Global Satellite Tracking and Detecting Systems for Military Mobiles and Troops

Dimov Stojce Ilcev

Space Science Centre (SSC), Durban University of Technology (DUT), Durban, South Africa, E-mail: ilcev@dut.ac.za

Abstract: This paper introduces the current and proposed satellite transponders for Global Satellite Tracking and Detecting (GSTD) systems to serve military mobiles and troops at sea, on the ground and in the air and to provide enhanced safety, security, traffic control and management. In fact, GDST systems are an integration network composed of Global Navigation Satellite Systems (GNSS) and Global Mobile Satellite Communication (GMSC) systems, whose main components are a special personal and installed onboard mobiles tracking transponders. Personal or mobile transponders are special satellite trackers composed of GNSS and GMSC units integrated into a single device with both antennas. These transponders are able to monitor all military mobile vehicles, to improve the safety of movements and collision avoidance, especially for navy and air forces assets. Tracking transponders dedicated to civilian application discreetly installed onboard ships or aircraft can provide reliable anti piracy or hijacking solutions, respectively.

Keywords: *DVB-RCS, GEO, MES, LES, IP, CNS, MSC, VoIP, VDVoIP, FIT, MIT, VSAT*

1. Introduction

After the Soviet Union launched the first in the world artificial satellite, Sputnik 1, satellite systems became the delivery mode of the choice for positioning information with developments of first Navigation Satellite Systems (NSS). The US military system Transit started with development from 1960 till the last launch in 1988 and the Soviet Union military system Cicada was established in 1974. After early experimentation with the doomed NSS Transit and Cicada systems, remember having to wait hours for the next satellite to appear overhead, new GNSS of GPS and GLONASS Medium Earth Orbits (MEO) satellite networks were created at the end of 20th Century to offer highly accurate global satellite positioning system in longitude and latitude, almost anytime and anywhere in the world.

The current Global Navigation Satellite Systems (GNSS) are represented by fundamental solutions for Position, Velocity and Time (PVT) of the US GPS and Russian GLONASS military 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 military and civilian mobile asserts. A major goal of the near-universal use of GNSS systems is their integration with satellite communication systems, which very small units will be able to improve tracking and positioning facilities of military personnel and mobile assets, such as ships, ground vehicles and aircraft.

As a result of these efforts, new tracking technologies have been projected and developed to utilize Communication, Navigation and Surveillance (CNS) solutions and services for enhanced traffic control and management of military mobile personnel and assets. Received tracking data by GPS/GLONASS Receiver (Rx) of military personnel or mobiles and troops via Geostationary Earth Orbit (GEO) or Non-GEO communication satellites. All mobiles and personnel require far more sophistication of the Global Satellite Tracking and Detecting Systems than standalone GPS or GLONASS positioning systems. Thus, it is proposed Global Mobile Satellite Tracking (GMST) system as an integrated configuration in device containing small GPS or GLONASS receivers and mini GEO and Non-GEO satellite transceivers with adequate antennas.

2. Integration of GNSS and GMSC Networks for Global Mobile Satellite Tracking

The US Transit satellite navigation system was switched off in 1996 to 2000 after more than 30 years of reliable service. By then, the US Department of Defence was fully converted to the new GPS network. However, the GPS service could not have the market and domination to itself, so as a result, the former Soviet Union (Russia) developed a similar system known as GLONASS in 1988 and ceased the previous Cicada system. While both, Transit or Cicada systems, provided intermittent two-dimensional (latitude and longitude when altitude is known) position fixes every 90 minutes on average and were the best suited to marine navigation, the GPS or GLONASS satellite networks provide continuous position and speed in all three dimensions, equally effective for navigation and tracking at sea, on land and in the air.

The military GPS and GLONASS represent the first generation of GNSS (GNSS-1) which were initially used for military applications only, and after that also for civilian applications. In the meantime, China started development own GNSS-2 navigation system known as Compass (BeiDou), which is operational. The BeiDou network consists of two separate satellite constellations that have been operating since 2000 and a full-scale global system is currently under construction. However, the second GNSS-2 satellite network still in the development stage is the European Galileo.

