Architecture of Iridium Big LEO Global Satellite System for Mobile and Personal Communications

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Abstract: The concept for the Iridium Mobile Satellite Communication (MSC) system was proposed in late 1989 by Motorola engineers and after the research phase, Iridium LLC system was founded in 1991, with an investment of about 7 billion US$. Maintaining its lead, Iridium LLC became operational MSC system on November 1, 1998. After a period of bankruptcy, the Iridium service was relaunched on March 28, 2001. This system was backed by 19 strategic investors from around the world and 17 investor partners also participated in the operation and maintenance of three Ground Earth Stations (GES) or Gateways that link the Iridium satellites for duplex voice and data service to terrestrial wireless and landline public telephone networks. Thus, GES operators around the world also served as regional distributors of Iridium products and added value services in their designated commercial territories.

Key Words: MSC, GES, GEO, MO, LEO, PVT, OSN, NCS, GES, SES, VES, PES, AES, PSTN, VDV, TCS

1. Introduction

Decades ago, U.S. and European MSC operators began developing new services for mobile and personal multi-purpose applications, ground access technology, and voice protocols to advance the commercial and military communications industry in the new millennium. In September 1991, Inmarsat was the first MSC international Geostationary Earth Orbit (GEO) operator to announce its strategy for the future development of the new Project-21. The highlight of this project was the presentation of a satellite prototype handheld phones to the world under the name of the Inmarsat-P standard. Thus, the implementation of this MSC service would require a new space segment, such as Middle Earth Orbit (MEO and Leo Earth Orbit (LEO) satellites. The first MSC system, ICO Global Communications, formerly known as the Inmarsat-P Affiliate Company project, was established in January 1995 as a commercial spin-off of Inmarsat, but without success.

In addition, new GMSC providers Globalstar, Iridium, Ellipso, Odyssey, and others proposed to exploit the Big LEO satellite constellation. However, on January 31, 1995 only Globalstar, Iridium and Odyssey were awarded licenses by the Federal Communications Commission (FCC) regulators to operate in the USA. The American organization TRW also proposed to exploit the MEO satellite solution using a configuration of satellites named Odyssey. The Odyssey constellation was to consist in 12 satellites, equally divided into three orbital planes, inclined at 55^{o} to the Equator. The satellites were to be placed 10,600 km above the Earth. The FCC awarded TRW a license to establish its MEO satellite system in 1995, with the caveat that building of the first two spacecraft should commence by November 1997. Odyssey was predicted to start service in 1999, at an estimated cost of 3.2 billion US$. Unable to find another major investor willing to support the project, Odyssey was abandoned in December 1997.

The Iridium system is a satellite-based network designed to provide truly global personal and mobile service of voice, facsimile, paging, data and tracking solutions, which also integrate the already developed GPS capability for satellite tracking capabilities. This, the mobile, handheld and semi-fixed satellite phones developed by Iridium MSC operator and their partners are new tools available to business and professionals in transportation and rural environments including those who want to have satellite telephone access at sea, on land and in the air. Special Iridium systems also provide SMS for mobile tracking as Position, Velocity and Time (PVT) data, determination of all mobile terminals and persons. Compared to little LEO, such as Orbcomm, the Iridium big LEO system is expected to be bigger and to have more power and bandwidth for various services to its subscribers. Their larger size of big LEO satellites allows more complex data processing in the transponders than the simple function of storing and forwarding small LEO systems. Leveraging the power of the new Iridium NEXT Certus solutions redefines the capabilities of MSC broadband, Internet of Things (IoT), service across maritime, land, aviation, and government applications.

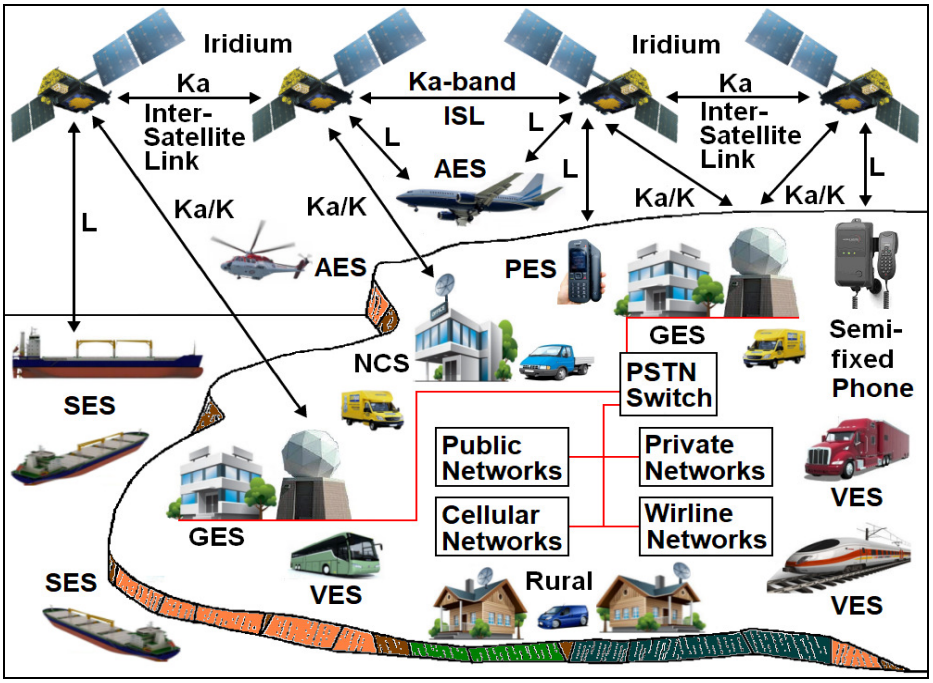

Figure 1. Architecture of Iridium Global MSC Network – Source: Ilcev

With full coverage of the Earth, including the polar regions, the big LEO Iridium MSC global satellite network provides substantial access to and from mobile terminals or rural users, where no other form of communication is available. The company's Iridium office is located in Leesburg, Virginia along with the satellite Operational Support Network (OSN), Network Control Station (NCS) and Gateway or GES terminals facilities in Tempe, Arizona for commercial applications and in Oahu, Hawaii for military applications.

Iridium system is a member of GSM-MoU association with arguments to provide complementary and value-added global roaming to augment cellular coverages and Terrestrial Telecommunication Networks (TTN). The Iridium system consists of three main integration parts, space, ground and user segments with services, which architecture is shown in **Figure 1.**

From the figure above it can be seen that Iridium satellites have Inter Satellite Links (ISL) or cross-links communications at Ka-band to provide a real global coverage and connect users from all positions with GES terminals (Gateways). For example, any Ship Earth Station (SES), Vehicle Earth Station (VES), Personal Earth Station (PES), Aircraft Earth Station (AES) or semi-fixed phones in any position on Earth may communicate on the L-band to visible Iridium satellite. The Iridium satellite further transmits signals on the downlink though Ka/K-band via the GES terminal to the Public Switched Telephone Network (PSTN) and other terrestrial telecommunication and rural networks. In the opposite direction, all users from PSTN and other networks can communicate with all mobile terminals via GES terminals and Iridium satellites.

