U.S. Department
Of Transportation

**FEDERAL AVIATION
ADMINISTRATION**

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FINAL REGULATORY IMPACT ANALYSIS

FINAL RULE

AUTOMATIC DEPENDENT SURVEILLANCE – BROADCAST (ADS-B) OUT PERFORMANCE REQUIREMENTS TO SUPPORT AIR TRAFFIC CONTROL SERVICE

(TITLE 14, CODE OF FEDERAL REGULATIONS, PART 91)

**Office of Aviation Policy and Plans
Regulatory Analysis Division**

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1.0 Executive Summary

The solution to managing growth in the National Airspace System (NAS) is the Next Generation Air Transportation System, or NextGen, which will assure the safe and efficient movement of people and goods as demand increases. NextGen will use technology to allow precise surveillance, permit accurate real-time communication, and vastly improve situational awareness.

ADS-B is the chosen new technology for surveillance in the NextGen system. It is a key component in achieving many of the goals set forth in the NextGen Integrated Plan. ADS-B is a critical component of NextGen and is being developed to transform today's radar-based aviation system to handle increased aviation demand. By itself, ADS-B presents significant benefits, but as a component of the NextGen system, the benefits will substantially increase.

We review the following three alternatives for surveillance in this analysis:

- Baseline radar – Maintain the current radar-based surveillance system and replace radar facilities when they wear out.
- ADS-B – Aircraft operators equip to meet performance requirements required by the rule and the FAA provides surveillance services based on downlinked aircraft information.
- Multilateration – The FAA provides surveillance using multilateration.

The estimated costs of the final rule are the costs of ADS-B Out incremental to radar. The estimated incremental cost of the ADS-B Out rule ranges from a low of $3.3 billion ($2.2 billion at 7% present value) to a high of $7.0 billion dollars ($4.1 billion at 7% present value). These costs include costs to the government, as well as to the aviation industry and other users of the airspace, to deploy ADS-B and are incremental to maintaining surveillance via current technology (radar). The aviation industry will begin incurring costs for avionics equipage in 2012 and will incur total costs ranging from $2.5 billion ($1.4 billion at 7% present value) to $6.2 billion ($3.3 billion at 7% present value) with an estimated midpoint of $4.4 billion ($2.3 billion at 7% present value) from 2012 to 2035. The estimated compliance cost of affected foreign operated airplanes operating in the United States is about $5.6 million to $134 million, with a midpoint around $70 million.[1] These estimated foreign operator costs are not included in this analysis.

The estimated quantified benefits of the rule range from $6.8 billion ($2.1 billion at 7% present value) to $8.5 billion ($2.7 billion at 7% present value) and primarily result from savings in fuel, operating cost and time, the net reduction in CO_2 emissions from more efficient flights and the consumer surplus associated with the additional flights accommodated because of the rule. The table below summarizes costs and benefits discounted by 7%.

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[1] Official Airlines Guide.

Table E.1 Summary of Costs and Benefits in Billions of 2009 Dollars Discounted by 7%

	Multilateration	Radar Baseline	ADS-B out		Difference between ADS-B out low costs and Radar	Difference between ADS-B out high costs and Radar	Midpoint [3]
FAA Ground Costs	$1.87	$1.25	$2.05		$0.80	$0.80	$0.80
			Low	High	Low Cost	High Cost	
Avionics Costs			$1.35	$3.31	$1.35	$3.31	$2.34
Total Cost	$1.87	$1.25	$3.40	$5.36	$2.15	$4.11	$3.14
			Low	High			
Total Benefits			$2.09	$2.74			
Gulf High Altitude Operations			$0.72	$0.72			
Delay Savings			$0.46	$0.46			
Additional Flights Accommodated			$0.12	$0.12			
Optimal and Direct Routing			$0.14	$0.14			
Improved En Route Conflict Probe Performance			$0.08	$0.52			
More Efficient Metering (improved TMA accuracy)			$0.40	$0.40			
Increased ability to perform OPD			$0.86	$0.86			
Value of Reduced CO2 Emissions			$0.02	$0.24			
					High benefit	Low Benefit	
Total Incremental Benefits [1], [2]			$2.09	$2.74	$2.74	$2.09	$2.41
					High benefit/low cost	Low benefit/high cost	
Net Benefits					$0.59	($2.02)	($0.73)

[1] Total Incremental Benefits are Relative to the Radar Baseline
[2] The benefits of radar are not estimated. We assume they far exceed the cost of radar. We look at the benefits of ADS-B relative to radar.
[3] The midpoint of the high and low

2.0 Introduction

Automatic Dependent Surveillance-Broadcast (ADS-B) is an advanced surveillance technology that enables equipped aircraft to periodically broadcast their identification, current position, altitude, and velocity, through an onboard transmitter, which can be received by ADS-B ground stations and by other aircraft appropriately equipped to receive this information. ADS–B Out provides air traffic controllers with real-time position information that is, in most cases, more accurate than the information available with current radar-based systems. With more accurate information, ATC will be able to position and separate aircraft with improved precision and timing.

