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Agenda Item 6: Review progress items due in 2005:

6.5 Cost and Benefit Study

BUSINESS CASE ANALYSIS OF EXPANDED AIR TRAFFIC SURVEILLANCE OVER HUDSON BAY

(Provided and presented by IATA)

SUMMARY

Business Case Analysis of Expanded Air Traffic Surveillance over Hudson Bay is attached

Business Case Analysis of Expanded Air Traffic Surveillance over Hudson Bay

March 2005

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Table of Contents

List of Tables

List of Figures

SUMMARY

Introduction

This report provides the Business Case Analysis for the proposal to expand air traffic surveillance over the Hudson Bay, using radar or Automatic Dependent Surveillance-Broadcast (ADS-B) “out”. ADS-B “out” refers to the broadcast of Global Positioning System (GPS) derived position data from aircraft equipped with an enhanced Mode-S transponder with 1090 Extended Squitter (ES 1090).

Expansion of surveillance, whether through radar or ADS-B “out”, will enable air traffic controllers to apply significantly reduced separation minima to the aircraft routinely traversing the Hudson Bay. Airspace capacity will be increased, flight profiles improved, operational flexibility increased and safety will be enhanced. While the cost of ADS-B “out” ground stations is considerably less than that of radar, aircraft would need to be suitably equipped to fully realize the safety and efficiency benefits of ADS-B “out”.

The Business Case Analysis involved the participation of the major airlines traversing the Hudson Bay, the International Air Transport Association (IATA) and air traffic controllers controlling this airspace. Considerable information and input was obtained from Airservices Australia, EUROCONTROL, the Federal Aviation Administration (FAA Safe Flight 21), the CAPSTONE Program in Alaska, MITRE Corporation, the Airline Pilots Association (ALPA) and the International Civil Aviation Organization (ICAO).

Purpose

The purpose of this Business Case Analysis was to determine whether expanded surveillance over the Hudson Bay would be cost-beneficial and to examine and compare the alternatives of using either radar or ADS-B “out”.

Customer Benefits

Expansion of surveillance over the Hudson Bay would increase the number of North Atlantic (NAT) flights that are flown entirely within air traffic surveillance coverage while operating in Canadian Domestic airspace. This would enable air carriers to flight plan and operate on random routes rather than fixed routes, which would generate fuel and time savings on a consistent basis.

Random routes are customer preferred routes that are not restricted to specific airways or routes such as the Northern Controlled Airspace (NCA) routes and enable operators to take advantage of tail winds and avoid head winds.

Access to rapid surveillance update rates from either radar or ADS-B “out” would enable controllers to apply five nautical mile (nm) aircraft separation standards and provide random route service. This assumes that 5nm separation for ADS-B “out” would be approved by ICAO. However, there is some uncertainty as to whether or not ADS-B “out” would be able to support the provision of random routes from a safety perspective. This uncertainty stems from the vulnerability created if both the surveillance and navigation are dependent on GPS. Currently

ICAO recommends completing an analysis that takes account of traffic complexity and the availability of an alternate means of navigation when setting a separation standard based on ADS-B.”out” Transport Canada (safety regulator) would not approve a 5nm standard without such an analysis.

With the same separation standard, the customer benefits from expanding surveillance through radar or ADS-B “out” would be equivalent for ADS-B “out” equipped aircraft. While aircraft not so equipped would still realize the same benefits under the radar option (no equipage cost necessary), they would incur a fuel penalty under an ADS-B “out” option as they would have to operate below FL290 (29,000 feet).

The Asia-Pacific (PAC) westbound traffic would improve their flight profiles through the realization of more fuel-efficient altitudes under expanded surveillance.

NAV CANADA and Customer Costs

The NAV CANADA radar and ADS-B “out” option costs were estimated by NAV CANADA Engineering and include the respective capital and operating and maintenance (O&M) costs. The ADS-B “out” option also includes the one-time cost of integrating the ADS-B “out” information with the existing radar data processing systems so that such information can be displayed for air traffic control.

NAV CANADA’s costs to expand surveillance with either radar or ADS-B “out” include an estimated amount of $6.3 million for providing continuous Direct Controller Pilot Communications (DCPC) coverage over the Hudson Bay. The costs for the 4 radars amount to $33.2 million. The total capital cost for the radar option is $39.5 million. The costs for 6 ADS-B “out” systems, which would be required, are $18.4 million. The total capital cost for the ADS-B “out” option is $24.7 million. For both alternatives, an additional cost of approximately $3 million per site may be incurred if site access is difficult and/or locations of equipment were to change from what has been assumed.

No additional customer equipage costs would be required to achieve the safety and efficiency benefits of radar surveillance. In contrast, ADS-B “out” surveillance benefits can only be realized by the aircraft equipped with suitable ADS-B “out” avionics, and would require exclusionary airspace in which to operate. In this option, the creation of exclusionary airspace means aircraft would have to be suitably equipped in order to operate in the airspace, and those unable or unwilling to equip would have to avoid the airspace. For some operators this would mean they would incur a cost to equip with ADS-B “out” avionics and in turn realize random route benefits. Those not equipping would incur a fuel penalty to avoid the ADS-B “out” airspace; they would also not incur any of the equipage costs or realize any of the random route benefits.

While all flights would benefit from radar, it was assumed that 90% of the flights would benefit from ADS-B “out”, beginning in 2010, recognizing that all aircraft would not equip. The percent of flights benefiting would increase gradually to 98% by 2016.

Benefit-Cost Comparison

The benefits and costs of expanding surveillance over the Hudson Bay were compared over the timeframe 2005 through 2029. This analysis timeframe was selected to include the 5-year implementation period plus a twenty-year benefit stream for the radar option. Twenty years was selected to reflect the expected useful life of the radar, the longest lived asset. In the case of the ADS-B “out” option, a capital re-investment, equal to one-half the initial expenditure, prior to reaching the estimated 15-year useful life of the ADS-B “out” equipment, was also included. The ADS-B “out” re-investment costs are required to generate the 5 years of additional benefits, to compare 20 years of radar benefits to 20 years of ADS-B “out” benefits.

The annual NAT and PAC customer benefits were assumed to increase with traffic by 4% per year from 2003 to 2020 and by 3% per year thereafter.

Benefits of radar surveillance are inclusive, accruing to all aircraft over the Hudson Bay upon commissioning. The ADS-B “out” benefits were compared to all of the costs expected to be incurred by customers (additional equipage costs and less than preferred altitude fuel penalties) plus the NAV CANADA costs.

The radar option has a 5-year (2005-2009) installation. The full benefits would accrue when the four radars are commissioned in early 2010. The ADS-B “out” baseline option has a 4-year (2006-2009) installation. The projected benefits would begin upon commissioning in January 2010. The baseline for the ADS-B “out” option serves as a basis for comparison with the radar baseline option and the other ADS-B “out” options examined. The other ADS-B “out” options that were analyzed are described and summarized in the Sensitivity Analysis in Section 6 of this report.

There were an estimated 1,800 unique NAT airframes traversing the Hudson Bay at FL290 and above in 2004. The MITRE Corporation forecast of future ADS-B “out” avionics equipage levels was applied in this analysis. MITRE prepared these forecasts in 2004 in support of the FAA Safe Flight 21 Program. According to MITRE, a 63% “natural” ADS-B “out” equipage level is expected in 2010. The term “natural” equipage refers to the acquisition of new ADS-B “out” capable aircraft or “voluntary” retrofits. For the ADS-B “out” baseline option, it was assumed that an additional 10% of these unique airframes, or 180 more aircraft, would equip if ADS-B “out” were implemented above FL290 over the Hudson Bay in 2010. Based on MITRE avionics cost information for an ADS-B “out” avionics package i.e. $94,000 (assumes GPS component only since all NAT aircraft will have the required Mode S transponder to meet the European Mandate), a total customer equipage cost of $18.1 million (inflated but undiscounted) for 2010 resulted.

Business Case Analysis Results

The benefits and costs are presented in two ways:

(a) Cumulative benefit/cost – undiscounted plus interest
NAV CANADA capital expenditures are expressed in terms of the annual depreciation expense and interest at 6% per annum that would arise from the expenditures.

(b) Cumulative benefit/cost – discounted cash flow
The discounted cash flow comparison reflects the time value of money, based on a discount rate of 6% per annum.

The annual benefits increase for both options with the expected air traffic growth. To express monetary values in current dollar terms, an annual inflation rate of 2% was also applied to the annual benefits, O&M costs and future capital expenditures.

Cumulative Benefit-Cost - Undiscounted Plus Interest

The results of the Business Case Analysis are summarized in Table S1 below. The annual costs and benefits are detailed in Tables 9A and 10A in Section 5 of this report. The benefits for the radar option are $369.2 million, which is $9.6 million higher than the $359.6 million in benefits for the ADS-B “out” option. The total cost of the radar option is $105.1 million, or $17.3 million lower than the ADS-B “out” cost of $122.4 million (NAV CANADA, customer equipage and fuel penalty costs). The overall result is that the net benefits of the radar option exceed the ADS-B “out” option by $26.9 million as shown in Table S1.

Table S1: Summary Comparison of Total Costs and Benefits of Expanded Surveillance for Hudson Bay (Millions $CDN)

Undiscounted plus Interest	OPTION 1 RADAR	OPTION 2 ADS-B “OUT”
TOTAL CUSTOMER BENEFITS	**369.2**	**359.6**
TOTAL CUSTOMER EQUIPAGE COST	0	18.1
TOTAL CUSTOMER PENALTY COST	0	8.7
TOTAL NAV CANADA O & M COSTS	37.8	47.9
TOTAL NAV CANADA DEPRECIATION & INTEREST	67.3	47.7
TOTAL COSTS	**105.1**	**122.4**
BENEFITS LESS COSTS	**264.1**	**237.2**
Difference between Options		**(26.9)**

See Tables 9A (Option 1) and 10A (Option 2) for annual benefit and cost details.

Cumulative Benefit/Cost - Discounted

The results are summarized in Table S2. The Present Value (PV) benefits for the radar option are $138.5 million, which is $4.7 million higher than the $133.8 million in PV benefits for the ADS-B "out" option. The total PV cost of the radar option is $46.1 million, or $13.7 million lower than the ADS-B "out" PV cost of $59.8 million (NAV CANADA, customer equipage and fuel penalty costs). This result is consistent with that of the undiscounted analysis above. The detailed discounted cash flow annual benefit-cost comparison results are shown in Tables 9B and 10B in Section 5.

Table S2: Summary Comparison of Total Costs and Benefits of Expanded Surveillance for Hudson Bay (Millions $CDN – Present Value)

Discounted Cash Flow @ 6.0% Discount Factor	OPTION 1 RADAR	OPTION 2 ADS-B "OUT"
TOTAL CUSTOMER BENEFITS	**138.5**	**133.8**
TOTAL CUSTOMER EQUIPAGE COST	0	14.4
TOTAL CUSTOMER PENALTY COST	0	4.5
TOTAL NAV CANADA O & M COSTS	15.2	19.2
TOTAL NAV CANADA CAPITAL COSTS	30.9	21.7
TOTAL COSTS	**46.1**	**59.8**
BENEFITS LESS COSTS	**92.4**	**74.0**
Difference between Options		**(18.4)**

See Tables 9B (Option 1) and 10B (Option 2) for annual benefit and cost details.

The Net Present Value (NPV) results indicate that, using a discount rate of 6%, the net benefit of radar is $92.4 million and the net benefit of ADS-B "out" is $74.0 million. The net present value benefits of radar exceed those of the ADS-B "out" option by $18.4 million.

Sensitivity Analysis Results

The following sensitivity analyses, presented in Table S3, were conducted:

- Traffic Growth – a 1% decrease in air traffic growth rates to 3% per year from 2003 to 2020 and to 2% thereafter;
- Fuel Price – an increase in fuel price from CDN $0.40/litre to $0.45/litre.
- Discount Rate – an increase from 6% to 10% per year
- Various ADS- B "out" options

In all cases, the net (present value) benefits of the radar baseline option exceeded those of the comparable ADS-B "out" options, as shown in Table S3.

Table S3: Summary of Sensitivity Analysis
(Millions $CDN – Present Value)

Option Description	Net Present Value ($ millions)		
	Radar	ADS-B "out"	Compared to Radar
Baseline Option: Benefits Start in 2010	**92.4**	**74.0**	**(18.4)**
Lower Traffic Growth Rate (from 4% per year to 3% per year)	72.4	54.9	(17.5)
Higher Fuel Price (from $0.40 per litre to $0.45 per litre)	106.1	86.7	(19.4)
Higher Discount Rate (from 6% per year to 10% per year)	43.2	31.0	(12.2)
		ADS-B "out"	Compared to Radar Baseline
ADS-B "out" in 2010 FL290 and above, 10% Incur Equipage Cost, 90% Flts Benefit, 10% Flts Penalized, Attribute 75% of Equipage Cost		77.6	(14.8)
ADS-B "out" in 2010 FL290 and above, 22% Incur Equipage Cost, 90% Flts Benefit, 10% Flts Penalized, Attribute 100% of Equipage Cost		56.1	(36.3)
ADS-B "out" in 2010 FL290 and above, 22% Incur Equipage Cost, 90% Flts Benefit, 10% Flts Penalized, Attribute 75% of Equipage Cost		63.9	(28.5)
ADS-B "out" in 2010 FL290 and above, 0% Incur Equipage Cost, 90% Flts Benefit, 10% Flts Penalized		89.0	(3.4)
ADS-B "out" in 2010-2015 FL350 and above, FL 290 and above 2016 thereafter, 8% Incur Equipage Cost, 66% Flts Benefit, 14% Flts Penalized, Attribute 100% of Equipage Cost		59.9	(32.5)
ADS-B "out" in 2010-2015 FL350 and above, FL 290 and above 2016 thereafter, 8% Incur Equipage Cost, 66% Flts Benefit, 14% Flts Penalized, Attribute 75% of Equipage Cost		63.5	(28.9)
ADS-B "out" in 2015 FL290 and above, 0% Incur Equipage Cost, 100% Flts Benefit, 0% Flts Penalized (No mandate required.)		73.7	(18.7)

It should be noted that the assumption of mandating the airspace as exclusionary under the ADS-B “out” option might not be realistic. The situation is different from the Reduced Vertical Separation Minima (RVSM) on the North Atlantic and now in North America. It is unlikely that the consensus necessary for mandating ADS-B “out” will develop.