The Iridium system uses only one-way satellite links at a time, which is known as time-duplexing and the user can rapidly switch modes between receiving and transmitting terminals. Like the cellular telecommunication systems, such as Global System for Mobile Communications (GSM) network, the user will be handed-off between beams in the same satellite and when required from one satellite to the next.

However, each Iridium satellite will have communication links to the satellite immediately ahead and behind on the same plane and up to four links with satellites on adjacent planes for cross or intersatellite hand-off. Therefore, Ka-band intersatellite links with four cross-links (ISL) on each satellite: front, back and two in adjacent orbits, high-speed communication and reliable links between neighboring satellites and connect a subscriber to a GES via various possible paths. This flexibility improves satellite call delivery efficiency and system reliability **[1, 2, 3, 4].**

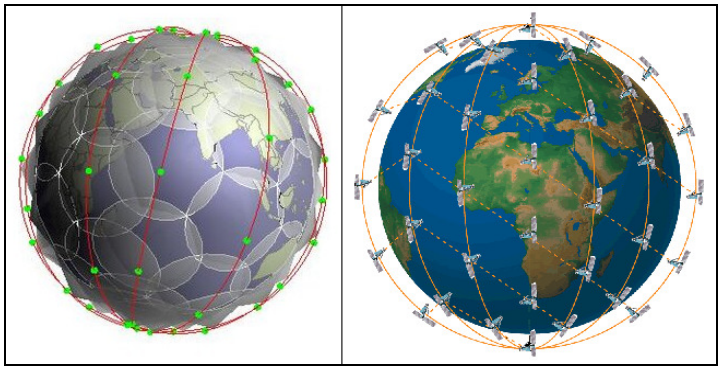

Figure 2. Iridium Spot Coverage and Satellite Constellation – Source: Iridium

2. Space Segment

The First generation of Iridium LEO satellites was 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 (ISL) to four other satellites, two satellites in the same orbital plane and two in an adjacent plane. The Iridium satellites provide real coverage and roaming over the entire globe with 48 spot overlapping beams and the diameter of each spot of about 600 km shown in **Figure 2 (Left)**. The 66 satellites enable 3,168 cells, of which only 2,150 need to be active and to cover the whole surface of the Earth. At this point, each cell covers about 15 million km^2 and each satellite simultaneously serves an average of 80 and a maximum of 240 cells. The global throughput varies between nominally 171 and 500 thousand simultaneous calls in the network. Thus, as the spacecraft moves with great speed, the user encounters adjacent beams about once a minute.

The Iridium first generation constellation of 66 operational satellites and 14 spares orbiting in a six polar planes is illustrated in **Figure 3 (Right)**. Each plane has 11 mission satellites performing as nodes in the telephony network. Thus, the 14 additional satellites orbit as spares are ready to replace any unserviceable satellite. This constellation ensures that every region on the globe is covered by at least one satellite at all times. The Iridium First generation spacecraft is shown in **Figure 3 (Left)** and the second NEXT generation spacecraft is shown in **Figure 3 (Right)**, both with main components. The new project for Iridium NEXT constellation also consist of 66 operational cross-linked, big LEO satellites intersecting over the North and South poles.

Iridium's fixed-price contract with Thales Alenia Space was provided for the deployment of 72 operational LEO satellites and spare parts in orbit between 2015 and 2017, as well as an additional nine ground-based spare parts, which allows greater risk mitigation for the new constellation. Thus, Iridium has entered into an Authorization to Proceed (ATP), which allows Thales Alenia Space to commence on the development of satellites prior to completion of the financing, with the plan to commence the launch of the first satellites during the first quarter of 2015.

