Performance-Based Navigation – PBN

The concept PBN – Performance-Based Navigation – is commonly used in satellite-based navigation and means that the aircraft self-navigates by using inertial systems in all phases of flight, as long as the aircraft falls within the range of the source of navigation. There are two different kinds of navigation specifications, RNAV and RNP, which are described in more detail below.

RNAV – aRea NAVigation

The system support for navigation on board an aircraft is called RNAV (aRea NAVigation). It was developed in the 1960s to enable more effective flying of routes rather than using flight beacons to navigate and is still used today.

The RNAV concept is illustrated in Figure 3. The initial RNAV technique was based on flight beacons (VOR) and their associated distance measures (DME). The graphical position of the navigation point was determined by combining the direction and distance to/from the beacons A, B, and C. In order to fly en-route without being within the range of the source, an inertial navigation system was introduced.

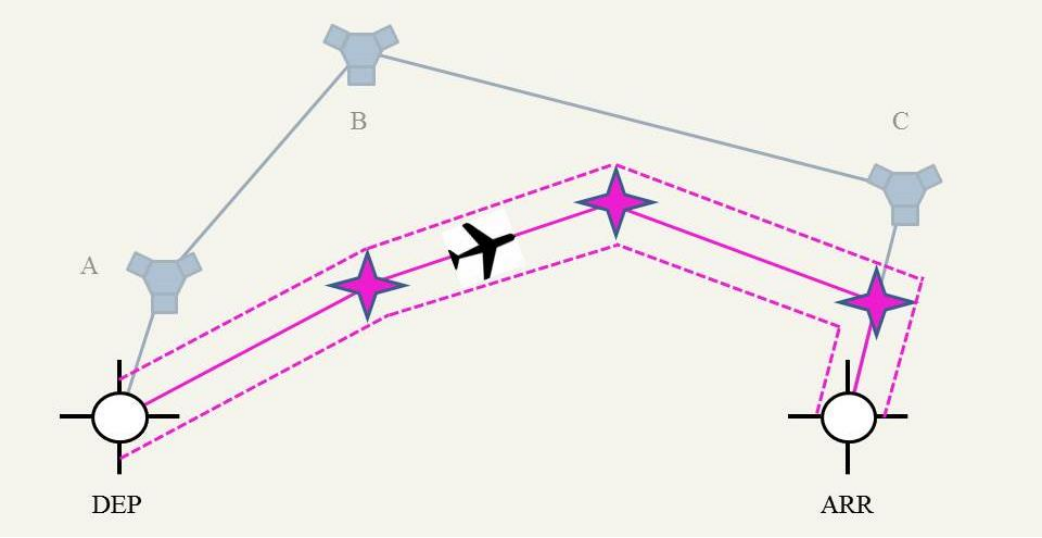

Figure 1: RNAV navigation (magenta line) via navigation points (magenta stars).

Required Navigation Performance – RNP

The development of GPS made it possible for civil aviation to include satellite signals in RNAV navigation, which improved position accuracy. Combined with a performance-monitoring and alerting system on board the aircraft, this formed a new concept called RNP (Required Navigation Performance).

The difference between RNAV and RNP is described in EASA Part SPA Subpart B, SPA.PBN.100:

There are two kinds of navigation specifications: area navigation (RNAV) and required navigation performance (RNP). These specifications are similar. The key difference is that a navigation specification that includes a requirement to have an on-board performance-monitoring and alerting system is referred to as an RNP specification. An RNAV specification does not have such a requirement. The performance-monitoring and alerting system provides some automated assurance functions to the flight crew. These functions monitor system performance and alert the flight crew when the RNP parameters are not met, or cannot be guaranteed with a sufficient level of integrity. RNAV and RNP performance is expressed by the total system error (TSE). This is the deviation from the nominal or desired position and the aircraft's true position, measured in nautical miles. The TSE should remain equal to or less than the required accuracy expected to be achieved at least 95% of the flight time by the population of aircraft operating within the airspace, route or procedure.

