WULFENIA JOURNAL KLAGENFURT, AUSTRIA ISSN:1561-882X

Vol 30, No. 9;Sep 2023

Contemporary Architecture of Satellite Global Aircraft Tracking (GAT) Network and Equipment

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Abstract: This paper describes Global Aircraft Tracking (GAT) system proposed in 2014 to the International Civil Aviation Organization (ICAO) by author of this article as major solution in the function of Global Aeronautical Distress and Safety System (GADSS) for reliable global tracking of missing and hijacking aircraft in any real time and space. The GAT device as an integration of GPS/GNSS Receiver and Satellite Transceiver is programmed to send Position, Velocity and Time (PVT) and other data via Geostationary Earth Orbit (GEO) Inmarsat or Leo Earth Orbit (LEO) Iridium satellites to the Ground Earth Stations (GES), Terrestrial Telecommunication Network (TTN) and ground Tracking Control Station (TCS). The ground TCS is the brain of the GAT network, which is receiving, processing and memorizing all PVT and other data sent by an aircraft. The TCS cites will have like radar display to indicate position of all aircraft in certain Flight Information Region (FIR). In case of any aircraft incident TCS will provide PVT data about certain aircraft in distress to be found by the Search and Rescue (SAR) forces in any real time and space of about 2 - 3 days and in range of few hundred mails. The GAT unit has to be fully independent of the pilot actions, power supply and other navigation and communication equipment in the cockpit. The GAT message has to include the airborne equipment identifier (aircraft ID), PVT data with altitude and the date/time of the transmission.

Key Words: GAT, PVT**,** GEO, LEO, TTN, TCS, SAR, GPS, GLONASS, CNS, Inmarsat, Iridium

1. Introduction

After the Soviet Union launched the the world's first artificial satellite, Sputnik 1, satellite systems became the method of choice for communication positioning information with the developments of first Global Navigation Satellite Systems (GNSS). Thus, the US military system Transit began with development in 1960 and the Soviet Union military system Cicada was established in 1974.

After early experimentation with the doomed Transit and Cicada systems, remember having to wait hours for the next satellite to appear overhead, new GNSS of Global Positioning System (GPS) and Global Navigation Satellite System (GLONASS) were created at the end of 20th Century to offer highly accurate global satellite positioning system, almost anytime and anywhere in the world, which space, users and ground segments are illustrated in **Figure 1.**

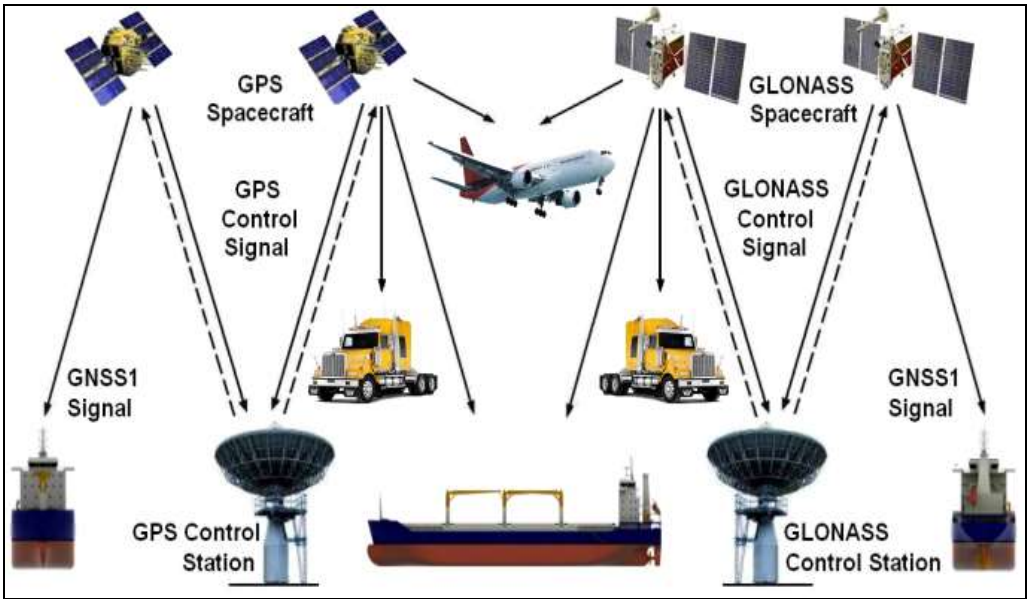

Figure 1. Military GNSS-1 Network – Source: **Ilcev [1]**

The Transit 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. The GPS service could not have the market to itself, the former Soviet Union (Russia) developed a similar system called GLONASS in 1988 and ceased the previous Cicada system. The Transit and Cicada systems, provided intermittent two-dimensional (latitude and longitude) position fixes every 90 minutes on average and were the best suited to marine navigation, The GPS or GLONASS GNSS-1 satellite networks provide continuous position and speed in all three dimensions (latitude, longitude, and altitude), equally effective for navigation and tracking at sea, on land and in the air.
Meanwhile, China has begun development of its own GNSS-2 navigation system known as BeiDou or Compass, which is regionally 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, while another GNSS-2 satellite network still under development is Europe's Galileo
The US GPS and Russian GLONASS GNSS-1 satellite positioning networks, as all-weather spacecraft, full jam resistant and continuous operation navigation system, utilize precise range measurements of Position, Velocity and Time (PVT), call sign of aircraft (also altitude) or other mobiles and ID data anywhere in the world. This GNSS system provides military and commercial maritime, land and aeronautical users via Medium Earth Orbits (MEO) satellites with highly accurate worldwide three-dimensional, common-grid, position and location data, velocity and precise timing to accuracies that have not previously been easily achievable.
The GNSS service is based on triangulation from known points similar to the technique of "resection" used with a map and compass that it is done with radio signals transmitted by satellites. The GNSS receiver must determine when the signal is sent and the time it is received. Nothing but aircraft and other mobile GNSS receivers are required to use the system for free, which does not emit any signals and thus cannot be detected electronically **[1, 2, 3].**

2. Global Satellite Asset Tracking (SAT) Systems

The GNSS network is represented by fundamental solutions for PVT, identification and other data of the US GPS and Russian GLONASS military satellite systems, which suffer from particular weaknesses that render them unsuitable for use in modern transportation state affairs as sole solutions for positioning, tracking and detecting of aircraft and other mobile assets. A major goal of the near-universal use of GNSS systems is their integration with aeronautical and other Mobile Satellite Communication (MSC) systems, which very small GNSS/Satellite units will be able to improve positioning, detecting and tracking facilities of aircraft and other mobile, such as ships and ground vehicles, which global Satellite Asset Tracking (SAT) network is shown in **Figure 2.**

