

getting to grips with

RNP AR

Required Navigation Performance
with Authorization Required

FEBRUARY 2009



AIRBUS

FOREWORD

The purpose of this brochure is to provide Airbus aircraft operators with the agreed interpretations of the currently applicable RNP AR regulations.

Should any deviation appear between the information provided in this brochure and that published in the applicable AFM, MMEL, FCOM and SB, the information given in above publications shall prevail unless agreement is obtained from the local operational authorities.

The brochure's objective is to provide recommendations, which satisfy RNP AR operational and certification requirements in order for an airline to obtain operational approval from the national operational authorities.

All recommendations conform to the current regulatory requirements and are intended to assist the operators in maximizing the cost effectiveness of their operations.

All brochure holders and users are encouraged to forward their questions and suggestions regarding this brochure.

Any questions with respect to information contained herein should be directed to:

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Main changes from previous edition are highlighted this way: **new wording**

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1. INTRODUCTION

The Performance Based Navigation concept allows to optimize the instrument procedure design with the aircraft navigation performance.

This concept is used en route, to reduce aircraft separation, and in terminal area to optimize arrival and departure procedures. The utmost development of Performance Based Navigation for approach, missed approach and departure is known under different names.

FAA initially referred to RNP SAAAR Operations, SAAAR standing for Special Aircraft and Aircrew Authorization Required.

ICAO now refers to RNP Operations with Authorization Required (RNP AR).

In this document we will use preferably the acronym RNP AR, instead of RNP SAAAR, which has an equivalent meaning.

Compared to standard RNAV approach procedures, the RNP AR approach procedures are characterized by:

- RNP values ≤ 0.3 NM and/or
- Curved flight path before and after the Final Approach Fix (FAF) or Final Approach Point.
- Protection areas laterally limited to $2 \times \text{RNP}$ value without any additional buffer.

These approach procedures are always designed to be flown with baro-VNAV capability.

RNP AR operations may include missed approach procedures and instrument departures with reduced RNP ($< 1\text{NM}$).

The RNP AR operations are accessible to aircraft and operators complying with specific airworthiness and operational requirements.

This brochure aims at providing Airbus customers with the background information necessary to launch an RNP AR project.



2. BACKGROUND

The RNP concept has already a long history. It has been developed by different organizations (ICAO, FAA, JAA/EASA, RTCA,...) for different types of use.

This multi-path history had the unfortunate effect that the acronym RNP (Required Navigation Performance) is related to different definitions with different levels of performance for different uses.

To illustrate this situation, we can mention the following uses of the RNP acronym:

- For enroute and in terminal area, we can see reference to an RNP, which is only a level of navigation accuracy, for example:
 - RNP 10 in oceanic area
 - RNP 1 or 2 in terminal area

Note: ICAO proposes now to use terms such as RNAV-1, or RNAV-2 for operations in terminal area with navigation accuracy requirements.
- RNP definition of the “Minimum Aviation System Performance Standards” (MASPS) EUROCAE/RTCA ED-75/DO-236
 - This definition includes requirements for:
 - Accuracy of navigation,
 - Integrity of containment,
 - Continuity of containment.
 - Equipment complying with this standard can fly RNP 0.3 RNAV approach procedures sometimes called RNP RNAV or RNP APCH, or basic RNP

Note: The terminology for this type of approach is still under discussion (early 2008)

- RNP definition of the FAA SAAAR requirements or ICAO Performance Based Navigation Manual (PBN Manual)
 - The level of performance goes beyond the requirements of EUROCAE/RTCA ED75/DO-236 MASPS
 - The operational requirements contribute to the overall Target Level of Safety (TLS)
 - The interpretation of this contribution is not harmonized between FAA and EASA.

A SAAAR operation was first introduced in the USA to develop “private” or “tailored” procedures based on a temporary FAA Notice (8000.287/300). In a later stage FAA has developed “public” SAAAR procedures design criteria (FAA Order 8260.52) and the associated operational specification (FAA AC90-101).

These procedures are “public” as they are published and available to all operators with a special authorization. This does not prevent an operator from developing “private” or “tailored” SAAAR instrument procedures with more flexible criteria, provided the concurrence of FAA or the relevant national authorities is obtained.

The ICAO, which has first introduced the RNP concept in the Manual for Required Navigation Performance (DOC 9613), has developed a new document called Performance Based Navigation (PBN) manual to address RNAV/RNP operations including RNP operations with Authorization Required (RNP AR). This manual is planned to replace ICAO DOC 9613. ICAO OCP (Obstacle Clearance Panel now called IFPP for Instrument Flight Procedure Panel) has published a final draft (2008) of a document called RNP AR Procedure Design Manual with some inputs from aircraft manufacturers, EASA and other regulatory authorities.

RNP AR Departures have been developed and are used although there is no published criteria for the time being (early 2008) to design such departures. Procedures designers have developed their own criteria based on the missed approach criteria of the FAA Order.

This brochure is based on the documents published by the FAA for “public” RNP AR (SAAAR) operations and the ICAO PBN Manual.

2.1. REFERENCES

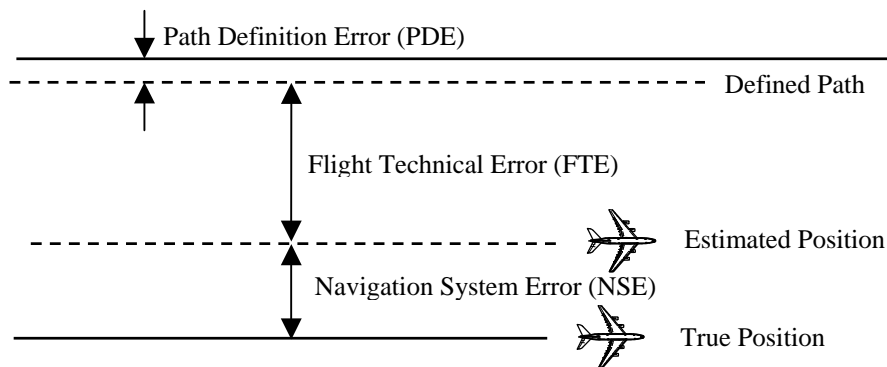
ICAO DOC 9613	MANUAL FOR REQUIRED NAVIGATION PERFORMANCE
ICAO	PERFORMANCE BASED NAVIGATION MANUAL
ICAO OCP (now IFPP)	REQUIRED NAVIGATION PERFORMANCE AUTHORIZATION REQUIRED, PROCEDURE DESIGN MANUAL
ICAO OCP (now IFPP)	DOC 8168 PANS OPS
FAA Order 8260.52	UNITED STATES STANDARD FOR REQUIRED NAVIGATION PERFORMANCE (RNP) APPROACH PROCEDURES WITH SPECIAL AIRCRAFT AND AIRCREW AUTHORIZATION REQUIRED (SAAAR)
FAA AC90-101	APPROVAL FOR REQUIRED NAVIGATION PERFORMANCE (RNP) PROCEDURES WITH SPECIAL AIRCRAFT AND AIRCREW AUTHORIZATION REQUIRED (SAAAR)
FAA AC20-129	AIRWORTHINESS APPROVAL FOR VERTICAL NAVIGATION SYSTEMS
ED 75 / DO236	MINIMUM AVIATION SYSTEM PERFORMANCE STANDARDS: REQUIRED NAVIGATION PERFORMANCE FOR AREA NAVIGATION
ED 76 / DO200A	STANDARD FOR PROCESSING AERONAUTICAL DATA.
EASA	AMC 20-26 AIRWORTHINESS AND OPERATIONAL APPROVAL OF RNP AR OPERATIONS



3. THE RNP CONCEPT

3.1. DEFINITIONS

The definition of the navigation error components is given in the drawing below (in a simplified manner) assuming that the AP is used.



The PDE has been demonstrated negligible, provided there is no systematic error such as navigation database coding error or error due to inadequate geodesic reference (other than WGS84).

The FTE is a characteristic of the pilot performance using FD or the Auto-Pilot guidance performance in the steering of the aircraft on the FMS defined flight path. The FTE has a cross-track statistical distribution.

The NSE is the error made by the navigation system in the computation of the aircraft position. The NSE has a circular statistical distribution around the aircraft true position. From this circular distribution, it is possible to derive a cross-track component of the NSE, which is relevant for the RNP lateral navigation.

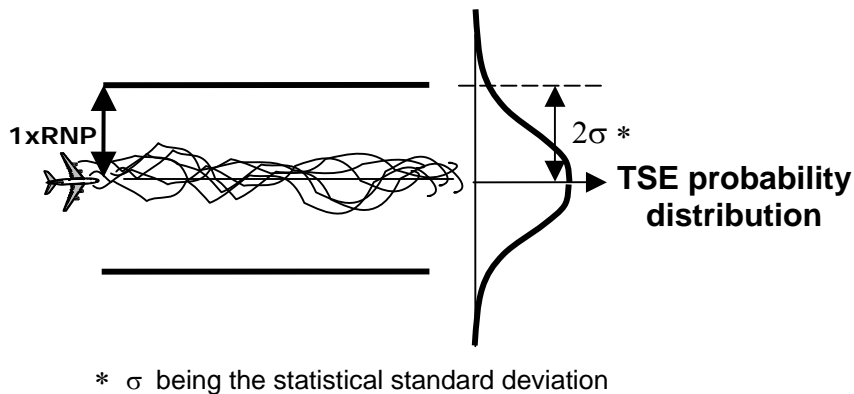
The Total System Error (TSE) is defined as follows:

$$TSE = \sqrt{(FTE)^2 + (NSE)^2 + (PDE)^2}$$

For the purpose of further development in this document the following simplified equation will be considered:

$$TSE = \sqrt{(FTE)^2 + (NSE)^2} \quad (1)$$

The TSE, which is calculated with equation (1) above has consequently as well a statistical distribution in cross-track direction as illustrated below.



3.2. THE LATERAL NAVIGATION REQUIREMENTS OF MASPS ED-75/DO-236

The three requirements of MASPS ED-75/DO-236 on lateral navigation performance for RNP are:

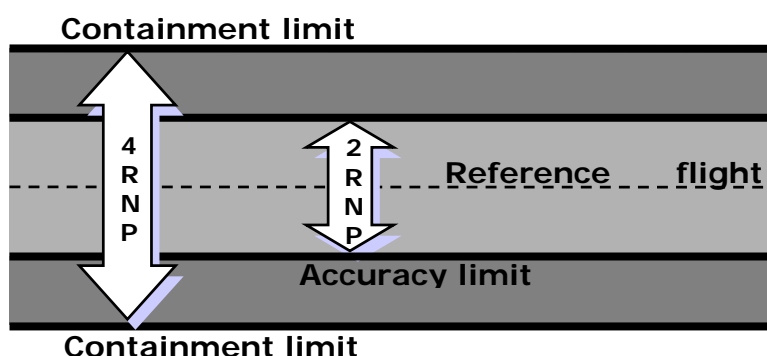
1°Accuracy:

Each aircraft operating in RNP airspace shall have Total System Error components in the cross-track and along track directions that are less than the RNP value for 95% of the flying time.

The TSE must be < RNP value for 95% of the flying time.

2°Containment Integrity

The probability that the Total System Error of each aircraft operating in RNP airspace exceeds the specified cross track containment limit without annunciation shall be less than $10^{-5}/\text{FH}$. The cross track containment limit is twice the RNP value.



The probability of TSE > Containment limit must be < $10^{-5}/\text{FH}$.

3°Containment Continuity

The probability of annunciated loss of RNP capability shall be less than $10^{-4}/\text{FH}$.

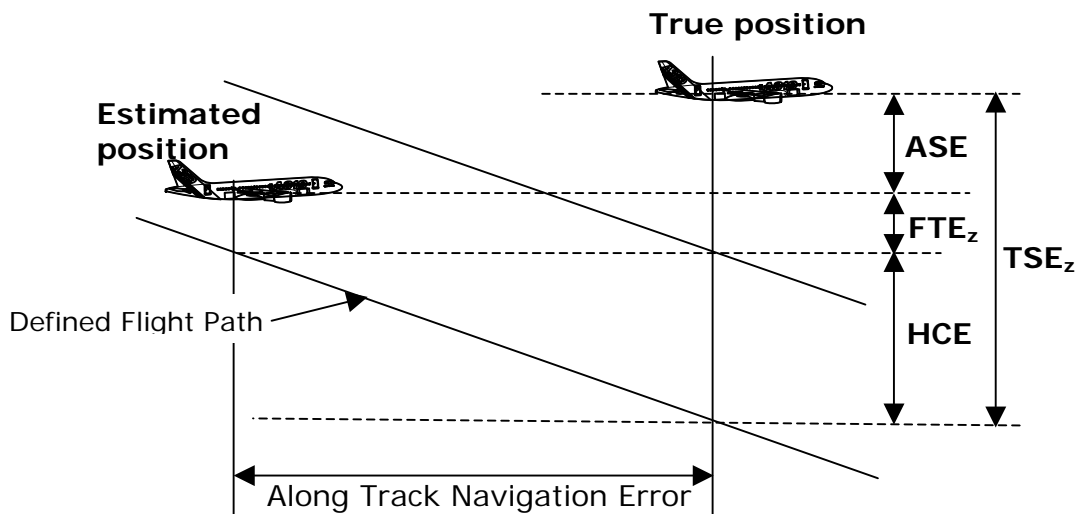
3.3. THE VERTICAL NAVIGATION REQUIREMENTS OF MASPS ED-75/DO-236

The along track navigation error on a descending vertical flight path induces a component of the vertical error called Horizontal Coupling Error (HCE).

The pilot performance using FD, or the performance of the guidance system, to control the aircraft on a vertical flight path is characterized by a vertical Flight Technical Error (FTE_z).

The Barometric Vertical NAVigation (Baro-VNAV) is a navigation capability of the FMS that computes vertical guidance referenced to a specified vertical path. The vertical guidance is based on barometric altitude.

This means that the Altimetry System Error (ASE) is also a component of the vertical Total System Error (TSE_z).



The Total System Error (TSE_z) is defined as follows:

$$TSE_z = \sqrt{(FTE_z)^2 + (HCE)^2 + (ASE)^2}$$

Each aircraft operating in airspace where vertical performance is specified shall have a Total System Error in the vertical direction (TSE_z) that is less than the specified performance limit 99.7% of the flying time.

For example, the specified performance at or below 5000ft in ED-75/DO-236 is 160 ft.

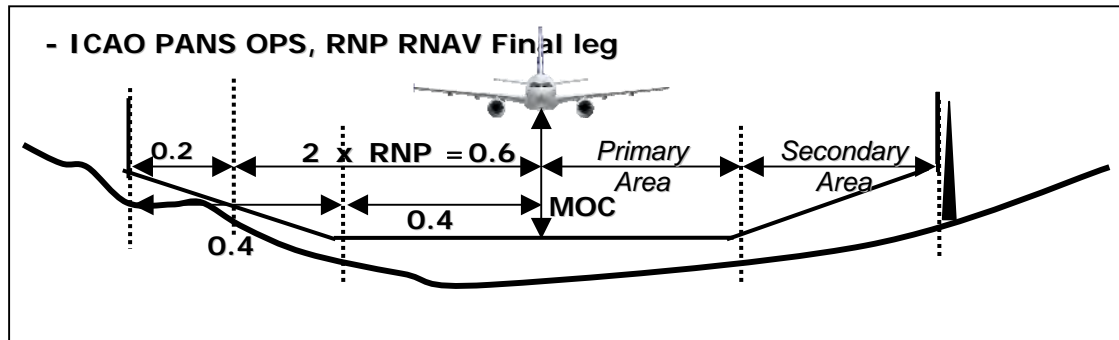
There is no integrity and continuity requirement for the vertical navigation.

3.4. INSTRUMENT APPROACH PROCEDURE DESIGN CRITERIA

The instrument approach procedures are designed using either ICAO PANS OPS or FAA TERPS standards. These standards define the protection area, which must be clear of obstacles. The size and the shape of these protection areas are a function of the type of approach and the accuracy of the associated navigation means.

