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ARTICLE

DEVELOPMENT OF NEW SATELLITE SOLUTIONS FOR MILITARY APPLICATIONS

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ABSTRACT

This paper introduces new projects of military satellite solutions for global tracking and Communication, Navigation and Surveillance (CNS) of mobile assets and personnel at sea, on the ground and in the air. Implementing new CNS systems military mobiles and personnel will be controlled, tracked and managed in more tactical and safe ways. The new satellite communication and navigation transponders are able to provide connections, monitoring and detection of all military mobile vehicles and personnel, to enhance traffic control and management, improve safety and security of movements and augment collision avoidance, especially for navy and air forces assets. Tracking transponders dedicated for civilian application discreetly installed onboard ships or aircraft can provide to military forces reliable anti piracy or hijacking solutions, respectively. Separately, the communication, navigation and surveillance solutions for navy, ground and air forces with their advantages and disadvantages are discussed.

Kew words
CNS, GEO, MEO, LEO, HEO, DVB-RCS, GNSS, GPS, GLONASS, VDVoIP, SCS, SNS, SSS

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INTRODUCTION

The satellite communication and navigation era began when the Soviet Union shocked the globe with the launch of the first ever artificial satellite, Sputnik 1, on 4 October 1957. Sputnik contained two radio transmitters, which sent back the “beep-beep-beep” signals heard round the globe as a first Satellite Communication link with the Control Centre on the ground. In the following years were developed fixed and mobile satellite systems via Geostationary (GEO), Medium (MEO) and Low Earth Orbits (LEO), including Highly Elliptical Orbits (HEO) and other satellite networks including combination of these constellations in Hybrid Satellite Orbits (HSO). After that, it was deployed new Digital Video Broadcasting-Return Channel via Satellite (DVB-RCS) network.

Global Navigation Satellite Systems (GNSS) are represented by fundamental solutions for Position, Velocity and Time (PVT) of the US GPS and Russian GLONAS 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, modern satellite technologies have been projected and developed to utilize CNS solutions and services for enhanced traffic control and management of military mobile assets and personnel staff. Received tracking data by GPS/GLONASS Receiver (Rx) of military personnel or mobile assets can be sent via adequate Geostationary Earth Orbit (GEO) or Non-GEO spacecraft. All mobiles and personnel require far more sophistication of new Satellite Asset Tracking (SAT) than standalone GPS or GLONAS GNSS positioning systems. Thus, it is proposed Global Mobile Tracking (GMT) system as integrated configuration in one SAT device containing small GPS or GLONASS receivers and mini GEO and Non-GEO satellite transceivers with omnidirectional antennas.

On the other hand, besides on existing military satellite systems, new satellite communication systems are offering many networks for civilian application also useful for tactical and defense solutions. For instance, Inmarsat, Intelsat and other existing satellite systems and networks provide sophisticated communication, navigation and other transponders, offering both CNS and DVB-RCS interactive networks for civilian and military applications.

DEVELOPMENT OF SATELLITE ASSET TRACKING (SAT) EQUIPMENT AND NETWORKS

The scenario of military SAT is system employing the GNSS subsystem of US GPS and Russian GLONASS to provide free of charge position data to different military or civilian assets. This PTV data can receive ships,

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land vehicles and aircrafts via onboard GPS/GLONASS Rx integrated with satellite transceiver. Then the Satellite transceiver (Rx/Tx) is providing frequently transmissions of PTV/ID data via GEO or Non-GEO spacecraft through Ground Erath Station (GES) and Internet to the Control and Operations Centres.

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 GMT system. For instance, if GMT 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 area of maximum 100-200 Nm. The GMT system will provide solutions for the global identification and tracking of mobiles and personnel [1, 2, 3].

