Implementation of African Satellite Augmentation System (ASAS) for Aeronautical Applications

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Abstract: This paper introduces implementation of the new project known as an African Satellite Augmentation System (ASAS) for Africa and Middle East designed by the CNS Systems Company and its research group supported by partners. The ASAS project as Regional Satellite Augmentation Systems (RSAS) will provide service for maritime, land (road and rail) and aeronautical applications. Thus, with existing and other new projected RSAS networks, it will be integrated in Global Satellite Augmentation System (GSAS) with new Satellite Communication, Navigation and Surveillance (CNS) for improved Air Traffic Control (ATC) and Air Traffic Management (ATM). This System also enhances safety and emergency systems, transport security and control of aircraft freight, logistics and the security of the crew and passengers onboard aircraft and helicopters as well. The current CNS 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 Space, Ground and User segment including Local Satellite Augmentation System (LSAS) are discussed as a new basic infrastructures for aeronautical and other mobile applications, which will be integrated with RSAS in the future GSAS network.

Key words: ASAS, RSAS, GSAS, CNS, STC, STM, GNSS, GPS, GLONAS, EGNOS, MSAS, WAAS, PVT, LVAS, LTC, ATC, Space Segment, Ground Segment

1. Introduction

The current Communication systems for aeronautical application are combined by conventional Radio (HF, VHF and UHF-band) and recently by Satellite communications, while the current Navigation applications are represented by old fundamental systems for the PVT military determination and tracking systems, such as GPS and GLONASS for US or Russia (former-USSR) requirements, respectively. In fact, the GPS and GLONASS are first generation of GNSS-1 infrastructures giving positions to about 30 meters, using simple GPS receivers (Rx) onboard chips, land vehicles or aircraft, and they therefore suffer from certain weaknesses, which make them impossible to be used as the sole means of navigation for all mobiles and particularly for aeronautical applications. Technically GPS or GLONASS GNSS-1 and BeiDou or Galileo GNSS-2 systems used autonomously are incapable of meeting civil maritime, land (road and railway) and aeronautical mobile very high requirements for integrity, position availability, continuity and very precise accuracy in particular and are insufficient for certain very critical navigation and sailing stages at sea.

Because these two systems are developed to provide navigation particulars of position and speed on the ship's bridges or in the airplane cockpits, only captains of the ships or airplanes know very well their position and speed, but people in Traffic Control Centers (TCC) cannot get in all circumstances their navigation or flight data without service of new CNS facilities. Besides of accuracy of GPS or GLONASS, without new CNS is not possible to provide full TCC in every critical or unusual situation. Also these two GNSS systems are initially developed for military utilization only, and now are also serving for all transport civilian applications worldwide, therefore, today many countries and international organizations would never be dependent on or even entrust people's safety to GNSS systems controlled by one or two countries.

Augmented GNSS-1 solutions known as Regional Satellite Augmentation System (RSAS) were recently developed to improve the mentioned deficiencies of current GNSS military systems and to meet the present transportation civilian requirements for high-operating Integrity, Continuity, Accuracy and Availability (ICAA).

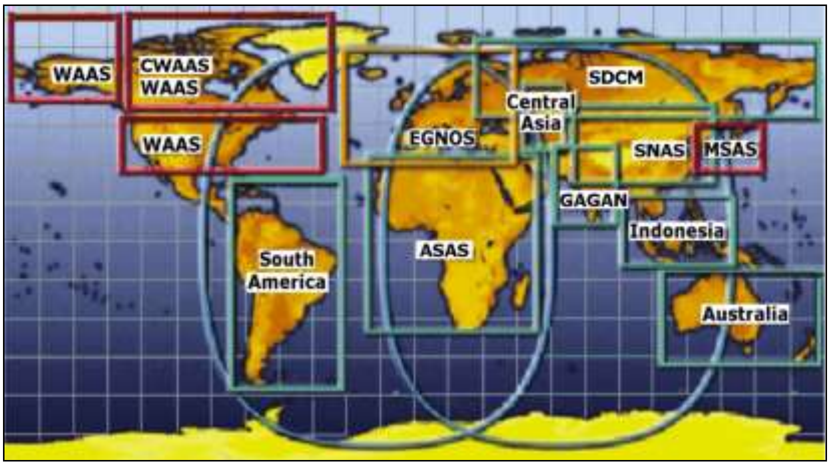

Figure 1. GSAS Network Integration – Source: Ilcev **[1]**

These new operational CNS systems are the US Wide Area Augmentation System (WAAS), the European Geostationary Navigation Overlay System (EGNOS) and Japanese MTSAT Satellite-based Augmentation System (MSAS), and there are able to provide CNS data from mobiles to the TCC in their RSAS network coverage. However, those three RSAS networks or Satellite-Based Augmentation System (SBAS) are recently operational and are interoperable and compatible. However, all RSAS infrastructures together are subsegments of Global Satellite Augmentation System (GSAS), which has to integrate all current and future RSAS projects worldwide.

Three operational systems are part of the GSAS network and integration segments of the GNSS-1 system of GPS and GLONASS and new GNSS-2 of the European Galileo and Chinese Compass, including Inmarsat CNSO (Civil Navigation Satellite Overlay) and new project of African Satellite Augmentation System (ASAS). The additional three new developed RSAS networks are the Russian System of Differential Correction and Monitoring (SDCM), the Chinese Sino (Satellite) Navigation Augmentation System (SNAS) and Indian GPS/GLONASS and GEOS Augmented Navigation (GAGAN) **[1, 2, 3]**.

1.1. Developments of RSAS Networks

The new developed NAV Canada's CWAAS is based on an extension of the current US WAAS coverage by deploying a network of additional Reference Stations (RS) and linking them to the US WAAS Master Control Stations (MCS). Only remain something to be done in South America, Central Asia, Indonesia and Australia for establishment of global GSAS, shown in **Figure 1.** In **Figure 2** are shown operational RSAS such as: WAAS, EGNOS, MSAS, SDCM, SNAS and GAGAN, all in Northern Hemisphere and Africa and Middle East have project of ASAS Network as a first in Southern Hemisphere.

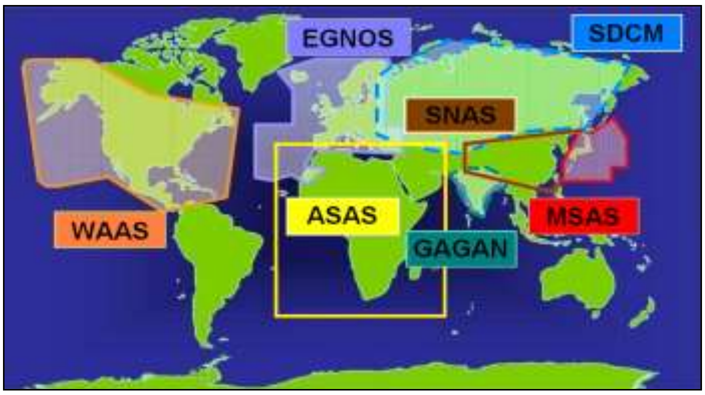

Figure 2. Operational and Projected RSAS – Source: Ilcev **[4]**

All of the RSAS networks comply with a common global standard and are compatible, namely do not interfere with each other. They are also interoperable, a user with a standard receiver can benefit from the same level of service and performance whether located in the EGNOS or WAAS and any other coverage area. In addition, to their use in the aeronautical sector, RSAS networks are essential for solutions where accuracy and integrity are critical. In particular, they are indispensable for all applications where people's lives are at stake or for which some form of legal or commercial guarantee is required. For example, the RSAS networks make it possible to improve and extend the scope of applications for GPS or GLONASS in areas such as precision farming, the guidance of agricultural machinery, on-road vehicle fleet management, oil exploration for the positioning of platforms at sea, in the airspace or for scientific applications such as geodesy and so on.

Several years ago GPS system started broadcasting civil signals suitable for maritime use on both the L1 and L5 frequencies. In addition, GLONASS and other future GNSS constellations will offer even greater number of dual frequency ranging measurements, so the RSAS systems can also be updated to exploit these new signals. Thus, such updates offer a variety of improvements over existing single GNSS frequency systems.

These dual GNSS frequency systems will be fully robust against ionospheric gradients that currently limit integrity and accuracy during severe ionospheric disturbances. At this point, they offer improved resistance against interference as operations can proceed when ship loses access to one frequency or the other.

These dual frequency systems will be fully robust against ionospheric gradients that currently limit vertical guidance during severe ionospheric disturbances. Further, they offer improved resistance against interference as operations can proceed when aircraft lose access to one frequency or the other. It will be also necessary to present the improvement to coverage that can be provided by integrating additional constellations into the RSAS coverage. Additional ranging signals dramatically improve the users geometry, even further extending coverage from Reference Station (RS) networks.

The significant benefit of RSAS networks is that users will take an advantage of both frequencies and that their enhanced availability can extend much further away from the RS augmented network. The uncertainty in the ionospheric behavior at the user site is essentially eliminated, which will provide an increased coverage. Importantly, this reliable availability can be extended into equatorial areas where the current single frequency, twodimensional grid can be a very poor fit to actual ionospheric behavior. Thus, availability to these regions can be reliably provided for the first time.

An important goal of International Maritime Organization (IMO) and International Civil Aviation Authority (ICAO) is the near-universal use of GNSS of the GPS and GLONAS networks, which propose and support augmenting GNSS to provide and enhance traffic control for civil maritime, land and aviation safety and security. As a result of these efforts, new RSAS networks have been projected and developed to utilize CNS solutions and services for enhanced STC, Vehicle Traffic Control (VTC), Air Traffic Control (ATC) and mobile managements providing improved safety and security in all transportation systems.

In order to meet the requirements for better ICAA of GPS or GLONASS for the African CNS needs, it is proposed to establish the ASAS network. The ASAS infrastructure will cover the entire African Continent including the Arabian Peninsula and all Middle East countries. The ASAS solutions will improve the basic GNSS signals, and allow GPS and GLONASS to be utilized as a primary means of navigation, tracking and determination for all mobiles within entire African Continent and Middle East region. Especially, it will be used for the control of seaports and for managing all ships and land vehicle movements in seaports area. Similarly, it will also be used for STC and management for ocean crossings, navigation at open sea, coastal navigation and surveillance, travel through sea channels and passages, anchorages, harbours and inside of seaports. Last but not least, it will improve LTC and management for land road and railways solutions.

