THE AIR TRAFFIC CONTROL IN BRAZIL AND THE NAVIGATION SYSTEM: Current status, future modifications and those already implemented

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Abstract: The model of functioning of air traffic service in Brazil, the existence and use of current navigation aid, the changes that are being implemented and planned for the near future, are not always aware of all users (crew, operators or persons directly linked to the aviation Branch). Particularly due to the growth of world air traffic, it is necessary a minimum of knowledge on the part of these people, so that, regardless of the area in which is linked, since in the field of aviation, be aware of the changes that are occurring. With this goal, will be shown in this work, the complexity that is the existing communication network on the ground to guarantee the safety of your flight, since the point of departure to the final destination. Today and for some time, the system used to track the route of an aircraft in Brazilian airspace, constitutes a true technological apparatus, consisting of powerful radars and antennas for communication, which has the mission to inform air traffic controllers of each plane positioning within a given space.

Keywords: Aircraft. Air Traffic Control. Air Navigation.

1. INTRODUCTION

It is known that flying has always been a desire of human being. Leonardo da Vinci, also in the 15th century, built a model airplane bird shaped and made several designs, such as propellers and parachutes, which were of great contribution later. The big challenge, which at the beginning was flying machines heavier than air, it has been superseded, and nowadays the aircraft began to dominate the skies of Brazil and of the world, some across continents in a matter of hours.

However, for an offset between two points is necessary to use some methods. In the early days, it used to be typically visual references, such as rivers, streams, trees, rocks, mountains, inter alia allowing the guidance through the ground.
Over time, there have also been developments of this navigation system, with the creation of instruments that made safer guidance task, even at night or in adverse weather conditions, however, specific knowledge is required to do so.

Aviation is the way to drive an aircraft with skill and safety through space, with the observation of significant points, which serve as reference.

In Brazil, the performance of air navigation covers an extensive area clipped by about 142,600 km of aero routes 55,560 km lower and upper airways, buoyed by a vast network of equipment and aid to flight operations en route, takeoffs and landings. Aero routes? Yes, it's like the existence of roads or highways (except in space), intended for the flow of aircraft. Similarly in the roads are plotted on maps, the specific publications listed in aero routes called cards.

Air navigation procedures have the function of providing more security for flights through the air traffic management (ATM). Responsibility for this management, using the available navigation AIDS and communications equipment, the air traffic controller. This, is responsible for the control of aircraft in their various stages of flight, in the areas of jurisdiction of the Brazilian airspace control – SISCEAB, acting in control towers of Aerodromes, in Terminal areas Approach controls or area control centres. All of these, called control organs. (Bernardes, 2011)

2. AIR TRAFFIC SERVICE

2.1. History

The structure of air navigation services and air traffic control has evolved and became more complex, because, as well as the aircraft evolved over the decades, air traffic control also became a sophisticated activity and highly dependent on technology. Before, only with some automated
facilities to improve information on radar surveillance equipment, the air traffic control systems, incorporate current systems with advanced flight data treatment and surveillance data, digital communications and automatic switching of messages, identification of routines operating security risks and decision support, among many others. These technical developments is remarkable pioneering deployment, Integrated Center of air defense and air traffic control, the CINDACTA I, which operates continuously since the mid-70 of last century. (Brazil 5)

The strategic vision sister-in-law since that time allowed, that the Brazilian industry reached the domain knowledge and technologies of this complex branch of activity, thus entering the Brazil among the small number of countries with know-how in systems of traffic management and airspace control.

As well as in many other countries, in Brazil, from the beginning it was common to use most of the airfields of shape shared by military and civil aviation, with a reasonably happy coexistence of airports and airfields. Simplistically, for example, we can say that the same radar capable of detecting a military aircraft, also detects a civil aircraft, the same beacon that serves as a guide for a guide to the other, too. The idea of shared use (civilian-military) Aviation media, therefore, imposes itself by itself.

This fact later realized the idea of deploying an integrated control of airspace, which extends far beyond the practice more or less common than shared use of airports and means of communications, navigation and surveillance.

2.2. Goals

For the purpose of aviation and air traffic control, airspace should be regarded as being a finite resource and, more limited are still the airports where, in a given track any, only fit a single aircraft at a time. Being so undeniable that we have limited resources, their use needs to be administered rationally and systematically, where they are then highlighted the objectives of air traffic services, which aim to provide the flow of aircraft safe, fast and orderly.