For RNP RNAV approaches designed with ICAO PANS OPS criteria (DOC 8168 §33 or §35 amdt 12), which are straight in approaches from the IF (Intermediate Fix) with RNP 0.3 NM, the lateral obstacle protection areas include a buffer in addition to the 2RNP half width corridor (see figure below). For example in the final approach leg the buffer is 0.2 NM and the Minimum Obstacle Clearance (MOC) is a fixed value of 250ft.

Note: These paragraphs of PANS OPS are planned to be modified in 2008 or later.



All Airbus aircraft with FMS and GPS, are certified for basic RNP approach in compliance with the ED-75/DO-236 and thus can fly this type of RNP RNAV approaches.

For RNP AR instrument approach procedures designed with the criteria of FAA Order 8260.52 or the ICAO RNP AR procedure design manual, the protected area is limited to $4 \times \text{RNP}$ (2RNP on both sides of the flight path **without buffer**) and the value of the RNP can be as low **as 0.1 NM**. The Required Obstacle clearance is linked to the aircraft Vertical Error Budget (VEB). The VEB has 3 main components, one associated with the aircraft navigation system longitudinal navigation error, the ASE and the FTE.

Note: The definition of the VEB is very similar to the definition of the TSE_z given in § 3.3 above.

The density of obstacle is not very often as suggested in the picture below, but it is the situation that the aircraft manufacturer has to take into consideration for the aircraft certification.



In addition, during RNP AR approach procedures, the intermediate and final approach legs can include turns (Radius to Fix (RF) FMS legs) even shortly before DA (Decision Altitude). It has been envisaged that in some cases the DA will be reached during a turn.

The RNP AR approach procedures are always designed to be flown with FMS vertical navigation based on Baro-VNAV principle.

Considering the more demanding environment of RNP AR, the authorities have developed more stringent regulations in addition to the MASPS ED-75/DO-236 of §3.2 and 3.3 above. These regulations involve certification but also operational requirements (FAA AC 90-101, OACI PBN Manual, AMC 20-26).

3.5. ADDITIONAL NAVIGATION REQUIREMENTS FOR RNP AR

As the obstacles can be located as close as a distance equal 2 times the RNP value, the probability to exceed this containment limit without annunciation must be lower than the 10^{-5} /FH of MASPS ED-75/DO-236.

All authorities have set the Target Level of Safety (TLS) at 10^{-7} /procedure for this type of operations. The challenge is that the existing on board navigation systems (FMS with IRS, GPS updating and AP guidance) are not capable to achieve this target without operational mitigations.

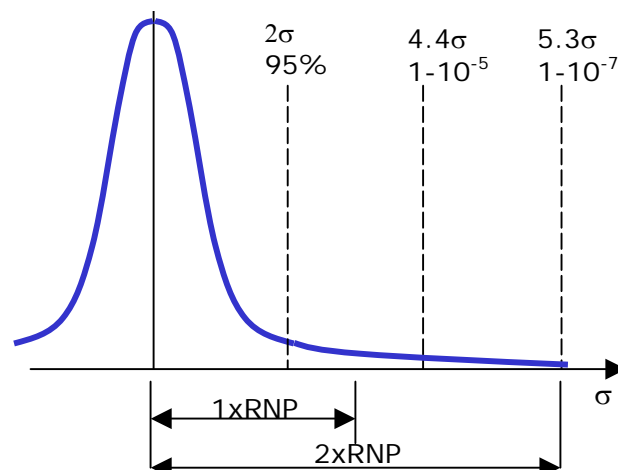
This is why a special authorization is required to ensure that operational procedures and pilot training will contribute at the adequate level to meet the expected target of level of safety.

To achieve this safety objective at the aircraft design level alone would require a new design architecture similar to what we have for CATII or CATIII operations. But for the time being no aircraft manufacturer has designed such a system. The RNP AR operational concept has been developed to take the best advantage of existing system architecture complemented by the most efficient operational standards.

If an overall target level of safety of 10^{-7} /procedure including the effect of failure cases cannot be demonstrated in certification alone without operational mitigation, the probability to exceed the containment limit at $2 \times \text{RNP}$ in normal conditions (without system or engine failure) can be demonstrated to be less than 10^{-7} /procedure.

This is computed with the statistical distribution of the TSE in the cross track direction for $5.3 \times \sigma$, (σ being the statistical standard deviation of the TSE distribution). We can see on the drawing below that this condition is more constraining than the accuracy requirement at $1 \times \text{RNP}$ (95% of the time ($\sim 2 \times \sigma$)).

TSE distribution in normal conditions



To demonstrate this level of performance, in addition to the NSE, the FTE also needs to be determined statistically based on flight and simulator tests. The statistical determination of the FTE has to consider the various conditions that may affect the flight path steering: tight turns, high speed, rare wind conditions, ...

In addition, the effect of failures on the FTE must be evaluated deterministically on a worst case basis.

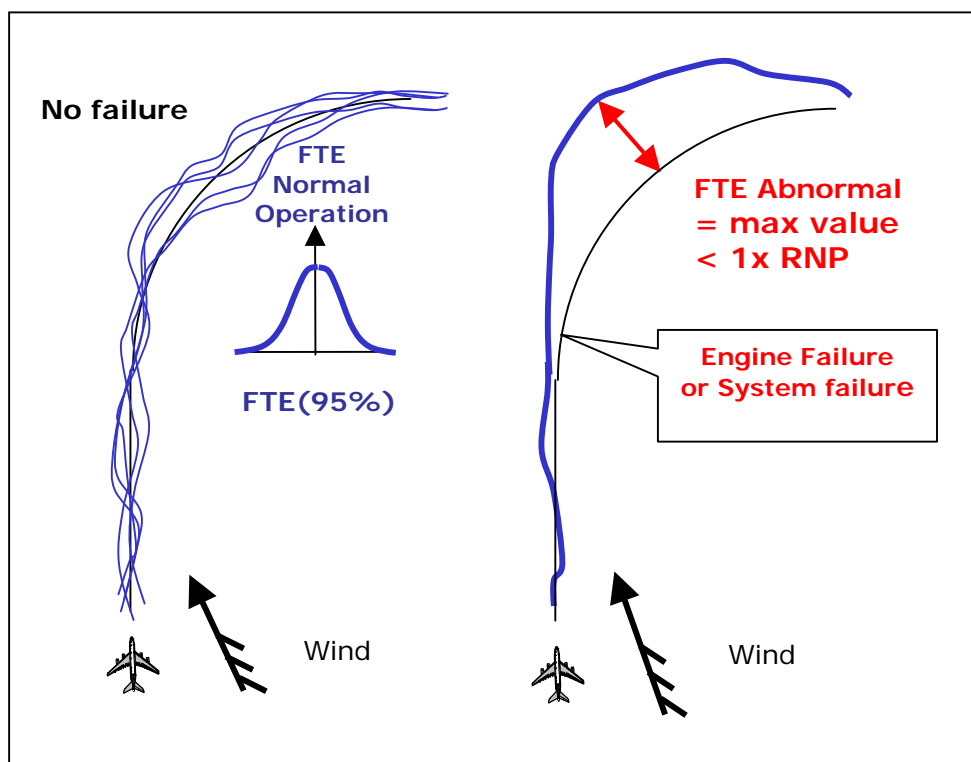
The One Engine Inoperative (OEI) condition and the effect of probable aircraft system failures tend to become the dimensioning conditions for the flight path steering performance and the FTE determination.

There are today 2 different positions for the FTE OEI evaluation:

- FAA considers the Engine failure condition as a remote event, and defers FTE OEI evaluation to the Operational approval. This means that the published RNP level for FAA certification is determined basically with All Engines Operative (AEO). During the operational demonstration, the Airline is expected to demonstrate that the engine failure will be contained **within the $\pm 2 \times \text{RNP}$ limit**.
- EASA considers that FTE OEI has to be evaluated during certification, **to demonstrate that the engine failure will be contained within the $\pm 1 \times \text{RNP}$ limit**. This FTE OEI must not be determined statistically but deterministically considering the worst case (tight turns, adverse wind conditions).

EASA standard for RNP AR also requires the aircraft manufacturer to reassess the effects of aircraft system failures in RNP AR environment to demonstrate that the probable failures (probability $> 10^{-5}$ /procedure) can be contained **within $\pm 1 \times \text{RNP}$** , including the failure of:

- RNP systems
- Flight controls
- Flight Guidance



EASA also requires that:

- The remote system failures (probability from 10^{-5} to 10^{-7} /procedure) can be contained **within $\pm 2 \times \text{RNP}$** ,
- The aircraft remains maneuverable for a safe extraction after extremely remote system failures (probability from 10^{-7} to 10^{-9} /procedure).

Pending further harmonization and maturity of the RNP AR standards, the EASA compromise is to allow the aircraft manufacturer to document both :

- RNP levels associated to the TSE in normal conditions, and
- RNP levels associated to the TSE with OEI or following probable/remote system failures.

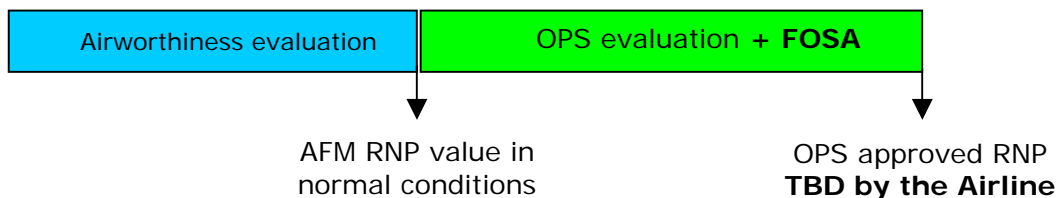
The vertical navigation requirements for RNP AR (SAAAR) are similar to those of the MASPS (described in §3.3).

The vertical system error includes altimetry error (assuming the temperature and lapse rates of the International Standard Atmosphere), the effect of along-track-error, system computation error, data resolution error, and flight technical error. The vertical system error with a 99.7% probability must be lower than the value given in the following formula (in feet):

$$\sqrt{\underbrace{((6076.115)(1.225)\text{RNP} \cdot \tan \theta)^2}_{\text{Component of the navigation error}} + \underbrace{(60 \tan \theta)^2}_{\text{WPT resolution error}} + \underbrace{75^2}_{\text{FTE}_z} + \underbrace{((-8.8 \cdot 10^{-8})(h + \Delta h)^2 + (6.5 \cdot 10^{-3})(h + \Delta h) + 50)^2}_{\text{ASE}}}$$

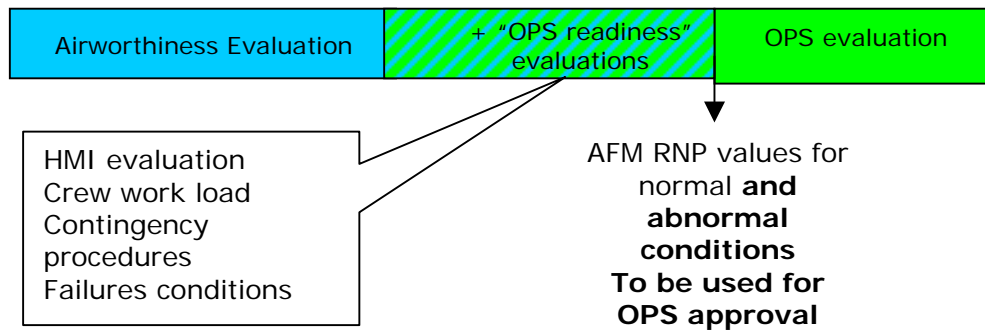
where θ is the vertical navigation (VNAV) flight path angle, h is the height of the local altimetry reporting station and Δh is the height of the aircraft above the reporting station. The FTE_z does not need to be determined statistically if the fixed 75ft value is established as an operational limit for maximal vertical deviation.

The difference of point of view between FAA and EASA lies in the line of demarcation between the airworthiness and the operational domain. For the FAA the contribution to the Target Level of Safety deferred to the operational approval is much greater as indicated comparing the two schematics below.



The airline has to conduct a Flight Operational Safety Assessment (FOSA) to determine, in the specific environment of the intended operation, the level of RNP adequate to cope with the abnormal conditions (engine failure, system failures).

The EASA objective is to facilitate the operational approval looking after the operational readiness during the RNP certification of the aircraft.



The Flight Manual provides approved data for RNP in normal and abnormal conditions. The RNP values in abnormal conditions with the associated training requirements can be used by the airline to significantly reduce or replace the need to perform a FOSA.



4. CERTIFIED RNP CAPABILITY

4.1. THE “BASIC” RNP CERTIFICATION BASED ON MASPS ED75/DO236

For Airbus aircraft with GPS, the compliance to the performance requirements of the MASPS ED75/DO236 have been demonstrated as specified in the AFM for the following typical RNP values.

	AP OFF, FD ON	AP ON
Terminal Area	0.51 NM	0.5 NM
Approach	0.3 NM	0.3 NM

For this initial basic RNP certification, the FTE was not determined in flight. Instead the default FTE values accepted without demonstration by DO208 (Minimum Operational Performance Standards for Airborne Supplemental Navigation Equipment Using Global Positioning System) were used.

DO 208 extract:

FLIGHT PHASE	MANUAL (nmi)	COUPLED	
		FLIGHT DIRECTOR (nmi)	AUTOPILOT (nmi)
Oceanic	2.0	0.50	0.25
En Route	1.0	0.50	0.25
Terminal	1.0	0.50	0.25
Approach	0.5	0.25	0.125

FTE values
used for
certification

The NSE measured in flight tests and the above default FTE values were used in the equation (1) to demonstrate that the TSE is lower than the RNP value given in the AFM.

For aircraft without GPS, only the accuracy performance criteria of MASPS ED-75/DO-236 have been demonstrated. No RNP capability has been claimed in the AFM, albeit the FMS can provide a certain level of integrity, due to series of reasonableness checking before being accepted for FMS position up-dating.

GPS is the only Navigation sensor enabling the rigorous demonstration of containment integrity, so both basic RNP and RNP AR require Navigation solutions based exclusively on GPS.

4.1.1. “LIMITED” RNP AR WITH THE “BASIC” RNP CERTIFICATION

The “basic” RNP certification based on EUROCAE/RTCA ED75/DO236 was mainly intended for flying instrument approach requiring RNP 0.3 or more, designed with standard ICAO PANS OPS or TERPS criteria for straight-in final approaches protected at 2xRNP value plus additional buffers and RNP 1.0 missed approach procedures.

The possibility to operate aircraft certified for “basic” RNP in “limited” RNP AR operations, without the “full” RNP AR certification, is supported by Airbus. The upgrade of the “full” RNP AR package described in paragraph 4.2. below is nevertheless highly recommended.

Although a “limited RNP AR” operations is not defined for the time being in the regulations, Airbus recognizes that all RNP AR operations are not equivalent in terms of exposure. For example, a curved final approach with RNP 0.3 implemented for noise abatement purpose, for airspace management or flight path optimization cannot be compared to an RNP<0.3 AR operation implemented in an environment with a high density of obstacles.

Airbus has initially developed a document called SAAAR Capability and Operational Compliance (SCOC) document for aircraft with Honeywell FMS2 and EIS1. This document not referenced in the AFM is stating an RNP 0.3 AR capability for non-demanding type of operations.

The SCOC was primarily intended for use by operators to support the operational approval by the appropriate regulatory authorities.

Compliance with this document did not grant an operational approval.

The operator and its operational authority were required to determine the adequacy of the aircraft definition with the intended operation.

In front of the difficulties to use the SCOC document and in particular the difficulty for the airlines and the authorities to determine if an operation is in a demanding or non-demanding environment, Airbus has decided not to disseminate the SCOC document any more.

To replace the SCOC document, Airbus intends to propose an RNP 0.3 AR certified capability with reference in the AFM associated with an Airworthiness Compliance Document (see next paragraph).

This capability will cover both the demanding and the non-demanding environment; the aircraft capability will only be limited by the minimum value of the RNP. It should be available by the end of 2009 with:

- FMS R1A Thales or Honeywell for SA aircraft
- FMS Thales R1A or Honeywell P3 for LR aircraft

This means that RNP 0.3 AR will be accessible for example to aircraft with EIS 1 without L/DEV or T2CAS without peaks mode or equivalent.

