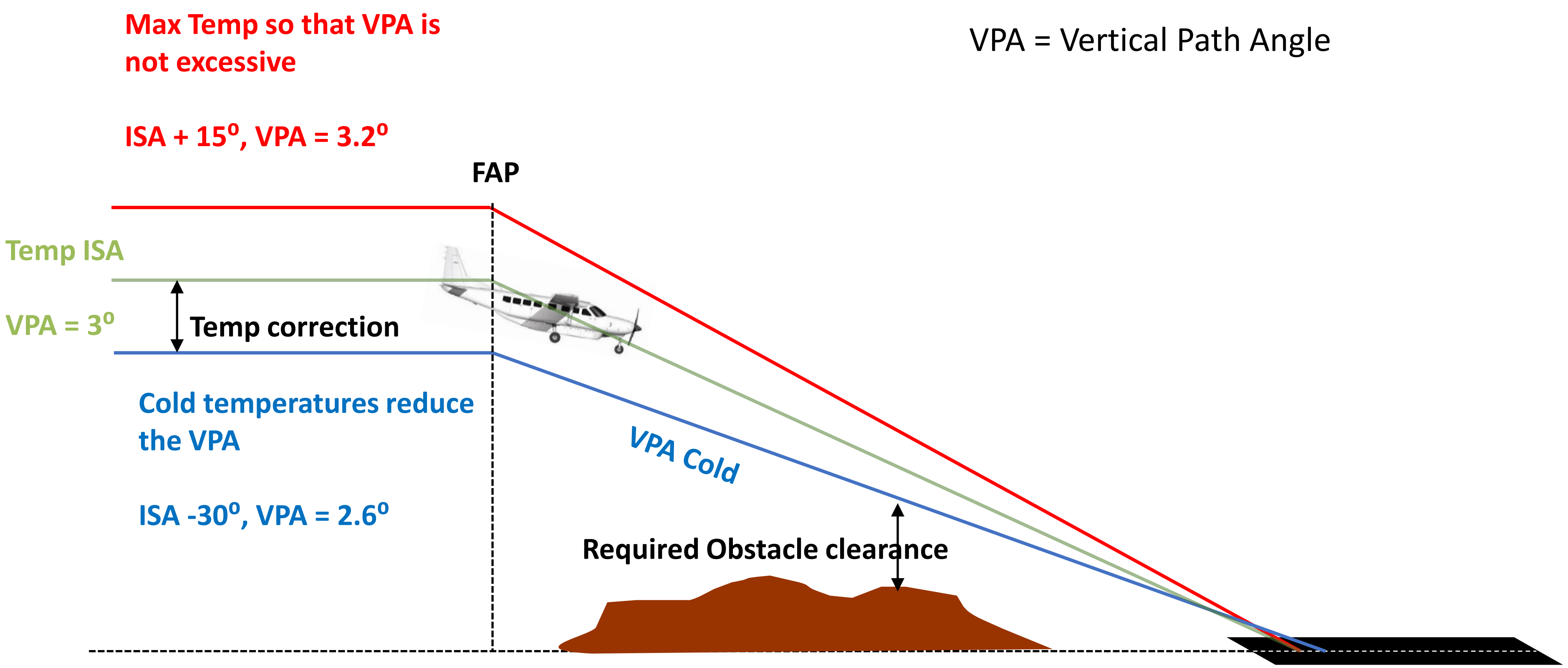
Not authorised below min FMS temp, revert to LNAV

Valid for AD temperature of -5°C.
Use of remote QNH not authorised.



APCH Monitoring Vertical on Baro-VNAV

VPA = Vertical Path Angle



Baro-VNAV (L/VNAV) vs <u>Advisory</u> Baro-VNAV (LNAV+V)

APV Baro-VNAV	Advisory Baro-VNAV

Within temp limit

3D Approach

LNAV/VNAV minima

DA/H

Outside temp limit

2D Approach with vertical advisory info

LNAV minima

MDA/H so requires minima buffer

Pilot to ensure step down altitudes complied with.

RNP APCH Monitoring

FTE normally limited to ½ RNP

+/- 75ft limit on glide path, brief deviations for configuration changes

FTE greater than 1 x RNP, pilot should execute missed approach

Brief deviations up to 1 x RNP acceptable during / after turns and on RNP 0.1 approaches in trying situations

WAIKATO AVIATION ACADEMY

Part 3 – PBN Issues

PBN APCH Charts

PBN Inconsistencies ?