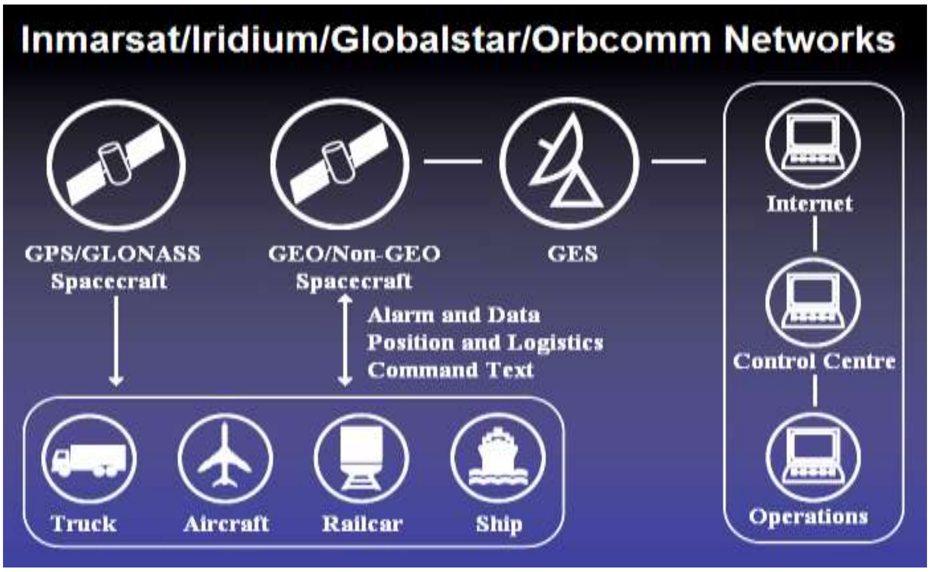

Figure 2. Configuration of SAT System – Source: Ilcev **[4]**

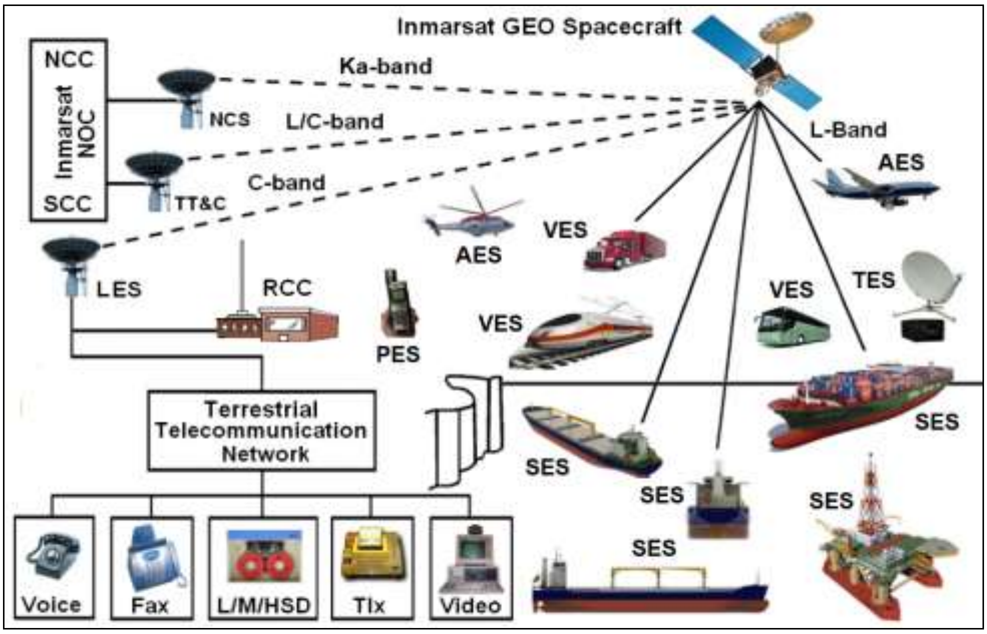

Figure 3. Inmarsat Maritime and other Mobile Satellite Network – Source: Ilcev **[1]**

Global Navigation Satellite Systems (GNSS) are represented by two fundamental current solutions for Position, Velocity and Time (PVT) data 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.

These two GNSS GPS networks belong to the first generation known as GNSS-1, which are in global use for military purposes, the US using the GPS network and Russia using the GLONASS network. Two new systems of the second generation of GNSS networks, such as the Chinese BeiDou or Compas and the European Galileo, are still in the project phase and are referred to as GNSS-2 networks.

Thus, a major goal of the near-universal use of GNSS systems is their integration with the GEO or LEO satellite communication systems, which very small units will be able to improve tracking and positioning facilities of mobile persons and mobile assets, such as oceangoing ships, ground vehicles (road and rail) and aircraft. As a result of these efforts, new tracking technologies have been projected, developed and proposed to utilize Communication, Navigation and Surveillance (CNS) solutions and services for enhanced traffic control and management of mobile persons and transport assets.

In this way, during the tracking [proces of persons or mobile asset systems, as in particular case of aircraft, the received tracking data via GPS or GLONASS (GNSS) receivers (Rk) of personnel or mobile assets can be sent via Geostationary Earth Orbit (GEO) or non- GEO spacecraft. All mobile devices and personnel require much more sophistication from the new Satellite Asset Tracking (SAT) than stand-alone GPS or GLONAS positioning systems.

In light of the International Civil Aviation Organization (ICAO) recommendation that aviation operators onboard aircraft are now required to know the location of each of their aircraft at least once every 15 minutes, this article is about the GADSS network, developed by the author of this paper in 1999, and the framework for live aircraft tracking, a subject that has become increasingly important in recent years. It is very important to be in tune with the needs, because it is always important to stay close to the necessity when finding solutions, and in the future there will be new solutions for the GADSS network and updates to its current status.

Therefore, the Global Mobile Tracking (GMT) system as the basis of the emerging GAT network and system is proposed as an integrated configuration in one SAT device containing small GPS or GLONASS receivers and mini GEO and Non-GEO satellite transceivers for sending computed PVT data through an adequate integrated satellite antenna **[4, 5, 6].**