The efficiency of the air traffic control service depends on the availability and performance of means of communication, navigation and surveillance, as well as the adequacy of other technical resources installed in the organs of control and the qualification of human resources, including air traffic controllers.

2.3. Integrated Model of Air Defense and Air Traffic Control

In Brazil, the integrated model of air defense and air traffic control, not only came as technical solution to overcome the enormous difficulties in the implementation of the protection service to flight, as has been pointed out as an example for other countries. Today is considered, by
the international civil aviation related agencies, extremely creative and efficient. In fact, the best use of the infrastructure of airports and airspace requires perfect coordination between the bodies responsible for control of military and civilian air traffic, a dynamic that just works without problems and risks when the Military Operations Centers (MOC) and area control Centres (ACC) complement each other in their respective features (Brazil 1, Brazil 2, Brazil 3, Brazil 4, Brazil 5).

The air traffic control service was widely established shortly after World War II. Over the next several decades, although the radars, navigation aid, means of communications and automated features have been modernized, with dramatic changes in the inner part of the planes where, for example, in many models don't even spot exists in the cockpit, the air traffic control service itself, little had evolved by the end of the last century. Prehistoric planes, little equipped, or next-generation high-end, it doesn't matter; since air traffic control receives the same treatment. However, in addition to ignore the fantastic capabilities of modern aircraft, soon identified that this fact would begin to generate growing constraints on the capacity of the system and cause significant operational losses. This, one of the reasons the numerous changes that have taken place and that are listed in this article.

3. AREA OF RESPONSIBILITY OF THE BRAZILIAN AIR TRAFFIC SERVICE

The Brazil is responsible for administering the territorial airspace (over 8.5 million km²) and the overlying airspace to the ocean, which extends to the Meridian 10° W, making a total of 22 million km² (Brazil 6).

In this space, there are several events that may be occurring at the same time, such as: commercial flights, military flights, flight test, probes and launches rockets, flights of hang gliding, parachute jumping, training of anti-aircraft gunfire, among others.

To facilitate the services provided, this whole area was divided into flight information regions (FIR)

3.1. Flight Information Region FIR

Airspace of defined dimensions in letters published by the airspace control Department (DECEA), within which are provided flight information services and alerting. In this space, are set a few other areas in which is also provided the air traffic control service. Currently the Brazilian airspace is subdivided into five FIR: Amazon, Atlantic, Brasília, Curitiba and Recife, shown in Fig. 2.
3.2. Airspace Structure

As already mentioned, the Brazilian airspace is divided into five FIR, however the structure of the same receives other divisions: the limits (lateral and vertical), as the name of the service that is provided and how the classification according to the type of flight that is permitted (IFR or VFR). Thus, for a better understanding of what will be shown below, it is significant to distinguish how this structure as their Division, description and classification.

- **Airspace Division as the limits:**
  
  **Upper Airspace**
  
  a) the upper vertical limit-unlimited);
  
  b) vertical limit lower-FL245 exclusive; and
  
  c) lateral limits-indicated in the ERC.
  
  **Lower airspace**
  
  a) vertical limit superior FL245 inclusive;
  
  b) vertical limit lower-ground or water; and
  
  c) lateral limits-indicated in the ERC.

- **Designation of the airspace and services that are provided:**
  
  a) Flight information regions (FIR) – in these parts are provided with flight information services and alerting.

  b) The control area and Control Zone (CTR) – part of airspace is contained in a FIR, which is equipped with the air traffic control service to IFR or VFR flights, as the airspace classification.

To facilitate the provision of air traffic services, the control Areas are called:
- UTA - comprising the upper airways and other parts of the upper airspace, as defined in AIP-Brazil;
- CTA - comprising the lower Airways and other parts of the lower airspace, as defined in AIP-Brazil; or.
- TMA - understanding parts of the lower airspace, as defined in AIP-Brazil.

c) Aerodrome Traffic zone (ATZ) – parts of the airspace around an airfield within which are applied special requirements for protection of aerodrome traffic.

