



WORKING PAPER

MULTIDISCIPLINARY MEETING REGARDING GLOBAL TRACKING

Montréal, 12 to 13 May 2014

Agenda Item 3: Explore the potential for strengthening ICAO provisions

USE OF SELF-ORGANIZING AIRBORNE NETWORKS TO MONITOR COMMERCIAL AIRCRAFT GLOBALLY

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SUMMARY

Actually, any internet connection can be used to provide global tracking of an internet connected device when this device informs of its geositions. The most important that the internet is a self-reserved network by physical nature. The similar approach in principle could be applied for the Global Tracking of civil aircraft and for other CNS/ATM applications by means of self-organizing airborne networks. This working paper briefly describes basic principles of self-organizing airborne networks deployment, as well as a potential goodness of this technical solution, which could be used as one of the elements of a Global Tracking system for civil aviation aircraft.

Action: Proposed actions by the Meeting are in paragraph 5.

1. INTRODUCTION

1.1 The recent accident with MH 370 flight shows the need of global tracking of airline flights. One of the subjects for consideration is what technologies have been already developed or could be developed by industry and might be acceptably proposed for this goal currently and in some future.

1.2 Due to “oceanic” nature of MH 370 case and its remoteness from routine ATC surveillance facilities, the first what come to mind is to use satellite communications data links (SatCom). Such proposals are rather universal and in principle, they might not depend on technical solutions performing the current delivery of information from aircraft to ATC and airline. Similar communications between aircraft and airline and/or ATC is actually oriented to loneliness of aircraft in some airspace. Being dependable on the type of airspace sometimes this solution might be appropriate and the only possible. However, this “monopoly solution” is characterized by set of disadvantages first of all due to requirement to install airborne expensive equipment, which will be used not always cost effectively. In the aircraft loneliness in airspace such solution will be reasonable but made to some extent mandatory for

all commercial aircraft how it will look for ATM flows over Atlantic? Let's consider the next analogy. Let's imagine some police department performs an operation and police men instead of use of compact handheld and effective walkie-talkie are communicating with each other and with the boss through expensive and bulky SatCom user units. Every aircraft flying in the column over Atlantic as well as in any remote areas is communicating with airline through space. Potential capability of sharing information via communicating aircraft with each other and with airline and/or ATC through the chain of aircraft is not considered.

2. **A BACKUP SOLUTION FOR AIRCRAFT'S TRAFFIC INFORMATION EXCHANGE IN THE "BEYOND RADIO LINE OF SIGHT" CONDITIONS**

2.1 In the Attachment A to State Letter AN 11/1.1.29-IND/14/4 there is a question should tracking systems be independent of other aircraft systems and/or systems used for ATC surveillance. At the same time, in ICAO's Questionnaire on Technology for Tracking Flights Globally we see typical requirements for surveillance under SSR or ADS-B. The content of information through use of SSR or ADS-B satisfies all aviation community and the subject of consideration should not be an independence of other aircraft systems and/or systems used for ATC surveillance, but how to transmit this information through reliable ways under BRLOS (Beyond Radio Line Of Sight) conditions. Tracking systems must be not independent, but should complement existing airborne systems solving surveillance task under BRLOS conditions.

2.2 NextGen and SESAR consider ADS-B as mandatory backbone of future air navigation systems. In our opinion, ADS-B should be mandatory not only from ATM point of view but also (and maybe primarily) from security point of view. Regardless of there are or not ground or airborne users that could receive ADS-B messages every aircraft should be equipped with ADS-B and permanently send ADS-B messages. SSR and ADS-B transponders shall be a non-switchable-off like an emergency radio. For people on board (either pilots or hijackers) to switch SSR and ADS-B transponders off must be equivalent to dismount more than a half of aircraft, it should be physically impossible (now it is possible to do with a small set of simple operations), airframe designers like Boeing and Airbus should take care of it. All people hijackers and dishonest pilots including should know that under ADS-B all movements of aircraft are always accompanied by sending information on this movement in broadcast mode to all possible receivers of this information. It is not technical requirement to tracking equipment; it should be ICAO regulatory requirement to aircraft from security and ATM points of view. SSR and ADS-B transponders might not work properly due to different technical reasons but all should know some technical failure happened, and technical solutions (backing-up, bypass and others) must be used to prevent or compensate similar failures. So let's imagine every aircraft mandatorily sends ADS-B messages, which content satisfy the task of global monitoring. How technically to project this capability to monitor aircraft globally?

2.3 If aircraft has possibility to respond to ATC facility with the help of non-switchable SSR transponder within Radio Line Of Sight (RLOS) or using non-switchable ADS-B transponder to send ADS-B message that under RLOS conditions is received by some ATC ADS-B ground station the task to monitor aircraft under these conditions is solved. Within BRLOS as it was mentioned it is possible to use SatCom data link.

