# Contemporary Innovations and Technologies for Modernization Global Maritime Distress and Safety System (GMDSS)

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**Abstract:** This paper introduces contemporary innovations and technologies for the modernization of the Global Maritime Distress and Safety System (GMDSS) by proposing new developments and integrations of the current Maritime Radio Communications (MRC) and modern Maritime Satellite Communications (MSC) networks with integrated maritime radio and satellite Communication, Navigation and Surveillance (CNS), Information and Communication Technolgy (ICT) and Global Ship Tracking (GST) systems in the function of enhanced Safety at Sea (SAS) and improved Search and Rescue (SAR) operations. The preliminary modernization aspects and plan for the GMDSS radio and satellite network are introduced in this paper. Based on the current state of the GMDSS and considerations on updating, upgrading and improving the system, some normative and technical aspects of the GMDSS modernization proposals are given. Further proposals on the GMDSS modernization plan were also considered.

**Key Words:** GMDSS, MRC, MSC, CNS, ICT, GST, SAS, SAR, IMO, SAR, STDS, PVT, GNSS, GPS, GLONASS, GST, LRIT, ETA, ITU, MF, VHF, HF, RCC, SOLAS, MSI, CRS, DSC, SES, VDES, VDL

## 1. Introduction

The existing Global Maritime Distress and Security System (GMDSS) network provides an integrated solution to distress, emergency, safety and conventional communications, and is the main platform for ship-to-shore, shore-to-ship and ship-to-ship interaction of maritime information. In order to coordinate the development with the E-navigation strategy, IMO Proposed GMDSS revision and modernization plan in April 2008.

Therefore, with the rapid development of the shipping market, the development of ships also tends to be large-scale, intelligent and specialized initiatives and the capabilities of existing shipborne communication equipment onboard ships can hardly keep up with navigation safety technology. Technological advances in electronics, radio and satellite communications, and ICT have led to new revolutionary proposals to an upgrade the equipment and systems used onboard oceangoing vessels. The standards and scope of the equipment onboard ships are playing key role in ensuring all these vessels' safety that strictly monitored by the International Maritime Organization (IMO) and its subsidiary bodies.

Oceangoing ships and other type of vessels are used as water vehicles for the transport of goods, passengers or other maritime transport operations. Such marine transport systems can be merchant ships, warships, barges or barges, etc., covering a wide range. Especially when the ship encounters special circumstances during the voyage, such as natural disasters, poor visibility or vessel damage, when the ship sinks and the equipment on it is damaged, it is impossible to seek help from the supervisory authorities in time, so such dangerous situations can cause great human casualties or heavy material losses.

If the Search and Rescue (SAR) authorities and units located in IMO member countries cannot receive the ship's position data in time, accurately locate the ship's in distress position, the relevant management department is unable to monitor and control the ship position without interruption and will not be able to affect the tracking and control capabilities, the safety of the ship's navigation and collision avoidance. In order to ensure the safety of the navigation of ships, a new Ship Tracking and Determination System (STDS) technology and instruments for installation on ships were invented, which can resolve that ships can automatically send their Position, Velocity and Time (PVT) and other data to SAR authorities and forces on time.

In order to ensure the safety of navigation, the following is necessary:

1. Mandatory to use STDS transponders and other navigational instruments to determine the ship's coordinates or to determine the ship's exact position independently without reference to any original position reference; and

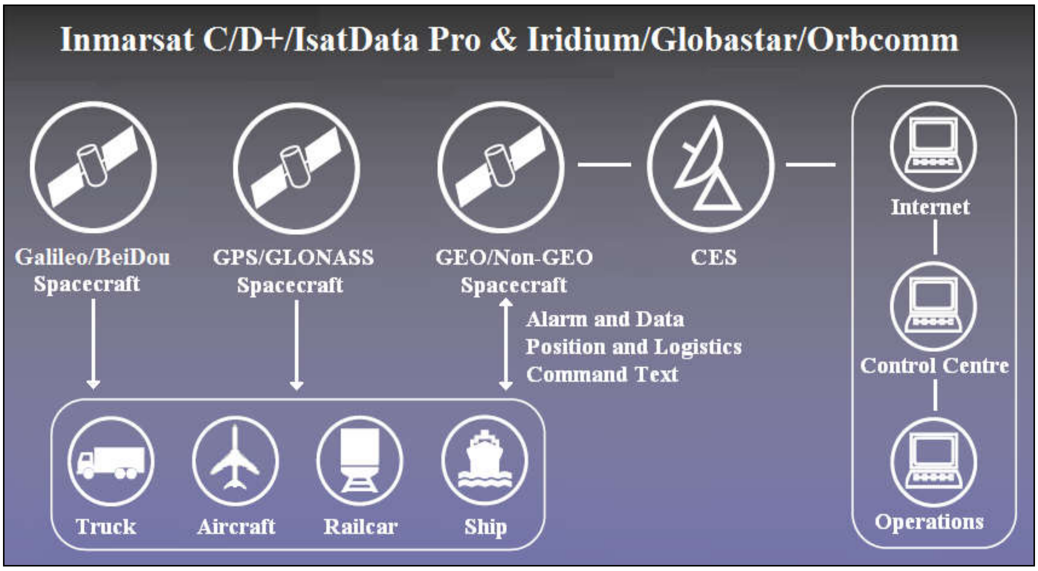


**Figure 1.** Configuration of SDTS via GNSS and GEO/Non-GEO Satellite Networks

2. Keeping oceangoing ships, other type of vessels or floating platform in a given PVT and other data or azimuth positioning method using STDS networks illustrated in **Figure 1.**
Implementation of SDTS networks together with ship positioning applications that have a very important security and commercial value, such as Global Navigation Satellite Systems (GNSS), are shown in **Figure 2.** Thus, the American Global Position System (GPS) and the Russian Global Navigation Satellite System (GLONASS) are GNSS-1 satellite networks that provide continuous position and speed in all three dimensions (latitude, longitude and altitude), equally effective for navigation and tracking of ships on the sea, on land (road vehicles and railways) and in the air,
Meanwhile, China has begun development of its own GNSS-2 satellite navigation system known as Compass (BeiDou), which is regionally operational. The shipborne STDS onboard equipment receives GNSS-1 or GNSS-2 determination signals from GPS, GLONASS, BeiDou or Galileo spacecraft (1) and sends PVT tracking messages of position (2) via GEO satellite to Ground Earth Station (GES (3) of Satellite Communication and Application Service Providers (Internet) to the TCS processor (4), which infrastructure is shown in **Figure 2.**