The part of the ADS-B system that broadcasts various aircraft information is called "ADS-B Out". The part of the system that provides aircraft with the ability to receive other aircrafts' ADS-B information and other aeronautical information is called "ADS-B In". The rule mandates ADS-B Out for operations in certain airspace.

The rule will require most aircraft to be equipped with avionics equipment that meets ADS-B Out performance standards. The rule will apply to aircraft operating in Class A, B, and C airspace, and in the Class E airspace at and above 10,000 ft MSL over the 48 contiguous United States and the District of Columbia, excluding the airspace at and below 2,500 ft above ground level (AGL). The rule also applies to all airspace within 30 nautical miles (NM) of an airport listed in Title 14 of the Code of Federal Regulations (14 CFR), Part 91, Appendix D, from the surface upward to 10,000 feet mean sea level (MSL) and all airspace above the ceiling and within the lateral boundaries of a Class B or Class C airspace area designated for an airport upward to 10,000 feet MSL. Additionally, the rule will apply to aircraft operating in Class E airspace at and above 3,000 feet MSL over the Gulf of Mexico from the coastline of the Untied States out to 12 nautical miles. The rule mandates a compliance date of 2020. The FAA has entered into service contracts with vendors who will provide an ADS-B ground surveillance infrastructure that includes the provision of Flight Information Services-Broadcast (FIS-B) and Traffic Information Services - Broadcast (TIS-B) in 2013. If these services are not available by that time, the FAA will consider extending the compliance date of the final rule. As the ground component of the ADS-B infrastructure becomes mature, the agency plans on decommissioning selected noncritical secondary surveillance radar sites. The agency plans on retaining approximately 50% of the current secondary radar sites and 100% of the existing primary radar systems that will serve as a redundant backup system in the event of a large scale ADS-B service disruption.[2] The rule will not mandate ADS-B In equipment, but the service contractor will provide ground services to enable ADS-B In.

This analysis presents estimates of the costs and incremental (relative to a radar alternative) benefits of the rule (the ADS-B Out scenario) as well as a second alternative - multilateration. The costs of a baseline scenario assumes that we continue to use and replace radar without further supplementing existing radar service and without requiring ADS-B Out or providing services for ADS-B. We also look at the costs of the alternative approach of using multilateration rather than radar or ADS-B Out.

Table 1 summarizes the substantive differences between the proposed rule and the final rule. We also made editorial changes and clarifications as explained in the preamble.

[2] After exploring various back-up alternatives, the FAA believes maintaining a smaller set of secondary radar systems provides the greatest level of certainty. This is because FAA has long-standing experience with secondary surveillance radar systems and they are already in place.

Table 1
Substantive Differences between the Proposed Rule and the Final Rule

Issue Area	The NPRM—	The final rule—	Effects on Costs/Benefits
Technical Standard Order	Proposed performance standards as defined in TSO–C166a (1090 MHz ES) or TSO–C154b (UAT).	Requires performance standards as defined in TSO–C166b (1090 MHz ES) or TSO–C154c (UAT).	
Airspace	Proposed requiring all aircraft above FL240 to transmit on the 1090 MHz ES broadcast link.	Requires all aircraft in Class A airspace (FL180 and above) to transmit on the 1090 MHz ES broadcast link.	Possible minimal increase in costs
	Proposed ADS–B performance standards for operations in all Class E airspace at and above 10,000 feet MSL.	Requires ADS–B performance standards for operations in Class E airspace at and above 10,000 feet MSL, excluding the airspace at and below 2,500 feet AGL.	Possible decrease in costs
NAC_P	Proposed a $NAC_P \geq 9$, which provides navigation accuracy < 30 meters.	Requires $NAC_P < 0.05$ NM. ($NAC_P \geq 8$)	No effect on ADS-B Out benefits
SIL	Proposed a SIL of 2 or 3	Requires an SDA of 2 or 3	
		Requires a SIL of 3	
Antenna Diversity	Proposed antenna diversity in all airspace specified in the rule.	Does not require antenna diversity.	No effect on ADS-B Out benefits, lower GA costs
Total Latency	Proposed latency in the position source < 0.5 seconds and latency in the ADS–B source < 1 second.	Requires uncompensated latency ≤ 0.6 seconds and maximum total latency ≤ 2.0 seconds.	
Message Elements	Proposed a broadcast message element for "receiving ATC services."	Does not require a broadcast message element for "receiving ATC services."	
An ability to turn off ADS–B Out	Proposed that the pilot be able to turn off ADS–B transmissions if directed by ATC.	Does not require the pilot be able to disable or turn off ADS–B transmissions.	

