SATELLITE BASED ADS-B FOR COMMERCIAL SPACE FLIGHT OPERATIONS

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ABSTRACT

The steadily increasing air traffic and commercial space traffic in particular on transcontinental routes or suborbital operations requires to extend the controlled airspace to those regions not yet covered by ground based surveillance. An ADS-B system with a strong focus on space-based ADS-B can provide global and continuous air and space surveillance to enhance the operation of spacecraft and spaceplanes in transit through the US National Airspace System (NAS) and Single European Sky (SESAR) and above. Such a system can overcome the prevailing surveillance constraints in non-radar airspace (NRA). The limitations of the different ADS-B systems will be discussed within the requirements for international operations. They have an influence on the performance requirements for Sat based ADS-B to allow minimized separation in NRA together with an impact on prevailing processes and flight safety standards for the integration of commercial space flight operations in the Air Traffic Management (ATM). Further, integration of the data to the information exchange concept of the System Wide Information System (SWIM) is proposed. Using a SWIM based service, spacecraft and spaceplanes can be integrated safely in the NAS/SESAR and in the worldwide system. Also applications for spacecraft tracking close to low earth orbits (LEO) during launch and reentry operation will be possible.paper should begin with an abstract not exceeding 300 words. It should describe the contents of the paper, including the topics, the facts, and the conclusions. It should provide a self-contained summary that does not require the reader to have seen the main text in order to understand. The abstract does not have to be identical to the one submitted during the call for papers, but it must adhere to the same topic for discussion proposed earlier.

INTRODUCTION

To briefly summarize the current development of commercial space transportation (CST), the core assumption is that commercialization in space will lead to reduced costs and an increased number of operations. This is already reflected by the number of commercial launches from the USA, which has significantly increased over the past decade [1]:

- Commercial launches prior 2008 totalling max. 5/year
- Commercial launches in 2014 = 23, 2017 = 33

As interest in the emerging market of commercial space operations grows, so too does the number of commercial launch sites (so called spaceports) is as well growing on a global level. In 2017 there are already 19 active U.S. governmental and commercial launch and reentry sites, of which 10 are licensed commercial launch sites, with 3 additional non-licensed sites. In addition, 16 non-US orbital launch sites are in operation worldwide [1]. The United Kingdom has recently announced the location of its first spaceport on the Sutherland peninsula in Scotland and explores building additional spaceports elsewhere in the UK, including Cornwall, Argyll and Wales [X1]. Worldwide, additional sites are under consideration or even evaluation, e.g. in Italy, Spain (Lleida Alguaire/Barcelona), Singapore, Curacao, and Germany.

Therefore, the CST industry does and will continue to affect European as well as the US National Airspace (NAS).

In order to integrate CST in the current Air Traffic Management System (ATM) a dynamic system for the separation of the airspace has to be implemented and shall also be used for space vehicles (SVs). A surveillance concept which also overcomes the constraints in non-radar airspace (NRA) has to be introduced. A system based on Automatic Dependent Surveillance-Broadcast (ADS-B) has been proposed [2].

ADS-B

ADS-B implemented in modern Mode-S transponders on board aircraft transmits periodically the flight position and other information by Extended Squitter messages (1090ES) on the 1090 MHz SSR-Mode-S downlink frequency (ADS-B Out). Another data link technology providing ADS-B is Universal Access Transceiver (UAT), which is operating at 978 MHz, but which is used within the US NAS only. The European ADS-B Mandate requires that all aircraft heavier than 5700 kg or faster than 250 knots have to be equipped with ADS-B-Out from 2020 on. In 2020 ADS-B surveillance shall become fully operational. Similar regulations exist for some Asian regions and the U.S., whilst in Australia ADS-B-Out was required from end of 2012 on. On the other hand most regions of the world are uncontrolled airspace, since in oceanic, polar or mountainous regions or underdeveloped continental areas the installation of ground based surveillance systems is either technically or economically impossible. In these so-called Non-Radar Airspaces (NRA) surveillance is applied procedurally, which means that the pilot issues position reports via aircraft radio when certain waypoints have been reached. Modern aircraft are also equipped with ADS-C (Automatic Dependent Surveillance–Contract), a point-to-point data link connection based on FANS1/A equipment and Satcom or HFDL data link. Due to limited bandwidth and service costs the system transmits the flight position and other information only every 15 minutes. In both cases no seamless and continuous flight surveillance is possible, with the consequence of separation distances of 50 – 80 NM due to safety reasons. [3, 4]

As ADS-B receiving ground stations are less complex and costly than radar stations, they will complement or even replace radar stations in the future, being integrated in the existing surveillance infrastructure.