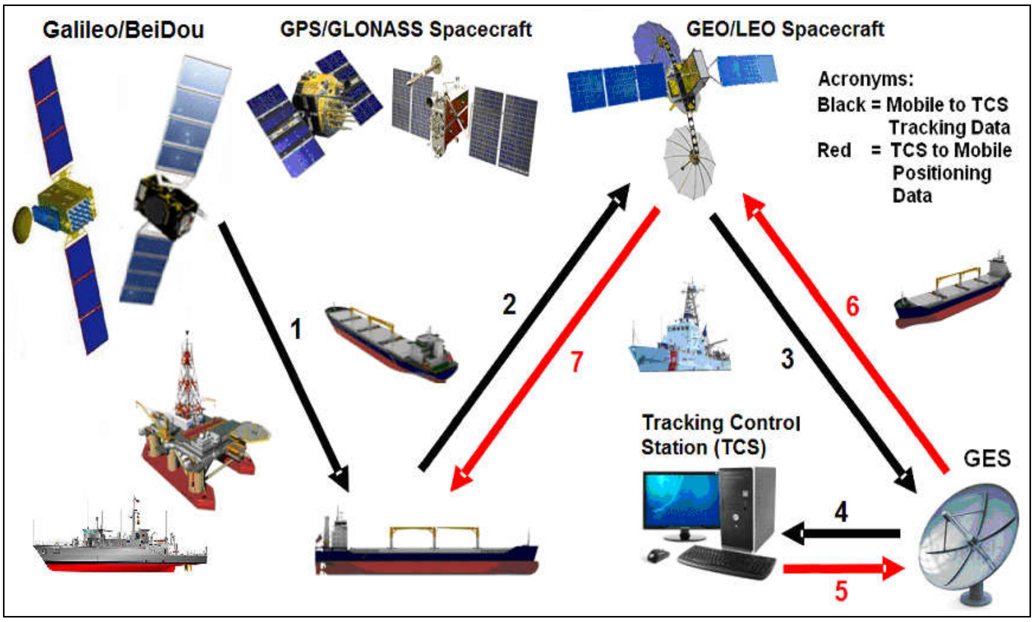


**Figure 2.** Commercial Maritime GNSS-1 and GNSS-2 Networks

As mentioned above, the operational Chinese BeiDou GNSS network consists of two separate satellite constellations that have been operating since 2000 and a full-band global system that is currently in operation. However, Europe's second GNSS-2 Galileo satellite network is still under development and will soon be fully operational.
Due to many incidents in the past with difficulties of searching ships in disaster and for enhanced ship collisions avoidance, the author of this paper proposed new tracking and determination solutions via Satellite CNS and determination systems known as Global Ship Tracking (GST). Similar to the Long Range Identification and Tracking (LRIT) network as a new more advanced GST solution contains the shipborne GST information transmitting equipment, such as integrated GPS or GLONASS Rx and GEO pr Non-GEO, such as Inmarsat or Iridium satellite transceivers, namely Transmitter and Receiver (Tx/Rx).
In addition to the GNSS networks, port authorities, shipping companies and agencies, including other ship port authorities can carry out all surveillance of oceangoing ships in their area, which enables better planning of port operations and guarantees the security of the seaport anchorage approach area. In fact, using SDTS devices and network, they will be also able remotely to monitor ship dynamics in real time and space to monitor and control ship safety management and execution of maritime operations schedules.
Finally, the support services for freight forwarding services, such as ship brokers, spare parts supply companies, and service providers can more accurately contact maritime agents or shipping owner' companies about ship Estimated Time of Arrival (ETA) in order to gain more secure business and commercial opportunities.

## 2. New Aspect of Satellite Global Maritime Distress and Safety System (GMDSS)

Since the invention of radio in the late 19th century, ocean-going ships at sea have relied on Morse code, invented by Samuel Morse and first used in 1844, for radio communications in distress, and on radio invented in early 1895 by Russian professor Alexander Stepanovich Popov. The need for ship and coast radio stations to use radiotelegraph equipment, and to listen Morse encoded distress calls, was recognized after the sinking of the liner Titanic in the North Atlantic in 1912.
The US Congress enacted legislation soon after, requiring US oceangoing ships to use Morse code radiotelegraph equipment for distress calls. The International Telecommunication Union (ITU), now a United Nations (UN) agency, followed suit for ships of all nations. Morse encoded distress calling has saved thousands of lives since its inception almost a century ago, but its use requires skilled radio operators spending many hours listening to the radio distress frequency. Its range on the Medium Frequency (MF) distress band of 500 kHz is limited, and the amount of traffic Morse signals can carry is also limited. Thus, the SOS distress alert call was transmitted on dedicated radiotelegraphy Medium Frequency (MF) band of 500 kHz, and the voice distress call Mayday was also conducted on MF radiotelephony bands of 2182 kHz.
At that time, not all ship-to-shore radio communications were short-range such MF using from 300 kHz to 3 MH and Very High Frequency (VHF) short range voice radio at 156,000-163,425 MHz. The crucial concept to grasp here is that these radios allow operators to select frequencies based on atmospheric conditions to establish communications over varying distances. In tehe meantime, Ships Radio Stations (SRS) provided long-range radio telephone, telegrams and telex services, in the High Frequency (HF) range of 3-30 MHz. Thus, maritime radio systems for commercial and distress communications have worked very successfully for decades, and after Marisat invented Maritime Satellite Communications (MSC) in 1976, with only three satellites they provided satellite communications services to cover the Atlantic, Pacific and the Indian Ocean.
By the end of the 1980s, MSC services at sea had started to take an increasingly large share of the market for ship-to-shore, shore-to-ship and intership (ship-to-ship) communications. By the end of the 1980s, MSC services at sea had started to take an increasingly large share of the market for ship-to-shore, shore-to-ship and intership (ship-to-ship) communications. For these reasons, the International Maritime Organization (IMO), as an UN agency, specialized in safety and security of shipping and preventing ships from polluting the seas began looking at ways of improving maritime distress and safety communications.

In 1979, a group of experts worldwide drafted the International Convention on Maritime Search and Rescue (SAR), which called for development of a global SAR plan. Soon after, this group also passed a resolution calling for development by IMO of an GMDSS to provide the communication support needed to implement the SAR plan more effective. This new SAR system, which the world's maritime nations are implementing, is based upon a combination of satellite and radio services, and has changed international distress communications from being primarily ship-to-ship based to ship-to-shore Rescue Coordination Center (RCC) based. It spelled the end of Morse code communications for all but a few users, such as amateur radio operators and some military is still using this service.
The GMDSS provides for automatic distress alerting and locating in cases where a radio operator doesn't have time to send an SOS or MAYDAY calls, and, for the first time, requires ships to receive broadcasts of maritime safety information which could prevent a distress from happening in the first place. In 1988, IMO amended the Safety of Life at Sea (SOLAS) Convention, requiring ships subject to it fit GMDSS equipment. Such ships were required to carry NAVTEX and satellite EPIRB units by 1 August 1993, and had to fit all other GMDSS equipment by 1 February 1999. By the way, US merchant ships were allowed to fit GMDSS in lieu of Morse telegraphy equipment by the Telecommunications Act of 1996.

