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

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This paper introduces implementation of the new project known as 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 newly designed RSAS networks, it will be integrated in Global Satellite Augmentation System (GSAS) with new Satellite Communication, Navigation and Surveillance (CNS) for improved Ship Traffic Control (STC) and Ship Traffic Management (STM). This System also enhances safety and emergency systems, transport security and control of ocean shipping freight, logistics and the security of the crew and passengers onboard ships and fishing vessels 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 maritime and other mobile applications, which will be integrated with RSAS in the future GSAS network.

KEY WORDS

~ African Satellite Augmentation System (ASAS)
~ Maritime, land & aeronautical applications
~ Satellite Communication, Navigation and Surveillance (CNS)
~ Ship Traffic Control (STC)
~ Global Navigation Satellite System (GNSS)
~ GPS
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1. INTRODUCTION

The current Communication systems for maritime application are combined by conventional Radio (MF, HF and VHF-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 the first generation of GNSS-1 infrastructures, giving positions up 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 maritime applications. Technically GPS or GLONASS GNSS-1 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 obtain in all circumstances their navigation or flight data without the service of new CNS facilities. Apart from the accuracy of GPS or GLONASS, without new CNS it is not possible to provide full TCC in every critical or unusual situation. Furthermore, 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), have recently been 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). These new operational CNS systems comprise the US Wide Area Augmentation System (WAAS), the European Geostationary Navigation Overlay System (EGNOS), and Japanese MTSAT Satellite-based Augmentation System (MSAS), and they are able to provide CNS data from mobiles to the TCC in their RSAS network coverage. However, these three RSAS networks or Satellite-Based Augmentation System (SBAS) have recently become 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.

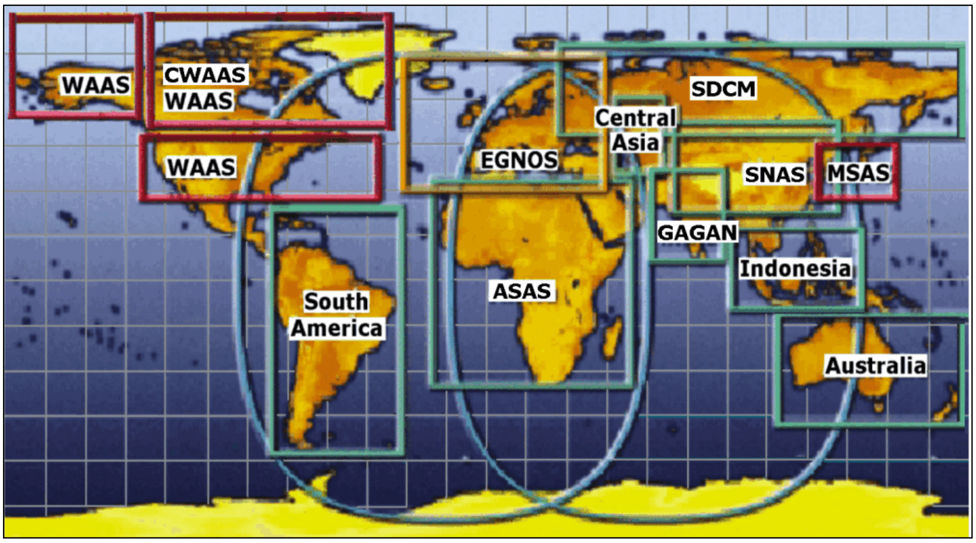

Figure 1. GSAS Network Integration (Source: Ilcev, 2017)

These 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 a 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). (Ilcev, 2017; Prasad & Ruggieri, 2005; Vilardell et al., 2021)

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). There only remains something to be done in South America, Central Asia, Indonesia, and Australia for the establishment of global GSAS, as shown in Figure 1. In Figure 2 operational RSAS are shown, such as: WAAS, EGNOS, MSAS, SDCM, SNAS, and GAGAN, all in the Northern Hemisphere and Africa, whereas the Middle East has a project of ASAS Network as the first in the Southern Hemisphere.

All of the RSAS systems comply with a common global standard and are therefore all compatible, namely they 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 maritime 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 a greater number of dual frequency ranging measurements, so the RSAS systems can also be updated to exploit these new signals. Thereby such updates offer a variety of improvements over the existing single GNSS frequency systems.

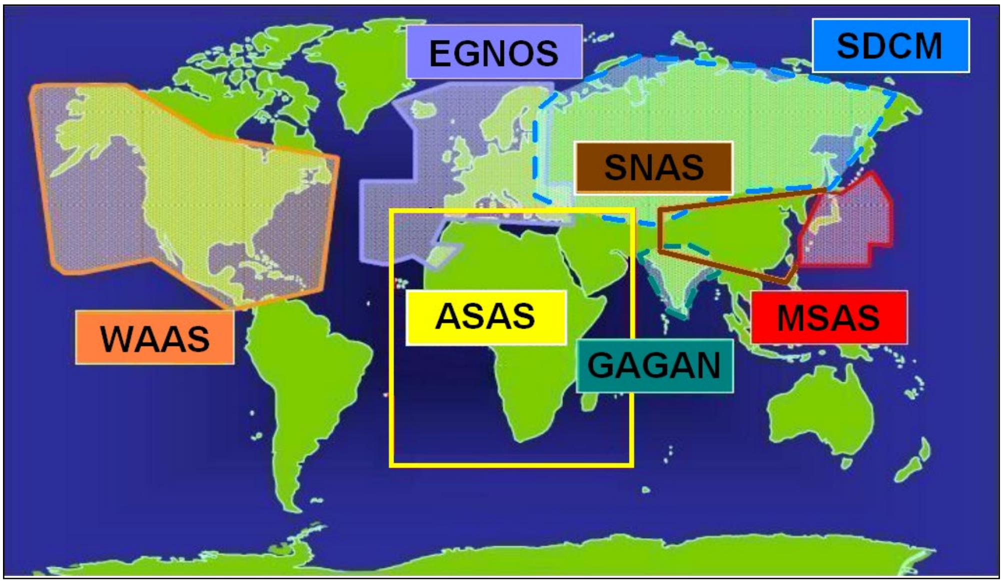

Figure 2. Operational and Projected RSAS Networks (Source: Ilcev, 2019)

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.