To appreciate the end project, it will require establishing partners and sponsors to form an augmentation standards service to set-up a Transport Augmentation Board (TAB). The TAB team shall be responsible for coordinating the operational implementation of existing and emerging satellite CNS technologies into the African Continent and Middle East region, such as Communication, Navigation and Surveillance integrated networks.

In fact, the TAB team will be instrumental body in the development of ASAS network and ground infrastructures as a whole and in the designing of the relevant criteria, binding standards and procedures for the use of the unaugmented and augmented GPS/GLONASS by the ASAS solution and to implement African Local VHF Augmentation Systems (LVAS) as well **[4, 5, 6, 7].**

1.2. Purpose and Benefits of ASAS Network

The design of ASAS network is to implement applications that fulfill a range of user service requirements by means of an overlay augmentation to GPS and GLONASS based on the broadcasting through Geostationary Earth Orbit (GEO) satellites of GPS-like navigation signals containing integrity and differential correction information applicable to the navigation signals of the GPS and GLONASS satellites. The ASAS project is going to lease the same GEO satellites used by the current EGNOS network, such as Inmarsat and Artemis GEO overlay satellites. The signals of these satellites can be received by a GNSS-1 user located inside the defined ASAS service area, and same as EGNOS service ASAS will address the needs of all modes of transport, such as maritime, land and aeronautical users.

The ASAS network will provide the similar configuration as the US WAAS, which is currently providing service for aeronautical and pleasure vessels, while Japanese MSAS, will be dedicated exclusively to air navigation. According to some statistics, the worldwide market for satellite navigation was worth about €50.000 million 10 years ago, therefore, the ASAS EGNOS GNSS program is an opportunity for Africa and Middle East to foster the development of a substantial market with good potential for creating new businesses and jobs in a wide range of industries.

Maritime Applications – The performance objectives for maritime utilities are generally broken down into open sea, coastal navigation, approaching to anchorages and inside of harbor areas. Thus, the related determination accuracy requirements considered today are for ocean and open sea navigation about 1–2 Nm, coastal navigation is 0.25 Nm and approaching to the anchorages and harbors will be 8–20 Nm.

Even without ASAS or other RSAS networks, therefore, GPS or GLONASS can easily meet sea and coastal navigation precision requirements. However, for navigation in extremely bad weather conditions, poor visibility, in areas with very high traffic, approaching to anchorages and during berthing of ships, differential techniques of CNS have to be applied for enhanced collision avoidance and grounding. The African coastal line is not very friendly, so the ASAS project has been set up to identify the possible maritime applications for the GNSS network, which includes: navigation, seaport operations, traffic management, casualty analysis, offshore exploration and fisheries. Once in operation, ASAS will be able to meet most of these requirements and will complement the services already provided by marine radio beacons.

2. Land Applications – In general, land vehicles do not need radio navigation as such but rather radio positioning and tracking. The two main land solutions under development worldwide making use of GPS receivers are route optimization and fleet management. Depending on the application, the accuracy required for the various systems ranges from a few to a hundred meters or more. In many cases, they then require the use of differential corrections. The ASAS network will be one of the keys to managing land transport in Africa and Middle East, whether it is by road, rail or inland waterways, which will increase both the capacity and the safety of land transport. Not only airlines but also companies that operate transport services need to know where their vehicles are at all times, as do other public services such as the police, the military, ambulance and taxi services.

3. Aeronautical Applications – The performance objectives for aeronautical applications are usually characterized by four main in-flight parameters: Integrity, Continuity, Accuracy and Availability (ICAA), which values are highly dependent on the phases of flight. The typical aircraft operations signal-in-space performance requirements are determined for Accuracy Lateral (AL)/Accuracy Vertical (AV), which values are for en-route is 2 Nm/N/A, en-route terminal is 0.4 Nm/NA, Initial Approach (IA) and Non-Precision Approach (NPA) is 220 m/NA, instrumental approach with Vertical Guidance (IAWVG) is 220 m/9.1 m and category I Precision Approach (PA) is 16 m/7.7-4.4 m. Neither GPS nor GLONASS can meet these typical phases of flight ICAA without an augmentation system and new CNS solutions [**4, 5, 6, 7**].

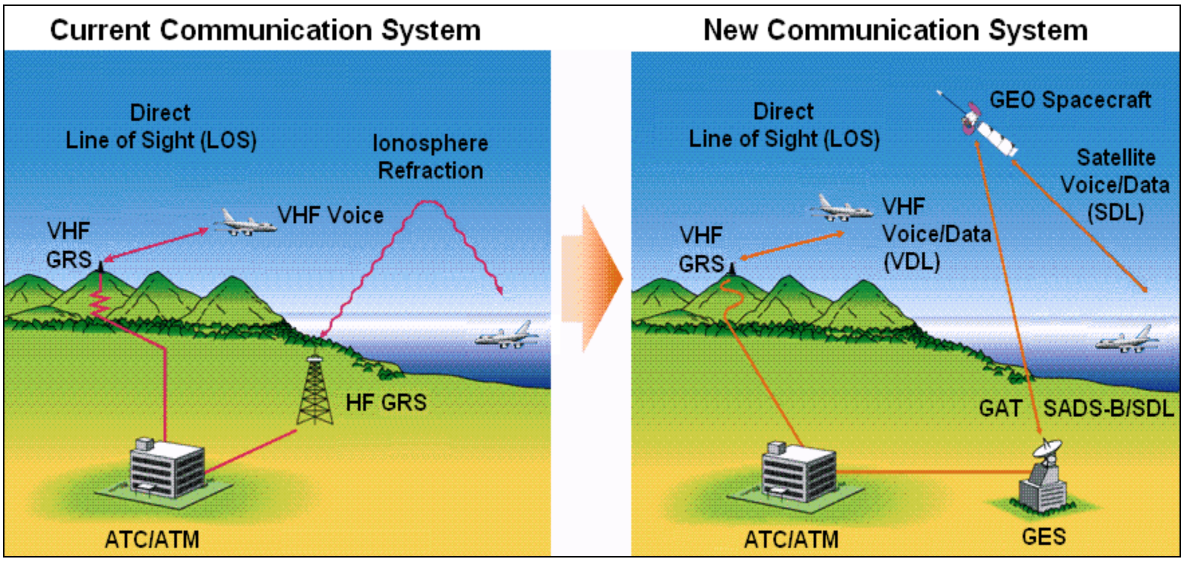

Figure 3. Current and New Communication Networks – Source: Ilcev **[9]**

1.3. Current and New Aeronautical CNS Subsystems

The current and new projected aeronautical CNS subsystems are integrated in regional and global Communication, Navigation and Surveillance systems and networks providing important solutions for enhanced ATC and ATM for all phase of longhaulage flight, local airliners and approaching to airports.

1.3.1. Aeronautical Communication Subsystem (ACS)

As stated before, the most of current communication between aircraft and ground traffic controllers are conducted via radio VHF (using direct LOS) and HF (using the ionospheric refraction) analog or digital voice, data and video RF-bands, known as Aeronautical Radio Communications (ARC) network. In such a way, the current communications subsystem facilitates between aircraft and ATC/ATM are executed by known traditional radio VHF and HF voice transmissions (radiotelephone system), which scenario is illustrated in **Figure 3 (Left)**.
The VHF voice link between aircraft on one the hand and Ground Radio Station (GRS) and ATC/ATM on the other, may have the possibility to be interfered with high mountainous terrain. On the other hand, in some busy portions of the world ARC system is reaching its limit, the frequency bands are very congested and have significant interference, additional frequencies are not available and successful radio communication in some heavy weather circumstances depends on luck of the propagation effects, the growth of traffic is reduced to those aircraft that have to be safely handled.
Moreover, the aeronautical HF radio link may not be established due to available frequencies, because many users are working on the same frequency band, owing to intermediation, unstable wave conditions and to very heavy rain or thunderstorms. The new Aeronautical MSC (AMSC) system is providing Satellite Voice and SDL including SADS-B and GAT (proposed by author) via GEO spacecraft and Ground Earth Station (GES). This system is integrated with new VHF Data Link (VDL) connecting ATC with Aircraft Radio Station (ARS) via GRS and vice versa, which is shown in **Figure 3 (Right).**
The Inmarsat satellite system can connect aircraft and aeronautical MCS customers via ISDN, Broadband ISDN (B-ISDN), ATM, UMTS and GPRS via SDL. In addition, AMSC can also deploy another GEO satellite system that provides DVB-RCS service of Voice, Data and Video over IP (VDVoIP) and SADS-B transmissions system. The AMSC Space Segment consists GEO and GPS or GLONASS spacecraft, while Ground Segment consists AES terminals connected to ATC/ATM via GEO satellite and GES terminals.

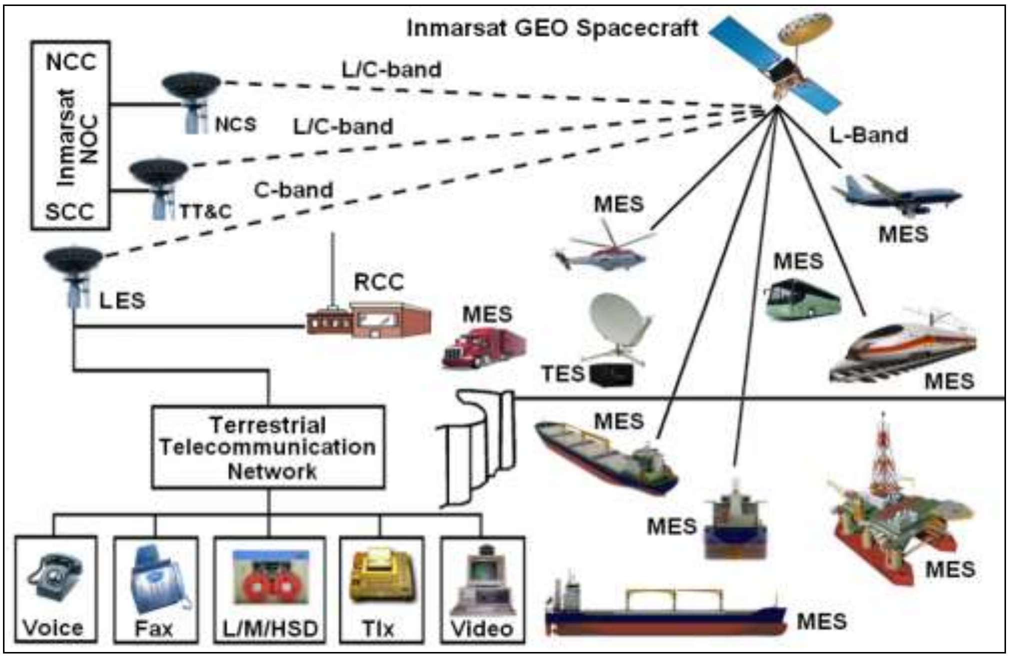

Figure 4. Inmarsat Communication Networks – Source: Ilcev **[1]**

Therefore, the ASAS or any RSAS network is integrating modern AMCS with GNSSS-1 solutions to provide signals from GPS or GLONASS spacecraft to AES terminals. In opposite way, however, all PVT and other data from GPS or GLONASS receivers onboard aircraft can be derived and sent by AES terminals manually or automatically via convenient GEO Satellites and GES terminals to ATC/ATM stations. Before that, the World's first military maritime MSC system was unveiled in 1976 by the US Comsat General with only three satellites and networks in the Atlantic, Pacific and Indian oceans.