The RNP concept is described in Figure 4, in which the RNP operation can be seen as the aircraft following the green line. The RNP concept enables a narrow flight corridor and great flexibility in how to design the airspace.

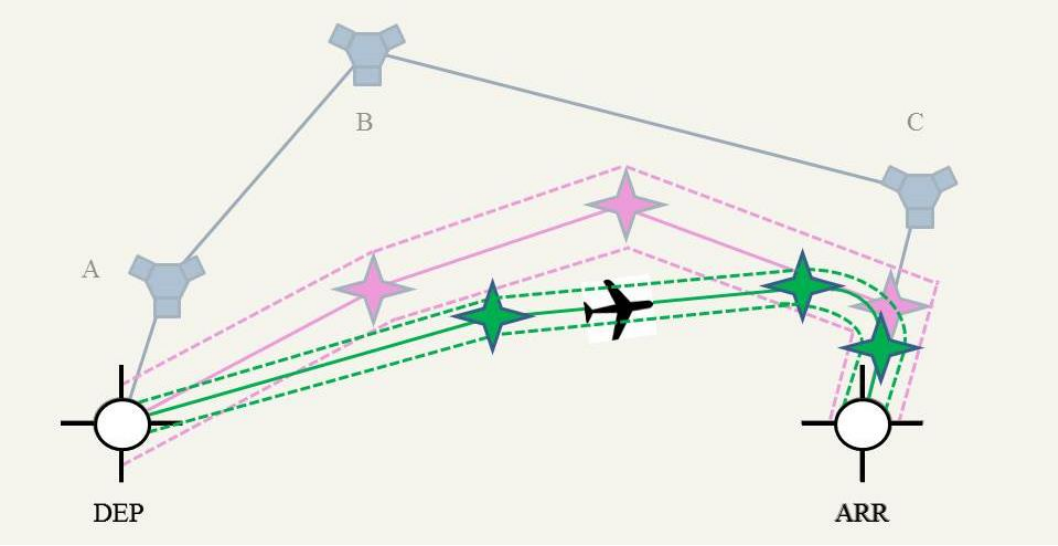

Figure 2: RNP navigation (green line).

Position accuracy

In PBN, the relevant navigation accuracy is stated so that a given airspace can meet certain requirements. RNAV is used for SID, STAR and en-route, which are phases of flight where the requirements for position accuracy are not as strict as for arrival and

departure procedures in terms of where obstacles need to be avoided; see Figure 5 below. However, beginning in 2024, the EU will also include these requirements for RNP (including SID and STAR) for the 20 largest airports in Europe, which include Stockholm Arlanda Airport.

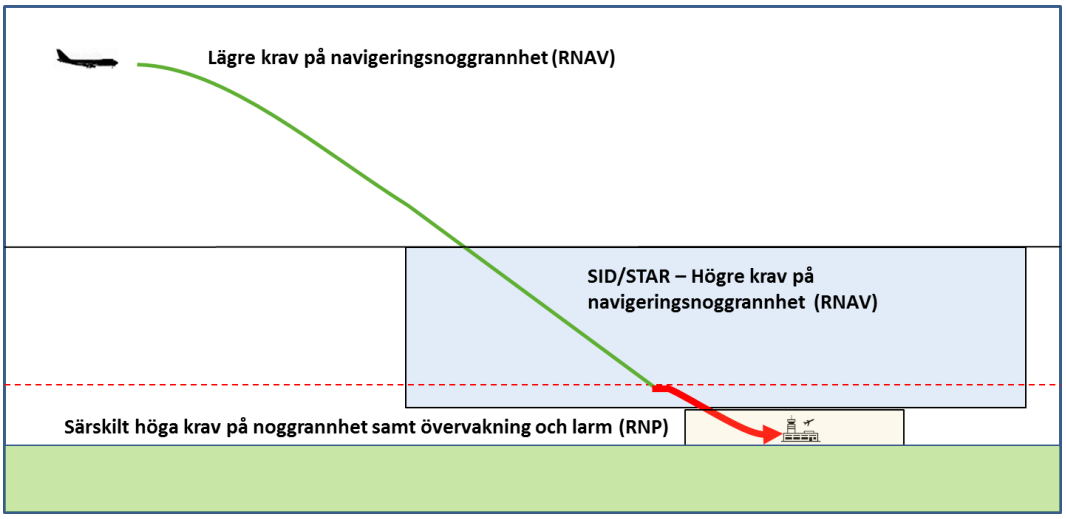

Figure 3: Simplified drawing of what position accuracy is required in different phases of flight.

