

ANSP Guidelines for Implementing ATS Surveillance Services Using Space-Based ADS-B

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ANSP Guidelines for Implementing ATS Surveillance Services Using Space-Based ADS-B

Foreword

CANSO provides the *ANSP Guidelines for Implementing ATS Surveillance Services Using Space-Based ADS-B* to support Member ANSPs as they consider whether to incorporate space-based automatic dependent surveillance - broadcast (ADS-B) into their air traffic management (ATM) infrastructure. Space-based ADS-B is expected to become available by 2018.

While acknowledging that ATS surveillance systems have been available for decades, and ANSPs have already considered the potential benefits of incorporating ground-based surveillance systems into their infrastructure, the availability of a global ATS surveillance coverage solution was not a possibility until recently. Space-based reception of ADS-B signals (space-based ADS-B) will use existing technologies (satellites, ADS-B transponders and ADS-B receivers) to leverage current capabilities and knowledge to provide global coverage.

A group of CANSO Member experts was formed to develop this practical guidance for ANSPs on how to re-evaluate their ATM infrastructure planning to account for being able to obtain uninterrupted ATS surveillance coverage for the airspace in which they provide services. This document provides background information on ATS surveillance systems and related services, along with pragmatic implementation considerations. Finally, business case guidelines are provided based on the work being undertaken by ANSPs currently analysing the introduction of space-based ADS-B.

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Executive Summary

Air traffic continues to grow, challenging the industry to continuously improve safety and efficiency. Aircraft operators expect improved ATM that provides benefits commensurate with aircraft equipage, certification and training investments. Increased efficiency normally equates to reduced fuel burn and lower greenhouse gas (GHG) emissions. As a result, improving efficiency contributes to international commitments to reduce the environmental impact of the aviation industry.

Space-based ADS-B has the potential to revolutionise air traffic services (ATS) surveillance in the aviation industry. It will enable global ATS surveillance, which provides opportunities to improve safety, efficiency and interoperability between air navigation services providers (ANSP) at the State, regional and global level. At the time of publication, space-based ADS-B systems are not yet operational. Such systems are, however, composed of well-understood technologies (satellites and ADS-B) whose performance can be modelled. It is understood, however, that the demonstrated performance of operational space-based ADS-B systems will determine the specific ATS applications they will support, particularly the aircraft to aircraft separation that can be applied.

This document provides ANSPs with an overview of the technical capabilities and requirements associated with providing ATS surveillance services. It also provides guidance for linking space-based ADS-B implementation to enabling or facilitating the implementation of some of the advances detailed in the International Civil Aviation Organization's (ICAO) Aviation System Block Upgrades (ASBU) framework. This document also outlines how space-based ADS-B will support the requirements for ICAO's performance-based standard on global flight tracking (GFT).

ANSPs are provided with business case development guidance, including lists of potential benefits for both ANSPs and aircraft operators from the implementation of space-based ADS-B. The document concludes with a summary of how global ATS surveillance could potentially benefit aviation.

Introduction

ICAO's *Global Air Traffic Management Operational Concept* (Doc 9854) highlights the challenge facing ANSPs and aircraft operators:

Because of the continued growth in civil aviation, in many places, demand often exceeds the available capacity of the air navigation system to accommodate air traffic, resulting in significant negative consequences not only to the aviation industry, but also to general economic health. One of the keys to maintaining the vitality of civil aviation is to ensure that a safe, secure, efficient and environmentally sustainable air navigation system is available at the global, regional and national levels. This requires the implementation of an air traffic management system that allows maximum use to be made of enhanced capabilities provided by technical advances.

ANSPs are therefore expected to develop ATM systems and the air navigation system (ANS) to meet the needs of aircraft operators. Aircraft operators increasingly require more fuel-efficient flight profiles (route, altitude and speed) that will reduce operating costs and show a return on operator investment in aircraft avionics. Where fuel burn is reduced, there are commensurate environmental benefits from reduced aircraft emissions. As highlighted in CANSO's *ATM Environmental Efficiency Goals for 2050*, "ATM's contribution to reducing climate change can best be achieved by increasing fuel efficiency for aircraft using the ATM system". ANSPs must develop and implement ATM systems with a strong focus on cost efficiency and flight safety. They must also determine how to integrate emerging technologies so as to maximise safety, efficiency and cost effectiveness.

Where ATS surveillance services are not provided, maintaining a safe, orderly and expeditious flow of air traffic requires the use of the largest air traffic control separation standards. To ensure that the required spacing will be maintained between aircraft, flights must often operate at less than

optimum flight levels, at fixed speeds and on fixed routes. The availability of ATS surveillance enables ANSPs to introduce more fuel and cost-efficient profiles than is possible without ATS surveillance, including free route operations and more user preferred routes (UPR).

Until recently, the potential coverage area of ATS surveillance was limited by where it was feasible to install and maintain ground-based infrastructure. Even where ground-based ATS surveillance systems have been installed, line of sight issues and range limitations mean that the effective coverage area for a ground-based ADS-B system is often less than 250 nautical miles (NM). Radar coverage is usually less. Likewise, redundancy using current ATS surveillance systems does not always ensure a complete back-up in case of failure. Space-based ADS-B could support contingency and redundancy capabilities and be entirely separate from ground-based infrastructure.

In the coming years, there will be a significant change, with the availability of systems that will be able to provide ATS surveillance coverage via satellite-reception of ADS-B signals from aircraft. Space-based reception of ADS-B signals will enable global ATS surveillance coverage. The specific operational improvements that can be achieved through the use of expanded ATS surveillance coverage will depend on the user requirements in the airspace concerned, taking account of available communications capabilities. Space-based ADS-B will provide:

- Real-time, global ATS surveillance coverage
- Improved situational awareness for air traffic controllers (ATCO)
- Improved conflict detection
- More flexibility for ATCOs to approve routes, speeds and altitudes
- Significant fuel and emissions savings
- Global aircraft tracking.

1

ATS Surveillance Systems

1.1 Introduction

The provision of services to aircraft in flight, particularly air traffic control separation services, is mainly dependent upon the ability of the ANSP to determine the position of the aircraft and communicate with it. Over the majority of the globe, ATCOs rely upon position reports from flights to periodically update their estimate of aircraft locations. The separation services provided on the basis of position reporting from the aircraft are often referred to as “procedural control”. The frequency and reliability of the position updates and the ease and frequency of communications between flights and ATCOs, determine how large the procedural separation standards need to be.

A significant factor in determining the appropriate separation standard is the communications capability in the airspace concerned. The more reliably and quickly an ATCO can contact a flight, the smaller the separation standard can safely be. The largest separation standards apply in oceanic and remote areas where communications, if available at all, are via High Frequency (HF). Often, HF voice communications are provided by third party services, increasing the potential delay for an ATCO to contact a flight. Smaller procedural separation standards have been developed for areas where very high frequency (VHF) direct controller- pilot communication (DCPC) is available.

In the late 1990s, data link communications began to be incorporated into the aviation infrastructure. The new systems allowed for equipped aircraft to communicate with equipped ANSPs using defined message structures to make requests, exchange information and provide clearances and instructions. This system is controller-pilot data link communications (CPDLC). These new data link capabilities also enabled ANSPs to define the frequency and content of automatic position reporting from the aircraft via automatic dependent

surveillance - contract (ADS-C). CPDLC and ADS-C services introduced into oceanic and other remote environments have reduced the reliance on HF voice for routine ATS communications. The ability to tailor the reporting rate and set-up parameters to monitor conformance to clearances using ADS-C resulted in new procedural separation standards being developed by ICAO. These standards are smaller than those that apply in HF voice only environments, but still larger than the standards that can be applied where VHF DCPC is available.

Until 2007, separation applications were either procedural as described above, or based on radar. Radar allows for the real-time determination of aircraft position, negating the requirement to obtain position reports from the aircraft whether by voice or automated means. The availability of VHF DCPC within radar coverage enables the application of the smallest possible separation minima. Radar technologies have continued to be enhanced but coverage continues to be limited by range and line of sight.

In 2007, ICAO formally acknowledged that radar-like systems had been developed and the 15th Edition of the *Procedures for Air Navigation Services - Air Traffic Management* (PANS- ATM; ICAO Doc 4444) incorporated updated references to “ATS surveillance” rather than “radar”. The PANS- ATM provides the following definition for an ATS surveillance system:

A generic term meaning variously, ADS-B, PSR, SSR or any comparable ground-based system that enables the identification of aircraft.

Note.— A comparable ground-based system is one that has been demonstrated, by comparative assessment or other methodology, to have a level of safety and performance equal to or better than monopulse SSR.

ICAO published *Circular 326 - Assessment of ADS-B and Multilateration Surveillance to Support Air Traffic Services and Guidelines for Implementation* to provide guidance and examples as to how ADS-B and multilateration (MLAT) systems were determined to meet the definition of "ATS surveillance system".