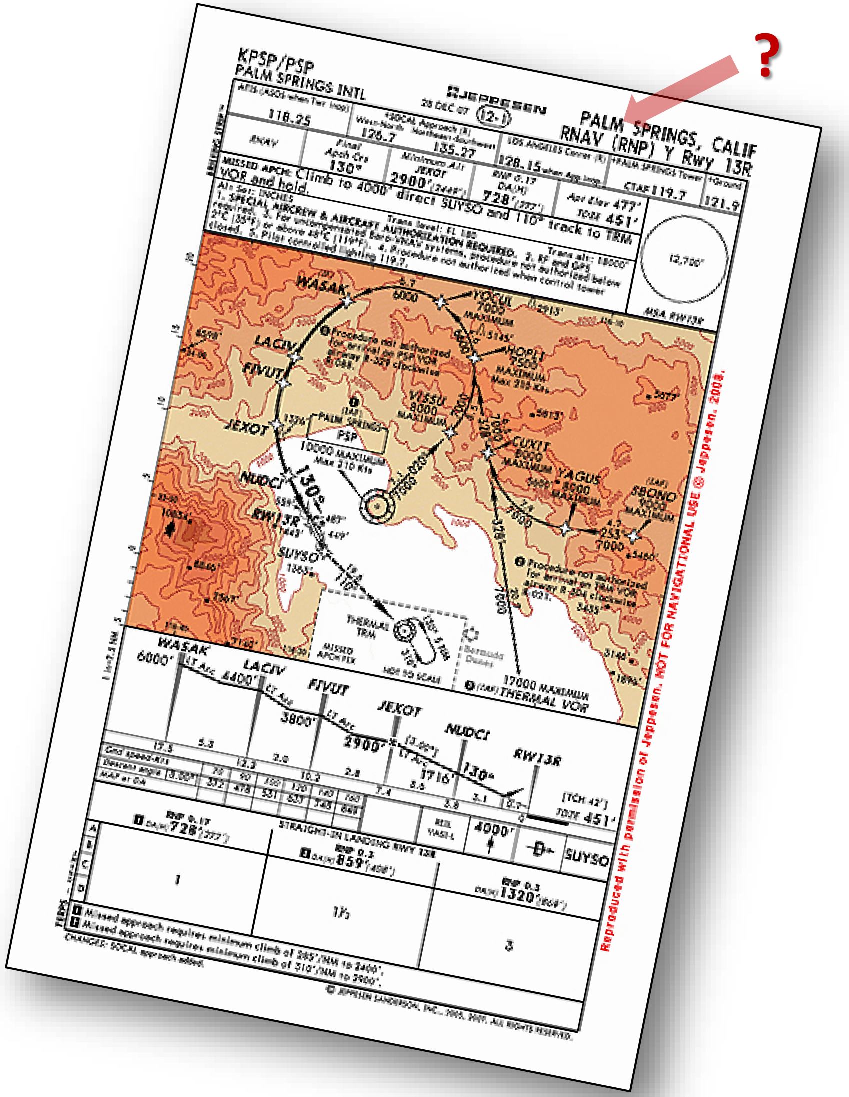
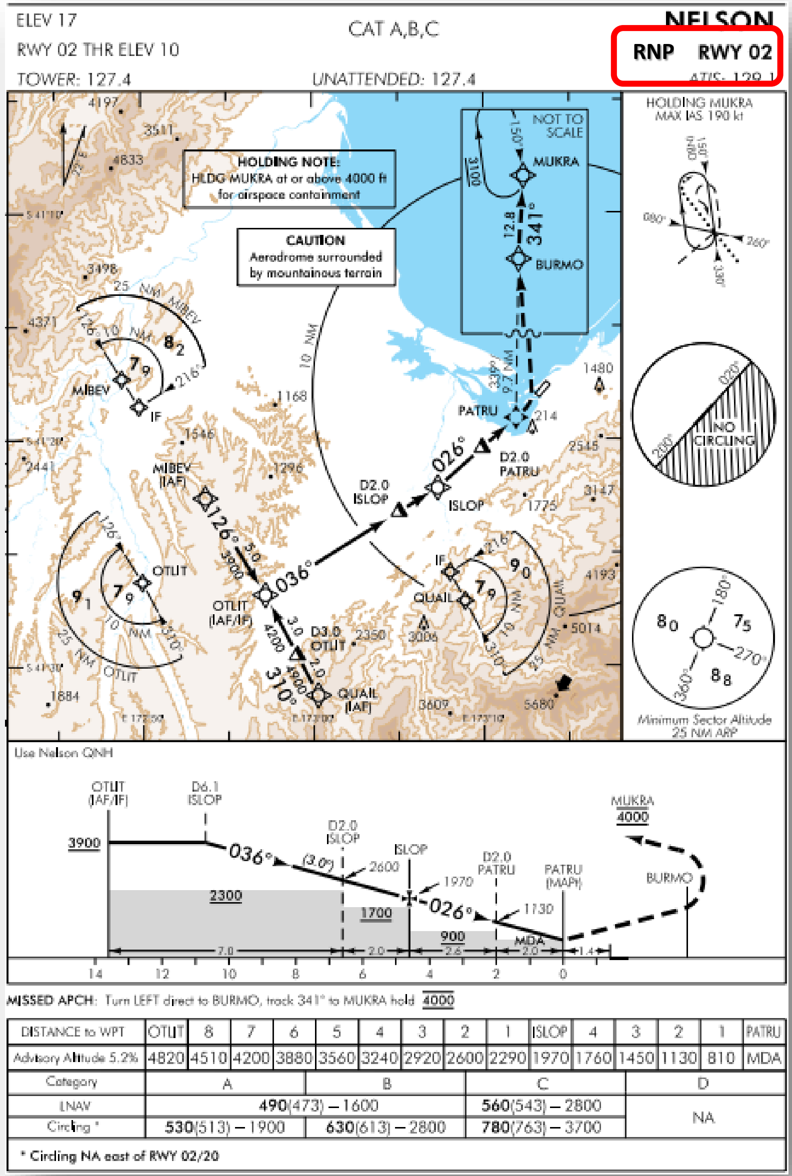