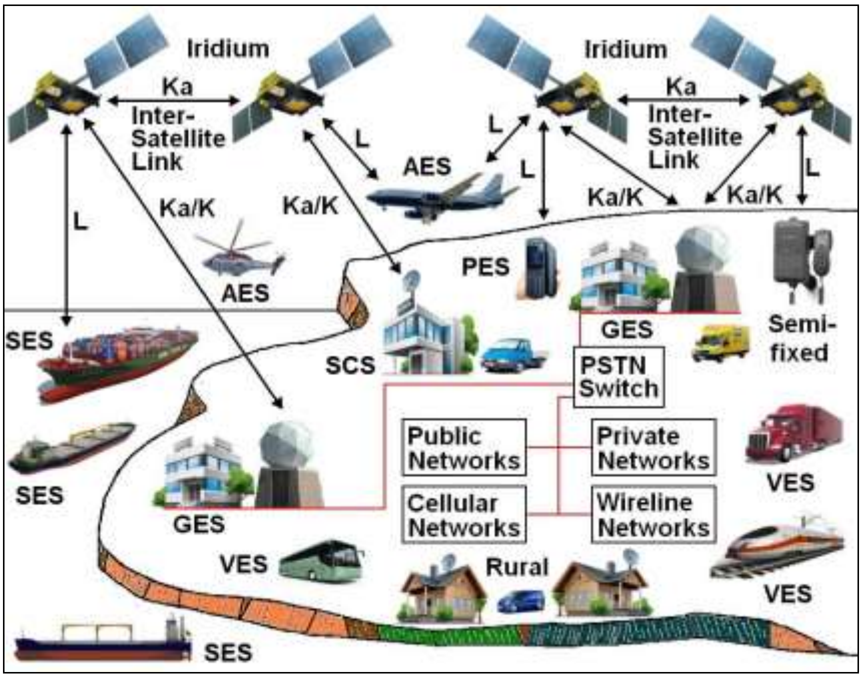

Figure 4. Iridium MSC Network – Source: Ilcev **[4]**

3. Global MSC Networks

Modern GMT and GAT systems can use GEO Inmarsat and Non-GEO or Big Low Earth Orbit (LEO) satellite constellations, such as Iridium and Globalstar networks**.**

3.1. Inmarsat MSC Network

Inmarsat was established as not-for-profit company in 1979 as the International Maritime Satellite Organization (Inmarsat) set up at the behest of the International Maritime Organization (IMO) and United Nations (UN), with its headquarter office in London. Initially was developed for the purpose of establishing a maritime satellite communications network for commercial, corporate and safety applications. It began trading in 1982 via GEO satellite constellation for oceangoing ships and sea rigs providing coverage up to 80^0 North and 80^0 South. Afterwards Inmarsat started with development service for land (road and rail), personal (handheld), transportable and aeronautical applications. The current Inmarsat-4 is providing service at the following RF bands: 1.6/1.5 GHz of L-band (Service Link) and at 6.4/3.6 GHz of C-band (Feeder Link) .
In 2016, the fourth generation of Inmarsat-4 satellite constellation is upgraded with fifth generation of Inmarsat-5 satellite constellation, which maritime and other MSC networks operate via L, C and Ka-band, which aeronautical and other mobile satellite network is shown in **Figure 3.** The current Inmarsat network provides commercial mobile service via Land Earth Stations (LES) and Inmarsat satellites for Ship Earth Stations (SES), Vehicle Earth Stations (VES), Aeronautical Earth Station (AES), Transportable Earth Station (TES), Personal Earth Station (PES) terminals **[4, 5, 7].**

3.2. Iridium MSC Network

The concept for the Iridium MSC system was proposed by Motorola engineers in late 1989 and after a phase of research, the Iridium LLC satellite system was founded in 1991, with an investment of about $7 billion. Maintaining its leadership, Iridium LLC became operational MSC system on 1st November 1998. After a period of bankruptcy, the Iridium service was relaunched on 28 March 2001, which MSC network is shown **in Figure 4.**

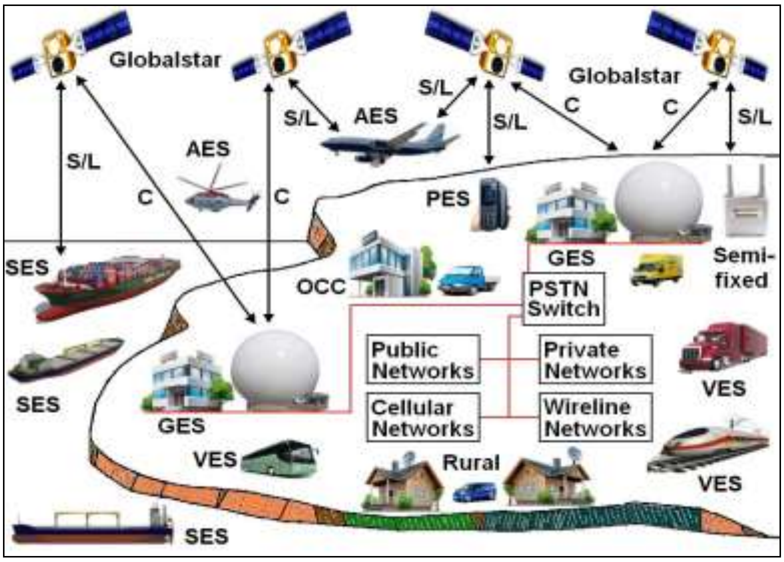

Figure 5. Globalstar MSC Network – Source: Ilcev **[4]**

The Iridium Big LEO satellites are situated in a near-polar orbit at an altitude of 780 km. They circle the Earth once every 100 minutes traveling at a rate of about 26,856 km/h. Each satellite is cross-linked via intersatellite links to four other satellites, with two satellites in the same orbital plane and two in the adjacent plane.

The Iridium satellite constellation consists in 66 operational satellites and 14 spares once orbiting in the satellite constellation of six polar planes. The Iridium system provides true global coverage and roaming globally over 48 spot overlapping beams, and the diameter of each spot is about 600 km. Iridium as a true global operator provides voice and data service including SAT for ships and all mobile applications via uplink/downlink at 1621.35-1626.5 MHz, feeder links at 29.129.3 GHz of Ka-band (uplink) and at: 19.4-19.6 GHz of K-band (downlink) and cross-link or intersatellite link at 23.1823.38 GHz of Ka-band. The current Iridium network provides aeronautical and other mobile service via Ground Earth Stations (GES) and Iridium LEO satellites connecting SES, VES, AES, PES as handhelds and semi-fixed terminals with Public Switched Telephone Network (PSTN) ground network. The PSTN switch system is connected to a Public Network, a Private Network, a Cellular Network, and a terrestrial Wireline Network.

The Iridium network is managed by the System Control Segment (SCS), which consists of three main components: four Telemetry Tracking and Control sites, the Operational Support Network, and the Satellite Network Operation Centre. The SCS network commands and controls all Iridium satellites. It provides global operational support and control services for the satellite constellation, and delivers satellite tracking data to the Gateways or Ground Earth Stations (GES) **[4, 5, 8].**

3.3. Globalstar MSC Network

The American company Loral Space & Communications, together with Qualcomm Incorporation, developed the concept of the Globalstar system at a similar time as Iridium. Globalstar received a license to operate from the USA Federal Communications Commission (FCC) in November 1996. In May 1998, the first launch of four Globalstar satellites took place, and therefore its space segment consists of 48 Big LEO spacecraft.