- **Airspace classification:**

  Aerospace, is also categorized according to flight arrangements on them allowed, i.e. flights with or without the aid of instruments, which are, respectively, the instrumental flight rules (IFR) and visual flight rules (VFR). These airspaces are classified and designated alphabetically and divided according to the rule of flight that is allowed, type of service that will be provided and the separation that is provided (under the responsibility of the control organ). Classified alphabetically, from A to G, where, for example, in class A space-only IFR flights are permitted; in the B-Class space are allowed IFR flights and VFR (Brazil 6). Other classifications would need an extensive explanation, which does not include the objective of the present work.

4. DESIGNATION OF AIR TRAFFIC OPERATIONAL ORGANS

Air traffic control, usually known by the abbreviation ATC (Air Traffic Control) is a service provided by controllers on the ground, that guide and monitor aircraft in the air and on the ground, to ensure a safe, orderly traffic flow and quick. Air traffic controllers provide indications and permits to fly, according to the operational characteristics of the aircraft and traffic conditions at any given time, using, for the most part, of information based on aid to navigation. These commitments may focus on the route, altitude and/or speed of the aircraft by the operator, proposals for a specific flight, pilots must comply with the instructions/authorizations received.

With that, currently, in Brazil are the following operational bodies responsible for the provision of air traffic control services.

4.1. Airdrome Control Tower (TWR-Tower)

Provides the aerodrome Control service to aircraft operating phases, takeoff, landing or overflight of airfield. Has as its main objectives to prevent collisions between aircraft and between aircraft and obstructions, or still, aircraft and vehicles moving on the ground. The area of jurisdiction of TWR covers the traffic circuit, its surroundings and the aerodrome maneuvering area. In a same control tower, there may be (according to the needs of each locality) other positions denominated Operating positions, each with specific responsibility. They are: Tower position,
position and position traffic Authorization.

4.2. Approach Control (APP)

Provides approach control service to aircraft that are running to get procedures or from the airfield. Visa, in particular, the separation of other aircraft or obstacles. The area of jurisdiction of the APP is the airspace called Terminal control area (TMA) or Control Zone (CTR). There are currently forty-seven APP installed in Brazil (Medeiros, 2010).

4.3. Area Control Center (ACC)

Provides the area control service to aircraft when they are already on the flight en route, in order to ensure separation between the same safely. The area of jurisdiction of the ACC is called space flight information region (FIR) and its sub areas. These regions are established spanning multiple Terminal Control Areas (TMA) and flight routes, known as aerovias. Currently there are five ACC installed in Brazil.

4.4. Aeronautical Telecommunication Station (Radio)

Is the air traffic agency (Ribeiro, 2008) which provides flight information service. Its core competency is providing information to aircraft, in order to inform them currently the existence of other aircraft and obstacles. There are more than 90 stations installed in airports in Brazil.

5. PLANNING A FLIGHT

Now that you've got cleared up what are the agencies and services that are provided, it is important to also know what an ATC unit must have to effectively provide the air traffic control service. Basically, what happens is that the ATC unit:

a) offers information about the intentional movement of each aircraft, or variations thereof, and current data about the actual progression of each one of them;

![FIG 3: Representation of the air movement between organs of control](http://abcta.org.br/index.asp?pagina=noticias_ver&noticia=11)
b) determines, based on information received from aircraft known, the relative positions, guarding each other;

c) issues permits and information with the purpose of preventing collisions between aircraft under his control and accelerate and maintain an orderly traffic flow; and

d) coordinates with other involved agencies permits whenever an aircraft can conflict with traffic under control of these bodies and before transferring control of an aircraft.

Important to know that all the Brazilian airspace is divided and that, for each portion, only an organ of control has jurisprudence and is responsible for the provision of air traffic services in that portion.

5.1. Stages of a Flight

Since before the takeoff of an aircraft, until later his landing, there are phases, which should be fulfilled by the pilot, crew or airline. The correct way is that, for each flight, there is an initial planning of all these stages.

Even before takeoff, should be planned the route that will be followed as well, which the rule of flight that will be employed, if VFR or IFR, or even both, in different parts of your flight.