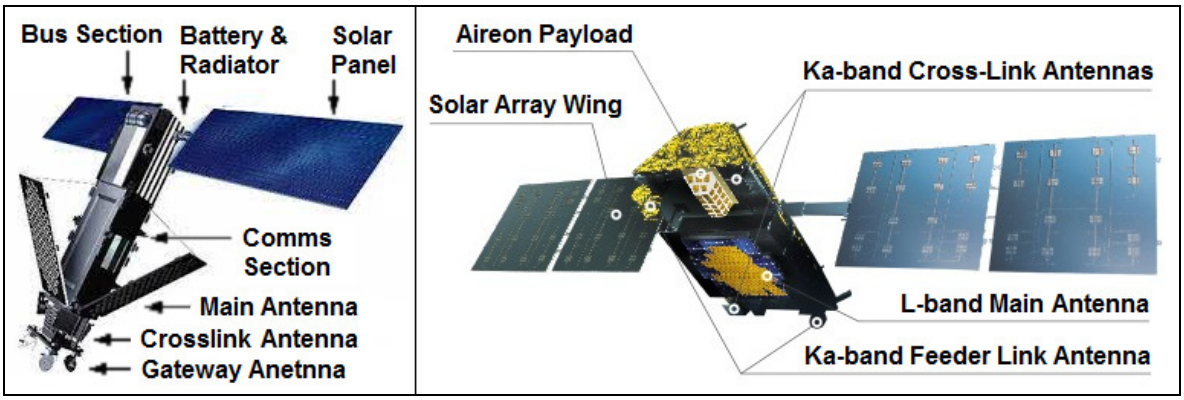

Figure 3. Iridium First and Second Generation of Spacecraft – Source: Iridium

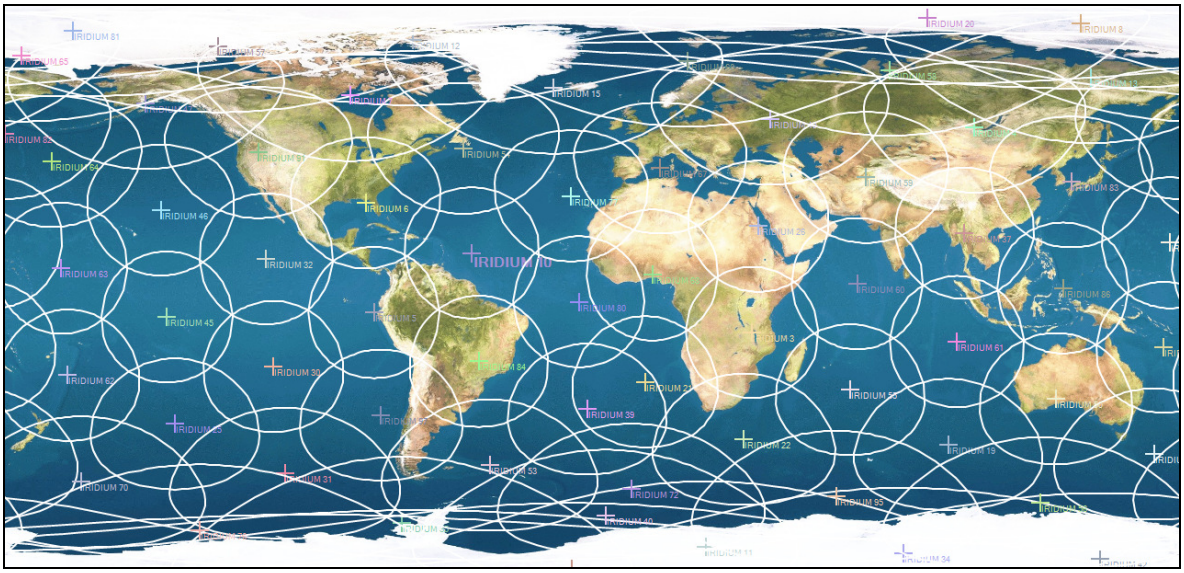

Figure 4. Iridium Coverage Map – Source: Lloyd

Each Iridium-NEXT satellites can provide an opportunity to fly an 50 kg secondary sensor payload using 50 W average powers. The mass of new spacecraft is 800 kg and it employs Proteus Bus, 2 deployable solar arrays with batteries lifetime of 10 years (design) and 15 years (planned). The NEXT spacecraft payload employs an L-band phased array antenna for generation of the 48-beam, 4,700 km diameter cellular pattern on the Earth's surface for connection with subscribers/users. The Ka-band links are also provided for communication with Gateways and for crosslinks with adjacent spacecraft in orbit. The cross-linked 66 Iridium satellite constellation forms a complete global network allowing communications from a ground or any mobile user in any location on Earth to virtually anywhere else on Earth, which coverage map is shown in **Figure 4 [2, 5, 6, 7].**

3. Ground Segment

As discussed, the Iridium ground segment consists of Operations Support Network (OSN), Network Control Station (NCS) and a Gateway or Ground Earth Station (GES), the locations of which are shown in **Figures 5 and 6**. The NCS ground terminals and two Gateways (GES) are designed to connect via Iridium satellites to a TTN infrastructure and the Internet.

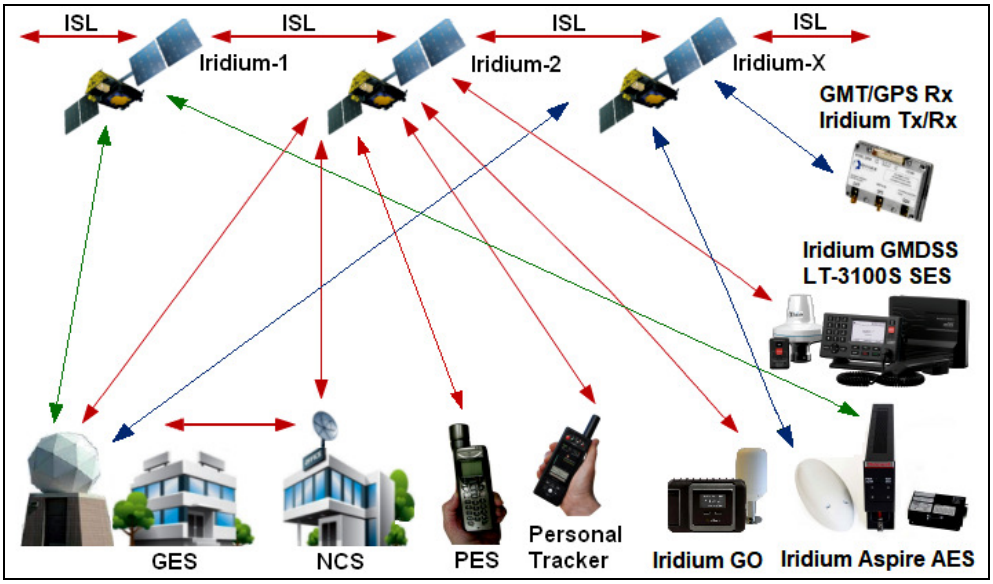

Figure 5. Iridium Space Segment with ISL, Ground and User Segments – Source: Ilcev

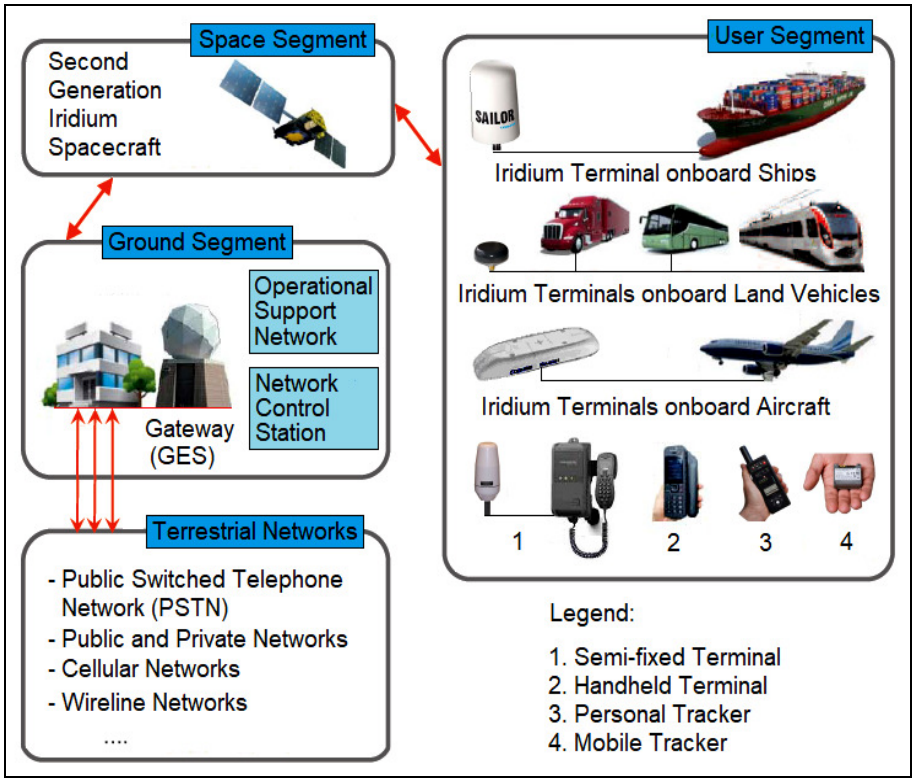

Figure 6. Iridium System Architecture – Source: Ilcev

The ground segment is comprised of the System Control Segment (SCS) as well as two telephony Gateways (GES) and is used to connect into the terrestrial telephone lines. The SCS is the central management component for the Iridium system. It provides global operational support and control services for the satellite constellation, delivers satellite tracking data to the Gateways and performs the termination control function of messaging services. The SCS system consists in three main integrated components: four TT&C sites, the OSN terminal and the Satellite Network Operation Centre or NCS terminal. The primary linkage between the SCS, the satellites and the Gateways is via K-Band feeder links and cross-links throughout the satellites.

