

African Satellite Augmentation System (ASAS) (African SBAS)

Presentation: [I. African Satellite Augmentation System \(ASAS\)](#)

1. ASAS Project - Regional Satellite Augmentation System (RSAS)

The African Satellite Augmentation System (ASAS) project is designed by author of this book together with the team of company CNS Systems (Pty) Ltd based in Durban, South Africa. The ASAS network is de facto RSAS infrastructure for entire African Continent and Middle East. Thus, it is interoperable and compatible with above discussed RSAS networks as integration segments of Global Satellite Augmentation System (GSAS) network. The ASAS network will be identical to the US WAAS as a system and with the same service as EGNOS providing solutions for maritime, land (road, rail and ground) and aeronautical application. The difference of this System is that other RSAS networks are just developed by one government, while ASAS project has to be invested and developed by 54 African countries and 15 from Middle East.

During the past 10 years the European Commission (EC) is providing efforts to develop an extension of EGNOS over Africa and Middle East. At first, sometimes in 2003 EC started plan with South African ATNS for development so called “Mini Project” with Ground Network of 13 RS terminals associated to the EGNOS ground facility. The problem was that EGNOS Testbed couldn’t provide safety and security and would be entirely dependent on the proper operations of the EGNOS system, network and maintenance of the EGNOS MSC, GES terminals and ground communications infrastructure and sometimes of GEO broadcast capacity. Therefore, this project was abandoned in 2007.

Sometimes in 2008, the ESA together with EC and ThalesAlenia is again offering EGNOS extension for Africa and Middle East, what is not acceptable for the following reasons:

- 1.** The EGNOS network has not own Space Segment, but leased two Inmarsat and one Artemis spacecraft, so our ASAS project can lease the same satellites or to build own Space Constellation of Multipurpose GEO spacecraft;
- 2.** Extension of EGNOS will be not our independent system, because the availability of the CNS service would be entirely depend on the proper operations and maintenance of the European Ground Infrastructure;
- 3.** The MCS for the EGNOS are in Europe and some of Remote Monitors in Africa and Middle East have to be connected via VSAT terminals, what will be not enough reliable and practical in case of failure of MS terminals;
- 4.** Changes made to the basic architecture of the EGNOS could have impacts on RS unit, which would represent unplanned and uncontrolled expenses;
- 5.** The extension of EGNOS will be architected for operational purposes only, providing communication facilities and not full CNS service, so will be not deployed with assured availability for Safety and Security, including safety-of-life for all transport applications;
- 6.** The extension of EGNOS cannot perform at APV-I level accuracies with an availability of 100%, because will not deploy enough reference and MCS terminals, but would speculate that communications infrastructure and satellite coverage are significant factors, what will be not enough; and

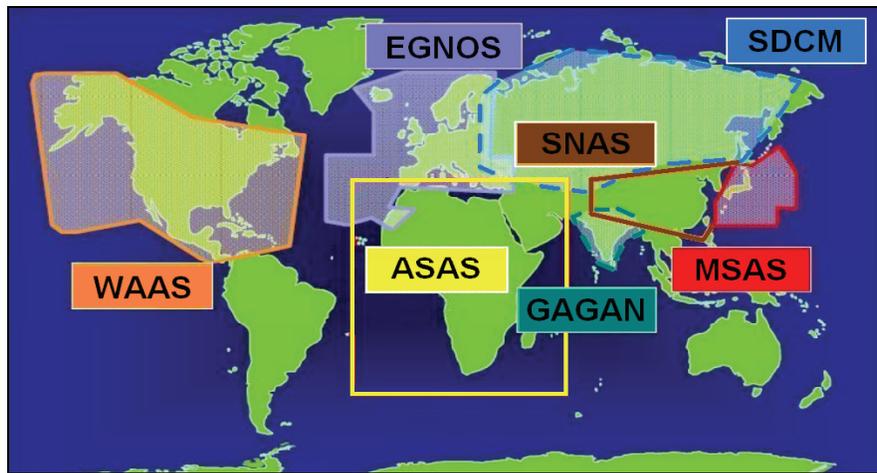


Figure 1. GSAS Network Integration

7. The cost of EGNOS extension will be more than 100M \$, what is not cost effective in comparison with the cost of ASAS project, which will cost 150M \$ in total. Third efforts of EC to provide extension of EGNOS for Southern Africa and South Africa occurred on meeting in April 2011 with South African government. The first question of one delegate from Portugal was: “ How EC can provide extension of EGNOS when still is not covering territory of East Europe”? The EC experts didn’t give real answers, which should be that EGNOS needs additional RS terminals in Eastern Europe countries, and to provide the extension of EGNOS in Africa needs minimum 50 RS terminals.

1.2. Operational and New RSAS Projects

A major goal of International Civil Aviation Organization (ICAO) is the near-universal use of GNSS of the US GPS and Russian GLONASS military systems. It is proposed augmentation of GNSS to provide and enhance Air Traffic Control (ATC) and Air Traffic Management (ATM) for civil air transport safety and security. Beside, International Maritime Organization (IMO) has to provide the similar CNS infrastructure for enhance Ship Traffic Control (STC) and Ship Traffic Management (STM).

In this presentation, the ICAO term Satellite-based Augmentation System (SBAS) will be replaced by Regional Satellite Augmentation System (RSAS) as better convenient nomenclature. The current augmented GNSS-1 infrastructure of GPS and GLONASS systems are platform for development of RSAS networks worldwide with tendency to improve mutual deficiencies and to meet the present transportation civilian requirements for high-operating Integrity, Continuity, Accuracy and Availability (ICAA). The new establishment of GNSS-2 infrastructure available for additional augmentation is already developed Compass or BeiDou by the Chinese authority and Europe also projected Galileo, with big question if this system will be completed at all.

Recently developed and operational RSAS systems are the US Wide Area Augmentation System (WAAS), the European Geostationary Navigation Overlay System (EGNOS) and Japanese MTSAT Satellite-based Augmentation System (MSAS), which provide CNS data from aircraft to ATC and vice versa in their network coverage, which coverages are shown in **Figure 1**. 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 new project of African Satellite Augmentation System (ASAS).

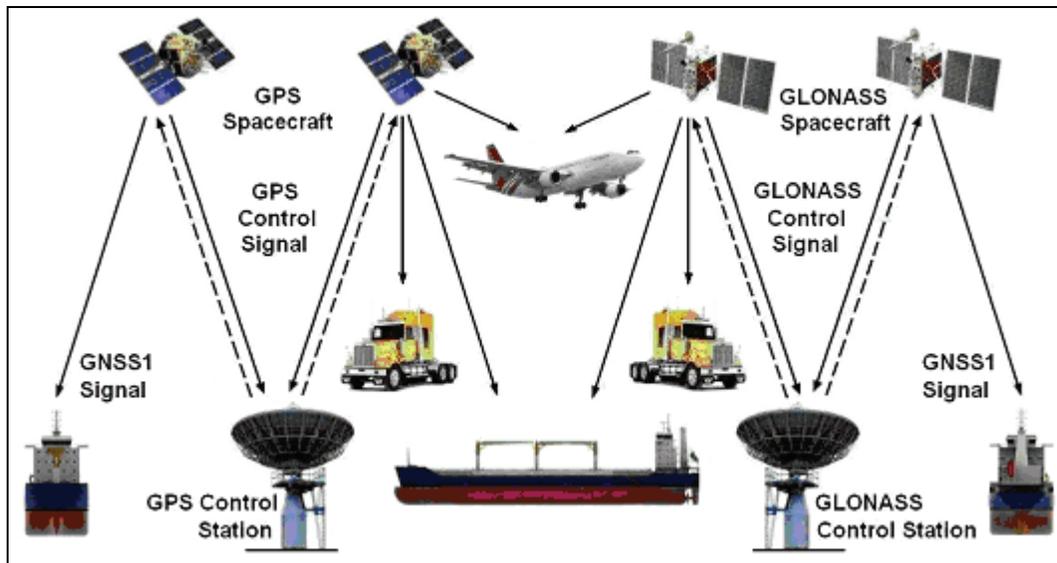


Figure 2. GNSS-1 Infrastructure of GPS and GLONASS Networks

The new RSAS developed projects and in development phase are the Russian System of Differential Correction and Monitoring (SDCM), the Chinese Satellite Navigation Augmentation System (SNAS) and Indian GPS/GLONASS and GEOS Augmented Navigation (GAGAN), including latest project of African Satellite Augmentation System (ASAS), shown in **Figure 1**. Only remain something to be done in South America and Australia for establishment of GSAS.

1.3. Augmentation of GNSS Networks

The integration platforms of ASAS network are GPS and GLONASS space segments, which consist of 24 GNSS1 spacecraft each and ground segment and both consist GPS and GLONASS ground stations and users segment, illustrated in **Figure 2**. The current GNSS network was established and become fully operational in 2009/10. The existing GNSS1 network is a satellite system that determines important PVT data for multimodal use onboard oceangoing ships, ground vehicles (road and railways) and aircraft.

The GNSS network includes user GPS or GLONASS not-augmented receivers, one or more GNSS satellite constellations, ground segments and a control organization with facilities to monitor and control the worldwide conformity of the signals processed by the user GNSS receivers to predetermined operational performance standards. The enhanced future GNSS network will improve, replace or supplement the current systems, which have shortcomings in regard to integrity, availability, control and system life expectancy.

The GNSS augmentation systems are available to enhance standalone GPS or GLONASS satellite PVT performances for maritime, land (road and railways) and aeronautical applications. Moreover, the onboard user devices can be configured to make use of internal sensors for added robustness in the presence of jamming, or to aid in vehicle navigation when the satellite signals are blocked in the “urban canyons” of tall city buildings. Some special applications, such as maritime and especially aeronautical, require far more accuracy than standalone GPS or GLONASS provide.

The new augmented GNSS solutions of GPS and GLONASS are known as RSAS, which provides new service for ASAS network onboard mobiles to use new augmented GPS or GLONASS augmented receivers.

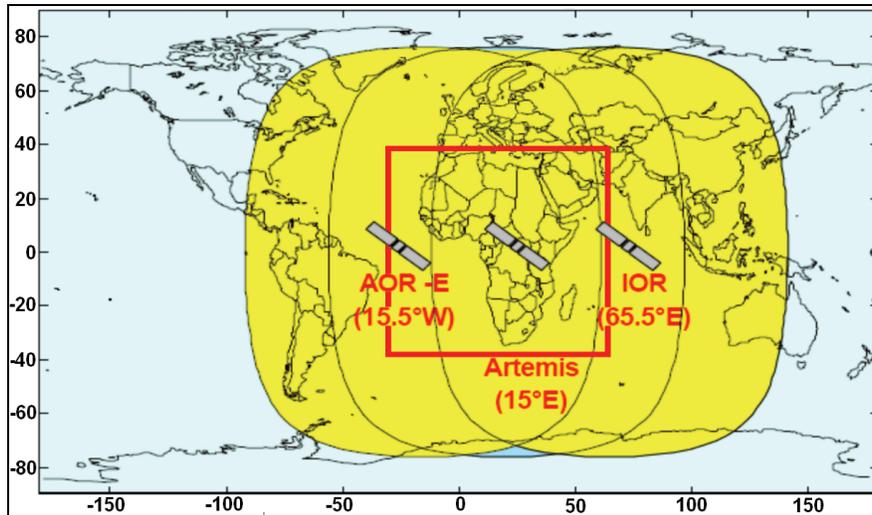


Figure 3. ASAS Space Segment and Leased Satellite Coverage

1.4. ASAS Space and Ground Segments

As stated earlier, the basic GPS and GLONASS service fails to meet the high-operating ICAA requirements that are needed by many civilian mobile users. In order to meet the requirements for better ICAA of GPS or GLONASS over African Continent and Middle East is necessary to design the ASAS network. The ASAS service will improve the ICAA requirements of the basic GPS or GLONASS signals and allows them to be used as a primary means of ships navigation at coastal waters and precision approach to the anchorages, for land applications and for en-route flight of airplanes, PA and NPA in the African and Middle East coverage area.

To start with realization of the project it will be necessary to form Augmentation Standards Service and to establish Transport Augmentation Board (TAB). The TAB team together with CNS Systems, as a designer of ASAS project, will be responsible for providing the leadership role in engineering, realization and coordination the operational implementation of existing and emerging modern satellite CNS technologies into the African Continent and the Middle East region. The TAB team has to be instrumental in the project and development of the criteria, standards and procedures for the use of unaugmented and as well an augmented GNSS signals by the ASAS and LVAS.

The ASAS Space Segment can be designed by using own project of Multipurpose GEO satellite constellation, what is more expensive, but better solution, or by leasing existing GEO Inmarsat-4 and Artemis spacecraft. The operational system can use 3 GEO satellites: Inmarsat-4 AORE at 15.5°W; Inmarsat-4 IOR at position 64°E, and ESA Artemis at 21.5°E over equator, illustrated in **Figure 3**. The navigation payloads on these GEO spacecraft are essentially bent-pipe transponders, so that a data message uploaded to a satellite is broadcast to all users in the GEO broadcast area of the satellite over entire African Continent and the Middle East region. The ASAS network can use service of existing Monitoring and Ranging Station (MRS) infrastructures located in Aussaguel (France), Kourou (French Guiana) and Hartebeeshoeck (South Africa), for monitoring GEO spacecraft and to implement a wide triangular observation base for ranging purposes.