Thus, these dual GNSS 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 also be necessary to present the coverage improvement that can be provided by integrating additional constellations into the RSAS network. 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 behaviour 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 behaviour, thereby reliably providing availability to these regions 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 designed 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, Arabian Peninsula and 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 the entire African Continent and the Middle East region. It will be particularly 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, inside of seaports and land vehicles. Last but not least, it will improve LTC and management for aircraft, land road, and railway 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 the 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 a body instrumental 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, as well as the implementation of African Local VHF Augmentation Systems (LVAS). (Ilcev, 2019; EGNOS, 2022; WAAS, 2022; JMA, 2022).

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, including new GEO 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.

However, the ASAS network will provide a similar configuration as the US WAAS, which is currently providing service for aeronautical and pleasure vessels, while the 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 a good potential for creating new businesses and jobs in a wide range of industries.

1.2.1. Maritime Applications

The performance objectives for maritime utilities are generally broken down into open sea, coastal navigation, approaching to anchorages, and inside of harbour 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 harbours will be 8–20 Nm.

Even without ASAS or other RSAS networks, 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.

1.2.2. Land Applications

In general, land vehicles do not need radio navigation as such, but rather radio positioning and tracking. The two main land applications under development worldwide making use of GPS receivers are route optimization and fleet management. Thus, 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.

1.2.3. Aeronautical Applications

The performance objectives for aeronautical applications are usually characterized by four main in-flight parameters: Integrity, Continuity, Accuracy, and Availability (ICAA), whose 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), whose values are as dollows: for en-route 2 Nm/N/A, en-route terminal 0.4 Nm/NA, Initial Approach (IA) and Non-Precision Approach (NPA) 220 m/NA, instrumental approach with Vertical Guidance (IAWVG) 220 m/9.1 m, and category I Precision Approach (PA) 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. (Vilardell, 2021; EGNOS, 2022; WAAS, 2022; JMA, 2022)

1.3. Maritime Communication Subsystem (MCS)

As stated before, the most current communications between ships and traffic controllers are conducted via VHF, HF and MF analogue or digital voice (radiotelephone), data and video RF-bands, known as Maritime Radio Communications (MRC) system, the old system being shown in Figure 3 (Left). The MRC system is offering ships communications on MF, HF and VHF frequency bands via Coast Radio Stations (CRS) to the Ship Traffic Control (STC) and Ship Traffic Management (STM) centres. In some busy portions of the world this system is reaching its limit, the frequency bands are very congested, additional frequencies are not available, and successful radio communication in some weather circumstances depends on luck or the propagation effects, the growth of traffic is reduced to those mobiles that have to be safely handled. In such a way, to improve the communication and traffic control facilities of all ships at sea and in harbours more than 30 years ago civilian Mobile Satellite Communication (MSC) system was implemented, as shown in Figure 3 (Right),which takes less time and can handle more information than MRC system alone. The Maritime MSC (MMSC) system is providing Satellite Voice and Satellite Data Links (SDL) via GEO spacecraft and Coast Earth Station (CES), including new VHF Data Link (VDL) to the Ship Earth Station (SES) and vice versa.

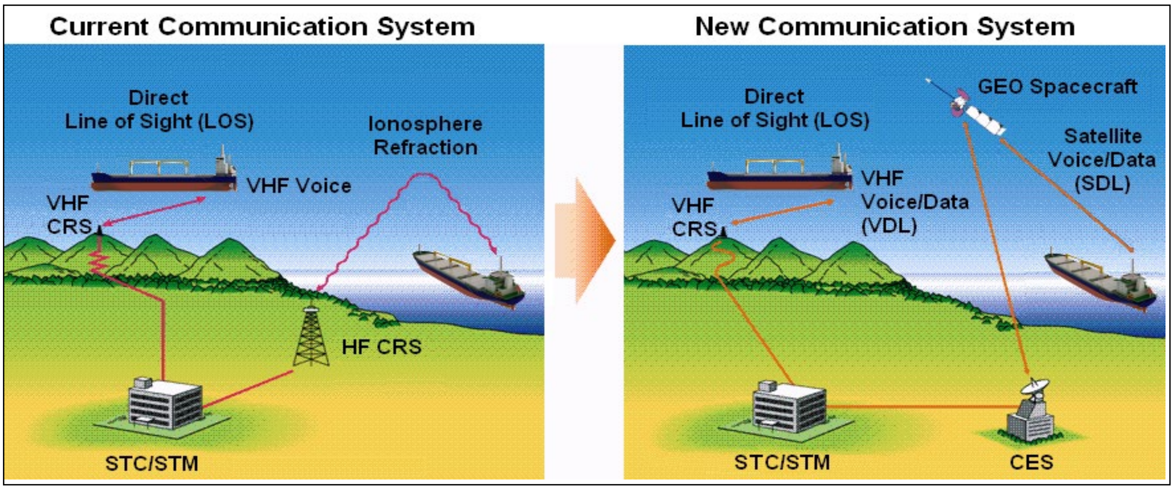

Figure 3. Current and New Communication Networks (Source: Ilcev, 2014.)

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. Figure 4 shows modern Inmarsat MSC Network with Mobile Earth Stations (MES) for maritime, land (road and railways), and aeronautical applications, including 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 the Inmarsat Headquarters in London, while within 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).

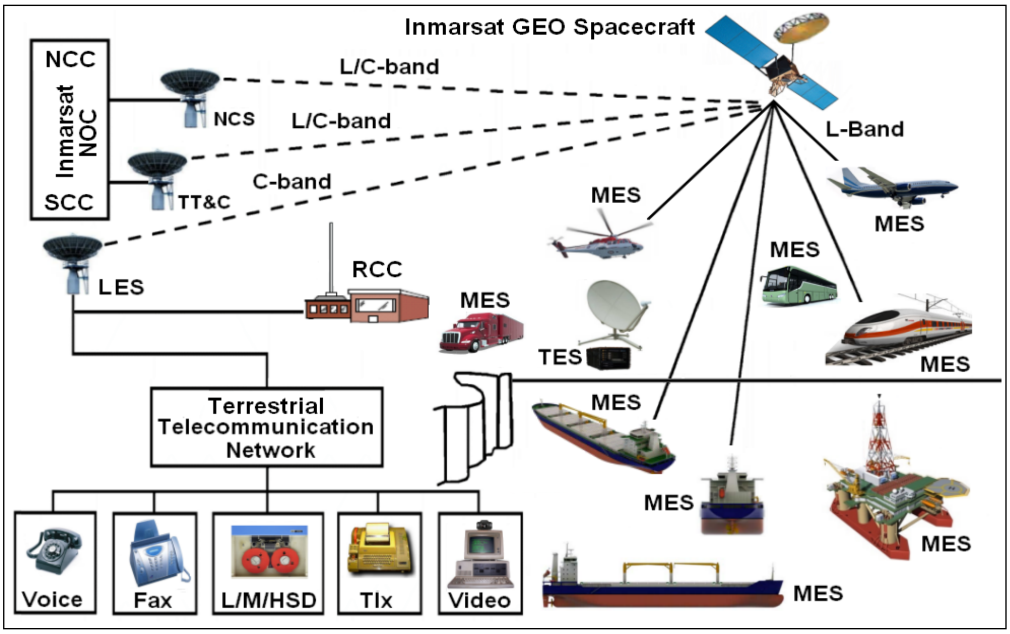

Figure 4. Inmarsat Communication Networks (Source: Ilcev, 2017)

Figure 5 illustrates a Digital Video Broadcasting-Return Channel via Satellite (DVB-RCS) network that can also be used for fixed, portable and mobile satellite communications and connect ground subscribers to 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).