Chart Identification

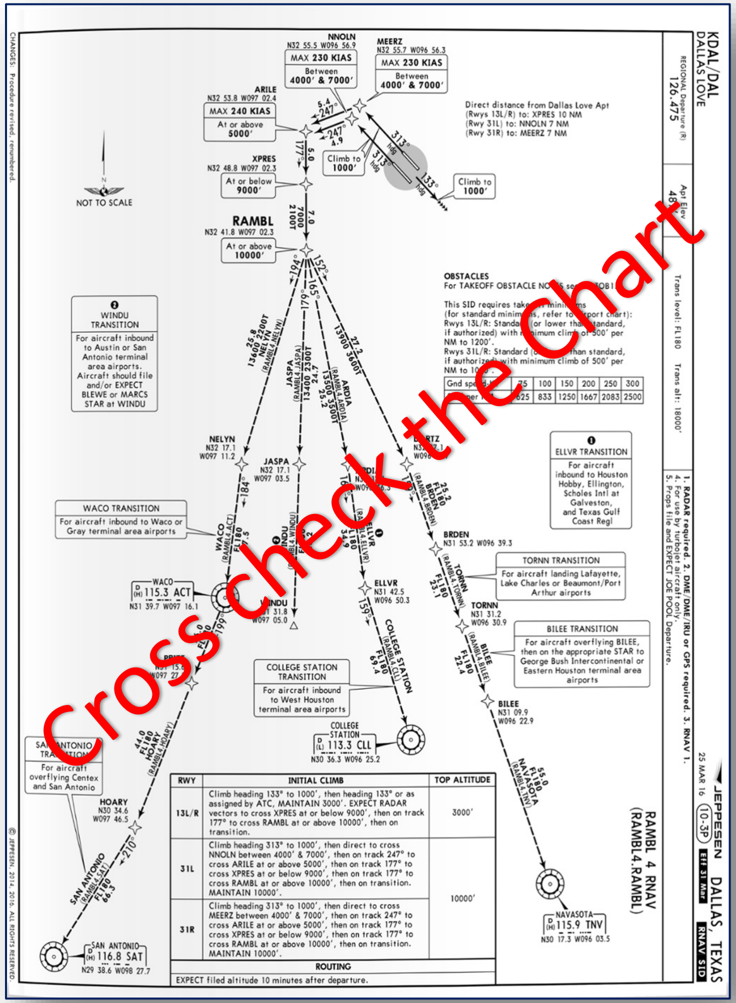
Standard naming convention from 2022

Additional approaches to same runway, include Z, Y, X, W working backwards from Z



Jeppesen - Caution

- Databases may not contain every SID, STAR and approach procedure.
- Database may not contain every leg or segment of the procedure being flown.
- Not everything needed is in the database.
- The location of each waypoint or navaid retrieved from the database should be confirmed.
- GNSS and electronic map displays with associated databases are not a substitute for current published charts.



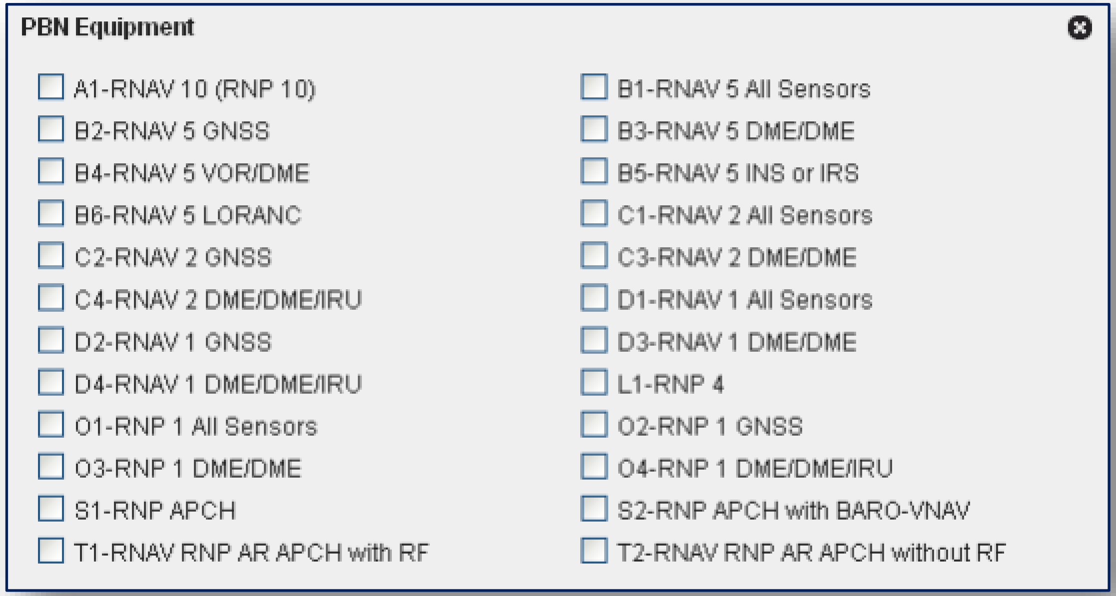
PBN Issues

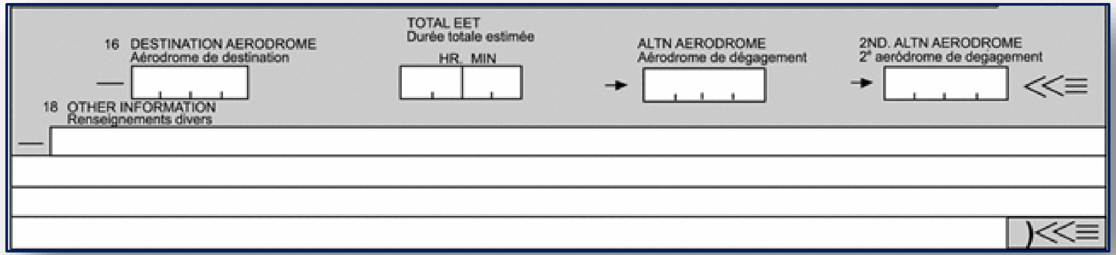
Flight Planning

No code for RNP 2, RNP 0.3, Advanced RNP

FF-ICE (Flight and Flow – Information for a Collaborative Environment)

- Reduce limitations with present flight plan
- New technologies and procedures incorporated
- PBN enhanced information e.g. RNP no.
- Earlier intent of operations





