AIRCRAFT SURVEILLANCE VERSUS TRACKING

A comprehensive analysis of the differences between surveillance and tracking of aircraft

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Surveillance Versus Tracking Whitepaper

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EXECUTIVE SUMMARY

Extensive search and rescue efforts following recent high-profile airline disasters have left the general public largely surprised that the exact location of aircraft is often unknown in oceanic and remote airspace. In response, the International Civil Aviation Organisation (ICAO) has recommended that aircraft provide position reports every 15 minutes by November 2018 and several tracking solutions are being considered by airlines, air navigation service providers (ANSPs) and regulators. Unfortunately, there exists a great deal of confusion around what should be considered “surveillance” and what should be considered “tracking”.

“Tracking”, “Surveillance” and “ATS (Air Traffic Services) surveillance” are all distinct concepts with different applications. The key difference between ATS surveillance, surveillance and aircraft tracking is an issue of precision.

<u>Aircraft tracking and some high altitude surveillance systems show where an aircraft *was* with large margins</u>. They obtain data on an aircraft’s last known position with a certain delay, which can be used for situational awareness or as conformance monitoring against a planned route. This involves large separation standards and rigid requirements on the aircraft’s path, speed and altitude. Automatic Dependent Surveillance-Contract (ADS-C), a communications technology that requires specialised and activated equipage to provide a delayed position update to the ground, is often used to for this so-called procedural control.

By comparison, <u>ATS surveillance systems shows where an aircraft *is* with a high level of precision</u>. ATS surveillance refers to the ability of air traffic control (ATC) to receive *near* <u>**real-time**</u> aircraft position updates to support the provision of ATS surveillance services. ATS surveillance satisfies all tracking requirements. It can also be used to provide tactical control of transponder equipped aircraft allowing for 5 or 3 nautical miles (NM) of separation with direct controller pilot communication (DCPC) such as very high frequency (VHF) radio and reduced oceanic separation of around 15 NM. This reduced separation allows aircraft to be spaced closer together, which therefore increases traffic flows, cuts flying time and reduces fuel burn, especially in high-traffic corridors.

Any system could be classified as ATS surveillance if it can provide a position report at least once every 8 seconds and exhibit latency (delay between its reception and presentation to ATC) of less than or equal to 2 seconds. Only primary surveillance radar (PSR), secondary surveillance radar (SSR), multilateration and both space- and ground-based Automatic Dependent Surveillance-Broadcast (ADS-B) meet known standards that describe the minimum level of performance of ATS surveillance systems. In comparison, ADS-C can send an update a maximum of once every 64 seconds and the latency of message delivery has never been demonstrated to be below 2 seconds.

	Update interval	**Latency**	**Frequency protection**	**Supports provision of ATS services?**	**Example technologies**
Tracking	*Varies*	*>2 seconds*	*Not required*	*No*	*Low power ADS-B receivers, specialised tracking avionics*
Surveillance	*>8 seconds*	*>2 seconds*	*Yes*	*Procedural conformance monitoring only*	*ADS-C*
ATS Surveillance	*<8 seconds*	*<2 seconds*	*Yes*	*Both procedural and tactical ATS services*	*Radar, multilateration and ADS-B*

SURVEILLANCE VERSUS TRACKING

1.1 Introduction

In December 2014, the Aircraft Tracking Task Force (ATTF) was established by the International Air Transport Association (IATA). ATTF has since submitted a report containing draft options for enhanced global aircraft tracking to ICAO. Based on this, ICAO has recommended that aircraft provide position reports at least every 15 minutes by November 2018. In line with this, airlines are now exploring the seemingly ever-increasing number of options that would ensure compliance with this mandate.

This discussion has become somewhat clouded and there exists a great deal of confusion as to the differences between various solutions and especially with regards to what should be considered "surveillance" and what should be considered "tracking". With no clear, accurate or standard industry definition that would help stakeholders make this distinction, this paper aims to eliminate misconceptions and act as a reference document for those looking to better understand the performance of different tracking and surveillance solutions so they can be correctly categorised.

1.2 Limitations of Existing Surveillance and Tracking Technologies

The attention around search efforts following the accidents in oceanic airspace of both Air France Flight 447 (AF447) and Malaysia Flight 370 (MH370) left the general public largely surprised that not every aircraft is being tracked or surveilled in all regions of the world. One of the main reasons is the dependence on land-based antennas for the primary means of surveillance as well as the slow, high altitude systems used for tracking. On top of that, maintenance of ground based systems in remote regions can be a real challenge. In August 2015, for example, copper cable thefts affected the United States (US) National Weather Service radar system as well as the Federal Aviation Administration (FAA) radar system at Indianapolis International Airport. Metal theft is also common in African regions, while radar failures are not infrequent in the Caribbean due to corrosion of components from salt in the air.

Surveillance and tracking of aircraft flying over the oceans via radar or alternatives such as wide area multilateration (WAM) and ground-based ADS-B is next to impossible given that the requisite supporting infrastructure needs to be installed upon the ground. A ground station on a ship or oil drilling platform as a workaround is impractical due to the fact that all these technologies are restricted by line-of-sight. That is, the detection range is limited to objects on the horizon due to the curvature of the earth and also, the fact that ships are constantly on the move.

