Architecture and Applications of Contemporary Oceangoing Ship Tracking and Detecting Systems (STDS)

Dimov Stojce Ilcev
University of Johannesburg (UJ), Johannesburg, South Africa

Abstract: This paper presents the architecture and applications of contemporary oceangoing Ship Tracking and Detecting Systems (STDS) through the integration of Global Navigation Satellite System (GNSS) and Geostationary Earth Orbit (GEO) or Non-GEO satellite transponders. These modern satellite transponders are able to monitor all assets at sea and to improve safety, security of vessel movements and collision avoidance, especially during very bad visibility and weather conditions and. By deployment of the GNSS in integration with Inmarsat, Iridium and other satellite systems in one integrated satellite transponder with antenna, it is possible to provide reliable positioning and tracking solutions for civilian and military mobiles and personnel at different Radio Frequency (RF) bands. Thus, the first generation of GNSS-1 networks includes the US Global Positioning System (GPS) and the Russian Global Navigation Satellite System (GLONASS), while the second generation of GNSS-2 networks includes Chinese BeiDou and European Galileo. In fact, existing and forthcoming space and ground segment for tracking and detecting such as modern STDS onboard ships and other relating systems are discussed and benefits of these new technologies and solution for improved tracking and detecting applications are explored.

Key Words: STDS, GNSS, GEO, Non-GEO, LEO, MEO, HEO, RF, GPS, GLONASS, BeiDou, Galileo, SAR, AIS, LRIT, ETA, Satellite Transceiver (Rx/Tx), CNS, PVT, GST, GCT

1. Introduction

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 cannot receive the ship's position data in time, accurately locate the ship's 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 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
2. Keeping oceangoing ships, other type of vessels or floating platform in a given VPT and other data or azimuth positioning method.

From the perspective of technical means, the selected ship positioning system has the following five main positioning methods:

1. Positioning of ships using coastal CDMA networks, that is, dynamic tracking of coastal ships via CDMA network;
2. Using up-to-date non-augmented or augmented GNSS networks and instruments on ships;
3. Using radio and satellite Automatic Identification System (AIS) networks and ship’s instruments for positioning and identification of all seagoing vessels;
4. Using the Long-Range Identification and Tracking (LRIT) system and ships instruments for providing the global identification and tracking of ships and to enhance the security of shipping for the purposes of safety and marine environment protection.

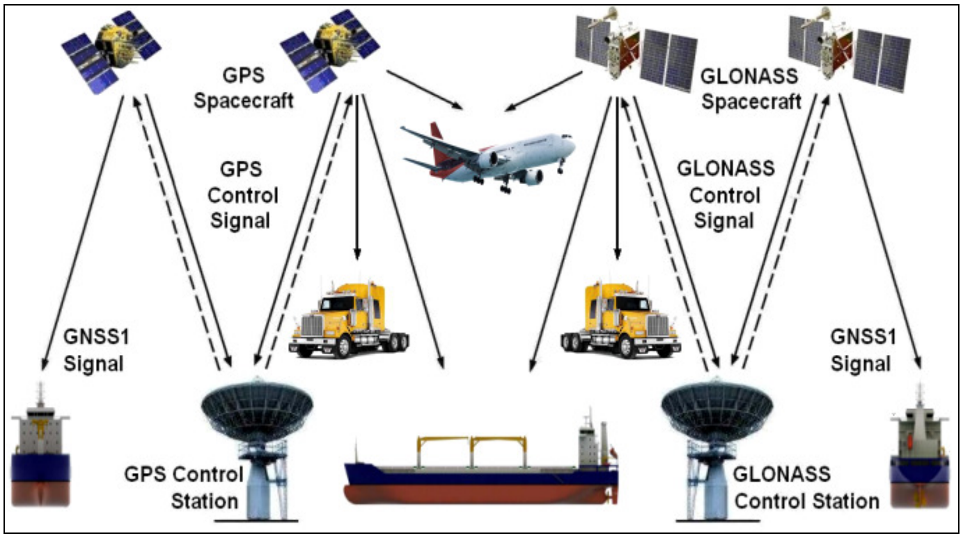

Figure 1. Commercial and Military Mobile GNSS-1 Networks – Source: Ilcev

5. Using STDS networks and transponders onboard ship for automatic and autonomous tracking and determination as a main possibility of all types of commercial and military vessels using VPT transponders and other identification data.

The implementation of a ship positioning networks and applications has a very important security and commercial value. In addition, shipping companies, charterers, agents and other ship operators can remotely monitor ship dynamics in real time and space to monitor and control ship safety management and execution of maritime operations schedules.

In addition, port authorities and shipping agencies can carry out all surveillance of ships in their area, which enables better planning of port operations and guarantees the security of the seaport anchorage approach area. Finally, support services for freight forwarding services, such as ship brokers, spare parts supply companies, and service providers can more accurately contact agents or shipping owners about ship Estimated Time of Arrival (ETA) in order to gain more business and commercial opportunities.

2. Development of STDS Network for Maritime Applications

After the Soviet Union launched the world's first artificial Earth satellite, Sputnik 1, which was launched into an elliptical low Earth orbit on 4 October 1957, satellite systems became the method of choice for communicating positioning information with the development of the first GNSS constellations and other commercial satellite communication networks.

The US military's Transit system began development from 1960, and the Soviet Union's or Russian Cicada military system was established in 1974. After early experimentation with the doomed Transit and Cicada systems, remember you had to wait hours for the next satellite to appear overhead, the new GNSS GPS and GLONASS were created at the end of the 20th century to offer a highly accurate global satellite positioning system in longitude and latitude, almost anytime anywhere in the world.

The transit system was shut down in 1996 to 2000 after more than 30 years of reliable operation. By then, the US Department of Defense was fully converted to the new GPS network.

The GPS service could not have a market for itself, thus almost at the same timethe former Soviet Union developed a similar system called GLONASS in 1988 and discontinued the previous Cicada system. The Transit or Cicada systems provided intermittent two-dimensional fixations (latitude and longitude) on average every 90 minutes and were most suitable for maritime navigation, GPS or GLONASS GNSS-1 satellite networks provided continuous position and velocity in all three dimensions (latitude, longitude and altitude), equally effective for navigation and tracking ships at sea, on land (road vehicles and rail) and aircraft in the air, whose space, users and ground segments are shown in **Figure 1.**