Text in figure 5:
Lower requirements for navigation accuracy (RNAV)
SID/STAR – Higher requirements for navigation accuracy (RNAV)
Especially high requirements for accuracy and for monitoring and alarming (RNP)

PBN – structure and nomenclature

The PBN concept is described in ICAO's PBN manual Doc 9613. An overall description of the PBN concept is presented in Figure 6 below. Two examples of position accuracy are provided to support the diagram:

RNAV position accuracy:
The position accuracy required for a given airspace can, for example, be specified as RNAV 10 (RNAV – En-route). This means that the aircraft must not be positioned more than 10 nautical miles (NM) from its planned position during at least 95 percent of the flight.

RNP position accuracy:
Similarly, RNP 1 (RNP – Terminal) requires position accuracy to be ±1 NM during 95 percent of the flight. To make sure that the RNP requirement is met, a system is required on board the aircraft that alerts the crew if the value is exceeded.

Advanced RNP

According to [13.], an Advanced RNP is defined as follows:

> *Advanced RNP is a route specification that is intended for use from terminal area to en-route to terminal area. Advanced RNP uses a variable RNP value from 2.0 NM to 0.3 NM and is inclusive of Standard Instrument Departures (SIDs) and Standard Arrival Routes (STARs) and RNP APCH – LNAV and LNAV/VNAV approach procedures. Advanced RNP encompasses the following PBN navigation specifications:*
>
> *a) RNAV 5,*
> *b) RNAV 1 and RNAV 2*
> *c) Basic RNP 1*
> *d) RF Turns*
> *e) RNP APCH – LNAV and LNAV/VNAV*

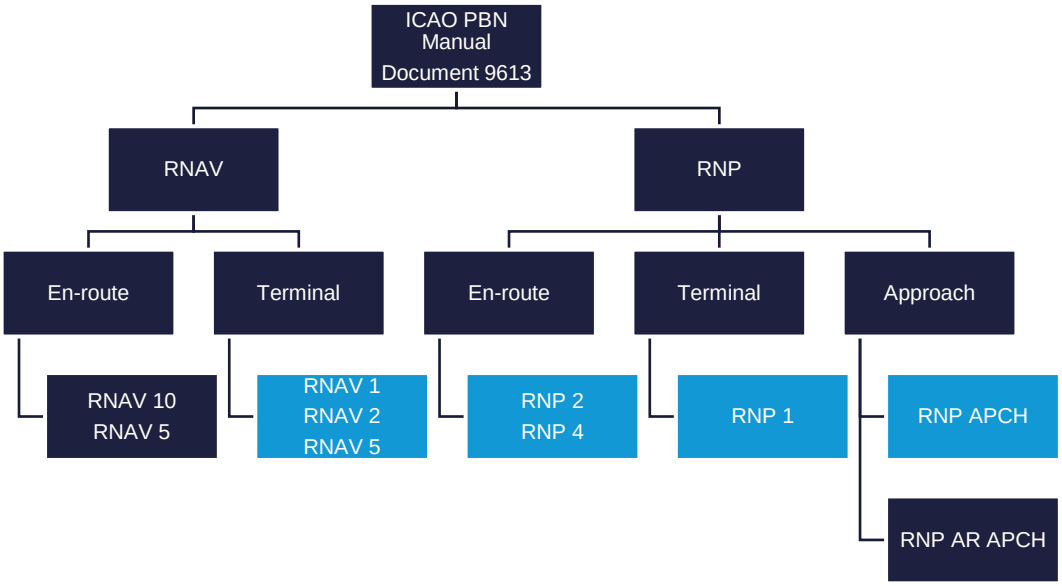

Figure 4: Navigation structure in PBN. The red boxes are connected to Advanced RNP.