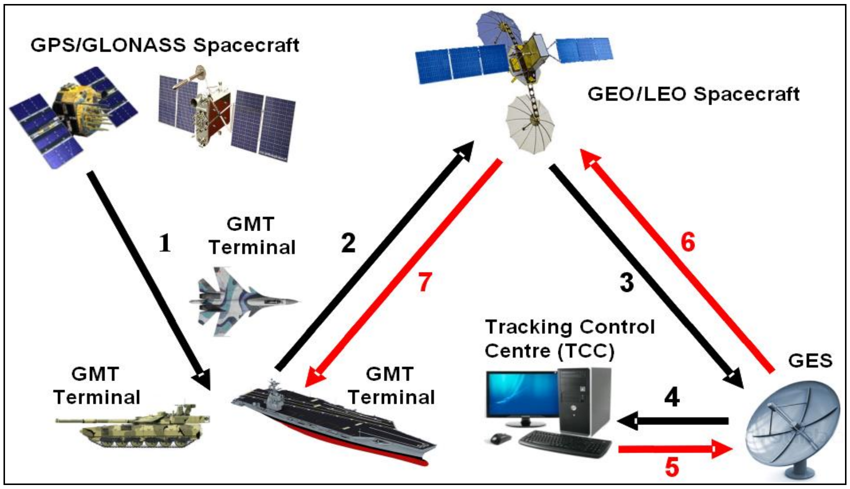

Fig. 1: Configuration of GMT via GNSS and Spacecraft – Courtesy of Manual: by Ilcev [2]

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The GMT 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 [Fig. 1]**.** All lines highlighted in red are indicating GMT receiving process, namely, the receiver in GMT terminal is receiving PVT data from TCC useful for collision avoidance and showing it on receiver display. Here will be introduced only two types of GMT that can be used for tracking of military mobile assets and personnel.

2. Axonn 4000 Mini Tracker – The Axonn SAT terminal is proposed as possible solution for GMT applications using Globalstar Big Low Earth Orbit (LEO) global satellite network, which diagram with electronic components is presented in [Fig. 2 (A)]**.** This equipment contains low power GPS engine, sensor and configuration interface, satellite modem, host processor, GPS receiver (Rx), Globalstar satellite transmitter (Tx), which is using Globalstar network powered by hybrid lithium thionyl chloride batteries. This SAT unit provides simplex (one-way) satellite transmission of PTV data, but it has not possibility to receive back PTV data from TCC of other mobiles for collision avoidance or any other information to onboard operator. For that reason can be used duplex (two-way) SAT via GEO Inmarsat or Big LEO Iridium satellite networks.

2. Quake 4000 Mini Tracker – The Q4000 tracker is a Short Burst Data (SBD) satellite GPS receiver and satellite transceiver designed by the US company Quake for use as a basic unit via different satellite constellations, illustrated in[Fig.2 (B)]**.** Though the Q4000 is small enough to fit in the hand, but on other hand it is a rugged industrial grade modem operational over multiple satellite constellations, such as Inmarsat, Iridium, Globalstar and Orbcomm, and some models can be integrated with GSM terrestrial networks all-in-one remote asset tracking solution. This very tiny, 99.3x64x15.9 mm and 170 grams, two-way transceiver is perfect for use for all mobiles and personal, including aircraft and for fixed remote asset tracking and M2M monitoring solutions.
Except dedicated military systems, Inmarsat and Iridium SAT transponders are the best solutions for GMT of military assets and personnel, because are providing full global coverage and the following service:

1. The SAT terminals can be installed in each mobile using onboard power supply or in emergency may use own batteries, and can be also employed for tracking of military personnel.

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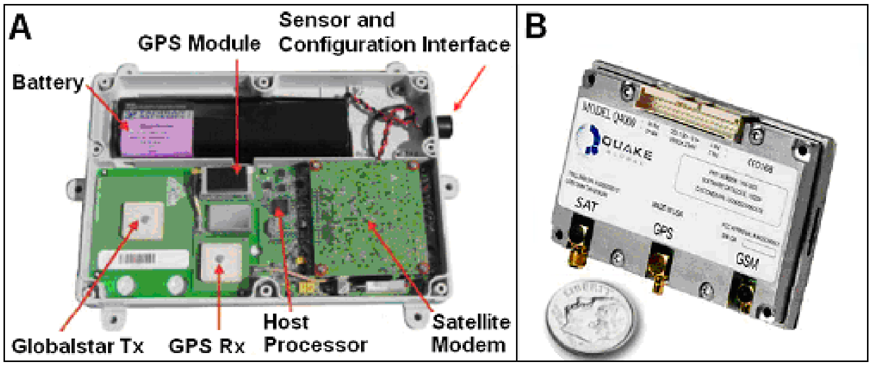

Fig. 2: GPS/Satellite Trackers – Courtesy of Brochure: by Globalstar/Iridium [3]