The introduction or expansion of ATS surveillance coverage enables safety and efficiency improvements. In the safety realm, ATCOs are provided with increased situational awareness. This allows them to quickly detect aircraft deviations from clearances and unsafe proximity between aircraft and between aircraft and terrain or restricted or danger areas. The better the communication capability, the more quickly and efficiently the ATCO can intervene to correct unsafe situations. The availability of ATS surveillance also allows ATCOs to provide more options and support to aircraft in contingency situations, such as encountering severe weather or experiencing mechanical difficulties.

In the efficiency realm, the application of ATS surveillance separation standards, rather than procedural standards, enables ATCOs to permit aircraft to operate at, or more closely to, their optimum flight profiles. Aircraft operators can plan for this increased flexibility, adding to the potential fuel savings. Less fuel burned equates to lower GHG emissions, a goal of the entire aviation community. Additionally, ATS surveillance provides the necessary information to support better inter-unit and flow management coordination, allowing for fewer or less extensive flight delays; these improvements also support reduced fuel burn and GHG emissions.

1.2 Primary Radar

Primary surveillance radar (PSR) systems calculate how far away an aircraft is by measuring the delay between when a signal is sent and when its echo returns to the transmitting site. The aircraft position calculation is based on the position of the radar antenna and the return time of the pulse. Primary radar is classified as a 'non-cooperative'

ATS surveillance system, because no signals from the aircraft are required to provide the aircraft's position. The primary echo gives no information about the aircraft detected, but PSR systems detect most objects within their range, including terrain and aircraft.

The typical maximum detection range of dedicated terminal PSR systems is 111 kilometres (km) (60 NM); these systems rely on a higher data refresh rate when using higher pulse repetition frequency (PRF) and higher antenna revolutions per minute (rpm). For most en-route PSR systems, the maximum detection range is 185 km (100 NM) to 463 km (250 NM); en-route PSR systems typically have lower PRF and slower rpm. For all PSR systems, the range and detection capability is subject to reflections and obstacles. Typical PSR systems designed for civilian purposes are not capable of providing information concerning the height of a detected aircraft. System enhancements are available, but the low resolution is not acceptable for separation purposes. Therefore, even such enhanced PSR systems are not yet capable of calculating height information that is sufficiently accurate to support air traffic control (ATC) requirements.

Primary surveillance radar systems are the only radar systems that will provide position information on most flying airborne vehicles within range. Smaller objects, such as small remotely piloted aircraft systems (RPAS), or military aircraft equipped with stealth technology will not be reliably detected. The capability to provide a reliable radar cross section satisfies system performance requirements within terminal management areas (TMA); accordingly, it is foreseen that these non-cooperative systems will be maintained as part of the ATS surveillance infrastructure in TMAs for the foreseeable future. Because no data from the aircraft is received by PSR systems, automatic correlation of a PSR echo to a specific flight plan is not possible.

1.3 Secondary Radar

Secondary surveillance radar (SSR) systems depend upon exchanges with transponder-equipped aircraft. SSR systems are classified as 'cooperative' ATS surveillance systems, since they can only detect an aircraft that is equipped with a functioning transponder. The aircraft transponder replies to an interrogation from the SSR system, providing a small amount of information in the response. The data transmission is very brief, and generally includes only the SSR code (Mode A) and the aircraft's altitude (Mode C) based on the air pressure measured by onboard avionics. SSR systems cannot detect aircraft that are not equipped with transponders or aircraft whose transponders are malfunctioning or have been turned off. If the transponder receives too many interrogations, it will cease replying, thereby decreasing the probability of detection of the aircraft. For this reason, SSR installations should follow applicable guidance and regulation for avoiding over-interrogation.

The transmitted four-digit SSR code is not unique to the aircraft and is comprised of the digits 0 through 7. Further processing is required to associate, or correlate, a specific transponder response with a specific flight. Depending on the level of sophistication of the ATM system, correlation can be automatic or require ATCO intervention. However, because the possible number of codes is considerably less than the number of aircraft, adjoining ANSPs are required to coordinate codes to avoid so-called 'code conflicts'. Code conflicts occur when more than one aircraft in the range of an SSR system are sending the same Mode A code. Often aircraft operate through the areas of responsibility of several ANSPs in a single flight. Even though some very sophisticated SSR code assignment regimes exist, code conflicts remain a common occurrence and many aircraft are required to change their SSR code at least once during the course of a flight.

Due to the rotation speed of the radar antenna, the maximum detection range of typical en-route SSR ATS surveillance systems is 463 km

(250 NM), subject to reflections and obstacles. The interrogative frequency is 1030 Mega Hertz (MHz) and the transponder response frequency is 1090 MHz. The aircraft altitude will be provided by Mode C capable transponders; most transponders in use include this capability. The following information can be provided to the ATCO via SSR:

- a. Mode A code
- b. Special purpose identification (SPI) which is used to confirm the identity of an SSR return (the pilot selects this mode on the transponder so that a special signal is sent when a flight is requested to "squawk ident" by an ATCO)
- c. Mode C pressure altitude (in 100-foot increments)

Mode S

Mode Select (Mode S) transponders are capable of providing additional information in the response to an interrogation. Mode S SSR systems can request responses from all Mode S transponders in range or selectively interrogate a specific transponder. The most significant benefit of Mode S transponders over Mode A/C transponders is that a unique 24-bit address is assigned to the aircraft. This unique identity is provided in each Mode S transponder response.

Elementary Mode S (ELS) transponders provide:

- a. ICAO 24-bit address
- b. Aircraft identification
- c. Mode A code
- d. SPI
- e. Emergency status (general emergency, no communications, unlawful interference)
- f. Mode C pressure altitude (in 25-foot increments)

In addition to the data provided by ELS transponders, Enhanced Mode S (EHS) transponders provide:

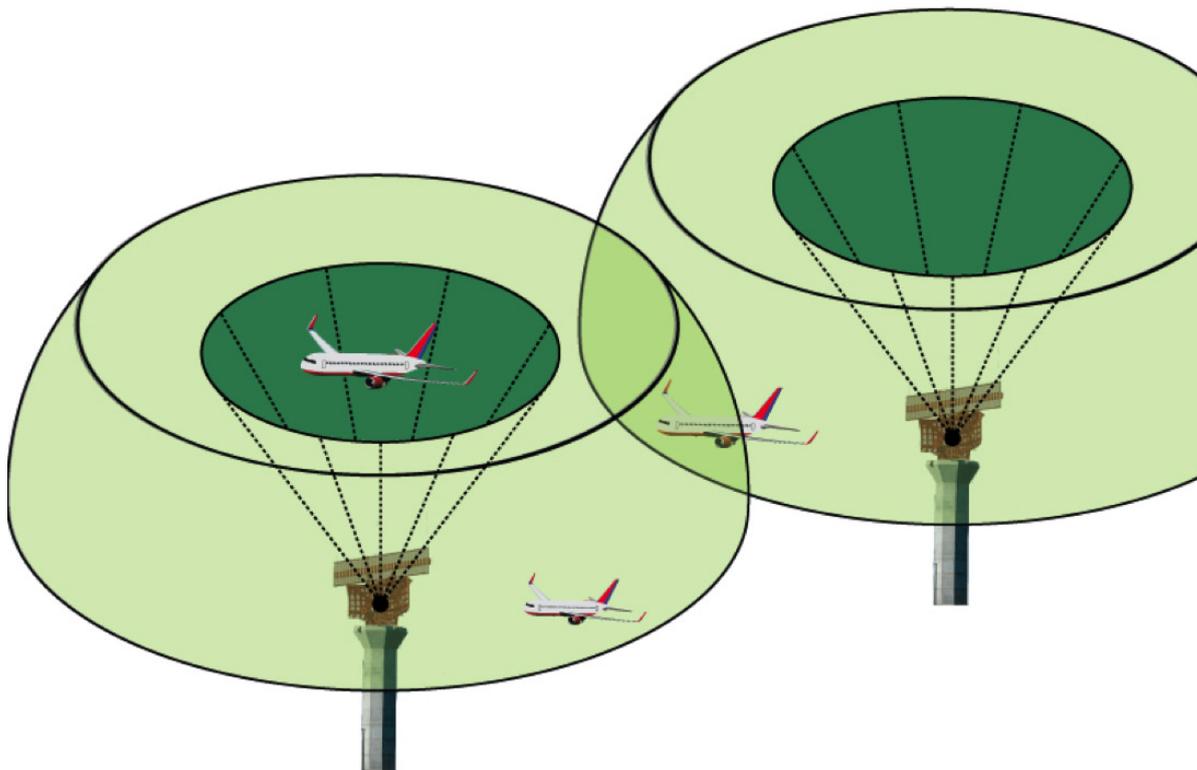
- a. Mode Control Panel / Flight Control Unit

- (MCP/FCU) selected altitude
- b. Roll angle
- c. True track angle
- d. Ground speed
- e. Magnetic heading
- f. Indicated airspeed or Mach number
- g. Vertical rate (Barometric or Baro-inertial)
- h. Barometric pressure setting (minus 800 hectoPascals)
- i. Track angle rate or true airspeed if track angle rate is not available

Mode S SSR systems have the same range characteristics as other SSR systems. The additional

data provided by Mode S transponders can only be received by Mode S SSR systems. Mode S transponder responses are detectable by non-Mode S SSR systems, but they would only process the Mode A and Mode C data. As with other SSR systems, aircraft will not be detected if they are not equipped with a transponder or if their transponder is malfunctioning or turned off.