WAIKATO AVIATION ACADEMY

PBN Issues

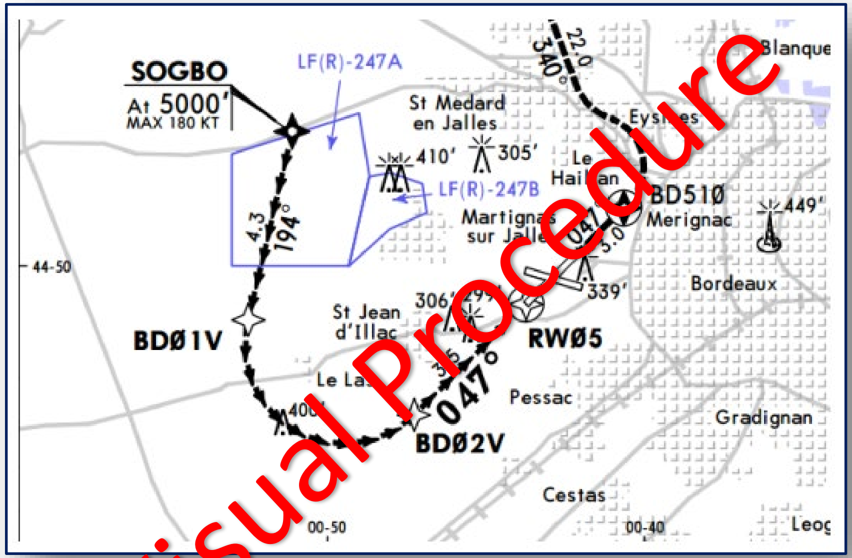
RNAV Visual Approach

No standard definition

- Many variants
- Different PBN navigation specifications
- May require RF legs
- Different visual/visibility requirements
- Different Navaid requirements
- Non standardised naming convention
  - RNAV Visual, Visual RNAV, RNVV Visual 02

Risks

- Responsibility of navigation is blurred, obstacle clearance, different charts



Pilots are to request a visual approach. Start descent from 5000 only when passing SOGBO. If visual reference to terrain not maintained, maintain altitude, follow the prescribed track and inform ATC

PBN Issues

GLS Approach

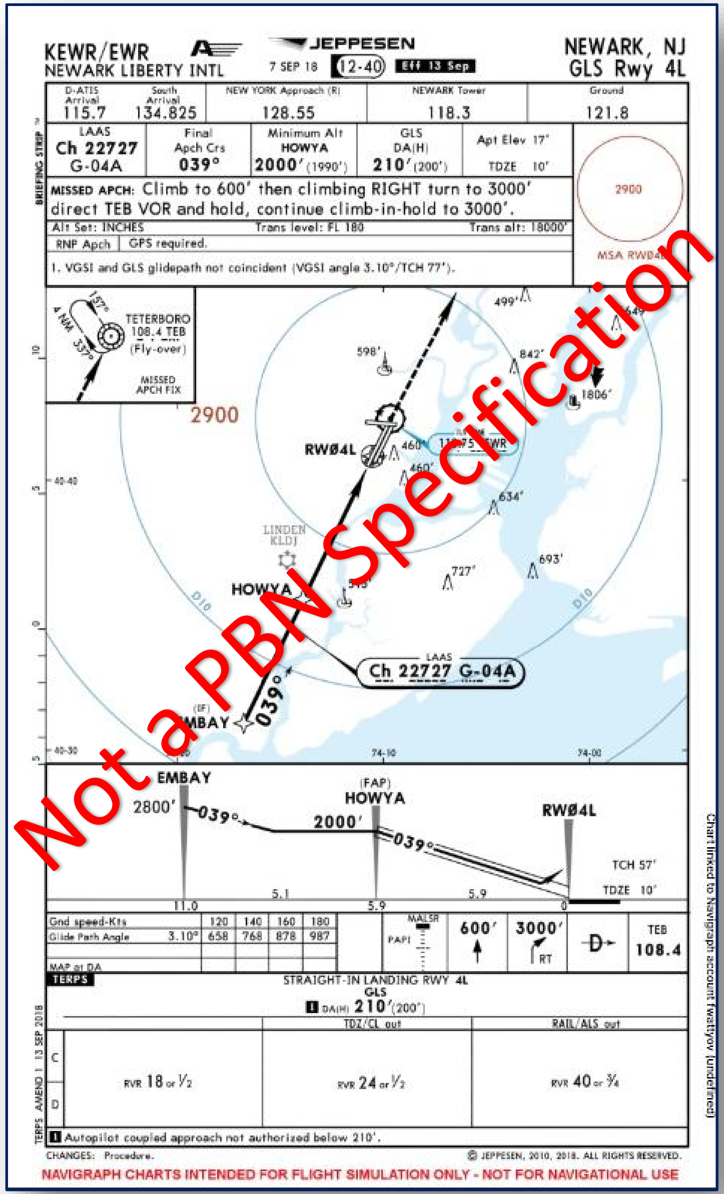
Based on GNSS augmented by Ground Based Augmentation System (GBAS)

Provides precision analogous to ILS

- Cat I currently
- Cat II/III in development

Ground based Omni directional correction signal 23nm radius up to 10,000ft located at airport. In the US it is called LAAS (local area augmentation system)

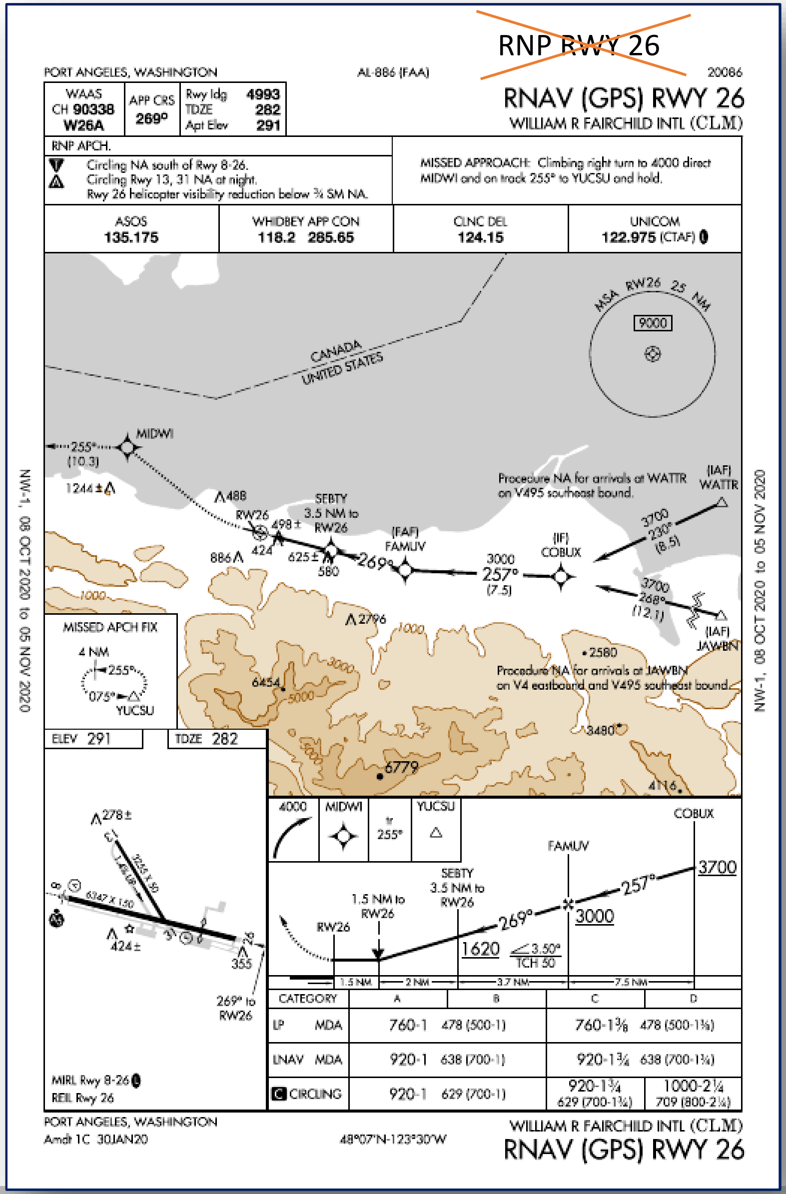
Presented here for the avoidance of confusion