The two Gateways (GES) are the ground communication terminals that enable connection to and from the PSTN or Rural areas via high-gain K-band parabolic antennas, to track Iridium satellites for communication services and network operations, as depicted in **Figure 1 and 6.** They support the interconnection of subscribers via the Iridium network to the terrestrial PSTN and provide network management functions of the entire infrastructure. Each GES is connected with up to 4 satellites and with other satellites has connections via intersatellite (cross) links. There are currently two commercial Iridium Gateways or GES cites located in Arizona, US and Fucino in Italy. The US government owns and operates an Iridium gateway located in Hawaii, US. Each Gateway generates and controls all user information pertaining to its registered users, such as mobile or personal user identity, geo-location and billing items.

The Gateways include the system control segment and telephony Gateways, which are used to connect to the public phone network. As an Iridium satellite orbits the Earth they can lose line of site as it leaves the area of the Gateway. The routing tables change and frames are forwarded to the next satellite coming in view of the Gateway. The Iridium constellation has intelligence built in the network where an outbound Iridium satellite call from Iridium satellite phone goes to one of the satellites then the call is either sent directly down to the receiving satellite phone. If the receiving satellite phone is not in the spots beam of the satellite receiving the call, then the call is switched from satellite to satellite till it reaches the satellite in area of the receiving phone where it is then sent down to the call destination. Iridium network uses more satellites than other satellite operators, such as Globalstar or Orbcomm **[2, 6, 7, 8].**

Figure 7. Iridium Phones and Pagers – Source: Kyocera & Motorola

4. User Segment

The Iridium NEXT satellite network offers Voice, Data and Video (VDV) for maritime, land, aeronautical and personal applications, which have to deliver innovative solutions to mobile and semi-fixed users around the world including polar area. In **Figure 5** is shown Iridium network that provides service for Ship Erath Station (SES) Sailor 4300 Certus transceiver serving Global Maritime Distress and Safety System (GMDSS), Aspire Aircraft Earth Station (AES) transceiver, Iridium GO Vehicle Earth Station (VES), Personal Earth Station (PES) handheld phone, Global Mobile Tracker (GMT) with GPS receiver, and personal tracker with GPS receiver.
The user segment configuration consists in three different kinds of mobile-mounted and fixed units, which solutions are shown in **Figure 6.** Thus, user terminals with omnidirectional antennas support data and facsimile at 2.4 Kb/s as well as numeric and alphanumeric paging. With the Iridium system all communications services voice and paging are delivered regardless of the user location or the availability of PSTN access. In addition, Iridium network offers tracking and determination service for maritime, land (road and rails), aeronautical and personal applications, which has to deliver innovative solutions to mobile and semi-fixed users across a diverse set of industries around the world including polar area.

4.1. Handheld and Fixed Satellite Terminals

As stated earlier, the design of the Iridium satellite network allows voice and data to be routed virtually anywhere in the world. They are relayed from one satellite to another until they reach the satellite above the Subscriber Unit or UT (handset) and the signal is relayed back to the Earth. The Iridium handheld telephones and pocketsize pagers receive short messages and connect MES applications for ships, vehicles and airplanes. Hence, a variety of fixed and mobile subscriber units is available to communicate with the Iridium network, including dual-mode handsets; numeric and alphanumeric pocket pagers; portable, fixed and payphone terminals and specialized maritime, land and aeronautical equipment.
1. Handheld Terminals – An Iridium portable telephone unit is quite similar to a conventional handheld cellular unit because dimensions, weight, battery lifetime and so on, are similar to cellular phones. Thus, it can operate in dual-mode: cellular or Iridium mode, so the Iridium terminal is also a cellular terminal and could be used where cellular networks are available.
a). Dual-mode handheld terminals provide a global roaming for cellular and Iridium users or mono-mode for Iridium users only, as shown **in Figure7 (A)** on the left and right, respectively. These two SS-66K models are products of the Japanese producer Kyocera and the unit on the left-hand side is dual-mode integrated adapter placed inside a standard cellular handset terminal along with all of its memories and functions, in such a way that it is possible to roam both cellular GSM and Iridium networks. In **Figure 7 (C)** is illustrated the Motorola mono-mode satellite series 9500 handheld telephones, for Iridium users only.

Figure 8. Iridium Handheld and Mobile Satellite Phones – Source: Iridium

b). An Iridium Pager system offers the first true global satellite roaming capability in small, belt-worn, personal message receivers. In **Figure 7** is shown the Kyocera model SP-66K Iridium pager **(B-top picture)** and Motorola 9501 Iridium pager **(B-lower picture)**.

2. Fixed Terminals – Iridium provides two types of fixed satellite terminals:

a). Payphone fixed terminals are single line Iridium fixed sets used to interface a payphone service into the PSTN for rural and remote areas out of cellular coverage. The portable or semi fixed, redeployable and freestanding payphone booths are designed to provide public access to the Iridium service in rural and remote areas. These units have their own satellite antenna and transceiver equipment and are able to operate on standard or solar power, reducing costs for the development of other expensive communication services.

b). Fixed or portable single line equipment offers communications services in remote/rural offices and can be a transportable unit in briefcase/car with external antennas, shown in the Motorola 9570 Portable Dock in **Figure 7 (D)**. This device is designed for integrated operation with the Motorola 9500 handheld portable telephone sets, to provide charging for
it and two additional batteries when connected to an AC/DC power source. An external antenna can be connected by special cable from temporary or fixed locations mounted on mast, roof or building walls. The terminal has a speakerphone for voice conferencing and a lightweight cord (passive) handset for private communications and enables data/Fax port access to 2.4 Kb/s asynchronous data service via SIM card as usual for cellular service **[2, 6, 8, 9].**

4.2. Handheld, Mobile and Transportable Satellite Terminals

The following satellite handset and Mobile Satellite Terminals (MST) can be used for any mobile applications and they can employ external antennas as well, shown in **Figure 7 (D).**

1. Iridium 9520 Mobile Telephone – This Iridium mobile terminal is satellite transceiver with wired handheld suitable for all mobile applications, illustrated in **Figure 8 (Left).** It works via SIM card for both Iridium and GSM Cellular networks.