2.4 Currently the solution to use high-orbit geostationary Inmarsat satellites is actively promoted. It will demand installation of special expensive airborne equipment. If this equipage will be determined by ICAO as mandatory for all commercial aviation then taking into account mandatory non-switchable SSR or ADS-B it might happen that airborne SatCom equipment will be used effectively only for non-remarkable part of time or not to be used at all.

2.5 In the light of use of airborne equipment, the joint NavCanada and Iridium project with low-orbit satellites looks rather prospective. Full low-orbit Iridium constellation of the second generation is going to be launched in 2017. After that aircraft equipped with regular ADS-B based on 1090 ES data link will be able to send ADS-B messages to Iridium satellites. Then these ADS-B messages through link between Iridium satellites will be directed to the ground hub and then to concerned customers. The project is attractive because no need in airborne equipment exists; only regular ADS-B Out transponders are used. The key issue is provision of global satellite coverage for surveillance and its cost for airlines. Russian Federation carries out the similar project with use also of Russian satellites “Gonets”, besides “Inmarsat” satellites.

3. SELF-ORGANIZING AIRBORNE NETWORKS

3.1 There is one more approach to inform airlines and ATC of positions, status and other data of aircraft with the help of self-organizing airborne networks (SOAN). SOAN idea was supported by 12-th Air Navigation Conference (Recommendation 1/10) and 38th ICAO Assembly. After the 38th Assembly session Air Navigation Commission “reviewed A38-WP/337, presented by the Russian Federation, which provided information on the Russian Federation’s concept of the use of self-organizing airborne networks to support integration of remotely piloted aircraft into civil controlled airspace. The Commission noted the potential benefits of the concept and the relationship to AN-Conf/12 Recommendation 1/10, Automatic dependent surveillance – self-organizing wireless data networks. The Commission requested that the ICAO Council study the proposal as part of the next revision of the Global Air Navigation Plan” [A38-WP/399 TE/176 30/9/13]. The brief technical description and requirements to SOAN are given in the Appendix of this paper.

3.2 The essence of proposal to use SOAN for global tracking is the following.

3.3 There are regions in the world where direct surveillance of aircraft by ground surveillance means is impossible due to BRLOS conditions. It concerns the flights not only in oceanic airspace but, for instance, to flights over some Siberian areas. Typically, the absence of surveillance takes place in the area with radius more than 400 km for flights on the altitude of 10 km. At the same time, it is hard to believe that at present in such a zone aircraft will fly alone for a long time. If some aircraft are flying in some vicinity of each other SOAN will promote self-organizing exchange of information including storing of all information on board of every aircraft.

3.4 All equipped aircraft in direct radio access form a common “cloud” with internetwork exchange rules. If just one aircraft of the cloud has got an access to ATC system, information of each aircraft from the cloud becomes available to ATC system with minimum delays. In its turn each aircraft from the cloud may timely receive necessary instructions or other information from ATC system. Two-way exchange of information (from aircraft to ATC and from ATC to aircraft) via airborne network allows to implement both applications based on surveillance like ADS-B Out/ADS-B In/TIS-B/A-SMGCS/search and rescue according to the latest ADS-B message and whole range of services based on two-way FIS-B (operative weather, D-AIM, SWIM, wake turbulence safety, CPDLC, AOC, etc), DGNSS navigation, etc.

3.5 Calculations for air traffic with MH 370 showed that availability of SOAN under mandatory ADS-B functioning would remarkably improve the level of information awareness of MH 370 positions. The last ADS-B message would point the location of the crash with high accuracy.

3.6 It is proposed to use two modes of SOAN functioning to monitor aircraft globally. The first one concerns routine tracking of ADS-B messages when all aircraft systems work without failures and aircraft is moving in accordance with declared flight plan. If needed the second emergency mode is

used; in this case, the network provides for its resource as much as possible to the aircraft being undergone with failures. It looks the emergency network frequency should be allocated worldwide by ICAO; the issue should be investigated might global emergency VHF frequency be used for that.

4. USE OF LOW-ORBIT SATELLITES LIKE “IRIDIUM” OR “GONETS (RUSSIA)”

4.1 Even equipped with SOAN transponder on board an aircraft will have no access to the cloud or to ATC if it has no radio access to any aircraft in the cloud or directly to ATC. For such a “lonely” aircraft when within about 400 km radius there are no other aircraft we study the following. Aircraft signals of ADS-B Out type, either 1090 MHz extended squitter signals (for Iridium and Gonets) or VDL-4 signals in airborne VHF range (for Gonets), enter low-orbit satellites like Iridium or Gonets, then these signals are relayed to ground receiving hub and further via ground links are delivered to concerned users – airline and ATC. Signals delays with the use of low-orbit satellites are minimized. The chain “lonely aircraft – satellite – ground station – ATC” becomes kind of a node of an air-space network with one-way direction of information. No additional on-board equipment is necessary here, except some software development to ADS-B transponder to provide network capabilities. While achieving radio access to aircraft from a cloud that has been “lonely” earlier, the aircraft enters airborne network and servicing via satellite is terminated thus minimizing the satellite link loading.

