Flying RNAV (GNSS) Approaches in Private and General Aviation Aircraft

Luftfartstilsynet
CIVIL AVIATION AUTHORITY - NORWAY

Flying RNAV (GNSS) Approaches in Private and General Aviation Aircraft

TECHNICAL INFORMATION, REQUIREMENTS & RECOMMENDATIONS

PILOTS' GUIDE TO FLYING RNAV (GNSS) APPROACHES IN GENERAL AVIATION AIRCRAFT

Introduction

Global Navigation Satellite Systems (GNSS) have changed the face of navigation dramatically in recent years, in that they can give an accurate and instant readout of position almost anywhere in the world. At the time of writing, the most familiar GNSS system is the US Department of Defense Global Positioning System (GPS), and this document is based on the use of GPS aviation receivers.

GPS has already brought the opportunity for accurate Area Navigation (RNAV) within the budget of most aircraft operators. The development of GNSS based instrument approaches has now also brought the requisite technology for RNAV approach operations to light and private aircraft.

RNAV brings with it many new techniques. As with any new technology, there is a natural transition from the experience and knowledge of the old, to the techniques of the new. During this time, the opportunities for error and misunderstanding are great and, for a time at least, the new technology is likely to represent an increased risk of error before the benefits of the system's greater accuracy can be realized.

This course contains information on training and operational use of GPS for the flying of RNAV (GNSS) Approaches. Whilst, for the purposes of background, some information is given on the concept of Performance-Based Navigation (PBN) and RNAV, this document focuses mainly on the application, training and operational use of RNAV approach operations. This document is intended as a guide to pilots and instructors of privately operated, non-complex general aviation aircraft but much of the information may also be of use to other operators in the preparation of their own PBN training and operations programs.

Background

IFR operations depend upon a variety of navigation aids and techniques. A combination of these effectively provides the monitor and crosscheck necessary to capture both technical and human error. Where a single technical facility becomes the primary steering reference (primary reference), in instrument meteorological conditions (IMC), situational awareness and some form of crosscheck become critical to flight safety.

Basic GPS

For the basic GPS signal in space, whilst there are monitors of the signal available to the aircraft, it is still possible for the satellites to give erroneous information and for receivers to display it. Once an anomaly has been detected, without access to or reception of the correcting (differential) signals, it can take up to several hours for the error to be removed or corrected by the GPS system itself. The GNSS receiver manufacturers have, therefore, developed systems, internal to some of their aircraft receivers, known as aircraft-based augmentation systems (ABAS), most of which now include some sort of integrity monitor such as Receiver Autonomous Integrity Monitor (RAIM).

The GPS constellation and the ground stations are controlled from Colorado, in the United States. The system has demonstrated exceptional reliability, but like all systems, it has suffered technical and human failure. The satellite clocks are critical to the integrity of the system and are subject to regular intervention. Furthermore, the designs for receivers vary; particularly in the software that manages the satellite data for navigation. It is for these reasons that GPS must be used with knowledge and caution when used as the primary steering reference, for flight critical applications, such as instrument approach.

Timing is everything in GNSS, and each satellite has up to four atomic clocks with accuracies measured in the order of thousandths of millionths of a second. Master control stations and monitoring stations around the world, track and manage the satellites, relaying critical correctional data to them.

The GNSS signals are transmitted on multiple frequencies. For example, the US GPS transmits the civil signal on the L1 frequency (1,575.42 MHz), just above the distance measuring equipment (DME) band. Military and authorised users can get more accurate measurements on the encrypted ‘L2’ frequency (1127.60 MHz).

The L5 frequency (1176.45 MHz) band is reserved for aviation safety services. It features higher power, greater bandwidth and an advanced signal design which reduces errors caused by passage of the GPS signal through the ionosphere—a layer of charged particles up to 1000 km above the Earth’s surface.

GPS-signal quality

Augmentation systems

Having a way of alerting users that GNSS is underperforming is critical to the safety of the system. GNSS avionics have software to protect integrity—the measure of trust in the information supplied by the total system.

Integrity includes the ability of a system to provide timely warnings to the user when the system cannot be used for the intended operation.

Aircraft based, satellite-based and ground-based augmentation systems can ensure integrity. A number of augmentation systems can be used to improve the navigational performance provided by the GNSS constellations.

Satellite Based Augmentation System (SBAS) and Ground Based Augmentation system (GBAS)

The principle behind GBAS and SBAS is the same. Both systems utilizes fixed reference antennas on the ground, and calculates a correction and integrity signal to the receivers (users). The main differences are that GBAS uses a ground based transmitter to send the correction (augmentation) signal, whilst SBAS uses a geostationary satellite to send a similar signal. GBAS systems are intended primarily to support precision approach operations local to the airport where the installation resides, whilst SBAS systems are intended to give wide area coverage for both enroute and approach navigation.

GBAS has two or more GPS receiving antennas placed in proximity of the runways the system serves. The exact position of these antennas are known, and the system compares the GPS derived position with the known actual position of the antennas to calculate signal error. By combining such errors from multiple monitoring antennas, the system is able to calculate the ranging error from each individual satellite and broadcast this via the VHF Data Broadcast (VDB) station on the ground. The VDB station also broadcasts approach path data for up to 26 approaches.

SBAS augments the core satellite constellation by providing ranging, integrity and correction information via a geostationary satellite. This system comprises a network of ground reference stations called RIMS (Ranging an Integrity Monitoring Stations) and master stations that process this observed data and generate SBAS messages for uplink to the geostationary satellite. The geostationary satellite is the one that broadcast the augmentation signal to receivers. The ground reference stations (RIMS) are physical antennas spread out over a given region. Each antenna knows its exact position, and compares this position to the calculated position from GPS satellite array. By comparing the error between known position and calculated position from multiple RIMS stations, the system can pinpoint which of the orbiting GPS satellites that are producing the error. The system can identify errors caused by:

- Signal delay caused by varying thickness of the ionosphere
- Clock/time errors of individual GPS satellites
- Position/oribital errors of individual GPS satellites

Due to the close proximity of receivers and reference antennas in GBAS systems, the accuracy of the correction signal is very high. Similarly, the SBAS correction will be less accurate as the reference antennas are spaced far apart and receivers may be far away from the reference antennas.

Obviously, one SBAS geostationary satellite can’t cover receivers on the other side of the earth or below the horizon from the satellite. Therefore, several geostationary satellites are placed in different postions over the earth and in combination covers most of the regions on the northern hemisphere. As geostationary satellites have to orbit the earth in a narrow band around the equator, coverage and signal strength deteriorates at high latitudes as the satellites gets closer to the horizon and eventually disappears below.

Within Europe the SBAS is provided by the European Geostationary Navigation Overlay Service (EGNOS). Many receivers are now available with a Vertical Navigation (VNAV) function using SBAS services.

Other SBAS services provided or under development in other regions of the world include:

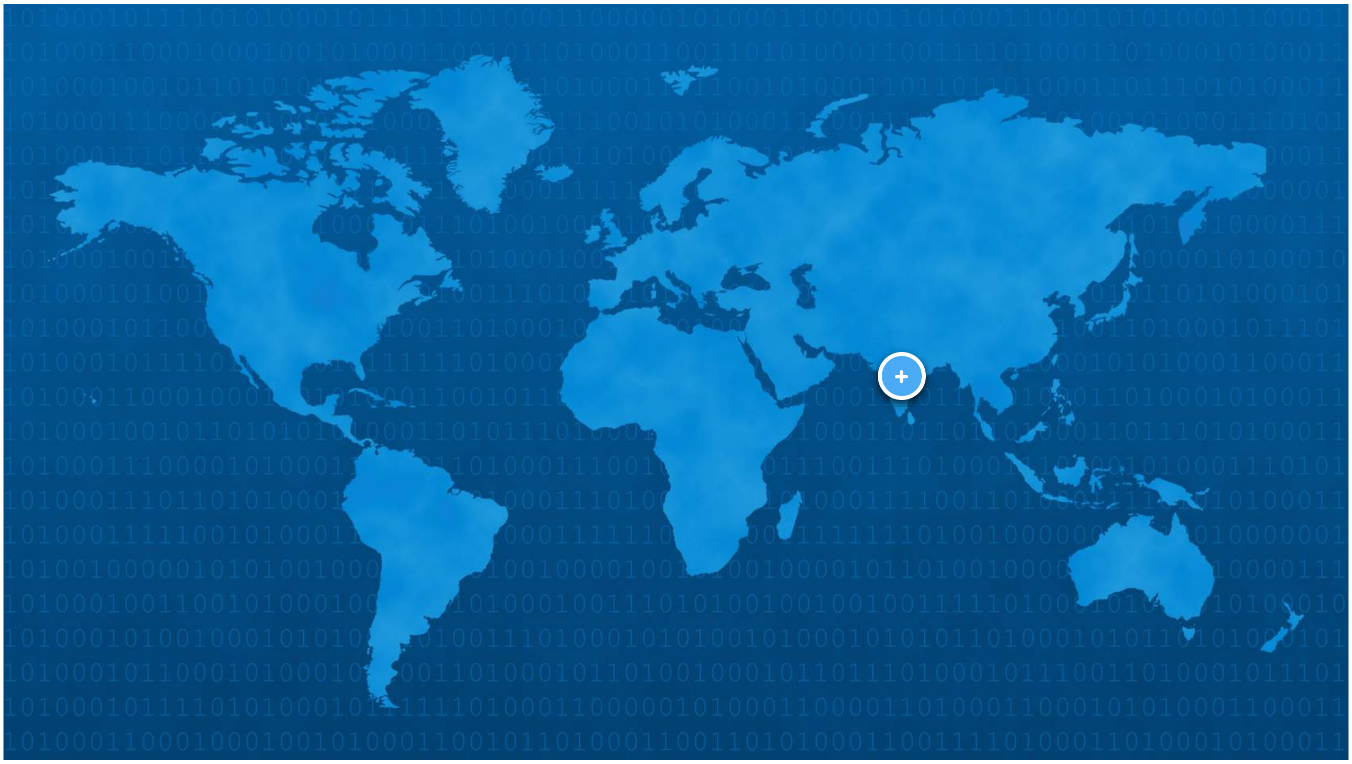
Wide Area Augmentation System (WAAS)* in the USA.

WAAS, a regional space-based augmentation system (SBAS) operated by the Federal Aviation Administration (FAA), supports aircraft navigation across North America.
Although designed primarily for aviation users, WAAS is widely available in receivers used by other positioning, navigation, and timing communities.
FAA is committed to providing WAAS service at the performance levels specified in the GPS WAAS Performance Standard. FAA is improving WAAS to take advantage of the future GPS safety-of-life signal to provide even better performance.
The WAAS service is interoperable with other regional SBAS services, including those operated by Japan (MSAS), Europe (EGNOS), and India (GAGAN).

Multi-functional Satellite Augmentation System (MSAS) in Japan

The MTSAT Satellite Augmentation System (MSAS) is the Japanese Satellite Based Augmentation System (SBAS) System: a GPS Augmentation system with the goal of improving its accuracy, integrity, and availability, and that uses the Multifunctional Transport Satellites (MTSAT) owned and operated by the Japanese Ministry of Land, Infrastructure and Transport and the Japan Meteorological Agency (JMA).

First tests were accomplished successfully, and MSAS system for aviation use was declared operational in September 27, 2007,[3][4][5] providing a service of horizontal guidance for En-route through Non-Precision Approach.



GPS Aided Geo Augmented Navigation (GAGAN) in India

The GPS Aided Geo Augmented Navigation system (GAGAN) is the SBAS implementation by the Indian government.

System for Differential Corrections and Monitoring (SDCM) in Russia

The System for Differential Corrections and Monitoring (SDCM) is the SBAS currently being developed in the Russian Federation as a component of GLONASS.

The main differentiator of SDCM with respect to other SBAS systems is that it is conceived as an SBAS augmentation that would perform integrity monitoring of both GPS and GLONASS satellites, whereas the rest of current SBAS initiatives provide corrections and integrity just to GPS satellites.

*The term ‘WAAS’ also tends to be used in a wider generic reference to SBAS services elsewhere in the world.

These services are expected to be ‘interoperable’, meaning the receivers should interpret whichever signal(s) they ‘see’ providing an apparently seamless operation from one area of coverage to another for example when taking off from Europe under EGNOS coverage and landing in USA under WAAS coverage.

WAAS is an extremely accurate navigation system developed for civil aviation. Before WAAS, the U.S. National Airspace System (NAS) did not have the potential to provide horizontal and vertical navigation for approach operations for all users at all locations. With WAAS, this capability is a reality. WAAS provides service for all classes of aircraft in all phases of flight - including en route navigation, airport departures, and airport arrivals. This includes vertically-guided landing approaches in instrument meteorological conditions at all qualified locations throughout the NAS.

FAA - About WAAS

Federal Aviation Administration.

FAA WEBSITE

FAA - STATUS

Federal Aviation Administration - William J. Hughes Technical Center. Further information on the status and performance of GPS.

FAA WEBSITE

- ICAO PBN Manual (Doc 9613)
- EASA AMC 20-27A
- EASA Opinion Number 01/2005 on "The acceptance of navigation database suppliers dated 14th January 2005
- TSO / ETSO C129A, C145A() and C146A()
- FAA AC 20-138()
- EASA AMC 20-5
- EASA Part FCL

- EASA Part OPS
- CAA CAP 804
- FAA AC 20-153
- CAA Safety Sense Leaflet 25
- Note: Appendix 5 is an extract from Australian Civil Aviation Safety Authority (CASA) Civil Aviation Advisory Publication CAAP 179A-(1) and is reproduced with the kind permission of CASA

References

- ICAO PBN Manual (Doc 9613)
- EASA AMC 20-28
- EASA Opinion Number 01/2005 on "The acceptance of navigation database
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Glossary

2D	Two Dimensional (Lateral Only)
3D	Three Dimensional (Lateral and Vertical)
ABAS	Aircraft Based Augmentation System
AC	Advisory Circular
ACAS	Airborne Collision Avoidance System
ADF	Airborne Direction Finder
AFM	Aircraft Flight Manual
AIP	Aeronautical Information Publication
AIRAC	Aeronautical Information Regulation And Control
AMC	Acceptable Means of Compliance
ANO	Air Navigation Order
ANP	Actual Navigation Performance
ANSP	Air Navigation Service Provider
APCH	Approach
APV	Approach with Vertical Guidance
ATC	Air Traffic Control
ATM	Air Traffic Management
ATS	Air Traffic services
Baro VNAV	Barometric data derived Vertical Navigation
B-RNAV	Basic Area Navigation
C/S	(aircraft) radio Call Sign
CA	Course Acquisition (code)
CAA	Civil Aviation Authority
CAAP	Civil Aviation Advisory Publication (Aus)
CAP	Civil Air Publication (UK)
CASA	Civil Aviation Safety Authority

CCO	Continuous Climb Operations
CDFA	Constant Descent Final Approach
CDI	Course Deviation Indicator
CDO	Continuous Descent Operations
CDU	Control Display Unit (in FMS)
DA/H	Decision Altitude / Height
DIS	Distance
DME	Distance Measuring Equipment
DOP	Dilution of Precision
DR	Dear Reckoning (navigation)
DTK	Desired Track
EASA	European Aviation Safety Agency
EFIS	Electronic Flight Instrument System
EGNOS	European Geostationary Navigation Overlay Service
EPE	Estimated Position Error
EPU	Estimated Position Uncertainty
ESSP	European Satellite Services Provider
ETA	Estimated Time of Arrival
ETSO	European Technical Standard Order
FAA	Federal Aviation Authority (USA)
FAF	Final Approach Fix
FAS	Final Approach Segment (of approach)
FAT	Final Approach Track
FD	Fault Detection
FDE	Fault Detection and Exclusion
FMC	Flight Management Computer
FMS	Flight Management System
FNPT	Flight Navigation Procedures Trainer
FSTD	Flight Simulation Training Device
GAGAN	GPS-Aided Geo-Augmented Navigation (India)
GBAS	Ground Based Augmentation System
GDOP	Geometric Dilution of Precision
GLS	GNSS Landing System
GNSS	Global Navigation Satellite System
GP	Glidepath

GPS	Global Positioning System
GPWS	Ground Proximity Warning System
GS	Groundspeed
HAL	Horizontal Alarm Limit
HIS	Horizontal Situation Indicator
HUL	Horizontal Uncertainly Level
IAF	Initial Approach Fix
ICAO	International Civil Aviation Organization
IF	Intermediate Fix
IFR	instrument Flight Rules
ILS	Instrument Landing System
IMC	Instrument Meteorological Conditions
INS	Inertial Navigation System
IR	Instrument Rating
IR(R)	Instrument Rating (restricted) (UK only)
JAA	Joint Aviation Authorities
LNAV	Lateral Navigation
LoA	Letter of Acceptance (navigation data base publication)
LOC	Localizer
LOI	Loss of integrity
LP	Localizer Performance
LPV	Localizer Performance with Vertical Guidance
MAP	Missed Approach Procedure
MAPt	Missed Approach Point
MDA/H	Minimum Descent Altitude / Height
MFD	Multi-function Display

MLS	Microwave Landing System
MSAS	Multi-functional Satellite Augmentation System (Japan)
NANU	Notices to Navstar Users
NATS	National Air Traffic Services (UK)
NDB	Non Directional Beacon
NOTAM	Notices to Airmen

NPA	Non-precision Approach
NTF	Nouvelle Triangulation de France (1970)
OPMA	On-board Performance and Monitoring & Alerting
Part FCL	EASA Regulation 1178/2011 Annex 1 - Flight Crew Licensing (as amended)
PBN	Performance Based Navigation
PDOP	Position Dilution of Precision
PIC	Pilot in Command
POH	Pilots' Operating Handbook
PPS	Precise Positioning Service
P-RNAV	Precision Area Navigation
RAIM	Receiver Autonomous Integrity Monitoring
RIMS	Reference Integrity Monitoring Station
RMI	Radio Magnetic Indicator
RNAV	Area Navigation
RNP	Required Navigation Performance
RTF	Radiotelephony (Phraseology)
RVR	Runway Visual Range
SA	Selective Availability
SARPS	Standards and Recommended Practices
SBAS	Satellite-based Augmentation System
SDCM	System for Differential Corrections and Monitoring (Russia)
SDF	Step-down Fix
SID	Standard Instrument Departure
SOP	Standard Operating Procedures
SPS	Standard Positioning Service
SRA	Surveillance Radar Approach
STAR	Standard Instrument Arrival
TA	Transition Altitude
TAA	Terminal Approach Altitude
TAWS	Terrain Awareness Warning System
TCAS	Traffic Collision Avoidance System
TGL	Temporary Guidance Leaflet
TSO	Technical Standard Order
US	United States

VAL	Vertical Alarm Limit
VFR	Visual Flight Rules
VGP	Vertical Glidepath
VMC	Visual Meteorological Conditions
VNAV	Vertical Navigation
VOR	VHF Omni-directional Range Beacon
WAAS	Wide Area Augmentation System
WGS 84	World Geodetic System (1984)
XTK	Cross-track Error

What is PBN?

