

## Alternative Maritime Satellite Solutions for Enhanced GMDSS Network

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**ABSTRACT:** In this paper are introduced alternative architectures for the novel development of the enhanced Global Maritime Distress and Safety System (GMDSS) satellite communication network and equipment within the Geostationary Earth Orbits (GEO and Non-GEO satellite constellations). Since its founding in 1959, the International Maritime Organization (IMO) and its member states, in close co-operation with the International Telecommunication Union (ITU) and other international organizations, notably the World Meteorological Organization (WMO), the International Hydrographic Organization (IHO), the International Mobile Satellite Organization (IMSO) and Cospas-Sarsat partners, have striven to improve maritime distress and safety radio and satellite communications, as well as general communications for operational and personal purposes. This paper also reviews the principal concept of the GMDSS network, an overview of existing LRIT and maritime Integrated Radio-Automatic Identification System (R-AIS) and Satellite-AIS (S-AIS) networks. In addition, new proposed by author networks of the Satellite Data Link (SDL), Maritime GNSS Augmentation Satellite Data Link (GASDL), Maritime Global Ship Tracking (GST), and Maritime Satellite Automatic Dependent Surveillance-Broadcast (SADS-B) are also described in this paper.

### 1 INTRODUCTION

The improved GMDSS network through the Global Mobile Satellite Communication (GMSC) systems has to provide more reliable communication solutions for alerting and Search and Rescue (SAR) operations of oceangoing ships in emergency and distress situations, which have to ensure more automated alerting and SAR operations of ships and aircraft in distress at sea. Recent developments and advancements in maritime mobile satellite technology and technique have made it vitally important for commercial and safety satellite communication systems and for the integration of other GMSC networks into GMDSS infrastructures.

In order to integrate various maritime satellite communication networks into their safety and commercial systems, access to satellite networks and data needs to be improved. The already developed Inmarsat GEO, Iridium Big Earth Orbit (LEO), and Orbcomm Little LEO satellite systems are very important for GMDSS network because they are providing large areas of coverage, making them reliable and cost-effective for distress, safety and business solutions everywhere. They also provide many benefits to private companies and public networks, including being a subsegment of the integration in the future modernization of the GMDSS network.

## 2 MARITIME SATELLITE LONG RANGE IDENTIFICATION AND TRACKING (LRIT)

The current LRIT maritime satellite system is not a mandatory part of GMDSS communication requirements, but is mandatory for ships on international voyages and all ships of 300 GRT must comply with IMO regulations. Initially, LRIT used the existing devices, such as Inmarsat-C or mini-C satellite equipment, and recently began using Iridium satellite devices to report the ship identities, locations, dates and times that are regularly sent to the owner's headquarters or flag authorities.

The satellite LRIT network was subject to the new SOLAS regulations contained in its Chapter V which apply to ships constructed after 31 December 2008 with a gradual period of application for existing ships. Vessels trading exclusively in the A1 sea area and having R-AIS are exempt from the LRIT requirement. Thus, LRIT equipment onboard ships must be directly interfaced to the ship's Global Navigation satellite Systems (GNSS) equipment or have internal US GPS or Russian GLONASS receivers for positioning capability.

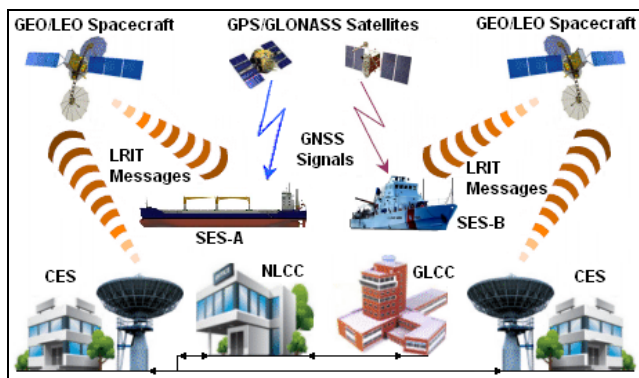


Figure 1. Maritime LRIT Network – Source: Ilcev

In Figure 1 is illustrated LRIT satellite network containing GNSS satellite constellation of GPS and GLONASS satellites, which provides GNSS signals to oceangoing or coastal going ships sent via GEO/LEO satellite systems. The LRIT network is also containing GEO/LEO satellite systems for transmitting position and other messages. Ships sailing in a certain area are sending LRIT messages to the National LRIT Control Centre (NLCC) and then messages are forwarded to the Global LRIT Control Centre (GLCC) for processing and delivering to potential users worldwide.