2. Iridium 9555 Handheld and Mobile Telephone – This is one of the smallest and most powerful handheld and mobile terminals, illustrated in **Figure 8 (Right)**. This unit can be used combined with docking station onboard any mobiles including ships and aircraft.

3. Iridium 9505 Handheld and Mobile Telephone – The 9505 Portable Satellite Phone now smaller, lighter and more resistant to water, dust and shock than the previous offering, this satellite phone addition is ideal for industrial or rugged conditions, yet appealing to the traveling professional. Although the functions and features of the 9505A handset are the same as the 9505, there are some modification to the 9505A to equipment and accessories, shown in **Figure 9 (Left)**.

Figure 9. Last Models of Iridium Handheld and Mobile Phones – Source: Iridium**.**

It has been introduced by Iridium to address obsolescence of some 9505 phones. The specifications of this phone are: Dimensions are 158 (L) x 62 (W) x 59 (D) mm, Weight is under 375 grams, Standby Time is 30 hours, Talk Time is 3.2 hours and Operating range is -10°C to +55°C. Thus, features of this phone are as follows: 4 x 16 character display, International access key sequence (+ key), Mailbox for numeric and text messages (160 characters), Selectable ring tone (10 choices) and Missed call indicator 100-entry in internal address book. The RST978 also provides a docking unit for the 9505A handheld telephone. The unit provides charging and docking of the handset, whilst the hands-free functionality enables the user to have a professional in-mobile installation, with the added benefits of having away from mobile communications with the handheld unit. This phone can be used combined with docking station or special kit onboard ships and aircraft.

4. Iridium Extreme 9575 Handheld and Mobile Telephone – This latest Iridium terminal is more than a satellite phone, because it will provide customers one solution in hand for voice, data, GPS, SOS, online tracking and SMS, which components are illustrated in **Figure 9 (Right)**. This is the only phone with integrated tracking, GPS location-based solutions and one-touch SOS button. A certified Satellite Emergency Notification Device (SEND), Iridium Extreme will notify help in an emergency, then notify when help is on the way. Therefore, GPS mode enables view/send GPS satellite position as SMS to another device or to StratosTrax tracking portal using Short Burst Data (SBD). Enhanced security provides program to SOS button and use the protective cover to avoid accidentally sending an SOS; there is also the keypad lock and PIN lock for additional security. Combined with this satellite handheld phone, Iridium Access Point allows to create a WiFi hotspot and to connect the Internet. This phone can be used as 9575 To Go Kit-Yellow in emergency situation of ships and aircraft.

5. Transportable RapidSAT 9555 Terminal – The complete kit is integrated into a high quality custom case, which includes speaker, microphone magnetic antenna with 5m cables, privacy handset and the compact 9555 dock unit, which is illustrated in **Figure 10 (Left).** There is also an optional battery pack that can be inserted into the RapidSAT 9555 that will provide extended talk-standby time for portable use. This unit is ideal for short-term use or applications where many people may need to access satellite communication for rapid deployment in emergency. The flexibility of this unit enables the unit to be easily transported between various road vehicles, ships, boats, machinery, helicopters or aircraft and simply connects to the vehicle's DC power source for in vehicle use or alternatively the optional battery back-up for away from vehicle use.

Figure 10. Transportable Satellite Terminals – Source: Beam

6. Transportable RapidSAT LBT Terminal – This unit provides global access to satellite communications as a portable system that can be used across several mobiles or away from mobile, such as ships and aircraft in distress and emergency situations, which is shown in **Figure 10 (Right).** The portable bag has an intelligent handset for supporting hands free or private voice calls along with accessing SMS functionality. The unit is very compact and can easily be installed onboard any type of ships or aircraft with subject to local approvals as primary or emergency communications. Thus, supporting all Iridium Voice, Data and Fax services makes it the ideal solution with ability to provide a fully integrated voice service through the mobile communications system. It can simply connect to the aircraft's DC power source or alternatively the optional battery back up for away from mobiles **[2, 6, 9, 10, 11]**.

4.3. Maritime, Land and Multipurpose Mobile Satellite Terminals

The Iridium satellite operator offers the following GMSC terminals similar to Inmarsat and Globalstar systems:

1. Maritime Sailor SC4000 SES Terminals – Iridium is providing for Ship Earth Stations (SES) installations of Sailor Above Deck Equipment (ADE) or antenna and Bellow Deck Equipment (BDE) or transceiver equipment. In **Figure 11 (Left)** is shown the maritime Sailor Iridium single channel fixed terminal SC4000 designed by S.P Radio A/S from Denmark (today Cobham Company). This unit provides one-channel voice and data at a rate 2.4 Kb/s of O-QPSK modulation, can be mounted onboard ships, with one external helical omnidirectional antenna and interfaced to Tel handset, Tel/PBX, data RS232 and position information NMEA183. The same model has the possibility of multichannel service, providing 4 channels at a rate of 2.4 Kb/s of O-QPSK modulation with 4 separate helical omnidirectional type antenna and the same interface solutions. The former-Japanese company Kyocera offers an Iridium model IM-S100 Maritime Phone with the possibility to use it onboard different types of oceangoing ships. This is a single channel transceiver unit with external helical omnidirectional antenna, a capacity of 2 handsets connection and with possibility to use and charge a single-channel Iridium handheld Kyocera SS-66K model.

Figure 11. Iridium Maritime and Land Mobile GMSC Equipment – Source: Cobham & Motorola

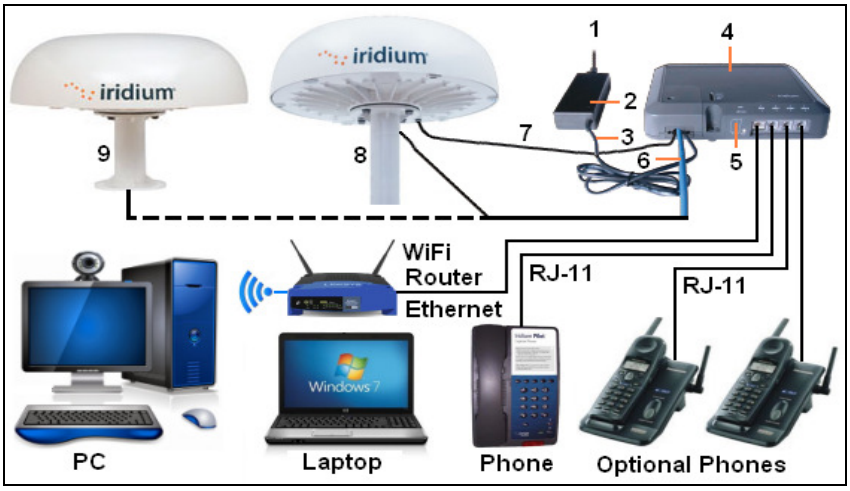

Figure 12. Iridium Pilot Broadband Station for Mobile and Fixed Applications – Source: Ilcev

2. Land Vehicle Motorola 9520 VES Terminals – The land Vehicle Earth Station (VES) terminal of Motorola's Iridium model 9520 is a permanently installed mobile telephone, as shown in **Figure 11 (Right)**. It is designed for in-vehicle operation with hands-free functionality and antenna mount options: magnetic, permanent and fixed mast. Its transceiver meets Military Standard 810 (MILSPEC 810). Italian company Telit offers a similar model for car-mounting the SAT550 and Japanese Kyocera offers the HF-S100.

