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Research paper

Implementation of innovative aeronautical communication, navigation and surveillance (CNS) systems

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Abstract

This paper introduces implementation of innovative Satellite Communication, Navigation and Surveillance (CNS) systems in function of Global Satellite Augmentation System (GSAS) integrated by the current and new projected Regional Satellite Augmentation System (RSAS) worldwide. The satellite communication and navigation systems are presently in use, however the main aspect of any hypothetical RSAS network is implementation of satellite surveillance system employing previous and new CNS solutions for improved Air Traffic Control (ATC) and Air Traffic Management (ATM) in all phases of flight, approaching to airports and during landing. The CNS network also enhances safety and emergency systems, transport security and control of transportation freight, logistics and the security of the crew and passengers onboard aircraft. The proposals for modern multifunctional space segment, DVB-RCS network, RSAS infrastructure, Satellite Automatic Dependent Surveillance-Broadcast SADS-B system for surveillance and movement guidance and control are also discussed as special solutions in airports environments.

Keywords: *CNS; GSAS; RSAS; ATC; ATM; DVB-RCS; SADS-B; ICAO; GNSS.*

1. Introduction

The present infrastructures of the first generation of the Global Navigation Satellite System (GNSS-1) networks are represented by old fundamental solutions for Position, Velocity and Time (PVT) of the satellite navigation and determination systems such as the United States NAVSTAR Global Positioning System (GPS) and Russian (former-Soviet Union) Global Navigation Satellite System (GLONASS) military requirements, respectively.

A major goal of the International Civil Aviation Authority (ICAO) is proposal of near-universal use of GPS and GLONASS military systems for augmentation of GNSS to provide and enhance ATC and (ATM) for civil air transport safety and security. Here, the use of the ICAO nomination Satellite-based Augmentation System (SBAS), which appear in the classification of the acronyms, will be replaced by Regional Satellite Augmentation System (RSAS) as more convenient nomenclature.

The current augmented GNSS-1 infrastructure of GPS and GLONASS satellite solutions were platform for development of RSAS (SBAS) networks worldwide with tendency to improve mutual deficiencies and to meet air transport civilian requirements for high-operating Integrity, Continuity, Accuracy and Availability (ICAA). The US GPS satellite navigation system of GNSS-1 network became fully operational with 24 satellites in 1993, while the Russian satellite navigation system GLONASS of GNSS-1 network declared operational in 1993 and brought to its optimal status of 24 operational satellites in 1955.

Besides, the new established GNSS-2 infrastructure available for new augmentation infrastructures are already developed Chinese Bei-Dou (Compass) and long term projected European Galileo.

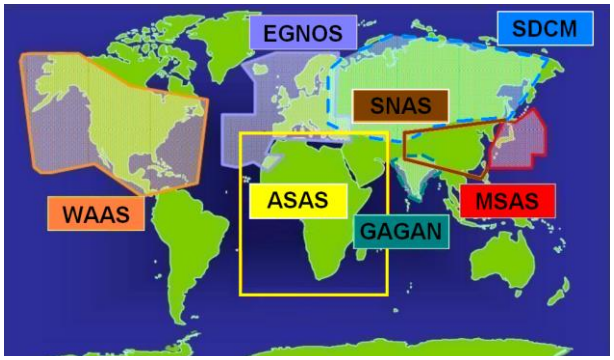


Fig. 1: GSAS Network Integration.

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Thus, the first operational RSAS systems are the US Wide Area Augmentation System (WAAS) developed in 2003 with full coverage of USA, Canada and Mexico territories, the European Geostationary Navigation Overlay System (EGNOS) and Japanese MTSAT Satellite-based Augmentation System (MSAS), which provide CNS data from aircraft to ATC and vice versa in their dedicated network coverage.
The new projected RSAS are Russian System of Differential Correction and Monitoring (SDCM), the Chinese Satellite Navigation Augmentation System (SNAS) and Indian GPS/GLONASS and GEOS Augmented Navigation (GAGAN), including latest project of African Satellite Augmentation System (ASAS) developed by Africans for Africa, illustrated in Figure 1. Only remain projects for South America and Australia for establishment of GSAS.