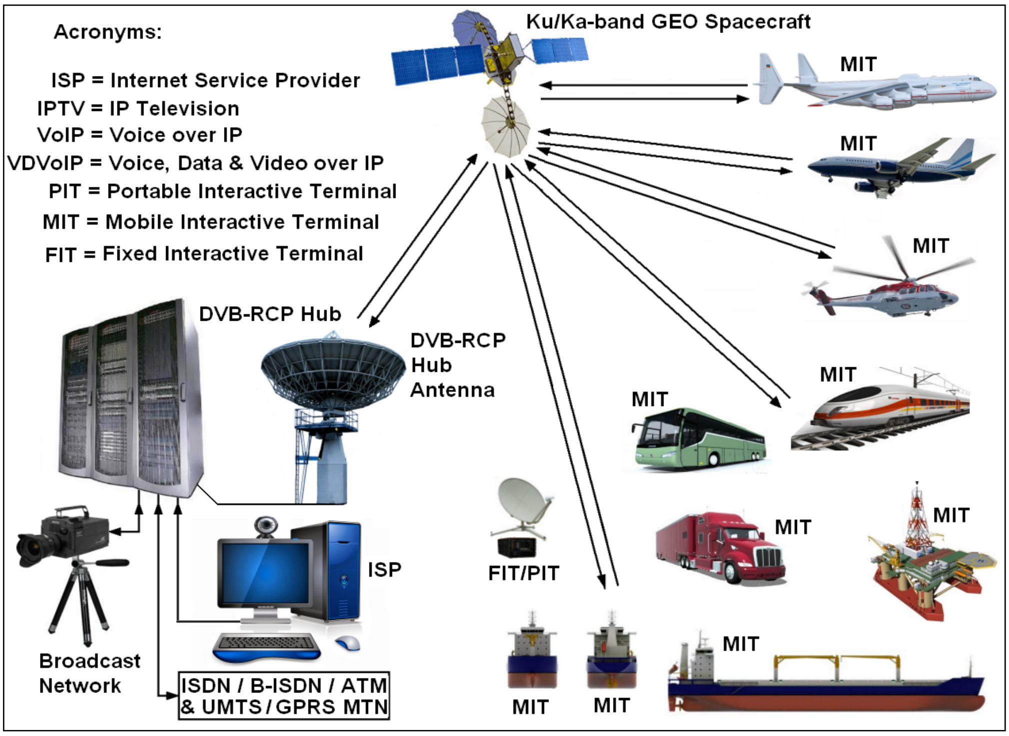

Figure 5. DVB-RCS Communication Networks (Source: Ilcev, 2017)

Both MSC networks are not only designed 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, are dramatically increasing. The size of the Earth requires multiple satellites to be placed in orbit in a constellation to cover areas of interest, typically needing a minimum of 3 to 4 satellites to provide adequate communications coverage.

The commercial and military MCS network is very important for the following reasons:

1. To provide communication links between mobiles and ground infrastructures and between mobiles alone;
2. To transfer augmented and non-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 be used for enhanced navigation and collision avoidance. (Ilcev, 2017; WAAS, 2022; Ghosh, 2022; Ilcev, 2014).

1.4. Maritime Navigation Subsystem (MNS)

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 consist of 24 GNSS1 spacecraft each and ground segment, consisting of Ground Control Station (GCS) and Users Segment, as illustrated in Figure 6. 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, whose modern name is Local VHF Augmentation System (LVAS). On the other hand, RSAS or SBAS networks, integrating GNSS1 infrastructures, have been developed.

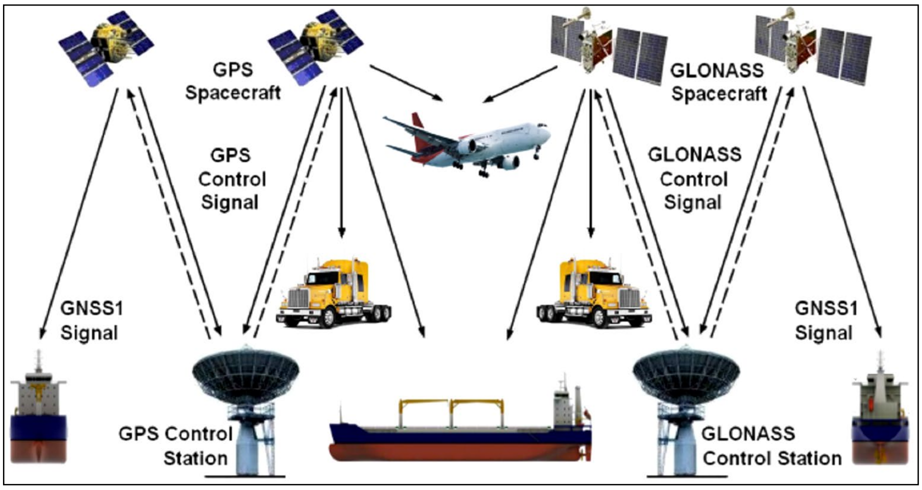

Figure 6. Existing GNSS-1 Networks (Source: Ilcev, 2014)

The MNS network integrated in ASAS or any RSAS infrastructure can also be used for sending and receiving navigation messages via voice or data solutions. When applying satellite navigation systems for ships, there is a case that its performance is insufficient to satisfy the accuracy and availability requirements for provision of ocean sailing, approaching to the coastal infrastructures and berthing inside of harbours. In fact, the ASAS network is a promising solution that enables the secure navigation under the various sea, meteorological and weather conditions, even during 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 CES terminals on the same GNSS frequency bands to the ships (SES) in all stages of sailing.