To connect all segments of ASAS infrastructure, such as RS, MCS and GES terminals including airports and aircraft station, the ASAS network can use landline TTN landlines and DVB-RCS solutions.

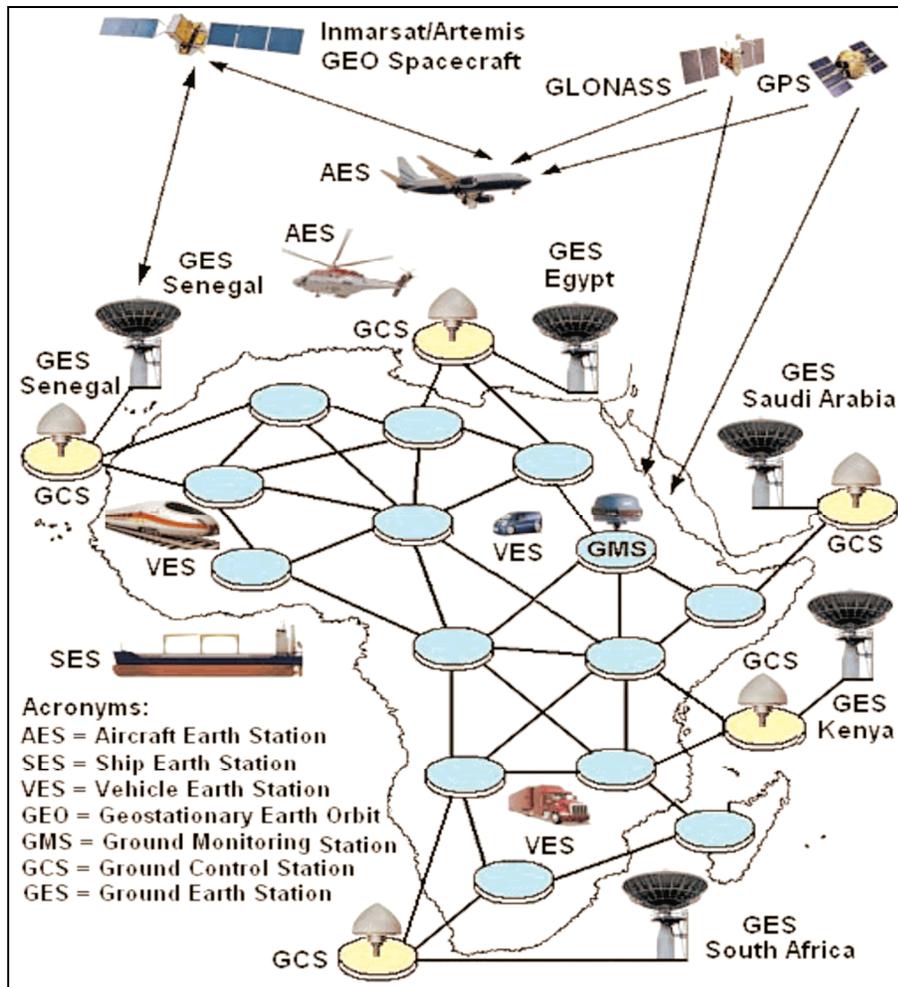


Figure 4. ASAS Ground Segment

The ASAS service is determined to correct GNSS-1 signals from both 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. The ASAS network, illustrated in **Figure 4**, will be based on minimum 55 to 60 GMS sites or RS terminals spread over entire Africa and Middle East, 5 GCS or MCS and 5 GES terminals covering large area and monitors GPS/GLONASS data. The GCS and GES sites will be located in South Africa, Saudi Arabia, Kenya, Egypt and Senegal. In such a manner, signals from GPS are received and processed at 55-60 GMS sites, which are distributed throughout the African/Middle East region and linked to form the ASAS network. In this instance, each of this precisely surveyed monitoring RS receives GPS signals and determines if any errors exist, while 5 GCS collect data from these GMS reference terminals, assess signal validity, compute all corrections and create the ASAS correction message of augmented signal.

Finally, all data received by GCS terminals are properly processed to be determined the differential corrections and bounds on the residual errors for each monitored satellite and for each 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 are then sent to each GES and unlinked along with the GPS/GLONASS navigation message to the GEO communication satellite. The GEO downlinks this data to the users via the current GPS L1 and new L5 Radio Frequency (RF) with GPS type modulation.

1.5. Special CNS Effects of ASAS Infrastructures

Business or corporate shipping and airways companies have used for several decades HF radio communication for long-range voice (telephone) and telex communications during intercontinental sailing and flights. Meanwhile, for short distances mobiles have used the well-known VHF radio communication with Line-of-Sight (LOS) onboard ships and VHF/UHF radio communication onboard aircraft. In addition, data communications are since recently also in use, primarily for travel plan and worldwide weather (WX) and navigation (NX) warning reporting. Apart from data service for cabin crew, cabin voice solutions and passenger telephony have also been developed.

The present mobile Aeronautical Radio Communications (ARC) for general international purposes has to be replaced by GADSS infrastructure integrated with all RSAS networks to enhance cockpit-to-ground and vice versa voice and data traffic or even to employ VDVoIP transmissions, for both commercial and safety purposes. The ARC system uses a current voice and data communication service of HF and VHF/UHF radio. On the other hand, the main type of voice communications above the each FIR is HF (non-DCPC). Over land, VHF voice communications (DCPC) and VHF data link for D-ATIS/AEIS are used. In the similar way, this avionic data link also uses the ACARS configuration and terrestrial communications use analog telephones and the Aeronautical Fixed Telecommunication Network (AFTN).

Mobile users at sea, on the ground and in the air are employing traditional electronic and instrument navigations systems, including GNSS devices and for surveillance facilities are employing radars. Besides, sometimes surveillance radars cannot work properly during very heavy interference caused by deep clouds, therefore for that reason can be used RSAS networks for augmentation of GPS and GLONASS solutions. As stated before, the US has its own Navstar GPS and Russians have GLONASS network as parts of GNSS1 system. On the other hand, China already developed its own BeiDou (Compass) system and Europeans will eventually have Galileo, both as part of new GNSS2 system.

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 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. However, 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.

1. Maritime Applications – The high performance objectives for maritime utilities are generally broken down into open sea, coastal navigation, approaching to anchorages and inside of harbor areas. 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, 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 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, therefore the ASAS project has been set up to identify a possible maritime applications for the GNSS network, which include as follows: navigation, seaport operations, traffic management, casualty analysis, offshore exploration and fisheries.

2. Land Applications – Land road and rail positioning and tracking using service of global GPS or GLONASS receivers for positioning with 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. Thus, 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 shipping companies and 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 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 and CNS solutions.

3. Current and New Maritime CNS Subsystems

3.1. Maritime Communication Subsystem (MCS)

The most current communications between ships and traffic controllers are conducted via VHF (through direct LOS) HF (using the ionospheric refraction) and MF analog or digital voice and data RF-bands, known as Maritime Radio Communications (MRC) network, which current communication system is shown in **Figure 5 (Above Left)**. The MRC system offers ships communications on MF, HF and VHF bands via Coast Radio Stations (CRS) to the Ship Traffic Control (STC) and Ship Traffic Management (STM) centers. In some busy portions of the world this system is reaching its limit, the frequency bands are very congested with significant interference, additional RF are not available, communication in some weather conditions depends on luck of the propagation effects and traffic growth is reduced to those mobiles that have to be safely handled.

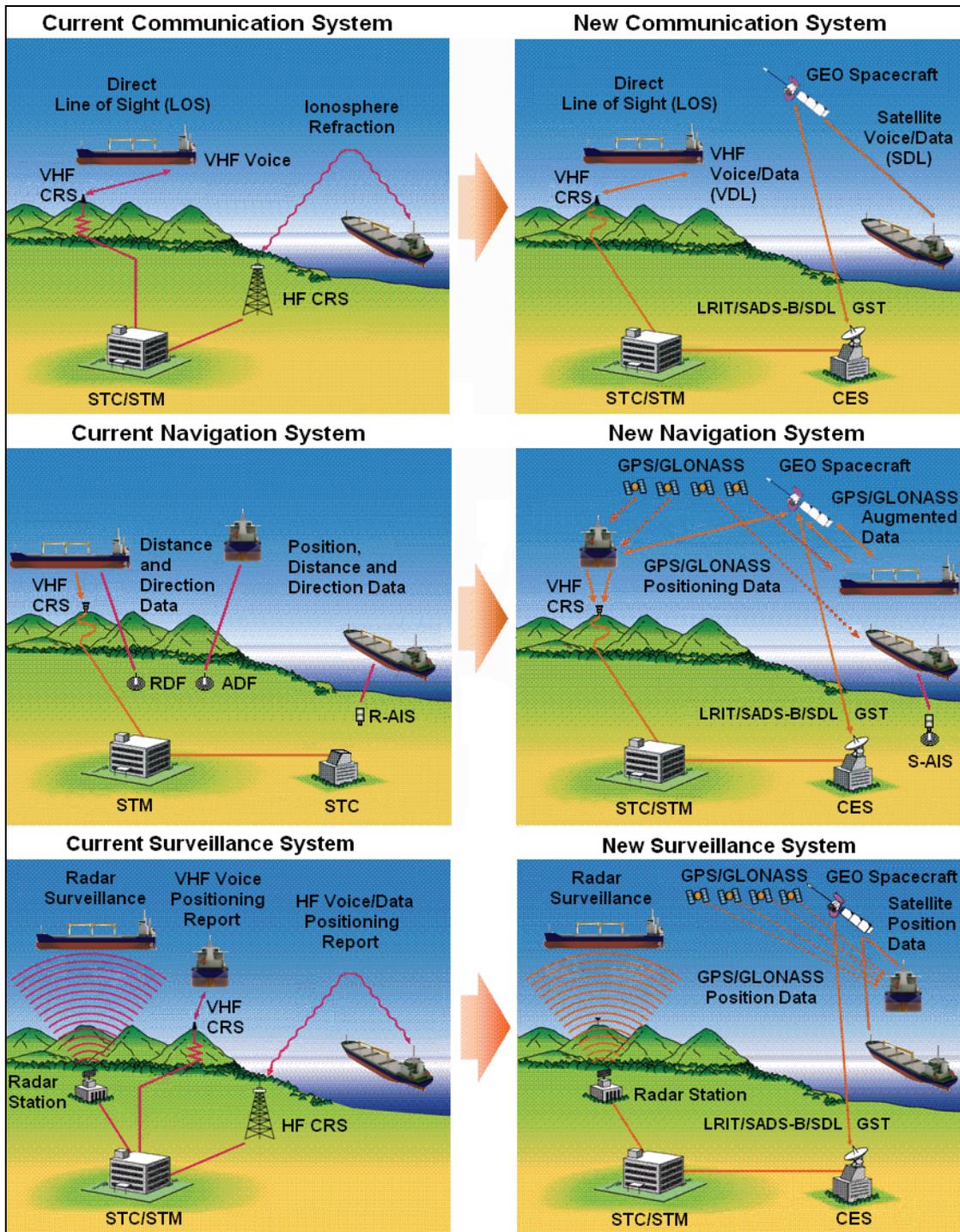


Figure 5. Current and New Maritime CNS/MTM System

The communication and STC facilities are improved with implementation of Mobile Satellite Communication (MSC), which network is shown in **Figure 5 (Above Right)**. The Maritime MSC (MMSC) system is providing Satellite Voice and Satellite Data Links (SDL), Satellite Automatic Dependent Surveillance-Broadcast (SADS-B) and Global Ships Tracking (GST) from Ship Earth Station (SES) via GEO spacecraft and Coast Earth Station (CES). This MMSC system is integrated with new VHF Data Link (VDL) connecting STC with Ship Radio Station (SRS) via CRS and vice versa.

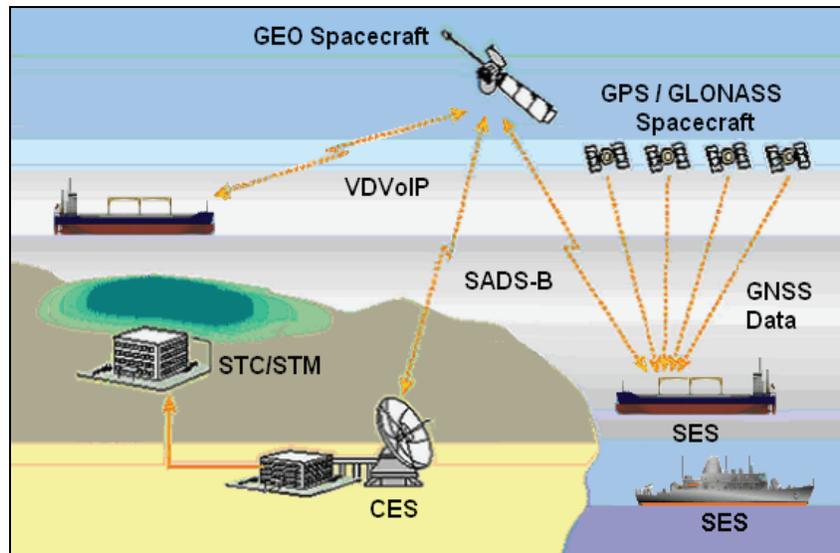


Figure 6. Modern MCS Network

All SES terminals are providing Voice (Phone), Facsimile (Fax), Low/Medium and High Speed Data (L/M/HSD), Telex (Tlx) and Video (Images) via Inmarsat GEO satellites, CES terminals and 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, and Telemetry, Command (TT&C). Otherwise, IGN is linked to Rescue Coordination Centre (RCC).