SATELLITE BASED ADS-B

A Since 2008 the German Aerospace Center (DLR) started to prove that 1090ES ADS-B signals broadcasted by aircraft can be received on board of low earth orbiting (LEO) satellites. This was validated in 2013 by world's first in-orbit demonstration (IOD) of a space based ADS-B system, hosted on the ESA satellite PROBA-V [3, 4].

Fig. 1. Proba-V-Satellite. Source: www.esa.int

The experiment was conducted in the frame of ESA's PROBA-V mission (PROBA Vegetation) and was successfully launched by Europe's newest launcher VEGA on 7th of May 2013 at 04:06:31 CEST from the European spaceport Centre Spatial Guyanese (CSG) in French Guyana.

The IOD is capable to receive, decode and forward all Mode S downlink telegram formats. This includes the DF17 Extended Squitter comprising ADS-B information and DF11Short Squitter. The ADS-B over Satellite was the first experiment of its kind and a first step for demonstration and verification of space based air traffic surveillance. The functional principle of space based ADS-B is shown in Fig. 2. A typical detection pattern of the satellite can be seen in Fig. 3.

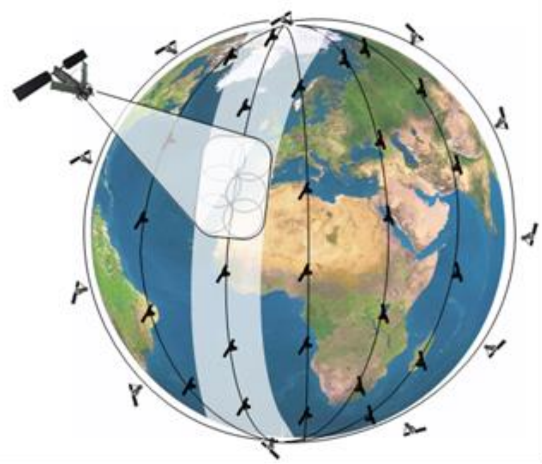

Fig. 2. Principle of satellite based ADS-B.

Fig. 3. Example Detection pattern of DLR's in orbit demonstrator with in one track
(no accumulation over concurrent tracks) [X1].

Fig 4 shows the tracks of aircraft flying over north America in the direction to the oceanic route to Europe. Clearly can be seen, that tracking of aircraft in higher altitude is feasible using a space base ADS-B system. Fig. 5

shows the SAT-ADS-B tracks of aircraft close to Singapore airport. In Fig. 6, the position of a detected high altitude balloon can be seen.

The examples are a good demonstration of the capability of SAT-ADS-B to track on a global as well as on local scale with the same system.

Fig. 4. Aircraft tracks near and over the Hudson Bay [X1].

Fig. 5. Tracking of aircraft at the the final of Singapore Changi Airport (ICAO Code WSSS) [X1].

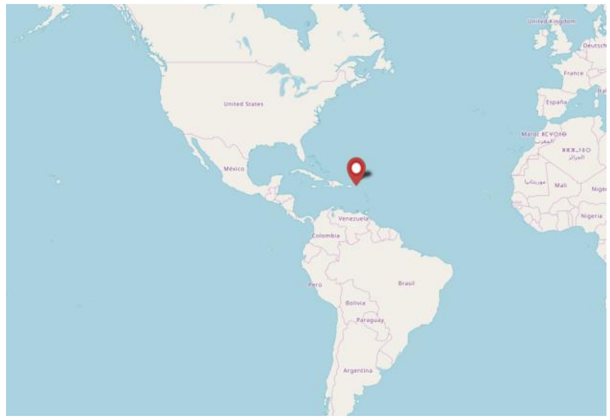

Fig. 6. High altitude balloon detect by ADS-B from space. Altitude 48,770 ft [X1].