A more detailed description of the sensitivity analysis, options analyzed and results are available in Section 6 of this report.

Conclusion

The Business Case results indicate that there is a positive Business Case for the expansion of surveillance based on either radar or ADS-B “out”. It is recognized that the ground equipment costs of ADS-B “out” are much lower than for radar and that the benefits of this technology are promising. However, careful assessment and analysis of all the costs to NAV CANADA and its customers indicate that the lower risk, more mature radar surveillance solution would yield higher net benefits to a wider range of customers than would the ADS-B ”out” option over the 2005 - 2029 timeframe. The results show that the net benefit of the radar baseline option exceeded that of the ADS-B “out” baseline option by $26.9 million or $18.4 million on a present value basis. The sensitivity analysis results also support this conclusion.

1.0 Introduction

1.1 Air Traffic Surveillance

1.1.1 Air traffic surveillance systems have been implemented for air traffic control to establish and monitor aircraft location and movement. Aircraft position information from surveillance systems supports various air traffic control functions. The main purpose is to give controllers situational awareness to enable the safe application of reduced aircraft separation minima compared to airspace with no surveillance. Expansion of continuous air traffic surveillance enhances safety, increases airspace capacity and enables the improvement of flight profiles.

1.1.2 In Canada, surveillance has been achieved through the use of terminal (primary) and enroute (secondary) radar for over 35 years. Radar scans the sky, returning aircraft azimuth and slant range which, when combined with the altitude of the aircraft broadcast to the ground via a transponder (Mode C), is transformed mathematically into an aircraft position displayed on a radar screen.

1.1.3 Automatic Dependent Surveillance (ADS) is a method of surveillance that is dependent on downlinked position from an aircraft's avionics that are generated automatically whenever specific events occur, such as an aircraft crossing a waypoint, or specific time intervals are reached. The ADS reports are converted by datalink ground stations into an ADS position and presented on the controller's air situation display, similar to conventional radar.

1.1.4 There are two forms of ADS: ADS-Contract (ADS-C) and ADS-Broadcast (ADS-B). There are some major differences between the two systems. ADS-C comprises air-to-ground transfer of data. The ground station controls reporting in all situations except for emergency contracts. ADS-B comprises air-to-ground and air-to-air (i.e. transmitted from one aircraft and received by another) data transfer. The reporting rate for ADS-B is significantly higher than ADS-C and, with reliable and accurate position information, makes ADS-B a good candidate for a surveillance system that can support separation standards possibly equivalent to radar.

1.2 Background

1.2.1 Airservices Australia has announced plans to significantly expand its air traffic surveillance capability in low traffic areas using a network of approximately 57 ADS-B ground stations at 28 sites by the end of 2005. Only operators of aircraft equipped with ADS-B technology will be able to take advantage of the expanded surveillance systems in Australia.[1]

[1] "ADS-B Program. Upper Airspace Project", Airservices Australia (ASA) Home Page, July 2004, 23 July 2004 <http://www.airservicesaustralia.com/pilot centre/projects/adsb/adsb.htm>

1.2.2 The Australian Strategic Air Traffic (ASTRA) Management Group is considering the proposed Australian ADS-B Lower Airspace Project (LAP) which envisages the following:

- An ADS-B Mandate for ADS-B "out"
- A subsidy for equipping
- Decommissioning enroute radars in 2009
- Removal of a number of Non-Directional Beacons (NDBs)

1.2.3 ADS-B is viewed as a key element in the surveillance infrastructure in Europe. Feasibility, safety, cost-effectiveness studies and planning are underway in support of a three-stage approach to achieving operational use of ADS-B in Europe (see sections 1.3.4 and 1.3.5 for a description of European Mandate).

1.2.4 ADS-B is being used to enhance safety in Alaska, U.S.A. as part of the CAPSTONE program. Aircraft equipped with ADS-B technology broadcast position information. The heightened situational awareness offered by satellite navigation, combined with data bases of current maps and charts, and onboard displays showing terrain and proximate aircraft, builds a picture in the cockpit. The so-called Cockpit Display of Traffic Information (CDTI) is similar to that on the ground used by the air traffic controller.[2]

1.2.5 As part of its Safe Flight 21 Program, the FAA expects to install more than 30 ADS-B ground stations along the U.S. East Coast in the next year. The FAA also plans to install ADS-B stations in the Gulf of Mexico to increase surveillance capability for rotorcraft operations servicing the oil platforms.[3]

1.3 Status of ADS-B Surveillance Development

1.3.1 NAV CANADA is considering the expansion of air traffic surveillance over the Hudson Bay using either Mode S Monopulse Secondary Surveillance Radar (MSSR), referred to as Option 1, or Automatic Dependent Surveillance-Broadcast (ADS-B "out"), referred to as Option 2. ADS-B "out" refers to the broadcast of Global Positioning System (GPS) derived position data from aircraft equipped with an enhanced Mode-S transponder with the 1090 Extended Squitter (1090ES). This data is transmitted to ADS-B "out" ground stations that receive only, for distribution to the appropriate air traffic control units.

1.3.2 The achievement of the full benefits of ADS-B "out" is dependent on all aircraft being suitably equipped with ADS-B "out" technology and on

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[2] Federal Aviation Administration (FAA), Alaskan Region Capstone Home Page, Phase 1, PowerPoint Presentation, 11 August 2004 <http://www.alaska.faa.gov/capstone/index.html>.
[3] "FAA Certifies First General Aviation ADS-B Transceiver", Flight Tech News, July, 2004 < http://www.FltTechOnline@aireconomics.com>

obtaining approval from Transport Canada for the application of a five (nm) separation minimum. Appropriate avionics and ICAO standards already exist for both ADS-B "out" using extended squitter, and elementary and enhanced surveillance. The FAA has already approved Air Traffic Control (ATC) procedures for using ADS-B positional information for Instrument Flight Rules (IFR) separation. In Alaska five-nm separation is currently used for ADS-B aircraft operating below FL600.[4] The Airline Pilots Association (ALPA) is not opposed to the application of ADS-B "out" derived five nm aircraft separation standards.[5]

1.3.3 ICAO Doc 9689 (Manual of Airspace Planning Methodology for the Determination of Separation Minima), recognizes that the comparison of a new system (such as ADS-B) with a reference system (such as secondary radar) is an acceptable means of determining that the new system is suitable for use in the separation of aircraft. Using this method, Airservices Australia have collected and analyzed several months of data comparing ADS-B performance to that of secondary surveillance radar. It has been compiled into a report and submitted to the Australian Civil Aviation Safety Authority (CASA) for review. If CASA accepts the findings in the report, a five-nm ADS-B separation standard will be authorized for the airspace in the sparsely-settled areas of Australia. They have also completed a full safety case that has been submitted to their Directorate of Safety and Environment Assurance and to CASA.

1.3.4 In parts of Europe, the increasing air traffic density will result in aircraft being in closer proximity, exacerbating known MSSR shortcomings e.g., garble, split plots, code swaps, to such an extent that airspace capacity will be further constrained. In response, certain European states have agreed to implement Elementary Mode-S (Belgium, France, Germany, Luxembourg, the Netherlands and Switzerland) by March 31, 2004 for new production IFR aircraft and a year later for retrofits. For Visual Flight Rules (VFR) the time scale for compliance is March 31, 2005 for new aircraft and March 31, 2008 for retrofits subject to State agreements. Elementary Mode-S will extract parameters (unique aircraft identifier, flight status and pressure altitude) from the aircraft that will be automatically downlinked to the air traffic control system. Aircraft must be equipped with Mode S transponders compliant with ICAO Annex 10, Amendment 77.[6]

1.3.5 New production aircraft operating in Europe must be equipped with new Enhanced Mode S transponders compliant with ICAO Annex 10

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[4] FAA, Alaskan Region Capstone Home Page. First Ever "Radar-Like" Vector Using ADS-B Radar-Like Service in Use at Bethel, Alaska, January 2001, 11 August 2004 <http://www.alaska.faa.gov/capstone/docs/jan1_01/betadsb.html>.

[5] Newman, Larry. "Application of 5 nm Separation Using ADS-B", E-mail to Rip Torn, 12 July 2004.

[6] "Aircraft Operators Information Notice 2 – Mode S Elementary Surveillance – Mode S Programme", European Air Traffic Management, EUROCONTROL, p.p. 6, 7, 10. 8 July 2004 <http://www.eurocontrol.int/mode_s/>

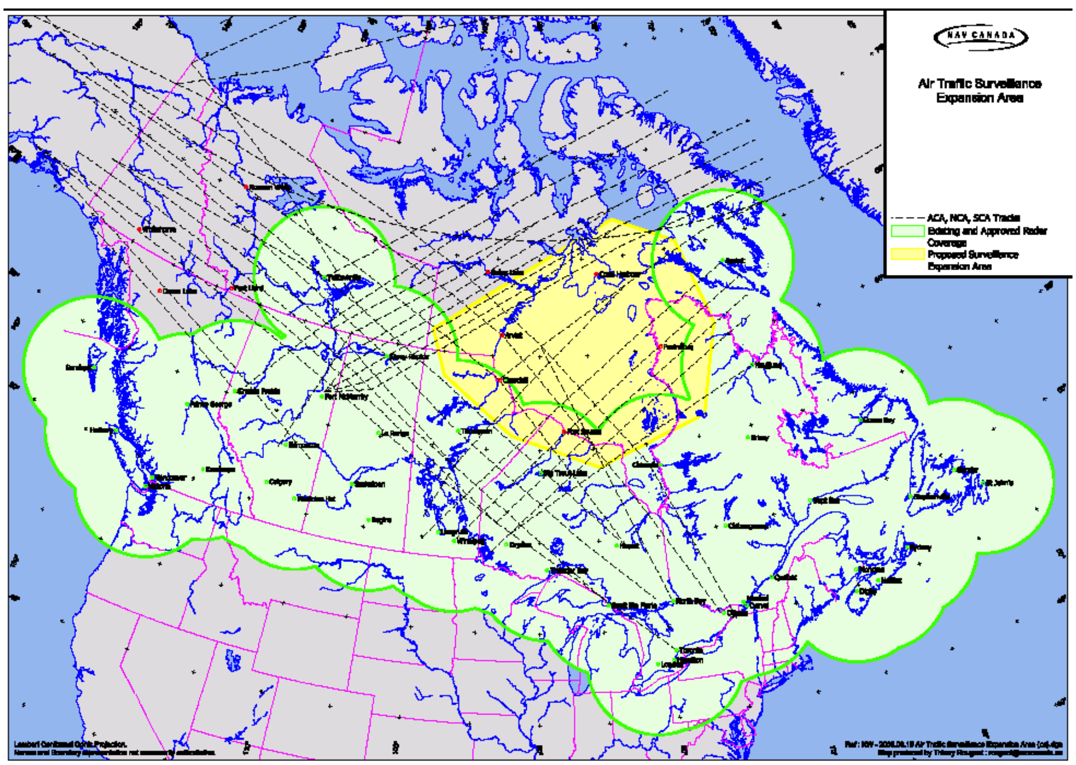
"Mode S Elementary Surveillance – Transition Plan", European Air Traffic Management Programme, EUROCONTROL, September 4, 2002, Edition 1.0, Section 4, Page 10 and Figure 4 Page 10. 8 July 2004 <http://www.eurocontrol.int/mode_s/>

Standards and Recommended Practices (SARPs) between mid 2003 and March 2007. These transponders will also include Mode S Extended Squitter functionality which will allow the downlink of aircraft parameters (aircraft heading, air and ground speed, selected altitude, roll angle, vertical rate, true track angle, and track angle rate data). Intentions to mandate Enhanced Mode-S surveillance have been declared by the United Kingdom, France and Germany.[7]

1.4 Current Canadian Situation: Procedural Airspace in Hudson Bay

1.4.1 Figure 1 shows the existing radar coverage in green and the proposed expansion of surveillance over Hudson Bay in yellow. As depicted in Figure 1, there are two distinct flows of traffic that operate in Hudson Bay airspace. There is the North Atlantic traffic (NAT) operating between Europe and North America and the Asia-Pacific (PAC) traffic operating between Asia and North America. Everyday the PAC and NAT flows cross in the vicinity of the Hudson Bay. The area of intersection of these flows can change daily, depending on the location of the jetstream (upper level winds). Today, procedural separation standards are applied in this airspace.

FIGURE 1: PROPOSED SURVEILLANCE EXPANSION OVER HUDSON BAY



[7] "Common Framework for the Regulation of Mode S Enhanced Surveillance", Regulatory Unit, Eurocontrol Informative Process, EUROCONTROL, July 2003, Edition 2.0, Sections 1.2, 1.3 and 1.4, Page 1. 8 July 2004 <http://www.eurocontrol.int/mode_s/>
"Mode S Enhanced Surveillance – 3 States Project – Master Plan", European Air Traffic Management Programme, EUROCONTROL, August 30, 2002, Edition 1.00, Section 1.3.3, Page 9 and Figure 8 Page 20. 8 July 2004 <http://www.eurocontrol.int/mode_s/>

1.4.2 The expansion of air traffic surveillance in the Hudson Bay area will leverage the benefits of existing neighbouring radar by increasing the number of flights that are entirely within surveillance coverage while operating in Canadian Domestic airspace. These include two enroute radars that have recently been installed at Iqaluit and Kuujjuaq. The installation of these radars significantly improved access to the northern portion of NAV CANADA's Montreal Flight Information Region (FIR). Nonetheless, their benefits cannot be fully realized without continuous surveillance coverage.