The detection pattern of typical primary and secondary radar systems is illustrated in Figure 1 below. The dark green area directly above the radar antennas depicts the "cone of silence". Aircraft cannot be detected while they are in a radar's cone of silence:



Source: FAA

Figure 1 - Detection Pattern of Typical Radar Systems

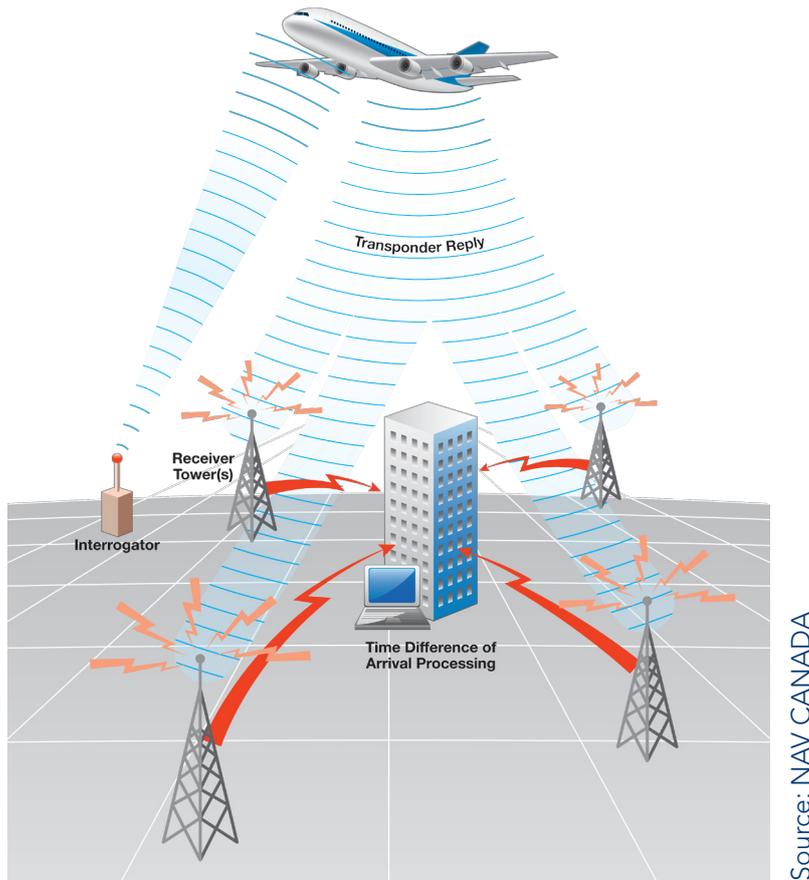


Figure 2 -
Multilateration Concept

1.4 MLAT

MLAT is a cooperative ATS surveillance system, which uses Mode S (including ADS-B) and Mode A/C transmissions on 1090 MHz to determine the positions of aircraft (or vehicles). MLAT systems calculate the position by measuring the time difference between when signals are received by a minimum of three stations.

MLAT systems can be purely passive, but are more often a mixture of passive and active systems. Passive MLAT systems will only receive Mode S data, which is transmitted from aircraft (or from vehicles) without an initiating interrogation, but will receive Mode A and C data if a nearby radar system is sending initiating interrogations. Active MLAT systems will include one or more stations capable of sending initiating interrogations.

MLAT systems, employing receivers placed at aerodromes, support ground movement management, with similar small-scale implementations being used to provide ATS surveillance in smaller local areas. The performance of the MLAT system is dependent of the number of stations within the area of interest and the geometry of the position of the stations. Coverage can be

extended beyond the area where the stations are installed but the position accuracy range is more limited than systems that rely on line of sight. An enhanced implementation of MLAT, wide area multilateration (WAM), can cover larger airspaces.

Due to the relatively large number of stations needed to implement a MLAT system, the technique is highly dependent on reliable telecommunication lines with sufficient bandwidth. A minimum of three stations must receive signals to determine the horizontal position of an aircraft. MLAT systems normally utilise Mode-C altitude information extracted from messages received at the stations to provide a three-dimensional position, however, MLAT systems can also determine a three-dimensional position solution if at least four stations receive the aircraft transmissions.

Figure 2 illustrates how multilateration works, with an interrogator eliciting transponder responses from the aircraft, which are received by a network of receivers. A processor then triangulates the aircraft's position by comparing the different times of arrival of the aircraft transponder signals at each of the receivers.

1.5 Ground-Based ADS-B

ADS-B is a cooperative ATIS surveillance system that relies on DO-260 series transponders compliant with RTCA's *Minimum Operational Performance Standards (MOPS) for 1090 MHz Automatic Dependent Surveillance-Broadcast ADS-B* (all DO-260 series transponders). It is considered a passive system because ADS-B transponders broadcast signals without an initiating interrogation. Usually, ADS-B receivers are part of an ATM system, but they can also be installed on aircraft or maintained by other stakeholders with a requirement to know aircraft locations.

ADS-B transponder systems are sometimes referred to as "ADS-B OUT", to differentiate from aircraft systems that receive ADS-B signals from other aircraft, known as "ADS-B IN". Ground-based ADS-B is the generic term for ATM systems that use ground-based ADS-B receivers to detect ADS-B signals from aircraft.

ADS-B transponders broadcast aircraft parameters, such as identification (24 bit address and flight identification as per the flight plan), position (latitude, longitude and pressure altitude), three-dimensional velocity and position integrity, via a broadcast-mode data link on 1090 MHz. Aircraft identification information is broadcast every five seconds while aircraft position and velocity data is typically broadcast twice per second. Aircraft position is derived from global navigation satellite system (GNSS) data; however, if aircraft are not configured correctly, there can be errors in the position data that is broadcast. Erroneous position data reveals itself in a number of ways, including unexpected "jumps" between position updates and mismatches between the expected and reported positions. It is important, for any ADS-B implementation, to ensure that such anomalies will be detected and addressed appropriately.

Different generations of ADS-B transponders transmit different data. The potential data that can be transmitted include:

- a. ICAO 24-bit address
- b. Aircraft identification
- c. Mode A code
- d. SPI
- e. Emergency status (general emergency, no communications, unlawful interference)
- f. ADS-B version number
- g. ADS-B emitter category
- h. Geodetic horizontal position (World Geodetic System revision 1984 (WGS-84) latitude and longitude), both while airborne or on the ground
- i. Geodetic horizontal position quality indicators (Navigation Integrity Category (NIC), 95% Navigation Accuracy Category (NAC), Source Integrity Level (SIL) and System Design Assurance level)
- j. Pressure altitude
- k. Geometric altitude in accordance with WGS-84 (provided in addition and encoded as a difference to pressure altitude)
- l. Geometric vertical accuracy (GVA)
- m. Velocity over ground, both while airborne (east/west and north/south airborne velocity over ground) or on the ground (surface heading/ground track and movement)
- n. Velocity quality indicator (corresponding to NAC for velocity)
- o. Coded aircraft length and width
- p. Global positioning system (GPS) antenna offset
- q. Vertical rate: barometric vertical rate when the aircraft is required and capable to transmit this data item via the Mode S protocol, or GNSS vertical rate
- r. MCP/FCU selected altitude using the same source as for the same parameter specified in the Mode S EHS aircraft derived data (ADD) elements when the aircraft is required and capable to transmit this data item via the Mode S protocol
- s. Barometric pressure setting (minus 800 hectoPascals) using the same source as for the same parameter specified in the Mode S EHS ADDs when the aircraft is required