Navigation application, navigation specification and navigation infrastructure

ICAO (**Fel! Hittar inte referenskälla.**) and Eurocontrol (**Fel! Hittar inte referenskälla.**) have developed recommendations for how PBN-based airspace should be constructed based on stakeholder requirements, existing airport infrastructure, environmental requirements, etc.

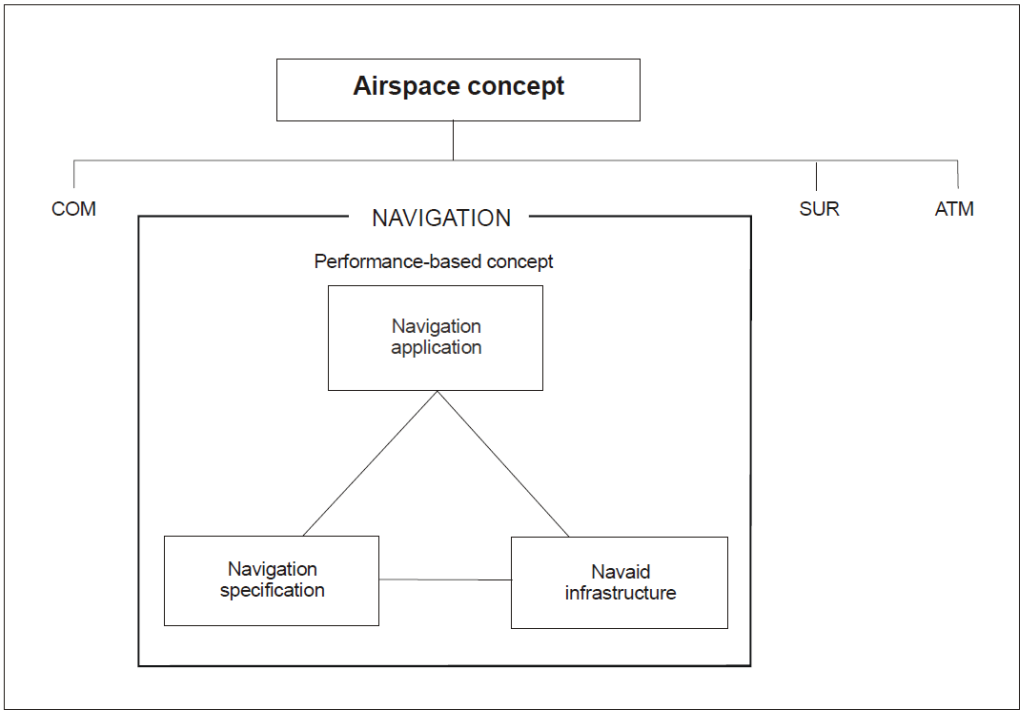

Figure 5: Performance-Based Navigation - Airspace Concept. From Fel! Hittar inte referenskälla.

Fel! Hittar inte referenskälla. illustrates how the PBN concept relates to the airspace concept through three different components:

- Navigation Application
- Navigation Specification
- Navigation Aid (NAVAID) Infrastructure

A **Navigation Application** contains a definition of the airspace to make sure that no capacity problems arise. It is also stated that all aircraft must be able to fly their optimal descent and climb profiles and/or that environmental conditions are complied with.

A **Navigation Specification** is a specification of technical and operational requirements that identifies what navigation accuracy is needed for ground-based equipment or equipment on board an aircraft in order to meet the navigation application's criterions.

The **Navigation Aid Infrastructure** describes what navigation aids are needed to meet the navigation specification's criterions. The infrastructure can be ground-based such as DME, VOR, NDB or ILS, or satellite-based such as GNSS. It can also be a combination of both, for example RNP to GLS (RNP being the satellite-based and GBAS being the ground-based infrastructure).