## 3. Current GMDSS Network

The current GMDSS network is an integrated radio and satellite communications to ensure that no matter where a ship is in distress, alert and aid can be dispatched. This System ensures also the provision of Maritime Safety Information (MSI), both meteorological and navigational information, on a global basis at sea. The GMDSS SAR Network combines various subsystems, which all have some different limitations with respect to coverage into one overall system and the oceans are divided into four sea areas:
**Sea Area A1** – This area is located within range of VHF Coast Radio Stations (CRS) and Ship Radio Stations (SRS) with continuous Digital Selective Call (DSC) alerting available in range from the coast to about 20 to 30 nautical miles (NM) offshore, which is controlled by a contracting government of one country. The distress signals can by voice as the name of ship and he position as MAYDAY on VHF Channel 16 (156.8 MHz) or use alarm signal on VHF-DSC. The VHF maritime radio is also capable of transmitting and receiving DSC on channel 70 and radiotelephony on channels 6, 13 and 16. Oceangoing ships in this area need a radio receiver capable of maintaining a continuous DSC watch on channel 70 VHF, free floating Cospas-Sarsat satellite EPIRB transmitter, capability of initiating a distress alert from a navigational position using DSC on either VHF, HF or MF; manually activated EPIRB or Inmarsat Ship Earth Station (SES) terminals.
**2. Sea Area A2 –** This area, excluding sea area A1, is located within the radiotelephone coverage of at least one Medium Frequency (MF) CRS, which provides continuous DSC alerting available, as may be defined by a Contracting Government. The general area is from the A1 limit out to about 100 miles offshore providing radio telephone MF voice or direct printing at 2182 kHz, and DSC on 2187.5 kHz. In addition, this area provides equipment capable of maintaining a continuous DSC watch on 2187.5 kHz, general working radio communications in the MF band (1605-4000 kHz) or Inmarsat SES with capability of initiating a distress alert by HF (using DSC), manual activation of an EPIRB or Inmarsat SES terminal.
**3. Sea Area A3 –** This is an area that excludes sea areas A1 and A2, within the coverage of gthe Inmarsat Geostationary Earth Orbit (GEO) satellite constellation in which continuous alerting is available. This area is from about 70°N to 70°S that provides MF Radio telephone at 2182 kHz and DSC 2187.5 kHz. The area also provides equipment capable of maintaining a continuous DSC watch on MF 2187.5 kHz, Inmarsat-B or -C (class 2) or Fleet 77 SES, Enhanced Group Call (EGC), or HF as required for sea area A4. It has capability of initiating a distress alert by two of the following: Inmarsat- B or -C (class 2) or Fleet 77 SES, manually activated EPIRB and HF/DSC radio communications.

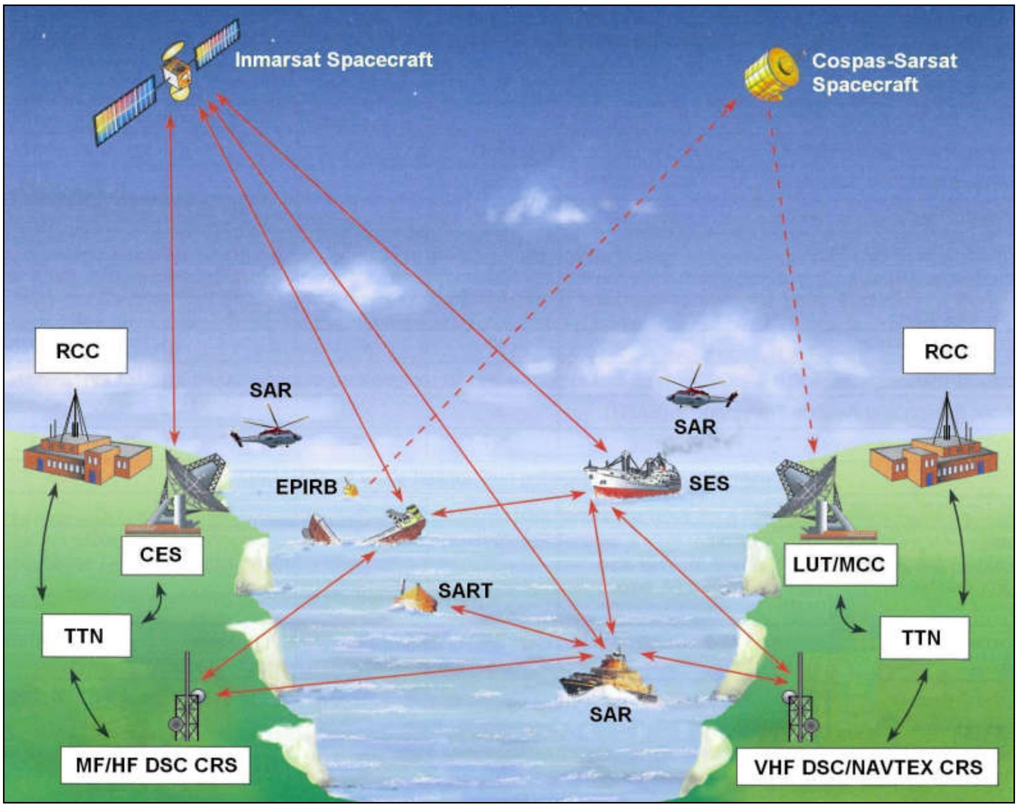


**Figure 1.** Current GMDSS Network – Source: IMO

**4. Sea Area A4** – This area is locating outside of sea areas A1, A2 and A3, which includes the Polar Regions above 70°N to 70°S geographical latitude, where Inmarsat GEO satellite coverage is not available. The area provides HF/MF receiving and transmitting equipment for frequency band 1605 to 27500 kHz using DSC, radiotelephone and direct printing, known as Narrow Band Direct Printing (NBDP). Besides, in this area can be used equipment capable of selecting any safety and distress DSC HF for band 4000 to 27500 kHz, maintaining DSC watch on MF 2187.5, HF 8414.5 kHz and at least one additional safety and distress DSC frequency in the band, and offers capability of initiating a distress alert from a Cospas-Sarsat LEOSAR, GEOSAR and MEOSAR manual activation of 406 MHz satellite EPIRB transmitters.

The regulation governing the GMDSS network is contained in the International SOLAS Convention for the Safety of Life at Sea (SOLAS) in 1974. The GMDSS requirements are contained in Chapter IV of SOLAS on Radiocommunications and were adopted in 1988. In fact, the GMDSS communications system under SOLAS complements the International Convention on SAR in 1979, which was adopted to develop a global SAR plan, which current integrated radio and satellite network is shown in **Figure 1.**

From 1 February 1999 all passenger vessels and all cargo ships of 300 gross tonnage and upwards on international voyages must comply with the GMDSS, and be fitted with all applicable satellite and radiocommunications GMDSS equipment, according to the sea area(s) in which the ship operates, for sending and receiving distress alerts and MSI, and for general communications. Specific equipment requirements for ships vary according to the sea area(s) in which the ship operates.

All type of oceangoing ships at sea and rivers must be capable of the following functional GMDSS requirements:

1. Ship-to-shore distress alerting; 2. Shore-to-ship distress alerting; 3. Ship-to-ship distress alerting; 4. SAR coordination; 5. On-scene communications in distress; 6. Transmission and receipt of emergency locating signals; 7. Transmission and receipt of MSI; 8. General radio communications; and 9. Bridge-to-bridge communications.