PBN Issues

- No PBN requirements Box
  - Information instead is in notes section or header section
  - PBN Navigation Specification detail omitted on terminal charts
  - DME-DME RNP 0.3 NA is stated
- No minimum Temperature Box
  - Information instead in general notes section (as per above)
- FMS/GNSS equipment procedure identification not consistent
  - RNV may be used

US/Canada after 2022 will continue to use RNAV (GPS) RWY XX

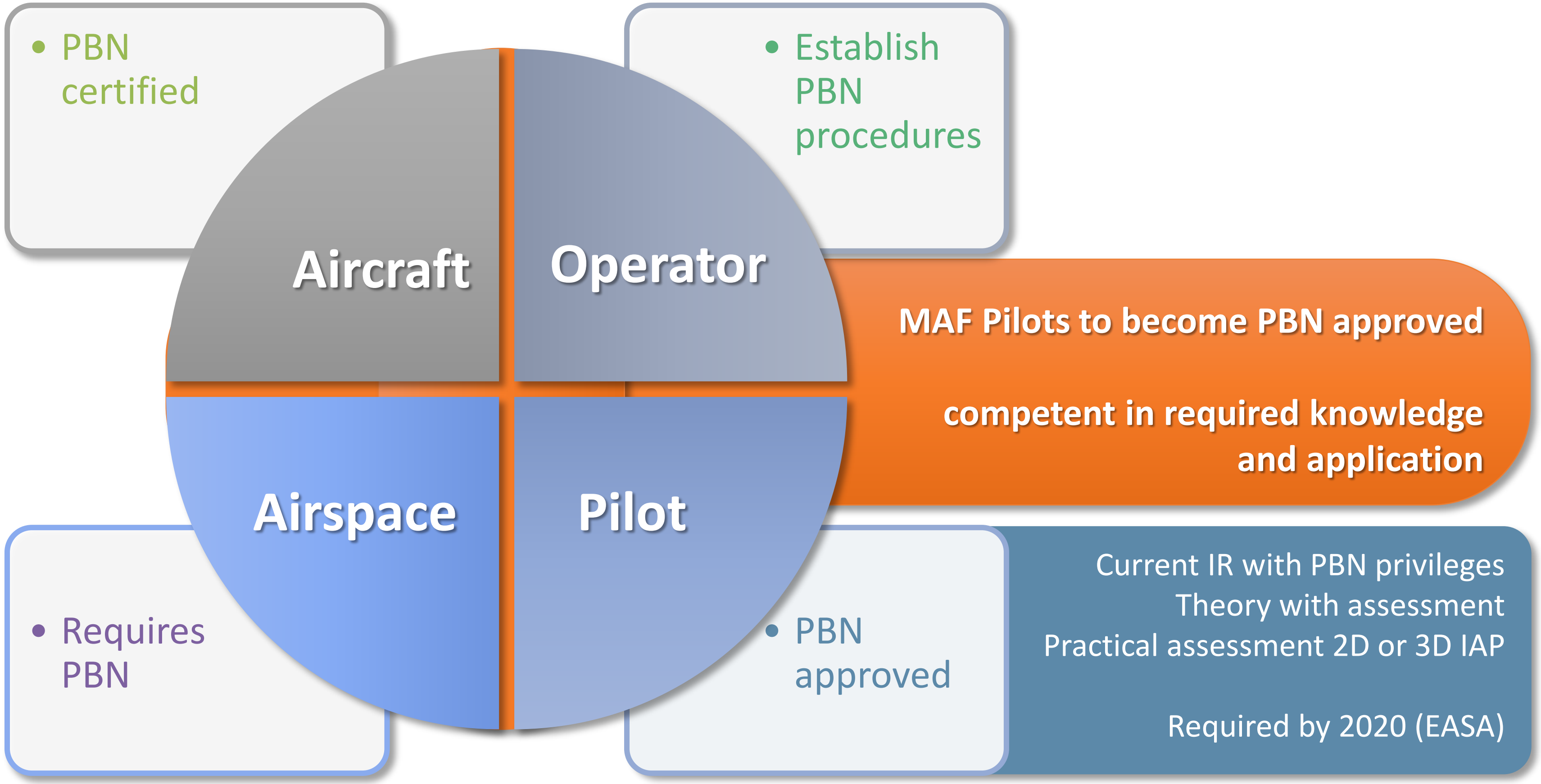


Part 4 - PBN Application

The Four requirements of PBN

WAIKATO AVIATION ACADEMY

The Four requirements of PBN



Human Factors

System Management and Technology

As compared to traditional flight management based on ground based Navaids, operations under PBN are more heavily focused on the management of systems and reliable application of technology. There is a shift away from a focus on handling skills to competency in the management of systems and safe application of technology.

