INTRODUCTION

The concept of **Area Navigation (RNAV)** has been widely used and developed in aviation over the last 40 years. RNAV was broadly based on the use of fixed ground beacons (VOR and DME) and supplemented with Inertial Navigation Systems (INS) for longer range operations. However, in recent years the introduction of space based navigation systems (e.g. GPS) has greatly increased the scope of what can be achieved by RNAV systems. Indeed, airspace design and aviation legislation has struggled to keep up with the advances made in these technologies. Consequently, in 2008 ICAO introduced the concept of **Performance Based Navigation (PBN)** to bring commercial aviation in line with advancing technology.

As satellite navigation accuracy and integrity has improved, it has allowed the accuracy of RNAV to be extended to instrument approaches. For many years all instrument approaches were exclusively flown using ground based radio aids and fell into 2 clear categories: **Precision and Non-precision approaches**. Now, with the introduction of RNAV/RNP approaches this distinction between the two basic categories of approach **has become less clear** to crews.

The aim of this document is bring flight crews up to date with the ICAO concept of PBN and in particular to establish some context between the various RNAV/RNP based approaches. With the introduction of the PBN concept and the advancement of satellite navigation the terminology and scope of area navigation has increased greatly. It can be difficult for crews to keep up with the changing technology and techniques.

Clearly, this subject can be as complicated as you may want it to be; however, this guide will aim to keep the subject simple and generic (nothing type specific) so that the general concept can be developed.

AREA NAVIGATION

Area Navigation (RNAV) uses VOR, DME, INS and GNSS(GPS) **to establish an accurate aircraft position** for use by the aircraft's Flight Management System (FMS). The accuracy required for this RNAV technique has depended on the airspace in which you flew and was described by the **Required Navigation Performance (RNP)**.

For flying en-route this was referred to as **Basic Area Navigation (B-RNAV)** and required a typical RNP of 5. In other words, the RNAV system was required to maintain an accuracy of 5NM for at least 95% of the time. RNAV departures and arrivals required more precision (P-RNAV) and would typically need an RNP of 1.

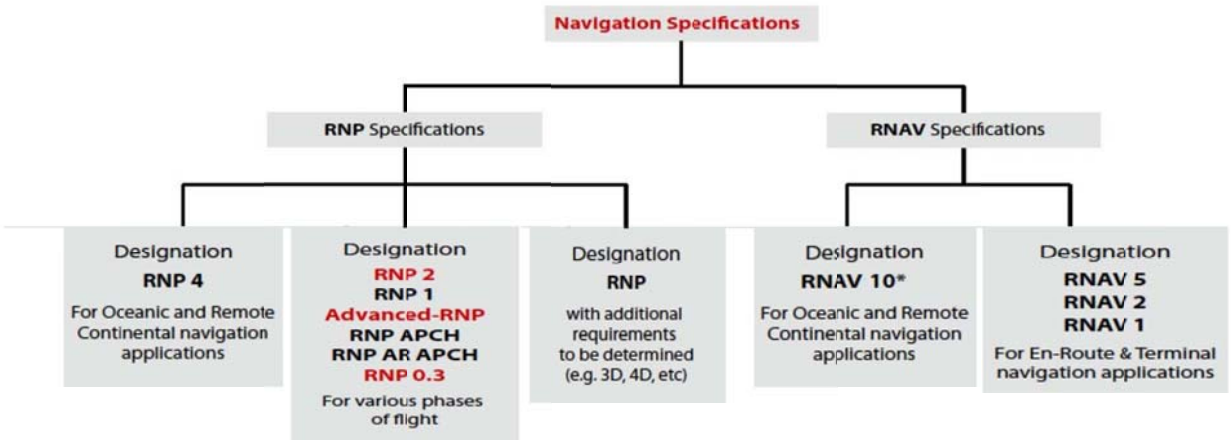
Forget about the terms B-RNAV and P-RNAV, **they are not used anymore**!

PERFORMANCE BASED NAVIGATION (PBN)

The introduction of PBN by ICAO in 2008 has changed the terminology used in Area Navigation (and this, understandably, can lead to some confusion with crews). Now the term “RNP” is used differently to the description above.

RNAV and RNP essentially mean the same thing, but with one main difference: RNAV refers to the area navigation technique as described above. However, RNP now means the same navigational technique as RNAV, but with the addition of an **on-board monitoring and alerting system** to monitor the integrity and accuracy of the system. This on-board monitoring has been made possible with the use of satellite navigation technology (e.g. GPS). An example of this on-board monitoring would be **RAIM (Remote Autonomous Integrity Monitoring)**. So airspace that requires area navigation techniques **with on-board monitoring** and alerting would be using an **RNP** system and complying with RNP specifications. If **no on-board monitoring** is required for a specific airspace then area navigation can be achieved by an **RNAV** system and complying with RNAV specifications.

