Infrastructure of the Global Aircraft Tracking (GAT) System as an Integration Component of the GADSS Network

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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 Communication, Navigation and Surveillance (CNS) solutions 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 a Global Navigation Satellite System (GNSS) receiver and satellite transceiver is programmed to transmit Position, Velocity and Time (PVT) and other data via Geostationary Earth Orbit (GEO) Inmarsat or Leo Earth Orbit (LEO) Iridium satellites to 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 via dedicated Aeronautical Telecommunications Network (ATN).

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

1. Introduction

The author of this article presented for the first time in the world a new project for the development of the GADSS network for more effective Search and Rescue (SAR) and GAT systems for aircraft in distress and emergency. The GAT sub-segment of the GADSS network is a very important infrastructure for providing reliable and efficient continuous and autonomous aircraft tracking on a global scale, which scenario is illustrated in **Figure 1.** The GAT space segment is composed by three integrated satellite constellations, such as Inmarsat GEO, Iridium LEO; and GNSS-1 (first generation) MEO constellation of the US GPS and Russian GLONASS networks.

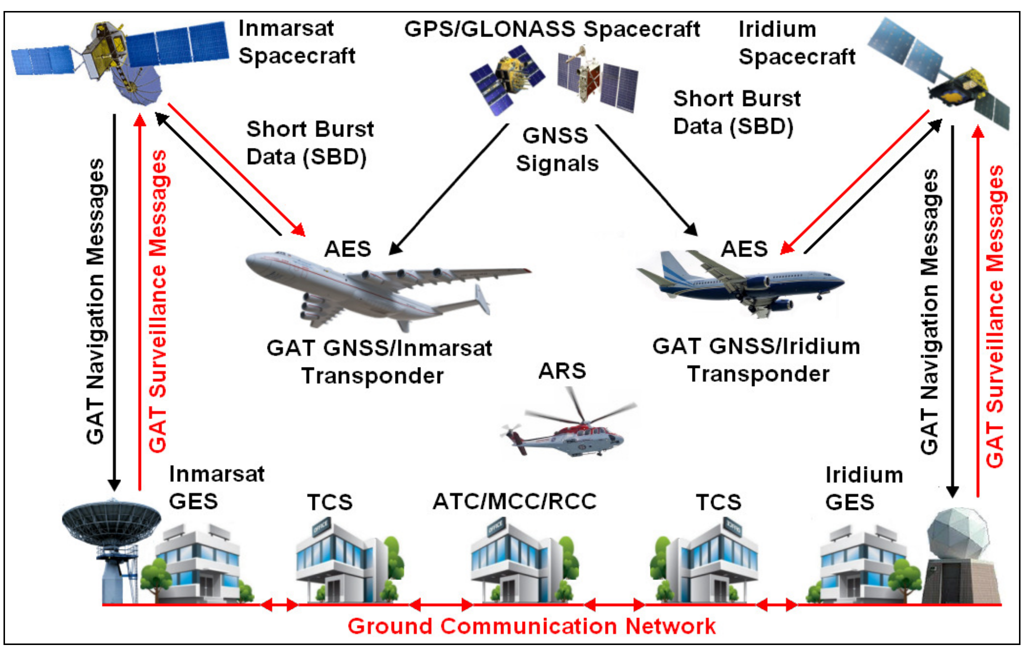

Figure 1. Aeronautical GAT Network – Source: Ilcev

The contemporary GNSS-2 (second generation) network can also be used as a space segment in the GAT system, such as the newly developed and operational Chinese BeiDou or Compass and still under development phase European Galileo constellations. Currently providing Initial Services, Galileo is interoperable with GPS and GLONASS, the US and Russian GNSS-1 networks.
The GAT ground segment is composed by both Inmarsat and Iridium GES transceiving terminals and Tracking Control Stations (TCS) infrastructure connected to separate cites of Air Traffic Control (ATC) structures, Cospas-Sarsat Mission Control Centres (MCC) and Rescue Coordination Centres (RCC) stations in the function of the SAR facilities.
The user segment is represented by the special GAT transceiver, installed onboard aircraft composed by GPS or GLONASS receivers and Inmarsat or Iridium transceivers. Thus, the GAT tracking device composed by the GNSS receiver and Inmarsat transceiver (transponder) can use Inmarsat space and ground networks, while GAT tracking device composed by the GNSS receiver and Iridium transceiver can use Iridium space and ground networks.
As illustrated in **Figure 1**, the GAT Navigation Message highlighted in black sent by the onboard aircraft GAT tracking device (GNSS receiver and Satellite transceiver), has direction via Inmarsat GEO or Iridium LEO spacecraft, GES stations and TCS terminals to ATC, MCC and RCC infrastructures.
In the opposite way, the GAT Surveillance Message highlighted in red sent on request of pilot or sent by reporting and polling system, similar to the Inmarsat-C solutions, has direction via Inmarsat GEO or Iridium LEO spacecraft to the GAT tracking receiver. In such a way, the GAT tracking device can be connected in cockpit to the special surveillance display like radar screen (monitor) with keyboard, which cannot switch off GAT device, but just monitor. The surveillance data will be positions of all adjacent aircraft in certain flight area and can be used for enhanced collision avoidance and awareness in air space.
A GAT tracking device and monitor with a display cannot be installed onboard aircraft in the cockpit, because it can be turned off or manipulated by hijackers and terrorists or in case the pilot gets some imagination or mental access. In fact, the best place to install this device will be any secret or discrete position onboard aircraft location, such as somewhere below the fuselage along with both GPS and satellite transceiving antennas and rechargeable batteries that can be used in the event of main electrical power failure.
As already stated, the author of this book invented GAT system along with GADSS network in 1999 as the best solution to be integrated in GADSS network for global aircraft tracking, detecting and positioning in any real time and space. Thus, in the case of GAT tracking devices, today at the avionic equipment market there are many types of Inmarsat or Iridium tracking devices that can be implemented in the GAT user segment, which applications are already introduced in Chapter 5 of GADSS book **[7].**

2. Future Air Navigation System (FANS) Network

In 1983 was developed FANS concept by the ICAO in partnership with Boeing, Airbus, Honeywell and other companies in the air transport industry to allow more aircraft to safely and efficiently utilize a given volume of airspace. Since than, FANS concept is used primarily in the oceanic regions flights taking advantage of both satellite communication and satellite navigation to effectively create a virtual radar environment for safe passage of aircraft.
The FANS plays a key role in supporting many of the evolving CNS/Air Traffic Management (ATM) strategies and mandates as an evolution that has been underway for more than ten years. Today, FANS-1 is the standard used on Boeing aircraft while the Airbus standard is known as FANS-A. Both are considered first generation FANS architectures. Second generation FANS will be discussed under the FANS Evolution paragraph.
The ICAO FANS committee has approved the global Satellite Data Link (SDL) as the primary medium for Oceanic ATC communication system. Although the current voice-based radio High Frequesncy (HF) system has adequately supported all ATC oceanic communication systems in the past, the increased traffic and message flow requirements are limited in the current radio data and voice-based system.