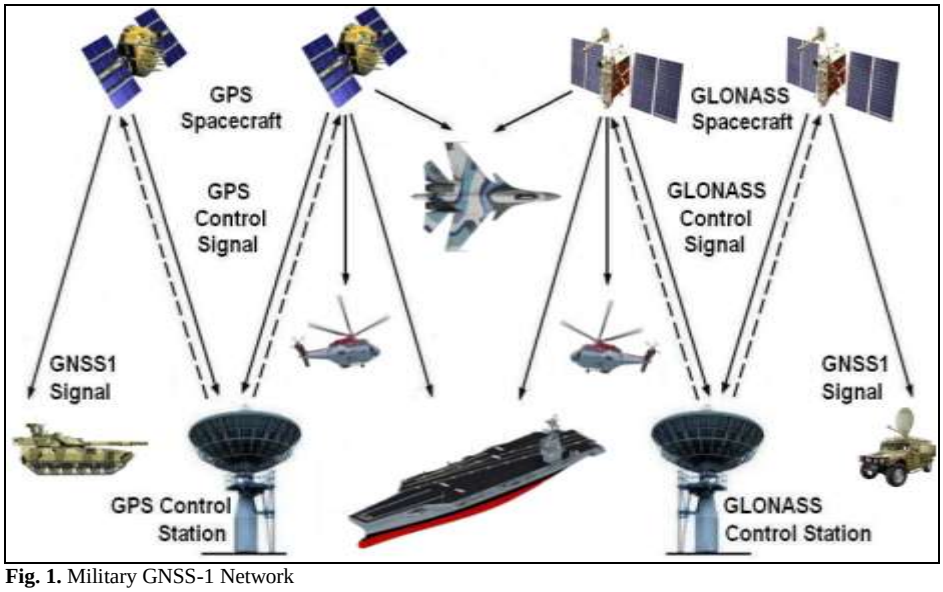

Fig. 1. Military GNSS-1 Network

The configuration of military GPS and GLONASS space, users and ground segments as a first integrated component of GMST is shown in **Figure 1,** which represent all-weather spacecraft, full jam resistant and continuous operation navigation system, utilize precise range measurements of PVT, altitude, ID other data anywhere in the world. This GNSS-1 networks provide PVT service with highly accurate worldwide three-dimensional, common-grid, position and location data, velocity and precise timing to accuracies that have not previously been easily attainable. Thus, the GNSS service is based on the concept of triangulation from known points similar to the technique of "resection" used with a map and compass, except that it is done with radio signals transmitted by satellites. The GNSS portable or onboard mobiles receiver must determine when a signal is sent and the time it is received. Nothing except onboard mobiles GNSS receivers is needed to use the system free of charge, which does not transmit any signals and therefore they are not electronically detectable.

On the other hand, most communications between mobiles and traffic controllers are still conducted via VHF and HF analog and digital voice or radiotelephone RF-bands. However, in some busy portions of the world this system is reaching its limit, the RF-bands are congested and additional frequencies are not available. Thus, to improve the communication and traffic control facilities of mobiles almost 40 years ago was implemented civilian Marisat GMSC Network as a second integrated component and soon after were established Inmarsat GEO and Iridium LEO networks, which scenario is shown in **Figure 2.**