1.4.3 NAT westbound traffic traversing the Hudson Bay enters the Montreal FIR with oceanic (procedural) separation standards applied. Montreal Area Control Centre (ACC) utilizes radar to accommodate flight level changes and apply radar separation (which is less than procedural separation) to crossing traffic. However, procedural separation is re-established prior to traffic exiting the Iqaluit and Kuujjuaq radar coverage areas. In consideration of the limited distance flown within radar coverage (approximately 480 nm across or 60 minutes enroute flying time) customers are not able to optimize their entire flight profile because of the large adjacent procedural airspace overlying Hudson Bay. The limitations of procedural airspace are further compounded by the daily NAT-PAC crossing flows of traffic.

1.5 Expanding Air Traffic Surveillance in the Hudson Bay

1.5.1 While the fixed route structure is efficient, it is not optimized to take account of winds that change every day. A Random Route is a flight-planned route generated for an individual flight. The route normally includes point to point navigation between significant points on the route of flight, and is not restricted to airways or published tracks. Random routes generated by customers' flight planning systems optimize the route to reflect the customers' preferences for each flight, and include factors such as the aircraft performance, enroute winds, flight schedule, service charges, and choice of alternates, minimum time/fuel and flight costs.

1.5.2 The reduced separation standards enabled by the expansion of air traffic surveillance, whether through radar or ADS-B "out", will maximize the operator's random routing capability on a consistent and reliable basis. Customers operating in this airspace will realize fuel and enroute flight time savings from improved flight profiles. It is expected that all of the traffic traversing the Hudson Bay airspace would benefit from improved flight profiles, enhanced safety and increased operational flexibility.

1.5.3 With the same aircraft separation standards, the customer benefits from expanding surveillance whether through radar or ADS-B "out" would be equivalent for ADS-B "out" equipped aircraft. However, while aircraft not so equipped would still realize the same benefits under a radar option (no equipage cost), they would incur a fuel penalty under an ADS-B "out" option as they would have to operate below FL290 (29,000 feet).

1.5.4 Direct Controller Pilot Communications (DCPC) is an essential and integral part of air traffic surveillance. In order to apply the reduced separation standards available with radar or ADS-B “out” surveillance, the controller must be able to communicate directly with the pilot at all times.

1.5.5 There were a total of 31 operating irregularities in the airspace in question over the period from 1998 until April 2004. While it is impossible to say that the operating irregularities would not have occurred if surveillance were present, it can be said that surveillance does provide the additional situational awareness tool that may allow the controller to identify and mitigate occurrences. Quantitative evidence from previous analyses has identified a higher rate of operating irregularities in non-radar airspace compared to radar controlled airspace.[8]

[8] Office of Safety and Quality Management (OSQM), NAV CANADA, 26 May 2004-08-10

2.0 Methodology

2.1 Business Case Objective

2.1.1 The purpose of the Business Case Analysis was to determine whether expanded surveillance over the Hudson Bay would be cost-beneficial and to examine and compare the alternatives of using either radar or ADS-B "out".

2.2 Framework and Scope

2.2.1 This Business Case involved the estimation and comparison of benefits and costs (NAV CANADA and customers) of expanding air traffic surveillance over the Hudson Bay for Option 1 (radar) and Option 2 (ADS-B "out"). The benefits and costs of surveillance were compared between the years 2005 through 2029.

2.2.2 The 2005-2029 analysis timeframe was selected to include the 5 years to implement radar plus the twenty-year radar benefit stream. Twenty years was selected to reflect the expected useful life of the radar, the longest lived asset. The useful life of an ADS-B "out" system was estimated to be 15 years. A re-investment in the 15th year equal to one-half the initial ADS-B "out" capital expenditure would be required to extend the useful life of the asset to 2029 so that it can be compared to the radar option. This re-investment was annualized so that only the 5 years of additional costs required to generate the 5 years of additional benefits were included.

2.2.3 The benefits and costs (NAV CANADA and customers) for each option were identified, described and quantified in Canadian dollar terms and then compared on an annual basis for each year of the analysis. An inflation rate of 2% was applied to express these monetary values in current dollar terms.

2.2.4 The Business Case analysis compared the annual NAV CANADA depreciation and interest expense as well as the company's operating expenses with the annual customer benefits and costs for both options. The analysis results were also presented on a discounted cash flow basis, expressed in present value terms that take into account the time value of money. In this way, nearer costs and benefits are accorded greater value than future, more uncertain values. The option with the greatest net present value benefits – that is with benefits that exceed costs by the widest margin, taking the time value of money into account, is considered the most cost effective.

2.2.5 For the Radar option, the benefits of expanded surveillance begin in 2010 once all of the radars are commissioned. The benefits of surveillance using ADS-B "out" are dependent on the aircraft operating in the airspace being suitably equipped. To satisfy the safety and efficiency case of providing random route service on a consistent and predictable basis, all of the aircraft must be ADS-B “out” capable. This would occur when either all of the aircraft operating over Hudson Bay are “naturally” equipped or the airspace is deemed exclusionary. Exclusionary airspace could mean, for example, that in order to operate in the airspace above FL290 over the Hudson Bay, all operators must be equipped with ADS-B “out” capable avionics. In this analysis, the ADS-B “out” baseline option benefits begin in 2010. For this baseline option, it was assumed that 90% of the flights would benefit from random routing, and 10% of the flights would sustain a fuel penalty from having to fly below FL290. It was also assumed that 10% of the aircraft would incur equipage costs.

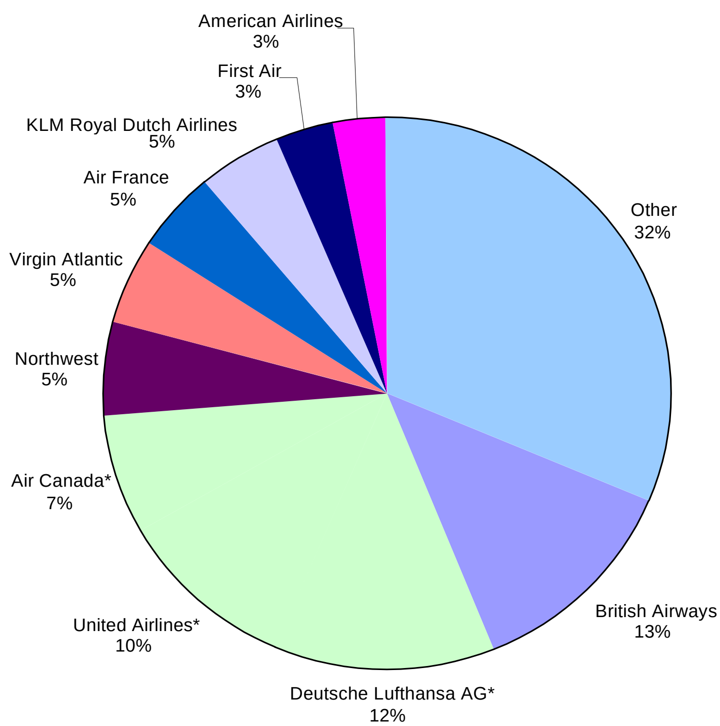
2.2.6 It should be noted that the assumption of mandating the airspace as exclusionary under the ADS-B “out” option might not be realistic. The situation is different from the Reduced Vertical Separation Minima (RVSM) on the North Atlantic and now North America. There is considerable risk that consensus necessary for mandating ADS-B “out” will not develop.

3.0 Benefits of Expanding Surveillance over Hudson Bay

3.1 Benefits Estimation for Options 1 and 2

3.1.1 A first step in quantifying the fuel and flight time saving benefits that accrue from flying random rather than fixed routes was to identify the operators that typically traverse the Hudson Bay. The percent distribution of the top 10 plus remaining "Other" customers that routinely traverse the Hudson Bay airspace is shown in Figure 2.[9] The "Other" category included approximately 1.4% military flights. Rather than relying on NAV CANADA data and assumptions regarding customer preferences, a collaborative Business Case approach was taken. NAV CANADA met with and sought Business Case Analysis participation of the major customers operating over the Hudson Bay including Air Canada, British Airways, Deutsche Lufthansa AG, Northwest, KLM Royal Dutch Airlines, United Airlines, and Virgin Atlantic airlines. The benefits of random routing through the Hudson Bay were quantified using customer-derived flight plan information.

FIGURE 2: TOP 10 CUSTOMERS TRAVERSING PROPOSED SURVEILLANCE EXPANSION OVER HUDSON BAY (2003)



Source: ISAT using FDE Data

* member of Star Alliance

[9] These flights were obtained from the NAV CANADA Integrated Sector Analysis Tool (ISAT) from the Flight Data Extract (FDE) database. Much of this data originates from the NAV CANADA Flight Data Acquisition Analysis System (FDAAS), which is also the source for NAV CANADA's invoicing.

3.1.2 Flight Operations personnel from the participating airlines were requested to run flight plans on fixed routes and then again on random routes for their city pairs and aircraft types that routinely traverse the Hudson Bay. The same monthly historical statistical wind conditions were applied to generate fuel and flight times for each city pair-aircraft type combination, over 12 months.[10] In this way, the focus of the analysis was on the comparison of the fuel and flight time differences between random and fixed routing, i.e., with and without surveillance rather than differences that could be attributed to different wind conditions. The fuel and flight time saving per route per month were then multiplied by the number of flights per month provided by the airlines. The monthly savings were added to determine an annual savings total. Once the savings were expressed in monetary terms they were reviewed and revised as required by each of the participating airlines before being included as part of the total Customer Benefits. This information was provided to NAV CANADA on a confidential basis. As a result, the annual fuel and time cost savings are reported as an aggregate total for all customers and not by individual customer.

3.1.3 The valuation of flight time savings in aviation benefit-cost analyses are typically based on variable aircraft operating costs including crew, maintenance and other costs. EUROCONTROL and the Federal Aviation Administration (FAA) may also assign values to passenger time and sometimes the “downstream" costs of delays.[11]

3.1.4 This analysis applied fuel cost at $0.40 per litre (CDN) and assumed this remains constant, in real terms, over the analysis time frame. This is consistent with the value used in the Transport Canada traffic forecasts.[12] One-half the variable aircraft maintenance cost[13] was also applied to the customer-provided fuel and enroute time savings, respectively. The application of one-half the variable maintenance costs and zero crew costs represents a lower bound valuation of relatively small time savings achievable for long haul flights. Moreover, the variable maintenance costs used to quantify the benefits from timesaving were generic rather than airline specific, as suggested by the participating airlines, and agreed to by the International Air Transport Association (IATA).

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[10] Whenever possible LIDO flight planning system and the associated monthly historical statistical winds were used, thereby minimizing the impact of wind and flight planning system differences on the results.

[11] “Standard Inputs for EUROCONTROL Cost Benefit Analyses”, EUROCONTROL, 2002, 24 August 2004 <http://www.eurocontrol.int/projects/cba.htm>;
“Economic Values for FAA Investment and Regulatory Decisions”, Prepared for the FAA Office of Policy and Plans (APO) by GRA Inc., May 2004, 24 August 2004 <http://apo.faa.gov/arcc/Research.htm>

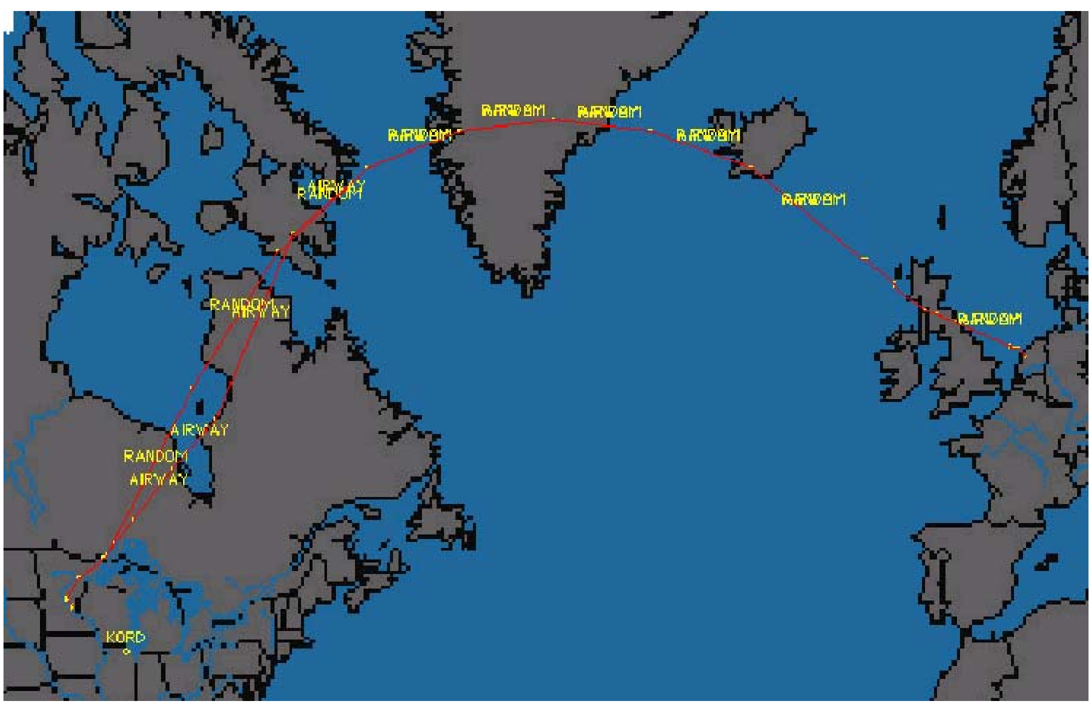
[12] Air Canada Quarterly Reports – 2002 to 2004, <http:/www.aircanada.com >;
“Preliminary Assumptions Report: 2004 – 2018”, Economic Analysis, Policy Group, Transport Canada, November 9, 2004, Section 9 – Fuel Cost/Fuel Efficiency;

[13] “Aircraft Operating Costs and Statistics – 12 Months Ended March 2003” Aviation Week’s Aviation Daily, May 27th, 2003 to June 2, 2003.