To meet the requirements of the functional ocean areas above the following is a list of the minimum communications equipment needed for all ships:

1. Ships VHF radio system capable of transmitting and receiving DSC on channel 70, and radio telephony on channels 6, 13 and 16;
2. Radio receiver capable of maintaining a continuous DSC watch on channel 70 VHF;
3. Search and Rescue Transponders (SART) are compulsory onboard ships and minimums of two have to operate in distress in the 9 GHz band. They are radar transponders portable devices, which are used as a complimentary distress alerting system. The SART unit enables any ship, airplane or helicopter in the area to locate survivors easily by just the use of their proper radar system;
4. Ship radio receiver capable of receiving NAVTEX broadcasts anywhere within range of MF 518 kHz used as the main NAVTEX channel, 490 kHz NAVTEX used for broadcasts in local languages, non-English, and HF 4209.5 kHz allocated for NAVTEX broadcasts in tropical areas, not widely used at the moment. The NAVTEX radio system is used for the automatic broadcast of localized MSI using Radio Telex, also known as NBDP;
5. Receiver capable of receiving SafetyNET anywhere NAVTEX is not available;
6. Satellite EPIRB manually activated and float-free self-activated; and
7. Two-way handheld VHF radios, two sets minimum on 300-500 GRT cargo vessels and three sets minimum on cargo vessels of 500 GRT and upward and on all passenger ships.

The GMDSS network except VHF/MH/HF radio systems are including the following three satellite operational systems:

**1. Inmarsat GEO Mobile Satellite Network** – Inmarsat mobile satellite operator is one of key players within GMDSS Network, which is providing GEO Space Segment, Land Earth Stations (LES), also referred to as maritime Coast Earth Stations (CES) and mobile Ship Earth Stations (SES). The main disadvantages of Inmarsat system is that Polar Regions are not visible to the operational satellites with coverage is available from about 75°N to 75°S.

This problem can be solved with interoperability with Big LEO Iridium network or better with establishment of hybrid satellite network with High Elliptical Orbit (HEO) such as Russian Molniya. The CES terminals provide the link between the Space Segment and the land-based national or international fixed communications networks (TTN). The data then travels from the CES to the Inmarsat Network Coordination Station (NCS) and then down to the SES terminals onboard ships at sea.

The onboard SES terminals, such as Inmarsat-B, C, F77 and FleetBroadband provide two-way communications between ship and shore. The main safety service via Enhanced Group Call (EGC) network of Inmarsat-C terminal, similar to VHF NAVTEX system, is broadcasting special SafetyNET services: 1. Navigational Warnings (NX); 2. Meteorological Warnings (WX); 3. Ice reports; 4. Search and rescue (SAR) information; 5. Meteorological forecasts 6. Pilot service messages (not in the U.S.); 7. Electronic navigation system messages.

**2. Iridium Big LEO Mobile Satellite Network –** Why GMDSS need Iridium maritime system? Inmarsat satellites can not cover both polar areas above 75º N and S latitude, so is important to include Big LEO Iridium constellation and provide more reliable maritime communications in Polar Regins than HF radio. Thus, it is necessary to understend that Inmarsat system is more professional than Iridium in providing service for MSS, so Iridium is needed just to provide coverage of polar regions.

In this case, on 27 November 2015 International Mobile Satellite Organization (IMSO) submitted proposal for Analysis of developments in maritime radiocommunication systems and technology for recognition of Iridium MSS as GMDSS service provider. Namely, this document provides in annex of IMSO report on the technical and operational assessment of the application by the USA to recognize and use the Iridium MSS in the GMDSS Network. The report is provided in response to the request by Maritime Safety Committee (MSC) 94 that IMSO should undertake the technical and operational assessment of the Iridium mobile satellite system (MSC 94/21, paragraph 9.20). The MSC operator, at its ninety-second session, considered a notification by the USA of an application by the Iridium MSS for recognition and use in the GMDSS (MSC 92/9/2) and having noted that, in principle, there were no objections, agreed to refer the matter to the Navigation, Communications and Search and Rescue Sub–committee (NCSR) for evaluation

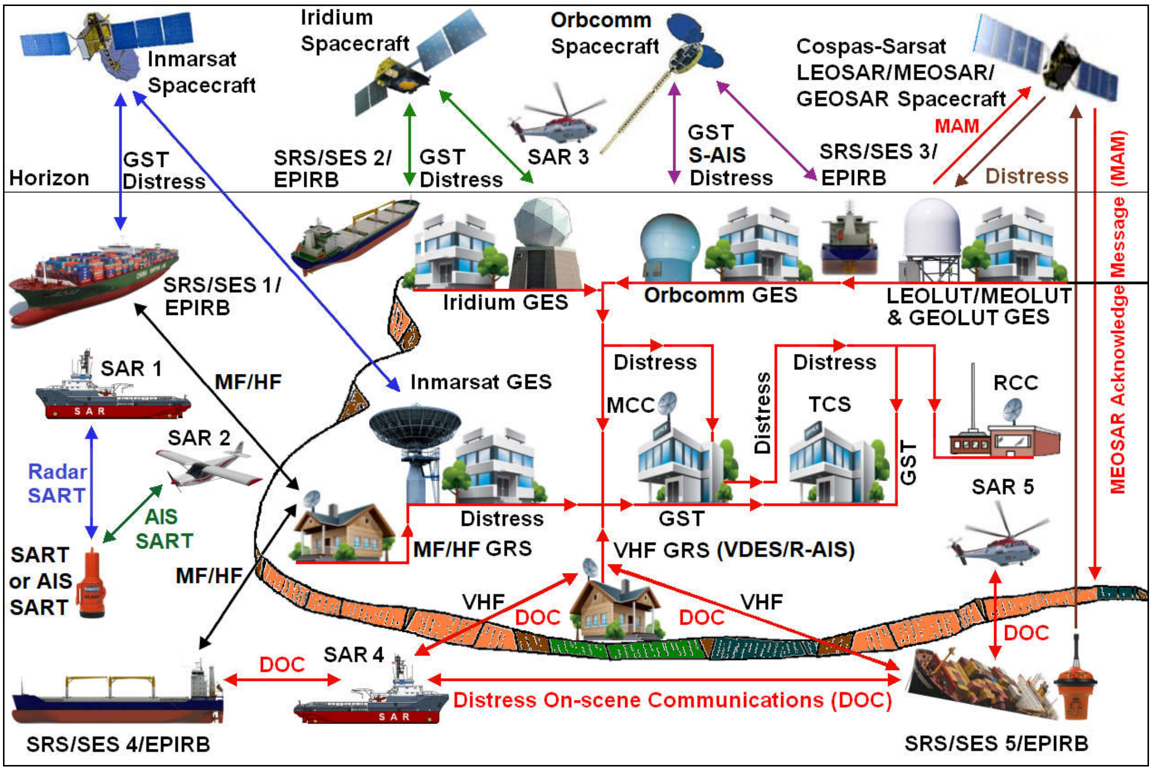


**Figure 2.** New Concept of GMDSS Network

**3. Cospas-Sarsat LEO/GEO/MEO Mobile Satellite Network** – This is satellite operator for all mobile application, which in particular provides an international SAR service for all ships via special 406 MHz satellite EPIRB transponders. Thus, each 406 MHz EPIRB incorporates a unique for certain ship, which after activation is automatically sending ship position via LEOSAR, GEOSAR and MEOSAR to LUT terminals, MCC and RCC.

**Traditional GMDSS Radio System** – As already stated, the traditional GMDSS radio system is providing VHF, MF and HF networks via Coast Radio Stations (CRS). While, Ships Radio Stations (SRS) consists onboard ship equipment terminals, such as Digital Selective Call (DSC), NAVTEX and Search and rescue radar Transponders (SART).