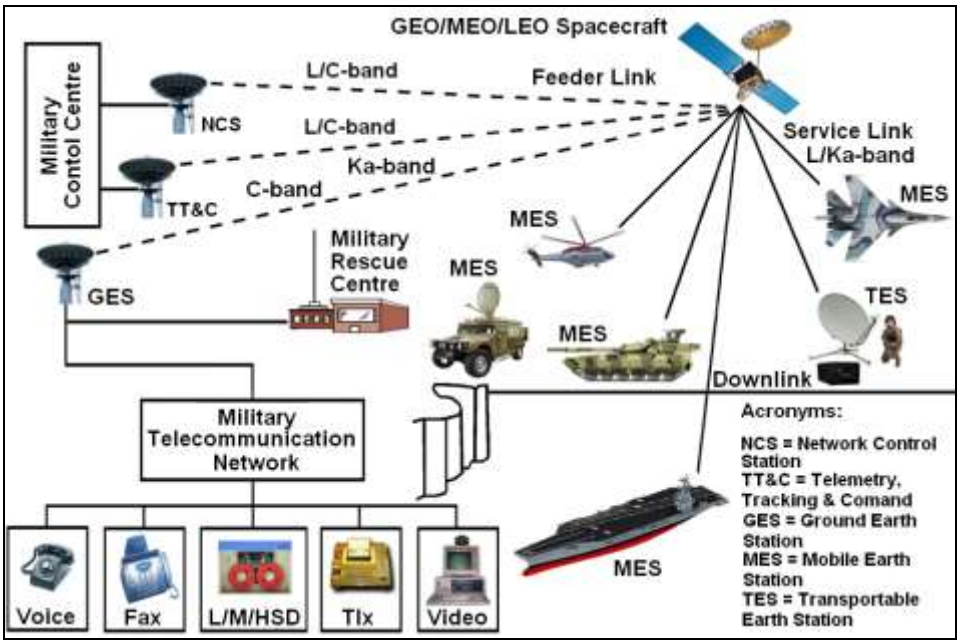

Fig. 2. Military GMSC Network

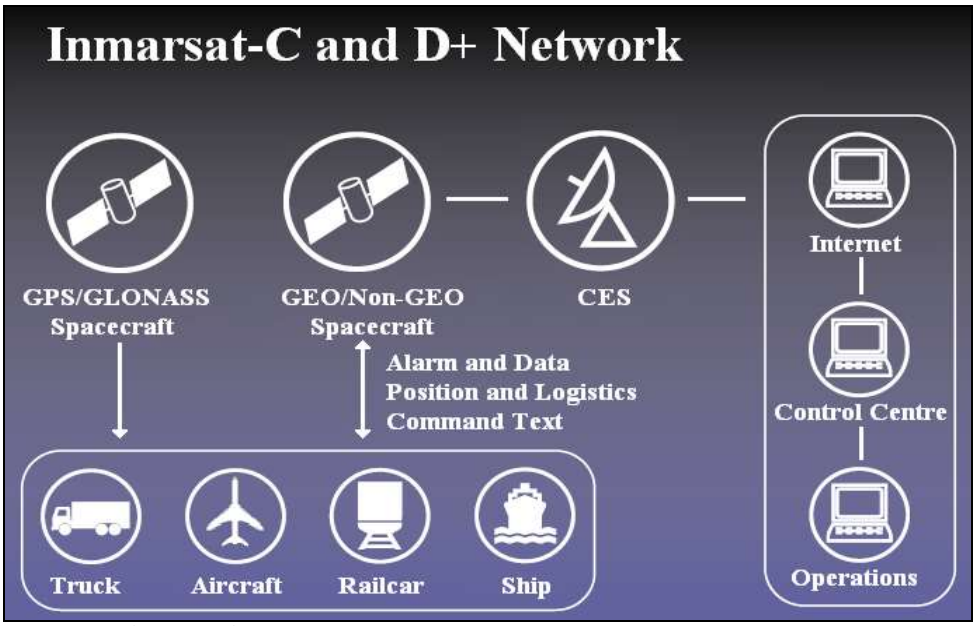

Figure 3. Configuration of GMST System

Therefore, the scenario of military GMST is an integrated satellite network deploying the GNSS subsystem of US GPS and Russian GLONASS network to provide free of charge PTV data to different military mobiles or troops, and the GEO or LEO satellite for providing communication facilities of PVT data to the Ground Erath Station (GES) terminals. The PTV data can receive ships, land vehicles and aircraft via onboard GPS/GLONASS Rx integrated with GEO and Non-GEO (LEO) satellite transceiver, which scenario is illustrated in **Figure 3.** Then the satellite receiver (Rx) and transmitter (Tx), known as transceiver is providing frequently transmissions of PTV data via GEO or Non-GEO spacecraft through GES or Gateway and the Internet to the Control and Operations Centres.