2.1 The Advantages of ADS-B Over Radar

According to operational evaluations, ADS-B provides improved accuracy over radar in almost every air traffic scenario. The ADS-B required by the rule is capable of achieving accuracy to within 30 meters, a capability exceeding any existing radar. ADS-B also provides more timely information updates than conventional radar. Unlike radar, the accuracy and integrity of ADS-B Out is uniform and consistent throughout the service areas. Therefore, the ability of air traffic control to accurately identify and locate aircraft that are further away from air traffic control facilities will be better than radar. ADS-B Out also provides more information to air traffic controllers, such as aircraft dimensions and aircraft heading, than the current system does, especially in non-radar areas. Furthermore, ADS-B position reports are not subject to interference (clutter) from terrain, ground structures, flocks of birds, or thunderstorms; whereas, radar is.

2.2 The ADS-B Out Final Rule

ADS-B Out will provide enhanced surveillance in areas where secondary surveillance radar (SSR) capability currently exists as well as over the Gulf of Mexico and areas in Alaska. The FAA believes that it is reasonable to require that aircraft meet the performance necessary for ADS-B Out for operation in airspace that currently requires transponders. With this rule, the FAA adds Section 91.225 to 14 CFR which requires ADS–B Out for operations in Class A, B, and C airspace. In addition, the rule requires that aircraft meet ADS-B Out performance requirements to operate in the Gulf of Mexico from the coastline of the United States out to 12 NM at and above 3,000 feet MSL. Similar to the transponder requirements, ADS-B Out also will be required within 30 NM of an airport listed in 14 CFR Part 91, Appendix D, from the surface upward to 10,000 feet MSL. The rule will permit aircraft not originally certificated with an engine-driven electrical system or not subsequently certified with such a system installed (such as a balloon or glider) to conduct operations without ADS-B Out under ATC authorization in the airspace within 30 NM of an airport listed in Appendix D if the operations are conducted: (1) outside any Class A, Class B, or Class C airspace area; and (2) below the altitude of the ceiling of a Class B or Class C airspace area designated for an airport or 10,000 feet MSL, whichever is lower. The rule also requires aircraft meet ADS-B Out performance requirements to operate in Class E airspace within the 48 contiguous states and the District of Columbia at and above 10,000 feet MSL, excluding the airspace at and below 2,500 feet above the surface.

Generally, Class A airspace is that airspace from 18,000 feet MSL to and including FL 600, including the airspace overlying the waters within 12 NM of the coastline of the United States. This rule will not require aircraft to meet the ADS-B Out performance standards for aircraft that operate in airspace beyond 12 NM from the U.S. coastline and do not enter U.S. domestic airspace.[3]

Class B airspace area locations shall include at least one primary airport around which the Class B airspace area is designated. The lateral limits should be initially designed in a circular configuration centered on the primary airport. The outer limits of the airspace shall not exceed a 30 NM radius from the primary airport and will generally be divided into three concentric circles: an inner 10 NM radius, a middle 20 NM radius, and an outer 30 NM radius. The inner 10 NM radius may be subdivided based on operational needs,

[3] There are numerous Offshore Airspace Areas that are designated as Class A airspace and the boundaries of those airspace areas extend beyond 12 NM from the coastline of the U.S. and into international waters. Under agreement with ICAO, the U.S. provides ATC services in these areas and may designate the airspace accordingly in order to indicate to pilots the type of ATC services that may be provided.

runway alignment, adjacent regulatory airspace, or adjacent airports. The vertical limits of a Class B airspace normally should not exceed 10,000 feet MSL. The inner 10 NM area shall normally extend from the surface to the upper limits of the airspace. The floor of the area between 10 and 20 NM will normally have a floor between 2,800 and 3,000 feet above airport elevation. This floor shall remain constant for that segment, but may be adjusted considering terrain and adjacent regulatory airspace. The floor of the area between 20 and 30 NM will normally be between 5,000 and 6,000 feet above the airport elevation. Class B airspace areas generally are configured and appear as an upside-down wedding cake and surround the nation’s busiest airports in terms of airport operation or passenger enplanements. The configuration of each Class B airspace area is individually tailored and is designed to contain all published instrument procedures. An ATC clearance is required for all aircraft to operate in the airspace area, and all aircraft that are so cleared receive separation services within the airspace. Under this rule, ADS-B Out will be required for aircraft operating in this airspace. Class B airspace areas experience a high volume of aircraft operations and complex transitions from the en route to the terminal environment. Consequently, ADS-B Out can result in better ATC surveillance and situational awareness for controllers and pilots in these areas.

