AERONAUTICAL STUDY
Canadian ADS-B Out Performance Requirements Mandate

NAV CANADA
Navigation & Airspace
Level of Service
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Executive Summary

ADS-B technology is an efficient means of providing enhanced surveillance services and provide air traffic services (ATS) with more accurate and up-to-date information for managing aircraft traffic to improve aviation safety and efficiency.

According to the Transport Canada Performance-Based Navigation (PBN) Operations State Plan – planning for the mandatory use of ADS-B in designated airspace is to take place between 2018 and 2022. To meet this goal, this Aeronautical Study examined a performance requirement mandate for aircraft surveillance using ADS-B Out.

Canadian airspace includes 18 million square kilometres of domestic and oceanic airspace, much of which remains without surveillance and is controlled with less efficient procedural airspace rules. The use of space-based reception of ADS-B for surveillance presents an opportunity to expand surveillance coverage and enhance safety while increasing operational efficiency.

The proposal to implement a performance requirements mandate within the Canadian Domestic Airspace is based on ADS-B enhancing safety and efficiency by providing air traffic services (ATS) with highly accurate position and velocity data. The superior surveillance capabilities of ADS-B coupled with the geographic coverage available through space-based reception will result in an increase in traffic capacity and operational efficiencies within the air navigation system (ANS) through reduced aircraft separation standards, improved ability of air traffic controllers to plan arrivals and departures, accommodation of shorter notice in changes to flight paths, assignment of more direct routes and more flexible use of flight levels and variable speeds. In addition, this system will allow the expansion of surveillance coverage to areas in Canada where it would not be practicable to use the current ground based ADS-B, or conventional systems of radar and MLAT. All these advantages translate into improved ability of our customers to manage their operations along with emission reductions and fuel savings.

The aeronautical study team consulted with numerous domestic and international stakeholders. The ADS-B Out performance requirements were heavily influenced by the potential advantages of space-based reception of ADS-B. Some of the primary considerations included:

- How would an ADS-B performance requirements mandate improve the overall safety and efficiency of aircraft operations within Canadian Domestic Airspace;
- How would a NAV CANADA proposed space-based ADS-B Out performance requirements mandate compares to other States’ planned mandates, particularly the FAA and Europe whose ADS-B systems are ground based, and how can the NAV CANADA mandate harmonize with these other State plans to help minimize any impacts on our customers;
- What are the aircraft avionics equipage upgrades or new installation impacts on our customers, including the benefits they could realize from an ADS-B Out based surveillance system vs costs;
- What would be the appropriate timelines and scope of a NAV CANADA ADS-B performance requirements mandate considering the avionics equipage impacts, the FAA’s and Europe’s ADS-B implementation plans and NAV CANADA goals for modernizing surveillance systems to increase the safety and efficiency of air traffic services for our customers; and
- Internal to NAV CANADA operations, what level of effort is required from ATS Standards and Procedures, Engineering, Technical Operations and other affected NAV CANADA departments to implement any ADS-B Out performance requirements mandate and how could this impact the scope and timelines of any mandate.

After completing an assessment of issues related to the implementation of a performance requirements mandate that supports space-based receipt of ADS-B and the issues and concerns raised by stakeholders during consultation, the study team concluded the following:

- The safety benefits of implementing space-based ADS-B surveillance through the proposed performance requirements mandate include: increased ATC situational awareness through improved accuracy of aircraft position and trajectory, earlier warnings/alerts of unexpected aircraft
deviations, implementation of common surveillance technology to current and new airspace for a more seamless operating environment and improved emergency response for tracking and locating aircraft in distress.

- The implementation of a performance requirements mandate based on the Aireon space-based ADS-B system for Canadian Domestic Airspace initially limited to Class A airspace with an implementation date of January 1, 2021, will result in safety and efficiency benefits for our customers’ operations;
- To achieve the maximum benefits of a performance-based mandate within acceptable timelines, the performance mandate should be expanded to include Class B airspace on January 1, 2022. Beyond this date, expansion of a performance requirements mandate to other Canadian Domestic Airspace will be based on an assessment of the safety and efficiency requirements for specific airspace and through the modernization of our surveillance systems, which includes the expansion of surveillance coverage, decommissioning of select radars and other ground-based surveillance systems.
- To provide the necessary functionality of the ADS-B surveillance system the proposed mandate will require customers to equip or upgrade their aircraft to meet ADS-B avionics standards equivalent to DO-260, DO-260A or DO-260B by the mandate deadline of January 1, 2021, with a requirement for all affected aircraft to meet the RTCA/DO-260B (equivalent to EUROCAE/ED-102A) standard by January 1, 2024;
- The proposed mandate will provide our affected customers with safety and the efficiency benefits to justify any expense they will incur to upgrade their avionics to meet the performance requirements mandate;
- The proposed mandate will harmonize with U.S. and European ADS-B Out mandates in that aircraft equipped with the required avionics for those mandates will be properly equipped for this mandate;
- A large percentage of our customers will already be suitably equipped with the avionics required for the NAV CANADA proposed mandate due to the prior implementation of the U.S. and European mandates and the timeline for the implementation of this mandate provides sufficient time for our other affected customers to properly equip;
- The timing and scope of the proposed performance mandate will provide the surveillance coverage required to facilitate any potential future proposed ground-based surveillance decommissioning initiative.
- The proposed mandate supports the requirements and timelines for ATS initiatives to modernize their surveillance systems and will support seamless ATS surveillance between continental and oceanic regions; and
- The proposed mandate will meet the Transport Canada Performance-Based Navigation (PBN) Operations State Plan, which states that planning for the mandatory use of ADS-B in designated airspace is to take place between 2018 and 2022. It also aligns with ICAO navigation and surveillance plans and recommended practices.

Based on these conclusions this study recommends the following:

- It is recommended that NAV CANADA implement an ADS-B Out performance requirement mandate for Canadian Domestic Airspace that enables reception of signals from space
- It is recommended that the implementation occur in phases and be limited in scope as follows:
  - The recommended Phase 1 implementation date is January 1, 2021, and includes Class A airspace, and Class E airspace above FL600.
  - The recommended Phase 2 implementation date is January 1, 2022, and is assigned to Class B airspace, which includes all low level controlled airspace above 12,500’ ASL to below 18,000’ ASL.
  - Beyond the phases outlined above, it is recommended that the performance requirements mandate be applied as required in class C, D and E airspace to provide the required safety and efficiency associated with aircraft operations enroute or at an airport starting no
Implementation will not proceed until Transport Canada has reviewed an addendum to this study and concurrence is granted.

- The ADS-B Out avionics performance standards required for the start of Phase 1 and 2 are DO 260, 260A, or 260B or equivalent including broadcast antenna diversity (an antenna mounted on the aircraft top and bottom). Antenna diversity supports space-based ADS-B signal reception. From January 1, 2024, the minimum standard for all aircraft operating within the airspace defined by Phase 1 and 2 will be RTCA/DO-260B (equivalent to EUROCAE/ED-102A) with specified data elements.
1.0 Purpose

This aeronautical study will examine the proposal to put forward a Canadian Automatic Dependent Surveillance – Broadcast (ADS-B) Out performance requirements mandate, to enhance surveillance services and provide air traffic control (ATC) with more accurate and up-to-date information for managing aircraft traffic to improve aviation safety and efficiency.

2.0 Background

2.1 Overview

NAV CANADA is the authority responsible for the management and operation of the Canadian Air Navigation System (ANS). NAV CANADA provides the necessary services for the safe, expeditious, orderly and efficient movement or air traffic within the Canadian Airspace.

The Civil Air Navigation Services Commercialization Act (CANSCLA) stipulates that NAV CANADA has “the right to plan and manage Canadian airspace…”

The full text of section 13 of the CANSCLA reads:

Subject to the Governor in Council’s right under the Aeronautics Act to make regulations respecting the classification and use of airspace and the control and use of aerial routes, the Corporation has the right to plan and manage Canadian airspace and any other airspace in respect of which Canada has responsibility for the provision of air traffic control services, other than airspace under the control of a person acting under the authority of the Minister of National Defence.

Airspace management encompasses those organizational, planning, and design functions and activities that determine levels of service, and the creation of designated airspace structures.

The principal activity of NAV CANADA in the planning and design of Canadian Domestic Airspace is to determine the classification of designated airspace structures. This includes the level of air navigation services to be provided, the corresponding user performance requirements (equipage), and rules of conduct for that airspace.

Airspace user requirements include the following considerations:

a. Airspace access – the need to be able to operate in a specific airspace to meet the interests or mission requirements of the user;
b. Safety;
c. Cost-effectiveness – the cost of operation must produce a beneficial outcome;
d. Predictability – the ability to operate on schedule and/or at a dependable level of performance;
e. Efficiency – the ability to operate at a time the user selects while minimizing impacts on operations;
f. Flexibility – the ability of airspace users to modify flight trajectories dynamically and adjust departure and arrival times, thereby permitting them to exploit operational opportunities as they occur;
g. Security – specific needs of a user for security; and
h. Environment – compliance with environmental requirements.

Changes at the airspace design level are generally visible to the airspace user as a change in the level or nature of service, or a change in operation where a change in regulatory reference is required. Examples of such changes are where a pilot experiences a change in level of service provided (e.g. airspace class or airspace boundary change), a change in required equipage (e.g. Transponder requirement, Reduced Vertical Separation Minimum - RVSM certification), or specific procedural and operating requirements (i.e. mountainous region, RVSM, altimeter setting region). These changes can
be to the area of applicability of an existing requirement or to implement new requirements, procedures, and services.

Airspace classification, service changes and user performance requirements, including changing uncontrolled airspace to controlled airspace, could be outcomes from an ADS-B mandate.

2.2 Today’s Surveillance Environment

Air traffic control (ATC) surveillance and aircraft separation services are currently provided in Canada using primary and secondary surveillance radar systems (PSR and SSR), MLAT (Multilateration) and ADS-B received by ground-based antennas.

Radar

While radar technology has advanced, it is essentially a product of 1940s World War II technology. Both primary and secondary radars are very large structures that are expensive to deploy and maintain and require land for site installation.

Primary Surveillance Radar (PSR) is a passive detection method that requires no special equipment aboard the aircraft. It transmits a beam that is reflected by a target. This reflection forms a return signal that is translated into an aircraft position by ATC automation systems. Primary radar, however, is not always able to distinguish aircraft from other objects that reflect radar beams, such as birds or severe weather, which can result in “clutter” on the ATC radar scope. In addition, with primary radar, ATC is provided only with an aircraft’s position relative to time and not any other information about the aircraft.

A Secondary Surveillance Radar (SSR) system consists of antennas, transmitters, receivers, processors installed in ATC facilities, and aircraft installed radio transponder devices. This system enhances PSR by improving the ability to detect and identify specific aircraft. An SSR transmits interrogation pulses that elicit responses from transponders on board the aircraft. A transponder installed on the aircraft “listens” for the interrogation signal and sends back a reply that provides that aircraft’s information. The aircraft is then displayed as a tagged icon on the radar screen.

Much of the SSR coverage in north eastern Canada comes from DND’s North Warning System radars. NAV CANADA has an agreement with DND for access to a limited set of this radar data; however, the availability of the supply does not fully meet NAV CANADA’s air traffic management needs. In addition, these systems do not belong to NAV CANADA, therefore; maintenance and/or repair of the facilities is beyond our control.

In Canada, there are two types of SSR radar: Mode A/C and S. Mode A and Mode C are unaddressed meaning every transponder receiving a Mode A or Mode C interrogation will reply. This causes two problems: garbling and FRUIT (False Replies Unsynchronised to Interrogator Transmission). Garbling is caused by the overlap of replies from multiple transponders. When multiple aircraft reply to the same interrogation, it becomes difficult to find out which transponder sent which pulse. This leads to false altitudes or false squawk codes. FRUIT is caused by replies that are triggered by other radars. When multiple radars operate in an area, transponders can be quite busy and the radar is easily misled by a reply to another radar. In addition to the timing (range) being wrong, the reply can be Mode A (squawk code) while the radar interrogated Mode C (altitude). There is no way to see what kind (A or C) reply was sent.

To overcome the problems associated with the operation of Mode A/C, Mode S was introduced. Mode S is quite different from Mode A/C and requires a more sophisticated radar and transponder. It uses a 24-bit address to distinguish responses from various aircraft and to interrogate specific aircraft. Most Mode S interrogations are addressed; the interrogation contains the unique 24-bit address of the aircraft it is interrogating. This reduces the probability of garbling since other aircraft will not reply. Unaddressed Mode S interrogations will solicit replies that contain the address of the interrogator (radar). This addressing format reduces FRUIT since the radar can verify that the reply is correctly addressed. Mode S radars can be operated in clusters and coordinate between them which radar is interrogating a specific aircraft at what time. This further reduces the message load and garbling /
FRUIT probability. NAV CANADA has a 10-year project to replace 11 mode A/C SSRs with mode S SSRs in southern Canada.

Currently there are many areas in which radar coverage is not feasible, due to topography (e.g., mountainous areas) or costs (e.g., remote areas). Space based ADS-B solves most line of sight constraints as well as PSR and SSR data limitations.

The future of air traffic surveillance will be enhanced by the use of space-based ADS-B in concert with ground-based surveillance technology. Comprehensive surveillance within the ANS is necessary to accommodate the projected level of traffic growth without increasing delay.

MLAT (Multilateration)

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, employing receivers placed at aerodromes, support ground movement management, with similar small-scale implementations being used to provide ATS surveillance in smaller local areas. 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.

Figure 1 below 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.

NAV CANADA has deployed MLAT to enhance surveillance of vehicles and/or aircraft traffic at Vancouver Harbour, Kelowna, BC, Fort St. John BC, Springbank AB, Calgary Intl, Toronto Intl, Montreal PET Int’l and Fredericton, NB.

Figure 1: Multilateration Concept

2.3 Non-Radar Airspace

There are large portions of the Canadian Domestic Airspace that are outside of radar or MLAT coverage and where IFR aircraft operations in controlled airspace are managed by ATC using
procedural separation. These procedures apply greater separation distances between aircraft than in a surveillance environment. This can result in less efficient aircraft operations including departure and arrival delays, less direct routings and inefficient assigned altitudes.

2.4 Automatic Dependent Surveillance Broadcast (ADS-B) Out

ADS-B is a surveillance technology that enhances safety and efficiency, and benefits pilots, controllers, airports, aircraft operators, and the public.

**ADS-B** is Automatic since it requires no pilot input or external interrogation, Dependent since it depends on accurate position and velocity data supplied by the aircraft’s navigation system, Surveillance since it provides aircraft position, altitude, velocity, and other surveillance data to facilities that require the information and Broadcast since the information is continually broadcast.

ADS-B Out is a system in which electronic equipment on board an aircraft automatically broadcasts flight information from the aircraft via a digital data link. The data can be used by air traffic control to depict the aircraft’s position and altitude on display screens without the need for radar and at a much lower cost. ADS-B data is broadcast every half second on a 1090 (digital data link frequency in MHz) ES (extended squitter) digital data link. The International Civil Aviation Organization (ICAO) specifies ADS-B Out 1090ES as the preferred surveillance system in the ICAO Global Air Navigation Plan as it provides richer and more accurate aircraft surveillance data, which enables more efficient use of airspace.

Furthermore, the Transport Canada PBN State Plan (Block 1 2018–2022, Section 9.2.3. – Surveillance) states as Key Goals:
- Require ADS-B equipment for use in designated airspace; and
- Regulatory changes to allow the implementation of ADS-B mandatory airspace and to set ADS-B avionics equipment standards.

**Ground Based ADS-B**

ADS-B ground stations are line-of-sight facilities. The ability for a ground station to receive ADS-B data from an aircraft depends on the aircraft’s altitude, distance from the station and obstructing terrain. Coverage at high altitudes is approximately 250 nautical miles. Using ground based ADS-B Out, NAV CANADA has extended Canadian air traffic surveillance to cover 4 million square kilometres of airspace (Figure 2). This expansion of surveillance coverage and enhanced ATC service, provided to aircraft at FL290 and above, is estimated to save our customers an estimated $374 million in fuel costs by 2020 by enabling more fuel-efficient routings, while reducing greenhouse gas emissions by an estimated 982,000 metric tons (Collaborative Initiatives for Emissions Reductions- CIFER report 2016).
NAV CANADA has been using ADS-B surveillance separation in the Hudson and Minto Sectors since 2009, in eastern Canada since 2010 and on Southern Greenland serving a portion of the North Atlantic Track (NAT) since 2012.

Hazard Identification Risk Assessments (HIRAs) for the use of ADS-B for aircraft surveillance were conducted prior to implementation of the ground-based system. The first HIRA was completed in two phases. The first phase (June 2006) addressed the generic use of ADS-B for a 5 NM separation standard and concluded that a 5 NM separation standard could be supported as the baseline for a site-specific implementation HIRA. The second phase (August 2007) dealt with the specific Hudson Bay operations and its associated five ADS-B receiver sites and concluded that ADS-B coverage is expected to fill Hudson Bay above FL370 but at FL290 there would be a coverage gap centred at 60°05' N 85°05' W expanding to approximately 100 NM x 100 NM. In addition, a HIRA for the use of ADS-B for surveillance in the airspace surrounding Southern Greenland, the NAT, Eastern Shore of Labrador and Baffin Island was conducted in 2010 prior to implementation.

2.5 The Future of Air Traffic Surveillance – Space-Based ADS-B

A significant step forward for Air Traffic Services (ATS) surveillance is the creation of global coverage via the reception of Automatic Dependent Surveillance – Broadcast (ADS-B) signals by Aireon receivers installed on Iridium Communications’ replacement constellation of Low Earth Orbit (LEO) satellites (See Figure 3). The Iridium NEXT constellation will consist of 66 in-service satellites operating on 6 near-polar orbits, 9 in-orbit spares and 6 additional ground spares. The first launch took place on January 14, 2017, with the Aireon service planned to be fully operational in late 2018. The Aireon receivers are currently compatible with all DO-260 (or equivalent) compliant transponders; software upgrades will enable compatibility with future specifications when required.
NAV CANADA, as an Aireon customer, will use the Aireon service to expand and augment ATS surveillance coverage. NAV CANADA is continuously assessing where and how space based ADS-B could be used to enhance ATS surveillance coverage in the Canadian Domestic Airspace (CDA). ATS surveillance can be used for separation and flight information services. As with any other form of ATS surveillance, the actual separation and other services that can be provided are dependent upon communications capability and aircraft equipage. Aireon will provide, free of charge, via a service called Aireon ALERT, registered users with the location and last available flight track of missing or overdue aircraft to assist emergency tracking and search and rescue authorities.

Where VHF voice coverage exists, the expected performance of the ATS surveillance service provided by Aireon could support the application of 3 nautical mile target to target separation between aircraft. The International Civil Aviation Organization (ICAO) has developed Advanced Surveillance-Enabled Procedural Separations (ASEPS) for use with communications media other than VHF voice.

In summary, an environment in which aircraft meet the proposed ADS-B Out performance requirements would maintain or enhance safety, result in greater capacity and efficiency in the ANS, and provide a flexible, expandable platform to accommodate future traffic growth while avoiding possible system delays and limitations in service.
Table 1: Summary of the technical capabilities of the ATS surveillance systems
(Source: CANSO ANSP Guidelines for Implementing ATS Surveillance Services Using Space-Based ADS-B)

<table>
<thead>
<tr>
<th></th>
<th>PSR</th>
<th>SSR</th>
<th>MLAT</th>
<th>Ground-based ADS-B</th>
<th>Space-based ADS-B</th>
</tr>
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<tbody>
<tr>
<td>Cooperative</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>Passive</td>
<td>Yes</td>
<td>No</td>
<td>Possible</td>
<td>Yes</td>
<td>Yes</td>
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<td>Automatic correlation</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<td></td>
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<td>Aircraft height</td>
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<td>Terminal</td>
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<td>(111 km (60 NM))</td>
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<td>En-route</td>
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<tr>
<td>(185-463 km (100-250 NM))</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes, using Mode C or independently if at least 4 sensors</td>
<td>Yes</td>
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<td>Typical effective</td>
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<td>detection range</td>
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<td>Terminal</td>
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<td>En-route</td>
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<tr>
<td>(185-463 km (100-250 NM))</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes, using Mode C or independently if at least 4 sensors</td>
<td>Yes</td>
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<tr>
<td>Range affected by terrain</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Minimal</td>
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<tr>
<td>or other obstacles</td>
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<td></td>
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<tr>
<td>Aircraft position</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No (GNSS position transmitted by aircraft)</td>
<td>No (GNSS position transmitted by aircraft)</td>
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<tr>
<td>determined independently</td>
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</table>

2.6 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 Direct Controller Pilot Communication (DCPC) range, ATC 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 communication, 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 event reporting, whereby ADS-C reports are sent if certain specified events occur. ADS-C event reporting is mainly used to report position at a given interval as well as next and next+1. The ATM system can set up a contract specifying that an ADS-C report be sent if the aircraft operates 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 communication functions with the aircraft flight management system (FMS). One specific procedure, which is supported by CPDLC, allows for aircraft operations to optimize 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 determine whether a different route from the flight planned route would be more fuel optimal. If a different route is more optimal, flight operations send 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.

