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Use of mobile-satellite service systems for flight tracking

M Series

Mobile, radiodetermination, amateur and related satellite services

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***Note**: This ITU-R Report was approved in English by the Study Group under the procedure detailed in Resolution ITU-R 1.*

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REPORT ITU-R M.2396-0

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(2016)

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1 Introduction

This Report describes the use of systems operating in the mobile-satellite service (MSS) to provide automatic dependent surveillance (ADS). Two different approaches for the provision of ADS are described in this Report: "Automatic Dependent Surveillance-Contract (ADS-C)" and the "MSS-satellite-retransmitted Automatic Dependent Surveillance-Broadcast (MSS ADS-B)".

Beyond the traditional form of primary radar surveillance of aircraft, ground based interrogator and aircraft transponder systems are employed which provide air navigation service providers (ANSP) with aircraft information such as identity, altitude, speed, heading, etc. These systems are known as secondary surveillance radar (SSR), and are extensively used worldwide.

Automatic Dependent Surveillance (ADS) is a cooperative surveillance technique to enhance the tracking and location of aircraft in flight. With ADS, aircraft automatically provide via a data link, data derived from on-board navigation and position-fixing systems. This could include aircraft identification, four-dimensional position (latitude, longitude, altitude, time), velocity of the aircraft, intent of the flight (such as the predicted route and other information) and additional data as appropriate. The term "Dependent" refers to the fact that the aircraft itself must originate and transmit the situational information.

The following ADS system types have been standardized within ICAO[1], each of which has one or more potential delivery mechanisms:

ADS-Broadcast (ADS-B): A means by which aircraft, aerodrome vehicles and other objects can automatically transmit and/or receive data such as identification, position and additional data, as appropriate, in a broadcast mode via a data link[2].

ADS-Contract (ADS-C): A means by which the terms of an ADS-C agreement will be exchanged between the ground system and the aircraft, via a data link, specifying under what conditions ADS-C reports would be initiated, and what data would be contained in the reports[3].

ADS-B involves the transmission of an aircraft's own situational information to other aircraft, ANSP and/or aircraft operators. These ADS-B systems have a number of important safety features, including greatly increased accuracy compared to other forms of surveillance technologies and a very high (1-2 seconds) rate of updating. Terrestrial ADS-B receivers are being deployed by many Administrations to complement surveillance radars currently used for air traffic control, facilitating 3-5 nautical mile separation between aircraft. Several administrations have mandated ADS-B equipage by 2020. However, despite the growing number of ADS-B equipped aircraft and deployed ground-based receivers, the majority of the world's airspace is currently without ADS-B surveillance capability since the unserved areas are beyond line-of-sight from terrestrial ADS-B ground based receivers. WRC-15 allocated the frequency band 1 087.7-1 092.3 MHz to the AMS(R)S for the purpose of satellite reception of ADS-B signals. Satellite constellations providing worldwide reception of ADS-B data using that frequency band and then relaying that data to the ground are considered in a separate document.

ADS-C involves the use of point-to-point communication channels to transmit aircraft situational information to an ANSP or to an aircraft operator. ADS-C is used to provide surveillance capability and other information and has been a part of the Future Air Navigation System (FANS) service since the early 1990s.

2 MSS and AMS(R)S allocations

Currently, several MSS systems provide or are planning to provide ADS-C or MSS-satellite-retransmitted ADS-B service over their networks.

ICAO has already indicated that they consider ADS-C to carry safety information, and that therefore use of AMS(R)S frequencies would be appropriate for this application.

Certain other MSS frequency bands are also being considered for the provision of this application but currently the arrangements have not been finalized.

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[1] The ICAO International Standards and Procedures that define and govern the use of ADS-B and ADS-C are contained in Annexes 2, 3, 6, 10, 11 and 15 to the Convention on International Civil Aviation and in ICAO Documents 4444 (Procedures for Air Navigation Services – Air Traffic Management) and 7030 (Regional Supplementary Procedures). Additional guidance material is provided in ICAO Documents 9694 (Manual of Air Traffic Services Data Link Applications), 9871 (Technical Provisions for Mode S Services and Extended Squitter), 9925 (Manual of Aeronautical Mobile-Satellite (Route) Service) and 10037 (Global Operational Data Link Document (GOLD) Manual). References to ADS-B and ADS-C in this document are intended for background and context only.