4.2. “UNLIMITED” RNP AR WITH FULL RNP AR CERTIFICATION

“Unlimited” means RNP AR with RNP values < 0.3 NM. The RNP AR certified capability is stated in the AFM with a reference to a document called ACD (Airworthiness Compliance Document).

The ACD is not distributed automatically. The airlines, which envisage an RNP AR project will need to request it to Airbus.

The ACD has been developed in response to specific requests from the Airworthiness Authorities to provide all the assumptions, limitations and supporting information necessary to conduct safe RNP AR operations.

The ACD includes the required aircraft definition for “unlimited” RNP AR operations.

The main modifications are:

- The L/DEV indication on PFD and the XTK error on ND with 2 digits after the dot ,
- The triple click audio warning in case of loss of NAV or FINAL APP modes (SA),
- The TAWS/EGPWS with peaks mode and capability to use GPS position alone if both FMGC are failed,
- NAV mode automatic re-engagement instead of GA TRACK upon GA initiation.

4.2.1. THE DEMONSTRATED RNP PERFORMANCE DURING CERTIFICATION

The ACD provides the RNP performance in normal and abnormal conditions achieved during flight and simulator tests.

For example the following performance was achieved with the SA Airbus aircraft in normal conditions (no failure):

- Demonstrated NSE: 0.04 NM 95%, NSE_CT * : 0.03 NM 95%
- Demonstrated FTE in FINAL APP mode: 0.07 NM 95%.
- Demonstrated TSE in FINAL APP mode: 0.08 NM 95%.
- Demonstrated FTE in NAV or APP NAV mode: 0.12 NM 95%
- Demonstrated TSE in NAV or APP NAV mode: 0.13 NM 95%

And the following performance has been demonstrated for the A330 in normal conditions (no failure):

- Demonstrated NSE_CT*: 0.01 NM 95%, NSE_AT*: 0.05 NM 95%
- Demonstrated FTE in FINAL APP mode: 0.04 NM 95%.
- In FINAL APP mode:
Demonstrated TSE_CT* = **0.04** NM and TSE_AT* = **0.06** NM 95%.
- Demonstrated FTE in NAV or APP NAV mode: 0.07 NM 95%
- In NAV or APP NAV mode:
Demonstrated TSE_CT* = **0.07** NM and TSE_AT* = **0.06** NM 95%

(*) CT: in cross-track direction, AT: in along-track direction

Typically the following RNP values have been demonstrated in normal conditions (no failure):

RNP AR Normal operations	AP ON		AP OFF with FD
	NAV mode	FINAL APP mode	
RNP SA aircraft	0.17	0.1	0.3
RNP A330	0.1 * * 0.3 in missed approach until implementation of automatic NAV mode reengagement at GA initiation		0.3

4.2.2. AIRCRAFT PERFORMANCE UNDER FAILURE CONDITIONS

With the A330, the following RNP levels have been determined from aircraft and aircrew performance in abnormal conditions including engine failure, latent system failures, Flight Guidance orders runaway, etc.) and are considered as envelope RNP levels following EASA requirements for demanding RNP AR operations. Aircrew performance is assuming ad-hoc training.

For the operator, the use of the hereunder table suppresses the requirement to perform a Flight Operational Safety Assessment (FOSA).

RNP with AR (SAAAR or equivalent) A330	Departure NAV mode	Approach		Missed approach NAV mode
		APP NAV mode	FINAL APP mode	
AP ON	0.3	0.3	0.3	0.3
AP OFF / FD ON	0.3	0.3	0.3	0.3

Alternatively, lower RNP levels may be approved on a case by case basis, based on a FOSA performed by the airline and under responsibility of the national authorities. The aircraft performance under failure conditions documented here below can be used as guidelines, for the national authorities, to determine a RNP level suitable for the considered operations, and ultimately approve it.

The tables below give demonstrated maximum TSE values for different failure conditions. The effects of engine failure and system failures have been assessed in flight and in the simulator.

- **Engine failure and OEI operations**

RNP AR Engine failure	AP ON	
	NAV mode	FINAL APP mode
TSE max in RF* SA aircraft	0.24	N/A
TSE max in TF* SA aircraft	0.18	N/A
TSE max in RF* A330	0.15	0.07
TSE max in TF* A330	0.09	0.07

(*) TF: Track to Fix FMS leg; RF: Radius to FIX FMS leg

Upon Engine Failure, Airbus recommends the use of AP, except in approach for SA with FMGC standard requiring to disconnect AP.

Besides engine failure, the effect of other system failures must be taken into consideration. As an example, an extract of the ACD for the A330 is given below.

- **Demonstrated TSE in Probable System Failures conditions**

Probable failures are considered when the probability of occurrence is more than 10^{-5} per operation (based on a 15min exposure time).

Sizing probable failure considered is: loss of FMS guidance.

Probable Failures	Departure	Approach		Missed Approach
		APP NAV mode	F.APP mode	
TSE_{max} in TF (straight) leg	0.10 NM	0.10 NM	0.10 NM	0.10 NM
TSE_{max} in RF (turning) leg	0.15 NM	0.15	0.15 NM	0.15 NM

- **Demonstrated TSE in Remote System Failures conditions**

Remote failures are considered when the probability of occurrence is from 10^{-5} to 10^{-7} per operation (based on a 15min exposure time).

Sizing Remote failures considered are: Loss of NAV mode, AP roll runaway.

Remote Failures	Departure	Approach		Missed Approach
		APP NAV mode	F.APP mode	
TSE_{max} in TF (straight) leg	0.2 NM	0.2 NM	0.2 NM	0.2 NM
TSE_{max} in RF (turning) leg	0.6 NM	0.6 NM	0.6 NM	0.6 NM

- Extremely Remote failures are considered when the probability of occurrence is from 10^{-7} to 10^{-9} per operation (based on a 15min exposure time).

Sizing Extremely Remote failures considered are : double severe FMS reset, erroneous FMS position.

For those failures, aircraft remains maneuverable for a safe extraction during a contingency procedure if corresponding procedure is published and made available to the flight crew.

All data of this paragraph are given for example. For a particular Airbus aircraft, the Airlines should refer to the aircraft Flight Manual and the associated ACD.



5. THE NAVIGATION AND GUIDANCE SYSTEM DESIGN

Only a navigation solution with IRS and GPS PRIMARY can meet all the requirements of RNP AR.

Consequently, it is essential to ensure that GPS PRIMARY will be available during the RNP procedure and to alert the flight crew of any loss of RNP capability.

As the FTE was demonstrated with AP ON, the AP guidance must be used in

- NAV and APP NAV for initial approach
- FINAL APP during the final approach
- NAV for missed approach and departure

The crew also needs to monitor the AP performance using the L/DEV and V/DEV indications on PFD, and the ND.

The detailed description of the navigation system and the automatic flight control system can be found in the FCOM.

5.1. NAVIGATION SYSTEM

5.1.1. AVAILABILITY OF GPS PRIMARY

The RNP capability depends on the availability of GPS/IRS integrity. For Aircraft equipped with Litton AIME or Honeywell HIGH ADIRU, the availability of GPS/IRS integrity has been demonstrated to be 100% in approach world-wide for GPS satellite constellation of 24 (or 23, see AFM) satellites.

The use of a Ground-Based Prediction Program is only required when less than 24 (or 23 see AFM) satellites are operative, or RNP<0.3 is intended. **However, in certain environments, such as mountainous terrain, a RNP ground-based predictive capability may be required to determine that the performance is adequate.** In these cases, the appropriate Ground-Based Prediction Program (AIME or HIGH predictive tools) should be used to assure that the performance calculations are representative of those performed in the resident navigation software.

5.1.2. A/C POSITION COMPUTATION

The estimation of the aircraft position is performed by the Flight Management System based on different sensors: Inertial (ADIRU), GPS, radio navigation (DME and VOR).

The FMS computes the best aircraft position estimate based on the following hierarchy of navigation modes:

- GPS/inertial,
- DME/DME/inertial,
- VOR/DME/inertial,
- Inertial only.

- **GPS/Inertial**

The Inertial system (ADIRU) computes the hybrid GPS/Inertial position.

Hybrid signals from IRS/GPS are used to compute GPIRS position.

As long as GPS/Inertial mode is active and integrity is ensured, neither DME/DME nor VOR/DME radio update is performed.

Different algorithms for GPS/Inertial integrity computation are available: NGC/Litton AIME, Honeywell HIGH and RAIM.

With Honeywell HIGH, the integrity estimate (Hybrid- RAIM) is calculated by the ADIRU's using integrity parameters resulting from RAIM computation provided by the MMR plus Air Data parameters for altitude aiding. The satellites exclusion is performed by the MMR.

With Litton AIME, the integrity estimate is calculated by the ADIRU's using the AIME algorithm. The satellites exclusion is performed by the ADIRS.

- **Radio Navigation (DME/DME/Inertial or VOR/DME/Inertial)**

The FMS computes a DME/DME position, if two DME stations are correctly received and their relative geometry to the aircraft is adequate. Otherwise a VOR/DME position can be computed, if at least one VOR/DME station is received. The FMS uses the VOR bearing associated to the DME to compute a VOR/DME position. **The FMS radio-updating is normally not suitable to support RNP AR operations.** To avoid FMS radio updating if GPS PRIMARY is lost, the crew should deselect the radio navaid stations that would be tuned by the FMS.

When basing its navigation on a single VOR/DME, the FMS position may become inaccurate depending on the quality of the ground station being used.

For approaches where ground NAVAIDS are available and could be used by the FMS for radio updating in VOR/DME mode in case of GPS PRIMARY loss, those VOR/DME shall be de-selected by the crew prior starting approach using the Position Monitor Page → SEL NAVAIDS. This de-selection capability is limited to 6 NAVAIDS. If a deselected navaid can be used to support a contingency procedure, this navaid should be tuned for display only. With Honeywell FMS release 1A, it will be possible to inhibit any FMS radio update.

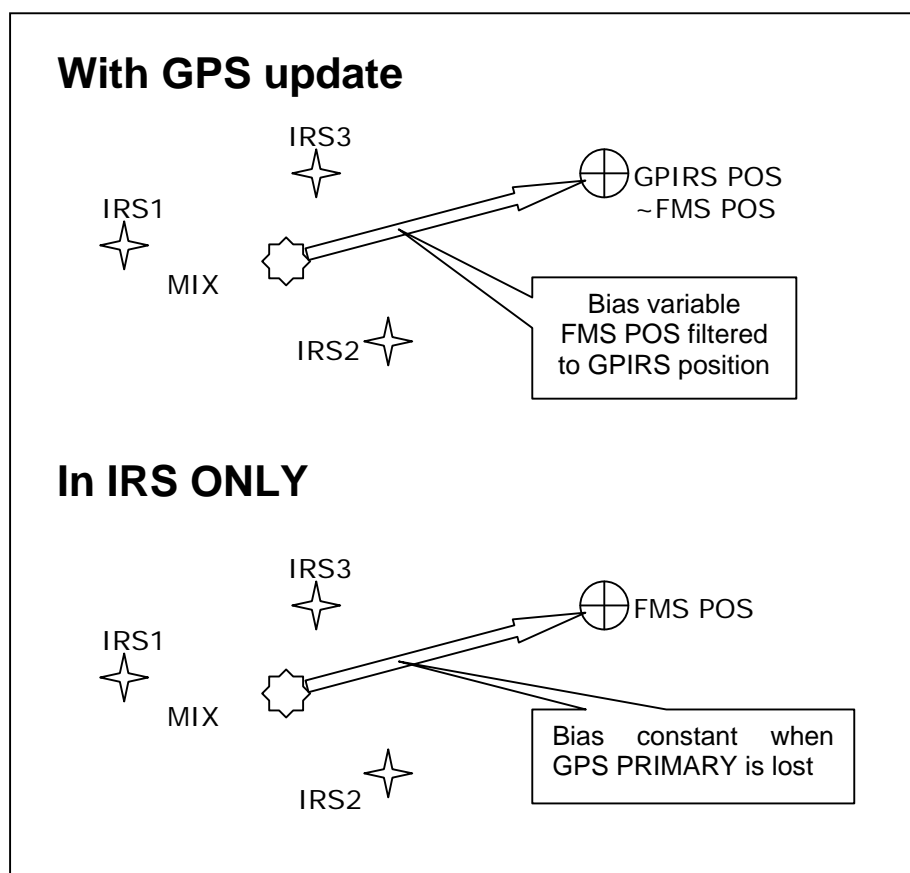
- **Inertial only**

The three ADIRU inputs are used and mixed together within each FMS to provide a MIX IRS position.

In case of IRS failure, each FMS will use its on side IRS (or IRS3).

In Inertial only navigation the FMS position will drift with the drift rate of the triple mixed position or the single IRS position. The last position bias computed between the GPIRS position and the IRS or MIX IRS position remains constant.

The drift rate is small enough to allow the " safe extraction" of the aircraft if a GPS PRIMARY LOST alert appears during the approach.



5.1.3. GPS PRIMARY AND REQUIRED ACCURACY

GPS/IRS mode is the basic navigation mode as long as accuracy and integrity criteria are satisfied:

- $EPE < \text{Required ACCURacy}$, and
- $HIL_{GPIRS} < HAL$

EPE: Estimated Position Error calculated by the FMS

HIL: Horizontal Integrity Limit

HAL: Horizontal Alarm Limit

The HIL is delivered by the RAIM or the AIME, it is the maximum error with an undetected satellite failure. It is a measure of GPS position integrity.

In approach, and in terminal area the $HAL = \text{MIN}(\text{UIL}, 2 \times \text{Required ACCUR})$.

UIL represents the Upper Integrity Limit, which is a function of the FMS flight area.

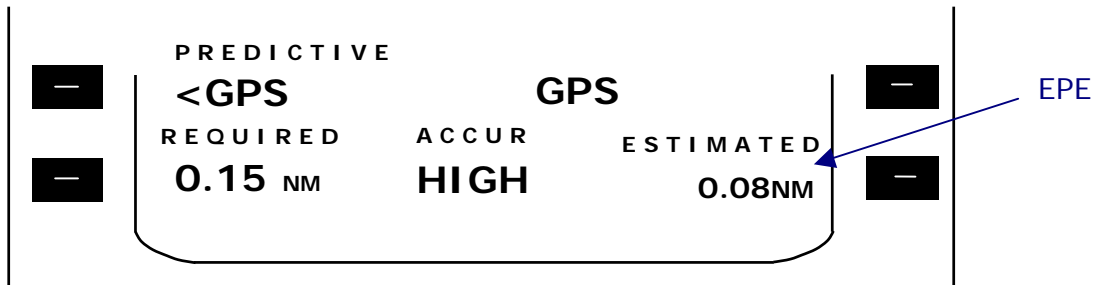
The FMS OPC (Operational Program Configuration) file defines the UIL and the default Required ACCURacy values for FMS terminal and FMS approach areas. The transition from the FMS terminal area to the FMS approach area will occur 5 NM before the first approach waypoint of the FMS flight plan.

In FMS terminal area the RNP default value is 1 NM and the UIL is 1 NM. If an RNP value < 0.5 NM is manually entered on MCDU or extracted from the navigation database, the HAL will be $2 \times \text{RNP}$.

In FMS approach area the RNP default value is 0.3 and the UIL is 0.3 NM.

If for example RNP 0.1 NM is manually entered the HAL will be $2 \times \text{RNP} = 0.2$ NM.

The EPE and the Required ACCURacy (=1xRNP) are indicated on the MCDU PROG page.



The EPE is a radial estimation of the navigation error, significantly more conservative than the statistically demonstrated NSE (see chapter 4).

When in “GPS PRIMARY” navigation mode the Estimated Position Error (EPE) compared to a 1xRNP threshold is computed as follows:

$$EPE = \sqrt{(HFOM)^2 + (\delta_{\text{Schuler Bleed thru error}})^2 + (\Delta_{\text{latency}} \times GS)^2}$$

Horizontal Figure Of Merit (HFOM) is an output of the ADIRU hybridisation algorithm and is a 2σ (or 95%) value of the position accuracy.