Regulations require that, by default, LRIT reports should be transmitted every six hours to the LRIT centres with frequency of transmission to be controlled remotely, allowing for reports to increase as security levels change up to a rate of one report every 15 minutes. The SOLAS regulation on LRIT establishes a multilateral agreement for sharing LRIT information between SOLAS contracting governments for security and SAR purposes. It maintains the right of flag states to protect information about the ships entitled to fly their flag, where appropriate, while allowing coastal states access to information about ships navigating off their coasts [01, 02, 03, 04].

## 3 MARITIME INTEGRATED R-AIS AND S-AIS

The existing VHF Radio-AIS (R-AIS) is the most attractive system for short-range tracking and detecting of ships in coastal navigation, sea passages and approaching to anchorages. Due to the limited R-AIS communication range that recently uses VHF bands, long-range satellite AIS (S-AIS) is proposed for global coverage via Inmarsat GEO, Iridium Big LEO and Orbcomm Little LEO satellite communication networks, whose integrated R-AIS and S-AIS Systems for Enhanced GMDSS Network are shown in Figure 2. The IMO Convention requires R-AIS to be fitted aboard oceangoing ships of 300 GRT or more, and all passenger ships regardless of size. The scenario is similar to the previous network, namely coastal sailing ships automatically broadcast information, such as their position, course, speed, rate of turn and navigational status at regular intervals via VHF transponder for enhanced Ship Traffic Control (STC) and Ship Traffic Management (STM).

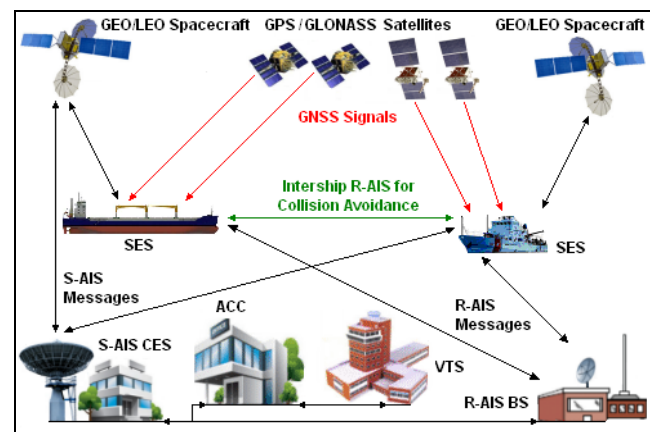


Figure 2. Integration of Maritime R-AIS and S-AIS Systems for Enhanced GMDSS Network – Source: Ilcev

Thus, the information originates from the ship's navigational sensors, typically its GNSS (GPS or GLONASS) receiver and gyrocompass, while other R-AIS information, such as MMSI, vessel name and call sign, are programmed during equipment installation and are also regularly transmitted. The signals are received by R-AIS transponders fitted onboard other ships and on the land R-AIS Base Station (BS), connected to the R-AIS Control Centre (ACC) and the Vessel Traffic Service (VTS). The received information can be displayed on radar or chart plotter, showing the positions of other vessels and their call sign information, in order to increase these systems and improve navigation safety. Other R-AIS data can be added to radar and chart plotting systems, making these critical systems much more efficient.

Thus, R-AIS provides coverage in the VHF band over short distances, so it can be integrated with Satellite AIS (S-AIS) to extend coverage, which onboard installed unit can send AIS data via GEO or LEO satellites to CES, STC and STM for processing. In this way, S-AIS messages detected by GEO or LEO satellites have become a very reliable method for detecting, tracking and collision avoidance solutions globally [01, 05, 06, 07].

