SAFETY AND EFFICIENT OPERATIONS USING GROUND-BASED AUGMENTATION SYSTEM (GBAS)

Amália Massumi Chujo  
Graduate Student (Master in Electronics Engineering)  
Instituto Tecnológico de Aeronáutica (ITA)  
Praça Marechal Eduardo Gomes, 50  
12228-900 – São José dos Campos – SP – Brasil  
amalia@ita.br

Fernando Walter  
Professor of Department of Electronics Engineering  
Instituto Tecnológico de Aeronáutica (ITA)  
Praça Marechal Eduardo Gomes, 50  
12228-900 – São José dos Campos – SP – Brasil  
fw2@ita.br
ABSTRACT

The current demand of air traffic constitutes a restrictive factor in some parts of the world. This growing demand for services will likely shift from scheduled operations towards more unscheduled operations as air taxi, fractional ownership, and on-demand small low-cost aircraft. There will be, therefore, need of implementation, total or partial, of the CNS/ATM (Communication, Navigation, Surveillance/Air Traffic Management) system proposed by ICAO (International Civil Aviation Organization). One of the main goals of the CNS/ATM system is to improve the capacity of the air traffic system mainly with respect to the arrivals and departures per minute rate, at the air transport terminals. The technologies through satellite, specifically, the GNSS (Global Navigation Satellite System) systems, among them, GPS (Global Positioning System) and GLONASS (Global Navigation Satellite System) and the augmentation systems, as for instance, SBAS (Space-Based Augmentation System) and GBAS (Ground-Based Augmentation System), they will bring great benefits for users and air traffic controllers, once the current systems of navigation do not supply accuracy and enough integrity to guarantee capacity, efficiency and safety in agreement with the current and future demands of the air transportation. This work seeks to evaluate systems configurations to assist the navigation requirements: accuracy, integrity, continuity and availability for precision approach and landing using a GBAS system in airports. For that, it is necessary to study the viability of the implementation of GBAS in the Brazilian scenario, which is quite different from the ones present in regions like the U.S.A and Europe. The impact of these new technologies on the airports operations it is presented taking into account the following parameters: great flow, increasing capacity, and safety in precision approach and landing operations.

KEY WORDS

CNS/ATM, GNSS, GBAS, SBAS, precision approach, landing, air traffic, safety and efficient operation.
INTRODUCTION

Air transportation has grown more rapidly than most other industries in the last two decades. The rapid growth is expected to continue in the foreseeable future. Aircraft movements at airports are forecast to increase globally by nearly 30% between 1995 and 2003. In Europe, air traffic is increasing at a rate of some 5% per year (1) and is predicted to continue to grow at this rate for the next several years.

In the United States, the air traffic growth in the National Airspace System (NAS) has outpaced airport and airspace capacity over the past two decades. The FAA has estimated that air traffic is expected to increase 30% by the year 2010, and Boeing’s commercial market outlook projects a doubling of air traffic by 2020 (2).

The increase in air traffic has resulted in a massive increase in delays in congested regions. In 2000, some 27% of all European flights were delayed by more than 15 minutes, and the average delay per movement was 14 minutes (1). In the US, the Federal Aviation Administration (FAA) reported a 20% increase in delays to US originating flights during 2000.

The delays represent a significant cost for airlines. The single largest cost factor is fuel. A two-minute delay during approach means that some 180 Kg of extra fuel is burned by a typical commercial jet airliner at a cost of 90 euros. Still, fuel is only one of the cost factors generated by delays. The European Commission (EC) has estimated to total annual cost to European airlines to 10 billion euros in less efficient use of staff and equipment, wasted fuel and passenger compensation (3).

In other regions, air traffic density itself is not the primary problem, but rather the lack of suitable infrastructure to efficiently accommodate the current and expected demand for air travel. Inadequate communication, navigation and surveillance facilities on the ground might lead to uncertainties, and an inefficient and potentially unsafe system.

BRAZILIAN SCENARIO

The increasing demand for air travel make important to evaluate operational conditions and infrastructure of some Brazilian airports. In this context, two major international airports in the state of São Paulo will be analyzed: Congonhas and Guarulhos.

With capacity to operate with 17 million passengers a year, in two terminals, the Guarulhos International Airport assists annually about 12 million users and gets ready for the construction of a third passengers terminal. This will increase capacity for 29 million passengers/year. The Congonhas Airport, built in the decade of 1930, was qualified to receive 6 million passengers and it operates with 12 million passengers a year (4).