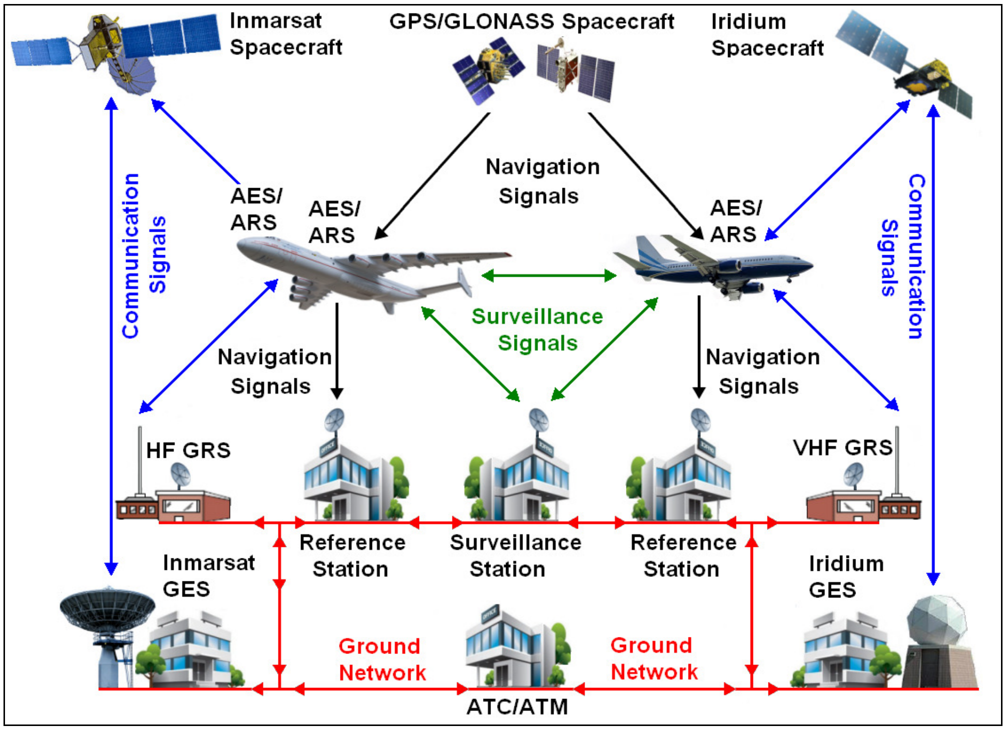

Figure 2. Aeronautical FANS Network – Source: Ilcev

In fact, there are other even cheaper HF radio solutions, such as radio digital transmission with the possibility of data transfer, such High Data Link (HDL) radio solution. In the meantime, HF radio communications for aeronautical application still will be in exploitation for uncovered Polar Regions by Inmarsat system. To cover Polar Regions Inmarsat can provide hybrid satellite network with 2 Russian Highly Elliptical Orbit (HEO) Molniya spacecraft, however Iridium network provides full global coverage including Polar Regions.

The existing capabilities and coverage of the avionic Very High Frequency (VHF) Aircraft Communications Addressing and Reporting System (ACARS) for Aeronautical Operational Control (AOC) solutions, ATC and Airline Administrative Control (AAC) services are expanded with new Global Satellite Supports Airline Operations (GSSAO) and ATC applications.

The GSSAO data link includes report on departure and destination locations and movement times, engine monitoring, arrival delays, aircraft position, maintenance reports and winds aloft observations. On the other hand, complicated ATC instructions, such as oceanic clearances, can now be displayed in written form on aircraft monitors and printers and retrieved at the pilot's convenience. Thus, the FANS-1/A avionic facilities provide transfer of information between ATC, aircraft and ground operators, which vision of FANS integrated network is shown in **Figure 2.**

1. FANS Communication Network – This FANS network shown in **Figure 1** consists interactive (two-ways) satellite communication signals between Aircraft Earth Stations (AES) and Ground Earth Station (GES) terminals via Inmarsat and Iridium satellite constellations highlighted in black and red. The aircraft has also highlighted in blue VHF and HF radio communication networks shown in **Figure 2**, which is direct Line of sight (LOS) between aircraft SRS and ARS terminals. Both, satellite and radio communication networks are providing commercial and distress links between aircraft and ground stations connecting ATC/ATM stations via ground communication networks, such as landline telecommunication infrastructures and Internet. The AES and ARS onboard aircraft terminals are also capable to send emergency and distress via GES and GRS terminals to MCC and RCC stations.

2. FANS Navigation Network – The FANS navigation network is providing GNSS signals highlighted in black, from GPS and GLONASS satellites to aircraft, which aircraft is resending to the ground reference stations. From there navigation signals like augmented GNSS messages can be forwarded to ATC/ATM stations.

3. FANS Surveillance Network – The FANS surveillance network highlighted in green is possible between aircraft station and ATC/ATM via ground surveillance stations, including between aircraft in the same air space as Aircraft to Aircraft (A/A) links. Applications include controller pilot data link communications and automatic dependent surveillance. The Air transport communications and information technology (SITA) system provides pre-FANS and FANS facilities through its new Air Traffic Services (ATS) AIRCOM service for ATC and Automatic Dependent Surveillance Services (ADSS). Satellite AIRCOM provides worldwide ACARS air-to-ground communication services that are fully compliant with Airline Electronic Engineering Committee (AEEC) characteristics 618 and 620, using Inmarsat Data-2 capabilities. The AAC between cabin crew and ground control staff can be improved through reliable and timely cabin management, configuration and provisioning.
The AOC communications encompass all aircraft flight operations, maintenance and engineering. The ARINC Value Added Service (VAS) also provides the FANS facilities mentioned above, including D-ATIS, WX data service and all information for pilots, pre-departure and departure clearance, communications between pilots and controllers, ATS Interfacility Data Communications (AIDC), Oceanic clearance delivery, Centralized ADSS broadcast, etc.

