

THE STATE-OF-THE-ART OF AERONAUTICAL CARTOGRAPHY IN BRAZIL

O Estado da Arte da Cartografia Aeronáutica no Brasil

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ABSTRACT

The Aeronautical Cartography in Brazil is used to support aviation. In this paper, it is possible to acquire knowledge about the state-of-the-art of aeronautical cartography in Brazil by reading information on methods, equipment and main products made available. Besides, this article shows a perspective for models of acquisition, processing, storage and publication of aeronautical data that comprise products related to safety and air navigation.

Keywords: Air Navigation, Aeronautical Information, Aeronautical Cartography.

RESUMO

A Cartografia Aeronáutica é usada para dar suporte à aviação. Neste trabalho é possível adquirir conhecimentos sobre o estado da arte da cartografia aeronáutica no Brasil através de informações sobre os métodos, equipamentos e os principais produtos disponibilizados. Também é apresentada uma perspectiva para os modelos de aquisição, tratamento, armazenamento e disponibilização dos dados aeronáuticos que compõem produtos ligados à segurança e à navegação aérea.

Palavras chaves: Cartografia Aeronáutica, Navegação Aérea, Informação Aeronáutica.

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1. INTRODUCTION

This paper aims at presenting the importance of cartography for air transport and its safety, contributing to the literature of aeronautical cartography, which currently has few references, and at providing more information regarding the demands of this sector.

A priori, the definition of some concepts and identification of agents is key for the proper understanding of this work. Supported by its own definition, aeronautics is the activity and the study of air transportation within the Earth atmosphere, as well as the means used for this purpose. Furthermore, navigation is one of the determining factors to perform the activity and it makes use of products and tools intrinsically connected to cartography. Consequently, using this author's freedom and the definition provided by the International Cartographic Association, Aeronautical Cartography can be described as the set of scientific, technical and artistic studies and operations which are involved in mapping design as a result of direct observations or document exploitation, as well as their use for air navigation purposes.

In Brazil, the Aeronautical Cartography production is performed exclusively by the Institute of Aeronautical Cartography, a unit subordinate to the Department of Airspace Control, from the Brazilian Air Force. The mission of the Institute of Aeronautical Cartography is planning, managing, controlling and performing the activities related to Cartography and Aeronautical Information. And its vision is: being recognized by the regulatory authority and by the users of their products as an institution of excellence in the processing and systemic dissemination of aeronautical information, comprising aeronautical cartography, and implementing knowledge and technology for corporate process purposes.

Aligned with this view, the human being has ceased to be the primary client of cartography. In other words, humans were the direct users of maps with intervention and manipulation directly on the product. Currently the major "clients" of cartography are systems that make use of the various cartographic products and which do not necessarily have direct interaction with humans. This fact is easily proven in aviation, an

aeronautics branch that deals with the locomotion of heavier-than-air apparatus.

Within the scope of this paper, methods, materials, technologies and products related to aeronautical cartography and its safety will be presented.

2. FIELD SURVEY

The topographic surveys are the most basic source of aeronautical data (data used to compose aeronautical information or somehow support aviation). Because of their easy acquisition and low cost, this tool is indispensable in virtually all the aeronautical universe, from the word etymology, or terrain datum, to the data surveyed with the finest precision for the assembly of an aircraft or installation of an air navigation aid.

In this paper we will only deal with topographic data related to the terrain and data which interfere directly in aeronautical activity. Data obtained from surveys can be seen in virtually all documentation involved in aviation.

A topographic survey is usually initiated in the aerodrome area. Its main study focus is the runway. Being aware of the runway dimensions is one of the determining factors for aerodrome activity. The use of topography allows scaling accurately all runway features and its surroundings. The most widely used method in topographic surveys is coordination transportation by irradiation, always starting from two points with already known coordinates. With this method, it is possible, for example, to determine the runway threshold coordinates, and indirectly obtain its length and also draw the longitudinal runway profile, information which is relevant to some aircraft for taking-off and landing procedures.

Still within the aerodrome area, topographic surveys are the basis for site survey projects (where it is possible to perform a study to verify the feasibility of implanting equipment to be used as an air navigation aid). This type of project requires a high precision level and knowledge of involved professionals. As a matter of illustration, we can bring to light an example of a piece of equipment which provides the aircraft with the approaching radial or the runway centerline. If the coordinate of this piece of equipment has an error of some centimeters in

its origin, it could result in a route error for the aircraft which is using this equipment kilometers away from it. Therefore, it would at least have an outcome of additional costs in terms of fuel and time.

The topographic surveys can extrapolate the aerodrome area in search for information that are generally connected to the safety of both the aircraft and the areas surrounding the aerodrome. In this case, the data survey focuses on acquiring altimetric information of natural or manmade features such as antennas, towers, buildings, poles, trees and hills. These data are used by professionals with specific knowledge of aircraft performance and aerodrome conditions to design the best landing or takeoff procedure, the most critical phases of flight. Once more, the experience and technical abilities of the professional conducting the datum survey can directly interfere in air navigation safety.