The graphs of the Figure 1 present the passengers traffic from 1990 to 2002 (a) in Guarulhos airport and (b) in the Congonhas airport (5). It possible to observe from this figures, Guarulhos airport had major increase in the period between 1994 and 1998. After this fast
pased increase the passenger traffic dropped considerably affected by international economy. On the other hand, in the Congonhas airport, there was a significant growth in terms of passengers traffic in the same period. This growth resulted in a demand larger than the operational capacity of the airport, jeopardizing the operational efficiency of the system. The Congonhas airport is under expansion work to adequate the terminal for current passengers traffic.

In the Figure 2, it is presented the traffic forecast to (a) Guarulhos airport and (b) the Congonhas airport for period between 2008 through 2023 (5). For both airports following an international trend the estimative foresee growth in the air traffic. The average growth expected to Guarulhos airport is 32%, 51% and 72% for years 2008, 2013 and 2023 respectively (year of 2002 estimative). For Congonhas airport, average growth expected is to be 26%, 47% and 73% for same the years considered previously.

Therefore, the forecasts indicate a great growth in the passengers traffic in the airports and, consequently, a major increase on air traffic for next decades. The need to guarantee safety, capacity, and efficiency requirements in the system of air transportation in these airports can be supplied by the GNSS (Global Navigation Satellite System) technology, augmentations systems (Differential Global Navigation Satellite System - DGNSS), and the SVS systems. For that, the implementation of SBAS/GBAS in the Brazilian scenario is quite different from the ones present in regions like the U.S.A and Europe. According to (6), the major source of error in the evaluation of the user position for single frequency GPS receivers is the effect caused by ionosphere on the satellite-transmitted signal. The GNSS Laboratory at ITA develops activities concerned with technology evolution to scientific knowledge and to keep a training center in GNSS and R&D.

**IONOSPHERIC EQUATORIAL ANOMALY**
The region around the geomagnetic equator, located between -20° and +20° of geomagnetic latitude is characterized by an anomaly on the ionospheric behavior (Figure 3), called the Ionospheric Equatorial Anomaly (IEA). The 3-D graphic illustrates the IEA (Figure 4), which is characterized by VTEC (Vertical Total Electron Content) peaks at ±20° geomagnetic latitude, and a maximum at around 2 pm (local time) (7). The IEA is caused by the combined action of electric and magnetic field consisting of two high density ionospheric plasma bands placed over tropical regions around the geomagnetic equator.

To minimize the ionospheric delay, the GPS message gives an estimation of the error caused by the ionosphere. This estimation is based on Klobuchar model (8), but this model does not take into account the IEA effects. This implies that new models must be developed in order to have a best fit in the IEA region.

![Figure 3 - Global VTEC map during a period of a solar storm at 08:00 (UT) Oct. 29, 2003. The Kp index is 9 (shown on the right), Flux is 280 and the Sun Spot Number 170.](image)

![Figure 4 - 3D Global VTEC map during a period of a solar storm at 08:00 (UT) Oct. 29, 2003. It can be seen the Ionospheric Equatorial Anomaly.](image)

Although the IEA is a phenomenon that generally occurs near the geomagnetic equator, researches made by (9) found periods in which the IEA extended to regions over USA, Europe, and Japan.

**NAVIGATION PERFORMANCE REQUIREMENTS**

Global Positioning System (GPS) and Global Navigation Satellite System (GLONASS), referred to as GNSS, have the capability to provide accurate position and time information worldwide. The accuracy provided by both systems meets aviation requirements for en-route through non-precision approach, but not the requirements for precision approach. Augmentation systems can be used to meet the four basic GNSS navigation operational performance requirements. Efforts to bring the full benefits of satellite navigation to users are focused on developing these augmentations and certifying them for operational use. The navigation performance requirements in an operational GNSS perspective are described:

**Accuracy**

GNSS position accuracy is the difference between the estimated and actual aircraft position. Ground-based systems such as VHF Omnidirectional Radio Range (VOR) and Instrument
Landing System (ILS) have relatively repeatable error characteristics. Therefore their performance can be measured for a short period of time (e.g. during flight inspection) and it is assumed that the system accuracy does not change after the measurement. GNSS errors however can change over a period of hours due to satellite geometry changes, the effects of the ionosphere and augmentation system design. While errors can change quickly for a core satellite constellation, satellite-based augmentation system (SBAS) and ground-based augmentation system (GBAS) errors would vary slowly over time.