The Inmarsat MSC system can connect fixed, portable and MCS customers via ISDN, Broadband ISDN (B-ISDN), ATM, UMTS and GPRS. Thus, alongside with Inmarsat MSC system that provides SDL can be also used GEO satellite that provides DVB-RCS service of VDVoIP and SADS-B transmissions system, which modern MMCS network is shown in **Figure 6**. The ASAS or any RSAS is integrating modern MCS with GNSS-1 solutions to provide signals from GPS or GLONASS spacecraft to SES terminals. In opposite way all PVT and other data from GPS or GLONASS receivers onboard ships can be sent by SES terminals manually or automatically to STC/STM via GEO satellites and CES terminals.

Both MSC networks are not designed only to provide more cost effective, redundant and fastest communication links between mobiles and traffic controllers, but also to connect all infrastructures in one hypothetical RSAS network, including ASAS, such as to provide links between GMS and MCS, 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 SES terminals. With the need for increased bandwidth capability, the numbers and sophistication of GEO and Non-GEO communication satellites is increasing dramatically. Thus, the size of the Earth requires multiple satellites to be placed in orbit in a constellation to cover areas of interest, which system typically needs 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 satellite communication links between mobiles and ground infrastructures in general, and between mobiles alone in particular via GEO satellite constellation only;

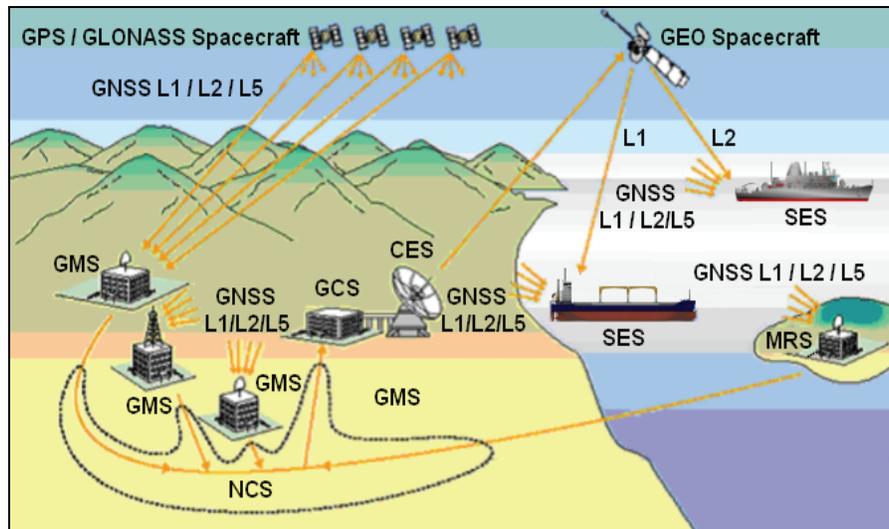


Figure 7. Modern MNS Network

2. To transfer augmented and not-augmented navigation PVT data from mobiles to traffic control centres via GEO satellite communication transponder;
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; and
4. To handle more information and takes less time than MRC system alone.

3.2. Maritime Navigation Subsystem (MNS)

The GNSS1 network is providing positioning 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. There is also Differential GPS (DGPS) developed by the US Coast Guard office, which modern name can be Local VHF Augmentation System (LVAS). On the other hand, there are developed RSAS or SBAS networks integrating and augmenting GNSS1 infrastructures. The MNS network integrated in ASAS or any RSAS infrastructure can be also used for sending only navigation messages via voice or data, which scenario is shown in **Figure 7**. The MNS network with GPS or GLONASS receivers onboard ships are receiving not-augmented GNSS signals and in the same time can receive augmented PVT signals via CES controlled by Network Control Station (NCS). Thus, by applying satellite navigation systems for vessels, there is a case that its performance is insufficient to safety and ICAA requirements for provision of ocean sailing, approaching to the coastal lines, anchorages and berthing inside of harbours. The ASAS network enables the secure navigation under the various 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 via GEO satellites to the ships (SES) in all stages of sailing.

The current navigation subsystem is using classical VHF radio transceiver onboard ships to send PVT, distance, direction and identification data via CRS to STC and STM via new VHF R-AIS transponder, which scenario is illustrated in **Figure 5 (Middle Left)**.

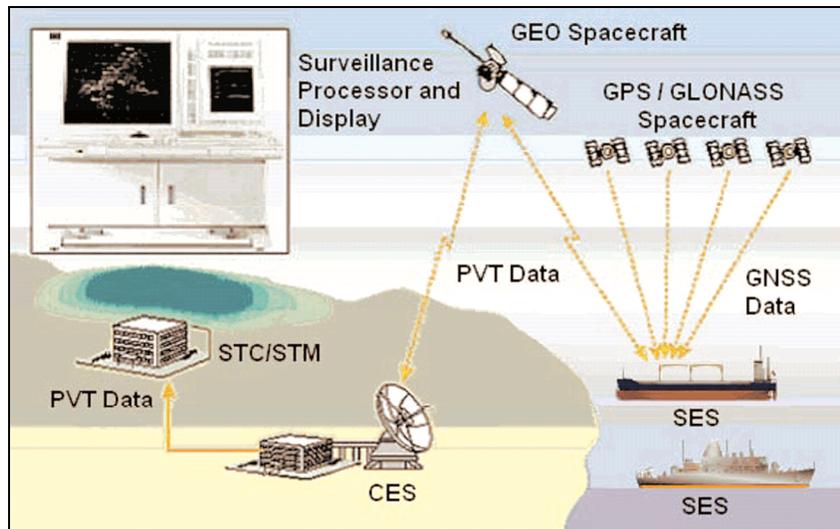


Figure 8. Modern MSS Network

In 2002 International Maritime Organization (IMO) adopted Safe 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) radio transceiver.

In fact, this was the first requirement for deployment of AIS equipment and so affected approximately 100,000 vessels. The AIS device is using VHF-band, so its more adequate name is Radio-AIS (R-AIS). This ships 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 watch standing officers and allow maritime authorities to track and monitor vessel movements and enhance collision avoidance. The R-AIS device integrates a standardized VHF transceiver with GPS and other electronic navigation sensors, such as a gyrocompass or rate of turn indicator. In such a way, oceangoing vessels fitted with R-AIS transceivers can be tracked by R-AIS base stations located along coastlines.

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 subsystems integrated with GEO spacecraft in ASAS or any RSAS networks are able to provide augmented navigation data, which scenario is illustrated in **Figure 5 (Middle Right)**. In this case, when MNS network is out of range from terrestrial network it can be used S-AIS, LRIT, SADS-B, SDL and GST satellite networks. The S-AIS can work through a growing number of GEO satellites connecting ships fitted with special S-AIS transceivers that upgrade R-AIS coverage. Better solution than LRIT is already introduced GST system developed by author of this book in 2000.

3.3. Maritime Surveillance Subsystem (MSS)

The modern MSS for ASAS or any RSAS network can implement both GEO Inmarsat and DVB-RCS MSC networks. The Inmarsat communication system is working in the way that all ships can derive their GNSS data from not-augmented or augmented GPS or GLONASS receiver and send PVT surveillance and other data with ships ID via GEO communication transponder and CES terminal to the ground STC/STM surveillance processor and display, which is depicted in **Figure 8**.

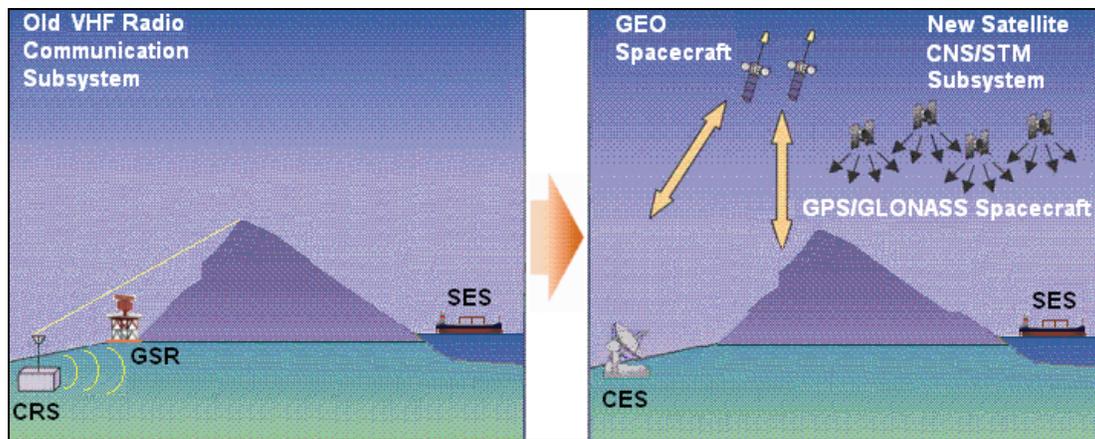


Figure 9. Maritime SESR Subsystem

In opposite way, STC/STM can send position of adjacent ships in certain area via CES to ship needs this data for collision avoidance. This scenario is very important for ships sailing across ocean during very bad weather condition, reduced visibility caused by deep clouds and thunderstorm when radar is not able to work properly. In such a way, the PVT data received by the STC/STM centres are transferred to the main computer processing and displaying of all surveillance information to the controllers on the like radar screen. In vice versa direction, on request sent by ships captain, the controllers in Surveillance Processor and Display centre 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.

The current surveillance subsystem is providing costal Ground Surveillance Radar (GSR) 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, which scenario is depicted in **Figure 5 (Bellow Left)**. However, the new satellite surveillance subsystem is integrating GPS and GLONASS with Inmarsat or other GEO satellite networks. Thus, ships receive positioning data from GPS or GLONASS satellites and automatically or manually send PVT and other data using SADS-B, SDL and GST via GEO spacecraft and CES to gather satellite position data to the STC/STM stations, which scenario is shown in **Figure 5 (Bellow Right)**. Additionally new surveillance subsystem can also deploy as a back the GSR system in the coverage of radar stations.

3.4. Special Effects of Maritime ASAS System

Special effects of the Maritime ASAS system can be deployed for secure CNS systems of ships at sea, in the channels, around the coastal waters and in the seaports infrastructures, such as Safety Enhancements on Short and Long Ranges, Reduction of Separation Minima, Flexible Sailing Profile Planning, Oceanic Sailing and Coastal Movement Guidance and Control. In fact, these effects of the ASAS network are very important to improve maritime CNS facilities in any phase of sailing, to enable better control of ships, provide flexible and economic trip with optimum routes, to enhance surface guidance and control in seaport and in any case to improve safety and security at sea and coastal waters.

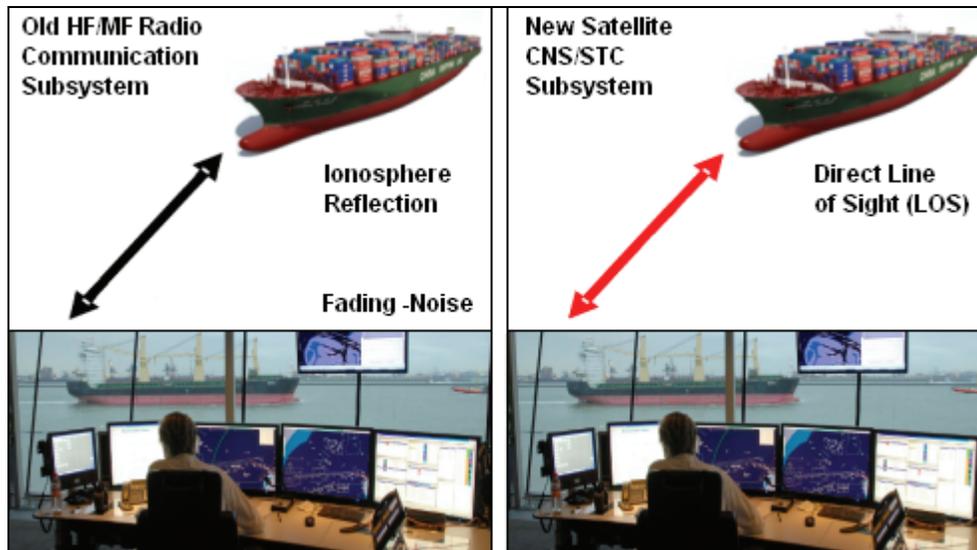


Figure 10. Maritime SELR Subsystem

3.4.1. Safety Enhancements at Short and Long Ranges

An important effect of the new ASAS system for CNS/STC is Safety Enhancement at Short Ranges (SESR) via VHF CRS shown in **Figure 9 (Left)**. Old radio system for short distances between vessels and CRS is provided by VHF or new DSC VHF voice and data equipment, so the ship's Master or Pilot have many problems establishing voice bridge radio communications when the ship position is in the shadow of high mountains in coastal waters or channels. Meanwhile, all vessels sailing in coastal waters, sea passages or fiords and in seaports can receive satellite navigation and communications even at short distances and where there is no navigation and communications coverage due to mountainous terrain, which diagram is shown in **Figure 9 (Right)**. This scenario is very important for safety and secure of navigation during bad weather conditions and reduced visibility in channels, approaching and coastal waters, to avoid collisions and disasters.

The ASAS infrastructure is also projected to provide Safety Enhancement at Long Ranges (SELR) via HF/HF radio communications illustrated in **Figure 10 (Left)**. The faded HF radio can be replaced by noise-free satellite system depicted in **Figure 10 (Right)**. In such a way, many ships out of HF range can provide their augmented or not augmented positioning to STC station or will be able to receive safety and weather information for secure navigation.