In **Figure 4** is shown modern Inmarsat MSC Network with Mobile Earth Stations (MES) for maritime, land (road and railways) and aeronautical applications, including for portable devices such as Transportable Earth Station (TES). All MES/TES terminals are providing MSC transmissions of Voice (Phone), Facsimile (Fax), Low/Medium and High Speed Data (L/M/HSD), Telex (Tlx) and Video (Images) via Inmarsat GEO satellites, Land Earth Stations (LES) and Terrestrial Telecommunication Network (TTN) to the ground subscribers and vice versa. The Network Operations Centre (NOC) is located at Inmarsat Headquarter in London, while in the frame of the Inmarsat Ground Network (IGN) are included Network Control Centre (NCC), Satellite Control Centre (SCC), Network Coordination Stations (NCS) and Tracking, Telemetry, and Command (TT&C). In any case of maritime or aeronautical distress alert IGN is linked to Rescue Coordination Centre (RCC).

In **Figure 5** shows Digital Video Broadcasting-Return Channel via Satellite (DVB-RCS) network that also can be used for fixed, portable and mobile satellite communications and connect ground subscribers to of the Mobile Telecommunication Networks (MTN), such as Integrated Services for Digital Network (ISDN), Broadband ISDN (B-ISDN, Asynchronous Transfer Mode (ATM), Universal Mobile Telecommunications System (UMTS) and General Packet Radio Service (GPRS).

Both MSC networks are not designed only to provide more cost effective, reliable, redundant and fastest communication links between mobiles and traffic controllers, but also to connect all infrastructures in one hypothetical RSAS network, such as ASAS, and to integrate GNSS data for implementing new service for enhanced navigation and surveillance solutions. The convergence of MSC and Internet technique has opened many opportunities to deliver new multimedia service over hybrid satellite systems to MES terminals. With the need for increased bandwidth capability, the numbers and sophistication of GEO and even Non-GEO communication satellites is increasing dramatically. The size of the Earth requires multiple satellites to be placed in orbit in a constellation to cover areas of interest typically need a minimum of 3 to 4 satellites to provide adequate communications coverage.

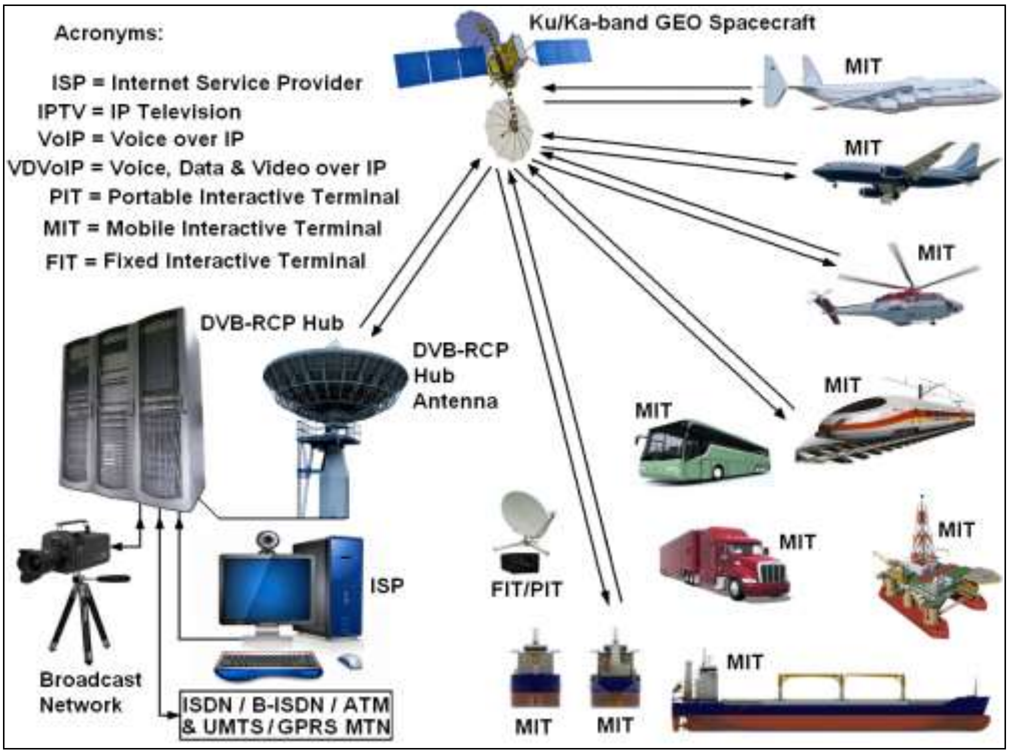

Figure 5. DVB-RCS Communication Networks – Source: Ilcev **[1]**

The commercial and military ACS network is very important for the following reasons:
1. To provide links between mobiles and ground infrastructures and between mobiles alone;
2. To transfer augmented and not-augmented navigation PVT data from mobiles to traffic control centres via GEO satellite communication transponder; and
3. To transfer augmented surveillance PVT data from traffic control centres to all mobiles via GEO satellite GNSS transponder, which will enhance navigation and collision avoidance **[1, 6, 8, 9]**.

1.3.2. Aeronautical Navigation Subsystem (ANS)

As stated before, the US has its own Navstar GPS and Russians have GLONASS as parts of GNSS1 system. Europeans will eventually have Galileo and China is implementing its BeiDou (Compass) system, both as part of new GNSS2 system. The GPS and GLONASS space segment consists of 24 GNSS1 spacecraft each and ground segment, which consist Ground Control Station (GCS) and Users Segment, illustrated in **Figure 6.**

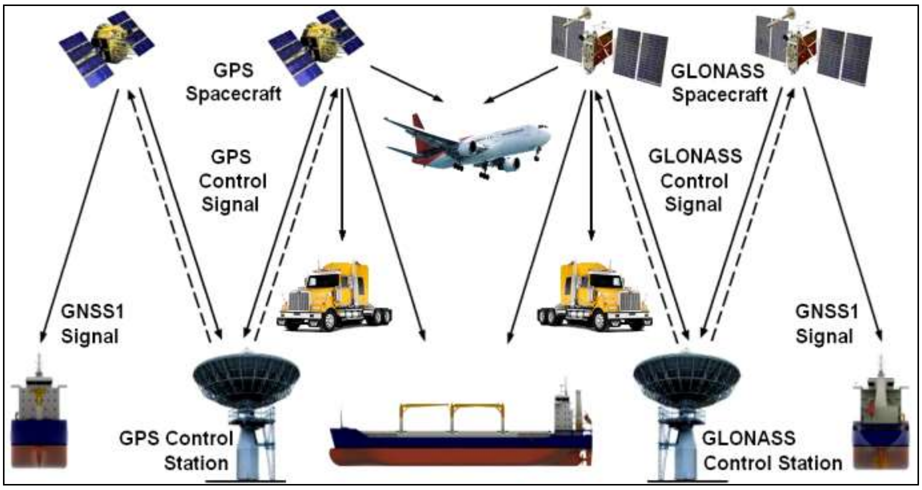

Figure 6. Existing GNSS-1 Networks – Source: Ilcev **[9]**

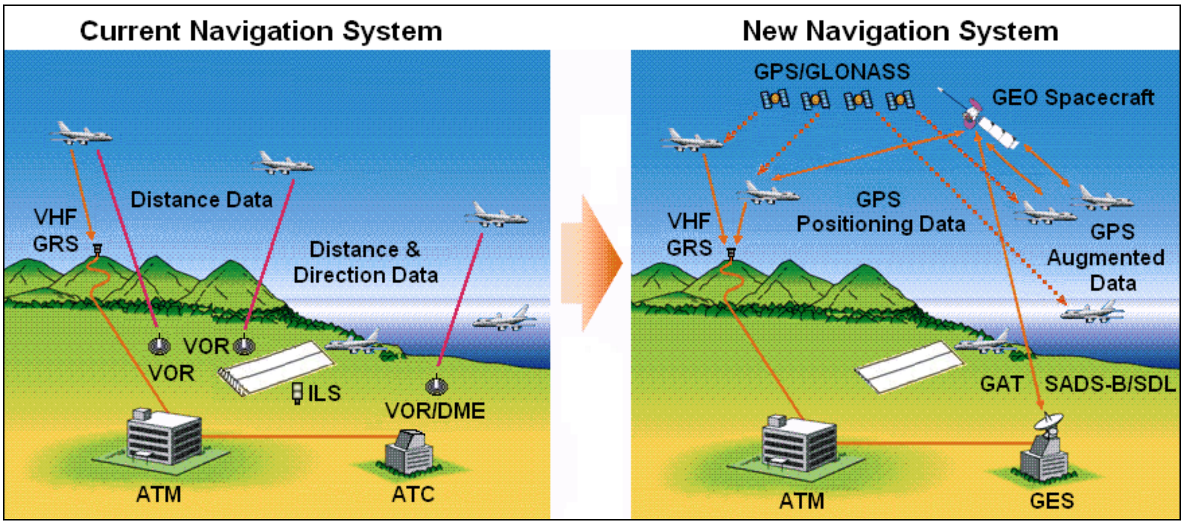

Figure 7. Current and New Navigation Networks – Source: Ilcev **[9]**

The GNSS1 network is providing service for maritime, land (road and railway) and aeronautical applications, which are receiving PVT signals by onboard installed mobile GPS or GLONASS receivers. The GNSS1 systems and accuracy are upgraded by VHF or Satellite augmentation of GPS or GLONASS solutions. In such a way, there is Differential GPS (DGPS) developed by the US Coast Guard, which modern name is Local VHF Augmentation System (LVAS). On the other hand, there are developed RSAS or SBAS networks integrating GNSS1 infrastructures

The ANS network integrated in ASAS or any RSAS infrastructure can be also used for sending and receiving navigation messages via voice or data solutions. When is applying satellite navigation systems for aircraft, there is a case that its performance is insufficient to satisfy the accuracy and availability requirements for provision of ocean flaying, approaching to the airports and landing at the airport. In fact, the ASAS network is a promising solution that enables the secure flying under the various air, meteorological and weather conditions even in very poor visibility. This network will be able to satisfy the higher categories of navigation accuracy and availability requirements by transmitting the augmentation GNSS data from the GES terminals on the same GNSS frequency bands to the aircraft (AES) in all stages of flaying. The GPS or GLONASS receivers onboard aircraft as a part of ANS network are receiving not-augmented GNSS signals and in the same time are receiving augmented PVT signals via GEO satellite navigation transponder and GES terminals. To provide GPS or GLONASS augmentation and connect all ground stations, such as GMS, GCS, MRS and Network Coordination Stations (NCS) that always monitor GPS or GLONASS signals, it is necessary this system to be integrated with GEO spacecraft constellation.