Δ_{latency} is the latency of the FMC = 0.74s

GS = Aircraft Ground Speed

$\delta_{\text{Schuler Bleed thru error}}$ = 15.511 m or 0.00837 Nm

The modes of the navigation function and associated interfaces are summarized in the table below:

	<i>EPE<Required ACCUR</i>	<i>EPE>Required ACCUR</i>
<i>HIL_{GPIRS}<HAL</i>	<i>GPS PRIMARY</i> Accuracy “ HIGH ” NAV Mode: 3IRS/GPS	<i>GPS PRIMARY LOST</i> Accuracy “ LOW ” NAV Mode: 3 IRS/GPS
<i>HIL_{GPIRS}>HAL</i>	<i>GPS PRIMARY LOST</i> Accuracy “ HIGH ” NAV Mode: 3IRS/DME-DME or 3IRS/VOR-DME or 3IRS => depending on radio accuracy	<i>GPS PRIMARY LOST</i> Accuracy “ LOW ” NAV Mode: 3IRS/DME-DME or 3IRS/VOR-DME or 3IRS => depending on radio availability

Note: The Required ACCURacy can be the default value function of the FMS flight area, a value retrieved from the Navigation Data Base or value entered on FMS MCDU progress page.

5.1.4. GPS AUGMENTATION

The augmentation of GPS availability may be needed in certain environments.

Different techniques are implemented to augment GPS PRIMARY function availability, they are labeled “coasting” to describe the capability to keep navigation integrity with a temporary loss of GPS integrity.

- **GPS/IRS Coasting with Litton System**

When GPS integrity is lost (less than 4 satellites available), the Litton GPS/IRS hybridization algorithm can continue to compute a HIL. The analysis of the Litton AIME system shows that Horizontal Integrity Limit ($HIL_{GPS/IRS}$) remains lower than $HAL=0.2$ NM up to a maximum of 7 minutes following loss of GPS.

The GPS PRIMARY function remains available and the GPS PRIMARY LOST indication will only appear up to a maximum of 7 minutes after loss of GPS.

- **FMS Coasting with Honeywell System**

The Honeywell HIGH system has no GPS/IRS coasting. When less than 5 GPS satellites are in view, Hybrid RAIM is not available ($HIL=NCD$).

When HIL is not available (i.e. $HIL=NCD$) or $HIL > HAL$ with no GPS satellite detected failure, the FMS computes an alternate integrity (“equivalent” HIL) for a limited period of time, based on an internal IRS drift model and the MIX IRS position updated with the last GPS/IRS position. As per design of current FMS, the minimum IRS drift model is 0.28NM. Thus, FMS coasting is not available for Required ACCURacy < 0.14 . For Required ACCURacy equal or higher than 0.14, the FMS provides a GPS/IRS position in GPS PRIMARY mode during a limited time.

Analysis of the Honeywell HIGH-ADIRU / FMS 2 system shows that “equivalent” HIL remains lower than $HAL = 0.28$ NM up to a maximum of 6 minutes maximum following GPS integrity loss.

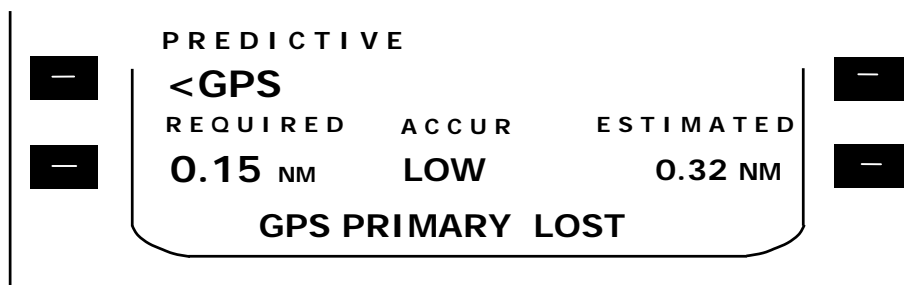
The GPS PRIMARY function remains available and the GPS PRIMARY LOST indication will only appear when alternate integrity is lost.

5.1.5. NAVIGATION ALERTS

An amber message, “GPS PRIMARY LOST”, is displayed at the bottom of the ND and in the scratchpad of the MCDU, in all modes when GPS/IRS updating is abandoned due to loss of GPS integrity detected or GPS/IRS updating is kept but estimated accuracy of GPS/IRS position is not satisfying the Required ACCURacy criteria.

For the latter case, loss of expected navigation accuracy, the “GPS PRIMARY LOST” message is associated with “NAV ACCUR DOWNGRAD” message on ND and in the scratchpad of the MCDU and “LOW” accuracy on MCDU PROGRESS page.

The display of GPS PRIMARY LOST or NAV ACCUR DOWNGRAD message on both navigation systems in approach will require the crew to perform a go around.



Other navigation alerts, far less probable may nevertheless be relevant as well:

- FM/GPS POSITION DISAGREE
- FM1/FM2 POS DIFF

If one of these alert occurs, the flight crew is expected to initiate a go around and try to determine the faulty system to navigate with the valid system.

5.2. FLIGHT GUIDANCE

For RNP AR procedures, the AP will be used in NAV or FINAL APP modes, which guides the aircraft along a pre-planned lateral and vertical trajectory.

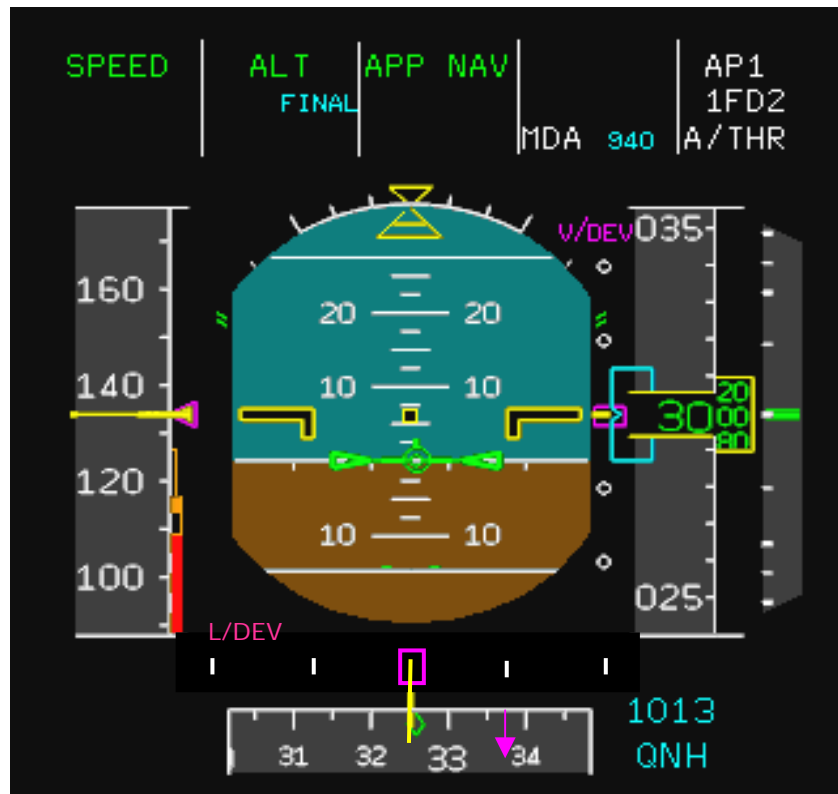
APP NAV is a lateral guidance mode and FINAL APP is a combined lateral and vertical guidance mode using Baro-VNAV principle.

5.2.1. APP NAV ENGAGEMENT CONDITIONS :

Engagement conditions of APP NAV are:

- A Non Precision Approach is selected in the Navigation Database (NDB) and,
- The FMS is in approach phase and,
- APPR push button is selected and NAV mode is engaged or the conditions to engage NAV mode are met and,
- Aircraft is above 400 ft AGL.

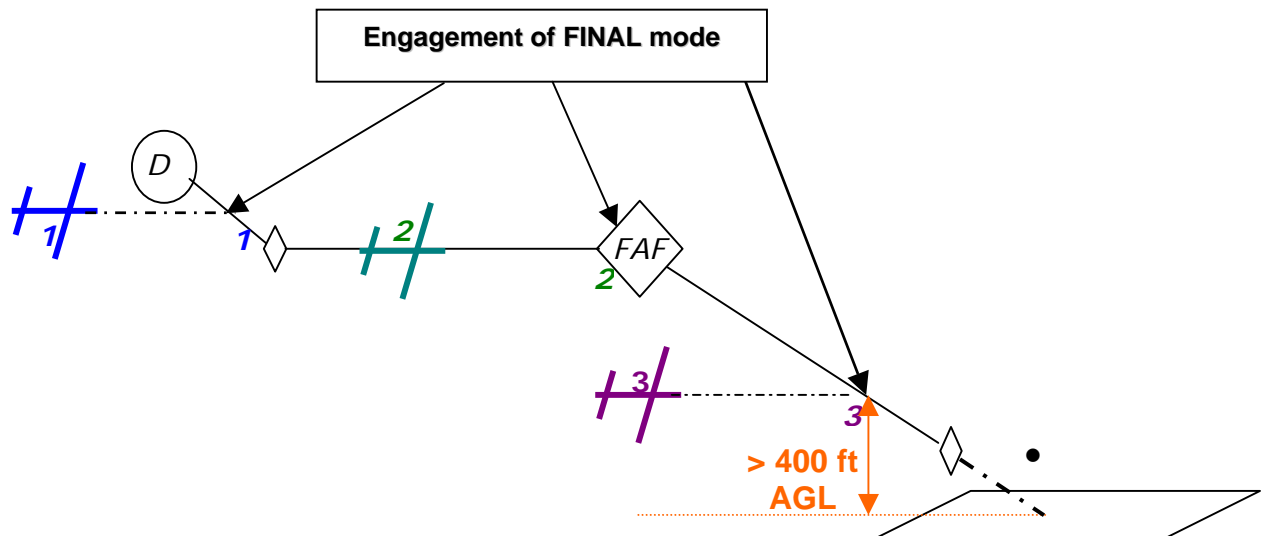
If HDG/TRACK is engaged, APP NAV engages when the intercept conditions are met (aircraft track line must intercept the flight plan active leg).



5.2.2. FINAL APP MODE ENGAGEMENT CONDITIONS (EXCEPT FMS HWI R1A):

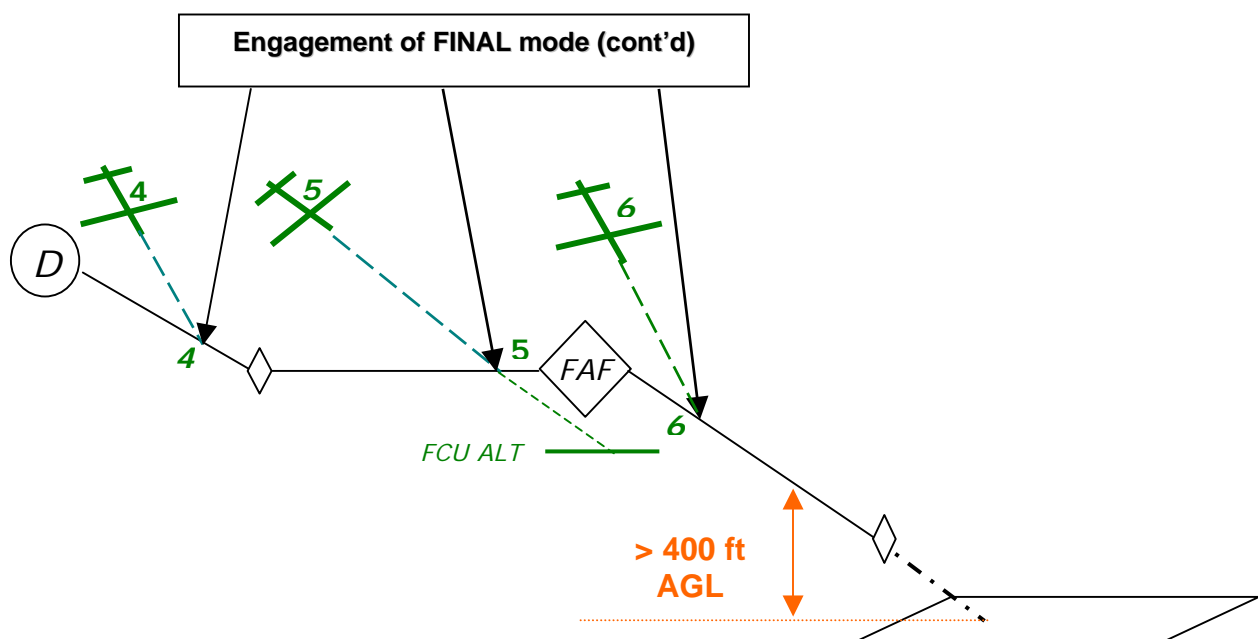
Engagement conditions of FINAL APP mode are:

- APP NAV mode is engaged
 - FINAL mode is armed and
 - The DECEL point is sequenced
- Aircraft is crossing in level flight (ALT, ALT CST), a descending leg of the approach profile Cases n°1 and n°2 and n°3 below:



Or,

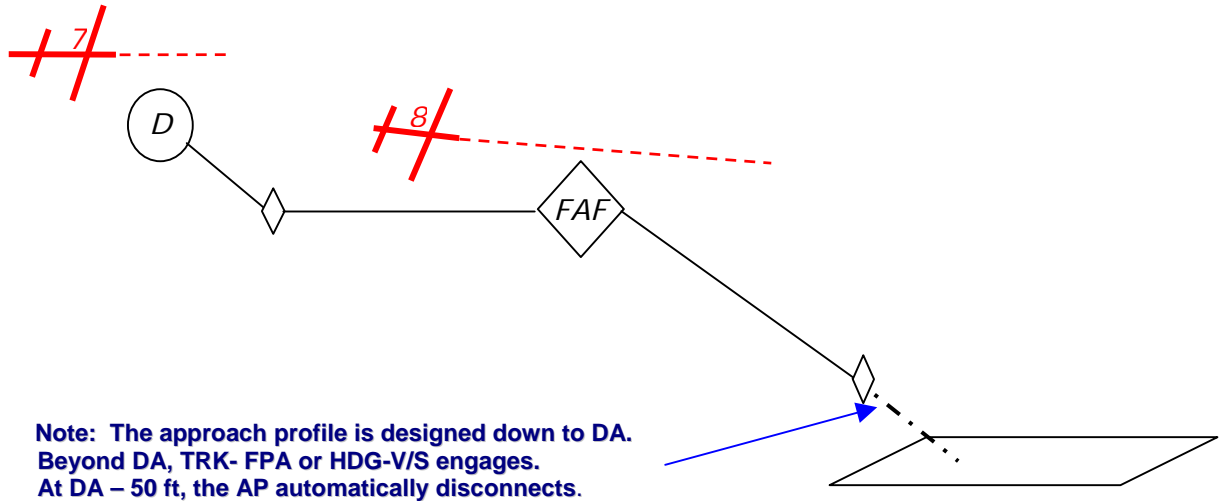
- Aircraft is descending toward the vertical flight path,
 - In V/S or FPA or OPEN DES or DES for cases n°4 or n°6 below:
 - In V/S or FPA or OPEN DES only for cases n°5 below, provided the FCU altitude is below the next approach level path:



FINAL mode engagement is not possible in the following situations:

7: Aircraft before Deceleration point D.

8: Aircraft trajectory does not cross the profile.



In FINAL APP mode, the aircraft V/S is limited to 1800 ft/min in CONF0 or CONF1 and 1200ft/min in CONF 2 or more. If the aircraft GS is too high the aircraft will not be capable to maintain the required vertical flight path angle. With strong tailwind this limit may be reached and if this happen, the aircraft will not be able to stay on the vertical flight path, the V/DEV will start to increase above flight path. This design characteristic must be taken into consideration in defining airspeed constraints and/or tailwind limitations. For example the 1200ft/min limitation will be reached on a 3°flight path with a GS of 226 kt. (These limitations have been modified with FMS HWI R1A)

In order to avoid unexpected FINAL APP mode disengagement, no constraint should be added or other FMS entries performed, once FINAL APP mode is engaged.