#### 4 MARITIME SATELLITE DATA LINK (SDL)

The proposed ships SDL network is similar to the VHF Data Link (VDL) radio network, the system configuration of which is illustrated in Figure 3. Namely, the SDL transponder for determination and traffic management can be installed onboard oceangoing ships sailing on the high seas outside of radio VHF coverage. Otherwise, the SDL transponder installed onboard ships is integrated with a GNSS receiver able to receive navigation signals from GPS or GLONASS satellites and resend them via CES to STC and STM stations.

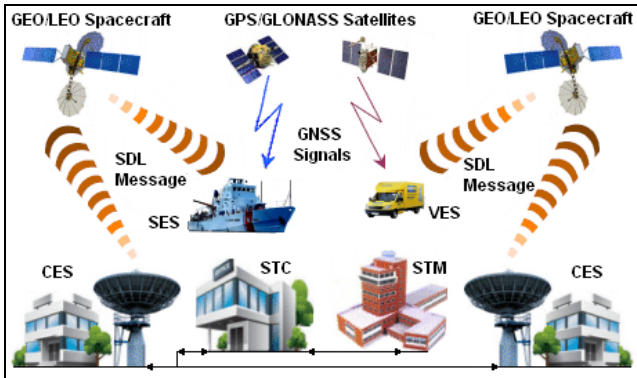


Figure 3. Maritime SDL System for Enhanced GMDSS Network – Source: Ilcev

All received Position, Velocity and Time (PVT) data from ships within SDL coverage will be processed and displayed on the radar like VDL display unit. In vice versa direction, a ship traffic controller can send PVT via GEO or LEO satellites to all ships outside seaports and manage their determinations and movements in a safer manner with enhanced collision avoidance. In such a way, captain of the ships can navigate more safely even in extreme bad weather conditions with zero visibility. The SDL network can be a part of an overall maritime satellite communication solution via Inmarsat or Iridium satellite networks for the following services:

1. **SDL Tracking Messages Service** – The concept of this service in similar way to VDS will be able to provide a satellite broadcast link supporting navigation and surveillance functions. Its transmission can be realized via Short Burst Messages (SBM) between SES terminals and CES connected to STC and STM. Vessels may be fitted with satellite transponders or satellite tracking devices integrated with a GNSS receiver (GPS or GLONASS), which may have autonomous SDL communication within the coverage of a particular CES or may operate with any compatible CES worldwide via the GEO satellite constellation. The SDL transponder can also support similar services via the Iridium network and well be able to provide real global coverage including both Poles. The SDL transponder allows ship captains and STC operators to “display” vessels traffic in ocean or coastal navigation outside VDL coverage with the greatest possible position accuracy, which can improve safety and security at sea. Thus, different CES terminals can operate within Inmarsat, Globalstar, Iridium or Orbcomm networks around the world, respectively. However, CES terminals and an interfaced terrestrial network will provide

increased functionality and capability for wide area coverage of advanced CTC and STM. The functionality of CES terminals is tailored to system specific service applications by its software configuration.

2. **SDL Communication Service** – Every seagoing vessel carries SDL transponders or satellite communication devices will be able to send and receive Short Burst Data (SBD) or High Speed Data (HSD) messages for Communication, Navigation and Surveillance (CNS) purposes. As part of overall maritime communications solutions, the new SDL technology can provide customers with a global secure and accurate messaging service. The ship’s captain can use two-way messaging, navigation data, text and graphics weather bulletins (WX), navigation warnings (NX) and route planning with just a few applications provided by Inmarsat and Iridium satellite operators around the world. Both operators also provide valuable redundancy to satellite services, while at the same time requiring minimal equipment or upgrade reliability, creating a cost-effective, safety and vital communications service for ships. This service will also provide real-time information on sailing, destinations, Estimated Time of Arrival (ETA), movement times, engine parameters, delays, positioning, maintenance, etc [08, 09, 10, 11].