2.7 Safety Enhancement Using Space-Based ADS-B

There are several qualitative safety benefits expected with the implementation of surveillance through space-based ADS-B:

a. Increased Situational Awareness
   Surveillance closes the gap between the expected aircraft position based on clearances or instructions issued to pilots, and the actual trajectory that aircraft fly. Moreover, with a target tag, surveillance can indicate whenever expectations are not matched. In addition to improved situational awareness for air traffic service, ADS-B Out messages can be directly received by aircraft using ADS-B In. For situational awareness there are numerous options for receipt and display of targets in the cockpit, ranging from certified integrated displays for traffic avoidance to non-certified carry-on tablets for general traffic awareness.

b. Earlier Warning/Alerting
   Early warning/alerting is the ability to immediately detect when an aircraft deviates from its assigned altitude or route, danger area infringement warnings, “blunder” detection and other similar alerts before they become conflicts. However, the benefit diminishes as the ability of the controller to monitor and process the information becomes saturated, and automation could be used to enhance the effectiveness of alerting systems.

c. More seamless operating environment
   Whenever changes to a flight trajectory or route are required as a result of traversing airspaces with differing rules and procedures, errors can be introduced that may result in aircraft manoeuvring to an incorrect altitude or route/fix. The chance that a flight will obtain its preferred trajectory or route is greater with surveillance, resulting in a consequent decrease in the number of requests for changes and the potential for error. Moreover, a seamless environment eliminates the requirement for ATC to intervene and increase aircraft spacing during transitions to non-surveillance airspace allowing a more predictable and orderly flow of traffic and reducing workload and stress.

d. Improved ability to respond to unexpected changes
   Increased safety from a more orderly flow is expected to be the norm and surveillance will facilitate an improved response when unexpected events occur such as emergencies, hazardous weather, severe clear air turbulence, etc. If the area of a hazard is known, the positional information and accuracy offered by surveillance will ensure that the aircraft can continue on the most efficient path while remaining at a safe distance from the hazard.

e. More accurate information
   Rapid data update rates, improved aircraft position accuracy, reduced speed error variability, more frequent and accurate velocity vectors all contribute to improved conflict prediction and resolutions.
f. Improved emergency tracking and Search and Rescue Response

Aircraft Locating and Emergency Response Tracking (ALERT) will be one of the services available to all aircraft equipped in Canadian airspace and provided globally. In such cases, notification time and position accuracy will allow a quicker response, with reduced chance of loss of life.

g. ALERT and Global Tracking

Through the use of the global Aireon ADS-B data set, there is a possibility of developing more options for meeting the intent and performance requirements of the ELT 406 beacon. Aireon Global Tracking already meets the ICAO criteria for Global Aviation Distress Safety System (GADSS).

2.8 Benefits Analysis

The ability to support certain ATS applications is highly dependent upon aircraft capabilities. NAV CANADA plans investments based on our knowledge of what capabilities exist or are planned in the fleets operating in our areas of responsibility. In general, efforts will be made to coordinate with aircraft operators to match the ATC improvements to aircraft capabilities.

The transition to equipage-based operations involves matching the level of service to the cost of equipage and services. NAV CANADA considered the potential costs of supporting a mixed mode environment when planning service improvements based on increased aircraft capabilities.

In areas where there is currently no or limited ATS surveillance coverage, introducing space-based ADS-B could enable significant safety, operational and infrastructure efficiency gains, reduce separation standards and increase route flexibility.

In areas where ATS surveillance already exists, the introduction of space-based ADS-B will provide value by removing coverage gaps. NAV CANADA will determine the potential benefits of using space-based ADS-B to support back up 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 in busier more congested airspace.

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. Any reduction in fuel burn lowers GHG emissions resulting in economic and environmental benefits.

The high-level Benefits Analysis can be found in Appendix B.

2.9 Foreign ADS-B Mandates

There are many examples of a partial or full ADS-B mandates proposed or implemented by other states/ANSPs. The ADS-B Out performance requirements mandate proposed for Canadian airspace is similar in scope and content to other mandates.

Australia:
Effective 2 February 2017, all aircraft operated under IFR must carry serviceable ADS-B 1090ES transmitting equipment that complies with an approved equipment configuration by meeting the conditions for approval set out in Appendix XI to Australian Civil Aviation Order 20.18.

New Zealand:
The Civil Aviation Authority (CAA) is currently developing policy and rule changes to support the replacement of New Zealand’s aviation surveillance radar infrastructure, which will reach the end of its operational life in 2021.

The proposal includes implementing ADS-B Out as the principle surveillance system in New Zealand. The ADS-B Out implementation project is a foundation project under New Southern Sky (NSS), a ten-
NSS proposes that ADS-B Out will be required on all aircraft operating in controlled airspace above Flight Level 245 (FL 245) after 31 December 2018 and all controlled airspace by 31 December 2021.

**United States:** In the U.S., aircraft that operate in airspace that currently requires a Mode C or Mode S transponder will need to be equipped with ADS-B Out by December 31, 2019. This includes Class A, B, or C airspaces, Class E airspace at and above 10,000 ft MSL over the 48 contiguous United States and the District of Columbia, and Class E airspace over the Gulf of Mexico from the coastline of the U.S. out to 12 NM and above 3,000 ft MSL. Outside of these categories an ADS-B Out solution will still be required for operations from the surface up to 10,000 ft MSL within 30 miles of most primary Class B airports. (see figure 4).

**Europe:** Currently, all aircraft weighing greater than 5,700 kg (12,500 lbs) or having a max cruise speed greater than 250 knots TAS in European airspace require ADS-B Out 1090ES with diversity. The current requirement is for forward fit of aircraft and after 2020, the rule applies to retrofit aircraft. By June 2020, all existing aircraft weighing greater than 5,700 kg (12,500 lbs.) or having max cruise speed greater than 250 knots TAS in European airspace require ADS-B Out 1090ES with diversity.

**Mexico:** Proposed requirements for 1090ES ADS-B Out are set for the beginning of January 1, 2020, in Class A, B, C, E above 10,000 feet, and other specified airspace. The requirement could take effect earlier in some airspace over the Gulf of Mexico.

**Hong Kong:** All aircraft operating in Hong Kong airspace at and above FL290 requires ADS-B Out 1090ES.

**Indonesia:** ADS-B Out 1090ES required at FL290 and above.

**Singapore:** All aircraft that operate on select airways and within a select region of the Singapore FIR at FL290 or above require ADS-B Out 1090ES.

**Sri Lanka:** 1090ES ADS-B Out is required within the Colombo Terminal Control Area (TMA), FL290 and above.
Taiwan: All aircraft operating in Taiwan airspace at and above FL290 requires ADS-B Out 1090ES.

Vietnam: All aircraft that operate on airways L625, M771, N892, L642, M765, M768, N500 and L628 at FL290 or above require ADS-B Out 1090ES.

3.0 Analysis

The study team assessed numerous aspects of implementing a space-based ADS-B Out performance mandate including:

- How an ADS-B performance requirements mandate improves the overall safety and efficiency of aircraft operations within Canadian Domestic Airspace;
- How a NAV CANADA proposed space based ADS-B Out performance mandate compares to other states planned mandates, particularly the FAA and Europe whose ADS-B systems will be ground based, and how can the NAV CANADA mandate harmonizes with these other states plans to help minimize any impacts on our customers;
- What are the aircraft avionics equipage upgrade or new installation impacts on our customers, including the benefits they could realize from an ADS-B Out based surveillance system vs costs;
- What would be the appropriate timelines and scope of a NAV CANADA ADS-B performance mandate considering the avionics equipage impacts, the FAA’s and Europe’s ADS-B implementation plans and NAV CANADA goals for modernizing surveillance systems to increase the safety and efficiency of air traffic services for our customers; and
- Internal to NAV CANADA operations, what level of effort is required from ATS Standards and Procedures, Engineering, Technical Operations and other affected NAV CANADA departments to implement any ADS-B Out performance mandate and how could this impact the scope and timelines of any mandate.

Considering these aspects, and upon assessment of the issues and concerns raised from consultations with stakeholders, the study team developed recommendations for a performance requirement mandate for specific classes of airspace with a phased timeline for implementation.

3.1 Methodology

The aeronautical study process conforms to the Canadian Standards Association’s CAN/CSA-Q850-97 Risk Management: Guideline for Decision Makers. This process emphasizes extensive consultations with stakeholders to gather their needs issues and concerns with a proposed change.

A study team was formed, led by a Manager, Level of Service and Aeronautical Studies, to gather all relevant information, comments and concerns, related to the proposal to put forward a Canadian Automatic Dependent Surveillance – Broadcast (ADS-B) Out performance requirements mandate and determine the minimum performance requirements for current and future use.

A HIRA was conducted to address all the safety and efficiency issues raised by customers and stakeholders and to develop mitigation, if required, to ensure the impact or risk associated with the change was reduced to as low as reasonably practicable (ALARP). See the HIRA summary as Appendix C.
3.2 Study Team

The study team comprised of the following:

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<tr>
<td>Project Manager</td>
<td>National Manager, Level of Service</td>
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<td>Team Leader</td>
<td>Manager, Level of Service and Aeronautical Studies</td>
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<tr>
<td>Contributors</td>
<td>Specialist, Level of Service and Aeronautical Studies</td>
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<td>Manager, New Surveillance</td>
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3.3 Consultation

NAV CANADA personnel from Level of Service surveyed and visited all ACCs and met with the Manager Program Coordination. The purpose of the discussions was to identify any needs, issues and concerns related to the implementation of a Canadian ADS-B Out performance requirements mandate.

Consultations were conducted with aircraft operators and associations and other stakeholders, both domestic and international, in person, by telephone, by e-mail and via WebEx. One meeting, arranged by the Saskatchewan Aviation Council (SAC), was held in Saskatoon with Saskatchewan-based commercial operators, flight schools and airport operators participating. Three WebEx were conducted, two specifically for international air operators and stakeholders and a third for all air operators and stakeholders both domestic and international to introduce an amended Terms of Reference (which was done post consultation) and request feedback as well as identify any new needs, issues or concerns.

A list of stakeholders from which feedback was requested and collected is included in Appendix A. Although not all stakeholders responded, those that did represent a cross-section of Canadian and international aircraft operators. While the aircraft operators supported the mandate, an on-going operational concern was identified for VFR operations in controlled airspace.

3.3.1 Hazards/Issues

Following is a summary of the hazards, issues and concerns identified during customer and stakeholder consultations including the NAV CANADA response to address or mitigate the issue. See also the Hazard Identification and Risk Assessment (HIRA) Table at Appendix C.

Hazard #1 - Loss of ADS-B Surveillance Information

A hazard associated with the ADS-B surveillance system would be the loss of surveillance information. This could be the result of a failure of the system itself (Iridium satellite, Aireon ADS-B receiver payload, satellite downlink, ground link, and/or air traffic management (ATM) system integration and/or loss of GPS signal to the aircraft either from jamming, GPS satellite failure or the on-board GPS receiver failure). The risk could be a loss of separation between aircraft resulting in a possible aircraft incident.

Response

The use of ADS-B Out for surveillance separation has already been examined in other safety assessments and been approved for operational use by Transport Canada. Any additional hazards specific to receipt of the signal from space-based versus ground-based antennas will be addressed during operational implementation of the Aireon signal following full operational capability of the Iridium Next constellation. The loss of surveillance information in the context of an airspace mandate is a change in the scope of the effect, having already examined each of the potential component failure
sources. NAV CANADA has been able to leverage operational experience since 2009 gained using the ground-based ADS-B system that has demonstrated robust, accurate and reliable surveillance data.

In preparation for the introduction of PBN in the enroute structure, NAV CANADA received an exemption to use the separation standards that are detailed in the ICAO document: Procedures for Air Navigation Service – Air Traffic Management (PANS-ATM Doc 4444). The conditions of this exemption require NAV CANADA to inform Transport Canada of the intent to use a Doc 4444 standard and meet other conditions such as ensuring implementation HIRAs are conducted and that any required training is complete prior to implementation.

It is expected that Transport Canada will recognize ICAO’s standards for ADS-B operations, which will be reflected in the proposed performance mandate. Regardless, NAV CANADA will demonstrate a safety case via a HIRA for ATC operations using space-based ADS-B in any mandated airspace that we deploy. NAV CANADA will keep Transport Canada apprised of our implementation plans and provide them with the required technical and procedural risk assessments and mitigations.

Prior to implementing any mandate associated with space-based ADS-B NAV CANADA will request:

a. permission to use the Doc 4444 separation standards associated with ADS-B; and,

b. a cancellation of Exemption NCR-104-2016.

The functionality of the system is outside the scope of this study.

Note: As a contingency related to the NAVAIDS Modernization Plan (NMP), NAV CANADA is retaining a system of NAVAIDS and non-GNSS reliant surveillance to ensure IFR aircraft can recover at a suitable airport in the event of a catastrophic failure of the GNSS. Failure of the GNSS will also result in a failure of the ADS-B surveillance system. With the NMP recovery system and the procedures established for failure of ADS-B, IFR aircraft operations will safely continue until all aircraft have landed.

Issue #1 - International Harmonization & ADS-B Out Performance Requirements

There is concern that the Canadian space-based ADS-B Out performance mandate may not align with the FAA and/or European mandates. If the performance requirements for Canadian airspace were different than these other states, such as lower aircraft separation distance standards, more transponder data outputs and/or higher positional accuracy, then the greatest efficiency benefits for NAV CANADA use of ADS-B may not be realized. NAV CANADA ATC services for aircraft transiting into the U.S. or Europe, particularly separation standards, will need to be at the same level and compatible with other ANSP ATC operations.

Aircraft that have equipped for a mandate with higher performance requirements may not realize the full benefit of their investment when operating in airspace with lower mandate requirements. (See Aircraft Equipage Issue #2)

Response

NAV CANADA intends to phase in the use of the DO-260B (TSO-C166b) ADS-B Out standard, which enables an aircraft to present important data such as accurate geographic position, aircraft identification, velocity, altitude, equipment status, plus other elements for use in ATC surveillance. The broadcast frequency will be 1090 MHz with ES (Extended Squitter). Since current ADS-B surveillance separation in Canadian airspace is supported by DO-260, DO-260A and DO-260B, as mandated airspace demands higher equipment performance after 2023, the use of DO-260B will become the only allowable standard. This standard is recommended by ICAO and will be used by several nations/states including the U.S. and in Europe. The application of similar equipment standards and alignment between states should allow provision of the same separation standards for consistent, compatible and harmonized ATC service and efficient flow of aircraft across state borders. In summary, with the implementation of the NAV CANADA harmonized performance mandate, the full efficiency benefits for ATC and aircraft operations in Canada, and between the U.S. and Europe, should be realized.
**Issue #2 - International Harmonization and Aircraft Equipage**

The U.S. and Europe are deploying a ground-based ADS-B Out 1090ES system while NAV CANADA will be deploying a space-based ADS-B Out 1090ES system. There is concern that aircraft equipped for the U.S. and/or European ADS-B mandates may not be properly equipped for any ADS-B Out performance mandate that NAV CANADA may propose for Canadian airspace.

Additional avionics equipage expenses for aircraft operators that results from any mandate NAV CANADA implements might be an unacceptable financial burden. Possible additional expenses could include equipping for transponder antenna ‘diversity’ (aircraft top and bottom mounted), installation or upgrade to a Mode S 1090ES transponder with the required data link parameters and/or installation or upgrade of GNSS avionics to achieve the required positional accuracy. This could result in an unacceptable financial burden on these customers resulting in a lack of support for the NAV CANADA mandate.

*Response*

NAV CANADA does not plan to implement any mandate in advance of the FAA or European mandates, which are Jan 1, 2020, & Jun 7, 2020, respectively.

An ACAS/TCAS II system uses a Mode S transponder that broadcasts on 1090 MHz and has antenna diversity (top and bottom mounted transponder antenna). Aircraft equipped to meet U.S. and European mandates, specifically aircraft that are equipped to meet the ACAS/TCAS II regulation in those countries including Canada, will have the required antenna diversity and transponder.

Aircraft that are not affected by ACAS/TCAS II regulations and do not currently have antenna diversity will be required to meet the recommended performance requirements set forth in this proposal to operate in ADS-B airspace. The phased timeline and targeted airspace approach allows these affected aircraft operators time to equip their aircraft to meet the performance requirements. (See Issue #4 – Implementation Lead Time)

**Issue #3 - PBN Alignment**

There is a concern that the proposed ADS-B Out mandate would not align with the Performance-based Navigation (PBN) implementation plan (U.S., Europe and Canada) in relation to aircraft equipage/accuracy requirements for Global Navigation Satellite System (GNSS) avionics.

*Response*

The NAV CANADA PBN Operations Plan aligns with both the ICAO and Transport Canada PBN Plan.

The ADS-B performance requirements will be implemented as closely as possible in accordance with the timelines stated in these plans.

Any Canadian mandated equipment performance requirements for GNSS is planned to align with current and future PBN plans for one minimum standard.

**Issue #4 - Implementation Lead Time**

There is a concern that operators will be unable to equip/upgrade their aircraft with the required avionics to meet the performance mandate due to insufficient lead time. Without access to the mandate affected airspace these operators will face reduced efficiency for aircraft operators.

*Response*

NAV CANADA is proposing to implement the first phase of the ADS-B performance requirements mandate on Jan 1, 2021, one year after the U.S. ADS-B rule (Jan 1, 2020), and 6 months after the European mandate (June 7, 2020). Subsequent phases will not begin until a minimum of one year later.
The recommended first phase of the mandate will apply to Canadian Domestic Class A Airspace as specified in the DAH and Class E Airspace FL600 and above. Current analysis of flight plans filed in this airspace show high percentages of aircraft operating in this airspace are already equipped and most air operators using this airspace will be equipped to meet the U.S. and/or Europe Mandates. In addition, most operators in this class of airspace are equipped to meet RVSM and/or ACAS/TCAS II and will require minimal avionics upgrades to meet the NAV CANADA mandate performance requirements. (See Appendix F – Aircraft Equipage Rate in Class A).

NAV CANADA will present the recommendations from this aeronautical study to customers and stakeholders prior to the end of 2018, a full two years prior to implementing the first phase of a Canadian ADS-B performance mandate.

This is expected to be sufficient lead time to meet the demand for the required avionics upgrades and installations.

**Issue #5 - Retrofit**

It was suggested that NAV CANADA allow aircraft that are equipped with legacy versions of the transponder standard, i.e. the DO 260 and DO260A, to operate in mandated airspace after the implementation date. This would provide operators with more time and flexibility to retrofit aircraft, which will help reduce their costs.

**Response**

Since the Aireon system recognizes all versions of the DO 260 standard transponders, allowances for retrofits will be accepted until Jan 1, 2024.

The recommended retrofit date aligns with both Transport Canada’s PBN State Plan and ICAO ISBU Block 2 (2023–2027) for Navigation and Surveillance. In addition, with the potential decommissioning of certain SSR’s, MLAT and ground-based ADS-B commencing between 2022–2024, surveillance requirements in specified designated airspace will primarily be supported through space-based ADS-B. The retrofit date also takes into consideration possible delays in certification and in availability of required equipment, as well as industrial capacity constraints for equipping aircraft.

The legacy ADS-B standards, DO 260 Version 0 and 1 (A), which have a different and smaller set of the ADS-B Out parameters enable surveillance services in mostly lower-density airspace for ATC separation and is oriented towards delivery of existing levels of ATC surveillance. For example, Version 0 does not independently report the accuracy and integrity metric and do not include a message element for Mode 3/A code which is required for mixed mode operations.

The use of ADS-B data elements made available by the DO 260B, enable increased safety through select altitude vs cleared altitude and the potential application of 3 NM separation in terminal airspace using ADS-B as a primary source of surveillance.

NAV CANADA must transition to more demanding ADS-B requirements over time as our airspace requirements change. It has been determined that legacy standards will not meet surveillance needs for ATC in Canada after January 1, 2024.

**Issue #6 - Benefits vs Costs**

Several stakeholders felt that the anticipated efficiency improvements from the mandate such a decrease in enroute separation of aircraft would not necessarily decrease overall delays or increase airspace capacity to a level that would offset their costs to equip to the mandate performance requirements. They also felt that NAV CANADA has not demonstrated that system choke points can handle the increased capacity if enroute separation is reduced. In summary, there is concern that reducing separation will not mitigate commercial traffic delays caused by an inadequate number of runways, weather, hub-and spoke operations, or airline scheduling practices.

**Response**
**ADS-B** will enhance ATC surveillance, which will result in safer and more efficient use of airspace and increase capacity to help meet the predicted future demand for ATC services.

Details on anticipated operational benefits are outlined in the Benefits Analysis in Appendix B. The main benefits are summarized below:

**Improved Safety:** There are several qualitative safety impacts expected with the implementation of surveillance through SPACE-BASED ADS-B as follows:

Surveillance closes the gap between the expected position of aircraft based on clearances or instructions issued to pilots, and the actual trajectory that aircraft fly. Moreover, with a target tag, surveillance can indicate whenever expectations are not matched.

The ability to immediately detect when an aircraft deviates from its assigned altitude or route, danger area infringement warnings, "blunder" detection and other similar alerts before they become conflicts. However, the benefit diminishes as the ability of the controller to monitor and process the information becomes saturated, and automation may be needed to enhance the effectiveness of these alerting systems.

Whenever changes to a flight trajectory or route are required as a result of traversing airspaces with differing rules and procedures, errors can be introduced that may result in aircraft manoeuvring to an incorrect altitude or route/fix. The chance that a flight will obtain its preferred trajectory or route is greater with surveillance, resulting in a consequent decrease in the number of requests for changes and the potential for error. Moreover, a seamless environment eliminates the requirement for ATCOs to intervene and increase aircraft spacing as it transitions to non-surveillance airspace and allows a more predictable and orderly flow of traffic, reducing air traffic workload and stress.

Notwithstanding the safety benefit of a more orderly flow, which is expected to be the norm, when unexpected events occur such as emergencies, hazardous weather, severe clear air turbulence, etc., surveillance will facilitate an improved response. If the area of a hazard is known, the positional information and accuracy offered by surveillance will ensure that the aircraft remains at a safe yet reasonable distance from the hazard.

With a rapid update rate, improved aircraft position accuracy and reduced speed error variability (from more frequent and accurate velocity vectors), not only is the potential conflict identified sooner, its resolution may be better planned and executed.

**Improved Position Reporting:** Radar accuracy decreases the further aircraft is from the receiver, while ADS-B provides consistent position accuracy regardless of the aircraft’s location. ADS-B also provides more timely information updates than conventional radar. ATC’s ability to accurately identify and locate aircraft that are further away from the air traffic control facilities will be better than radar. ADS-B does not scan an environment in the same way as radar; therefore, ADS-B does not provide unnecessary returns based on weather or other obstructions, which can impede the effectiveness of primary radars. ADS-B provides consistent, frequently updated position reporting and additional aircraft information for ATC decision-support tools, which increases ATC confidence in aircraft position. This will allow ATC to apply existing separation standards more exactly and without the need to correct for possible radar inaccuracies.

**Continuous Descent Operations (CDOs):** CDOs are a type of terminal arrival procedure, specifically designed to keep an aircraft at, or near idle power during the arrival phase until the final approach fix. These procedures increase flight efficiencies while reducing noise, fuel consumption, and emissions. CDOs eliminate step-down altitudes and the associated inefficient power adjustments. CDOs depend on minimal aircraft vectoring to maintain the arrival pattern. During CDO aircraft must be accurately metered using spacing and sequencing tools prior to and during descent and approach, which is more effective using the ADS-B Out system rather than radar.