[2] ICAO Document 4444 – Air Traffic Management Chapter 1 Definitions.

[3] ICAO Document 4444 – Air Traffic Management Chapter 1 Definitions.

MSS feeder links, associated with all the above systems and operating across various frequency ranges including the 4, 5, 6/7, 20 and 30 GHz frequency bands, operate within allocations to the fixed-satellite service (FSS). No change in regulatory status for the feeder link bands is needed and no special protection for the feeder links is required despite the fact that they are carrying safety-related traffic. FSS allocations are currently used for safety services without the need of a special status. The same applies to inter-satellite links where they are used.

Several MSS networks are currently in operation, and provide regional and, in some cases, global coverage. At least one MSS network provides complete global coverage, including the poles.

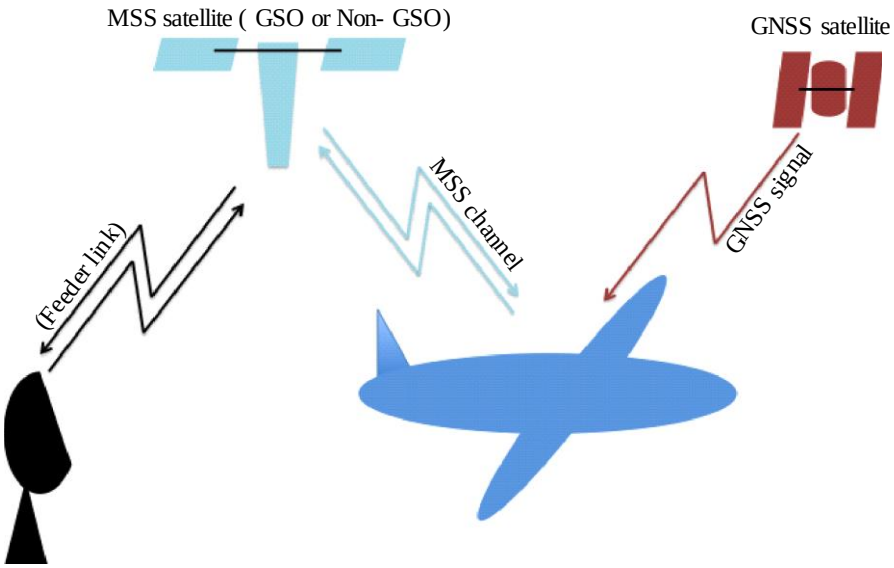
3 Automatic Dependent Surveillance – Contract

ADS-C overview

MSS networks can provide secure and reliable data channels for an ADS-C system with aircraft having been suitably equipped with FANS 1/A ADS-C systems and associated SATCOM terminals (see Fig. 1). ADS-C is a component of the FANS 1/A system[4] and provides active aircraft position tracking to an ANSP for an aircraft, suitably equipped to accommodate FANS 1/A, operating in remote and oceanic airspace, including alerts related to deviation from its planned trajectory.

FIGURE 1

MSS networks providing ADS-C



ADS-C uses various systems on board the aircraft to automatically provide aircraft position (altitude, longitude, and latitude), velocity, predicted route and meteorological data, which can be sent in a report to an ANSP or the airline operations center (AOC) facility ground system for surveillance and route conformance monitoring. The ability for an AOC to receive an ADS-C report in a readable format is enabled through an additional subscription service provided by a participating communications service provider.