3. Multipurpose Pilot Broadband Station – With the launch of multi solutions Pilot Broadband Station Iridium provides essentially expanding the reach of its predecessor OpenPort satellite service for maritime, land, aviation and terrestrial users. This station allows mobile and fixed users everywhere on the globe in off-the-grid locations to access Internet and voice calling at all times.

Thus, the Iridium Pilot Broadband Station can be installed in either a fixed location or mounted on a vehicle, and provides pole-to-pole coverage, broadband data speeds and independent voice lines for simultaneous voice and data communications. In addition, this station can be used for disaster recovery, remote education, business continuity and exploration in integration with KVH TrackPhone.

In **Figure 12** is depicted Pilot Broadband Station for mobile and fixed application that is containing the following components: 1. Mains power cord of 2 metres is providing 100 to 220 V AC power supply to power module; 2. Power module is transforming main power to 24 V DC, however direct DC power supply is also supported for vehicle or other DC power locations; 3. Cable for connection power module with indoor unit or for ships installation is known as BDE; 4. Indoor Unit (IDU) or BDE is the appliance to which are connected PC, Laptop and telephones, which is capable of handling three POTS/RJ11 corded or cordless telephone handsets and one Ethernet data connection for Router; 5. SIM card validates the system at start-up, allows connection to the Iridium network and provisions the appropriate phone and data lines; 6. Cable of up to 30 m is available to connect antenna or Outdoor Unit (ODU) to the IDU, which has a waterproof connection for the ODU; 7. Ground cable is included to provide grounding for IDU at the installation location; 8. Radome antenna or ODU with mast is useful for mounting onboard ships; and 9. Optional radome antenna with short mast for installation on the roof is providing fixed communications. The same low profile antenna without mast and with four magnets is usable for magneting mounting onboard units with metal surface, such as vehicles, toolboxes, metal roofs, and carports. However, the same antenna without mast can be used for installations on aircraft fuselage.

Pilot Broadband Station voice or data call is received by the closest mobile or fixed device located on the Globe. The traffic is routed through the meshed satellite network and lands at the Alaska GES and is then routed over terrestrial networks to the Gateway in Arizona. At the Gateway, traffic is converted back to Internet Protocol (IP) and voice, depending on call type and delivered to the IP cloud or PSTN.

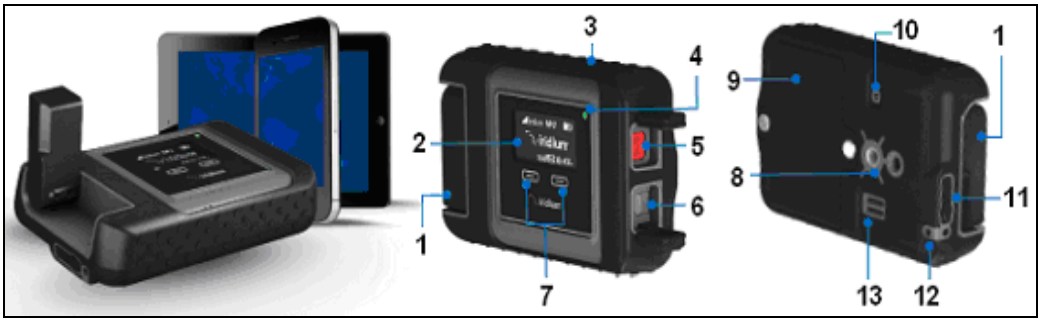

Figure 13. Multipurpose Iridium GO Handheld Satellite Terminal – Source: Iridium

4. Multipurpose Iridium GO Handheld Satellite Terminal – The Iridium Go is Iridium's newest and most exciting satellite connectivity device to date that is providing backbone via WiFi users to connect their own Smartphone, iPad or Android via satellite for voice and fast data communication anywhere in the world, which is illustrated in **Figure 13 (Left).** The main components of Iridium GO depicted in **Figure 12 (Middle)** and **(Left)** are as follows: 1. Swivel Antenna; 2. Device Screen; 3. Power Button; 4. LED Status Indicator; 5. SOS Button; 6. USB Power/Data Socket; 7. Navigation Buttons; 8. Accessory Connector; 9. Battery Cover/Box; 10. Pressure Vent; 11. External Antennal; 12. Lanyard Connector; and 13. Loudspeaker.

With the Iridium GO mobile and fixed users get a new platform for apps of all kinds, which are optimized for the Iridium network. Thus, with apps downloaded and ready, users can use own Smartphones, Tablet or Laptop devices for a wide range of functions, including: initiate a voice call, send an E-mail and a text message, update social media, check GPS, make a satellite-backed WiFi data call, initiate an emergency SOS distress message and check battery life of the unit. In particular, Iridium GO transforms users smartphone into a global satellite phone, which enables reliable voice and data capabilities for smartphone or up to 5 mobile devices. The Iridium GO has integrated GPS for tracking over the entire Planet, which enables for the unit allowing users to see, in real time and space, position on a dedicated individual WebPages where family or friends can track their location.

In any case, Iridium GO enables satellite connectivity for mobile devices where terrestrial networks cannot. Simply flip up the integrated antenna and the battery-powered unit connects quickly and automatically to the Iridium LEO satellite constellation to create an anywhere WiFi hotspot within an approximately 100 ft (30 m) radius. The Iridium GO external antenna adapter (9560 External RF Cable) is necessary to connect an external antenna to Iridium GO device. This may be advantageous in situations where it is impossible to locate the Iridium GO with a 360° view of the horizon while simultaneously within 100 feet of WiFi enabled smart phone or tablet. In fact, if different sites of users are surrounded by tall trees, buildings, hills, mountains or the superstructure of a ship, the view of the internal Iridium GO antenna could be obstructed. Here will be introduced some typical mobile applications where an external antenna is needed:

In **Figure 14 (Left)** is shown Iridium GO antenna for maritime and fixed applications. The mast helix antenna in radome can be installed onboard ship usually on compass deck above the navigation bridge or atop roof of the buildings. If customers using their Iridium GO below decks onboard ships or inside a building, outfitter satellite sells a mast antenna or a special ruggedized mast antenna can be located above decks or building to improve users Iridium signal reception. Namely, outfitter satellite offers 10, 20 and 30 metre antenna cables to connect antenna with Iridium Go via dedicated cable adaptor.