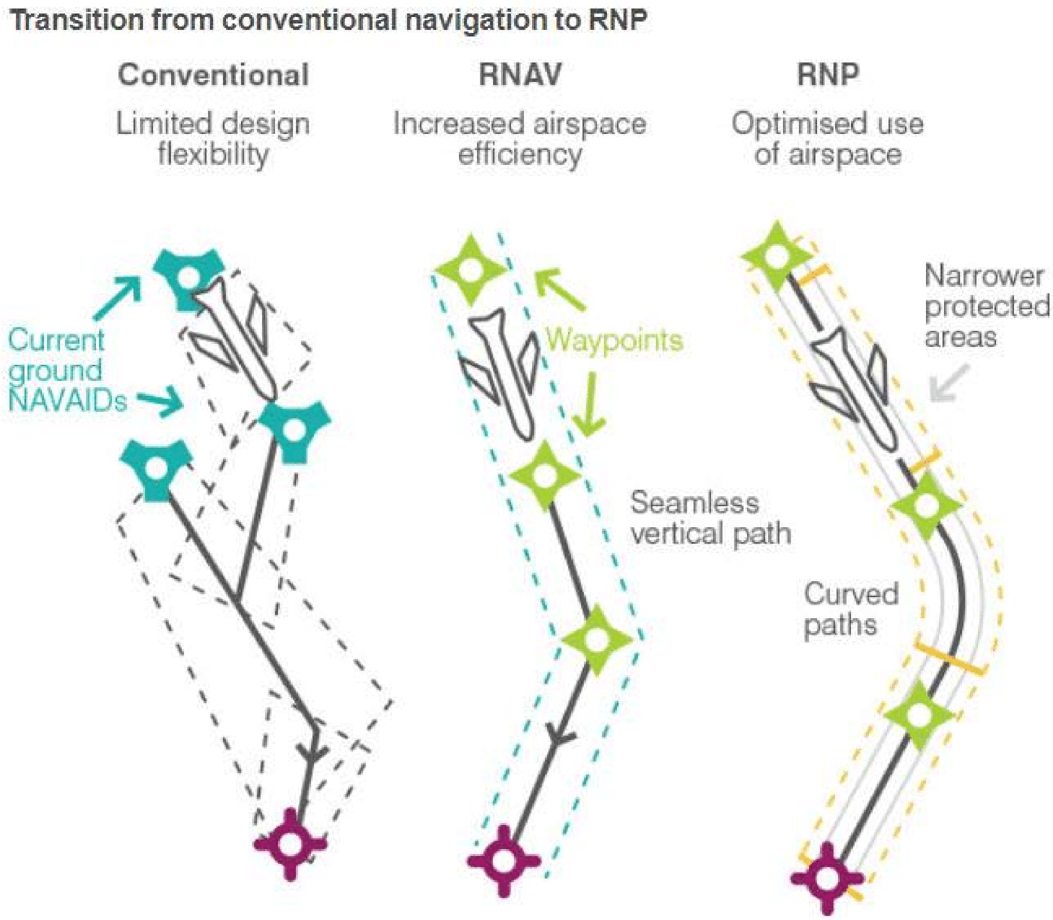
PBN is a term that covers all types of so-called “area navigation”. Area navigation means navigation to points on the surface of the earth that are defined through other means than a single radio navigation installation. So flying directly to an NDB, a VOR station or similar, would not be considered area navigation. Flying to a point that is not directly defined by a radio navigation installation, would be considered area navigation. Earlier systems navigated to such points through using multiple DME stations over land and Inertial Navigation Systems (INS) over the ocean or areas without DME coverage. INS was further developed and replaced the internal accelerometers with equipment that measured wavelength shift in internal laser beams that covered all axis of motion. These newer systems are called IRS (inertial reference systems). When the US launched the GPS system and opened it for civilian use, GPS took over as the primary area navigation system. This has led to a common misconception that PBN equals GPS navigation. This is not the case. Today, few onboard navigation systems rely solely on GPS. More common are FMS systems that utilizes multiple input sources such as GPS, IRS, DME/DME.

PBN encompasses two types of navigation specifications:

- RNAV (area navigation), and
- RNP (required navigation performance).

The difference between the two specifications is that on-board performance monitoring and alerting is required for RNP but not for RNAV. RNAV requires independent performance monitoring of an aircraft’s position.

RNP has parallel lateral performance requirements and can be supported by a variety of technologies.



RNAV is an acronym coined from the word "area navigation" which was shortened to "Area Nav" then "R-Nav" and eventually RNAV. RNP is a more literal acronym derived from Required Navigation Performance. The phrase was introduced when specifications for RNAV equipment started to emerge. That meant in certain areas the accuracy of the equipment used for area navigation had to meet certain standards. Initially these standards were defined through stating what type of equipment/hardware was acceptable in certain regions. This hampered development of area navigation technology as users now were locked to specific manufacturers rather than to a defined standard of accuracy. The shift came with PBN which re-defined standards from specific equipment to defined accuracy standards instead. Today the difference between RNAV and RNP are used to describe accuracy requirements like RNAV-1, RNAV-10, RNP4, RNP 0.3, however there is a difference which we will get back to.

During the emergence of the new standards as consequence of rapidly developing technology, there were no international coordination or guidance agreement on where and how to implement the emerging standards. This lead to a plethora of different standards, different terms and different interpretation and implementation of terms. PBN aims to ensure global standardization of RNAV and RNP specifications and to limit the proliferation of navigation specifications in use world-wide. It is a new concept based on the use of RNAV systems. Significantly, it is a move from a limited statement of required performance accuracy to the following:

The International Civil Aviation Organization (ICAO) PBN Manual (Doc 9613) definition is: Area navigation based on performance requirements for aircraft operating along an Air Traffic Services (ATS) route, on an instrument approach procedure or in a designated airspace.

Where:

Airborne performance requirements are expressed in navigation specifications in terms of accuracy, integrity, continuity and functionality needed for the proposed operation in the context of a particular airspace concept. Within the airspace concept, the availability of GNSS Signal-In-Space or that of some other applicable navigation infrastructure has to be considered in order to enable the navigation application.

PBN is then described through means of RNAV and RNP applications with respective RNAV and RNP operations.

PBN is one of several enablers of an airspace concept. The others are Communications, ATS Surveillance and Air Traffic Management (ATM). The PBN Concept is comprised of three components: The Navigation Specification, the Navaid Infrastructure and the Navigation Application.

The Navigation Specification prescribes the performance requirements in terms of accuracy, integrity, continuity for proposed operations in a particular Airspace. The Navigation Specification also describes how these performance requirements are to be achieved i.e., which navigation functionalities are required to achieve the prescribed performance. Associated with the navigation specification are requirements related to pilot knowledge and training and operational approval. A Navigation Specification is either a Required Navigation Performance (RNP) specification or an RNAV specification. An RNP specification includes a requirement for On board Performance Monitoring and Alerting (OPMA) where the receiver provides an alert to the flight crew if the navigation position is in error, while an RNAV specification does not.

The Navaid Infrastructure relates to ground- or space-based navigation aids that are called up in each Navigation Specification. The availability of the navaid infrastructure has to be considered in order to enable the navigation application.

The Navigation Application refers to the application of the Navigation Specification and Navaid Infrastructure in the context of an airspace concept to ATS routes and instrument flight procedures.

The Navigation Capability Graphic shown at the end of Part 2 depicts the overall Navigation Capability and the relationship between the navigation specifications defined within the ICAO PBN Concept.

Note: Precision approach and landing systems such as the Instrument Landing System (ILS), Microwave Landing System (MLS) and GNSS Landing System (GLS) form part of the navigation suite, but are not included within the concept of PBN. Whilst GLS is based on satellite navigation, it differs from PBN applications in that it is not based on area navigation techniques.

The PBN manual (ICAO doc 9613)

The PBN Manual comprises two Volumes. Volume I of the PBN Manual is made up of two parts: Part A describes the PBN Concept, The Airspace Concept and how the PBN Concept is used in practice. Part B provides Implementation Guidance for Air Navigation Service Providers (ANSP's) in the form of three processes. Volume II of the PBN Manual is also made up of three parts. Part A describes on-board performance monitoring and alerting and Safety Assessments, whilst Parts B and C contain ICAO's RNAV and RNP specifications which are to be used by States as a basis for certification and operational approval.

PBN in Norway

Enroute and Terminal RNAV developments in Norway have been performance-driven since their inception. Some of the impact of ICAO's PBN Concept in Norway includes:

The B-RNAV standard contained in European Aviation Safety Agency (EASA) Acceptable Means of Compliance - AMC 20-4 is identical to the RNAV 5 specification in ICAO PBN. The term B-RNAV has been replaced by RNAV 5. RNAV 5 is now required for operation on all ATS routes in Norwegian airspace.

The P-RNAV standard is not identical to the ICAO RNAV 1 specification but may be viewed as a European Application of the RNAV 1 specification. The difference between P- RNAV and RNAV1 centers on the allowable ground navigation aids and the PBN Manual identifies additional requirements for obtaining RNAV 1 approval for an operator already having approval against Joint Aviation Authorities (JAA) Temporary Guidance Leaflet (TGL) 10. In Norway the plan is to migrate from P-RNAV terminology to RNAV 1 as procedures are introduced. Some airports may have both P-RNAV and RNAV 1 procedures. For example STAR at Bodoe.

Note: For the differences between P-RNAV and ICAO's RNAV 1 specification, see PBN Manual Vol. II, Part B, Chapter 3, paragraph. 3.3.2.4.

Approach operations in Norway are already RNP Approach compliant. All future navigation developments will be aligned with ICAO's PBN Strategy.

Terminology

Approach applications based on GNSS are classified RNP Approach (RNP APCH) in accordance with the PBN concept and include existing RNAV (GNSS) approach procedures designed with a straight segment. The flight deck displays and charting will likely retain the RNAV (GNSS) label for some time and until standardization can be achieved, pilots should expect to use the terms RNP APCH and RNAV (GNSS) interchangeably. This course therefore uses both terms interchangeably.

Benefits from PBN

The principal benefit derived from PBN is the transition to a total RNAV environment. This will lead to flight efficiency and allow optimization of the airspace including reduced holding containment areas. Without the constraints of navigating via fixed, ground-based aids, the airspace designer has a powerful tool in terms of positioning of routes and instrument flight procedures in relation to areas of congestion or population density.

Of concern to the industry is the potential cost from proliferation of regional and State navigation specifications. PBN brings about a more disciplined approach through a limited set of specifications which are globally applied. The aircraft and equipment manufacturers therefore have greater certainty in their market place and can anticipate a tangible return on their capital investment in the aircraft's performance capability.

From an aircraft operator perspective, certain carriers have long claimed that their fleet capability far exceeded anything the airspace could offer by way of capacity and environmental benefits. So with the modern air transport aircraft having this enhanced performance and functionality, PBN starts to harness that aircraft capability. For those with less well equipped aircraft, pressure to upgrade or be faced with exclusion from certain routes or procedures, has to be applied as an incentive rather than as a threat to their business.

What PBN can offer

- [ ] Predictable and repeatable path trajectories moving to a systemized environment with designed interactions;
- [ ] Closer spaced routes;
- [ ] Curved path transitions;
- [ ] Greater tactical flexibility through parallel offsets; and
- [ ] Higher integrity from RNP which brings greater assurance to the safety equation and reduces flight crew workload.

From an airspace and airports perspective the envisaged benefits of PBN include:

- [ ] Increase in capacity in controlled Airspace;
- [ ] Greater access to airports, especially for General Aviation (GA) aircraft which have traditionally been limited to higher operating minima due to their basic Equipment;
- [ ] Improvement in safety through onboard monitoring and performance alerting to the flight crew; and

- Reduction in the effects that flights have on the environment from more efficient routes, more accurate path keeping for noise abatement and, in conjunction with other airspace initiatives such as increased Transition Altitude (TA), the increased use of Continuous Climb Operations (CCO) and Continuous Descent Operations (CDO).

- Increase in capacity in controlled Airspace;

From an ATM service provider perspective the envisaged benefits of PBN include:

- Reduced service cost through reduced navigational infrastructure, increased systemization and increased controller Productivity;

- Improvement in safety through the introduction of flight path monitoring tools and alerting to controllers; and

- Improvement in the quality of the service to meet new airspace-user requirements.

- The navigation infrastructure is a key element in PBN and the transition to an RNAV environment is linked to a move towards a space-based navigation environment (GNSS) and a move away from dependence on traditional ground-based navigation infrastructure such as VOR and NDB facilities. This in turn will allow rationalization of infrastructure leading to savings from capital investment; maintenance and spectrum utilization with commensurate savings passed onto the operators through reduced navigation services charges and a requirement to carry less Equipment.

Introduction to approach applications

Approach Applications which are classified as RNP Approach (APCH) in accordance with ICAO Doc 9613 Performance Based Navigation (PBN) Manual (and ICAO state Letter SP65/4-10/53) give access to minima (on an instrument approach procedure) designated as:

2D approaches

Two dimensional approaches use lateral guidance only. Examples are NDB, VOR, localiser (LLZ) or GNSS (required navigation performance—RNP).

With 2D approaches it is the pilot's responsibility to adhere to all step-down altitudes and use the minimum descent altitude (MDA) procedure.

3D approaches

Three dimensional approaches use both lateral and vertical guidance, with the vertical profile provided by the guidance system. A decision altitude (DA) minimum procedure is used.

Instrument landing systems (ILS), microwave landing systems (MLS) and ground-based GNSS augmentation landing systems (GLS) can provide Cat I, II or III level of minimums.

There are several types of RNP APCH with 3D vertical guidance, and they differ in the way in which they source their vertical guidance information.

LNAV (Lateral Navigation)

This is a Non-Precision or 2D Approach with Lateral only navigation guidance provided by GNSS and an Aircraft Based Augmentation System (ABAS). Receiver Autonomous Integrity Monitoring (RAIM) is a form of ABAS. Lateral guidance is linear with accuracy to within +/- 0.3 NM parallel to either side of the final approach track.

LP (Localizer Performance)

This is a Non-Precision or 2D Approach with Lateral only navigation guidance provided by GNSS and SBAS. The EGNOS is a form of SBAS in Europe. The lateral guidance is angular with increasing sensitivity as the aircraft continues along the final approach track; much like a localizer indication.