## 4. Enhanced GMDSS Network

The enhanced GMDSS space and ground network is developed and designed by author of this thesis, which integrated system architecture is illustrated in **Figure 2.** Components of enhanced GMDSS network are as follows: Radio, Satellite Communications and Satellite Cospas-Sarsat networks. The current radio system provides the same services in the VHF and MF/HF bands, such as voice DSC and NAVTEX transmissions of the current radio GMDSS network, including new VHF-band Data Exchange System (VDES), Radio-Automatic Identification System (R-AIS), and Navigation Data (NAVDAT). The autor of this thesis proposes new radio systems such as: Radio Automatic Dependent Surveillance-Broadcast (RADS-B), VHF Data Link (VDL), and GNSS Augmentation VDL-Broadcast (GAVDL-B).

As shown in **Figure 2** in the event of a distress alert, the GMDSS radio network provides a very important Distress On-scene Communications (DOC) service in the radio maritme VHF-band. The special VHF radio DOC links may be establsiihed between the ships in distress alert and SAR forces, such as SAR ships and helicopters. The radar SART transmitters provide links with radars onboard SAR ships, while the AIS SART transimtter provides links with R-AIS onboard SAR aircraft. However, it is also possible to provide MF Data Links (MDL) or HF Data Links (HDL) with DSC system, between ships in distress and SAR forces that are outside the radio VHF range.

In addition, **Figure 2** shows the current Inmarsat GEO satellite as a part of the GMDSS network and the proposed by author of this thesis Big Earth Low Orbit (LEO) Iridium, and Small LEO Orbcomm satelllite. The GMDSS network also include current Cospas-Sarsat LEOSAR, MEOSAR and GEOSAR subnetworks.

Among the current satellite systems, such as the Long Range Identification and Tracking (LRIT) and Satellite-Automatic Identification System (S-AIS), and based on the author's proposals, the Inmarsat and Iridium mobile satellite networks will be able to use Satellite Automatic Dependent Surveillance-Broadcast (SADS-B), Satellite Data Link (SDL), Global Ship Tracking (GST), and GNSS Augmentation Satellite Data Link (GASDL). The next proposal is to include the Orbcomm and O3b MSC systems in the GMDSS network, as Orbcomm has already developed its S-AIS satellite network.

In this case, there are discussions at IMO that may result in redefining Sea Areas A3 and A4 based on satellite coverage of systems other than Inmarsat, if such systems are approved for use within the GMDSS. This is not expected to come into force for several years. However, the new concept of enhanced GMDSS space and ground network is developed and designed by CNS Systems Company, which integrated system architecture is illustrated in **Figure 2.**

The main integrated components of enhanced GMDSS network are Radio VHF/MF/HF subsystem, Inmarsat and Iridium satellite communication subsystems and Cospas-Sarsat LEOSAR, MEOSAR and GEOSAR satellite subsystems. Radio system provides the same service via VHF and MF/HF bands, such as DSC and NAVTEX transmissions, including all applications listed in Sea Area A1 and same in A2, Inmarsat network provides all service listed in A2 and A3, while and Iridium network provides service listed in A4.

In such a way, new concept of GMDSS satellite system will provide Inmarsat and three Cospas-Sarsat subsystems including new proposals for Iridium. On the other hand, the LEO Orbcomm and Medium Erath Orbit (MEO) O3b networks, including the best hybrid constellation of GEO and Highly Elliptical Orbit (HEO) Molniya networks.

## 5. Modernization and Improvements of the GMDSS Sea Operational Areas

The modern technology deigns of global Satellite CNS system and maritime GMDSS equipment include Global Ship Tracking (GST) as enhanced Long Range Identification and Tracking (LRIT), Satellite AIS (S-AIS), Satellite Data Link (SDL), Satellite Automatic Dependent Surveillance - Broadcast (SADS-B) and GNSS Augmentation SDL (GASDL) to benefit for improved emergency alerts and SAR operation of ships in distress.

Due to the different radio and satellite communication systems incorporated into the GMDSS network having individual coverage limitations with respect to range and service provided, the equipment required to be carried by a ship is determined by the ship's area of operation, rather than by its size. The GMDSS network has divided the world's oceans into four distinct areas. The current requirements of GMDSS recommendations and regulations all GMDSS ships are required to carry onboard equipment appropriate to the sea area or areas coverage in which they operate, such as the following operational areas:

**Sea Area A1** – This are is within the radiotelephone coverage of at least one VHF coast station in which continuous VHF Radio DSC alerting is available in area of approximately of 20-30 nm range. As stated in abstract, according to the new technologies and developments in this sea GMDSS area can be included Radio Ship Tracking (RST), VHD Data Link (VDL) similar to aeronautical VDL Mode 4 or new proposed VHF Data Exchange System (VDES),

Radio-Automatic Identification System (R-AIS) known as VHF AIS, Radio Automatic Dependent Surveillance-Broadcast (RADS-B), GNSS (GPS or GLONASS) Augmentation VDL-Broadcast (GAVDL-B);

**2. Sea Area A2** – This area is within the radiotelephone coverage of at least one MF coast station in which continuous MF Radio DSC alerting is available in sea area of approximately 100 nm range (excluding Sea Area A1). However, in this area can be used VDL Mode-4 or VDES, RADS-B and Inmarsat mini-C or Inmarsat-C service;

**3. Sea Area A3** – This large area is within the coverage of an Inmarsat GEO satellite constellation in which continuous alerting is available in sea area of approximately between 76º N and 76º S range, (excluding Sea Areas A1 and A2). Besides, in this area can be used Global Ship Tracking (GST) proposed by the CNS Systems company from Durban, Satellite Data Link (SDL), Satellite Automatic Dependent Surveillance - Broadcast (SADS-B), GNSS Augmentation SDL (GASDL), Long Range Identification and Tracking (LRIT), Orbcomm Satellite-Automatic Identification System (S-AIS) and HF Data Link (HDL). Therefore, except Orbcomm S-AIS and HDL, all above stated satellite communication solutions can use Inmarsat GEO and Iridium Big Low Earth Orbit (LEO) satellite constellation;
**4. Sea Area A4** – This is the remaining sea coverage outside areas A1, A2 and A3 (basically in the range of the Polar Regions). In both polar areas can be used Iridium satellite constellation employing equipment such as Iridium GST, SDL and SADS-B and as well as Orbcomm S-AIS and HDL. In this case, there are discussions at IMO that may result in redefining Sea Areas A3 and A4 based on satellite coverage of systems other than Inmarsat, if such systems are approved for use within the GMDSS. This is not expected to come into force for several years. However, the new concept of enhanced GMDSS space and ground network is developed and designed by CNS Systems Company, which integrated system architecture is illustrated in **Figure 2.**