3. Future Global Aeronautical Distress and Safety System (GADSS) Network

Over 10,000 aircraft have been fitted with Inmarsat Aero terminals to improve commercial, corporate, passenger and safety communications. These include more than 4,000 corporate and government aircraft and over 6,000 installations in airline companies. Corporate users favor telephone and Fax services, while the airlines also make use of the data services for commercial and safety Aeronautical Mobile Satellite Communication (AMSC). In addition, more than 2,000 business airplanes, helicopters and military air transports are fitted only with the Aero-C terminals.
New installation onboard aircraft are represented by last generations of Inmarsat satellite communication equipment, such as SwiftBroadband-Safety (SB-S) and GlobalXpress (GX)
for improved commercial, distress and safety awareness. In addition, on the avionic market arrives Iridium satellite equipment. Both satellite networks are providing SDT, SADS-B and other transmission applications for more efficient aircraft tracking.
The DVB-RCS/S2 standards via special GEO communication satellite constellations provide special satellites broadcasting, broadband and Internet mobile applications.
On the other hand, HF and VHF radio communication systems are providing HDL, VDL, RADS-B, LDACS, AeroMACS and other solutions.
The Cospas-Sarsat satellite network for distress and safety communications provides three integrated LEOSAR, MEOSAR and GEOSAR network, which together with Inmarsat and Iridium networks are main components of the future GADSS network.
All these installations will improve commercial and safety aeronautical communications, current ATC/ATM and implement the new Global Satellite Augmentation System (GSAS) network as important chain in more efficient flight safety and security. The GSAS concept and other issues related to their integrated Regional Satellite Augmentation Systems (RSAS) networks can be found in Chapter 6 of GADSS book **[7],** such as the European EGNOS, US WAAS, Japanese MSAT, Russian System of Differential Correction and Monitoring (SDCM), Chinese Sino (Satellite) Navigation Augmentation System (SNAS), Indian GPS-aided GEO Augmented Navigation (GAGAN) and new project of African Satellite Augmentation System (ASAS) for Africa and Middle East.

3.1. Components of GADSS Network

In addition to the ATM function, the AMSC provides an important distress alerting and aircraft locating service via the Inmarsat network, GES and RCC terminals, although the AMSC distress and safety system is still not completely developed and implemented. The ICAO has the only "long way" project known as FANS, which does not include enough enhancements regarding distress AMSC solutions.

Thus, there is confusion today in global AMSC systems because new satellite applications are mixed with old aeronautical information solutions, instead of generally being defined as follows:
1) Global Aeronautical Corporate and Commercial System (GACCS) – The GACCS has to enable all Radio and AMSC service between aircraft and airport on one hand and between aircraft and airways companies of offices on the other. This service can include all Notice to Airmen (NOTAM) information, ATS inter-facility data communication (AIDC), Estimated Time of Arrival (ETA) messages, arrival clearance, departure and pre-departure clearances, Oceanic Clearance Delivery (OCD), Operation control and maintenance and engineering data, Flight plans and progress, course changes information, position data and reports (0001), controller to pilot data link communications, voice communications between cabin crew and ground staff and all commercial voice/Fax or data messages.
2) Global Aeronautical Distress and Safety System (GADSS) – Without consideration of the main subject of ICAO FANS, the best solution will be the establishment of Future GADSS separately, more effective and similar to a current Global Maritime Distress and Safety System (GMDSS) of International Maritime Organization (IMO). Thus, there are necessary predispositions for Future GADSS mission such as: Inmarsat AMSC system and terminals; Cospas-Sarsat system with Emergency Locator Transmitter (ELT) and new Digital Selective Call (DSC) HF/VHF Digital Radio system. Without doubt, the Cospas-Sarsat Emergency Position Indicating Radio Beacon (EPIRB) terminals and SAR Transponders have to be mandatory onboard every aircraft in case it has to land at sea, owing to engine or other troubles, or to use as well as ELT with floating possibilities. Thereafter, the SAR procedure for aircraft floating on the sea's surface has to be same as for ships in distress. Besides distress and SAR mission, this system has to provide an additional service including all Safety ATC communications, centralized ADSS position reporting, WX (weather), NX (navigation) reports, Aeronautical Highlights and Navigation Information Services (AHNIS), hijacking prevention and information, medical service, technical advice, etc.
Without doubt, the GADSS network and service will be indispensable and important for the safety of air traffic, similarly to the already successfully developed GMDSS mission by IMO maritime. In any event, the development of new missions for GADSS has to be led by the ICAO and supported by other communities involved in AMSC services, including Inmarsat and Cospas-Sarsat systems. Without the new GADSS integrated mission, all other solutions and technical implementations will not be complete and successful.
The current function of Inmarsat AMSC is also accomplished by equipping aircraft with special emergency distress satellite beacons, known in the aeronautical industry as an ELT satellite beacons, which can be detected and located by the special Cospas-Sarsat LEOSAR and GEOSAR satellite system's, Local User Terminal (LUT) and RCC ground terminals. This service has to be integrated with a new solution to the Digital Selective Calling (DCS) HF/VHF radio system in the new GADSS emergency mission. In this sense, the radio system will be used to provide reliable communications for both Polar Regions uncovered by the Inmarsat System. The readers can find more detailed information about the Cospas-Sarsat LEO, Medium Earth Orbit (MEO) and GEO systems in Chapter 5 of GADSS book **[7]**.

3.2. Concept of GADSS Network

The huge limitations in the current air navigation and tracking and determination system, which have hampered the timely identification and localization of aircraft in distress, have been recently highlighted by tragedies such as the losses of Air France 477 and Malaysia Airlines 370. These limitations significantly hindered both effective SAR efforts and the recovery operations. Finally, 15 years later than GADSS invention and design provided by the author of this book, the ICAO experts have identified that the current effectiveness of alerting search and rescue services could be enhanced by developing and implementing the future GADSS network. The main objective from a high level perspective, the GADSS is designed to address three specific issues such as:
(1) The late notification of SAR services when aircraft are in distress;
(2) Missing, not sent or inaccurate end of flight aircraft position information message (for example, the location of wreckage in the event of a crash); and