Nowadays, the topographic survey is no longer employed as an isolated method. The advancement of satellite positioning technology has significantly contributed to save time when performing surveys that combine these two methods and it has brought new possibilities of collection, storage and exchange of data.

3. GLOBAL NAVIGATION SATELLITE SYSTEM (GNSS)

It would be redundant and unnecessary to list in this paper how the advancement of satellite positioning technology provided benefits to cartography.

The satellite positioning virtually replaced or gained much room in surveys where topography used to be consecrated. The primary factors in choosing to use this technology in aeronautical cartography is that above all, it is time-saving and besides, coordinates are precisely defined in an easy way, without the need to mobilize large teams. The only limiting factor for the use of this technology is the impossibility to remotely obtain information, such as measurements that are taken by the use of laser.

Currently, receivers are employed mainly to determine vertex coordinates which can serve as reference for topographic surveying or even future tracking.

As precision has improved in the last

years, it became possible to employ methods of satellite positioning in works connected to a restrict number of equipment which allowed the precision prescribed by ICAO to be reached, such as the determination of longitudinal runway profile due to altimetric precision. Nowadays, the Real Time Kinematic (RTK) is becoming more and more accepted due to the fact it is productive and enables satisfactory accuracy. It is possible to collect precise coordinates in large areas, with description and organization which save time and improve quality, not only in the field but also in the office.

The relative positioning method helped revolutionize the collection of geographic data used in aeronautical cartography. Besides the above-mentioned, these methods are fundamental to collect data which transcend aerodrome limits. A few years ago the collection of this type of data involved transportation of coordinates with theodolites or total stations with higher total run time and possibility of gross errors. Nowadays, vertices with known coordinates are easily deployed at short time intervals to be occupied by other equipment.

In addition to direct employment in cartography and in aeronautical information fields, GNSS enabled higher navigation precision. This phenomenon is natural and coherent, whereas as more and more accurate data are becoming available, the use of all the potential it entails requires compatible technology and platforms. It is the case of aircraft authorized to execute a Performance Based Navigation (PBN) procedure, where the accuracy of their paths are refined with the support of GNSS receivers (Figure 1).

In Figure 2, where paths taken by non-RNP (Required Navigation Performance) and RNP aircraft are shown, it is possible to see how time is saved and, consequently, spending is decreased due to reduced fuel use and better airspace organization.

Next, in figures 3 and 4, air traffic, before and after RNP, are shown for Guarulhos International Airport, in São Paulo. Among all benefits from this procedure, the improvement of comfort for air traffic controllers can be highlighted.

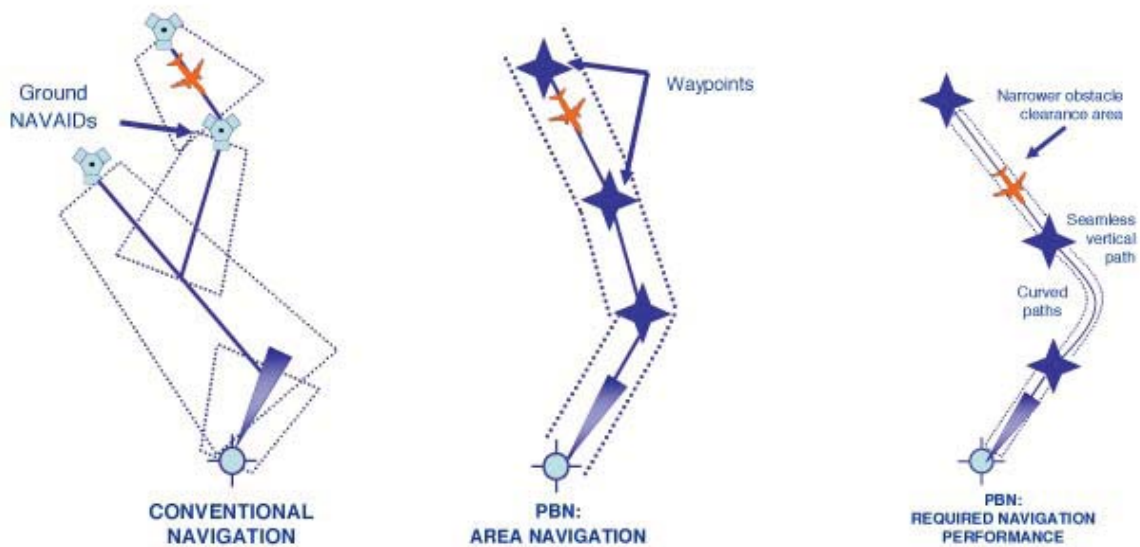


Fig. 1 - Performance-Based Navigation. Source: www.faa.gov.