**Reduced Aircraft Separation:** In non-radar airspace, ADS-B Out allows ATC to apply radar-like separation standards in areas where ATC currently applies non-radar, procedural separation. In some
cases, routes laterally separated without radar by as much as 90 NM are now separated with ADS-B at only 20 NM. Longitudinal separation of typically 10 minutes (80 NM) can be reduced to 5 NM.

NAV CANADA will examine the feasibility of utilizing 3 NM separation to provide terminal control service at some locations in the ANS. NAV CANADA will not move forward with reduced separation until all safety and operational analysis have been completed, space-based ADS-B has been certified to perform this service, and the proper procedures are in place.

Expanded Surveillance Coverage: There are opportunities for ATC to use space-based ADS-B surveillance in areas where existing radar surveillance has limitations.

Surveillance of Ground Operations: ADS-B surveillance could also be extended to ground level, in conjunction with other ground based infrastructure, to help improve the safety and efficiency of airport operations.

Routes: NAV CANADA expects that ADS-B Out will enable the broader use of User Preferred Routes, which reduces fuel consumption, emits less greenhouse gases, and increases the overall efficiency of ANS operations.

In summary, while it is not possible to exactly quantify these benefits for an individual aircraft, the ANS as a whole will be more efficient and safer and all customers will realize these benefits. The application of the ADS-B performance requirements mandate will result in safety and efficiency benefits over current surveillance operations.

**Issue #7 - ADS-B Out Equipage Costs vs Benefits for General Aviation**

The general aviation (GA) sector believes that equipage costs for ADS-B Out would likely exceed the benefits for both their IFR and VFR operations.

**Response**

NAV CANADA acknowledges that the cost to equip the average light general aviation aircraft to meet an ADS-B Out performance mandate if there is no existing GNSS or transponder capability already on the aircraft could be relatively significant. In southern Canada primary and secondary radars will be retained for the foreseeable future and aircraft that operate in this radar serviced airspace where there is currently a Mode C transponder requirement need only be equipped with a Mode C transponder. This is where many GA aircraft operate.

The cost to equip with ADS-B must be balanced against the foundation this capability provides in moving toward new technologies provided by space-based ADS-B infrastructure and benefits from its overall usage. Benefits to aircraft operations, including GA, are as follows:

- expanding ATC flight following, enroute and terminal like service, including lower separation standards, to areas and aerodromes currently not covered by radar or MLAT;
- access to inexpensive ADS-B In traffic situational awareness tools running portable tablet type computers;
- enabling potential new services such as automatic closure of flight plans based on the aircraft position at the destination airport;
- enhancements to search and rescue or aircraft in distress by determining the aircraft’s current or last known position with great accuracy, at all altitudes and any terrain;
- positional information for FICs to enable more tailored flight information services enroute (FISE);
- provision of radar like data to enhance air traffic control and airport advisory service at control tower and FSS sites respectively, where there is currently no NAV CANADA Auxiliary Radar Display System (NARDS);
- where DCPC communications exist, ATC could provide emergency navigation assistance; and
- more efficient handling of potential enroute conflicts.

Additionally, NAV CANADA, along with the Canadian Owners and Pilots Association (COPA) have put forward a proposal to study the applicability of ADS-B technology for emergency applications.
Transport Canada has given its support to further explore the potential for an improvement to the safety outcome related to the carriage of Emergency Locator Transmitters (ELT) for general aviation. (CPAA/T/12 WP/06)

Most GA operations will not be impacted by the recommended ADS-B performance requirements mandate. For those that are, while it is not possible to exactly quantify these benefits for an individual aircraft the ANS will be more efficient and safer and all customers will realize these benefits. Aircraft suitably equipped will also have higher residual value and conversely aircraft that are not could be harder to sell.

**Issue #8 - Financial and Operational Incentives for GA**

General aviation (GA) has suggested that, like the FAA, NAV CANADA should offer financial and operational incentives to offset their costs to equip for an ADS-B Out mandate.

**Response**

NAV CANADA will continue to address the financial impact on GA of meeting an ADS-B equipage mandate taking into consideration our governance model.

**Issue #9 - Regulatory Requirements**

Transport Canada has granted NAV CANADA an exemption to CAR 801.01 (2) (a), 801.08 (b) and relevant provisions of Standard 821 – Canadian Domestic Air Traffic Control Separation, to allow the use of ADS-B for aircraft surveillance and the application of current ATC aircraft separation services. This exemption was requested for the airspace supported by the ground-based ADS-B system established for the Hudson Bay and Minto Sectors, north-eastern Canada and over Southern Greenland that serves a portion of the North Atlantic Track system (NAT). The exemption allows NAV CANADA to apply the same separation standards and procedures in these portions of airspace as used with enroute radar surveillance.

One of the conditions of Exemption NCR 104-2016 is that NAV CANADA must not create exclusionary airspace. Without the ability to exclude aircraft that are not equipped to meet a NAV CANADA ADS-B performance mandate from the applicable airspace, the full efficiency benefits of utilizing the space-based ADS-B system will not be realized since the spacing between conforming and non-conforming aircraft would need to be increased. This adjusting of separation standards also results in complexity for ATC operations.

**Response**

The Reduced Vertical Separation Minimum (RVSM) airspace and related aircraft equipage mandate offers an example of how designating exclusionary airspace together with equipment performance requirements can take advantage of new technology capabilities. In the case of RVSM this has resulted in operational benefits by providing aircraft with more track and altitude options resulting in significant efficiency gains (fuel savings).

With the implementation of space-based ADS-B, the current ground based ADS-B system will be re-evaluated and possibly decommissioned. In preparation for the introduction of PBN in the enroute structure, NAV CANADA received an exemption to use the separation standards that are detailed in the ICAO document: Procedures for Air Navigation Service – Air Traffic Management (PANS-ATM Doc 4444). The conditions of this exemption require NAV CANADA to inform Transport Canada of the intent to use a Doc 4444 standard and meet other conditions such as ensuring implementation HIRAs are conducted and that any required training is complete prior to implementation.

Prior to implementing any mandate associated with space-based ADS-B NAV CANADA will request:

a. permission to use the Doc 4444 separation standards associated with ADS-B; and,

b. request a cancellation of Exemption NCR-104-2106.

It is expected that Transport Canada will recognize ICAO’s standards for ADS-B operations, which will be reflected in the proposed performance mandate. Regardless, NAV CANADA will demonstrate a
safety case via a HIRA for ATC operations using space-based ADS-B in any mandated airspace that we deploy. NAV CANADA will keep Transport Canada apprised of our implementation plans and provide them with the required technical and procedural risk assessments and mitigations.

**Issue #10 – Regulatory Administration Delays**

There is concern that Transport Canada may not be capable of meeting the demand for aircraft avionics equipment STC approvals, and other regulatory demands related to a mandate.

**Response**

The performance mandate will be implemented in phases with sufficient lead time for the various affected sectors of aviation to properly equip. With the planned notice, which in the case of the initial implementation of Phase 1 will be two years, Transport Canada should have sufficient advance knowledge of our implementation plans to prepare to meet the expected demand for their services. NAV CANADA can also provide Transport Canada with estimates of the number of aircraft that may be affected at any stage of the project.

Many foreign operators who will be affected by the initial implementation will already be equipped due to the US and European mandates and will be properly certified under those states regulatory requirements. Canadian operators will also be certified to operate in those states airspace under their mandates prior to the NAV CANADA mandate, thus helping to relieve the initial potential workload.

The NAV CANADA statistics on the number of aircraft affected by the mandate’s initial phase of implementation can be found in Appendix F.

**Issue #11 - Military Exemptions & Security**

Some Department of National Defence (DND) aircraft and some foreign military aircraft will be unable to equip to meet the ADS-B Out mandate and there are concerns that the open broadcast of ADS-B Out data can cause unacceptable operational security risks to DND’s execution of certain missions. NAV CANADA must accommodate these aircraft in their vital and unique operations.

**Response**

NAV CANADA acknowledges that not all DND aircraft will be equipped to meet the performance mandate, either before or after January 1, 2021, as it is not economically viable to equip DND aircraft that are facing imminent retirement. Additionally, cost, budget, and depot schedule constraints make it prohibitive to equip all DND aircraft in time for the proposed mandate. DND has a mature equipage plan in place for their fleet and some aircraft will be suitably equipped in advance of the proposed compliance date.

Regardless, both parties recognize that accommodations to the mandate will be necessary for non-equipped state aircraft. To ensure that the air navigation system meets Canadian national defence needs, NAV CANADA will partner with DND to develop procedures to minimize or, where possible, eliminate negative impact on DND and foreign state aircraft operations due to lack of ADS-B Out equipment, while ensuring safety.

Additionally, NAV CANADA acknowledges that the open broadcast of ADS-B Out data can cause unacceptable operational security risks to DND’s execution of certain missions. DND aircraft with mission requirements that will not align with the broadcast nature of ADS-B Out, will either not be equipped or will, at times, suppress ADS-B Out data. DND and NAV CANADA agree to research and develop mutually acceptable solutions and procedures, which will accommodate their aircraft when not broadcasting ADS-B Out data and that will lower operational security risks to levels deemed acceptable by DND.

Regarding foreign state aircraft operating in Canada, ADS-B Out performance requirements will be published in the AIP. If foreign aircraft cannot meet the mandate, they will be required to request an exemption when submitting their overflight request to Global Affairs Canada (GAC). Any requests from military aircraft are forward to DND 1 Canadian Air Division for review prior to approval by GAC.
As is current practice, DND will work with NAV CANADA to ensure that operators of foreign State aircraft in Canadian airspace are informed of the mandate performance requirements. Military aircraft (Canadian and Foreign) will be eligible for an exemption. NAV CANADA units will know an aircraft’s ADS-B Out status based on the equipment codes on their ICAO flight plan and/or through notification by DND.

NAV CANADA ATC currently has procedures for and experience in accommodating aircraft that do not meet performance requirements related to RVSM or transponder mandatory airspace. These procedures are adaptable to the requirements of an ADS-B mandate.

**Issue #12 – ATC Systems Implementation Delays**

There is concern that the NAV CANADA ATC infrastructure required to yield all the advantages of an ADS-B Out mandate may trail the recommended timelines set for aircraft equipage. This would result in a delay in taking full advantage of the operational safety and efficiency benefits afforded for both ATC and aircraft operators. Operators could also be dissatisfied as they would have spent money to upgrade their avionics without experiencing maximum benefits. This would not support our objective to avoid costly upgrades.

**Response**

Our major flight data systems (both CAATS domestically and GAATS+ in oceanic) are currently capable of processing space-based ADS-B data, and are being augmented to provide greater functionality to eventually reduce separation in areas where we currently have no ground-based surveillance. NARDS is also capable of ingesting and displaying space-based ADS-B data. Edmonton and Gander will be the first two ACC sites to use space-based ADS-B operationally. Additional ACC and Sectors will be brought online as the mandate progresses and ATM system upgrades permit.

Initial operations utilizing space based ADS-B data will occur prior to a mandate being in place. When the space-based ADS-B data are certified by both Aireon and NAV CANADA, we will begin to use it operationally (late 2018 or early 2019).

**Issue #13 - Privacy and Security**

There is concern that operators will be unable to maintain/obtain privacy of their operations under the ADS-B-Out system. The system should be able to accommodate privacy and security requirements of state, corporate and military aircraft.

**Response**

This issue is being actively researched by the FAA in collaboration with the National Business Aviation Association (NBAA). Aircraft equipped with Mode S transponders broadcast a 24-bit address code that is assigned to each aircraft registration number, the ICAO address. This means the privacy concerns that business aviation operators have to go beyond ADS-B.

One solution is to establish an assortment of ICAO codes for business aircraft operators that would not translate to an aircraft registration. That would mean, while the code itself may still be able to be tracked publicly, there would be no associated availability of the aircraft registration and therefore no information on its owner or operator either.

A second similar solution that is being worked in the United States is the establishment of a privacy office to administer assignment of random 24-bit ICAO addresses as anonymous flight IDs, rolling every 30 days or so.

Another possibility discussed was developing an anonymity mode for the 1090ES datalink. The anonymity mode exists for the 978UAT standard, but is not part of the 1090ES standard. This was purposely omitted for 1090ES after objections were raised by Europe.
A longer-term option could be the encryption of the 1090ES message; however, the signal broadcast by 1090ES ADS-B is a 112-bit message that is not suitable for encryption with traditional algorithms. A format-preserving encryption cryptographic engine could be a low-cost method to encrypt ADS-B communications. The FAA is investigating potential future changes to the operational performance standard (RTCA DO-260B), such as expanding the bandwidth, which might enable functions such as encryption.

It is primarily through commercial/private applications where the public can track the position and identity of airborne aircraft. The aircraft owner/operator is required to contact the appropriate application provider to request to remain anonymous and these providers should accommodate the requests.

NAV CANADA will monitor closely other states (FAA, Europe, ICAO) and work collaboratively to find the best possible solution to the privacy issue. The solution is beyond the scope of this aeronautical study.

**Issue #14 - Transponder Frequency Congestion**

There is concern that as traffic levels increase, frequency congestion with ADS-B 1090 MHz broadcasts may disrupt surveillance services.

**Response**

Frequency congestion can occur with transponders transmitting and responding frequently in a given area. For example, in Europe, overlapping radars regularly interrogate the same aircraft. At the same time, this aircraft is subject to ACAS/TCAS interrogations from other aircraft. The more interrogations the transponder receives, the more often it replies. Factor this by more and more Mode S equipped aircraft and congestion may be the result.

In Canada, our traffic density is much lower and except for the Toronto and Vancouver areas where multiple NAV CANADA and FAA radars are located, spacing of radars results in minor coverage overlaps. Implementation of ADS-B and subsequent decommissioning of select radars will reduce the potential for interrogation congestion experienced by aircraft transponders.

NAV CANADA will continue to assess 1090 MHz frequency congestion in the future air traffic environment and will enact the necessary mitigations to reduce the 1090 MHz frequency congestion risk.

**Issue #15 - ADS-B In**

Some stakeholders asserted that ADS-B Out alone would not be cost-beneficial or provide them with any added benefits compared to their operations today and commented that the majority of the ADS-B benefits will be derived from ADS-B In, and that this should be mandated also.

**Response**

NAV CANADA recognizes that ADS-B In and other future air-to-air applications are functions that could provide benefits to aircraft operators such as improved situational awareness for pilots. Operators voluntarily equipping with ADS-B In will have the benefit that accrues from that technology.

**Issue #16 - Performance Functionality**

There is concern that after an aircraft has been equipped with the required ADS-B avionics to meet the performance mandate, there will be no means to confirm that the equipment is functioning properly prior to the aircraft entering the mandate affected airspace. If the aircraft’s ADS-B avionics did not function properly NAV CANADA may refuse clearance into that airspace, which could result in the aircraft’s return to point of origin, a diversion or other additional expense.

**Response**
NAV CANADA will determine whether it is practicable to establish a public web-based tool that will allow aircraft operators to check the performance functionality of their ADS-B installation in order to assist aircraft owners, operators, and avionics installers with the validation of the performance of the ADS-B Out equipment installed on aircraft.

The tool could be similar to the one the FAA has developed, ADS-B Performance Monitor Flight Test Data Review Report, to generate a report of the accuracy/functionality of the aircraft’s ADS-B performance during the period requested.

**Issue #17 - Equipment (re) certification (Transponder)**

There is concern that there will be extra costs associated with ongoing recertification of ADS-B avionics.

**Response**

Transport Canada has advised the following:

ADS-B certification is different from a transponder certification. Transport Canada National Aircraft Certification is harmonized with the FAA and EASA, in that the ADS-B systems and the ADS-B functions are strictly regulated. Guidance on ADS-B Out installations is described in the FAA AC 20-165B and AC 20-172B respectively. EASA also provides guidance in CS-ACNS, which Transport Canada also recognizes. In Canada, there will be two Canadian Advisory Circulars that will provide specific guidance on aircraft installation airworthiness and operational certification.

**Issue #18 - IFR vs VFR operations**

Some stakeholders felt that there would be minimal benefits to VFR operations with ADS-B while costs to equip would be high and that NAV CANADA should consider a mandate that applies only to IFR operations.

**Response**

The proposed mandate is not expected to have any impact on VFR operations until Phase 3 (see recommendations below). Prior to establishing an ADS-B mandate in low level controlled airspace, including class C, D, or E control zones, class E airways, Terminal and Transition areas, specific guidelines will be developed and coordinated to ensure that the concerns of VFR operators are addressed and mitigation is provided.

**Issue #19 – Retention of Mode C vs ADS-B Out Transponders**

There was a concern that where radar coverage exists and NAV CANADA intends to maintain and/or replace the related radars, some customers and stakeholders questioned why they would require the 1090ES ADS-B Out transponder.

**Response**

In areas where NAV CANADA plans to retain a surveillance capability other than ADS-B, a mandate might not be required. However, the 1090 ES solution can satisfy both the ADS-B “Out” and functioning transponder requirement with the same piece of equipment. For more details, see system redundancy below.

**Issue #20 – System Redundancy**

There is concern that use of the space-based ADS-B system in areas that currently use radars or other ground-based source for surveillance would be a redundant system resulting in added expense (cost of equipping) to operators with no additional operational benefit.

**Response**

Until recently, the potential coverage area of ATS surveillance was limited to where it was feasible to install and maintain ground-based infrastructure. Even where ground-based 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 backup in case of failure. Space-based ADS-B will support contingency and redundancy capabilities and be separate from ground-based infrastructure.

Including space-based ADS-B as an additional surveillance source will increase redundancy, because this service will use a separate transport network. It would also increase the ability for NAV CANADA to provide contingency services.

**Issue #21 - ADS-B and the Emergency Locator Transmitter (ELT) Requirement**

Several organizations and individuals indicated their support for ADS-B Out performance requirements would be greatly enhanced if NAV CANADA could develop a means to use the ADS-B system as an alternative to the ELT requirement for Canadian general aviation aircraft.

**Response**

NAV CANADA, along with the Canadian Owners and Pilots Association (COPA) have put forward a proposal to study the applicability of ADS-B technology for emergency applications. Transport Canada has given its support to further explore this proposal toward an improvement to the safety outcome related to the carriage of Emergency Locator Transmitters (ELT) for general aviation. (CPAAT/12 WP/06).

Space-based ADS-B via Aireon will enhance current search and rescue procedures which could lead to an increase in the number of successful rescues. ADS-B tracking services provided by Aireon (ALERT) will be used for search and rescue to aid in locating missing aircraft.

NAV CANADA recognizes the value of an application that could allow for timely and accurate flight tracking of downed aircraft and is evaluating this capability separate from this mandate.

Since the regulatory requirement associated with the carriage of an ELT in Canada is the responsibility of Transport Canada, it is beyond the scope of this study to further mitigate. NAV CANADA will continue to collaborate with Transport Canada and COPA in the development of a proposal to study the applicability of ADS-B technology for emergency locating services.

**Issue #22 - ADS-B Out mandate deviations**

There is a concern that when an aircraft has an equipment failure or requires operating in ADS-B Out mandated airspace and does not meet the minimum performance requirements, they would not be accommodated and face unnecessary penalties such as unfavourable flight paths, airport diversions, etc.

**Response**

This mandate requires operators to broadcast ADS-B Out information when operating in specified airspace.

If an aircraft is not capable of meeting the performance requirements, the operator may request a deviation from the ATC facility responsible for that airspace, similar to operations in Mode C required airspace. An ATC authorization may contain conditions necessary to provide the appropriate level of safety for all operators in the airspace. ATC may not be able to grant authorization in all cases for a variety of reasons including workload, runway configuration, ATC flow and/or weather conditions.

**Issue #23 - Hot Air Balloon and Glider Exemptions**

Glider and hot air balloon pilots were concerned that the exemption they now hold for transponder airspace may not be applicable to ADS-B Out mandated airspace and they would not be able to
operate in certain airspace. A requirement to equip with ADS-B would pose a financial burden, a power burden and avionics space burden.

Response
NAV CANADA recognizes that Gliders and hot air balloons face unique issues with avionics installations. Gliders and hot air balloons are 100% battery powered. Recent battery technologies have helped; but, they are still very sensitive to the total power requirements of any required avionics. There is limited space and weight available for batteries and wire harnesses so increasing battery capacity is often problematic if not impossible and instrument panel space is also extremely limited.

Gliders and hot air balloons generally operate away from Class A, B or C airspace and when operating in Class D or E transponder required airspace they have an exemption from the transponder requirement.

NAV CANADA plans to sustain the current exemption they now hold for Mode C transponder required airspace for the same reasons it was given for Mode C.

Issue #24 - Airspace for which ADS-B will be required

There’s a concern that the scope of the airspace that would require ADS-B Out is extensive and in some parts of the ANS, is unnecessary. Numerous customers and stakeholders suggested that NAV CANADA limit mandated ADS-B performance requirements to aircraft operating in Class A airspace only, or Class A and B airspace. They questioned the proposed ADS-B performance requirements in Class C, D and E airspace. Additionally, varying requests were made to NAV CANADA concerning the proposed altitudes for which ADS-B Out would be required.

Response:
ADS-B is most effective for ATC surveillance if all aircraft are appropriately and homogeneously equipped. Moreover, it is unreasonable to implement varying regulatory frameworks of performance standards. The airspace requirements specified in this mandate for ADS-B Out meet current and future ATC surveillance needs in Canadian domestic controlled airspace and are designed to meet the safety and efficiency needs for all our customers’ operations.

See recommendations in section 4.1.

Issue # 25 - 978 UAT

In the FAA’s ADS-B performance mandate there is an option to equip an aircraft to use the Universal Access Transceiver (UAT) broadcast link for operations in the specified mandated airspace below 18,000 feet ASL rather than the 1090 ES broadcast link. UAT uses a broadcast link of 978 MHz and provides ADS-B In capability. ADS-B In allows appropriately equipped aircraft to receive and display another aircraft’s ADS-B out information as well as the ADS-B In services provided by the FAA’s ground-based ADS-B stations including Traffic Information Service – Broadcast (TIS-B) for pilot situational awareness in aircraft not equipped with TCAS/ACAS, and Flight Information Service – Broadcast (FIS-B) that includes weather information, NOTAMs, temporary flight restrictions and other relevant flight information. None of these services are possible using the 1090 ES broadcast link.