Risk: Not to become knowledgeable, accurate and competent in applying a systems and technology based approach to your flying. Operate without foundational understanding of PBN.

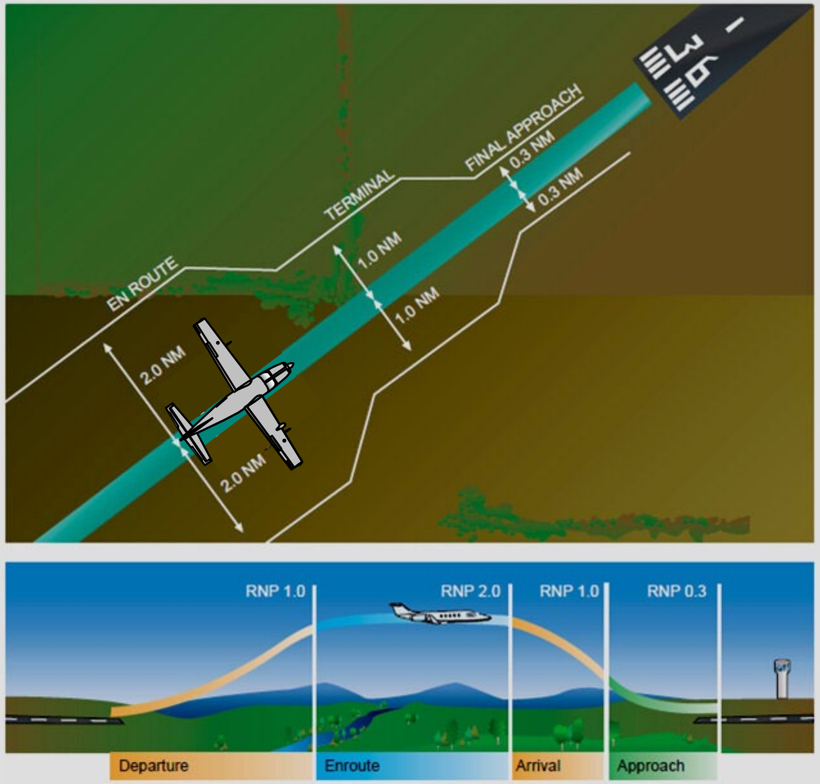


Figure 1-11. Required Navigation Performance.

Human Factors

Data entry and cross checks

The combination of high reliability in the navigation system but with detailed data entry requirements and cross checking is an area of significant risk. The human condition favours taking short cuts and negating the importance of consistently cross checking database information with the charts.

Risk: A tendency towards a disregard to cross checking the reliability of the data due to an extrapolated period of reliability. This relaxation does not protect you from human error.

Human Factors

Automation induced complacency

GPS has an excellent record and the continued experience of using such a highly accurate navigation system can lead to an impression of infallibility.

Monitoring of the system for gross errors becomes tedious; as the system appears to do it all for you and the temptation simply to trust the system regardless, becomes powerful.

Risk: This can result in a form of complacency that leaves the pilot more vulnerable to error and to failure or inaccuracy of the system for whatever reason


WAIKATO AVIATION
Go Beyond
Waikato Aviation
Performance Based Navigation (PBN) Assessment
Click the Start button to proceed
Waikato Aviation PBN

START

Flight Planning - PBN

1. Aircraft's PBN specifications

2. Airspace PBN capability

3. Confirm destination approaches published as RNP or conventional and check destination and alternate minima requirements.

4. Confirm GNSS navigation as primary means or sole means. Primary means requires conventional Navaid redundancy for alternate planning. Ask the question: **What will I do if I lose GNSS signals?**

5. Check RAIM availability for flight using local or international tools e.g.

6. Check weather picture, if unable to receive a reliable TAF, or if weather reporting information is limited from AIS provider, careful assessment through reliable sources must be obtained. If unable to gain reliable/accurate information, you will need to carry additional fuel to achieve a reliable weather alternate or hold a very reliable VFR alternate. You will also need to comply with NAA SEIFR aerodrome requirements.

7. Complete flight planning and preparation tasks as per VFR operations, e.g. Weight and Balance, Performance and MEL considerations

Pre-Flight - PBN

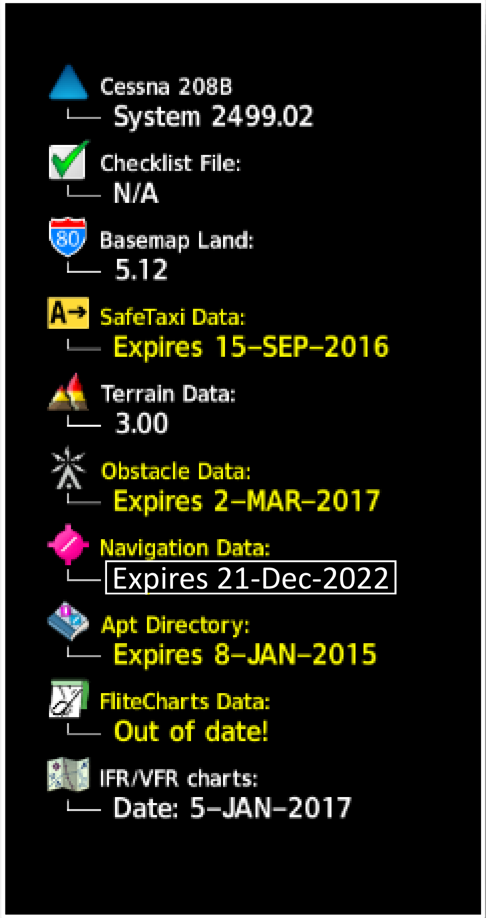
1. GNSS data base **<u>must</u>** be current and with required coverage