The current navigation subsystem is using classical VHF radio transceiver onboard ships to send distance and direction data via CRS to STM and STC, and new VHF R-AIS transponder is providing position, distance and direction data, as illustrated in Figure 7 (Left).

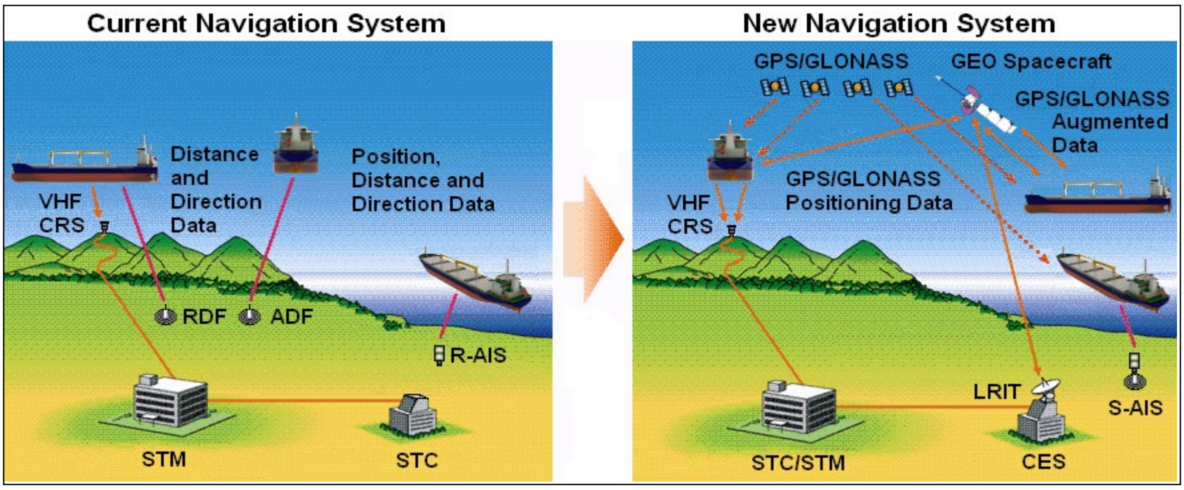

Figure 7. Current and New Navigation Networks (Source: Ilcev, 2014)

In 2002 International Maritime Organization (IMO) adopted Safety of Lives at Sea (SOLAS) Agreement as a mandate that required most vessels over 300 GRT on international voyages to fit a Class A type Automatic Identification System (AIS) transceiver. In fact, this was the first requirement for the use of AIS equipment and affected approximately 100,000 vessels. The AIS device is using VHF-band, so its more adequate name is Radio-AIS (R-AIS). This unit provides unique identification, position, course and speed, which can be displayed on a screen or an Electronic Chart Display & Information System (ECDIS). The R-AIS network is intended to assist a ship's watchstanding officers and allow maritime authorities to track and monitor vessel movements and collision avoidance. The R-AIS device integrates a standardized VHF transceiver with a positioning system, such as an GPS and other electronic navigation sensors, such as a gyrocompass or rate of turn indicator. Thus vessels fitted with R-AIS transceivers and transponders can be tracked by R-AIS base stations located along coast lines.

The new navigation subsystem is employing already developed GPS and GLONASS systems, which provides in real time and space direct not-augmented positioning data. However, both GNSS-1 systems integrated with GEO spacecraft in some RSAS network are able to provide augmented data, as illustrated in Figure 7 (Right). When out of range of terrestrial networks, the S-AIS network can work through a growing number of satellites with ships fitted with special S-AIS receivers, thereby upgrading R-AIS coverage (Ilcev, 2017; Ghosh, 2022; Ilcev, 2014; Xiao et al., 2021).

1.5. Maritime Surveillance Subsystems (MSS)

In a modern MSS network for ASAS infrastructure can be implemented both GEO Inmarsat and DVB-RCS MSC networks, whose infrastructure is shown in Figure 8.

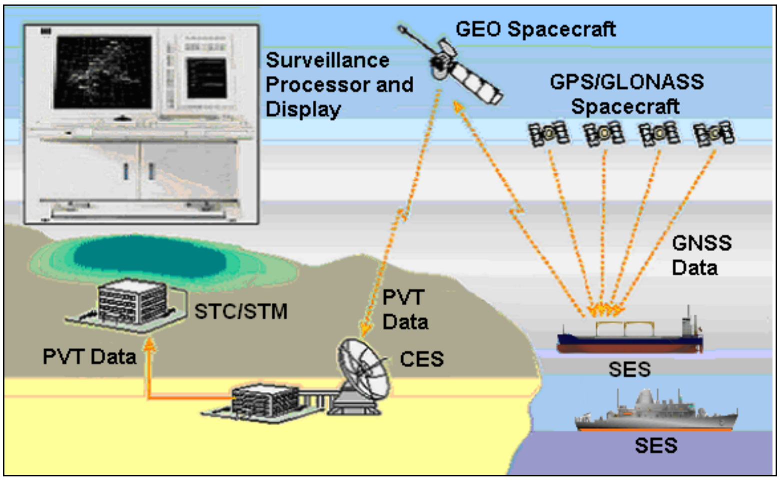

Figure 8. Modern MSS Network (Source: Ilcev, 2014)

The MSS system using Inmarsat system is working in the way that all mobiles in general, or ships in particular, can derive their GNSS data from non-augmented or augmented GNSS-1 (GPS or GLONASS) receiver and send PVT surveillance data and ships ID via GEO satellite communication transponder and CES terminal to the ground SRC/STM infrastructures, which contains surveillance processor and display. In such a way, the PVT data received by the SRC/STM centres are transferred to the main computer processing and displaying of all surveillance information to the controllers on the like radar screen, the diagram of which is shown in Figure 8. In vice versa direction, on request sent by ships captain, the controllers in the SRC/STM TCC stations can send PTV data and ID of all ships in certain area for collision avoidance, especially during very bad weather conditions. Therefore, data reports may be sent from ships regularly, randomly, or in response to a polling command from a shore-based operational centre. This system is using special data reporting and polling communication protocol to obtain PVT data and other information.