3.1.5 Random route savings for the “Other” remaining customers, who were not requested to provide flight plan data because they traverse the Hudson Bay less frequently, were determined by applying the average fuel and flight time savings derived from the data submitted by those who were asked to respond. For example, if the supplied flight plan data indicated an average 5-minute random route savings for the westbound B747 for the major customers – then this average was applied to the “Other” B747 westbound flights not already accounted for. The annual number of “Other” flights was taken from the NAV CANADA billing data traffic source for those city pair flights for calendar 2003 that typically traverse the Hudson Bay.[14]

3.1.6 A sample flight profile illustrating a random and fixed (along airways) routing for a flight between Amsterdam and Minneapolis St-Paul is shown in Figure 3. This particular flight depicts savings of 415 kilograms (482 litres) of fuel and 2 minutes of enroute flight time realized from flying a random (more westerly in this case) rather than fixed route based on airways. It is expected that expanding surveillance over the Hudson Bay will enable customers to maximize their random routing capability on a consistent and predictable basis – avoiding additional reserve fuel requests, improving flight profiles and enhancing safety.

FIGURE 3: ILLUSTRATION OF RANDOM VERSUS FIXED ROUTING



Random route is to the left and slightly above the fixed route.

[14] See Footnote 9

3.1.7 Since the NAT customer benefits were computed based on confidential customer derived information, an example is provided below to illustrate the methodology of how the benefits were computed. A typical westbound flight traversing the Hudson Bay on a daily basis could expect to realize a savings of 550 litres of fuel and 4 minutes of enroute flying time from flying random rather than fixed routes. At $0.40 per litre of fuel and one-half the variable maintenance cost at $10 per minute, this translates into $220 CDN of fuel and $40 CDN in avoided aircraft maintenance costs, for a total of $260 savings CDN per flight. According to the NAV CANADA billing traffic data, there were about 16,200 westbound flights that traversed the Hudson Bay in 2003 above FL290. The illustrative example results in random route savings in the order of $4.2 Million (M) CDN for westbound flights, with 2003 traffic levels. It was expected that 70% of the 11,000 eastbound flights would also realize random route benefits, lower than westbound because the enroute winds do not favour traversing the Hudson Bay as frequently. Therefore, random route savings for the eastbound flights would yield $2M in annual savings. The estimated $6.2M CDN in annual random route benefits for 2003 was increased at an annual rate of 4% for traffic growth and 2% for inflation from 2003 to 2010, reaching an estimated $9M CDN in 2010. This is consistent and comparable with the NAT annual customer benefit results of $9.9 CDN for 2010 shown in Table 3 of Section 3.2.

The results above are consistent with the random route trials conducted in September 2004 in the Montreal FIR which found typical random route savings of 600 to 1000 pounds of fuel (315 to 525 litres) and 4 minutes flying time per flight in radar airspace.

3.1.8 The Asia-Pacific (PAC) traffic will also benefit from improved flight profiles. Expanded surveillance in the Hudson Bay area will enhance safety and facilitate more efficient crossing of NAT-PAC flows. The extension of surveillance will enable some of the PAC westbound traffic to realize preferred altitudes earlier and could improve routing for at least the duration of expanded coverage. Only westbound traffic was assessed since there was very little eastbound PAC traffic traversing the affected airspace.

3.1.9 The improved flight profile benefits for the PAC westbound traffic were quantified based in part on estimates provided by air traffic controllers with extensive experience in controlling this airspace on a daily basis. As PAC westbound traffic crosses the NAT westbound traffic in procedural airspace, the PAC westbound traffic is normally restricted to stay below Flight Level 340 (34,000 feet (FL 340)). While many of these aircraft are too heavy to climb, it is estimated that one-quarter can and would prefer to climb but are prevented from doing so because they cannot be readily accommodated with the crossing NAT traffic in procedural airspace. As a result, these aircraft incur an “off-preferred” altitude penalty for approximately 105 minutes (two-thirds would be 2000 feet off and the other one-third would be 4000 feet off altitude). The duration reflects the typical time it is expected to take a westbound PAC aircraft to traverse the extended surveillance airspace. The improved routing benefits were not quantified.

3.1.10 The PAC westbound customer benefits were determined by estimating the dollar value of the fuel savings from achieving higher altitudes for the one-quarter of PAC westbound traffic that was directly attributable to the expansion of surveillance in the Hudson Bay airspace. There were a total of 4,728 PAC westbound flights in 2003. PAC eastbound benefits were assumed to be zero, as there are very few eastbound flights that traverse the Hudson Bay.

3.1.11 The PAC westbound customer benefits were computed by estimating the additional fuel burned for each minute the aircraft was not at its preferred altitude (2,000 and 4,000 feet off preferred altitude), times the number of minutes this penalty would have been incurred, times the price of fuel. It is estimated that the typical PAC westbound aircraft burns 9,894 litres of fuel per hour at cruising altitude. If the aircraft were 2000 feet off-preferred altitude it would have burned 1.8% more fuel (3.0 litres/minute) and at 4000 feet off-altitude, it would have burned 3.3% more fuel or 5.4 litres more per minute. At a fuel cost of $0.40 per litre (CDN), this means savings of $1.19 per minute and $2.18 per minute if the aircraft were not 2000 feet or 4000 feet off-preferred altitudes, respectively. The derivation of these costs is shown in Table 1 below.

Table 1: Deriving Additional Fuel Cost per Minute

	Deriving Additional Fuel Cost per Minute	Equation	Result
A	Weighted Average Cruise Fuel Burn (l/hr)		9,894
B	Fuel Price per Litre ($)		$0.40
C	Fuel Burn Penalty -- 2,000' off altitude (%)		1.80%
D	Fuel Burn Penalty -- 4,000' off altitude (%)		3.30%
E	Additional Fuel per Minute - 2000' off (litres)	A * C / 60	2.97
F	Additional Fuel per Minute - 4000' off (litres)	A * D / 60	5.44
G	Additional Fuel Cost per Minute - 2000' off ($)	B * E	$1.19
H	Additional Fuel Cost per Minute - 4000' off ($)	B * F	$2.18

The total PAC Customer benefits are estimated to be $187,875 per year as shown in Table 2.

Table 2: Deriving Annual Avoided Fuel Cost

	Deriving Annual Avoided Fuel Cost	Equation	Result
I	Annual PAC West Bound Flights		4,728
J	% of Flights Affected		25%
K	Annual Affected Flights	I * J	1,182
	Flights that are 2,000' Off Altitude:		
L	% of Affected Flights		67%
M	Annual Affected Flights	K * L	792
N	Minutes Off Altitude per Flight		105
O	Annual Off Altitude Flight Minutes	M * N	83,154
G	Additional Cost per Minute Off Altitude	G	$1.19
P	**Annual Avoided Fuel Cost**	**O * G**	**$98,727**
	Flights that are 4,000' Off Altitude:		
Q	% of Affected Flights		33%
R	Annual Affected Flights	K * Q	390
S	Minutes Off Altitude per Flight		105
T	Annual Off Altitude Flight Minutes	R * S	40,956
H	Additional Cost per Minute Off Altitude	H	$2.18
U	**Annual Avoided Fuel Cost**	**T * H**	**$89,149**
V	**Total Annual Avoided Cost (2,000' & 4,000')**	**P + U**	**$187,875**

3.2 Annual Surveillance Benefits

3.2.1 With the same aircraft separation standard, the NAT and PAC customer benefits from expanding surveillance for either Option 1 or 2 are equivalent, as long as all of the aircraft in the ADS-B "out" option are suitably equipped. However, while aircraft not so equipped would realize the same benefits under a radar option (no equipage cost), they would incur a fuel penalty as they would have to operate below FL290 under an ADS-B "out" option. Customers routinely traversing the Hudson Bay that benefit from expanded surveillance would be able to improve their flight profiles by flying random rather than fixed routes, realizing savings in fuel and flight time.

3.2.2 For Option 1 the customer benefits begin in 2010, once all of the radars have been commissioned. In addition to the NAT and PAC benefits, customers operating below FL290 can also expect to realize safety and direct routing benefits from expanding surveillance radar surveillance. The direct routing benefits for domestic flights were estimated to be

$51,000 in 2010, reflecting 3% traffic growth and 2% inflation per annum. The safety benefits arising from improved advisory and monitoring service as well as collision avoidance for these customers were not quantified. The total annual benefits for radar over 20 years amount to approximately $369 million, reflecting the 20-year useful life of the asset, as shown in Table 3.

3.2.3 For Option 2, the customer benefits begin in 2010, once all of the ADS-B "out" ground stations have been commissioned. For this baseline option, it was assumed that exclusionary airspace would have to be mandated at FL290 and above over the Hudson Bay. Based on the MITRE forecast, 63% of all airframes can be expected to be "naturally" ADS-B "out" equipped. In the baseline, it was assumed that 90% of the flights would benefit, 10% would incur an equipage cost and that 10% would sustain a fuel penalty. It was believed that none of the non-equipped PAC airframes would equip due to the low level of benefit. Based on these assumptions, the NAT and PAC customer benefits for ADS-B "out" were estimated to accrue to 90% and to 80% of total flights, respectively in 2010, increasing to 99% in 2020 and thereafter. This assumed that a very small percentage would still not equip over the timeframe of the analysis.

3.2.4 NAT and PAC benefits for future years were assumed to increase with traffic by 4% per year from 2003 to 2020, and by 3% per year thereafter.[15] An inflation rate of 2% per annum was also applied to express annual benefits, O&M costs and future capital expenditures in current dollar terms. The total annual benefits for ADS-B "out" over the 20 years amount to $360 million as shown in Table 4.

[15] "Summary of Discussions and Conclusions", The North Atlantic Traffic Forecasting Group (NATTFG), ICAO, 34th Meeting, April 19th to 28th, 2004.

Table 3: Customer Benefits of Expanding Surveillance over Hudson Bay Using Radar – Option 1 ($000s Current CDN)

	YEAR[1]																									Future	
	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	Years	TOTAL
CUSTOMER BENEFITS[2]																											
NAT	-	-	-	-	-	9,935	10,539	11,180	11,860	12,581	13,346	14,157	15,018	15,931	16,899	17,927	18,834	19,787	20,788	21,840	22,945	24,106	25,326	26,607	27,954	-	**357,559**
PAC	-	-	-	-	-	278	295	313	332	353	374	397	421	446	474	502	528	555	583	612	643	676	710	746	783	-	**10,020**
DOMESTIC	-	-	-	-	-	51	53	56	59	62	65	68	72	75	79	83	86	90	94	97	101	105	110	114	119	-	**1,638**
TOTAL	-	-	-	-	-	10,264	10,888	11,549	12,251	12,995	13,784	14,622	15,510	16,452	17,452	18,512	19,448	20,431	21,464	22,549	23,689	24,887	26,145	27,467	28,856	-	**369,218**

1 Calendar Year.
2 Annual 'NAT' & 'PAC' Customer Benefits are assumed to increase with traffic by 4% per year from 2003 to 2020, and by 3% per year thereafter, considering 2004 ICAO North Atlantic Forecasts.
Annual 'DOMESTIC' Customer Benefits are assumed to increase with traffic by 3% per year from 2003 to 2020, and by 2% per year thereafter, considering 2004 Transport Canada Forecasts for Churchill, Iqaluit and Yellowknife.
NAT is North Atlantic Traffic; Benefits from random routes include fuel savings and 50% of Maintenance Cost per minute as per Aviation Daily Reports (2003).
PAC is Asia Pacific Traffic; Assumes altitude fuel savings only, at 3.0 and 5.4 additional litres of fuel per minute for 2,000' and 4,000' off altitude, respectively.
Customer benefits begin in 2010 at 100% of the projected annual benefit.
Fuel savings is based on fuel price of $0.4 (CDN) per litre.
3 Inflation is included at 2% per year.

Table 4: Customer Benefits of Expanding Surveillance over Hudson Bay Using ADS-B "out" – Option 2 ($000s Current CDN)

	YEAR[1]																									Future	
	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	Years	TOTAL
CUSTOMER BENEFITS[2]																											
NAT	-	-	-	-	-	8,942	9,627	10,363	11,130	11,952	12,807	13,721	14,671	15,686	16,704	17,789	18,689	19,635	20,628	21,672	22,769	23,921	25,131	26,403	27,739	-	**349,977**
PAC	-	-	-	-	-	223	244	268	291	317	344	372	401	433	463	495	520	546	574	603	633	665	699	734	771	-	**9,595**
TOTAL	-	-	-	-	-	9,164	9,871	10,630	11,421	12,269	13,150	14,094	15,073	16,118	17,167	18,284	19,209	20,181	21,202	22,275	23,402	24,586	25,830	27,137	28,510	-	**359,573**

1 Calendar Year.
2 Annual 'NAT' & 'PAC' Customer Benefits are assumed to increase with traffic by 4% per year from 2003 to 2020, and by 3% per year thereafter, considering 2004 ICAO North Atlantic Forecasts.
NAT is North Atlantic Traffic; Benefits from random routes include fuel savings and 50% of Maintenance Cost per minute as per Aviation Daily Reports (2003).
PAC is Asia Pacific Traffic; Assumes altitude fuel savings only, at 3.0 and 5.4 additional litres of fuel per minute for 2,000' and 4,000' off altitude, respectively.
Customer benefits begin in 2010 at 100% of the projected annual benefit.
Fuel savings is based on fuel price of $0.4 (CDN) per litre.
3 Inflation is included at 2% per year.

4.0 Costs of Expanding Surveillance

4.1 Introduction

4.1.1 There are significant technical challenges in providing surveillance coverage over Hudson Bay ranging from the hostile yet fragile Northern Canadian environment to the line-of-sight coverage required over more than 500 nm of water. The provision of air traffic service over the bay is highly dependent on the performance of the proposed technology as advertised by suppliers and on NAV CANADA's ability to implement it at the proposed sites.