The convergence of GMSC and Internet technique has opened many opportunities to provide positioning and tracking data to the ground infrastructure. With the need for increased bandwidth capability, numbers of new GEO and Non-GEO satellites is increasing dramatically. The size of the Earth requires multiple satellites to be placed in orbit constellation to cover areas of users interest and adequate communications coverage. The current integrated network for the Global Mobile Satellite Tracking (GMST) system that consists GNSS and GEO/LEO satellite constellation is depicted in **Figure 4.**

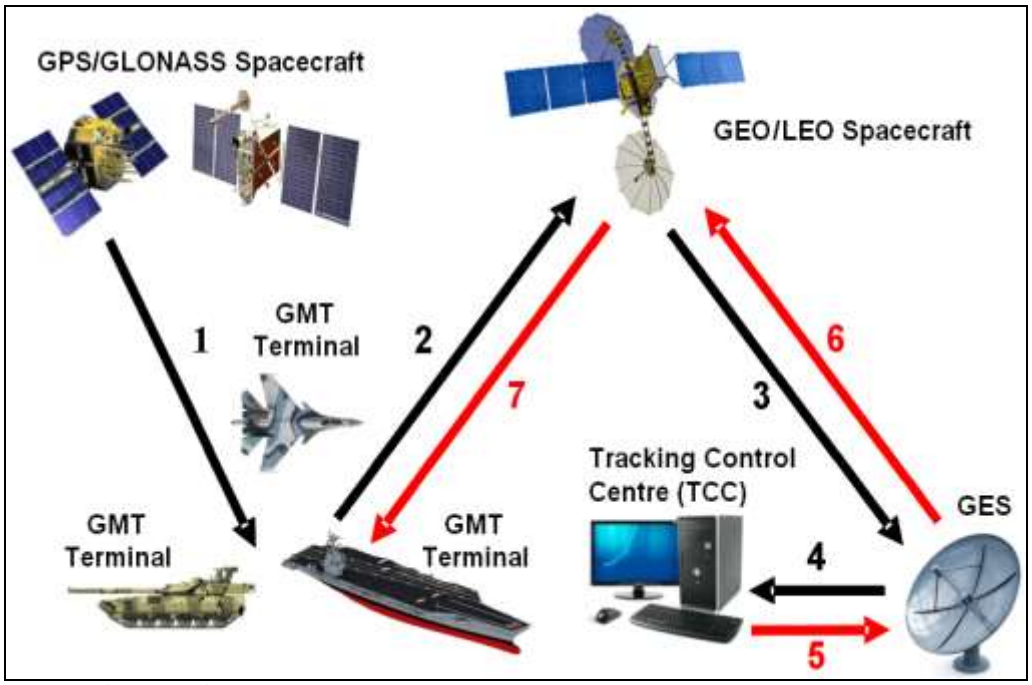

Fig. 4. Configuration of GMST via GNSS and GEO/Non-GEO Satellites

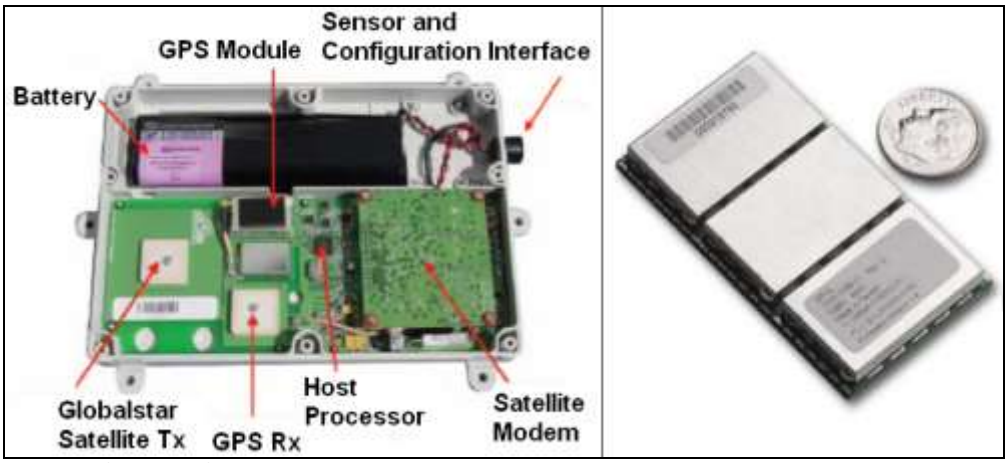

Fig. 5. Configuration of GMST Equipment

Because of many incidents in past time, without successful search and tracing of ships or aircraft disappeared in some disasters caused by collision or grounding were proposed new tracking and detecting solutions via GMST network. For instance, if the GMST transponder was fixed in Air France or Malaysian aircraft crashed in 2009 and 2014, respectively, Search and Rescue (SAR) forces should find the wreck in 1-2 days and in an area of maximum 100-200 miles.