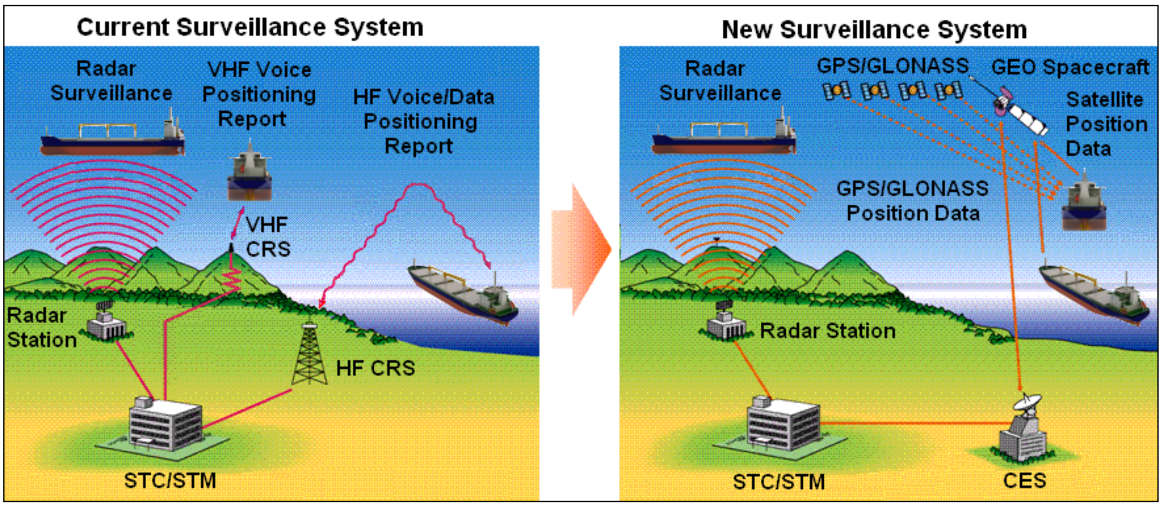

Figure 9. Current and New Surveillance Networks (Source: Ilcev, 2014)

The current surveillance subsystem is providing costal radar surveillance of ships via range of ground radar stations, classical radio VHF voice positioning report via VHF CRS, and HF voice/data positioning report via HF CRS to the STC/STM stations, as shown in Figure 9 (Left). The new surveillance subsystem is also employing costal radar surveillance in the coverage of radar stations, already developed GPS and GLONASS systems for position data and GEO spacecraft to gather satellite position data to the STC/STM stations via CES, as shown in Figure 9 (Right). (Ilcev, 2014; Ilcev, 2013; Yoon et al., 2020; Del Re & Ruggieri, 2008)

2. ASAS DEVELOPMENT PROCESS

The ASAS project development team, managed by Durban-based CNS Systems company foreign systems contractors, are conducting research 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.

The TAB team function is to coordinate and operationalize the implementation of CNS technologies in Africa and Middle East, also to 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 modelling and simulation of the ASAS availability performances.

Figure 10. ASAS Ground Segments (Source: Ilcev, 2019)

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 the ASAS ground network must be set up. Each GMS terminal needs installation of three very precise GPS Reference Receivers (RR) G-II with antenna system of Canadian producer NovAtel. Each RR costs about 50,000 $, so the total cost of 55 GMS terminals will be about 8.250M $. All GMS sites 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 a minimum of five Ground Control Station (GCS) centres through terrestrial or space communication networks. Each GCS needs to be provided with 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 the hardware and software used for each installation.

The optimal location of surface resources of ASAS Ground Segment over the African Continent and Middle East is illustrated in Figure 10. GMS or Reference Stations, GCS or Master Stations and Ground Earth Stations, (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 behaviour of space-based navigation systems (i.e., satellite orbiting sensors) and to help determination low performance service areas.

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 costs about 90K $ and GUS Signal Generators about 120K $. All the five 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, five GCS uplinks, five GES, one Operational Control Centre (OCC), and initially with three leased GEO satellites. The ASAS 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 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, equipped with multiple GPS receivers and processors, will be established, including one or more pseudolites and VHF data link to support quick and precise approaches to the seaports and airports. Finally, road and rail TCC and 2nd/3rd civil RF to improve GNSS-1 and GNSS-2 robustness and ICAA will be added.

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 that adequate standards are observed throughout these phased processes (Prasad & Ruggieri, 2005).

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 $ which is half the price of the European project EGNOS. By the way, the cost of so call EGNOS extension for Africa without Ground network is about 70M Euro, which is not a good solution for Africa and which does not provide CNS solutions, safety and security, especially for MTC and ATC. The cost of ASAS project for each country in the Region can be calculated by dividing the total cost of ASAS project with 69 countries, which is about 2M $ per country. Thus the investors in the ASAS project can sell for about 3M $ access to ASAS network and service to each country in the Region (Ilcev, 2017; Ilcev, 2014; Ilcev, 2020; Grewal et al., 2008).

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 RSAS will also be included in development phase such as: Russian SDCM, Chinese SNAS, and Indian GAGAN.

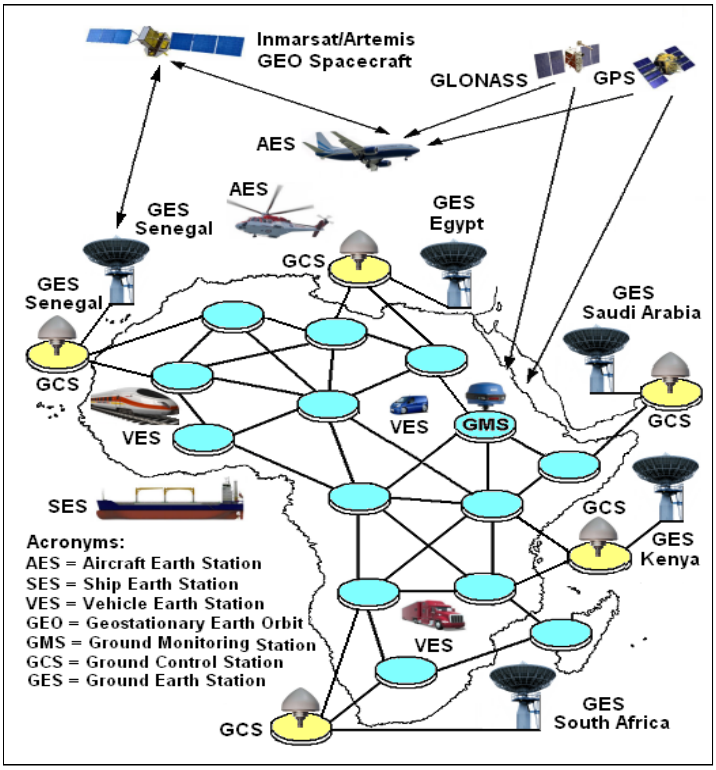

Figure 11. ASAS Space and Ground Segments (Source: Ilcev, 2017)

The ASAS network will cover the entire African Continent and the 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, it will help ground controllers move more vessels, land vehicles, and aircraft safely through the Transportation Augmentation System (TAS) of ASAS Space and Ground Segment, as shown in Figure 11.