2. CDI scaling – automatic

3. SBAS on if available

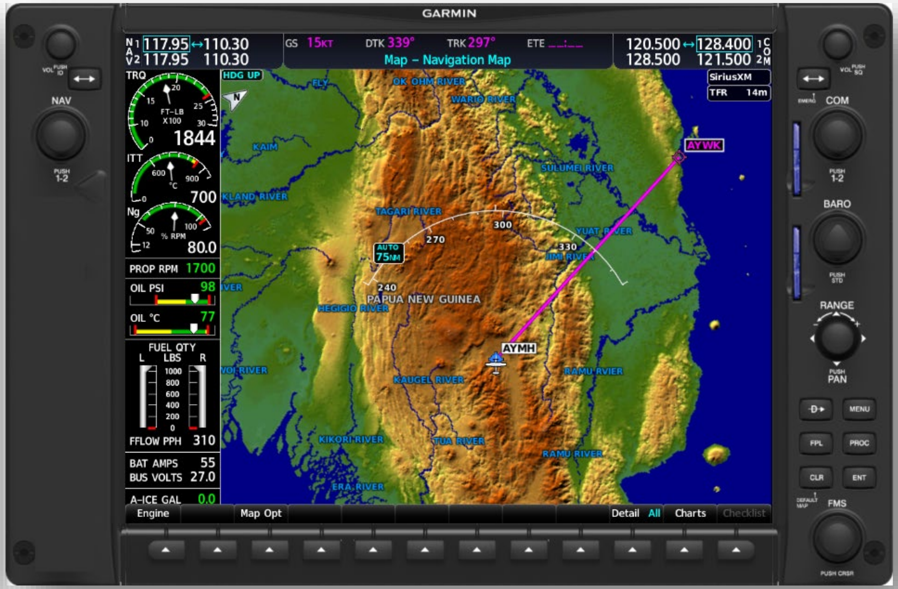
4. WGS84?

5. Navigation system consistent with display of required parameters DTK, GS, DIS, Time, CDI



Pre-Taxi - PBN

1. GNSS **Active**
2. TAWs system active and OK
3. FPL GNSS tracks checked with flight Log
4. GNSS route ranged out for “big picture” confirmation
5. Instrument check during taxi



Departure - PBN

Departure procedure available

1. Load and Activate SID with destination entered

2. Confirm database waypoints and sequencing against chart.

Departure procedure not available – Visual Departure to AMA or Route LSALT

1. Lateral guidance available by 500ft agl, confirm **DEPT or TERM** annunciator

2. Carefully plan flight path clear of weather/terrain remaining in VMC to get to AMA or Route LSALT. MFD maps are displayed for departure on correct scaling until AMA / LSALT with careful management of Rad Alt and TAWs system. Left hand PFD inset <u>**MUST**</u> have TAWs overlay set to about 10 nm range. Red in the box is a warning.

3. If airspace is busy, consider having Nearest in RH inset up to provide you with a quick bearing and distance to departure airport.

4. Carefully consider contingency responses in the situation of engine, navigation systems or GNSS LOI during the climb segment.

Automation - PBN

Autopilot

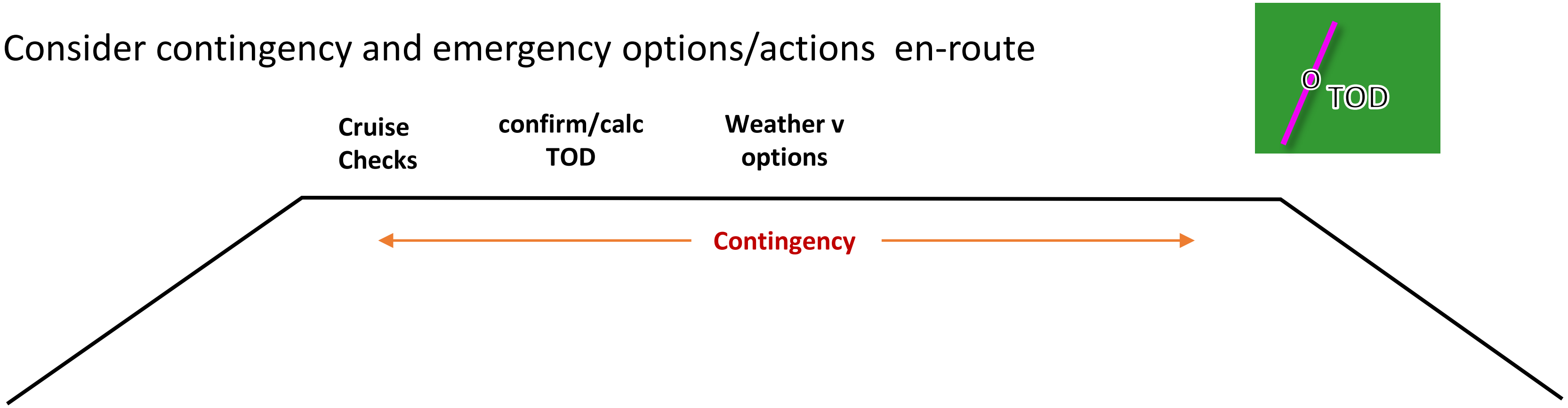
1. Must be proficient in knowledge and application, especially **VNV,** Arm mode, Active mode.
2. Must be knowledgeable on autopilot limits, minimum operational heights above terrain
3. Utilise autopilot to enhance situational awareness when workload is high.
4. When engaging modes, always check for stability of mode and cross track with mode annunciation prior to diverting attention.
5. Consider level of automation. Sometimes heading mode is safer than TRK/GPS mode.