PBN airspace is now **divided** into **two specifications, RNAV specification** and **RNP specification**. Each of these specifications are further divided, depending on the accuracy required. For example, airspace requiring 4NM accuracy and an RNP system will be designated RNP4; conversely, airspace requiring an accuracy of 10NM and an RNAV system would be designated RNAV10. The chart below summarizes this:



Source: *Eurocontrol, 2013, Introducing Performance Based Navigation (PBN) and Advanced RNP (A-RNP).*

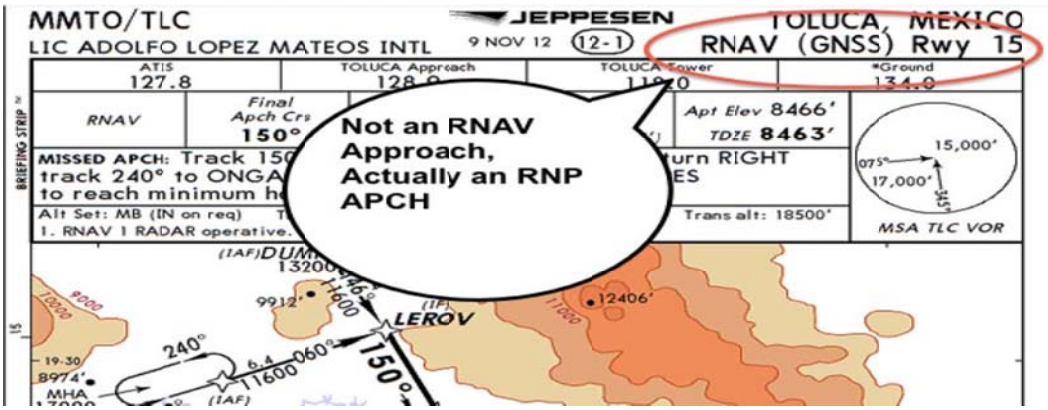
The RNP values in red show the additions to the RNP specification in 2013 to indicate how quickly this concept is developing. It could also be noted from the above table that the PBN concept not only covers terminal and en-route area navigation techniques, as did conventional area navigation, but also extends to the approach phases of flight. Previously instrument approaches have only been achievable by using ground based radio aids (ILS, VOR, NDB etc..).
Today, approaches can be flown using on-board area navigation systems to the **RNP specification** (area navigation with on-board monitoring and alerting), this is known as an **RNP APCH**.

RNP APCH

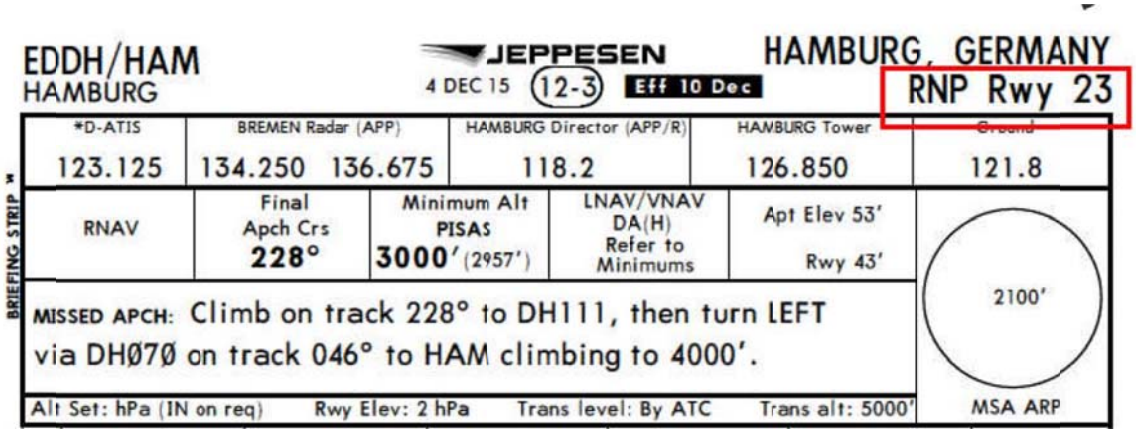
The ICAO PBN concept allows for instrument approaches to be flown using RNP systems. RNP systems are a development of RNAV systems **with the addition of on-board monitoring** and alerting of the system (for example RAIM). These on-board monitoring systems are generically known as **Aircraft Based Augmentation Systems (ABAS)** and use satellite information to monitor the performance and integrity of the RNP system and alert the crew if it is not performing correctly.