LIMITATIONS

Until today, most ADS-B systems commercially available use GPS data for position data input of the aircraft. However, it is to be known, that in GPS technology, the so known COCOM limits are most likely implemented. This refers to a limit placed on GPS tracking devices that disables tracking when the device calculates that it is moving faster than 1,000 knots (1,900 km/h) at an altitude higher than 18,000 m (59,000 ft). This was intended to prevent the use of GPS in intercontinental ballistic missile-like applications. The rules are still valid under ITAR. [6] Some manufacturers apply this limit only when both speed and altitude limits are reached, while other manufacturers disable tracking when either limit is reached. In the latter case, this causes some devices to refuse to operate in very high altitude balloons.

The ADS-B data format, ES as well as UAT have a maximum altitude to be included into the messages of 101,337.5 ft. [2]. New message types or encodings must be developed in order to allow the broadcast of higher altitude information.

INTERNATIONAL INTEGRATION

Space vehicle operation has to become an integrated part of Air Traffic Management. The nature of space flight and its comparably lower target level of safety compared to commercial air traffic is specifically challenging for such integration. The introduction of trajectory based operations under the regimes of the Single European Sky Air Traffic Management Research (SESAR) and the U.S. Next Generation Air Transportation System (NextGen) can be utilized to address these challenges, as prototypical solutions for a SWIM based integration of space vehicle operations have demonstrated, including a technical setup to achieve interoperability between SESAR and NextGen and a European / U.S. harmonization. To address specific questions concerning the impact of space vehicle operations to certain air traffic regions and to validate the concepts and technologies to mitigate these impacts, a Space and ATM Operational testbed as well as a traffic impact analysis framework has been developed and established [7, 8].

The trajectory information of the space vehicles as well as of the other airspace users has to be exchanged via an integrated system wide information platform (SWIM). This will provide the information of the trajectory utilization as well as a provision of the data in a worldwide secured system. A special system was developed to integrate the Space-ADS-B data. [Fig. 7 - Fig. 8].

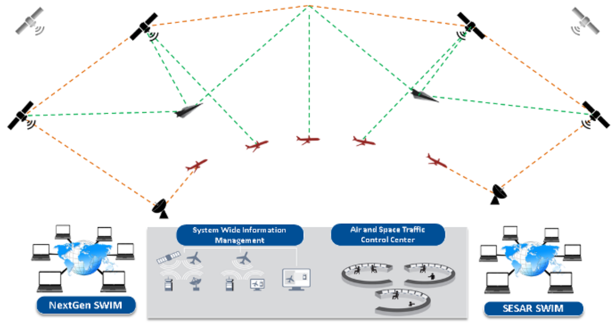

Fig. 7. International data exchange of SAT-ADS-B data via SWIM.

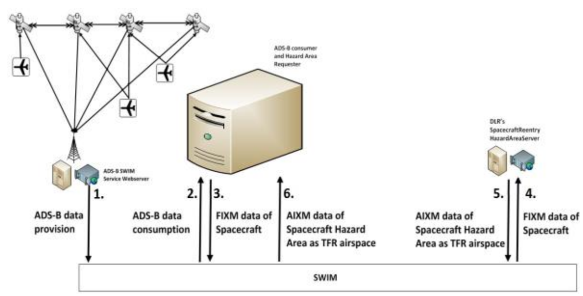

Fig. 8. SWIM system for worldwide provision and consumption of trajectory and hazard zone data using SAT-ADS-B

CONCLUSIONS

DLR's in orbit demonstrator is receiving SAT-ADS B data in space in a reliable manner. Data analysis shows, that SAT-ADS-B can be used to track space vehicle operations on a world wide scale. The data can be incorporated in an interconnected SWIM system. Further work on regulatory, legal (ITAR) and standardisation matters will be necessary.

ACKNOWLEDGEMENTS

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