5.2.3. MANAGED SPEED VERSUS SELECTED SPEED

During the operational evaluation, the operator will need to determine if managed speed can be used or if selected speed technique is better to fly a specific RNP procedure. It is a characteristic of RNP AR operations that each individual RNP procedure has its own particularities that need to be addressed.

When the FMS approach phase is activated, the short term managed speed target will be Green Dot, "S" Speed, "F" Speed, or V_{APP} according to the aircraft configuration (although the displayed speed target is V_{APP}) and speed constraints are no longer considered.

If managed speed is used, procedures should be established so that the speed targets and aircraft configuration are compatible with the intended flight path tracking.

Speed constraints that may be entered by the pilot, or that are coded in the navigation data base, are "at or below" constraints.

Considering the above limitation and the close relationship between aircraft speed and lateral guidance performance, the use of selected speed may have to be considered. Also, the procedure should be assessed to determine if the use of the minimum Ground Speed function is adequate (for example if the approach flight path includes a circling procedure).

5.2.4. BANK ANGLE LIMITATIONS

The maximum commanded roll angle is limited by the Flight Management System (FM) and by the AP/FD Flight Guidance (FG).

With All Engines Operative (AEO), the FG limits the bank angle to 30°.

With one engine inoperative, the maximum bank angle is limited when the IAS is lower than the manoeuvring speeds (Vman) “F”, “S”, “Green Dot” depending of the flap configuration:

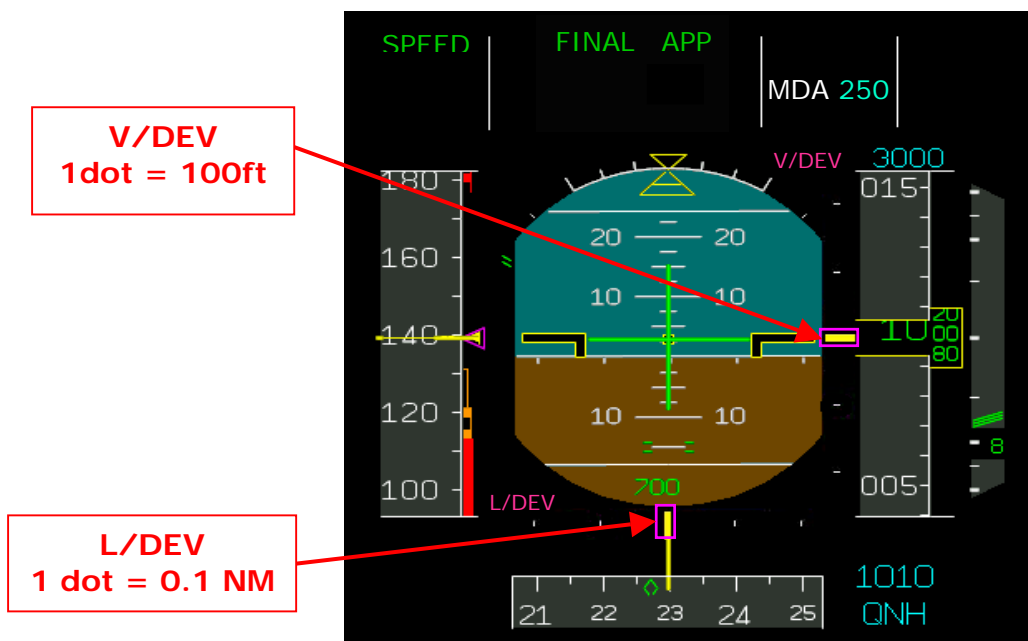
- At IAS < Vman - 10 kt the bank angle limit is 15°
- At IAS > Vman - 3 kt the bank angle limit is 30° (25° on LR aircraft)
- With a ramp between both values

During go-around or departure with one engine inoperative, the IAS may be lower than the above manoeuvring speed, which will limit the bank angle accordingly.

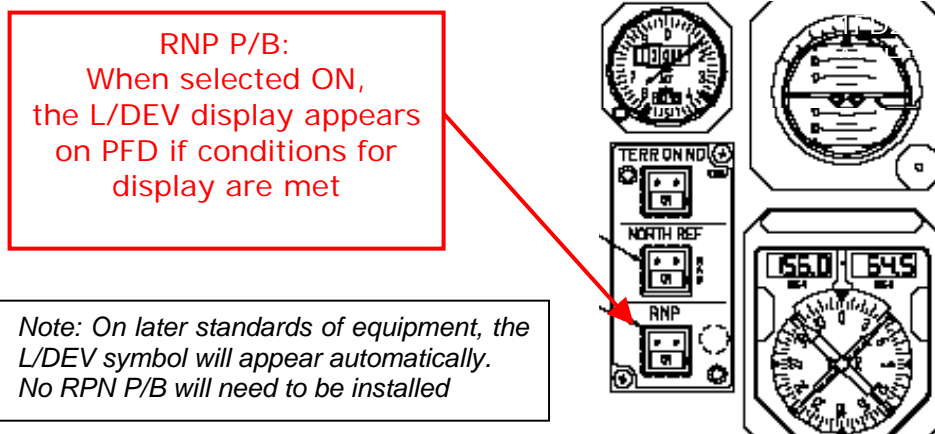
5.3. L/DEV AND V/DEV MONITORING

The L/DEV and the XTK error with 2 digits are essential features for the pilot to monitor the AP guidance in operations with RNP<0.3NM.

Flight crew procedures must be established and trained to ensure that the pilots will not let the L/DEV or the V/DEV exceed the maximum allowable deviation without appropriate reaction, taking over manually and initiating a go around.



Note: On later standards of DMC, the L/DEV and V/DEV symbols will be in green color more representative of the FMS flight plan on ND and to increase the differentiation with LS symbols (magenta diamond).



XTK with 2 digits after the dot when $RNP \leq 0.3$ and below Transition Altitude, whatever the RNP P/B position.

When the RNP P/B is selected ("ON" label illuminated blue), the EIS2 internal logics for the display of the L/DEV scale are enabled.

The EIS2 displays L/DEV if **one** of the following conditions is met:

- A/C is on ground
Note: On ground and during TO roll, the L/DEV remains centered and is temporarily out of view between 50 to 90 kt.
- A/C is below transition altitude climbing
Note: If necessary, the Transition Altitude may be modified prior to departure on PERF T/O page or prior starting the approach on PERF APPR page.
- When a Non Precision Approach is selected on FMS ARRIVAL page and:
 - A/C is in the FMS approach area (5 NM to the first approach waypoint of the FMS F-PLN), or
 - The FMS approach phase is ACTIVATED, or
 - FINAL mode is armed or engaged (APPR P/B selected)

When the cross-track error is more than 0.2NM left or right, the deviation index is replaced by a half-box displayed on the corresponding dot.

Full scale is ± 0.2 NM, 1 dot = 0.1 NM

If the LS P/B is pressed on the FCU, the L/DEV scale is inhibited.

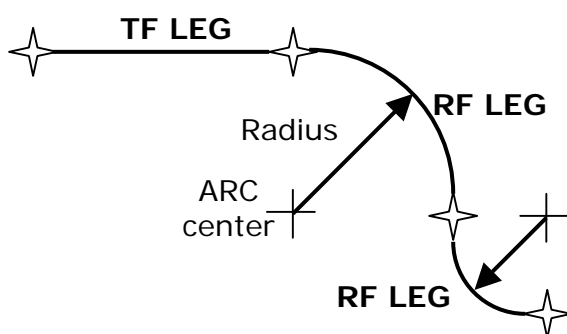


6. RNP AR INSTRUMENT PROCEDURES

6.1. RNP AR INSTRUMENT PROCEDURE DESIGN

RNP AR (SAAAR or equivalent) are designed using criteria of FAA Order 8260.52. or ICAO Manual for Implementation of the Required Navigation Performance.

The flight path is constructed with sequences of TF-RF legs or RF-RF legs.



Sequences of TF-TF legs are normally not used as the waypoint fly-by transitions will be calculated by the FMS as a function of the aircraft GS.

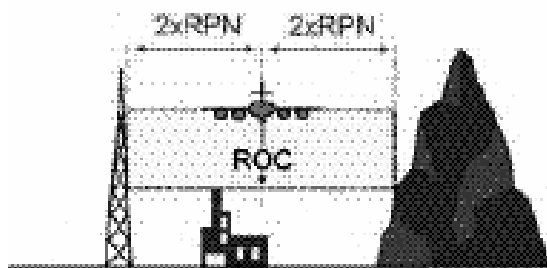
Nevertheless, some RNP AR procedures not requiring RF capability can be published with sequences of TF legs.

In the Final approach segment, fly-by turns are normally not authorized, but RF legs can be used.

The protection area along the flight path has a semi-width equal $2 \times \text{RNP}$.

The RNP value is in the range: $0.3 \geq \text{RNP} \geq 0.1$

Only the obstacles within the $4 \times \text{RNP}$ corridor need to be considered for obstacle clearance.



In the initial and intermediate approach segments the Required Obstacle Clearance (ROC) is 1000ft and respectively 500ft, values that are quite standard for any NPA.

The Final approach segment is constructed based on baro-VNAV principle, the ROC is a function of the Vertical Error Budget (VEB).

The components of the VEB are:

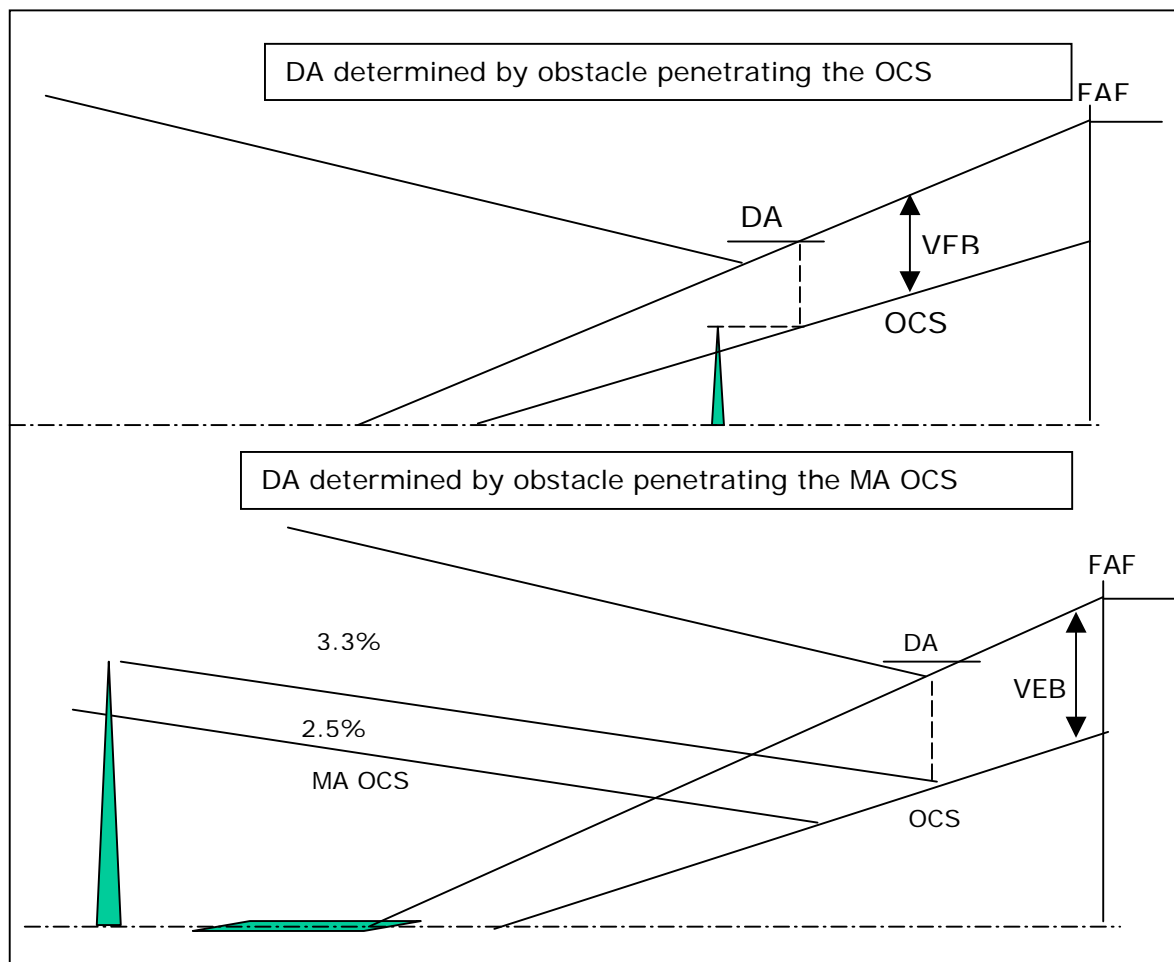
- The 95% navigation accuracy
- The maximum vertical FTE fixed at 75ft if not demonstrated
- The ASE
- The waypoint precision error
- The vertical angle error
- The ATIS QNH error fixed at 20ft

The formula to compute the VEB also takes into consideration the temperature correction to the international standard atmosphere and the semi-wing span of the aircraft.

The VEB associated to the nominal vertical flight path defines an Obstacle Clearance Surface (OCS), which must be free of obstacle penetration.

A Missed Approach OCS (MA OCS) with a slope of 2.5% is normally used to analyze obstacles relevant for DA determination. If necessary a higher minimum climb gradient can be established to lower the DA.

The standard RNP value for the Missed Approach segment is 1 NM. However, a lower value can be used to avoid obstacles.



6.2. RNP AR PROCEDURE CHARTING

The title of RNP AR procedures on the approach chart is

RNAV (RNP).

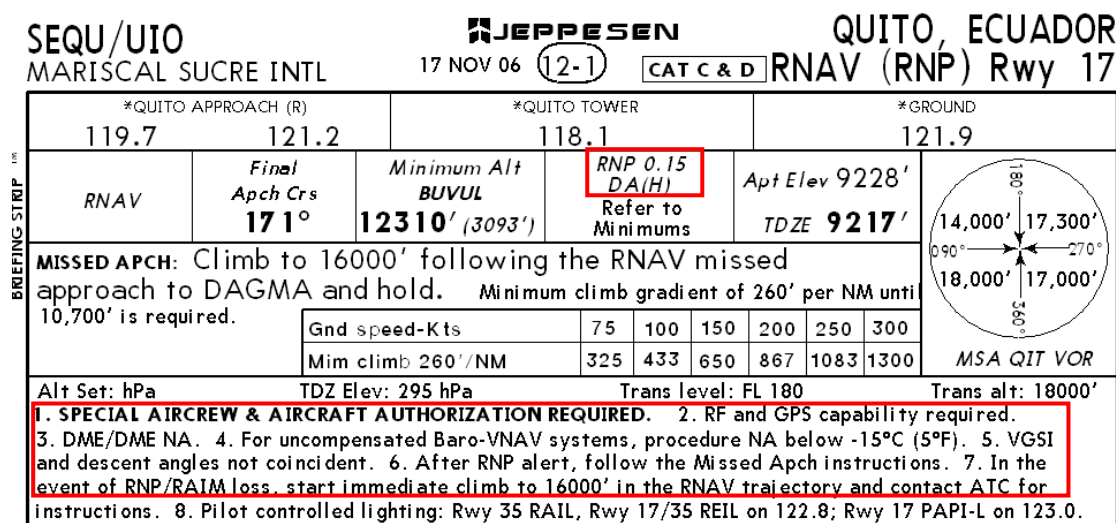
The indication “**Special Aircraft & Aircrew Authorization Required**” or “**Authorization Required**” is written in the notes area of the approach chart with other indications relative to the applicable limitations:

- OAT limitation,
- Wing span limitation if applicable,
- Limitation for FMS not capable of RF leg,
- Missed Approach climb gradient limitations if more than 200ft/NM is required,
- The RNP value for Missed Approach **if <1 NM** is required (FAA)

RNP AR approaches cannot be flown with a remote or forecast QNH.

If necessary several lines of minima may be published for different RNP values.

As an example, an extract of a “public” RNP SAAAR approach chart for RNP 0.15 is given below to illustrate the specific notes printed on these approach charts:



The example of approach chart given below is a study initiated by Airbus for an RNP 0.3 AR Approach in Katmandu designed by CGX AEROinSYS and ENAC. The benefit of this approach compared to the existing published VORDME approach is to replace the step down and steep vertical flight path by a constant 3° flight path angle.