It is worth noting at this point that this is where some confusion can creep in. These approaches are **RNP approaches**. However, due to legacy reasons they appear on Jeppesen charts as 'RNAV' approaches (for example RNAV (GNSS)). They are not 'RNAV' approaches, but RNP system approaches that have been confusingly named on the chart.

All charts are eventually to be renamed more correctly to (for example) '**RNP RWY** 15', instead of the current format. This will bring all charts in line with the PBN concept. However, this is only mandated for December 2022 and until then you can expect to see the variety of naming formats for RNP Approaches continuing. At the time of writing only 25 airports in the world had adopted the new naming format.



Below is an example of the new chart naming convention to be implemented by December 2022:



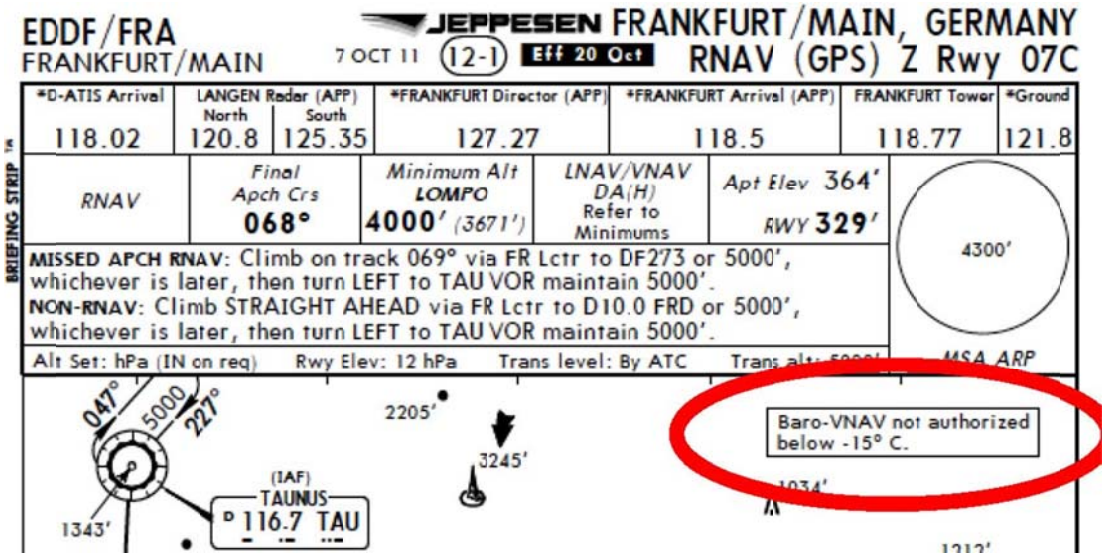
RNP approaches are designated **RNP APCH** and can be sub-divided as follows:

RNP APCH LNAV

These approaches are flown using **horizontal guidance only**, there is **no vertical guidance**. This approach would be flown as a NPA using a vertical mode (VS for example) and the CDFA technique. Horizontal guidance is given by the FMS (with GPS as the navigation mode) and the approach is flown to LNAV minimums. This is a NPA and the vertical portion of the approach would be expected to be flown using a CDFA technique; because of this the minimums are shown as DA(H) on the Jeppesen charts and crews should add 50ft to avoid undershooting the DA(H) in case of going around at the minimum.

RNP APCH LNAV/VNAV

This type of RNP approach uses **horizontal guidance from the FMS**, the same as for a RNP APCH LNAV, but also **provides vertical guidance**. The vertical guidance uses the **barometric** vertical channel to produce the vertical guidance. The FMS uses the altitude/height of the FAF and the runway touchdown point and 'draws' a line between the two points. This profile could be flown in the VGP/VNAV mode (type-specific). As the vertical profile is based on barometric data it is subject to the usual errors we associate with a barometric system (remember the errors of an altimeter?), in particular **temperature error**. Some approach plates will state that the approach should not be flown below a certain temperature:

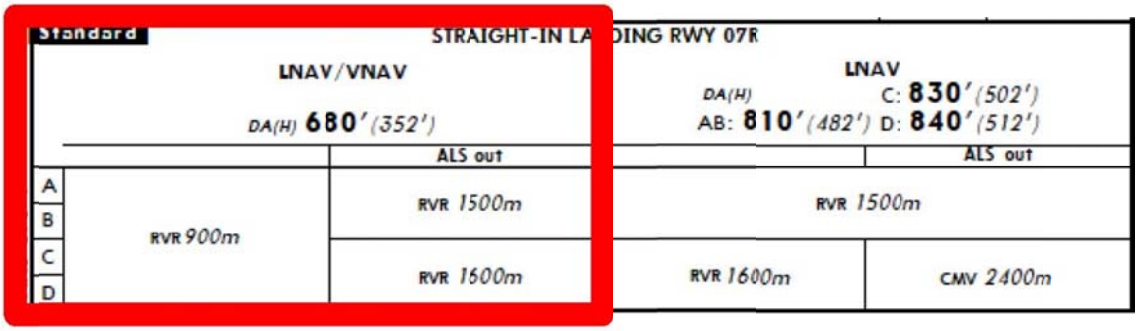


As the **FMS vertical profile on RNP** approaches **must never be adjusted manually**, manual temperature compensation cannot be used and the temperature limitation on the chart must be observed. However, if your aircraft has an in-built temperature compensation capability then this may be utilized to allow the approach to be flown below the charted temperature limitation, provided that the aircraft manufacturer's instructions for the use of BARO-VNAV functions are followed. The temperature compensation function must also be authorized by the appropriate Air Navigation Service Provider (ANSP).

The reason is that for temperatures down to -15°C the more simple formula of "4% per 10°C deviation from ISA" will be accurate enough. For temperatures lower than that a more precise formula has to be used and that can only be done with the help of in-built temperature limitation functions.

Should the temperature be below the charted minimum and your FMS cannot compensate the temperature, all is NOT lost: you can always fall back to RNP APCH LNAV and control the vertical profile of the approach with a standard vertical mode like VS. Don't forget to **correct the final approach altitude, intermediate check altitudes and the minimum for temperature errors**.

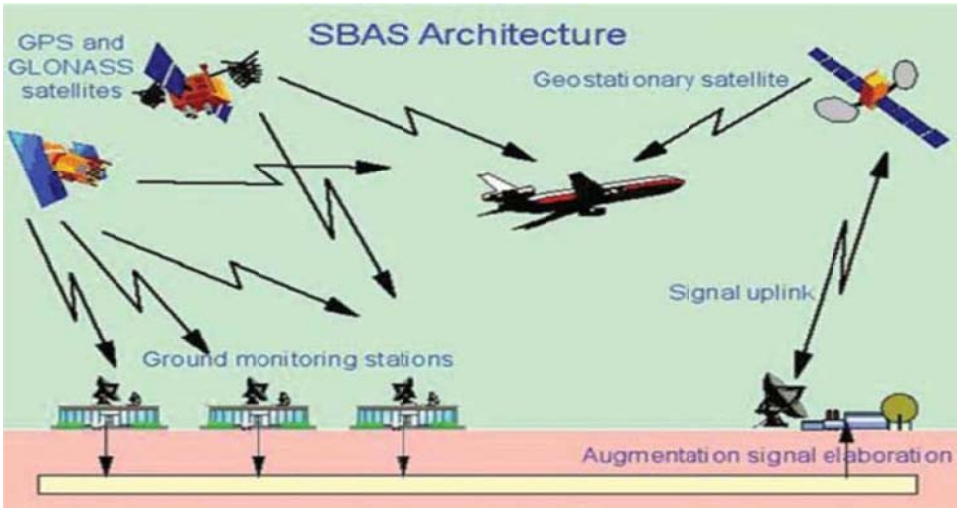
Despite providing vertical guidance, the accuracy of this approach is not good enough to make it equivalent to a Precision Approach; however, it does not fall into the NPA category either. Accordingly, **RNP LNAV/VNAV** is also known as an **APV approach** (**AP**proach with **V**ertical Guidance). In fact, as it uses a barometric vertical channel, it is called an **APV (Baro)** approach. Minimums are given as a DA/DH on the Jeppesen chart. (Note: there is **no** requirement to add 50ft to the charted minimums as the approach provides vertical guidance).



RNP APCH LP

RNP approach with **Performance (LP)**. This approach requires **extra equipment on-board the aircraft** known as **Space Based Augmentation System (SBAS)** or **Wide Area Augmentation System** (**WAAS**).
This equipment improves the accuracy of the GNSS input to the RNP system and so the horizontal guidance is similar to that provided by the localizer on an ILS.