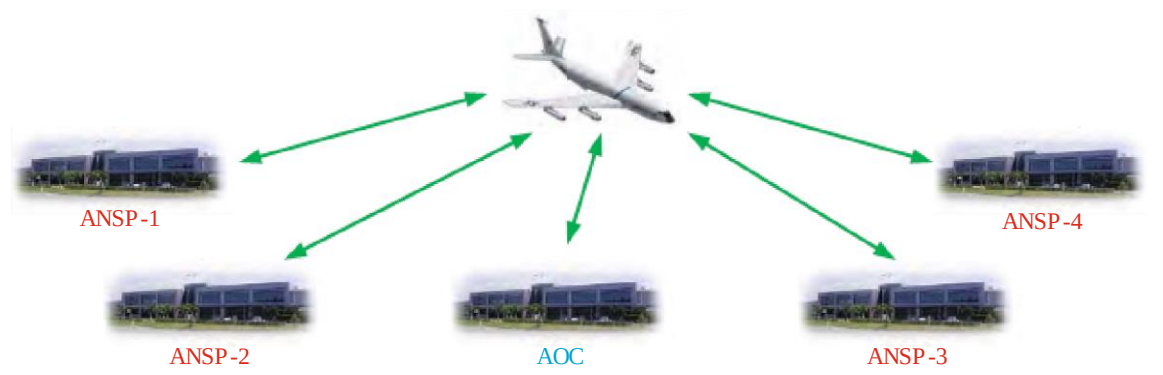
The ANSPs that are able to manage FANS 1/A can establish “contracts” with the aircraft ADS-C function that reports this information at regular intervals or when defined events occur. This

[4] See ICAO Document 10037 (Global Operational Data Link Document (GOLD) Manual).

information is transmitted on point-to-point data links with up to five individual links from one aircraft (see Fig. 2 below). This means the information on a particular contract cannot be accessed by other parties (i.e. other aircraft or other ATM systems). The aircraft operator and ATM provider each establish service agreements with a data link service provider for delivery of the ADS-C messages.

FIGURE 2

Multiple ADS periodic contracts with different ground systems groups (maximum of five contracts)



Reference: Modified from ICAO Global Operational Data Link Document (GOLD), p. 2-61

Information that may be transmitted in ADS-C reports includes, but is not limited to:

– present position (latitude, longitude and altitude) plus time stamp and figure of merit;
– predicted route in terms of next and (next +1) waypoints;
– velocity (ground or air referenced); and
– meteorological data (wind speed, wind direction and temperature).

The ground systems negotiate with airborne systems the conditions under which the aircraft submits the following reports:

– **Periodic report:** The aircraft transmits ADS-C reports at a pre-set regular rate.
– **Event report:** The aircraft transmits ADS-C reports when certain events occur. An event could be, for example, a change in altitude or speed of the aircraft or a lateral or vertical deviation from the planned route. This is independent of any periodic contract in place or pilot action.
– **On-demand report:** The aircraft transmits a single ADS-C report when requested by an ATC controller (or requested by the ATC system). This may be done because an anticipated periodic report that was due to be transmitted by the aircraft did not reach the ANSP at the expected time.

Additionally, only the airborne systems can only establish the following type of report:

– **Emergency report:** A special case of periodic reporting during emergency events which is indicated through instructions received from the flight crew.

Reports received by those ATM systems able to manage FANS 1/A are processed to track the aircraft on displays at the ANSP and used to give the controllers a situation-awareness of the traffic in oceanic and remote airspace. In this case, the controller will apply procedural control. The AOC ground facilities may have access to a similar display, derived from ADS-C reports, through functionality provided by an additional Communications Service Provider (CSP) subscription service. The reporting rate for current oceanic operations is normally about 14 to 25 minutes depending on the

separation standards in use. It is however possible for controllers to increase the reporting rate to support specific operations, with a minimum update rate dependent upon satellite system capabilities.

The capabilities of ADS-C include:

– provision of surveillance in areas where the installation of radar or multilateration systems (MLATs) is not practical;

– reporting of aircraft intent data (e.g. future waypoints), which is useful in avoiding potential air space conflicts; and

– provision of a data link between the aircraft and ground, allowing relevant aircraft data to be sent to flight data processing systems to inform controllers and AOCs.