As such, the only way to keep tabs on an aircraft overflying remote regions is via satellite. As this paper explains, tracking is carried out via satellite but the inherent performance limitations of such solutions mean that they are unsuitable for real-time surveillance purposes. The use of ADS-C is a case in point and some 11,000 aircraft (approximately 50% of the total global commercial fleet) are fitted with the equipment to provide position updates via this technology. Though more aircraft are equipped with ADS-B, the space segment that would allow for global tracking and surveillance is still a couple of years away from commercial launch. ADS-B, ADS-C and other tracking technologies are explained in greater detail later in this paper.

1.3 Surveillance, ATS Surveillance and Aircraft Tracking

In a document published in June 2014 by IATA that provides answers to frequently asked questions of ATTF, it is made explicitly clear that ATTF's remit is to focus solely on tracking and not surveillance. It goes on to provide the following definition on the difference between the two:

"Aircraft surveillance is considered to be an ATC function – its primary purpose is to ensure separation between aircraft. Aircraft tracking is the ability to know where a plane is at any point – it does not make distinctions between aircraft relative to where they are to other aircraft, objects etc. It's simply where the aircraft is at a point in time."

This definition is somewhat true but also a little misleading and there are several reasons for this. First, there needs to be a recognition that "surveillance" and "ATS surveillance" are two different concepts and that the former should not be used in place of the latter. Surveillance refers to the ability to determine the position of an aircraft for the purposes of providing it with services such as procedural control (explained in greater detail in Section 1.4). ATS surveillance, on the other hand, is much more precise and refers to the ability of ATC to receive *near* **real-time** aircraft position updates to support the provision of ATS surveillance services.

An ATS surveillance system able to provide ATS surveillance services is defined by ICAO in the 15th Edition of *Procedures for Air Navigation Services – Air Traffic Management (PANS-ATM doc 4444)* as:

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

Second, the ATTF definition does not mention known standards that describe the minimum level of performance of ATS surveillance systems. PANS-ATM defines a comparable ground-based system as:

> *"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".*

It is this comparative level of performance that ultimately dictates if a solution can be used for the purposes of ATS surveillance. If it cannot, it must therefore be considered to be aircraft tracking.

Though there are numerous key parameters against which systems can be assessed in order to determine whether or not its performance is equal to or better than monopulse SSR, the two most important are update interval and latency. In simple terms, update interval refers to how often ATC receives an update of the aircraft's position. European Organisation for Civil Aviation Equipment (EUROCAE) ED-129B describes the technical specifications for a 1090 MHz extended squitter ADS-B ground station, which can be used as a reference for the minimum performance requirements expected of all ATS surveillance systems. In it, an update interval of at least 8 seconds is specified and such systems must be capable of providing aircraft position updates within 8 seconds 95% of the time. Latency is equal to the time difference between the creation of the position information and when this is presented to an ATM automation platform. The maximum allowable latency of an ATS surveillance system according to EUROCAE ED-129B is 2 seconds.

A key difference between ATS surveillance and aircraft tracking therefore boils down to an issue of precision meaning aircraft tracking systems cannot actually show where an aeroplane is at any point in time as the ATTF definition suggests. Rather, aircraft tracking systems show where an aircraft *was*. By comparison, ATS surveillance systems – as accurately as is possible – show where an aircraft *is*.

Another important difference concerns the protection of spectrum. ATS surveillance technologies are recognised in the International Telecommunication Union (ITU) Radio Regulations as safety of life services. This means spectrum used by these technologies is primary protected such that no other entity can interfere with that frequency band. Spectrum used by tracking technologies is not deemed to be safety of life and is not, therefore, afforded the same protection.

1.4 ADS-C is not an ATS Surveillance System

A third point that needs further clarification when explaining the difference between aircraft tracking and ATS surveillance lies at the heart of two key technologies used for these purposes: ADS-B and ADS-C. As mentioned earlier, ADS is an acronym for Automatic Dependent Surveillance. The B suffix stands for “Broadcast” and the C suffix stands for “Contract”. Although very similarly named, these are two distinct technologies. In short, ADS-B is a way for aircraft to determine position via satellite navigation and frequently and in near real-time, broadcast it, via transponder. The information can be received by ground stations and displayed for ATC use and by aircrew in other aircraft to provide situational awareness. In simple terms, ADS-B can be considered an upgrade to radar and, as is explained in the following section, it is considered an ATS surveillance system. ADS-C communications, on the other hand, are carried out via SATCOM or VHF radio using the Aircraft Communications Addressing and Reporting System (ACARS) protocol.

The main area of confusion surrounds the way in which ADS-C is named. Because the second letter of the acronym relates to the word “surveillance”, a common and understandable misconception is that ADS-C can be used for ATS surveillance services. However, the inherent performance limitations of ADS-C mean that this is not true. Indeed, PANS-ATM states that ADS-C will not support the provision of ATS surveillance services due to the fact that the update interval and latency associated with this technology do not meet any of the required minimums mentioned previously. Rather, ADS-C is a communications technology that can be adapted for the purposes of aircraft tracking.

ADS-C position reports are automatically sent according to a contract (software arrangement) between ATC and the aircraft’s navigational system on a specified periodic basis. Usually, this is every 15 minutes but can be less. Crucially, the highest possible update interval for Future Air Navigation System (FANS) 1/A avionics, via which the majority of ADS-C signals are sent, is 64 seconds. If the ground system specifies a time interval less than this, the aircraft system will respond with a non-compliance notification and establish a periodic contract with a 64-second reporting interval. The main industry standards describing the operation of FANS-1/A products are EUROCAE ED-100 and Radio Technical Commission for Aeronautics (RTCA) DO-258, both of which discuss interoperability requirements for ATS applications using ARINC 622 data communications.