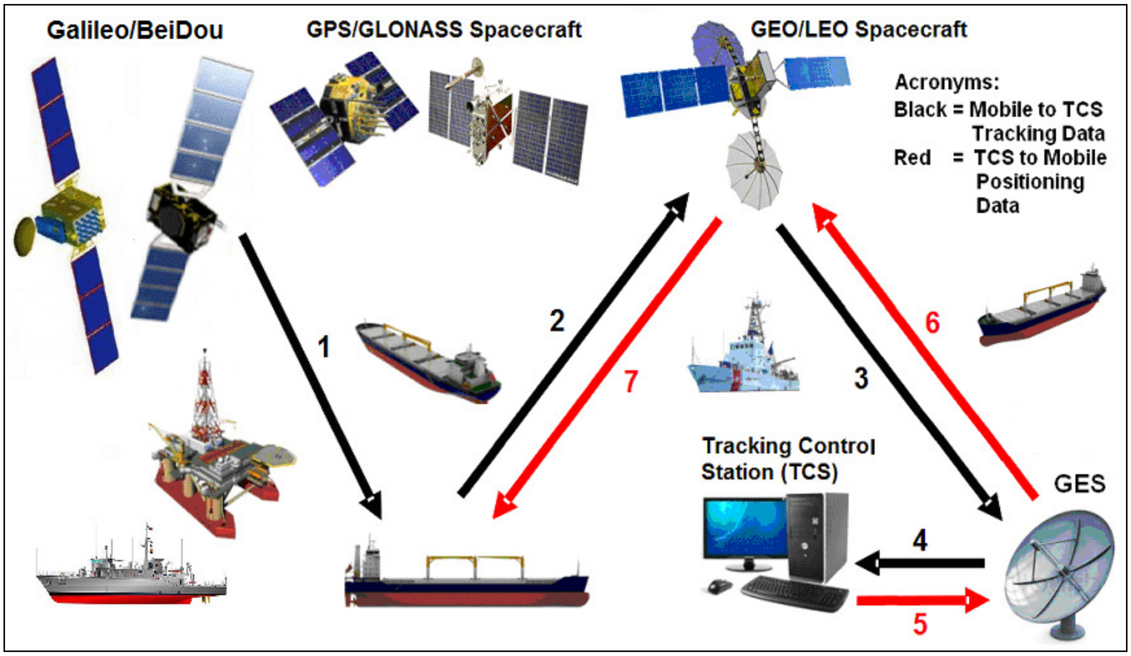

Figure 2. Commercial Military Maritime GNSS-1 and GNSS-2 Networks – Source: Ilcev

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 PTV 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.**

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) new and 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).

3. Global Satellite Ship STDS Networks and Solutions

The GNSS network is represented by fundamental solutions for PVT, identification and other data of the US GPS and Russian GLONASS military satellite systems, which suffer from particular weaknesses that render them unsuitable for use in modern transportation state affairs as sole solutions for positioning, tracking and detecting of oceangoing ships, land vehicles (road and rail), aeronautical and other mobile assets.

Thus, a major goal of the near-universal use of GNSS systems is their integration with maritime and other mobile satellite systems, which very small integrated GNSS/Satellite transponder units will be able to improve positioning, detecting and tracking facilities of ships, crew, passengers and other mobile, such as ground vehicles and aircraft.

As a result of these significant efforts, new positioning, detecting and tracking technologies have been projected and developed to utilize modern space (radio and satellite) Communication, Navigation and Surveillance (CNS) solutions and services for enhanced traffic control, monitoring, and management of civilian and military mobile personal and assets.

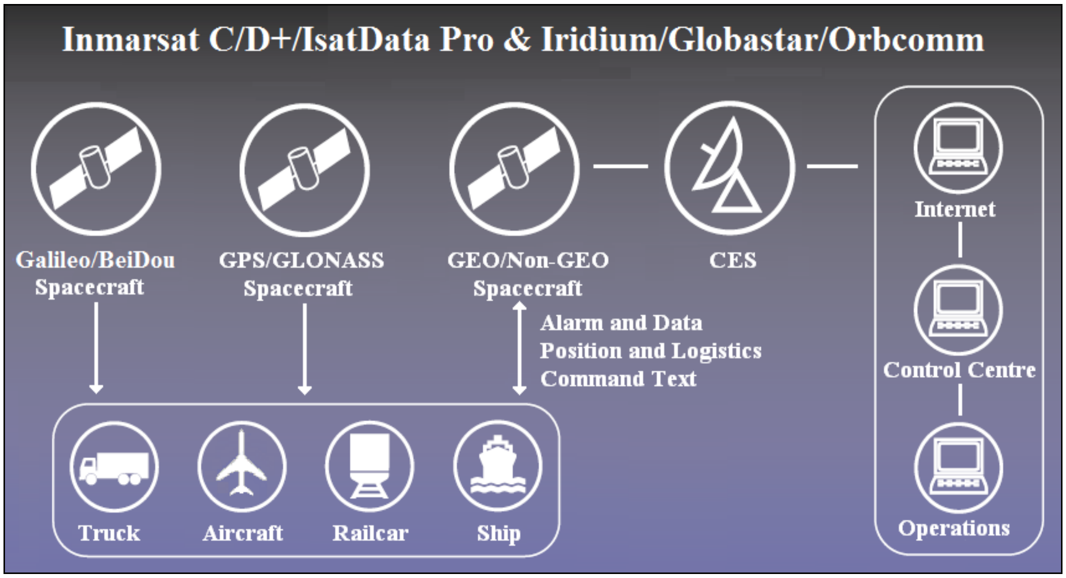

Figure 3. Configuration of SDTS via GNSS and GEO/Non-GEO Satellites – Source: Ilcev

Received tracking data by GPS/GLONASS Receiver (Rx) onboard oceangoing ships and other offshore objects can be sent via Inmarsat GEO or Iridium Non-GEO spacecraft, Ground Earth Stations (GES) terminals and Internet to the Control Centres and Operations Control. In fact, all ships and crew require far more sophisticated service from modern satellite tracking systems than standalone GPS or GLONAS positioning systems in distress and Search and Rescue (SAR).

In fact, it is proposed STDS network as integrated configuration in one satellite transponder is containing very small GPS or GLONASS receivers integrated with miniature GEO and Non-GEO satellite transceivers with both adequate antennas in one radome. The configuration of STDS infrastructure for civilian applications is illustrated in **Figure 3**, which integration is deploying the GNSS subsystem of US GPS and Russian GLONASS to provide free of charge PTV and other data to oceangoing ships an d all mobiles in seaport area. This PTV and other data can receive ships and vehicles, such as trucks and railcars and ships via onboard GPS/GLONASS Rx integrated with satellite transceiver.

Then the Satellite Transceiver (Rx/Tx) is providing frequently transmissions of PTV and other data via GEO or Non-GEO spacecraft through GES or Gateway terminals and Internet to the Control and Operations Centres. Because of many incidents in past time, without successful search, detecting and tracing of oceangoing ships disappeared in some disasters caused by collision or grounding, were proposed new positioning and tracking and detecting solutions via SAT onboard devices and ground facilities. Therefore, STDS network and shipborne satellite transponders will provide solutions for the global identification and tracking of all type of vessels and crew, such as cargo ships, cruise vessels and containers.

At present only the following mobile satellite operators are providing global or near-global satellite constellations for civilian and military STDS service: (1) Inmarsat GEO near-global satellite network provides coverage up to 80^0 North and South; (2) O3b MEO satellite network provides near-global global coverage up to 50^0 North and South; (3) Iridium Big Low Earth Orbit (LEO) satellite network provides only real complete global coverage, because of intersatellite links; (4) Globalstar Big LEO satellite network with limited coverage that is depending on distributed number of Gateways; and (5) Orbcomm Little LEO global satellite network with limited coverage depending on distributed number of Gateways.

The problem of current satellite fixed and mobile operators is that they are providing service via GEO satellite constellations and in this case are not able to cover both polar areas, such as Inmarsat, Eutelsat and Intelsat. To realize a real global coverage will be necessary to implement Hybrid Satellite Orbits (HSO) combined between Inmarsat, O3b, Globalstar and Orbcomm High Elliptical Orbit (HEO), such as Russian Molniya satellite constellations.

