ADVANCED NAVIGATION USING SATELLITE

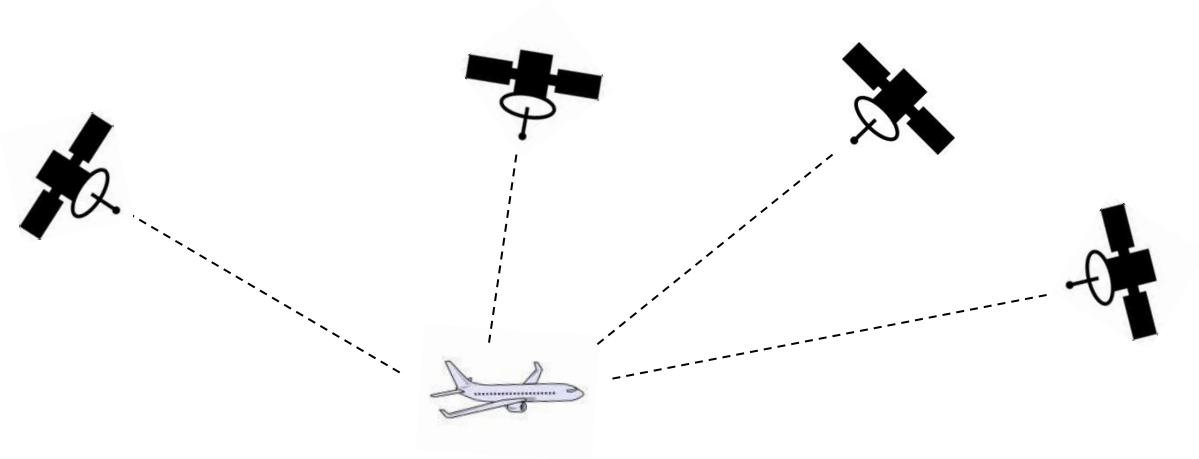
1. Introduction

With the progress of electronic systems (computers) and the Global Navigation Satellite System (GNSS) like the global positioning system (GPS), aircraft can travel with more accuracy and efficiency.

2. Satellite navigation origins

Early navigation system predecessors were the ground based like DECCA, LORAN, GEE and Omega which used terrestrial longwave radio transmitters instead of satellites.

The United States began the GPS project in 1973 to overcome the limitations of previous navigation systems. The global positioning system (GPS) is a global navigation satellite system (GNSS) that provides location and time information in all weather conditions, anywhere on or near the Earth where there is an unobstructed line of sight.



The GPS system provides critical positioning capabilities to military, civil, and commercial users around the world. The United States government created the system, maintains it, and makes it freely accessible to anyone with a GPS receiver.

The GPS accuracy should meet the minimum requirement of base surface navigation B-RNAV:

- Minimum ±5NM accuracy during 95% of the flight duration
- 99.99% service availability during flight

The current system can now have better accuracy down to 1NM or less.

3. Positioning system concept

The GNSS concept is based on time and the known position of specialized satellites. The satellites carry very stable atomic clocks that are synchronized to each other and to ground clocks.

A GNSS receiver monitors multiple satellites and solves equations to determine the precise position of the receiver and its deviation from true time. At a minimum, four satellites must be in view of the receiver for it to compute four unknown quantities (three position coordinates and clock deviation from satellite time).

4. Global Navigation Satellite System (GNSS)

GNSS includes two different kinds of satellite meant for two different purposes:

- Positioning system: it allows positioning an object everywhere on earth in relation to its coordinates and its altitude.
- Augmentation system: it allows making sure the positioning system's integrity is reliable, thus there is no gap in positioning signal.

Examples of a few GNSS positioning systems:

- GPS (USA)
- GLONASS (Russia)
- Galileo (Europe)
- Compass (China)
- IRNSS (India)
- QZSS (Japan)

4.1. Positioning System

4 satellites are necessary to compute a 3-dimension position:

- Longitude,
- Latitude,
- Height and integrating dimension:
- Time.

The position is computed from the distances to the satellites. Aircraft can use up to 6 satellite signals:

- 4 signals is basic positioning
- 5 signals will allow detecting a faulty signal: **RAIM function**
- 6 signals will allow determining which satellite is faulty: **FDE function**

4.2. Accuracy and Integrity

GNSS must meet essential criteria to ensure flight safety:

- Accuracy: amount of error between computed and true position
- Integrity: ability to alert the user when accuracy decreases
- Continuity: amount of time the system will operate without interruption
- Availability: amount of time the system is actually able to function

Receiver Autonomous Integrity Monitoring (RAIM) enables to achieve integrity when using GNSS.
It enables detecting a discrepancy in satellite signal, which leads to a decrease in position accuracy.
Since the monitoring is continuous, pilot can be immediately alerted when inaccuracy hit a critical threshold, generally the required specification.

For ABAS-based approach (LNAV and LNAV/VNAV), RAIM must be operative to ensure Required Navigation Performance (RNP).
Some systems have RAIM built-in predictions, enabling to know whether the RAIM function will be available or not in a specific location at a specific time.

The **Fault Detection and Exclusion (FDE)** function allows the user deselecting a faulty satellite to ensure continuity and availability of GNSS.

4.2.1. Augmentation System

For approach operations, positioning system is basic, and computation needs strict accuracy monitoring.

That's why all approach operations are RNP specifications and not RNAV specifications.
In order to achieve this degree of precision, GNSS signals are correlated with augmentation systems.

There are three types of augmentation systems:

- Satellite-Based Augmentation System (SBAS)
- Ground-Based Augmentation System (GBAS)
- Autonomous/Aircraft-Based Augmentation System (ABAS)

Each of these systems is meant for a different use, and in particular, different kinds of RNAV approach, which we have already dealt with in this document.

As said, augmentation will magnify and enhance satellite signals and position computation to monitor its accuracy and thence the integrity of the system.

Examples of a few SBAS augmentation systems used for LPV & LNAV/VNAV approaches:

- WAAS (USA)
- EGNOS (Europe)
- MSAS (Japan)

Example of GBAS augmentation system used for GLS approaches:

- LAAS (USA)

Examples of ABAS augmentation systems used for LNAV & LNAV/VNAV approaches:

- Redundant position cross feeding comparison (GNSS & DME / DME for instance)
- RAIM / FDE

5. GPS receiver

5.1. Basic receivers

Garmin GNS430 is one of the basic GNSS systems used in general aviation.

5.2. Advanced receiver

With the Garmin GTN750, we have a larger screen with much information depicted on screen which is a touchscreen with many configuration menus and it can include an extensive chart database.

5.3. Receiver on liners

With the introduction of GNSS inside the flight management computer onboard of the commercial aircraft, the information is given by two means:

- Flight management computer: Entering data using keyboard and display text and data calculated using GNSS and various information
- Primary flight display and navigation display: Displays on larger screen positioning data and different values calculated with conventional means and GNSS data, route. Also displays primary flight parameters (attitude, speed, altitude, vertical speed, heading…)

Boeing flight management computer

Primary flight display

Navigation display