The approach charts for RNP AR have usually a conventional layout with a map and a vertical flight path profile.

Few details deserve attention:

- The FAF (or PFAF) position from where the obstacle clearance is defined relative to an Obstacle Clearance Surface (OCS). Obstacle clearance is only ensured if the aircraft is flying on the defined vertical flight path.

- INSTRUMENT APPROACH**
CAT. A B C D
ALT AD : 4390, TDZE : 4351 (156 hPa)

APP: TRIBHUVAN Approach 120.6
 TWR: TRIBHUVAN Tower 118.1
 GND: TRIBHUVAN Ground 121.9
 ATIS: 112.3

TRIBHUVAN INTL
AD2 VNKT IAC 02
FNA RNAV (RNP) Y RW02

VAR
0° E
(06)

NOT FOR OPERATIONAL USE
 Only usable on Flight Simulator.
 This procedure needs flight check before operational approval.

Conventional holding
 Max Protection
 Altitude : **14000**
 Max IAS : 230 kt

LDK 358
 27°44'41"N
 085°06'18"E

For uncompensated Baro VNAV :
 - maximum temperature = 40°C,
 Missed Approach :
 - RNP less than 1.0 needed, to keep 0.3 until KT406
 - 304 ft/NM MA Climb Gradient requested up to 10500 ft

CAUTION
 RF Capacity Required
 RNP 1.0 at RATAN
 RNP 0.5 at NOPEN
 RNP 0.3 after KT401

TA: 13500
 12100 (7749)
 RATAN

IAF NOPEN
 IF KT401

PFAF
 KT402 KT403 KT404
 RW02 KT 405

ALT MNM 25 NM RW02
 20400
 10600
 11800

Next WP (NM) : 8
 RW02 (NM) : 25.6

MNM AD : vertical distances in feet, VIS in Statut Miles.

Category	A	B	C	D
RNP 0.3 with lights		4720 - 3/4		
no lights (DA)		4720 - 1		

Missed Approach :
Climb to 10500 ft, via the RNAV RNP missed approach track **303.2°T** to **LDK NDB** and **hold**.
 Do not exceed 185 kt until KT406.

SPECIAL AIRCRAFT & AIRCREW AUTHORIZATION REQUIRED

Procedure Design Suite

CHG: Segments altitudes -Profile - CDA intercept point symbol
 (the present edition cancels and replaces the edition in date of 28 SEP 2006)

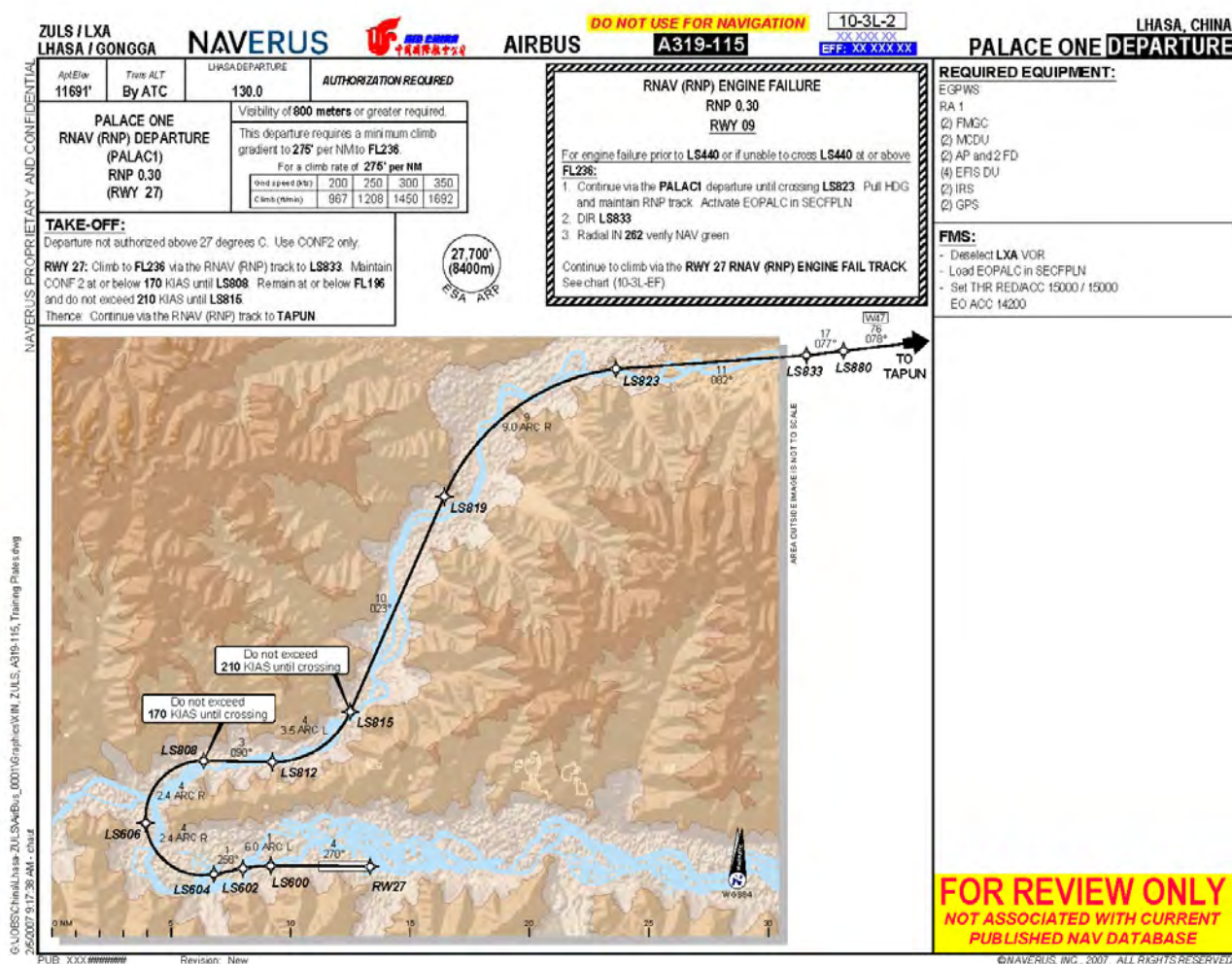
ENAC **CGX**

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Today (2008), there is no procedure design standard for RNP AR departures. Naverus and ENAC/CGX have developed their own standards, which meet the concurrence of FAA and other national authorities.

An example of departure procedure developed by Naverus for Lassa is given below.



The procedure only defines an horizontal flight path and airspeed constraints to avoid reaching bank angle limitations.

Associated to this flight path, the procedures designer must publish the position and height of the obstacles that are within the corridor of $\pm 2^{\circ}$ RNP.

These obstacles must be used by the airline to compute takeoff performance data, which ensures that the takeoff flight path clears the obstacles with the regulatory margin.

Adapted flight crew procedures, compatible with the lateral flight path, may have to be developed.



7. RNP AR OPERATIONS AND TRAINING

As indicated by the FAA acronym “SAAAR”, this type of operations is Aircraft & Aircrew specific, which means that specific flight crew procedures need to be developed and trained. A parallel is sometimes made with CAT III operations giving the impression that RNP AR operations are standardized and identical everywhere. This is obviously not true. If the final vertical flight path has in general a constant slope, preferably about 3°, the choice for the horizontal flight path is quite flexible. This gives its operational efficiency to the RNP AR concept, but also its constraints, as complex horizontal flight paths may require to define adapted flight crew procedures.

The instrument procedure environment may as well impose its own constraints. A procedure designed in a mountainous area requires additional precautions in the development of contingency procedures to maintain an adequate level of safety.

Although the same general characteristics may be found from one destination to the other, RNP AR operations are often airport or runway specific.

7.1. RNP AR (SAAAR) INSTRUMENT PROCEDURE EVALUATION

Each RNP AR instrument procedure needs to be thoroughly evaluated in a simulator to:

- Verify the fly ability of new designed instrument procedure (in particular, private or tailored airlines' procedures),
- Define adequate normal and abnormal flight crew procedures,
- Validate the FMS navigation database coding,
- Evaluate the absence of TAWS warning when the aircraft is on the nominal flight path.

7.1.1 NORMAL CONDITIONS (NO FAILURE)

During this evaluation, the effect of the aircraft design must be taken into consideration and evaluated in variable conditions such as normal or rare wind and temperature conditions. As necessary wind and/or temperature limitations may have to be defined in addition to the temperature limitation, which may be mandated by the design criteria of RNP AR approach procedures.

The use of AP is required for RNP<0.3 and is recommended for RNP=0.3.

The capacity of the AP to fly an RF leg is a function of the radius of turn, IAS, altitude, OAT and wind conditions. With all engines operative (AEO), the bank angle is limited to 30°. Airspeeds, RF radii and bank angles are linked values. The operator has to check during the operational evaluation that sufficient margin is available between the nominal bank angle to fly the turn and the aircraft roll limit. A 5° bank angle margin between the bank limit and the nominal bank angle (no wind) is usually considered as sufficient to fly a RF leg under normal wind conditions.

The FTE performance demonstration during certification has been made with a maximum ground speed function of the RF turn radius.

The table below gives for a nominal bank angle of about 20° the TAS function of the turn radius R and the wind intensity. The wind intensity (in kt), whatever the wind direction is, should be subtracted to the listed figure. Ex: R 1.6 NM, Wind = 30 kt, Max TAS = 170 kt

Turn Radius R in NM	Max TAS in Kt
0.8	141-wind
1	158-wind
1.2	173-wind
1.4	187-wind
1.6	200-wind
1.8	212-wind
2	222-wind
R>2.2	233-wind

7.1.1.1 GO AROUND AP/FD MODE

For the majority of SA and LR aircraft, at GA initiation, the AP/FD mode will revert from NAV, APP NAV or FINAL APP to GA TRK mode and will maintain the previous track filtered by a 15s time constant, until the NAV mode is re-engaged by the flight crew. **Therefore, prompt re-engagement of NAV mode is required after go-around initiation to remain on the lateral flight path.**

For the aircraft with this AP/FD definition the minimum RNP certified by EASA is 0.3 NM during missed approach.

New standard of the Flight Guidance part of FMGC are, or will be, certified to implement an automatic NAV mode reengagement at go around initiation.

With these standards RNP<0.3 are, or will, be approved in missed approach. Initiation of missed approach from any point in the approach, including during RF legs, should be assessed, during the operational evaluation.

A missed approach must be considered from any point of the approach, and obstacle clearance must be considered with respect to the certified RNP.

7.1.2 ABNORMAL CONDITIONS

7.1.2.1 ENGINE FAILURE

With One Engine Inoperative (OEI) the bank angle is a function of the IAS relative to the maneuvering speed (V_{man}). V_{man} is equal to S in CONF 1, F in CONF 2 and 3, V_I in CONF FULL and Green Dot in clean configuration.

The OEI bank limitation is as follows:

- 30° on SA and 25° on LR at IAS > V_{man} – 3 kt
- 15° at IAS < V_{man} - 10 kt
- An intermediate bank angle at IAS between above values

In some cases a specific airspeed constraint may need to be defined to ensure sufficient bank angle margin so that the AP will always be able to steer the aircraft on the defined flight path.

During departure or missed approach, the AP performance with OEI during acceleration and configuration changes needs to be assessed. On some Airbus aircraft types, acceleration during turns will produce lateral flight path deviations that may not be compatible with the expected AP performance to remain within the RNP lateral limit. In that case, adapted flight crew procedures will have to be developed to define an acceleration point (instead of an acceleration altitude) where engine out acceleration has to take place.

7.1.2.2 AIRCRAFT OEI CLIMB PERFORMANCE

For departure, missed approach and balked landing, the aircraft climb performance needs to be assessed taking into account the obstacles within the 2xRNP limit. The Airbus performance software tools can be used for takeoff analysis.

The calculated performance must be in adequacy with the defined flight crew procedures to cope with the AP performance for lateral navigation.

7.1.2.3 AIRCRAFT SYSTEM FAILURES

In the context of each RNP AR procedure, the airline should address the effect of aircraft system failures and validate the adequacy of the associated abnormal procedures. The failure cases to be addressed are listed in the ACD and with indication of major procedure steps. They include mainly:

- Loss of GPS PRIMARY or NAV ACCUR DOWNGRAD
- Navigation alerts
- Failures of the FMS
- Failures of AP and AP/FD modes

The objective of this evaluation is to establish mitigation means to demonstrate an appropriate level of safety.

The airline may have to develop a Flight Operational Safety Assessment (FOSA), to comply with AC 120-29A requirements of § 4.3.1.1 quoted below:

Note: For AC 120-29A, RNP approaches are included in the CAT I approach category!

4.3.1.1. Operational Safety Evaluation. For any instrument approach using either Category I or Category II minima, the operator must adequately consider and provide for safe operations considering at least the following:

a. The possibility of a failure of any one of the pertinent navigation systems, flight guidance system, flight instrument system, or annunciation system elements used for the approach or missed approach (e.g., ILS receiver failure, Autopilot disconnect, etc.).

b. The possibility of a failure of a key aircraft component or related supporting system during the approach or missed approach (e.g., engine failure, electrical generator failure, single hydraulic component failure). Even though a particular failure may in itself be considered too remote based on exposure time (e.g., engine failure), it is nonetheless important to address these considerations since, in practical circumstances, a “go-around” may be due to a factor which relates to or leads to the failure, and thus is not an independent event (e.g., flocking bird

ingestion). This is consistent with the long standing principle of safety of operation of multi-engine aircraft in air carrier operations which notes that after passing V1 on takeoff, until touchdown, the aircraft should typically be able to sustain a failure such as engine failure and still safely be able to continue flight and land.

c. The possibility of a bailed landing or rejected landing at or below DA(H), or MDA(H), as applicable.

d. The possibility of loss or significant reduction of visual reference, that may result in or require a go-around.

e. Suitable obstacle clearance following a missed approach, considering applicable aircraft configuration during approach and any configuration changes associated with a go-around (e.g., engine failure, flap retraction).

f. For special airports identified IAW section 121.445 (e.g., mountainous terrain), or other airports with critical obstacles that have not otherwise been accounted for, the ability to ensure suitable obstacle clearance following a rejected landing; applicable aircraft configuration(s) during approach and any configuration changes associated with a go-around and missed approach should be considered.

g. Unusual atmospheric or environmental conditions that could adversely affect the safety of the operation (e.g., extreme cold temperatures, known local atmospheric or weather phenomena that introduce undue risk, etc.).

When conducting a safety assessment of issues listed above, and uncertainty exists as to aircraft failure condition effects, procedural design intent or margins, aircraft characteristics or capabilities following failure, or other such issues, the operator should consult with an appropriate organization source able to provide reliable and comprehensive information. Typically this includes consultation with one or more of the following as applicable, and as necessary:

- ☐ Aircraft manufacturer,
- ☐ Avionics manufacturer;
- ☐ Procedure designer;
- ☐ Air Traffic Service provider, or regulatory authority.

The ACD provides the airline with the aircraft manufacturer information necessary to prepare a FOSA. In addition the evaluation conducted by the EASA, during certification as part of the operational readiness, takes into account the probable and remote aircraft system failures for the RNP values determined in abnormal conditions (engine failure or system failures whichever is dimensioning). The use of these RNP values relieves the operator from the need to conduct a formal FOSA for system failures.

7.1.3 NAVIGATION DATABASE CODING VALIDATION

The validation of the Navigation Data Base (NDB) coding is essential for RNP AR operations. When the RNP AR procedure is first introduced in the NDB or if any modification of the NDB affecting the concerned RNP AR procedure coding is made, the procedure must be validated using a flight simulator or an equivalent training tool (MFTD) fitted with software representative of the aircraft FMGC.

This is an important aspect of the NDB integrity check even if the NDB is obtained from an “approved” supplier (DO-200A / ED-76 or AC 20-153).

As the RNP AR procedure needs to be coded in the airline’s FMS NDB to conduct the operational evaluation, it is the right time to perform this NDB validation.