The GMST system will provide solutions for the global identification and tracking of military and civilian personnel and mobiles. The GMST onboard equipment receives GNSS signals from GPS/GLONASS spacecraft (1) and sends PTV tracking messages of position (2) via GEO satellite to GES (3) of Satellite Communication and Application Service Providers (Internet) to the TCC processor (4), shown in **Figure 4.** All lines highlighted in red are indicating the GMST receiving process, namely, the receiver in GMST terminal is receiving PVT data from TCC useful for collision avoidance and showing it on the receiver display.

The Axonn GMST terminal is proposed as possible solution for GMST applications using Globalstar Big Low Earth Orbit (LEO) satellite network, which diagram with electronic components is illustrated in **Figure 5 (Left).** This GMST equipment contains GPS module, sensor and configuration interface, satellite modem, host processor, GPS receiver (Rx), Globalstar satellite transmitter (Tx), which is using Globalstar network only, and battery. The GMST unit provides simplex (one-way) satellite transmission of PTV data, but it has not the possibility to receive back PTV data from TCC of other mobiles for collision avoidance or any other information. For that reason can be used duplex (two-way) GMST via GEO Inmarsat or Big LEO Iridium satellite networks. In **Figures 5 (Right)** is illustrated other samples of Axonn GMST small unit.

It is important to state that Globalstar is also providing duplex GMST satellite transmissions. The fourth mobile operator for GMST applications is Little LEO Orbcomm, which satellite network is providing both simplex and duplex service.

The Inmarsat and Iridium GMST transponders are the best solutions for GMST of military assets and personnel, because are providing full global coverage and the following service:

1. The GMST terminals can be installed in each mobile using onboard power supply or in emergency situation may use own batteries, and can be also employed for tracking of military personnel.
2. The GMST unit can be pre-programmed for different requirements and to send GPS location and other data on pre-defined intervals. Messages are transmitted via the Inmarsat or Iridium duplex satellite networks through a message routing infrastructure and then sent to host (TCC) or can be integrated with a hosted mapping application.

3. Tracking and Detecting Mobile Terminals via Inmarsat Satellite Network

Inmarsat was established in 1979 as the International Maritime Satellite Organization (Inmarsat) initially began trading in 1982 via GEO satellite constellation offering service for maritime application at first, and after for land, aeronautical and personal communication and tracking. Inmarsat is providing service at the following bands: 1.6/1.5 GHz of L-band (Service Link) and at 6.4/3.6 GHz of C-band (Feeder Link). The Inmarsat D+ tracking terminal is developed on basis of the Inmarsat-C standard as the best solution for GMST solutions. It is able to transmit and receive data anywhere via Inmarsat satellite constellation and is ideal for asset tracking, fleet management and SCADA (M2M) applications. It is low powered by onboard and batteries power supply, and with special sensors can provide mileage, consumption of fuel, temperatures and other characteristics of mobiles.

The former SkyWave manufacturer of Inmarsat satellite tracking and detecting transponders provide reliable civilian and military GMST terminals. These small terminals offer reliable communications for defense organizations, which operate in some of the world's harshest and most remote environments, far from the reach of most communications systems. The SkyWave terminals are fully programmable and low-powered applications optimized to work over satellite and even terrestrial networks. They provide PVT data communications for effective and efficient tracking, monitoring, control and management of personnel, equipment and mobiles, regardless of location. In fact, there are five reasons to choose such kind of equipment and service:

Fig. 6. First and Second Generation of Inmarsat SkyWave GMST Terminals

1. Personnel Safety**:** Co-ordinate location of friendly units for full situational awareness and text message field personnel in dangerous or remote regions.
2. Defense Asset Tracking: Track the location of military vehicles, trailers and containers.
3. Cargo Security: Monitor container doors to detect cargo theft and ensure security.
4. Increase Efficiency: Transmit electronic documents like order instructions.
5. Access Control and Logistics: Transmit identification of personnel on transport buses.