**Integrity and time to alert**

Integrity includes the ability of the system to tell the user when the system must not be used for the intended operation (or phase of flight). The necessary level of integrity for each operation is established with respect to specific horizontal/lateral (and for some approaches, vertical) alert limits. The type of operation and the phase of flight dictate the maximum allowable horizontal/lateral and vertical errors and the maximum time to alert the pilot, according to Table 1.

**Continuity**

Continuity is the capability of the system to perform its function without non-scheduled interruptions during the intended operation. This is expressed as a probability. For GNSS example, there must be a high probability that the service remains available throughout a full instrument approach procedure.

**Availability**

The availability of a service is the portion of time during which the system is simultaneously delivering the required accuracy, integrity and continuity. Table 1 specifies the navigation performance requirements for all phases of flight, according to FAA and ICAO (International Civil Aviation Organization) recommendations.

<table>
<thead>
<tr>
<th>Typical Operation</th>
<th>Accuracy Horizontal (95%)</th>
<th>Accuracy Vertical (95%)</th>
<th>Integrity</th>
<th>Continuity</th>
<th>Horizontal Alert Limit (HAL)</th>
<th>Vertical Alert Limit (VAL)</th>
<th>Availability</th>
<th>Time to Alert</th>
</tr>
</thead>
<tbody>
<tr>
<td>En-Route</td>
<td>3.700 m</td>
<td>NA</td>
<td>1·10⁻⁷/h</td>
<td>1·10⁴/h - 1·10⁸/h</td>
<td>7.408 m</td>
<td>NA</td>
<td>0.99 - 0.9999</td>
<td>60 s</td>
</tr>
<tr>
<td>Terminal</td>
<td>740 m</td>
<td>NA</td>
<td>1·10⁻⁷/h</td>
<td>1·10⁴/h - 1·10⁸/h</td>
<td>3.704 m</td>
<td>NA</td>
<td>0.99 - 0.9999</td>
<td>15 s</td>
</tr>
<tr>
<td>LNAV (NPA)</td>
<td>220 m</td>
<td>NA</td>
<td>1·10⁻⁷/h</td>
<td>1·10⁴/h - 1·10⁸/h</td>
<td>1.852 m</td>
<td>NA</td>
<td>0.99 - 0.9999</td>
<td>10 s</td>
</tr>
<tr>
<td>LNAV/ VNAV</td>
<td>220 m / 20 m</td>
<td>1·2·10⁻⁷/ approach</td>
<td>1·8·10⁻⁸/ 15 s</td>
<td>556 m / 50 m</td>
<td>0.99 - 0.999</td>
<td>10 s</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LPV</td>
<td>16 m</td>
<td>20 m</td>
<td>1·2·10⁻⁷/ approach</td>
<td>1·8·10⁻⁶/ 15 s</td>
<td>40 m / 50 m</td>
<td>0.99 - 0.999</td>
<td>10 s</td>
<td></td>
</tr>
<tr>
<td>APV II</td>
<td>16 m / 20 m</td>
<td>1·2·10⁻⁷/ approach</td>
<td>1·8·10⁻⁶/ 15 s</td>
<td>40 m / 20 m</td>
<td>0.99 - 0.999</td>
<td>6 s</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CAT I (GLS)</td>
<td>16 m / 6 m to 4 m</td>
<td>1·2·10⁻⁷/ approach</td>
<td>1·8·10⁻⁶/ 15 s</td>
<td>40 m / 12 m / 10 m</td>
<td>0.99 - 0.9999</td>
<td>6 s</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CAT II CAT IIIa</td>
<td>6.9 m / 2.0 m</td>
<td>1·10⁻⁹/15 s / 15 s</td>
<td>1·4·10⁻⁹/ 15 s</td>
<td>17.3 m / 5.3 m</td>
<td>0.99 - 0.9999</td>
<td>1 s</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CAT IIIb</td>
<td>6.2 m / 2.0 m</td>
<td>1·10⁻⁹/30 s (vertical)</td>
<td>1·2·10⁻⁹/30 s (vertical)</td>
<td>15.5 m / 5.3 m</td>
<td>0.99 - 0.9999</td>
<td>1 s</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Figure 5 shows how the alert limits decrease as the aircraft gets closer to the runway and to obstacles on the ground. 5) The precision approach phase, acted by CAT I, II and III, is characterized by the parameters DH (Decision Height) and VAL (Vertical Alert Limit). According to the values set for each category, an aircraft just can continue the operation if the runway is visible.