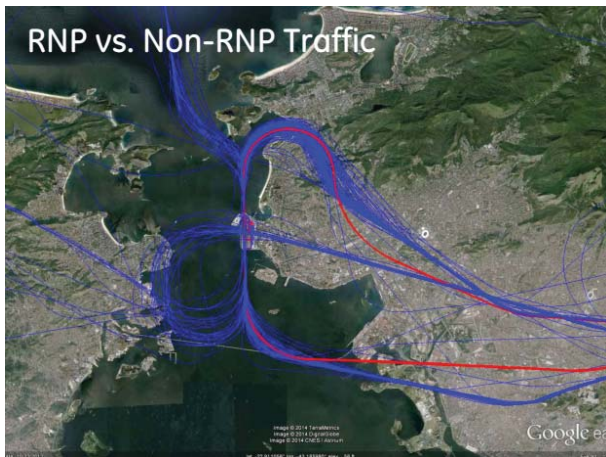


Fig. 2 - Non-RNP Flights in blue and RNP flights in red. Source: GOL, BLUE and GE.

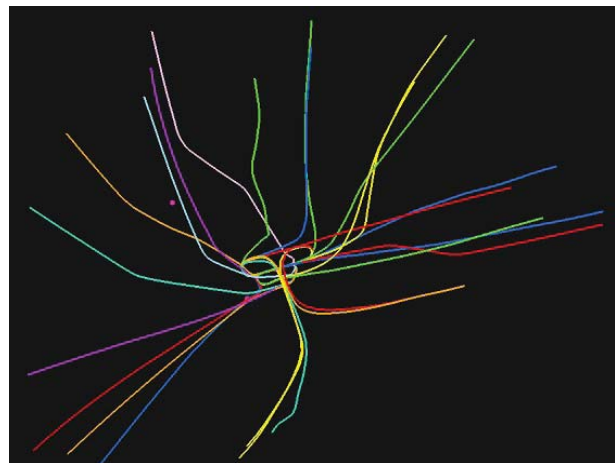


Fig. 4 - Air Traffic in Guarulhos after the RNP. Source: GOL, BLUE and GE.

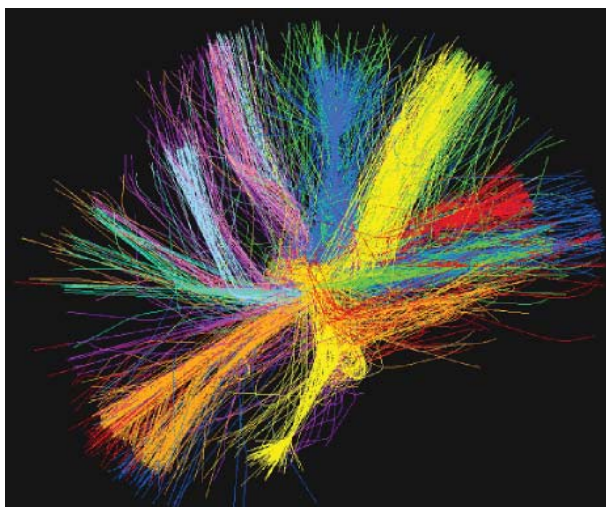


Fig. 3 - Air Traffic in Guarulhos before the RNP. Source: GOL, BLUE and GE.

4. AERIAL SURVEY

Aerial surveys are employed in aeronautical cartography when the final product comprises large areas (typically greater than 10 km of radius). This type of data is the basis for the systematic production of terrain cartography in Brazil, which is the foundation of aeronautical cartography.

Nowadays, the aerial surveys are providing data to generate digital surface models and digital terrain models. These models are used as one more source of data to ensure air navigation safety.

The main customer of this product is the Institute of Aeronautical Cartography (ICA)

itself, and more specifically, the Subdivision of Procedures and Airspace Design, where data are loaded into a platform capable of interpreting models and pointing out possible terrain/surface interferences in aircraft procedures.

Aerial surveys are also used in the production of charts for special purpose, usually charts of military purpose. In this case, the Brazilian Air Force squads certified to perform the imaging process send the data to ICA and these data are processed into products to be used in air missions.

Despite being a high cost input, the volume of data required to meet the various platforms which use digital models are increasing, so the aerial surveys will still be in great demand. ICA shows the use of aerial photographs combined with Light Detection and Ranging (LiDAR) data. In this way, digital models are generated more accurately and in less time.

It is also noteworthy the beginning of use of digital models in some aircraft panels, enabling the pilot to follow in real time the behavior of the relief or surface in their route.

5. REMOTE SENSING

In aeronautical cartography remote sensing is employed especially in the process of updating an aeronautical chart. In this process, professionals seek in the orbital images specific features which could provide visual support to air safety and navigation, such as: highways, streets, urban sprawl, rivers, lakes, railways and transmission lines. Images must be processed, corrected and georeferenced in order to enable vectorization of these features.