In **Figure 6 (A)** is illustrated the first generation of SkyWave Inmarsat D+, in Figure **6 (B Above)** is shown third generation of SkyWave Inmarsat IsatData IDP 600 series GMST for maritime applications and in **Figure 6 (B Below)** is shown the same terminal for land (vehicle) applications. These terminals can be used even for aircraft tracking if integrated GPS Rx can be adapted to work under high speed conditions.

4. Tracking and Detecting Mobile Terminals via Iridium Satellite Network

The Iridium satellite constellation is situated in a near-polar orbit at an altitude of 780 km. They circle the Earth once every 100 minutes at a rate of about 26,856 km/h. Each satellite is cross-linked to four other satellites with two satellites in the same orbital plane and two in an adjacent plane. The Iridium constellation consists of 66 operational satellites and 14 spares orbiting in six polar planes.

Iridium system provides real global coverage and roaming globally via 48 spot overlapping beams and the diameter of each spot is about 600 km. Iridium as a real global operator provides voice and data service including GMST for 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) offering many types of GMST transponders for all mobile and personal applications:

1. Quake 9602 Mini Tracker – The 9602 is a Short Burst Data (SBD) transceiver designed for use as the basic unit for many trackers using the Iridium Network, which is illustrated in **Figure 7 (Left).** This very tiny, 41x45x13 mm and 27.22 grams, the two-way transceiver is perfect for use for all mobiles and personal, including aircraft and for fixed remote asset tracking and M2M monitoring solutions. This Iridium unit has not GPS Rx, but can be connected to onboard GPS via built-in GPS input/output ports. However, other similar units have integrated GPS receiver and they are able to work independently of the onboard mobile GPS Rx.

2. Quake Q-Pro Multipurpose Tracker – This unit is a small 119.2x119.4x57.6 mm and 390.6 grams rugged multi-satellite GPS/Iridium, Globalstar, Orbcomm and GSM modem, shown in **Figure 7 (Middle).**

3. E-Track Alpha Tracker – This unit is an autonomous satellite tracking device, whish provides real-time and global coverage via Iridium network, illustrated in **Figure 7 (Right).** Features of this 116x64x 46 mm and 239 grams unit are automatic transmission of the PVT and other data.

Fig. 7. Iridium Miniature Satellite Trackers

Fig. 8. Iridium Personal Satellite Trackers

5. Personal Tracking and Detecting via Iridium Satellite Network

The following Iridium personal satellite trackers that can be used for tracking troops or individual soldier are ideal units for tracking of mobile crew and personnel:

1. E-Track Epsilon Personal Tracker – This tracker is waterproof satellite messaging and personal tracking device, providing real-time autonomous and global coverage, which unit is illustrated in **Figure 8 (A).** Developed around 9602 Iridium satellite 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 incident.

2. GeoPro Personal Messenger – This tracking terminal is a remote workforce safety, location awareness and two-way personal messaging solution, presented in **Figure 8 (B).** When work takes staff off the grid they often have no reliable means of maintaining communication. It is the affordable and rugged device supporting global two-way text messaging and can be used in one hand with a non-slip form factor network by a joystick to navigate on-display menus and keyboard.

3. NANO Personal Tracker – This pocket-size unit has ultra-low power consumption less than 35μA during sleep, shown in **Figure 8 (C)**. This 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 device ON/OFF and selects highlighted item on the equipment menu; (2) Arrow Up/Down/Right is navigating the cursor; (3) Check-In Soft Key is accessing Check-In feature. 4. Way Point Soft Key is using for Way Point features; (5) USB Port is serving to charge the battery and connects PC; (6) Emergency key can send an emergency alert, distress and notification to search and rescue forces; (7) Guard button protects emergency button from being accidentally activated; (8) LED is displays tracking and emergency statuses; (9) Antenna post is showing GPS antenna; and (10) Antenna post is showing the Iridium antenna.