Some of our customers, particularly those from the GA community, want the option to equip their aircraft with UAT avionics instead of 1090ES and for NAV CANADA to provide the same UAT ADS-B In-flight services as the FAA. This is the only way they believe they would receive sufficient benefits to offset their equipage costs for any performance mandate we would deploy.

Response:
NAV CANADA’s ADS-B system will be a space-based and is only 1090ES capable.

Due to the remoteness and lack of telecommunication ground infrastructure in many areas of Canada it would be unreasonably costly to establish UAT 978 MHz ADS-B services.
NAV CANADA recently upgraded the Flight Information Services Enroute (FISE) Remote Communications Outlet (RCO) system, which included the establishment of additional RCO’s to expand coverage and installation of discrete VHF frequencies to eliminate congestion and interference. With these enhancements, pilots enroute across Canada can contact the Flight Information Centres (FICs) to obtain essentially the same services provided by the FAA’s UAT ADS-B In system including weather and NOTAM information and to update their flight plans.

**Issue #26 - Flight ID does not match the aircraft ACID**

The FAA has provided NAV CANADA with a list of aircraft and incidents where their ATC has observed that aircraft under ADS-B surveillance broadcast an Aircraft Identification (ACID) that did not match the Flight Identification (Flight ID) - call sign or flight number - filed on the flight plan. The aircraft’s broadcast ACID must match the ADS-B Flight ID to ensure that the target on the controller’s display correlates with the actual aircraft. Without this match, surveillance separation services cannot be assured when aircraft are under ADS-B surveillance.

The same problem occurs when aircraft owners/operators trade transponders between aircraft or install a loaner transponder and do not revise the transponder’s configuration settings to match the aircraft’s ID.

Experience has shown that not all aircraft owners/operators are aware of this unique requirement. Consequently, there is concern that with the loss of target correlation on the ATC surveillance display, an aircraft will not be correctly identified by the controller.

**Response:**

*ADS-B uses two means of identifying transmitting aircraft.*

*The first is the aircraft’s Mode S address, also known as the International Civil Aviation Organization (ICAO) 24-bit aircraft address which is associated with a specific aircraft registration. In Canada, the aircraft address is printed at the bottom of the aircraft’s certificate of registration, is entered into the transponder during installation, and it remains associated with that specific aircraft registration.*

*The second is the Flight ID which is the aircraft’s call sign. The Flight ID enables the air traffic service’s surveillance displays to correctly correlate with the flight plan information. To ensure uninterrupted surveillance separation services, the Flight ID must exactly match the ACID entered in item 7 of the ICAO flight plan.*

*Air operators that use assigned three-letter radiotelephony designators followed by a flight number usually require a different Flight ID for each flight segment. In these operations to ensure the ACID broadcast by the transponder matches the Flight ID in the flight plan, prior to taxi for each departure the flight crew enters the Flight ID through either a transponder control panel or through the flight management system (FMS). Pilots must always ensure that the ACID entered is exactly the same as the Flight ID that was filed in item 7 of the ICAO flight plan. Same as the ACID, the Flight ID in the flight plan should never contain hyphens, dashes, or added spaces, and zeros should only appear if they form part of the ACID.*

*Example:*  
Generic Airlines Flight 045, using ICAO assigned airline code GEN. If entered in item 7 on the ICAO Flight Plan as GEN045, then the Flight ID input by the pilot in the FMS must be entered as GEN045 (and not GEN45, GEN_045, or as the aircraft registration CFABC).

*For general aviation transponder installations, Flight ID will be equal to the aircraft registration. In these cases, ADS-B installers should program Flight ID during the initial configuration. Trading transponders between aircraft or using a loaner transponder will necessitate reprogramming the correct aircraft address and flight ID into the transponder configuration settings.*

*To help inform aircraft operators/owners of this unique requirement of the ADS-B transponder, NAV CANADA has published an AIC (Aeronautical Information Circular) (see Appendix E– AIC 29/17).*
**Issue #27 - SDA value equal 0**

The FAA notified NAV CANADA of aircraft they have observed under ADS-B surveillance with a System Design Assurance (SDA) parameter (available only with RTCA/DO-260B (equivalent to EUROCAE/ED-102A)) that is equal to 0, the result of which is that their ADS-B Out generated target is not visible on the controller display systems.

*Response:*

Transport Canada has advised the following:

An SDA value of 0 will be set if the aircraft installation does not meet the performance requirements. The system may transmit a value of 0 on its own (in case of failure or redundancy problems), or Transport Canada may have required it during certification, as there was no operational mandate for ADS-B when that specific system was installed, but the aircraft operator wanted to track his aircraft for safety reasons. Once a mandate for ADS-B Out is approved, the system installation will meet design assurance levels (for new installations). Older aircraft will need to be retrofit and re-certified, as per the mandate timeline.

**Issue #28 - RVSM Special Authorization**

According to a newly proposed FAA regulation, aircraft equipped with ADS-B Out capabilities will no longer be required to specifically apply for approval to operate in Reduced Vertical Separation Minima (RVSM) airspace. The proposal would authorize operators of aircraft, equipped with qualified ADS-B Out systems that can be monitored by the FAA to conduct RVSM operations without submitting an application for an authorization to operate in RVSM airspace. NAV CANADA stakeholders may expect the same benefit with the implementation of our mandate.

*Response:*

The FAA established the North American Approvals Registry and Monitoring Organization (NAARMO) as the official regional monitoring agency supporting the implementation and continued safe use of the North American Reduced Vertical Separation Minimum (RVSM). NAV CANADA maintains two Aircraft Geometric Height Measurement Element (AGHME) for altimetry system error (ASE) calculations used in RVSM certifications. However, the regulatory requirement for RVSM authorization for Canadian aircraft operators is a Transport Canada responsibility (TC AC-700-039).

ADS-B Out enables continual monitoring of aircraft height-keeping performance and rapid notification of altimetry system errors (ASE). Geometric Height is a message element available only with the RTCA/DO-260B (equivalent to EUROCAE/ED-102A) standard.

*Should a proposal to remove the special authorization to operate in RVSM for aircraft equipped with ADS-B be approved by the FAA, Transport Canada could follow suit. This issue is outside the scope of this study.*

### 3.4 Risk Analysis

The HIRA summary table at Appendix C provides a complete analysis of the hazards and risks, issues and concerns identified under the proposals. Following is a summary of the hazards and risks.

#### 3.4.1 Hazards

The hazard identified with use of ADS-B relates to the loss of surveillance information due to system failure or loss of GPS signals to the aircraft due to outages or interference or related aircraft avionics failure.

#### 3.4.2 Risks

Loss of aircraft ADS-B Out surveillance information could result in a decrease in the required safe distance separating aircraft.
3.5 Mitigation

3.5.1 Service

3.5.1.1 To ensure customer and stakeholder concerns are addressed, the deployment of the space-based ADS-B Out performance requirements mandate will be implemented using a phased approach. The phases, as described in section 4.1.3 under Recommendations, were determined based on current equipage rates (see Appendix F), anticipated air operator equipage to meet the US and European mandates, anticipated SSR and other ground surveillance decommissioning, ATM system implementation and the ICAO and Transport Canada’s PBN plans.

3.5.1.2 NAV CANADA will continue to collaborate with Transport Canada and the general aviation community to assess the feasibility of using ADS-B technology as an alternate means for search and rescue.

3.5.2 Technical

3.5.2.1 The ADS-B system will be integrated with the Air Traffic Management System in accordance with the ANS Standards and Procedures documents.

3.5.2.2 Antenna diversity

For aircraft to meet optimum system performance equipping with both a top and a bottom antenna to support space-based ADS-B Out applications will be required.

NAV CANADA realizes that antenna diversity will increase the cost of ADS-B equipage for some customers; however, space-based transponder use does necessitate both top and bottom mount antennas. Where surveillance will be based on the space-based ADS-B Out system, antenna diversity will be required to achieve the level of service desired.

Antenna diversity is a requirement for other aircraft systems such TCAS II. Additionally, NAV CANADA is working in conjunction with Transport Canada and the Canadian Owners & Pilots Association (COPA) to develop an alternate source for emergency location using space-based ADS-B. Initial assessments indicate that antenna diversity will improve this feature of ADS-B out.

3.5.2.3 ADS-B Performance Monitor Flight Test Data Review Report

NAV CANADA will determine whether it is practicable to establish a public web-based tool that will allow aircraft operators to check the performance functionality of their ADS-B installation to assist aircraft owners, operators, and avionics installers with the validation of the performance of the ADS-B Out equipment installed on aircraft.

The tool could be similar to the one the FAA has developed to generate a report of the accuracy/functionality of the aircraft’s ADS-B performance during the period requested.

3.5.2.4 ADS-B ASE processing in Support of RVSM Operations

The FAA established the North American Approvals Registry and Monitoring Organization (NAARMO) as the official regional monitoring agency supporting implementation and continued safe use of the North American Reduced Vertical Separation Minimum (RVSM). NAV CANADA maintains two Aircraft Geometric Height Measurement Element (AGHME) for altimetry system error (ASE) calculations used in RVSM certifications. However, the regulatory requirement for RVSM authorization for Canadian aircraft operators is a Transport Canada responsibility (TC AC-700-039).
ADS-B Out enables continual monitoring of aircraft height-keeping performance and rapid notification of altimetry system errors (ASE). Geometric Height is a message element available only with the RTCA/DO-260B (equivalent to EUROCAE/ED-102A) standard.

Should a proposal to remove the special authorization to operate in RVSM for aircraft equipped with ADS-B be approved by the FAA, Transport Canada could follow suit. This issue is outside the scope of this study.

3.5.3 Human Factors

3.5.3.1 With the implementation and operational use of the ADS-B ground-based system (Hudson Bay, East Coast, Greenland) ATC training plans and procedures associated with the function and use of that system have been established and refined. Transport Canada has determined that for ATS operations there is no difference between the ground-based and space-based ADS-B systems. There are no extraordinary human factors impacts expected with the deployment of a Canadian space-based ADS-B Out performance requirements mandate.

3.5.3.2 Flight ID vs ACID (see issue #27)

To help inform aircraft operators/owners of this unique requirement for an ADS-B transponder, NAV CANADA has published an Aeronautical Information Circular (AIC) (see Appendix E–AIC 29/17). This AIC also advises Air Operators that use flight number designators to include proper Flight ID entering procedures on checklists for FMS initialization, particularly for departures where the avionics have not been reset through a power-down cycle. This will ensure pilots are aware of this unique requirement related to ADS-B surveillance.

4.0 Conclusion

Upon examining the proposal to put forward a Canadian ADS-B Out performance requirements mandate, to enhance surveillance services and provide ATC with more accurate and up-to-date information for managing aircraft traffic to improve aviation safety and efficiency, this study concludes:

a. The safety benefits of utilizing space-based ADS-B for surveillance through the proposed performance requirements mandate includes: increased ATC situational awareness through improved accuracy of aircraft position and trajectory, earlier warnings/alerts of unexpected aircraft deviations, implementation of common surveillance technology to current and new airspace for a more seamless operating environment and improved emergency response for tracking and locating aircraft in distress.

b. The implementation of a performance requirements mandate based on space-based ADS-B system for Canadian Domestic Airspace initially limited to Class A airspace with an implementation date of January 1, 2021, will result in safety and efficiency benefits for our customers’ operations and reduce costs to operate the ANS.

c. To achieve the maximum benefits of a performance-based mandate within acceptable timelines, the performance mandate should be expanded to include Class B airspace on January 1, 2022. Beyond this date, expansion of a performance requirements mandate to other Canadian Domestic Airspace will be based on an assessment of the safety and efficiency requirements for specific airspace and through the modernization of our surveillance systems, which includes the expansion of surveillance coverage, decommissioning of select SSR radars and other ground-based surveillance systems.

d. To provide the necessary functionality of the ADS-B surveillance system the proposed mandate will require customers to equip or upgrade their aircraft to meet ADS-B avionics standards equivalent to DO-260, DO-260A or DO-260B by the mandate deadline of January 1, 2021, with a requirement for all affected aircraft to meet the RTCA/DO-260B (equivalent to EUROCAE/ED-102A) standard by January 1, 2024;

e. The proposed mandate will harmonize with U.S. and European ADS-B Out mandates in that aircraft equipped with the required avionics for those mandates will be properly equipped for this mandate;
f. A large percentage of our customers will already be suitably equipped with the avionics required for the NAV CANADA proposed mandate due to the prior implementation of the U.S. and European mandates and the timeline for implementation of this mandate provides sufficient time for our other affected customers to properly equip;

g. The timing and scope of the proposed performance mandate will provide the surveillance coverage required to facilitate any potential future ground-based surveillance decommissioning initiative (see Appendix 2, Benefits Analysis, section 6);

h. The proposed mandate supports the requirements and timelines for ATS initiatives to modernize surveillance systems and will support seamless ATS surveillance between continental and oceanic regions; and

i. The proposed mandate will meet the Transport Canada Performance-Based Navigation (PBN) Operations State Plan, which stated that planning should take place for the mandatory use of ADS-B in designated airspace between 2018 and 2022. It will also align with ICAO navigation and surveillance plans and recommended practices.

4.1 Recommendations

NAV CANADA has determined that it is not operationally feasible to assign different performance requirements dependent on the nature of the operation. It would not be effective to require both pilots and controllers to verify specific performance parameters before any given operation or change of airspace. Therefore, NAV CANADA is specifying minimum performance requirements for all ADS-B Out equipped aircraft to operate in certain designated airspace to support 5 NM separation standards. The following recommended ADS-B Out performance requirements, airspace and timelines were selected in collaboration with internal stakeholders to ensure alignment with the Performance-Based Navigation (PBN) plans, standards and procedures initiatives and future traffic management and flow tools as well as with external stakeholders to ensure interoperability.

a. It is recommended that NAV CANADA implement a space-based ADS-B Out performance requirements mandate for Canadian Domestic Airspace and that the implementation occur in phases and be limited in scope.

b. The recommended Phase 1 implementation date is January 01, 2021, and includes Class A airspace as well as Class E airspace above FL600. The recommended Phase 2 implementation date is January 01, 2022, and includes Class B airspace.

c. Beyond Phase 2 it is recommended that the performance requirements mandate be applied as required in Class C, D and E airspace to provide the required safety and efficiency within a specific airspace associated with aircraft operations enroute or at an airport starting no sooner than 2023. Please see 4.1.3.3 for details.

d. The ADS-B Out avionics performance standards required for the start of Phase 1 and Phase 2 are DO 260, 260A, or 260B or equivalent including broadcast antenna diversity (an antenna mounted on the aircraft top and bottom). From January 01, 2024, the minimum standard for all aircraft operating within the airspace defined by Phase 1 and Phase 2 will be RTCA/DO-260B (equivalent to EUROCAE/ED-102A) with specified data elements.

e. Exemptions to the ADS-B Out performance requirements are specified in issue #11 and issue #23.

4.1.1 Performance Requirements

The following performance requirements align with ICAO’s recommendation of the RTCA/DO-260B (equivalent to EUROCAE/ED-102A), Minimum Operational Performance Standards for 1090 MHz ADS-B as the preferred standard. These performance requirements will be required in all mandated airspace as of January 01, 2024. (Performance requirements for ADS-B mandated airspace prior to this retrofit date can be status quo, as stated in Issue #5 and Recommendations 4.1 c.).

Message elements descriptions are included in Appendix D.
1. The following message elements shall be made available to the transponder and be transmitted via the extended squitter (ES) ADS-B Out in accordance with the formats specified in ICAO document 9871.

   a. Aircraft Identification;
   b. Mode A Code;
   c. ICAO 24-bit aircraft address;
   d. Airborne and Surface Horizontal Position — Latitude and Longitude;
   e. Airborne/Surface Navigation Integrity Category (NIC);
   f. Airborne/Surface Navigation Accuracy Category for Position (NACp);
   g. Airborne/Surface Source Integrity Level (SIL)
   h. Airborne/Surface System Design Assurance (SDA);
   i. Barometric Pressure Altitude (incl. NIC baro);
   j. Special Position Identification (SPI);
   k. Emergency State;
   l. Emergency Indication;
   m. AD-B Version Number;
   n. Airborne 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); (East/West and North/South);
   o. Airborne/Surface Navigation Accuracy Category for Velocity: NACv;
   p. Emitter Category;
   q. Vertical Rate: Global Navigation Satellite System (GNSS) vertical rate;
   r. Movement (surface ground speed);
   s. Length/width of Aircraft
   t. GNSS Antenna Offset;
   u. Geometric Altitude;
   v. Geometric Vertical Accuracy (GVA);
   w. Selected Vertical Intention:
   x. Barometric Pressure Setting; using the same source as Mode S transponder
   y. ACAS Resolution Advisory: when the aircraft is equipped with TCAS II

2. This study is recommending requiring a NIC (1e) greater than or equal to 4, which provides navigation integrity of less than 2 NM. NAV CANADA will review this requirement and determined what NIC value is necessary for ATC separation services in the approach environment.

3. This Study is recommending a NACp (1f) greater than or equal to 5. This is equivalent to horizontal position accuracy of less than 555.6 metres (0.3 NM) to support ATC surveillance for 5 NM separation standard in an enroute environment;

4. The mandate requires a maximum probability of exceeding the NIC containment radius of \(1 \times 10^{-7}\) per hour or per sample which equates to a SIL (message element 1 g) of 3 and a maximum probability of \(1 \times 10^{-5}\) per hour of a failure causing false or misleading data to be transmitted which equates to an SDA (message element 1 h) of 2.

   In DO-260A SIL was defined as surveillance integrity level and represented two separate components: (1) The maximum probability of exceeding the NIC containment radius and (2) a maximum probability of a failure causing false or misleading data to be transmitted. DO-260B separates these two components into two distinct parameters. SIL is now referred to as source integrity level and defines the maximum probability of exceeding the NIC containment radius; SDA now defines the maximum probability of a failure causing false or misleading data to be transmitted.

   Changing the proposed probability of exceeding the NIC containment radius from \(1 \times 10^{-5}\) per hour or per sample to \(1 \times 10^{-7}\) per hour or per sample should not impact users. This is because currently available ADS-B Out systems using GNSS will provide an integrity metric based on \(1 \times 10^{-7}\) per hour.
5. Message element 1 s) will be used as an input for ground detection systems and allows the NAV CANADA to review the decommissioning of ASDE radars. The length-width code will be pre-set when ADS-B equipment meeting the standards is installed in the aircraft;

6. Aircraft equipped with 1090 MHz ES should have a minimum 125-watt transmit power performance.

7. Latency must be defined at the aircraft level and not the equipment level. The latency requirements are set at the maximum value that will allow ATC surveillance. Although the latency requirements will drive wiring changes in some aircraft, the requirements will minimize the number of aircraft affected to the maximum extent possible. The latency requirements are defined as total latency and uncompensated latency.

Total latency and uncompensated latency requirements are specified in the RTCA/DO-260B (EQUIVALENT TO EUROCAE/ED-102A). Aircraft velocity, as well as position accuracy and integrity metrics (NACP, NACV, NIC, SDA, and SIL), must be transmitted with their associated position measurement, but are not required to be compensated.

8. Position sources typically provide accuracy and integrity metrics with each position that is output. To allow GNSS-based position sources time to detect and eliminate possible satellite faults, GNSS systems allow the integrity metric associated with a position to lag behind the output of the position. TSO-C145/146 and TSO-C196 GNSS systems have up to 8.0 seconds to alert to an integrity fault. TSO-C129a systems or equivalent do not have an overarching integrity fault time-to-alert requirement, but they do have navigation mode specific integrity fault time-to-alert requirements. Specifically, TSO-C129a systems must indicate an integrity fault within 10 seconds in terminal and approach modes.

9. In order for aircraft to meet optimum system performance, this study recommends equipping with both a top and a bottom antenna to support space-based ADS-B Out applications.

NAV CANADA realizes that antenna diversity will increase the cost of ADS-B for some customers; however, space-based transponder use does necessitate both top and bottom mount antennas. Where surveillance will be based on the space-based ADS-B Out system, antenna diversity will be required to achieve the level of service desired.

Antenna diversity is a requirement for other aircraft systems such TCAS II. Additionally, NAV CANADA is working in conjunction with Transport Canada and GA (COPA) to develop an alternate source for emergency location using space-based ADS-B.

10. Selected Altitude (message element 1 w) is the altitude set by pilots on the unit controlling the autopilot system. If the aircraft is not equipped with an autopilot this information may be derived from equipment generating an alert when the Flight Level is reached (e.g. altitude alerting system).

Including conformance alert for selected altitude and cleared flight level if they do not match is a response to a Transport Canada Safety finding (see table 2), this study is recommending this element be integrated by January 01, 2024.
Table 2 - Gander ICAO Aviation Occurrence Reports (AORs)
Includes Deviations resulting from Gross Navigational Errors, TCAS RAs and aircraft following contingency procedures (counted as both lateral and vertical deviations)

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<th>2018 (Jan-Jun)</th>
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<td>Vertical Deviations</td>
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<td>19</td>
<td>27</td>
<td>24</td>
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<tr>
<td><strong>Total</strong></td>
<td><strong>31</strong></td>
<td><strong>44</strong></td>
<td><strong>53</strong></td>
<td><strong>46</strong></td>
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</table>

4.1.2 Non-compliance of Performance Requirements

If the benefits of ADS-B are to flow to the aviation industry, misleading and non-compliant ADS-B transmissions need to be curtailed to the extent possible. As such, the following procedure will be applicable in the concerned airspace on commencement of ADS-B based surveillance services:

All aircraft that emit position information using a 1090 MHz extended squitter (1090ES) may be provided surveillance separation services from NAV CANADA, provided they meet the airworthiness compliance requirements defined in AIP Canada ENR section 1.6.3. ADS-B Out systems that are unable to meet these requirements must disable ADS-B transmission unless:

1. the aircraft always transmits a value of 0 (zero) for one or more of the position quality indicators (NUCp, NIC, NAC or SIL); or
2. the operator has received an exemption from NAV CANADA.

As a precaution against the possibility of ongoing display of non-compliant ADS-B data, lists of affected aircraft are maintained and filtered from display. Isavia maintains a list on behalf of the NAT Air Navigation Service Providers, while NAV CANADA maintains a second exclusion list to filter domestic operations. These lists are shared at ICAO’s surveillance panel in order to catalogue continuing airworthiness issues.