4.1.2 All of the capital and recurring costs to expand surveillance and provide the additional required communications coverage over Hudson Bay for Option 1 (radar) and Option 2 (ADS-B "out") were estimated by NAV CANADA Engineering and included in this analysis. These costs were determined on an annual basis and were estimated assuming no change to the present airspace sectorization and Flight Information Region (FIR) boundaries. The 2004 costs were inflated to current dollars by applying an annual inflation rate of 2% per year.

4.2 Communications Costs

4.2.1 Specialized high power and directional communications equipment in addition to the existing communications infrastructure would be required to provide DCPC communications at FL290 throughout and including the centre of Hudson Bay. The additional communications capital cost estimates for four sites amounting to $6.3 million ($1.575 million X 4) were added to the Radar (Option 1) and ADS-B "out" (Option 2) as they are the same for all options. See Figure 4 for a photo of a communications site in Northern Canada. The expected service life of DCPC is 20 years.

FIGURE 4: PHOTO OF COMMUNICATIONS SITE IN NORTHERN CANADA

4.2.2 The capital cost for one communications site is $1.6 million and includes site civil works, communications systems and spares, shipping and installation.

4.2.3 The annual operating and maintenance (O&M) cost for one typical communications site is $140,000 and includes communications and maintenance.

4.3 Radar Costs – Option 1

4.3.1 Cost estimates for the standard Mode-S Monopulse Secondary Surveillance Radar (MSSR) systems for Hudson Bay were based on historical costs of the northern radar program. The MSSR system includes a 10 meter radome, antenna, 18 meter structural type, tower, pedestal with dual drive motors, dual monopulse interrogators and plot extractors (400 target capacity), dual remote control monitoring, dual site monitors, dual Static Uninteruptible Power Units (SUPUs), Heating, Ventilating, and Air Conditioning (HVAC), and an Interruptible Power Unit (IPU) with an Automatic Transfer Switch. The expected service life of radar is 20 years.

4.3.2 For most northern areas like those surrounding the Hudson Bay, redundant satellite communications will be required. The communications will have to meet a technical specification of 64 kilobyte per second (kbps) circuit multiplexed with surveillance data, control and monitoring and voice. Equipment external to the shelter, including the dual site monitor will need to be rated to operate over a temperature range from –50º Celsius to +50º Celsius. Equipment in the shelter will be rated to operate from 10º Celsius to 35º Celsius. The site will require approximately one acre of land and will be located on high ground. The site will be fenced and contain an environmentally approved fuel tank and secure area for parking a vehicle.

4.3.3 Because of its design, Mode-S radar has a maximum range limit of 250 nm. This is the line of sight limit for aircraft flying at FL410. Enroute radar sites are usually located not more than 400 nm apart so that contiguous coverage is provided down to at least FL290. A photo of Mode-S radar in Northern Canada is shown in Figure 5.

FIGURE 5: PHOTO OF MODE S RADAR IN NORTHERN CANADA

4.3.4 Option 1 – Four Northern MSSR Sites around Hudson Bay. In this option, it is assumed that each of the four sites will be located close to a settlement. The four proposed sites are: Inukjuak, Fort Severn, Arviat and Coral Harbour.

4.3.4.1 The capital cost for each of the four Mode-S radar sites is $8.3 million and includes site work, hydro and access road, MSSR system, spares, installation and telecom equipment.

4.3.4.2 The annual operating and maintenance (O&M) cost for one typical northern MSSR is $205,000 and includes communications and maintenance.

4.3.4.3 Four Mode-S radar sites are required to provide coverage over most of Hudson Bay FL290 and above. While DCPC would be provided, this approach would leave a gap in radar coverage over the Hudson Bay. The total estimated capital costs including the communications costs (as per section 4.2) would be expended over five years 2005 through 2009 as shown in Table 5.

Table 5: Capital Cost Profile for Communications and Four Mode-S Radar Sites

Year	2004 $000 CDN
2005	1,300
2006	2,970
2007	11,760
2008	11,760
2009	11,710
Total Capital Costs	**$39,500**

4.4 ADS-B “Out” Costs - Option 2

4.4.1 ADS-B is a newer surveillance system that is a derivative of a Mode-S radar system that costs much less. The useful life of an ADS-B “out” system is expected to be 15 years. Before reaching the 15th year, it is estimated that a re-investment equivalent to one-half of the initial system cost would be required to continue to provide the projected surveillance benefits. Further, the ADS-B “out” generated aircraft targets must be seamlessly integrated with the radar targets on air traffic control displays. A resectorization cost for Edmonton would also be required to accommodate the impact of mandating the airspace above FL290 for ADS-B “out”. A one-time cost of $19,000 and an annual on-going cost of $202,000 were included for this, in addition to the other NAV CANADA costs, such as communications, ground based ADS-B “out” stations, and air traffic management integration. These were addressed in this Business Case Analysis, and are described in Sections 4.2, 4.4, and 4.6, respectively.

4.4.2 The ADS-B “out” ground based system comprises a Distance Measuring Equipment (DME) sensor omni-directional antenna, a self supporting 18 meter tower, dual ADS-B “out” processors (200-250 target capacity), dual remote control and monitoring, dual data servers, dual site monitors, dual SUPUs, an IPU with an Automatic Transfer Switch. For most northern sites, redundant satellite communications will be required. One 64kbps circuit will be required and multiplexed with surveillance data control and monitoring and voice. Equipment external to the shelter, including the dual site monitor will need to be rated to operate over a –50º Celsius to +50º Celsius temperature range. Equipment in the shelter will be rated to operate from 10º Celsius to 35º Celsius. The site would require approximately one acre of land and would be located on high ground. The site will be fenced and contain an environmentally approved fuel tank and secure area for parking a vehicle. A photograph of a typical ADS-B "out" ground station is shown in Figure 6.

FIGURE 6: PHOTO OF ADS-B "OUT" GROUND STATION

4.4.3 The estimated capital cost for an ADS-B "out" ground station is $3.1 million and includes site civil works, the ADS-B system, site monitoring, spares and installation.

4.4.4 The annual operating and maintenance Cost for a northern ADS-B "out" site is $165,000 and includes communications and maintenance.

4.4.5 ADS-B systems are presently designed for a range up to 200nm. This is based on ICAO standards, the use of a non-directional antenna and link margins. A major difference in the ADS-B down link signal when compared to the MSSR is the present use of a DME type omni-directional antenna that has 12 to 18 dB less gain than an MSSR Large Vertical Aperture antenna. However, it is possible to increase the ADS-B signal margins to achieve a better range by using additional ADS-B systems coupled with directional antennae. While a better range can be achieved, both the receiver amplifier gain and the antenna's gain limit it.

4.4.6 Six ADS-B "out" ground station receiver systems would be required to provide coverage over most of Hudson Bay at FL290 and above. One system would be installed at each of Inukjuak and Arviat, while two systems (one omni-directional and one directional with a high gain antenna directed toward the centre of the bay) would be required at each of Fort Severn and Coral Harbour, for a total of six systems. While DCPC would be provided, this approach would leave a gap in ADS-B "out" coverage over the Hudson Bay. These surveillance systems would be supported by the same communications technology and infrastructure as identified for the radar option and outlined in Section 4.2.1.

4.4.7 The total estimated capital costs to expand air traffic surveillance using ADS-B "out" systems plus communications over Hudson Bay would be expended over the four years 2006 through 2009 as presented in Table 6.

Table 6: Capital Cost Profile for Communications and Six ADS-B "out" Systems

Year	2004 $000 CDN
2006	1,300
2007	1,160
2008	14,800
2009	7,400
Total Capital	**$24,660**

4.5 Aircraft Avionics Requirements and Costs for ADS-B "out"

4.5.1 In order to benefit from increased airspace capacity and random routing offered by the reduced separation of the ADS-B "out", investments are not only required in the ground infrastructure, but also in the avionics of the aircraft.

4.5.2 Specifically the aircraft must have a GPS that can be connected to an Enhanced Mode S transponder with Extended Squitter (1090ES) capability. GPS derived aircraft position information was assumed to be necessary in the ADS-B “out” option and the associated cost for any aircraft not so equipped was addressed in this Business Case. GPS was Airservices Australia’s choice for position information in their ADS-B trials.

4.5.3 There is some uncertainty from a safety perspective as to whether ADS-B “out” may be able to support the same separation standard as radar, and this could affect the magnitude of fuel savings that could be realized by customers. This situation stems from the vulnerability created if both surveillance and navigation are dependent on GPS. The Separation and Safety Panel (SASP) and the Navigation Systems Panel (NSP) of ICAO have been requested to review GPS performance and vulnerability, with the intent of providing appropriate guidance and mitigation measures. It is expected that Transport Canada will require an analysis to support a 5nm or other separation standard.

4.5.4 In January 2004, NAV CANADA distributed a survey to the top 30 airline customers that operated over the Hudson Bay with the objective of obtaining aircraft fleet data and ADS-B “out” airborne avionics cost information. It was evident from the 53 percent who responded to the survey that the costs of equipage ranged from minimal to quite significant. Many of the respondents indicated that they were already ADS-B “out” capable. Such information from the NAV CANADA ADS-B “out” airborne avionics survey results was not considered sufficiently representative to support a customer equipage cost estimate for the Business Case.

4.5.5 Instead, avionics equipage information was extracted from other sources, including flight plans filed with NAV CANADA (fields indicate equipment on board the aircraft), MITRE Corporation and aircraft manufacturers (Boeing and Airbus). Information from all of these sources formed the basis for the estimation of an ADS-B “out” customer equipage cost for Hudson Bay.

4.5.6 A paper presented to the ICAO Separation and Safety Panel (SASP) indicated that … “For most modern ATC transponders, the ADS-B “out” capability can be accomplished with software modifications to the transponder and the addition of wiring to input GPS position information to the transponder for ADS-B reporting. Others not capable of software modifications will require the addition or replacement of existing transponder equipment with avionics that supports ADS-B capability.”[16] It is expected that some older aircraft not yet equipped with GPS could incur significant ADS-B “out” equipage costs.

4.5.7 The estimated equipage costs in this analysis are for retrofits given that new deliveries will be suitably equipped for ADS-B “out” (see 4.5.17). As a result, these aircraft are assumed to have an inertial navigation system, eliminating the requirement for dual GPS. Any new Enhanced Mode S transponder installations, however, must be dual redundant.

[16] “ADS-B Deployment from the Airborne Equipage Perspective”, Chris Nehls, Honeywell, Phoenix, U.S.A., March 2003 paper presented at the ICAO ADS-B Study & Implementation Task Force, Brisbane, Australia

4.5.8 The equipage costs for ADS-B “out” avionics represent a conservative cost estimate of the requirement. A single thread Multi Mode Receiver (MMR) with GPS installed in an existing air transport aircraft is estimated to cost approximately $94,000 (CDN), including the required connection to the Mode S transponder. The cost of installing a dual redundant Mode S with ES functionality is estimated to cost between $100,000 to $110,000 (CDN) per aircraft, depending on the aircraft’s existing avionics and age[17]. Upgrading a Mode S to achieve the required ES functionality with a transponder that can technically be upgraded is estimated to cost $17,000 (CDN) per aircraft. This typically involves a software modification and a connection to the GPS.[18]

4.5.9 For the NAT aircraft, the estimated avionics cost assumes all aircraft will meet the European Mandate for an Enhanced Mode S (EHS) transponder by March 2007. This means that all aircraft would already have the EHS transponder with Extended Squitter (1090 ES) functionality. The mandate does not require a GPS, so the $94,000 cost of a GPS was used for the NAT ADS-B “out” equipage cost for those aircraft complying with a mandate.

4.5.10 For aircraft operating in the PAC region, the European Mandate is not applicable. Without the requirement for an EHS transponder, aircraft may not have a Mode S, or may have an older generation Mode S that cannot be upgraded to 1090 ES functionality. In these instances a new dual redundant Mode S transponder will need to be installed. As well, a GPS will be required for aircraft not already so equipped. These costs apply only to aircraft choosing to comply with a mandate to equip. It was assumed that the PAC aircraft would not equip because the equipage costs would exceed the benefits of doing so.

4.5.11 The airframes affected are primarily large air transport aircraft. The number of unique airframes was identified using NAV CANADA’s ISAT system. The flights reviewed cover the period January 1, 2004 to November 30, 2004. Along with aircraft type, registration number and operator, the data indicated whether the aircraft operates in the North Atlantic (NAT) or Asia-Pacific (PAC) region.

4.5.12 The ISAT system identified approximately 2,000 unique aircraft (1,800 NAT and 200 PAC) operating in the Hudson Bay airspace at FL290 and above. About 25 percent of these (NAT and PAC) have GPS available, based on the flight plan data contained in this system. A 2004 survey of aircraft operators in the U.S. (see Footnote 18) conducted by MITRE indicated about 40 percent of U.S. air transport aircraft are currently ADS-

[17] These costs are for broadcasting only and do not include a connection to a CDTI display (which is not required for ADS-B ”out”).

[18] U.S. ADS-B Fleet Forecast and Equipage Costs, analysis completed in 2004 for the Federal Aviation Administration, Safe Flight 21 Office, by The MITRE Corporation, Center for Advanced Aviation System Development; Contact: James D. Nickum Voice: 703-883-6961 Fax: 703-883-6653 e-mail: jdnickum@mitre.org

B capable, increasing to about 60 percent by 2008. This is consistent with an ICAO Working Paper that projected FANS (Future Air Navigation System) equipage of NAT aircraft traversing the Hudson Bay[19]. FANS aircraft are equipped with GPS. The ISAT source reveals a lower equipage level since the equipment field indicating “GPS” is often not indicated on the flight plan.

4.5.13 Table 7 below summarizes the GPS equipage levels by source. The Business Case sensitivity analysis assessed the impact of increasing “natural” equipage levels beginning in 2010 at 63 percent of aircraft (NAT and PAC) being GPS-equipped and reaching 70% by 2012. It is noted that:

a) The MITRE survey results included narrow body air transport aircraft flying in continental U.S. airspace, which are thought less likely to be GPS-equipped than the wide body jets operating in oceanic airspace.
b) The ICAO Working Paper on FANS equipage excluded GPS-equipped aircraft that are not FANS capable.