A wider use of satellite images is only limited by the absence of altitude information, a very important factor for navigation safety. Therefore, this type of input is used only to update the charts and not to design them, since the maximum altitude of each grid must be determined and displayed for the pilot to be aware of the behavior of features underneath him/her. When a cartographic product needs to be designed from this type of image, they are called image chart and present only planimetric information and aeronautical information layers necessary for navigation (Figure 5).

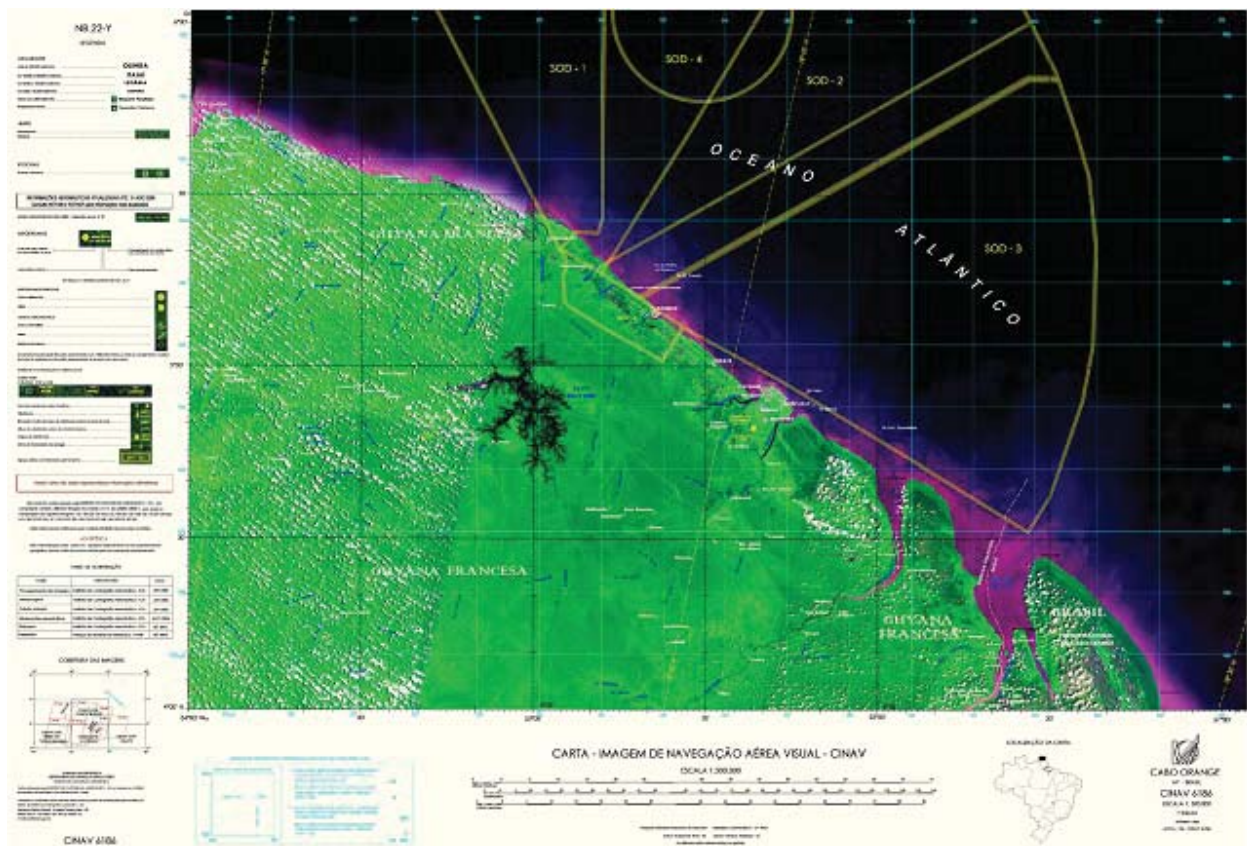


Fig. 5 - Image Chart.

With the advancement of stereoscopic imaging technologies, that reality may, in accordance with the required precision, replace the inputs originated from aerial surveys. This is already a reality for the generation of Digital Surface Models. Some tests are being run at the Institute and it is already possible to conclude that the use of stereoscopic orbital images already meet some of the ICAO requirements.

6. DATABASE

The management of the large volume of data which comprise the aeronautical charts is directly dependent on a good database structuring.

The adjustments of interchangeable formats are very important for aviation because the exchange of aeronautical data at a global level will be intensified in the medium term due to the ongoing use of platforms enabling the interaction among geographic databases. Besides, the concept of Big Data is already a reality for aeronautical cartography and the study about the best way to store digital models and data which comprise different layers of information is an ongoing and continuously updated task.

The database that includes all data that may compose an aeronautical cartography product currently meets the different tools with different goals but, at the end of the process, they can all target the same production of a specific product: tables with lists of coordinates which can be used in manuals, in tools to analyze obstructions, deploy air navigation aids and study aerodrome protection zones.

7. PRODUCTS

In a simple web search, you can find numerous aviation sites with information on cartographic products used by pilots or by other professionals in the field of aviation.