#### 5 MARITIME GNSS AUGMENTATION SATELLITE DATA LINK (GASDL)

The Regional Satellite Augmentation System (RSAS) networks of GNSS infrastructures are a combination of ground monitoring and satellite communications systems dedicated for providing augmentation of standard GPS or GLONASS signals, which GASDL diagram for enhanced GMDSS Network is illustrated in Figure 4. The major functions being provided by RSAS are as follows: 1. Differential corrections are determined to improve the accuracy of GNSS signals; 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.

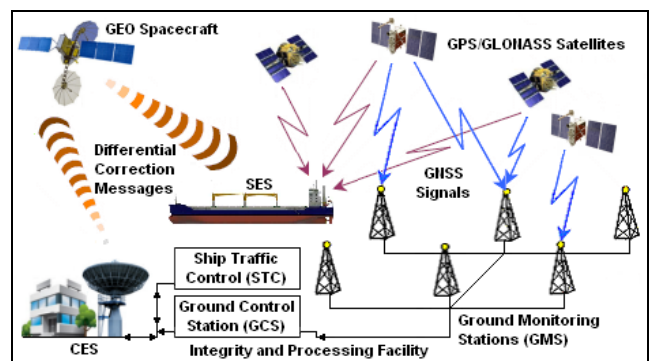


Figure 4. Maritime GASDL System for Enhanced GMDSS Network – Source: Ilcev

The numbers of Reference Stations or Ground Monitoring Stations (GMS) are receiving not augmented signals of GPS or GLONASS satellites,

and then processing and forwarding this data to Master Station or Ground Control Stations (GCS). Thus, GCS terminals provide processing of GNSS data to determine the differential corrections and bounds on the residual errors for each monitored satellite. They are also providing determination of the clock, ephemeris and ionospheric errors (ionospheric corrections are broadcast for a 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.

These separate differential corrections are broadcast by RSAS CES through GEO SDL via GNSS transponder on the same frequency used by the not augmented GPS receiver. The augmented GPS receiver (Rx) receives augmented signals of GPS satellite and determines the more accurate position of ships. The not-augmented GPS Rx can also receive augmented signals if the appropriate software or hardware is provided. The most important stage in this network is to provide a technical solution so that the augmented position of ships can be automatically sent via SDL or voice to CES and STC centre. These positioning signals can be processed by a special processor and displayed on look like radar display, which the traffic controller uses for STC and STM enhanced ship traffic control and improved collision avoidance in certain monitoring sea area, (09.12,13).

## 6 MARITIME GLOBAL SHIP TRACKING (GST)

Today, there are specific shipborne technologies that were designed for purposes of vessels tracking and monitoring of oceangoing vessels. For example, R-AIS network is a good global general radio coverage of maritime assets, but it is practically not what it was built for. There are applications for ships in which R-AIS is good for safety during navigation, but sometimes it is a problem to get the position of a cargo ship at night or during extremely bad weather conditions and poor visibility, or ship navigation devices are switched off etc. Namely, today oceangoing ships need discrete and autonomous systems with their own GNSS receiver that run highly intelligent satellite tracking devices, such as the proposed Global Ship Tracking (GST), whose diagram is shown in Figure 5.