How does SBAS work? SBAS is a system that comprises of a series of ground based satellite receivers. Each site is accurately surveyed, so when a GNSS (e.g. GPS) signal is received by the ground station, the difference in the received GNSS position is compared to the accurately surveyed position. The **position error is sent to a central processing station** and then **transmitted to a geostationary satellite**, which in turn **re-transmits the error** to the aircraft. The **on-board SBAS receiver** processes this error signal to produce a very accurate GPS position to the aircraft's RNP system as well as improved integrity monitoring information.



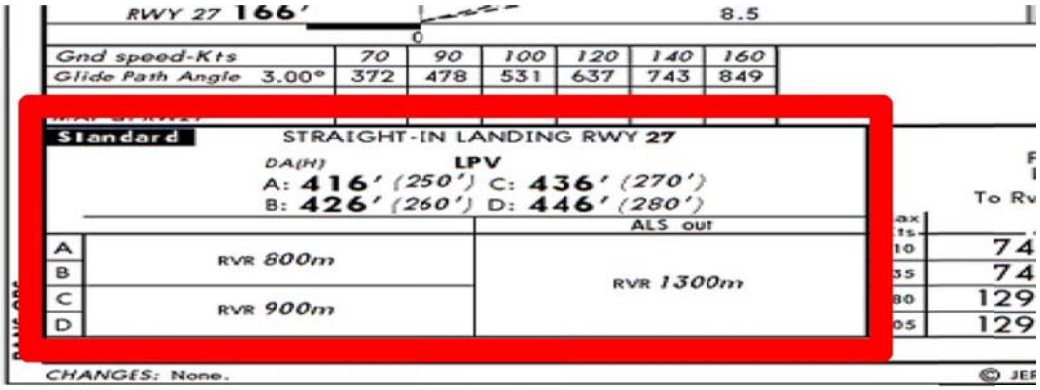
Vertical guidance for RNP APCH LP is **not** provided, so it is a NPA and a CDFA technique is expected to be flown; consequently, minimums will be shown as a DA(H) on the Jeppesen chart and crews need to **add 50ft** to the minima. This would require an autopilot mode such as Vertical Speed or Path to fly the vertical profile.

RNP APCH LPV

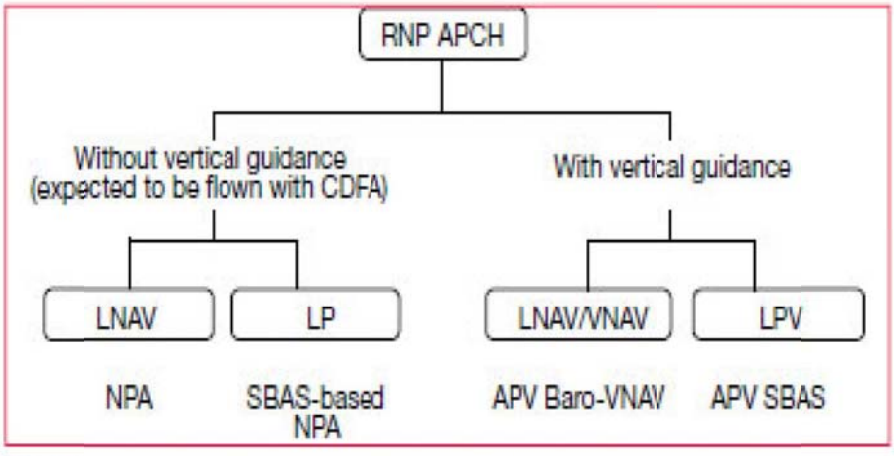
RNP approach, **L**ocalizer **P**erformance with **V**ertical guidance (**LPV**). This approach also requires an **SBAS receiver** to be installed on-board the aircraft. The approach uses the improved accuracy and integrity of the SBAS signal to provide horizontal guidance equivalent to the accuracy of a localizer, but **also provides vertical guidance**. Hence, this approach is also sometimes called an **APV SBAS** approach. Instead of using barometric altitude/height to calculate the vertical profile (as in the APV (Baro) approach) the LPV approach uses the GPS vertical channel. The GPS vertical position of the Final Approach Point (FAP) and the touchdown point provides a notional (geometric) glidepath. There are a few advantages to using the GPS vertical position as opposed to the barometric positions:

1) thanks to the SBAS corrections, the GPS vertical position is **more accurate** than the barometric
2) the GPS vertical position does **not** suffer from the errors that affect a barometric system and so **no** temperature error corrections/limitation for the vertical profile of the approach apply (DA(H) still needs to be temp-compensated!).