(3) Lengthy and costly retrieval of flight data for accident investigation.
The biggest problem in this even is that aircraft didn't send any PVT, ID and other data in last few hours, because of failure of equipment, hijacking or its switching off by force, and what is more important, because aviation still has not adequate tracking, determination and positioning devices onboard aircraft.
The consequent objectives of the GADSS are therefore to:
(1) Ensure timely detection of aircraft in distress situation;
(2) Initiate SAR operations actions as efficiently and as quickly as is possible;
(3) Ensure frequently and efficient tracking of aircraft in distress and provide timely and accurate location of end of flight;
(4) Accurately direct SAR actions and enable efficient and effective SAR operations; and
(5) Ensure timely retrieval of Flight Recorder Data
Again, if avionic industry cannot provide autonomous, independent, efficient, reliable and discrete GAT solutions for aircraft in all phase of flight ICAO cannot be successful in full implementation of GADSS network.
According to the ICAO Concept of Operations, the GADSS network will address all phases of flight under all circumstances including distress. This GADSS concept will maintain an up-to-date record of the aircraft progress and, in case of a crash, forced landing or ditching, the location of survivors, the aircraft and recoverable flight data. The following three main functions of the GDASS network are: (1) Global Tracking; (2) Autonomous Distress Tracking; and (3) Post Flight Localization and Recovery;
1. Aircraft Tracking – The solution of the GDASS Aircraft Tracking function is planned to provide an automated 4 dimensional position (latitude, longitude, altitude and time) at a reporting interval of 15 minutes or less. Here are missing very important component of ID and velocity of aircraft, so it will be more convenient that tracking message consists PVT, ID, altitude and other data. In fact, this reporting interval will result in a reduction of the time necessary to resolve the status of an aircraft or, when necessary, help to locate an aircraft. Besides, if ATS obtain an aircraft position at 15 minute intervals or less, it will not be necessary for the operator to track the aircraft. However, should the aircraft be operating within an area where ATS obtains the aircraft position at intervals greater than 15 minutes, the operator will be required to ensure that the aircraft is tracked. In general, the aircraft tracking function does not introduce any change to current ATC/ATM alerting procedure, establishes operator responsibilities for tracking based on areas of operation and establishes communication protocols between operator and ATC station.
2. Autonomous Distress Tracking (ADT) – The ADT function will be used to identify the location of an aircraft in distress with the aim of establishing the location of an accident site within a 6 NM radius. An aircraft is considered to be in a distress condition when it is in a state that, if the aircraft event is left uncorrected, may result in an accident. Thus, triggering criteria might include items such as unusual attitudes, altitudes or velocity, as potential collision with terrain, total loss of thrust on all engines, Mode A squawk codes, and others as defined by the operator. The ADT function will use on-board systems to broadcast either aircraft position (latitude and longitude), or a distinctive distress signal from which the aircraft position and time can be derived. In fact, once the ADT has been triggered by a distress condition event, the aircraft position information will be transmitted at least once every minute.
3. Post Flight Localization and Recovery - In the event of an aircraft accident, the immediate priority is the rescue of any survivors. At this point, the ADT function will greatly reduce the potential search area and even more accurate aircraft position information will be provided through the Post Flight Localization function by means of ELT transmitter and/or homing signals to guide SAR services on site. To facilitate the ability to locate the wreckage and recover the flight recorder data after an accident, the post flight localization and recovery function specifies a number of requirements for ELT beacons, Underwater Locator Beacon (ULB) and flight recorders which are being incorporated into the provisions of ICAO Annex 6. In this context is very important to conclude that without GAT network and TCS terminals specialized to receive, process and host all GAT received messages in one FIR area, it will be not possible to provide reliable and effective GADSS network.

The future operational concept for GADSS successful implementation revolves around a cooperative relationship between ATS, the aircraft operators and RCC terminals. The first two have an active role and responsibility for tracking an aircraft in flight and will advise the third in the event that loss of position update is experienced or that ADT system is activated. Again GADSS will need GAT with TCS terminals between some distress and SAR operations. Similarly, if a search and rescue asset detects an emergency signal, such as an ELT from an aircraft, the affected RCC will notify ATC and the operator. The RCC, ATS and the aircraft operators each have specific duties and responsibilities during each of the three defined ICAO Emergency Phases (Uncertainty Phase, Alert Phase and Distress Phase). For complete details of these responsibility relationships, refer to the GADSS Concept of Operations manual listed under Further Reading below.

3.3. Implementation of GADSS Network

It has to be of prime importance to all aeronautical personnel for it is likely that elements within the GDASS will affect every individual in the future. This also has to be very important for aircraft crew, because in case that pilot is unable to provide distress alert, it can be conducted by any crewmember for saving of crew and passenger lives. However, the major importance of the GDASS will be to provide enhanced Safety of Lives in Distress (SOLID) of aircraft incidents at sea and on the ground.

The GADSS has to be an international system that uses radio and satellite technology to ensure rapid, automated alerting of ground-based communication and rescue authorities, in addition to ships in the immediate vicinity of aircraft in distress at sea, and in the event of an aircraft distress on the ground. The basic concept is that SAR authorities ashore, as well as shipping in the immediate vicinity of the aircraft in distress at sea, will be rapidly alerted through radio and satellite communication so that they can assist in a coordinated SAR operation with the minimum of delay.

The main aeronautical systems and equipment implemented in GADSS have to be integrated Radio Distress and Safety Systems (RDSS) and Satellite Distress and Safety Systems (SDSS). Aircraft fitted with GADSS equipment has to be safer in flight and in case of landing at sea or on the ground, and more likely to receive assistance in the event of a distress alerts. The GADSS network has to provide manual alerting and also possibility for automatic alerting and locating when aircraft's staff does not have time to send out a full distress call. The GADSS also requires aircraft to receive broadcasting of Aeronautical Safety Information (ASI), which could prevent a distress from happening, and requires aircraft to carry satellite ELT, including even ships EPIRB and SART devices, which float free at sea and can alert SAR authorities similar as a ship in distress.

The GADSS regulation has to be adopted by the ICAO and by means of amendments to the International Implementation of the future GADSS requirements is the responsibility of Contracting Governments to SOLID capacity and capability of on scene communications. This means the Administrations of individual member countries have to ratify the GADSS requirements into their national law. In practice, this also means that individual aircraft owners have to be responsible for ensuring their aircraft meet GADSS requirements, since they must obtain certificates from their flag State certifying conformity with all relevant ICAO regulations and recommendations. According to new GADSS, SOLID and Future Aeronautical Communications (FAC) concept, each aircraft and helicopter has to carry onboard by compulsory adequate Radio VHF and HF communication devices and Satellite equipment for Commercial and Safety operations. Thus, to provide pilot concept of new projected GADSS on the road, ICAO team has to engage worldwide experts with complete experience in Radio and Satellite CNS networking.

3.4. Future GADSS Network

Traditionally, aircraft is subject to the current ICAO Convention and Regulation relating to the aeronautical communication and navigation. Long time ago ICAO developed the Future Air Navigation System (FANS), which until recently was attribute as a future. As stated earlier, author of this book proposed GADSS system in 1999 and in 2000 provided a project, while n 2016 ICAO proposed GADSS as own system not respecting, recognizing and admitting his invention.

