International Journal of Engineering &Technology, 8 (4) (2019) 567-571

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper

Architecture of African satellite augmentation system (ASAS) for Africa and middle east

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Abstract

This paper introduces architecture of African Satellite Augmentation System (ASAS) project designed by African for Africa, with coverage of entire African Continent and Middle East for maritime, land (road and rail) and aeronautical applications. The ASAS network is de facto Regional Satellite Augmentation System (RSAS) as integration component of the Global Satellite Augmentation System (GSAS) employing current and new Satellite Communication, Navigation and Surveillance (CNS) for improved traffic control and management at sea, on land and in the air. This Network also enhances safety and emergency systems, transport security and control of transportation freight, logistics and the security of the crew and passengers onboard transport systems. The current infrastructures of the first generation of Global Navigation Satellite System (GNSS-1) applications are represented by old fundamental solutions for Position, Velocity and Time (PVT) of the satellite navigation and determination systems such as the US GPS and Russian (former-USSR) GLONASS military requirements, respectively. The establishment of Local Satellite Augmentation System (LSAS) and mobile movement guidance and control are also discussed as special infrastructures in seaports, land and airports environments.

Keywords: *ASAS; RSAS; GSAS; CNS; GNSS; GPS; GLONAS; LSAS; CMGC; SMGC; LMGC.*

1. Introduction

A major goal of ICAO is the near-universal use of GNSS of the US GPS and Russian GLONASS military systems. It is proposed augmentation of GNSS to provide and enhance Traffic Control Management (TCM) for civil transport safety and security. As a result of these efforts, new ASAS network has been projected by DUT Research Group in Space Science for entire Africa and Middle East, which will utilize CNS solutions and services for Maritime Traffic Control (MTC), Land Traffic Control (LTC) and Air Traffic Control (ATC) providing improved safety and security in all transportation systems.

In this paper, 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 better convenient nomenclature. Augmented GNSS-1 of GPS and GLONASS solutions including new GNSS-2 Chinese Compass all recently known as an RSAS were developed to improve deficiencies and to meet the present transportation civilian requirements for high-operating Integrity, Continuity, Accuracy and Availability (ICAA). The second GNSS-2 solution is the European Galileo and is big question if this system will be developed at all.

Recently operational RSAS systems are the US Wide Area Augmentation System (WAAS), the European Geostationary Navigation Overlay System (EGNOS) and Japanese MTSAT Satellite-based Augmentation System (MSAS), which are able to provide CNS data from mobiles to the Traffic Control Centre (TCC) and vice versa in their network coverage.

Those 3 RSAS networks will be integrated in GSAS together with the 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 ASAS shown in Figure 1. Only remain to realize projects in South America and Australia for establishment of GSAS [1 - 3].

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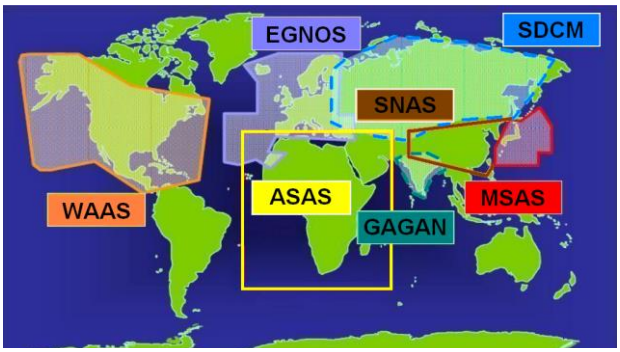


Fig. 1: GSAS Network Integration [3].

2. Development process of ASAS

The development process of ASAS space and ground segments for all mobile applications is shown in Figure 2, which may integrate the same three Geostationary Earth Orbit (GEO) satellites leased by the EGNOS network, such as Inmarsat and Artemis spacecraft.