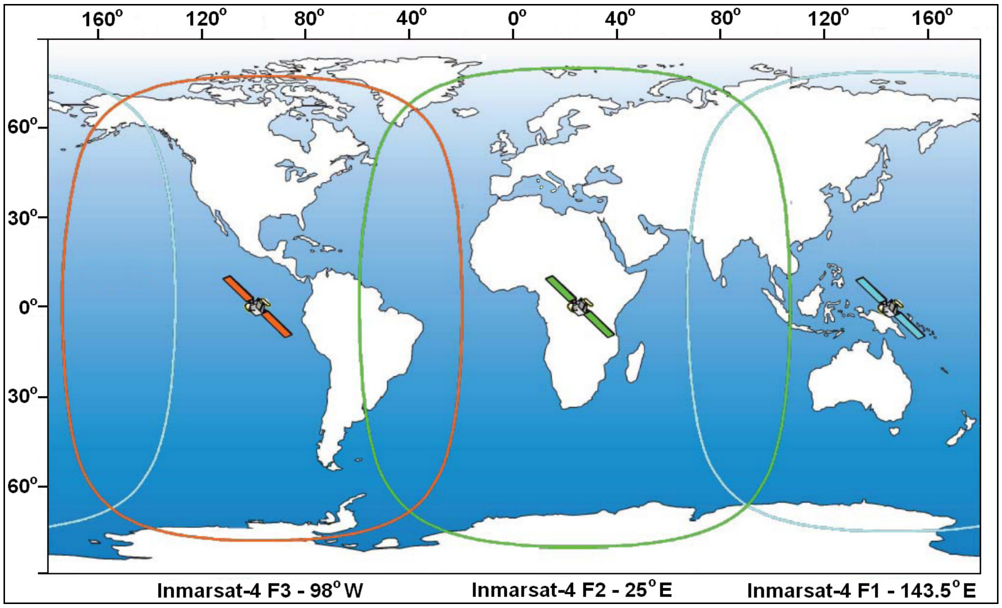

Figure 4. Inmarsat-4 Satellite Coverage Source: Inmarsat

4. Inmarsat Mobile Satellite Communication (MSC) Network and Equipment

Inmarsat was established as not-for-profit company in 1979 as the International Maritime Satellite Organization (Inmarsat) set up at the behest of the International Maritime Organization (IMO) and United Nations (UN), with its headquarter office in London. Initially was developed for the purpose of establishing a maritime satellite communications network for commercial, corporate and safety applications. It began trading in 1982 via GEO satellite constellation for oceangoing ships and searigs providing coverage up to 80^0 North and 80^0 South. Afterwards Inmarsat started with development service for land (road and rail), personal (handheld), transportable and aeronautical applications. The current Inmarsat-4 is providing service at the following RF bands: 1.6/1.5 GHz of L-band (Service Link) and at 6.4/3.6 GHz of C-band (Feeder Link).

In 2016, the fourth generation of Inmarsat-4 satellite constellation, shown in **Figure 4**, is upgraded with fifth generation of Inmarsat-5 satellite constellation, which maritime and other MSC networks operate via L, C and Ka-band, are illustrated in **Figure 5.**

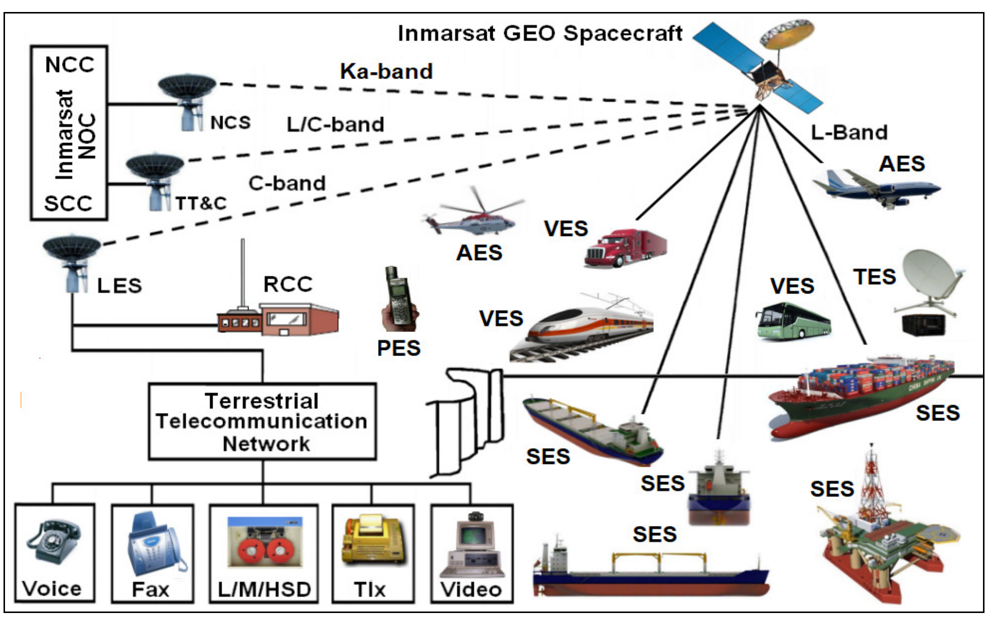

Figure 5. Inmarsat Maritime and other Mobile Satellite Network – Source: Ilcev

The current Inmarsat network provides commercial mobile service via Land Earth Stations (LES) and Inmarsat satellites for Ship Earth Stations (SES), Vehicle Earth Stations (VES), Aeronautical Earth Station (AES), Transportable Earth Station (TES), Personal Earth Station (PES) terminals. Today Inmarsat network is transformed in Private operating company providing duplex satellite communication at the following Radio Frequency (RF) bands: 1.6/1.5 GHz of L-band (Service Link) and at 6.4/3.6 GHz of C-band (Feeder Link).

Inmarsat I-4 satellite constellation is providing three ocean region coverage such as: I-4 F3 (Americas) at position 98ºW, I-4 F2 (Europe, Middle East and Africa) at position 25ºE and I-4 F1 (Asia-Pacific) at position 143.5ºE. In fact, the Inmarsat I-4 and I-5 satellite constellations cover STDS applications and units for civilian and military applications.

However, the current fourth generation of Inmarsat-4 satellite constellation is upgraded with fifth generation of Inmarsat-5 satellite constellation. Inmarsat has contracted Boeing, the US aerospace manufacturing company, to build a new constellation of Inmarsat-5 (I-5) satellites as a part of a new 1.2 billion US$ worldwide wireless broadband network called Inmarsat-5 Global Xpress (GX), which includes launch costs. Boeing already built three Inmarsat-5 (I-5), F1, F2 and F3 satellites based on its 702HP spacecraft platform. The Inmarsat-5 GX system may be used for government and defence applications for Navy, Ground and Air Forces. This network can serve as well for civilian and military positioning and tracking of all kind of military assets and personnel.