By using GNSS-1 chain, the new ASAS network is estimated to 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 indispensable in supporting 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, supplements GPS, thereby increasing GPS signal availability. Thus an 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 is, in addition to the GIC and RGIC services, expected 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, as illustrated in Figure 12.

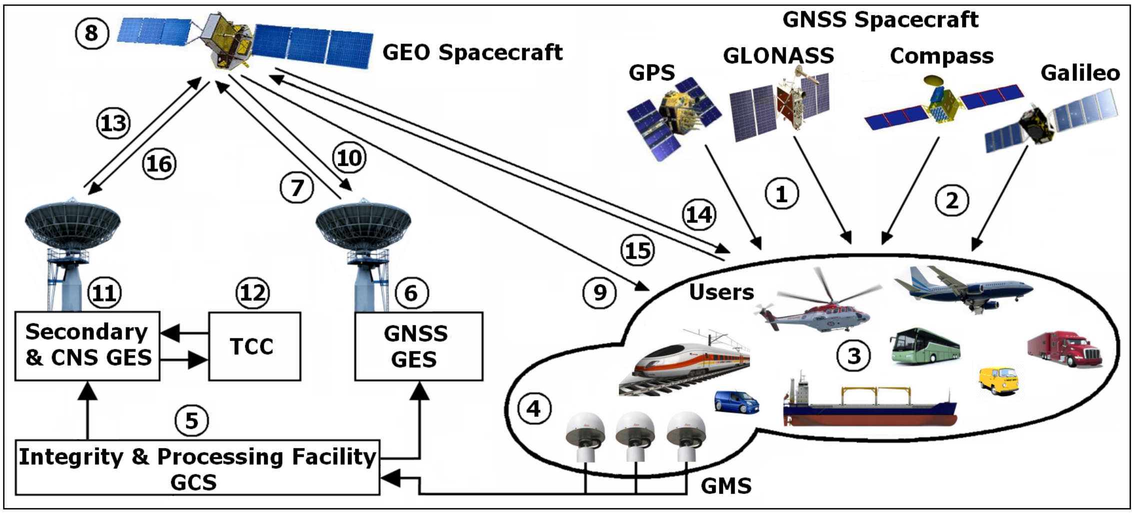

Figure 12. ASAS Architecture of the CNS Network Configuration (Source: Ilcev, 2017)

As is shown in this figure, all mobile users **(3)** receive navigation signals **(1)** from GPS or GLONASS satellites. In the near future GNSS-2 signals of Galileo and Compass satellites can be used. 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 is 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 determined in a very precise manner in order for the signal to 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 requests 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 display it on the screen, similar to the radar display, their current positions obtained very accurately and in real time.

The ASAS or any RSAS constellation could formally consist of 24 operational GPS and 24 GLONASS satellites and a minimum of three GEO satellites for each of the four 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 originating on from the Gold Code family of 1023 possible codes (19 signals from PRN 120-138). (Ilcev, 2017; Diggelen, 2009; Ilcev, 2022; NovAtel, 2022).

4. ASAS SPACE SEGMENT

The ASAS Space Segment can be designed by using its own project of GEO satellite constellation, which can be in the next stage, or by leasing the existing GEO Inmarsat-3 and Artemis spacecraft. The European EGNOS network is using the same satellites in lease, although they claim that these three spacecraft belong 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 the equator, as illustrated in Figure 13. In this figure global coverage of three spacecraft and coverage of ASAS service inside the red square is indicated.

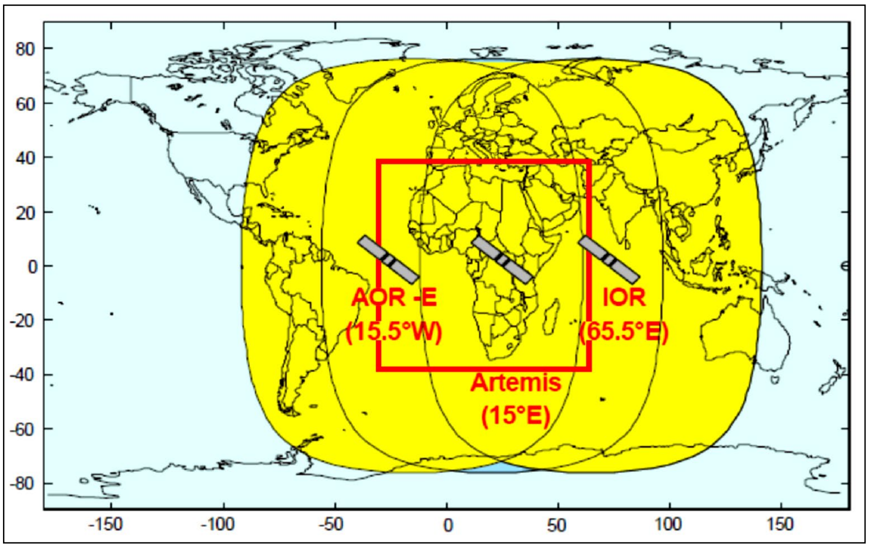

Figure 13. Coverage of ASAS Space Segment (Source: Ilcev, 2017)

The navigation payloads broadcasts a data message uploaded via satellite to all users in the GEO broadcast area of the satellites over the entire African Continent and the Middle East region. Same as EGNOS, the ASAS can use service of the 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 fulfil two key roles:

1) Transmission of a spread-spectrum timing and ranging signal on 1 or 2 navigation L-band RF;
2) Relay in near-real-time the data obtained on the ground and for use in user Rx with a view to improving 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 soon be ready to ensure a proper replenishment policy when the current Inmarsat-4 birds terminate their operational life.

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 at 1575.42 MHz 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 planned to be launched in 2005 for civil aviation safety-of-life and security services and other precision positioning and navigation applications.

The L1 and L5 downlink signals can be received in integrated L1/L5 GPS/RSAS Receiver (Rx), which can be at the disposal of future ASAS users as well. At this point, the multimodal prototypes of GNSS Rx will enable users to carry out a 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 shown 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 mobile phone) would use satellite navigation to avoid traffic jams in city centres, 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).