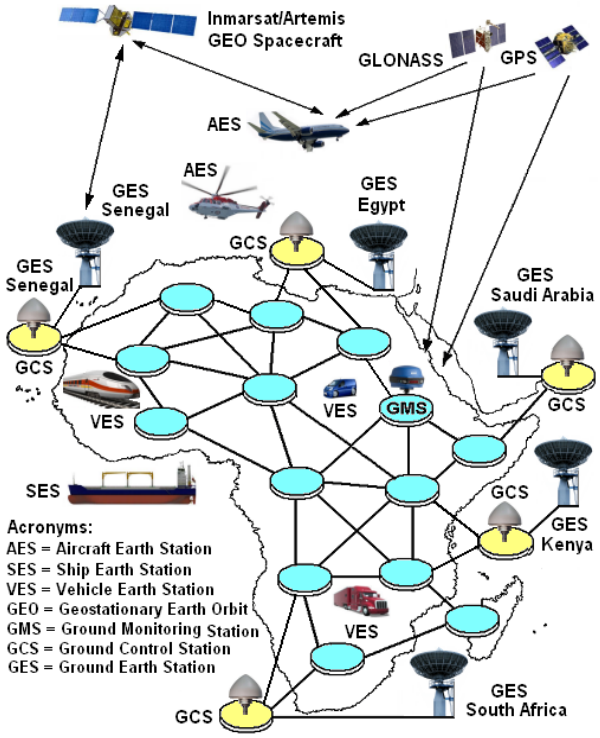


Fig. 2: ASAS Space and Ground Segments [4].

In addition, the ASAS ground network needs also to integrate minimum 50 Ground Monitoring Stations (GMS) or reference stations, 5 Ground Control Stations (GCS) or master stations and 5 Ground Earth Stations (GES) or gateways. The preliminary cost of ASAS project is about 150M $, so if all 69 countries in the Region participate in its funding, each participant has to provide about 2M $. To build one surveillance radar system in some airport is costing about 50M $. New RSAS networks are going to provide CNS solutions including broadcast satellite surveillance, which has to work in more precise way than radar surveillance under any weather condition. In Figure 3 are shown coverage footprints of two Inmarsat and one Artemis GEO spacecraft [4], [5].

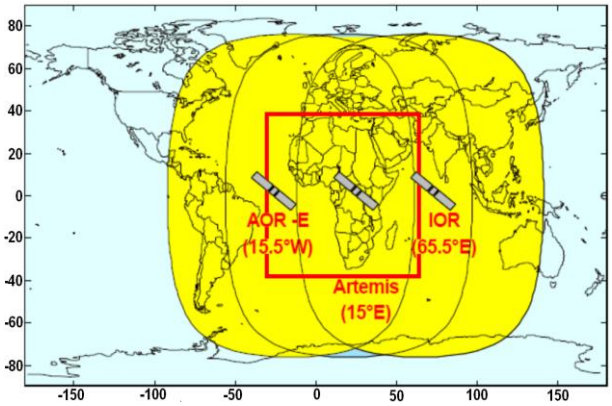


Fig. 3: Coverage of ASAS Space Segment [4].

Thus, the most important service of ASAS network will be establishment of reliable Communication, Navigation and Surveillance (CNS) solutions for all mobile applications, which diagram is illustrated in Figure 4. The ASAS CNS network will integrate two space segments, GNSS-1 containing 24 GPS and 24 GLONASS spacecraft and 2 or 3 GEO spacecraft covering entire Africa and Middle East.
The next original proposal for ASAS is development and supports the following services:

1) The transmission of integrity and health information on each GPS or GLONASS satellite in real time to ensure all 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 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).

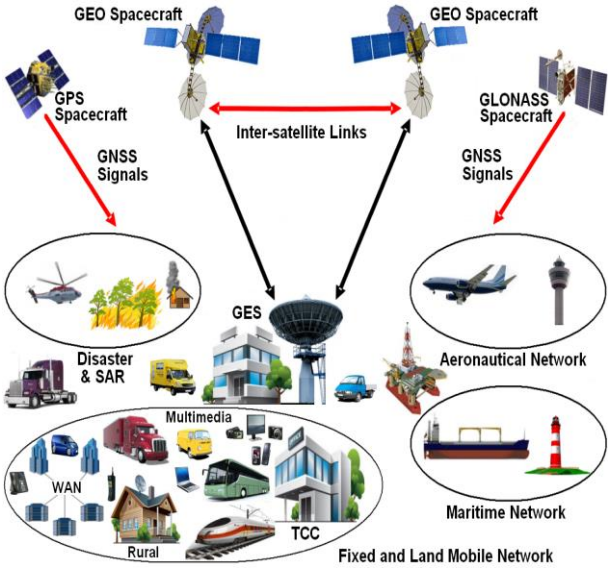


Fig. 4: CNS Solutions of ASAS Network [6].

In fact, the combination of the Inmarsat spacecraft overlay service and Artemis spacecraft integrated with both GNSS-1 and GNSS-2 spacecraft will be referred to as the ASAS network illustrated in Figure 5. As observed in this figure, all potential mobile users (3) receive navigation signals (1) from GNSS-1 of GPS or GLONASS satellites. Thus, in the near future should be used GNSS-2 signals of the Chinese Compass and European Galileo satellite.
These signals are also received by all reference GMS terminals of integrity monitoring networks (4) operated by some governmental agencies in many countries within Africa and Middle East region. The monitored data are sent to a regional Integrity and Processing Facility of GCS terminal (5), where the data is processed to form the integrity and WADGNSS correction messages, which are then forwarded to the Primary GNSS GES (6).