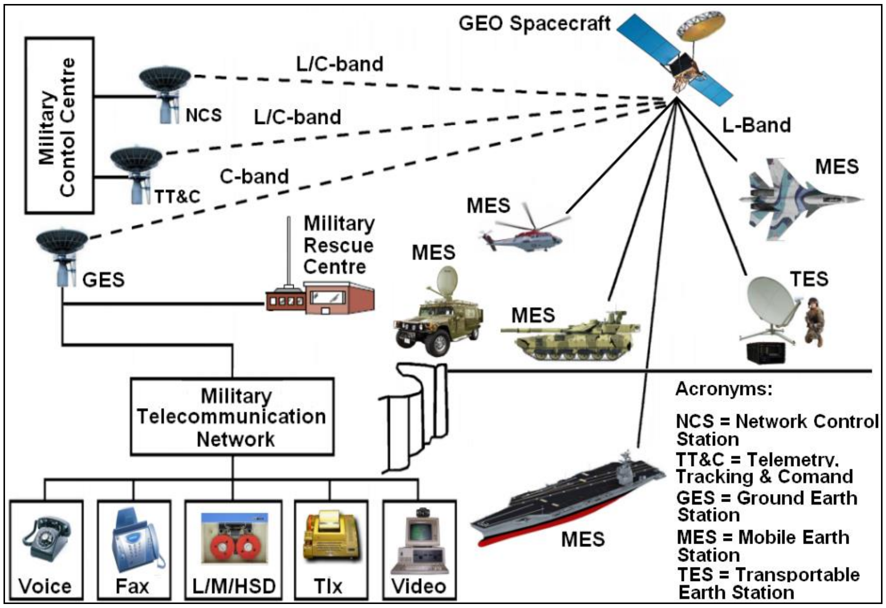

Fig. 3: Military Satellite Communication Network – Courtesy of Manual: by Ilcev [4]

2. The SAT 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.

It is important to state that Globalstar is also providing duplex SAT satellite transmissions. The fourth mobile operator for SAT solutions is Little LEO Orbcomm, which network is providing both simplex and duplex service [2, 3, 4, 5].

SATELLITE COMMUNICATION SYSTEM (SCS)

Most current communications between mobiles and traffic controllers are conducted via radio VHF, UHF and HF RF-bands, which in some busy portions of the world is reaching its limit. Thus, the RF-bands are congested and additional frequencies are not available.

Thus, to improve the communication and traffic control facilities of all mobiles more than 30 years ago was implemented civilian Mobile Satellite Communication (MSC) system, which takes less time and can handle more information than radio system alone. Before that, the World's first military maritime MSC system was

unveiled in 1976 by the US Comsat General with only three satellites and networks in the Atlantic, Pacific and Indian oceans. In [Fig. 3] is illustrated modern military mobile satellite communication network for navy, ground and air forces using L/C-band. However, military satellite communications can use UHF, S, X, Ka and Ka-band between Mobile earth Stations (MES) and Military Control Centre. The MSC systems are not designed only to provide more cost effective, reliable, redundant and fastest communication links between mobiles and traffic controllers, but also to integrate GNSS data for implementing new service for enhanced navigation and surveillance solutions.
The convergence of MSC and Internet technique has opened many opportunities to deliver new multimedia service over hybrid satellite systems to MES terminals. With the need for increased bandwidth capability, the deployed numbers and sophistication facilities of GEO and Non-GEO communication satellites are every year increasing dramatically.

The size of the Earth shape requires multiple satellites to be placed in orbit in a constellation to cover uncovered areas of interest typically need a minimum of 3 to 4 satellites to provide adequate communications coverage. Secondly, for existing users, upgrading satellites is not feasible, which means new capabilities are required and new satellites means new launches. Thirdly, more developed countries are recognizing the huge advantages of Military Satellite Communication (MILSATCOM) capabilities and are looking to implement or expand their networks.
The commercial and military SCS networks are very important for the following reasons:
1. To provide communication links between mobiles and ground infrastructures and between mobiles alone;
2. To transfer augmented and not-augmented navigation PVT data from mobiles to traffic control centres via GEO satellite communication transponder; and
2. To transfer augmented surveillance PVT data from traffic control centres to all mobiles via GEO satellite GNSS transponder, which will be used for enhanced navigation data and collision avoidance.