Generally, Class C airspace lateral limits are initially designed as two circles centered on the airport reference point. The inner circle is a 5 NM radius, and the outer circle is a 10 NM radius. The vertical limits of a Class C airspace should be 4,000 ft above the primary airport’s field elevation (charted in MSL). The airspace within the 5 NM circles shall extend down to the surface and the airspace between the 5 and the 10 NM circles shall extend no lower than 1,200 ft AGL. Although the configuration of each Class C area is individually tailored, the airspace lateral and vertical limits are in accordance with the information above, to the extent possible. For a site to be considered for Class C airspace designation, the airport must be serviced by an operational airport traffic control tower and a radar approach control; and either an annual instrument operations count of 75,000 at the primary airport, an annual instrument operations count of 100,000 at the primary and secondary airports in the terminal area hub, or an annual count of 250,000 emplaned passengers at the primary airport. Additionally, each person intending to operate an aircraft within Class C airspace must establish two-way radio communications with the ATC facility providing air traffic services prior to entering the airspace and must maintain those communications while within the airspace.

2.3 Market Failure

Given the benefits that ADS-B equipage will generate, it might initially appear that users of the system will have economic incentives to equip with ADS-B even in the absence of a federal requirement to do so. However, it is to each operator’s advantage to wait until everyone else has equipped or at least until each user knows that all other users will equip within a defined time horizon because full benefits of ADS-B will not be realized until a sizable percent of aircraft are equipped within a given airspace. Specifically, stakeholder analysis of whether to equip voluntarily will not take into account positive externalities that equipage will have on other stakeholders. These externalities create a “last mover advantage” because users who equip prior to other users will have to wait longer and face greater uncertainty before seeing a full return on their investment. As a result, users will have incentives to delay ADS-B equipage, and there is a significant risk that the aviation system will never achieve the critical mass of ADS-B-equipped users that is needed to generate benefits. The rule will correct this market failure.

The delay reduction and fuel savings generated for users of ADS-B (and the "performance-based" NAS that it enables) depend highly on extensive adoption among users. According to a recent study, "without extensive equipage adoption among airlines … ADS-B therefore offers little value except in cases where an airline is a heavy user of an ADS-B equipped hub and can gain value from reduced separation between its own aircraft and improved management of surface traffic."[4]

In other words, the financial analysis for an individual firm or individual pilot is very different from the industry-wide analysis. An individual will bear a full share of the equipage costs but will only receive benefits if a substantial number of other users in the airspace in which that firm operates also equip.

This introduces two factors with negative impacts on any individual firm's analysis of ADS-B: delayed benefits and uncertainty. If some other users in the relevant airspace have not yet committed to ADS-B, any firm considering ADS-B will know that benefits will not fully realized until the other users adopt the technology—assuming those users choose to adopt the technology at all. In a financial environment where the aviation industry requires extremely fast returns on capital investments, individual stakeholders will likely heavily discount future returns both for the time value of money and for the uncertainty over whether those benefits will arise at all. Many stakeholders may only consider the very limited known benefits that they will achieve, assuming no action by other users; these benefits, as noted above, are unlikely to be sufficient to justify the capital investment. The impact to the rest of the industry from enabling others to achieve benefits will not be considered in an individual firm's analysis.

Those who install ADS-B late in the adoption process will be, in essence, "free riders" because they will receive many of the benefits as those who installed earlier in the process, but will have invested less cost on a present value basis, since the time between investment and payback will be significantly shorter. Furthermore, those who install ADS-B early in the adoption process will not only have to bear the cost of capital for that investment, but the cost of the equipment, installation and maintenance may be higher due to manufacturers being in the steep part of the learning curve.

An appropriately-structured government mandate, combined with government investment in the necessary air traffic control infrastructure such as ADS-B ground stations (another precondition for achieving user benefits), can address this market failure by eliminating uncertainty associated with user benefits. With a known mandate deadline, users can make an undistorted evaluation of the optimal time to equip. The mandate provides

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[4] Marais, Karen and Annalisa L. Weigel, "Encouraging and Ensuring Successful Technology Transition in Civil Aviation," Department of Aeronautics and Astronautics, Massachusetts Institute of Technology, Cambridge, MA, March 2006. http://esd.mit.edu/wps/esd-wp-2006-07.pdf

certainty that other preconditions necessary to achieve benefits will be met even though they are out of an individual user's control.