LNAV/VNAV (Lateral Navigation / Vertical Navigation)

This is a 3D Approach Procedure with Vertical Guidance (APV). The lateral navigation guidance is provided by GPS and Aircraft Based Augmentation Systems (ABAS) such as RAIM in the same way as for LNAV. The vertical guidance uses the Barometric Altimeter as the source to display glide path guidance. This type of approach is commonly known as APV/Baro VNAV. Lateral guidance is normally linear with accuracy to within +/- 0.3 NM parallel to either side of the final approach track. Some aircraft systems may provide angular guidance, however, and pilots should be aware of the display format of their system.

Vertical guidance derived from the barometric data in the Flight Management System (FMS) is based on normal altimetry and any displacement from the indicated glidepath represents the same altitude error throughout the final approach. This is fundamentally different from the angular indications such as on an ILS glidepath.

WARNING! At the time of writing this course, the use of SBAS to provide augmentation for the VNAV element of a notified LNAV/VNAV approach is not permitted in Norway. Notwithstanding any certification for RNAV VNAV approach operations using SBAS,

aircraft which are not certified for the use of barometric VNAV data are currently precluded from flying approach operations to LNAV/VNAV minima. These aircraft are not authorized to continue RNAV approach operations below the published LNAV-only minima.

LPV (Localizer Performance with Vertical Guidance)

This is an Approach Procedure with Vertical Guidance (APV). The Lateral and Vertical guidance is provided by GPS and SBAS. Lateral and vertical guidance are angular with increasing sensitivity as the aircraft progresses down the final approach track; much like an ILS indication.

NOTE: The instrument approach procedures associated with RNP APCH are entitled RNAV (GNSS) to reflect that GNSS is the primary navigation system. With the inherent onboard performance monitoring and alerting provided by GNSS, the navigation specification qualifies as RNP, however these procedures pre-date PBN, so the chart nomenclature has remained RNAV.

RNP Approach Model

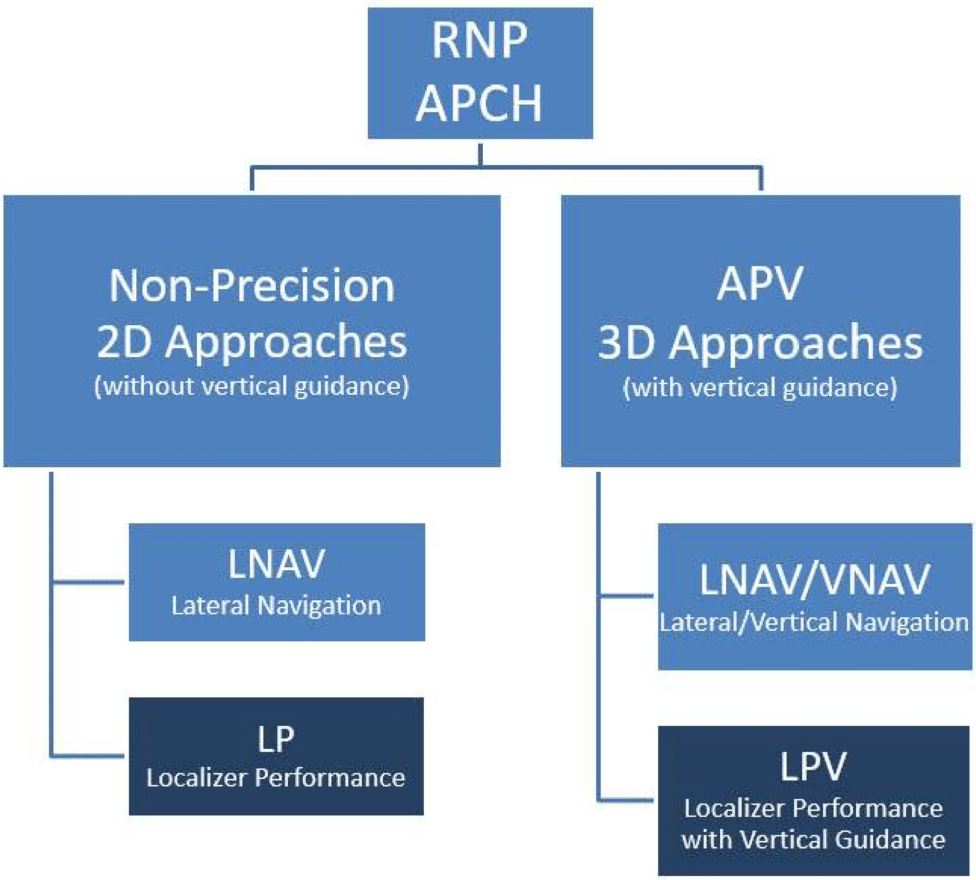


Figure 1 RNP Approach model

NOTE: APV (Approach with Vertical Guidance) is defined in ICAO Doc 8168 as:
An instrument procedure which utilizes lateral and vertical guidance but does not meet the requirements established for precision approach and landing operations.

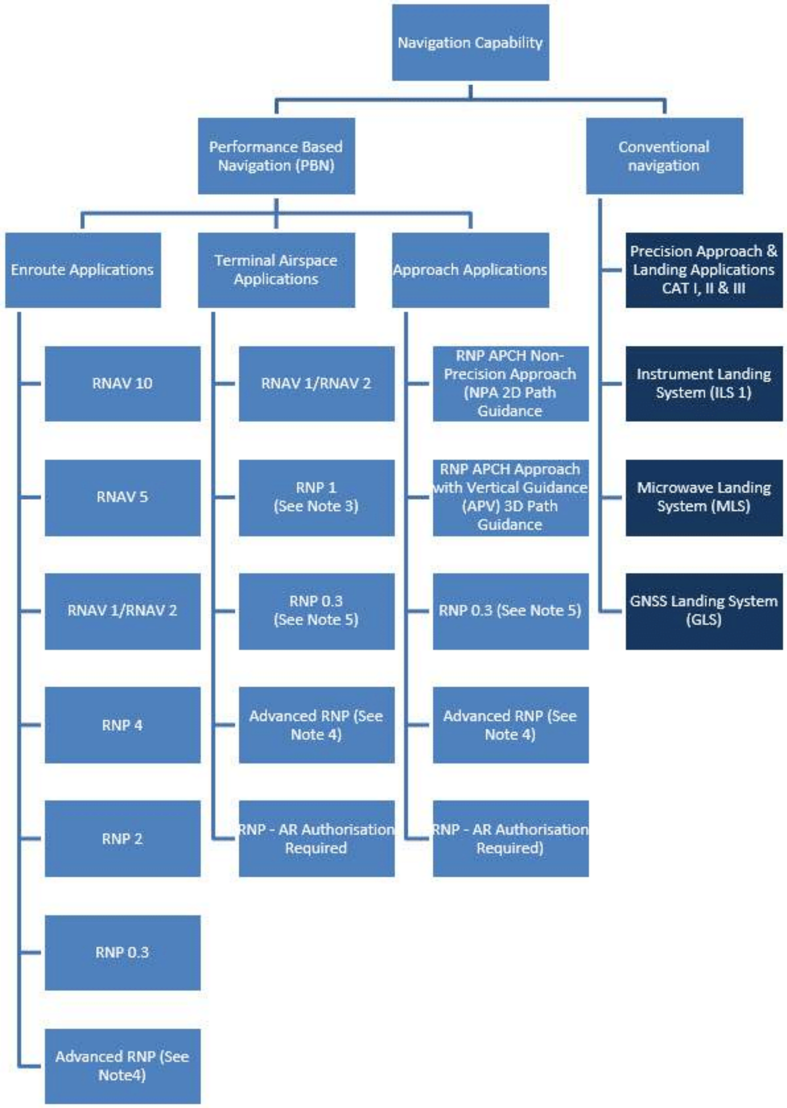


Figure 2 Navigation Capability Graphic

Note 1
Application of RNAV 1 Performance aspects, not terminal airspace functionally.

Note 2
Including Fixed Radius Transition (FRT).

Note 3
Equivalent to RNAV 1 + GNSS, Typically associated with Radius to Fix (RF).

Note 4
Including Radius to Fix (RF).

Human factors

Data Entry and Familiarity with the System

All systems using RNAV principles must compute the aircraft's position velocity and time, in order that steering and other information towards a future position can be presented to the flightcrew. This is accomplished either by the crew manually entering the co- ordinates of the next position, or by the automatic extraction of these co-ordinates from a database.

Experience of RNAV systems and Flight FMS in general, has identified the pitfalls of waypoint entry error at the receiver as well as inaccuracies and errors in the database itself. Extensive research by the UK CAA, and experience by other States, has shown that human error, often the result of a lack of familiarity with the airborne equipment, represents the major hazard in operations using RNAV systems. Therefore, it is imperative that pilots understand their system thoroughly and are able to determine whether it is safe to proceed. This requires robust procedures, which check for possible errors in the computer database, monitor continued performance of the RNAV systems and enable pilots to identify and avoid not only their own mistakes but also errors in the information presented to them.

Automation Induced Complacency

Whilst the GPS is an excellent system, it is neither error free nor totally dependable. However, GPS has an excellent record and the continued experience of using such a highly accurate navigation system can lead tan impression of infallibility.

Monitoring of the system for gross errors becomes tedious; as the system appears to do it all for you and the temptation simply to trust the system regardless, becomes powerful. This can result in a form of complacency that leaves the pilot more vulnerable to error and to failure or inaccuracy of the system for whatever reason.

A GPS receiver with RAIM provides some integrity monitoring of position which apparently reduces the requirement for cross checking. However, it cannot alert the pilot to other flight technical or data error. The pilot(s) must continue to monitor data entry, system management, progress against intended flight-path and steering performance against a Course Deviation Indicator (CDI) or Flight Director/Autopilot.

Training and licensing

The advent of RNAV approach operations presents new opportunities for human error at a critical phase of flight. The programming skills required of the crew, and the errors and failure modes of approach-enabled RNAV systems (such as GPS), are different from those associated with the established network of ground-based approach aids. Pilots using any type of GNSS equipment must ensure that they are familiar with and competent in operating that type of equipment, before using it in flight the wider aviation community generally now accepts that thorough training of pilots in the procedures required for use of these systems is paramount.

Flying an instrument approach procedure in IMC in Norway requires the pilot to hold an Instrument Rating (IR). The syllabus of training for these ratings should already include all types of Non-precision Approach (NPA), including Surveillance Radar Approach (SRA), Localizer (LOC) only, VOR and NDB, with and without DME.

When operating under Visual Flight Rules (VFR), all pilots are recommended to obtain training from an Approved Training Organisation or an appropriately experienced and qualified instructor (see below) before using any RNAV system, including GPS.

For IFR operations, public and commercial air transport operators are required by the operating regulations to ensure that their pilots have been tested as to their proficiency in using instrument approach-to-land systems of the type in use at the aerodrome of intended landing and any alternate aerodrome.

Private operators are strongly advised to follow suit and engage in a structured training program before attempting to fly any RNAV approach procedure, including GNSS approaches, and when operating any RNAV system.

Training organizations (ATOs) are encouraged to develop differences training for RNAV (GNSS) approaches and include this in any IMC or Instrument Rating syllabus as soon as practical. Detailed guidance on training structure and techniques, together with suggested syllabus content is contained in the INSTRUCTORS' GUIDE in Part 5 of this course.

Practice instrument approaches

Pilots are reminded of the requirements of the Rules of the Air Regulations. In the case of practice approaches in Visual Meteorological Conditions (VMC) requires not only that the appropriate air traffic control unit be informed beforehand, but that a competent observer must be carried. If the pilot is flying in simulated instrument flight conditions, a safety pilot must be carried with access to dual controls and adequate vision.

Instructors

Instructors carrying out this training must hold a recognized, current instructor rating and be qualified to teach for the IR (IR(R) in an EASA license) in accordance with Part FCL, and be entitled to act as Pilot in Command (PIC) on the aircraft during any flight instruction.

The Instructors' Guide in Part 5 of this course is intended as an aide-memoire for Instructors. The Guide should not be considered in isolation and instructors should themselves be trained in the use of the particular system on which they are teaching. Instructors should be familiar with all available technical and training material available for the system, including manuals, training and demonstration programs, CD's, DVD's and simulators etc. Use of these facilities in student training courses is strongly encouraged.

GPS equipment

Receiver Standard General

The additional accuracy required on approach requires additional logic and functionality (to that required for enroute navigation) suitable for navigation through the initial, Intermediate, final and missed approach phases of an instrument approach. The occasions when these additional criteria can be met may be fewer, giving rise to lower GPS availability. Not all receivers are configured to meet the criteria for RNAV(GNSS) approach operations (giving the impression of good availability) as they may be configured only to meet the requirements for enroute accuracy.

Approach operations with lateral guidance (LNAV) only

To fly a non-precision RNAV(GNSS) approach, to LNAV only minima, all GNSS receivers and equipment must be manufactured in accordance with at least Technical/European Technical Standard Order (TSO/ETSO) C129a – Class A1, TSO/ETSO 145a or TSO/ETSO 146a. These receivers must be correctly installed in the aircraft (see below).

Approach operations with lateral and vertical guidance using APV Baro-VNAV

GNSS stand-alone navigation systems

If the RNAV installation is based on GNSS stand-alone system, the equipment shall be approved in accordance with TSO-C129a/ETSO-C129a Class A1 or ETSO-C146()/TSO- C146() Class Gamma, operational class 1, 2 or 3.

Multi-sensor navigation systems

If the RNAV installation is based on GNSS sensor equipment used in a multi-sensor system (e.g. FMS), the GNSS sensor shall be approved in accordance with TSO-C129( )/ ETSO-C129( ) Class B1, C1, B3, C3 or ETSO-C145( )/TSO-C145( ) class Beta, operational class 1, 2 or 3.

Multi-sensor systems using GNSS should be approved in accordance with AC20-138C or TSO-C115c/ETSO-C115c, as well as having been demonstrated for RNP capability.

> **Note 1: For GNSS receiver approved in accordance with ETSO-C129()/TSO-C129(), capability for satellite Fault Detection and Exclusion (FDE) is recommended, to improve Continuity of function.**

Altimeter sensor requirement for APV Baro-VNAV operation

In addition to requirements for the GNSS receiver systems above, the RNAV equipment that automatically determines aircraft position in the vertical plane should use inputs from equipment that can include:

- ETSO-C106/TSO-C106, Air Data Computer; or
- Air data system, ARINC 706, Mark 5 Air Data System, ARINC 738 (Air Data and Inertial Reference System); or
- Barometric altimeter system compliant with DO-88 ‘Altimetry’ and/or ED-26 ‘MPS for Airborne Altitude Measurements and Coding Systems’; or
- Type certified integrated systems providing an Air Data System capability comparable to item under bullet two.

For further information on airworthiness criteria for approach operations with APV Baro-VNAV see ED 2013/026R of 12/09/3013 - AMC 20-27A.

GNSS SBAS Stand-alone Navigation system

GNSS SBAS stand-alone equipment should be approved in accordance with ETSO-C146c Class Gamma, operational class 3.

Note: Equipment approved to ETSO-C145/146 could be eligible for:
Integrated navigation system incorporating a GNSS SBAS sensor

The equipment should incorporate a GNSS SBAS sensor approved in accordance with ETSO-C145c Class Beta, operational class 3.

For further information on airworthiness criteria for LPV approach operations using SBAS see Annex ii to ED 2012/014R of 17/09/2012 - AMC 20-28.

Note 2: GNSS receivers approved in accordance with ETSO-145/TSO-C145a or ETSO-C146/TSO-C146a (DO 229C) and used outside SBAS coverage area may trigger inappropriate Loss of Integrity (LOI) warning. DO229D paragraph 2.1.1.6 provides a correct satellite selection scheme requirement to address this issue. Although most of the ETSO-C145/TSO-C145a or ETSO-146/TSO-C146a approved receivers comply with this satellite selection scheme, a confirmatory statement from the equipment manufacturer is still necessary. It should be noted that such confirmatory statement is not necessary for equipment compliant with TSO-C145b or TSO-C146b.

None of the available **hand-held receivers** are approved for Instrument Flight Rules (IFR) or approach operations.

System Integrity & RAIM

In the context of GPS, integrity is the system's own ability to identify when it may be unreliable for navigation and to provide timely and appropriate warning to the user. There always remains, of course, the possibility of a false alarm and a failure of the monitor itself, to provide such an alarm. Without RAIM, however, the pilot has no assurance as to the accuracy of the GPS position. Herein lies the essential difference between an RNAV and an RNP navigation specification. An RNAV specification requires no on-board augmentation of the navigation solution whereas RNP specification does. All the RNAV (GNSS) approach procedures published in Norway are compliant with the PBN Navigation Specification (except GLS SCAT 1). RAIM is a form of augmentation that enables a GPS system to be RNP compliant.