The fifth generation of Inmarsat network known as Global Express GX) developed by Boeing for about $1.2 billion will include a new plan for the Orchestra satellite network roadmap, which currently includes seven satellites over the next three years to provide additional L and K-band capacity for Fleet GX users. Five of those satellites will operate in GEO orbit, with two being placed in Highly Elliptical Orbits (HEO) to provide polar coverage on the network for the first time. In addition, Orchestra will bring together existing GEO satellites with new LEO and terrestrial 5G into an integrated solution for about $3 billion. Therefore, this network can serve as well for civilian and military positioning and tracking of all kind of military assets and personnel. The Inmarsat I-4 and I-5 satellite constellations are covering the following SAT applications and units for civilian and military applications

The Inmarsat I-4 and I-5 satellite constellations are providing g STDS service for maritime applications onboard seagoing or inland vessels are providing IsatData Pro, IsatM2M, Inmarsat-C, mini-C, FleetPhone and old Standard-D devices. The ground segment comprises a network of LES terminals managed by LES operators. However, the major part of the ground segment and network for maritime applications are SES terminals as mobile subscribers. Each LES operator provides a transmission link between satellite network and TTN, capable of handling many types of calls to and from MES terminals simultaneously over the Inmarsat networks.

The emergency and distress service is provided via special Rescue Coordination Centres (RCC). Entire Inmarsat network is managed by Network Control Centre (NCC) in London, Network Coordination Stations (NCS), Network Operations Centre (NOC), and Telemetry, Tracking and Command (TT&C).

The Global Maritime Distress and Safety System (GMDSS) radio and satellite integrated networks are already developed and implemented for ships safety, distress alert and SAR communications. Namely, this system is not enough effective to provide a real tracking and detecting system of ships for every day navigation aids. The GMDSS radio and satellite networks need an additional integration with new Communication, Navigation and Surveillance (CNS) systems as a proposal that has to be developed providing seafarers with global communications and tracking networks introduced in this research.

4.1. Inmarsat-C and mini-C Terminals

The Inmarsat-C and mini-C standards are a two-way packet data small satellite terminals dedicated for installation onboard ships or other mobiles for transmission of two-way data and telex messages at an information rate of 600 b/sec on L-band. These messages are transmitted only in ship-to-shore direction via LES terminals, TTN and Internet to PC terminals with special software to bi processed and memorized, which PVT data can be used for tracking of ships and any other mobiles.

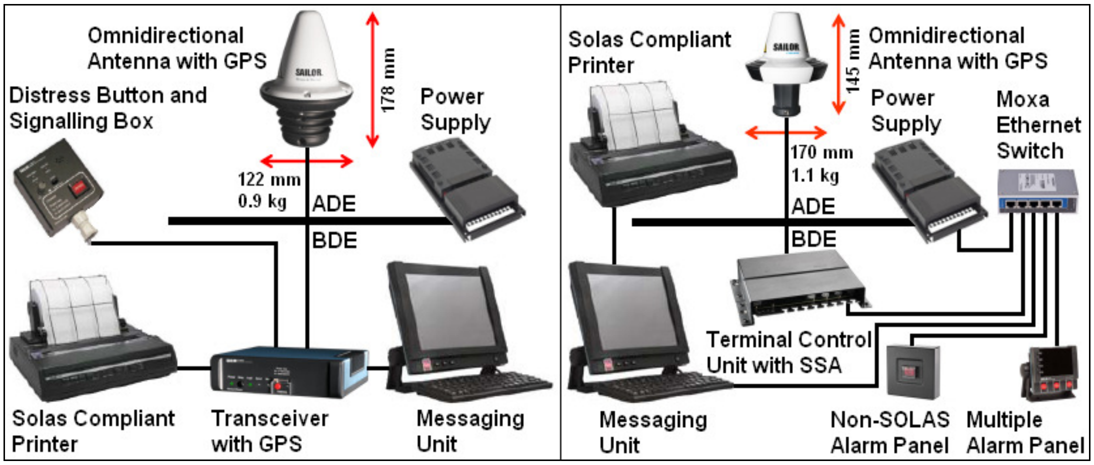

Figure 6. Maritime Sailor Inmarsat-C and mini-C Terminals – Source: Ilcev

Inmarsat standard-C is developed in 1988 for commercial and distress application for merchant fleets. The typical SES-C has a small and compact omnidirectional antenna in radome as an Above Deck Equipment (ADE), which can be easily mounted on all type of ships, yachts, fishing boats, offshore rigs and other mobiles. The main components of Standard-C terminal shown in **Figure 6 (Left)** contains ADE and Below Deck Equipment (BDE) with peripherals. The ADE can be a single Inmarsat-C or combined Inmarsat-C with GPS omnidirectional antenna. The BDE component can be an Inmarsat/C transceiver only or combined with a built-in GPS receiver installed in the radio station or on the navigating bridge interfaced to messaging unit, printer and distress button with signaling box. Some SES-C has built-in message preparation and display facilities and others have a standard RS-232 port so that users can connect their PC or other data equipment. This standard provides data, E-mail, position reporting and polling, Fax, Tlx, X.25, inters-hip communication, Supervisory Control and Data Acquisition (SCADA) or Machine-to Machine (M2M), etc.

The Inmarsat mini-C terminal was introduced in 2002 as smallest and very compact ships Inmarsat satellite communication transceiver integrated with 2-channel GPS Rx in one single device, with a total with of 1.1 kg and a size of 15 cm, which is depicted in **Figure 6 (Right).** The mini-C unit provides the same service as Inmarsat-C, and both can be deployed as ships solutions for Global Maritime distress and Safety System (GMDSS), Long Range Identification and Tracking (LRIT), and Vessel Monitoring System (VMS). The power requirements of both terminals can be met from a ship's mains or via battery sources via power supply unit with rechargeable facilities.

4.2. Inmarsat-D/D+ and Inmarsat-IDP Terminals

Inmarsat-D introduced in 1997 offers global one-way (simplex) and Inmarsat-D+ two-way (duplex) data communications utilizing equipment no bigger than a personal CD player, which 1st and 2nd generations respectively are shown in **Figure 7.**

Figure 7. Maritime Inmarsat-D+ Generations – Source: Inmarsat

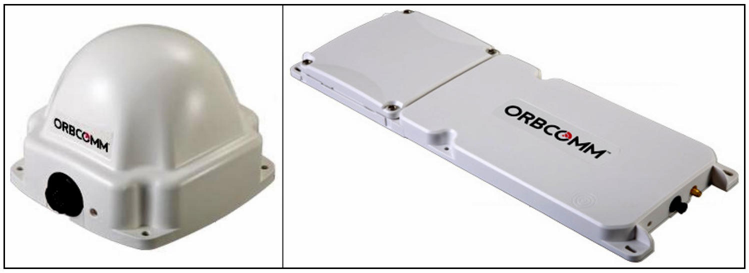

Figure 8. Shipborne Inmarsat-IDP – Source: Orbcomm

These units are integration of a Standard D+ transceiver with the US GPS or Russian GLONASS receivers and both antennas. It is ideally suited for ships and mobile tracking, short data messaging, SCADA (M2M), broadcast of information, financial data, stock exchange, and many other data. These terminals can store and display at least 40 messages of up to 128 characters each, and will also be able to transmit PVT data derived from integrated GPS or GLONASS receivers. All messages sent to SES will be numbered to enable the subscriber to identify any lost messages. Repeated messages will be sent with the same message number to allow repeated call indication. The Inamrsat D+ standard equipment is capable to transmit from ships subscribers to base stations: a) Acknowledgement Burst, b) Short Burst Data (SBD) and c) Long Burst Data (LBD).