Because of the rule industry knows that everyone will have to equip by a specified time period and the FAA will have to install the necessary ground equipment early to meet the rule's compliance date. Some operators will equip early because they will be able to achieve benefits early. Some may equip early because of when their aircraft is due for maintenance cycle (it is more cost effective to install the avionics when they send the aircraft out for a major maintenance cycle which they do every 5 years), and some may equip early to get the experience with the system.

In summary, mandating ADS-B Out equipage to operate in designated airspace is necessary because market failures will otherwise dissuade individual users from adopting the technology that will generate net benefits for society. The issues these market failures generate include an incomplete accounting of societal benefit, a potential time lag between a firm's investment and benefits, and uncertainty about whether those benefits will be achieved at all. Government action is required in order to achieve the capacity, safety, and efficiency benefits of ADS-B.

The FAA currently believes it would be premature to mandate ADS-B In equipage, because standards to accommodate air-to-air applications are not in place yet. In the future, the agency expects to move forward with reduced separation standards and possibly allow some self-separation, and at that point further rulemaking may be warranted.

2.4 General Assumptions for the Benefits Analysis and Government Cost Analysis

The following general assumptions are used in the analysis. Scenario- and benefit-specific assumptions are listed later within the individual sections.

- All costs and benefits are denominated in 2009 dollars.
- The final rule will be published in 2010 and have a compliance date of 2020.
- Present value rates are 3% and 7%. [5]
- Costs that are consistent across scenarios are not included. For instance, primary radar will be maintained across all scenarios and therefore the cost to continue primary radar is not included in any scenario. We assume that all NAS infrastructure costs other than surveillance, such as cost of runways, runway extensions and air traffic control facilities are the same across all the scenarios and we assume that all

[5] Except for discounting of the social cost of carbon which uses 5% for the low value and 2.5% for the high value, as noted in the interagency report titled "Highlights of Appendix15A: Social Cost of Carbon for Regulatory Impact Analysis under Executive Order 12866."

NAS personnel costs are the same across scenarios. Therefore we do not consider these costs in any of the scenarios.

- Period of Analysis: 2009-2035.

- The agency intends to provide ADS-B services where radar surveillance exists today (plus the Gulf of Mexico and areas in Alaska). We may in the future decide to implement ADS-B services in other areas. However, for the purpose of the regulatory impact analysis, we assume ADS-B surveillance and broadcast service will only be provided in areas where we have radar today, plus the Gulf and Juneau.

- The ADS-B ground infrastructure and rules and procedures will be in place by 2013 to support the following applications and services.

  Services:
  - ATC Surveillance, and
  - FIS-B and TIS-B and ADS-R.

  Applications:
  - Final approach runway occupancy awareness,
  - Enhanced visual acquisition,
  - Enhanced visual approach,
  - Airport surface situational awareness, and
  - Conflict detection.

- For the purposes of the regulatory impact analysis we assume that current separation standards will be maintained in radar surveillance airspace [6]. However, the FAA is investigating whether and to what extent ADS-B may allow the FAA to reduce separation standards.

- Once ADS-B Out is implemented in the Gulf of Mexico and assuming a 5 mile separation standard is approved based on ADS-B Out data being available for separation purposes, the hourly capacity for sectors in the Houston CTA[7]/FIR[8] is estimated to increase from 56 to 84 aircraft. This capacity is higher than that used in the NPRM because of additional routes and resectorization.[9] Also, additional capacity at key airports in Mexico is expected to be complete soon and this will further alleviate the constraints built into the original capacity gains.

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[6] With the implementation of ADS-B application of radar separation standards can now be applied in the non-radar airspace of the Gulf Of Mexico.

[7] Control Area: A control area is airspace wholly contained beyond the 12 mile limit whereby an ICAO state has been designated as the ATS authority for the control of air traffic.

[8] Flight Information Region: FIR's designate regions for informational services only, not ATC control.

[9] Houston, Merida, and Monterrey Centers are close to finalizing a new RNP-10 route structure that will add additional routes and capacity. Additionally, Houston and Merida Center are planning to resectorize airspace to more efficiently handle GOMEX traffic and increase capacity.

- We assume that low-altitude operations over the Gulf of Mexico will be equipped with ADS-B Out because of a Memorandum of Agreement (MOA)[10] signed by the FAA and helicopter operators, among others, and not because of the rule. The platform/helicopter companies have agreed to equip with appropriate avionics and equipment to take advantage of FAA enhancements to the communications, weather reporting, and surveillance capabilities outlined in the Agreement. The FAA will install ground equipment under the MOA. The MOA is to be renewed every five years. Therefore we do not include the costs and benefits of low altitude operations over the Gulf of Mexico as a function of the rule.

- We assume there will be no self-separation.