Table 7: Current and Forecast GPS Equipage Levels by Source

Source	2003	2010	2012
ISAT (NAV CANADA Fight Data)	25%	N/A	N/A
MITRE Survey (ADS-B for Air Transport Aircraft)	40%	63%	70%
ICAO WP12 FANS aircraft (Linear + 763s Scenario)	41%	63%	70%

4.5.14 With the European Mandate in effect, only PAC aircraft will need to upgrade or install new 1090 ES transponders. The 1090 ES levels for 2010 assumed in the Business Case sensitivity analysis are presented in Table 8.

Table 8: Assumed Mode S 1090ES Equipage Levels by Traffic Segment

Traffic Segment	2003	2010
NAT	63%	100%
PAC	90%	95%

[19] “Projected FANS 1/A Equipage in the NAT”, The North Atlantic Fans 1/A Implementation Group (NATFIG), ICAO, 11th Meeting, October 18th to 22nd, 2004.

4.5.15 The proportion of aircraft that will require GPS under an ADS-B "out" option is a critical assumption since the current equipage level is relatively low and the equipage cost is high. It is essential from both a safety and efficiency perspective that all of the aircraft operating in ADS-B "out" airspace be ADS-B "out" capable. This would require consideration of a mandate that designates the avionics requirements for aircraft to include GPS and 1090ES. It is likely that some of the aircraft lacking the necessary ADS-B "out" avionics will not comply with such a mandate for a number of business reasons. In turn, these aircraft would sustain a fuel penalty because they would be forced to fly at less than preferred altitudes to avoid the exclusionary airspace over the Hudson Bay.

4.5.16 As noted in section 4.5.12, there were an estimated 1,800 unique NAT airframes operating over the Hudson Bay in 2004. For the ADS-B "out" baseline option it was assumed that 90% of the flights would benefit from random routing, 10% of the flights would incur a fuel penalty. It was also assumed that 10% of the aircraft would incur equipage costs and. Using $94,000 (CDN) for an ADS-B "out" avionics package (assumes GPS component only since all NAT aircraft will have the required Mode S transponder to meet the European Mandate), a total customer equipage cost of $16.9 million undiscounted (1,800 X 10% X $94,000) resulted in $18.1 million (including inflation).

4.5.17 The percentage of ADS-B "out" capable aircraft is expected to increase over time as older aircraft are replaced with newly manufactured ADS-B "out" capable aircraft. Boeing has indicated that all new aircraft delivered will have GPS and be wired to accommodate an Enhanced Surveillance Mode S (EHS). However, the EHS transponder is an available option and not standard equipment. All new Airbus aircraft will be delivered with the full ADS-B "out" capability (GPS and EHS) at minimal cost.[20]

4.5.18 The investment in ADS-B "out" avionics is a one-time cost, but the benefits for the aircraft operator may extend beyond those for the Hudson Bay area. It was assumed that the operators that traverse most frequently would most likely "naturally" equip their aircraft and would already be included in the MITRE forecast. For the baseline ADS-B "out" option, it was assumed that 100% of the additional retrofit equipage costs would be in response to a mandate for ADS-B "out" over Hudson Bay and therefore 100% of these equipage costs would be attributable to the Hudson Bay project in the Business Case Analysis.

4.5.19 The present value of total equipage costs (including the GPS and Mode S costs) was based on the assumption that a quarter of the "non-equipped" aircraft would be retrofitted in each of four years prior to the year of

[20] "ADS-B 'out' query" E-mail from Brook Assefa of Boeing [brook.assefa@boeing.com], July 27th, 2004; "AIRBUS Cost of ADS-B Wiring" E-mail from Greg Dunstone of Airservices Australia [Greg.Dunstone@AirservicesAustralia.com], July 28, 2004

implementation. This schedule assumed that avionics retrofits would be performed with scheduled major aircraft service checks, which were expected to occur randomly over these years. For Options 1 & 2, 100% of the equipage costs were attributed to the Hudson Bay, because it was assumed that all of the costs over and above the “natural” level of equipage (retrofits) would be incurred because of Hudson Bay.

4.5.20 ADS-B ”out” capability can be used wherever ADS-B ”out” surveillance is provided (e.g. Australia and East Coast of the U.S. currently planned for 2005 and possibly other areas in the future). Moreover, GPS can have other navigational benefits, to the carrier, such as Precision Area Navigation (P-RNAV), GPS approaches, RNP4 based 30NM lateral and longitudinal separation standards in oceanic and remote airspace. Therefore, the impact of attributing 75% of the equipage costs to the Hudson Bay project was assessed for the ADS-B “out” options in the Sensitivity Analysis.

4.6 Air Traffic Management ADS-B “Out” and Radar Information Integration

4.6.1 The following software updates are required to the core Air Traffic Management (ATM) systems in order to handle the ADS-B “out” messages from the new Hudson Bay ground stations so as to provide the same level of service as would be provided using MSSRs:

- Radar Data Processing System Rehost (RDPSR);
- Radar Target Information Server (RTIS);
- Canadian Automated Air Traffic System (CAATS);
- NAV CANADA Auxiliary Radar Display System (NARDS);
- Air Traffic Controller Training Systems.

4.6.2 The need for these updates is primarily driven by the new target identification methodology used with ADS-B “out”. The flight identification and track data content as well as the traffic association logic must be updated to utilize the discrete address received for each flight. In addition, the enhanced update rates and data integrity inherent in ADS-B transmissions demands some adjustment in NAV CANADA’s track update logic. ADS-B reports that meet stringent integrity measures will be integrated into NAV CANADA’s traffic mosaic for display to ATC as if they were radar reports but will be identified by source type.

4.6.3 The additional one-time cost of integrating ADS-B “out” surveillance data into NAV CANADA’s ATM infrastructure is estimated as $512,000, and included in the capital cost for the ADS-B “out” option.

5.0 Business Case Analysis Results

5.1.1 A comparison of Option 1 annual benefits beginning in 2010 and costs of expanding air traffic surveillance using radar is shown in Table 9A (showing cumulative benefits and costs undiscounted) and Table 9B (showing cumulative benefits and costs discounted cash flow). These results indicate that the total benefits of radar $369.2 million outweigh the costs of $105.1 million over the analysis timeframe. Total net benefits amount to $264.1 million, which yields an NPV of $92.4 million when using a discount rate of 6%. From an economic perspective, there is a positive business case for the expansion of surveillance based on radar.

5.1.2 A comparison of Option 2 annual benefits beginning in 2010 and costs of expanding air traffic surveillance using ADS-B “out” is shown in Table 10A (showing cumulative benefits and costs - undiscounted) and Table 10B (showing cumulative benefits and costs - discounted cash flow). The ADS-B “out” customer equipage and fuel penalty costs were included in this comparison. These results indicate that the total benefits of $359.6 million for ADS-B “out” also outweigh the costs of $122.4 million (NAV CANADA ($95.5 million) plus Customer costs ($26.9 million)) over the analysis timeframe. The total net benefits amount to $237.2 million, which yields an NPV of $74.0 million when using a discount rate of 6%. From an economic perspective, there is a positive business case for the expansion of surveillance based on ADS-B “out”.

5.1.3 These results indicate that the total net (present value) benefits of the radar option of $92.4 million outweigh the total net (present value) benefits of the ADS-B “out” option of $74.0 million by $18.4 million over the analysis timeframe. The Sensitivity Analysis in Section 6 also shows that the net benefits of the radar option are greater than for the ADS-B “out” option.

Table 9A: Option 1 – Comparison of Benefits and Costs of Using Radars to Expand Surveillance over the Hudson Bay ($000s Current CDN)

	YEAR[1]																										
	2005	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**Future Years**	**TOTAL**
CUSTOMER BENEFITS[2]																											
NAT	-	-	-	-	-	9,935	10,539	11,180	11,860	12,581	13,346	14,157	15,018	15,931	16,899	17,927	18,834	19,787	20,788	21,840	22,945	24,106	25,326	26,607	27,954	-	**357,559**
PAC	-	-	-	-	-	278	295	313	332	353	374	397	421	446	474	502	528	555	583	612	643	676	710	746	783	-	**10,020**
DOMESTIC	-	-	-	-	-	51	53	56	59	62	65	68	72	75	79	83	86	90	94	97	101	105	110	114	119	-	**1,638**
TOTAL	-	-	-	-	-	10,264	10,888	11,549	12,251	12,995	13,784	14,622	15,510	16,452	17,452	18,512	19,448	20,431	21,464	22,549	23,689	24,887	26,145	27,467	28,856	-	**369,218**
NAV CANADA COSTS[3]																											
ANNUAL O&M	-	-	-	-	-	1,554	1,585	1,617	1,649	1,682	1,716	1,750	1,785	1,821	1,857	1,894	1,932	1,971	2,010	2,051	2,092	2,133	2,176	2,220	2,264	-	**37,761**
DEPRECIATION[4]	-	-	-	-	-	1,975	1,975	1,975	1,975	1,975	1,975	1,975	1,975	1,975	1,975	1,975	1,975	1,975	1,975	1,975	1,975	1,975	1,975	1,975	1,975	-	**39,500**
INTEREST[5]	39	167	609	1,315	2,019	2,311	2,192	2,074	1,955	1,837	1,718	1,600	1,481	1,363	1,244	1,126	1,007	889	770	652	533	415	296	178	59	-	**27,848**
TOTAL	39	167	609	1,315	2,019	5,840	5,752	5,666	5,579	5,494	5,409	5,325	5,241	5,159	5,077	4,995	4,915	4,835	4,756	4,677	4,600	4,523	4,447	4,372	4,298	-	**105,109**
BENEFITS LESS COSTS	(39)	(167)	(609)	(1,315)	(2,019)	4,424	5,135	5,883	6,671	7,501	8,375	9,297	10,269	11,294	12,375	13,517	14,534	15,597	16,709	17,872	19,090	20,364	21,698	23,095	24,558	-	**264,109**
CUMULATIVE NET BENEFITS	(39)	(206)	(815)	(2,130)	(4,148)	276	5,411	11,295	17,966	25,467	33,842	43,139	53,408	64,702	77,077	90,594	105,128	120,725	137,433	155,305	174,395	194,759	216,457	239,552	264,109	264,109	

1 Calendar Year.

2 Annual 'NAT' & 'PAC' Customer Benefits are assumed to increase with traffic by 4% per year from 2003 to 2020, and by 3% per year thereafter, considering 2004 ICAO North Atlantic Forecasts.
Annual 'DOMESTIC' Customer Benefits are assumed to increase with traffic by 3% per year from 2003 to 2020, and by 2% per year thereafter, considering 2004 Transport Canada Forecasts for Churchill, Iqaluit and Yellowknife.
NAT is North Atlantic Traffic; Benefits from random routes include fuel savings and 50% of Maintenance Cost per minute as per Aviation Daily Reports (2003).
PAC is Asia Pacific Traffic; Assumes altitude fuel savings only, at 3.0 and 5.4 additional litres of fuel per minute for 2,000' and 4,000' off altitude, respectively.
Customer benefits begin in 2010 at 100% of the projected annual benefit.
Fuel savings are based on fuel price of $0.4 (CDN) per litre.

3 'NAV CANADA COSTS' include Communications.

4 'DEPRECIATION' is based on 20 years useful life from date of radar commissioning.

5 'INTEREST' is based on cash outlay and undepreciated asset value in mid year using a rate of 6% per year. Sensitivity is performed at different rates.

6 Comparison of benefits and costs are in current dollars; inflation is included at 2% per year.

Table 9B: Option 1 – Comparison of Benefits and Costs of Using Radars to Expand Surveillance Over the Hudson Bay ($000s Current CDN) – Discounted Cash Flow

	YEAR[1]																									Future	
	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	Years	TOTAL
CUSTOMER BENEFITS[2]																											
NAT	-	-	-	-	-	9,935	10,539	11,180	11,860	12,581	13,346	14,157	15,018	15,931	16,899	17,927	18,834	19,787	20,788	21,840	22,945	24,106	25,326	26,607	27,954	-	**357,559**
PAC	-	-	-	-	-	278	295	313	332	353	374	397	421	446	474	502	528	555	583	612	643	676	710	746	783	-	**10,020**
DOMESTIC	-	-	-	-	-	51	53	56	59	62	65	68	72	75	79	83	86	90	94	97	101	105	110	114	119	-	**1,638**
TOTAL	-	-	-	-	-	10,264	10,888	11,549	12,251	12,995	13,784	14,622	15,510	16,452	17,452	18,512	19,448	20,431	21,464	22,549	23,689	24,887	26,145	27,467	28,856	-	**369,218**
NAV CANADA COSTS[3]																											
ANNUAL O&M	-	-	-	-	-	1,554	1,585	1,617	1,649	1,682	1,716	1,750	1,785	1,821	1,857	1,894	1,932	1,971	2,010	2,051	2,092	2,133	2,176	2,220	2,264	-	**37,761**
CAPITAL	1,300	2,970	11,760	11,760	11,710	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**39,500**
TOTAL	1,300	2,970	11,760	11,760	11,710	1,554	1,585	1,617	1,649	1,682	1,716	1,750	1,785	1,821	1,857	1,894	1,932	1,971	2,010	2,051	2,092	2,133	2,176	2,220	2,264	-	**77,261**
ANNUAL NET BENEFITS	(1,300)	(2,970)	(11,760)	(11,760)	(11,710)	8,710	9,303	9,932	10,602	11,313	12,069	12,872	13,725	14,632	15,595	16,618	17,516	18,460	19,454	20,499	21,598	22,754	23,969	25,247	26,592	-	**291,957**
CUMULATIVE NET BENEFITS	(1,300)	(4,270)	(16,030)	(27,790)	(39,500)	(30,790)	(21,487)	(11,555)	(954)	10,359	22,428	35,299	49,024	63,656	79,251	95,869	113,384	131,845	151,299	171,798	193,395	216,149	240,118	265,366	291,957	291,957	
PRESENT VALUE																											
DISCOUNT FACTOR[4]	0.916	0.864	0.815	0.769	0.725	0.684	0.646	0.609	0.575	0.542	0.511	0.482	0.455	0.429	0.405	0.382	0.361	0.340	0.321	0.303	0.286	0.269	0.254	0.240	0.226		
CUSTOMER BENEFITS	-	-	-	-	-	7,025	7,030	7,035	7,040	7,045	7,050	7,055	7,060	7,065	7,070	7,075	7,012	6,950	6,888	6,826	6,765	6,705	6,645	6,586	6,528	-	**138,455**
ANNUAL O&M	-	-	-	-	-	1,064	1,024	985	948	912	878	844	813	782	752	724	697	670	645	621	597	575	553	532	512	-	**15,127**
CAPITAL	1,191	2,566	9,586	9,044	8,496	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**30,883**
NET PRESENT VALUE (NPV)	**(1,191)**	**(2,566)**	**(9,586)**	**(9,044)**	**(8,496)**	**5,961**	**6,007**	**6,050**	**6,092**	**6,133**	**6,172**	**6,211**	**6,247**	**6,283**	**6,318**	**6,351**	**6,315**	**6,279**	**6,242**	**6,205**	**6,168**	**6,130**	**6,092**	**6,054**	**6,015**	-	**92,445**
CUMULATIVE NPV	(1,191)	(3,757)	(13,343)	(22,387)	(30,883)	(24,921)	(18,915)	(12,865)	(6,772)	(639)	5,533	11,744	17,991	24,274	30,592	36,943	43,258	49,537	55,780	61,985	68,153	74,284	80,376	86,430	92,445	92,445	

1 Calendar Year

2 Annual 'NAT' & 'PAC' Customer Benefits are assumed to increase with traffic by 4% per year from 2003 to 2020, and by 3% per year thereafter, considering 2004 ICAO North Atlantic Forecasts.