2. Specific development process for RSAS

The development process of any hypothetical RSAS space and ground segments for Aeronautical Mobile Satellite Communications (AMSC) and other CNS solutions is illustrated in Figure 2. The RSAS network may integrate minimum two or more own or leased multipurpose Geostationary Earth Orbit (GEO) satellite constellations containing few communication and one navigation (GNSS) transponders. In this satellite payload can be included the DVB-RCS transponder as well, so can provide enhanced satellite communication facilities.
Ground RSAS infrastructure needs several Ground Earth Stations (GES) deployed inside coverage area to provide simultaneous communication transmissions at Ka, Ku and L/C-band and GNSS L-band transponder is using the same frequencies as for instance GPS system.
The RSAS system may also employ recently developed Digital Video Broadcasting-Return Channel via Satellite (DVB-RCS) standards for communication between aircraft and ATC or any ground customers and airports, which is illustrated in Figure 3. Using Very Small Aperture Terminals (VSAT) can be established RSAS communication network between number of Ground Monitoring Stations (GMS) or reference stations, Ground Control Stations (GCS) or master stations and few Ground Earth Stations (GES) or gateways. The DVB-RCS satellite network will provide new broadcasting, broadband and multimedia solutions onboard aircraft, such as Internet, Voice over IP (VoIP), Video, Data and Voice over IP (VDVoIP), Videoconference, IPPC, IPTV and airborne Entertainment for passengers.
The most important service of RSAS network will be establishment of reliable Communication, Navigation and Surveillance (CNS) solutions for all aeronautical applications, which will integrate two space segments, GNSS-1 containing 24 GPS and 24 GLONASS spacecraft and 2 or 3 GEO spacecraft covering entire RSAS footprint. The next original proposal by author for RSAS is design and supports the following services and CNS solutions:

1) The transmission of integrity and health information on each GPS or GLONASS satellite in the real time to ensure all potential aviation users do not use faulty satellites for navigation, known as the GNSS Integrity Channel (GIC).
2) The continuous transmission of ranging signals in addition to the GIC service, to supplement GPS, thereby increasing GPS signal availability. Thus, increased GNSS signal availability also translates into an increase in Receiver Autonomous Integrity Monitoring (RAIM) availability, which is known as Ranging GIC (RGIC).
3) The transmission of GPS or GLONASS wide area differential corrections has, in addition to the GIC and RGIC services, to increase the accuracy of civil GPS and GLONASS signals. Namely, this feature has been called the Wide Area Differential GNSS (WADGNSS).

The combination of the GEO satellites integrated with GNSS-1 and GNSS-2 spacecraft will be referred to as the RSAS network shown in Figure 4. As observed, Aircraft Earth Stations (AES) (3) receive navigation signals (1) from GNSS-1 of GPS or GLONASS satellites. In the near future should be used GNSS-2 signals of the Chinese Compass and European Galileo satellites. These signals are also received by all reference GMS terminals of integrity monitoring networks (4) operated by governmental agencies. The monitored data are sent to a regional Integrity and Processing Facility of GCS (5), where the data is processed to form the integrity and WADGNSS correction messages, which are then forwarded to the Primary GNSS GES (6). The navigation signals at the GES are precisely synchronized to a reference time and modulated with the GIC message data and WADGNSS corrections and sent to a satellite on the C-band uplink (7) via GNSS payload in GEO spacecraft (8), the augmented signals are frequency-translated to the mobile user on L1 and new L5-band (9) and to the C-band (10) used for maintaining the navigation signal timing loop.