At present, three methods exist in airborne equipment, to provide this integrity information:

1. Receiver Autonomous Integrity Monitor (RAIM)

RAIM is a mandatory part of the software function of the ETSO C129 () and 145/6 () standard receivers detailed above.

The RAIM function is intended to provide integrity by detecting the failure of a GPS satellite (Fault Detection (FD) RAIM). Some systems (including those meeting the (E)TSO 145/6 standard) provide subsequent exclusion of the faulty satellite, allowing the possibility of continued navigation following a satellite anomaly or failure FDE RAIM).

For a GNSS receiver approved in accordance with E/TSO-C129(), FDE RAIM is recommended to improve continuity of function as, with FD RAIM only, a faulty satellite remains in the navigation computation and integrity will be lost..

2. Integrated navigation systems

using other navigation sensors (such as Inertial Navigation Systems (INS), VOR / DME) in addition to GPS.

3. SBAS sensor

which provides correction information via geostationary satellites. This system comprises a network of ground reference stations that observe satellites signals, and master stations that process observed data and generate SBAS messages for uplink to the geostationary satellites, which broadcast the SBAS message to the users

SBAS is a mandatory part of the software function of the ETSO C146 (c) standard receivers.

Within Europe the SBAS facility is the European Geostationary Navigation Overlay Service (EGNOS), owned by the European Commission and managed and run by the European Satellite Services Provider (ESSP).

ESSP is a company owned by the European ANSP's, including Avinor.

In an airborne receiver, three satellites are needed for a two-dimensional fix and four for a three-dimensional fix. The elevation above the horizon (mask angle) and the geometry of the satellites' positions, relative to the receiver must meet certain alignment criteria before they are included in the navigation solution and the system accuracy can be achieved. One additional satellite is required to perform the FD RAIM function and a further (sixth satellite) is required for FDE RAIM.

Where a GPS receiver uses barometric altitude to augment the RAIM function (so-called baro-aided) the number of satellites needed to perform the RAIM function may be reduced by one. If barometric altitude input is used to contribute to the RAIM function itself, loss of this altitude information should be indicated to the pilot by the RNAV system.

Heading

A technique used by the US Department of Defense to inhibit the accuracy of the GPS to all but approved users. An artificial error can be introduced to degrade the system accuracy but in 2000 this was set to zero by Presidential decree.

Some of the older receivers were hard wired for SA and assume it still applies. This inhibits the fault detection capability of the receiver's RAIM function and reduces the availability for approach operations. Information on the status of any particular receiver should be available from the manufacturers.

Installation

All hand-held and many existing aircraft installations do not meet the requirements for approach operations and their use is not authorized for any RNAV operations, including approach. Pilots must ensure that the equipment and its installation in the particular aircraft to be flown meet the airworthiness requirements for the intended flight.

To fly GNSS RNAV approach operations, all GNSS receivers and equipment must be not only meet the airworthiness certification standards but they must also be installed in the aircraft in accordance with the standards set out in EASA AMC 20-27A or AMC 20-28 as applicable to the approach applications of the intended operations.

Operators in any doubt over these requirements should seek the advice of the approved installer or an appropriately licensed engineer.

NOTE 3: Caution: The development of the RNAV and RNP airspace environment with the evolving PBN requirements will lead to progressive changes in the carriage requirements within some airspace. The development of technology will undoubtedly keep pace with this evolution but operators are advised that many of the currently available GPS receivers may not meet all the future carriage requirements of the developing airspace environment.

Certification

There are many installations of GPS equipment in light aircraft that appear, from the cockpit, to meet the required standard. Many of these receivers have been built to the necessary standard but unless the installation itself has been approved for RNAV (GNSS) approach operations, and the correct approval documentation is complete, the equipment shall be considered unsuitable for RNAV (GNSS) approach operations.

All approved installations must have the appropriate certification for RNAV (GNSS) Approach Operations entered in the Aircraft Flight Manual (AFM), Pilots' Operating Handbook (POH) or equivalent document. Only those receivers installed in the aircraft as specified at 3.3 above will be approved for RNAV (GNSS) or PBN approach operations.

Existing Installations

Those installations that meet the requirements above but that are not certified in the AFM/POH as meeting the requirements are not permitted to be used for RNAV approach operations but may be the subject of an application to EASA (for changes to an aircraft's type certificated standard) via EASA Form 31 or 32.

For further information visit:

EASA WEBSITE

The CAA recognizes existing installation approvals made in accordance with FAA AC 20-138() or the EASA AMC's. For new or modified aircraft, the AFM or the POH, whichever is applicable, should provide at least the following information:

1. A statement which identifies the equipment and aircraft build or modification standard certificated for RNAV (GNSS) Approach Operations (or RNP APCH Operation).

2 Appropriate amendments or supplements to cover RNAV (GNSS) approach operation will need to be provided for the following sections of the Flight Manual, or the Pilot's Operating Handbook, whichever is applicable:

Limitations

Normal Procedures

Abnormal and Emergency Procedures

This limited set assumes that a detailed description of the installed system and related operating instructions and procedures are available in other operating or training manuals. This means there should be specific reference within these sections of the appropriate manual detailing any limitations or procedures that are specific to RNAV (GNSS) approach operations in the particular Aircraft.

Before flying any RNAV (GNSS) approach, the pilot **must ensure** that the GPS installation in the aircraft is correctly approved for RNAV (GNSS) approach operations in accordance with the above standard. This approval must be certificated in the aircraft's individual **AFM/POH** or equivalent document.

Basic Area Navigation (B-RNAV) & Precision Area Navigation (P- RNAV) Approval

Some GPS installations have been certified as meeting the B-RNAV or RNAV 5 requirements under IFR. If a system has been so approved, this will be stated in a supplement to the AFM or equivalent document. However, a system which meets the B- RNAV certification (enroute) requirements is only required to be accurate to within +/- 5 nautical miles for 95% of the flight time). This is clearly inadequate for approach operations and B-RNAV or RNAV 5 certification does NOT include certification for RNAV operations in either terminal areas (including Standard Instrument Departures (SID's) and Standard Instrument Arrivals (STAR's) and P-RNAV operations) or on approach.

Additionally, a system that meets the P-RNAV or RNAV 1 certification (flying in the terminal area on RNAV SID's and STAR's and runway transitions) is required to be accurate to within +/- 1 nautical mile for 95% of the flight time. This still does not meet the required navigation performance for use in approach operations.

In seeking an installation approval for a GNSS Receiver, the operator is advised to seek approval for all types of operation likely to be considered and not just for approach operations.

System settings and display parameters

RNAV and Electronic Flight Instrument Systems (EFIS) displays and installations have many functions and the display of information may be presented in a number of different ways. This can lead not only to confusion but the absence or inaccuracy of important information at a critical stage of flight and, potentially, flight critical error.

All aircraft owners and operators (especially training organizations, private aircraft rental operators and ownership groups) are strongly advised to develop their own Standard Operating Procedures (SOP) for the settings and display parameters of their system(s). This includes defining the data to be displayed in each field, including both the units of display and the units of other system functions. Some systems offer a series of user profiles that control these parameters by way of a pre-set menu. These profiles should be used with extreme caution, as these menu settings are not normally protected in any way. Pilots must be able to check these settings when using such user profiles.

These SOP should be made available in writing to all pilots of the particular aircraft.

In any event, the appropriate displays should be selected so that at least the following information can be monitored during approach:

- [ ] The waypoint identifier to which navigation is being given
- [ ] The GPS computed desired track (DTK)
- [ ] Aircraft lateral offset relative to the DTK (Cross-track Error or XTK) (and vertical position relative to glidepath for 3D approach operations) – This should be

available on the pilot's main CDI/HIS

- [ ] Groundspeed (GS)

- [ ] Distance to next waypoint (DIS)

- [ ] Absence of RAIM or (Loss Of Integrity) LOI alert.

All pilots, especially of rented or group owned aircraft, must check that the system settings and display parameters are correctly set before every flight. After flight, and before shutting down the system, pilots are responsible for ensuring that the system settings remain in accordance with the operator's SOP before leaving the aircraft for use by another pilot.

Selection of approach procedures

Published Procedures

RNAV (GNSS) approaches must be in accordance only with published approach procedures that are current and coded into the proprietary aeronautical database of the GPS receiver, and are unalterable by the pilot. This engages a series of safety precautions that may not otherwise be in Place.

Display Scaling

Activating a published and coded RNAV (GNSS) approach from the aeronautical database should enable the CDI or Horizontal Situation Indicator (HSI) to change display scale automatically during the approach. The display should automatically become more sensitive when transitioning from the enroute phase of flight, through the intermediate or 'terminal' phase, to be at its most sensitive on the Final Approach Sector (FAS) inside the Final Approach Fix (FAF).

Unless a published and coded approach is armed and active in the receiver, the HSI/CDI scaling and any VNAV path indicator will not change automatically, providing inadequate sensitivity both laterally and vertically for the approach to be flown safely.

Horizontal Alarm Limit (HAL)

Unless a published and coded approach is armed and active in the receiver, the receiver's RAIM function will not transition to an approach mode (even if the CDI scaling is changed manually) and this can allow a position error of up to 2 nautical miles before any alarm is given, potentially placing the aircraft dangerously out of position without any indication of error.

Flying one's own 'user-defined' procedure for approach, even if CDI scaling is changed manually, is potentially dangerous and should never be attempted.

Overlay Approaches

An overlay approach is one that allows pilots to use GPS equipment to fly existing, conventional instrument approach procedures. However, many of these overlays may not accurately reflect the correct approach procedure and may even represent a different speed category of aircraft. The normal equipment for that approach must always be used as the primary reference – and not the GPS - otherwise any disparity between the displays and the potential for mistakes are just as likely to diminish the safety margins on approach as enhance them.

For example: VOR and NDB approaches to beacons actually on the destination aerodrome usually provide a FAS path or track which is not aligned with the main runway centerline. Even on a direct approach to a particular runway, pilots should not necessarily expect to be on the extended centerline of the runway.

The terrestrial approach procedure may include DME ranges from the threshold, missed approach point or some other reference, such as the beacon. The GPS may give distance guidance to a different point, such as the runway threshold or the Aerodrome Reference Point. Pilots should be aware of any differences in the distance information given to step-down fixes and/or the MAP, as this has the potential for catastrophic error.

Vertical Navigation

At the time of publication (Autumn 1014), RNAV (GNSS) approaches with vertical guidance provided by the GPS+SBAS (APV or LPV) are limited in Norway. There are a number of approaches published with LNAV/VNAV minima shown on the chart. Approach to the LNAV/VNAV minima may only be flown using a BARO-VNAV installation approved in accordance with EASA AMC 20-27A.

Aircraft fitted with a GNSS navigation system using SBAS for vertical navigation and approved in accordance with AMC 20-28 ARE NOT authorized to fly these approaches to the published LNAV/VNAV minima.

At the time of writing the use of SBAS for vertical navigation on approach is only permitted where the approach is designated with defined LPV minima. The body responsible for the approach (normally the airport authority or approach sponsor) is required to meet a number of additional requirements in order to provide information about the availability and integrity of the approach for use with the EGNOS SBAS signal. Without these additional measures, the availability, integrity and accuracy of the vertical guidance cannot be assured. On an RNAV (GNSS) approach, other than a notified LPV approach using SBAS, the primary vertical reference must, therefore, be the aircraft pressure altimeter at all times and not the GPS derived vertical guidance.

Aeronautical database checks

All navigation database suppliers must hold a Type 2 Letter of Acceptance (LoA 2) or equivalent, issued for the GNSS equipment in accordance with EASA Opinion Number 01/2005 on "The acceptance of navigation database suppliers dated 14th January 2005, or equivalent; e.g., Federal Aviation Authority (FAA) Advisory Circular (AC) 20-153.

In an attempt to eliminate critical errors, the minimum check on the integrity of an approach procedure should be made by the pilot (or aircraft operator) and include at least a check of the co-ordinates (Lat. & Long.) of the FAF and the track and distance to the Missed Approach Point (MAPt). For approaches with vertical guidance, pilots should check the correct altitude at the Final Approach Fix (FAF) and the descent gradient. The definition of the flight path between the Intermediate Fix (IF) and the Missed Approach Point (MAPt) shall not be modified by the flight-crew in any circumstances. The database itself must also be the current issue and in date.

GPS and EGNOS use the World Geodetic System 1984 (WGS 84) as their Earth model and most instrument approach procedure charts are now produced using this datum. In some receivers, the geodetic system reference can be changed between WGS 84 and other systems (such as European Datum 1950 or Nouvelle Triangulation de France 1970 (NTF) . Whilst these references may be accurate for limited areas of the Earth, there may be a disparity of several hundred meters between the positions of coordinates in one datum, when compared with the positions at the same coordinates in WGS 84. Pilots must be able to check this setting in their receiver, and be able to restore WGS 84 where it has been changed. Some receivers will not reset this geodetic reference when resetting factory defaults and pilots must be able to check / change this setting manually.

Pilots must also be familiar with the display format of the position. Although the database reference may be WGS 84, the format of the position display may be changed in some receivers between degrees, minutes and seconds (eg; N 53º21’51”) and degrees with minutes to two decimal places (eg; N 53º21.85’).

User waypoints

For navigation under IFR, manual entry of co-ordinates creating ‘user-defined waypoints’ should be used only for enroute navigation above safety altitude.

For operations in IMC, below safety altitude (including P-RNAV Operations and RNAV Approaches) the use of user waypoints, and modification of the published procedure using temporary waypoints or fixes not provided in the database, is potentially hazardous and should never be attempted. The manual entry of coordinates into the RNAV system by the flight crew is not permitted for RNAV operations within the terminal area and should never be done below safe altitude in any location

Air traffic considerations

Whilst the expected approach may be loaded into the flight plan at any time, in systems where a separate activation of the approach is required, pilots should not activate the approach in the system until they have obtained a clearance to fly it. A last minute amended clearance or change to the runway in use may require some degree of re- programming at a time of already high cockpit workload and it may not be possible to re- activate the approach correctly if it has already been started. Cancelling the approach mode, once the aircraft is established on the FAS should result in the HSI/CDI reverting Immediately to 1 nm sensitivity at full-scale deflection. Pilots should be capable of reverting to alternative navigational information should the clearance change at the last minute or not be forthcoming.

Tracking to a waypoint or position not included in the approach profile contained in the GPS database may lead to incorrect approach-mode activation and waypoint sequencing. Some receivers allow selection of the approach by way of vectors to the FAS and pilots should be familiar with the selection and activation of the approach using vectors to the FAS by Air Traffic Control (ATC).

The RNAV approach chart

The design and chart presentation of the RNAV approach differs from other approaches such as ILS, NDB and VOR. The RNAV approach presentation typically includes a choice of more than one Initial Approach Fix (IAF), often many miles from the destination. The intervening sections of intermediate approach, delineated by a series of waypoints, replace the familiar 'teardrop' or reversal approach procedures from the overhead and lead directly to the FAF. The RNAV procedure is performed, therefore, by descending or 'stepping down' between each of these waypoints in turn, as opposed to flying a turning 'let-down' pattern from overhead the aerodrome.

A significant difference, therefore, is one of distance display: Distance information to the next waypoint is presented to the pilots, instead of to a DME station that may be near the runway. As a result of this, distance to the runway is not always immediately apparent, causing the pilots to lose awareness of the descent profile previously determined by comparison of the aircraft's level with the distance to touchdown. This means the pilots must be fully aware of the correct level to maintain to the next waypoint – not just against an overall distance to run. This will require familiarity with all waypoint names and almost certainly require frequent reference to the approach chart.