Due to the development of the new Inmarsat IsatData Pro and IsatM2M standards, as of 31 December 2015, new Inmarsat-D + activations have been suspended. Alternatively, Inmarsat offers a new generation of similar telematics known as IsatData Pro and IsatM2M satellite terminals, which are fully programmable and environmentally sealed, use the global two-way Inmarsat Isat satellite service integrated with GPS or GLONASS data for remotely managing fixed and mobile assets. This equipment, whether used for oceangoing ships, fishing vessels, buoys, containers, vehicle tracking, SCADA (M2M) or oil and gas equipment, these standards facilitates improved asset tracking and fleet management in lower operating costs and regulatory compliance.

1. IsatData Pro – This standard is a global two-way packet data service for M2M that enables companies to track and monitor their fixed or mobile assets, giving them increased visibility of business operations, enhanced efficiency, and greater safety and security for their assets, cargo and drivers, while lowering operational costs. It sends 6,400 bytes and receives 10,000 bytes, with a latency of 15 to 60 seconds depending on the size of the message.

2. IsatM2M – This standard is global, store-and-forward low data rate messaging (SBD) to and from remote assets for tracking, monitoring and control operations. It supports critical applications such as ships and other mobile tracking and monitoring system at speed rate of 10.5 or 25.5 bytes in the transmit direction and 100 bytes in the receive direction, with a latency typically between 30 to 60 seconds. The Inmarsat IDP-690 new generation Orbcomm's shipborne terminal shown in **Figure 8 (Left)** is part of the IDP 600 series of terminals for vessel tracking device, while in **Figure 8 (Right)** is the IDP-800 dedicated to monitor trailers, containers, and vessels.

Thus, Inmarsat-IDP terminals with their serial interface and published communication protocol enable easy integration with an external controller, mobile display terminal or PC (Laptop) terminal. If there is not enough space for a laptop or PC, both Inmarsat-IDP terminals can be interfaced to small Thrane&Thrane's (Cobham) message terminal shown in **Figure 9 (Left)** with a key board and a very small printer shown in **Figure 9 (Right)**.

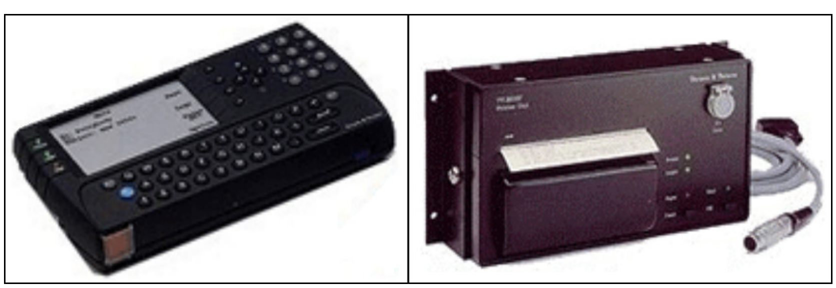

Figure 9. Message Terminal and Capsat Printer – Source: Cobham

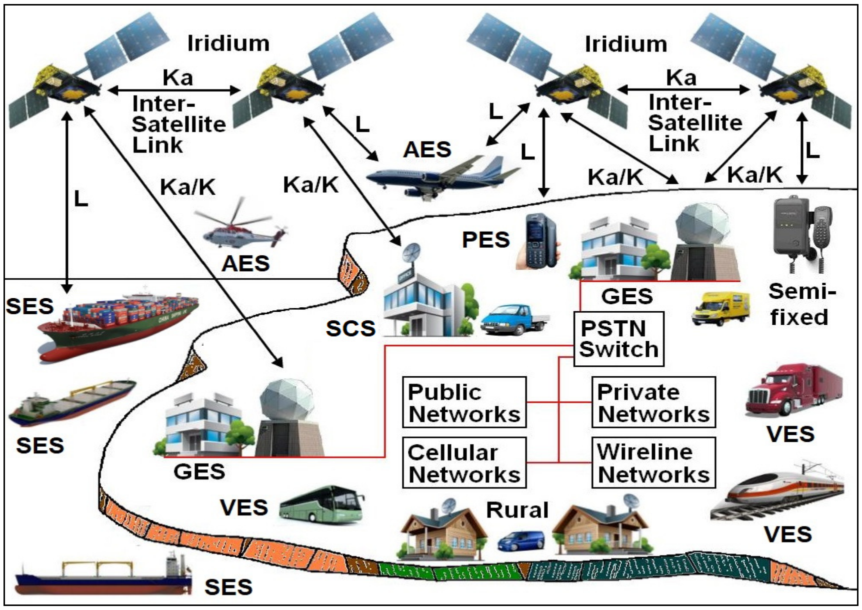

Figure 10. Iridium MSC Network – Source: Ilcev

5. Iridium MSC Network and Equipment

The concept for the Iridium MSC system was proposed by Motorola engineers in late 1989 and after a phase of research, the Iridium LLC satellite system was founded in 1991, with an investment of about $7 billion. Maintaining its leadership, Iridium LLC became operational MSC system on 1st November 1998. After a period of bankruptcy, the Iridium service was re-launched on March 28, 2001. The Iridium Big LEO satellite constellations are situated in a near-polar orbit at an altitude of 780 km. They circle the Earth once every 100 minutes traveling at a rate of about 26,856 km/h. Each satellite is cross-linked via intersatellite links to four other satellites, with two satellites in the same orbital plane and two in the adjacent plane.
The Iridium satellite constellation consists in 66 operational satellites and 14 spares once orbiting in the satellite constellation of six polar planes. The Iridium system provides true global coverage and roaming globally over 48 spot overlapping beams, and the diameter of each spot is about 600 km. Iridium as a true global operator provides voice and data service including SAT for ships and all mobile applications via uplink/downlink at 1621.35-1626.5 MHz, feeder links at 29.129.3 GHz of Ka-band (uplink) and at: 19.4-19.6 GHz of K-band (downlink) and cross-link or intersatellite link at 23.1823.38 GHz of Ka-band.
The current Iridium network illustrated in **Figure 10** provides maritime and other mobile service via Ground Earth Stations (GES) and Iridium LEO satellites connecting SES, VES, AES, PES as handhelds and semi-fixed terminals with Public Switched Telephone Network (PSTN) ground network. The PSTN switch system is connected to a Public Network, a Private Network, a Cellular Network, and a terrestrial Wireline Network. The Entire Iridium network is managed by the System Control Segment (SCS), which consists of three main components: four Telemetry Tracking and Control sites, the Operational Support Network, and the Satellite Network Operation Centre. The SCS ground network is what commands and controls the satellites for the Iridium system. It provides global operational support and control services for the satellite constellation. It also delivers satellite tracking data to the Gateways.

5.1. Iridium MSC and Fleet Management Terminals

The Online Tracking Platform (OTP) system is a Web based integrated Iridium, Inmarsat and Global System for Mobile Communications (GSM) or cellular system tracking solution, which is compatible with modern Web browsers and works on a multilingual platform and displays and manages them in a single unified interface.