In fact, Globalstar does not have an inter-satellite connection and thus needs a large number of GES terminals around the world, the spacee, ground and user network of which is shown in **Figure 5.** The current Globalstar network controlled by the Operations Control Centre (OCC) provides maritime and other mobile service via GES and LEO satellites connecting SES, VES, AES, PES as handhelds and semi-fixed terminals with PSTN and other ground networks. The Globalstar satellite operator is providing service for users via satellite at 1.610-1.621 GHz (uplink) and at 2.483-2.500 GHz (downlink) and from satellite to GES at 5.091-7.055 GHz (feeder link) **[4, 5, 9].**

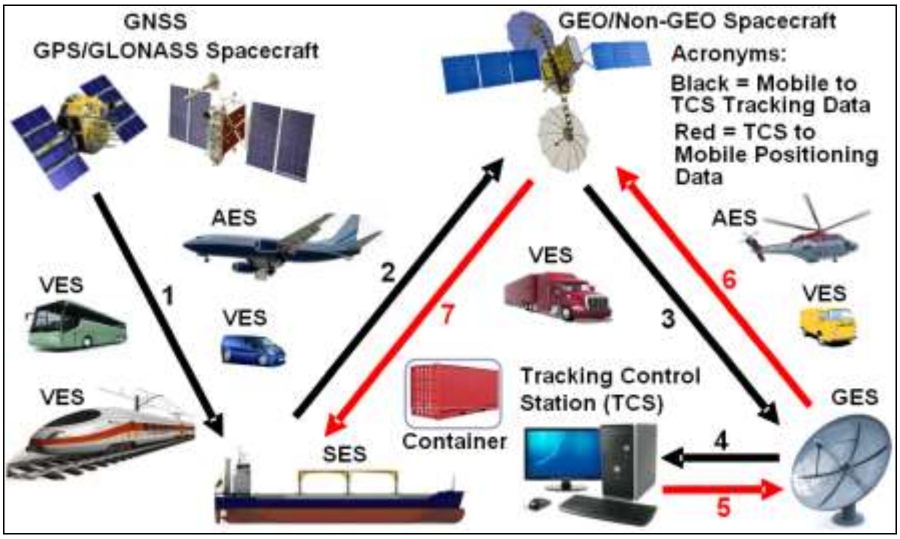

Figure 6. Package of GMT Satellite Network – Source: Ilcev **[1]**

4. Satellite Global Mobile Tracking (GMT) Network

The mobile GMT is system employing the GNSS subsystem of US GPS and Russian GLONASS to provide free of charge Position (PTV) data to different mobile civilian or military assets. This PTV data can receive ships, land vehicles and aircrafts via onboard GPS/GLONASS Rx integrated with satellite transceiver subsystem. Then the Satellite Transceiver (Rx/Tx) is providing frequently transmissions of PTV data via GEO or Non-GEO spacecraft through Ground Earth Station (GES) and Internet to the Control and Operations Centres.
In **Figure 6** is depicted space, user and ground segments of GMT network. The space segment is formed by GNSS and GEO/Non-GEO satellite constellations. The GNSS subsystem is formed by the GPS or GLONASS exsisiting GNSS-1 networks, which can be also integrated with GNSS-2 network, such as the Chinese BeiDou and European Galileo. All Ships Earth Stations (SES), Ships Containers, Vehicle Erath Station (VES) and Aircraft Earth Stations as Users Segment, are receiving GNSS-1 signals by onboard GPS or GLONASS Rx (1). Onboard satellites transceiver is sending PVT and other data (2) via GEO or Non-GEO satellites (3) to the GES terminals. Uisng TTN or Intenrt GES is forwrding PVT message (4) to the Tracking Control Stations (TCS).
This communication space segment can be composed by GEO Inmarsat, LEO Iridium, Globalstar or Orbcomm and Medium Earth Orbit (MEO) O3b mobile satellite communication networks. The ground segment can be composed by TCS sites with antenna systems, Control and Operations Centres. The TCS sites can be connected to Ship Traffic Control (STC), Container Control, Vehicle Traffic Control (VTC) or Air Traffic Control (ATC) and Air Traffic Management (ATM). With regards to the ships and aircraft in distress, TCS sites have to be connected to SAR stations.
In **Figure 6** is also presented opposite directions of messages for enhanced collision avoidance of ships and aircraft. Namely, in the processor of TCS sites are memorized the PVT data of all ships or aircraft in certain area. The PVT data reporting can be sent by TCS sites (5) via GES terminal to the GEO or Non-GEO satellites (6) to the users (7). Besides, ship captain or aircraft pilot can also provide polling of PVT data from TCS processor. In addition, shipping companies can get info about position of their containers and road or rail vehicles can be better managed with received PVT data of all participants in the traffic **[4, 10, 11, 12].**

5. Autonomous Global Aircraft Tracking (GAT) Satellite Network

Due to many incidents in the past time without possible search and tracking of wrecks and grounded aircraft, the author of this paper proposes new solutions for tracking and determining aircraft through satellite CNS systems known as Autonomous Global Aircraft Tracking (GAT) as the main integration segment of GADSS network.

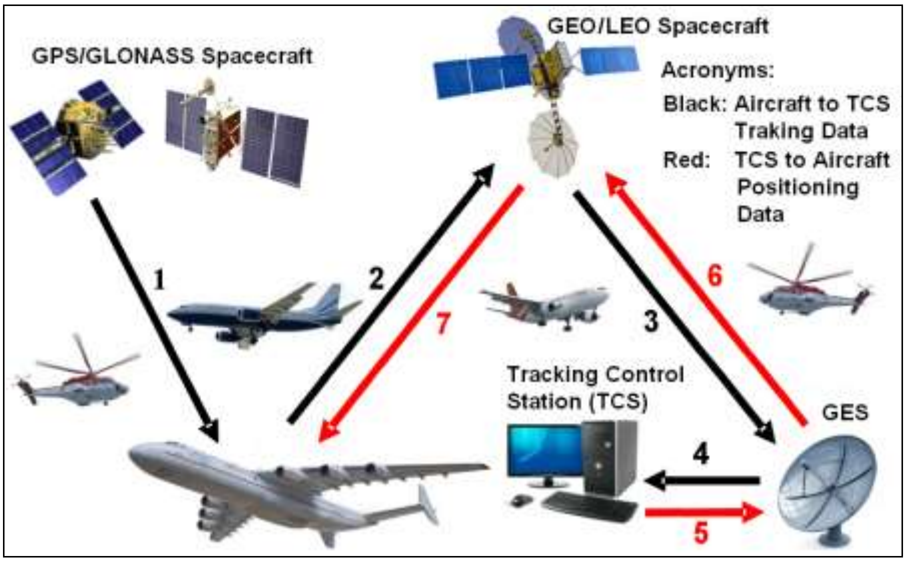

Figure 7. Package of GAT Network – Source: Ilcev **[4]**

For instance, if GAT equipment (GPS receiver and Satellite transceiver) was fixed in Air France aircraft crashed in 2009 over Atlantic, SAR forces should find the wreck in few days and in area of maximum 100 miles, instead in 2 years and in area about 2,000 - 3,000 miles. In such a way, the GAT as unique system will provide solutions for the global identification and tracking of aircraft in any real time and space.