3.4.2. Reduction of Separation Distance (RSD)

One of the greatly important safety navigation effects deployed by ASAS network is the Reduction of Separation Distance (RSD) between oceangoing ships or other moving object on the sea routes by almost half, as shown in **Figure 11**.

The current system has an RSD controlled by conventional VHF or HF Radio system and GSR, which allows only large distances between vessels. However, the new maritime CNS/STC system controls and ranges greater numbers of ships for the same sea corridors (channels), which enables minimum secure separations, with a doubled capacity for vessels and enhancements of safety and security. Therefore, a significant RSD for sailing ships will be available with the widespread introduction and implementation worldwide of the new ASAS or any RSAS technologies on the CNS system.

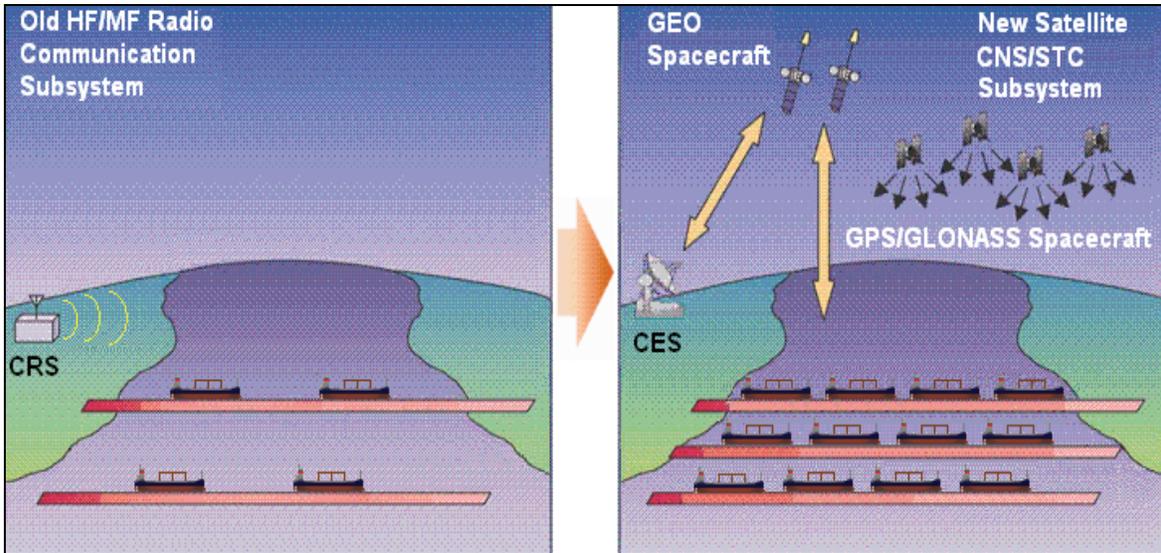


Figure 11. Maritime RSD Subsystem

3.4.3. Flexible Sailing Profile Planning (FSPP)

The next positive effect of ASAS network is Flexible Sailing Profile Planning (FSPP) of shortest or optimal course, shown in **Figure 12**. The old system uses fixed courses of orthodrome, loxodrome and combined navigation by NavAids. Thus, the fixed course is controlled by the vessel's on-board navigation instruments only, which is a composite and not the shortest possible route from departure to arrival at the destination port. The FSPP allows the selection of the shortest or optimum course between two seaports and several sub points. With thanks to new RSAS technologies on CNS/STC system FSPP will be available for more economic and efficient sailing operations. This means that the ship's engines will use less fuel by selecting the shortest sailing route of new CNS/STC system than by selected the fixed courses of current route composition.

3.4.4. Oceanic Sailing Guidance and Control (OSGC)

The Oceanic Sailing Guidance and Control (OSGC) network for communication facilities can use voice, data and video of Inmarsat MMSC system, new SADS-B, SDL, Digital Video Broadcasting-Return Channel via Satellite (DVB-RCS) with Voice, Video, Data over IP (VDVoIP) or MMSC via other GEO satellite constellations to send GNSS-1 data (received from GPS or GLONASS satellites by SES) to CES on L/C, Ku or Ka-band, what depends on the type of GEO spacecraft.

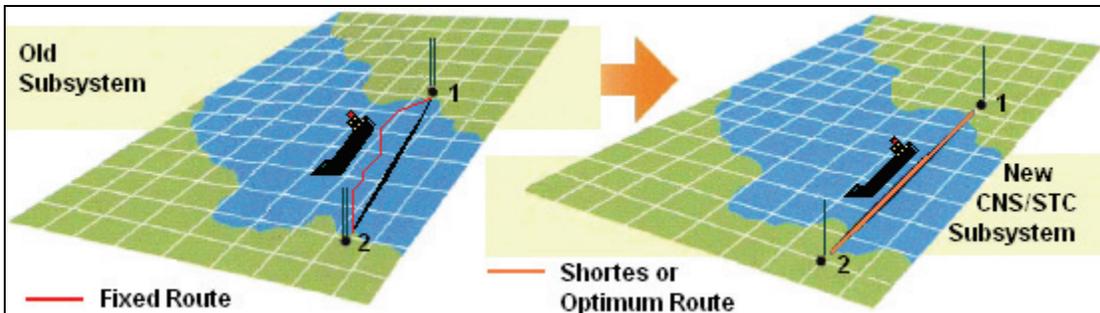


Figure 12. Maritime FSPP Subsystem

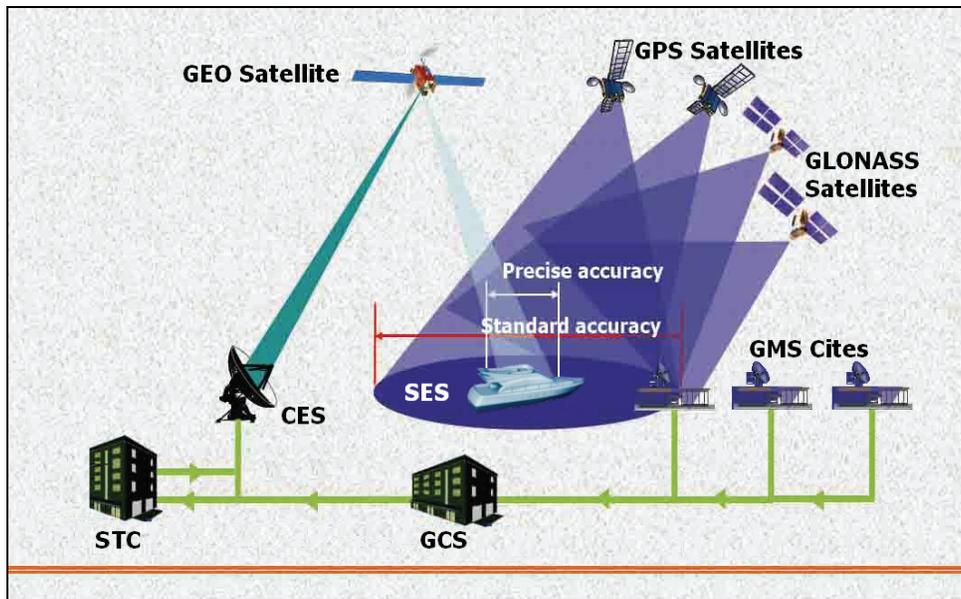


Figure 13. Maritime OSGC Subsystem

In addition, Ground Monitoring Station (GMS) sites are able to receive GNSS signals and forward them to Ground Control Station (GCS) for processing and then via GEO Satellite and CES terminal sends augmented signals to SES by the same L1 or L5-band GNSS-1 frequencies.

The GCS signals can also be sent to maritime Ship Traffic Control (STC) for processing and displaying them at radar like display. Then, STC can send to any ship position of near by ships in certain sea area for awareness and enhanced collision avoidance. The scenario of OSGC is illustrated in **Figure 13**, which has to provide more safety and security in navigation across the oceans.

3.4.5. Coastal Movement Guidance and Control (CMGC)

The Local VHF Augmentation System (LVAS) infrastructure is intended to complement the CNS service for local environment of seaport or airports using a single differential correction that accounts for all expected common errors between a local reference and mobile users at sea or in the air. In fact, the LVAS network will broadcast navigation information in a localized volume area of seaports or airports using VHF service of CSN solutions. In addition, this local service can be also covered by any of mentioned RSAS networks developed in Northern Hemisphere or even the future service of ASAS network.

As stated earlier, any hypothetical RSAS or ASAS network will consist a number of GMS (Reference Stations), several GCS (Master Stations) and enough CES (Gateways), which service has to cover entire mobile environment of dedicated region as an integrated part of GSAS. Inside of this coverage the RSAS network will also serve to any other customers at sea, on the ground and in the air users, who needs very precise determinations, tracking and positioning, such as:

1. Maritime (Shipborne CNS, Tracking, Seafloor Mapping and Seismic Surveying);
2. Land (Vehicleborne CNS, Tracking and Transportation Steering and Cranes);
3. Aeronautical (Airborne CNS, Tracking and Mapping);
4. Agricultural (Forestry, Farming and Machine Control and Monitoring);
5. Industrial, Mining and Civil Engineering;

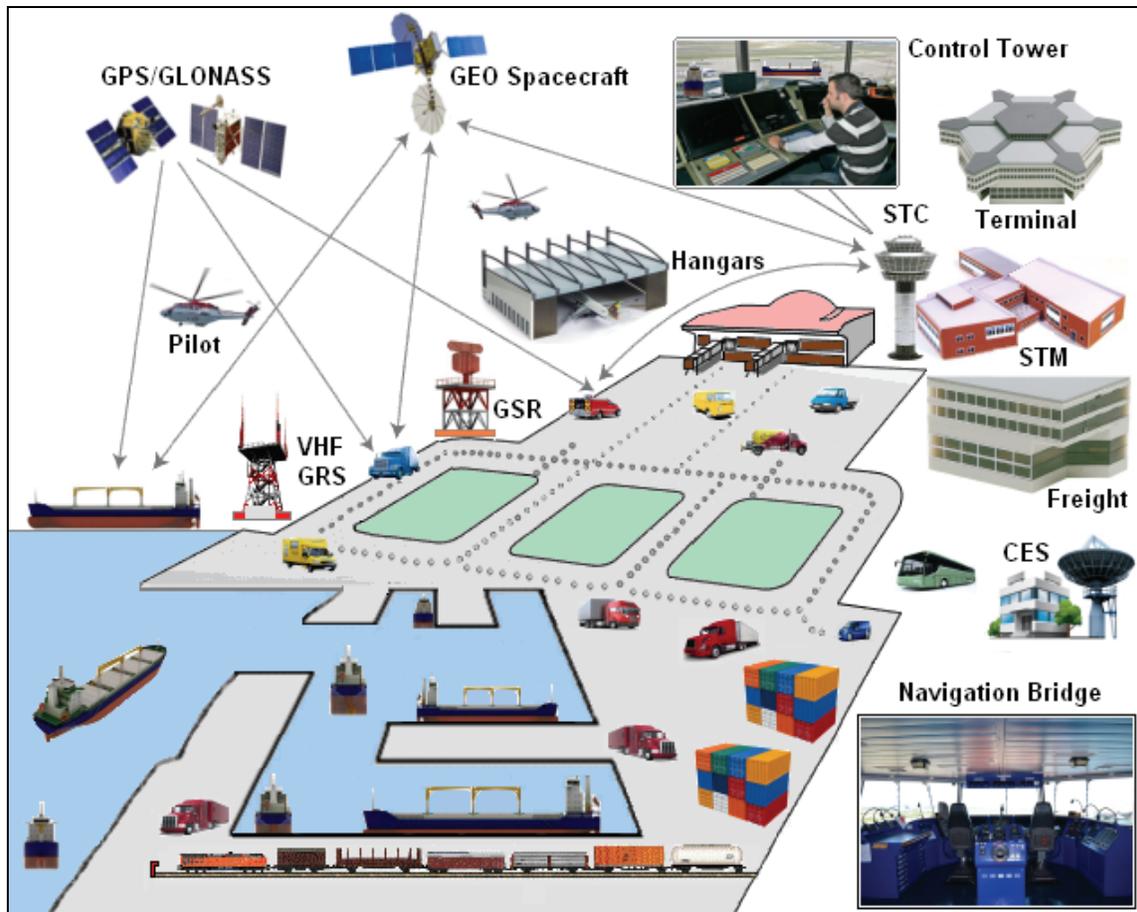


Figure 14. Maritime CMGC Subsystem

6. Structural Deformations Monitoring;
 7. Meteorological, Cadastral and Seismic Surveying; and
 8. Government/Military CNS, Tracking (Police, Intelligent services, Firefighting); etc.

In a more general sense, all above applications will be able to assess CNS service inside of any RSAS or ASAS networks coverage directly by installing new Rx equipment known as augmented GPS or GLONASS (GNSS-1) onboard mobiles terminals, and so to use more accurate positioning and determination data. This scenario will be more important for establishment STC or ATC CNS service using augmented GNSS-1 signals from the ships or aircraft, respectively. In this sense, the RSAS or ASAS network can be utilized for seaports known as Coastal Movement Guidance and Control (CMGC) and for airports as Surface Movement Guidance and Control (SMGC).