### 5.1. Developing Scope for Pre-modernization of the GMDSS Network

The preliminary modernization plan of the GMDSS network is prepared by IMO, Inmrsat, Cospas-Sarsat and other participants is known as Work Program of the Modernization, which is consisting the following main components: General provisions; Functional requirements in accordance with the International Telecommunications Union (ITU) Radio Regulations (RR) and other documents of the ITU-R; The provision of satellite services to the GMDSS and the redefinition of the sea area A3; VHF Data Exchange System (VDES) or known as VDL; Navigation Data (NAVDAT); Routing distress signals and related information; Search and Rescue (SAR) technologies; High Frequency (HF) Data Link (HDL) and radio communication; Requirements for the transportation of GMDSS racks; False alerts; Training; Outdated provisions; and Explanations.
In the process of modernization of the GMDSS, the following provisions should be taken into account of the IMO Subcommittee on Navigation, Radio Communication and Search and Rescue (NCSR) [NCSR 3, 2016]:
**1. Modernization Process** – This process and including new and revised documents, should not exclude vessels that are not parties to the SOLAS Convention from any technical and economic reasons. The documentation and equipment intended for such vessels must fully comply with the GMDSS system;
**2. Communications Statements** – These systems of the IMO to the radiocommunication sector of the ITU should be guided by the principle that ships not party to the SOLAS Convention can use the GMDSS and the integrity of the system should be preserved in this case. Including, if necessary, ITU-R recommendations prescribed for these vessels the equipment and use of the GMDSS frequencies;
**3. E-navigation System** – The GMDSS modernization project should continue to support the needs of the new E-navigation strategy; and
**4. New Technologies** – In order to note the effectiveness of new technologies, as well as the compliance with the set goals, the human factor, in the process of modernization the GMDSS will be involved both onboard ships and at shore infrastructures.
Taking into account the above components of the IMO GMDSS Modernization Plan and a special work program were adopted that included the revision and development of regulatory documents, standards and also reference materials. Thus, the following list is presenting the necessary actions considered at the session of the NCSR subcommittee [NCSR 4/12, 2016], of the IMO coordinated work plan for the modernization project:
**a). In 2018** – The NCSR subcommittee is completing the development of a Modernization Plan First draft amendments to the SOLAS Convention and related documents and finalizing draft revision of the criteria for the provision of mobile satellite services;

**b) In 2019** – Second draft amendments to the SOLAS Convention and related documents are provided together with testing the draft revision of the criteria for the provision of mobile satellite services in the GMDSS network;
**c) In 2020** – Final draft amendments to the SOLAS Convention and related documents and draft functional requirements for NAVDAT have to be are performed;
**d) In 2021 –** Approval of amendments to the SOLAS Convention with related technical documents and as well as testing functional requirements for NAVDAT facilities have to be resolved;
**e) In 2022 –** Adoption of amendments to the SOLAS Convention (and related addition documents, as appropriate) has to be prepared; and
**f) In 2023/24 –** All proposed amendments to the SOLAS Convention have to enter into force in a due course.

### 5.2. Statements of the Problems and Aspects of a Modernization Plan

The GMDSS network is integration complex of radio and satellite CNS systems, solutions and equipment intended to provide reliable emergency alert of any ship in distress situation, to ensure that any distress message will be received by shore or other ships in the immediate vicinity, to determine position of ship in distress, engage SAR operations with improved means of locating survivors and arrange prompt saving of their lives.
The GMDSS concept was developed trough the IMO and other contributors to change the way for conducting maritime distress communications for enhanced SAR operations. The GMDSS solutions and equipment are mandatory for all ships subject to the SOLAS convention, which include cargo ships of 300 gross tones or greater and all passenger vessels on international voyages.
The GMDSS network was developed to modernize and enhance previous emergency ships radiocommunication system and to provide a more effective distress alerting by using DSC and other radio VHF, MF and HF-band equipment and backed up with new satellite techniques and technologies. In fact GMDSS uses various types of radio and satellite equipment to transmit and receive accurate and real distress signals and also to improve rescue communications, coordination and increases the following tasks:
**1)** Ability to locate position of survivors from ship in distress situation and including from aircraft landed at sea;
**2)** Likelihood that distress alert will be received by shore radio and satellite stations or other ships in vicinity;
**3)** Probability that an alert in distress situation will be sent when a vessel is in a real distress and not false alert;
**4)** Capacity to provide mariners with vital Maritime Safety Information (MSI);
**5)** It is necessary to define the terms “Security messages” and “Other messages " and as well as state the requirements for radio installations to perform the above functions;
**6)** Provide the more reliable and effective types of GMDSS shipborne radio equipment to transmit and receive accurate and reliable distress signals; and
**7)** Modern tracking systems for maritime applications are developed in high level, but still there are problems of reliability of existing tracking networks and equipment respectively. Several problems of tracking system for maritime applications can be further emphasized.

## 6. Technical Aspects of the Modernization Plan

The more critical scenario for distress alerting situations is when ships are sailing across oceans and unfriendly coastal areas in very bad weather and sea conditions, when visible and audibility is almost zero, when sometimes technically is not possible to use surveillance radar and when is very difficult to detect surrounded ships for collision avoidance.
In order to ensure a more reliable, accessible and efficient situation on board in the event of possible awareness of distress, it will be necessary to use all new networks and monitoring and detection equipment, duchs as VHF-band Data Exchange System (VDES), Global Ships Tracking (GST) and GNSS Augmentation Satellite Data Link (GASDL).