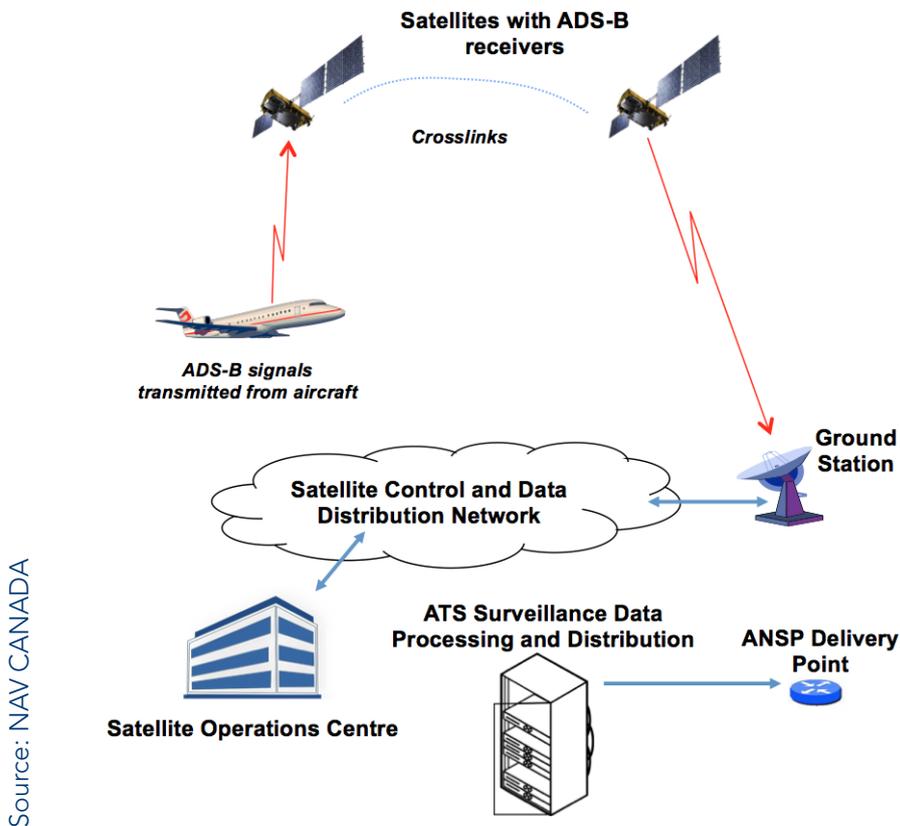


Figure 3 - Space-Based ADS-B Concept

and capable to transmit this data item via the Mode S protocol

availability to ATM systems for processing. This is illustrated in Figure 3 above.

Ground-based ADS-B systems have similar range characteristics to SSR systems. As with other cooperative ATS surveillance systems, aircraft will not be detected if they are not equipped with a transponder or if their transponder is malfunctioning or turned off.

1.6 Space-Based ADS-B

When operational, space-based ADS-B technology will allow the receipt of ADS-B signals by receivers on a low earth orbit constellation of satellites. These will facilitate continuous global coverage of the Earth including polar areas depending on the satellite constellation coverage. Typically, ADS-B data from aircraft will be received by the satellite-borne ADS-B receivers and be routed via secure cross-link architecture connecting the satellites then to a terrestrial gateway station, before being transferred to terrestrial data networks for

Space-based ADS-B will offer an ATS surveillance capability to ANSPs and aircraft operators in areas of the world where ground-based ATS surveillance is not possible. It will allow integration of received ATS surveillance data from oceanic and remote regions with data from ground-based ATS surveillance networks to provide global coverage and a seamless surveillance picture.

Reliable detection of ADS-B data by space-based systems is dependent upon aircraft having top-mounted antennas rated for transmitting power of 125 Watts or greater. Space-based ADS-B is compatible with all DO-260 series transponders, as is ground-based ADS-B. As with other cooperative ATS surveillance systems, aircraft will not be detected if they are not equipped with a transponder or if their transponder is malfunctioning or turned off. Space-based ADS-B is not affected by the line of sight issues that can limit the effective range of ground-based systems.

1.7 Summary

The following table summarises the technical capabilities of the ATS surveillance systems described above:

	PSR	SSR	MLAT	Ground-based ADS-B	Space-based ADS-B
Cooperative	No	Yes	Yes	Yes	Yes
Passive	No	No	Possible	Yes	Yes
Automatic correlation possible	No	Yes	Yes	Yes	Yes
Aircraft height	No	Yes	Yes, using Mode C or independently if at least 4 sensors	Yes	Yes
Typical effective detection range	Terminal 111 km (60 NM) ----- En-route 185-463 km (100-250 NM)	463 km (250 NM)	Varies with number of sensors and their placement	463 km (250 NM)	Global (with a low earth orbiting constellation)
Range affected by terrain or other obstacles	Yes	Yes	Yes	Yes	Minimal
Aircraft position determined independently	Yes	Yes	Yes	No (GNSS position transmitted by aircraft)	No (GNSS position transmitted by aircraft)

2**Communication Capability**

Communication capability is a crucial element, which must be considered when determining the appropriate ATS surveillance service to provide, including separation minima, within a specific airspace or between certain aircraft. Outside VHF DCPC range, ATCOs must revert to procedural methods of separation where the minima to be applied are directly related to the navigational accuracy of the aircraft and the frequency and accuracy of the position updates provided to ATC. Where the aircraft position is determined using ATS surveillance, navigational capability is not required for the separation standard.

The communication capabilities within the current global fleet vary widely, with individual aircraft having one, some or all of the following systems:

- VHF voice
- VHF data link
- HF voice
- HF data link
- SATCOM (data link via satellite)
- SATVOICE (voice communication via satellite)

In the late 1990s the Future Air Navigation System (FANS-1/A) capabilities were introduced into fleets operating in oceanic/remote regions. FANS-1/A provided an integrated communications, navigation, and surveillance capability; and was the first operational use of CPDLC and ADS-C to support the application of reduced procedural separations. FANS 1/A applications operate over the Aircraft Communication, Addressing and Reporting System (ACARS) network, providing for integrated operations between ATC, the flight crew and aircraft operations.

ADS-C includes a position reporting capability, where the content and frequency of the position reports is specified by the ATM system and also

event reporting, whereby ADS-C reports are sent if certain specified events occur. ADS-C event reporting is mainly used to support conformance monitoring, because the ATM system can set up a contract specifying that an ADS-C report be sent if the aircraft is operating or goes outside a specified vertical or lateral range or changes its route.

The capability for the ATM system to specify the frequency of ADS-C reports has enabled the development of procedural separation minima that are smaller than those that were previously required in oceanic and remote areas. These minima may be applied between aircraft with specified performance-based navigation (PBN) capabilities and have provided significant benefits where they have been implemented.

FANS 1/A CPDLC supports two main benefits: reducing communication errors and integrating communications functions with the aircraft flight management system (FMS). One specific procedure, which is supported by CPDLC, allows for aircraft operations to optimise the flight profile post-departure. Under this procedure, the dynamic airborne reroute procedure (DARP), the flight crew uses ACARS data link to send updated aircraft parameters to aircraft operations; aircraft operations then determines whether a different route from the flight planned route would be more fuel optimal. If a different route is more optimal, flight operations sends the new route to the flight crew via ACARS data link. The flight crew then uses CPDLC to transmit this new route in a request to ATC. If the requested route can be accommodated, ATC uses CPDLC to approve the requested route, which can then be transferred directly to the aircraft's FMS. Since data link is used for all parts of the transaction, the possibility of transcription errors or FMS input errors is eliminated.

3

ATM Systems

In general, areas with a greater density of operations require higher levels of performance from the communication, navigation and surveillance (CNS)/ATM systems used to support those services. The highest levels of performance are required to support terminal operations with parallel approaches. Lower levels of performance are appropriate in more remote airspace. Typical en-route operations, where aircraft are spaced further apart than in a terminal environment, can be safely supported using CNS/ATM systems with less stringent levels of performance.

The separation minima applied in different areas take account of aircraft and ATM system performance and capabilities. In the past, performance criteria were not specifically cited for separation minima, although they were implied. For example, current ATS surveillance separation minima can only be applied where DCPC is via VHF. New separation standards now include specified navigation performance, usually expressed as a required navigation performance (RNP) or area navigation (RNAV) requirement for aircraft to qualify for the application. These so-called "PBN separations" are usually subject to regionally imposed communications performance criteria; it is expected that required communication performance (RCP) will soon become globally applicable to PBN separations.

Likewise, a required surveillance performance is implied for the application of certain ATS surveillance separation minima. ICAO documentation specifies accuracy and latency requirements to apply 5 NM or 3 NM ATS surveillance separation minima. In general, however, more detailed surveillance performance requirements are specified at the regional or national level, such as the following documents that detail ATM system and performance requirements for the application of ATS surveillance separation and services:

EUROCONTROL Standard Document for Radar Surveillance in En-Route Airspace and Major Terminal Areas.

- This sets out the prescriptive requirement for ANSPs to maintain duplicate SSR radar coverage in en-route airspace (supporting application of 5 NM separation) and to maintain duplicate SSR coverage and single PSR coverage in major terminal areas (supporting application 3 NM separation).