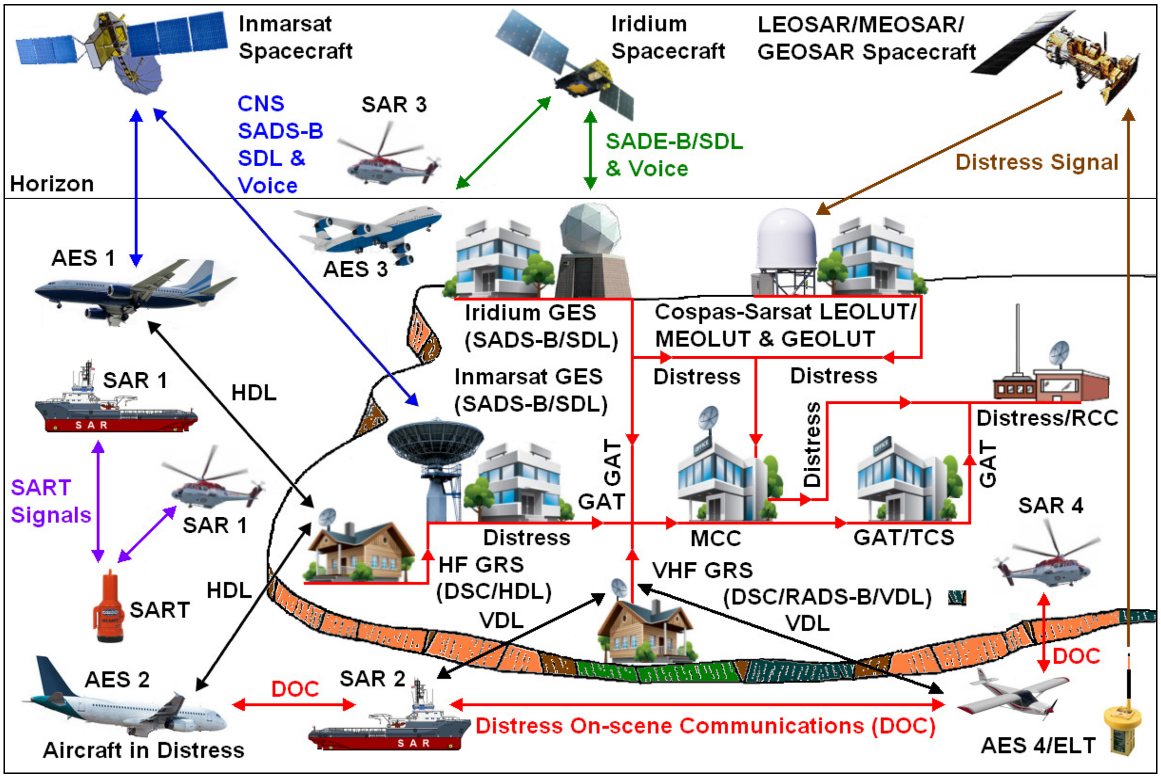

Figure 3. Concept of GADSS Network – Source: Ilcev

However, CNS is a well-established acronym for new Communication, Navigation and Surveillance, which together with proposed GADSS will be de facto the future real systems as successors to FANS. In the future will be necessary to provide some more simple aeronautical system for air-to-ground, ground-to-air and air-to-air commercial, safety and distress radio and satellite voice or data communications, navigation data and surveillance information. The synonym surveillance as a part of CNS system means Radio and Satellite surveillance and not radar surveillance only. At present aircraft have on board in use two kinds of communication systems: Radio VHF and HF old Traditional Communications and new Satellite Communications. Integration of these two types of aircraft communications has to provide basis for development GADSS. The main tasks of ICAO will be to initiate GADSS project and to produce guidelines for identifying system requirements and effectiveness.

The basic concept of the GADSS has to be Safety and Security, reliable Distress alert and effective Search and Rescue (SAR) local and regional authorities. The SAR forces have to come quickly in the immediate vicinity at sea or on the land, and in the same time have rapidly to alert all possible rescue resources about position of distress incident. In such a way, all together can assist in a coordinate SAR operation with the minimum delay. The GADSS space and ground network is developed and designed by author of this book in 2000, which integrated architecture is shown in **Figure 3.** The main components of GADSS network are Radio, Satellite Communications and Satellite Cospas-Sarsat SAR Networks. Radio system will provide service via VHF and HF bands such as DSC, VDL and RADS-B transmissions.

1. Inmarsat Satellite Subnetwork – This satellite communication network is highlighted in blue on upper left side of **Figure 3.** The aircraft AES 1 in emergency can send distress alert via Inmarsat spacecraft, Inmarsat GES terminal and ground network to the MCC and RCC terminals to arrange SAR operations. The satellite links use CNS, Satellite Automatic Dependent Surveillance – Broadcasting (SADS-B), Satellite Data Link (SDL) and Voice communications between AES 1 and GES terminals. In the same time, if aircraft AES 1 is equipped with SAR Transponder (SART), highlighted in violet, rescue ship and helicopter SAR 1 can provide surveillance of distress its position. However, the same aircraft AES 1 can have HF Data Link (HDL) or radio voice communications with HF Ground Radio Station (GRS).

2. Iridium Satellite Subnetwork – This satellite communication network is highlighted in green on upper middle side of **Figure 3.** The aircraft AES 3 in emergency can send distress alert via Iridium spacecraft, GES terminal and ground network to the MCC and RCC terminals to arrange SAR operations. The satellite links use SADS-B, SDL and Voice communications between AES 3 and GES terminals. Besides, rescue helicopter SAR 3 is giving assistance in SAR operations.
3. HF Radio Subnetwork – This radio communication network is highlighted in black on below left side of **Figure 3.** The aircraft AES 2 in emergency can send distress alert via HDL to HF GRS terminal or can establish VHF Distress On-scene Communications (DOC) with rescue ship SAR 2. In addition, the ship in emergency AES 2 will be also able to establish distress links via Inmarsat or Iridium satellites with ground infrastructures.
3. VHF Radio Subnetwork – This radio communication network is highlighted in black on below middle side of **Figure 3.** The aircraft AES 4 in emergency can send distress alert via VDL to VHF GRS terminal or can establish VHF DOC with rescue ship SAR 2 and rescue helicopter SAR 4. In addition, the ship in emergency AES 4 will be also able to establish distress links via Inmarsat or Iridium satellites and ground infrastructures.
4. Cospas-Sarsat Satellite Subnetwork - This SDSS network is highlighted in brown on upper right side of **Figure 3.** The aircraft AES 4 in emergency can send distress alert via ELT beacon, Cospas-Sarsat LEOSAR, MEISAR or GEOSAR satellites and LEOLUT, MEOLUT and GEOLUT ground receiving station to the MCC and RCC terminals to arrange SAR operations.
5. GAT Satellite Subnetwork – Aircraft equipped with GAT GNSS (GPS-GLONASS) receivers/Satellite transponders will be able to send PVT, ID and altitude data via Inmarsat or Iridium satellites, GES terminals, MCC and Tracking Control Station (TCS) for eventual emergency situation and SAR operations, which is shown in the middle of **Figure 3.**

4. Concept of ATC via GADSS System

The new GADSS concept involves improvements with integration of Radio and Satellite CNS systems and equipment for providing enhanced ATC and ATM services.

4.1. Improvements of Aeronautical Communication Systems

These improvements involve a transition from voice to digital communications on one hand, and from radio to satellite communication on another hand. There is a problem with radio wave propagation of VHF and HF systems, but they are needed and will be always in service in case of some war. Still there are problems with satellite coverages, reliability and professionalism. Thus, Inmarsat system has a problem to cover especially North Pole area, so to cover this zone is needed improvement of HF digital radio or to provide coverage with two Molnya satellites. Iridium is deployed as personal communication systems and after that became system for mobile applications as well. For instance, because of smaller size of payloads onboard Iridium satellites, they cannot be involved easily as multipurpose platforms, such as case with new Inmarsat communication and navigation payloads. In addition, there are other new satellite systems that provide DVB-RCS communications of Voice, Data and Video (VDV) solutions.
The established ACARS system is a digital data link for transmission of short, relatively simple messages between aircraft and ground station via radio or satellite. The protocol, which was designed by ARINC to replace their VHF voice service and deployed in 1978, uses telex formats. SITA later augmented their worldwide ground data network by adding radio stations to provide ACARS service. However, over the next 20 years, ACARS will be superseded by the ATN protocol for ATC communications and by the Internet Protocol (IP) for airline communication systems. This allowed other application improvements, especially of satellite DVB-RCS communications. The CPDLC application was hosted on the airplane, which allows the flight crew to select from a menu of standard ATC communications, send the message, and receive a response. A peer application exists on the ground for the air traffic controller. They can select from a set of messages and send communications to the airplane. The flight crew will respond with a WILCO, STANDBY or REJECT with current standard for message delivery under 60 sec one-way.