It is also worth noting that with ADS-C, there can be a significant delay between the time a position report is created and the time it reaches the ATM automation platform, regardless of whether it was sent via high frequency (HF), VHF or SATCOM. ADS-C data is measured against Required Surveillance Performance specification 180 (RSP180). This is derived from criteria established for the application of 30 NM and 50 NM longitudinal separation minima in procedurally controlled airspace and contained within PANS-ATM. Specifically, RSP180 states downlink latency should not exceed 180 seconds 99.9% of the time and 90 seconds 95% of the time. Though ADS-C downlink latency is oftentimes below 30 seconds (but still above the maximum 2 seconds allowable for an ATS surveillance system) it can sometimes be as high or even higher than 240 seconds.

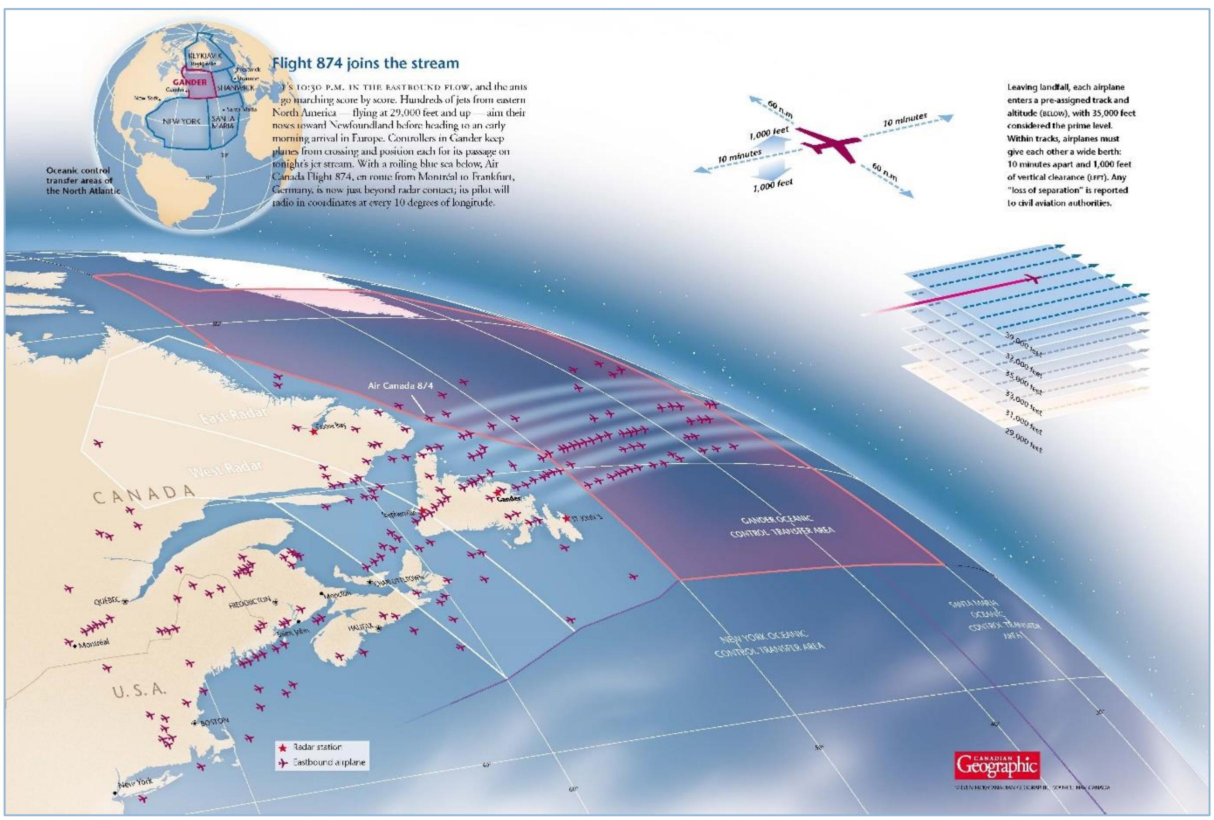
ADS-C is used in oceanic regions and other remote environments for procedural control. Procedural control is a method of providing ATC services (note, this is not the same as ATS surveillance services) without the use of radar or a comparable system that meets the minimum requirements of an ATS surveillance system. As is the case with ATS surveillance services, the basic premise of procedural control is to reduce the risk of aircraft colliding by applying separation standards. With procedural control, these separation distances need to be longer due to less frequent update intervals and higher latency. The process of separation is achieved by clearing aircraft to fly a predetermined route (airway) and then defining a block of protected airspace around it that other aircraft cannot enter. ADS-C has a built-in capability for conformance monitoring such that if a position report indicates the aircraft is no longer following this predetermined route, ATC is automatically alerted.