Annual 'DOMESTIC' Customer Benefits are assumed to increase with traffic by 3% per year from 2003 to 2020, and by 2% per year thereafter, considering 2004 Transport Canada Forecasts for Churchill, Iqaluit and Yellowknife.

NAT is North Atlantic Traffic; Benefits from random routes include fuel savings and 50% of Maintenance Cost per minute as per Aviation Daily Reports (2003).

PAC is Asia Pacific Traffic; Assumes altitude fuel savings only, at 3.0 and 5.4 additional litres of fuel per minute for 2,000' and 4,000' off altitude, respectively.

Customer benefits begin in 2010 at 100% of the projected annual benefit.

Fuel savings are based on fuel price of $0.4 (CDN) per litre.

3 'NAV CANADA COSTS' include Communications.

4 'DISCOUNT FACTOR' is mid-year using a Discount Rate of 6%. Sensitivity is performed at different rates.

5 Comparison of benefits and costs are in discounted dollars using a nominal discount rate; inflation is included at 2% per year.

Table 10A: Option 2 – Comparison of Benefits and Costs of Using ADS-B "out" to Expand Surveillance over the Hudson Bay ($000s Current CDN)

YEAR[1]	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
CUSTOMER BENEFITS[2]												
NAT	-	-	-	-	-	8,942	9,627	10,363	11,130	11,952	12,807	13,721
PAC	-	-	-	-	-	223	244	268	291	317	344	372
TOTAL	-	-	-	-	-	9,164	9,871	10,630	11,421	12,269	13,150	14,094
CUSTOMER COSTS												
EQUIPAGE		4,401	4,489	4,579	4,670							
NON-COMPLIANCE[3]	-	-	-	-	-	1,144	1,050	941	840	724	620	501
NAV CANADA COSTS[4]												
ANNUAL O&M	-	-	-	-	-	1,973	2,012	2,053	2,094	2,136	2,178	2,222
DEPRECIATION[5]	-	-	-	-	-	1,713	1,713	1,713	1,713	1,713	1,713	1,713
INTEREST[6]	-	40	115	619	1,315	1,490	1,388	1,285	1,182	1,079	976	874
TOTAL	-	40	115	619	1,315	5,176	5,113	5,050	4,989	4,928	4,868	4,809
BENEFITS LESS COSTS	-	(4,441)	(4,604)	(5,198)	(5,985)	2,844	3,708	4,639	5,592	6,617	7,662	8,784
CUMULATIVE NET BENEFITS	-	(4,441)	(9,045)	(14,242)	(20,227)	(17,383)	(13,675)	(9,036)	(3,443)	3,174	10,836	19,619

YEAR[1]	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	Future Years	TOTAL
CUSTOMER BENEFITS[2]															
NAT	14,671	15,686	16,704	17,789	18,689	19,635	20,628	21,672	22,769	23,921	25,131	26,403	27,739	-	**349,977**
PAC	401	433	463	495	520	546	574	603	633	665	699	734	771	-	**9,595**
TOTAL	15,073	16,118	17,167	18,284	19,209	20,181	21,202	22,275	23,402	24,586	25,830	27,137	28,510	-	**359,573**
CUSTOMER COSTS															
EQUIPAGE															**18,139**
NON-COMPLIANCE[3]	399	282	224	159	167	175	184	193	203	213	224	236	248	-	**8,729**
NAV CANADA COSTS[4]															
ANNUAL O&M	2,266	2,312	2,358	2,405	2,453	2,502	2,552	2,603	2,655	2,709	2,763	2,818	2,874	-	**47,940**
DEPRECIATION[5]	1,713	1,713	1,713	1,713	1,713	1,713	1,713	1,713	827	827	827	827	827	-	**29,832**
INTEREST[6]	771	668	565	463	378	311	450	685	720	670	621	571	521	(0)	**17,755**
TOTAL	4,750	4,693	4,636	4,581	4,544	4,526	4,715	5,001	4,203	4,206	4,211	4,216	4,223	(0)	**95,527**
BENEFITS LESS COSTS	9,923	11,143	12,306	13,544	14,498	15,480	16,302	17,080	18,996	20,166	21,395	22,685	24,039	0	237,178
CUMULATIVE NET BENEFITS	29,543	40,686	52,992	66,537	81,034	96,514	112,816	129,897	148,893	169,059	190,454	213,139	237,178	237,178	

1 Calendar Year.

2 Annual 'NAT' & 'PAC' Customer Benefits are assumed to increase with traffic by 4% per year from 2003 to 2020, and by 3% per year thereafter, considering 2004 ICAO North Atlantic Forecasts.
NAT is North Atlantic Traffic; Benefits from random routes include fuel savings and 50% of Maintenance Cost per minute as per Aviation Daily Reports (2003).
PAC is Asia Pacific Traffic; Assumes altitude fuel savings only, at 3.0 and 5.4 additional litres of fuel per minute for 2,000' and 4,000' off altitude, respectively.
Customer benefits begin in 2010 at 100% of the projected annual benefit.
Fuel savings are based on fuel price of $0.4 (CDN) per litre.

3 'NON-COMPLIANCE' represents the cost of an additional fuel burn for aircraft forced to operate below preferred altitude because they choose not to be ADS-B equipped.

4 'NAV CANADA COSTS' include Communications, re-sectorization and ADS-B display integration.

5 'DEPRECIATION' is based on 15 years useful life from date of ADS-B commissioning and continues beyond re-investment.

6 'INTEREST' is based on cash outlay and undepreciated asset value in mid year using a rate of 6% per year. Sensitivity is performed at different rates.

7 Comparison of benefits and costs are in current dollars; inflation is included at 2% per year.

Table 10B: Option 2 – Comparison of Benefits and Costs of Using ADS-B "out" to Expand Surveillance Over the Hudson Bay ($000s Current CDN) – Discounted Cash Flow

	YEAR[1]																									Future	
	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	Years	TOTAL
CUSTOMER BENEFITS[2]																											
NAT	-	-	-	-	-	8,942	9,627	10,363	11,130	11,952	12,807	13,721	14,671	15,686	16,704	17,789	18,689	19,635	20,628	21,672	22,769	23,921	25,131	26,403	27,739	-	**349,977**
PAC	-	-	-	-	-	223	244	268	291	317	344	372	401	433	463	495	520	546	574	603	633	665	699	734	771	-	**9,595**
TOTAL	-	-	-	-	-	9,164	9,871	10,630	11,421	12,269	13,150	14,094	15,073	16,118	17,167	18,284	19,209	20,181	21,202	22,275	23,402	24,586	25,830	27,137	28,510	-	**359,573**
CUSTOMER COSTS																											
EQUIPAGE		4,401	4,489	4,579	4,670																						**18,139**
NON-COMPLIANCE[3]	-	-	-	-	-	1,144	1,050	941	840	724	620	501	399	282	224	159	167	175	184	193	203	213	224	236	248	-	**8,729**
NAV CANADA COSTS[4]																											
ANNUAL O&M	-	-	-	-	-	1,973	2,012	2,053	2,094	2,136	2,178	2,222	2,266	2,312	2,358	2,405	2,453	2,502	2,552	2,603	2,655	2,709	2,763	2,818	2,874	-	**47,940**
CAPITAL[5]	-	1,326	1,183	15,618	7,567	-	-	-	-	-	-	-	-	-	-	-	614	559	7,522	3,717	-	-	-	-	(8,275)	-	**29,832**
TOTAL	-	1,326	1,183	15,618	7,567	1,973	2,012	2,053	2,094	2,136	2,178	2,222	2,266	2,312	2,358	2,405	3,067	3,061	10,074	6,321	2,655	2,709	2,763	2,818	(5,400)	-	**77,772**
ANNUAL NET BENEFITS	-	(5,727)	(5,672)	(20,197)	(12,238)	6,047	6,809	7,637	8,487	9,409	10,352	11,370	12,407	13,525	14,585	15,720	15,975	16,945	10,944	15,760	20,543	21,664	22,843	24,083	33,663	-	**254,934**
CUMULATIVE NET BENEFITS	-	(5,727)	(11,399)	(31,596)	(43,834)	(37,786)	(30,977)	(23,340)	(14,853)	(5,444)	4,907	16,278	28,685	42,209	56,794	72,514	88,489	105,433	116,377	132,137	152,681	174,344	197,187	221,271	254,934	254,934	
PRESENT VALUE																											
DISCOUNT FACTOR[6]	0.916	0.864	0.815	0.769	0.725	0.684	0.646	0.609	0.575	0.542	0.511	0.482	0.455	0.429	0.405	0.382	0.361	0.340	0.321	0.303	0.286	0.269	0.254	0.240	0.226		
CUSTOMER BENEFITS	-	-	-	-	-	6,272	6,374	6,475	6,563	6,651	6,726	6,800	6,861	6,922	6,955	6,988	6,926	6,864	6,803	6,743	6,683	6,624	6,565	6,507	6,449	-	**133,752**
CUSTOMER EQUIPAGE	-	3,803	3,659	3,521	3,388	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**14,371**
CUSTOMER NON-COMPLIANCE	-	-	-	-	-	783	678	573	483	393	317	242	182	121	91	61	60	60	59	59	58	58	57	57	56	-	**4,445**
ANNUAL O&M	-	-	-	-	-	1,350	1,299	1,250	1,203	1,158	1,114	1,072	1,032	993	955	919	885	851	819	788	758	730	702	676	650	-	**19,205**
CAPITAL	-	1,146	965	12,011	5,490	-	-	-	-	-	-	-	-	-	-	-	221	190	2,414	1,125	-	-	-	-	(1,872)	-	**21,690**
NET PRESENT VALUE (NPV)	-	**(4,948)**	**(4,624)**	**(15,532)**	**(8,878)**	**4,139**	**4,396**	**4,652**	**4,877**	**5,101**	**5,294**	**5,486**	**5,648**	**5,808**	**5,908**	**6,008**	**5,760**	**5,764**	**3,512**	**4,771**	**5,867**	**5,837**	**5,806**	**5,775**	**7,615**	-	**74,040**
CUMULATIVE NPV	-	(4,948)	(9,572)	(25,104)	(33,982)	(29,843)	(25,447)	(20,795)	(15,918)	(10,817)	(5,523)	(37)	5,611	11,419	17,327	23,335	29,095	34,858	38,370	43,141	49,008	54,844	60,651	66,425	74,040	74,040	

1 Calendar Year.

2 Annual 'NAT' & 'PAC' Customer Benefits are assumed to increase with traffic by 4% per year from 2003 to 2020, and by 3% per year thereafter, considering 2004 ICAO North Atlantic Forecasts.

NAT is North Atlantic Traffic; Benefits from random routes include fuel savings and 50% of Maintenance Cost per minute as per Aviation Daily Reports (2003).

PAC is Asia Pacific Traffic; Assumes altitude fuel savings only, at 3.0 and 5.4 additional litres of fuel per minute for 2,000' and 4,000' off altitude, respectively.

Customer benefits begin in 2010 at 100% of the projected annual benefit.

Fuel savings are based on fuel price of $0.4 (CDN) per litre.

3 'NON-COMPLIANCE' represents the cost of an additional fuel burn for aircraft forced to operate below preferred altitude because they choose not to be ADS-B equipped.

4 'NAV CANADA COSTS' include Communications, re-sectorization and ADS-B display integration.

5 Residual Value on 'CAPITAL' (displayed in parentheses) is calculated as total investment times proportion of economic life remaining at end of benefits stream.

6 'DISCOUNT FACTOR' is mid-year using a Discount Rate of 6%. Sensitivity is performed at different rates.

7 Comparison of benefits and costs are in discounted dollars using a nominal discount rate; inflation is included at 2% per year.

6.0 Sensitivity Analysis

6.1 Introduction

6.1.1 This sensitivity analysis illustrates the impact of changes in assumptions on the Business Case results. Only the discounted cash flow approach was used for the sensitivity analysis, as it accounts for the time value of money.