- While there may be some improvements in air traffic controller productivity with ADS-B Out, we are unable to quantify any improvement at this point.

2.5 Definition Of Scope

The ADS-B Out scenario analysis includes user costs incurred and benefits attained due to the final rule, as well as the costs incurred by the government to deploy and maintain a surveillance system. Costs and benefits that will occur without the rule are not included in the analysis. Costs that are incurred in anticipation of the rule are included, as are the benefits resulting from those expenditures.

3.0 Definition Of Approach

In the following sections we present costs and benefits of the following scenarios:

- A radar baseline scenario to represent current surveillance practice and a universe without the final rule,
- ADS-B Out scenario to represent the final rule,
- Multilateration as a surveillance alternative to ADS-B.

We compare the costs and benefits of the ADS-B Out scenario with those of the baseline scenario to derive the incremental costs and benefits of ADS-B Out. The multilateration and baseline scenarios demonstrate an alternative to the ADS-B Out scenario.

[10] Memorandum of Agreement between Federal Aviation Administration, and Helicopter Association International, Platform/Helicopter companies, Platform Owners and Helicopter Operators to Enhance Communication, Weather and Surveillance Capabilities Gulf of Mexico.

4.0 Scenarios Analyzed

4.1 No-Rule Baseline Scenario

4.1.1 Definition

The baseline scenario is the no-rule scenario. Under this scenario we maintain the current radar-based surveillance system, and replace radar facilities once they wear out. This scenario assumes no expansion beyond the current Operational Evolution Plan (OEP).

This section presents the cost of continuing full radar surveillance, which we compare to alternative scenarios. It assumes that all other components of the air traffic system remain constant over the scenarios and therefore these costs are not included. These components include runways, air traffic facilities and personnel. Also, we assume the cost of primary radars and precision runway monitoring systems will be constant across all scenarios and therefore we do not include them.

4.1.2 Cost to Aircraft Operators of the Baseline Scenario

There will be no direct cost to aircraft operators because they are already equipped to operate under the current radar-based system.

4.1.3 Cost to FAA of Continuing Full Radar Surveillance Under the Baseline Scenario

<u>Surveillance</u>

Airborne Surveillance Radar

With this scenario we include the cost of continuing to support all classes of airborne secondary (beacon) radars (i.e. terminal and en route), and surface surveillance radar and the cost of replacing these radars at the end of their life cycles.[11]

The specific secondary surveillance radar includes BI4, BI5, BI6 and Mode S radar. The ASR-11 (primary/secondary surveillance radar) is a terminal air traffic control radar system that replaces current analog systems with new digital technology. These costs are also included. The ASR-11 system consists of two electronic subsystems: primary surveillance radar and secondary surveillance radar sometimes called the beacon.

Surface Surveillance Radar

Surface surveillance radar includes Airport Surface Detection Equipment (ASDE-3 and ASDE-X/3X). ASDE-3 provides radar surveillance of aircraft and airport surface vehicles at high activity airports. ASDE-3 is a primary radar for surface surveillance and

[11] Exhibit 300 Attachment 2, Business Case Analysis Report - Future Surveillance, JRC Phase 2A, pg. 35.

is combined with the Airport Movement Area Safety System (AMASS) software which provides conflict alerts based on ASDE-3 surveillance data.

ASDE-X is a traffic management system that fuses information from radar, multilateration and other sensors, for the airport surface that provides seamless coverage and aircraft identification to air traffic controllers. The system uses a combination of surface movement radar and transponder multilateration sensors to display aircraft position labeled with flight call signs on an ATC tower display. The costs of ASDE-3, ASDE-X/3X and AMASS are included below.

The cost to sustain and replace airborne and surface radar, assuming there is no ADS-B Out, would be $2.9 billion [12] ($1.2 billion when discounted by 7%) over the years 2009 to 2035. The aggregate costs by year are presented in Table 2 below.