After a brief explanation about methods and technologies used to produce aeronautical cartography, the reader may get to know the main products currently used in Brazil and required by ICAO.

Aeronautical Charts are primarily meant for the use of Civil and Defence Pilots, Airlines, Air Traffic Controllers, Planning & Engineering, Communication officials, Search & Rescue Personnel, Fire Section, Meteorological and various other organizations.

7.1 Aerodrome Obstacle Chart Type ‘A

It shows the obstacles within the approach funnel of the landing and take-off paths of airports and it provides necessary operational data. Pilots take necessary precautions to avoid those obstacles (Figure 6).

7.2 Precision Approach Terrain Chart

It provides detailed terrain profile information within a defined portion of final approach of the aircraft landing at an airport.

7.3 Enroute Chart

Provides information to flight crew to facilitate navigation along air traffic services routes. Thus the pilots flying The figure 7 shows an Enroute Chart.

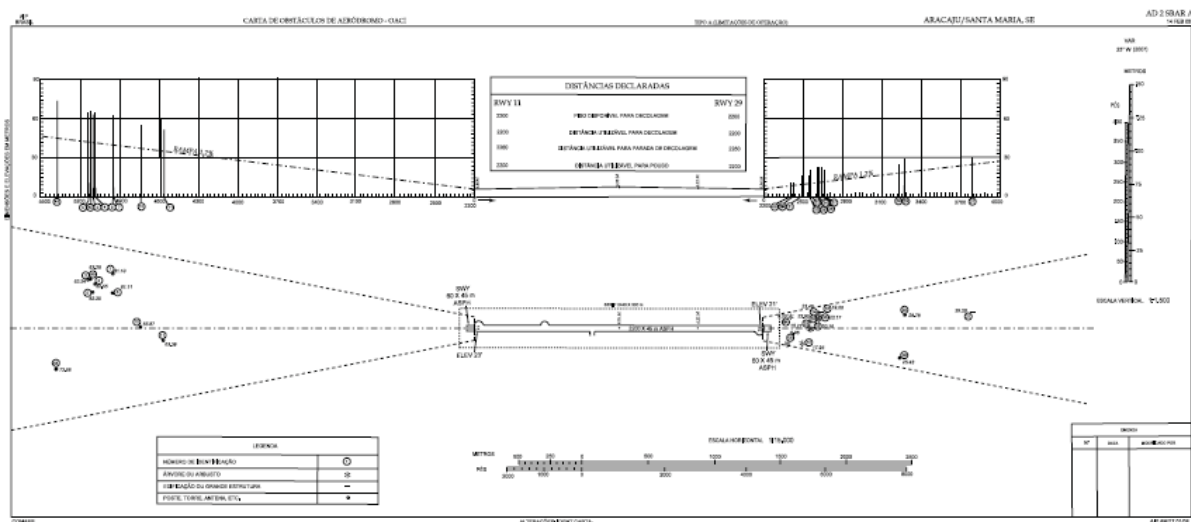


Fig. 6 - Aerodrome Obstacle Chart Type A. Source: www.aisweb.aer.mil.br.