The reader should note that procedural control is fundamentally different to tactical control. With tactical control, approved ATS surveillance technologies are used to ensure minimum separation distances between aircraft. This also allow much greater flexibility to manoeuvre an aircraft for speed, altitude and route. Because this involves systems that update at least once every 8 seconds with minimal latency, separation standards are much shorter. For example, in controlled en-route airspace (i.e. where ATS surveillance services are being provided), the horizontal separation standard between aircraft flying at the same altitude is 5 NM. In terminal area airspace, it is 3 NM. Both these separation standards require appropriate navigational aids and communications with the ground.

In a procedural environment, separation is divided into three categories. Vertical, longitudinal and lateral. Frequently mentioned is 30/30 horizontal separation where aircraft must be 30 NM apart laterally and longitudinally. However, lateral separation is typically driven by topography such that aircraft are separated by degrees of latitude, while longitudinal separation is time-based. It is common to see an applied longitudinal separation minimum of ten minutes (about 80 NM). The 30/30 horizontal separation standard is a best-case scenario. There must also never be less than a minimum of 1,000 feet of vertical spacing between aircraft. Compared to tactical control, there is much less flexibility as an aircraft is cleared to fly a predetermined route with other aircraft prevented from entering a block of protected airspace around it.

When space-based ADS-B becomes available, tactical control can be extended to oceanic regions.

Figure 1: Diagram Showing the Transition from Radar to Procedural Airspace



Source: NAV CANADA

1.5 ATS Surveillance Systems

Prior to 2007, ICAO defined separation applications either as procedural, or based on radar (tactical). The publication of PANS-ATM that year saw ICAO formally acknowledge that radar-like systems had been developed and incorporated updated references to "ATS surveillance" rather than "radar". Following the subsequent publication in 2012 of ICAO Circular 326, which provides an assessment of ADS-B and MLAT surveillance to support ATS, only the following systems can currently be defined as meeting the aforementioned minimum performance requirements of an ATS surveillance system:

- **PSR**: These systems transmit a high-power signal, some of which is reflected by the aircraft back to the radar. The radar determines the position of an in-range aircraft from the elapsed time between transmission and reception of the reflection. Unlike SSR (below), PSR does not require any specific equipment on the aircraft.
- **SSR**: These systems depend upon exchanges with transponder-equipped aircraft. SSR is classified as a "cooperative" ATS surveillance system, since it 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.
    - **Mode-S**: This is essentially a form of SSR. Mode-S transponders are capable of providing additional information in response to an interrogation.
- **Multilateration (MLAT)**: MLAT is a cooperative ATS surveillance system that calculates an aircraft's position by measuring the time difference between a signal being sent by existing aircraft transponders and when it is received by a minimum of three ground stations. An enhanced implementation, WAM, can cover larger airspaces.
- **ADS-B**: This is a system in which, like radar, the aircraft transmits identity and altitude information to the ground station. However, unlike radar, the position of the aircraft is also determined on the aircraft and transmitted to the ground. Data is broadcast periodically and any receiver (ground or airborne) may receive the data.
    - 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.
    - Space-based ADS-B is the receipt of ADS-B signals by receivers on a low earth orbit (LEO) constellation of satellites. Typically, data is routed via cross-links connecting the satellites then to a terrestrial gateway station, before being transferred to terrestrial data networks for availability to ATM systems for processing.

1.5.1 Benefits of Surveillance

In June 2015, all commercial flights across New Zealand were grounded for nearly two hours due to a radar fault that affected the entire country's entire airspace. This example highlights the degree to which ATC is reliant upon ATS surveillance services to ensure separation over land. It also goes to show that there is not a comparable degree of panic when airlines fly over oceanic regions where radar is not present. Instead, procedural control is accepted as an adequate means of keeping tabs on aircraft, even though traffic density may be similar. This begs the question: why is procedural control not adopted as a backup means of ensuring aircraft are adequately separated should a land-based radar fail? As discussed throughout this paper, the performance capabilities of ATS surveillance systems like radar ensure a much greater degree of flexibility when controlling aircraft such that they can be spaced much closer together while maintaining safe and orderly travel. Once global space-based ADS-B is operational, ATM management will massively improve efficiency and safety over the oceans.

1.5.2 Aircraft Tracking and ICAO Recommendations

As has been established in this paper, there exist performance-based standards for determining the position of an aircraft such that it can be provided with ATS surveillance services. However, there is little detail on the tracking side, which is why, in the face of recent airline disasters, particularly the disappearances of AF447 and MH370, ICAO is in the process of developing such applicable standards. The Global Aeronautical Distress and Safety System (GADSS) concept of operations has now been initiated and describes a three-tiered approach for global aircraft tracking over the short, medium and long-term, covering normal, abnormal, and distress conditions.

In normal conditions, ICAO recommendations require aircraft to provide position reports every 15 minutes using currently available technologies. These recommendations must be implemented by airline operators by November 2018 at the latest. By 2018, only ADS-C and space-based ADS-B will fulfil the ICAO recommendations in remote environments and in oceanic regions. There are key differences between these two technologies and the mandates that have/will force equipage, the operational benefits of implementation and the costs involved. The following two sections provide a thorough assessment of the use of space-based ADS-B and ADS-C for global flight tracking.