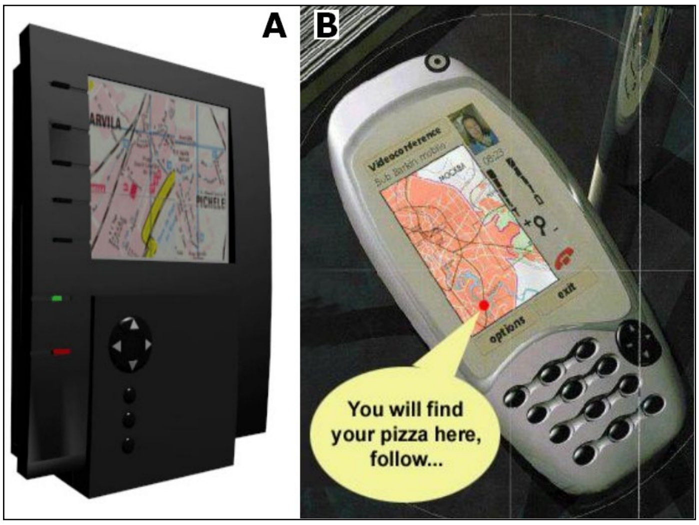

Figure 14. RSAS Receivers (Source: EGNOS, 2022)

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. (EGNOS, 2022; Ilcev, 2014; Yoon et al., 2020; NovAtel, 2022)

5. ASAS GROUND SEGMENT

The ASAS service will provide corrections of GNSS-1 signals from the 24 GPS and 24 GLONSS 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 the entire Africa and the 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 is 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 Point (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.

Figure 15. Reference Station with Antenna (Source: NovAtel, 2022)

Thus the message is broadcast 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 communication satellites also act as an additional navigation (GNSS) constellation, providing supplementary 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, as shown in Figure 15 (Left), and three very precise Reference Receivers (RR), located at a precisely surveyed position, as shown in Figure 15 (Right). (Ilcev, 2013; Del Re & Ruggieri, 2008; Ilcev, 2020; NovAtel, 2022)

5.1. Equipment for ASAS Ground Infrastructure

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

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, is shown in Figure 16 (Left). Each RS terminal has to be geographically located at a well-known position and composed by three NovAtel RR G2 (RRG2), situated in some suitable building.

Figure 16. NovAtel RSAS Ground Equipment (Source: NovAtel, 2022)

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 principal 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 the most prominent being multipath reduction. This is particularly important for difficult roof installation, such as an ATC Centres, 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 centres. 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, with 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. (Ilcev, 2017; Diggelen, 2009; Ilcev, 2022; NovAtel, 2022)

5.1.3. Ground Earth Stations (GES)

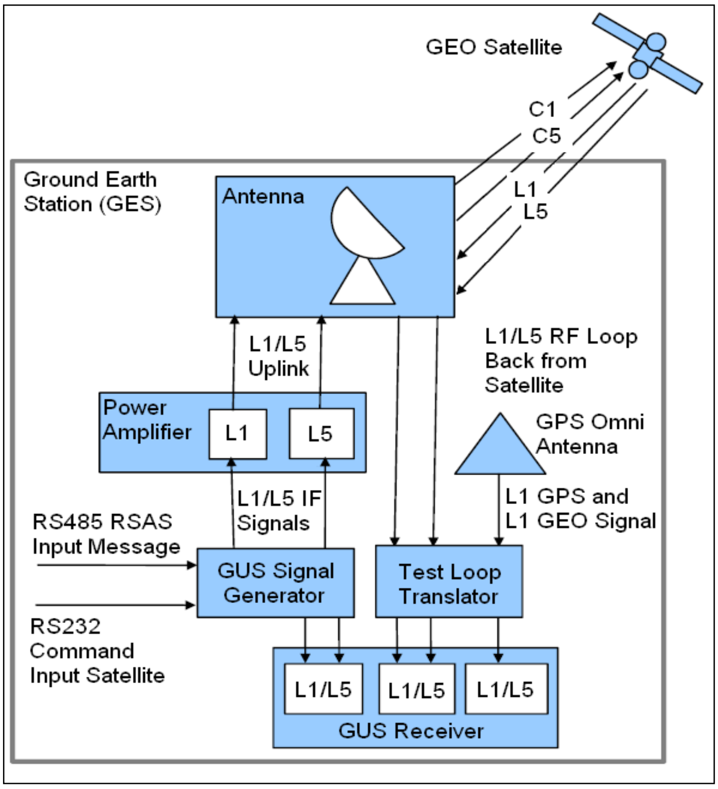

Figure 17. Ground Earth Station (GES) (Source: Ilcev, 2017)

The GES infrastructure is usually calling the Ground Uplink Subsystem (GUS). Each GUS terminal needs the implementation of 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, as illustrated in Figure 16 (Right), fitted with adequate GES large dish antenna system. The configuration of GES terminal with antenna system, GUST Receiver/Signal Generator, GPS Receiving segment and all electronic components are shown in Figure 17. Figure 18 shows all comports of one hypothetical RSAS network, such as the already mentioned 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).

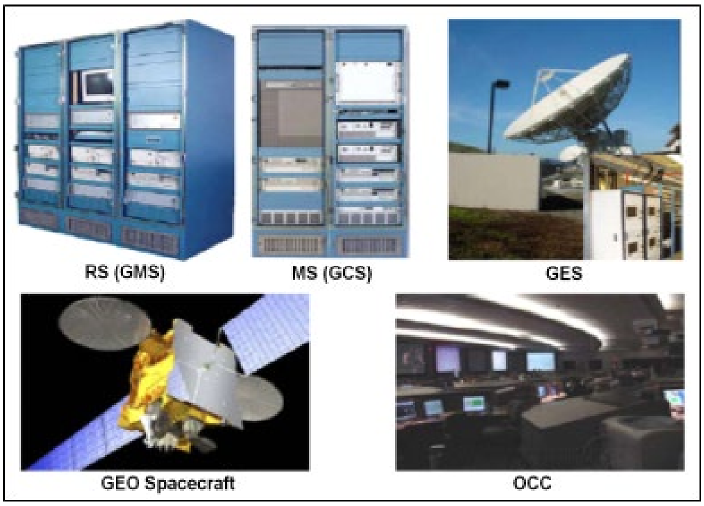

Figure 18. RSAS Ground and Space Segments (Source: Ilcev, 2017)

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. In addition, one section of the Receiver is connected to an omni antenna and receives a standard navigation message from GPS constellation to provide GPS time to the other Receiver sections.

The GUS Signal Generator is a high performance L1 and L5 independent signal generator designed for use in the ground uplink system of any GPS Augmented system, precisely controlling 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.