EUROCONTROL Specification for ATM Surveillance System Performance (ESASSP)

- This document, consisting of two volumes, provides performance requirements for ATM surveillance systems when supporting 3 NM and 5 NM separation applications. It was developed in parallel with the Surveillance Performance and Interoperability Implementing Rule (EU Regulation No 1207/2011 (SPI IR)).
Note: EUROCAE is developing further guidance, which is expected to be incorporated into an updated version of ESASSP.
- ESASSP:
 - can be used by air navigation service providers to define, the minimum performance to be met by their surveillance system
 - defines how the associated conformity assessment must be performed.
 - is generic and independent of technology
 - is written to be compatible with recently published EUROCAE standards for specific surveillance sensor technologies and applications (ADS-B Radar and non-radar airspace and WAM).

EU Regulation No 1207/2011 Surveillance Performance and Interoperability Implementing (SPI IR)

- This Regulation lays down requirements

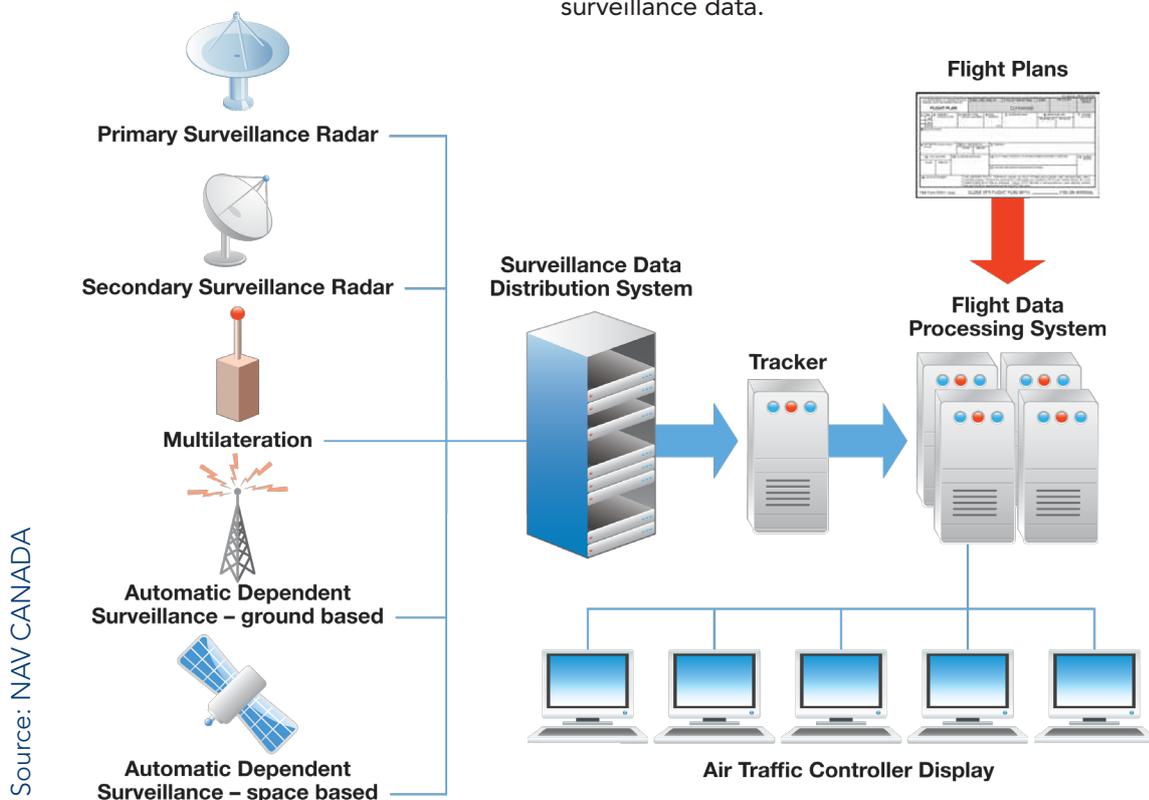
on the systems contributing to the provision of surveillance data, their constituents and associated procedures in order to ensure the harmonisation of performance, the interoperability and the efficiency of these systems within the European Air Traffic Management Network and for the purpose of civil-military coordination

- The key objective of EU Regulation No 1207/2011 is to establish performance requirements for surveillance.

When considering the performance of ADS-B systems, positional accuracy depends on the ability of the aircraft avionics to supply high integrity position information to the ADS-B transponder. Different

classes of ADS-B transponder specify how the position information is provided to the transponder. For certain environments where reduced separation is desired, it may be necessary to specify a higher performance on the ADS-B avionics; for example, some jurisdictions require DO-260B series transponders to support terminal operations where a 3 NM separation is applied.

As illustrated in Figure 4 below, an ANSP could obtain ATS surveillance data from numerous sources. Some radar-based ATM systems only process surveillance data that is received at pre-set intervals. When adding ADS-B to the possible surveillance sources, ANSPs may need to upgrade their surveillance tracker, surveillance data distribution or ATCO display systems to support non-synchronous receipt and update of ADS-B surveillance data.



Source: NAV CANADA

Figure 4 - Multiple ATS Surveillance Sources

Automatic correlation is possible if the ANSP's surveillance data is integrated with the flight data. This allows for displaying flight identity and other pertinent information with the aircraft position symbol on the ATCO display.

4

ATS Surveillance Services

4.1 ATS Surveillance Services

As defined by ICAO, ATS surveillance services are services provided directly by means of an ATS surveillance system. These services include:

- Flight information service
- Alerting service
- Air traffic advisory service
- ATC services:
 - area control service
 - approach control service
 - aerodrome control service

The PANS-ATM lists the following ATC services that may be provided using an ATS surveillance system:

- Services as necessary in order to improve airspace utilisation, reduce delays, provide for direct routings and more optimum flight profiles, as well as to enhance safety
- Vectoring to departing aircraft for the purpose of facilitating an expeditious and efficient departure flow and expediting climb to cruising level
- Vectoring to aircraft for the purpose of resolving potential conflicts
- Vectoring to arriving aircraft for the purpose of establishing an expeditious and efficient approach sequence
- Vectoring to assist pilots in their navigation, e.g. to or from a radio navigation aid, away from or around areas of adverse weather
- Applying separation and maintaining normal traffic flow when an aircraft experiences communication failure within the area of coverage
- Flight path monitoring of air traffic
- Maintaining a watch on the progress of air traffic, in order to provide a procedural controller with:
 - Improved position information regarding aircraft under control

- Supplementary information regarding other traffic
- Information regarding any significant deviations by aircraft from the terms of their respective air traffic control clearances, including their cleared routes as well as levels, when appropriate

4.2 Space-Based ADS-B Applications

In continental en-route and terminal airspace where VHF DCPC is available, the expected performance of space-based ADS-B will support the application of 5 NM ATS surveillance separation. Some regulatory regimes permit the application of 5 NM ATS surveillance separation using a single source, but others may require dual source coverage.

In terminal airspace where the application of 3 NM or time-based separation is currently permitted, space-based ADS-B may support the same applications, subject to the same performance-based considerations as for ground-based ATS surveillance systems.

Coincident with the development of a space-based ADS-B service is the development of appropriate global standards to support the provision of ATS surveillance services outside areas of VHF DCPC coverage. The Separation and Airspace Safety Panel (SASP) has been tasked by the ICAO Air Navigation Commission to develop provisions to support the use of space-based ADS-B.

SASP is initially focused on validating whether reduced longitudinal and lateral procedural separation standards of 15 NM or less can be applied using space-based ADS-B with the current communication performance exhibited by CPDLC (with HF as back-up). ICAO plans to publish these provisions in the PANS-ATM in 2018.

In remote/oceanic airspace outside VHF DCPC coverage and where CPDLC is not available, space-based ADS-B can provide complete situational awareness to support the provision of flight information and alerting services.

SASP is developing additional ATS surveillance separation minima for different levels of communication performance. This will allow ANSPs to provide ATS surveillance separation using whatever communications media are available in their airspace. This will also enhance interoperability between continental and remote/oceanic airspaces, allowing transitions to be managed similarly to how they are managed between continental en-route and terminal airspaces. These new separation standards are expected to be available in the PANS-ATM in the 2020-2022 timeframe.

Space-based ADS-B, like any other ATS surveillance system, should be capable of supporting the provision of ATS surveillance services to aircraft operating in the vicinity of an aerodrome. Space-based ADS-B might also be used to support or augment the provision of surface movement guidance and control system (SMGCS) services.

5

Linkages to ICAO

5.1 ASBU Framework

ICAO has provided industry with a capabilities and readiness perspective. The global building blocks are known as the ASBU Modules, which have been arranged by availability dates; Block 0 ASBU Modules are capabilities available today while Block 1 represents capabilities that are projected to be ready by 2018. Block 2 capabilities are projected to be available in the 2023 time period. The ASBU planning framework supports coordinated planning and development of technology; associated procedures to make use of the technology; and the regulatory requirements for standardisation, certification, approvals and authorisations. The ASBU framework is described in the *Global Air Navigation Plan (GANP; ICAO Doc 9750)*. The main focus of the ASBU framework is toward seamlessness and interoperability and coordinated implementation between States, Regions, ANSPs and aircraft operators.