1.5.3 Using Surveillance for Flight Tracking

1.5.3.1 EQUIPAGE

ADS-B has been described as the cornerstone of next generation of radar and of air traffic modernisation. The sheer size of some countries can make providing radar coverage across an entire landmass too costly. Canada, for example, lacks radar coverage over Hudson Bay which is crossed by busy traffic flows that would benefit from efficiency and safety gains through improved surveillance. With ADS-B, ATC can more quickly obtain more accurate position reports containing data on the intent of an aircraft. Thus, it offers a way to achieve these goals at a relatively low cost; an equivalent radar site is some 12 times more expensive than an ADS-B ground installation.

For these reasons, many countries have mandated equipage of ADS-B. The FAA requires that by 2020, all aircraft entering US airspace must have ADS-B capabilities to perform separation services. Europe has a similar mandate for ADS-B equipage on certain aircraft. Other countries to have mandated ADS-B equipage include: Australia, Hong Kong, Indonesia, Singapore, Sri Lanka, Taiwan, Vietnam and the Seychelles. China has no formal ADS-B mandate currently in place or any future mandate planned but authorities are testing the technology along certain airways. Canada has also not mandated ADS-B equipage but is, nonetheless, already using the technology for ATC.

Additionally, the transnational nature of air transport means many countries will de facto equip as a result of mandates in neighbouring countries. In support of the potential for global surveillance of aircraft and hence a more interoperable aviation world, the ITU has reached an agreement to extend the existing radiofrequency spectrum for global flight tracking in civil aviation. The decision, announced at the 2015 World Radiocommunication Conference (WRC-15) in Geneva in November 2015, sees protection of the 1087.7-1092.3 MHz frequency band extended to the dimension of aircraft to space. Previously, this spectrum was protected only for transmission of signals from aircraft to terrestrial stations within line of sight.

The upshot of all this is that the vast majority of commercial passenger aircraft will have ADS-B technology as we move closer to 2020. Indeed, all new Boeing and Airbus models already roll off the line with ADS-B transponders installed as standard.

1.5.3.2 ADS-B TECHNOLOGY STRENGTHS AND LIMITATIONS

It is worth re-iterating that ADS-B has been demonstrated as meeting the minimum performance requirements of an ATS surveillance system in accordance with PANS-ATM. The aforementioned ICAO Circular 326 document provides details of an assessment undertaken by the Separation and Airspace Safety Panel (SASP) and demonstrates that

ADS-B is better or at least no worse than the reference SSR against which it was compared. The conclusion was that ADS-B can therefore be used to provide ATS surveillance services and a 5 NM separation minimum in accordance with PANS-ATM. Specifically, the performance requirements ADS-B had to meet to provide this separation minimum were:

- Position Accuracy (A 95 percentile accuracy of 0.5 NM)
- Position Integrity (A containment radius of <2 NM and the likelihood of the position error exceeding containment radius of 1e – 5)
- Position Latency (4 seconds)
- Position Update Rule (12 seconds)

There can be no bigger endorsement for the use of ADS-B as ATS surveillance than the number of countries that have mandated equipage of this technology. Singapore, for an example, is a major air hub encountering a huge amount of traffic on a daily basis. Since the mandate was announced in 2011, ATC there has benefitted from a more accurate picture of air traffic due to the higher update rate of ADS-B compared to traditional radar. Likewise, Airservices Australia (Australia's ANSP), has seen excellent acceptance of ADS-B by ATC and its customers, both having already benefitted from lower costs in addition to safety and efficiency gains.

A key strength of ADS-B is that it is GPS based with data integrity and accuracy built into the message protocol. What this means, in simplistic terms, is that ADS-B messages contain an internal check (called a "Navigational Uncertainty Category Position" [NUCp] value) to indicate the reliability of the position report. This NUCp value is expressed as an integer between 0 and 9. PANS-ATM indicates that ADS-B shall only be used for the provision of ATC services if the quality of the information contained in the ADS-B message exceeds the values specified by the appropriate ATS Authority. Generally, ADS-B information is used for the provision of ATS surveillance services provided the NUCp is greater than or equal to 5. Otherwise, the position report is discarded.

Because ADS-B OUT is a one-way transmission, there are some who suggest its use in enhancing the development of ATC based on surveillance over the oceans is limited. The argument being that in order to deliver safe and orderly ATC, there must exist surveillance capabilities, navigational aids and communications between the aircraft and the ground. Communications options over the oceans today consist mainly of HF radio and SATCOM but these are not sufficient to provide ATC and the smallest separation distances between aircraft. Nevertheless, the introduction of ADS-B (which provides only the surveillance element of safe and orderly ATC) combined with already existing communications and navigation capabilities will represent a huge step forward in for safe flight in oceanic regions. The addition of potential future technologies such as push-to-talk SATCOM will provide the communications aspect such that the pilot and ATC could converse with one another (in real-time) should an intervention be required in order to prevent a collision. This would be less costly than adopting FANS 1/A equipment and benefitting from associated two-way ADS-C messaging.

1.5.3.2.1 ADS-B Reception from Space

One of the major strengths of ADS-B is that when the space-based segment is fully operational, it will be a truly global solution. This is because ADS-B receivers are being built in to each of the 66 satellites that comprise Iridium's second-generation satellite constellation, Iridium NEXT. Iridium NEXT, like the current network it is set to replace, is unique in that it is the only constellation to cover 100% of the earth's surface. Other satellite constellations, such as those operated by Inmarsat, are not truly global because they do not provide coverage of the polar regions. This is important as airlines can save huge amounts of fuel flying polar routes. Arctic routes are commonly flown by airlines with services between Asia and North America but few fly routes that cross the Antarctic.