Work is underway in response to ICAO's proposed increased reporting rate[5], to evaluate increased basic automatic ADS-C periodic reporting rates in normal situations. Separately evaluations are underway to evaluate a five minute reporting rate for individual aircraft in the event of an unexpected situation for the duration of the event until cancelled.

4 MSS-satellite-retransmitted ADS-B

MSS-satellite-retransmitted ADS-B[6] assumes that the aircraft are already equipped with either a 1 090 MHz extended squitter (1090ES) or a 978 MHz universal access transceiver (UAT) transponder (or both) capable of transmitting ICAO approved ADS-B messages. As shown in Figs 3 and 4, using this approach the ADS-B message is also transmitted on an MSS link directly to the appropriate ANSP network. The original content, including the standardized message format, is preserved and transmitted with the same periodicity as the original ADS-B transmission, i.e. twice per second. Thus, the same ADS-B data intended for reception by a terrestrial receiving station, including other aircraft in line-of-sight, is relayed to the ANSP completely through a satellite channel. MSS-satellite-retransmitted ADS-B is currently operating on an experimental basis. MSS-satellite-retransmitted ADS-B could have identical reporting intervals as the terrestrial ADS-B systems.

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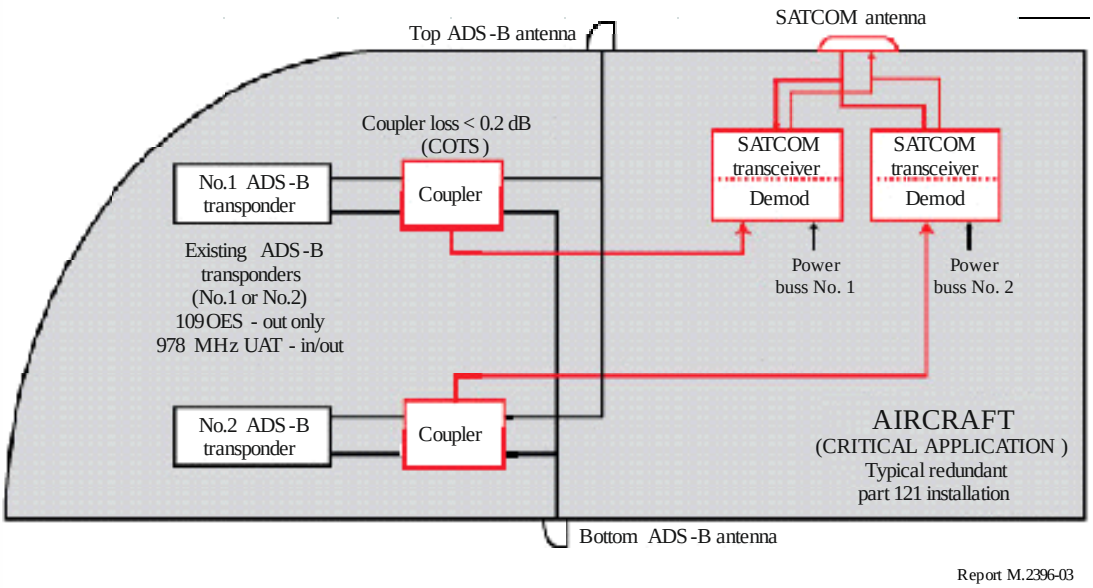
5 See, ICAO Montreal Declaration 2nd High Level Safety Conference (February 2015).

6 The source of the message transmitted by satellite-retransmitted ADS-B is the same as that for the message received by a terrestrial ADS-B receiver, namely, the 1090ES/UAT transponder on board the aircraft. This ICAO standard ADS-B message is then modulated onto a carrier transmitting in the 1 610-1 626.5 MHz MSS band, received by the MSS satellite, transmitted to the ground using the MSS system feeder link and forwarded to the ANSP provider. The same information sent to a terrestrial ADS-B receiver, where coverage is available, is sent via an MSS channel to the ANSP provider, hence the term satellite-retransmitted ADS-B.