The L1/L2 frequency bands are nominated for the transmission of GNSS-1 signals from GPS or GLONASS spacecraft in ground and air directions. These signals can be detected by the Reference, Master and GES terminals including by GPS/GLONASS receiver onboard aircraft. The Ku-band can be used for up linking GPS or GLONASS augmentation signals to the ATC centre via operational ASAS spacecraft. In vice versa direction, the ASAS GEO satellite navigation (GNSS) transponder uses the L1 frequency band to broadcast GPS or GLONASS augmentation signals in the direction to AES GNSS receivers via GES terminals. Therefore, the whole ground infrastructure including ANS network is controlled by the AMCS links.

The current navigation subsystem possibilities for recording and processing the Radio Direction Information (RDI) and Radio Direction Distance Information (RDDI) between aircraft and ATC are performed by ground landing navigation equipment, such as the Instrument Landing System (ILS), VHF Omnidirectional Ranging (VOR) and Distance Measuring Equipment (DME), which scenario is illustrated in **Figure 7 (Left).** However, this subsystem will need more time for ranging, safe approaching and secure landing, using an indirect way of flying in a semicircle. In that manner, this subsystem is using classical VHF radio transceiver onboard aircraft to send PVT, altitude, direction and identification data via GRS to ATC and ATM via new radio VHF transponder.

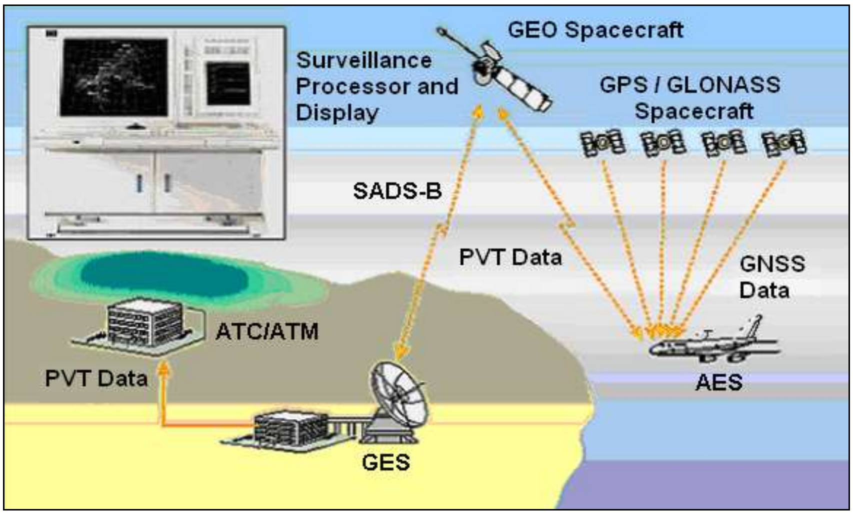

Figure 8. Modern ASS Network – Source: Ilcev **[9]**

The new navigation subsystem is employing GPS and GLONASS networks as parts of GNSS1 system, which provides in real time and space direct not-augmented positioning data. However, both GNSS-1 systems integrated with GEO spacecraft in ASAS or any RSAS network is able to provide augmented navigation data, which scenario is illustrated in **Figure 7 (Right).** In such a way, when ANS network is out of range from terrestrial VHF infrastructures can be used SADS-B and SDL to transmit GNSS augmented data via GEO navigation transponders to AES terminals. In addition, GAT station onboard aircraft can send PVT and other data via satellite to special Tracking Control Station (TCS) in case if aircraft is missing or hijacked. The GAT project as the best solution for global aircraft tracking is developed by author of this paper.

The Wide Area Navigation (WANAV) system is a way of calculating own position using the Flight Safety Satellite Equipment (FSSE) facilities and installed air navigation devices to navigate the desired course. Until now, the airways have made mutual use of the FSSE, which often led to broken line routes. Thus, in the case of WANAV (RNAV – an original version) routes it has been possible to connect in an almost straight line to any desired point within the area covered by the satellite equipment and service. Setting the WANAV routes has made it possible to ease congestion on the main air routes and has created double tracks. This system enables more secure and economical air navigation routes **[1, 8, 9, 10]**.

1.3.3. Aeronautical Surveillance Subsystem (ASS)

In a modern ASS network for ASAS infrastructure, both GEO Inmarsat and DVB-RCS MSC networks can be implemented using ASS solutions, which infrastructure is shown in **Figure 8.** Consequently, the advanced CNS/ATC ASAS system utilizes the SADS-B data function, which automatically reports all current aircraft PVT data measured by unaugmented and augmented GPS or GLONASS data to ATC/ATM centre.

In such a manner, the approaching aircraft receives unaugmented positioning data from GPS spacecraft and augmented data via GEO GNSS payload and then via SDL sends its current position for recording and processing to the ATC Centre via GES terminal. After that, the ATC/ATM centre is forwarding all Augmented data to the Surveillance Processor and Display to be processed and displayed on look like Radar display as positions of all aircraft in surrounded area. Thus, in opposite direction, it is possible to be established additional service that, on request of pilot, ATC/ATM centre may use displayed data of aircraft positions in certain area and send to the onboard aircraft SDL unit.

More exactly, the display looks just like a pseudo-radar coverage picture and is showing the traffic situation in certain air space. The coming SADS-B system and network will increase air safety and reduce aircraft separation, improve functions and selection of the optimum route with more economical altitudes.

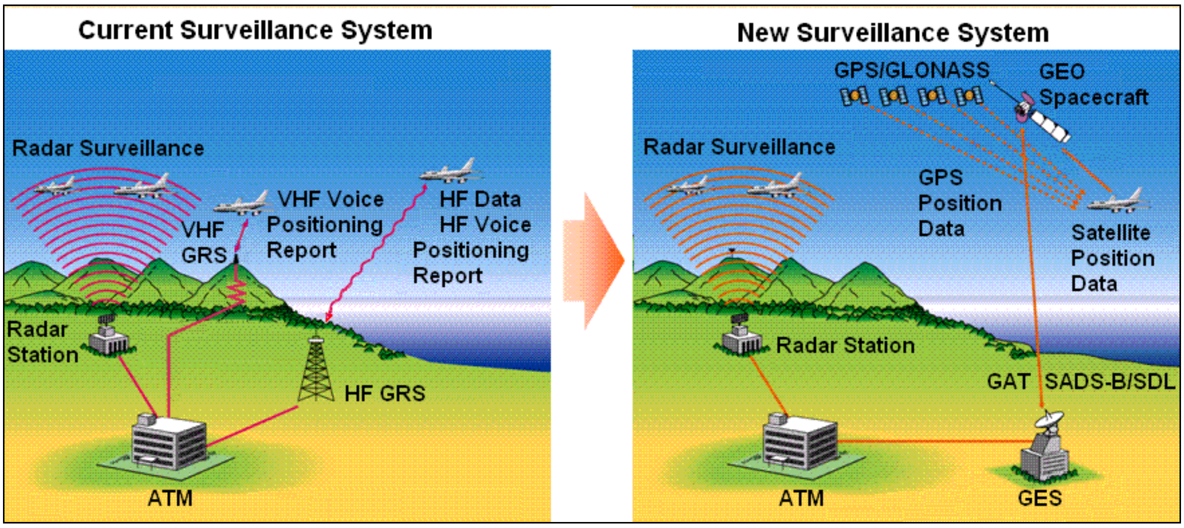

Figure 9. Current and New Surveillance Navigation Networks – Source: Ilcev **[9]**

In addition, the system will also increase the accuracy of each aircraft position and reduce the workload of both controller and pilot, which will improve safety. Thus, aircraft can be operated in a more efficient manner even with zero visibility and since the areas where VHF radio does not reach due to mountainous terrain will disappear, small aircraft and helicopters will be able to obtain meteorological data on a regular basis. These functions are mandatory to expand the traffic capacity of the entire air region and for the optimum air route selection under limited space and time restraints.

The current surveillance subsystem utilities for receiving airborne Radar, VHF Voice Position Reports (VPR) and HF Radio Data/VPR signals between aircraft and TCC are detected by Surveillance Radar and Ground VHF/HF GRS terminals, respectively. This subsystem may have similar HF voice radio communications problems or when airplanes are flying behind high mountains they cannot be detected by Radar, which scenario is shown in **Figure 9 (Left)**. The very bad weather conditions, deep clouds and heavy rain in some circumstances could block radar signals totally and on the screen will be blanc picture without any reflected signals, so in this case cannot be visible surrounded obstacles or traffic of aircraft in the vicinity, and the navigation situation is becoming very critical, dangerous and may cause collisions. The ASS network is conducted and mainly supported by VHF GRS terminal, which enables display of real-time positions of the nearby approaching flying aircraft using radar and VHF voice radio equipment. Due to its limitations, the VHF service being used for domestic airspace cannot be provided over the ocean. Meanwhile, out of radar and VHF coverage and range on the oceanic routes, the aircraft position is regularly reported by HF voice or via data terminals to the HF GRS.