After being held this planning will be presented a document-flight plan, mandatory character (with some exceptions) and that has form and specific regulations for each flight mode. The following are some of the related information to be included in this document:

- Aircraft identification (registration and call sign radio telephonic);
- Flight rule that will be used (IFR, VFR, or both – in distinct phases);
- Departure aerodrome and estimated time for takeoff;
- Route and flight level requested (both subject to approval of the ATC unit). In the case of flight level, throw all the desired levels for each portion of the route;
- Cruising speed that will be employed;
- Aerodromes of destination and Choice, along with total duration of scheduled flight;
- Radio equipment, navigation aid and to approach that offers;
- Approval status PBN (Performance-based navigation).

In the case of a flight that uses the rule for instruments (virtually all commercial flights, regular or corporate aircraft), it must be considered that this will go through various stages of operation. Some of them are mentioned below for the reader to become familiar with the procedures performed during the shift of aircraft between two airfields and understand how they are decisive for the air traffic scenario:

- Preflight: comprises planning phases.
- Taxi (taxi out): the aircraft receives authorization to fire up the engines and to maneuver until near the head of the runway, where the pilot is awaiting permission to take off.

- Take off (take off): airfield Control Tower authorizes takeoff of the aircraft. Upon reaching a certain altitude, the aircraft leaves the control tower (TWR) and passes it to the approach control (APP), that will guide you during the procedure of climb inside the terminal sector (TMA).

- Ascent (climbing): the aircraft continues to climb towards the planned cruising altitude in the flight plan, always with the necessary restrictions or new commitments. When you reach the altitude specified in route letter (15000 feet on average), the aircraft departs the TMA and continues to rise in contact with the area control centre (ACC) until the desired airway.

- Cruise (cruise): the aircraft altitude and adjusts its speed.

- Initial descent (descent): the aircraft gradually reduces its altitude until it reaches the TMA. If the terminal is congested, is applied a restraint measure to delay the entry of the aircraft in the TMA. The aircraft under this condition go into a queue logic, usually flying in circles or arcs, causing the unwanted standby problem, which considerably increases the financial cost of the transfer. Important to understand, that when you get in a terminal, these aircraft will be performing the descent both of different relative positions, but also to different altitudes.

- Final approach and landing (approach and landing): when it comes to the destination terminal, the control back to the APP. From this point, the aircraft decreases the gradient of descent in order to arrive at the airstrip with the proper speed. For the landing, the aircraft has the approval of the control tower (TWR).

- Taxi (taxi in): After touching the runway, the aircraft gradually decreases the speed and maneuver toward the arrivals gate. Control of soil (subsector of a TWR) is responsible for driving the aircraft by courtyard without interfering in other takeoffs and landings until the full stop of the same.

6. TRAFFIC CONTROL BASED ON AIR NAVIGATION AID SYSTEMS

Who's got his eye on a plane in the sky you can't imagine the complex network of communication that there are on the ground to guarantee the safety of your flight, since the point of departure to the final destination. Today and for some time, the system used to track the route of an aircraft in Brazilian airspace, constitutes a true technological apparatus, consisting of powerful radars and antennas for ground/air communication, which has the mission to inform air traffic controllers of each plane positioning within a given space.

As each plane follows his destiny by avoiding collisions in heaven? This response is achieved, not only by the fact that each aircraft could be "under surveillance radar" and monitored
by an air traffic controller. What occurs, moreover, is that the so-called aerovias (Airways), are buoyed by aid to navigation that serve to guide and direct the aircraft as the intended route.

During the flight, the aircraft maintains its flight levels (altitudes), which are stipulated in 1,000 thousand feet (after authorization by the ATC unit). That is, the vertical separation between aircraft is approximately 300 meters. These Airways are laid down in the Enroute Charts (ENRC)-Route cards. The plane flies within these "paths" in the sky, and the pilot, in accordance with the control organ, will adopt a flight level.


Currently, the control of aircraft, for the most part, is still made using conventional technologies, through the navigation aid on the ground, although many of them have already be able to orient yourself in other ways (Brazil 5).

Electromagnetic waves are used to generate positioning and direction, a real technological paraphernalia-including several antennas located on Earth, air navigation aid calls, ensuring aircraft spatial orientation, guiding them in the midst of predetermined routes. To understand how this works, during the flight, the aircraft exchange signals with these antennas, that become benchmarks for the confirmation of the route. Namely, to take its course, the plane must fly over the range of these antennas, which demarcate the trajectory of flight. This type of navigation is called conventional and the aircraft does not fly straight since the departure to your destination, but rather making a sum of small excerpts, lengthening the time of travel.