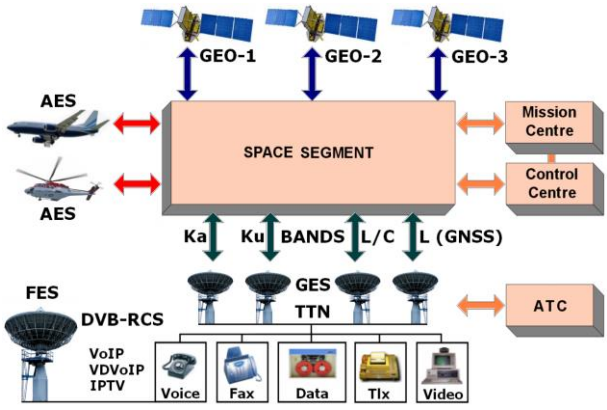


Fig. 2: RSAS Space and Ground Infrastructure.

The timing of the signal is done in a very precise manner in order that the signal will appear as though it was generated onboard the satellite as an GNSS ranging signal. The secondary GNSS GES can be installed in Communication CNS GES (11), as a hot standby in the event of failure at the Primary GNSS GES.

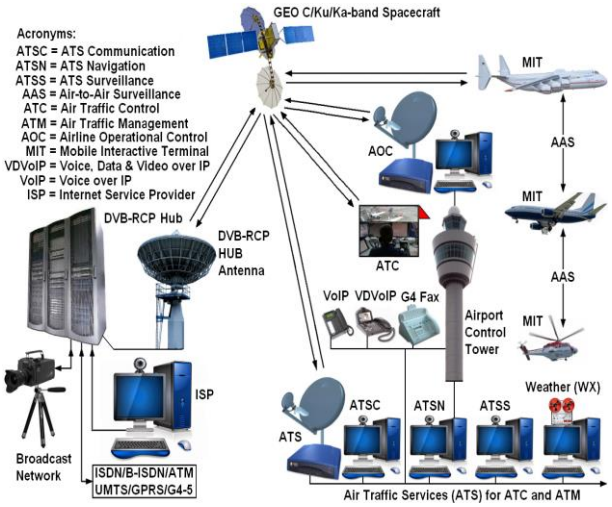


Fig. 3: CNS Solutions of RSAS Network Via DVB-RCS Standards.

The ATC terminals (12) could send request to all particular mobiles for providing CNS information by VDV on C-band uplink (13) via Communication payload located in GEO spacecraft and on C-band downlink (14) to AES users (3), which are able to send augmented CNS data on L-band uplink (15) via the same spacecraft and L-band downlink (16). The ATC sites are processing CNS data received from AES by Host and displaying on the navigation screen like radar display as very accurate positions in the real time and space (12).

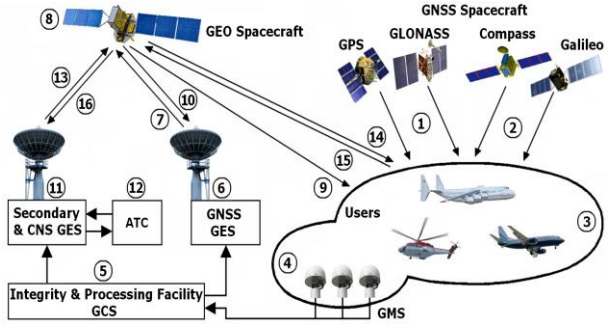


Fig. 4: RSAS Network Configuration.

The traffic controller can use this position data for managing certain traffic in more safe way than radar for collision avoidance. In addition, on pilot request ATC operator may send position data of each aircraft mobile in his vicinity for enhanced collision avoidance (13 and 14). Pilot will be also able to provide own polling of selected PVT and ID data of adjacent aircraft especially during very poor visibility caused by fog and volcano ashes or in case if radar is obstructer by very heavy clouds. In such a way, all mobiles like ships, land vehicles and aircraft will be able to get from traffic controllers position data of any adjacent mobile and use it for enhanced collision avoidance and awareness.