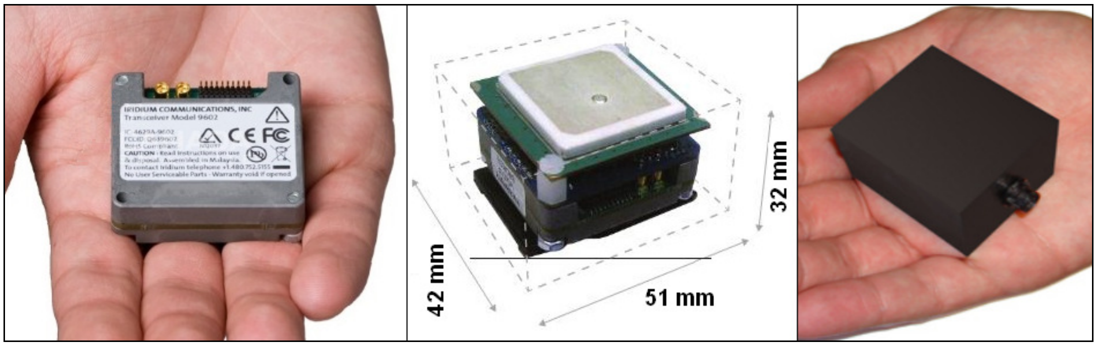

Figure 11. Iridium Miniature SAT Terminals – Source: Iridium

With OTP, asset locations and movements, including position, speed, altitude and heading are tracked in real-time worldwide via GPS updates. This system may be integrated GSM and satellite tracking in one solution which via Web provides superior GPS tracking and mapping, no special hardware or software is required, seamless software and firmware updates, reliably tracks personnel, equipment, ships or vehicles, anywhere in the world. On the other hand, some trackers may use adequate software and not OTP system.

1. Quake 9602 Mini Tracker – The 9602 is a short-burst data transceiver designed for use as a basic unit for many tracking devices using the Iridium Network, illustrated in **Figure 11 (Left).** This very tiny, 41x45x13 mm and 27.22 grams, two-way transceiver is perfect for use in a variety of applications for fast-growing mobile devices, including remote tracking of aircraft and real estate and M2M tracking solutions.This Iridium unit unit does not have a GPS Rx, but can be connected to the built-in GPS via input/output ports. In addition, appropriate sensors can be connected to the inputs of this device, such as mileage, fuel consumption, temperature, doors, cargo etc.

2. Iridium SL Mini Tracker – Iridium very small and lightweight SBD modem with integrated GPS Rx is the smallest self contained Iridium tracker in the world, which 32 bit Advanced RISC Machine (ARM) processor supported by a fully user customizable LUA scripting language, where RISC is Reduced Instruction Set Computing. Its internal dimensions 1.77 x 1.77 x 1.34 inches (45 x 45 x 34mm), including the battery, which modem and antenna are illustrated in **Fig. 11 (Middle).** It can transmit the location from anywhere in the world and is built on the latest satellite, antenna and electronics technology tfor tracking and monitoring all mobiles in real time, the actual size of which is shown in **Figure 11 (Right).**

3. Quake Q4000 Tracker – The Iridium Q4000i tracker manufactured by the American company Quake is small enough to fit in your hand. It is a two-way rugged transponder that can combines dual-mode operability over Iridium satellite and GSM terrestrial networks with GPS into a versatile, all-in-one mobile asset tracking solution, illustrated in **Figure 12 (Left).** Quake is also supplying the same Q4000 modem that can be optionally used for service over Inmarsat, Globalstar and Orbcomm integrated with 50 channels of GPS Rx and with optional GSM cellular service. In **Figure 12 (Middle)** is shown bolt, magneting or adhesive mount Hirschmann low profile Iridium antenna (63x63x18mm) for Iridium/GPS/3G/GSM WLAN and other mobile applications, which can be used for Q4000i and other satellite trackers onboard all mobiles.

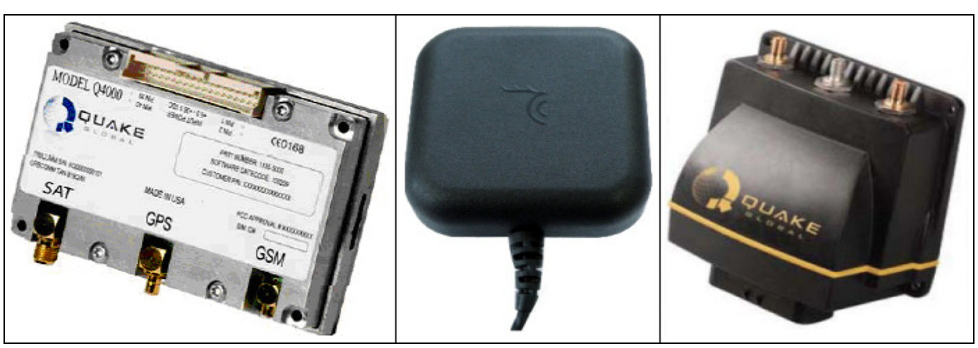

Figure 12. Iridium Mobile SAT Terminals with Antenna – Source: Quake

Figure 13. Iridium Personal Satellite Trackers – Source: Iridium

Technically, this is am SBD transceiver designed for use as a base unit for many mobile trackers using the Iridium network, such as oceangoing ships and container tracking, as well as for tracking land vehicles and aircraft. In addition, this equipment without integrated GPS can be implemented for monitoring of many machines, pipelines, devices, instruments, power stations and so on over the SCADA (M2M) network. This unit provides the following interfaces: 3 serial RS-232C, J1939 can bus, input/output 2 analog inputs, 8 digital GPIO and digital outputs (relay). Its dimensions are size: 3.91"x 2.52"x .63" (99.3mm x 64mm x 15.9mm) and weight is 375lbs (170 grams).
4. Quake Q-Pro Multipurpose Tracker – This unit is small (119.2x119.4x57.6 mm and 390.6 grams) and rugged, environmentally-sealed multi-satellite GPS integrated with Iridium, Globalstar, Orbcomm and GSM modem with many options, which is shown in **Figure 12 (Right).** For STDS applications this unit has an integrated GPS receiver with 50 channels and can also be connected to Hirschmann low profile Iridium antenna, shown in **Figure 12 (Middle).**

5.2. Personal Satellite Trackers

The following personal Iridium operator satellite trackers are ideal units for tracking passengers and crew after grounding or in emergency situations without any luck with distress alert and SAR communications:
1. E-Track Epsilon Personal Tracker – This personal tracker is a waterproof satellite messaging and personal tracking device, which provides autonomous and global real-time coverage, shown in **Figure 13 (Left).** Developed around 9602 Iridium modem, it benefits from the latest developments in satellite technology of GPS and is IP67. The unit provides two-way texts messaging, predefined and free-text "HELP" key to send a distress message with accurate GPS position of the incident.
2. GeoPro Personal Messenger – This personal tracker is a solution for remote workforce security, location awareness and a two-way solution for exchanging personal messages,, shown in **Figure 13 (Middle).** When work takes staff off the grid they often have no reliable means of maintaining communication. It is an affordable and rugged device supporting global two-way text messaging and can be used in one hand with a non-slip network of factors using a joystick to navigate through on-screen menus and the keyboard.
3. NANO Personal Tracker – This unit has an ultra-low power consumption of less than 35μA during sleep, shown in **Figure 13 (Right).** This pocketsize and self-contained personal satellite tracker provides 256-bit transmit and receive encryption, precise GPS positioning, real-time reporting and truly global coverage via the following features: (1) Power/Enter turns the device ON/OFF and selects highlighted item on the menu; (2) The Up/Down/Right Arrow navigates the cursor; (3) The Check-In Soft Key is accessing Check-In feature; (4) The Way Point Soft Key is used for Way Point functions; (5) The USB Port is serving to charge the battery and connects the PC; (6) The Emergency key may send an emergency alert, distress and notification to the search and rescue (SAR) forces; (7) The Guard button protects the emergency button from accidentall activation; (8) The LED unit displays tracking and emergency statuses; 9. The Antenna post shows the GPS antenna; and (10) The Antenna post shows the Iridium antenna.