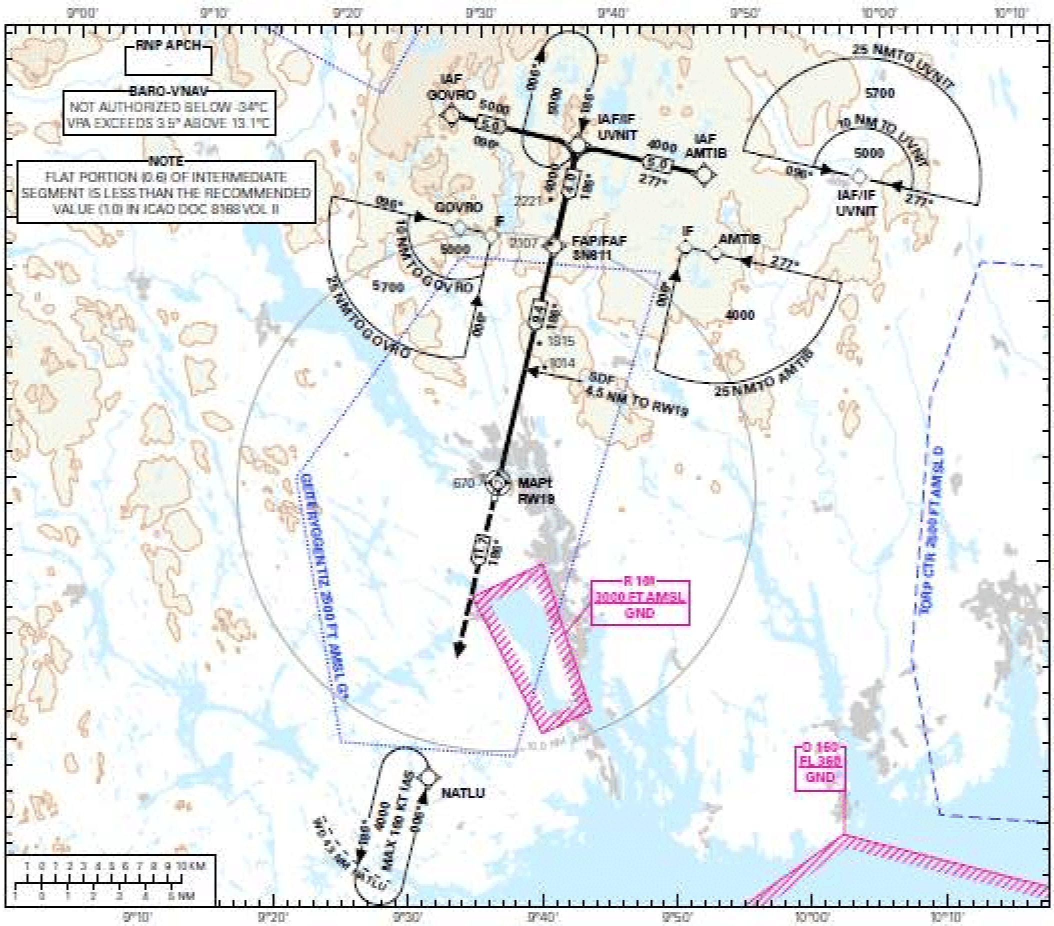
Pilots should never fly an RNAV procedure without the appropriate chart immediately to hand in the cockpit.

Terminal Approach Altitudes (TAA) may be shown on the chart presentations of RNAV approaches and appear as sectors of an incomplete circle, like slices of cake (see sample chart at Appendix 4). On an RNAV approach chart TAA's normally take the place of Minimum Sector Altitudes when approaching a particular waypoint from within (usually) 25 NM. One TAA sector will typically be shown centered on each Initial Approach Fix (IAF). Since the approach will, by its very nature, be flown through the most convenient IAF, depending on the aircraft's inbound track, only the TAA applicable to that IAF is relevant for the occasion of that particular approach.

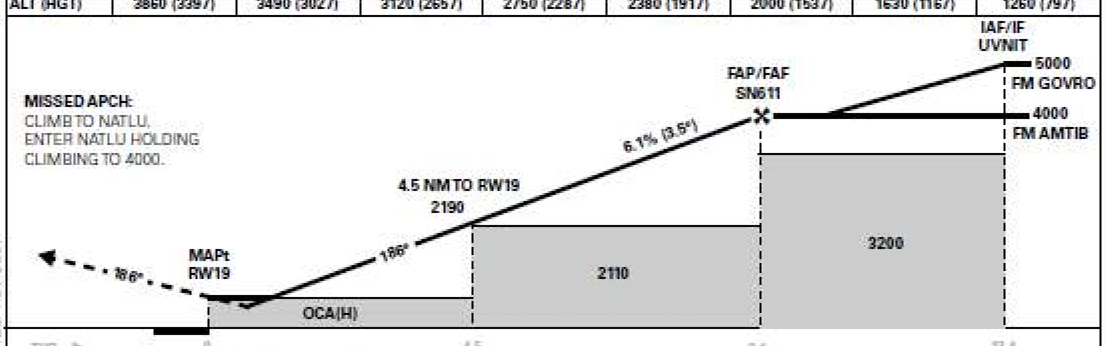
*ATS AIRSPACE CLASSIFICATION: REF ENR 1.4

INSTRUMENT APPROACH CHART - ICAO   PLAN VIEW SCALE: 1:450 000

	APP: 134.050 124.350	AD ELEV: 463		SKIEN
	AFIS: 119.200	THR ELEV: 463	DIST IN NM	GEITERYGGEN
	VDF: 119.200	HGT RELATED TO THR RWY 19	ELEV, ALT AND HGT IN FT	RNAV(GNSS) RWY 19
		CIRCLING HGT RELATED TO AD ELEV		TRANSITION ALTITUDE 7000
		BEARINGS ARE MAGNETIC - VAR 2.2 ° E (2015)		



DIST TO RW19	9	8	7	6	5	4	3	2
ALT (HGT)	3860 (3397)	3490 (3027)	3120 (2657)	2750 (2287)	2380 (1917)	2000 (1537)	1630 (1167)	1260 (797)



CAT OF ACFT		A	B	C	D	FINAL APCH	DIST FAF - MAPt: 9.4					
OCA(H) STRAIGHT - IN	LNAV/VNAV	780 (317)	800 (337)	-	-	SPEED	KT	70	90	100	120	130
	LNAV	870 (407)	890 (427)	-	-	TIME	MIN:SEC	08:03	06:16	05:38	04:42	04:20
		-	-	-	-	ROD	FT/MIN	435	560	620	745	805
CIRCLING		1200 (737)	1310 (847)	-	-							
NOTE:												

CHANGES: COMPLETELY REVISED.

Flight planning

Route planning

When using GPS or FMS, pilots are recommended to plan each flight and prepare a chart and log in the normal way. Doing this first and then entering the route information from the log, directly into the receiver as a “Flight Plan,” achieves following;

1. The route information is created visually on a chart, helping to eliminate any gross error.

2. There is a backup should the GPS information become unreliable or unavailable in flight.

3. All tracks and distances (not just those displayed for the current/active segment or leg) are immediately available without recourse to changing the display.

4. Pilots are more likely to be aware of the terrain over which they intend to fly, and can calculate safe altitudes more easily (many GPS navigation databases do not consider terrain).

When using GPS or FMS, pilots are recommended to plan each flight and prepare a chart and log in the normal way. Doing this first and then entering the route information from the log, directly into the receiver as a “Flight Plan,” achieves following;

NOTAMs & NANUs

Pilots should take account of any NOTAMs and operator's briefing material that could adversely affect the intended flight. NOTAMS should give details of any known, local jamming or interference and the availability of required navigation aids, both enroute and at the destination, or any alternate airport.

Pilots should also take account of any Notices to Navstar Users (NANU's) from the

United States (US) Coastguard Navigation Center

Pilots should also take account of any Notices to Navstar Users (NANU's)

VISIT WEBSITE HERE

This site gives details of the status of the constellation and scheduled maintenance, interruptions and anomalies that could adversely affect the availability or accuracy of the GPS information.

WARNING: Like the RAIM prediction services, the NANU service is unable to predict short notice 'outages' and failures. There have also been instances where the actual disruptions to the signal have varied from the information contained in the NANU publications.

SBAS NOTAMs

SBAS NOTAM generation is the responsibility of the national ANSP. At the time of writing (August 2014) the provision of SBAS NOTAM data in Norway is given only to airports providing LPV approach.

NOTE 4: The use of SBAS equipment to fly an LNAV/VNAV (ie 'Baro VNAV') approach procedure means inaccurate GPS data could be used without notification to either the pilot or the controller resulting in potentially catastrophic inaccuracy.

WARNING: The current status of the SBAS NOTAM provision should provide at least 72 hours notice of scheduled outages. The promulgation by EGNOS NOTAM of errors and unscheduled outages of both GPS and EGNOS signals may be subject to delays of up to 16 hours before notification is received at the airport. This service level for the provision of SBAS NOTAM data is expected to remain without improvement at least until 2016.

Availability of Alternate Aerodrome

In the event that either the GPS or the EGNOS signal is not available at the destination, by the nature of the system, and its susceptibility to interference, there exists the possibility that it will also be unavailable over a wide area. Therefore it is probable that the signal will also be unavailable at a nearby diversion aerodrome.

Notwithstanding any normal operational requirements for the identification of an alternate aerodrome, where a RNAV approach is to be flown in conditions where a visual approach will not be possible; pilots should always ensure that either;

1. A different type of approach system is available at the destination, not dependent on GPS data and for which the weather is forecast to be suitable to enable a landing to be made from that approach, or;

2. There is at least one alternate destination within range, where a different type of approach system is available, which is not dependent on GPS data and for which the weather is forecast to be suitable to enable a landing to be made from that approach.

Pre-flight planning & checks

The previous Part 3 contains important information and guidance on the function, requirements and recommendations for the use of GNSS for RNAV approach operations. Pilots should be familiar with the contents of Part 3 and not read this Part in isolation.

Pilots should not plan to use a GNSS (RNAV) procedure, and therefore not consider the approach during the selection of aerodromes for the intended flight, if any of the following verifications cannot be made:

Approach selection

The intended approach procedure must be published and identified as a PBN or RNAV Approach (e.g.: RNAV(GNSS) RWY 27…) see “Introduction to Approach Applications” at paragraph 2.6 the approach minima available must clearly be identified as LNAV (or LNAV Only); LNAV/VNAV, LP and/or LPV.

Overlay approaches

Other types of approach may be overlaid by the GPS database, however, many of these overlays do not accurately reflect the correct approach procedure and may even represent a different speed category of aircraft. The normal equipment for that approach must always be used as the primary Reference.

Integrity, accuracy & RAIM prediction

Before the availability of Wide Area Augmentation Systems (WAAS) (such as the EGNOS SBAS signal in Europe) flight crew were required to perform a check on the availability of the RAIM function for the GPS signal prior to flight when planning to use a GPS receiver certified in accordance with TSO/ETSO C129 for any RNAV (GNSS) approach.

Even today, when using these "C129 standard" receivers, during the pre-flight planning phase, the availability of RAIM (or equivalent monitor) at the destination must be verified as closely as possible before departure, and in any event, not more than 24 hours before takeoff. (RAIM should be confirmed as available from 15 min before Estimated Time of Arrival (ETA) until 15 min after ETA).

This may be established either by an internal function of the receiver See Note 5 or an air navigation service provider may offer an approved RAIM availability service to users (for example: http://augur.ecacnav.com/augur/app/npa?number=02&icao . See Note 6)

> **Note 5:** Receiver-based RAIM prediction programs are not able to predict short notice 'outages' and failures, and will not take account of scheduled disruptions to the satellite signals. Consequently, a receiver-based RAIM prediction may appear sound when the actual availability proves insufficient to provide the RAIM function. RAIM predictions also do not normally take account of terrain above the horizon. Where terrain interrupts the 'view' of a satellite from the receiver as the aircraft descends on approach, availability may be affected.

> **Note 6:** Research has shown that such independently available RAIM prediction tools may not have the latest accurate availability data and are also unable to predict short notice outages and failures. A RAIM prediction from these service providers is also not guaranteed.

Using SBAS

With SBAS receivers certified in accordance with TSO/ETSO C146 a RAIM check is no longer required unless the SBAS signal either fails or is lost for any reason. In the event of loss of the SBAS signal, pilots must meet the RAIM check requirements of the simpler ‘C129’ standard receivers; the receiver will not do it for you without the SBAS signal.

The SBAS receiver monitors the integrity and accuracy of the position both vertically and horizontally. The HAL and the Vertical Alarm Limit (VAL) are adjusted automatically according to the phase of flight and the integrity of the position is monitored against both of these, continuously, all the time the SBAS signal is available. In the event of loss of the SBAS signal, different receivers will display different messages. In any event, if the HAL for the current phase of flight is exceeded, a loss of integrity message will be displayed.

NOTE: LP is not a failure reversion or downgrade for LPV. Should the SBAS signal be lost, augmentation for both LPV and LP are lost. It may be possible to continue with LNAV only but this is reliant on the availability of RAIM.

When flying an approach with vertical guidance, the HAL is reduced to 50m or less (as opposed to 0.3 nm (556 m) when flying LNAV only approach). Should the integrity of the signal exceed either the HAL or the VAL during approach, a message will be displayed. In the event that the requisite 0.3 nm for LNAV remains available, however, the approach may be downgraded to LNAV minima. In this event, continuing the approach relies on reversion to the RAIM function within the receiver and a timely adjustment to using the LNAV minima by the flight crew. For this reason it is advisable to do a RAIM check before departure, even when planning for LPV.

Unless the aircraft is equipped with a BARO-aided receiver, the RAIM check must be of the “Non Baro-aided” availability published.

Whenever an RNAV approach is planned, a suitable alternative approach or alternate aerodrome should be available.

Receiver software

Pilots must ensure that the GPS navigation computer is using the correct and current version of the manufacturer's software.

Aeronautical database

The pilot should ensure that approaches that are to be used for the intended flight (including those at alternate aerodromes) are not prohibited by a company instruction or NOTAM and selectable from a valid aeronautical navigation database (current AIRAC cycle) that has been verified by the appropriate process of the supplier.

Other equipment

For missed approach procedures based on conventional means (VOR, NDB, DME) the appropriate airborne equipment required to fly this procedure must be installed in the aircraft and operational. Also, the associated ground-based navigation facilities must be operational. NOTAMs should provide this information.

Functional check on start-up

The pilot should confirm the status of the system and correct operation before flight. Most systems provide an automated system check on initial start-up. This check should be monitored as it runs for correct operation of the system and associated display and instrument function.

System settings and display parameters

Pilots must ensure that the system settings are correct, before flight (see also 3.4 above). This may require adherence to any standard procedures as determined by the aircraft operator and should include at least the following:

- [ ] Checks on the CDI scaling, alarms, airspace and altitude buffers, any map display settings and orientation.
- [ ] Verification of or changes to heading and track display (magnetic, true etc...)
- [ ] Verification of or changes to map datum (WGS84)
- [ ] Verification of or changes to the units of measure of distance, speed, altitude, barometric pressure and position format.
- [ ] Verification or changes to the navigation displays including setting of the fields to give correct indication of distance to next waypoint, speed, time, desired track and cross-track error.
- [ ] Verification of or changes to the date and time format.
- [ ] Verification of or changes to other units of measure such as fuel quantity and temperature.
- [ ] Once the system is operating correctly, the RAIM prediction should be confirmed, if not completed by this stage

It is recommended that the expected RNAV (GNSS) approach at the destination be added to the receiver system ‘flight plan’ or ‘route’. Pilots should also be aware of how to add an approach procedure to the current flight plan or route, and how to change to a different procedure for the destination, should it become necessary to make these changes whilst enroute.

As a further crosscheck at this stage, the pilot could check the expected approach procedures as extracted by the system (e.g. FMS Control Display Unit (CDU) flight plan page) and presented graphically on the moving map, where possible, in order to confirm the correct loading and apparent accuracy of the procedure content.

Where an RNAV SID is to be flown using an autopilot set to ‘NAV’ mode, the HSI/CDI will need to be set to the primary navigation source (possibly GPS) shortly after take-off. Pilots are urged to ensure that any local radio navigation aids are also tuned and displayed to verify aircraft position and confirm accuracy of the RNAV display.

Use of autopilot

When using any autopilot or flight director function, pilots must observe the limitations on the use of the autopilot in that mode, as detailed in the AFM supplement or equivalent document, particularly with reference to minimum level of operation above terrain. Pilots must be familiar with the procedures for disconnecting the autopilot at any time and, in any event, at the appropriate point on the approach.

Making the approach

Further assurance as to the GPS accuracy can be obtained by using the receiver's own functions to check the status of the satellite constellation. The receiver may also display information on the navigation status of the receiver itself (eg '3D Navigation') as well as the number of satellites in view, their signal strength, Estimated Position Error (EPE) of the system, Dilution of Precision (DOP) (See Note 7) and Horizontal Uncertainty Level (HUL) appropriate for the phase of flight.

Note 7: DOP is an estimate of the inaccuracy of the position based on the relative geometry of the satellites in view. The solution is presented on a scale of 1-10 and without any more detailed guidance from the receiver manufacturer, if the system displays DOP as more than 5.0, the GPS should not be used for navigation at all

Before reaching the IAF, the flight crew should verify that the correct procedure has been loaded into the receiver's route or flight plan. A comparison with the approach chart should be made including the following:

- [ ] The waypoint sequence.
- [ ] Reasonableness of the tracks and distances of the approach legs, accuracy of the inbound course and mileage of the FAS.

- [ ] Verify from the charts, map display or CDU, which waypoints are fly-by and which are fly-over.

- [ ] Check any map display to ensure the track lines actually ‘fly-over’ or ‘fly-by’ the respective waypoints in the procedure.

By the time the aircraft reaches the IAF the pilot should have completed the above and been cleared for the approach. Also, the approach must have been activated in the receiver at least by this time.