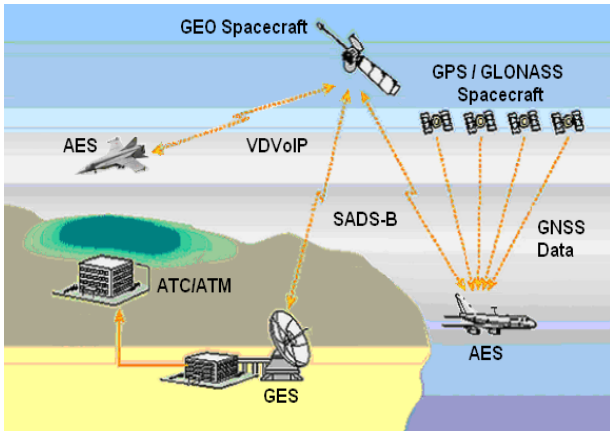


Fig. 5: ASCS Solution of RSAS Network.

3. Communication, navigation and surveillance (CNS) facilities

1) Aeronautical Satellite Communication System (ASCS) – This system is implemented about 20 years ago by Inmarsat and today is providing AMSC service deploying VDVoIP by DVB-RCS and Satellite Automatic Dependent Surveillance-Broadcast (SADS-B), illustrated in Figure 5. Thus, current communications between mobile terminals and ATC are conducted via radio VHF, UHF and HF RF-bands, which in some busy portions of the world, is reaching its limit. Thus, the RF-bands are congested and additional frequencies are not available.

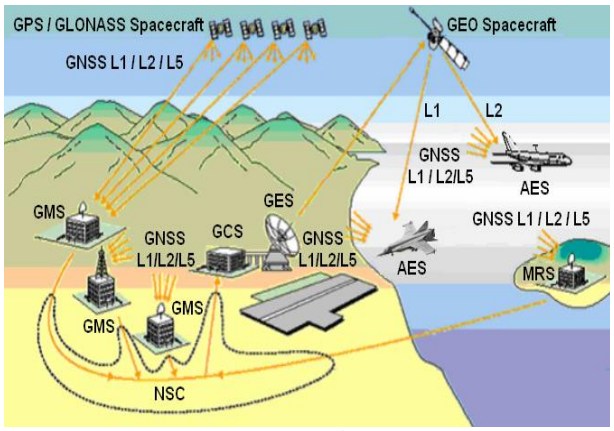


Fig. 6: ASNS Solution of RSAS Network.

2) Aeronautical Satellite Navigation System (ASNS) – Two generations of this system exist more than 40 years, which network is shown in Figure 6 and which is working in the same way shown in Figure 4. As stated before, the US has its own Navstar GPS and Russians have GLONASS, both as a part of GNSS1 system. The Chinese Compass (BeiDou) is built regionally and soon will be available globally, while Europeans will eventually have Galileo, both as a part of new GNSS2 system.

Although GNSS-1 and GNSS-2 systems are enough precise of up to 30 meters, there is some kind of problem. Namely, GNSS system can give to aircraft pilots their own position, but not positions of adjacent aircraft especially during very bad weather conditions and visibility.

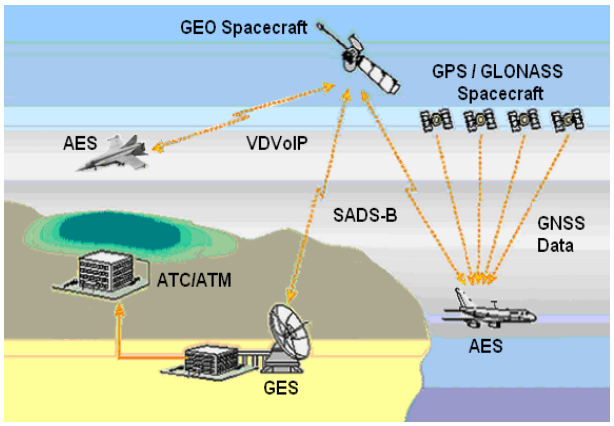


Fig. 7: ASSS Solution of RSAS Network.