6.2. Some Navigation AIDS that Are Used

- **NDB**

  The NDB (Non Directional Beacon-non-directional Beacon) is a non-directional radio beacon station installed at airports or on the route, allowing the aircraft to navigate toward these aerodromes or fixed points of marking of routes, assisting air navigation, in order to allow the best track of airways and minimum flight altitude, with a view to the safety of the crew and passengers on the routes and terminals.

  The NDB receiver, known as ADF (Automatic Direction Finding – Automatic Direction Finder), located on board the aircraft, has the property to indicate the direction of the Transmitter Station automatically (NDB) for which is tuned by continuously and automatically, any markings transmitting station selected within the range of frequency and reach.

  The transmission frequency of the NDB station is in AM (Amplitude Modulation-Amplitude modulation), i.e. the rider can tune to a local radio station from a particular city, and, in addition to listening to music, will receive the indication in the respective air navigation instrument,
which will be shown in a direction indicator instrument, known as RMI (Radio Magnetic Indicator-Radio Magnetic Indicator).

In Brazil, the DECEA issued an aeronautical information Circular-AIC in March 2013, which established criteria and deadlines for gradual deactivation NDB stations on airspace control system (SISCEAB). Such a program is already in place, and at the end of 2020 all NDB will be disabled.

- **VOR**
  The VOR (VHF Omnidirectional Range – VHF Omnidirectional radio beacon) which means very high frequency radio beacon in every direction and is more modern than the NDB System.

  The VOR is a radio aid to navigation short-range air, which allows the pilot to determine the position, orientation and implementation of en-route descent procedures (landing) in airports that have this type of aid. The VOR Station provides an indication of azimuth with the increments of the angles by moving in the direction of movement of the hands on the clock. The relative azimuth information is then detected and interpreted on the aircraft through on-board receiver and associated instruments.

- **ILS**
  The instrument Landing System, known as ILS (Instrument Landing System) provided the success of modern aviation and, especially, made landings safer, even under conditions of low ceiling and visibility. Materially reduced service disruptions at airports due to bad weather conditions. ILS provides the pilot, the electronic information of alignment with the runway axis and angle of descent in final approach for landing. I.e., it is a precision approach system which allows landing with low or no visibility condition.

  Offers the information of trajectory (Localizer and Glide Slope), distance and altitude (bullets and recessed module), audible and Visual.

- **VHF/DF**
  The system known as VHF/DF (VHF/Direction Finder), which means VHF Direction Finder, which in Brazil is known as Recalada (in English, Homer), consists of a Radiogoniômetro Station, installed in the control towers of most airports, the air traffic controller determine through the signals emitted by a radio transmitter (located in the aircraft), the direction of the incoming waves. The primary objective is to locate the direction, in degrees, with respect to the physical position of the transmitter signals, allowing the controller to determine the position of an
aircraft in relation to TWR, providing directly the markup and the position in which she finds herself. One of the main purposes of VHF/DF System is to guide the pilot to fly to the station or to another location in that you can land in Visual conditions (even continuing until close to that in conditions by instrument) through an organ ATS with a VHF/DF station.

- Other equipment for air navigation support

Some equipment like DVOR (DOPPLER VHF Omnidirectional Radio Range-Doppler VOR), and the MLS (Microwave Landing System-microwave Landing System), were developed with the same features of the ILS and VOR systems, providing crew carry out their flights more securely and reliably, compared to previous.

In addition to these facilities, there is a RADAR (Radio Detecting And Ranging-detection and location via radio waves) and DME (Distance Measuring Equipment – Multifunction Meter away) that works with the same principles of RADAR, where the distance is determined by the round-trip time of the pulses (signals) of RF between two points, and those that do not depend on ground stations as the Doppler navigation systems and the inertial frame. All are modern equipment that help, too, to air navigation, based on the principles of functioning of the previous systems and electromagnetic waves.

7. SEPARATION BETWEEN AIRCRAFT

7.1. Minimum Distances

The distance between the aircraft, both in flight and on the ground, is a critical factor of safety, because this distance shall ensure that the manoeuvres made by them do not endanger themselves as well as their crew or to third parties, such as buildings or other aircraft. Security is without doubt the most important aspect to be considered, but it is not the only one. One must also take into account aspects such as the maximum use of available space, wake turbulence, emergency situations, the State system of radars, among others. All these factors together define the values that should be adopted for the minimum distance between aircraft.