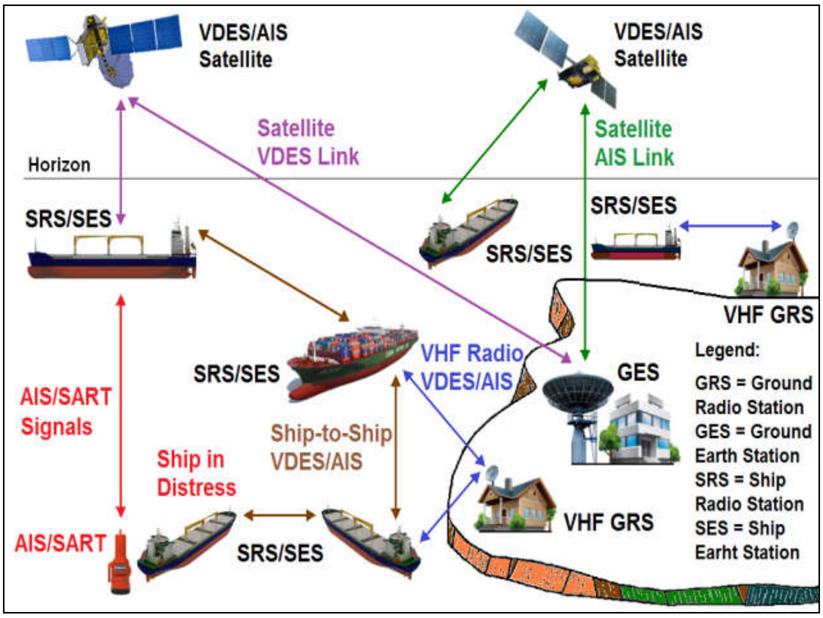

**Figure 3.** New Concept of VDES/AIS Network

### 6.1. VHF-band Data Exchange System (VDES)

The new developed VHF-band Data Exchange System (VDES) was developed by the International Association of Maritime Aids to Navigation and Lighthouse Authorities (IALA) to address the emerging signs of data transmission channel overload in the AIS (VDL) band and at the same time provides more wide and unhindered data exchange for the maritime community. The initial concept of VDES includes the function of an AIS (R-AIS), Application Specific Messages (ASM), VHF terrestrial and satellite communication segments.
The VDES network is one of the potential elements of E-navigation, which will exchange ASM transmission, thereby arranging operation of numerous applications to ensure safety, efficiency and protection of shipping, as well as environmental protection. In the future, the VDES network will have a significant positive impact on MSI network including Navigation Assistance Services (NAS) and Vessel Traffic Management System (VTMS).
In **Figure 3** is illustrated the modern concept of integrated VDES/AIS Network, which consists VDES/AIS space segment, ground segment integrated with GES and VHF GRS terminals and users segment containing SRS/SES terminals and AIS/SART beacons. The VDES/AIS Network provides satellite and VHF radio VDES/AIS links, inter-ship (ship-to-chip) communications, and AIS/SART signals. Thus, the AIS signals can be received by the R-AIS receiver and SART signals can be received by the onboard ships radars. Using VDES network can potentially provide a local VTMS, however VDES can also inlude concept deploying a space (satellite) segment for global coverage. The space segment of the system can be used for VTMS transmission in remote areas [Recommendation ITU-R M.2092-0, 2015]. An insufficient study and proposals of the issue of sharing and comparability between the new developed satellite segment of the VDE system and the existing services in the same and adjacent frequency ranges caused the operating frequency range to not be determined at the World Radiocommunication Conference in 2015 (WRC-2015) .
As a result, VDES as a whole is still not a complete functional system. As part of the 2015 IGC, the ITU approved the standard for VDES in the form of Recommendation ITU-R M.2092-0 [PP, 2015]. The issue of the approval of the satellite segment for data exchange channels in the VHF band (VDE) remains unresolved, which approval is one of the goals of the World Radiocommunication Conference (WRC-2019) in 2019. The study of the free frequency bands 156.0125-157.4375 MHz and 160.6125-162.0375 MHz will mainly concern the interaction with existing mobile services, primarily for land and maritime mobile services, as well as services within the adjacent lower bands (from 154 MHz to 156 MHz) high (from 162 MHz to 164 MHz) frequency ranges.

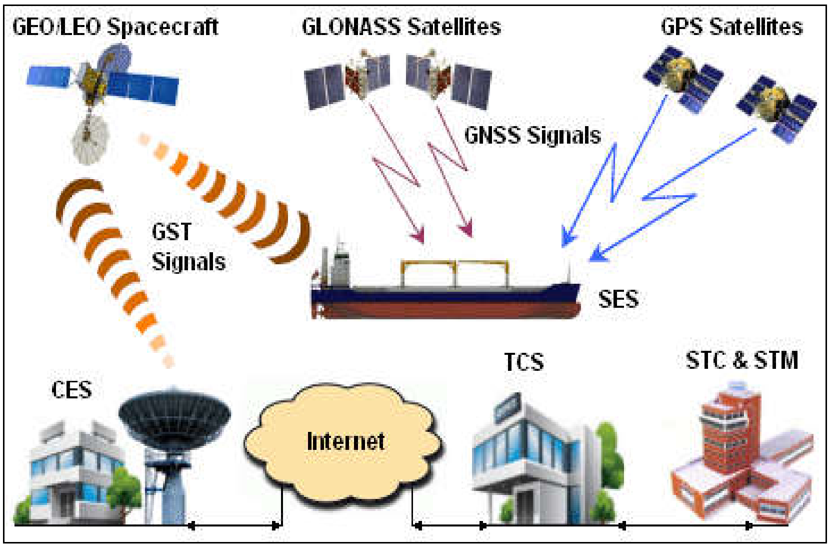


**Figure 4.** New Concept of GST Network

The concept of a VDES network and equipment will be developed under agenda item 1.9.2 at WRC-19:
**1)** Amendments to the ITU Radio Regulations, including new spectrum allocations to the maritime mobile-satellite service (Earth-to-space and space-to-Earth), preferably in the frequency bands 156.0125-157.4375 MHz and 160.6125-162.0375 MHz of Appendix 18, to create conditions for the operation of the VDES while ensuring that this segment does not impair the operation of existing VDES terrestrial segments, ASM, AIS network and does not impose any additional restrictions on existing services in these and adjacent frequency bands referred to in d) and e) of the section, recognizing ITU Resolution 360 (Rev. WRC-15).
**2)** In addition to other applications, the use of VDES must be considered in all kinds of future VTMS dissemination mechanisms.

**6.2. Global Ship Tracking (GST)**

The proposed GST network and onboard equipment, as the best solution for modernization GMDSS, can be any airborne GPS/Iridium or GPS/Inmarsat equipment installed together with GPS/Iridium or GPS/Inmarsat antenna secretly onboard ship. Because these devices are not very expensive can be installed two onboard ships or one as a back up. In fact, the GST mission can use existing GNSS satellite network for receiving GNSS signals, a real global Iridium Big Low Earth Orbit (LEO) satellite network with intersatellite links or a near-global Inmarsat GEO satellite network for commercial and distress data communications.
There are specific shipborne technologies that were designed for special and practical purposes and they are great at providing the intended service for the dedicated solution. For instance AIS network is a good global generalized picture of assets in the loosest terms possible because it’s not what it was built for.
There are applications where AIS is good to great, safety while sailing at sea, not getting ran over by a cargo ship at night or low visibility, etc. But oceangoing ships need discrete and autonomous systems coming up that are capable to replace medium to high intelligence satellite tracking devices such is already proposed by author of this book known as Global Ship Tracking (GST), which diagram is shown in **Figure 4.**
The new GST network has to provide special Maritime Information Service (MIS) for positioning data of ships in certain sailing ocean area. Namely, this service will be an automatically messaging system of Position, Velocity and Time (PVT) data of autonomous onboard ships unit containing GPS receiver, satellite transceiver and own battery power supply in combination with main ship power supply.

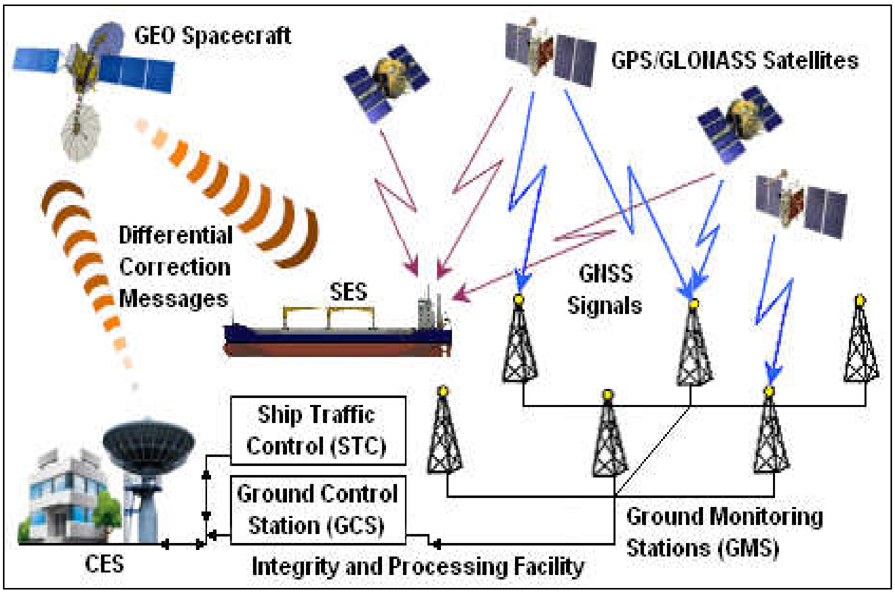


**Figure 5.** Maritime GASDL System for Enhanced GMDSS Network

The PVT data will be sent in certain intervals via Inmarsat or Iridium satellite, Coast Earth Stations (CES), Internet network to the special and independent Tracking Control Stations (TCS). Thus, these TCS terminals will receive, process and store PVT data of all ship sailing in its ocean area and show on a special screen similar to the radar display. Each TCS terminal has to be directly connected to the MCC, RCC, Ship Traffic Control (STC) and Ship Traffic Management (STM) systems. In addition, for enhanced service of collision avoidance, all ships sailing in certain ocean area can request from TCS terminals position of all adjacent ships or they simply can provide polling position data of all adjacent ships.