However, the new satellite surveillance subsystem is integrating GPS and GLONASS with Inmarsat or other GEO satellite networks, which are not affected by very high mountains. In such a way, aircraft can receive positioning data from GPS or GLONASS satellites and automatically or manually send PVT and other data using SADS-B, SDL and GAT via GEO spacecraft and CES to gather satellite position data to the ATC/ATM stations, which scenario is illustrated in **Figure 9 (Right).** Additionally new surveillance subsystem can also deploy as a back the GSR system in the coverage of radar stations **[9, 11, 12, 13]**.

2. ASAS Development Process

The ASAS project development team managed by Durban-based CNS Systems company and together with GNSS experts and foreign systems contractors are conducting research and studies on operational network performance requirements. All project paricipants and partners are introducing new algorithms to produce highly reliable augmentation information of GNSS signals and designing communication methods to deliver augmentation information from the ground.

Figure 10. ASAS Ground Segments – Source: Ilcev **[4]**

The optimal location of surface resources of ASAS Ground Segment over African Continent and Middle East is shown in **Figure 10**, such as GMS or Reference Stations, GCS or Master Stations and GES or Gateways will be determined as well and the impact that design changes might have to alter equipment performance or location. The TAB team will also be used as a tool to demonstrate the behavior of space-based navigation systems (i.e., satellite orbiting sensors) and to help determination low performance service areas.

The TAB team function is to coordinate and operationalize implementation of CNS technologies in Africa and Middle East, also assist in establishing performance demands for the ASAS and to provide technical data to other teams that will evaluate contractor proposals. Following the contract award, the TAB will need to assist in the transfer of the project to the prime contractors, to provide them with technical advice about the ASAS design with respect to safety and security, to participate in design and to arrange prototype modeling and simulation of the ASAS availability performances.

The African Satellite Test Bed (ASTB), which includes all parties, must be established at first. Followed by a minimum of 55 Ground Monitoring Satiations (GMS) infrastructures over the African Continent and Middle East must be set-up the ASAS ground network. Each GMS terminal needs installation of 3 very precise GPS Reference Receivers (RR) G-II with antenna system of Canadian producer NovAtel. Each RR is costing about 50,000 $, so the total cost of 55 GMS terminals will be about 8.250M $. All GMS cites are getting signals of GNSS data from GPS or GLONASS spacecraft and forwarding them via telecommunication landline or Digital Video Broadcasting-Return Channel via Satellite (DVB-RCS) facilities to the GCS terminals.

In addition, it is necessary to establish minimum 5 Ground Control Station (GCS) centers through terrestrial or space communication networks. Each GCS needs to be provided enough processors with adequate software for correction of GNSS data received from GMS terminals known as an augmentation GPS data. The costs of one GCS cite is about 1M $ depending on hardware and software used for each installation.

Then, the corrected and healthy GNSS data are sent from the GCS to the Ground Uplink System (GUS) or GES. The GES broadcasts them to MES or SES terminals via adequate satellite of the ASAS Space Segment. The GES terminal consists 2 L5 GUS Receivers (Rx) and L1/L5 2 GUS Signal Generators. Each L5 GUS Rx is costing about 90K $ and GUS Signal Generators about 120K $. All 5 GCS and GES have to be located in Senegal, Egypt, Kenya, Saudi Arabia and South Africa. A phased development approach initiated by TAB has to complete the ASAS network including Space and Ground segments and is proposed as follows:

1. Phase 1 (2023–2025) – Will start with initial ASAS commissioned of 55 GMS, 5 GCS uplinks, 5 GES, 1 Operational Control Centre (OCC) and initially with 3 leased GEO satellites. It will enable reliable wide en-route navigation for ships and aircraft, including for raid and rail applications.

2. Phase 2 (2025–2027) – Will finalize full ASAS infrastructures over Africa and Middle East and start with testing the complete ground Network. Redundant coverage of the initial ASAS operational restrictions will be removed. The LSAS with Traffic Control Centres (TCC) ground structures will be deployed at major African seaports and airports.

Precisely surveyed ground stations with multiple GPS receivers and processors will be established, including one or more pseudolites and VHF data link to support non and precise approaches to the seaports and airports. Finally, will be added road and rail TCC and 2nd/3rd civil RF to improve GNSS-1 and GNSS-2 robustness and ICAA.

3. Phase 3 (2027–2030) – Will provide reducing ground-based navaids and finalize the evaluation of ASAS network. Full constellations of GPS or GLONASS and new Galileo and Compass constellations with 2nd and 3rd civil GNSS RF available for ASAS and LSAS have to be modified accordingly to IMO and ICAO recommendations and regulations.

International regulatory bodies in this area shall be involved to ensure adequate standards are observed throughout these phased processes **[2].**

The ASAS network will cover the following 69 countries and governments:

- Comesa Countries (19): Burundi, Comoros, D.R. Congo, Djibouti, Egypt, Eritrea, Ethiopia, Kenya, Libya, Madagascar, Malawi, Mozambique, Rwanda, Seychelles, Sudan, Swaziland, Uganda, Zambia and Zimbabwe.

- Other African Countries (35): Algeria, Angola, Benin, Botswana, Burundi, Burkina Faso, Gambia, Cameroon, Cape Verde, Central African Republic, Chad, Gabon, Ghana, Guinea, Guinea-Bissau, Ivory Coast, Liberia, Mali, Mauritania, Mauritius, Morocco, Namibia, Niger, Nigeria, Republic of the Congo, Reunion, Sao Tome and Principe, Saharawi, Senegal, Seychelles, Sierra Leone, Somalia, South Africa, Tunisia and Western Sahara.

- Middle East Countries (15): Bahrain, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Oman, Palestine, Qatar, Saudi Arabia, Syria, Turkey, United Arab Emirates (UAE) and Yemen.

The total cost of ASAS project is about 150M $ what is double less than the European project EGNOS. By the way the cost of so call EGNOS extension for Africa without Ground network is about 70M Euro, what it is not good solution for Africa and what is not providing CNS solutions and safety and security especially for MTC and ATC. The cost of ASAS project for each country in the Region can be done by dividing the total cost of ASAS project with 69 countries, what is about 2M $ per country. Thus, investors in the ASAS project can sell for about 3M $ access to ASAS network and service to each country in the Region **[1, 9, 14, 15].**

3. Configuration of ASAS Network

The future ASAS network as RSAS for Africa and Middle East will be a part of GSAS and integrated with the existing networks of US WAAS, European EGNOS and Japanese MAAS. As stated earlier, in the GSAS integration will be also included RSAS in development phase such as: Russian SDCM, Chinese SNAS and Indian GAGAN.

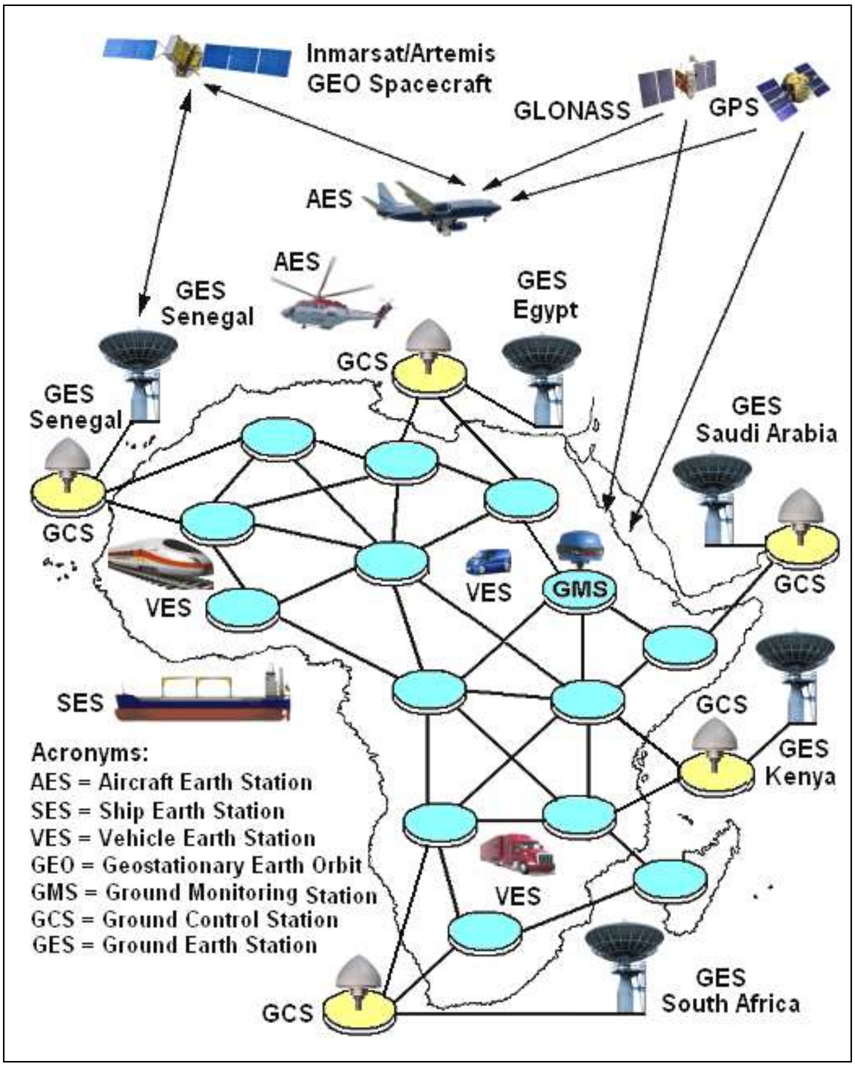

Figure 11. ASAS Space and Ground Segments – Source: Ilcev **[1]**

The ASAS network will cover the entire African Continent and Middle East and will provide new CNS solutions for 54 countries on the Continent and 15 countries in the Middle East. With the availability of new tools of satellite surveillance that have been developed as part of GSAS combined with surface radars, to help ground controllers move more vessels, land vehicles and aircraft safety through the Transportation Augmentation System (TAS) of ASAS Space and Ground Segment shown in **Figure 11.**

By using GNSS-1 chain, the new ASAS network it is estimated that this will improve the GPS or GLONASS satellite signal accuracy from about 30 meters to approximately 1-3 meters. In comparison, the US WAAS system provides 1-2 meters horizontal accuracy and 2-3 meters vertical accuracy throughout the US territory.