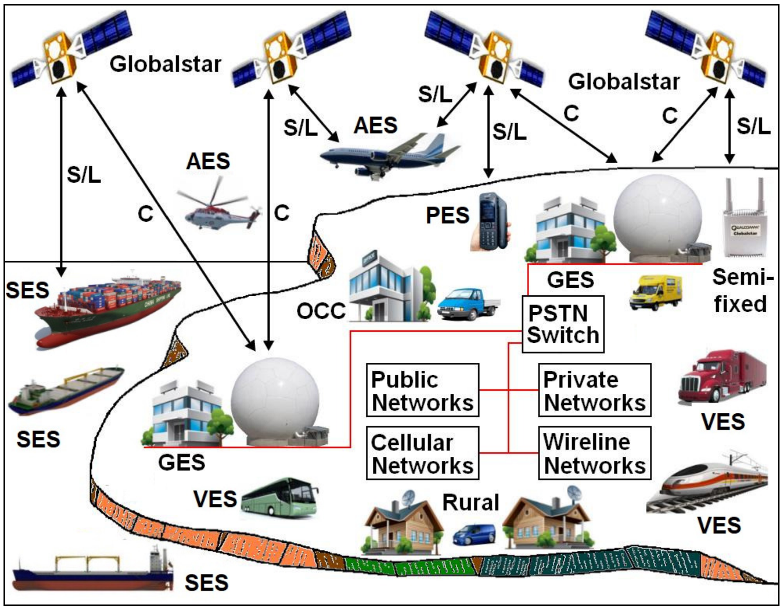

Figure 14. Globalstar MSC Network – Source: Ilcev

6. Globalstar MSC Data Network and Equipment

The US company Loral Space & Com., together with Qualcomm Inc., developed Globalstar system at a similar time as Iridium, and Globalstar received a license to operate from the USA Federal Communications Commission (FCC) in November 1996. In May 1998, the first launch of four Globalstar satellites took place, and therefore its space segment consists of 48 Big LEO spacecraft.
In fact, Globalstar does not have an inter-satellite connection and thus needs a large number of GES terminals around the world, the spacee, ground and user network of which is shown in **Figure 14.** The current Globalstar network controlled by the Operations Control Centre (OCC) provides maritime and other mobile service via GES and LEO satellites connecting SES, VES, AES, PES as handhelds and semi-fixed terminals with PSTN and other ground networks
The Globalstar satellite operator is providing service for users via satellite at 1.610-1.621 GHz (uplink) and at 2.483-2.500 GHz (downlink) and from satellite to GES at 5.091-7.055 GHz (feeder link). Globalstar equipment such as Axonn mobile satellite tracker devices are designated for asset tracking of ships and other mobiles such as land vehicles, trains, containers, and trailers, but with simply modification of GPS Rx can be used for aircraft tracking as well. Here will be introduced 2 simplex and 1 duplex Globalstar mobile satellite trackers manufactured by Axonn company:
1. Simplex AxTracker – This unit provides a battery-operated, self-contained SAT transmitting PVT data only (simplex) device, delivered complete and ready-to-go with no need for an external antenna or power source, which is shown in **Figure 15 (Left).**

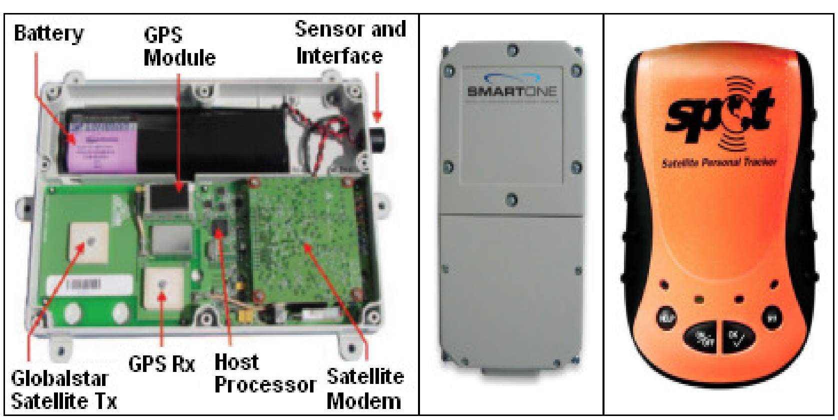

Figure 15. Simplex and Duplex Satellite Trackers – Source: Globalstar

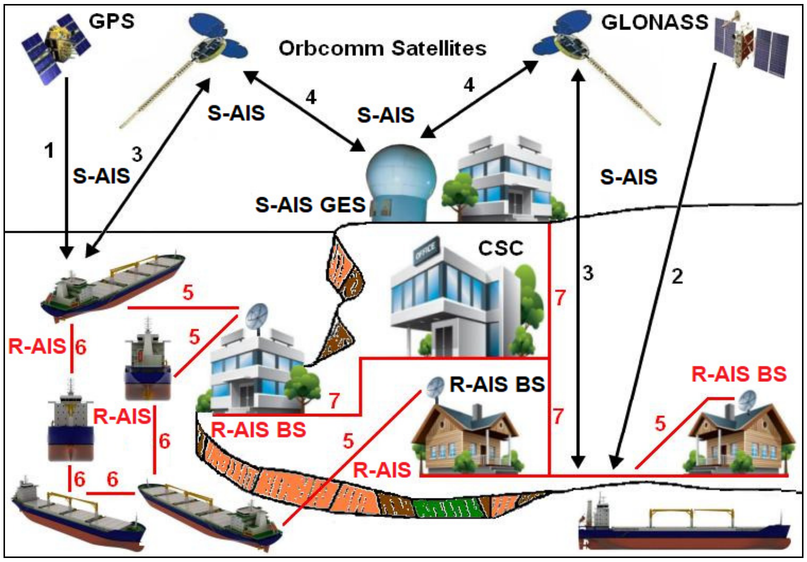

Figure 16. Orbcomm Satellite AIS (S-AIS) – Source: Ilcev

It measures 9.25x6.25x1and is ideal to operate in hazardous environments, such as ships container, because can work independently of power source and any inspection. The units can be pre-programmed according to the requirements and to send GPS location and other information at predefined intervals.

2. Simplex Axonn SMARTONE Tracker – This GPS Rx/satellite Tx mobile traking device is designed for the intelligent tracking and management of powered and non-powered movable assets, and is a practical solution to improve operating efficiency and security, which is illustrated in **Figure 15 (Middle).** The design of this unit allows it to be easily installed and field managed without the need for harnesses, antennas and external power. The advantages of independent power supply, this unit can work and send position data even if ships is emergency grounded or a missing ships container without any power sources. The SMARTONE device is powered by 4 AA 1.5 V lithium batteries providing 3+ years of battery life and removes the need to purchase expensive proprietary batteries for replacement.