4.1.3 Airspace and Timelines

To apply consistent separation standards for improved safety and efficiency in a volume of airspce, all aircraft must be appropriately equipped with ADS-B. The airspace specified in this mandate for ADS-B Out performance requirements, along with recommended timelines, meet current and future ATS surveillance needs.

Transport Canada will remain the approving authority for any change in airspace as per the current process (request to change the DAH).

4.1.3.1 Phase 1

The performance requirements specified in 4.1.1 will be required in all Canadian Class A, which consists of the Southern, Northern and Arctic Control Areas from 18,000’ and above, FL230 and above and FL270 and above respectively, and Class E airspace above FL600 as defined in the Canadian Designated Airspace handbook (DAH) effective January 01, 2021, notwithstanding retrofit allowances and exemptions mentioned above.

It is reasonable to assume that most air operators using this airspace will be equipped to meet the U.S. and/or Europe Mandates. In addition, most operators in this class of airspace are equipped to meet RVSM and/or ACAS/TCAS II and will require minimal avionics upgrades to meet the NAV CANADA performance requirements.
4.1.3.2 Phase 2

Effective January 01, 2022, notwithstanding retrofit allowances and exemptions mentioned above, the performance requirements specified in 4.1.1 will be required in all Canadian Class B airspace, which is all low level controlled airspace above 12,500´ ASL to below 18,000´ ASL, as defined in the Canadian Designated Airspace handbook (DAH).

It is reasonable to assume that most air operators using this airspace will be equipped to meet the U.S. and/or Europe Mandates.

It is reasonable to assume that the availability of avionics to meet the performance requirements stated in this mandate is acceptable.

It is reasonable to assume that the wait time, over a period of two (2) years, for avionics certification from Transport Canada is acceptable.

4.1.3.3 Phase 3

The performance requirements specified in 4.1.1 may be required in Canadian Class C, D and E controls zones or in other class E airspace and Terminal Airspace and Transition Areas as defined in the Canadian Designated Airspace handbook (DAH). Each class of airspace mentioned above will be considered on a case-by-case basis. Action on this phase will occur no sooner than January 01, 2023.

NAV CANADA will append an addendum to this Aeronautical Study to specifically address any changes proposed to airspace classified as Class C, Class D and Class E (not including class E above FL600). The addendum will be presented to Transport Canada for concurrence and will include:

- Specific criterion of evaluation for each airspace being considered as part of the Canadian ADS-B performance requirements mandate;
- Complete consultation list of affected customers and stakeholders. The current process of consultation for an aeronautical study will be followed which includes posting a notice of consultation on the NAV CANADA website prior to the start of consultation and a notice of change which would state the proposed change in a specific airspace.
- Summary of hazards and issues following consultation;
- Mitigation;
- Conclusion and recommendations;

Implementation will not proceed until the Transport Canada review of the addendum is complete and concurrence is granted. NAV CANADA will also submit a request to change the DAH for approval by Transport Canada; and

All regulatory requirements will be met with respect to communication the changes including Notification of all affected NAV CANADA departments (Operations, Engineering, Communications, Training and Aeronautical Information Services); AIP; publication of an AIC as soon as practicable but no less than one year prior to the change, and a publication of a Notice in accordance with the Civil Air Navigation Services Commercialization Act.

Sufficient lead time will be given to airspace users to equip with the required avionics to meet the performance requirements specified in this Study. Implementation and communication of the change will be done in the same way as specified in 4.3 and 4.4 of this Study.
4.2 Change Management Table

<table>
<thead>
<tr>
<th>Present</th>
<th>Proposed System</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Controlled airspace where there is currently no surveillance and ATC separation is based on procedural standards.</td>
<td>Space-based ADS-B Out surveillance using ADS-B avionics with mandated performance requirements.</td>
<td>Uniform application of radar equivalent separation standards by ATC resulting in increased capacity, safety and efficiency of aircraft operations.</td>
</tr>
<tr>
<td>Airspace where ATC separation is based on SSR surveillance.</td>
<td>Space-based ADS-B Out surveillance using ADS-B avionics with mandated performance requirements as redundant surveillance where SSRs are being retained.</td>
<td>Space-based ADS-B surveillance as a redundant system to be used as a contingency to SSRs resulting in minimal disruption should radar failure occur.</td>
</tr>
<tr>
<td>Airspace where ATC separation is based on SSR or other ground-based surveillance and the ground-based systems will be decommissioned.</td>
<td>The implementation of space-based ADS-B Out surveillance using ADS-B avionics with mandated performance requirements for surveillance in controlled airspace to replace decommissioned SSRs or other ground-based surveillance.</td>
<td>Uniform application of radar equivalent or better separation standards by ATC resulting in increased capacity, safety and efficiency of aircraft operations.</td>
</tr>
</tbody>
</table>

4.3 Implementation

This project will take several years to complete. In addition to the normal Aeronautical Study Communication described in 4.4 below, coordination with all affected users will also take place based on the phased timelines and its implications.

In airspace where the use of ADS-B 1090 ES will be used for surveillance, this performance requirements mandate will become applicable and shall be initiated through a change to the Designated Airspace Handbook (DAH). NAV CANADA will follow the process for requesting amendments to the DAH.

NAV CANADA will proceed with each implementation phase upon receipt of the Transport Canada approval of the DAH amendment.

4.4 Communication

NAV CANADA will continue to communicate and coordinate with stakeholders to ensure the concepts defined in this Study are respected while recognizing the specific application of infrastructure change continues to meet the agreed level of service. This outreach will be through the existing multiple NAV CANADA forums.

All regulatory requirements will be met with respect to the changes listed in this report including:

- Notification of all affected NAV CANADA departments (Operations, Engineering, Communications, Training and Aeronautical Information Services)
- AIP
- Publication of an Aeronautical Information Circular a minimum of one publication cycle prior to implementation of the change
- Publication of a Notice in accordance with the Civil Air Navigation Services Commercialization Act
Aeronautical Information Publication changes will be co-ordinated with the change implementation date. Additionally, the Hazard Identification and Risk Analysis (HIRA) conducted as part of the Aeronautical Study (see Appendix D), will be supplemented with NAV CANADA’s Safety Management System (SMS) process which includes the use of implementationHIRAs prior to the introduction of operational change. Therefore, as this project unfolds the implementation HIRAs will identify if any new risks have arisen since the study was completed. Prior to implementing changes resulting from this study, all current risks will be appropriately mitigated. Implementation will occur on regularly scheduled AIRAC effective dates.

5. Monitoring

Level of Service is responsible for monitoring the implementation and post implementation of approved recommendations to ensure that service changes are performing as expected and that no unforeseen risks or hazards are introduced. In the event of any discrepancy, appropriate corrective action will be identified and initiated. The following monitoring actions will take place:

1. AIM publication changes will be reviewed for accuracy;
2. ANS safety reporting will be monitored for events related to the service changes;
3. Occurrence reporting will be monitored for events related to the service changes;
4. Customer Service reports will be monitored for issues related to the service changes; and,
5. An initial and a follow-up post implementation assessment will be completed approximately 90 days and one year after each implementation phase of the recommendations. These reviews will assess the effectiveness of the service change in terms of aviation safety, customer service and NAV CANADA efficiency, and may include interviews with customers and other stakeholders as required.
APPENDIX A

STAKEHOLDER LIST
Domestic and International Stakeholders

Consultations were conducted with aircraft operators and associations and other stakeholders, both national and international in all areas of the country, in person, by telephone, by e-mail and via WebEx. The following were contacted and feedback was requested and collected.

<table>
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<tr>
<td>Information Management, Operational Analysis, Air Traffic Service System Integration</td>
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**INTERNATIONAL CUSTOMERS**

- Aer Lingus
- Atlas Air
- American Airlines
- Ethihad
- United Emirates
- Swiss International Airlines
- British Airways
- KLM
- Quantas
- DHL
- Cathay Pacific
- Bombardier
- Japan Airlines
- Austrian Airlines
- COPA Airlines
- Iceland Air
- Jet Airways
- Midwest Aviation/Kiewit Engineering
- United Airlines
- Virgin Airlines/ Alaska Air
APPENDIX B

BENEFITS ANALYSIS

May 2017
Benefits Analysis of Space-Based ADS-B in Canadian Domestic Airspace (CDA)

Summary

This report presents the Benefits Analysis (BA) of implementing space-based ADS-B in the CDA. Space-based ADS-B will provide surveillance where it does not currently exist in the Northern CDA, provide a more cost-efficient solution where surveillance does exist in the Central CDA, and provide surveillance redundancy in the Southern CDA. The analysis period is 2017 to 2032 inclusive, with benefits beginning in 2019.

The achievable benefits are in the form of shorter flight times in the Northern CDA and avoided costs of maintaining and replacing existing higher cost surveillance throughout the Central CDA.

The achievable fuel burn reduction enabled by space-based ADS-B is expected to average 160 kg and $120 USD per ADS-B equipped flight operating in the Northern CDA. The benefits in the Central CDA where Secondary Surveillance Radar (SSR) and ground-based (GB) ADS-B sites will be decommissioned are the avoided operating and maintenance costs and avoided replacement costs. Greenhouse Gas (GHG) emissions are expected to be reduced by an estimated 1 million metric tonnes over this period.

Real-time surveillance provides value from increased safety and efficiency through greater flexibility, predictability and reliability. Space-based ADS-B will increase situational awareness, provide earlier warning and alerting of un-cleared flight deviations, improve the ability to respond to unexpected changes in operational conditions, offer more accurate information, improve emergency tracking and search and rescue response and provide a seamless surveillance environment at a lower cost across the country.
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3.0 The Current Operating Environment  
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1.0 Introduction

This report presents the benefits analysis (BA) of applying space-based Automatic Dependent Surveillance – Broadcast (SB ADS-B) capability across Canadian Domestic Airspace (CDA).

Ground-based ADS-B is a proven technology that uses the Global Navigation Satellite System (GNSS) to provide accurate aircraft position information in near real time. Space-based ADS-B is similar to ground-based ADS-B but without the restriction of line-of-sight to a suitable and accessible land mass since the system receivers are located on a constellation of Low Earth Orbiting Satellites (LEOS). It offers precise flight tracking, and enhanced safety and security to remote and oceanic airspaces, more cost-effective surveillance opportunity and redundancy in areas already covered with ground-based surveillance and it supports seamless equipment interoperability.

Space-based ADS-B will provide surveillance where it does not currently exist in Northern Canada, while providing a more cost-efficient solution in some areas where surveillance does exist. Most of the existing ground-based surveillance infrastructure comprises Primary Surveillance Radar (PSR), Secondary Surveillance Radar (SSR) and ground-based ADS-B.

This benefits analysis assesses the benefits of providing surveillance with the existing ground-based surveillance infrastructure compared to using a combination of ground-based and space-based surveillance.

The benefits of space-based ADS-B include the expansion of surveillance in Northern Canada, which is expected to reduce the amount of fuel consumed and associated Greenhouse Gas (GHG) emissions through a reduction in separation standards. Other benefits include the avoided costs of replacing and maintaining radars and ground-based ADS-B that could be decommissioned with the introduction of space-based ADS-B.

2.0 Benefits Analysis and Scope

The benefits will vary over the analysis period with changes in traffic volume, aircraft capability, investment schedules and other parameters.

This benefits analysis includes all Canadian Domestic Airspace, which is serviced by a number of different surveillance systems. In the northern part of the country, defined as Northern CDA, there is no surveillance. The central corridor of the country, defined as Central CDA is serviced with SSR, in combination with ground-based ADS-B. In the southern part of the country, defined as Southern CDA, the busy terminal airspaces require SSR and PSR. The current 2017 surveillance is displayed below in Figure 1.
There are 46 SSR sites across the country. There are 22 SSRs co-located with PSRs along the United States-Canada border, shown in blue in Figure 1, to support busy international airports and terminal airspace. SSR locations that are not associated with terminal airspace are shown in orange and there are 24 of these. There are also 15 ground-based ADS-B sites, shown in purple, five that cover Hudson Bay, six installed on the East Coast of Canada and four in Southern Greenland.

Space-based ADS-B will have differing benefits depending on the airspace in which it is used. For this reason, the business case analysis has been divided into three regions, as shown in Figure 2.
Figure 2: Three different impacts of Space-Based ADS-B in CDA

1. Northern Canadian Domestic Airspace (CDA)

Space-based ADS-B will provide surveillance in the Northern CDA, where surveillance does not currently exist. This will provide fuel savings to operators through a reduction in separation, by allowing shorter flight times, more efficient routings and a more seamless operating environment.

2. Central Canadian Domestic Airspace (CDA)

Space-based ADS-B can provide a more cost-effective surveillance solution in this airspace, replacing the existing SSR and ground-based ADS-B infrastructure.

3. Southern Canadian Domestic Airspace (CDA)

Space-based ADS-B will be able to provide some surveillance redundancy in the busiest parts of the country.

By 2018, ADS-B receivers are expected to be installed on 66 Iridium NEXT satellites in six low earth orbits and will provide global real-time position updates to Air Traffic Services (ATS). Figure 3 below displays the global air traffic tracked by one Aireon receiver over a 62-hour period.
The analysis time horizon is 15 years. Benefits to the Northern CDA are assumed to commence as soon as SB ADS-B is operational in 2018. Decommissioning of the SSRs and ground-based ADS-B begins in 2022, once space-based ADS-B is fully operational and ADS-B equipage is higher. It is assumed the decommissioning of SSR and ground-based ADS-B will take approximately four years. Their total operating and maintenance costs will gradually decrease over this period.

### 3.0 The Current Operating Environment

CDA covers an area of roughly 14 million square kilometres. The airspace stretches from the Pacific Coast of British Columbia to the East Coast of Newfoundland and from the busy U.S.-Canada border to the North Pole where aircraft fly more direct polar routes to reach Asian destinations.

In 2016, approximately 3.3 million IFR and VFR flights operated in CDA (Source: NAV CANADA Flight Data Extract (FDE), Data Warehouse (UDR))

- 2 million flights exclusively within CDA
- 625,000 overflights
- 500,000 flights between Canada and the U.S.
- 175,000 flights between Canada and other locations

Traffic for the three regions in CDA was assessed for 2016 using NAV CANADA Flight Data Extract (FDE) Data and the Integrated Sector Airspace Tool (ISAT). ISAT can filter flights for any defined airspace. The flights and flight hours were assessed for flights operating at or above 10,000 feet for the three regions as follows:

1. **Northern CDA**
   The Northern Domestic Airspace represents the area where no ground-based surveillance currently exists. The airspace is illustrated in Figure 4. IFR flights and flight-hours operating at or above 10,000 feet were extracted for this airspace for 2016.

2. **Central CDA**
   The Central Domestic Airspace has surveillance provided by SSR and ground-based ADS-B. The coverage is predominately for enroute flights and outside of Terminal radar airspace found in the Southern CDA. The airspace is illustrated in Figure 5. One week of data was analyzed for each month and total IFR flight counts and flight-hours were extrapolated for 2016 for flights operating at or above 10,000 feet.
3. **Southern CDA**

   The Southern Domestic Airspace comprises the airspace around the terminal radars, and is the remaining portion of Canadian domestic airspace. Southern IFR flight-hours were derived by subtracting the IFR flight-hours in the Northern and Central CDAs from the total Canadian Civil Domestic IFR flight-hours.

2016 IFR Flight and Flight-Hours are shown for the three regions in Table 1.

<table>
<thead>
<tr>
<th>Area</th>
<th>All Altitudes</th>
<th>Flights at or above FL100</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>IFR Flights (000s)</td>
<td>IFR Flight Hours (000s)</td>
</tr>
<tr>
<td>1. Northern CDA</td>
<td>111</td>
<td>118</td>
</tr>
<tr>
<td>2. Central CDA</td>
<td>550</td>
<td>600</td>
</tr>
<tr>
<td>3. Southern CDA</td>
<td>N/A(^1)</td>
<td>2,282</td>
</tr>
<tr>
<td>Total</td>
<td>2,500</td>
<td>3,000</td>
</tr>
</tbody>
</table>

\(^1\) Flight counts are not unique to each region and have not been calculated for Southern CDA

\(^2\) Estimated assuming 95% of flight hours above FL100

Figure 6 below illustrates example flight routes throughout the Northern CDA.
In order to provide surveillance with space-based ADS-B, aircraft must be appropriately equipped. The U.S. ADS-B Out Mandate requires aircraft operating in U.S. Mode-C airspace to have an ADS-B system that meets specific requirements by January 1, 2020. The European Single Sky Committee has extended its previous ADS-B Out mandate for retrofit aircraft operating in the European Union to June 1, 2020. New aircraft must already be ADS-B equipped. (Source: “The Ins and Outs of the ADS-B DO-260B Compliance”. Honeywell Aerospace. Web. Mar. 2017)

The possibility of an ADS-B mandate in Canadian Domestic Airspace is currently being assessed. The mandate would include the introduction of the requirement for DO-260 (all versions) transponder ADS-B equipage in Class A High Level airspace by 2021, with the requirement to follow in Class B and C airspace.

Space-based ADS-B relies on aircraft transponders to provide real-time position to ATC. ADS-B signals can be confirmed from satellites when aircraft have top mounted antennas, but has not proven to be effective for aircraft with bottom only antennas at this point. Traffic Alert and Collision Avoidance System (TCAS) requires top and bottom antennas. This benefits analysis assumes that all aircraft operating at and above FL100 will benefit from space-based ADS-B.

4.0 Base Case and Option

4.1 Introduction

The Base Case represents the operating environment in 2017. The Option Case is defined by the implementation of space-based ADS-B throughout the country which will provide additional Air Traffic Management (ATM) functionality and customer and NAV CANADA cost savings.

4.2 Base Case

There will continue to be no surveillance in the Northern CDA. The existing ground-based surveillance will remain the same as it is today and require ongoing maintenance and replacement. All 24 SSR and 15 ground-based ADS-B sites identified as potential sites for decommissioning with space-based ADS-B will be replaced with the SSR and ground-based ADS-B in line with what is currently installed in 2017, and associated annual operating and maintenance costs and one-time replacement costs will be incurred.

4.3 Space-Based ADS-B Option

The Option Case consists of the expansion of surveillance coverage using space-based ADS-B. The impact of this deployment will introduce surveillance in the Northern CDA for the first time, a more cost-effective surveillance solution throughout the Central CDA, and surveillance redundancy in the Southern CDA.

The impact of the deployment on the three areas is as follows:

1. **Northern CDA Impacts**
   Space-based ADS-B would enable a reduction in separation standards in the Northern CDA, as highlighted in Table 2. The customer fuel benefits for flights in Northern CDA have been quantified by assuming shorter flight times. Note that the separation standards proposed under space-based ADS-B are currently being assessed by the ICAO Separation and Airspace Safety Panel, and have therefore not yet been endorsed by ICAO.
<table>
<thead>
<tr>
<th>Element</th>
<th>Base Case</th>
<th>SB ADS-B Option Case</th>
</tr>
</thead>
<tbody>
<tr>
<td>Longitudinal</td>
<td>20 nm with Very High Frequency (VHF) communication 10 minutes without VHF</td>
<td>5 nm with VHF 15 nm with Controller-Pilot Data Link Communications (CPDLC)</td>
</tr>
<tr>
<td>Lateral</td>
<td>60 nm 50 nm RNP10</td>
<td>5 nm with VHF 15 nm with CPDLC</td>
</tr>
<tr>
<td>Vertical</td>
<td>1,000 feet</td>
<td>1,000 feet</td>
</tr>
</tbody>
</table>

2. **Central CDA Impacts**
   As space-based ADS-B is a more cost-effective surveillance system than the current 2017 surveillance system. The benefits in the Central CDA where ground-based surveillance already exists will be the avoided costs of replacing, operating and maintaining the SSR and ground-based ADS-B sites.

   Once space-based ADS-B is operational across the country, decommissioning of radar and ADS-B sites across the central corridor of the country can begin.

   Aircraft currently operating with a Mode A, C or S transponder that are under surveillance within the existing SSR coverage in this region would not benefit from ATS surveillance separations using solely space-based ADS-B until equipped with ADS-B transponders that include both top and bottom mounted antennae.

3. **Southern CDA Benefits**
   There will be no changes to the surveillance coverage provided in the Southern CDA, however space-based ADS-B will provide some redundancy in the area.

5.0 **Benefits, Analytical Approach and Assumptions**

   This section describes the approach and assumptions used to quantify benefits

5.1 **Northern CDA**

   The introduction of surveillance, through space-based ADS-B will offer aircraft operators greater and better choices in routing and flight levels. There will be more seamless operations across the entire country, and with adjacent sectors, such as Anchorage and Reykjavik. With space-based ADS-B in these regions, flights will not need to be routed to specific entry points, can achieve more efficient routes, and take better advantage of tailwinds or avoid headwinds. As a result, flight times and fuel burns are expected to be reduced.

   Quantifying these impacts is difficult as they are highly dependent on individual flight circumstances and carrier operating characteristics (operations dispatch procedures and cost structure). This benefits analysis captures the essence of these benefits by assuming flights operating within a space-based ADS-B environment are able to fly more direct routes. The shortest distance route is defined by the Great Circle Route (GCR).

   An analysis of the difference between actual flown distance and GCR distance determined that on average flights operating in the Northern CDA fly an additional 135 nautical miles (NM) when compared to the GCR. On average, flights operating in other parts of the country fly 45 NM above the GCR. If flights in the North flew 45 NM greater than the GCR, it would equate to a saving of 90 NM (135-45). Based on average speeds in the Northern CDA, a 90 NM savings is equal to a 12-minute savings. (UDRDW)

   There are still remaining restrictions with the adoption of space-based ADS-B, including limited points of entry into Russian airspace.
For the analysis, a conservative 3-minute flight time savings were applied to 50% of flights operating above FL100 in the Northern CDA. Fuel burns were calculated based on the average FL 330 for each aircraft type and BADA 3.10 data. Aircraft crew and Maintenance costs for time saved were not included in the analysis.

It should be noted that providing surveillance coverage in this region via traditional ground-based infrastructure such as ADS-B would be prohibitively expensive due to its remoteness (and considerably higher than the replacement costs assumed for the Central CDA).

5.2 Central CDA

The Base Case cost of replacing all 24 existing Enroute SSR and 15 ground-based ADS-B systems is compared to the Option Case cost of decommissioning these sites and using space-based ADS-B as surveillance. The possible decommissioning would be based on a phased approach over four years.