In such a way, the TCS terminal can receive PVT data from any ship, process and display on radar like display. What LRIT cannot do, GST can provide determination and surveillance of all ships in certain sea area for enhanced collision avoidance, assist SAR to find in shortest time any missing ship, provide data for immediate detecting position of ship captured by pirates and it is able to improve GMDSS facilities.

### 6.3. Maritime GNSS Augmentation Satellite Data Link (GASDL) Network

The Regional Satellite Augmentation System (RSAS) network is a combination of ground monitoring and space communication infrastructures dedicated to provide augmentation of standard GPS or GLONASS signals, which diagram of GNSS Augmentation Satellite Data Link (GASDL) network is illustrated in **Figure 5.** The major functions being provided by RSAS are as follows: 1. Differential corrections are determined to improve GNSS signal accuracy; 2. Integrity monitoring is predisposed to ensure that errors are within tolerable limits with a very high probability and thus ensures safety; and 3. Ranging is proposed to improve availability.

In the same way, the numbers of Reference Stations (GMS) are receiving not augmented signals of GPS or GLONASS satellites, processing and forwarding this data to Master Station (GCS). The GCS terminals provide processing of GNSS data to determine the differential corrections and bounds on the residual errors for each monitored satellite and for each area. The GCS terminal is providing determination of the clock, ephemeris and ionospheric errors (ionospheric corrections are broadcast for selected area) affected during propagation. The corrections and integrity information from the GCS terminal are then sent to each RSAS CES and uplinked to the GEO Satellites. Thus, these separate differential corrections are broadcast by RSAS CES through GEO satellite data link via GNSS transponder at the same frequency used by not augmented GPS receiver. For instance, augmented GPS Rx is receiving augmented signals of GPS satellite and determining more accurate position of ships.

Not augmented GPS Rx can also receive augmented signals if is provided an adequate software or hardware. The most important stage in this network is to provide technical solution that augmented position of ships can be sent automatically via SDL or voice to CES and STC centre. Finally, these positioning signals can be processed by special processor and displayed on look like radar display, whish traffic controller is using for STC and management for enhanced ship traffic control and improved collision avoidance in certain monitoring sea area.

### 6.4. Navigation Data (NAVDAT)

An MF radio system designed for use in the maritime mobile service operating in the 500 kHz band for digital broadcasting of information relating to maritime safety and security in the coast-to-ship direction. The NAVDAT system uses a time slot allocation similar to the International Automated Alert System known as Navigational Telex (NAVTEX) network, which IMO can coordinate in the same way.

The NAVDAT system can also operate in Single Frequency Network (SFN) mode. In this case, the transmitters are synchronized in frequency, and the data for transmission should be the same for all transmitters. Thus, the digital NAVDAT 500 kHz system provides broadcast transmission of any type of message in the shore-to-ship direction with encryption capability.

Any broadcast message must come from a secure and managed source. Types of messages for broadcast transmission include, but are not limited to, the following particulars:

1) Navigation safety; 2) Security Issues; 3) Data on piracy event; 4) SAR; 5) Meteorological reports; 6) Pilot or port communications; and 7) File transfer of the ship traffic system.

These messages broadcast information for vessels, groups of vessels, or in certain areas of navigation. Besides, these messages can be addressed to a single vessel using the Maritime Mobile Service Identity (MMSI).

The organization of the NAVDAT system is determined by five factors that ensure the performance of the following functions [Text. ITU-R M.2010, 2012]:

**1. System of Information and Management (SIM) –** Collects all types of information and manages this information, creates message files to be transmitted and creates transmission programs in accordance with the priority of message files and the needs of the replay;

**2. Coastal Network** – Provides transportation of message files from sources to transmitters;

**3. Shore Transmitter** – Accepts message files from SIM, converts message files to a signal with Orthogonal Frequency Division Multiplexing (OFDM) and transmits an RF signal to the antenna for broadcast to ships;

**4. Transmission Channel –** Transmits radio frequency signals at 500 kHz; and

**5. Ship Receiver** – Receive and demodulates an RF signal with OFDM, restores message files and sorts message files and makes them available to the target equipment in accordance with the application of the message files.

## 7. Normative Aspects of a Modernization Plan

Marine safety requirements are provided in chapter XI-2 of the IMO SOLAS Convention. The Ship Security Alert System (SSAS) does not imply the establishment of communications with other ships or coastal radio stations, and therefore, security messages are not part of the ship-to-ship and ship-to-shore communications. In fact, these messages are directly addressed to the competent authorities. It follows from the above that security messages should not be a functional requirement for the GMDSS network, however, chapter IV should oblige vessels to be able to provide security-related communications and give a clear definition “Security related communications”. Therefore, it is proposed to add to definition IV/2 the definition that “Security related messages” means messages associated with updating security levels, incidents or security threats, as well as security information prior to entry to the port.

At present, many maritime Coastal Radio Stations (CRS), state-owned are providing public correspondence in most cases are closed, in contrast to the time when the GMDSS system was just in its infancy. However, the equipment providing this type of communication is still relevant.

This type of communication is carried out through commercial services that are in no way associated with coastal radio stations, and the term "Private Messages" itself is no longer widely used. In this regard, for the GMDSS Modernized System, it is proposed to change the term "Private Messages" to "Other Messages" and include new features in this definition, but not as part of the functional requirements of the GMDSS. It is proposed to revise the term "General Radio Communication (GRC)" by agreeing it with the Radio Regulations. The Proposed new definition for GRC [NCSR 4/12, 2016] is as follows: "General radio communication means the exchange of official messages, but not about distress, transmitted by radio".

## 8. Conclusion

Discussions on the modernization of the GMDSS network are ongoing. The future of the GMDSS Modernization Plan is closely connected with the development of the e-Navigation project, and it is important to note the role of radio systems in this process. Undoubtedly, the data network will become one of the most important parts of the e-Navigation and reliable tracking systems projects. When carrying out modernization of the GMDSS network, it is necessary, firstly, to identify the needs of real users, and secondly, to realize that the modernization of maritime radio and satellite communications should not be limited only by technical requirements. In addition to the above, it is necessary to provide a sufficient amount of a real human-machine interface and human resources, including staff training.

When upgrading the system, all the "flaws" of the initial development and operation of the GMDSS network should be taken into account. In addition, the modernization process must be continuous and open, remain modern, and meet the expected requirements of electronic navigation. To ensure this, a mechanism for the continuous evolution of GMDSS should be created on a systematic basis. With this approach to the modernization of the GMDSS, it is very important that the integrity of the system is not violated.

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