4.2 Russian Federation has organized works on the creation of a satellite system for maritime surveillance using Automatic Identification System (AIS) with VHF radio channel and for aircraft surveillance using ADS-B systems based both on 1090 ES and VDL-4. AIS and VDL-4 transponders are based on common technology of self-organizing time division multiple access (STDMA). In 2014 Russian Federation will launch its first satellite with AIS receiver on board, in the nearest years there will be executed launches aimed on VDL-4 ADS-B implementation.

4.3 GosNIIAS is developing the airborne transponder performing ADS-B and other functions mentioned above with network capabilities. The mass of the unit is within 300 g, expected terms of test flights – the first half of 2015.

5. ACTION BY THE MEETING

5.1 The meeting is invited to:

- a) to consider mandatory use of non-switchable-off SSR and ADS-B transponders for civil aviation aircraft; to commit ASP to develop regulatory documents concerning non-switchable-off SSR and ADS-B transponders; and
- a) to consider self-organizing airborne network approach as one of directions of solving the task to monitor civil aircraft globally; to propose industry to investigate the possibility to develop corresponding equipment with network capabilities, particularly within ADS-B transponders; after that to carry out full-scale test flights to confirm the effectiveness of self-organizing airborne network approach as one of the elements of a Global Tracking system for civil aviation aircraft.

APPENDIX

REQUIREMENTS TO SELF-ORGANIZING AIRBORNE NETWORK

1. Main self-organizing airborne network (A-network) function is to provide for the data exchange between objects within ordinary radio access area. Such objects include any manned and unmanned aircraft, moving and fixed ground and sea facilities with transmitters/receivers equipped with hardware/software to perform functions of switched network nodes.
2. All A-network objects are referenced with geographical coordinates and with time e.g., by GNSS. Ordinary radio access area is an area where every object has got a radio access to one neighboring object at least.
3. Data is being exchanged in a batch mode. All information circulating in the network is available to all users (nodes). If necessary, every user may send data to another one in point-to-point mode. If there is no direct radio access between objects, the information is transmitted (relayed) via other objects.
4. To estimate the authenticity of signals, reveal natural interferences and artificial false simulated signals and their discard, subsequent use in “detect and avoid” system, the time of every batch sending is referenced with the time scale, this time is input in the batch message. The time of the signal arrival with the user is determined at its reception. The difference between the signal sending and reception allows to calculate the distance between the sender and the receiver.
5. Routing and batch switching functions are delegated to the network hardware/software which supplies protocols of interaction coordination, search for assigned objects, provision and integrity monitoring of batches.
6. For the case when all network nodes apply one and the same radio frequency to send and receive messages, the node should store all received messages till sending them. Management of the network operation should provide for the minimization of the data store period in all nodes participating in the relay chain to deliver data to necessary user.
7. Another approach is available when each transponder uses simultaneously two frequencies. Receiving a message on one frequency a transponder immediately without any delay is transmitting this message on another frequency if needed. So there is no delay in the A-network to send and to get data.
8. A-network is built on a self-organizing principle; it stores and regularly updates the network map which includes:
 - a) current architecture of the network – space graph whose nodes are defined by geographical coordinates and available for the connection of objects and their interaction;
 - b) table of distances between objects calculated on their geographical coordinates;

- c) table of distances between objects calculated on measured time value of the signal propagation between objects;
 - d) table of obvious discrepancies in distances determined from coordinates and propagation time;
 - e) table of communication channel throughput between objects; and
 - f) database of the locality and obstacles to forecast boundaries of the direct radio access area.
9. Network addresses (numbers) of objects with geographical, time and network references are known to all network objects.
10. A-network provides for following additional telecommunications functions:
- a) search for an object in the A-network. When it is necessary to transmit information to a certain object the “storm” principle may be applied, that is to send a broadcasted request protected from re-broadcasting in the same link between nodes;
 - b) message priorities are defined/assigned according to the to delivery time) messages are forwarded according to the minimum number of relay stations contents. Messages may be routed both manually and automatically depending on their rating. Urgent (or critical. Messages demanding for increased authenticity are forwarded along the shortest possible routes with the highest stability to interferences. Routing of messages not demanding for special attention is performed with the aim to decrease the throughput losses in channels between nodes;
 - c) ability to store information received beforehand from other objects when aircraft is beyond A-network, and deliver it to the network within the access area (mail service); and
 - d) protection of transmitted information from unauthorized access, replacement, interception, insertion of false information with the aim to check the authenticity of messages.

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