Though it might sound obvious, reception of an ADS-B signal in space is no different to on the ground. It is another form of ATS surveillance – the only difference being that a global satellite constellation is used to provide coverage in those remote regions where, previously, it was not possible to benefit from ATS surveillance services.

1.5.3.3 BENEFITS OF ADS-B IMPLEMENTATION IN PROCEDURAL AIRSPACE

As discussed previously in this paper, the introduction of space-based ADS-B means tactical control can be extended to oceanic regions. Simply put, the extension of ADS-B into the procedural ATC environment offers the potential for more frequent position updates as well as information on the future intent of the aircraft. In an environment where position reports are communicated directly from the aircraft to ATC, and where ATC is automatically kept up to date on the intentions of the aircraft, significant reductions in separation minima will be possible.

Reduced separation in oceanic regions allows aircraft to be spaced closer together, which will increase capacity, cut flying time and reduce fuel burn, especially in high-traffic corridors such as the North Atlantic. As it stands, airways (sometimes referred to as tracks) are separated by one degree of latitude – the equivalent to 60 NM. Space-based ADS-B from Aireon will bring 15 NM separation over the North Atlantic. According to NAV CANADA, a privately run, not-for-profit corporation that owns and operates Canada's civil air navigation system and an investor in Aireon, space-based ADS-B will allow airlines to fly more direct routes with more optimal climbs and descents. In the North Atlantic region alone, this is expected to translate to some $125 million per year in fuel savings.

A major advantage of being ADS-B equipped is that an aircraft can receive ATS surveillance services and comply with ICAO tracking recommendations. Importantly, ICAO recommendations and the proposed EU flight tracking mandate both state that if an aircraft is receiving ATS surveillance services, there is no requirement for the airline to track it. As such, it can be stated that ATS surveillance systems can be used for global flight tracking but tracking solutions cannot be used to provide ATS surveillance services.

An aircraft travelling over the ocean that goes off frequency can travel a long distance in the thirty minutes before search and rescue actions need to be initiated resulting in a huge search area. The use of ADS-B in tracking aircraft has important implications for search and rescue efforts. As position reports can be updated every 8 seconds and with latency under 2 seconds, potential search areas can be dramatically reduced. The table below shows the impact of different update intervals on potential search areas for common aircraft types in the area.

Table 1: Impact of Different Update Intervals on Search Areas

		Example prop aircraft	**Common turboprop in ASECNA airspace**	**Common jet in ASECNA domestic airspace**	**Common jet in ASECNA oceanic airspace**
		Cessna C172	Bombardier Dash 8	Boeing 737	Boeing 777
	Cruise speed (knots)	122	360	444	493
Potential search area (sq km)	PIREP (30min)	12,763	111,129	169,039	208,409
	ADS-C (15min)	3,191	27,782	42,260	52,102
	SB ADS-B (8sec)	0.3	2.2	3.3	4.1

Source: Aireon

1.5.3.4 COSTS INVOLVED WITH ADS-B EQUIPAGE

ADS-B systems rely upon two avionics components: a high-integrity GPS navigation source and an ADS-B transponder to transmit the ADS-B signal. Most modern aircraft already have a GPS device. Most are also required to be ACAS capable and are therefore very likely to be fitted with a Mode-S transponder, which provides the basic capability for ADS-B. ADS-B-capable Mode-S transponders use a so-called "extended squitter" (an extended portion of a transponder's transmission bandwidth) to transmit ADS-B OUT data. Thus, most aircraft already are already fitted with the required equipment to become ADS-B capable. Those that are not are limited in number and the cost to retrofit is low.

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 ATC display systems to support non-synchronous receipt and update of ADS-B data. Importantly, the expected fuel savings from ADS-B equipage are expected to significantly outweigh costs.

1.5.4 Using ADS-C for ATS Surveillance

1.5.4.1 EQUIPAGE

Most wide-body aircraft that travel long distances over water have an L-band SATCOM unit installed to maintain communications between the flight deck and ATC for operational and safety services. This means about half of the world's current commercial aircraft fleet have ADS-C messaging capabilities. There are a couple of mandates that will increase this number on both transoceanic and transcontinental aircraft in the next few years. These are as follows:

- The North Atlantic Track (NAT) data link mandate requires aircraft flying at certain altitudes within the NAT region to be FANS-equipped. The first phase of this mandate came into effect in February 2013 and requires equipage between flight level (FL) 360 and FL390 in some NATs. Phase 2A came into effect in February 2015 and requires equipage between FL350 and FL390 on all tracks within the NAT organised track system (OTS). Phase 2B comes into effect in December 2017 and requires equipage between FL350 and FL390 throughout the entire ICAO NAT region. Phase 2C comes into effect in January 2020 and requires equipage at FL290 and above throughout the entire ICAO NAT region.
- In January 2013, the Civil Aviation Administration of China (CAAC) implemented a policy that states 50% of Chinese commercial transport aircraft must be equipped with a SATCOM unit by 2015 and 100% by the end of 2017. It is understood that compliance has slipped somewhat and that the proportion of equipped aircraft is, at the time of writing, still some way shy of the 50% mark.

In summary, ADS-B equipage exceeds ADS-C equipage and this will remain the case in future, especially as not all aircraft (i.e. non wide-bodies) can be fitted with FANS 1/A equipment.