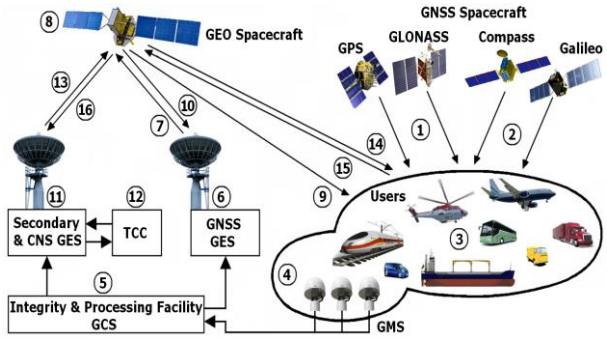


Fig. 5: ASAS Network Configuration [1].

Besides, at the GES terminal, the navigation signals are precisely synchronized to a reference time and modulated with the GIC message data and WADGNSS corrections. The signals are sent to a satellite on the C-band uplink (7) via GNSS payload located in GEO Inmarsat and Artemis 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. The timing of the signal is done in a very precise manner in order that the signal will appear as though it was generated on board 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. The Traffic Control Centre (TCC) ground terminals (12) could send request to all particular mobiles for providing CNS information by Voice, Data and Video (VDV) on C-band uplink (13) via Communication payload located in Inmarsat or Artemis spacecraft and on C-band downlink (14) to mobile users (3). The mobile users are able to send augmented CNS data on L-band uplink (15) via the same spacecraft and L-band downlink (16). The TCC ground sites are processing CNS data received from mobile users by Host and displaying on the navigation screen like radar display as very accurate positions in the real time (12). This position data traffic controller can use for managing certain traffic in more safe way than radar for collision avoidance. In addition, on mobile request TCC operator

may send position data of each mobile in vicinity for enhanced collision avoidance (13 and 14). Mobiles, such as ships and aircraft will be also able to get from TCC position data of any adjacent mobile and use it for collision avoidance [1, 4, 6, 7, 8].

3. Integration of local satellite augmentation systems (LSAS) with ASAS network

The ASAS network is designed to provide the following three integration of LSAS subsystems:

1) Coastal Movement Guidance and Control (CMGC) – The CMGC infrastructure is a special guidance, security and control system that enables a ships controller at MTC to guide and monitor all vessels movements at sea in coastal navigation, in the cramped channel strips, approaching areas to the anchorage and seaports, all movement in harbours: ships, land vehicles in port and around the port's coastal environment, in poor visibility conditions at an approaching to the harbours, shown in Figure 6.

The controller issues instructions to ship masters and pilots with reference to a command display in a control tower that gives vessels position information detected via satellite and by sensors on the ground. Using special onboard equipment TCC may provide traffic control movements in seaport of all road vehicles and trains.

The CMGC infrastructure is providing the following segment:

a) GPS or GLONASS GNSS Satellite measures the vessel or seaport vehicle's the exact position.
b) GEO MSC Satellite is integrated with the GPS positioning data network caring both communication and navigation payloads, In addition to complementing the GPS satellite, it also has the feature of communicating data between the ships or vehicles and the ground facilities, pinpointing the mobile's exact position.
c) Control Tower is the centre for monitoring the traffic situation on the channel strips, approaching areas, in the port and around the port's coastal surface. The location of each vessel and ground vehicle is displayed on the command monitor of the port control tower. The controller performs sea-controlled distance guidance and movements for the vessels and ground-controlled distance vehicles and directions based on this data.
d) Light Guidance System (LGS) is managed by the controller who gives green light or red-light guidance whether the ship should proceed or not by pilot in port, respectively.
e) Radar Ground Station (RGS) is a part of previous system for STC of ship movement in the channels, approaching areas, in port and around the port's coastal environment.

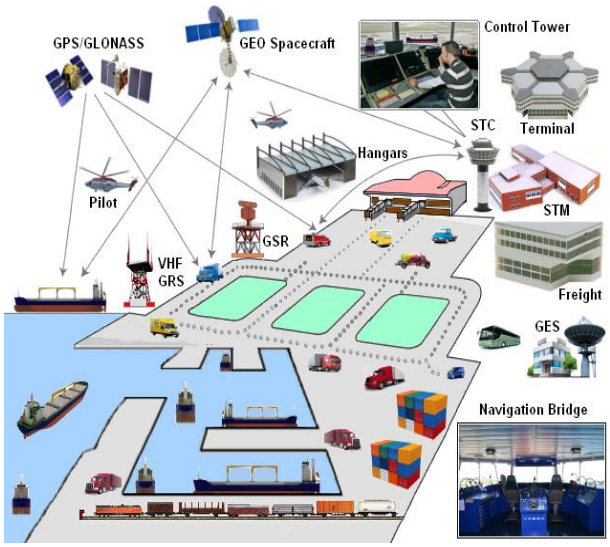


Fig. 6: ASAS Coastal Movement Guidance and Control [6].