7.1.4 NAVIGATION DATABASE CONTROL

Means to check that RNP AR (or SAAAR) procedures are not modified at each AIRAC cycles need to be implemented.

Usually automatic means are used to check that RNP AR procedure coding was not modified compared to the original validated procedure.

The operator must in addition implement a process to ensure that the FMS are loaded with up to date NDB.

The flight crew, as usual will also verify that the NDB is up-to-date.

7.1.5 TAWS TERRAIN DATABASE AND FLIGHT PATH ADEQUACY

The instrument procedure design for RNP AR (SAAAR) operations must be assessed for the absence of nuisance warnings and cautions when flying on the nominal flight path. This assessment should be part of the operational evaluation of the procedure including simulator tests and as necessary a verification during demonstration flight(s).

Nuisance alerts can be minimized through:

- Adaptation of the Terrain Data Base,
- Redesign of the instrument procedure,
- Inclusion of appropriate speed constraints.

7.2. RNP AR (SAAAR) OPERATIONAL PROCEDURES

We will review in this chapter the main steps in the preparation and the conduct of RNP AR operations. This review is generic, and the reader should keep in mind that adaptations may be required as RNP AR operation is, as per definition, specific to each destination.

7.2.1 FLIGHT PREPARATION

In addition to the usual preparation, which is done before any flight, the following topics need to be addressed:

- The aircraft RNP AR certification status and the required equipment to start an RNP AR procedure
- The GPS PRIMARY availability at the ETA or ETD
- The navigation database is up-to-date and the RNP AR procedures planned to be flown are authorized by the airline.
- The weather forecast are compatible with the minima listed for the approved RNP value.

7.2.1.1 REQUIRED EQUIPMENT

The list of required equipment should be established during the operational evaluation and the approval process, considering the available operational mitigation means for each individual procedure.

The following list of equipment should be considered to start an RNP AR procedure in a demanding environment:

- 2 FMGC (2 FM required for RNAV approach)
- 2 MCDU
- 2 FD
- 1 AP, but 2 AP if RNP < 0.3 for approach, or RNP < 1.0 in go around or departure, is required
- EFIS DU with 2 L/DEV and 2 V/DEV displays and RNP P/B (if installed)
- 2 GPS (MMR) (2 GPS required for RNAV approach)
- 3 ADIRS (2 ADIRS for a departure)
- EGPWS
- FCU with both channels

This list should be used to update the airline MEL if RNP AR capability is predicated for the intended operation.

During the preparation of a flight where RNP AR procedure will be flown, the flight crew must verify that none of the above equipment is reported inoperative.

7.2.1.2 GPS PRIMARY AVAILABILITY

GPS PRIMARY availability should be verified using if required a dedicated prediction software and GPS NOTAM (refer to §5.1.1).

7.2.2 RNP AR DEPARTURE

The following information is to be considered in addition to the SOP.

7.2.2.1 COCKPIT PREPARATION

- TOW and takeoff speed appropriate for RNP AR departures.
- SID and EOSID F-PLN verifications
- THR RED altitude and ACC altitude or waypoint, ENG OUT ACC altitude or waypoint
- RNP value insertion and radio nav aids deselection

The takeoff performance must be determined with airport data corresponding to the RNP AR departure. Sometimes the airline may produce different sets of performance data, one for a conventional departure, one for a departure in VMC and one for the RNP AR departure. Different obstacles are taken into considerations. The crew must therefore verify that the appropriate set of data are used to determine the takeoff weight and the associated speeds.

The RNP AR departure will be loaded in the FMS F-PLN and checked with the departure chart. The flight crew will check the speed constraints that may be mandatory to fly some RF legs. If the speed constraints are not coded in the NDB the flight crew may have to use selected speed.

If an EOSID different from the SID is defined, the EOSID loaded in the FMS F-PLN must also be checked.

The flight crew must be aware on the way the EOSID will be activated, using the EOSID automatic function or by activation of the SEC F-PLN.

In both cases, it is essential that the SID/EOSID diversion waypoint is clearly identified on the F-PLN. The requirement to INSERT the EOSID or ACTIVATE SEC F-PLN before the diversion point must be briefed. In case of engine failure, as this selection is not reversible, both crew members must crosscheck before selection.

The flight crew will check or enter the THR RED, ACC and ENG OUT ACC altitudes on MCDU. For some departure the ENG OUT acceleration will have to take place at or above an altitude but not before a given waypoint. The airline documentation should highlight this kind of special procedures, which should also be part of the flight crew takeoff briefing.

The crew will insert the RNP for departure as REQUIRED ACCURACY on the MCDU PROG page. To avoid unsatisfactory FMS radio-update in case of loss of GPS PRIMARY the radio nav aids will be deselected, as requested by the Airline documentation.

7.2.2.2 BEFORE TAKEOFF

During taxi the flight crew will select the RNP P/B to display the L/DEV on PFD.

The L/DEV indication will remain centered on ground.

Note: With some recent aircraft definition the L/DEV is automatically selected, no RNP P/B is installed.

TAWS/EGPWS terrain mode will be selected by both pilots unless weather radar is required on one side.

The crew will check on FMA that the NAV mode is armed.

On the MCDU PROG page the crew will check that GPS PRIMARY is available and on the GPS MONITOR page, that both GPS sensors are in NAV mode.

7.2.2.3 TAKEOFF AND CLIMB OUT

During take roll the L/DEV remains centered (-may be temporarily out of view between 50 and 90kt) . After takeoff when reaching 100ft the NAV mode engages and the PF will call AP ON. Both pilots will monitor the L/DEV.

The departure is quite standard, but as required by the departure flight path design, the crew will monitor that the correct speed constraints are taken into consideration or will select the appropriate speed on FCU to fly the RF legs.

The aircraft clean up must be adapted to the speed constraints.

Reaching the transition altitude, the L/DEV indication disappears.

7.2.3 LATERAL AND VERTICAL DEVIATION MONITORING

There is no automatic callout or alert when the L/DEV exceeds the budget allocated to ensure that containment is achieved. The crew must continuously monitor the displayed L/DEV on PFD against the limit specified for a given RNP value.

This maximum lateral budget is associated to the RNP value entered as REQUIRED ACCURacy in the MCDU.

The maximum L/DEV budget and its associated REQUIRED ACCURacy are defined for different RNP value in the table below.

RNP	MCDU REQUIRED ACCUR	MAX L/DEV
0.2 – 0.3	0.2 – 0.3	2 DOT
0.15 – 0.19	0.15 – 0.19	1.5 DOT
0.1 – 0.14	0.1 – 0.14	1 DOT

The operator must establish crew procedures to require the PNF to make callout so that the L/DEV limit is not exceeded unnoticed.

If an abnormal increase of the L/DEV is observed , the AP should be disconnected and crew should take corrective actions. In approach a GA should be initiated.

A discrepancy between PF and PNF L/DEV display may be the result of an FMS position error.

If the wrong FMS cannot be identified immediately, a go around must be initiated unless alternative means of navigation exist. During departure or Go Around, appropriate contingency procedures must be used.

The vertical deviation is available in approach only.

When a Non Precision Approach is selected on FMS F-PLN page for arrival, the V/DEV is displayed if **one** of the following conditions is met:

- A/C is in the FMS approach area (5 NM to the first approach waypoint of the FMS F-PLN)
- The FMS approach phase is ACTIVATED
- FINAL mode is armed or engaged (APPR P/B pressed)

Full scale is $\pm 200\text{ft}$, 1 dot = 100ft.

If the LS button is pressed on the FCU, the V/DEV scale is inhibited.

Prior to starting the final approach, the flight crew must cross check their altimeter setting and altitude indications.

FAA requirement:

Altimeter Setting. *Due to the reduced obstruction clearance inherent in RNP SAAAR instrument procedures, the flight crew must verify the most current airport altimeter is set prior to the final approach fix (FAF) but no earlier than the IAF. Execution of an RNP SAAAR instrument procedure requires the current altimeter setting for the airport of intended landing. Remote altimeter settings are not allowed.*

I. Altimeter Crosscheck. *The flight crew must complete an altimetry crosscheck ensuring both pilots' altimeters agree within ± 75 feet prior to the final approach fix (FAF) but no earlier than the IAF. If the altimetry crosscheck fails then the procedure must not be continued.*

When the FINAL APP mode is active after the VIP (or FDP), at the latest at FAF, the crew must continuously monitor the V/DEV on PFD. The PNF should make a callout when the V/DEV is $\frac{1}{2}$ dot below or $\frac{1}{2}$ dot above the vertical flight path.

A GA must be performed before $\frac{3}{4}$ dot below the vertical flight path is reached.

Corrective action when V/DEV is above the nominal flight path is a question of energy management in the approach, which is different from one approach to the other. The operator should adapt its procedure to each particular case.

7.2.4 RNP AR APPROACH AND MISSED APPROACH

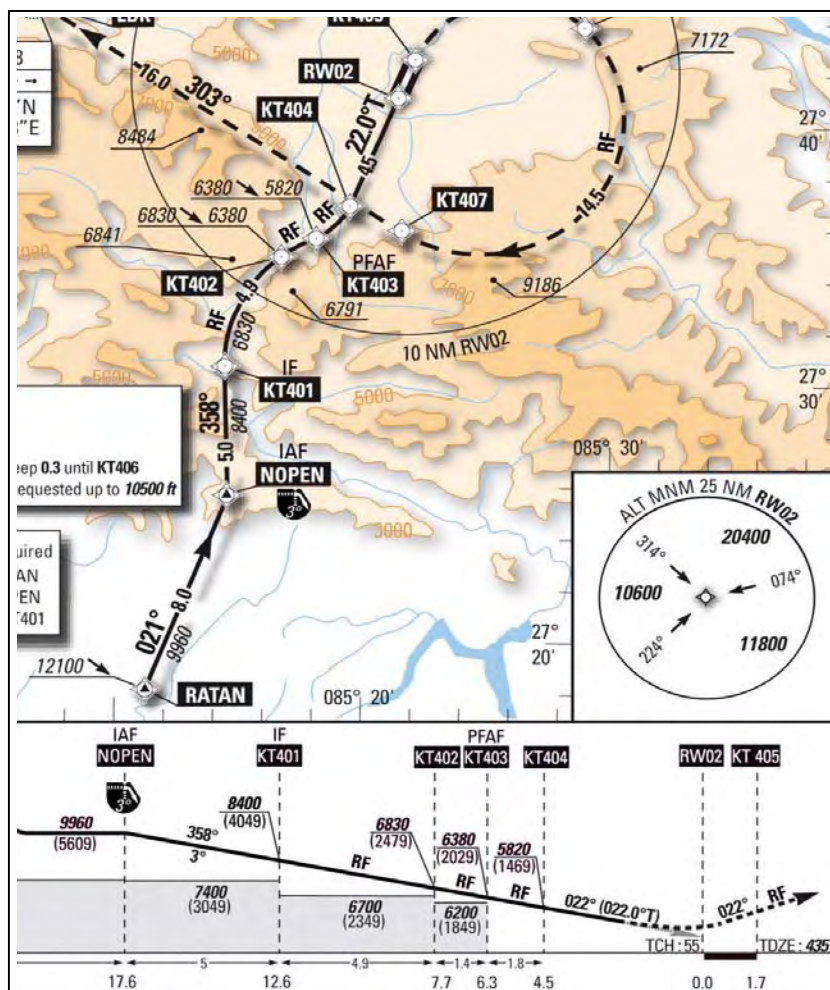
The following information is to be considered in addition to the SOP.

7.2.4.1 APPROACH PREPARATION

In addition to the usual preparation, which is done during any flight, the following items need to be addressed:

- Check the weather report to confirm that OAT and surface wind as applicable are within limits for the RNP AR procedure.
- Review the aircraft status against the minimum equipment for RNP AR approach
- Confirm that the approach with the label RNV XY listed in the FMS is the intended RNP AR approach, and check it carefully with the approach chart, including the missed approach, check
 - Waypoint sequences
 - Altitude and speed constraints
 - Location of the waypoint where the FINAL APP mode must be engaged
- Review the RNP value for approach and missed approach. Unless the RNP is coded in the FMS NDB, the more limiting RNP must be entered in the MCDU.
- Deselect the radio-navaids as indicated in the Airline documentation,
- Enter the DA, corresponding to the RNP value, in the MDA (or BARO) field of the MCDU approach page.
- Review the GO AROUND page and check that THR RED altitude and ACC altitude or waypoint, ENG OUT ACC altitude or waypoint
- Review any specific flight crew procedure as indicated in the Airline documentation for the intended approach.

From an approach procedure design point of view the latest point where the FINAL APP mode must be engaged is the FAF or FAP. From this waypoint, an Obstacle Clearance Surface is defined for obstacle assessment. Consequently, from this waypoint, the aircraft must follow the FMS vertical flight path and FINAL APP mode must be engaged. Earlier in approach, the vertical obstacle clearance is conventional with minimum altitude steps. The RNP AR approach are usually constructed so that a constant angle flight path can be flown from a waypoint well before the FAF(VIP, or FDP). This waypoint, where the FINAL APP mode can be engaged, should also be the decision point to start or not the final approach (minimum equipment, weather).



Katmandu Project

In this example, KT403 is the FAF.

But a constant 3° vertical flight path angle has been defined from NOPEN to the runway.

It is recommended to plan the approach so that FINAL APP mode engages at NOPEN

Depending the aircraft type, the minimum certified RNP in approach can be different in APP NAV mode and FINAL APP. In this situation, typically for RNP 0.1, the crew must ensure that FINAL APP is engaged before flying the leg with RNP 0.1.

The flight crew should review and brief the particularities of the approach and the missed approach procedure, for example the radius of turns and the associated speed constraints. In approach, when the FMS approach phase is activated the speed constraints are considered as maximum speeds, the target speed being S, F or Vapp function of the flap configuration. If a specific speed is required to fly a part of the procedure, in some cases, the best technique is to fly selected speed.

7.2.4.2 FLYING THE APPROACH

During descent, the crew will select the EGPWS terrain on both ND unless weather radar is required on one side.

Before the IAF, the flight crew will check that both GPS sensors are in NAV mode on the GPS MONITOR page and on PROG page that GPS PRIMARY is available.

The RNP P/B must be selected ON to display the L/DEV indication.

Note: With some recent aircraft definition the L/DEV is automatically selected, no RNP P/B is installed.

The FMS approach phase should be activated unless it has automatically activated. Considering the conditions of FINAL APP mode engagement described in paragraph 5.2.2 above, it is recommended to conduct the descent so that the altitude of the vertical flight path intercept point is reached slightly before that point. In the above example for Katmandu the aim would be to be at 9960 ft slightly before NOPEN in ALT mode with S speed and CONF 2. Before NOPEN, the crew will select APPR and check FINAL blue is displayed on FMA and that the blue descent arrow is displayed close to NOPEN.

Depending where the FINAL APP mode is planned to activate, some kind of decelerated approach can be considered. The aircraft configuration must be compatible with the airspeed constraints to cope with the flight path radius of turns. The airline documentation should also define the point during the approach where landing configuration and stabilized Vapp is expected to be established.

The use of the TRK/FPA display is relevant for straight in approaches. For RNP AR approaches with turns in the final approach segment, the use of FD with cross bars is recommended. Cross bars are also better for the crew to identify AP/FD malfunctions.

When the FINAL APP mode activates, the crew will check that the aircraft is guided on an appropriate vertical flight path (attitude, V/S) and will select the go around altitude on FCU. During the final approach segment, the crew will monitor the L/DEV and the V/DEV and check that altitude constraints are observed.

With the present FMGC logic, the AP will disconnect at DA-50ft and the FD mode will revert to HDG-V/S. For future FMGC standards, Airbus investigates the possibility to keep AP in FINAL APP mode below DA.

When visual conditions are reached, the PF will disconnect the AP and both pilot will select FD OFF.

7.2.4.3 MISSED APPROACH PROCEDURE

At DA, at the latest if visual conditions are not met, a go around must be initiated.

For aircraft without the automatic NAV mode reengagement at GA initiation, it is essential to immediately reengage the NAV mode manually.

The missed approach is quite standard, but as required by the flight path design, the crew will monitor that the correct speed constraints are taken into consideration or will select the appropriate speed on FCU to fly the RF legs.