The GAT system works in the same way as the GMT netwrk, namely their space and ground segments are the same, while the users segment consisted only by airplanes and helicopters. The scenario of GAT system is functioning by employing the GNSS subsystem of US GPS and Russian GLONASS to provide free of charge Position (PTV) data to different users at sea, on the ground and in the air. This PTV data can receive ships, land vehicles and aircrafts via onboard GPS/GLONASS Receivers (Rx) and used in navigation purpose, shown in **Figure 7.**

Thus, if GPS/GLONASS Rx is integrated with Satellite Transceiver (RC/Tx) in an integrated unit with both antennas known as SAT, it will be possible to provide frequently transmission of PTV data via GEO or LEO spacecraft through GES and Internet to the TCS. Therefore, same as GMT network, GAT system is providing uplink of aircraft to TCS tracking data (black lines) and downlink TCS to aircraft positioning data (red lines).

The PDC facilities should store all incoming GAT information received from aircraft and distributed this data to different users according to the GAT Data Distribution Plan (DDP). Otherwise, the PVT data users can be airways companies, ATC and ATM stations, regional SAR forces and any aircraft flying in area of certain TCS for purpose of enhanced collision avoidance. Therefore, the GAT unit is presenting digital transmission system that provides automatically messaging or reporting of PTV data and polling data from TCS as well.

Furthermore, the GAT satellite unit onboard aircraft will be able to receive PVT data of all aircraft flying in certain area and be used for enhanced collision avoidance. The GAT receiver unit can be connected to the special display with keyboard in cockpit showing PTV data of all adjacent airplanes during flight.

As stated earlier, all operations of GAT transceiver integrated with GPS receiver are automatic, so cannot be controlled by pilot or any operator at all, but it can be connected to laptop or palmtop, so pilot will be able to send own PTV report to TCS terminals and to receive or poll data in return. This solution is also very important tool during extremely bad weather conditions, thunderstorms and very poor visibility.

The TCS is de facto brain of the GAT system, which is receiving PVT and other data sent by GAT units from GES via Inmarsat or Iridium satellites, and then its Processing Data Centre (PDC) is processing and memorizing this data. The TCS units have to be distributed in each FIR or smaller flight arrears and to be connected to nearest ATC/ATM.

The TCS terminal will display all processed GAT data on like radar display showing position of all aircraft in certain flight area. In case of any incident, TCS terminal will send all necessary particulars about certain aircraft in distress or emergency to the SAR forces, which will find it in few days and in radius of several tenths of nautical miles. Therefore, by implementing GAT devices and service, in the future will be not possible to have situation similar as Air France and Malaysian aircraft anymore.
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6. Autonomous Satellite Global Aircraft Tracking (GAT) Project

The need to develop an adequate GAT system as a major part of GADSS network is a very important issue because presently there is not some applicable and reliable avionic system that can perform tracking and detection of missing or hijacked aircraft. The currrent ACARS and new developed ADS-B are not able at to carry out this serious task and functions. The innovative GAT is better than ACARS and ADS-B because is discrete, independent and has own power supply. In fact, the GAT unit has to be installed onboard aircraft secretly, i.e. discrete, and in such a way to protect accidental or forced shutdown of the device as a whole.
The GAT unit is always ON and programmed to receive GPS or GLONASS data and to transmit Short Burst Data (SBD) message via satellite and GES to the PDC unit of TCS. In any emergency or distress situation, TCS will send PVT data of aircraft to SAR forces, which than will participate in SAR operations.

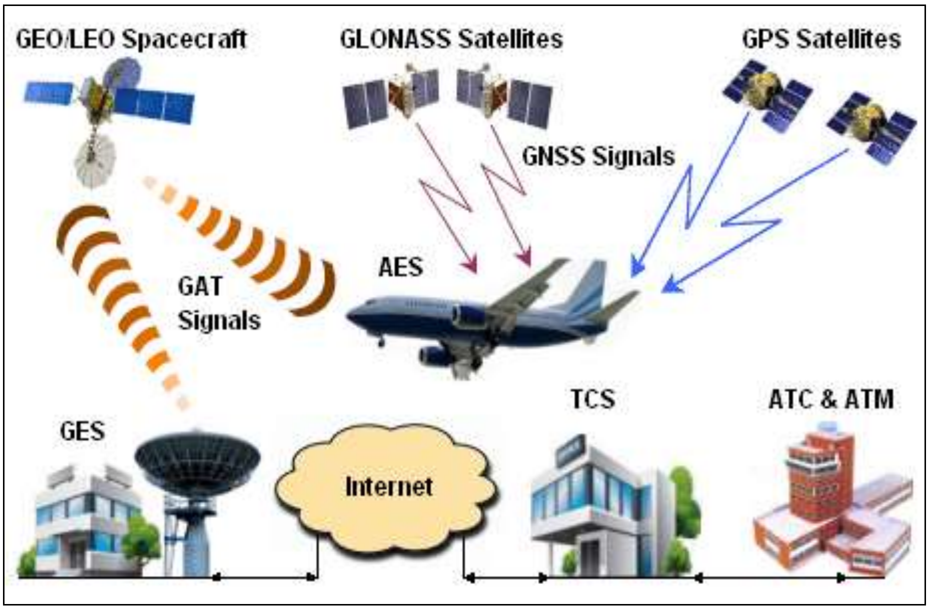

Figure 8. Aeronautical GAT System for GADSS Network – Source: Ilcev **[12]**

Right now, there is a similar system developed by the International Maritime Organization (IMO). In fact, the Long Range Identification and Tracking (LRIT) as new compulsory system onboard ships established by IMO on 19 May 2006, as good solution for global ships tracking worldwide. However, before that, author of this book in 2000 proposed to IMO his Global Ship Tracking (GST) as better detecting solution and with more convenient designation than LRIT. Namely, the additional nomination problem for LRIT is that in satellite meteorology already existed synonym Low Rate Information Transmission (LRIT).

As stated at the beginning of this chapter, earlier in 2000 author of this book proposed to ICAO for the first time an unique project known as Global Aircraft Tracking (GAT). This project is the best and only solution for aircraft tracking in real time and space in the function of GADSS network, which functional diagram is illustrated in **Figure 8.**

In the same way as maritime GST network, an aircraft in flight is receiving GNSS Signals from GPS or GLONASS spacecraft by its GAT equipment and then is sending PVT and other data as GAT Signals to TCS via GES and TTN/Internet. The TSC unit is connected to ATC and ATM terminals for eventual coordination in SAR, tracking and collision avoidance. Thus, the PVT data of GAT signals as messages include the airborne equipment identifier, altitude, positioning PVT data of latitude and longitude including the date and time of the transmission. In addition, the GAT system has to specify that flag States should ensure a minimum of 30 to 60 GAT messages daily per hour are sent, though the frequency of messages can be changed to a minimum of once every 5 minutes through an user request.