Table 2
Cost to Sustain and Replace Radar without ADS-B Out
2009K $

Year	Airborne	Surface	Total	3% Discount Rate	7% Discount Rate	3 % Discounted Total Radar Cost	7 % Discounted Total Radar Cost
2009	$61,644	$24,085	$85,728	1	1	$85,728	$85,728
2010	$42,336	$19,223	$61,559	0.9709	0.9346	$59,766	$57,532
2011	$40,600	$16,054	$56,654	0.9426	0.8734	$53,402	$49,484
2012	$40,580	$17,321	$57,901	0.9151	0.8163	$52,988	$47,264
2013	$40,561	$14,253	$54,814	0.8885	0.7629	$48,702	$41,817
2014	$80,163	$14,253	$94,416	0.8626	0.7130	$81,444	$67,317
2015	$80,145	$14,253	$94,398	0.8375	0.6663	$79,057	$62,901
2016	$80,127	$14,253	$94,380	0.8131	0.6227	$76,739	$58,775
2017	$88,914	$22,312	$111,226	0.7894	0.5820	$87,803	$64,735
2018	$88,897	$19,177	$108,074	0.7664	0.5439	$82,830	$58,785
2019	$88,880	$39,878	$128,758	0.7441	0.5083	$95,808	$65,454
2020	$88,864	$39,135	$127,999	0.7224	0.4751	$92,469	$60,811
2021	$88,848	$39,135	$127,983	0.7014	0.4440	$89,764	$56,826
2022	$88,832	$39,135	$127,967	0.6810	0.4150	$87,139	$53,102
2023	$49,196	$43,135	$92,331	0.6611	0.3878	$61,042	$35,807
2024	$74,379	$47,110	$121,489	0.6419	0.3624	$77,979	$44,033
2025	$74,364	$43,135	$117,499	0.6232	0.3387	$73,222	$39,801
2026	$66,139	$57,063	$123,202	0.6050	0.3166	$74,540	$39,003
2027	$85,652	$57,063	$142,715	0.5874	0.2959	$83,830	$42,224
2028	$85,652	$57,063	$142,715	0.5703	0.2765	$81,388	$39,462
2029	$85,652	$57,063	$142,715	0.5537	0.2584	$79,018	$36,880
2030	$85,652	$32,181	$117,832	0.5375	0.2415	$63,341	$28,458
2031	$85,652	$32,181	$117,832	0.5219	0.2257	$61,496	$26,596
2032	$85,652	$32,181	$117,832	0.5067	0.2109	$59,705	$24,856
2033	$85,652	$28,181	$113,832	0.4919	0.1971	$55,998	$22,442
2034	$85,652	$28,181	$113,832	0.4776	0.1842	$54,367	$20,974
2035	$60,453	$28,181	$88,634	0.4637	0.1722	$41,099	$15,262
Total	$2,009,136	$875,183	$2,884,319			$1,940,663	$1,246,331

Source: FAA SBS Program and Terminal Surveillance

[12] The FAA developed these estimates internally.

We assume the life cycle of the current ground-based surveillance systems is 20 years from their initial service.[13]

4.1.4 Benefits

There is one benefit of the baseline scenario relative to the other alternatives, and that is certainty. We know it works with today's margin of safety.

4.2 ADS-B Out – The Final Rule (Preferred Alternative)

4.2.1 Definition

Under this scenario, aircraft operators will equip to meet the performance requirements of the rule. The FAA will make surveillance services available based on down-linked aircraft information.

Costs presented in this section will be borne both by the FAA and industry. The FAA has been incurring costs to install ground facilities in order to provide ADS-B services. Costs incurred before 2009 are considered sunk costs and are not included in the FAA costs of the rule presented in this report. We assume industry will begin incurring costs in 2012.

4.2.2 Requirements of the Rule

The rule requires that no person may operate an aircraft in the following airspace unless that aircraft meets ADS-B Out performance requirements laid out in the final rule unless otherwise authorized or directed by air traffic control (ATC).

- Class A, Class B, and Class C airspace areas, and in the Class E airspace at and above 10,000 ft MSL over the 48 contiguous United States and the District of Columbia, excluding the airspace at and below 2,500 ft above ground level (AGL).
- U.S. airspace over the Gulf of Mexico, which is from the coastline of the United States out to 12 nautical miles at and above 3,000 feet MSL.
- Within 30 nautical miles of an airport listed in 14 CFR, Part 91, Appendix D, from the surface upward to 10,000 feet MSL.

However, the rule will permit aircraft not originally certificated with an engine-driven electrical system or not subsequently certified with such a system installed (such as a balloon or glider) to conduct operations without ADS-B Out in the airspace within 30 nautical miles of an airport listed in Appendix D if the operations are conducted: (1) outside any Class B or Class C airspace area; and (2) below the altitude of the ceiling of a Class B or Class C airspace area designated for an airport or 10,000 feet MSL, whichever is lower.

[13] Exhibit 300 Attachment, Business Case Analysis Report for Future Surveillance, JRC Phase 2A, pg. 5.

While in the affected airspace, each person operating an aircraft equipped with ADS-B Out must operate this equipment at all times in the transmit mode, including when on the airport surface.

4.2.3 Industry Estimation of ADS-B Equipage Costs

4.2.3.1 Introduction

Despite some significant changes between the NPRM and final rule language, there has been very little change in the total compliance costs. The seven percent present value base-case cost in the NPRM is $2.1 billion and in the final rule is $2.3 billion.