The aircraft clean up must be adapted to the speed constraints.

Reaching the transition altitude, the L/DEV indication disappears.

7.2.5 ABNORMAL PROCEDURES

The flight crew must be ready to react to abnormal situations that may require specific procedures and training in RNP AR environment.

7.2.5.1 ENGINE FAILURE

In case of engine failure, it is recommended to keep AP in command (except in approach on SA aircraft with FMGC standard that prohibits it). During departure or missed approach, the crew may observe a lateral excursion when the engine fails or during acceleration and clean up with OEI, which normally remains within the 1XRNP limit. If the 1xRNP limit is going to be exceeded, the PF will disconnect AP, and correct manually increasing slightly the bank angle and using the L/DEV indication to converge towards the FMS flight path. When converging, the AP can be reengaged.

7.2.5.2 NAVIGATION AND GUIDANCE SYSTEM FAILURE

Two systems must be operative to start an RNP AR procedure, but in many situations the procedure can be continued with one system.

Alerts relative to the navigation and guidance system in approach such as:

- GPS PRIMARY LOST on both sides
- FM/GPS POSITION DISAGREE
- FMS1/FMS2 POS DIFF
- Loss of FINAL APP mode
- Loss of both FMGC or severe dual reset

require the flight crew to initiate a missed approach procedure.

After the loss of GPS FMS position update, the FMS position will drift with the IRS position. But the drift rate is sufficiently low to ensure safe navigation the time necessary to reach the MSA.

For the FM/GPS POSITION DISAGREE and FMS1/FMS2 POS DIFF alerts, the flight crew must continue the missed approach or departure procedure using mitigations means (e.g. conventional radio nav aids EGPWS, adequate procedure charts with all the relevant information, ...)

The loss of NAV or FINAL APP mode will require the PF to disconnect the AP, fly manually using the L/DEV indication (disregarding the FD orders) until the PNF can re-engage NAV and the opposite AP.

Following the loss of both AP the crew will continue the procedure using FD and the L/DEV indications. In approach with $RNP < 0.3$, as the FTE with FD has not been demonstrated during certification, the airline procedure may be to require a go around. The same situation may also occur following engine failure for SA aircraft with an FMGC standard, for which the AP must be disconnected in approach with OEI.

For $RNP < 0.3$, the airline has the option to demonstrate that the pilots have been trained to continue an approach using FD and can meet the expected RNP level.

In case of loss of both FMGC or severe dual reset, the flight crew will revert to mitigations means (e.g. conventional radio nav aids, EGPWS, adequate procedure charts with all the relevant information, ...).

Both FMGC failure means total loss of RNAV capability and may also include loss of AP and/or A/THR. The crew procedures to deal with such a situation should be based on the mitigations means available for each individual approach or departure. This evaluation should be part of the operational approval. Specific procedures must be established and trained when use of TAWS/EGPWS terrain display is considered following loss of both FMGC.

7.2.6 RNP MONITORING PROGRAM

The airline are required to implement an RNP Monitoring Program, which has some similarities with what is usually required for CAT II/III operations.

This program must ensure continued compliance with the guidance of AC 90-101 and to identify any negative trends in performance.

Statistics on the number of RNP AR successful and unsuccessful procedure should be kept.

The reasons of unsuccessful procedures such as:

- Navigation system performance alerts.
- Navigation and Flight Guidance system failures.
- Navigation database coding errors.
- Excessive lateral or vertical deviation.
- EGPWS cautions or warnings.
- Flight crew procedures deviations.

should be reported for analysis and corrective actions.

Extract of AC 90-101(Appendix 6, 12/15/2005)

1. The operator must have an RNP monitoring program to ensure continued compliance with the guidance of this AC and to identify any negative trends in performance. At a minimum, this program must address the following information. During the interim approval, the operator must submit the following information every 30 days to the CHDO or FSDO granting their authorization. There-after, the operator must continue to collect and periodically review this data to identify potential safety concerns, and maintain summaries of this data.

a. Total number of RNP SAAAR procedures conducted.

b. Number of satisfactory approaches by aircraft/system (Satisfactory if completed as planned without any navigation or guidance system anomalies).

c. Reasons for unsatisfactory approaches, such as:

1) UNABLE REQ NAV PERF, NAV ACCUR DOWNGRAD, or other RNP messages during approaches.

2) Excessive lateral or vertical deviation.

3) TAWS warning.

4) Autopilot system disconnects.

5) Nav data errors.

6) Pilot report of any anomaly.

d. Crew comments.

7.2.7 MAINTENANCE

There is no specific or scheduled maintenance tasks for RNP AR operations.

The maintenance organization should be aware of the minimum equipment required to fly the intended RNP AR operations.

7.3 FLIGHT CREW AND DISPATCHER TRAINING

The airline needs to define a flight crew training that is adequate to the type of operations being envisaged.

The training can be generic if all operations are equivalent, but may need to be specific for operations that are significantly different considering the type of flight path, DA location or environment.

The flight crew training to fly RNP AR procedures should include a ground school segment and a Full Flight Simulator segment.

The ground school segment should include a briefing (or briefing note) on:

- The concept of RNP AR operations,
- The aircraft systems to fly RNP AR procedures,
- Flight crew procedures in addition to the FCOM SOP for RNAV procedures,
- The specificities of each RNP AR procedure,
- RNP AR procedures charting.

The Full Flight Simulator segment should highlight:

- The use of FINAL APP mode,
- The flight crew procedures specific to RNP AR operations in general or specific to particular RNP AR procedures,
- The effect of aircraft failures (e.g. loss of navigation capability, engine failures,...)

A minimum of one 4 hours simulator session is required. Depending of the specific characteristics of the intended operation, more training time may be necessary. During the operational evaluation, the airline with its national authorities will ensure that the level of training is in adequacy with the intended operations.

The flight crew training should highlight in particular the following topics:

- The departure, approach and missed approach F-PLN verification,
- The verification of the navigation system required accuracy and the availability of GPS PRIMARY,
- The required equipment to start the approach,
- The arming and activation of the FINAL APP mode,
- The requirement to observe the speed constraints in RF legs, as well as the minimum airspeed to avoid any undesirable bank angle limitation in case of engine failure,
- The monitoring of the lateral and vertical deviations and the associated callout,
- The GA procedure and the requirement to reengage the NAV mode immediately to remain within RNP limit for the aircraft without automatic reengagement of the NAV mode,
- The appropriate course of action following navigation system alerts
- The use of the appropriate airspeed technique (managed versus selected speed),
- The effect of engine failure on the lateral performance,
- The appropriate procedure to select the EOSID FMS F-PLN prior reaching the diversion point if an EOSID different from SID is defined; The importance of this procedure step must be highlighted during the training,
- The use of EGPWS to extract the aircraft in case of dual loss of FMGEC,
- The procedure to recover from FMS failure such as FMS auto-reset,

- Departure and GA procedures using the L/DEV in manual flight FD OFF to address cases of FG system failures.

For demanding RNP AR operations, a line familiarization may be required before flying the procedure as a Pilot in Command. This may have to be combined with an aerodrome competence qualification as per JAR OPS 1.975.

The dispatcher training consists in a ground training segment only, which can be derived from the flight crew training with special focus on:

- GPS availability prediction,
- FMS Navigation Database
- Weather minima, and wind and/or temperature limits if any,
- Aircraft takeoff performance data if specific for a particular RNP AR operation

7.3.1 FLIGHT CREW RECURRENT TRAINING

The airline should implement an RNP recurrent training in its overall crew recurrent training program.

For each recurrent training cycle, 2 RNP AR approaches must be flown by each pilot for each duty position (PF, PNF). One of these approaches must be followed by a go around and a missed approach procedure.

If the airline is flying several RNP AR procedures, the recurrent training should be performed on the more demanding procedure.



8 OPERATIONAL APPROVAL

The process to obtain an operational approval will be initiated by an application sent by the airline to its national authorities.

The application should describe the project and the strategy chosen by the airline to comply with the applicable regulation.

The project may have quite different implications depending the **level** of RNP AR that is envisaged or if the project is to fly an existing public procedure or to develop a private (or tailored) procedure.

The airline with its national authorities will need to determine the aircraft equipment and the level of aircraft certification adequate for the intended type of RNP AR operations. The level of operational requirements and the way the national authorities will supervise how the airline comply, may influence this decision.

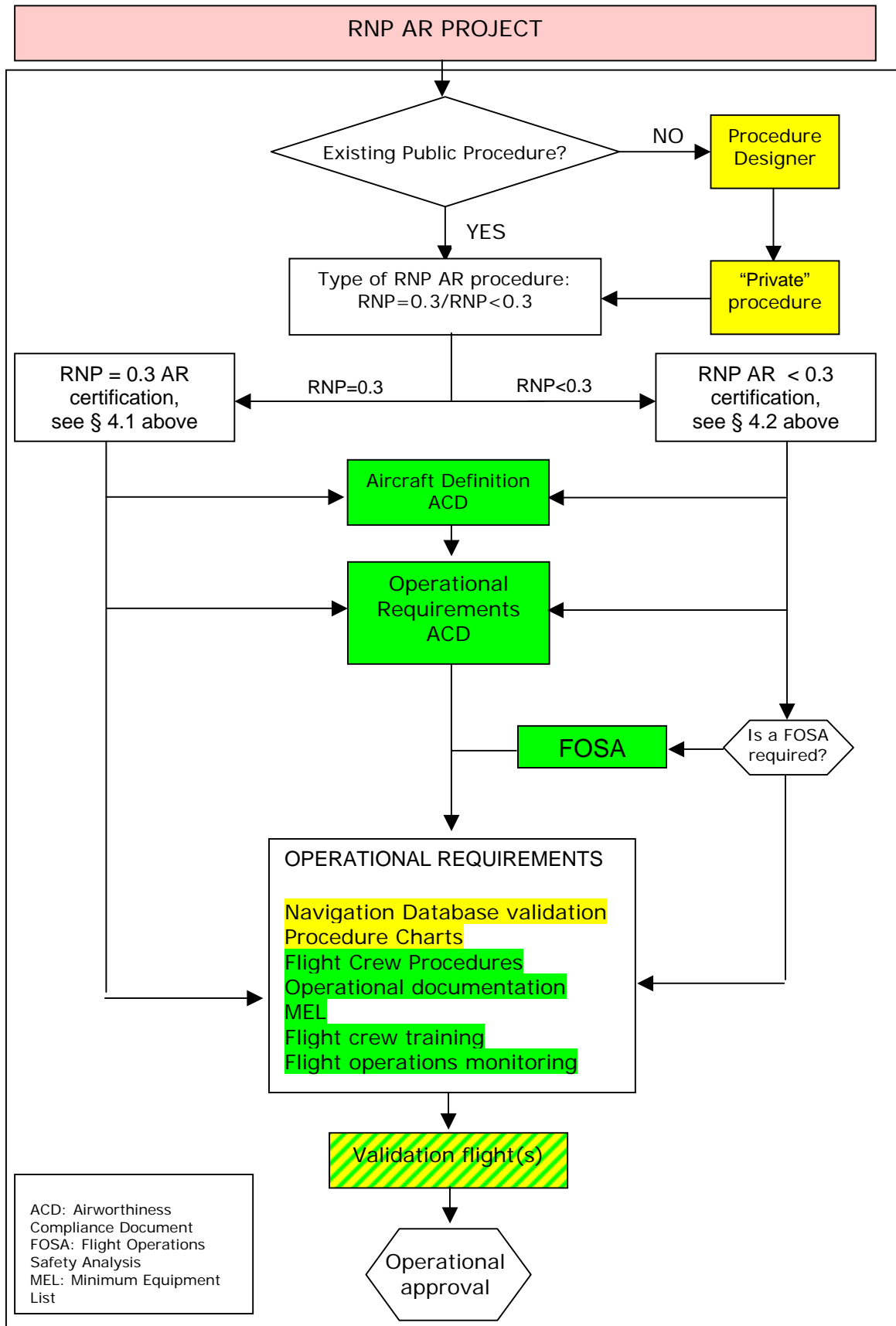
The ACD referenced in the AFM should be used to support the airline's operational approval. When the intended RNP value is lower than the Airbus demonstrated values in abnormal conditions, the airline must perform a Flight Operations Safety Analysis (FOSA) for the specific procedures being envisaged. When the RNP values in abnormal conditions are used no FOSA is required.

The operational evaluation will need to be reviewed by the national authorities, as it may induce specific operational requirements.

The overall check of the aircraft capability to fly the intended procedure, but also that the flight crew procedures and training are adequate, will be made during one (or more) validation flight(s) in good weather conditions (VMC).

The authorities may require the airline to accumulate a minimum experience during revenue flights with higher weather minima before granting approval to the lowest minima

The general process is described in the schematic below:



8.2 AIRBUS OPERATIONAL SUPPORT

The airline has the ownership of its RNP AR project. It will require the full commitment of the airline organization from executive management to the flight operations and training at all levels.

An RNP AR project cannot be “bought” out of the shelf, but the airline may expect support from Airbus and selected service providers.

The areas where Airbus can provide assistance is indicated in green in the above schematic. The area where the airline may need to seek the support of a service provider is underlined in yellow.

For the design of private (tailored) RNP AR procedures, the airline will usually need to contract such a support.

Airbus is already working with such organizations for different projects and can put the airline in contact with selected providers.

To be successful, the project will require close coordination between the airline the service provider and Airbus.

Airbus may support the airline in the following tasks:

- Definition of the aircraft configuration in adequacy with the RNP AR project,
- Operational evaluation in the simulator to verify the fly-ability of the procedure and to define if necessary specific flight crew procedures,
- Compliance with operational requirements:
 - Statement of aircraft capability,
 - Development of additional flight crew procedures, FOSA.
 - Operational documentation and MEL,
 - Flight crew training (generic and if required specific),
 - Flight operations monitoring.
- Validation flight .

8.3 AIRBUS DELIVERABLE

The following deliverable are (or will be) available for RNP AR operations:

- The Airworthiness Compliance Document (ACD) and FM revision,
- Updated FCOM for aircraft with RNP AR certification (FM+ACD)
- Flight Crew Training
 - Ground CBT course,
 - Simulator training and simulator check for RNP AR (generic),
- Flight Operations Monitoring with AirFASE



9 LIST OF ABBREVIATIONS

The following list includes the abbreviations that are linked to RNP AR operations. Abbreviations defined in the FCOM are normally not listed here below.

ACD	Airworthiness Compliance Document
ASE	Altimetry System Error
AT	Along Track
CT	Cross Track
DA	Decision Altitude
EPE	Estimated Position Error
FAF	Final Approach Fix
FDP	Final Descent Point
FH	Flight Hours
FOM	Figure of Merit
FOSA	Flight Operations Safety Analysis
FTE	Flight Technical Error
FTE _z	Flight Technical Error in vertical direction
HAL	Horizontal Alarm Limit
HCE	Height Coupling Error
HFOM	Horizontal Figure of Merit of GPRS or GPS position
HIL	Horizontal Integrity Limit
IFPP	Instrument Flight Procedure Panel, new name of OCP
MA OCS	Missed Approach Obstacle Clearance Surface
MFTD	Maintenance and Flight Training Device
MOC	Minimum Obstacle Clearance
NDB	Navigation DataBase
NSE	Navigation System Error
OCP	Obstacle Clearance Panel (ICAO)
OCS	Obstacle Clearance
OEI	One Engine Inoperative
OPC	FMS Operational Program Configuration file
PDE	Path Definition Error
RF	Radius to Fix type of FMS path terminator, or FMS flight path leg
RNP	Required Navigation Performance
RNP AR	RNP with Authorization Required
ROC	Required Obstacle Clearance
SAAAR	Special Aircraft Aircrew Authorization Required

TF	Track to Fix type of FMS path terminator, or FMS flight path leg
TLS	Target Level of Safety
TSE	Total System Error
TSE _z	Total System Error in the vertical direction
VEB	Vertical Error Budget
VIP	Vertical Intercept Point
VNAV	FMS vertical navigation based on Baro VNAV principle
SA	Single-Aisle Airbus aircraft
LR	Long Range Airbus aircraft
AEO	All Engines Operative

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