Terrain awareness and terrain displays

Some systems provide terrain information on a Multi Function Display (MFD). However, some of these rely on the altimeter setting in the receiver unit (regardless of the pilot's pressure altimeter setting) and unless the system's own barometric setting is correctly set, the aircraft height above terrain shown in the display may be incorrect.

Even those systems linked to an altitude encoder or air data computer, may reference the primary pressure altimeter setting for terrain displays. In these systems, unless the pilot's primary altimeter is set to local QNH, these displays may contain significant height errors, critical to terrain separation. Pilots should not rely on these displays for terrain separation, without considerable detailed knowledge of the system function.

Conventional pressure altimetry, and the current local topographical chart, should always be used as the primary terrain References.

Baro-aided receivers

For RNAV/GNSS systems with RAIM using barometric-altitude information (so called baro-aided) where this information is not transmitted automatically to the RNAV system by an air data computer or altitude encoder, the crew should enter manually the proper altimeter setting at least by the IAF or 30 NM from the airport., whichever comes first. These systems use the barometric input to increase the availability of the RAIM function only and must never be used in APV BARO-VNAV operations.

For APV BARO-VNAV operation, the crew must confirm the correct altimeter setting. The procedure must only be flown With:

1. a current local altimeter setting source available; and
2. the QNH/QFE, as appropriate, set on the aircraft’s altimeters.

Procedures using a remote (regional) altimeter setting source cannot support APV BARO-VNAV approach.

For APV BARO-VNAV operation, pilots are responsible for any necessary cold temperature compensations to all published minimum altitudes/heights. This includes:

1. the altitudes/heights for the initial and intermediate segment(s);
2. the Decision Altitude/Height (DA/H); and
3. subsequent missed approach altitudes/heights.

When the descent profile is based on barometric altimetry as opposed to GPS data, with aerodrome temperature below ISA, actual aircraft altitude on the glidepath is lower than the design procedure glideslope. For this reason, and to contain this error within safe limits, the lowest temperature in which the approach may be flown safely should be stated on the approach chart. APV BARO-VNAV procedures are not permitted when the aerodrome temperature is below the promulgated minimum aerodrome temperature for the procedure, unless the RNAV system is equipped with approved cold temperature compensation for the final approach

Setting the display

At approximately 30 nm from the destination the system should transition from enroute to an intermediate or 'terminal' mode and the HSI/CDI scaling should change gradually from the enroute setting (full scale deflection at 5nm cross track error) to the terminal setting (full scale deflection at 1nm cross track error). By this point, the pilot's HSI/CDI should be confirmed as selected to GPS/FMS information display (as opposed to VOR/LOC) and, where necessitated by analogue or manual systems, be aligned correctly to display the track of the current or next leg.

Approaching the IAF, the pilot must confirm that the approach has been activated in the receiver. This may not be automatic and, in many stand-alone systems, may require positive action by the pilot at this time.

Gross error crosschecks

All the RNAV (GNSS) approach procedures published in Norway are compliant with the PBN Navigation Specification. This means the OPMA and RAIM functions in the receiver will provide an alert to the flight crew if the navigation position is in error (e.g., if the GPS position may be in error from an Horizontal Alarm Limit being exceeded). This does not account for any error associated with inaccurate pilot tracking or steering (Flight Technical Error (FTE)) however, but does cover the integrity of basic position information coming from the receiver. All RNP procedures assume that the aircraft has this monitoring facility.

Whilst a manual cross check between raw radio aids and an RNP approach-approved GPS installation is not a requirement, Pilots should, by this stage of the flight, have a good overview of the accuracy of the FMS / RNAV display. When working correctly, the accuracy of GPS will often expose the operational error of the local radio aids. When comparing GPS position with data from these radio aids, errors of up to 5º may be normal in a VOR display, and DME may only be accurate to about half a mile. DME indicates slant range but GPS displays horizontal range, giving rise to a further small discrepancy, which increases as you approach the DME station overhead.

Setup the missed approach

Before commencing the approach, pilots should tune and identify any navigation aids that may be required for the Missed Approach Procedure (MAP). Where the MAP is based on terrestrial navigation aids only such as NDB, in the event that the necessary radio aids are not available, pilots should not commence the approach.

Activating, arming or enabling the approach

Before reaching the IAF the pilot should activate or enable the selected approach and pilots must be familiar with how to do this in their receiver. Failure to activate the approach correctly, or in time, will result in inaccurate or misleading information being displayed to the pilot.

Radar vectors & ATC procedures

The manual entry of co-ordinates into the RNAV/GNSS system by the flight crew for operation should not be performed anywhere within the terminal area and never below MSA

Route modifications may take the form of radar headings or clearances to “route direct” to any waypoint and pilots should be capable of reacting in a timely fashion. Pilots must be familiar with the procedures to activate any particular leg and how to use any ‘direct to’ routing function for any waypoint in the flight plan, route or approach procedure. Pilots should also be capable of re-activating a previous leg or waypoint in the event of returning to a previous waypoint.

Some receivers allow selection of the approach by way of vectors to the Final Approach course and pilots should be familiar with the selection and activation of the approach using vectors by ATC to the final track. A clearance direct to the FAF, however, is not acceptable. Modifying the procedure to intercept the final approach course prior to the FAF is acceptable for radar vectored arrivals or at other times with ATC approval. However, vectors to a waypoint not included in the approach profile contained in the GPS database may lead to incorrect approach-mode activation and waypoint sequencing. When faced with such a clearance, pilots are advised to request vectors to a procedure waypoint prior to the FAF instead.

Some receivers will allow re-selection and activation of a different approach at this point and pilots must be capable of changing the selected approach (eg; from a procedural to the vectored approach on the same runway) should ATC insist on changing a procedural clearance to radar vectors or vice versa.

Some receivers will not transition easily between the full procedure and the vectored approach. Unless the pilot is fully conversant with the technique to switch procedure quickly, or transition directly to a successive waypoint in the procedure, it is recommended that pilots self-positioning for the procedural approach through an IAF, should not then accept vectors to any point other than the Initial Approach Fix (IAF) instead electing to hold at the IAF, or outside the approach area completely, until a further clearance for the approach is given.

For more information on ATC procedures and RTF phraseology see Appendix 3.

Adjustment to ETA

When using a ETSO C 129a Class A1 receiver or when SBAS is not available, if enroute ETA becomes significantly different from the ETA used during the pre-flight planning for RAIM (or equivalent) availability check, a new check by the crew is necessary (and advisable in preparation for any RNAV approach). However, it should be noted that this check is processed automatically 2 NM before the FAF by the C129a class receivers. In the event of any warning of unavailability or alarm/failure within the RAIM function, the pilot should discontinue or go around from the approach.

Spatial orientation & situation awareness

During RNAV operations the presentation of distance to the next waypoint automatically, instead of to a selected navigation aid, cross-track error displayed as a distance instead of an angle and the absence of some errors such as slant-range and scalloping, all contribute to a significant change in the navigation environment and some of the familiar rules of thumb no longer apply.

Most importantly, and unlike many conventional instrument approaches, distance information is not necessarily displayed to the aerodrome or runway during an RNAV approach. This means the distance display may repeatedly count to zero and then jump to a higher figure at the passage of each successive waypoint and the cues for the next stage of the approach – such as step descents or turns – may be less obvious to the flight crew.

It is critical to the safety of the flight, therefore, that pilots anticipate the passage of each successive waypoint in the procedure. This requires continuous monitoring of the aircraft position against the approach chart, and checking that the receiver is sequencing correctly to the next leg of the procedure.

Pilots must be fully familiar with the vertical profile of the approach to be flown (including the Missed Approach Procedure) together with the names and geography of each of the waypoints throughout the sequence. Until reaching the FAF, distance to the next waypoint should be displayed but overall distance to the destination or runway threshold may not be apparent. This causes the pilots easily to lose awareness of position along the associated descent profile, previously determined by comparison of a continually eroding distance to destination against the aircraft's level. Pilots may not always, therefore, rely on distance indication to monitor the descent and must determine the correct level to fly by reference to each successive waypoint name instead. This will require familiarity with all waypoint names and almost certainly require repeated reference to the approach chart. For reference, a sample RNAV (GNSS) approach chart appears at Appendix 4.

When flying an RNAV procedure, pilots must always have the appropriate chart immediately to hand in the cockpit.

When flying a “T” or “Y” shaped RNAV procedure, the transition of the intermediate fix will normally require a turn onto the final approach track. Most systems will display a message reminding the pilot of the next track and that a turn is required but the pilot must retain satisfactory spatial orientation and, in many display systems, adjust the HSI/CDI alignment manually and in time to turn onto the next track.

Final approach

The final approach course should be intercepted no later than the FAF in order that the aircraft is correctly established on the final approach before starting the descent (to ensure terrain and obstacle clearance).

At least 2 NM before the FAF, the crew should check that the approach has been correctly activated in the receiver and that any approach mode annunciator (or equivalent) is active.

If the approach procedure is not correctly activated, the display may not be accurate, the sensitivity may not be correct and the safety protection limits of the system itself will not be correctly set. The instrument display and any system message page should also be checked, prior to reaching the FAF, to ensure that there are no warnings, messages or instrument flags prohibiting the continued approach.

Flight progress should be monitored for plausibility – using XTE display, CDU, glidepath and map indications, for the track-keeping and vertical assessments, as applicable to the approach being flown. Where a multi sensor FMC/FMS is used, the Estimated Position Error/Uncertainty (EPE/EPU) or Actual Navigation Performance (ANP) as appropriate should be monitored to determine the navigational accuracy. If any doubt exists about the navigational accuracy, the procedure should be discontinued.

Monitoring the final decent

2D approaches

Some procedures, particularly 2D approaches, contain additional level restrictions in the final descent, before reaching the (M)DA/H, known as Step-Down Fixes (SDF). These limitations, when present in the final descent between the FAF and the MAPt, represent absolute minimum heights above terrain (or other restrictions) and are included in the procedure design as an additional safety measure. Some RNAV equipment displays present these restrictions as additional waypoints in the database and the correct distance to the runway is then replaced with the shorter distance to the next SDF.

This removes the simple distance comparator that normally enables the pilot to calculate a stable descent profile to the runway, using altitude (or height) against distance to threshold. Before passing the step-down fix the distance displayed is the shorter distance to the step-down fix and not the threshold. The incorrect assumption that this shorter displayed distance is now to the runway (and not, as it actually is, to the SDF), might easily lead the pilot to descend below the approach profile and into the under-shoot area.

This is a significant difference from the technique normally used on an NPA with distance guidance such as on an LOC/DME approach and full familiarity with the equipment display and the descent profile is critical at this stage of flight.

The Constant Descent Final Approach (CDFA)
The published minimum heights associated with step-down fixes are sometimes well below a stable, continuous descent profile. Whilst the initial and intermediate approach will be a series of descents between waypoints, no longer is it considered best practice to fly the final descent in a succession of level steps. Instead, pilots must be fully familiar with the procedure

presentation in their own equipment (and on the chart) and should be able to follow the advisory vertical profile by way of a stable and continuous descent to MDA/H at the MAP without destabilizing the approach with a level segment. On the final descent, pilots should endeavor to maintain aircraft altitude within +/- 75’ of the advisory CDFA descent profile published on the chart and not below the level of any SDF until the aircraft has passed it.

3D approaches

Where a VGP is displayed on a 3D approach (either LNAV/VNAV or LPV) pilots should endeavor to maintain a steady and stable descent within a half scale deviation of both the glidepath indication and the final approach track in the same way as for an ILS.

Missed approach procedures

GNSS systems are more susceptible to interference and jamming than the terrestrial approach aids. Before commencing an RNAV (GNSS) missed approach, a MAP should be possible without reference to GPS derived navigation so that, in the event of a loss of GPS accuracy or loss of integrity during the approach, a safe return to above Minimum Sector Altitude can be made. This may be possible by dead reckoning (DR) navigation but where this is not possible and the MAP requires reference to terrestrial navigation aids, these must be available, tuned and correctly identified before passing the IAF and remain available throughout the approach.

Reasons for a missed approach are many and if GPS information remains available for the MAP, the pilot must be able to sequence the system correctly past the MAPt, in order to follow the published MAP correctly. The receiver may not do this automatically and pilots should be fully competent in the necessary selection routines required by their own equipment, in order to transition to the MAP and preserve accurate navigation throughout. Some systems will transition to a 'suspense' mode and may not give any guidance as to the correct MAP until a further selection is made by the crew. Often these systems will give an indication straight ahead during suspense mode and not take account of any lateral deviations of the MAP necessary to avoid terrain or obstacles in a climb straight- ahead.

When GPS navigation is NOT available for the MAP, it may be necessary to re-set the display function of the HSI/CDI to disengage GPS information and regain VOR/LOC display. Pilots must be fully conversant with these navigation display selections in order safely to follow the MAP.

Abnormal procedures

When using receivers certified to ETSO C129 (a) (LNAV Only, without SBAS), as the aircraft approaches the FAF, the receiver should automatically perform a final RAIM (or RAIM (FD)) prediction for the approach. These receivers will not enter the approach mode if this RAIM prediction is negative. If this happens, the approach should be discontinued. However, this RAIM check assumes availability of the full constellation and will not take account of scheduled interruptions or failures. This can lead to a successful RAIM prediction at this point when the RAIM function itself is not available.

If RAIM is lost after passing the FAF the equipment should continue to provide navigation, where possible for five minutes, before giving a RAIM loss indication and this should be enough to complete the approach. Should RAIM detect an out of tolerance situation, an immediate warning will be given and a missed approach should be initiated immediately.

When using receivers certified to ETSO C146 (LNAV & LNAV/VNAV with SBAS) the SBAS signal may continue to augment the position solution and enable the approach to be continued with fewer GPS satellites than is necessary for the RAIM algorithms required by a ‘C129 standard’ receiver.

With either specification of receiver, the approach should always be discontinued:

1. If the receiver fails to engage the correct approach mode or;

2. In case of Loss Of Integrity (LOI) monitoring or;

3. On LPV if loss of vertical guidance is indicated even if lateral guidance is displayed.

NOTE: Reversion to LNAV minima may be possible with some systems and pilots must be familiar with this option and the associated display messages. If in doubt the approach must be discontinued.

1. Whenever the HSI/CDI indication (or GP indication where applicable) exceeds half scale displacement or;
2. If a RAIM (or equivalent) warning is activated or;
3. With a ‘C129 standard’ receiver if RAIM (or equivalent) function is not available and annunciated before passing the FAF

In the event of communications failure, the flight crew should continue in accordance with published lost communication procedures.

The flight crew should react to ACAS/TCAS and GPWS/TAWS warnings in accordance with approved procedures.

The flight crew should notify ATC of any problem with the RNAV/GNSS system that results in the loss of the approach capability using the RTF phraseology detailed in Appendix 3.

Introduction

This part of the document contains guidance on the organization and structure of training. This includes recommendations on training techniques, safety considerations and suggested syllabus content. It is intended as an aide-memoire for Instructors teaching RNAV instrument approaches using GPS receivers that meet the airworthiness standards of ETSO C129 and 145/6.

The Guide should not be considered in isolation and instructors should themselves be trained in the use of the particular system they are teaching on. Instructors should be familiar with all available technical and training material available for the system, including manuals, training and demonstration programs, CD's, DVD's and simulators etc. Use of these facilities in student training courses is strongly encouraged.

The training should cover general information and procedures applicable to all types of GNSS equipment as well as the particular operating procedures for a specific type of receiver and aircraft installation. Pilots going on to use other types of GNSS equipment must ensure that they are familiar with and competent in operating that type of equipment, before using it in operations. It is recommended that such familiarization be undertaken with the further supervision of an instructor experienced in the use of the new type of equipment.

For ease of reference to parts 1-4 of this document:

- Part 1 is an introduction to GPS and RNAV approach operations
- Part 2 contains an overview of PBN, some of the terminology, specification and infrastructure together with current RNAV approach applications.

- Part 3 contains important information and guidance on the function, requirements and recommendations for the use of GNSS for RNAV approach operations.
- Part 4 is intended as a practical guide to RNAV approach operations with GPS.
- Appendix 1 contains suggested training syllabus content.
- Appendix 2 contains an operational checklist intended to assist in the development of operators’ own checklists for their particular aircraft.
- Appendix 3 contains detailed guidance on ATC operational procedures and RTF phraseology.
- Appendix 4 contains a sample RNAV (GNSS) approach chart from the AIP.
- Appendix 5 of this document contains technical information on the function and performance of GPS and is reproduced with the kind permission of CASA.
- UK CAA publishes basic guidance on the use of GPS in Safety Sense Leaflet 25.

Instructors should be familiar with the information in this document and are free to use it to help develop and support their own training material.