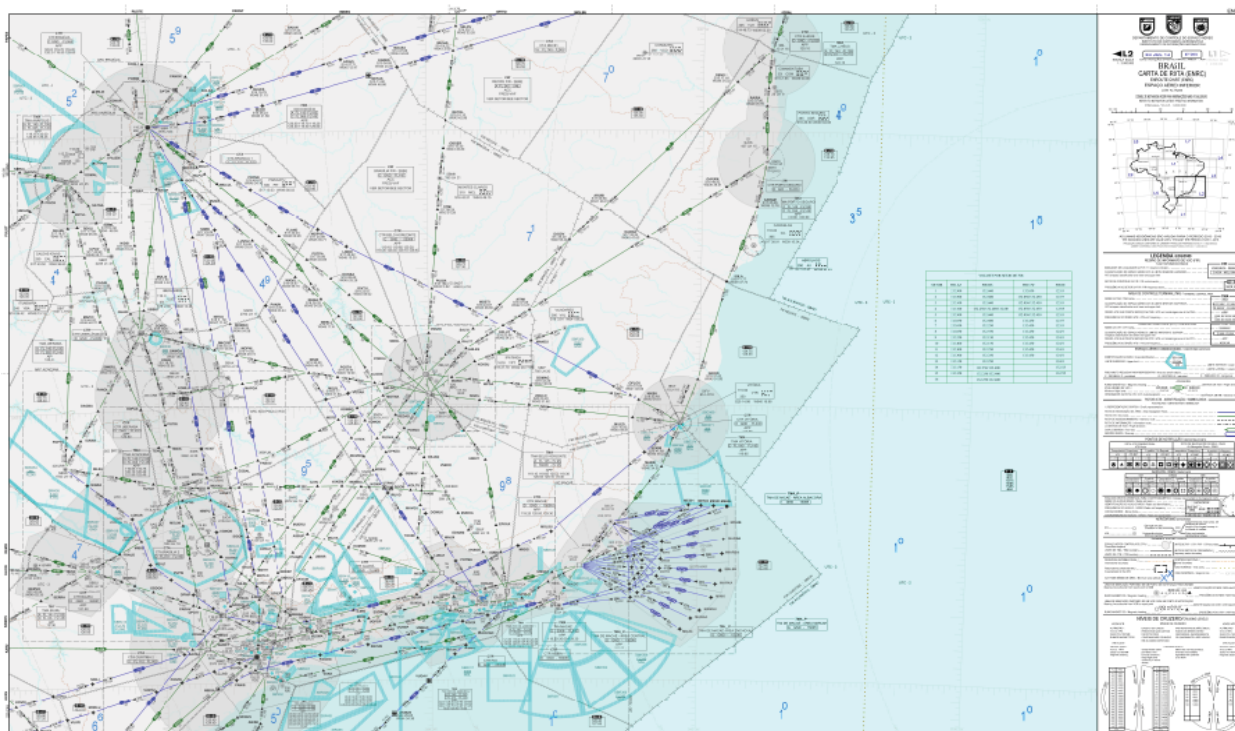


Fig. 7 - Enroute Chart. Source: www.aisweb.aer.mil.br.

7.4 Instrument Approach Chart

Provides necessary information for instrument approach procedure. Thus a pilot of an aircraft landing at a particular airport is able to follow the specified procedure meant for bringing the aircraft below a particular height to see the runway and land there. This kind of chart make possible landing in some bad weather conditions. Figure 8.

7.5 Aerodrome Chart

Provides essential operational information about an aerodrome. This kind of chart is mandatory and provides to the pilot the essential information to start a conversation with the control tower about the aircraft movement in the airport (figure 9).

7.6 World Aeronautical Chart

They contain small scale maps (1:1 million) of a particular area showing various geographical features of the land, hills, roads, lakes, rivers, roads etc. and are meant for en-route flying (figure 10). These charts has a systematic production. According to ICAO, the countries must update the terrestrial information each 4 years and the aeronautical thematic each 2 years. It is one of the most important charts for visual flight rules.

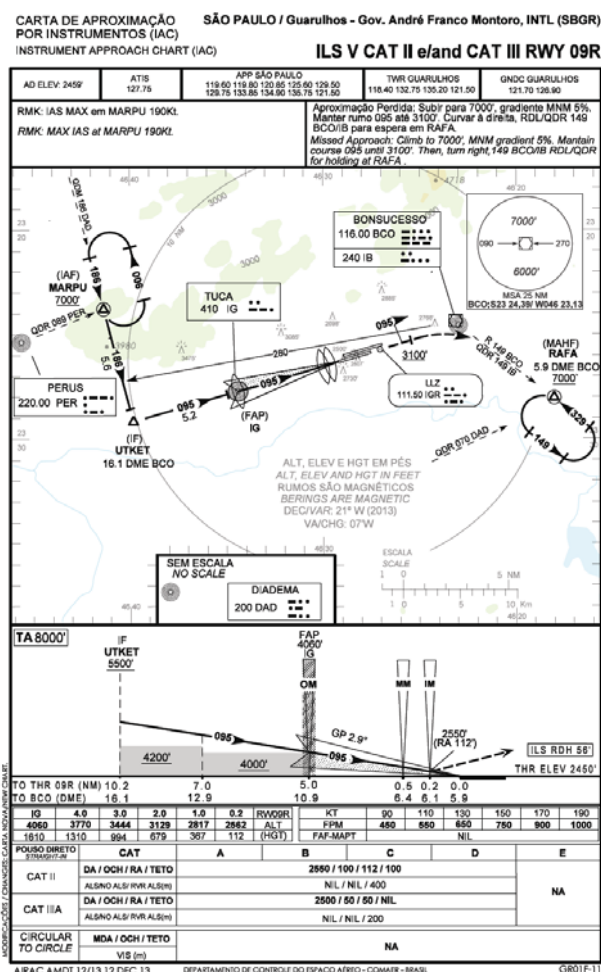


Fig. 8 - Instrument Approach Chart. Source: www.aisweb.aer.mil.br.

7.7 e-TOD (Electronic Terrain and Obstacles Data)

Is a terrain and obstacles dataset (figure 11) used in procedures design or in specific aircraft panels. The terrain dataset can be a Digital Terrain Model or a Digital Elevation Model. An obstacle database is a digital representation of the obstacles which includes the horizontal and vertical extent of man-made and natural significant features.