The minimum distances adopted aim to always expedite traffic flow and ensure security. Some important technical concepts for the complete understanding that should be highlighted are:

- Radar separation is the separation used when aircraft position information is obtained using a radar system;
- The Landing sequence is the order in which the aircraft are positioned for landing; and
- The sequence approach is the order in which two or more aircraft are positioned on
the approach to the airfield inside a TMA, CTR or near these.

### 7.2. Wake Turbulence

Another very important factor to be considered by the air traffic controller is the treadmill of turbulence caused by medium and large aircraft. That was always a subject known from most aviators, and is nothing more than a set of vortices generated in wingtips. These vortices intensifies with the increase of the induced drag of the aircraft.

Therefore, in addition to the planned separations, the driver must always pay attention to category of aircraft.

![FIG. 4: Separation based on the heels of turbulence](http://www.oaviac.com.br/textos_tecnicos/esteiras_turbulencia.htm)

**7.3. Separation of Aircraft of Conventional Form (Not Control Radar)**

The air traffic controller that is providing the service do not control radar, said "conventional", you should separate the aircraft vertically or horizontally. Both the radar control, as in conventional vertical separation minimum is 1,000 feet (300 meters). However, often it will be necessary to maintain aircraft at the same flight level or level crossing there. In these situations, the separation will be held horizontally (laterally or longitudinally). As the basic aid is considered to perform the separation, the controller should provide a minimum lateral separation of:

- VOR → 15º
- NDB → 30º
- FIXO → 45º

The separation over time will be held as follows:

- For aircraft that follow the same route → 15 minutes;
- If the aid may determine continuously positions and aircraft speeds, and if both follow the same route → 10 minutes;
When the preceding aircraft maintained an indicated speed that far exceeds 20 knots or more the speed of that which follows → 5 minutes.

8. NEW SYSTEM ATM (AIR TRAFFIC MANAGEMENT)

The advent of digital communications and satellite navigation, represent the main foundations of the new airspace control concepts. The air transport industry is developing a new operating concept for the management of this system. This concept involves significant changes both in aircraft navigation systems with the introduction of new satellite technologies.

8.1. Global Situation

At the beginning of the Decade of the 80 years, the International Civil Aviation Organization-ICAO, having noted a steady growth of international civil aviation, as well as the emergence of new technologies, understand it would take a complete analysis and assessment of the procedures and systems in use. In this occasion, it was recognized that the existing way of providing air traffic services and the structure of the air navigation system in General would be limiting aviation growth and inhibiting the implementation of improvements in safety, efficiency and regularity of air operations.

With the development of new technologies, notably the use of satellites and on-board automated systems, ICAO developed the concept CNS/ATM conceived the evolution of air navigation, from the existing technology at the time (Sethi, 2005).

The symbol CNS/ATM, has the meaning of: Communication Navigation Surveillance/Air Traffic Management (Communication Navigation Surveillance/air traffic management), summarizing the changes that are being made in the various aviation segments.

8.2. National Situation

In Brazil, the Air Force Command, given the recommendations of ICAO adopted a guideline, the "DCA 351-2-Operating National ATM Design, which features the prospective vision for the evolution of the National ATM system (Brazil 5).

DCA 351-2, consolidates the vision of the National ATM Operating Concept in a performance-based plan of action, which allows you to define the enterprises which should be prioritized in order to enable:

- the more rational use of airspace;
- the best efficiency of the air traffic Management;
- the reduction in the emission of gases into the atmosphere;
- noise reduction to communities near airports;
• reducing the workload for controllers and pilots;
• cost reduction in the provision of air navigation services; and
• to provide better services to users of air transport.

The name given to this project is SIRIUS, which represents, in the context of the SISCEAB, the projects and activities required for the implementation of the ATM operational concept in Brazil.

9. GLOBAL NAVIGATION SATELLITE SYSTEM (GNSS)

The Global Navigation Satellite System (GNSS) is the key element of air navigation according to the CNS/ATM concept, constituting the basis of the improvement of air navigation due to its characteristics of wide coverage and accuracy.