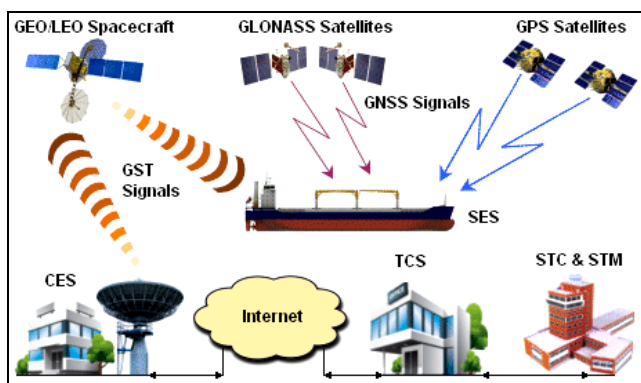


Figure 5. Maritime GST System for Enhanced GMDSS Network – Source: Ilcev

To sum it up, R-AIS only onboard device improves the safety of navigation by assisting the Officer of the Watch (OOW) or whatever entity. It's pretty easy to install as well, as R-AIS is generally integrated with ship bridge navigation systems of GPS and radar or multifunctional display, but what can happen if someone intentionally turns off the ship's GPS or radar or those devices have failed to work properly. The additional limitations of R-AIS include: (1) Its information may not be accurate and it could become overwhelmed; (2) The information could be misinterpreted; (3) It is not compulsory on every vessel and operators may deactivate their R-AIS device; (4) Users must be aware that erroneous information might be transmitted by the R-AIS from another ship; The OOW could become over-reliant on R-AIS service, and (6) The ships position received on the R-AIS display might not be referenced to the World Geodetic System (WGS) 84 datum, and also the information could be misinterpreted.

The flow of R-AIS vessels positioning data is good and which is also designed to prevent collisions and identify nearby vessels and even aircraft for safety, but its reception is unpredictable and unverifiable. In addition, the R-AIS network is designed on a low reliability and unknown coverage of land based transponders and provide delayed reports if is used satellite S-AIS relays. Thus, all of the above disadvantages of the R-AIS network may be managed by commercially controlled and predictable S-AIS satellite receivers, but R-AIS is not designed or installed around satellite transmission because the ship's antenna is linearly polarized and not directed toward the sky.

On the other hand, the current LRIT satellite system as the first compulsory equipment onboard ships designed by the IMO to collect and disseminate vessel position information received from IMO member states ships that are subject to the International Convention for the SOLAS vessels. It is also obvious that this system is not very successful for vessel tracking worldwide, because the problem is not due to ship's LRIT devices inability, but because of not at all the functional design of LRIT system and network. However, the biggest disadvantage of LRIT network is that it cannot as a GST system to transmit in real time and space navigation data of adjacent ships on request of any ship sailing in certain sea area for collision avoidance, to provide polling of this data and that LRIT is not able to provide tracking of missing or captured ships by pirates.

However, the proposed GST solution is able to provide all service as LRIT does including to provide tracking of missing and hijacking ships. It is the best solution for satellite tracking of ships in any real time and space worldwide, to determine positions of all ships sailing in vicinity to the ship requesting this data for collision avoidance or operator can get this data by polling from Tracking Control Station (TCS). In fact, using satellite links of GEO or LEO satellites any ship equipped with GST unit is able to send automatically its PVT and other data, provided by GPS and/or GLONASS spacecraft, separately via Inmarsat, Iridium, Globalstar or Orbcomm satellites to CES, Internet, TCS and Ships Operations (STC and STM). In such a way, the TCS terminal can receive

PVT data from any ship, process and display on radar like display.

Thus, whatever LRIT and S-AIS networks can implement, the new proposed GST network will be best to provide PVT data for the tracking, identification, and monitoring of all ocean-going vessels in a given marine area to improve collision avoidance. In addition, GST satellite network, will be only able to provide PVT data for immediate detecting position of ship captured by pirates and it is able to improve GMDSS network facilities. Integrated with special RFID units, the GST satellite devices can be used for only possible and reliable Global Container Tracking (GCT).

In conclusion, it can be stated that by using the GST system on each vessel, all the shortcomings of the LRIT, R-AIS and S-AIS networks can be avoided. The new proposed GST network and ships installations can provide the following services: (1) Autonomous and discrete satellite tracking and detection system, the installation of which is unknown to anyone onboard ship; (2) Own power supply via ships generator and rechargeable batteries; (3) Remotely control of terminal parameters and Data Terminal Equipment (DTE) installed on the bridge used as small message terminal with keyboard and display; (4) Communication with person in distress and emergency (5) Command, control and different sensor monitoring; (6) Terminal information, location, firmware and device diagnostics; (7) Re-key or encryption and authenticated negotiation; (8) Geofencing or integration with GNSS or Radio Frequency Identification (RFID) equipment and hybrid network support; and (9) GPS quality and jamming detection [08, 09, 14, 15].