3) Aeronautical Satellite Surveillance System (ASSS) – This system can provide what previous alone cannot, namely together with ASCS and ASNS is possible to get PVT/ID data of all adjacent aircraft. As shown in Figure 7 AES is sending his own augmented or not augmented PVT/ID data to the ATC and are processed at Surveillance Processor and Display. This is display like radar screen and is used by ATC for ATM and control of all aircraft in its range. In addition, this data can be sent to aircraft by pilot request or polled for enhanced collision avoidance and awareness without use of surveillance radar.

4. Integration of RSAS with guidance and control networks

The RSAS networks are designed technically to provide wide and local guidance and control subsystems such as follows:

1) Oceanic Flight Guidance and Control (OFGC) – The OFGC may use VDV of DVB-RCS, SADS-B or new generation of AMSC system to send GNSS data from GPS or GLONASS received by AES to GES on L/C, Ku or Ka-band, what depends on the type of GEO spacecraft, shown in Figure 8 and 4. Also GMS sites are getting GNSS signals and forwarding them to GCS for processing and then via GES are sending augmented signals to AES via RF at L1 or L5-band. From GCS signals can also be sent to ATC for processing and displaying them at radar like display. So, ATC operator can send to any aircraft position of near by aircraft for awareness and collision avoidance.

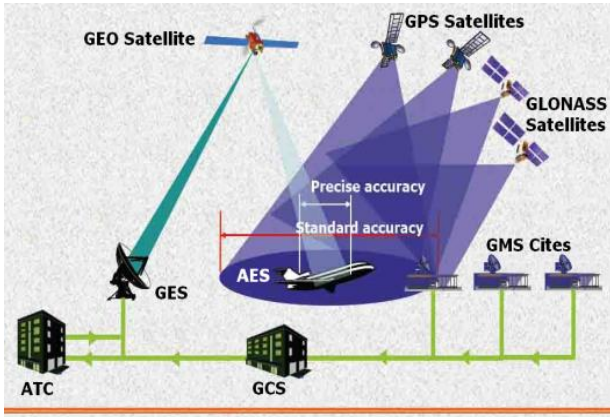


Fig. 8: OFGC Network Configuration.

2) Surface Movement Guidance and Control (SMGC) - The SMGC infrastructure is a special security and control system that enables a controller at ATC to guide and monitor aircraft in air and on the ground, even in poor visibility conditions at approaching and on airport surface, shown in Figure 9. The controller issues instructions to all pilots with reference to a command display in a control tower that gives aircraft position data detected via satellite and by sensors on the ground. The command monitor also displays reported position information of landing or departing aircraft and all auxiliary vehicles moving onto the airport's surface in more secure and safety way.

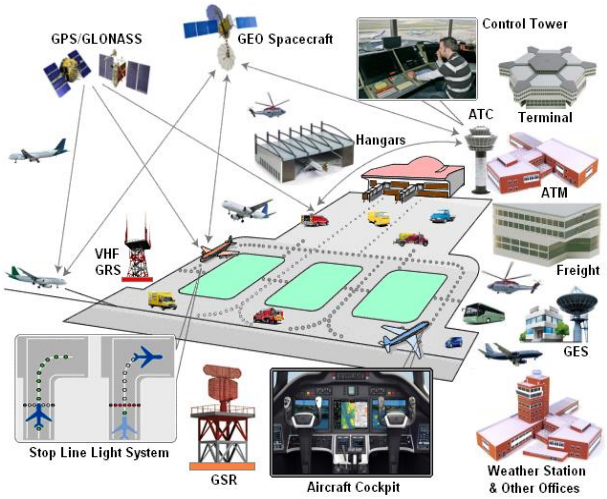


Fig. 9: SMGC Network Configuration.

5. Conclusion

The majority of RSAS networks on Northern Hemisphere are already developed and ready for mutual integration in GSAS together with future developments in Southern Hemisphere. The main goals of RSAS networks are to improve safety and security for aeronautical transport systems, especially in airports with surveillance radars as a backup. The final goal of these essential networks will boost the aeronautical and airways industry, increase economic growth and provide job creation in all countries worldwide.

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