Organizing the training

Instructors

Instructors carrying out training must hold a current instructor rating and be qualified to teach for the IR EASA license in accordance with EASA Part FCL subpart J.

Training facilities

Classroom facilities should be available throughout the training, which should include theoretical knowledge instruction, flight briefing and flight training.

The use of full flight simulators, Flight Navigation Procedures Trainers (FNPT's), Part Task Trainers and Basic Training Devices is actively encouraged, as is the use of computer based training programs.

Flight training

Any flight training in the use of these systems must be executed with extreme caution. Live flight training, whether in an aircraft or Flight Simulation Training Device (FSTD), is desirable in most circumstances however, where FSTD(s) cannot be used or are not available, actual flights must form an integral part of the training.

Students should be cautioned over the complexity of the system and the distractions it can cause. These systems are very beguiling and programming the display and accessing the information available is likely to engage the trainee inside the cockpit to an excessive degree in the early stages. Attention to lookout and other safety related in-flight tasks is likely to be significantly diminished and instructors are urged to pay particular attention to airmanship issues, such as lookout, utilization of airspace and fuel and engine management, during training flights.

It is important not to overload the student with too much information at the outset. Training flights should each have a clear objective. Teaching the basics and instilling a desire in the student to learn the finer points over time, may be more effective than detailed comprehensive instruction in the functionality of the whole system in a single lesson. Covering the full functionality of such a system and its use in flight is best achieved through a structured approach to a defined syllabus of training and exercises, presented over a series of lessons. Each exercise should be clearly identified from the syllabus and have a definite objective, and completion standards. The associated airmanship aspects should be briefed before every flight.

Research has shown that in-flight practice of these approaches provides a considerable learning advantage and much of the necessary situation awareness. Students are most likely to gain valuable awareness of the necessary process from watching a demonstration and should be allowed to practice at least three approaches, initially in VMC, and to the satisfaction of their instructor before training is considered Complete.

Reference material

The range of differences between systems is such that generic requirements for training cannot easily be set. The primary reference for any training should be the manufacturers' manuals and guidance material, used together with this guide. It is the responsibility of the instructor and the training organization to ensure that such training includes all relevant aspects of the particular system, its installation and use, taking into account the experience and qualification of the pilot undergoing training.

The purpose of this guide is to provide training organizations and instructors with the basis to formulate their own syllabus for the provision of training in the use of GPS and should not be used as a syllabus in itself.

Principles of PBN and RNAV approach

- [ ] Principles and benefits of PBN
- [ ] Definitions and PBN terminology
- [ ] Differing RNAV approach applications and equipment to be used
- [ ] RNAV approach design criteria and operating minima
- [ ] 2D approach operations including LNAV and LP
- [ ] 3D approach operations including LNAV/VNAV (BARO VNAV) and LPV

Principles of GPS

- [ ] System components – Space, control & user
- [ ] Basic system function – Satellite signal and pseudo random code
- [ ] Number of satellites, their orbit and operational coverage
- [ ] Integrity, availability and continuity
- [ ] SBAS system components, principles and function (EGNOS in Europe)Minimum number of satellites for navigation
- [ ] Receiver function, pseudo ranges and determination of position
- [ ] Use of WGS 84 coordinate system
- [ ] Receiver Autonomous Integrity Monitoring (RAIM) including baro-aided
- [ ] Errors of the signal and accuracy of the system position:

Ephemeris

Clock

Receiver

Atmospheric / Ionospheric

Multipath

PDOP / GDOP (see Appendix 5)

Dynamic Masking

Susceptibility to interference

Comparison of horizontal and vertical accuracy

Tracking accuracy and collision avoidance

Receiver software function and currency

Aeronautical database function including updates, checks and potential for error

Alarm limits and receiver mode activation

Accuracy and availability in Enroute, Terminal and Approach modes.

Loss of integrity and degraded signal – including loss of VNAV data

system installation & limitations

- [ ] Performance limitations of various equipment types
- [ ] Handheld units
- [ ] Installed units (E)TSO C129 /145 / 146
- [ ] FD & FDE RAIM
- [ ] Components of the installation including antennae and instrumentation
- [ ] Integration of GPS information with FMS / HSI / RMI / CDI as appropriate
- [ ] System interface with autopilot/flight director as appropriate
- [ ] System integration with flight management system – if equipped
- [ ] System warnings, cautions, alerts and messages
- [ ] Flight manual supplement - authorized use and limitations
- [ ] Approval and certification of installation for use in;

VFR navigation

IFR enroute navigation (aircraft’s PBN and RNAV approval status)

RNAV approach operations approval status including LNAV & VNAV

Human factors

- [ ] Database errors & checking
- [ ] Data entry errors & cross or double-checking routines
- [ ] System familiarity and programming
- [ ] Approach procedure familiarity
- [ ] Spatial orientation
- [ ] Automation Induced Complacency
- [ ] System monitoring
- [ ] Reference to approach charts
- [ ] Use of checklists
- [ ] The need for initial and recurrency training
- [ ] Published and operator-specific aerodrome competency requirements

Preflight preparation

- [ ] Use of conventional navigation charts and planning as primary reference
- [ ] Web-based RAIM Predictions
- [ ] NOTAMS (including SBAS NOTAMS) and NANUS
- [ ] Powering up the system and self-test function
- [ ] Display test monitoring
- [ ] Acquisition of satellites and preparation for navigation
- [ ] Checking aeronautical database currency and area of operational coverage
- [ ] Checking receiver software currency
- [ ] Cross check of current displayed position
- [ ] System settings and display parameters see Note 5
- [ ] Assessment of system status and signal reception
- [ ] RAIM function – use of receiver-based prediction facility

☐ Navigation functions:

Data-base waypoint checking

User defined waypoints

Entering and storing ‘Routes’ or ‘Flight Plans’

Checking and selecting of stored flight plan routes

Data entry errors and correction Modifying existing routes / flight plans for use

Checking and selection of departure and arrival routes (SIDs and STARs)

Adding SIDs, STARS and instrument approaches to selected flight plan route.

Checking and selection of published instrument approach procedures see Note 9

Checking accuracy of instrument approach data

Checking of correct loading and reasonableness of approach procedure

Using map displays as a data entry crosscheck.

Data retrieval, display and other available functions

Any MEL restriction must also be observed.

> **Note 8**: Aircraft owners and operators (especially training organizations, private aircraft rental operators and ownership groups) must be encouraged to develop their own SOP for

the settings and display parameters of their system(s). This includes defining the data to be displayed in each field, including the units of both the display and other system functions. Some systems offer a series of user profiles that control these parameters by way of a pre-set menu. These profiles should be used with extreme caution as these menu settings are not normally protected in any way. Pilots must be able to check these settings – and change them where necessary - when using such user profiles.

Instructors should assist in the development process of an operator's own SOP and ensure that any training they provide is strictly in accordance the resulting procedures. These SOP should be made available in writing to all pilots of the particular aircraft.

Note 9: Published Instrument Approach Procedures

It should be stressed during training that only published instrument approach procedures, selected from the receiver's own valid aeronautical database (current AIRAC cycle) and unalterable by the pilot, may be used in making an instrument approach. Pilots must ensure that the procedure is not prohibited by company instruction or NOTAM Demonstrations of user-defined approaches must not be made to pilots at any time.

In flight

- [ ] Terrestrial radio navigation aids
- [ ] Visual navigation techniques
- [ ] Monitoring system performance;
- [ ] Satellite availability
- [ ] Signal strength
- [ ] EPE
- [ ] DOP
- [ ] HUL
- [ ] Navigation mode / performance
- [ ] System message display;
- [ ] Systems Caution Messages
- [ ] System Warning Messages

Enroute navigation

- ☐ Activating stored flight plan route
- ☐ Manually active route or flight plan including adding and removing listed waypoints
- ☐ Deviation from flight plan route
- ☐ Activating selected flight plan legs
- ☐ Routing directly to any waypoint in the ‘flight plan’
- ☐ Diverting to alternate aerodromes enroute
- ☐ Other use of “Direct to”, “Nearest” and other navigation functions
- ☐ Maintaining a lookout
- ☐ Vertical accuracy and use of VNAV function
- ☐ Selecting and flying RNAV SID’s and STAR’s
- ☐ Use of GPS/FMS overlay and display of raw navigation aids data
- ☐ Integration of SIDs, Routes and STAR’s in the ‘Flight Plan’
- ☐ Holding procedures

Flying the approach

- [ ] Selecting instrument approaches from the database
- [ ] Routing directly to the IAF and IF
- [ ] Vectors to Final Approach Track (FAT) and to the FAF
- [ ] RTF phraseology
- [ ] Use of check-lists in the air
- [ ] Approach mode activation and indication
- [ ] Monitoring of HSI/CDI display scaling
- [ ] Monitoring of approach progress and vertical profile
- [ ] Transition to visual flight at minima
- [ ] Missed approach procedures with and without GPS navigation

Preparing for landing

Pilots must prepare and configure the aircraft for landing in accordance with the aircraft checklist. Whilst learning the new techniques of RNAV approaches it is recommended that pilots slow their aircraft to approach speed, earlier than they would normally, in order to give time to assimilate the new RNAV approach environment.

General

Action in the event of;

- [ ] Loss of Navigation
- [ ] Loss of or unavailability of RAIM function
- [ ] Loss of SBAS signal (where applicable)
- [ ] Loss of VNAV capability and reversion to LNAV minima when possible
- [ ] Disparity between GPS and conventional nav-aids.
- [ ] Other messages and warnings during the approach
- [ ] Reverting to alternative navigation techniques
- [ ] Overlays & Monitored Approaches

Training, testing and currency of pilots engaged in RNAV approach operations – see Note 10

Note 10: Where the aircraft is suitably equipped, flight tests for the issue and revalidation/renewal of an Instrument Rating may include enroute navigation utilizing RNAV and a RNAV (GNSS) approach, whenever a published approach is available. For more information see “Skill tests and proficiency checks” below

Introduction

The following checklist is provided as an aide memoire for those pilots intending to perform an RNAV (GNSS) approach at their destination and should not be considered an exhaustive preparation. It is expected that pilots will use this as a model for the development of their own checklist.

The usual ‘outbrief’ practice of checking one’s health, license and aircraft documents, weather, NOTAMS and aircraft serviceability, must be followed as must all the normal, abnormal and emergency checklists for the aircraft to be operated.

Flight planning

- [ ] Confirm approach published as “RNAV (GNSS) Approach”
- [ ] Identify alternate approach facility or alternate aerodrome
- [ ] Check weather suitability
- [ ] Perform RAIM prediction
- [ ] Check NOTAMS (including SBAS NOTAMS) & NANUS
- [ ] Other Equipment – Check NOTAMS for availability of other navaids

Pre-flight checks

- [ ] Check receiver software version current
- [ ] Check aeronautical database version current
- [ ] Perform functional check on start-up. Monitor auto-test function, confirm status of system and navigation availability
- [ ] Check system settings and display parameters (as applicable to receiver type)
- [ ] Set CDI scaling to ‘automatic’,
- [ ] Check setting of alarms, airspace and altitude buffers
- [ ] Check Map display settings, de-clutter and map orientation
- [ ] Check heading and track display (magnetic, true etc...)
- [ ] Check map datum to WGS84
- [ ] Check the units of measure of distance, speed, altitude, barometric pressure and position format
- [ ] Select display to show, at least:

Desired Track (DTK)

Groundspeed (GS)

Distance to next waypoint (DIS)

Check date and time format.

- [ ] Check setting of other units of measure such as fuel quantity

- [ ] Enter Flight Plan or Route

- [ ] Add expected approach to Flight Plan or Route using Name or SBAS channel number (where applicable)

- [ ] Review loaded approach procedure for reasonableness and accuracy against published approach plate or chart

Before reaching IAF

Within 30 nm of destination:

- [ ] Confirm revised ETA within RAIM Prediction Window
- [ ] Check status of system and satellite coverage
- [ ] Check navigation mode, EPE, DOP or HUL where applicable
- [ ] Obtain Clearance for Approach
- [ ] Re-check loaded procedure for:

Waypoint sequence.
Reasonableness of the tracks and distances,
Accuracy of the inbound course and length of final segment.
Identify any fly-over waypoints
Check presentation of procedure on any map display
Check/Set HSI / CDI navigation source to FMS/GPS
Check display mode & CDI Scaling (1nm or “terminal”)
Complete approach brief including minima and MAP
Set FMS/GPS system altimeter setting to destination QNH (baro-aided receivers)

Approaching the IAF

- [ ] Re-check/Set HSI / CDI Navigation Source to FMS/GPS
- [ ] Check Approach correctly activated in receiver
- [ ] Set and identify terrestrial navaids as required
- [ ] Check next Track, Distance and Level from approach chart
- [ ] Complete aircraft approach checks as applicable to type
- [ ] Descend in accordance with the procedure (if applicable)

At the IAF

- [ ] Set HSI/CDI to next track and turn aircraft when advised by receiver
- [ ] Descend in accordance with procedure (if applicable)

At the IF

- [ ] Set HSI/CDI to final or next approach track and turn aircraft when advised by receiver

- [ ] Descend in accordance with procedure (if applicable)

Approaching the FAF

- [ ] Complete aircraft landing checks as applicable to type
- [ ] Check altimeters set and crosschecked
- [ ] Check correct approach mode annunciator as applicable to approach type
- [ ] Check CDI Scaling correctly adjusted to final approach setting
- [ ] Check system messages and flags clear
- [ ] Cross-check final track on approach chart
- [ ] Review minima (Step-down, MDA/H and RVR/visibility)
- [ ] Review MAP

Final Decent

- [ ] Monitor lateral deviation on HSI / CDI
- [ ] For APV Monitor vertical (glidepath) deviation on display
- [ ] For LNAV only Monitor CDFA descent profile using altimeter against vertical profile on chart

Missed approach

- [ ] Go-around in accordance with normal aircraft procedures

If RNAV information is lost or a loss of integrity (or RAIM) message or warning is visible:

- [ ] Re-set HSI/CDI navigation source to VOR/LOC
- [ ] Continue with published MAP or as directed by ATC
- [ ] Inform ATC that RNAV navigation has been lost (see Appendix 3 for radiotelephony (RTF) phraseology)

If RNAV information is still available:

- [ ] Ensure display has not entered a suspense mode at the MAPt. If necessary, unsuspend receiver to enable correct MAP in the display Continue with RNAV (GNSS) MAP or as directed by ATC
- [ ] Monitor any terrestrial navaids available during the MAP phase

RTF praseology

Pilots should request clearance to fly the procedure using the phraseology:

‘(Aircraft c/s), request RNAV approach, via (IAF Designator), runway xx’

Where traffic conditions permit, air traffic controllers shall clear the pilot to follow the procedure using the following phraseology:

‘(Aircraft c/s), cleared RNAV approach, runway xx, (report at [IAF designator])’

For traffic sequencing and to aid situational awareness, air traffic controllers may request the pilot to report when established on final approach track or to report at any other relevant point in the procedure. For example:

‘(Aircraft c/s), report established on final approach track’

‘(Aircraft c/s), report 2 miles from final approach fix’

Air Traffic Controllers shall instruct the pilot to report at the FAF, using the phraseology:

‘(Aircraft c/s), report final approach fix’

After reaching the FAF, the pilot will continue to fly the procedure towards the next waypoint, normally the runway threshold. At the appropriate time, the pilot will either continue with the air traffic clearance received or will execute the MAP.

When Air Traffic Control is aware of problems with the GNSS system, the following phraseology shall be used:

‘*(Aircraft c/s), GNSS reported unreliable’*

OR

‘*(Aircraft c/s), GNSS may not be available due to interference in the vicinity of (location) (radius) [between (levels)]’*

OR

‘…In the area of (description) [between (levels)]’

‘*(Aircraft c/s), GNSS unavailable for (specify operation) [from (time) to (time) (or until further notice])’*

Following a RAIM alert, pilots shall inform the controller of the event and subsequent intentions.

‘*(Aircraft c/s) Unable RNAV (due to [reason eg Loss of RAIM or RAIM alert]) (plus intentions)’*

‘*(Aircraft c/s) Loss of RAIM or RAIM alert (plus intentions)’.*

Loss of Communications
In the event of communications failure, the pilot should continue with the RNAV (GNSS) procedure in accordance with published loss of communication procedures as detailed in AIP ENR.