The basic principle of operation of satellite positioning systems consists in determining the position of the user from the knowledge of the position coordinates of three points any and the distance between the user and each of these points. The GNSS is formed by a set of satellites and ground stations that allow a mobile can determine its position with accuracy and reliability required.

9.1. GNSS in Brazil

In Brazil, is regulated using the GPS as a "Supplement" en-route navigation, in terminal area and in non-precision approach. However, to operate IFR (instrument flight rules) aircraft should also possess basic equipment like the VOR and DME.

The extent to which the performance of GNSS navigation is improved, this will half to middle of primary supplementary navigation, thus replacing, in the future, all traditional aid.

9.2. Satellite-Based Augmentation System (SBAS)

Is a system consisting of two elements:

-ground segment: composed of a network of ground stations (tracking and processing), who receive the GPS signal and calculate the differential correction;
-space segment: composite of geostationary communications satellite, which receives information from correction of ground stations and relays for the aircraft.

This system promotes enough performance improvement of navigation (accuracy, integrity, continuity and availability), required to support all phases of flight en-route, terminal area and in non-precision approach.

Currently the only operational SBAS is the American, named wide area augmentation system (WAAS). Other countries are developing similar systems and compatible with WAAS. The Brazilian Government is considering the possibility of acquiring a SBAS itself, which is in
advanced stage of study, however without having been found more details by the end of this article.

9.3. Advantages of Satellite Navigation

The aerovias mostly lead to flight distances that exceed the minimum distances between source and destination. This is due to the fact that the aircraft fly a radio fixed aid on the ground to another. These equipments are installed at specific locations on the surface of the ground, where it is in favour of the line of sight of electromagnetic waves, in order to expand their coverage areas useful.

![FIG. 5: Air Navigation conventionally](http://surcandoloscielos.es/blog/la-navegacion-aerea-i/)

With the use of satellite-based navigation, if it reduces the time of aircraft in the air, therefore the cost, as well as, help in solving environmental (reduction of greenhouse gas emissions and noise).

![FIG. 6: Satellite-based air navigation](http://clientes.netvisao.pt/medeiros/Duarte.pdf)
10. IMPLEMENTED MODIFICATIONS AND FUTURE PROJECTIONS

10.1. Performance-Based Navigation-PBN

Performance-based navigation (or PBN, the English Performance-Based Navigation) redraws and optimizes the structure of air navigation paths.

Before the routes if restricted to aid delimited paths installed in the soil, the PBN expands the number of alternatives, since the feature makes navigation procedures targeted also by satellites.

Thereby, the aerovias are spending progressively by a major overhaul. Used to fly so angular, the aircraft can navigate more linear. The routes will see point-to-point navigation and not the radial interception and magnetic.

With more precise routes and shortened distances, in turn, the PBN enables a significant reduction in spending on fuel, the emission of polluting gases and even the noise of aircraft, since these are approaching to land in continuous descent and more regular speed.

PBN implementation in Brazil, is consolidating new standards of navigation, in addition to transforming the national airspace, managing more effectively to growing demand for domestic air traffic.

10.2. Area Navigation (RNAV)

The navigation area, can be defined as a method of navigation that permits aircraft operation on any route within the navigation aid coverage referenced in season or within the limits of the capacity of aid.

Thus, the constraints imposed by conventional procedures and routes, where the aircraft was forced to spend over the ground stations, are removed, increasing the flexibility and operational efficiency.

There is a wide variety of RNAV systems that may range from just a sensor-based systems to systems with multiple types of navigation sensors. These may or may not, be coupled to other systems like auto-throttle and autopilot, thus enabling a more automated flight operation.

For the pilots, one of the biggest advantages in using RNAV systems lies in the fact the navigation be effected by precise and sophisticated equipment, enabling a reduction in workload and increasing security.

A navigation specification establishes performance requirements required a RNAV system in terms of: accuracy, integrity, availability and continuity; navigation features required; necessary navigation sensors; and requirements required to crews. For Oceanic operations, remote, en route or terminals, RNAV specifications are designated for RNAV X (example: RNAV 1). The expression "X" (when used) is for the side navigation precision in nautical miles, which is expected to be
reached 95% of the time of flight of the aircraft operates within airspace, route or procedure.