In Figure 14 (Middle) is depicted Iridium GO vehicle bolt or mag-mount (magnetic) kit with a 1.5 and 5 metre antenna cables, which can be installed on the roof of cars and other commercial vehicles including railway locos.

This flat patch antenna is designed for all type of land vehicle applications allowing many users to put the Iridium GO on the dashboard of their vehicle. If this does not produce adequate results, placing an antenna on the roof of the vehicle should improve performance.

Figure 14. Multipurpose Iridium GO Handheld Satellite Terminal – Source: Iridium

In **Figure 14 (Right)** is illustrated Iridium GO with avionic antenna useful for onboard small aircraft and helicopters. This aviation unit offer to pilots and passengers a way to stay connected in flight and on the ground, in a compact, well-built device, small enough users to carry in flight bag and placed on any glare shield or dash for reliable, always-on cockpit communications. All above stated possibilities and services for fixed, maritime and land mobile applications are the same.

4.4. Aeronautical Satellite Communication Terminals

In this section will be introduced several solutions for aeronautical satellite broadcasting and communication systems.

1. Integrated ICG Sora ig+ Airborne Terminal – This solution provides communication and safety service for aircraft via three-channel system integrated with peripherals and IGA SwiftBroadband antenna, which scenario is illustrated in **Figure 15.**

The ICG Sora ig+ Airborne Terminal is special packed with features that are important to conducting pilots with reliable communications and business on the fly. The ICG NxtLink ICS 220A is three transceiver Iridium device which combines two channels of global voice and a dedicated cockpit datalink channel via a third SBD channel to support ACARS, FAN messaging and Controller Pilot Data Link Communications (CPDLC). The ICG Sora ig+ satellite terminal is designed specifically to provide an aircraft flight crew with reliable communications facilities for both Aeronautical Operational Control (AOC) and ATS messaging. It is a three transceiver device which combines dual channels of global voice and 2.4 Kb/s data service with a third SBD channel in a single 2MCU (Microcontroller Unit) and Line Replaceable Unit (LRU).

Figure 15. Integrated Satellite Terminal – Source: ICG

Figure 16. SkyConnect Transceiver and Peripherals – Source: SkyConnect

In addition, the aeronautical voice and data transceiver is available for cabin crew and passenger services, credit card clearing and providing communications in case of medical emergencies. This aircraft terminal permits different connections of conventional telephony devices through either standard 2-wire "Tip and Ring" electronic circuits or 4-wire audio connections and Digital European Cordless Communication (DECT) units. In such a way, telecommunication features include intercom onboard calling, call transfer, conferencing and follow-on dialing.

The device connects to standard aircraft systems via 4-Wire audio for flight deck voice and AR INC 429circuits for MCDU dialing or Datalink messaging exchanges. The devices have external CIM card readers making them a true LRU and various types of handsets including cordless can be connected for cabin use. Therefore, the ICG NxtMail Server provides a local Wireless Access Point (WAP) permitting interface of WiFi or WiMAX to capable devices such as a smartphones and personal computers to access conventional Internet Protocol (IP) services. The Cobham SDU-7320 is 2-MCU Satellite Data Unit providing a full-featured SwiftBroadband channel with data speeds at 332 Kb/s. The Cobham HLD-7260 is a highly compact unit that combines a High Power Amplifier (HPA) and Diplexer/Low Noise Amplifier (DLNA), delivering SwiftBroadband where other systems can't. The Cobham IGA-5001 is smallest intermediate gain antenna on the market today that delivers full SwiftBroadband capabilities. It is considered to be one of the optimum antenna solutions for Inmarsat's SwiftBroadband Class 7 service offering.

The Cobham SDU-7320 is 2-MCU integrated satellite data unit providing a SwiftBroadband with data speeds at 332 Kb/s. The Cobham HLD-7260 is a highly compact unit that combines a High Power Amplifier (HPA) and Diplexer/Low Noise Amplifier (DLNA), delivering SwiftBroadband where other systems can't. The Cobham IGA-5001 is smallest intermediate gain antenna on the market today that delivers full SwiftBroadband capabilities. It is considered to be one of the optimum antenna solutions for Inmarsat's SwiftBroadband Class 7 service offering. The ICG Sora Lg Terminal is similar as previous, which instead The ICG NxtLink ICS 220A is using ICG ICS-120A unit and instead of Cobham SDU-7320 is using Cobham SDU-7310 unit.

2. SkyConnect Transceiver – This integrated satellite telephones and tracking systems are becoming very mission-critical equipment for helicopter operations that require communications with disparate and ever-changing entities. Designed for the crews with a busy workload in helicopter cockpits, this device easily accommodates virtually any operational scenario, including fixed-wing missions. The SkyConnect transceiver, L-band antenna, Mission Management Unit (MMU) Cockpit Dialer, Tactical Dialer and Flush-Mount Cradle are shown in **Figure 16.** The MMU-II is a computer-controlled dialer and is very flexible operation. It communicates with the transceiver over an RS-232 port and can be programmed in the aircraft with new message sets, or software. It has a four step-dimming feature to the display. The MMU makes it a breeze to send standard company-specific messages, such as number of passengers, current fuel load, patient status, Estimated Time of Arrival (ETA), and more.

Figure 17. Integrated Transceivers and Peripherals – Source: EMS & Honeywell

This unit has two Tactical Dialers, a 6- and an 11-position. The 11-position has a backlit faceplate and the dimming feature to the panel lights and the annunciations can be separate or together.

3. EMS Sky Connect Forté Phone System – This unit is similar to previous and designed specifically for aircraft operators who want a phone that works when and where they need it, and at a cost they can afford. Each Forté satellite line can support any combination of four wireless, corded or MMU-II telephones. In contrast to other elaborate systems, Forté with antenna and few peripherals delivers the basic service aviators need to remain productive and in touch no matter where their fleet fly.

Using the Iridium network it delivers cell phone convenience anytime, anywhere, shown in **Figure 17 (Left)**. It includes a built-in intercom feature to accommodate multiple telephones. It makes it easy for the flight crew to talk to passengers and vice versa, and is supporting phone equipment in the cockpit. It allows telephone selection on audio panel, so anyone on the flight deck can hear and be heard with the best fidelity.