In addition, the annual cost of operating and maintaining these aging ground-based systems would be avoided with space-based ADS-B. These costs have been fairly constant over the last ten years and are expected to remain so over the analysis period, largely as a result of the “life cycle extension projects”. The cost of these projects is included in the annual operation and maintenance.

5.3 Southern CDA

Although the existing SSR sites in terminal airspaces will not be replaced by space-based ADS-B, there are additional benefits available through using space-based ADS-B as redundant surveillance. In the case of radar malfunctions and outages, space-based ADS-B may enable ATC to continue to provide uninterrupted service to operators in the airspace without the need to re-route or increase separation standards. space-based ADS-B will also allow more flexibility in repair and maintenance of the existing systems – if space-based ADS-B is available as backup surveillance, there may be a reduced urgency in repair, potentially avoiding travel and labour premiums associated with a high priority response.

In 2015 and 2016, there were close to 167 unplanned Interrupt Report radar outages. These issues represented just under 3,300 outage hours.

5.4 Forecast Traffic and Aircraft Assumptions (Source: NAV CANADA Traffic Analysis Forecast (TAF))

Two traffic growth forecasts were used for the benefits analysis. Many of the flights operating in the Northern Domestic Airspace without surveillance are polar route flights, which have grown significantly in the recent years. 2015 traffic grew 17% over 2014, and 2016 traffic grew 9% over 2015.

The traffic forecast for this region has been relatively strong and a 6% to 7% annual growth is expected for the next few years. This is based on information from the IATA passenger forecast and is also predicated on a continued strong Chinese economy. Since the sustainability of this increase in traffic over the 15-year benefit horizon is uncertain, a more modest rate of 2.5% is assumed for all airspaces.

5.5 Forecast ADS-B Equipage

Appropriate ADS-B equipage is required for flights to benefit. 2017 ADS-B equipage in the Northern and Central CDA is 70% to 75% for all flights and 90% to 95% for flights above FL290. Many of these flights are international flights and will be required to be ADS-B equipped by 2020 under U.S. and European Mandates. Equipage assumptions for the Northern and Central CDA above FL100 are as follows:

Table 3: Forecast ADS-B Equipage Northern and Central CDA
ADS-B Equipage in the Southern CDA is much lower, as there are many domestic flights that do not require ADS-B equipage due to current mandates. ADS-B equipage will increase significantly in 2020 due to the U.S. and European mandate deadlines and will reach 100% by 2022 assuming a Canadian ADS-B mandate similar to the U.S. All SSR and ground-based ADS-B surveillance systems will be retained until the ADS-B equipage of aircraft operating in the airspace above FL100 is at 100%.

Table 4: Forecast ADS-B Equipage Southern CDA

<table>
<thead>
<tr>
<th></th>
<th>2018</th>
<th>2019</th>
<th>2020</th>
<th>2021</th>
<th>2022 +</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>55%</td>
<td>65%</td>
<td>85%</td>
<td>95%</td>
<td>100%</td>
</tr>
</tbody>
</table>

5.6 Other Assumptions

A number of additional assumptions, several of which are common to both the Base Case and Option deployments, are identified in Table 5.

Table 5: Other Assumptions

<table>
<thead>
<tr>
<th>Variable (units)</th>
<th>Value</th>
<th>Source/Assumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel Price ($US/Gallon)</td>
<td>$2.44</td>
<td>US Energy Information Administration</td>
</tr>
<tr>
<td></td>
<td>$0.75</td>
<td>$1.22 USD/gallon 2016 average</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Forecast +100% in Jet Fuel price (average for analysis period)</td>
</tr>
<tr>
<td></td>
<td></td>
<td><a href="http://www.eia.gov/forecasts/aec/data/browser/#/?id=12-AEO2016&amp;cases=ref2016&amp;sourcekey=0">http://www.eia.gov/forecasts/aec/data/browser/#/?id=12-AEO2016&amp;cases=ref2016&amp;sourcekey=0</a></td>
</tr>
<tr>
<td>Discount Rate (%)</td>
<td>5%</td>
<td>Assumption</td>
</tr>
<tr>
<td>Greenhouse Gas Emissions (kg CO₂</td>
<td>3.16</td>
<td>US Energy Information Administration</td>
</tr>
<tr>
<td>Equivalent per kg fuel)</td>
<td></td>
<td><a href="http://www.eia.doe.gov/olaf/1605/coefficients.html">http://www.eia.doe.gov/olaf/1605/coefficients.html</a></td>
</tr>
<tr>
<td>CAD/USD Exchange Rate</td>
<td>0.75</td>
<td>CAD/USD Exchange Rate Lookup Bank of Canada March 2017</td>
</tr>
<tr>
<td>SSR and GB ADS-B Replacement Year</td>
<td>2028</td>
<td>Based on information from NAV CANADA Engineering</td>
</tr>
</tbody>
</table>

6.0 Benefit Results

6.1 Northern CDA Time Savings

The fuel benefits as a result of shorter flight times are included in Table 6. The table includes the benefits per flight, annually and the total 15-year projection. The savings are based on 50% of flights operating above FL100 saving an average of 3 minutes each.
Table 6: Potential Fuel Savings from Shorter Flight Times (undiscounted)

<table>
<thead>
<tr>
<th></th>
<th>Fuel Saved</th>
<th>$USD Saved</th>
<th>Avoided GHG Emissions (CO2e Reduction)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Per Flight Saving</td>
<td>160 kg</td>
<td>$120</td>
<td>500 kg</td>
</tr>
<tr>
<td>2018 Total Savings</td>
<td>15 Million kg</td>
<td>$11 Million</td>
<td>47 Million kg</td>
</tr>
<tr>
<td>15 Year Total Benefit</td>
<td>316 Million kg</td>
<td>$234 Million</td>
<td>999 Million kg</td>
</tr>
</tbody>
</table>

6.2 Central CDA

The benefits in the Central CDA include avoided costs of replacing the ground-based surveillance infrastructure in 2028 and its associated annual operating and maintenance costs. The replacement and operating costs are presented in Table 7.

Table 7: Avoided SSR and Ground-Based ADS-B Costs (undiscounted) (Source: NAV CANADA Engineering Finance)

<table>
<thead>
<tr>
<th></th>
<th>Replacement Costs ($Million USD)</th>
<th>O&amp;M Costs ($Million USD)</th>
<th>Total ($Million USD)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Annual</td>
<td>Total⁹</td>
<td></td>
</tr>
<tr>
<td>SSR</td>
<td>147.3</td>
<td>2.5</td>
<td>28.5</td>
</tr>
<tr>
<td>GB ADS-B</td>
<td>3</td>
<td>0.3</td>
<td>3.6</td>
</tr>
<tr>
<td>Total</td>
<td>150.3</td>
<td>2.8</td>
<td>32.1</td>
</tr>
</tbody>
</table>

⁹ Only included for 11 years following SSR and ground-based ADS-B decommissioning (2022–2032) plus $300K every 5 years

6.3 Safety Benefits

There are several qualitative safety impacts expected with the implementation of surveillance through space-based ADS-B in the Northern CDA as follows:

a. **Increased Situational Awareness**

   Surveillance closes the gap between the expected aircraft position based on clearances or instructions issued to pilots, and the actual trajectories that aircraft fly. Moreover, with a target tag, surveillance can indicate to air traffic controllers whenever expectations are not matched.

b. **Earlier Warning/Alerting**

   The ability to immediately detect when an aircraft deviates from its assigned altitude or route, danger area infringement warnings, “blunder” detection and other similar alerts BEFORE they become conflicts. However, the benefit diminishes as the ability of the controller to monitor and process the information becomes saturated, and automation may be needed to enhance the effectiveness of these alerting systems.

c. **More seamless operating environment**

   Whenever changes to a flight trajectory or route is required as a result of traversing airspaces with differing rules and procedures, errors can be introduced that may result in aircraft manoeuvring to an incorrect altitude or route/fix. The chance that a flight will obtain its preferred trajectory or route is greater with surveillance, resulting in a consequent decrease in the number of requests for changes and the potential for error. Moreover, a seamless environment eliminates the requirement for ATCOs to intervene and increase aircraft spacing as it transitions to non-surveillance airspace and allows a more predictable and orderly flow of traffic, reducing workload and stress.
d. *Improved ability to respond to unexpected changes*
   Notwithstanding the safety benefit of a more orderly flow, which is expected to be the norm, when unexpected events occur such as emergencies, hazardous weather, severe clear air turbulence, etc., surveillance will facilitate an improved response. If the area of a hazard is known, the positional information and accuracy offered by surveillance will ensure that the aircraft remains at a safe yet reasonable distance from the hazard.

e. *More accurate information*
   With a rapid update rate, improved aircraft position accuracy and reduced speed error variability (from more frequent and accurate velocity vectors), not only is the potential conflict identified sooner, its resolution may be better planned and executed.

f. *Improved emergency tracking and Search and Rescue Response*
   Aircraft Locating and Emergency Response Tracking (ALERT) will be one of the services provided globally. In such cases, notification time and position accuracy will allow a quicker response, with reduced chance of loss of life.

### 7.0 Conclusion

This Benefits Analysis delivers value from increased safety and efficiency through greater flexibility, predictability and reliability. Space-based ADS-B will increase situational awareness, provide earlier warning and alerting of un-cleared flight deviations, improve the ability to respond to unexpected changes in operational conditions, offer more accurate information, improve emergency tracking and search and rescue response and provide a seamless surveillance environment at a lower cost across the country.
APPENDIX C

HAZARD IDENTIFICATION AND RISK ASSESSMENT SUMMARY TABLE
<table>
<thead>
<tr>
<th>Hazard/Issue</th>
<th>Existing Mitigation (Defence) in the System</th>
<th>Risk Estimations</th>
<th>Risk Evaluation</th>
<th>Mitigation</th>
<th>Evaluation (of mitigation)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hazard #1</td>
<td>The use of ADS-B Out for surveillance separation has already been examined in other safety assessments and been approved for operational use by Transport Canada. Any additional hazards specific to receipt of the signal from space-based versus ground-based antennas will be addressed during operational implementation of the Aireon signal following full operational capability of the Iridium Next constellation. The loss of surveillance information in the context of an airspace mandate is a change in the scope of the effect, having already examined each of the potential component failure sources. NAV CANADA has been able to leverage operational experience since 2009 gained using the ground-based ADS-B system that has demonstrated robust, accurate and reliable surveillance data. In preparation for the introduction of PBN in the enroute structure, NAV CANADA received an exemption to use the separation standards that are detailed in the ICAO document: Procedures for Air Navigation Service – Air Traffic Management (PANS-ATM Doc 4444). The conditions of this exemption require NAV CANADA to inform Transport Canada of the intent to use a Doc 4444 standard and meet other conditions such as ensuring implementation HIRAs are conducted and that any required training is complete prior to implementation. It is expected that Transport Canada will recognize ICAO’s standards for ADS-B operations, which will be reflected in the proposed performance mandate. Regardless, NAV CANADA will demonstrate a safety case via a HIRA for ATC operations using space-based ADS-B in any mandated airspace that we deploy. NAV CANADA will keep Transport Canada apprised of our implementation plans and provide them with the required technical and procedural risk assessments and mitigations. Prior to implementing any mandate associated with space-based ADS-B NAV CANADA will request: a. permission to use the Doc 4444 separation standards associated with ADS-B; and, b. a cancellation of Exemption NCR-104-2016. The functionality of the system is outside the scope of this study.</td>
<td>The risk that a loss of ATC surveillance due to the failure of the ADS-B system could result in an aircraft collision is estimated to be Low.</td>
<td>All ATC systems undergo thorough and extensive quality assurance prior to operational use. Nearly a decade of NAV CANADA experience using ADS-B has demonstrated that this surveillance system is more accurate and as capable if not more than radar or MLAT. In summary, using space-based ADS-B for surveillance is assessed to result in an aircraft collision risk level that is as low as reasonably practicable (ALARP). No further mitigation required.</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Hazard/Issue</td>
<td>Existing Mitigation (Defence) in the System</td>
<td>Risk Estimations</td>
<td>Risk Evaluation</td>
<td>Mitigation</td>
<td>Evaluation (of mitigation)</td>
</tr>
<tr>
<td>-------------</td>
<td>---------------------------------------------</td>
<td>------------------</td>
<td>----------------</td>
<td>------------</td>
<td>---------------------------</td>
</tr>
<tr>
<td><strong>Issue #1</strong>&lt;br&gt;International Harmonization &amp; ADS-B Out Performance Requirements&lt;br&gt;There is concern that the Canadian space-based ADS-B Out performance mandate may not align with the FAA and/or European mandates. If the performance requirements for Canadian airspace were different than these other states, such as lower aircraft separation distance standards, more transponder data outputs and/or higher positional accuracy, then the greatest efficiency benefits for NAV CANADA use of ADS-B may not be realized. NAV CANADA ATC services for aircraft transiting into the U.S. or Europe, particularly separation standards, will need to be at the same level and compatible with other ANSP ATC operations.&lt;br&gt;Aircraft that have equipped for a mandate with higher performance requirements may not realize the full benefit of their investment when operating in airspace with lower mandate requirements. (See Aircraft Equipage Issue #2.)&lt;br&gt;Note: As a contingency related to the NAVAIDS Modernization Plan (NMP), NAV CANADA is retaining a system of NAVAIDS and non-GNSS reliant surveillance to ensure IFR aircraft can recover at a suitable airport in the event of a catastrophic failure of the GNSS. Failure of the GNSS will also result in a failure of the ADS-B surveillance system. With the NMP recovery system and the procedures established for failure of ADS-B, IFR aircraft operations will safely continue until all aircraft have landed.</td>
<td>The risk that NAV CANADA will not realize the full efficiency benefits of ADS-B due to misaligned performance standards with neighbouring states is estimated to be low.</td>
<td>NAV CANADA will deploy the ADS-B performance standards established by ICAO and neither the U.S. or Europe have indicated they will apply for any differences. In summary, the risk that the NAV CANADA performance mandate will be not be harmonized with U.S. and European operations to provide the full efficiency benefits for ATC and aircraft operations in Canada is assessed as ALARP. No further mitigation required.</td>
<td>N/A</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td><strong>Issue #2</strong>&lt;br&gt;International Harmonization &amp; Aircraft Equipage&lt;br&gt;NAV CANADA does not plan to implement any mandate in advance of the FAA or European mandates, which are Jan 1, 2020, &amp; Jun 7, 2020, respectively.</td>
<td>The risk that the implementation of the NAV CANADA ADS-B performance mandate</td>
<td>The NAV CANADA timeline for implementing an ADS-B performance mandate will be after the U.S. and European</td>
<td>N/A</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Hazard/Issue</td>
<td>Existing Mitigation (Defence) in the System</td>
<td>Risk Estimations</td>
<td>Risk Evaluation</td>
<td>Mitigation</td>
<td>Evaluation (of mitigation)</td>
</tr>
<tr>
<td>--------------</td>
<td>---------------------------------------------</td>
<td>------------------</td>
<td>----------------</td>
<td>------------</td>
<td>--------------------------</td>
</tr>
<tr>
<td>The U.S. and Europe are deploying a ground-based ADS-B Out 1090ES system while NAV CANADA will be deploying a space-based ADS-B Out 1090ES system. There is concern that aircraft equipped for the U.S. and/or European ADS-B mandates may not be properly equipped for any ADS-B Out performance mandate that NAV CANADA may propose for Canadian airspace. Additional avionics equipage expenses for aircraft operators that results from any mandate NAV CANADA implements might be an unacceptable financial burden. Possible additional expenses could include equipping for transponder antenna ‘diversity’ (aircraft top and bottom mounted), installation or upgrade to a Mode S 1090ES transponder with the required data link parameters and/or installation or upgrade of GNSS avionics to achieve the required positional accuracy. This could result in an unacceptable financial burden on these customers resulting in a lack of support for the NAV CANADA mandate.</td>
<td>An ACAS/TCAS II system uses a Mode S transponder that broadcasts on 1090 MHz and has antenna diversity (top and bottom mounted transponder antenna). Aircraft equipped to meet U.S. and European mandates, specifically aircraft that are equipped to meet the ACAS/TCAS II regulation in those countries including Canada, will have the required antenna diversity and transponder. Aircraft that are not affected by ACAS/TCAS II regulations and do not currently have antenna diversity will be required to meet the recommended performance requirements set forth in this proposal to operate in ADS-B airspace. The phased timeline and targeted airspace approach to the implementation of the NAV CANADA mandate allows these affected aircraft operators time to equip their aircraft to meet the performance requirements. (See Issue #4 – Implementation Lead Time)</td>
<td>will result in additional avionics equipage expenses that would be an unacceptable financial burden to our customers is estimated to be low.</td>
<td>mandates. Initially the NAV CANADA mandate will apply to Canadian Domestic Class A high level airspace. Most of the aircraft affected by these implementation scenarios will have avionics capabilities that will require minimal or no upgrades. With this implementation approach the risk that customers will experience an unacceptable financial burden to equip their aircraft with the required avionics and will not support the mandate is assessed as ALARP.</td>
<td>No further mitigation required.</td>
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**Issue #3**  
**PBN Alignment**  
There is a concern that the proposed ADS-B Out mandate would not align with the Performance-based Navigation (PBN) implementation plan (U.S., Europe and Canada) in relation to aircraft equipage/accuracy requirements for Global Navigation Satellite System (GNSS) avionics. | The NAV CANADA PBN Operations Plan aligns with both the ICAO and Transport Canada PBN Plan. The ADS-B performance requirements will be implemented as closely as possible in accordance with the timelines stated in these plans. Any Canadian mandated equipment performance requirements for GNSS is planned to align with current and future PBN plans for one minimum standard. | The risk that operators will need to perform upgrades to meet different performance requirements is estimated to be low. | No further mitigation required | N/A | N/A |

**Issue #4**
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<th>Issue #5</th>
<th>Retrofit</th>
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<td>It was suggested that NAV CANADA should allow aircraft that are equipped with legacy versions of the transponder standard, i.e. the DO 260 and DO260A, to operate in mandated airspace after the implementation date. This would provide operators with more time and flexibility to retrofit aircraft, which will help reduce their costs.</td>
<td>Since the Aireon system recognizes all versions of the DO 260 standard transponders, allowances for retrofits will be accepted until Jan 1, 2024. The recommended retrofit date aligns with both Transport Canada’s PBN State Plan and ICAO ISBU Block 2 (2023–2027) for Navigation and Surveillance. In addition, with the potential decommissioning of certain SSR’s, MLAT and ground-based ADS-B commencing between 2022–2024, surveillance requirements in specified designated airspace will primarily be supported through space-based ADS-B. The retrofit date also takes into consideration possible delays in certification and in availability of required equipment, as well as industrial capacity constraints for equipping aircraft. The legacy ADS-B standards, DO 260 Version 0 and 1 (A), which have a different and smaller set of the ADS-B Out parameters enable surveillance services in mostly lower-density airspace for ATC separation and is oriented towards delivery of existing levels of ATC surveillance. For example, Version 0 does not independently report the accuracy and integrity metric and do not include a message element for</td>
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### Hazard/Issue