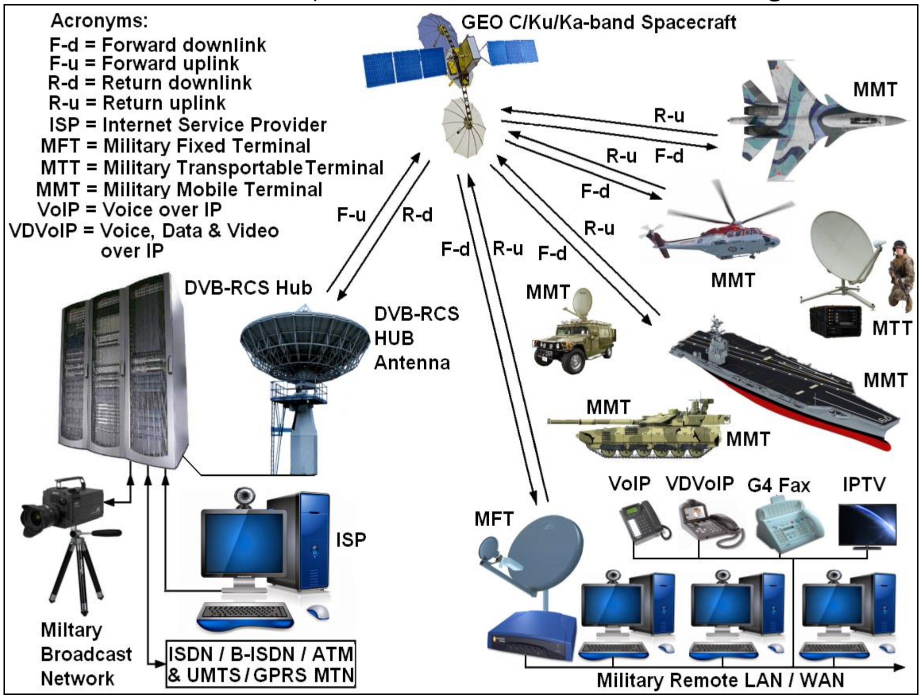

Fig. 4: Military DVB-RCS Communication Network – Courtesy of Manual: by Ilcev. [4]

New mobile DVB-RCS system illustrated in [Fig.4] is derived from current fixed DVB-RCS sometimes in 2000/01. The DVB-RCS mobile network includes an HUB as a GES (Gateway) with C, Ku or Ka-band antenna to interface the Terrestrial Telecommunication Network (TTN) or DVB-T cell via corresponding satellite connections at C, Ku or Ka-band GEO to the MES and TES terminals or Remotes (DVB-S) cells for the following services: Navy, Ground Vehicles and Aircraft. This new infrastructure is the best solution for establishment a network for connection of all military communications at sea, on the ground and in the air.

New mobile DVB-RCS networks are very suitable for mobile-to-ground and ground-to-mobile solutions. Both systems are providing sophisticated Voice, Data and Video over IP (VDVoIP) for corporate, private, military, traffic control and management, meteorological and navigation information, training and medical service, technical and maintenance data, Search and Rescue (SAR), Satellite Augmentation Data (SAD) of GNSS signals for surveillance and Inter Mobile Links (IML). 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 real global coverage will be necessary to implement hybrid GEO and LEO, MEO or other satellite constellations or to use existing LEO satellite constellations of Globalstar, Iridium and Orbcomm networks [2, 4, 6, 7].

SATELLITE NAVIGATION SYSTEM (SNS)

As stated before, the US has its own Navstar GPS and Russians have GLONASS as parts of GNSS1 system. Europeans will eventually have Galileo and China is implementing its Beidou system, both as part of new GNSS2 system. Thus, a future development in US GPS capability is the United States Air Force (USAF) GPS-2F constellation of 12 satellites that will provide around-the-clock, ultra precise navigation and timing services for military and civilian users.
New generation of GPS satellite provides better accuracy through advanced atomic clocks, a more jam-resistant military signal and a longer design life than earlier satellites. The GPS 2F will also increase precision navigation and timing to combat forces, increase the signal power, precision and capacity of the system and form the core of the GPS constellation for years to come.

The GPS and GLONASS space segment consists of 24 GNSS1 spacecraft each including ground segment, which contains Ground Control Station (GCS) and Users Segment, shown in [Fig.5]. The GNSS1 network is providing service for ships, land vehicles and aircraft, which are receiving PVT signals by onboard installed mobile GPS or GLONASS receivers. The GNSS1 systems and accuracy are upgraded by VHF or Satellite augmentation of GPS or GLONASS solutions. In such a way, there is Differential GPS (DGPS) developed by the US Coast Guard, which modern nomination is Local VHF Augmentation System (LVAS).