Consequently, an RNP LPV approach, although not technically considered a precision approach, can provide similar accuracy and performance as an ILS. Minimums are shown as DA(H) on the Jeppesen chart and there is **no** requirement to add 50ft.



The different types of RNP approaches can be summard as follows:



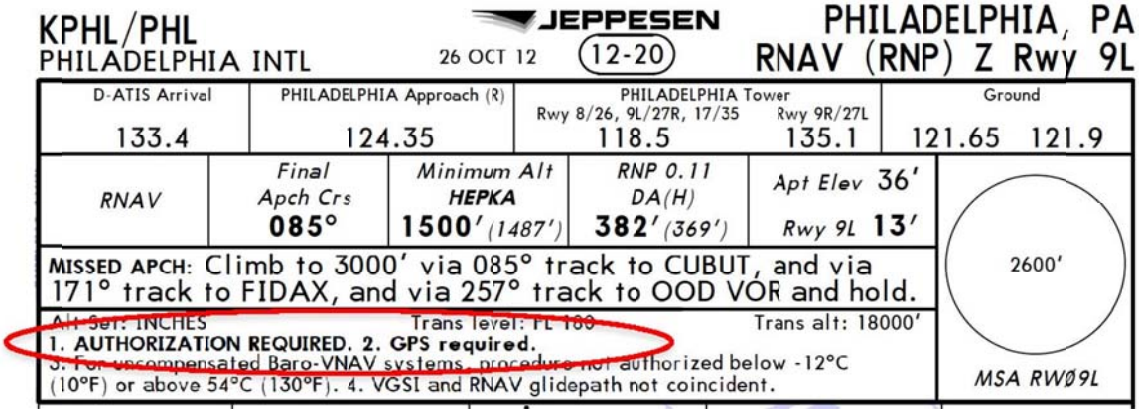
Remember: if your type of approach does **not** provide any vertical guidance, you better **add 50ft** to your DA(H) as it will avoid you undershooting the minimum altitude(height) when going around at decision altitude(height).

RNP (AR) APCH

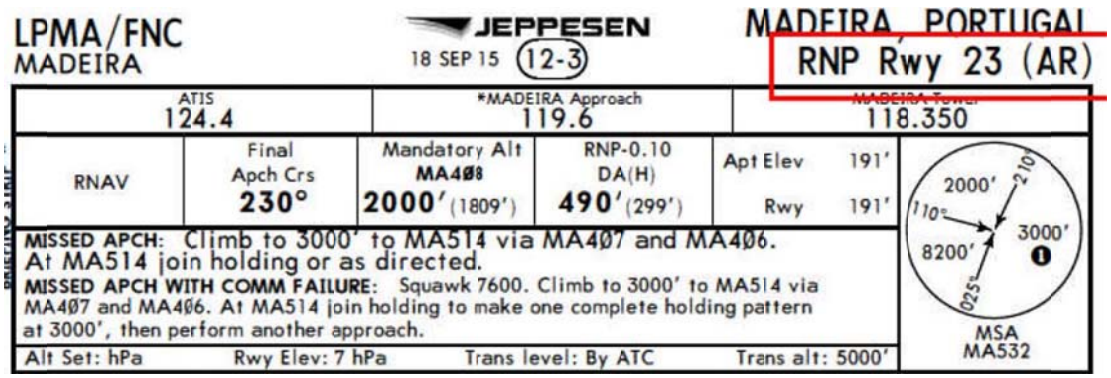
RNP APCH, **A**uthorization **R**equired. These approaches are a development from RNP APCH.
Before you can fly these approaches a specific authorization by the authority for an operator is required. The authorization will require that the operator will need to meet additional aircraft and flight crew requirements in terms of quality and training. This is sometimes referred to in the US as Special Aircraft and Aircrew Authorization Required (SAAR).

RNP (AR) approaches provide a high level of navigational performance (accuracies from 0.3 to 0.1nm) and will allow curved approaches to be flown to low minimums. The approaches are designed for use when a direct approach is not operationally possible. Clearly, this kind of approach can provide big advantages to operators that routinely fly to remote or mountainous VFR-only airports where there are no approach aids. For example, one could imagine the operational and commercial advantages of being able to fly to CAT 1 minimums at LSZS (Samedan) during the ski season.