3. Duplex Spot Satellite Personal Tracker (Spot 1) – The Spot Personal Tracker or Spot 1 was introduced to the market by Axonn in early 2008, shown in **Figure 15 (Right).** Using Spot Tracker, people in emergency and their families ones have peace of mind knowing help is always within reach. It is using the GPS Rx to acquire its coordinates, and then sending its location with a link to Google maps and a pre-programmed message via a satellite network. This unit does more than just call for help and checking emergency progress, non-emergency assistance are also available, just by pressing a button. Spot features four key functions that enable users to send messages to friends or family, based upon varying levels of need, (05, 15, 16, 17).

7. Orbcomm MSC Equipment and Data Network

The Orbcomm MSC system is a wide area packet switched and two-way data transfer network that provides GPS/Orbcomm Satellite tracking, determination and monitoring services via similar SAT devices shown in Figure 12. This system may also provide Satellite Automatic Identification System (S-AIS) integrated with Radio AIS (R-AIS) for tracking, monitoring and determination of maritime and other mobile assets via 36 Orbcomm Little LEO satellites, which space, ground and user network is shown in **Figure 16.**

Except S-AIS service, Orbcomm also provides SAT for oceangoing ships onboard broadcast system that transmitted ship identification, PVT and other critical data received from GES can be used to assist in navigation and improve maritime safety and security at sea. Most current terrestrial-based Radio AIS (R-AIS) system is already implemented by IMO and provides only VHF limited coverage nearby shorelines via Base Stations (BS) and not able to provide global coverage.

The Orbcomm system overcomes many of these issues thanks to a fully S-AIS and SAT data service, which is able to monitor vessels well beyond coastal regions and horizon in a cost-effective and timely fashion and send this data via GES to the Coastal Surveillance Centre (CSC) or Tracking Control Station (TCS). To spread R-AIS coverage globally some institutions and companies also started with development S-AIS.

8. Benefits of Maritime STDS Network

Maritime STDS Network offers many benefits to various stakeholders involved in sea operations:
1. Enhanced Safety – It monitors oceangoing vessel movements and provides real-time updates on their location, ETA and status, maritime tracking enhances safety at sea. It enables timely detection of potential hazards, such as collisions, grounding, or adverse weather conditions and visibility, allowing for proactive measures to mitigate risks and ensure the safety of vessels, onboard crew, and loaded cargo.
2. Cargo Security and Loss Prevention – It monitors the movement and condition of different cargo and containers throughout the supply chain. It provides visibility into cargo handling, loading, and unloading processes, reducing the risk of theft, loss, or damage to cargo during transit.
3. Regulatory compliance – It provides accurate data on vessles movements at sea and activities to facilitate compliance with maritime regulations and international standards. They enable vessels to report their positions, course, and speed in real time, ensuring adherence to safety at sea, security, and environmental regulations.
4. Optimized Operations – It offers real-time visibility into vessels movements at sea and enables businesses to optimize their operations. It helps in efficient route planning, scheduling, and resource allocation, reducing transit times, fuel consumption, and operational costs.
5. Enhanced Customer Service – It allows businesses to provide better customer operation service by offering accurate and up-to-date information on shipment and expected delivery times. This service improves customer satisfaction, builds trust, and enhances the overall customer experience.
6. Risk Mitigation – It helps businesses to proactively identify and mitigate risks associated with vessel operations, such as delays, disruptions, and security threats. By anticipating potential issues and taking preventive measures, businesses can minimize financial losses and protect their assets and reputation.
7. Improved Supply Chain Management – It integrates seamlessly with supply chain of maritime management systems, providing end-to-end visibility into the movement of goods, from origin to destination.
In **Table 1** is highlights the differences between manual and STDS-powered Systems.

Table 1. Differences Between Manual and STDS-powered Systems

Aspect	Manual Tracking System	Maritime STDS Syste
Human dependency	Relies on human operators and traditional methods	Utilizes advanced technologies, including machine learning and predictive analytics
Visibility	Offers limited real-time visibility	Provides comprehensive, real-time tracking and monitoring
Response time	Reactive response to issues and deviations	Proactively identifies anomalies and exceptions
Resource allocation	Requires significant allocation of human resources	Optimizes resource allocation and reduces costs
Efficiency	Prone to errors and inefficiencies	Enhances efficiency, reduces transit times and costs
Data availability	Relies on periodic updates, limited data availability	Offers comprehensive data on container movements
Integration	Manual integration with existing systems	Seamlessly integrates with supply chain and logistics, including STDS deployment
Predictive capabilities	Lacks predictive insights	Provides predictive maintenance insights for preventive action

In general, maritime STDS network generates commercial and safety benefits. It is a valuable tool for businesses seeking to maximize their performance and competitiveness in the maritime industry. The Global Ship Tracking (GST) and Global Container Tracking (GCT) satellite systems can help faster and safer shipping and transport of goods. These technologies can offer real-time analytics and predictive decision-making capabilities. The effectiveness of these networks improves not only on the monitoring technology of ships itself, but also on strategic deployment practices. They can leverage learning and machine learning models to generate real-time ETA predictions for container vessels tracking. Therefore, by continuously assessing congestion levels at seaports, it provides accurate ETA, enabling real-time monitoring of shipments throughout the supply chain.

9. Conclusion

Shipborne STDS networks and solutions for maritime and all mobile applications that can be used for both civilian and military applications are described. Thus, STDS maritime networks can operate anywhere in the world, providing services across the horizon to ships, vehicles, planes and people on the move. Tracking messages are transmitted via the above-mentioned commercial satellites in near real time and space, whose mobile locations are displayed on computers with maps of the Geographic Information System (GIS).
Otherwise, STDS networks and transponders operate through various existing GEO or non-GEO satellite constellations, and some of them are designed to automatically switch from one satellite system to another, depending on the situation on earth. On the othet hand, some of the STDS terminals are designed to operate over 2 or 3 satellite operators, such as Inmarsat, Iridium, Globalstar and Orbcomm. Otherwise, all messages are encrypted from end to end, including the addresses of the sender and recipient for information security purposes. The future of mobile STDS and CNS systems in general will be a combination of GEO, LEO and other Non-GEO satellite orbits, such as MEO and HEO or Molniya satellite orbit in so-called hybrid satellite orbits (HSO), which can provide reliable service globally level even across the North Pole.

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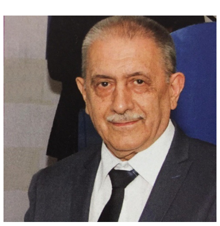
BIOGRAPHY OF AUTHOR



Prof. Dimov Stojce Ilcev is a senior research professor at University of Johannesburg (UJ). He has three BSc degrees in Radio Engineering, Nautical Science and Maritime Electronics and Communications. He got MSc and PhD in Mobile Satellite Communications and Navigation as well. Prof. Ilcev also holds the certificates for Radio operator 1st class (Morse), for GMDSS 1st class Radio Electronic Operator and Maintainer and for Master Mariner without Limitations. He is the author of 9 academic books and more than 300 research papers in mobile Radio and Satellite CNS, DVB-RCS, Satellite Asset Tracking (SAT), Stratospheric Platform Systems (SPS) for maritime, land (road and railways), and aeronautical applications.