Because GPS satellite geometries are least favorable in the vertical direction, and because obstacles are more threatening in the vertical direction, the VAL is the driving requirement. It means that the VAL requirement for a given operation insures that the corresponding HAL or LAL (Horizontal/Lateral Alert Limit) requirements are met in practically all cases. The values of these parameters start to be more restrictive as the aircraft approaches to the ground. More accuracy and tighter bounds are required to reach great performance.

The initial phase of WAAS is capable of providing acceptable availability for approaches down to the “APV 1.5” or “LPV” level shown in Figure 5, which has a decision height (lowest height at which WAAS guidance is sufficient) of about 350 feet above ground level and a VAL of 50 meters. Early LAAS installations will support approaches down to Category I decision height of 200 feet (10 – 12 meter VAL).

Figure 5 - The maximum allowable horizontal/lateral and vertical errors and the maximum time to alert the pilot (11).

DGNSS SYSTEMS

To implement the process of integration GNSS systems proposed to be used in civil aviation, aircraft ground or satellite-based augmentation techniques have to be deployed to improve their performance and to monitor the systems’ status which will allow them to be approved as safe for the intended use. This section describes two of the DGNSS existing: SBAS and GBAS.

Satellite-based Augmentation System (SBAS)
Satellite-based Augmentation System (SBAS) might be regarded as part of the CNS/ATM systems concept and there are procedures SARPs (Standards and Recommended Practices)
developed by ICAO. This system operates navigation payloads flown on stationary satellites. The role is to augment the performance of GPS by improving their service integrity and accuracy of their measurements. This system would use dispersed reference stations with the possibility of providing Category I precision approaches at airports across a large region.

The provision of satellite-based augmentation by geostationary satellites has certain limitations and therefore cannot be expected to support all phases of flight, especially precision approach and landing of higher categories. Since these satellites orbit above the equator, their signals would not be available in Polar Regions and may be masked by aircraft structure or terrain. This suggests that other GNSS augmentation satellite orbits and/or ground-based augmentation might need to be considered to alleviate these shortcomings.

SBAS data will allow satellite navigation to meet the stringent reliability, availability and integrity requirements set by air traffic control (ATC) and maritime authorities. Land-based users will also be able to take advantage of the improvements in positioning accuracy, as illustrated in Figure 6.

Figure 6 – Users of SBAS system (www.esa.int).

SBAS Operation
An SBAS consists of a network of ground reference stations (Monitors Stations) at precisely defined locations that monitor the satellite signals and send their observations to one or more Master Control Stations (Mission Control Center or MCC), which generate the augmentation message. The MCC also estimate corrections for ionospheric delays. This is in turn sent to uplink stations (Satellite Uplink), which transmit it to the navigation transponders on board the geostationary satellites (EGNOS Geo-stationary Satellite). These, finally, broadcast the SBAS message to airborne users, modulated on a GPS look-alike signal at the L1 (1575.42 MHz) GPS frequency (12). This means that, with slightly modified equipment, GPS users can receive integrity and more accurate position information. The Figure 7 shows EGNOS operation.

Researches made by (14) revealed that several countries have begun to develop and implement augmentation systems, and these initiatives are at advanced, though different, stages of development. In Europe, the European Tripartite Group (ETG, composed of the European Union, the European Space Agency and Eurocontrol) is developing EGNOS, which will cover the European Civil Aviation Conference (ECAC) region. In the United States, the Federal Aviation Administration (FAA) leads the development of the WAAS, covering essentially the continental United States (CONUS). In close cooperation with the FAA, Nav Canada is developing the Canadian WAAS (C-WAAS), as part of its SatNav programs. The
Japanese Civil Aviation Bureau is implementing MTSAT Satellite Based Augmentation System (MSAS), which will cover Japan's Flight Information Region (FIR). China is building the Chinese Satellite Navigation Augmentation System (SNAS), and India also plans to build a SBAS.

The complex scenario of the worldwide SBAS program is summarized in Figure 8. Interoperability at the receiver level is the compliance with DO-229C standard and it is guaranteed, at the moment, by EGNOS, MSAS, WAAS and C-WAAS systems.