1.5.4.2 ADS-C TECHNOLOGY STRENGTHS AND LIMITATIONS

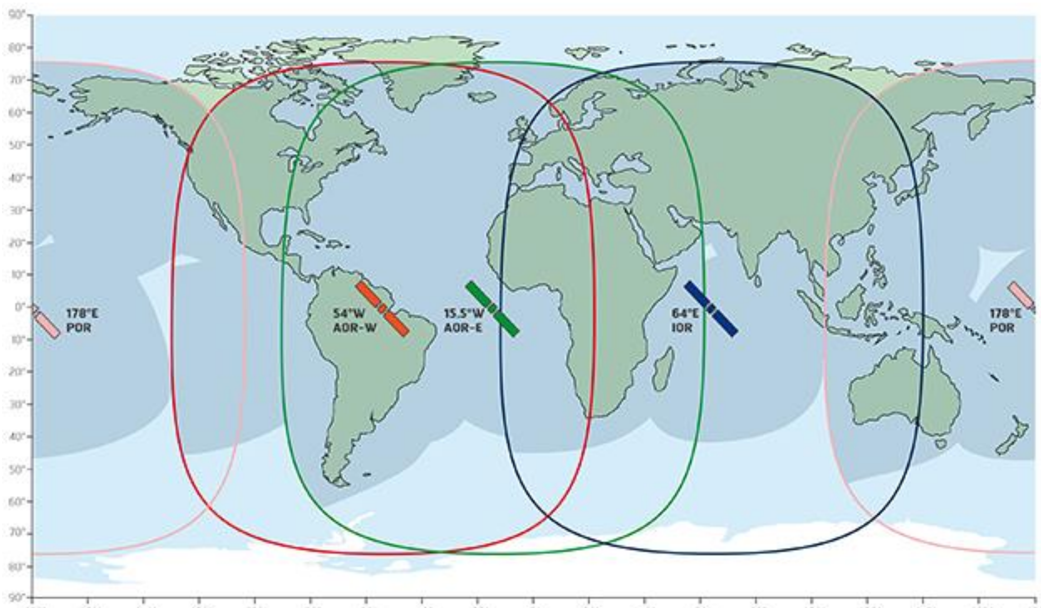
While ADS-B is a one-way transmission containing the aircraft's identity, altitude and position, ADS-C is a communications technology that has been adapted to transmit aircraft positions where no other alternatives could provide this capability. Controller Pilot Data Link Communications (CPDLC) and ADS-C 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 has resulted in 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 direct DCPC is available.

ADS-C provides a two-way communications function with ATC ground systems, and in addition to GPS-derived position reporting, includes information such as altitude, airspeed, directional flight and position following. It is argued that this allows for 4-dimensional (4D) trajectory based operation, which means more aircraft can share the same space. However, it is important to note that two ADS-C equipped aircraft are required to enable the lowest possible separation minima and both of these also need to be contracted (i.e. the contract between the aircraft and ATC needs to activated). In some cases, airlines do not activate the contract due to cost reasons (see Section 1.5.4.4). As an example, and according to the Airports Authority of India, just 30% of the aircraft operating in the Bay of Bengal and 12% of aircraft operating in Arabian Sea log on to ADS-C/CPDLC.

Because the maximum update interval for ADS-C is 64 seconds, it does not meet the minimum performance required of an ATS surveillance system and cannot be used to provide ATS surveillance services. Even though ADS-C downlink latency has been recorded in the single digits during recent testing of SwiftBroadband safety services, which is well within RSP180, it is never been shown to satisfy the 2 second maximum allowable latency of an ATS surveillance system as defined by EUROCAE ED-129B. Additionally, it has been suggested that Inmarsat's L-band satellite network may not be able to support a large number of aircraft sending ADS-C position updates at one minute intervals in line with ICAO's flight tracking requirements. However, the chances of multiple aircraft being in distress at the same time are, of course, very slim.

One of the drawbacks of ADS-C messaging via SATCOM is that it that the majority of systems operate over Inmarsat L-band satellites. Coverage for Inmarsat's Classic Aero services (Aero I, Aero H and Aero H+) excludes the polar cap regions, plus some areas of Russia, Greenland and Canada. Today, FANS over Iridium represents a very small proportion of all FANS 1/A equipped aircraft but it is expected to become increasingly viable in future, especially given enabling equipment is less costly than Inmarsat compatible equipment (see Section 1.5.4.4).

Figure 2: Inmarsat I-3 Satellite Coverage Map



Source: Inmarsat

With ADS-C, an Actual Navigation Performance (ANP) value is provided by avionics so that positional data is accompanied by a figure of merit (FOM), which is essentially, an accuracy value. Unlike ADS-B, no measure of integrity is built into the message protocol and thus conveyed to ATC. That said, and according to ICAO's Guidance

Material on Comparison of Surveillance Technologies published in September 2007, “downlinked data is subject to stringent transmission error detection algorithms virtually eliminating the risk of false data”.

It is also worth mentioning that ADS-C can only establish a connection with a maximum of five other entities. These entities are generally the ANSP an airline is currently in contact with, the adjacent ANSP monitoring operations close to its boundary, the ANSP that the airline will be controlled by next, as well as airline operational control (AOC). As this maximum is generally more than enough for standard usage, this limitation does not adversely impact ATM with ADS-C.