Designed and implemented as a primary means of satellite CNS the ASAS solution will facilitate control of airports approaching and management of all aircrafts and vehicle movements on airports surface, and will be principle in supporting the following services:

1) The constant transmission of integrity and health information on each GPS or GLONASS satellite in real time to ensure all mobile users do not use faulty satellites for navigation, known as the GNSS Integrity Channel (GIC).

2) The continuous transmission of satellite ranging signals in addition to the GIC service, to supplement GPS, thereby increasing GPS signal availability. In such a way, increased signal availability also translates into an increase in Receiver Autonomous Integrity Monitoring (RAIM) availability, which is known as Ranging GIC (RGIC).

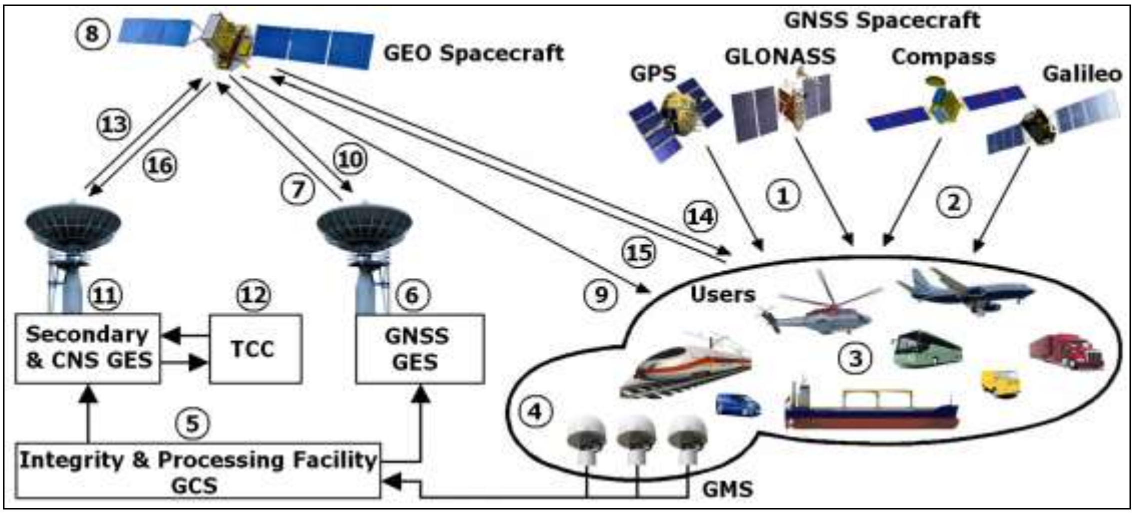

Figure 12. ASAS Architecture of the CNS Network Configuration – Source: Ilcev **[1]**

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 Inmarsat overlay services and Artemis spacecraft supported by the US GPS and Russian GLONASS will be referred to as the ASAS network illustrated in **Figure 12.**
As observed this figure, all mobile users **(3)** receive navigation signals **(1)** from GPS or GLONASS satellites. In the near future can be used GNSS-2 signals of Galileo and Compass satellites. These signals are also received by all reference GMS terminals located within CNS area of integrity monitoring networks **(4)** operated by governmental agencies in many countries within GSAS network. 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)**. Then at the GES, the navigation signals are precisely synchronized to a reference time and modulated with the GIC message data and WADGNSS corrections. The augmented signals are sent to a satellite on the C-band uplink **(7)** via any GEO spacecraft such as MTSAT, Inmarsat, Artemis and others **(8)**, they 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 a GPS ranging signal.
The Secondary GNSS GES can be installed in Communication CNS GES **(11)**, as a hot standby station in the event of failure at the Primary GNSS GES. The Traffic Control Centre (TCC) terminals **(12)** could send request to all particular mobiles for providing CNS information by Voice or Data, including Voice over IP (VoIP) and Voice, Data and Video over IP (VDVoIP) on C-band uplink **(13)** via GEO Communication payload and on C-band downlink **(14)** to GPS or GLONASS Receivers (Rx) of mobile users **(3)**. The mobile users are able to send augmented CNS data on L-band uplink to TCC **(15)** via the same spacecraft and L-band downlink **(16)**. The TCC sites are processing CNS data received from mobile users by Host and displaying on the screen, similar to the radar display, their current positions very accurate and in the real time.
The ASAS or any RSAS constellation could be formally consisted in the 24 operational GPS and 24 GLONASS satellites and minimum of 3 GEO satellites for each of 4 regions worldwide, and will be used as a primary means of navigation during all phases of motion for all mobile applications at sea, on the ground and in the air. The GEO satellites downlink the data to the users on the GPS L1 and new L5 RF with a modulation similar to that used by GPS. Information in the navigational message, when processed by an ASAS Rx, allows the GEO satellites to be used as additional GPS-like satellites, thus increasing the availability of the satellite constellation. At this point, the ASAS signal resembles a GPS signal origination from the Gold Code family of 1023 possible codes (19 signals from PRN 120-138) **[1, 16, 17, 18].**

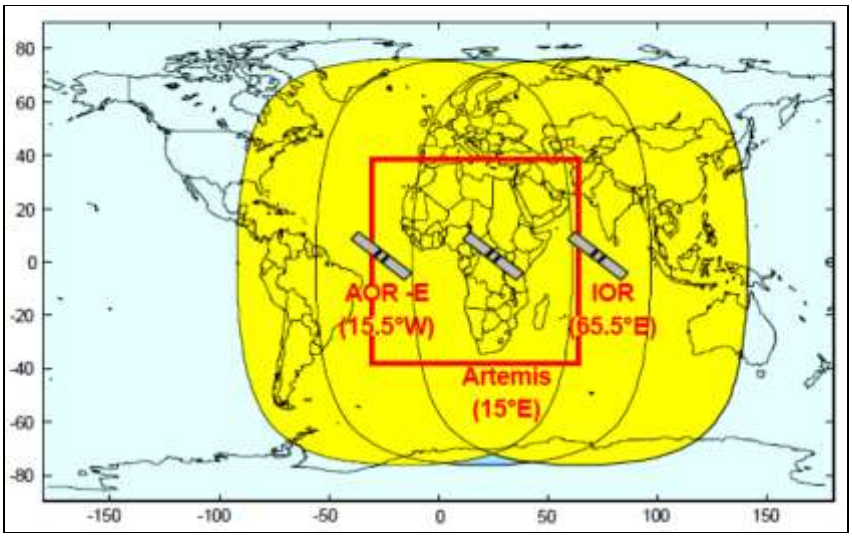

Figure 13. Coverage of ASAS Space Segment – Source: Ilcev **[1]**

4. ASAS Space Segment

The ASAS Space Segment can be designed by using own project of GEO satellite constellation, what can be in next stage, or by leasing existing GEO Inmarsat-3 and Artemis spacecraft. The European EGNOS network is using the same satellites in lease, although is pronouncing that these three spacecraft belongs to them? The operational system can use 3 GEO satellites: Inmarsat-3 AORE at 15.5ºW; Inmarsat-3 IOR at position 64ºE, and ESA Artemis at 21.5ºE over equator, illustrated in **Figure 13**. In this figure is indicated global coverage of three spacecraft and coverage of ASAS service inside red square.

The navigation payloads is broadcasting a data message uploaded via satellite to all users in the GEO broadcast area of the satellites over entire African Continent and the Middle East region. Same as EGNOS, the ASAS can use service of existing Monitoring and Ranging Stations (MRS) sites and to implement a wide triangular observation base for ranging purposes with the ground stations located in Aussaguel (France), Kourou (French Guiana) and Hartebeeshoeck (South Africa).

In general, navigation payloads of GEO spacecraft for GNSS augmentation systems must fulfill 2 key roles, as follows:

1) Transmission of a spread-spectrum timing and ranging signal on 1 or 2 navigation L-band RF;

2) Relay in near-real-time of data originated on the ground and for use in user Rx to improve performance (reliability, accuracy) with GPS and GLONASS signals.

As mentioned earlier, GEO is able to augment the performances of GPS and GLONASS by providing a separate ranging channel to transmit integrity and correction data. This concept dates back to the late eighties and has evolved to its current form known as RSAS. In this sense, RSAS data will allow GNSS to meet the stringent reliability, availability and integrity requirements set by STC and ATC. Land users will also be able to improve in positioning accuracy by VTC for road and railway applications.

In response to improve this need, Inmarsat got a new navigation transponder to support RSAS functions on its last generation of GEO Inmarsat-4 at the beginning of 2005, which is developed to provide new broadband services and which can be used for ASAS space segment as well. Throughout the evolution of the RSAS concept, Inmarsat played an active role in GNSS. In November 1990, it decided to include navigation transponders on its third generation of GEO satellites, Inmarsat-3, developed to provide the space capacity needed by WAAS and EGNOS. Inmarsat-3 satellites alone, however, do not give sufficiently redundant coverage for EGNOS and WAAS systems to offer operational services throughout their respective service areas. In fact, new Inmarsat-5 GEO constellation will be ready soon to assure a proper replenishment policy when the current Inmarsat-4 birds terminate their operational life.