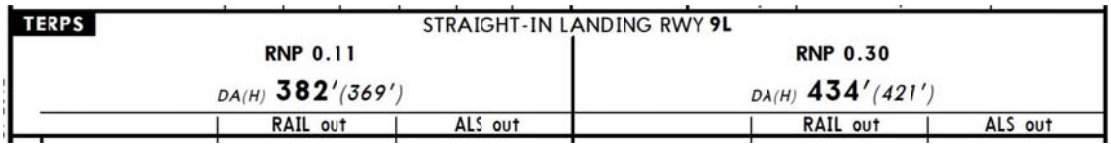
Once again, these approaches are slightly confusingly labelled on the Jeppesen charts. They are RNP approaches (not RNAV, as on-board monitoring is required); however, the charts are currently labelled as RNAV(RNP) as shown below.



As explained in Chapter 4, the naming convention for RNP (AR) approaches is also mandated to change by December 2022. Below is an example of the new PBN naming convention:

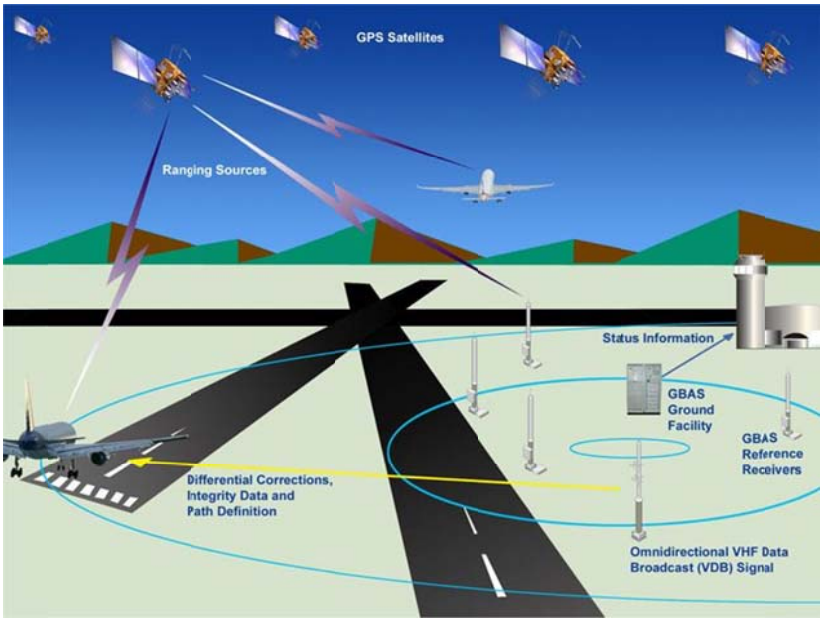


Note the minima label on a RNP (AR) APCH:



RNP GBAS

Ground Based Augmentation System (GBAS) is a system that is used to provide a correction, or error, to GNSS signals in the vicinity of an airport.
The GNSS receivers on the ground at an airport compare the accurately surveyed position of the antenna on the ground to the position indicated by GNSS. This error signal is then **broadcast directly to aircraft using a VHF signal**. Thus the aircraft can have a very accurate updated GNSS position with good integrity. GBAS works out to a relatively **short range** (typically 23nm) and allows RNP GBAS approaches to be flown to Cat I, and eventually Cat II and III, precision approach minima. GBAS has demonstrated accuracy of less than 1 meter both horizontally and vertically. RNP GBAS approaches can also be called **GBAS Landing Systems (GLS)**.



The number of RNP GBAS approaches in the US continues to grow steadily. As of 2017 there are currently 4 airports in Europe with an approved GBAS station; they are Bremen/EDDW, Malaga/LEMG, Frankfurt/EDDF and Zurich/LSZH.

CONCLUSION

Concluding this document, flight crew shall take away the following key points: PBN terms have changed since the introduction of area navigation, e.g. “B-RNAV” and “P-RNAV” do not exist anymore.

Navigation performance is now categorized as
- **RNAV** (unmonitored accuracy)
- **RNP** (monitored accuracy)

Approach procedures now provide a variety of options, depending on onboard and ground equipment. All users of RNP approach procedures need to be aware that approach charts are confusingly named. The only correct header shall be “**RNP**”, but many are still named “RNAV (GNSS)”, “RNAV (GPS)” or “RNAV (RNP)”, although they are RNP approaches, not RNAV approaches. Until 2022 all charts will be named the same and you can expect wrong chart titles until then.

Some approaches base their vertical path on barometric altitudes and are therefore susceptible to classic altimeter errors due to temperature errors and incorrect pressure settings. Caution has to be exercised, approach plates need to be checked for temperature limitations.
The above is the case for **LNAV** (horizontal guidance only, add 50ft to your minimum) and **LNAV/VNAV** (horizontal and vertical guidance) approaches. An **On-Board Monitoring System**, such as **RAIM**, is required.