The GAT system has to develop three segments: Space, Users and Ground, and to provide complete GAT Network. Thus, GAT messages can be sent via Inmarsat and Iridium (if aircraft is flying over the North Pole) communications satellite. The Ground infrastructure components are GES terminals with antenna system, Internet or TTN and TCS with PDC, while users are all type of commercial aircraft and helicopters.

The integrated GAT satellite unit can be installed in any small or different longhoul jets and all types of rotarywing aircraft without any additional software to upgrade of an existing system and does not need modification of ground and/or satellite equipment. In fact, GAT unit with antenna is totally new aircraft hardware with firmware and has to be installed discrete below fuselage together with batteries, charger and interfaced to onboard powers supply.

The Space Science Centre (SSC) at Durban University of Technology (DUT) leaded by author of this article has complete GAT installation for a trial and is looking for interested companies and individuals for collaboration **[1, 4, 10, 12].**

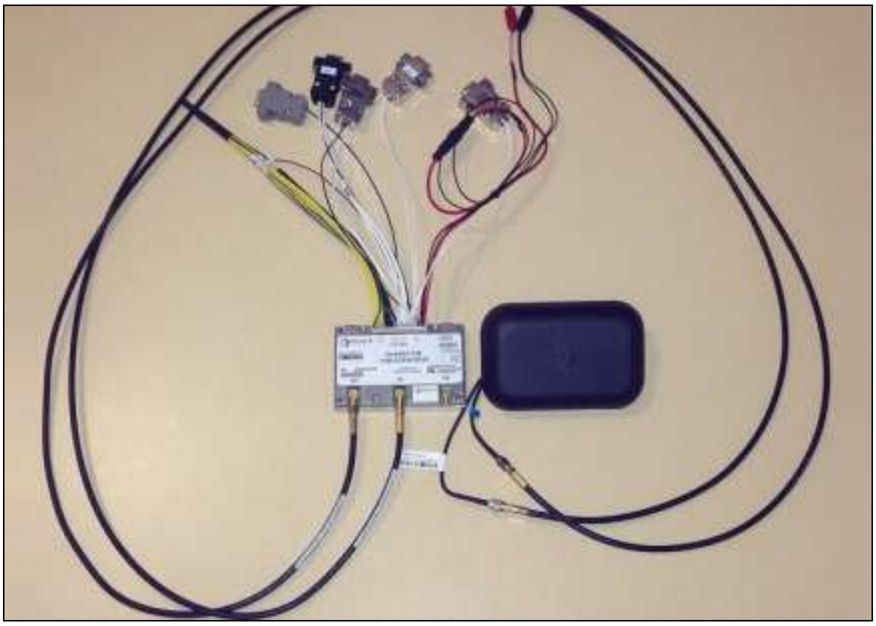

Figure 9. Airman GAT Device for GADSS Network – Source: Quake **[10]**

The GAT device is a dual mode solution that is ready for global use, which is designed to communicate with terrestrial cellular network systems when a cell signal is available, and to slide seamlessly into its back-up mode and communicate with a satellite system when a cell signal is not available. Besides this advanced modem functionality, this unit has additional processing power, memory and I/Os that allow sophisticated customer applications to run within the modem. Using an integrated power regulator, the GAT device is designed to operate over a 6-32 volt input range. It has been specifically designed to meet the requirements of mobile environments and supports communication over a mobile (aircraft) bus using SAE J1939 standards. These features make this unit an ideal stand-alone solution for a large variety of mobile applications including ships, vehicles, aircraft transportation, oil and gas and heavy equipment markets.

In **Figure 9** is depicted the GAT device connected to the GPS/Iridium antenna. On the left side of the GAT device it is possible to see the interface for the Iridium satellite transceiver that connect antenna through the cable. The middle interface connects the GPS antenna with the GPS receiver inside the GAT device. Thus, the right inreface can be used to connect to the GSM transceiver via optional cable to the optional GSM antenna. However, inside black antenna fiberglass box there are GPS and transceiver antennas, which are connected with cables to the GAT device. The red cable is connecting power supply via batteries and charger. In such a way, battery charger can be connected to aircraft any mobile power generator.

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Therefore, the GAT terminal represents the best solution and is able to provide a much better and reliable not limited aircraft tracking service, especially via Iridium satellite, than any current tracking system such as not autonomous ADS-B and ACARS systems **[4, 12, 13, 14].**

Figure 10. Inmarsat-IDP GMT System – Source: Orbcomm **[14]**

The GAT satellite transceiver with and antenna unit has been specifically designed to meet the requirements of mobile environments and supports communication over a mobile (aircraft) bus using SAE J1939 standards. These features make this unit an ideal stand-alone solution for a large variety of mobile applications including ships, vehicles, aircraft transportation, oil and gas and heavy equipment markets.

In **Figure 9** is depicted the GAT device connected to the GPS/Iridium antenna. On the left side of the GAT device it is possible to see the interface for the Iridium satellite transceiver that connect antenna through the cable. The middle interface connects the GPS antenna with the GPS receiver inside the GAT device. The right inreface can be used to connect to the GSM transceiver via optional cable to the optional GSM antenna. However, inside black antenna fiberglass box there are GPS and transceiver antennas, which are connected with cables to the GAT device. The red cable is connecting power supply via batteries and charger. In such a way, battery charger can be connected to aircraft any mobile power generator.

Therefore, the GAT system is project of SSC integrating GPS receiver and Iridium, Inmarsat or any Satellite transceiver with both antennas installed onboard aircraft. The tracking unit has to be installed discrete to protect accidental or forced shutdown of the tracking device. It will have both power supplies from aircraft engine or long term batteries, so if the power supply is disconnected by accident or by force the tracking unit will continue to work sending PVT and other data via adequate satellite, GES and TTN/Internet to the TCS terminal. This unit is fully independent of the pilot actions and other navigation and communication equipment in the cockpit. In such a way, the discrete installed GAT unit will be able to send information even if aircraft is hijacked by terrorist group. The GPS Receiver/Satellite Transceiver unit with both antennas has to be installed below top fuselage inside metal waterproof box with antenna situated behind transparent and very strong plastic plate for smooth transmissions of radio signals. Using another solution is to mount both antennas anywhere along the top of the aircraft fuselage.

The Inmarsat system is able to cover all transmissions of GAT transmitter via 3 Inmarsat GEO satellite constellations with coverage up to 75^0 North and South latitude. Purchasing SkyWave company, Orbcomm satellite operator reproduced under its brand two standards that provide mobile tracking solutions. First Inmarsat IDP-690 terminal is part of IDP 600 series of GMT terminals designed low elevation-angle applications is shown in **Figure 10 (Left).** Second terminal shown in **Figure 10 (Right)** is IDP-800 dedicated to monitor trailers, containers, vessels and more with fully programmable satellite tracking enabled by GPS or GLONASS PVT data.