5. Military Transportation Management Systems (TMS)

The military Transportation Management Systems (TMS) is a logistics communication platform designed for commanders to track mobile assets and personnel on the battlefield with encrypted text messaging of PVT data via GMST terminals. The PVT data can also contain heading, altitude (for aircraft) and ID of mobile or soldier. Namely, it is a satellite tracking, detecting and communicating system dedicated to providing command and control over distributed assets supporting and conducting theater operations.

This system provides units with digital Geographic Information System (GIS) maps, GPS or GLONASS GNSS system (GNSS) for location data, and L-band GEO/LEI satellite two-way text messaging system, which network is shown in **Figure 9 (A).** Troops on the ground are equipped with Honeywell (ex-EMS Satcom) GMST terminals, such as eNcompass PDT-300i, illustrated in **Figure 9 (B Above)** or eNcompass PDT-100, illustrated in **Figure 9 (B below).** The eNcompass terminals have integrated GNSS and satellite transceivers with both antennas, which have to be well protected by a plastic radome and properly mounted atop road vehicles. The requirements are the same for military ships and aircraft installations. However, soldiers on the field or in mobiles can use personal tracking and detecting terminals shown in **Figure 8.**

The TMS network can operate anywhere in the world giving over-the-horizon communications to ships, vehicles, aircraft and personnel on the move. Messages are transmitted via already discussed commercial satellites in near real-time and vehicle locations are displayed on computers with GIS maps. Thus, the GMST transponders of TMS network operate over the variety of existing GEO satellite constellations and are designed to transition automatically from one satellite system to another, as required the situation on the ground. In fact, some of GMST terminals are designed to work via 2 or 3 satellite operators, such as Inmarsat, Iridium, Globalstar and Orbcomm. Otherwise, all messages are encrypted end-to-end, including sender and recipient addresses for information security purposes.

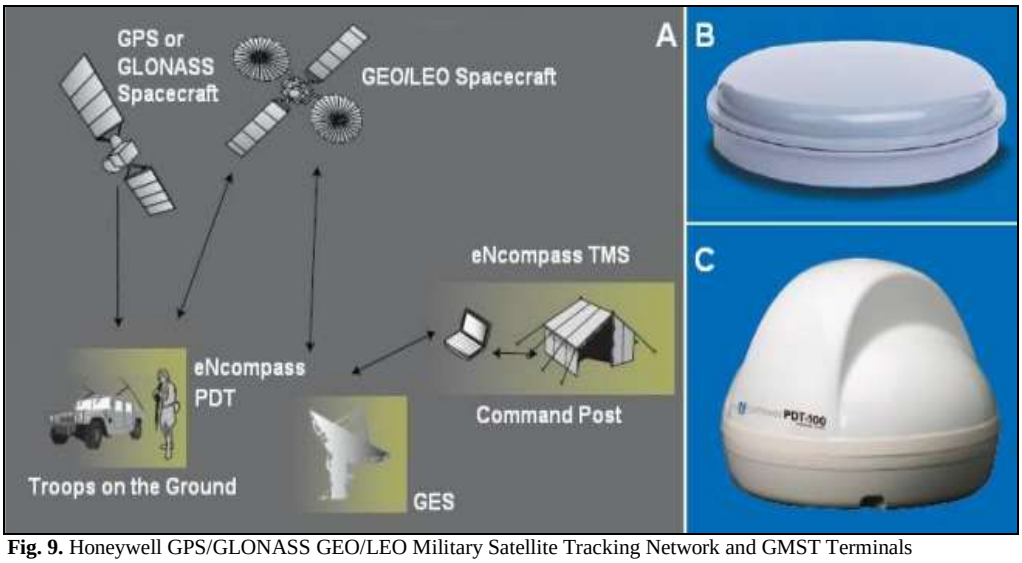

Fig. 9. Honeywell GPS/GLONASS GEO/LEO Military Satellite Tracking Network and GMST Terminals

The TMS computer systems come in two configurations, a mobile system that mounts in tactical vehicles and a laptop control station for use at a command post or at a higher headquarters. With this system implemented, it enables soldiers to communicate with other TMS-enabled vehicles and control stations as well as seeing their position. It is ideal for accurately identifying current vehicle locations and sending messages to and from the unit. With these two systems, the commander has the accountability of the missions and orders directed and the subordinate units have a higher level of force protection due to the ability of the tracking system. Leaders can pass critical information such as mission changes, alternate routes and other information essential to the mission to subordinate units in the field.