Approach chart Geitryggen

*ATS AIRSPACE CLASSIFICATION: REF ENR 1.4

INSTRUMENT APPROACH CHART - ICAO   PLAN VIEW SCALE: 1:450 000

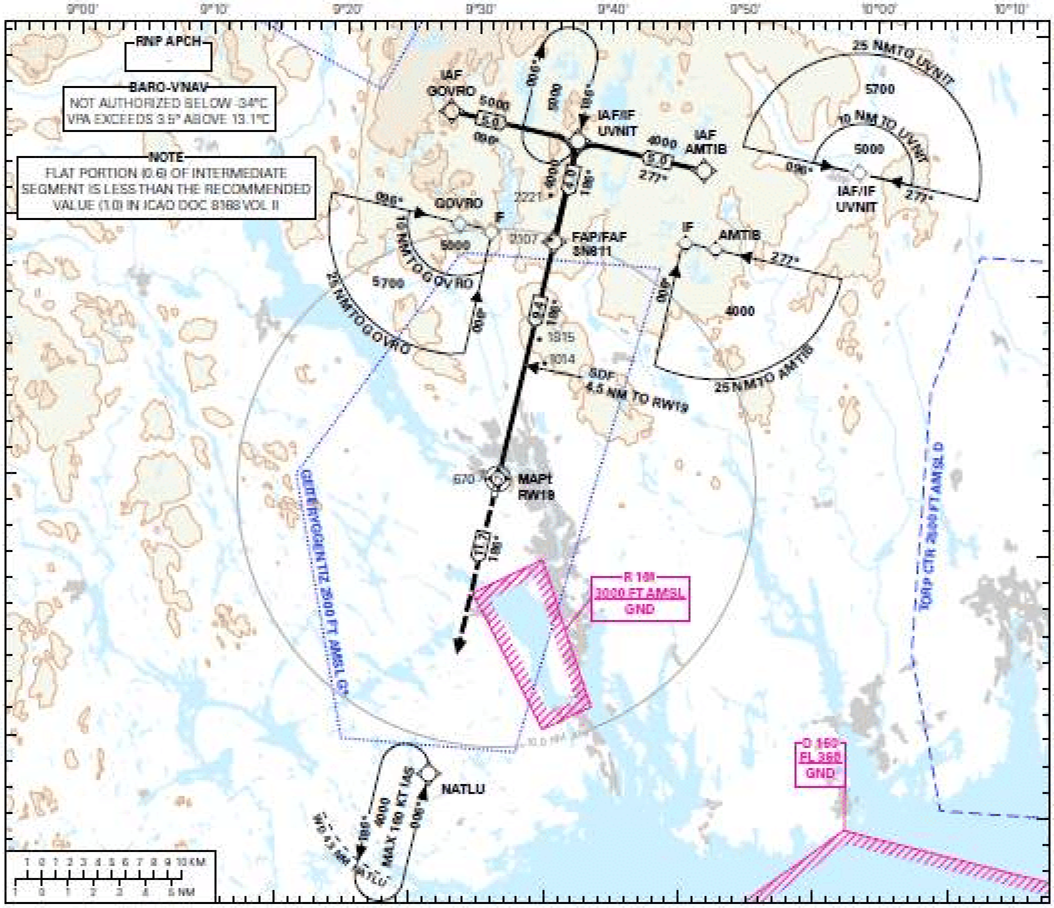
APP: 134.050 124.350	AD ELEV: 463		
AFIS: 119.200	THR ELEV: 463	DIST IN NM	
VDF: 119.200	HGT RELATED TO THR RWY 19	ELEV, ALT AND HGT IN FT	
	CIRCLING HGT RELATED TO AD ELEV		
	BEARINGS ARE MAGNETIC - VAR 2.2 ° E (2015)		

SKIEN

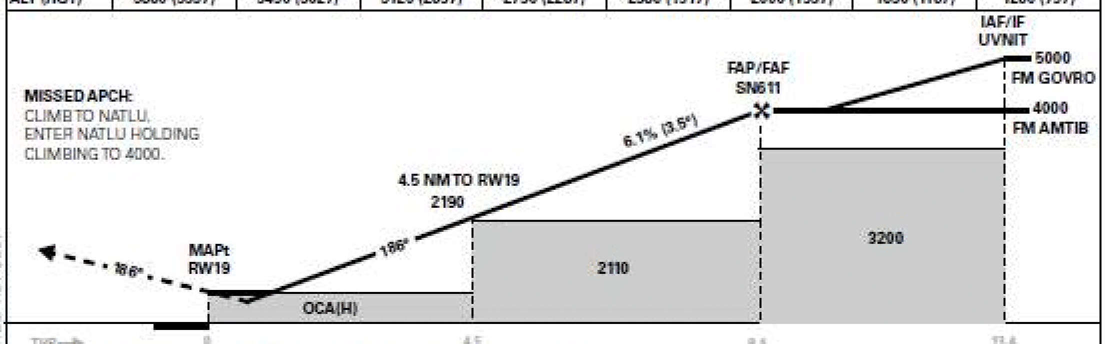
GEITERYGGEN

RNAV(GNSS) RWY 19

TRANSITION ALTITUDE
7000



DIST TO RW19	9	8	7	6	5	4	3	2
ALT (HGT)	3860 (3397)	3490 (3027)	3120 (2657)	2750 (2287)	2380 (1917)	2000 (1537)	1630 (1167)	1260 (797)



CAT OF ACFT		A	B	C	D
OCA(H) STRAIGHT - IN	LNAV/VNAV	780 (317)	800 (337)	-	-
	LNAV	870 (407)	890 (427)	-	-
		-	-	-	-
CIRCLING		[illegible]	[illegible]		

FINAL APCH	DIST FAF - MAPt: 9.4					
SPEED	KT	70	90	100	120	130
TIME	MIN:SEC	08:03	06:16	05:38	04:42	04:20
ROD	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

CHANGES: COMPLETELY REVISED.

NOTE:

Australian Civil Aviation Advisory Publication CAAP 179A -1(1) (MARCH 2006)

The following text is an extract from the Australian Civil Aviation Advisory Publication CAAP 179A -1(1) (MARCH 2006) and is reproduced with the kind permission of the Australian Government Civil Aviation Safety Authority (CASA). Letters in italics indicate where the text has been changed or updated and aligned with European and/ or Norwegian current standards.

GPS is a United States Government system operated by the Department of Defense. The two levels of service provided are known as the Standard Positioning Service (SPS) and the Precise Positioning Service PPS). SPS is available to all users and provides horizontal positioning accuracy in the order of 25 meters in the horizontal plane and 43 meters in the vertical plane, each with a probability of 95 percent. PPS is more accurate than SPS, but available only to US military and a limited number of other authorized users.

GPS consists of three distinct functional elements: the space element, the ground-based control element and the aircraft-based user element. The space element consists of 24 or more satellites in six orbital planes (with four or more in each plane) located approximately

11,000 miles above the Earth. The exact number of satellites operating at any one particular time varies depending on the number of satellite outages and operational spares in orbit. Read more about the GPS constellation here. These are circular orbits at 55º to Earth's polar axis. Unlike the geostationary EGNOS satellites, the GPS satellites are not in geostationary orbit. The ground-based control element consists of a network of GPS monitoring and control stations that ensure the accuracy of satellite positions and their clocks. The aircraft-based user element consists of the GPS antennae and satellite receiver-processors on board the aircraft that provide positioning, velocity and precise timing information to the pilot.

GPS operation is based on the concept of ranging and triangulation from a group of satellites, which act as precise reference points. Each satellite broadcasts a pseudo- random code called a Course Acquisition (CA) code, which contains orbit information about the entire constellation ("almanac"), detail of the individual satellite's position ("ephemeris"), the GPS system time and the health and accuracy of the transmitted data. The GPS receiver matches each satellite's CA code with an identical copy of the code contained in the receiver's database. By shifting its copy of the satellite's code, in a matching process, and by comparing this shift with its internal clock, the receiver can calculate how long it took the signal to travel from the satellite to the receiver. The distance derived from this method of computing distance is called a pseudo-range because it is not a direct measure of distance, but a measurement based on time. Pseudo-range is subject to several error sources, including atmospheric delays and multipath errors.

The GPS receiver mathematically determines its position using the calculated pseudo- range and position information supplied by the satellite. At least four satellites are required to produce a three-dimensional position (latitude, longitude and altitude) and time solution. The receiver computes navigational values, such as distance and bearing to a waypoint or groundspeed, by using the aircraft's known latitude/longitude and referencing these to a database. The system is unaffected by weather and provides a worldwide common grid referencing system based on the Earth-fixed coordinate system. For its Earth model, GPS uses the World Geodetic System of 1984 (WGS84) datum.

Performance

The GPS performance may be measured in a number of ways. While accuracy is the most obvious quality of a navigation system, other measures such as data integrity, continuity of service, system availability and vulnerability to interference are also important attributes.

Accuracy

Accuracy is the measure of the precision of the navigation solution. ICAO Standards and Recommended Practices (SARPS) specify the accuracy requirements for various phases of flight. Current technology can use the GNSS constellations to meet IFR accuracy requirements for oceanic and domestic enroute use as well as terminal area and non- precision approaches. Precision approaches will require some form of GNSS augmentation to overcome the known limitations of the constellation systems.

The most common causes of reduced accuracy are:

Ephemeris
Although the satellite orbits are extremely stable and predictable, some perturbations do exist. These are caused by gravitational effects of the Earth and Moon and the pressure of solar radiation.

Clock
Timing errors due to inaccuracies in both the satellite and receiver clocks, as well as relativity effects, can result in position errors of up to two meters.

Receiver
Due to the low signal strength of GNSS transmissions, the receiver's pseudo- random noise codes are at a lower level than the receiver ambient noise. This results in a fuzzy correlation of the receiver code to the satellite code, and produces some uncertainty in the relationship of one code to another. The position error that results form this effect is about one meter.

Ionosphere
One of the most significant errors in the pseudo-range measurements results from the passage of the satellite signal through the Earth's ionosphere, which varies depending on the time of day, solar activity and a range of other factors. Ionospheric delays can be predicted and an average correction applied to the GPS position, although there will still be some minor error introduced by this phenomenon.

Multipath
An error in the pseudo-range measurement results from the reflection and refraction of the satellite signal by objects and ground near the receiver. This is known as Multipath error. Ghosting of television pictures is an example of Multipath effect.

Because GNSS is a three-dimensional navigation system, the errors do not all lie along a line and therefore should not be added algebraically. Total system range error is calculated by the root-sum-square method, where the total is the square root of the sum of the squares of the individual errors.

Dilution of Precision

Geometric Dilution of Precision (GDOP) is an effect that degrades the accuracy of a position fix, due to the number and relative geometry of satellites in view at the time of calculation. The value given is the factor by which the system range errors are multiplied to give a total system error.

Position Dilution of Precision (PDOP) is a subset of GDOP that effect latitude, longitude and altitude. Many GPS receivers are able to provide an estimate of PDOP.

Integrity

Integrity is the ability of the system to provide timely warnings to the user when the equipment is unreliable for navigation purposes. The concept of integrity includes a failure to alarm and a false alarm.

In Europe, conventional ground-based navigation aids incorporate monitoring equipment at the ground site. Should the equipment detect an out-of-tolerance condition, the transmitter is shut down, and the user alerted by a means of a flag or loss of aural identification. GNSS integrity relates to the trust that can be placed in the correctness of the information supplied by the total system. This includes the ability of the system to notify the pilot if a satellite is radiating erroneous signals.

Individual GNSS satellites are not continuously monitored, and several hours can elapse between the onset of a failure and the detection and correction of that failure. Without some additional integrity monitoring, a clock or ephemeris error, for example, can have a significant effect on any navigation system using that satellite. Receiver Autonomous integrity monitoring (RAIM) is the most common form of integrity monitoring and is discussed (in this document at 3.1.3 above). Many GPS receivers do not monitor integrity and will continue to display a navigation solution based on erroneous data.

Availability

Availability may be defined as the percentage of time the services of a navigation system are accessible. It is a function of both the physical characteristics of the environment and the technical capabilities of the transmitter facilities. GNSS availability is the system's capacity to provide the number of satellites required for position fixing within the specified coverage area. At least three satellites need to be in view to determine a two-dimensional (2D) position, while four are required to establish an accurate 3D position.

Selective Availability (SA) was a technique used by the US Department of Defense to limit the accuracy of GPS to other than approved users. It was achieved by artificially degrading the accuracy or 'dithering' the satellite clock, or broadcasting less accurate ephemeris parameters. With growing reliance upon GPS in civil applications, SA was discontinued by Presidential decree in 2000.

Many early GPS receivers were "hard-wired" for SA in the expectation that civil use would always need to assume that SA was active. For receivers that cannot take advantage of SA being discontinued, average RAIM (Fault Detection) availability (is slightly less than for receivers that can take advantage of SA having been discontinued.)

Continuity

Continuity of service is the ability of the total navigation system to continue to perform its function during the intended operation. Continuity is critical whenever reliance on a particular system is high, such as during an instrument approach procedure. Although the GPS constellation has been declared fully operational, the possibility exists that unserviceability will occur and reduce the number of 'healthy' satellites in view to less than the operational requirement.

Vulnerability

Vulnerability is a qualitative measure of the susceptibility of a navigation system to both unintentional and deliberate interference. All navigation systems have vulnerabilities and the effect of thunderstorms on an ADF receiver is a well-known example. The issue of GNSS vulnerability has become prominent because of early proposals to replace multiple terrestrial navigation systems with a single source (GPS). A variety of mitigation strategies are being used to address the vulnerability risks of transitioning to a GNSS-dependent navigation infrastructure. These include advances in receiver and antenna design, augmentation systems, alternative constellations, multiple frequencies, integrated GNSS/INS receivers, retention of a core terrestrial navaid network and careful management of the radiofrequency spectrum.

Hva har du lært om PBN og GNSS? - Quiz

Question

01/10

What is the relationship between RNAV and RNP?

- ○ An RNAV-system is identical to an RNP- system.
- ○ An RNP-system is an RNAV-system with on board performance monitoring and alerting.
- ○ An RNAV-system is an RNP-system with on board performance monitoring and alerting.
- ○ RNP is a prerequisite for having an RNAV-system.

Question

02/10

PBN is an acronym for Performance Based Navigation. What statement is true?

- ◯ PBN came about as a misspelling of RNP.
- ◯ PBN superseded RNP, as 3D and 4D approaches were added.
- ◯ PBN evolved into RNP
- ◯ PBN was developed by Pilatus Britten-Norman in the late 1990s

Question

03/10

What is the difference between LPV and LNAV/VNAV approaches?

- ○ Nothing, they are the same.
- ○ LPV typically gives the same precision as an ILS, whereas LNAV/VNAV give less accurate guidance and has higher minima and rely on barometric altitude information.
- ○ LPV generally give lower minima, but both systems are GNSS-based for both lateral and vertical navigation.
- ○ Whereas LPV give lateral guidance, LNAV/VNAV give both lateral and vertical guidance.

Question

04/10

What is LNAV+V?

- This is a term used by the receiver manufacturer for an advisory glidepath to LNAV approaches.
- LNAV+V is the development of LNAV/VNAV approaches to include vertical guidance based on GNSS.
- LNAV/VNAV
- LNAV+V is a term for lateral navigation added with barometric vertical navigation.

Question

05/10

If you do not fly an FMS-equipped aircraft, what approach require SBAS-equipped aircraft?

- ○ LPV only.
- ○ LPV and LNAV/VNAV only.
- ○ LP, LPV and LNAV/VNAV
- ○ ILS, PV, LPV and LNAV/VNAV

Question

06/10

On what approach(es) must vertical navigation be derived from barometric pressure?

- LP, LNAV, LNAV/VNAV, NDB, VOR and LOC.
- LP, LNAV, LNAV/VNAV, NDB, VOR, ILS and LOC
- LPV, LP, LNAV, LNAV/VNAV, NDB, VOR, and LOC
- LP, LNAV, LNAV/VNAV, NDB, VOR, MLS and LOC

Question

07/10

To fly a PBN approach legally, you must:

- Hold a valid instrument rating
- Hold a valid instrument rating with PBN-privileges
- Hold a valid instrument rating with PBN-privileges and fly a PBN-approved aircraft
- Hold a valid instrument rating with PBN-privileges and fly a PBN-approved aircraft in accordance with an approved PBN operations manual.

Question

08/10

The correct action when receiving a Loss Of Integrity (LOI) alert is:

- To go missed approach always
- To continue LP if the vertical signal is lost in an LPV approach
- To fly continuous descend to missed approach point and VMC from there. Alternatively go missed.
- Transfer to a conventional approach, for example VOR/DME approach.

Question

09/10

ATC call you and say “GNSS reported unreadable”. What does this imply?

- ○ The Great National Service Station is not publishing any news.
- ○ Satellite data are lost.
- ○ The Great Northern Steamship company has failed to report its position.
- ○ ATC is unable to hear your communication.

Question

10/10

Flying a satellite approach, the distance normally displayed on the receiver is:

- DME distance to the ILS for the runway.
- DME distance to the main navigation VOR.
- Distance to the runway threshold.
- Distance to the next waypoint.