The original Inmarsat aeronautical service provides two modes, circuit mode supporting voice communications and packet mode supporting "always-on" data communications. Aircraft operators use the Inmarsat circuit mode to offer voice service to passengers and flight deck crew. Aircraft operators use the Inmarsat packet mode, which provides a data rate approaching that of some home high-speed lines.

The move of aircraft communications from voice to data has motivated some operators of HF radio GRS to install new so called HDL computers that enable the transport of ACARS data, and so manufacturers of aircraft HF radios have added capabilities to support ACARS. The new HF radios can switch between voice and data mode using the same components, but they are required to give voice communications precedence over data link. This has a tendency to limit the HDL availability and this is not a commonplace application.

The HF Radio data link has been found to provide better availability than HF voice on trans-Polar routes beyond the 80-degree North/South limit of Inmarsat satellite coverage. The HDL capacity is only limited by the frequencies available in the HF band. The allocation of HF frequencies to data link has required a very complex co-ordination process and the system will quickly reach its limits. The addition of data link capability to HF radio is a way for aircraft operators to get additional use out of the radios they still carry in order to meet ATC rules when most communications migrate from voice to data.

However, the HDL radio system provides delivery of 95 % of transmitted messages in three to four minutes compared to 20 to 30 seconds via satellite communications, so it is likely to be limited to providing a safety net in case of failure of satellite avionics, rather than a good alternative to satellite communications. The US State FAA Central Reporting Agency report as of July 2003 found 95 % of uplink messages took 4 minutes, 20 sec and 96 % took up to 10 minutes.

Thus, the term VHF Digital Link system was adopted by the ICAO Aeronautical Mobile Communications Panel (AMCP), at its first meeting in November 1991, to refer to digital communications carried on the Aeronautical VHF band. The Aeronautical VHF Band is the section of the Very High Frequency spectrum allocated to Aeronautical Service by the ITU organization. It is made up of the following two groupings: 108 - 118 MHz assigned to the purpose of radio-navigation and 118 - 137 MHz, which is used for radio-communications.

Then, the plan for VHF band to become a data carrier was proposed in the ICAO FANS committee report issued in 1988. The airline community had recognized the benefits of aircraft data link communications 10 years before the FANS report and had implemented the VHF version of ACARS. The ICAO reserved four VHF channels: 136.900, 136.925, 136.950, and 136.975 MHz for data communications worldwide. In fact, this later decision catered for the reservation of frequencies in order for such data service to be implemented in an environment when the existing aviation VHF spectrum was considered saturated and congested with existing VHF channels for air traffic analog voice.

In the meantime, the AMCP has developed standards for VDL Modes 1 - 4 in which the solutions provide different capabilities that currently have political divisions. Mode 1 was created with the intent of using analog radios incorporating a device to install a coded signal on the existing carrier wave. This mode was never carried forward as analog radios were already viewed as dinosaurs. Further considerations brought about Mode 2 and 3 which present the position of the FAA wanting to use all new digital radios with 25 KHz frequency spacing and the Eurocontrol concept of going with 8.33 KHz frequency spacing for high speed data communications. The Swedish firm Swedavia discovered that the VDL Mode 4 system could simultaneously support CNS applications. The combined functions used in the VDL Mode 4 system may be its greatest deterrent as each function has specific performance requirements that cannot be met by a combined system.

On air transport aircraft, the CNS functions will continue to be processed by separate devices: Communications with VHF data radio or a satellite data unit; Navigation with GPS or GLONASS GNSS systems and ILS multi mode receivers; and Surveillance with Mode S transponder and GNSS Data Link via VDL (GVDL).

In addition, the GADL signal should be included in the CNS network, which is sent by the ground control station (GCS) via the GEO satellite navigation payload to ships and aircraft on the same frequency as the GPS or GLONASS signals.

4.2. Improvements of Aeronautical Navigation Systems

This involves a transition from Inertial Navigation to Satellite Navigation using the GPS satellites. This also introduced the concept of Actual Navigation Performance (ANP). Previously, flight crews would be notified of the system being used to calculate the position (radios, or inertial systems alone).

Because of the deterministic nature of the GPS satellites (constellation geometry), the satellite navigation systems can calculate the worst-case error based on the number of satellites tuned and the geometry of those satellites. At this point note, that it can also characterize the potential errors in other navigation modes as well. So, the improvement not only provides the airplane with a much more accurate position, it also provides an alert to the flight crew should the actual navigation performance exceed the Required Navigation Performance (RNP).

Navigation system performance requirements are defined in manual of ICAO on RNP (DOC 9613) for single aircraft and for the total system that includes the Signal-In-Space (SIS) the airborne equipment and the ability of the aircraft to fly the desired trajectory. All the navigation aids must fulfill four basic performance requirements in order to be certified i.e. Integrity, Continuity, Accuracy and Availability (ICAA):

1. Integrity – It is the ability of the navigational aid (s) to warn the pilot that it has failed or giving incorrect message.

2. Continuity – It is the ability of the entire system to carry out its function without any interruption during planned operating period.

3. Accuracy – It is the ability of the navigational aid(s) is to guide the path of an aircraft within pre-defined tolerances.

4. Availability – It is the ability of the system to transmit signals of the required quality most of the time. This is a critical requirement in landing guidance and for this reason stand by equipment is added to ground-based aids.

The previous GPS and GLONASS components of the GNSS infrastructure have a precision of about 100 meters on the horizontal plane 95% of the time, and new precision is about 30 meters. The GPS signals available for civil users are degraded SIS due security reason. However, it is estimated that GLONASS signal can be manipulated in a similar fashion. It is available as intended for civil users. It should also be borne in mind that a satellite fix in space is an ellipsoid in which the vertical axis of error is almost 50% larger than the horizontal axis error.

There are three type of navigation system:

1. Supplementary Navigation System – This system must meet the precision and integrity requirements but not the availability and continuity requirement.

2. Primary Navigation System – This system must meet the precision and integrity requirements on approval for a given operation of flight phase but not the availability and continuity. Safety is achieved by limiting flights to specific periods of time and establishing certain procedural restrictions.