The CMGC mobile network is a special security, safety, guidance and control system that enables a shore controller at STC centres to guide and monitor all ships movements at sea in coastal navigation, in the cramped channel strips, approaching areas to the anchorage and seaports, which scenario is shown in **Figure 14**. In addition, the CMGC system is managing all movement in harbours, such as ships, land vehicles (Road and railways) in seaport and around the seaport's coastal environment, especially during very bad weather and poor visibility conditions. The controller issues instructions to ship Masters and seaport Pilots with reference to a command surveillance display in a seaport control tower that gives ships position information detected via GEO satellite and by sensors on the ground, which can be VHF Ground Radar Station (GRS) and Ground Surveillance Radars (GSR).

On the other hand, using CMGC, ship's captain on the navigation bridge together with harbour Pilot are more comfortable and safe in any situation during maneuvering inside and out of seaports. The command monitor in Control Tower also displays reported position data of coming or departing vessels and all auxiliary land vehicles (road and railways) moving into the port's surface. This position is measured by GNSS, using data from GPS/GLONASS and GEO satellite constellation. A controller is also able to show the correct ship course to Masters and seaport Pilots under bad weather conditions and poor visibility or to give information on routes and separation to other vessels in progress. The following segments of CMGC infrastructure are illustrated in **Figure 14**:

1) GPS or GLONASS GNSS Satellite measures the vessel or seaport vehicle's the exact position.

2) GEO MSC Satellite is integrated with the GPS positioning data network caring both communication and navigation payloads, In addition to complementing the GPS satellite, it also has the feature of communicating data between the ships or vehicles and the ground facilities, pinpointing the mobile's exact position.

3) Control Tower is the centre for monitoring the traffic situation on the channel strips, approaching areas, in the port and around the port's coastal surface. The location of each vessel and ground vehicle is displayed on the command monitor of the port control tower. The controller performs sea-controlled distance guidance and movements for the vessels and ground-controlled distance vehicles and directions based on this data.

4) Light Guidance System (LGS) is managed by the controller who gives green light or red light guidance whether the ship should proceed or not by pilot in port, respectively.

5) Radar Ground Station (RGS) is a part of previous system for STC of ship movement in the channels, approaching areas, in port and around the port's coastal environment.

6) Very High Frequency (VHF) is Coast Radio Station (CRS) is a part of RCS and VHF or Digital Selective Call (DSC) VHF Radio communications system.

7) Coast Earth Station (CES) is a main part of satellite communications system between GES terminals and shore telecommunication facilities via GEO satellite constellation.

8) Pilot is small boat or helicopter carrying the special trained man known as a Pilot, who has safely to proceed arrival vessel in port, departure vessel out of port to anchorage or to manage vessels sailing through the channels and rivers.

9) Bridge Instrument onboard each vessel displays the ship's position and course during all stages of navigation at open sea or inside of seaports.

4. Land Movement Guidance and Control (LMGC)

The Land Movement Guidance and Control (LMGC) infrastructure is a special security and control system that enables a vehicle controller at Land Traffic Control (LTC) to monitor and manage road vehicles or rail locos with wagons, which scenario is illustrated in **Figure 15**. The controller issues instructions to all drivers with reference to a command display in a control tower that gives to all vehicles their position and speed information detected from GPS or GLONASS satellites and derived via GEO satellite via GES or by radars.

The road vehicle controller situated in Road Traffic Management (RTM) tower next to the road lanes is managing, monitoring road lines, giving warning to any driver if is exceeding the speed or doing violations on the roads. In addition, the RTM system also provides information to motorists which lines have less traffic congestion and conditions on the roads.

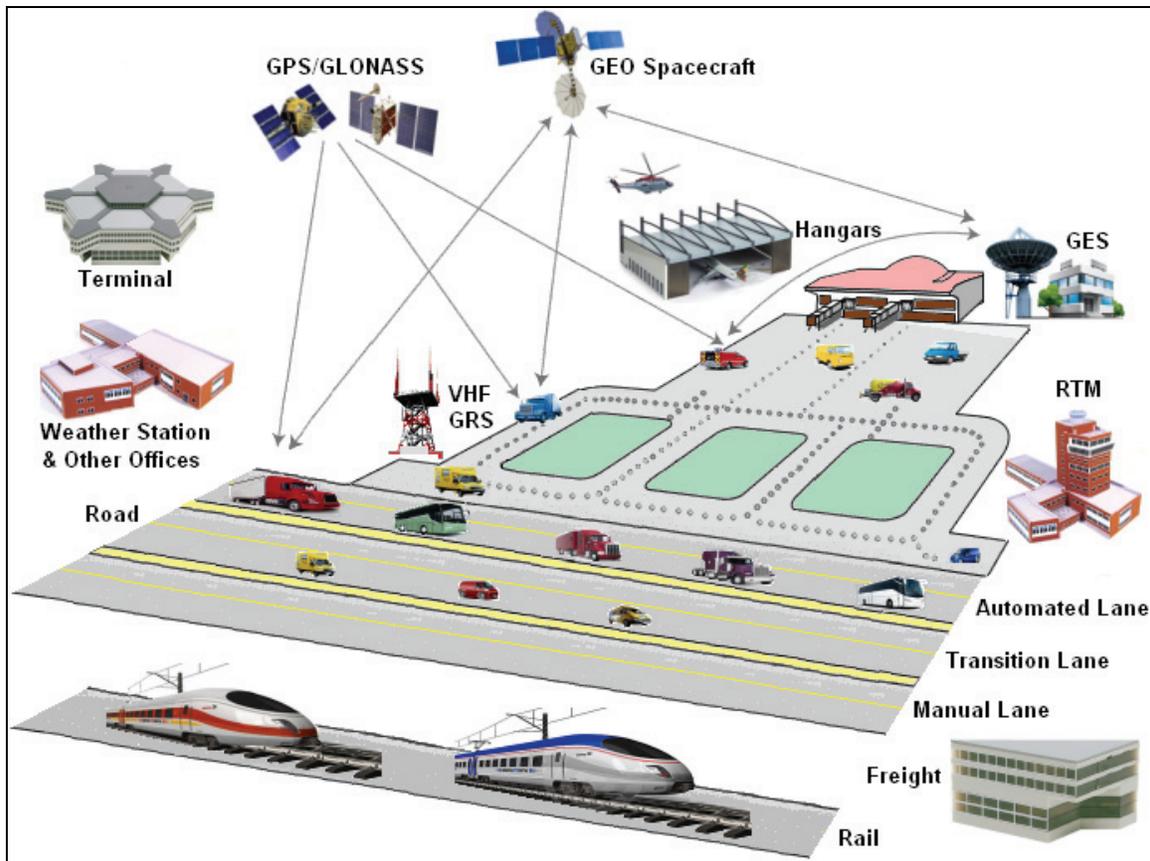


Figure 15. Land Mobile LMGCS Subsystem

The rail controller situated in Rail Traffic Management (RTM) tower is giving the similar information to the rail drivers, such as about speed, conditions of rail lanes and RTM is also providing enhanced signalization for loco drivers. The availability and accuracy of the US GPS and Russian GLONASS GNSS-1 systems offer increased efficiency and safety for road vehicles using highway lanes, streets and mass transit systems. In the similar way rail wagons and locos can be managed more safe and secure on the railways with enhanced signalization. Many of the problems associated with the routing and dispatch of commercial vehicles is significantly reduced or eliminated with the help of GPS. This is also true for the management of mass transit systems, road maintenance crews and emergency vehicles.

All road and rail vehicles with onboard installed GPS or GLONASS receivers enable own automatic vehicle location and guidance, but cannot provide tracking of vehicles without integration with radio or satellite transceivers. The satellite tracking system is using special units containing GPS or GLONASS Rx integrated with small satellite transceivers, such as Inmarsat, Iridium, Globalstar or Orbcomm, which can provide regional or global tracking and determination of all kind of land vehicles. By combining GPS position technology with systems that can display geographic information or with systems that can automatically transmit data to display screens or computers, a new dimension in surface transportation is realized. In fact, a Geographic Information System (GIS) stores, analyzes, and displays geographically referenced information provided in large part by GPS. Today GIS is used to monitor vehicle location, so mass transit systems use it to track rail, bus and other services to improve on-time performance. Integration of GPS and GLONASS with Land CNS networks is the best way for LMGCS solutions

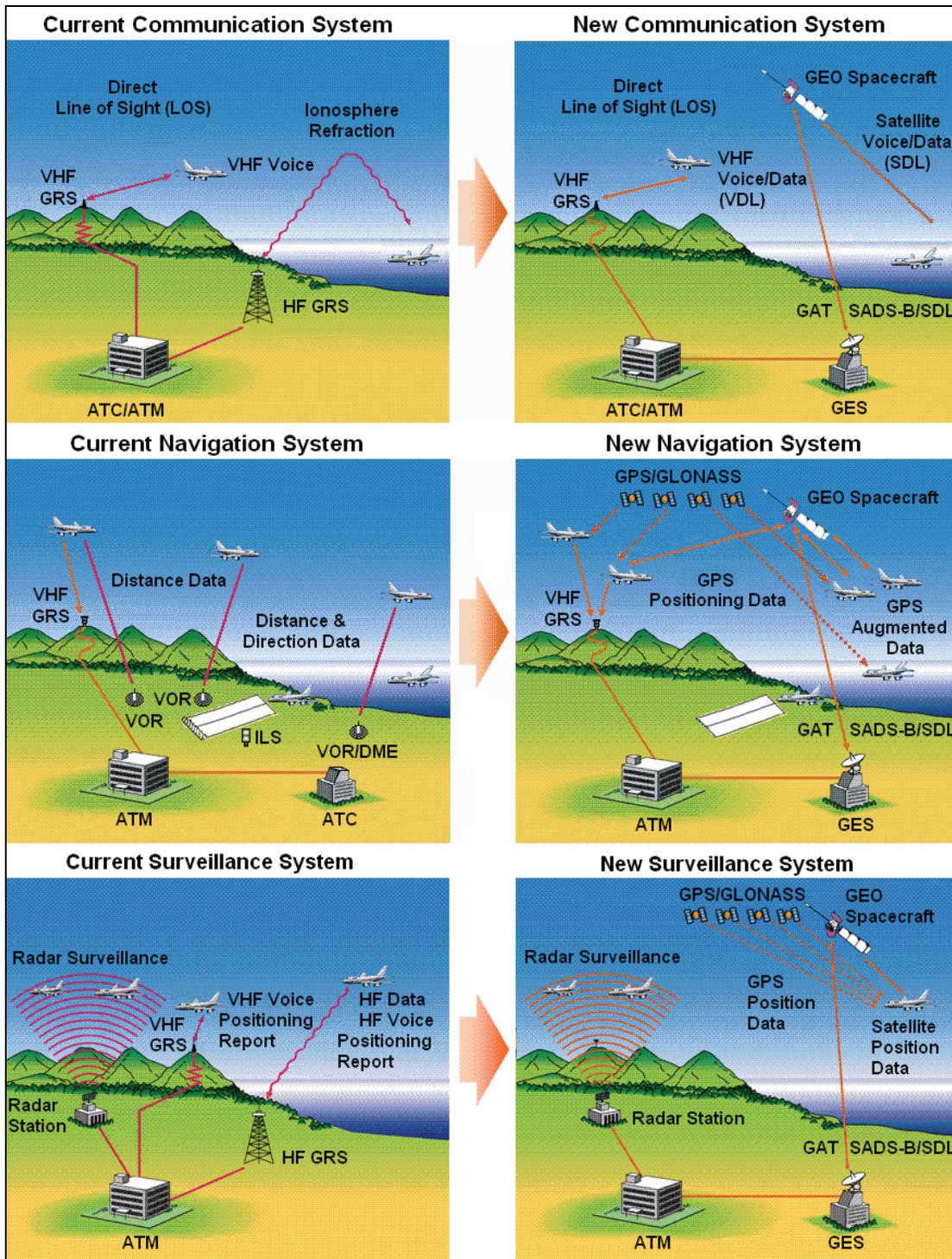


Figure 16. Current and New Aeronautical CNS/ATC System

5. Current and New Aeronautical CNS Subsystems

The current and new aeronautical CNS subsystems are integrated in regional and global Communication, Navigation and Surveillance systems providing important solutions for enhanced Air Traffic Control (ATC) and Air Traffic Management (ATM) for all phase of longhaulage flight, local airliners and approaching to airports, which complete scenario is illustrated in **Figure 16**.

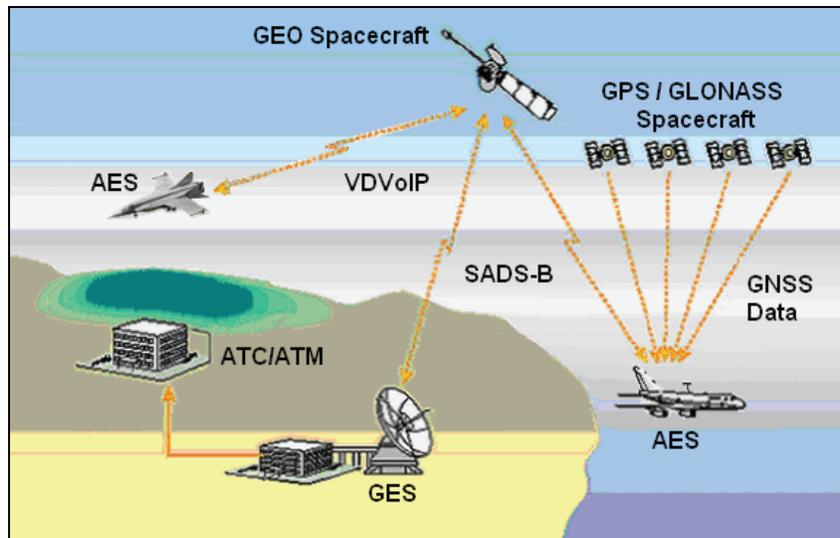


Figure 17. Modern ACS Network

5.1. 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 16 (Above 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.