When you are facing an **RNP LP** (horizontal guidance only, add 50ft to your minimum) or **LPV** approach (horizontal and vertical guidance), temperatures won’t have any effect on your vertical path, because these are geometric approaches, where your altitude and path are determined by GPS. Its precision comes from a **Satellite Based Augmentation Systems (SBAS/WAAS)** that corrects for signal errors.

Furthermore there are **RNP AR** approaches into special places or with special paths, for which an **Authorization** is **Required** (training etc.).

Finally you may come along **RNP GBAS** approaches or **GLS (GBAS Landing Systems)**, where a **Ground Based Augmentation System** sends you a correction signal directly, when tuned to the right frequency. GBAS approaches provide excellent precision like ILS CAT1 approaches, or better.

Carrying this information over to your flight simulator cockpit, you will need to know how to load the relevant procedures from your FMC database, prepare your approach and then finally execute it. Depending on your aircraft type, you may set your altitude selector down to your minimum, threshold elevation or missed approach altitude. In most cases the missed approach altitude will be set to avoid inadvertent level-offs during the approach, but some avionics may not let you descend as long as the altitude selected is equal or higher than your current altitude.

Another good idea is to **NOT** fly directly to your FAF (final approach fix), but intercept the final approach path (centerline) at least 3 NM prior to the FAF or go direct to another WPT (waypoint) prior to your FAF. Some planes need a lineup of at least 2 NM to be established on the centerline before descending.

So, **please go and find out for aircraft you fly on your FS**, practice those approaches, actively request them from ATC. Don’t be surprised if ATC initially has no clue what “*RNP approach runway xx*” means, you may have to tell from “*RNAV GPS approach*”, because of all the confusing naming conventions.

REFERENCES

EASA Annex III to ED Decision 2009/019R/R of 16/12/2009, AMC 20-27 – Airworthiness Approval and Operational Criteria for RNP APCH Operations including APV BARO VNAV Operations.

Eurocontrol, 2013, Introducing Performance Based Navigation (PBN) and Advanced RNP (A-RNP).

ICAO Doc 9613, 2012, Performance based Navigation (PBN) Manual

ICAO Doc 9997, 2015, Performance Based Navigation (PBN) Operational Approval Manual.

ICAO Doc 9905, 2009, Required Navigation Performance Authorization Required (RNP AR) Procedure Design Manual

TERMINOLOGY

RNAV	Area Navigation	Required accuracy of position during 95% of the time, level of accuracy depends on airspace and procedures. Accuracy **NOT** monitored.
RNP	Required Navigation Performance	Required accuracy of position during 95% of the time, level of accuracy depends on airspace and procedures. Accuracy **IS** monitored by on-board equipment.
PBN	Performance Based Navigation	Airspace that is defined as PBN allows either RNAV or RNP
B-RNAV	Basic Area Navigation	An outdated term when RNAV was new, it described an accuracy of 5 NM during 95% of the time. **Not used anymore!**
P-RNAV	Precision Area Navigation	An outdated term when RNAV was new, it described an accurary of 1 NM during 95% of the time. **Not used anymore!**
ABAS	Aircraft Based Augmentation System	Onboard systems monitor position data and warn the crew if an error is suspected. RAIM is one those systems
RAIM	Receiver Autonomous Integrity Monitoring	GPS receivers monitor incoming position data and can determine faulty data
SBAS/WAAS	Satellite Based Augmentation System/Wide Area Augmentation System	Position errors are measured by ground stations and broadcast to aircraft through a specialized satellite
GBAS	Ground Based Augmentation System	Position errors are measured by ground stations and broadcast directly to aircraft in their area by VHF communication
APV (Baro)	Approach with Vertical Guidance	e.g. LNAV/VNAV approach, it provides guidance for both a the horizontal as well the vertical path, like an ILS. It is based no barometric measurements and requires corrections for low temperatures
NPA	Non-Precision Approach	An approach that provides horizontal guidance only, the vertical profile has to be achieved manually by crew
CDFA technique	Continuous Descent Final Approach technique	Approaches without vertical guidance should be flown in such a manner that achieves a continuous descent profile to avoid large changes in vertical profile, pitch and power
RNP APCH LP	Localizer Performance	This approach requires SBAS and provides horizontal guidance only, achieves the precision of a classical localizer
RNP APCH LPV	Localizer Performance with Vertical Guidance	This approach requires SBAS and provides both horizontal and vertical guidance, achieves the precision of a classical ILS. Due to its geometrical setup it does not suffer from temperature errors