Figure 11. Iridium GMT with Antenna – Source: Quake/Hirschmann **[13, 14]**

Figure 12. Aeronautical SDL System for GADSS Network – Source: Ilcev **[12]**

However, Iridium network is using intersatellite links, and in such a way is providing a real global coverage via 66 LEO satellites including both poles. This possibility is very important to cover communication facilities for international flights over North Pole. In **Figure 11 (Left)** is shown Quake Q4000 Tracker as proposed satellite transceiver for GAT system, in **Figure 11 (Middle)** is shown bolt, magneting or adhesive mount Hirschmann low profile Iridium satellite antenna for Iridium/GPS/3G/GSM modes, and in **Figure 11 (Right)** is shown Quake Q-Pro Multipurpose Tracker. Otherwise the Globalstar and Orbcomm LEO satellite systems can be used for local tracking systems of small aircraft **[4, 12, 13, 14, 15].**

7. Alternative Non-autonomous Aeronautical Satellite GADSS Solutions

Alternative non-autonomous airborne satellite GAT transceivers in the GADSS network function are characterized as non-autonomous because they usually do not have their own intergated GNSS receivers and alternative power supply via own rechargeable batteries. These solutions are as follws: Satellite Data Link (SDL), GNSS Augmentation SDL (GASDL), and Satellite Automatic Dependent Surveillance.

7.1. Aeronautical Satellite Data Link (SDL) Network

The SDL network is a part of total aeronautical satellite communication configuration that provides very important Aeronautical Satellite Data Link (SDL) via GEO Inmarsat mobile network or via LEO Iridium satellite constellation. The data link network operates at 200 b/s, uses Forward Error Correction (FEC) coding and employs a terminal monitor that provides interfaces to onboard avionics data recording equipment or even onboard airport vehicles and an industry-standard Personal Computer (PC) system. The PC terminal serves as a user terminal as well as a real-time monitor of Bit-Error-Rate (BER) performance.
The SDL network is a part of total aeronautical communication solutions for:
1. SDL Tracking Messages Service – The concept of this message service is similar to VDL Mode 4 system, which is able to provide a satellite broadcast link supporting navigation and surveillance functions. The SDL can provide transmission of Short Burst Messages (SBM) between mobile stations or mobile units with GES, ATC and ATM, which scenario is illustrated in **Figure 12.** In mobiles, such as aircraft and surface vehicles, can be installed satellite transponders or satellite tracker devices, which are getting GNSS signals from GPS or GLONASS spacecraft. Mobile transponders can send PVT and other data via any GES covering Inmarsat or Iridium satellites to ATC and ATM centres.

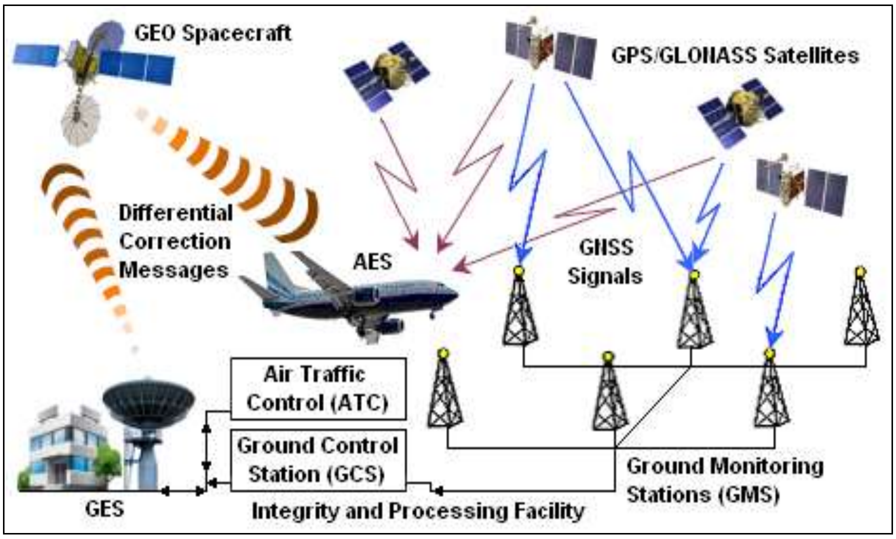

Figure 13. Aeronautical GASDL for GASDL Network – Source: Ilcev **[12]**

Therefore, the SDL transponder can support the similar services that provide VDL4, but if is using Iridium transponder can provide near global coverage via Inmarsat network or real global coverage including both poles. The transponder allows pilots and air traffic controllers to ”display” aircraft traffic in the air and on the airport surface including vehicle movements with the highest possible precision. The GES units can easily interface with other surveillance systems through the standardized Asterix protocol, enabling a complete surveillance picture at the airport derived from several sources. Ground stations and a ground-based network will provide increased functionality and capability for wide area coverage of advanced ATM applications. The functionality of the ground station is tailored to system specific service applications by its software configuration.
2. SDL of SBM and High Speed Data (HSD) Service – Every aircraft and helicopter caring transponders or satellite communication devices will be able to send and receive SBD or HSD for CNS purposes. As part of our total aeronautical communications solution, ARINC Direct delivers its customers global SDL services and accurate AOC messages. Two-way text messaging, flight movement data, text and graphical weather, NOTAM alerts, and in-flight route planning are just a few of the applications made possible by Inmarsat and Iridium satellite services around the world. Both operators also provide valuable redundancy for satellite services while requiring minimal equipage or upgrade costs, creating a cost-effective and vital communications service for aircraft. ARINK Direct also provides real-time information on departures, destinations, movement times, engine parameters, delays, positioning, maintenance and winds aloft **[3, 4, 12, 16, 17].**

7.2. Aeronautical GNSS Augmentation Satellite Data Link (GASDL) Network

The Regional Satellite Augmentation System (RSAS) network infrastructure, as a part of the Global Satellite Augmentation System (GSAS) network is a combination of ground and space equipment to provide augmentation of standard GPS or GLONASS signals, which is shown in **Figure 13.** The major functions being provided by RSAS are as follows: 1. Differential corrections are determined to improve GNSS-1 signal accuracy of GPA or GLONASS spacecraft; 2. Integrity monitoring is predisposed to ensure that errors are within tolerable limits with a very high probability and thus ensures safety; and 3. Ranging is proposed to improve availability.
The numbers of Reference Stations (GMS) are receiving not augmented signals of GNSS (GPS or GLONASS) spacecraft, processing and forwarding this data to Reference Stations or GSC. The GCS terminals process the data to determine the differential corrections and bounds on the residual errors for each monitored satellite and for each surveying area. Therefore, the GCS terminal is providing determination of the clock, ephemeris and ionospheric errors (ionospheric corrections are broadcast for selected area) affected during propagation. The corrections and integrity information from the GCS terminal are then sent to each RSAS GES and uplinked to the GEO Satellites.