To improve the communication and traffic control facilities of aircraft it is necessary to implement new Mobile Satellite Communication (MSC) systems, which scenario is shown in **Figure 16 (Above Right)**. The Aeronautical MSC (AMSC) system is providing Satellite Voice and SDL communications 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.

The Inmarsat system can connect aircraft and AMCS 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 VDVoIP and SADS-B transmissions system, which modern AMCS network is shown in **Figure 17**. 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.

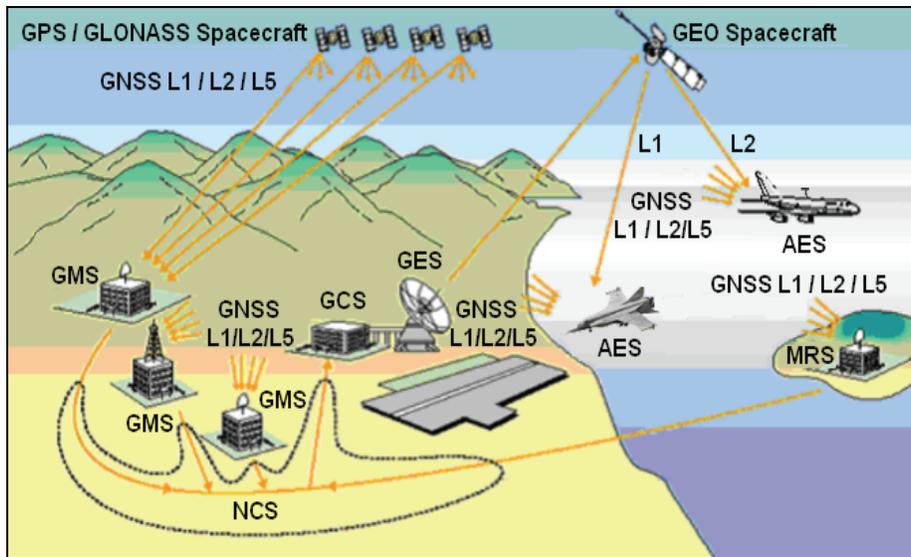


Figure 18. Modern ANS Network

Therefore, the ASAS or any RSAS network is integrating modern AMCS with GNSS-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.

5.2. Aeronautical Navigation Subsystem (ANS)

The ANS network integrated in ASAS or any RSAS infrastructure can be also used for sending only navigation messages via voice or data, which scenario is depicted in **Figure 18**. 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 receivers onboard aircraft. In fact, 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 network.

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 shown in **Figure 16 (Middle Left)**.

However, this subsystem needs more time for ranging 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 VHF transponder.

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 16 (Middle 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 book.

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, so it enables more secure and economical air navigation routes.

5.3. Aeronautical Surveillance Subsystem (ASS)

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 16 (Below 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. 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 shown in **Figure 16 (Bellow Right)**. Additionally new surveillance subsystem can also deploy as a back the GSR system in the coverage of radar stations.

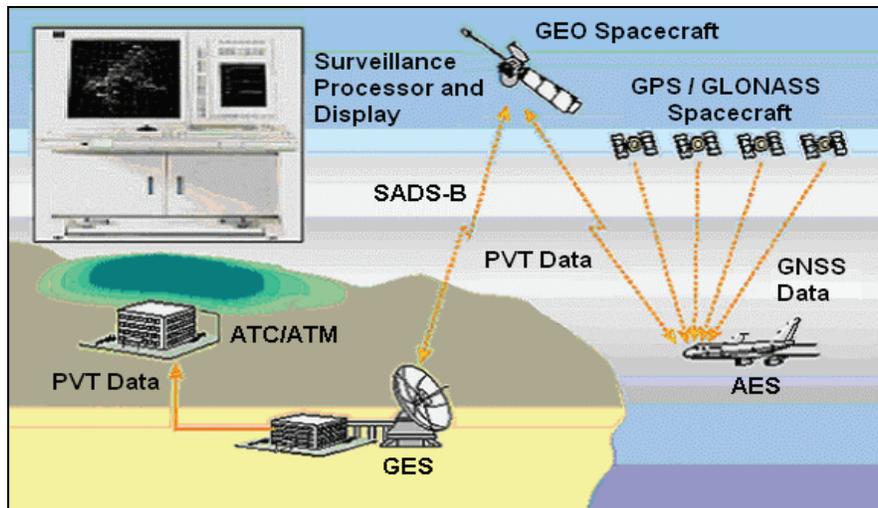


Figure 19. Modern ASS Network – Courtesy of Presentation: by Ilcev

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 centre, which scenario is illustrated in **Figure 6.37**. 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, which diagram is illustrated in **Figure 19**. After that, the ATC 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 may use displayed data of aircraft positions in certain area and send to 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 will increase air safety and reduce aircraft separation, improve functions and selection of the optimum route with more economical altitudes. 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.

5.4. In Flight Special Effects of ASAS Networks

The special effects of the ASAS networks used for secure CNS, logistics, ranging, tracking, control and management of air and surface traffic are Safety Enhancements in Low and High Altitudes, Reduction of Separation Minima, Flexible Flight Profile Planning, Oceanic Flight and Surface Movement Guidance and Control. These effects are very important to improve aircraft communication facilities in any phase of flight, enable better control of aircraft, provide flexible and economic flight with optimum routes, enhance surface guidance and control and to improve safety and security.

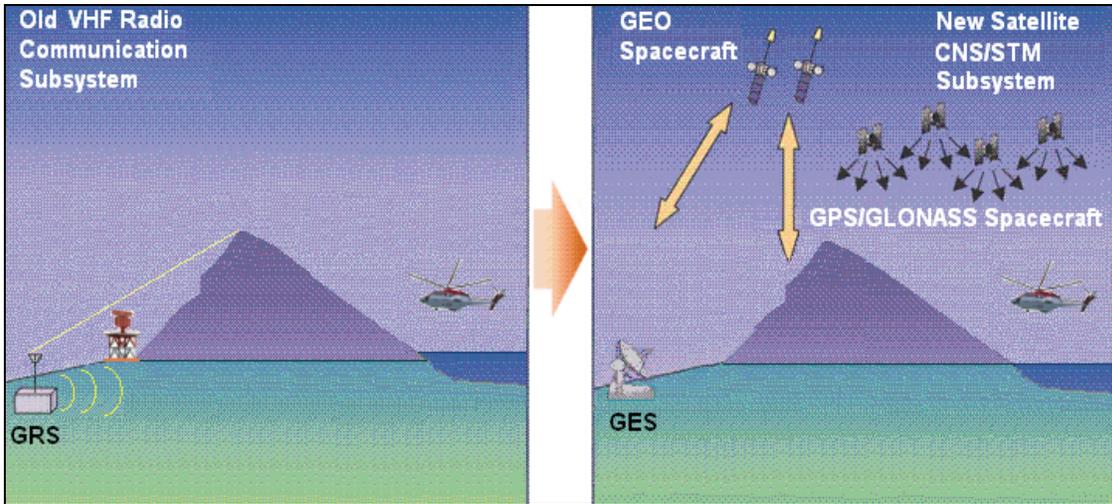


Figure 20. Aeronautical SELA Subsystem – Courtesy of Presentation: by Ilcev

5.4.1. Safety Enhancements at Low and High Altitudes

A very important effect of the future ASAS network is to provide new Safety Enhancement at Low Altitudes (SELA) via GRS terminals illustrated in **Figure 6.38 (Left)**. Old system for short distances between aircraft and GRS is provided by VHF radio voice equipment, so the pilot will have problems establishing voice cockpit radio communications when the aircraft's is flying position is in the shadow of high mountains or other obstacles.

Meanwhile, all aircraft in flight can receive satellite navigation and communications even at low altitude and where there is no navigation and communications coverage due to mountainous terrain, which scenario is illustrated in **Figure 20 (Right)**. This service is very important for secure flying during bad weather conditions and reduced visibility.

The future ASAS network will be able also to provide new Safety Enhancement at High Altitudes (SEHA) via GEO spacecraft and GES terminal shown in **Figure 21**, by using HF faded radio or the noise-free satellite system. The HF radio sometimes is not useful owing to very bad weather conditions and heavy clouds.

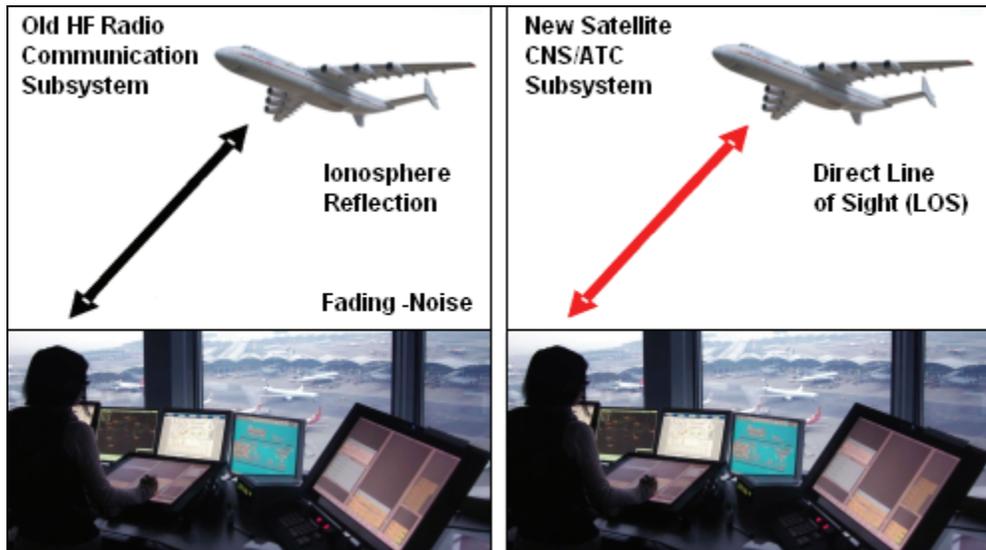


Figure 21. Aeronautical SEHA Subsystem – Courtesy of Presentation: by Ilcev

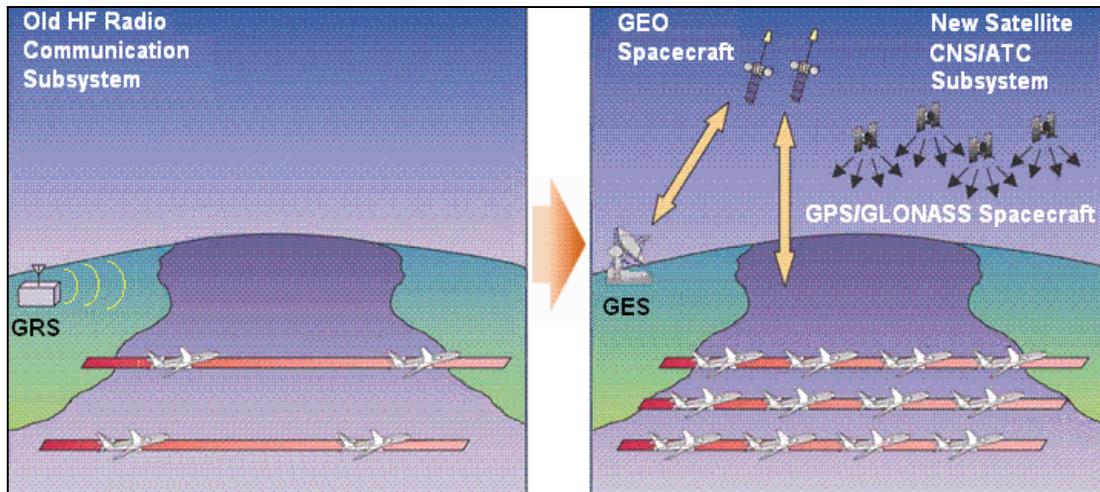


Figure 22. Aeronautical RSM Subsystem – Courtesy of Presentation: by Ilcev

5.4.2. Reduction of Separation Minima (RSM)

One of the very important RSAT navigation effects is the Reduction of Separation Minima (RSM) between aircraft on the air routes by almost half, as shown in **Figure 6.22**. The old HF radio communication subsystem has an RSM controlled by conventional HF radio and Radar systems, which allows only large distances between aircraft. However, the new satellite CNS/ATC subsystem controls and ranges greater numbers of aircraft for the same air space corridors, which enables significant reduction of the separation minima for flying aircraft with a doubled capacity.

5.4.3. Flexible Flight Profile Planning (FFPP)

The next significant effect of ASAS network is Flexible Flight Profile Planning (FFPP), which old subsystem uses fixed air routes (courses) and flying altitudes controlled by the aircraft onboard navigation instruments only. These instruments are composite and not able to provide the shortest route from departure to arrival at the airport. Moreover, FFPP allows the selection of the shortest or optimum route and flying altitude between two airports, shown in **Figure 23**. In the other words, with thanks to new wide augmentation satellite technologies on CNS system FFPP will be available for more economic and efficient flight operation. This means that the aircraft's engines will use less fuel by selecting the shortest flying route of new CNS/ATC subsystem than by selected the fixed route and altitude of old route composition.