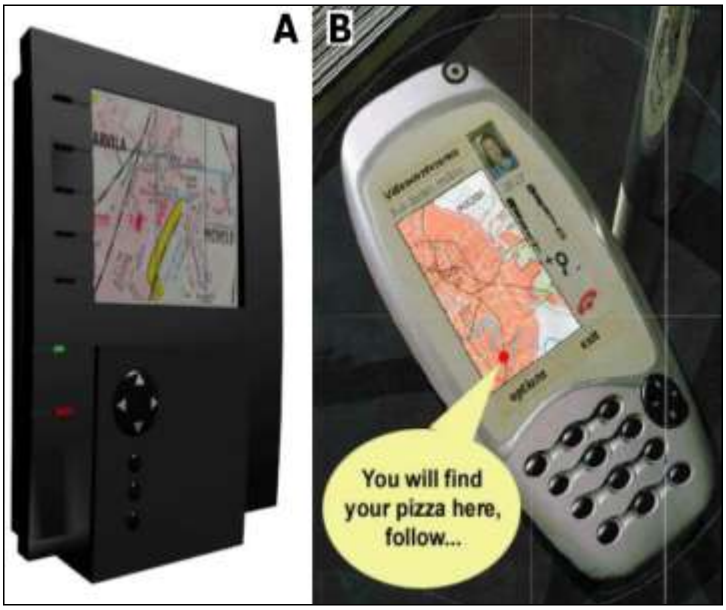

Figure 14. RSAS Receivers – Source: EGNOS **[5]**

The Inmarsat-4 satellite navigation payload is a dual-channel bent-pipe transponder that converts two C-band (C1 and C5) uplink signals from one GES to two downlink signals in two separate bands. In such a way, Inmarsat designed its Inmarsat-4 navigation transponder to be, as far as possible, backward compatible with the existing RSAS and suitable for the future RSAS projects.
However, the satellite communication design had to respect the technical constraints imposed by the Inmarsat-4 space segment primary communications mission. In the proper manner, the Inmarsat-4 navigation payload will transmit satellite navigation signals at the GPS L1 and L5 frequencies and allow the real-time relay from a single ground-monitoring network of integrity and accuracy augmentation data for orbiting GNSS constellation.
In the meantime, the US government made a commitment to support civil applications of GPS including the modification of future generations of spacecraft to meet civil requirements. Thus, the GPS modernization initiatives will make two new civil signals available: a second signal at 1227.60 MHz (L2) and a third civil signal at 1176.45 MHz (L5) RF. Moreover, in 2004 FAA expressed its intention to have the L5 signal also available on GPS augmentation satellites planed to be launched in 2005 for civil aviation safety-of-life and security services and other precision positioning and navigation applications.
The L1 at 1575.42 MHz and L5 downlink signals can be received in integrated L1/L5 GPS/RSAS Receiver (Rx), which can be on disposal of future ASAS users as well. At this point, the multimodal prototypes of GNSS Rx will enable users to carry out few tests on the ASAS system: static and/or dynamic platform testing; user ASAS Rx validation and system performance demonstration comparison with reference position: geodetic marks (static), trajectography data (dynamic), such as the model of EGNOS Rx prototype depicted in **Figure 14 (A)**.
The ASAS Standard Rx will be also developed to verify the Signal-In-Space (SIS) performance. In the meantime a set of GPS/GLONASS Rx equipment has been manufactured for civilian maritime, land and aeronautical applications. This equipment can be used in the future to validate and eventually certify ASAS for the different applications being considered. In addition, a handheld personal receiver (like a cell phone) would use satellite navigation to avoid traffic jams in city centers, find the nearest free parking space, or even the nearest pizza restaurant in an unfamiliar city, as shown in the Personal-Nav 400 in **Figure 14 (B)**.
Precise position via the Internet and ASAS system will be possible anytime after completing and testing the ASAS network, thanks to the SIS technology developed by the ESA. This technology combines the powerful capabilities of satellite navigation and the Internet. As a result, the highly accurate navigation information that comes from the ASAS SIS will be available on the Web in real time over the Internet **[5, 9, 12, 18].**

Figure 15. Reference Station with Antenna – Source: NovAtel **[18]**

5. ASAS Ground Segment

The ASAS service will provide corrections of GNSS-1 signals from the 24 GPS and 24 GLONASS orbiting satellites, respectively, which can be in error because of satellite orbit and clock drift or signal delays caused by the atmosphere and ionosphere, or can also be disrupted by jamming. As stated before, the ASAS ground network, shown in **Figure 10**, can be based on minimum 55 GMS or RS spread over entire Africa and Middle East (see red cubes), 5 GCS or MS (see red circles) and 5 GES (see red triangles), covering large areas of the Region and monitors GPS and GLONASS data. The GCS and GES sites will be located in South Africa, Saudi Arabia, Kenya, Egypt and Senegal.

Signals from GPS or GLONASS spacecraft will be received and processed at about 55 GMS, which are distributed throughout the African and Middle East territories and linked to form the ASAS network. In this instance, each of this precisely surveyed monitoring GMS (RS) sites receive GPS signals and determine if any errors exist, while 5 GCS sites collect data from these GMS terminals, assess signal validity, compute all corrections and create the ASAS correction message.

Furthermore, data from the GMS sites are forwarded to the GCS, which process the data to determine the differential corrections and bounds on the residual errors for each monitored satellite and for each Ionospheric Grid Points (IGP). The bounds on the residual errors are used to establish the integrity of the ranging signals. Hence, the corrections and integrity information from the GCS cites are then sent to each GES and unlinked along with the GPS navigation message to the GEO communication satellite. The GEO downlinks this data to the mobile users via the current GPS L1 and new L5 frequency with GPS type modulation.

Thus, the message is broadcasting on the same frequency as GPS to the aircraft augmented GPS receivers that are within the broadcast coverage area of the entire ASAS network. In fact, these three GEO communications satellites also act as an additional navigation (GNSS) constellation providing supplemental signals for aircraft or other mobiles position determination. Each satellite covers a part of the hemisphere, except for both Polar Regions. Otherwise, each ASAS ground-based terminals or subsystem configuration communicates with the terrestrial landline infrastructures. The GMS is a special ground Reference Station (RS) with antenna and adequate equipment located at a precisely surveyed position. The RS terminal is integrated with antenna assembly, shown in **Figure 15 (Left)** and three very precise Reference Receivers (RR) located at a precisely surveyed position, shown in **Figure 15 (Right) [13, 14, 18].**

5.1. Equipment for ASAS Ground Infrastructure

Terrestrial RS terminals are the key equipment of the entire ASAS ground segment. Integrated with GCS and GES sites they together provide complete ground infrastructure in particular for ASAS and in general for RSAS networks.

Figure 16. NovAtel RSAS Ground Equipment – Source: NovAtel [18]

5.1.1. NovAtel Reference Receiver G-II

The specific NovAtel product is WASS RR G-II very precise GPS Rx as a part of each RS or GMS, shown in **Figure 16 (Left)**. Each RS terminal has to be geographically located at well-known position and composed by three NovAtel RR G2 (RRG2) situated in some suitable building.
The RRG2 terminal is designed to provide the GPS or GLONASS monitoring function for the RS terminal and it is precisely surveyed with exactly determined position. In fact, the principle function is to provide GPS or GLONASS outputs that are virtually free from multipath effects to be disturbed as a reference signal over the RSAS GEO downlink. The RRG2 unit also provides data to allow generation of the ionospheric grid and to provide data for use in integrity calculations. A number of significant, customized functions have been designed into these receivers and the most prominent being multipath reduction. This is particularly important for difficult roof installation, such as an ATC Centers, where signal reflections are likely to result in significant multipath effect.
The WASS RRG-II incorporates many years of technical innovation developed for RSAS networks around the world using GPS L1 and L2 frequency band. Thus, this research has resulted in superior protection against RF interference, which is often found in areas with high communication traffic such as air traffic control centers. This includes digital pulse blanking on the L2 signal to mitigate against in-band interference from radar and pulsed DME units. While providing today’s leading edge technology, the RR G-II has the added advantage of expandability for the future. However, with the capability to hold up to 12 Euro form factor cards in three independent receiver sections, the WASS RR G-II is ready to support additional receiver cards for tracking such signals as GPS L5 and L2C, Galileo and GLONASS. As a result, the RR G-II is ready for the future in the world’s wide area reference networks.
This receiver has an LCD monitor on the front panel, which reports version information and status of all receiver cards, the clock status card, the fans and the lock state to the external oscillator. Warnings and errors are also reported on the LCD monitor, which the backlight of the LCD flashing if a fatal error occurs. The antenna, data, external frequency input and 1PPS interfaces are provided on the back panel of the receiver.

5.1.2. Master Control Station (MCS)

Each of the RS (GMS) terminals sends any determined errors of GPS or GLONASS signals through Communication Network to some MCS or GCS, which has to assess signal validity, compute corrections and create the ASAS correction message. Each GCS terminal has processors to process data and determines the differential corrections and bounds on the residual errors for each monitored satellite and for each IGP. However, the bounds on the residual errors are used to establish the integrity of the ranging signals. The corrections and integrity information from the GCS are then sent to one of three GES **[1, 16, 17, 18]**.

5.1.3. Ground Earth Stations (GES)

The GES infrastructure is usually calling the Ground Uplink Subsystem (GUS). Each GUS terminal needs implementation two GUS-Type 1 Receivers per uplink site, introduced in **Figure 16 (Middle)**. In addition, each GUS also needs two GUS-Type Signal Generators per uplink GES terminal, illustrated in **Figure 16 (Right),** with adequate GES large dish antenna system.

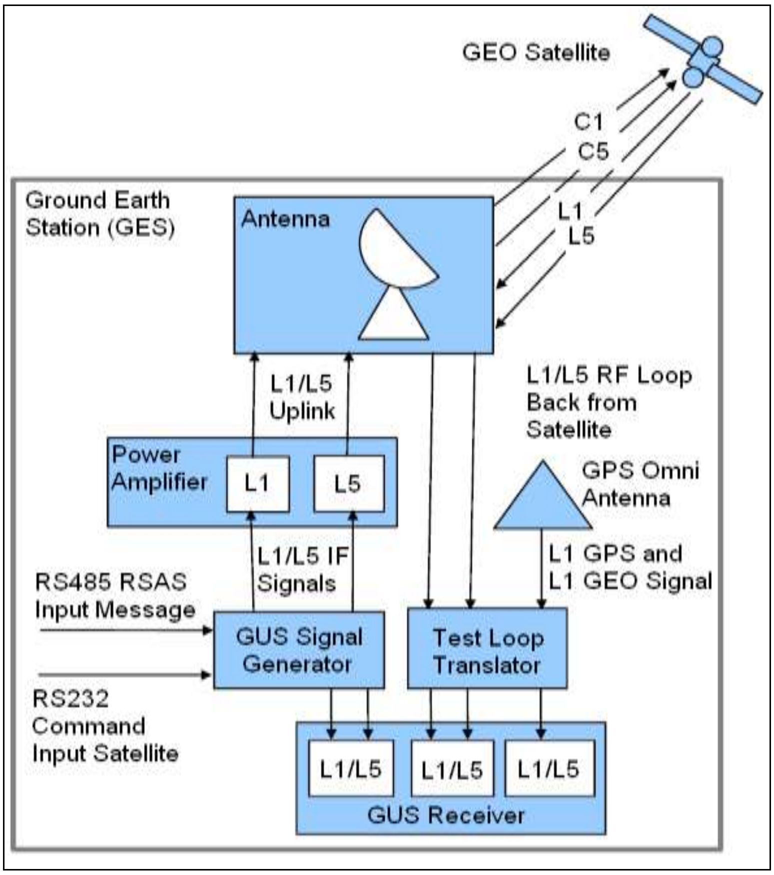

Figure 17. Ground Earth Station (GES) - Source: Ilcev **[1]**

The configuration of GES terminal with antenna system, GUST Receiver/Signal Generator, GPS Receiving segment and all electronic components are shown in **Figure 17.** In **Figure 18** shows all components of one hypothetical RSAS network, such as already stated Reference Station (RS) or GMS, Master Station (MS) or GCS, GES with antenna system and GUST Rx/Signal Generator, GEO Spacecraft and GNSS Links and Operational Control Centre (OCC).