1.5.4.3 BENEFITS OF ADS-C IMPLEMENTATION

The main benefit of ADS-C is the reduction of separation in remote regions and over the oceans due to improved conformance monitoring. When the technology was introduced in the 1990s, separation standards could be reduced from 100 NM to 30 NM, essentially tripling the capacity of the ocean regions using ADS-C. With more frequent position reports, separation can be reduced further and as with ADS-B, cut flying time and reduce fuel burn. Instead of having to adopt a holding pattern for a period of time, aircraft can absorb delays en-route.

ADS-C meets ICAO’s recommendations for current technology to provide the position of aircraft to provide position updates every 15 minutes in normal conditions and every one-minute in the event of an abnormal event. The one-minute tracking interval is designed to provide search and rescue agencies with a more manageable search radius in the event of a crash or aircraft disappearance. Due to the fact that ADS-C cannot provide sub one minute updates, this search area would be larger than if ADS-B were used for tracking purposes. Both the 15-minute and one-minute tracking proposals include the requirement for position reports to contain the aircraft’s identification and its 4D position information. A 4D position report includes the aircraft’s latitude, longitude, altitude and the precise time it was at each position, all of which is contained within an ADS-C message.

1.5.4.4 COSTS INVOLVED WITH ADS-C EQUIPAGE

An aero-certified Inmarsat compatible SATCOM unit is estimated to cost between $50,000 and $250,000. Aero-certified Iridium-compatible SATCOM units cost in the region of $20,000 and $60,000. The cost of the remaining FANS 1/A equipment ranges between $100,000 and $750,000.

ACARS transmission costs depends on the contract an airline has in place with the service provider, which will be either SITA or ARINC (now part of Rockwell Collins) who operate a duopoly in this market. Typically, a certain number of kilobytes of traffic is included with each aircraft that is registered to use ACARS with any overages incurring an extra charge. Often, costs associated with ADS-C messaging via ACARS are hidden from airlines because they subscribe to a data package that can support a much broader set of communications. Indeed, there is a reluctance to use ADS-C to provide position updates more frequently than 10-15 minutes as the cost of providing once a minute update rates across the globe would quickly add up.

1.6 Key Takeaways

- Search efforts following recent airline disasters have left the general public surprised that not all aircraft can be tracked or surveilled in all regions of the world
- There exist important differences between the terms “surveillance”, “ATS surveillance” and “tracking” yet there is no clear, accurate or standard industry definition to help make this distinction
- ATS surveillance refers to the ability of ATC to receive near real-time aircraft position updates to support the provision of ATS surveillance services
- Known standards describes the minimum level of performance of ATS surveillance systems

- If the update interval of a solution exceeds 8 seconds and latency is greater than 2 seconds, a solution is tracking by definition
- Ground-based and space-based ADS-B are classified as ATS surveillance systems
- ADS-C can be used for tracking of aircraft but it is not an ATS surveillance system
- ADS-C has reduced separation standards in procedural environments. The inherent performance capabilities of ADS-B mean that it can reduce the level of separation further
- Position updates via ADS-C and ADS-B can provide search and rescue agencies with more manageable search radiuses in the event of a crash or aircraft disappearance
- ADS-B equipage exceeds ADS-C equipage and has been mandated in many regions
- Only space-based ADS-B can provide global surveillance and tracking of aircraft
- ADS-C equipage and associated transmission costs are expensive
- ATS surveillance systems can be used for global flight tracking but tracking solutions cannot be used to provide ATS surveillance services

APPENDIX 1 - ACRONYM AND ABBREVIATION LIST

4-D 4-Dimensional

ACARS .... Aircraft Communications Addressing and Reporting System

ADS-B .... Automatic Dependent Surveillance-Broadcast

ADS-C .... Automatic Dependent Surveillance-Contract

ANP .... Actual Navigation Performance

ANSP .... Air Navigation Service Provider

AOC .... Airline Operational Control

ASECNA .... Aerial Navigation Safety in Africa and Madagascar

ATC .... Air Traffic Control

ATM .... Air Traffic Management

ATTF .... Aircraft Tracking Taskforce

CAAC .... Civil Aviation Administration of China

CPDLC .... Controller Pilot Data Link Communications

DCPC .... Direct Controller Pilot Communication

EUROCAE .... European Organisation for Civil Aviation Equipment

FAA .... Federal Aviation Administration

FANS .... Future Air Navigation Services

FL .... Flight Level

FOM .... Figure of Merit

GADSS .... Global Aeronautical Distress and Safety System

HF .... High Frequency

IATA .... International Air Transport Association

ICAO .... International Civil Aviation Organisation

ITU .... International Telecommunication Union

LEO .... Low Earth Orbit

NAT .... North Atlantic Track

NM .... Nautical Mile

NUCp .... Navigational Uncertainty Category Position

Mhz .... Megahertz

OTS .... Organised Track System

PANS-ATM .... Procedures for Air Navigation Services – Air Traffic Management

PSR .... Primary Surveillance Radar

RSP .... Required Surveillance Performance

RTCA .... Radio Technical Commission for Aeronautics

SASP .... Separation and Airspace Safety Panel

SSR .... Secondary Surveillance Radar

VHF .... Very High Frequency

WAM .... Wide Area Multilateration

WRC .... World Radiocommunication Conference