6. SPACE SEGMENT

The Space Segment of RSAS Network will be integration of 24 GPS and/or 24 GLONASS satellites, which will provide free of charge GNSS Unaugmented signals for RS or GMS terminals. The RSAS Network can provide its own multipurpose GEO spacecraft or will lease Inmarsat, Intelsat, Roscosmos, ISRO or any current GEO satellite constellation, which will serve to uplink Augmented signals from GCS.

7. GROUND SEGMENT

As stated above, mobile GNSS-1 receivers as user segment are represented by the US GPS and Russian GLONASS network developed in the 20th Century, mainly to help military personnel to find their way of self-determination, but civilian applications soon became numerous, rendering both systems more cost effective. Besides, other mobile GNSS-2 as second-generation receivers are represented by the Chinese BeiDou or Compass and EU Galileo. The BeiDou GNSS declared operational for use in China and surrounding areas on 27 December 2011 and the system will provide global coverage by 2020. Galileo system, however, is not yet fully operational, and the question is when that will happen.

8. SHIPBORNE RSAS EQUIPMENT

Ocean going ships and boats can use GNSS to navigate all of the world's lakes, seas and oceans. Maritime GNSS units include functions useful on water, such as “Man Overboard” (MOB); functions that allow instantly marking the location where a person has fallen overboard, which simplifies rescue efforts. In addition, GNSS may be connected to the ships self-steering gear and Chart plotters using the NMEA 0183 interface. The GPS and GLONASS as a part of GNSS-1 can also improve the safety and security deploying Global Ship Tracking (GST), LRIT and security of shipping traffic by enabling AIS. Here will be introduced the following three shipborne RSAS equipment will be introduced.

1. **Raytheon Raymarine Raynav 300 SDGPS** – New Raymarine RayNav 300 Satellite Differential GPS (SDGPS) device, illustrated in Figure 19 (Left), features built-in Wide Area Augmentation System (WAAS) compatible with any RSAS corrections to its 12-channel GPS receiver (Rx), which in general delivers accuracy to within 4.5 meters or about 15 feet. In fact, an easy-to-use marine navigation device, this unit coordinates and interfaces with the onboard system equipment of Raymarine, to provide positioning accurately. The increased GPS WAAS differential signals with the inbuilt receiver of this GPS Rx uses the integrated WAAS system of ground based Reference Stations (GMS) to position all ships accurately up to 2.5m within coverage area across any RSS network.

Figure 19. Mobile Augmented GPS Receivers (Source: Raytheon & Garmin, 2022)

Satellite systems became the delivery mode of choice for navigational information. After early experimentation with the doomed US Sat-Nav or Russian Cicada system (having to wait hours for the next satellite to appear overhead), new GPS and GLONASS were created in the 20th Century to offer highly accurate global satellite positioning system in longitude and latitude, almost anytime and anywhere in the world.

This GNSS equipment features the following characteristics: Built in compact SDGPS navigator and WAAS receivers that provide signals for very high accuracy; Flexible waypoint and route building with Loran system TD input; Live cursor exchange between radar and chart; Up to 1,000 waypoints and up to 20 routes with 50 waypoints each; Choice of orientation modes (Head Up, North Up and Course Up); Intuitive soft key prompts; User configurable SeaTalk Databoxes mode; SmartRoute automatically builds waypoints and routes from previous tracks; and Complete SDGPS Navigator, supplied with active antenna and 10m(33') cable. It also provides alarms for programmable arrival, cross track error, anchor drift, position fix, and data loss warning, countdown timer and alarm clock.

2. **Furuno Marine GPS/WAAS Navigator with Video Plotter** – This equipment is model GP-32 with GPS/WAAS and Video Plotter functions, as shown in Figure 19 (Middle). It is designed to be installed onboard oceangoing ships, fishing boats and pleasure craft. The powerful processor performs high-speed processing of position fixing and augmentation using WAAS correction. It comes with an easy-to-use track plotter that stores up to 1,000 track points. This compact and cost-effective unit offers extremely accurate position fixes. It is accurate to ten meters, and with WAAS mode activated it is accurate to within three meters. The display modes include Plotter, Nav Data, Steering, Highway, Speedometer, and two customizable modes.

The Steering mode provides an intuitive indication of course to steer and Cross Track Error (XTE). The Highway mode is useful when you are heading for your fishing ground or following a series of waypoints along a planned route. The user-friendly design permits easy and straightforward operation with minimum keystrokes. Otherwise, the system has various alarm functions to warn of arrival to or departure from a predefined area (arrival/anchor watch), XTE exceeding a preset limit, Alarm Clock and more.

3**. Koden KGP-913D MKII DGPS** – This is shipborne universal GPS/DGPS Navigator that provides a superior positioning accuracy with RSAS correction, as shown in Figure 19 (Right). This equipment is fully operated with the US WAAS, European EGNOS, Japanese MSAS, Russian SDCM and other operational and projected RSAS networks. With parallel 18-channel RSAS receiver it provides precise and quick positioning at any time, and it has a built-in beacon receiver. In fact, it can be used as high-accuracy differential GPS (DGPS) navigator onboard large commercial vessels, recreation cruisers, fishing vessels, scientific and other types of ships. Full alphanumeric keypad enables ease of use and simple waypoint entry. Common features include auto or manual compensation or magnetic variation, MOB button, alarms for cross track error, waypoint proximity and anchor watch. Thus the Koden KGP-913D MKII has the ability to convert the latitude and longitude display into Decca Lanes of Position (LOP) mode. However, there is also the facility to enter a LOP correction for either the red, green, or purple lanes. It also provides large LCD display with backlight, Position Data Lat/Lon, DECCA conversion with total of 400 stored waypoints can be used to create up to 20 reversible routes. A route may be taken in forward or reverse order and GPS option is also available (KGP-913 MKII). In addition, thanks to a built-in beacon receiver, this device can be used as a high-accuracy differential GPS navigator to track ship history (up to 2,000 points) and course line to the destination is simultaneously displayed. Beacon stations are pre-installed in countries where differential beacons are located (Ilcev, 2017; Raytheon, 2022; Garmin, 2022; Groves, 2018; Lawal, 2021)

9. CONCLUSION

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

The ASAS project is ready for employment and implementation as the best RSAS solution for Africa and Middle East. In order to provide the regular ASAS project, accepted by the government, a country in Africa and the Middle East has to send an official proposal to ICAO. After that the ASAS project has to get an official sponsor for funding and arrange an agreement with prime contractors who will build and test the 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 create jobs in both Africa and the Middle East and therefore should be fully supported.

CONFLICT OF INTEREST

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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