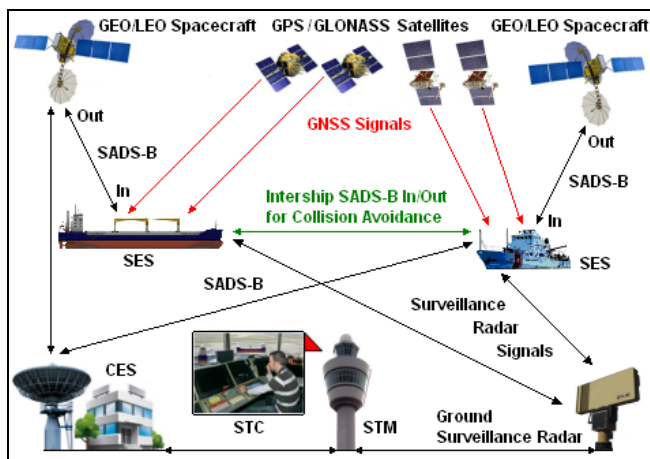


Figure 6. Maritime SADS-B System for Enhanced GMDSS Network – Source: Ilcev

## 7 MARITIME SATELLITE AUTOMATIC DEPENDENT SURVEILLANCE-BROADCAST (SADS-B)

The satellite SADS-B network is a new system developed for airborne mission similar system to radio RADS-B network with the only difference that it operates via satellite instead of the VHF radio, and

which can be implemented for maritime applications, shown in Figure 6.

Thus, each letter of the SADS-B means the following explanation:

- Satellite indicated that it is used for transmission of information and for RADS-B means that is using VHF radio for data transmissions;
- Automatic means that SADS-B periodically transmits information with no ship, vehicle or aircraft operator input required, nor common or specific interrogation;
- Dependent stands for sending position and velocity vector derived from GNSS1 (GPS or GLONASS) Receivers (Rx) terminals. In the future can be used GNSS2 receivers, such as Chinese BeiDou (Compass) and European Galileo systems;
- Surveillance is a method of determining the position of ships, vehicles, aircraft or other mobile assets; and
- Broadcast is transmitted information available to anyone onboard mobile or at shore with the appropriate receiving equipment.

The proposed SADS-B satellite network is a modern shipborne satellite broadcasting system proposed by author of this book, which is similar to current airborne SADS-B in development phase. This system will provide PVT and other data that have been detected and computed by onboard ships sensors, such as GNSS (GPS or GLONASS) receivers, ground surveillance radar, gyrocompass and other instruments. Typical SADS-B maritime system is similar to the RADS-B with additional differences that the SADS-B network is covering large distances and is using service of GEO or LEO satellites to send OUT or receive IN SADS-B information to STC and STM via CES ground terminals, which configuration is shown in Figure 7.13. A single CES terminal can provide ships-to-ship, ship-to-shore and shore-to-ship broadcasting in ocean areas for surveillance service to ships sailing on the high seas, in critical straits passages with an enhanced traffic, approaching to anchorages and even in large ports.

Therefore, an SADS-B system is a special integrated satellite surveillance technology in which a ship determines its position via satellite navigation and periodically broadcasting via satellite own VPT and other data important for safely and secure navigation. The information can be received by STC as a replacement for maritime ground radar system. It can also be received by other ships to provide situational awareness, allow safe sailing and enhanced collision avoidance.

In addition to the good characteristics, the ADS satellite network has not some features as GST does such as:

1. This system is not discrete so that someone uninvited, under force by pirates or purposely can turn off the unit completely, part of the unit or just GNSS receiver;
2. This system cannot work properly if it has not an integrated GNSS (GPS or GLONASS) receiver; and
3. This system needs to be installed to some secret place and although is powered by ship sources it needs own charger and batteries [01, 09, 14, 15, 16].

## 8 CONCLUSION

The Iridium network is the largest commercial satellite system in the world and the only network that offers true global communication coverage of totally 100% of our planet. Uniquely, new Iridium NEXT satellites also cover the entire Earth, including the poles, and provide voice, data and video services via the new Certus terminals at sea, on land and in the air. Importantly, the new Iridium Certus communication system provides for the first time a global broadband and Internet network via the NEKT satellite constellation.

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