10.3. Required Navigation Performance (RNP)

The concept of RNP can be defined as a measure of required navigation performance, operations in a given airspace. The RNP system is basically a RNAV system, whose features support performance monitoring and alert on board. Their requirements include the ability to follow a desired route safely, repeatable and predictable, including curved routes. When vertical profiles are included for vertical orientation, the requirements also include the use of vertical angles or altitude, constraints specified in order to define a desired route.

The function of alarm and performance monitoring on board is the main element that determines whether the navigation system meets the required level of safety associated with a RNP implementation.

Is related to the performance of lateral and vertical navigation and allows the crew to detect, in the case of the navigation system does not reach or cannot guarantee with 10-5, integrity.

As there are performance requirements for each navigation specification, an aircraft approved for RNP specification are not automatically approved for all specifications RNAV. Similarly, an aircraft approved for RNAV or RNP specification, with a higher accuracy level (RNP 0.3), are not automatically approved for a lower precision specification (RNP 4).

A summary of the categorizations of RNAV or RNP required as the area of flight of the aircraft, is shown in Table 1.

<table>
<thead>
<tr>
<th>Designação da Operação</th>
<th>Precisão Lateral da Navegação</th>
<th>Área de Aplicação</th>
</tr>
</thead>
<tbody>
<tr>
<td>RNP 10 (RNAV 10)</td>
<td>10</td>
<td>Em rota – Oceânica / Remota</td>
</tr>
<tr>
<td>RNP 5</td>
<td>5</td>
<td>Em rota – Continental</td>
</tr>
<tr>
<td>RNAV 1 e 2</td>
<td>1 e 2</td>
<td>Em rota – Continental / Área Terminal</td>
</tr>
<tr>
<td>RNP 4</td>
<td>4</td>
<td>Em rota – Oceânica / Remota</td>
</tr>
<tr>
<td>RNP 1</td>
<td>1</td>
<td>Área Terminal</td>
</tr>
<tr>
<td>RNP APCH</td>
<td>0.3</td>
<td></td>
</tr>
<tr>
<td>RNP AR APCH</td>
<td>0.5 – 0.1</td>
<td></td>
</tr>
<tr>
<td>APV/BARO-VNAV</td>
<td>-</td>
<td>Aproximação</td>
</tr>
</tbody>
</table>

Figures 8 and 9 illustrate in summary form the differences between conventional system and based on performance:
10.4. Non-Approved Aircraft Operations for the RNAV/RNP Navigation Specifications

Aircraft and operators do not approved for RNAV navigation specifications and/or RNP can continue flying in Brazilian airspace, through the use of routes and/or procedures "conventional" (VOR, VOR/DME, ILS or NDB) or through vectoring radar employed by the ATC units involved in the operations of aircraft. However, the ATC units concerned will be obliged to authorize the operation of these aircraft out of their profiles great flight, either by increasing the distance flown, either by use of altitude restrictions.
In Brazil, the FAA issued a Complementary Statement (IS 21-013) to obtain approval and equipment installation GNSS (Global Navigation Satellite Systems) for VFR and IFR operations PBN (Performance-Based Navigation).

The certification process involves the adaptation of operations manuals, minimum equipment list (MEL), program operations and maintenance training, manuals and maintenance controls, as well as specific training.

11. CONCLUSION

The new types of navigation technologies have the potential to provide precision procedures with higher levels of security systems used currently, once it comes to procedures based on satellites and with much more advanced technology. These systems are already implemented in several locations around the globe, having proven their worth throughout its operation.

The use of airspace, using performance-based systems, including those using satellite navigation, certainly provide improvements in the integrity of the operations. This allows more air routes close to each other providing enough security so that a better use of that space.

In controlled airspace, separation and lower minimum spacing of routes constitute a great benefit when compared with conventional systems existing until then. The specifications with the function of alarm and performance monitoring, facilitating the work of air traffic controllers by providing new means of risk mitigation. The use of RNP system can thus offer a significant security and major operational benefits.

However, it is the exception, that even with these new navigation systems, air traffic controllers will also have, for a long time, you are able to manage the flow of aircraft and have ability to provide air traffic control service to aircraft that are already employing performance-based navigation, but also to those who need to use conventional navigation. Certainly, leading to an increased need of concentration.

REFERENCES

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