6. Conclusion

There was described GMST equipment and network very important for military tracking and detecting of mobiles and troops. In such a way, every operators at military Transportation Management Systems (TMS) and commanders of Navy, Ground and Air Forces can find out position of their navy vessels, land vehicles and movable weapon , aircraft and troops in any real space and time. The GNSS integrated network provides global coverage for tracking devices, with one problem that in case of war the GPS will work alone for the US army, while GLONASS for the Russian army.

On the other hand, there are several GMSC networks as an integrated component, however only Inamrsat GEO and Iridium LEO can meet the requirements for a successful satellite tracking and detecting service. The Inmarsat GEO satellite operator provides near-global coverage up to 80^0 North and South, but regards to available coverage this system and equipment can be used for any type of military mobiles and troops. However, for sailing or flights over the North Pole can be used HF radio communication systems instead. Iridium LEO satellite operator is providing full global coverage thanks to the intersatellite links, however, Globalstar and Orbcomm LEO satellites have limited coverages. The new GMSC networks can be designed as a combination of GEO, LEO and other satellite orbits, like Medium Earth Orbit (MEO) and High Elliptical Orbit (HEO) in so-called Hybrid Satellite Orbits (HSO), which can provide a professional service globally even over both poles.

References

[1] Wellenhof-Hofmann B. & Other, (2008) “Global Navigation Satellite Systems (GNSS)”, Springer, Boston, US, 516.
[2] Kaplan D.E., (2006), “Understanding GPS Principles and Applications”, Artech House, Boston-London, 683.
[3] Ilcev D. S. (2015), “Global Satellite Tracking for Mobile Applications”, DUT, Durban, South Africa, 75.
[4] Spidertracks, (2011), “Portable Tracking Satellite Terminals”, Palmerston North, New Zealand, 25.
[5] Diggelen V.F., (2009), “A-GPS, Assisted GPS, GNSS and SBAS”, Artech House, Boston-London, 599.
[6] Ilcev D. St., “Global Mobile Satellite Communications for Maritime, Land and Aeronautical Applications”, Theory and Applications, Volume 1 and 2, Springer, Boston, 2016/17.
[7] Inmarsat, (2014), "M2M and Tracking for Government", Inmarsat, London, UK, 24.
[8] Iridium, (2016), "Satellite Tracking for Government", Iridium, McLean, VA, US, 18.
[9] Ilcev D. S. (2018), “Presentation of Global Mobile Satellite Tracking”, DUT, Durban, South Africa, 45.
[10] Quake, Q4000 Family Technical Data Sheet San Diego, CA, 2010.

[11] Richharia M. (2001), “Mobile Satellite Communications – Principles and Trends”, Addison-Wesley, Harlow, UK, 560.
[12] Ilcev D. S. (2011), “Global Mobile CNS”, Manual, CNS Systems, Durban, South Africa, 285.
[13] EMS, (2011), “Global Tracking Solutions”, Ottawa, Canada, 28.
[14] Ilcev, (2019), “Global Aeronautical Distress and Safety System - Theory and Applications" Springer, Boston, US, 821.
[15] Del Re E. & Ruggieri M., (2008), “Satellite Communications and Navigation Systems”, Book, Springer, 772.

BIOGRAPHIES OF AUTHORS

Prof. Dimov Stojce Ilcev is a research leader and founder of the Space Science Centre (SSC) for research and postgraduate studies at Durban University of Technology (DUT). He has three BSc degrees in Radio, 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 author of several books in mobile Radio and Satellite CNS, DVB-RCS, Satellite Asset Tracking (SAT), Stratospheric Platform Systems (SCP) for maritime, land (road and railways) and aeronautical applications.