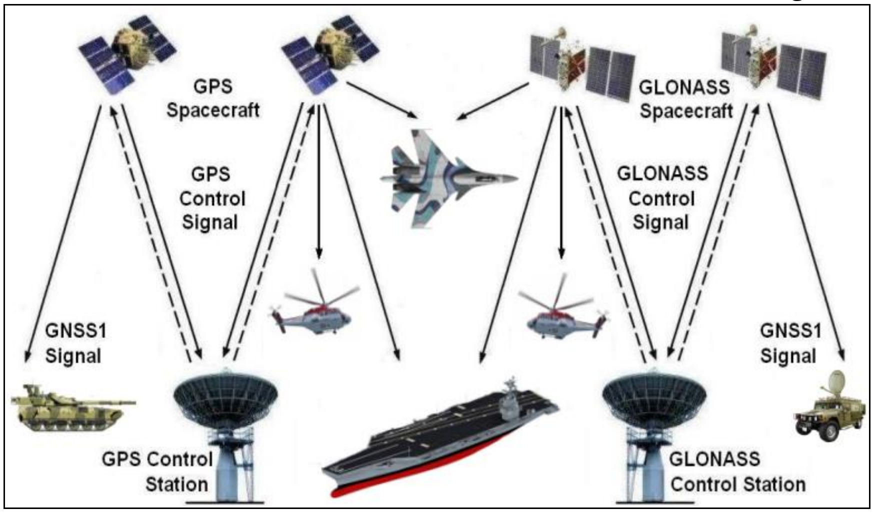

Fig. 5: Military GNSS Network – Courtesy of Manual: by Ilcev [2]

On the other hand, there is modern Regional Satellite Augmentation System (RSAS) or Satellite-Based Augmentation System (SBAS), WAAS developed by the USA, EGNOS by Europe, Chinese SNAS, Russian SCDN and Indian GAGAN. The new project African Satellite Augmentation System (ASAS) is proposed by Research Group in Space Science at Durban University of Technology (DUT) [2, 4, 7, 8].

SATELLITE SURVEILLANCE SYSTEM (SSS)

The new SSS network will integrate SCS and SNS solutions with Wide Area Multilateration (WAM). The traditional surveillance radar with Automatic Dependent Surveillance (ADS) facilities can be also included in this integration or can be even used as back up. The SSS solutions are set up for the traffic control systems to know where the mobile is and where it is heading. The current surveillance is achieved through the use of long-range and terminal radars, which sometimes cannot work properly caused by very bed weather condition or other natural influence, like dust coming from volcanoes and so on.

The SSS system for satellite SADS-B is working in the way that all mobiles can derive their GNSS data from not-augmented or augmented GNSS receiver and send PVT surveillance data via satellite GEO GNSS satellite

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transponder to the traffic control system for computer processing and displaying of surveillance information to the ground controllers on the like radar screen, which diagram is shown in [Fig. 6].

Many research centres worried are working with the aeronautical agencies, institutions and other stakeholders on design of more sophisticated Satellite Automatic Dependent Surveillance - Broadcast (SADS-B) capability that periodically broadcasts an aircraft's position and supporting information, heading, altitude including aircraft identification (ID or name) and short-term intent, more accurately and reliable than the current radar capabilities.