Figure 18. RSAS Ground and Space Segments – Source: Ilcev **[1]**

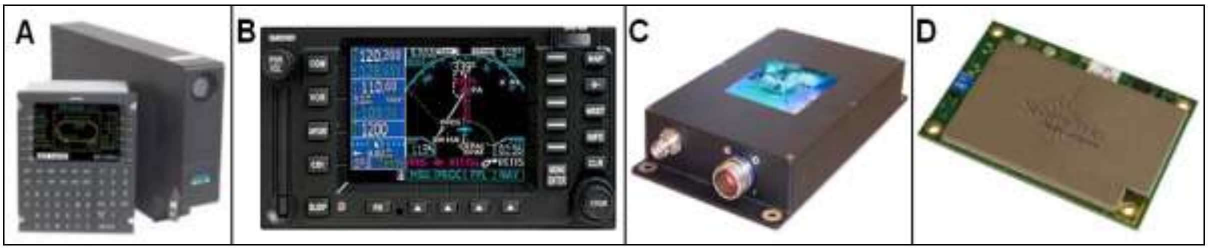

Figure 19. Airborne RSAS Receivers and Sensors – Source: UASC, Garmin and Septentrio **[19, 20, 21]**

The GUST Receiver provides superior tracking of L1 and L5 GEO satellite signals, as well as L1 and L5 GPS or GLONASS signal tracking, which aids in precise system timing. It monitors signals within the GES and provides outputs that are used in the GES control loop. It has three separate L1/L2 and L5 sections, each of which is connected to different parts of the GES signal control system. One section monitors the L1/L5 outputs from the Signal Generator at GES, other monitors downlink signal from the GEO satellite and in the same time monitors down convert C-band uplink signal. One section of the Receiver is connected to an omni antenna and receives standard navigation message from GPS constellation to provide GPS time to the other Receiver sections.
The GUS Signal Generator, shown in **Figure 17**, is a high performance L1 and L5 independent signal generators for use in the ground uplink system of any GPS Augmented system, which precisely control the frequency and phase of L1 and L5 code and carrier. Using Binary Phase Shift Keying (BPSK), the Signal Generator provides two modulated 70 MHz Intermediate Frequency (IF) signals. The Signal Generator generates L1 and L5 signals and combines critical integrity and correction messages that are received from GCS. The enhanced signals are then passed onwards for amplification, frequency conversion and transmission up to the GEO via GES dish antenna. It also generates parallel RF signals that are used for quality monitoring of its primary outputs.

5.2. Ground Communication Network (GCN)

The GCN interfaces all sites of GMS with GCS and GES, which can use the current facilities of terrestrial telecommunication wire and fiber optical lines or if is not possible, will use new satellite DVB-RCS Hub and Fixed (FIT), Portable (PIT) and Mobile Satellite Interactive Terminals (MIT) as a cheapest, easy-to-go and more reliable alternative **[1, 19, 20].**

5.3. Airborne RSAS Equipment

Air navigation systems usually have a moving map display and are often connected to the autopilot for en-route navigation. Cockpit-mounted GNSS receivers and glass cockpits are appearing in general aviation aircraft of all sizes, using technologies such as WAAS or LAAS to increase accuracy. Many of these systems may be certified for instrument flight rules navigation, and some can also be used for final approach and landing operations. Glider pilots use GNSS Flight Recorders to log GNSS data verifying their arrival at turn points in gliding competitions. Flight computers installed in many gliders also use GNSS to compute wind speed aloft, and glide paths to waypoints such as alternate airports or mountain passes, to aid en route decision making for cross-country soaring. As the RSAS signal is now available, RSAS receivers and augmented-related procedures are becoming available. The GPS augmented receivers certified for aviation operations are arriving on the market to be available to avionic and other mobile users. There is possibility to adopt all airborne unaugmented GPS by installing adequate hardware or implementing software. The hectic activity from avionics manufacturers started in late 2002 production of the following examples of RSAS certified receivers:
1. Universal Flight Management System – Universal Avionics Systems Corporation (UASC) is a producer of the advanced navigation systems. In **Figure 19 (A)** is shown new RSAS GPS augmented receiver as new capable Flight Management System, which incorporates an integral GPS WAAS/RSAS receiver. For more information on this product, click on the link below: http://www.uasc.com/special-missions/uns1fw.aspx.

2. Garmin RSAS LPV Receiver GNS 480 – Internal Precision Vertical (IPV) Guidance is RSAS capable avionics GPS augmented receiver, shown in **Figure 19 (B).** This unit will utilize satellite navigation aids for precise lateral and vertical approach guidance, which are similar to ILS operations without the need for ground-based navigation aids of any kind, since avionics certified to Gamma-3 requirements meet the FAA's standards for LPV guidance. The main component of this unit is a 15-channel RAAS Rx that updates the aircraft's position at a rate of five times per second. It provides oceanic-approved IFR GPS/NAV/COM functionality and ILS/VOR capabilities shown on a 3.8-inch (diagonal), 256-color moving-map display. For more information look into Website of Garmin.

3. Garmin RSAS LPV Receiver GNS 480 – FreeFlight Systems introduced the new 1203 GNSSW (Global Navigation Satellite WAAS) Sensor, shown in **Figure 19 (C).** It was the first to certify RAAS for navigation in accordance with ARINC 429 I/O and TSOC145a under the auspices of the FAA's Capstone Project and has shipped more than 12 hundred WAAS sensors to date. This unit features a number of hardware improvements including robust aluminum housing, additional signal filtering and a 37-pin sealed circular connector. Software has been updated to provide more stable operation outside the North American WAAS coverage area making this product a true World Navigation System.

Unlike traditional ground navigation aids, the satellite GPS/RAAS system covers nearly all of the Regional Airspace System. On the other hand, RAAS enhances the ICAA values of basic GPS position information over that available from previous TSO-C129a systems when is in areas of RAAS coverage. In addition, TSO-C145a sensors, including the 1203, and TSO C146a navigators are approved for sole means navigation for remote and oceanic operations. Moreover, the GPS/RAAS networks will make precision lateral and vertical guidance to be possible at thousands of airports and airstrips where no precision landing capability currently exists. In fact, both the 1201 and the new 1203 GNSSW sensors are anticipated to work with the operational and planned RSAS networks when they become available.

Coming next from FreeFlight will be a radar altimeter certified to TSO-C87 and designed for use with Electronic Flight Instrument System (EFIS) cockpits. The new RA 4000, designed for most EFIS systems, is lightweight, easily installed, and equipped with electronic tuning for zeroing the altitude when installed. The RA 4000 will also feature a highly competitive price compared to other certified radar altimeters. Learn more about FreeFlight at ttp://www.freeflightsystems.com.

3. Septentrio AsteRx-m GPS/GLONASS/RSAS Receiver – The AsteRx-m Receiver has benefited from a new RF design and clever power management and as a consequence is now one of the lowest power, high-performance and dual-frequency Receiver around, illustrated in **Figure 19 (D).** Septentrio is poised to move further into its existing machine control, ships/port-container, Altus survey and Galileo specialty programs, along with other niches including avionic solutions. A new venture with Free-Flight will see an L1 + L5 capable GPS/Galileo airborne certified receiver as the receiver engine in next-generation Free-Flight avionics. Septentrio sees this as a first step along the road into not only general aviation, but also potentially into civil transport aviation at some point in the future. For more information on this product deal: www.septenrio.com.

In general, there are three functional classes of WAAS receivers:

1. Class Beta – This Rx generates WAAS position and integrity information but does not have its own navigation function, is used in conjunction with a flight management system.

2. Class Gamma – This Rx is an integrated beta sensor, navigation function, and database that provide a complete, stand-alone WAAS navigation capability. It is the typical panel-mount receiver used by most general aviation aircraft.

3. Class Delta – This Rx provides guidance deviations only to a precision final approach (similar to ILS) and consists of a class beta sensor and navigation processor. The requisite database is typically resident in a flight management system and accessed by the class delta receiver, which includes navigation functions.

Within each functional class, there are four operational classes:

- Class 1: Receivers can be used for oceanic, en route, departure, terminal, and nonprecision approach operations.
- Class 2: Receivers add the ability to fly LNAV/VNAV approach procedures.

- Class 3: Receivers add the ability to fly precision LPV/CAT. I approach procedures.
- Class 4: Receivers provide navigation to a precision final approach and do not support other navigation functions.

At the end it will be necessary to conclude that all modern airborne equipment and more advanced technologies including RSAS Augmented Receivers are not enough without development of innovative SADS airport infrastructures for radar like ATC system. **[1, 19, 20, 21, 22]**.

6. Conclusion

The ASAS GNSS network being proposed by Prof. Ilcev as co-author of this paper will enable new CNS applications that will provide services to mobile sites, such as ocean vessels, land vehicles and airplanes. Hence, the ASAS network has to improve CNS facilities for maritime, land and aeronautical applications across the contiguous Africa and Middle East territories. The high requirements for better ICAA of GNSS (GPS or GLONASS) in this Region will be realized with implementation of multifunctional GEO satellite constellation for CNS applications, GNSS-1 and new coming GNSS-2 determination solutions.

The ASAS project is ready for deployment and implementation as the best RSAS solution for Africa and Middle East. Thus, to provide regularly ASAS project accepted the government of one country in Africa and Middle East has to send an official proposal to ICAO. 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.

The ASAS network solution has the potential to accelerate the availability of ICAA CNS services especially for airports and flying corridors over the Continent and for seaports and coastal navigation around unfriendly African seawaters. As a final result, this essential African project for Africa will boost the transportation industry, increase economic growth and provide job creation in Africa and Middle East, and therefore, should be fully supported.

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