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| Mode 3/A code which is required for mixed mode operations.  
The use of ADS-B data elements made available by the DO 260B, enable increased safety through select altitude vs cleared altitude and the potential application of 3 NM separation in terminal airspace using ADS-B as a primary source of surveillance.  
NAV CANADA must transition to more demanding ADS-B requirements over time as our airspace requirements change. It has been determined that legacy standards will not meet surveillance needs for ATC in Canada after January 1, 2024. | N/A | N/A | N/A |
| **Issue #6**  
**Benefits Vs Costs**  
ADS-B will enhance ATC surveillance, which will increase airspace efficiency and capacity to help meet the predicted future demand for ATC services. Several stakeholders felt that the anticipated efficiency improvements from the mandate such a decrease in enroute separation of aircraft would not necessarily decrease overall delays or increase airspace capacity to a level that would offset their costs to equip to the mandate performance requirements. They also felt that NAV CANADA has not demonstrated that system choke points can handle the increased capacity if enroute separation is reduced. In summary, their argument is that reducing separation will not mitigate commercial traffic delays caused by an inadequate number of runways, weather, hub-and spoke operations, or airline scheduling practices.  
**Details on anticipated operational benefits are outlined in the Benefits Analysis in Appendix B. The main benefits are summarized below:**  
**Improved Safety:** There are several qualitative safety impacts expected with the implementation of surveillance through SPACE-BASED ADS-B as follows:  
Surveillance closes the gap between the expected aircraft position based on clearances or instructions issued to pilots, and the actual trajectories that aircraft fly. Moreover, with a target tag, surveillance can indicate whenever expectations are not matched.  
The ability to immediately detect when an aircraft deviates from its assigned altitude or route, danger area infringement warnings, "blunder" detection and other similar alerts before they become conflicts. However, the benefit diminishes as the ability of the controller to monitor and process the information becomes saturated, and automation may be needed to enhance the effectiveness of these alerting systems.  
Whenever changes to a flight trajectory or route are required as a result of traversing airspaces with differing rules and procedures, errors can be introduced that may result in aircraft manoeuvring to an incorrect altitude or route/fix. The chance that a flight will obtain its preferred trajectory or route is greater with surveillance, resulting in a consequent decrease in the number of requests for changes and the | The risk that the ADS-B performance mandate will not produce sufficient operational efficiency benefits to offset operators costs to equip their aircraft to meet the mandate is estimated to be low.  
The application of the ADS-B performance mandate will result in safety and efficiency benefits over current surveillance operations. While it is not possible to exactly quantify these benefits for an individual aircraft, the ANS as a whole will be more efficient and safer and all customers will realize these benefits.  
In summary, the risk that the cost for customers to equip to meet the performance mandate requirements will outweigh the resulting safety and efficiency benefits is assessed as ALARP.  
No further mitigation required. | N/A | N/A |
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<td>potential for error. Moreover, a seamless environment eliminates the requirement for ATCOs to intervene and increase aircraft spacing as it transitions to non-surveillance airspace and allows a more predictable and orderly flow of traffic, reducing workload and stress. Notwithstanding the safety benefit of a more orderly flow, which is expected to be the norm, when unexpected events occur such as emergencies, hazardous weather, severe clear air turbulence, etc., surveillance will facilitate an improved response. If the area of a hazard is known, the positional information and accuracy offered by surveillance will ensure that the aircraft remains at a safe yet reasonable distance from the hazard. With a rapid update rate, improved aircraft position accuracy and reduced speed error variability (from more frequent and accurate velocity vectors), not only is the potential conflict identified sooner, its resolution may be better planned and executed. Improved Position Reporting: Radar accuracy decreases the further aircraft is from the receiver, while ADS-B provides consistent position accuracy regardless of the aircraft’s location. ADS-B also provides more timely information updates than conventional radar. ATC’s ability to accurately identify and locate aircraft that are further away from the air traffic control facilities will be better than radar. ADS-B does not scan an environment in the same way as radar; therefore, ADS-B does not provide unnecessary returns based on weather or other obstructions, which can impede the effectiveness of primary radars. ADS-B provides consistent, frequently updated position reporting and additional aircraft information for ATC decision-support tools, which increases ATC confidence in aircraft position. This will allow ATC to apply existing separation standards more exactly and without the need to correct for possible radar inaccuracies. Continuous Descent Operations (CDOs): CDOs are a type of terminal arrival procedure, specifically designed to keep an aircraft at, or near idle power during the arrival phase until the final approach fix. These procedures increase flight efficiencies while reducing noise, fuel consumption, and emissions. CDOs eliminate step-down altitudes and the associated inefficient power adjustments. CDOs depend on minimal aircraft vectoring to maintain the arrival pattern. During CDO aircraft must be accurately metered using spacing and sequencing tools prior to and during descent and approach, which is more effective using the ADS-B Out system rather than radar.</td>
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<td>Reduced Aircraft Separation: In non-radar airspace, ADS-B Out allows ATC to apply radar-like separation standards in areas where ATC currently applies non-radar, procedural separation. In some cases, routes laterally separated without radar by as much as 90 NM are now separated with ADS-B at only 20 NM. Longitudinal separation of typically 10 minutes (80 NM) can be reduced to 5 NM.</td>
<td>NAV CANADA will examine the feasibility of utilizing 3 NM separation to provide terminal control service at some locations in the ANS. NAV CANADA will not move forward with reduced separation until all safety and operational analysis have been completed, space-based ADS-B has been certified to perform this service, and the proper procedures are in place.</td>
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<td>Expanded Surveillance Coverage: There are opportunities for ATC to use space-based ADS-B surveillance in areas where existing radar surveillance has limitations.</td>
<td>Surveillance of Ground Operations: ADS-B surveillance can also be extended to ground level to help improve the safety and efficiency of airport operations.</td>
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<td>Routes: NAV CANADA expects that ADS-B Out will enable the broader use of User Preferred Routes, which reduces fuel consumption, emits less greenhouse gases, and increases the overall efficiency of ANS operations.</td>
<td>In summary, while it is not possible to exactly quantify these benefits for an individual aircraft, the ANS as a whole will be more efficient and safer and all customers will realize these benefits. The application of the ADS-B performance requirements mandate will result in safety and efficiency benefits over current surveillance operations.</td>
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<td>Issue #7 ADS-B Out Equipage Costs vs Benefits for General Aviation</td>
<td>NAV CANADA acknowledges that the cost to equip the average light general aviation aircraft to meet an ADS-B Out performance mandate if there is no existing GNSS or transponder capability already on the aircraft could be relatively significant. In southern Canada primary and secondary radars will be retained for the foreseeable future and aircraft that operate in this radar serviced airspace where there is currently a Mode C transponder requirement need only be equipped with a Mode C transponder. This is where many GA aircraft operate. The cost to equip with ADS-B must be balanced against the foundation this capability provides in moving toward new technologies provided by space-based ADS-B infrastructure and benefits from its overall usage. Benefits to aircraft operations, including GA, are as follows:</td>
<td>The risk that GA will not experience sufficient safety and efficiency benefit to justify any avionics upgrades they would be required to employ to meet an ADS-B performance mandate is estimated to be low.</td>
<td>Most GA operations will not be impacted by any ADS-B performance requirements mandate. For those that are, while it is not possible to exactly quantify these benefits for an individual aircraft the ANS as a whole will be more efficient and safer and all customers will realize these benefits. In summary, the risk that the costs to equip GA aircraft to</td>
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<td>- expanding ATC flight following, enroute and terminal like service, including lower separation standards, to areas and aerodromes currently not covered by radar or MLAT; &lt;br&gt; - access to inexpensive ADS-B In traffic situational awareness tools running portable tablet type computers; &lt;br&gt; - enabling potential new services such as automatic closure of flight plans based on the aircraft position at the destination airport; &lt;br&gt; - enhancements to search and rescue or aircraft in distress by determining the aircraft’s current or last known position with great accuracy, at all altitudes and any terrain; &lt;br&gt; - positional information for FICs to enable more tailored flight information services enroute (FISE); &lt;br&gt; - provision of radar like data to enhance air traffic control and airport advisory service at control tower and FSS sites respectively, where there is currently no NAV CANADA Auxiliary Radar Display System (NARDS), where DCPC communications exist, ATC could provide emergency navigation assistance; and &lt;br&gt; - more efficient handling of potential enroute conflicts.</td>
<td>meet an ADS-B performance mandate will exceed the safety and efficiency benefits is assessed as ALARP.</td>
<td>No further mitigation required.</td>
<td>N/A</td>
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Additionally, NAV CANADA, along with the Canadian Owners and Pilots Association (COPA) have put forward a proposal to study the applicability of ADS-B technology for emergency applications. Transport Canada has given its support to further explore the potential for an improvement to the safety outcome related to the carriage of Emergency Locator Transmitters (ELT) for general aviation. (CPAAT/12 WP/06)

Most GA operations will not be impacted by the recommended ADS-B performance requirements mandate. For those that are, while it is not possible to exactly quantify these benefits for an individual aircraft the ANS will be more efficient and safer and all customers will realize these benefits. Aircraft suitably equipped will also have higher residual value and conversely aircraft that are not could be harder to sell.

**Issue #8**  
**Financial and Operational Incentives for GA**

General aviation (GA) has suggested that, like the FAA, NAV CANADA should offer

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<td>Financial and Operational Incentives for GA</td>
<td>NAV CANADA will continue to address the financial impact on GA of meeting an ADS-B equipage mandate taking into consideration our governance model.</td>
<td>N/A</td>
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The Reduced Vertical Separation Minimum (RVSM) airspace and related aircraft equipage mandate offers an example of how designating exclusionary airspace together with equipment performance requirements can take advantage of new technology capabilities. In the case of RVSM this has resulted in operational benefits by providing aircraft with more track and altitude options resulting in significant efficiency gains (fuel savings).

With the implementation of space-based ADS-B, the current ground based ADS-B system will be re-evaluated and possibly decommissioned. In preparation for the introduction of PBN in the enroute structure, NAV CANADA received an exemption to use the separation standards that are detailed in the ICAO document: Procedures for Air Navigation Service – Air Traffic Management (PANS-ATM Doc 4444). The conditions of this exemption require NAV CANADA to inform Transport Canada of the intent to use a Doc 4444 standard and meet other conditions such as ensuring implementation HiRAs are conducted and that any required training is complete prior to implementation.

Prior to implementing any mandate associated with Space-Based ADS-B NAV CANADA will request:
- permission to use the Doc 4444 separation standards associated with ADS-B; and,
- request a cancellation of Exemption NCR-104-2106.

It is expected that Transport Canada will recognize ICAO’s standards for ADS-B operations, which will be reflected in the proposed performance mandate. Regardless, NAV CANADA will demonstrate a safety case via a HIRA for ATC operations using space-based ADS-B in any mandated airspace that we deploy. NAV CANADA will keep Transport Canada apprised of our implementation plans and provide them with the required technical and procedural risk assessments and mitigations.

NAV CANADA will treat ADS-B mandated airspace in much the same way as transponder airspace is managed today. Transponder required airspace is exclusionary in that aircraft should not normally operate there unless properly equipped. There will be requirement for a certain ADS-B equipage level to operate in the mandated airspace; however, exceptions for state aircraft and emergency situations will occur. These are addressed in issues 11, 22 and 24.

Controlling airspace where aircraft that are equipped with ADS-B 1090 ES Out are provided separation based on a surveillance standard and others a provided procedure separation unnecessarily complicates the provision of service. By creating exclusionary airspace NAV CANADA is reducing risk to aviation safety in ADS-B mandated airspace.

For the safety of all aircraft operating in ADS-B mandated airspace aircraft must be equipped thus creating de-facto exclusionary airspace. With an equipage requirement in place risk associated with a mixed mode traffic will be reduced to ALARP. This can be achieved when the conditions of Exemption NCR 104-2016 are no longer in place.

No further mitigation required.
### Issue #10
**Regulatory Administration Delays**

There is concern that Transport Canada (TC) may not be capable of meeting the demand for aircraft avionics equipment STC approvals, and other regulatory demands related to a mandate.

The performance mandate will be implemented in phases with sufficient lead time for the various affected sectors of aviation to properly equip. With the planned notice, which in the case of the initial implementation of Phase 1 will be two years, TC should have sufficient advance knowledge of our implementation plans to prepare to meet the expected demand for their services. NAV CANADA can also provide TC with estimates of the number of aircraft that may be affected at any particular stage of the project.

Many foreign operators who will be affected by the initial implementation will already be equipped due to the US and European mandates and will be properly certified under those states regulatory requirements. Canadian operators will also be certified to operate in those states airspace under their mandates prior to the NAV CANADA mandate, thus helping to relieve the initial potential workload on TC.

The NAV CANADA statistics on the number of aircraft affected by the mandate’s initial phase of implementation can be found in Appendix F.

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<td>The risk that aircraft will not be equipped and certified to operate in the airspace affected by the ADS-B performance requirements mandate due to TC delays in provision of the required certification is estimated to be low.</td>
<td>With the advance information on potential certification demand provided and the introduction of similar performance mandates by the U.S. and Europe one year and 6 mos respectively in advance of the NAV CANADA mandate, the risk that TC will cause delays in aircraft certifications is assessed as ALARP.</td>
<td>N/A</td>
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### Issue #11
**Military Exemptions & Security**

Some Department of National Defence (DND) aircraft and some foreign military aircraft will be unable to equip to meet the ADS-B Out mandate. In addition, NAV CANADA acknowledges that the open broadcast of ADS-B Out data can cause unacceptable operational security risks to DND’s execution of certain missions. NAV CANADA must accommodate these aircraft in their vital and unique operations.

Having non-ADS-B equipped aircraft operating in airspace where the performance mandate applies will result in application of increased separation standards which could result in reduced efficiency of customer operations.

NAV CANADA acknowledges that not all DND aircraft will be equipped to meet the performance mandate, either before or after January 1, 2021, as it is not economically viable to equip DND aircraft that are facing imminent retirement. Additionally, costs, budgets, and depot schedule constraints make it prohibitive to equip all DND aircraft in time for the proposed mandate. DND has a mature equipage plan in place for their fleet and some aircraft will be suitably equipped in advance of the mandate’s proposed compliance date.

Regardless, both parties recognize that accommodations to the mandate will be necessary for non-equipped state aircraft. To ensure that the air navigation system meets Canadian national defence needs, NAV CANADA will partner with DND to develop procedures to minimize or, where possible, eliminate negative impact on DND and foreign state aircraft operations due to lack of ADS-B Out equipage, while ensuring safety.

Additionally, NAV CANADA acknowledges that the open broadcast of ADS-B Out data can cause unacceptable operational security risks to DND’s execution of certain missions. DND aircraft with mission requirements that will not align with the broadcast nature of ADS-B Out, will either not be equipped or will, at times, suppress ADS-B Out data.

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<td>The risk that efficiency of customer operations will be materially reduced due to the accommodation of DND or foreign state aircraft that do not meet the performance mandate requirements is estimated to be low.</td>
<td>With the protocols and procedures currently in place for accommodating DND and foreign aircraft that do not meet current mandated airspace performance requirements, the risk that efficiency of customer operations will be materially reduced with accommodating these aircraft in the ADS-B performance requirement mandated airspace is assessed as ALARP.</td>
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<tr>
<td>ATC Systems Implementation Delays</td>
<td>DND and NAV CANADA agree to research and develop mutually acceptable solutions and procedures, which will accommodate their aircraft when not broadcasting ADS-B Out data and that will lower operational security risks to levels deemed acceptable by DND. Regarding foreign state aircraft operating in Canada, ADS-B Out performance requirements will be published in the AIP. If foreign aircraft cannot meet the mandate, they will be required to request an exemption when submitting their overflight request to Global Affairs Canada (GAC). Any requests from military aircraft are forward to DND 1 Canadian Air Division for review prior to approval by GAC. As is current practice, DND will work with NAV CANADA to ensure that operators of foreign State aircraft in Canadian airspace are informed of the mandate performance requirements. Military aircraft (Canadian and Foreign) will be eligible for an exemption. NAV CANADA units will know an aircraft's ADS-B Out status based on the equipment codes on their ICAO flight plan and/or through notification by DND. NAV CANADA ATC currently has procedures for and experience in accommodating aircraft that do not meet performance requirements related to RVSM or transponder mandatory airspace. These procedures are adaptable to the requirements of an ADS-B mandate. Our major flight data systems (both CAATS domestically and GAATS+ in oceanic) are currently capable of processing space-based ADS-B data, and are being augmented to provide greater functionality to eventually reduce separation in areas where we currently have no ground-based surveillance. NARDS is also capable of ingesting and displaying space-based ADS-B data. Edmonton and Gander will be the first two ACC sites to use space-based ADS-B operationally. Additional ACC and Sectors will be brought online as the mandate progresses and ATM system upgrades permit. Initial operations utilizing space-based ADS-B data will occur prior to a mandate being in place. When the space-based ADS-B data are certified by both Aireon and NAV CANADA, we will begin to use it operationally (late 2018 or early 2019).</td>
<td>The risk that there will be a delay in taking full advantage of the operational benefits afforded for both ATC and aircraft operators is estimated to be low. With the ATC data systems in place and capable of ingesting and displaying space-based ADS-B data, there should be no delays in taking full advantage of all the operational benefits the system will provide once it becomes fully operational. Therefore, the risk that there will be a delay in implementation and that there will be no short term operational benefits is assessed ALARP. No mitigation required</td>
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Issue #12

There is concern that NAV CANADA’s ATC system, required to yield all the advantages of an ADS-B Out mandate, may trail the recommended timelines set for aircraft equipage. This would result in a delay in taking full advantage of the operational safety and efficiency benefits afforded for both ATC and aircraft operators. Operators could also be dissatisfied as they would have spent money upgrading their avionics without experience maximum benefits. This would not support our objective to avoid costly upgrades.

The risk that there will be a delay in taking full advantage of the operational benefits afforded for both ATC and aircraft operators is estimated to be low. With the ATC data systems in place and capable of ingesting and displaying space-based ADS-B data, there should be no delays in taking full advantage of all the operational benefits the system will provide once it becomes fully operational. Therefore, the risk that there will be a delay in implementation and that there will be no short term operational benefits is assessed ALARP. No mitigation required | N/A | N/A |
### Issue #13
**Privacy and Security**

There is concern that operators will be unable to maintain/obtain privacy of their operations under the NAV CANADA ADS-B-Out system. The system should be able to accommodate privacy and security requirements of state, corporate and military aircraft.

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<td><strong>This issue is being actively researched by the FAA in collaboration with the National Business Aviation Association (NBAA). Aircraft equipped with Mode S transponders broadcast a 24-bit address code that is assigned to each aircraft registration number, the ICAO address. This means the privacy concerns that business aviation operators have to go beyond ADS-B.</strong></td>
<td>N/A</td>
<td>N/A</td>
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<td><strong>One solution is to establish an assortment of ICAO codes for business aircraft operators that would not translate to an aircraft registration. That would mean, while the code itself may still be able to be tracked publicly, there would be no associated availability of the aircraft registration and therefore no information on its owner or operator either.</strong></td>
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<td><strong>A second similar solution that is being worked in the United States is the establishment of a privacy office to administer assignment of random 24-bit ICAO addresses as anonymous flight IDs, rolling every 30 days or so.</strong></td>
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<td><strong>Another possibility discussed was developing an anonymity mode for the 1090ES datalink. The anonymity mode exists for the 978UAT standard, but is not part of the 1090ES standard. This was purposely omitted for 1090ES after objections were raised by Europe.</strong></td>
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<td><strong>A longer-term option could be the encryption of the 1090ES message; however, the signal broadcast by 1090ES ADS-B is a 112-bit message that is not suitable for encryption with traditional algorithms. A format-preserving encryption cryptographic engine could be a low-cost method to encrypt ADS-B communications. The FAA is investigating potential future changes to the operational performance standard (RTCA DO-260B), such as expanding the bandwidth, which might enable functions such as encryption.</strong></td>
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<td><strong>It is primarily through commercial/private applications where the public can track the position and identity of airborne aircraft. The aircraft owner/operator is required to contact the appropriate application provider to request to remain anonymous and these providers should accommodate the requests.</strong></td>
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<td><strong>NAV CANADA will monitor closely other states (FAA, Europe, ICAO) and work collaboratively to find the best possible solution to the privacy issue. The solution is beyond the scope of this aeronautical study.</strong></td>
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<td>Hazard/Issue</td>
<td>Existing Mitigation (Defence) in the System</td>
<td>Risk Estimations</td>
<td>Risk Evaluation</td>
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<td>Evaluation (of mitigation)</td>
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<td><strong>Issue #14</strong>&lt;br&gt;Transponder Frequency Congestion</td>
<td>Frequency congestion can occur with transponders transmitting and responding frequently in a given area. For example, in Europe, overlapping radars regularly interrogate the same aircraft. At the same time, this aircraft is subject to ACAS/TCAS interrogations from other aircraft. The more interrogations the transponder receives, the more often it replies. Factor this by more and more Mode S equipped aircraft and congestion may be the result. In Canada, our traffic density is much lower and except for the Toronto and Vancouver areas where multiple NAV CANADA and FAA radars are located, spacing of radars results in minor coverage overlaps. Implementation of ADS-B and subsequent decommissioning of select radars will reduce the potential for interrogation congestion experienced by aircraft transponders. NAV CANADA will continue to assess 1090 MHz frequency congestion in the future air traffic environment and will enact the necessary mitigations to reduce the 1090 MHz frequency congestion risk.</td>
<td>N/A</td>
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<tr>
<td><strong>Issue #15</strong>&lt;br&gt;ADS-B In</td>
<td>NAV CANADA recognizes that ADS-B In and other future air-to-air applications are functions that could provide benefits to aircraft operators such as improved situational awareness for pilots. Operators voluntarily equipping with ADS-B In will have the benefit that accrues from that technology.</td>
<td>N/A</td>
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<tr>
<td><strong>Issue #16</strong>&lt;br&gt;Performance Functionality</td>
<td>NAV CANADA will determine whether it is practicable to establish a public web-based tool that will allow aircraft operators to check the performance functionality of their ADS-B installation in order to assist aircraft owners, operators, and avionics installers with the validation of the performance of the ADS-B Out equipment installed on aircraft. The tool could be similar to the one the FAA has developed, ADS-B Performance Monitor Flight Test Data Review Report, to generate a report of the accuracy/functionality of</td>
<td>N/A</td>
<td>N/A</td>
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<tr>
<td>Issue #17</td>
<td>ADS-B Equipment Certification</td>
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<td><strong>Hazard/Issue</strong></td>
<td>Avionics did not function properly, NAV CANADA may refuse clearance into that airspace, which could result in the aircraft’s return to point of origin, a diversion or other additional expense.</td>
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<td><strong>Existing Mitigation (Defence) in the System</strong></td>
<td>The aircraft’s ADS-B performance during the period requested.</td>
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<td><strong>Risk Estimations</strong></td>
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<td><strong>Risk Evaluation</strong></td>
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<td><strong>Mitigation</strong></td>
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<td><strong>Evaluation (of mitigation)</strong></td>
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<tr>
<th>Issue #18</th>
<th>IFR vs VFR operations</th>
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<tbody>
<tr>
<td><strong>Hazard/Issue</strong></td>
<td>There is concern that there will be extra costs associated with ongoing recertification of ADS-B avionics.</td>
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<td><strong>Existing Mitigation (Defence) in the System</strong></td>
<td>Transport Canada has advised the following: ADS-B certification is different from a transponder certification. Transport Canada National Aircraft Certification is harmonized with the FAA and EASA, in that the ADS-B systems and the ADS-B functions are strictly regulated. Guidance on ADS-B Out installations is described in the FAA AC 20-165B and AC 20-172B respectively. EASA also provides guidance in CS-ACNS, which Transport Canada also recognizes. In Canada, there will be two Canadian Advisory Circulars that will provide specific guidance on aircraft installation airworthiness and operational certification.</td>
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<td><strong>Risk Estimations</strong></td>
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<td><strong>Risk Evaluation</strong></td>
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<td><strong>Mitigation</strong></td>
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<td><strong>Evaluation (of mitigation)</strong></td>
<td>N/A</td>
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<tr>
<th>Issue #19</th>
<th>Retention of Mode C vs ADS-B Out Transponders</th>
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<tbody>
<tr>
<td><strong>Hazard/Issue</strong></td>
<td>There was a concern that where radar coverage exists and NAV CANADA intends to maintain and/or replace the related radars, some customers and stakeholders questioned why they would require the 1090ES ADS-B Out transponder.</td>
</tr>
<tr>
<td><strong>Existing Mitigation (Defence) in the System</strong></td>
<td>NAV CANADA will retain its Mode C and Mode S transponder requirements for flight in transponder required airspace (to provide a secondary radar backup to ADS-B, as well as communicate with other aircraft that have traffic warning systems), the 1090 ES solution can satisfy both the ADS-B “Out” and functioning transponder requirement with the same piece of equipment. For more details, see System Redundancy in Issue #20 below.</td>
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<td><strong>Risk Estimations</strong></td>
<td>N/A</td>
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<td><strong>Risk Evaluation</strong></td>
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<td><strong>Mitigation</strong></td>
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<td><strong>Evaluation (of mitigation)</strong></td>
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<td>Hazard/Issue</td>
<td>Existing Mitigation (Defence) in the System</td>
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<td><strong>ISSUE #20</strong> System Redundancy</td>
<td>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 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 backup in case of failure. Space-based ADS-B will support contingency and redundancy capabilities and be entirely separate from ground-based infrastructure. Including space-based ADS-B as an additional surveillance source would increase redundancy, because this service will use a separate transport network. It would also increase the ability for NAV CANADA to provide contingency services.</td>
</tr>
<tr>
<td><strong>ISSUE #21</strong> ADS-B and the Emergency Locator Transmitter (ELT) Requirement</td>
<td>NAV CANADA, along with the Canadian Owners and Pilots Association (COPA) have put forward a proposal to study the applicability of ADS-B technology for emergency applications. Transport Canada has given its support to further explore this proposal toward an improvement to the safety outcome related to the carriage of Emergency Locator Transmitters (ELT) for general aviation. (CPAAT/12 WP/06). Space-Based ADS-B via Aireon will enhance current search and rescue procedures which could lead to an increase in the number of successful rescues. ADS-B tracking services provided by Aireon (ALERT) will be used for search and rescue to aid in locating missing aircraft. NAV CANADA recognizes the value of an application that could allow for timely and accurate flight tracking of downed aircraft and is evaluating this capability separate from this mandate. Since the regulatory requirement associated with the carriage of an ELT in Canada is the responsibility of Transport Canada, it is beyond the scope of this study to further mitigate. NAV CANADA will continue to collaborate with Transport Canada and COPA in the development of a proposal to study the applicability of ADS-B technology for emergency locating services.</td>
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<tr>
<td>Issue #22</td>
<td>ADS-B Out mandate deviations</td>
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<tr>
<td>Issue #23</td>
<td>Hot air balloon and glider exemptions</td>
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<tr>
<td>Issue #24</td>
<td>Airspace for which ADS-B will be required</td>
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See recommendations in section 4.1.
### Performance Requirements to Aircraft Operating in Class A Airspace Only, or Class A and B Airspace

They questioned the proposed ADS-B performance requirements in Class C, D and E airspace. Additionally, varying requests were made to NAV CANADA concerning the proposed altitudes for which ADS-B Out would be required.