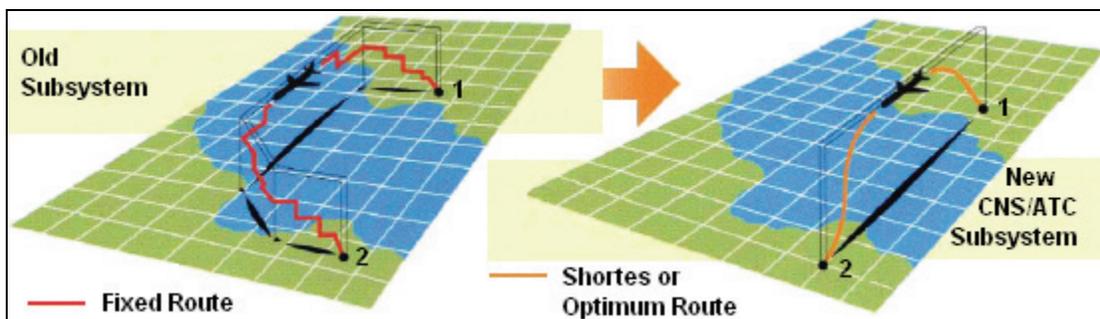


Figure 23. Aeronautical FFPP Subsystem – Courtesy of Presentation: by Ilcev

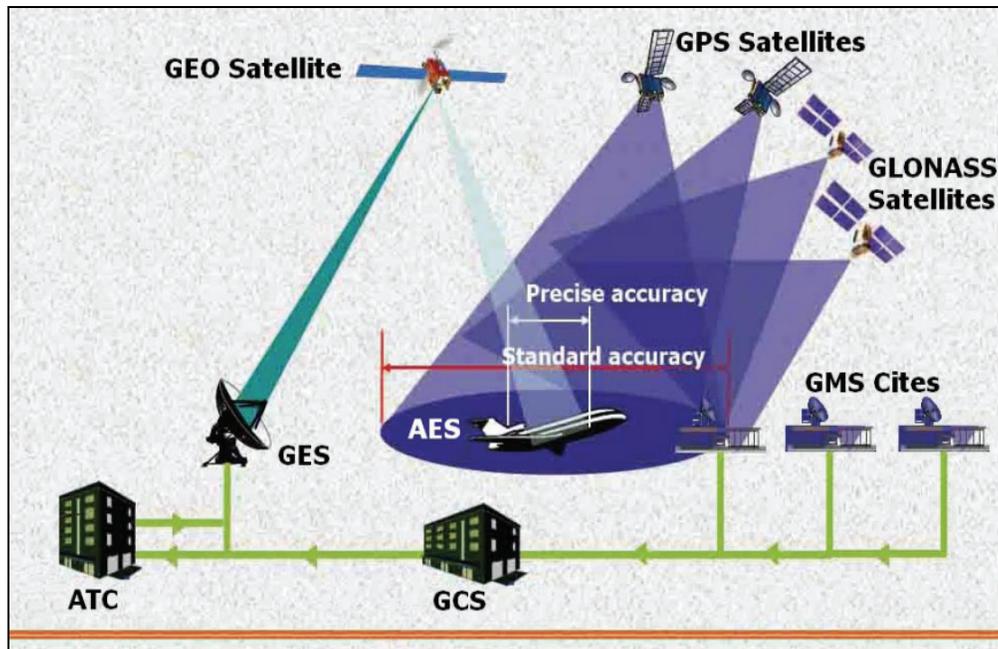


Figure 24. Aeronautical OFGC Subsystem – Courtesy of Presentation: by Ilcev

5.4.4. Oceanic Flight Guidance and Control (OSGC)

The Oceanic Flight Guidance and Control (OSGC) network for communication facilities can use voice, data and video of Inmarsat MMSC system, new SADS-B, SDL, satellite DVB-RCS with VDVoIP or MMSC via other GEO satellite constellations to transmit GNSS-1 data (received from GPS or GLONASS satellites by AES) to GES on RF L/C, Ku or Ka-band, what depends on the type of GEO spacecraft.

Also GMS sites or Reference Stations are getting GNSS-1 signals and forwarding them to GCS or Master Stations for processing and then via GES is sending augmented signals to AES via GEO satellite navigation transponder at the same L1 or L5-band frequencies used by GPS or GLONASS satellites. From GCS terminal signals can also be sent to ATC station for processing and their displaying at radar like display. Then, ACC can send to any aircraft position of near by aircraft for awareness and collision avoidance. The scenario of OFGC is illustrated in **Figure 24**, which has to provide more safety and security in navigation across the oceans.

5.4.5. Surface Movement Guidance and Control (SMGC)

As stated above, the novel Local VHF Augmentation System (LVAS) is intended to complement the ASAS service using a single differential correction mode that accounts for all expected common errors between a local Reference Station terminals and mobile users. The LVAS infrastructure will broadcast navigation information in a localized volume area of seaports or airport using satellite service of new projected ASAS or any RSAS networks already developed in Northern Hemisphere.

The new LVAS network can be also implemented as a Surface Movement Guidance and Control (SMGC) system integrated in any ASAS infrastructure. It is a special aeronautical security and control system that enables an airport's controller from Control Tower on the ground to collect all navigation and determination data from all aircraft, to process these signals and display on the surveillance screens.

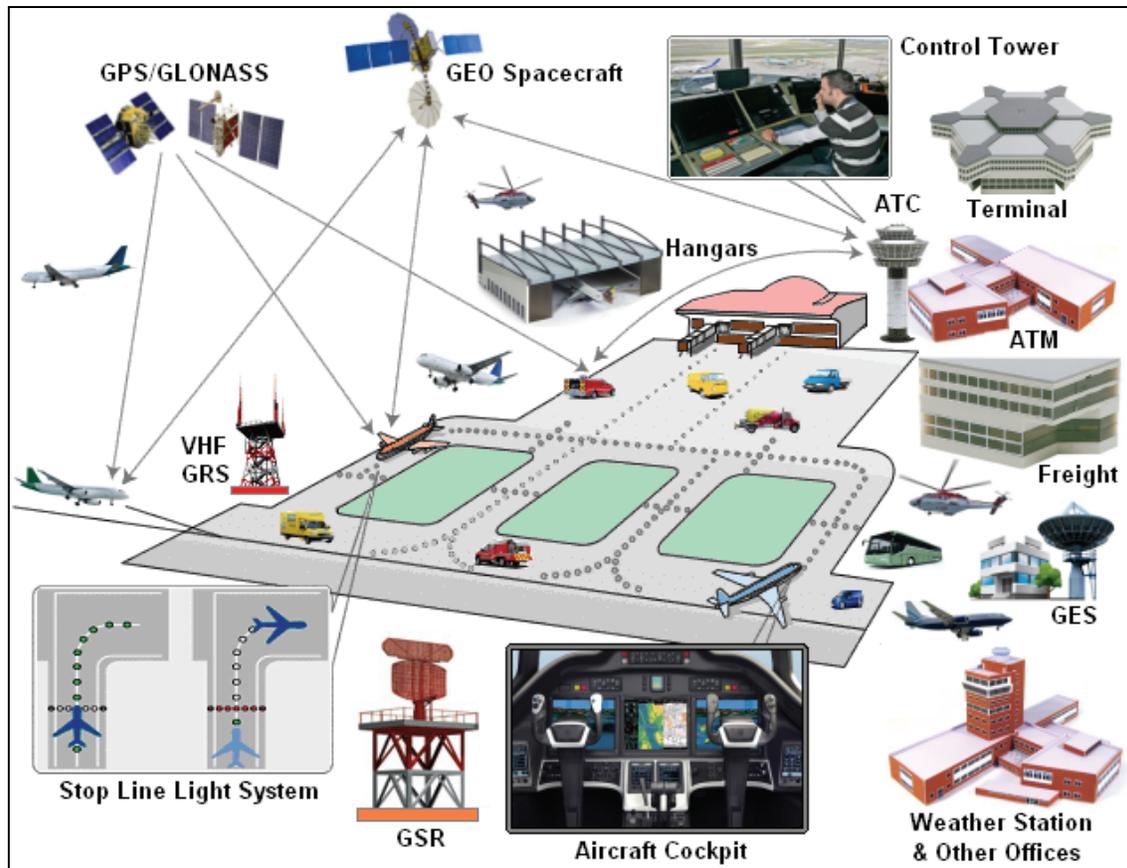


Figure 25. Aeronautical SMGC Subsystem – Courtesy of Presentation: by Ilcev

On the surveillance screen in Control Tower can be visible positions and courses of all aircraft in vicinity flight areas, but outside of VHF radio and Radar ranges, so they can be controlled, informed and managed by traffic controllers in any real time and space, which configuration is shown in **Figure 25**. In such a way, the LVAS traffic controller provides essential control, traffic management, guide and monitor all aircraft movements in the vicinity of the certain aircraft, approaching areas to the airport, aircraft movement on the airport surface, including movement of land vehicles in airport and around the airport, even when aircraft flights in very poor visibility conditions at an approaching to the airport.

Each aircraft and land vehicles circulating on airport surface can have installed onboard special satellite transponders known as GPS Receiver/Satellite Transceiver Unit using GEO or Non-Geo satellite constellations. Thus, the controller issues instructions to the aircraft's pilots or vehicle driver with the reference to a command surveillance display in a Control Tower that gives all aircraft position information in the vicinity detected via satellites and by sensors on the ground.

The command monitor in Control Tower also displays reported position data of landing or departing aircraft and all auxiliary vehicles moving onto the airport's surface. This position is measured by GNSS-1 network using data from GPS or GLONASS and ASAS or any RSAS/GEO satellites. An airport controller is able to show the correct taxiway to pilots under poor visibility, by switching the taxiway centreline light and the stop bar light on or off. The development of head-down display and head-up display in the cockpit that gives information on routes and separation to other adjacent aircraft is in progress. The following segments of SMGC are shown in **Figure 25**:

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

6. Development Process of ASAS Network

The development team of the ASAS project together with Space Science Centre (SSC) for Research and Postgraduate Studies in CNS at Durban University of Technology (DUT) is conducting research and studies of the performance requirements for operational network, introducing of new algorithms to produce highly reliable augmentation information and design of communication methods to deliver augmentation information from the ground.

The Transport Augmentation Board (TAB) team function is to coordinate and provide implementation of CNS technologies in Africa, also assist in establishing performance demands for the ASAS network 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 Stations (GMS) 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. All GMS sites are getting signals of GNSS data from GPS or GLONASS spacecraft and forwarding them via telecommunication landline or DVB-RCS facilities to the Ground Control Station (GCS) terminals. In addition, it is necessary to establish minimum 5 GCS centers through terrestrial or space communication networks. Each GCS terminal needs to be provided enough processors with adequate software for correction of GNSS data received from GMS terminals known as an augmentation GPS or GLONASS data.



Figure 26. ASAS Ground Segments – Courtesy of Presentation: by Ilcev

The optimal location of surface resources for ASAS Ground Segment over Africa and Middle East is shown in **Figure 26**, such as GMS or Reference Stations, GCS or Master Stations and GES or Gateway terminals 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. In addition, 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 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. The projected 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 (2017–2019) – 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. The ASAS will enable reliable wide enroute navigation for ships and aircraft, including for road and rail applications.

2. Phase 2 (2019–2024) – Will finalize full ASAS infrastructures over Africa and Middle East regions and start with testing the Network. Redundant coverage of the initial ASAS operational restrictions will be removed. The LVAS with STC and ATC ground structures will be deployed at major African seaports and airports, respectively. Precisely surveyed ground stations with multiple GPS or GLONASS 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 traffic control centres and 2nd/3rd RF to improve GNSS-1 and GNSS-2 robustness and ICAA.

3. Phase 3 (2024–2030) – Will provide reducing ground-based NavAids and finalize the evaluation of ASAS network. Full constellations of GPS or GLONASS and new Compass and Galileo constellations with 2nd and 3rd civil GNSS RF available for ASAS and LVAS 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.

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, RSA, Tunisia and Western Sahara.

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

The total cost of ASAS project for ground segment is about 200M \$ 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 is not good solution for Africa and what is not providing CNS solutions and safety and security especially for STC 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 to each country in the Region of about 3M \$ access to ASAS network and service. However, ASAS network can lease Inmarsat and Artemis satellites, but later can include project to build own GEO multipurpose satellite.

7. System 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 the US WAAS, European EGNOS and Japanese MAAS. As stated earlier, in the GSAS network integration will be also included developed RSAS such as: Russian SDCM, Chinese SNAS and Indian GAGAN. The ASAS network will cover the entire African Continent and Middle East region and will provide new CNS solutions for 54 countries on the Continent and 15 countries in the Middle East. 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.

At the Ground Earth Station (GES), the navigation signals are precisely synchronized to a reference time and modulated with the GIC message data and WADGNSS corrections. The signals are sent to the GEO satellite on the C-band uplink (7) via communication payload located onboard Inmarsat and Artemis satellite (8). In the future ASAS can get own multipurpose GEO satellite. The augmented signals at GCS are frequency-translated and after sent to the mobile user via GEO navigation transponder on GNSS L1 and new L5-band, the same frequencies used by GPS or GLONASS satellites (9) and also sent to the C-band (10) used for maintaining the navigation signal timing loop. Moreover, 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 or GLONASS ranging signal. The Secondary GNSS GES can be separate or installed in Communication CNS GES (11), as a hot standby in the event of failure at the Primary GNSS GES. The Traffic Control Centres (TCC) terminals (12), are actually STC or ATC centres, which could send request for CNS information by Voice, Data and Video (VDV) on C-band uplink (13) via GEO communication payload located and on C-band downlink as well (14) to mobile users (3). The mobile users are able to send augmented CNS data on L-band uplink (15) via GEO communication payload and downlink (16). The TCC terminals are processing CNS data received from mobile users and displaying on the like radar screen their current positions very accurate and in the real time for traffic control and management purpose.