The first space-based ADS-B ATS surveillance system is expected to be available in 2017. This would be within the 2013-2018 implementation horizon for ASBU Block 0 and the planning horizon for Block 1. It can be foreseen that the availability of global ATS surveillance will have a significant impact on future planning for the global aviation system.

Space-based ADS-B is being considered mainly to support en-route applications. It should be highlighted that numerous ASBU Modules would provide even more benefits if they were implemented in an environment where global ATS surveillance was available.

This chart details the correlation between space-based ADS-B and ICAO's ASBU framework.

Performance Area	Thread	Module	Relation to space-based ADS-B
Area 1: Aerodrome Operations	Remote Aerodrome Control Towers (RATS)	B1-RATS: Remotely Operated Aerodrome Control	Enables implementation without requiring ground-based ATS surveillance infrastructure
Area 2: Globally Interoperable Systems and Data – Through Globally Interoperable SWIM	Flight and flow information for the collaborative environment (FICE)	<p>B0-FICE: Increased Interoperability, Efficiency and Capacity through Ground- Ground Integration</p> <p>B1-FICE: Increased Interoperability, Efficiency and Capacity through FF-ICE, Step 1 application before Departure</p> <p>B2-FICE: Improved Coordination through Multi-centre Ground-Ground Integration (FF-ICE, Step 1 and Flight Object, SWIM)</p> <p>B3-FICE: Improved Operational Performance through the Introduction of Full FF-ICE</p>	Seamless ATS surveillance enables FICE across different air traffic service units within an ANSP and between different ANSPs because consistent information is available to all

Performance Area	Thread	Module	Relation to space-based ADS-B
Area 3: Optimum Capacity and Flexible Flights	Free-Route Operations (FRTO)	B0-FRTO: Improved Operations through Enhanced En-Route Trajectories	Seamless ATS surveillance enhances the ability to safely implement FRTO operations
		B1-FRTO: Improved Operations through Optimized ATS Routing	
		B3-FRTO: Traffic Complexity Management	
	Network Operations (NOPS)	B0-NOPS: Improved Flow Performance through Planning based on a Network-Wide view	Seamless ATS surveillance facilitates NOPS and more effective and efficient ATFM across different air traffic service units within an ANSP and between different ANSPs because consistent information is available to all
		B1-NOPS: Enhanced Flow Performance through Network Operational Planning	
B2-NOPS: Increased user involvement in the dynamic utilization of the network			
Alternative Surveillance (ASUR)	B0-ASUR: Initial capability for ground surveillance	Space-based ADS-B is subject to minimal coverage gaps due to line of sight issues.	
Optimum Flight Levels (OPFL)	B0-OPFL: Improved Access to Optimum Flight Levels through Climb/Descent Procedures using ADS B	Seamless ATS surveillance facilitates access to optimum flight levels	
Safety Nets (SNET)	B0-SNET: Increased Effectiveness of Ground-Based Safety Nets	Seamless ATS surveillance supports conflict alerting and minimum safe altitude warnings in all airspace. Space-based ADS-B is subject to minimal coverage gaps due to line of sight issues.	

Performance Area	Thread	Module	Relation to space-based ADS-B
Area 3: Optimum Capacity and Flexible Flights	Free-Route Operations (FRTO)	<p>B0-FRTO: Improved Operations through Enhanced En-Route Trajectories</p> <p>B1-FRTO: Improved Operations through Optimized ATS Routing</p> <p>B3-FRTO: Traffic Complexity Management</p>	Seamless ATS surveillance enhances the ability to safely implement FRTO operations
	Network Operations (NOPS)	<p>B0-NOPS: Improved Flow Performance through Planning based on a Network-Wide view</p> <p>B1-NOPS: Enhanced Flow Performance through Network Operational Planning</p> <p>B2-NOPS: Increased user involvement in the dynamic utilization of the network</p>	Seamless ATS surveillance facilitates NOPS and more effective and efficient ATFM across different air traffic service units within an ANSP and between different ANSPs because consistent information is available to all
	Alternative Surveillance (ASUR)	B0-ASUR: Initial capability for ground surveillance	Space-based ADS-B is subject to minimal coverage gaps due to line of sight issues.
	Optimum Flight Levels (OPFL)	B0-OPFL: Improved Access to Optimum Flight Levels through Climb/Descent Procedures using ADS B	Seamless ATS surveillance facilitates access to optimum flight levels
	Safety Nets (SNET)	B0-SNET: Increased Effectiveness of Ground-Based Safety Nets	Seamless ATS surveillance supports conflict alerting and minimum safe altitude warnings in all airspace. Space-based ADS-B is subject to minimal coverage gaps due to line of sight issues.

Performance Area	Thread	Module	Relation to space-based ADS-B
Performance Improvement Area 4: Efficient Flight	Continuous Descent Operations (CDO)	B0-CDO: Improved Flexibility and Efficiency in Descent Profiles (CDO) B1-CDO: Improved Flexibility and Efficiency in Descent Profiles (CDOs) using VNAV B2-CDO: Improved Flexibility and Efficiency in Descent Profiles (CDOs) using VNAV, required speed and time at arrival	Seamless ATS surveillance should facilitate implementation of supporting procedures
	Continuous Climb Operations (CCO)	B0-CCO: Improved Flexibility and Efficiency in Departure Profiles - Continuous Climb Operations (CCO)	Seamless ATS surveillance should facilitate implementation of supporting procedures
	Trajectory-Based Operations (TBO)	B0-TBO: Improved Safety and Efficiency through the initial application of Data Link En- Route B1-TBO: Improved Traffic synchronization and Initial Trajectory-Based Operation B3-TBO: Full 4D Trajectory-based Operations	Seamless ATS surveillance should facilitate implementation of supporting procedures
	Remotely Piloted Aircraft Systems (RPAS)	B1-RPAS: Initial Integration of Remotely Piloted Aircraft (RPA) into Non-Segregated Airspace B2-RPAS: Remotely Piloted Aircraft (RPA) Integration in Traffic B3-RPAS: Remotely Piloted Aircraft (RPA) Transparent Management	Seamless ATS surveillance should facilitate implementation of supporting procedures Space-based ADS-B is subject to minimal coverage gaps due to line of sight issues.

5.2 Global Flight Tracking (GFT)

In response to the disappearance of Malaysia Airlines Flight MH370, the aviation industry and ICAO worked together in multi-disciplinary groups to examine the potential near, mid and long-term requirements to provide global flight tracking. ICAO has adopted new standards and recommended practices regarding normal aircraft tracking. These provisions are detailed in State Letter AN 11/1.3.28-15/85, *Adoption of Amendment 39 to Annex 6, Part I*, issued on 15

December 2015. These new provisions become effective on 8 November 2018.

The ICAO provisions will require aircraft operators to track the position of most passenger carrying aircraft where those flights operate in oceanic areas and an ATS unit obtains position information at intervals greater than 15 minutes. ATS surveillance systems provide the necessary performance to meet this requirement. Space-based ADS-B meets this requirement globally for all suitably equipped aircraft.

6

Regulatory Aspects

6.1 Safety Cases

Annex 11 to the International Convention on Civil Aviation - Air Traffic Services specifies that any significant safety-related change to the ATS system, including the implementation of a reduced separation minimum or a new procedure, shall only be effected after a safety assessment has demonstrated that an acceptable level of safety will be met. Under most regulatory regimes, ANSPs will be required to complete appropriate safety assessments before implementing a change as significant as introducing a new ATS surveillance source and associated services into the ANS. Similarly, ANSPs should complete safety assessments prior to expanding current ATS surveillance coverage or replacing one ATS surveillance source with another.

CANSO provides guidance for ANSPs conducting such assessments in the *CANSO Standard: Common Safety Methods on Risk Evaluation and Assessment for ANSPs*. ICAO also provides guidance relevant to collecting safety data and assessing risk in the *Safety Management Manual (SMM)* (Doc 9859).

6.2 ANSP Requirements

In some areas, ADS-B services are differentiated between those provided where radar coverage exists and those provided where no radar coverage is available. Although the global standards promulgated in ICAO documents make no such distinction, each ANSP will need to account for their regulatory requirements.

6.3 Regulatory Guidance on Aircraft Equipage

Reliable detection of ADS-B data by space-based systems depends on aircraft having top-mounted antennas; a top-mounted antenna is one component of an airborne collision

avoidance system (ACAS). Part 1 of Annex 6 to the International Convention on Civil Aviation - Operation of Aircraft specifies the following with respect to international commercial aircraft (similar provisions apply to international general aviation aircraft):

6.18.1 All turbine-engine aeroplanes of a maximum certificated take-off mass in excess of 5 700 kg or authorised to carry more than 19 passengers shall be equipped with an airborne collision avoidance system (ACAS II).