6.2 Sensitivity Parameters Affecting ADS-B "out" – Option 2 only

6.2.1 A factor affecting the net (present value) benefit of an ADS-B "out" option is the aircraft equipage cost. In order to estimate the aircraft equipage cost, the number of aircraft that would have to be equipped and the cost of equipping must be determined.

6.2.2 The number of aircraft that would still have to be equipped at the time of ADS-B "out" implementation (over and above those already "naturally" equipped) was estimated based on the 2,000 unique airframes operating over the Hudson Bay in 2004, and the MITRE Corporation GPS and Mode S 1090ES forecasts. GPS represents the most significant component of the ADS-B "out" equipage requirements.

Forecast Level of GPS Use – is affected by:

a) Current GPS equipage – this is estimated to be between 25 to 40 percent presently.
b) Fleet replacement rate – new Boeing and Airbus aircraft are GPS equipped as standard equipment.
c) European Mandate – requires Mode S 1090ES, but does not require GPS.
d) Implementation year for ADS-B "out" – because all of the aircraft flying above FL290 over Hudson Bay would have to be equipped with ADS-B "out" avionics to ensure safety and realize the full random route benefits of expanded surveillance.
e) Flight frequency of aircraft operating over the Hudson Bay – the less frequent the less likely to equip.
f) Other benefits and areas where GPS can benefit the operator.
g) Airline Business Case for GPS equipage – do the benefits of equipping outweigh the costs of equipping?

6.2.3 The cost of equipping an aircraft with GPS and Mode S 1090ES was also determined based on MITRE avionics cost information prepared for the FAA Safe Flight 21 Program in 2004.

Retrofit Cost per Aircraft – is affected by:

a) Existing avionics and age of the aircraft – older aircraft are more costly to retrofit.
b) Equipment Purchased – variations in cost due to manufacturer, features selected, and number purchased. ADS-B "out" requires a GPS sensor at minimum, but airlines may choose to equip with MMR at higher cost but this is not directly a requirement of ADS-B "out" equipage.

6.2.4 While the cost to retrofit aircraft with ADS-B "out" avionics is a one-time cost incurred because of Hudson Bay, and therefore was attributed 100% to the Hudson Bay project in the baseline option, it is recognized that the benefits can extend beyond this area. On this basis, the attribution of equipage costs was also assessed at 75%.

Proportion of Equipage Cost Attributable to Hudson Bay – can be affected by the benefits equipped aircraft can accrue elsewhere, such as:

a) Airspace beyond Hudson Bay that may be designated ADS-B "out", such as Australia, southeastern U.S and Oceanic airspace or airspace with sparse ground-based navigation aids.
b) GPS approaches and other navigational benefits.
c) Improved situational awareness in all airspace where Air Traffic Control (ATC) has capability to display ADS-B "out" equipped aircraft, including airport surface surveillance and visual approaches.

6.2.5 The proportion of aircraft that do not equip with ADS-B "out" affects the number of flights that sustain fuel penalties from avoiding the ADS-B "out" exclusionary airspace and fly at less than preferred altitudes. It was assumed that NAT fuel penalties of 5% and PAC fuel penalties of 2.3% would be incurred. NAT traffic typically operates at relatively higher altitudes over the Hudson Bay than PAC traffic and would have to decrease altitude by between 4,000' and 10,000' range. The PAC flights would likely have to decrease altitude by between 2,000 and 5,000 feet.

Proportion of Flights That Sustain Fuel Penalty Costs to Avoid ADS-B "out" Airspace is affected by:

a) Infrequency of operating over the Hudson Bay – may not be worthwhile to equip.
b) Altitude penalty may be less than the cost to equip, which is likely for PAC traffic.
c) Age of aircraft or prohibitive cost of equipage.

6.3 ADS-B “out” Options Analyzed

6.3.1 The following seven ADS-B “out” options were analyzed and are presented in Table 11:

A1 - Baseline ADS-B “out” option with 75% equipage cost attributed to Hudson Bay project;

A2 - ADS-B “out” in 2010, where 90% flights benefit from ADS-B “out”, 10% flights incur fuel penalty, 22% aircraft incur cost to equip, with 100% equipage cost attributed to Hudson Bay project;

A3 - ADS-B “out” in 2010, where 90% flights benefit from ADS-B “out”, 10% flights incur fuel penalty, 22% aircraft incur cost to equip, with 75% equipage cost attributed to Hudson Bay project;

A4 - ADS-B “out” in 2010, where 90% flights benefit from ADS-B “out”, 10% flights incur fuel penalty, 0% aircraft incur cost to equip;

A5 - ADS-B “out” Phased-in Implementation – at FL350 and above for 2010 – 2015 and FL290 and above for 2016 thereafter, with 100% equipage cost attributed to Hudson Bay project;

A6 - ADS-B “out” Phased-in Implementation – at FL350 and above for 2010 – 2015 and FL290 and above for 2016 thereafter, with 75% equipage cost attributed to Hudson Bay project;

A7 - ADS-B “out” in 2015, where 100% flights benefit from ADS-B “out”, 0% flights incur fuel penalty, 0% aircraft incur cost to equip.

Table 11: Sensitivity Analysis of ADS-B "out" Options Compared to Baseline Options (using 6% Discount Rate)

	Option Description	Net Present Value ($millions)	Compared to Radar ($millions)
	Baseline Options		
O1	**Radar Baseline Option 1: Benefits Start in 2010**	**92.4**	
O2	**ADS-B "out" Baseline Option 2: Benefits Start in 2010 FL290 and above, 10% Incur Equipage Cost, 90% Flts Benefit, 10% Flts Penalized, Attribute 100% of Equipage Cost**	**74.0**	**(18.4)**
	Sensitivity Analysis Options		
A1	ADS-B "out" in 2010 FL290 and above, 10% Incur Equipage Cost, 90% Flts Benefit, 10% Flts Penalized, Attribute 75% of Equipage Cost	77.6	(14.8)
A2	ADS-B "out" in 2010 FL290 and above, 22% Incur Equipage Cost, 90% Flts Benefit, 10% Flts Penalized, Attribute 100% of Equipage Cost	56.1	(36.3)
A3	ADS-B "out" in 2010 FL290 and above, 22% Incur Equipage Cost, 90% Flts Benefit, 10% Flts Penalized, Attribute 75% of Equipage Cost	63.9	(28.5)
A4	ADS-B "out" in 2010 FL290 and above, 0% Incur Equipage Cost, 90% Flts Benefit, 10% Flts Penalized	89.0	(3.4)
A5	ADS-B "out" in 2010-2015 FL350 and above, FL 290 and above 2016 thereafter, 8% Incur Equipage Cost, 66% Flts Benefit, 14% Flts Penalized, 20% not Impacted, Attribute 100% of Equipage Cost	59.9	(32.5)
A6	ADS-B "out" in 2010-2015 FL350 and above, FL 290 and above 2016 thereafter, 8% Incur Equipage Cost, 66% Flts Benefit, 14% Flts Penalized, 20% not Impacted, Attribute 75% of Equipage Cost	63.5	(28.9)
A7	ADS-B "out" in 2015 FL290 and above, 0% Incur Equipage Cost, 100% Flts Benefit, 0% Flts Penalized (assessed to 2029)	73.7	(18.7)

6.4 Sensitivity Analysis Results Affecting ADS-B “Out” Surveillance Options

6.4.1 When comparing the ADS-B “out” options where the equipage cost assumptions are affected (sensitivity options A1, A2, A3 and A4 listed in Table 11), it is noted that:

a) The NPV decreases as the percentage of aircraft assumed to incur equipage cost (i.e. equip for ADS-B ”out”) increases;
b) The NPV increases as the percentage of equipage cost attributable to Hudson Bay decreases.

6.4.2 The ADS-B “out” options with a “phased-in” schedule (options A5 and A6) do not perform as well as the baseline ADS-B “out” option. The slight reduction in equipage cost (8% versus 10%) is insufficient to offset the much larger decrease in flights that benefit (66% versus 90%) for the initial five years of the benefits stream.

6.4.3 The last option, A7, assuming 100% “natural” equipage in 2015, yields an NPV comparable to the baseline ADS-B “out” option. Delaying implementation increases the cumulative benefits due to higher traffic volumes. However, this option includes 15 rather than 20 years of benefits.

6.5 Sensitivity Parameters Affecting Both Radar and ADS-B “out” Options

6.5.1 For both surveillance options, the total net benefit is affected by the expected growth in air traffic and the price of fuel. North Atlantic Traffic (NAT) represents about 80 percent of the traffic transiting the Hudson Bay airspace. Therefore, it is appropriate to apply the established forecasts for the NAT to this analysis. The most recent forecasts prepared by ICAO (May 2004) indicate an average baseline growth rate of 4.0 percent per year. It was assumed that traffic over Hudson Bay would increase by 4% per year from 2003 to 2020 and by 3% per year thereafter. The impact of lowering the traffic growth rates to 3% per year from 2003 to 2020 and to 2% thereafter was assessed.

6.5.2 The Baseline options assumed a fuel price of $0.40 CDN per litre and is consistent with the fuel price indicated in Transport Canada’s assumptions report for its most recent air traffic forecasts.

6.5.3 Transport Canada projects fuel price to remain stable or increase slightly, in constant year dollars over the period 2003 to 2017. Given uncertainty in supply and the continued threats from the Middle-East, it is unlikely that fuel price will decrease from current levels. As a result, only one fuel price scenario was assessed – namely, a higher fuel price of $0.45 CDN over the analysis time frame.

6.5.4 The baseline options assumed a discount rate of 6%. In order to assess the impact of greater uncertainty with respect to the future benefits and costs of radar or ADS-B “out”, a higher discount rate of 10% was tested.

6.6 Sensitivity Analysis Results Affecting Both Surveillance Options

6.6.1 The sensitivity results are shown in Table 12. It is observed that if lower than expected growth in traffic is realized, the net benefits of both surveillance options decrease proportionally. The net benefits of the radar baseline would exceed those of the ADS-B “out” 2010 baseline option by approximately $17.5 million in this circumstance. Similarly, if the fuel prices were to increase to $0.45 in real terms, the overall effect would be a corresponding increase in the net benefits of both baseline surveillance options. The result would be that the net benefits of the radar option would exceed the ADS-B ”out” option by $19.4 million. Increasing the discount rate decreases the NPV for both options.

Table 12: Sensitivity Analysis

	Option Description	Net Present Value ($millions)	Compared to Radar ($millions)
	Radar Options		
O1	**Radar Baseline Option: Benefits Start in 2010**	**92.4**	
A8	Lower Traffic Growth Rate (from 4% per year to 3% per year)	72.4	
A9	Higher Fuel Price (from $0.40 per litre to $0.45 per litre)	106.1	
A10	Higher Discount Rate (from 6% per year to 10% per year)	43.2	
	ADS-B "out" Options		
O2	**ADS-B "out" Baseline Option: Benefits Start in 2010 FL290 and above, 10% Incur Equipage Cost, 90% Flts Benefit, 10% Flts Penalized, Attribute 100% of Equipage Cost**	**74.0**	**(18.4)**
A11	Lower Traffic Growth Rate (from 4% per year to 3% per year)	54.9	(17.5)
A12	Higher Fuel Price (from $0.40 per litre to $0.45 per litre)	86.7	(19.4)
A13	Higher Discount Rate (from 6% per year to 10% per year)	31.0	(12.2)

7.0 Conclusions

7.1.1 Based on the results of this analysis there is a positive Business Case for the expansion of surveillance based on either radar or ADS-B “out”. The total net (present value) benefits of the radar baseline option exceed those of the ADS-B “out” baseline option by $18.4 million. This result is also supported by the Sensitivity Analysis.

7.1.2 There are higher risks and uncertainties of ADS-B “out”, compared with radar, which represents mature and proven technology.

7.1.3 It is also recognized that the radar option would benefit all customers without the need for additional avionics equipage. From a Business Case Analysis perspective, radar is a better choice than ADS-B “out” for expanding surveillance over the Hudson Bay for the 2005 through 2029 timeframe.

APPENDIX A: LIST OF ACRONYMS

Acronym	Description
ACC	Area Control Centre
ADS	Automatic Dependent Surveillance
ADS-B	Automatic Dependent Surveillance-Broadcast
ADS-C	Automatic Dependent Surveillance-Contract
ALPA	Airline Pilots Association
ASTRA	Australian Strategies Air Traffic
ATM	Air Traffic Management
ATS	Air Traffic Services
CAATS	Canadian Automated Air Traffic System
CASA	Civil Aviation Safety Authority (Australia)
CDN	Canadian Currency ($)
CDTI	Cockpit Display of Traffic Information
DCPC	Direct Controller Pilot Communication
DME	Distance Measuring Equipment
EHS	Enhanced Surveillance Mode S
FAA	Federal Aviation Administration
FANS	Future Air Navigation system
FDAAS	Flight Data Acquisition Analysis System
FIR	Flight Information Region
FL	Flight Level
FMS	Flight Management System

Acronym	**Description**
GPS	Global Positioning System
HVAC	Heating, Ventilating and Air Conditioning
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
IFR	Instrument Flight Rules
IPU	Interruptible Power Unit
ISAT	Integrated Sector Analysis Tool
LAP	Lower Airspace Project (Australia)
MMR	Multi-Modal Receiver
MSSR	Mode-S Monopulse Secondary Surveillance Radar
NARDS	NAV CANADA Auxiliary Radar Display System
NAT	North Atlantic Traffic
nm	nautical miles
NDB	Non-Directional Beacon
NPV	Net Present Value
NSP	Navigation Systems Panel
O&M	Operating and Maintenance
PAC	Pacific
PALs	Peripheral Air Links
RDPSR	Radar Data Processing System Rehost
P-RNAV	Precision Area Navigation
RTIS	Radar Target Information Server
RVSM	Reduced Vertical Separation Minima

Acronym	Description
SARPs	Standards and Recommended Practices
SASP	Separation and Safety Panel
SUPUs	Static Uninteruptible Power Units
TC	Transport Canada
VFR	Visual Flight Rules
VHF	Very High Frequency