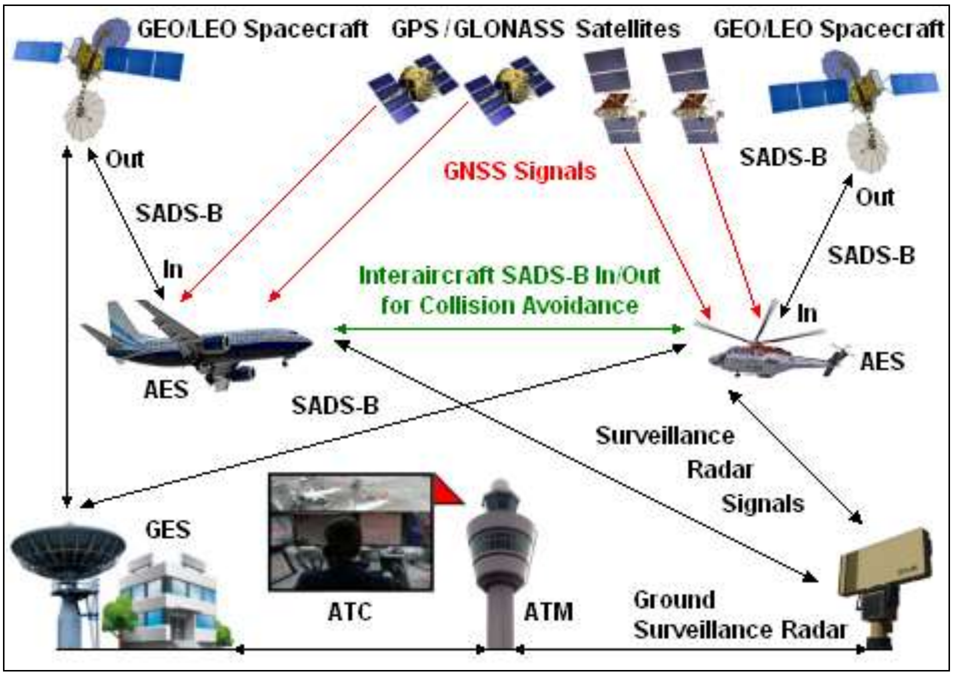

Figure 14. Aeronautical SADS-B System for GASDL Network – Source: Ilcev **[12]**

Because of very robust satellite payloads, Iridium satellite will be not able to carry communication and GNSS transponders. Thus, these separate differential corrections are broadcast by RSAS GES terminal through GEO satellite data link via GNSS transponder at the same frequency used by not augmented GPS receiver. Augmented GPS Rx is receiving augmented signals of GPS satellite and determined more accurate position of aircraft. Not augmented GPS Rx can also receive augmented signals if is provided an adequate software or hardware.
The most important stage in the GASDL network is to provide technical solution that augmented position of aircraft can be sent automatically via SDL or even voice to ATC and ATM centres via Inmarsat GES terminal. Finally, these GNSS satellite positioning signals can be processed by special processor and displayed on look like radar display, whish traffic controller is using for ATC and ATM for enhanced ship traffic control and improved collision avoidance in certain monitoring sea area **[3, 4, 12, 18].**

7.3. Aeronautical Satellite Automatic Dependent Surveillance-Broadcast (SADS-B) Network

The SADS-B network is a new system in development phase for airborne mission similar to RADS-B network, with the only difference that it operates via GEO or LEO satellite constellations instead of the conventional VHF radio. This airborne system is modern satellite broadcasting from aircraft via satellites and GEO terminals to provide position, velocity, altitude, positional integrity, flight identity, 24-bit aircraft address and other data that have been detected and computed by onboard aircraft sensors.
This SADS-B system will provide PVT and other data detected and computed by onboard ships sensors, such as GNSS (GPS or GLONASS), radar and other instruments. On 23 May 2013 a German DLR trial was switched on for the first time onboard A320, recording over 12,000 ADS-B messages within two hours at an altitude of 820 kilometers.
In the same year, the author of this book published two-volume book by AIAA publishers shortly introducing in it about SADS-B system.Typical SADS-B aeronautical network is similar to the airborne RADS-B with additional differences that the SADS-B network is covering long distances and is using transmission service of GEO or LEO satellites to send OUT or receive IN SADS-B information to STC and STM via GES ground terminals, which configuration is shown in **Figure 14.** The SADS-B network can provide the following service within avionic routes in ocean areas and approachings for enroute opeartions:

1. Air-to-air transmission implies data broadcast from one aircraft with the possibility of the reception and display of data in other aircraft and vice versa;
2. Air-to-ground transmission implies data broadcast from an aircraft with the possibility of reception and display in certain ATC units; and
3. Ground-to-air transmission implies data broadcast from the ground with the possibility of reception and display onboard certain aircraft.

Therefore, an SADS-B is a surveillance in which an aircraft determines its position via GNSS and periodically broadcasting signals. This data can be received and send by interaircarft communication IN/OUT for enhanced collision avoidance and can be also received by ATC as a replacement for airborne ground radar system. Otherwise the ground surveillance radars can be used as back up to SADS-B system. The SADS-B system requires new equipage for aircraft and SADS-B accuracy and integrity is subject to the source of the navigation data (usually GNSS).

In addition to the good characteristics, ADS has not some features as GST does such as:
1. This system is not discrete so that someone uninvited, under force by pirates or purposly can turn off the unit completely, part of the unit or just GNSS receiver;
2. This system cannot work properly if it has not an integrated GNSS receiver; and
3. This system needs to be installed to some secret place and although is powered by ship sources it needs own charger and batteries **[3, 4, 12, 19].**

8. Conclusions

There was described GAT system very important for aircraft, crew and passengers safety and security in all phase of flights. Every aircraft operators can use any system and equipment according to the ICAO regulations and cost-effective sense, but the point is to find out the best and reliable solutions for aircraft communication, tracking, determination and collision avoidance system with priorities of safety and security.

Inmarsat GEO satellite operator is only professional system providing near global coverage up to 80^0 North and South, but regards to available coverage this system and equipment can be used for any types of aircrafts and helicopters. Thus, for flights over North Pole can be used HF communication systems instead. Iridium LEO satellite operator as not professional system is providing full global coverage thanks to intersatellite links, however Globalstar and Orbcomm LEO have limited coverages. The future of aeronautical and other mobile satellite communication is combination of GEO, LEO and other 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 North Pole.

The ICAO, IATA and other avionic experts have to understand that GAT system using very small GPS/Satellite tracking devices is the best solution, very cost and technical effective mode for future global air tracking, detecting, safety and SAR of missing or hijacked aircraft in any real time and space. The GAT network is also one the best solution for enhanced collision avoidance across oceans, along the corridors and during approaching to airports.

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