3. Sole Means Navigation System - This system is approved for a given operation or flight phase which must meet, the four navigation system performance requirements i.e. ICAA for that operation of flight phase

The GNSS network, such as GPS or GLONASS, fails to provide ICAA values to allow for its use as the sole means of navigation for all phases of flight. In order to meet operational requirements, augmentation must be applied to basic GPS or GLONASS signals to eliminates the errors. The basic category of augmentation of GNSS signals has to recognize with new adequate words: Global Satellite Augmentation System (GSAS).

4.3. Improvements of Aeronautical Surveillance Systems

Surveillance is the function of providing air traffic information in an operating airspace to ATC operators and pilots to improve their situational awareness. Secondary Surveillance Radar (SSR) is many years employed for this purpose. Thus, the future surveillance systems must support modern operational methods for airspaces and with reduced initial and operational costs.

At this point, the aims of this initiative are to develop the innovative airborne technical performance requirements for surveillance systems that can support conventional and new airspace operation methods, and to implement a measurement method for very low probability numbers such as the integrity, reliability and preciseness of all surveillance information. Whilst Primary and SSR have been the core systems providing Air Traffic Management (ATM) surveillance services for over 30 years, the continuous growth in air traffic has led to a need to enhance these surveillance systems to help support increased airspace capacity, even during very bad weather situation and conditions. Moreover, it has long been recognized that there are parts of airspace where rotating SSR systems are not feasible or are too costly. An emerging technology that may resolve the above issues is Automatic Dependent Surveillance (ADS), as a surveillance technique in which an aircraft transmits onboard data from avionics systems to ground-based and/or airborne receivers. In fact, the data may include: aircraft identity, position, altitude, velocity, and intent.

There are two forms of ADS, such as ADS Contract (ADS-C), also known as ADS Addressed (ADS-A) and RADS Broadcast (RADS-B). ADS-C comprises air-to-ground data transfer. RADS-B comprises air-to-ground and air-to-air (i.e. transmitted from one aircraft and received by another) data transfer. Thus, an AD is seen as being a key element in the surveillance infrastructure worldwide. Feasibility, safety, cost-effectiveness studies and planning for operational use of ADS systems worldwide shall therefore be carried out.

This new system involves the transition from voice reports (based on inertial position) to automatic digital reports. The application is known as ADS-C (Automatic Dependent Surveillance - Contract). In this system, an Air Traffic Controller can set up a contract with the airplane navigational system to automatically send a position report on a specified periodic basis (such as every 5 minutes). The controller can also set up deviation contracts, which would automatically send a position, report if a certain lateral deviation was exceeded. These contracts are set up between ATC and the aircraft systems. The flight crew has no workload associated with this set up.

The RADS-B system is a system that uses transmissions from aircraft, approximately once a second, to provide position, altitude, positional integrity, flight identity, 24-bit aircraft address, velocity and other data that have been detected and computed by onboard aircraft sensors. Typically, the airborne position sensor is a GNSS receiver, or the GNSS output of a Multi-Mode Receiver (MMR). Thus, an RADS-B ground station uses a non-rotating omni-directional antenna to receive messages transmitted by the surveyed aircraft. This mode is designed as a multiple use surveillance technique for aerodrome surface, terminal, en-route airspace, and is applicable to both ATC and aircraft-to-aircraft surveillance. In the other words, surveillance is the eye of the ATC. For effective ATC to be possible, people or systems on the ground must know the position of the aircraft on a continuous basis and be able to estimate their future position. In any rate, surveillance provides the controller with the information necessary to insure specified separation between aircraft, to manage the airspace efficiently and to assist the pilot in the navigation.

5. Alternative Aeronautical Satellite GADSS Solutions

The satellite CNS segment is more important than all other avionic techniques and devices. The particulars about satellite CNS will be here explained the following important systems: Satellite Data Link (SDL), GNSS Augmentation SDL (GASDL), Global Aircraft Tracking (GAT) and Satellite Automatic Dependent Surveillance, which can be integrators in future GADSS network.

5.1. 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 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.

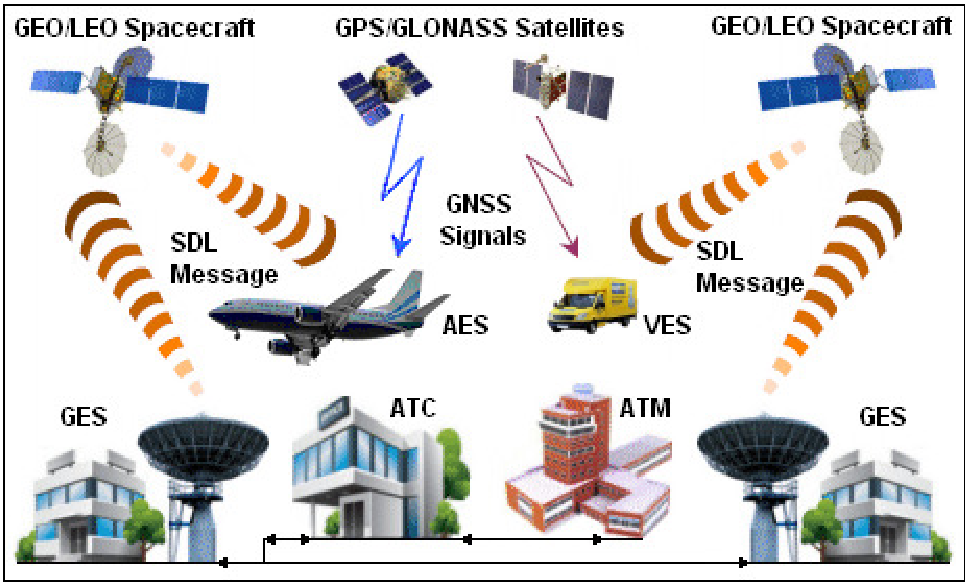

Figure 4. Aeronautical SDL System – Source: Ilcev

The SDL network is a part of total aeronautical communication systems and solutions for providing the following services:

1. SDL Tracking Messages Service – The concept of this 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 4.** 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. 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.

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

The RSAS network infrastructure, as a part of GSAS infrastructure is a combination of ground and space equipment to provide augmentation of standard GPS or GLONASS signals, which is illustrated in **Figure 5**.