**Ground-based augmentation System (GBAS)**
The DGNSS system that might also become part of the CNS/ATM concept is Ground-based Augmentation System (GBAS), which are designed to improve accuracy, integrity, and availability for precision approach operations according to ICAO CAT I-III requirements. These local-area ground stations monitor the satellite system status and calculate correction
terms which are up linked to the approaching aircraft to enhance the on-board position calculation.

The Local Area Augmentation System Figure 9 is the FAA version of the Ground Based Augmentation System (GBAS) that has been defined by the International Civil Aviation Organization (ICAO). Aircraft landing at a LAAS-equipped airport will be able to perform precision approach operations up to at least Category I weather minima. The pseudolite or pseudo-satellite shown in the Figure 9 is a ground-based differential GPS receiver which transmits a signal like that of an actual GPS satellite, and can be used for ranging. Originally intended as an augmentation for LAAS to aid aircraft landings, pseudolites may also be used where signal obstructions are such that insufficient GPS satellites can be tracked. In fact, pseudolites are feasible in circumstances where no satellite signals are observable, as for indoor applications.

While computing and broadcasting differential GPS corrections is now straightforward, the largest challenge in designing and fielding LAAS is the need to verify aircraft safety (in terms of not exceeding a safe error bound known as the alert limit) to a probability of two in ten million (2x10\(^{-7}\)) per approach for Category I and one in one billion (1x10\(^{-9}\)) per approach for Category III.

The proposed methodology by (16) with ARIMA model uses individual satellite information and determines differences that can be compared synchronously with range differences estimated by base stations. If RAIM (Receiver Autonomous Integrity Monitoring) algorithms detect a failure condition, statistical threshold variations between the ARIMA modeled differences and DGPS (or GBAS) differential corrections will reveal the failing satellite or satellites.

Interoperability of ground and satellite-based augmentation components represents a key issue for the effectiveness of air navigation system. Figure 10 highlights the interoperability potential of WAAS/LAAS in aviation. WAAS/LAAS combine or alternate operations cover terminal and approach flight phases, and LAAS-only operations pertain to surface services.
SYNTHETIC VISION SYSTEM (SVS)

Synthetic Vision Systems (SVS) may improve flight safety by increasing the pilots’ situational awareness in low to near-zero visibility conditions to a level of awareness similar to daytime clear weather flying. This is accomplished by providing the pilots with a depiction of the external environment, the so-called virtual visual environment. This depiction can be portrayed on a Head-Up Display (HUD) and provides aircraft state information (e.g. altitude, attitude, airspeed, etc.), guidance and navigation information, and a perspective depiction of the terrain as viewed “from the cockpit”, as illustrate the Figure 11 and Figure 12.

Other types of information can also be presented such as traffic and weather. NASA’s Aviation Safety Program has been investigating SVS as a mitigation strategy for accident categories such as Controlled Flight Into Terrain (CFIT), runway incursions, low visibility loss-of-control scenarios, and also to allow for advanced precision approach procedures.

The SV component is simple to use with its intuitive and easy-to-understand visual imagery, and SV may help decrease pilot workload. While it has its limitations (most notably the lack of real-time sensing capability), the SV component of the fused Enhanced Vision and Synthetic Vision System should drastically increase pilots’ spatial awareness in low visibility conditions (14).
DGNSS is enabled through the US based WAAS and the European EGNOS. DGNSS has the potential to provide highest accuracy in kinematic SVS for low costs. It seems therefore be suited for GA. However, DGNSS shortcomings lie within the reliability. The GPS signal was sometimes lost for several minutes because of jamming from other radio emitters nearby and sometimes for over 30 minutes not enough satellites were visible at all.

Therefore, investigate a combination of GNSS and Loran-C for low cost systems could be done for better performance. And, from the above results, it can be concluded that DGNSS has adequate performance for supplemental GA SVS. For commercial transport aircraft SVS hybrid navigation is needed.

**BRAZILIAN PERSPECTIVE**

In the Brazilian application scenario, the air traffic system can be developed to make flight operations safer, more efficient and to obtain better use of the airspace. Based on these assumptions, the main operational concepts and technologies can be selected.

**RVSM (Reduced Vertical Separation Minima) capability**

RVSM reduces the vertical separation between flight levels (FL) 290–410 from 2000 ft to 1000 ft and makes six additional FL’s available for operation. The additional FL’s enable more aircraft to fly more time/fuel efficient profiles and provides the potential for enhanced airspace capacity. The RVSM concept was introduced in Brazil on January 20, 2005.