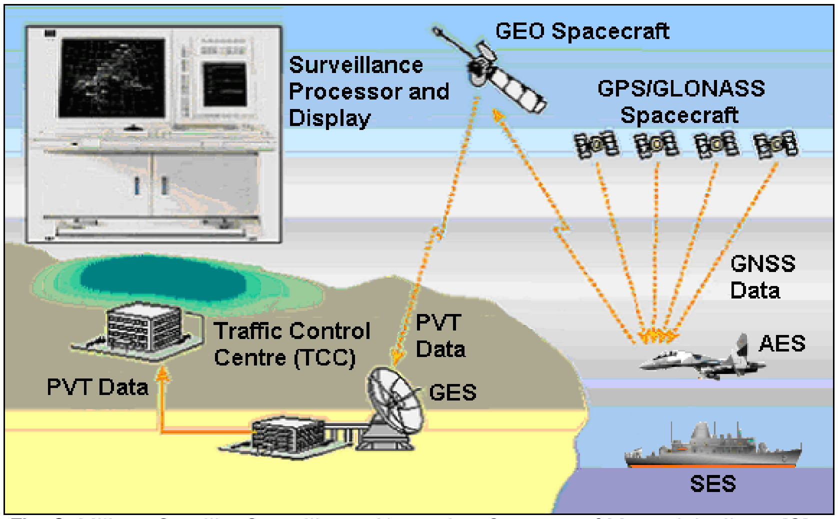
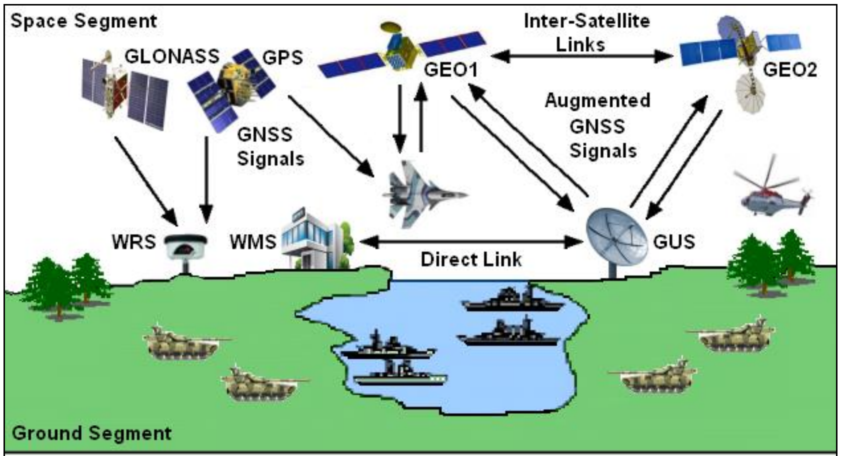


Fig. 6: Military Satellite Surveillance Network – Courtesy of Manual: by Ilcev .[2]



Legend:
WRS = Wide Reference Station
WMS = Wide Monitoring Station
GUS = GEO Upling Subsystem or GES
GNSS = Global Navigation Satellite System
GEO = Geostationary Earth Orbit
GES = Ground Earth Station

Fig. 7: Military Geospatial Augmentation System – Courtesy of Manual: by Ilcev [4]

In this instance, SADS-B system can be used to increase a pilot's onboard situational awareness, particularly important in not familiar places like where aviation is vital with minimum ground infrastructure, because of the extreme harsh conditions and weather changes quickly and in unpredictable fashions. In the similar way satellite ADS is going to be implemented for maritime and land applications and for all military applications as well.

The RSAS network will be the core of the future development of military GNSS augmentation system for navy, ground and air forces via multipurpose GEO spacecraft for both mobiles to support the TCC facilities and meteorological mission for weather observations, which Space and Ground Segments are presented in [Fig. 7]. The Military Geospatial Augmentation System (MGAS) is working in the same way as RSAS. Namely, WRS and mobiles are getting GNSS signals, while WRS is determining difference of the GNSS signal and WMS provides its augmentation and sending via GUS to mobiles at GNSS frequency bands. The main part of MGAS is that TCC is receiving GNSS augmentation positions from all mobiles, processing positions and show onto like radar display. Then TCC is sending via satellite to certain aircraft position data of all aircraft in its vicinity for collision avoidance and awareness [2, 3, 8, 9].

CONCLUSION

The development of modern civilian and military CNS depends on the design, deployment and improvement of contemporary satellite systems, networks and ground infrastructures. While early satellite communications systems had a life span of days or weeks, today's systems have design lives extending to 20 years and beyond, with a typical mean mission duration of 15 years. Thus, this is necessary to justify system effort and cost of development and operations. Another change over time is that satellite communication and navigation terminals for fixed and mobile applications have become smaller and more numerous. These terminals have evolved from a few large fixed terminals to thousands of small mobile terminals. On the other hand, satellites have also become bigger, from early 50-kilograms satellites to modern 10-ton structures with solar panels spanning several tenths of meters. Finally, satellites have become greatly capable, having ranged over the years from simple state machines to computers with millions of lines of code.

CONFLICT OF INTEREST

There is no conflict of interest.

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None

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