TAWS and SVS

1. TAWS must always be on and at least the left hand inset window displaying TAWs terrain scaled to provide adequate forward monitoring.
2. SVS must always be on to provide visual warnings of lowering terrain separation.
3. Become familiar with the SVS picture when in VMC to gain more accurate appreciation of representation of information

En-route - PBN

1. Complete Cruise Checks and confirm **ENR** annunciator, CDI should be set to 2 nm FSD
2. Calculate next event time/location (normally top of descent) so as to establish a time frame until the next flight phase. Therefore once in the cruise with cruise checks complete, confirm TOD position. You may want to insert an altitude into the FPL page to activate VNV and display TOD on track ahead. The altitude that you insert should be no lower than the minimum commencement altitude of the destination approach.
3. Ensure routing is in accordance with SE IFR RISK profile
4. Project ahead and monitor approach requirements at the earliest – weather, traffic, risks, **options and trends**
5. Monitor routing and AMA / LSALT requirements
6. Consider contingency and emergency options/actions en-route



Prior to top of descent *(load and check)*

1. Select and load approach procedure and appropriate IAF. Check waypoint sequence against chart.

2. Carry out **I** of IBC and check RAIM prediction on G1000 for destination. The **RAIM** check is valid for 15 minutes either side of the selected time. Checking the satellite status of EPU and HDOP/HFOM can provide greater insight as to the position estimation accuracy on the day.

3. Check for conventional Navaid redundancy (if any) and set up for a loss of PBN on finals track.

4. Plan when you will activate the approach before IAF and carry out your "approach **B**riefing " and "pre-landing **C**hecks". Activation is the point at which you will track from en-route to IAF.

5. CFIT assessment
   - Check MSAs and TAAs relevant to route and approach
   - Check DME/GNSS altitude restrictions
   - Check terrain separation and weather impacts for descent
   - Check terrain separation when diverting from DCT to track to IAF

6. Select the VNV mode on the autopilot to arm VPTH (normally done with VNV warning)

7. Check Altimetry Baro and Rad Altimeter

Prior to IAF - Activate approach *(<u>activate</u> and <u>brief</u>)*

1. <u>Activate</u> the approach
2. Carefully consider CFIT risk with new routing to IAF
3. Check **“big picture”** makes sense
4. Confirm Waypoint sequencing
5. <u>Brief</u> the Approach in logical sequence as per OM-B
   - Review approach segment distances (5 nm), and any flyover waypoints
6. Carry out **Pre-landing Checks** about 5nm before IAF unless you foresee high workload approaching IAF, then complete Pre-Landing checks earlier.

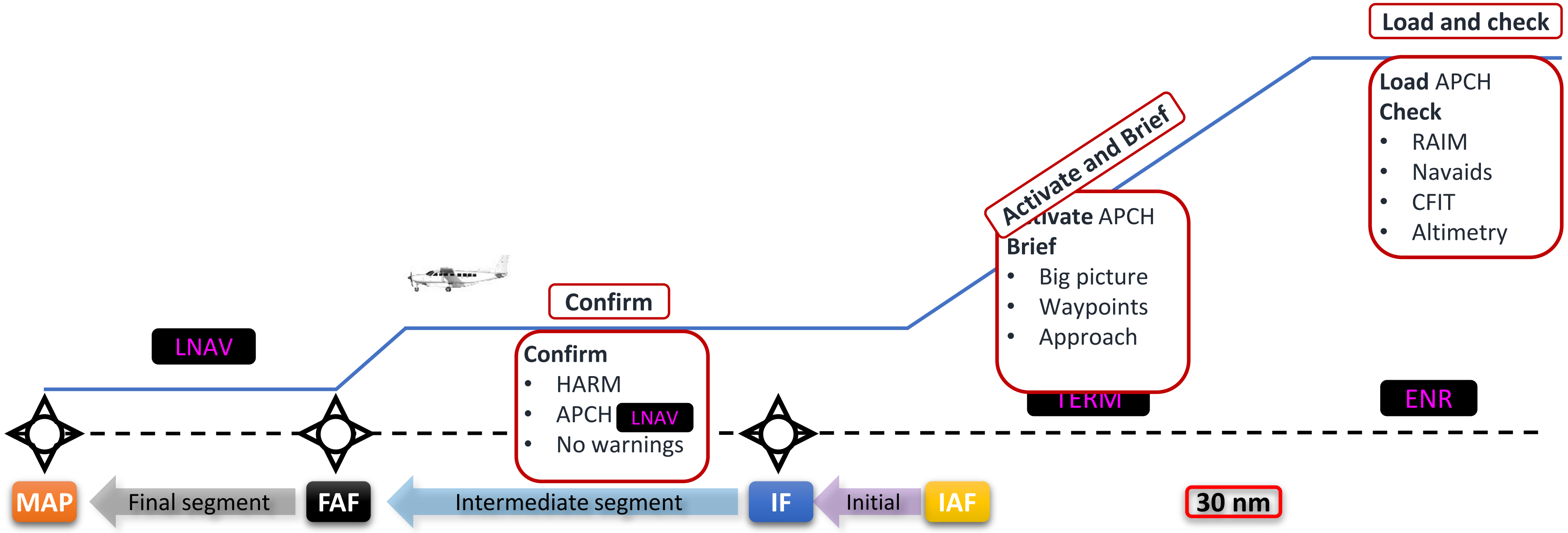
Approach (IF - FAF) *(confirmation)*

1. Confirm HARM checks and missed approach procedure (HAR**M**) (tracks, altitudes, hold)

2. Within **2 nm** of the FAF confirm activation of **LNAV** (or other APR available), otherwise go missed approach.

3. Confirm no other cautions, warnings, flags

4. LNAV approach without SBAS is 0.3 nm linear (sensitivity remains the same). Endeavour to remain within ½ scale deflection.



Missed Approach

1. Activate the missed approach **after** passing the Mapt, by cancelling the suspend mode.

2. As the missed approach may be unexpected, reference Aviate, Navigate, Communicate

3. You should have some back-up plan in place in the situation of not being able to carry out the missed approach using the GNSS, either conventional Navaids, DR or independent system e.g. ipad.

Contingency on Approach

1. Loss of Navigation
2. Loss of Integrity
3. Loss of SBAS signal
4. Loss of VNAV capability
5. Disparity between GNSS and conventional Navaids (overlay)
6. Other messages warnings during the approach
7. Reverting to alternative navigation techniques