This device is a standard size DZUS-mounted peripheral interface with a dimmable two-line display, full telephone keypad and sophisticated set of unique features that make it cockpit-friendly. Forté Cordless Handset convenient for larger cabins or just for those who don't want to wrangle with a cord, these handsets are designed for jet cabins with typical noise levels. Despite its compact size, the large color display and backlit keypads on this handset make it very easy to use. Up to four telephone handsets can be installed throughout the cabin and on the flight deck.

Forté Corded Handset is designated for crew and passenger cabins with higher noise levels, this tethered handset is very effective at making your words loud and clear. It also boosts the earpiece volume so that your conversation is comfortable and easy.

4. Honeywell AIRSAT 1 Terminal – This aircraft single channel terminal was developed by Honeywell for use aboard private aircraft and offers voice and data communications for airborne applications, shown in **Figure 17 (Right)**.

The system is composed of an ITU 100 Iridium Transceiver Unit and Blade Antenna ANT-100 for external or fuselage mount (**Fig. Above**) and Telephone Dialer Unit TDU-100 and Aircraft Integration Unit AIU-100 (**Fig. Below**). This terminal is including handset phones for pilot in cockpit, similar to phones shown in **Figure 17 (Left).**

This terminal provides the following requisites: the system function does not interfere with the other systems onboard; if the system should be subject to any type of failure, this will not affect the normal function of other equipment onboard, or create any danger for the remaining flight and the installation of all devices, including the antenna, is designed so that they will not have any effect or compromise the aircraft structure or dynamics, especially in the case of emergency landings.

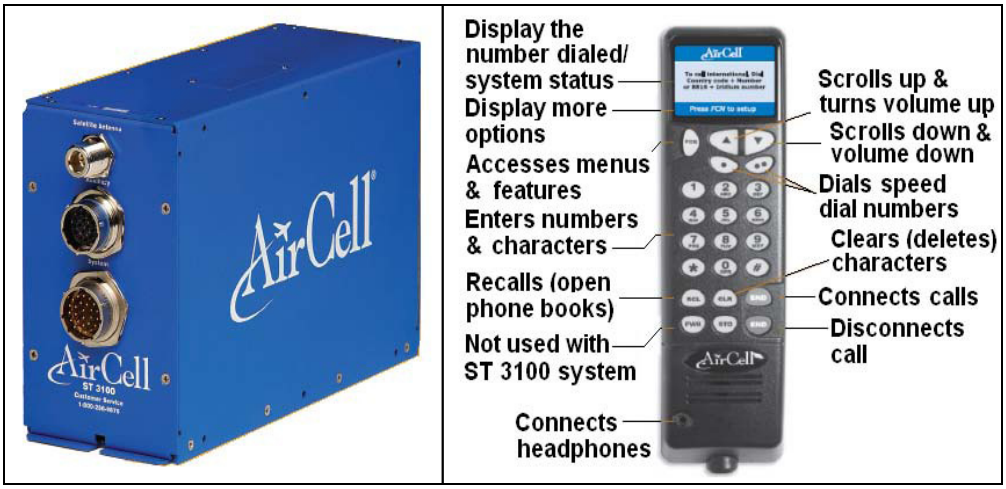

Figure 18. Aircraft Satellite and Cellular Terminal – Source: AirCell

5. AirCell 3100/3500 - The most used terminal of Iridium satellite solutions is the AirCell ST 3100 or 3500, which supports airborne telephone, fax and narrowband data worldwide including local cellular connections, shown in **Figure 18 (Left).**
Moreover, this unit also provides access to weather bulletin, news, financial data, ATC information and messaging, and inflight medical emergency help via Aircell's service partners. Along with its global coverage, it improves communications between the cabin and cockpit with an audio intercom feature. Easy to install, this unit is available with a wide range of antenna and handset options including a corded or cordless handsets with a full-color display, illustrated in **Figure 18 (Right).** However, the flush or bulkhead-mount cordless handsets free users for convenient mobility throughout the cabin. In Iridium mode, onboard phone accesses the Iridium Network via AirCell ST 3100 or 3500 operating in the 1616 MHz to 1625.5 MHz range with maximum power level of transmissions is 7 W **[2, 6, 12, 13, 14]**.

5. Cobham LT-3100S GMDSS Shipborne Transceiver

This unit is the new solution for Global Maritime Distress and Safety System (GMDSS) distress alert and commercial communications via the Iridium NEXT satellite constellation produced by Cobham company, which Certus configuration is shown in **Figure 19.** This SES terminal includes control unit and bracket mount, handset and cradle, antenna unit and power cable. The standard version fulfills all the GMDSS and business basic voice requirements with interface and control, satellite and phone handset, while optional are alarm panel and printer. It supports both safety voice as priority and standard voice as non-priority. The terminal can be configured to automatically setup a safety voice call (priority: Distress), if the Distress button has been activated.

Figure 19. Iridium LT-3100S GMDSS Transceiver – Source: Cobham

Figure 20. Iridium Mobile and Personal Trackers – Source: Quake & Iridium

6. Global Mobile and Personal Satellite Trackers

The Online Tracking Platform (OTP) system is an integrated Web-based Iridium or GSM and GPS tracking solution compatible with modern Web browsers and a multilingual platform that displays and manages them in a single unified interface, which solution Q4000 Tracker of the US Quake producer with antenna is depicted in **Figure 20 (Left/Middle).** With OTP, mobile locations and movements, including PVT, speed, altitude and direction, are tracked in real time around the world via GPS updates.

This Quake tracker is a two-way rugged modem that can combines dual-mode operability over Iridium or GSM terrestrial networks with GPS into a versatile, all-in-one mobile asset tracking solution. Thus, the integrated GPS in the tacker receives GPS signals, processes the determination data and sends the PVT, Identification Number (ID) of mobile and other data via satellite or GSM to the Tracking Control Station (TCS). In such a way, the TCS terminal can receive PVT data from any mobile, process and display on radar like displays for traffic control. Technically this is a Short Burst Data (SBD) communicating transceiver designed for use as basic unit for many mobile trackers using the Iridium network, such as ocean ships and container tracking and as well as for land vehicles and aircraft tracking. Handhelds Personal Satellite Trackers is a waterproof two-way satellite personal tracking device that provides autonomous and global coverage in real time, which is shown in **Figure 20 (Right).**

By pressing a predefined and free text "HELP" the device can send a distress message with the correct GPS position according to the programmed frequency, and receive a message in less than 15 seconds, provides visual and audible warning, motion activated tracking, etc. **[2, 14, 15, 16].**

7. 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 NEXT satellite constellation.

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