The States are required to ensure the availability of electronic TOD, in accordance with stringent numerical requirements established for four distinct Areas of the State territory. These areas are:

- a) Area 1: the entire territory of a State;
- b) Area 2: terminal control area (or limited to a 45-km radius – whichever is smaller), subdivided in 4 smaller sections;
- c) Area 3: aerodrome/heliport area: area that extends from the edges of the runway to 90 m from the runway centre line and for all other parts of aerodrome/heliport movement areas, 50 m from the edges of the defined areas;
- d) Area 4: Category II or III operations area

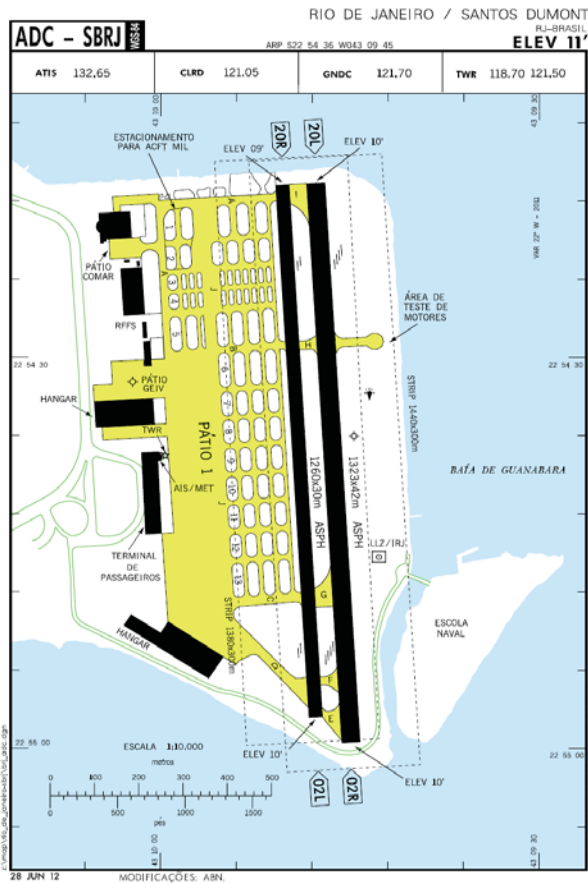


Fig. 9 - Aerodrome Chart. Source: www.aisweb.aer.mil.br.

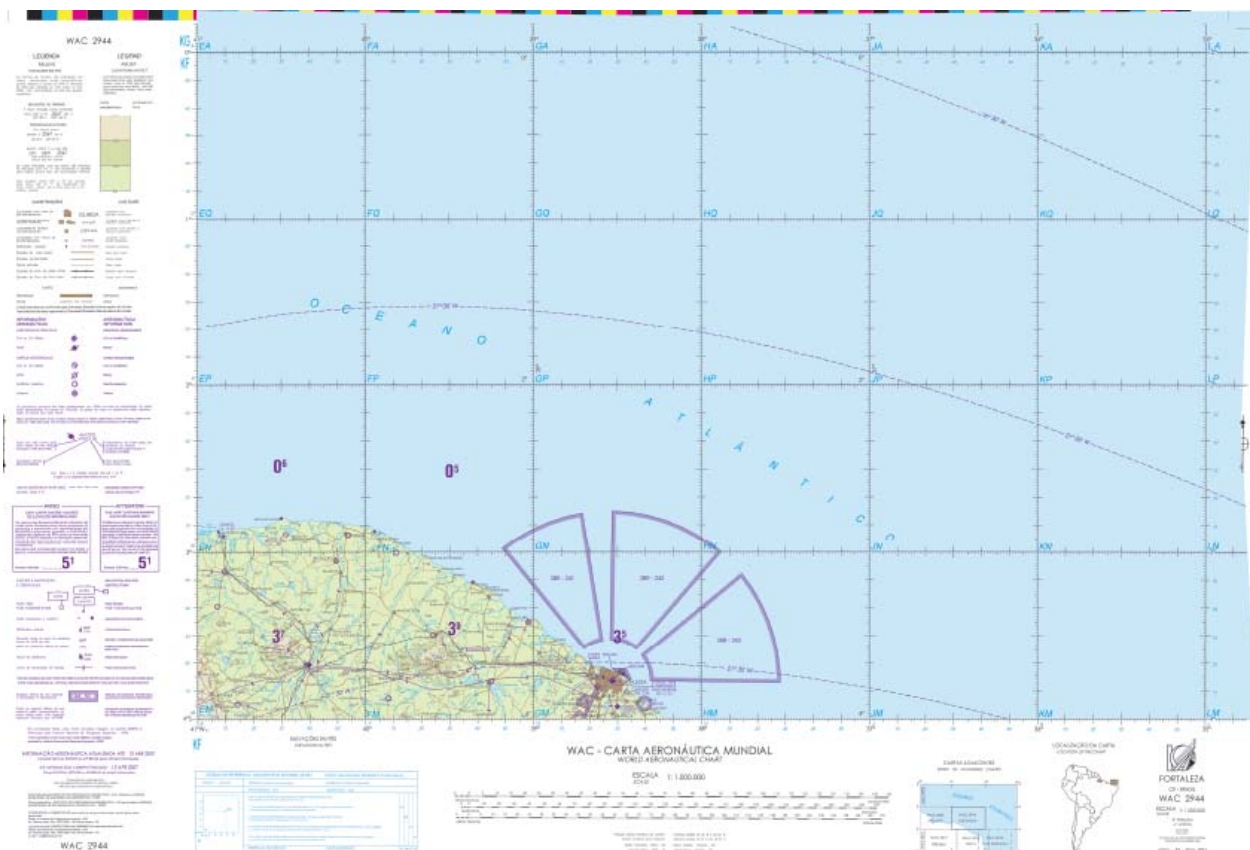


Fig. 10 - World Aeronautical Chart. Source: www.aisweb.aer.mil.br.