The most important and unique sequence in this stage is that traffic controller at TCC can use the position data for managing certain traffic in more safe way than surveillance radar for collision avoidance, during any weather or visibility conditions. In addition, on mobile request TCC operator may send position data of each mobile in vicinity for enhanced collision avoidance (13 and 14). Each mobile, such as ships and aircraft will be also able to provide polling of position data memorized in TCC display for any adjacent mobile (ship or aircraft) and use it for enhanced collision avoidance.

8. Equipment for ASAS Infrastructure

The RS terminals are the key equipment of any RSAS network. Each RSAS network needs certain number of RS, MCS and GES terminals. Thus, the RSAS network consists of a series of RS (GMS) and MCS terminals, a Ground Uplink Subsystem (GUS) or GES, containing Receiver and Signal Generator and GEO Satellites. The RS terminals, which are strategically located to provide adequate coverage, pick up GPS satellite data and route it to the MCS terminals. The MCS terminals then process the data to determine the signal integrity, signal corrections and residual errors for each monitored GPS satellite. This information is sent to the GUS terminal for transmission to the GEO spacecraft, which then re-transmits the data on the GPS L1 frequency.

8.1. NovAtel Reference Receiver G-II

The specific NovAtel product is WWAS RR G-II very precise GPS Rx as a part of each RS or GMS terminal, which device is illustrated in **Figure 28 (A)**. 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.



Figure 28. NovAtel Ground Equipment – Courtesy of Manual: by NovAtel

In fact, the principle function is to provide GPS or GLONASS outputs that are virtually free from multipath effects, which have to be disturbed as a reference signal over the ASAS GEO downlink. In that manner, the RRG2 terminals also provide 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. However, this is particularly important for difficult roof installation on the building, such as an STC or ATC centres, where signal reflections are likely to result in significant multipath effect.

The WWAS 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. Moreover, with the capability to hold up to 12 Euro form factor cards in three independent receiver sections, the WWAS 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. The NovAtel Company has project to utilize new model of two WAAS G-III receivers with modified SW configurations to deliver full GUS receiver functionality, which will be good successor to G-II generation of GUS Receiver. It is expectation FAA to contract NovAtel to prototype this configuration in 1H 2017 and to have production ready by 1H 2018. This receiver will be potential for DAL-D GUS and to reuse WAAS G-III units as GUS G-III.

8.2. Master Control Station (MCS)

Each of RS (GMS) terminals send 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 determine 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.

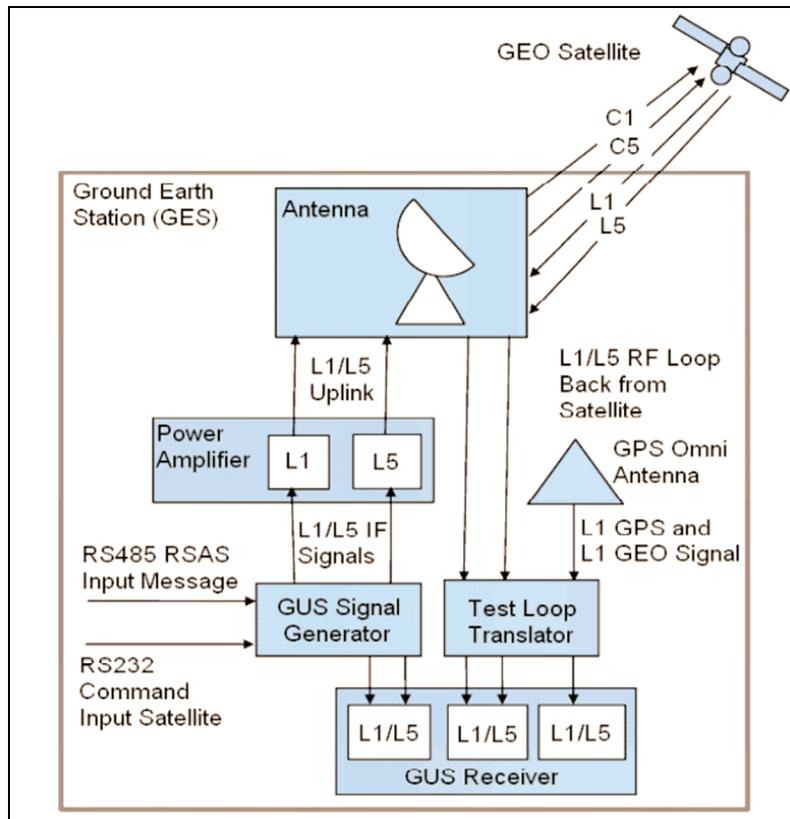


Figure 29. GES with Antenna and GUST Rx/Signal Generator

The ASAS infrastructure will also have a secondary mission of UTC (GMT) universal time distribution determined by the Master Clock, which represents the approved time standard source for the ASAS network. Time distribution will be accomplished by providing users with a time offset between ASAS Network Time (ANT) and UTC. This time offset will be determined at the some Time Observatory in Africa by a Time Distribution System (TDS). The TDS receives ASAS messages from the GEO satellites within its view and computes the time difference between the epoch time of the start of an ASAS message and the 1 Pulse Per Second (PPS) of the Observatory Master Clock, which is the physical realization of UTC and the time reference for GPS or GLONASS time. The data collected from each observed satellite by the TDS receiver are passed onto an UTC data acquisition system. The data is then transferred to the ASAS Master Stations through an interface between the ASAS and the UTC. The ASAS Master Station collects the ANT/UTC offset and creates a Type 12 Message that is then sent to the Geostationary Uplink Station (GUS) or GES, which transmits it to the GEO satellite. The purpose of the Type 12 Message is to provide time users with an accurate source of time referenced to UTC.

8.3. 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, shown in **Figure 28 (B)**. In addition, each GUS also needs two GUS-Type Signal Generator per uplink GES terminal, shown in **Figure 28 (C)**, with adequate GES 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 29**.

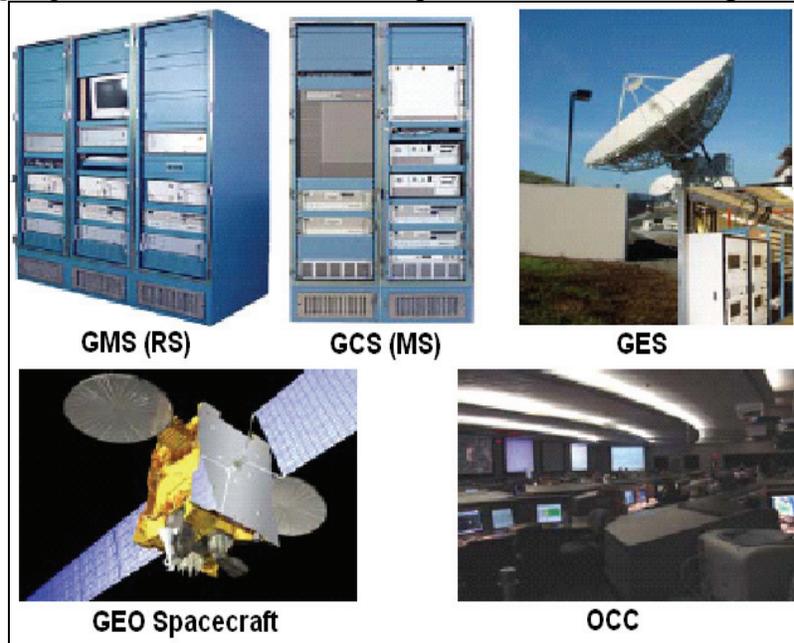


Figure 30. RSAS Ground and Space Segments

In **Figure 30** are illustrated 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 Communications and GNSS Links and Operational Control Centre (OCC).

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, one monitors the downlinked signal from the GEO satellite, and also monitors the down converted C-band uplink signal. In addition, 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 GUST Signal Generator is a high performance L1 and L5 independent signal generators designed 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.

8.4. 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 VSAT or Satellite Interactive Terminals (SIT) as a cheapest, easy-to-go and more reliable alternative, explained in Chapter 3.



Figure 31. Shipborne RSAS Equipment – Courtesy of Manual: by Raytheon, Furuno and Koden

5.6. 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 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.

9. Mobile RSAS Equipment

As stated above, mobile GNSS-1 receivers are represented by the US GPS and Russian GLONASS developed in 20th Century, mainly to help military personnel find their way of self-determination, but civilian applications soon became numerous providing 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, however Galileo system is not yet fully operational and is question when.

9.1. 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:

1. Raytheon Raymarine Raynav 300 SDGPS – New Raymarine RayNav 300 Satellite Differential GPS (SDGPS) device, illustrated in **Figure 31 (Left)**, features built-in Wide Area Augmentation System (WAAS) compatible to 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. Get increased GPS WAAS differential signals with the inbuilt receiver of this GPS Rx, which 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.

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

This GNSS equipment provides: Build in compact SDGPS navigator and WAAS receiver that provide signals for very precision 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 is also providing 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, shown in **Figure 31 (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 10 meters, and with WAAS mode activated it's accurate to within 3 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, shown in **Figure 31 (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 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 type 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 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.



Figure 32. Vehicleborne RSAS Equipment

9.2. Vehicleborne RSAS Equipment

Here will be introduced three vehicleborne RSAS devices:

1. Trimble EZ-Guide 250 – This is a proven leader in GPS/RSAS guidance technology designed for installations onboard vehicles, which is shown in **Figure 32 (Left)**. With common sense interface and a color screen, the EZ-Guide 250 is easy to operate right out of the box. Plus, this device can be upgraded to the EZ-Steer 500 assisted steering system, delivering a total package for affordable price. A color screen allows to operator see at a glance where he is, where he has been and what he has been doing. Guidance with 15 LED modes will provides to user quick on-line visual feedback to keep him on track. Record the location of obstacles and hazards with point, line and area feature mapping.

2. Magellan RoadMate 700 – This automotive device gives the great advantages of GPS auto navigation in a compact, lightweight and portable package, illustrated in **Figure 32 (Middle)**. It provides dynamic turn-by-turn guidance with TrueView 3D navigation, true mobility, comprehensive mapping and friendly voice prompting clearly indicates when to make your next turn. The voice prompt tells to users when to turn and they can confirm the direction at a glance. There's no need to watch the screen as you follow your route with confidence. This device also offers built-in tutorial helping to users on the road, advanced points of interest database, four ways to select routes, three guidance screens with easy to use interface, vehicle route exclusion, easily enter addresses with QuickSpell, auto re-route, address book and instant location. The Magellan RoadMate 700 uses 12-channel WAAS enabled accuracy to provide exceptional GPS accuracy and reliability. Tracking up to 12 GPS satellites is locating users position to within 3 meters assuring them to know and rest where they are and where they are going.

3. Garmin StreetPilot 2620 – In **Figure 32 (Right)** is shown Garmin StreetPilot 2620 GPS plug-and-play portable automotive navigator that features preloaded MapSource, detailed maps right out of the box. This means no unlocking or uploading map data to users unit. The Garmin StreetPilot 2620 offers a number of new and exclusive software upgrades for cars, buses, trucks and other road vehicles, which has integrated mapping system for easier navigation on the roads and get chosen destination. In addition, this GPS receiver features a high-resolution color touch screen with voice prompted turn-by-turn navigation and a powerful microprocessor for fast route calculation and map redraw. It provides many other features such as: multiple destinations; road segment and area avoidance; find nearest on route destination like gas stations or restaurants; users can adjust road class preference about taking major, medium and minor road categories. The system includes a unique wireless infrared remote control, which allows easy operation

of the unit from a distance. The Garmin StreetPilot 2620 also offers WAAS-enabled support to ensure the highest degree of GPS accuracy.

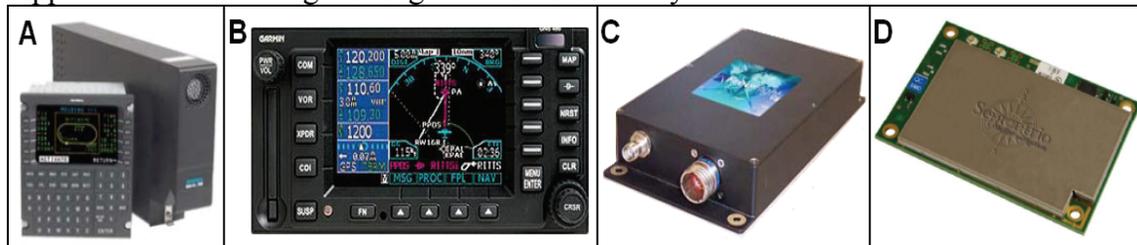


Figure 33. Airborne RSAS Receivers and Sensors

9.3. Airborne RSAS Equipment

Air navigation systems have a moving map display and are 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 is a producer of the advanced navigation systems. In **Figure 33 (A)** is presented 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 33 (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

3. Garmin RSAS LPV Receiver GNS 480 – FreeFlight Systems introduced the new 1203 GNSSW (Global Navigation Satellite WAAS) Sensor, shown in **Figure 33 (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 a 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.

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, shown in **Figure 33 (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.septentrio.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.