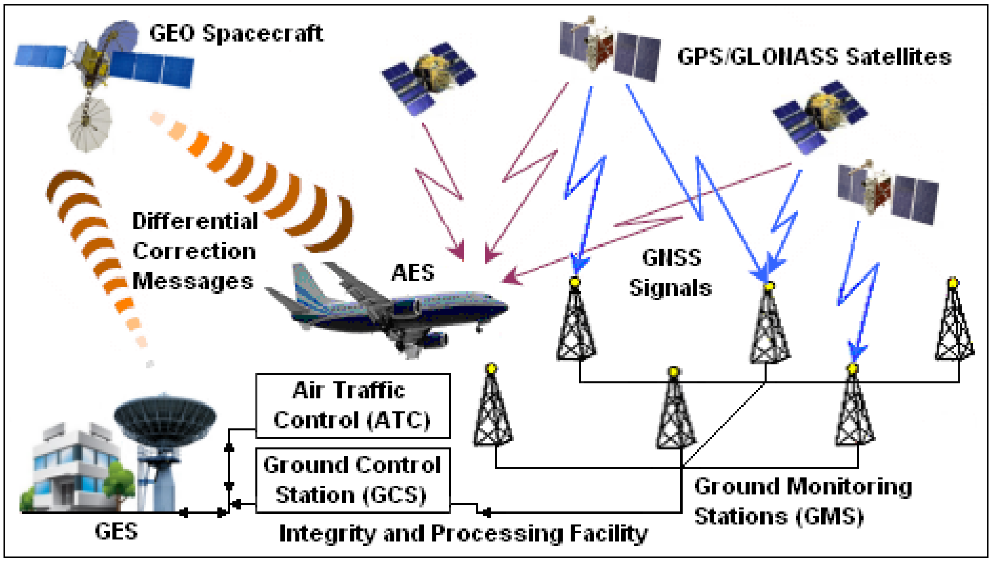

Figure 5. Aeronautical GASDL System – Source: Ilcev

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), shown in **Figure 5** are receiving not augmented signals of 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, GCS 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. 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 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 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 system or even voice to ATC and ATM grpound centres via Inmarsat GES terminal. Finally, these GNSS 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.

5.3. Aeronautical Global Aircraft Tracking (GAT) Network

The Long Range Identification and Tracking (LRIT) is new compulsory system onboard ships established by IMO on 19 May 2006, as the best 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 solution and with more convenient designation than LRIT. 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 unique project known as Global Aircraft Tracking (GAT). This project is the best and only solution for aircraft tracking in real time and space, which diagram is depicted in **Figure 6.**

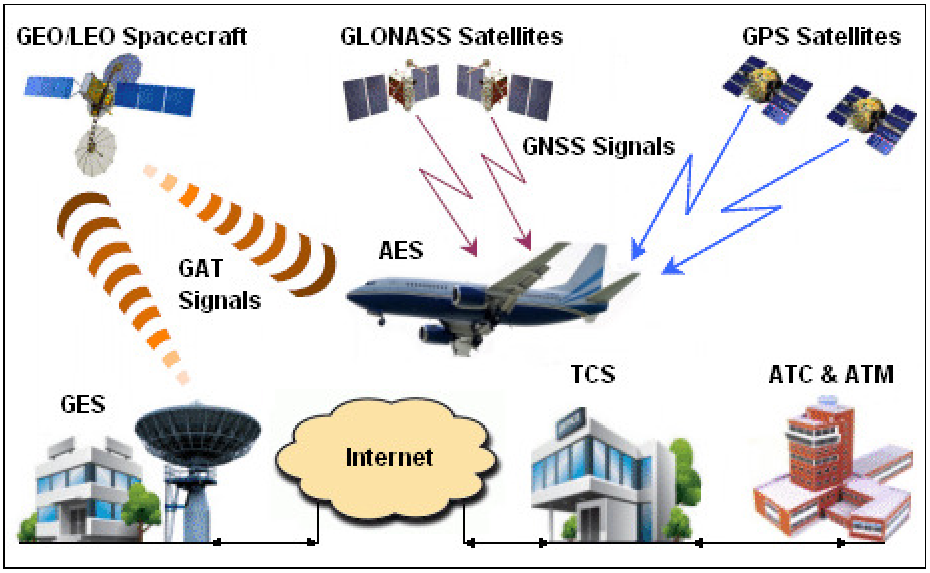

Figure 6. Aeronautical GAT System – Source: Ilcev

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 data to Tracking Control Station (TCS) via GES and Internet, which infrastructure is illustrated in **Figure 6.** The TSC unit is connected to ATC and ATM terminals for eventual coordination in SAR scenario, tracking and collision avoidance. At this point, 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. The 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 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. Thus, in the future is not acceptable to have situation similar as Air France and Malaysian aircraft anymore.

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

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 units, 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.

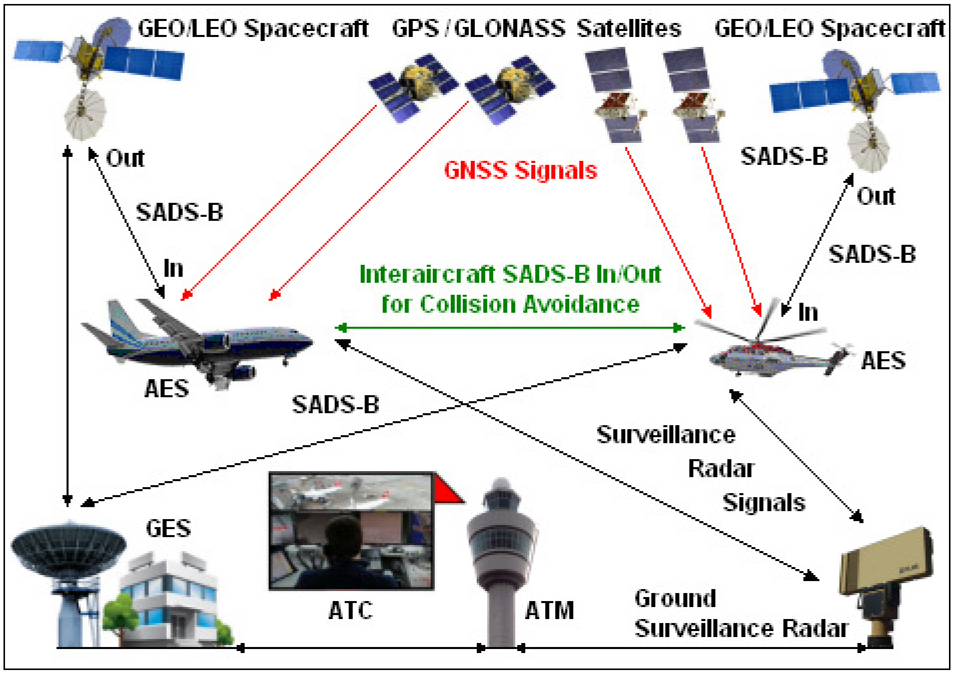

Figure 7. Aeronautical SADS-B System for GASDL Network – Source: Ilcev

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 data and to transmit 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. The GAT unit can be installed in any small or different longhoul jets and 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 and interfaced to onboard powers supply. The Space Science Centre (SSC) leaded by author of this book has complete GAT installation for a trial, looking for interested companies and individuals for collaboration.

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

The Aeronautical Satellite Automatic Dependent Surveillance - Broadcast (SADS-B) 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 system is a 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 to aircraft in intercontinental flight PVT, ID, altitude 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 illustrated in **Figure 7.** The SADS-B 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 satellite navigation 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.

6. 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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