(restricted to those runways intended for Category II or III precision approaches): the width of the area shall be 60 m on either side

of the extended runway centre line while the length shall be 900 m from the runway threshold measured along the extended runway centre line.

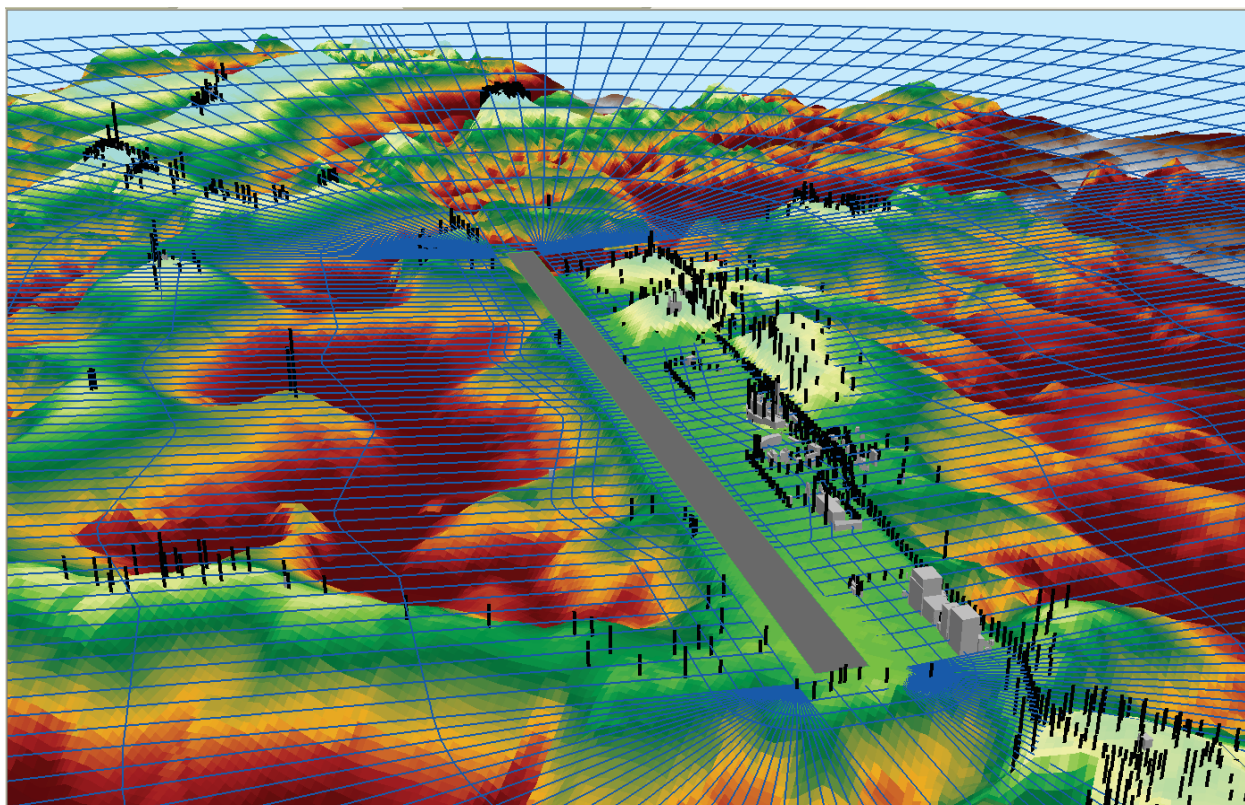


Fig. 11 - Electronic Terrain and Obstacles Data of Confins.

8. PERSPECTIVE

The future of aeronautical cartography is connected to the structure of databases associated with the Geographic Information Systems which enable the end user to assemble his/her own map to navigate on digital platforms, abandoning all or virtually all paper formats. The publication of layers of information on the web is an ever-increasing requirement for users of geographic information.

There is a pent-up demand for the use of electronic aeronautical charts which depend not only on the structure of aeronautical information layers but also on the certification of equipment for this specific purpose.

With future platforms in operation, another demand that will take place immediately is the availability of increasingly faster and more precise information. This issue affects the entire production line of aeronautical cartography and entails its provision, whose best way is certainly via the web.

The advancement of topographic and geodetic equipment will enable the integration of data collected from the field in real time, ie, the technician will be able to load directly into the database the information collected at the work site.

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