6.18.2 Recommendation. — All aeroplanes should be equipped with an airborne collision avoidance system (ACAS II).

Volume IV of *Annex 10 to the International Convention on Civil Aviation - Aeronautical Telecommunications* requires aircraft with gross mass in excess of 5700 kg or a maximum cruising true airspeed capability in excess of 463 km/h (250 kt) to operate with antenna diversity (i.e. top and bottom mounted antennas). Annex 10 further specifies that Mode S transponders used in conjunction with ACAS must have antenna diversity.

Although it is expected that the ACAS requirement for top-mounted antennae will make most ACAS-compliant aircraft visible to space-based ADS-B systems, the analysis of operational data will have to validate this assumption.

Testing has shown that space-based ADS-B receivers will be compatible with all DO-260 series transponders. Some States and Regions have mandated ADS-B equipage on aircraft and/or issued guidance and requirements associated with aircraft ADS-B equipage.

The following table provides examples of existing regulatory material, which may be useful for States and ANSPs considering regulation and requirements to support ADS-B operations. ANSPs should consider their individual requirements while also attempting to harmonise ADS-B equipage requirements, (to the extent possible) with adjacent areas. This would recognise the benefits for aircraft equipage and ATM system development when there is consistency within the industry.

Source	Published Material Regarding ADS-B Equipage
European Aviation Safety Agency (EASA)	Commission Regulations (EU) Nos. 1207/2011 and 1028/2014 mandate for the entire European airspace an ADS B equipage with version 2 (ED-102A / DO-260B) from 8 June 2016 for new aircraft and from 7 June 2020 for all aircraft (retrofit). ADS-B Equipment Certification requirements are laid down in the EASA documents CS-ACNS and AMC 20-24, where CS-ACNS includes AMC 20-24, which covers only non-radar airspace.
Transport Canada	<p>Providing ATS surveillance separation using ADS-B Out since November 2010.</p> <p><i>Transport Canada Aeronautical Information Manual (TP1437)</i></p> <p>Any aircraft that emits position information using a 1090 MHz Extended Squitter (1090ES) may be provided surveillance separation services, if they meet the airworthiness compliance requirements defined in:</p> <ul style="list-style-type: none"> (a) European Aviation Safety Agency (EASA) AMC 20-24; or (b) FAA AC No. 20-165A – Airworthiness Approval of ADS-B; or (c) Configuration standards reflected in Appendix XI of Civil Aviation Order 20.18 of the Civil Aviation Safety Authority (CASA) of Australia. ADS-B systems that are unable to meet the above requirements are required to disable ADS-B transmissions unless the aircraft is configured by the operator to always transmit a value of zero for one or more of the position quality indicators (NUCp, NIC, NAC or SIL), or the operator has received an exemption from NAV CANADA.
Civil Aviation Safety Authority of Australia	Guidance material: CAO 20.18, Amend Order No. 3, dated December 2009 • Mandates ADS-B Out for upper airspace (≥FL290) in December 2013

Source	Published Material Regarding ADS-B Equipage
Civil Aviation Department of Hong Kong	<ul style="list-style-type: none"> — Guidance material: Airworthiness Notice 102F, Issue 2, 28 February 2011 — Implement the use of ADS-B Out: <ul style="list-style-type: none"> — After 31 December 2013 for aircraft flying over PBN routes L642 or M771 between FL290 and FL410 — After 31 December 2014 for aircraft flying within Hong Kong Flight Information Region (FIR) between FL290 and FL410 — Must meet DO-260 (Version 0) requirements of ICAO Annex 10 and ICAO Doc 9871 Chapter 2, or DO-260A (Version 1) requirements of ICAO Doc 9871 Chapter 3 — Means of compliance per EASA AMC 20-24 or CASA CAO 20.18 Appendix XI
Civil Aviation Authority of Singapore	<ul style="list-style-type: none"> — Guidance material: CAAS AIP ENR 1.8, 7: Automatic Dependent Surveillance Broadcast (ADS-B) OUT Exclusive Airspace Within Parts of the Singapore FIR — Implement the use of ADS-B Out after 12 December 2013 within certain parts of the Singapore FIR (\geqFL290) — Must meet EASA AMC 20-24, or FAA AC NO. 20-165A, or CASA CAO 20.18 Appendix XI, otherwise must fly at $<$FL290
Taipei FIR	<ul style="list-style-type: none"> — Guidance material: AIP SUP 20/13 and AIP SUP 08/14 for Taipei FIR — Implement the use of ADS-B out: <ul style="list-style-type: none"> — With effect from 12 December 2013 for aircraft operating on routes B576 or B591 at or above FL290 when ATC radar surveillance services unavailable (Phase 1) — With effect from 31 December 2016 for aircraft flying at or above FL290 within Taipei FIR when ATC radar surveillance services unavailable (Phase 2) — Must meet EASA AMC 20-24 or CASA CAO 20.18 Appendix XI
Other Asia Pacific Regulatory Agencies	<ul style="list-style-type: none"> — Expected to follow ADS-B Avionics Requirements template per APANPIRG Conclusion 21/39 — Template states: Must meet EASA AMC 20-24 or CASA CAO 20.18 Appendix XI
Federal Aviation Administration of the United States (FAA)	<ul style="list-style-type: none"> — TSO C-154c — TSO C-166B (requires DO-260B compliance) — TSO C195a, Avionics Supporting Automatic Dependent Surveillance-Broadcast (ADS-B) Aircraft Surveillance Applications — AC 20-165a, Airworthiness Approval of Automatic Dependent Surveillance-Broadcast (ADS-B) — AC 20-138C, Airworthiness Approval of Positioning and Navigation Systems — AC 20-172A, Airworthiness Approval for ADS-B in Systems and Applications — AC 90-114 change 1, Automatic Dependent Surveillance-Broadcast (ADS-B) Operations

7

Business Case Guidelines

7.1 Introduction

The ability to support certain ATS applications is highly dependent upon aircraft capabilities. ANSPs should plan their investments in improved ATM systems and procedures based on their knowledge of what capabilities exist or are planned in the fleets operating in their areas of responsibility. In general, shorter term ATM improvements should be based upon current fleet capabilities and efforts should be made to coordinate with aircraft operators to determine their medium and longer term fleet plans so as to match the ATM improvements to aircraft capabilities.

The transition to equipage-based operations involves matching the level of service to the cost of equipage and services. When the services to be provided are based on aircraft equipage, ANSPs must consider the ability to support so called 'mixed mode' operations, where aircraft of differing capabilities operate in the same airspace. ATCO decision support tools are required to ensure that the appropriate separation minima are being applied between each aircraft pair. These tools may be as simple as indications on a flight progress strip or aircraft target or as complex as automated conflict prediction with resolution options. Mixed mode operations introduce, by their very nature, more complexity into the ATM environment. ANSPs should consider the potential costs of supporting a mixed mode environment when planning service improvements based on increased aircraft capabilities. ANSPs should coordinate with aircraft operators and regulators to develop options for avoiding mixed mode operations where the safety, efficiency and implementation costs could significantly impact the ability to deliver benefits from the new or improved services.

7.2 Implementation Scenarios

The potential business case depends on the implementation scenario for introducing space-based ADS-B into the ATM infrastructure.

As sole ATS surveillance source

In areas where there is currently no ATS surveillance coverage, introducing space-based ADS-B could enable significant safety, operational and infrastructure efficiency gains. This scenario would be relevant for ANSPs without any ATS surveillance coverage, or with limited coverage, that wish to reduce separation standards, increase route flexibility or move to tactical air traffic control. This scenario would also pertain to ANSPs that wished to limit or avoid major infrastructure investment to implement seamless ATS surveillance coverage.

To fill gaps in existing ATS surveillance coverage or augment ATS surveillance signals

In areas where ATS surveillance already exists, the introduction of space-based ADS-B could provide value by removing coverage gaps. The ANSPs under this scenario would be those without 100 percent ATS surveillance coverage and those which are planning to replace ground-based ATS surveillance infrastructure.

As additional ATS surveillance source

Space-based ADS-B service will be provided to ANSPs over a separate network than communications or other surveillance data. Some regulators require ANSPs to apply larger separation minima unless there are multiple ATS surveillance layers.

As contingency ATS surveillance source

Under this scenario, ANSPs would determine the potential benefits from using space-based ADS-B to support area control centre (ACC) backup and/or contingency services.

Space-based ADS-B could be available as a back-up in case of the failure of the primary ATS surveillance system. Equally, space-based ADS-B could be used in lieu of ATS surveillance data from a neighboring ANSP to provide contingency services or be used by a neighbouring ANSP to provide contingency services or for cross-centre utilisation within one ANSP with multiple ACCs.