### Issue #25

**UAT**

In the FAA’s ADS-B performance mandate there is an option to equip an aircraft to use the Universal Access Transceiver (UAT) broadcast link for operations in the specified mandated airspace below 18,000 feet ASL rather than the 1090 ES broadcast link. UAT uses a broadcast link of 978 MHz and provides ADS-B In capability. ADS-B In allows appropriately equipped aircraft to receive and display another aircraft’s ADS-B Out information as well as the ADS-B In services provided by the FAA’s ground-based ADS-B stations including Traffic Information Service – Broadcast (TIS-B) for pilot situational awareness in aircraft not equipped with TCAS/ACAS, and Flight Information Service – Broadcast (FIS-B) that includes weather information, NOTAMs, temporary flight restrictions and other relevant flight information. None of these services are possible using the 1090 ES broadcast link.

Some of our customers, particularly those from the GA community, want the option to equip their aircraft with UAT avionics instead of 1090ES and

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<tr>
<td>Performance requirements to aircraft operating in Class A airspace only, or Class A and B airspace. They questioned the proposed ADS-B performance requirements in Class C, D and E airspace. Additionally, varying requests were made to NAV CANADA concerning the proposed altitudes for which ADS-B Out would be required.</td>
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<tr>
<td>Issue #25</td>
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<tr>
<td>UAT</td>
<td>NAV CANADA’s ADS-B system will be a space-based and is only 1090ES capable. Due to the remoteness and lack of telecommunication ground infrastructure in many areas of Canada it would be unreasonably costly to establish UAT 978 MHz ADS-B services. NAV CANADA recently upgraded the Flight Information Services Enroute (FISE) Remote Communications Outlet (RCO) system, which included the establishment of additional RCO’s to expand coverage and installation of discrete VHF frequencies to eliminate congestion and interference. With these enhancements, pilots enroute across Canada can contact the Flight Information Centres (FICs) to obtain essentially the same services provided by the FAA’s UAT ADS-B In system including weather and NOTAM information and to update their flight plans.</td>
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<td>N/A</td>
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For NAV CANADA to provide the same UAT ADS-B In-flight services as the FAA, this is the only way they believe they would receive sufficient benefits to offset their equipage costs for any performance mandate we would deploy.

### Issue #26
**Flight ID does not match the aircraft under surveillance**

The FAA has provided NC with a list of aircraft and incidents where their ATC has observed that aircraft under ADS-B surveillance broadcast an Aircraft Identification (ACID) that did not match the Flight Identification (Flight ID) - call sign or flight # - filed on the flight plan. The aircraft’s broadcast ACID must match the ADS-B Flight ID to ensure that the target on the controller’s display correlates with the actual aircraft. Without this match surveillance separation services cannot be assured when aircraft are under ADS-B surveillance.

The same problem occurs when aircraft owners/operators trade transponders between aircraft or install a loaner transponder and do not revise the transponder’s configuration settings to match the aircraft’s ID.

Experience has shown that not all aircraft owners/operators are aware of this unique requirement. Consequently, there is concern that with the loss of target correlation on the ATC surveillance display, an aircraft will not be correctly identified by the controller.

### ADS-B uses two means of identifying transmitting aircraft.

The first is the aircraft’s Mode S address, also known as the International Civil Aviation Organization (ICAO) 24-bit aircraft address which is associated with a specific aircraft registration. In Canada, the aircraft address is printed at the bottom of the aircraft’s certificate of registration, is entered into the transponder during installation, and it remains associated with that specific aircraft registration. The second is the Flight ID which is the aircraft’s call sign. The Flight ID enables the air traffic service’s surveillance displays to correctly correlate with the flight plan information. To ensure uninterrupted surveillance separation services, the Flight ID must exactly match the ACID entered in item 7 of the ICAO flight plan.

Air operators that use assigned three-letter radiotelephony designators followed by a flight number usually require a different Flight ID for each flight segment. In these operations to ensure the ACID broadcast by the transponder matches the Flight ID in the flight plan, prior to taxi for each departure the flight crew enters the Flight ID through either a transponder control panel or through the flight management system (FMS). Pilots must always ensure that the ACID entered is exactly the same as the Flight ID that was filed in item 7 of the ICAO flight plan. Same as the ACID, the Flight ID in the flight plan should never contain hyphens, dashes, or added spaces, and zeros should only appear if they form part of the ACID.

Example: Generic Airlines Flight 045, using ICAO assigned airline code GEN. If entered in item 7 on the ICAO Flight Plan as GEN045, then the Flight ID input by pilot in the FMS must be entered as GEN045 (and not GEN45, GEN_045, or as the aircraft registration CFABC).

For general aviation transponder installations, Flight ID will be equal to the aircraft registration. In these cases, ADS-B installers should program Flight ID during the initial deployment.

### Risk Estimations

The risk that an aircraft target will not be properly correlated on the controller’s display due to mismatched Aircraft ID broadcast by the ADS-B transponder and the Flight Planned ID is estimated to be low.

While the risk is estimated to be low it would be prudent to employ mitigation to ensure that to the extent practicable all aircraft owners/operators are aware of the transponder ACID matching Flight ID in flight plans requirement to help prevent ATC uncorrelated target events with ADS-B surveillance.

Further mitigation is recommended.

### Mitigation

NAV CANADA will initiate additional measures to educate aircraft owners/operators of the transponder ACID Vs Flight Planned ID requirement, including information briefings and printed material.

### Evaluation (of mitigation)

Considering the two-year lead time until the NC mandate and with ongoing education, the risk that uncorrelated targets will appear under ADS-B surveillance is assessed as ALARP. No further mitigation required.
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<th>Evaluation (of mitigation)</th>
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<tr>
<td>Issue #27</td>
<td>Configuration. Trading transponders between aircraft or using a loaner transponder will necessitate reprogramming the correct aircraft address and flight ID into the transponder configuration settings. To help inform aircraft operators/owners of this unique requirement of the ADS-B transponder, NAV CANADA has published an AIC (Aeronautical Information Circular) (see Appendix E– AIC 29/17).</td>
<td>N/A</td>
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<tr>
<td>Issue #28</td>
<td>Transport Canada has advised the following: An SDA value of 0 will be set if the aircraft installation does not meet the performance requirements. The system may transmit a value of 0 on its own (in case of failure or redundancy problems), or Transport Canada may have required it during certification, as there was no operational mandate for ADS-B when that specific system was installed, but the aircraft operator wanted to track his aircraft for safety reasons. Once a mandate for ADS-B Out is approved, the system installation will meet design assurance levels (for new installations). Older aircraft will need to be retrofit and re-certified, as per the mandate timeline.</td>
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**Issue #27**

**SDA value equal 0**

The FAA notified NAV CANADA of aircraft they have observed under ADS-B surveillance with a System Design Assurance (SDA) parameter (available only with RTCA/DO-260B (equivalent to EUROCAE/ED-102A)) that is equal to 0, the result of which is that their ADS-B Out generated target is not visible on the controller display systems.

**Issue #28**

**RVSM special Authorization**

According to a newly proposed FAA regulation, aircraft equipped with ADS-B Out capabilities will no longer be required to specifically apply for approval to operate in Reduced Vertical Separation Minima (RVSM) airspace. The proposal would authorize operators of aircraft, equipped with qualified ADS-B Out systems that can be monitored by the FAA to conduct RVSM operations without submitting an application for an authorization to operate in RVSM airspace. NAV CANADA stakeholders may expect the same benefit with the implementation of our mandate.

The FAA established the North American Approvals Registry and Monitoring Organization (NAARMO) as the official regional monitoring agency supporting the implementation and continued safe use of the North American Reduced Vertical Separation Minimum (RVSM). NAV CANADA maintains two Aircraft Geometric Height Measurement Element (AGHME) for altimetry system error (ASE) calculations used in RVSM certifications. However, the regulatory requirement for RVSM authorization for Canadian aircraft operators is a Transport Canada responsibility (TC AC-700-039).

ADS-B Out enables continual monitoring of aircraft height-keeping performance and rapid notification of altimetry system error (ASE). Geometric Height is a message element available only with the RTCA/DO-260B (equivalent to EUROCAE/ED-102A) standard.

Should a proposal to remove the special authorization to operate in RVSM for aircraft equipped with ADS-B be approved by the FAA, Transport Canada could follow suit. This issue is outside the scope of this study.
APPENDIX D

ADS-B OUT BROADCAST ELEMENTS DESCRIPTION
Transponder Mode S 1090ES ADS-B Out Required Message Data Elements Descriptions

1. Position: These parameters are derived from the position source and provide a geometric based position. Reference all geometric position elements broadcast from the ADS-B unit to the World Geodetic System 1984 (WGS-84) ellipsoid. Latitude and longitude is required to be transmitted.

2. Navigation Integrity Category (NIC): The NIC parameter specifies a position integrity containment radius. NIC is reported so that surveillance applications, such as ATC or other aircraft, may determine whether the reported geometric position has an acceptable level of integrity for the intended use. The NIC parameter is closely associated with the SIL. While NIC specifies the integrity containment radius, SIL specifies the probability of the actual position lying outside that containment radius without indication. ADS-B systems should derive the NIC from an approved position source’s integrity output, such as the horizontal protection level (HPL) from the GNSS.

3. Navigation Accuracy Category for Position (NACP): The NACP specifies the accuracy of the aircraft’s horizontal position information (latitude and longitude) transmitted from the aircraft’s avionics. The ADS-B equipment derives a NACP value from the position source’s accuracy output, such as the HFOM from the GNSS. The NACP specifies with 95% probability that the reported information is correct within an associated allowance.

4. Source Integrity Level (SIL): The SIL field defines the probability of the reported horizontal position exceeding the radius of containment defined by the NIC, without alerting, assuming no avionics faults. Although the SIL assumes there are no un-annunciated faults in the avionics system, the SIL must consider the effects of a faulted signal-in-space (SIS), if a signal-in-space is used by the position source.

5. System Design Assurance (SDA): The SDA parameter defines the failure condition that the ADS-B system is designed to support. The supported failure condition will indicate the probability of an ADS-B system malfunction causing false or misleading position information or position quality metrics to be transmitted. The SDA includes the position source, ADS-B equipment, and any intermediary devices that process the position data.

6. Geometric Altitude: The geometric altitude is a measure of altitude provided by a satellite-based position service and is not affected by atmospheric pressure. Geometric altitude is only available with a GNSS position source. Geometric altitude for ADS-B purposes is the height above the WGS-84 ellipsoid (HAE).

7. Horizontal Velocity: The horizontal velocity provides the rate at which an aircraft changes its horizontal position with a clearly stated direction. Horizontal velocity is provided with the north/south velocity and the east/west velocity parameters while airborne. Horizontal velocity is provided by a combination of the ground speed and heading or ground track while on the surface. The north/south velocity, east/west velocity, ground speed, and ground track must come from the same source as the position. Heading information may come from a separate source.


9. Barometric Pressure Altitude: This parameter indicates the aircraft’s barometric pressure altitude referenced to standard sea level pressure of 29.92 inches of mercury or 1013.2 hectopascals. The barometric altitude used for the ADS-B broadcast must be from the same source as the barometric altitude used for the ATC transponder Mode C reply, if an altitude-encoding transponder is installed in the aircraft.

10. Call Sign/Flight ID: The term “aircraft call sign” is the radiotelephony call sign assigned to an aircraft for voice communications purposes. (This term is sometimes used interchangeably with “flight identification” or “flight ID”). For general aviation aircraft, the aircraft call sign is normally the national registration number; for airline and commuter aircraft, the call sign is usually comprised of the company identification and flight number (and therefore not linked to a particular airframe) and, for the
military, it usually consists of numbers and code words with special significance for the operation conducted.

11. ICAO 24-bit Address: The ICAO 24-bit address is the primary parameter used to identify the aircraft that is transmitting the ADS-B messages. ICAO 24-bit addresses are defined blocks of addresses assigned for participating countries or states worldwide. Additional information regarding the 24-bit address can be found in the International Civil Aviation Organization (ICAO) Annex 10, Part I, Volume III, appendix to Chapter 9, A World-Wide Scheme for the Allocation, Assignment and Application of Aircraft Addresses.

12. Aircraft Length and Width: This parameter provides ATC and other aircraft with quick reference to the aircraft's dimensions while on the surface.

13. Emergency Status: This parameter alerts ATC that the aircraft is experiencing emergency conditions and indicates the type of emergency. Applicable emergency codes are found in ICAO Annex 10 Volume 4, Surveillance Radar and Collision Avoidance Systems. This information alerts ATC to potential danger to the aircraft so it can take appropriate action.

14. IDENT: ATC may request an aircraft to “IDENT,” to aid controllers to quickly identify a specific aircraft. The pilot manually enables the IDENT state, which highlights the aircraft to ATC.

15. Mode 3/A Code: Currently ATC automation relies on the Mode 3/A code to identify aircraft under radar surveillance and correlate the target to a flight plan. Secondary surveillance radars (SSRs) and ADS-B will concurrently provide surveillance, so the Mode 3/A code is included in the ADS-B Out message.

17. TCAS Installed and Operational: This parameter indicates whether the aircraft is fitted with a TCAS II and if the TCAS II is turned on and operating in a mode that can generate resolution advisory alerts.

18. TCAS Traffic Status: This parameter indicates if a TCAS II equipped aircraft is currently generating a TCAS resolution advisory.

19. Emitter Category: The Emitter category provides an indication of the aircraft’s size and performance capabilities. Emitter category is designed primarily to provide information on the wake turbulence that an aircraft produces.

20. Vertical Rate: The barometric or geometric rate at which the aircraft is climbing or descending, measured in feet per minute. The vertical rate is typically generated by an air data computer or GNSS position source, or equipment which blends barometric vertical rate with inertial vertical rate and/or GNSS vertical rate.

21. NIC BARO: NIC BARO indicates if pressure altitude is provided by a single Gillham encoder or another more robust altitude source. Because of the potential for an undetected error in a Gillham encoding, many Gillham installations are cross-checked against a second altitude source. NIC BARO annotates the status of this cross-check.

22. Geometric Vertical Accuracy (GVA): The GVA indicates the 95% accuracy of the reported vertical position (geometric altitude) within an associated allowance.

23. Ground Speed: This parameter is also derived from the position sensor and provides ATC with the aircraft’s speed over the ground. This parameter is reported in the surface position message.

24. Heading: Heading indicates the direction in which the nose of the aircraft is pointing. There is no heading accuracy metric. Heading or ground track is required to be transmitted while on the ground in order to transmit complete velocity information.
25. Ground Track Angle: The ground track angle is the direction of the horizontal velocity vector over the ground. Ground track or heading is required to be transmitted while on the ground in order to transmit complete velocity information.

26. GNSS Antenna Offset and Position Offset Applied:

a. The GNSS Antenna Offset indicates the longitudinal distance between the nose of the aircraft and the GNSS antenna and the lateral distance between the longitudinal centre line of the aircraft and the GNSS antenna.

b. The position offset applied setting of the GNSS antenna offset indicates that the broadcast position is referenced to the aircraft’s ADS-B position reference point versus the GNSS antenna location. See paragraph 2.1.2.5 and figure 2-1 of RTCA/DO-242A for a depiction of the ADS-B position reference point.

27. Airspeed: True airspeed or indicated airspeed may be transmitted. The airspeed source should be approved to output airspeed data. Do not interface an airspeed source to the ADS-B that has not been approved for cockpit display.

28. Version Number: The applicable TSO minimum operational performance standard (MOPS) level is communicated through the version number, which is fixed at the time the ADS-B equipment is manufactured. Version 2 applies to ADS-B equipment that meets MOPS documents RTCA/DO-260B. ADS-B equipment outputting version 2 or higher is required.
AERONAUTICAL INFORMATION CIRCULAR 29/17

AIRCRAFT IDENTIFICATION AND AUTOMATIC DEPENDENT SURVEILLANCE – BROADCAST FLIGHT IDENTIFICATION

Purpose of Circular
This aeronautical information circular highlights the requirement for Aircraft Identification (ACID) and Automatic Dependent Surveillance-Broadcast (ADS-B) Flight Identification (Flight ID) to match.

Background
ADS-B is a surveillance system that uses an aircraft’s Mode S transponder to relay a range of aircraft parameters such as identification, position, and altitude to air traffic services. ADS-B uses two means of identifying transmitting aircraft. The first is the aircraft’s Mode S address, also known as the International Civil Aviation Organization (ICAO) 24-bit aircraft address. The second is the Flight ID which is the aircraft’s call sign.

Every aircraft has a unique 24-bit aircraft address assigned by the State of aircraft registry. In Canada, the aircraft address is printed at the bottom of the aircraft’s certificate of registration in three formats: binary (24 ones and zeros), octal (eight numerical digits), and hexadecimal (six alpha-numeric digits). The aircraft address is entered into the transponder during installation, and it remains associated with that specific aircraft registration.

Flight ID is the ACID entered on the ICAO flight plan in item 7. The Flight ID enables the air traffic service’s surveillance displays to correctly correlate with the flight plan information. To ensure uninterrupted surveillance separation services, the Flight ID must exactly match the ACID entered in item 7 of the ICAO flight plan.

Use of Flight ID without an Assigned Radiotelephony Designator or Flight Number
For general aviation transponder installations, Flight ID will be equal to the aircraft registration. In these cases, ADS-B installers should program Flight ID during the initial configuration. After this, the Flight ID will not be an editable field during normal operation. Aircraft operators should obtain confirmation from installers that the Flight ID entered into the transponder matches the aircraft registration, without any leading zeros, hyphens, dashes or added spaces. Aircraft operators are also reminded that trading transponders between aircraft or using a loaner transponder will necessitate reprogramming the correct aircraft address and flight ID into the configuration settings.

Use of Flight ID with an Assigned Radiotelephony Designator followed by a Flight Number
Air operators that use assigned three-letter radiotelephony designators followed by a flight number may require a different Flight ID for each flight segment. In these operations, prior to taxi for each departure, the flight crew enters the Flight ID through either a transponder control panel or through the flight management system (FMS). Pilots must always ensure that the Flight ID entered is exactly the same as the ACID that was filed in item 7 of the ICAO flight plan. Flight ID should never contain hyphens, dashes, or added spaces, and zeros should only appear if they form part of the ACID.

Note: Cette information est aussi disponible dans l’autre langue officielle.
Example

Generic Airlines Flight 045, using ICAO assigned airline code GEN. If entered in item 7 on the ICAO Flight Plan as GEN045, then the Flight ID input by pilot in the FMS must be entered as GEN045 (and not GEN45, GEN_045, or as the aircraft registration CFB4C).

Air operators are strongly encouraged to include proper Flight ID entering procedures on checklists for FMS initialization, particularly for departures where the avionics have not been reset through a power-down cycle.

Further Information

For further information please contact:

NAV CANADA
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77 Metcalfe Street
Ottawa, ON K1P 5L6

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Fax: 877-003-6656
E-mail: service@navcanada.ca

James Ferrer, Director
Aeronautical Information Management
APPENDIX F

EXISTING AIRCRAFT EQUIPAGE IN CANADIAN CLASS A
### ADS-B Equipage in Class A Airspace - December 2017

<table>
<thead>
<tr>
<th>Airspace</th>
<th>Total Flights</th>
<th>ADS-B Equipped Flights</th>
<th>ADS-B Equipage %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class A - Southern Control Area</td>
<td>137,412</td>
<td>73,483</td>
<td>53%</td>
</tr>
<tr>
<td>Class A - Northern Control Area</td>
<td>9,841</td>
<td>8,238</td>
<td>84%</td>
</tr>
<tr>
<td>Class A - Arctic Control Area</td>
<td>880</td>
<td>855</td>
<td>97%</td>
</tr>
<tr>
<td>All Canadian Class A</td>
<td>138,236</td>
<td>73,575</td>
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</table>

### ADS-B Equipage in Class A by Transponder Standard - December 2017

<table>
<thead>
<tr>
<th>Airspace</th>
<th>DO-260</th>
<th>DO-260A</th>
<th>DO-260B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class A - Southern Control Area</td>
<td>31%</td>
<td>3%</td>
<td>20%</td>
</tr>
<tr>
<td>Class A - Northern Control Area</td>
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<td>34%</td>
</tr>
<tr>
<td>Class A - Arctic Control Area</td>
<td>53%</td>
<td>3%</td>
<td>41%</td>
</tr>
<tr>
<td>All Canadian Class A</td>
<td>30%</td>
<td>3%</td>
<td>20%</td>
</tr>
</tbody>
</table>