**SVS technology**

In the last years, new avionics systems were introduced in the aircraft. Since then, a change of direction was observed in the causes of accidents: failure based on human factors started to have larger evidence than failures from equipment. This is not because the man has committed more mistakes, but in consequence of the equipments that became more sophisticated and, consequently it puts human failures in evidence.

The use of the SVS technology starts to have fundamental role in this evolutionary process. The main purpose is to increase the pilot's situational awareness for increased safety in the air transportation and to make possible more predictable the flight in critical situations as low visibility in adverse weather conditions. Therefore, the technology SVS can help the crew on decision-making process during flight operations. For this, appropriate training is indispensable so that human failure can be minimized.

**New GPS signals**

The GPS modernization process can bring two great contributions for the aviation community:

- Reduction of the ionospheric delay: With GPS modernization, the ionospheric delay caused by Ionospheric Equatorial Anomaly (IEA) should be minimized. It is intended to introduce an improved code L2c and a new code L5 to enable civilian receivers to better account for ionospheric error, as well as to be more immune to RF interference and multipath. Better results can be reached with the availability of a new civil signal
in applications that require higher accuracy, integrity and availability of the GPS signals.

- Better performance in flight operations using DGNSS: The L5 signal will have an equally important effect on DGNSS, especially on GBAS and SBAS. An evaluation of a DGNSS configuration to assist the growing demand of the main Brazilian airports is under development in GNSS Laboratory at ITA. The reception of the GNSS signal will be similar to SBAS system to assist larger area cover. However, the signal will be sent to the user through a terrestrial link (VHF Data Broadcast), as in GBAS configuration. Therefore, this proposal for a DGNSS system to Brazil is similar to the Australian system. Like Australia, Brazil doesn't have geostationary satellites for sending information to the user, but Brazil has a great number of VHF stations that could be used to replace those satellites.

In this context of technological development, DGNSS-RVSM-SVS, the three major demands from main airports (capacity, efficiency, and safety increase) would be fulfilled (Figure 13). Basically, the system is composed by four fundamental columns to hold on the bases of technological knowledge:

- Satellites technologies (GNSS and DGNSS – columns 1 and 2) offer effective support to be applied to aviation. Naturally, the GNSS and DGNSS application must consider certain inherent risks of satellite technology (ionospheric delay, multipath). Every user of GNSS technology should be aware of those risks, which can affect their operations and require appropriate actions according to each scenario. Even though the risks, the investment in GNSS leads to an excellent payback. This would allow the best accomplishment of a lot of activities and make possible others that could not be achieved without support of this technology.

- The combination of SVS technology and Operational Concepts based on the assurance of minimum separation RVSM (column 3) and Human Training (column 4) complete the base for the fulfillment of the needs required in the world context.

Therefore, technological development and human training should be balanced, since one of the parts isolated is not able to satisfy the three needs verified. The appropriate application of these resources, technological and human, will provide better occupation of air space and more efficient use of existent airports, particularly Congonhas and Guarulhos, where there are great demand for air transportation services.
CONCLUSIONS

Global Navigation Satellite Systems (GNSS), Augmentation Systems (DGNSS), and an airborne display unit with a moving map feature (SVS), will allow aircrews to view the precise position of the own aircraft in relation to obstacles at all times, as well as the position of possible conflicting traffic based on airborne position reports from nearby aircraft. Besides, DGNSS has the potential to provide highest accuracy in kinematic SVS for low costs.

The new civil signals L2c and L5 will have great importance in the performance of the air traffic systems. They will minimize ionospheric delay and improve GBAS and SBAS signals. Therefore, get better accuracy, integrity, continuity and availability will bring great benefits in operations with high performance, as in precision approach and landing operations.

The GNSS Laboratory at ITA develops studies to minimize delay caused by the Ionospheric Equatorial Anomaly (IEA), as well as maps for visualization of it behavior. Besides this study, it has been in progress a research about configuration of SBAS/GBAS system to assist the growing demand of great airports as Congonhas and Guarulhos.
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REFERENCES

(3) IATA. World Civil Aviation Infrastructure & Development, 2001.
(13) Jenkins, B. EGNOS Programme Status, IV CEA, September, 2005.

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