f) Very High Frequency (VHF) is Coast Radio Station (CRS) is a part of RCS and VHF or Digital Selective Call (DSC) VHF Radio communications system.
g) Coast Earth Station (CES) terminal is a main part of satellite communications system between GES terminals and land or shore telecommunication facilities via GEO satellite constellation.
h) Pilot is small boat or helicopter carrying the special trained man known as a Pilot, who has safely to proceed arrival vessel in port, departure vessel out of port to anchorage or to manage vessels sailing through the channels and rivers.
i) Bridge Instrument onboard each oceangoing vessel displays the ship's position and course during all stages of navigation at open sea or inside of seaports.

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 an airport, shown in Figure 7. 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 ground.

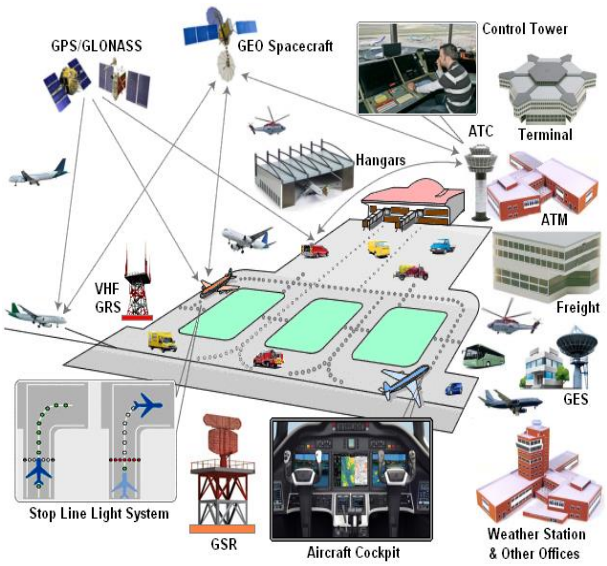


Fig. 7: ASAS Surface Movement Guidance and Control [6].

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 way.

The SMGC infrastructure is providing the following segment:

a) GPS or GLONASS satellite measures precise positions of all aircraft or airport vehicles moving on the airport surface;
b) RSAS network is integrated with the GPS satellite positioning data network. In addition to complementing the GPS satellite, it also has the feature of communicating data between the aircraft and the ground facilities, pinpointing the aircraft's exact position;
c) Control Tower is the centre for monitoring the traffic situation on the landing strip around the airport's environment. The location of aircraft and vehicles is displayed on the command monitor of the control tower. The air controller performs ground-controlled distance guidance for the aircraft and vehicles based on this data;
d) Stop Line Light System is managed by the air controller, who gives guidance on whether the landing aircraft should proceed to the runway by turning on and off the central guidance line lights and stop line lights as a signal, indicating whether the aircraft should proceed or not.
e) Ground Surveillance Radar (GSR) is a part of previous system for ATC of aircraft approaching areas, in airport and around the airport air environment;
f) Very High Frequency (VHF) is Ground Radio Station (GRS) is a part of ARC via VHF or UHF Radio communications system;
g) Ground Earth Station (GES) is a main part of global satellite communications system between GES terminals and the landline telecommunication facilities via GEO satellite constellation; and
h) Aircraft Cockpit displays the aircraft position and routes on the headwind protective glass (head-up displays) and instrument panel display (head-down display).
3) Land Movement Guidance and Control (LMGC) - The LMGC infrastructure is a special security and control system that enables a controller at LTC separately to manage all trains and vehicles on the road [2], [6].

4. Conclusion

The ASAS project is ready for deployment and implementation as the best RSAS solution ever designed for Africa and Middle East by Africans. Therefore, to provide in regular way regional ASAS project accepted for development, the government of one country in Africa and Middle East has to send an official proposal to ICAO administration. After that ASAS project has to get an official sponsor for funds and arrange an agreement with prime contractors who will build and test ASAS Network. Thus, the main goal of ASAS project is to improve safety and security for maritime, land (road and rail) and aeronautical transport systems, especially in airports without surveillance radars. The final overall gain of this essential regional project in Africa and Middle East will boost the transportation related industry, increase economic growth and developments in all participated countries providing job creation in this entire region, and therefore, should be fully supported by all countries.

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