FIGURE 3

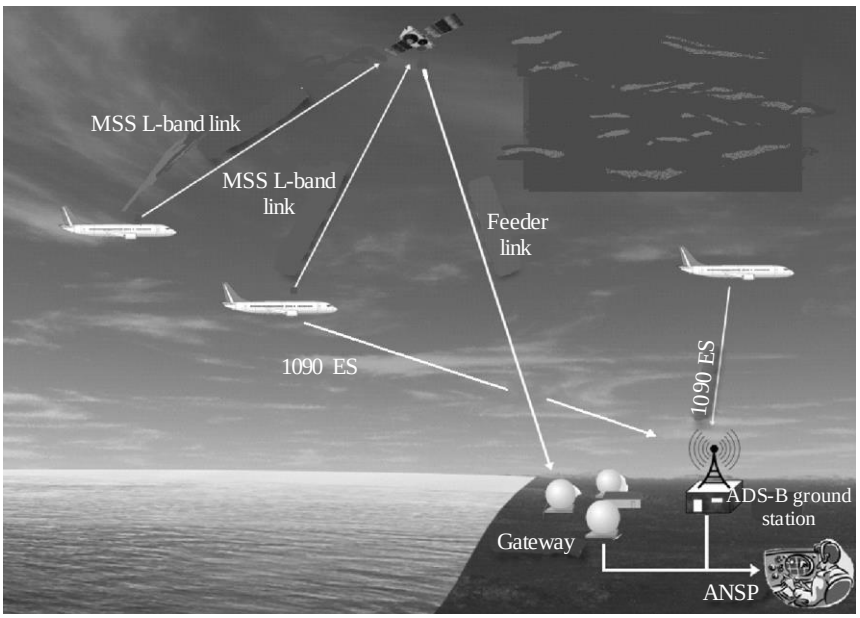
Example diagram of aircraft equipment for MSS-satellite-retransmitted ADS-B



MSS-satellite-retransmitted ADS-B additional equipment is denoted in red.

FIGURE 4

MSS-satellite-retransmitted ADS-B



The MSS-satellite-retransmitted ADS-B concept is based on establishing dedicated MSS links with each aircraft. ADS-B messages are 112 bits in length and are transmitted twice per second using existing MSS modulation, channel bandwidths and bit rates.

The characteristics of mobile-satellite service systems are available from the Space Network List of the Radiocommunication Bureau, in Recommendation ITU-R M.1184 and in the ITU-R mobile-satellite service Handbook.

4.1 Features of MSS-satellite-retransmitted ADS-B

The features of MSS-satellite-retransmitted ADS-B for ANSP application include:

– A dedicated AMS(R)S connection for each aircraft is used to provide a secure air traffic control link for portions of the flight not covered by terrestrial facilities.

– Depending on the configuration of the MSS system, the ANSP may be able to receive its domestic en-route surveillance data within its own borders on its own satellite gateway ground systems.

4.2 Other elements of MSS-satellite-retransmitted ADS-B

For terrestrial ADS-B, an aircraft's messages are deliberately transmitted at a higher than necessary rate to reduce the likelihood of interference from transmissions from other aircraft and to ensure reception of the ADS-B information at the end-user at the desired rate. Since MSS retransmission of ADS-B is provided by giving each aircraft its own MSS channel, the ADS-B information would only need to be provided to the ANSP at the desired rate (i.e. not every ADS-B message would need to be retransmitted).

It should be noted that though the use of dedicated MSS channels per aircraft for the duration of the flight would reduce the number of messages sent to the ANSP, it may still have cost implications for the aircraft operator.

A satellite retransmitted ADS-B system would require sufficient capacity to provide dedicated channels for each aircraft.

As shown in Fig. 4, a non-GSO, bent-pipe satellite constellation relies on availability of strategically positioned feeder link gateway stations around the globe, especially in oceanic and Polar Regions, in order to establish the necessary links to its satellites at all times and then communicate the received ADS-B messages to the ANSPs.