7.3 Benefits and Costs

Each ANSP's situation will be unique when developing their business case; however there are a number of benefits and costs that should be considered for applicability to the analysis, based on whether the ANSP would use space-based ADS-B to implement, or to expand, ATS surveillance coverage.

Implementation Scenario 1: Benefits from implementing ATS surveillance

The application of procedural control techniques usually requires flights to operate at fixed and/or less than optimum speeds, routes and altitudes. Decreased fuel burn and GHG emissions should be calculated based on the increased percentage of flight hours during which flights would operate on fuel optimum flight profiles. The increased likelihood of, and time at, optimum profiles should result in operators carrying less fuel.

If adjacent airspace operates under ATS surveillance, there will be increased interoperability across the airspace boundary. This should result in increased efficiencies in both airspaces, which should be accounted for when calculating fuel burn and GHG reductions.

The availability of ATS surveillance would enhance the support possible for Search and Rescue (SAR) operations.

Reducing or removing transitions between separation standards (i.e. between ATS surveillance and procedural separations) may help to reduce

the number of operational errors associated with such transitions. This may improve the overall safety level from the timely detection of operational errors and the ability for ANSPs to implement ATS surveillance-based safety nets.

Introducing ATS surveillance separation minima could facilitate more timely and efficient service to aircraft experiencing in-flight contingencies or seeking to avoid turbulence or other adverse meteorological conditions.

Implementing ATS surveillance coverage could enable an ANSP to introduce or expand controlled airspace.

The efficiency and effectiveness of air traffic flow management (ATFM) and collaborative decision making (CDM) could be improved through the availability of real-time information. The improvements would be enhanced if multiple stakeholders had access to the same ATS surveillance data, for a shared situational awareness.

Implementation Scenario 2: Benefits from expanding or supplementing existing ATS surveillance

If the implementation involves introducing smaller ATS surveillance separation standards, this may increase in the number of flight hours during which flights will operate on fuel optimum flight profiles. This should also facilitate more efficient service to aircraft experiencing in-flight contingencies or seeking to avoid turbulence or other adverse meteorological conditions.

Eliminating gaps in ATS surveillance coverage will eliminate areas where flights must be transitioned between procedural and ATS surveillance separations. This will reduce operational errors associated with such transitions along with supporting the seamlessness of efficient operations for the flights concerned. Eliminating

such gaps may also increase interoperability between adjacent ANSPs, which often translates into increased flight efficiency and fewer opportunities for operational errors.

Reducing or eliminating a requirement to rely on ground-based ATS surveillance would allow an ANSP to reduce or avoid the costs to replace and maintain the associated infrastructure. There would also be reduced environmental impacts due to the elimination or reduction of emissions to provide power to infrastructure sites and for personnel to travel to and from these sites.

Including space-based ADS-B as an additional ATS surveillance source would increase redundancy, because this service will use a separate transport network. It would also increase the ability for any ANSP to provide contingency services on behalf of another.

The implementation of ATS surveillance services would not be affected by where it is possible or economically feasible to install or maintain ground-based infrastructure.

Benefits For Aircraft Operators

The introduction or expansion of ATS services will increase operational flexibility and predictability for operators. Where operators are confident of being able to operate at or near their optimum flight profiles, it may be possible to reduce the amount of fuel carried, which will also reduce the amount of fuel burned by that flight. Any reduction in fuel burn will result in lower GHG emissions, which may lead to economic as well as environmental benefits for the operator.

Aircraft that will operate within ATS surveillance coverage will not be subject to mandatory tracking by the operator. The global coverage afforded by space-based ADS-B could lead to significant cost avoidance for operators

who would otherwise be required to implement or expand their own flight tracking capability.

Space-based ADS-B reception does not require additional aircraft equipment. The system will be compatible with all DO-260 series transponders and the global ACAS standards require most aircraft to have antenna diversity.

Operators would benefit from any increase in airspace safety levels.

Costs

ANSPs will have a subscription cost to receive the space-based ADS-B service and implementation costs to add this service as an ATS surveillance source. For ANSPs without existing ATS surveillance, there will be additional implementations costs to prepare personnel and ATM systems to provide entirely new services. It should also be noted that different ANSPs have different approaches to how they pass on their operating costs to aircraft operators.

Due to the existing global standards for ACAS equipage (ICAO Annex 6, Volumes I,II and II and ICAO Annex 10, Volume IV),there should be no additional costs for most transport category aircraft to equip for space-based ADS-B provided appropriately equipped aircraft are providing usable ADS-B signals from their top-mounted antennas.

8

Conclusions

Space-based ADS-B will support seamless ATS surveillance, which would enable more seamless and interoperable operations between continental and oceanic regions, increasing safety, efficiency and predictability for aircraft operators and ANSPs.

Space-based ADS-B will support a common view of the ATM system by all stakeholders that would enable more effective collaborative decision-making and more efficient ATFM.

There are environments (oceans, deserts, polar and mountainous areas) where it can be uneconomic or difficult to install and maintain ground-based infrastructure.

Reliance on space-based infrastructure would avoid installation and maintenance costs for ground-based infrastructure, including the environmental costs associated with travelling to and from sites and supplying power to those sites.

ATS surveillance meets GFT requirements; space-based ADS-B can support GFT globally.

Space-based ADS-B would support seamless application of ATS surveillance separation between ACAS-capable aircraft equipped with DO-260 series transponders, independent of aircraft PBN capability.

The potential for improved flight efficiency and safety benefits increases with the expansion of ATS surveillance coverage and improvements to communications capabilities. This includes reducing communication delays for existing technologies and expanding VHF DCPC coverage. These improvements would also enable a more seamless application of separation standards between ANSPs.

Acronyms

ACARS	Aircraft communication, addressing and reporting system
ACAS	Airborne collision avoidance system
ACC	Area control centre
ADD	Aircraft derived data
ADS-B	Automatic dependent surveillance - broadcast
ADS-C	Automatic dependent surveillance – contract
ANS	Air navigation system
ANSP	Air navigation service provider
ASBU	Aviation System Block Upgrades
ATC	Air traffic control
ATCO	Air traffic controller
ATFM	Air traffic flow management
ATM	Air traffic management
ATS	Air traffic services
CANSO	Civil Air Navigation Services Organisation
CDM	Collaborative decision making
CNS	Communication, navigation, surveillance
CPDLC	Controller-pilot data link communications
DARP	Dynamic airborne reroute procedure
DCPC	Direct controller-pilot communication
EHS	Enhanced Mode S
ELS	Elementary Mode S
ESASSP	EUROCONTROL Specification for ATM Surveillance System Performance
EU	European Union
FCU	Flight control unit
FIR	Flight information region
FMS	Flight management system
GANP	ICAO Global Air Navigation Plan
GFT	Global Flight Tracking
GHG	Greenhouse gas
GNSS	Global navigation satellite system
GPS	Global positioning system
GVA	Geometric vertical accuracy
HF	High frequency
ICAO	International Civil Aviation Organization
IR	Implementing rule
km	Kilometer

MCP	Mode control panel
MHz	Mega hertz
MLAT	Multilateration
NAC	Navigation accuracy category
NIC	Navigation integrity category
NM	Nautical mile
PANS-ATM	Procedures for Air Navigation Services - Air Traffic Management (ICAO) (Doc4444)
PBN	Performance-based navigation
PRF	Pulse repetition frequency
PSR	Primary surveillance radar
RCP	Required communication performance
RNAV	Area navigation
RNP	Required navigation performance
RPAS	Remotely piloted aircraft systems
rpm	Revolutions per minute
SAR	Search and rescue
SASP	Separation and Airspace Safety Panel
SATCOM	Data link via satellite
SATVOICE	Voice communication via satellite
SDA	System design assurance
SIL	Source integrity level
SMGCS	Surface movement guidance and control system
SPI	Special purpose identification
SPI IR	Surveillance performance and interoperability implementing rule (European Union)
SSR	Secondary surveillance radar
TMA	Terminal management area
UPR	User preferred route
VHF	Very high frequency
WAM	Wide area multilateration
WGS-84	World Geodetic System revision 1984

References

CANSO; Standard: *Common Safety Methods on Risk Evaluation and Assessment for ANSPs*

International Civil Aviation Organization (ICAO); *Annex 6 to the International Convention on Civil Aviation - Operation of Aircraft*

ICAO; *Annex 10 to the Convention on International Civil Aviation - Aeronautical Telecommunications, Volume IV - Surveillance and Collision Avoidance Systems*

ICAO; *Annex 11 to the Convention on International Civil Aviation - Air Traffic Services*

ICAO; *Procedures for Air Navigation Services - Air Traffic Management (PANS-ATM, Doc 4444), Fifteenth Edition - 2007*

ICAO; *Global Air Traffic Management Operational Concept (Doc 9854)*

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