This section starts with a discussion of the changes between the NPRM and final rule which affect the ADS-B Out estimated total costs. Next, we define a set of assumptions used to estimate ADS-B Out costs for equipping aircraft in the NAS. We then discuss the derivation of the future affected U.S. aircraft fleet. Next, we explain the methods used to estimate ADS-B Out equipage costs on transport category turbojet, turboprop and General Aviation (GA) aircraft. Lastly, we follow the ADS-B Out cost discussion with an estimate of the cost savings from learning curve efficiencies and additional maintenance and operating [14]costs.

Industry has commented that there remains some ambiguity related to the performance standards because the RTCA documents and associated Technical Standard Orders (TSOs) were not finalized. The final determination, at the time of this analysis, is unknown. These cost estimates are based on industry's understanding of the performance characteristics discussed in RTCA meetings up to June 2009. Any significant changes in the performance characteristics could have an impact on the estimated ADS-B Out equipage costs provided in this analysis.

NPRM and Final U.S. Fleet, Unit Costs, and Estimated Total Cost Changes

This section discusses changes between the NPRM and final rule which affect the ADS-B Out estimated costs.

The three changes between the NPRM and final rule are:

- U.S. fleet,
- ADS-B Out unit cost, and
- ADS-B Out estimated total cost.

We estimated the changes to the U.S. fleet by comparing the number of aircraft during the NPRM and final rule analysis for the forecasted years of 2012 and 2025. In this final rule analysis, the large category turbojet fleet dropped 21.47 percent in 2012 and dropped 12.47 percent in 2025 from that of the NPRM. The regional turboprop fleet dropped

[14] The operating costs consist of additional fuel burn caused by the weight of hardware mandated by this final rule.

17.15 percent in 2012 and 22.5 percent in 2025. These two declines occurred because of the downturn in the economy. Lastly, in this final rule analysis, the GA fleet rose one-third of a percentage in 2012 and another two percent in 2025. Table 3 details these results.

Table 3

U.S. Fleet Changes - 2012 & 2025

	2012		2025	
	NPRM	**Final**	**NPRM**	**Final**
Large Category Turbojet	8,269	6,494	10,346	9,056
Regional Turboprop	1,032	855	1,012	784
GA - total	198,575	199,215	223,344	218,755
GA - piston	165,195	162,230	170,959	164,550
GA - turbine	22,615	24,725	36,167	37,410
GA - rotorcraft	10,765	12,260	16,218	16,795

ADS-B Out unit costs for modern large category turbojet airplanes were similar for the NPRM and the final rule. For the older large category turbojet airplanes (DC-9/10, 737 classics, A300, etc.) industry reported the final rule unit costs rose between 20-30 percent from those in the NPRM. One reason for the higher unit costs may be the need to recoup high fixed costs as many older airplanes have been parked or retired. To recoup their initial development costs and with fewer large category turbojet airplanes in the fleet, the unit costs rose. Another reason for the higher unit costs is that in the NPRM, our lower bound ADS-B Out equipage cost estimate should have included the cost of aircraft manufacturer's service bulletins.

Regional turboprop ADS-B Out unit costs between the NPRM and final rule were similar. The ADS-B Out unit costs for GA piston engine airplanes and rotorcraft dropped 10-15 percent. With more ADS-B Out providers in the marketplace and the FAA relaxing the antenna diversity costs GA unit costs dropped. Lastly, ADS-B Out unit costs for GA turboprop and turbojet engine aircraft increased by 20-30 percent. We do not have a reason for this price increase.

For the base-case scenario, ADS-B Out estimated final rule total costs for modern large category turbojet airplanes, relative to those in the NPRM, were up about 20 percent. Including the cost of manufacturer's service bulletins in the lower bound estimates largely explains the increase in the base-case costs. Regional turboprops ADS-B Out final rule total costs dropped about 90% in the final rule because ADS-B Out costs will be prohibitive for analog/hybrid regional turboprop airplanes. The final rule assumed that analog/hybrid regional turboprop airplanes will be retired prior to the rule's effective date. The cost to retire an analog/hybrid regional turboprop early is much less than retrofitting with ADS-B Out. Lastly, ADS-B Out estimated final rule total costs for GA turboprop and turbojet engine aircraft decreased from the NPRM by about 15 percent because of the drop in unit costs for GA piston engine airplanes.

4.2.3.2 Equipage Cost Assumptions

The ADS-B Out equipage cost evaluation for this final rule makes the following assumptions:

1. The base year is 2009.
2. This final rule will be published in 2010.
3. The analysis period extends for 27 years from 2009 through 2035.
4. Compliance date is 2020.
5. The ADS-B ground infrastructure will be in service and fully operational by 2013.[15]
6. Manufacturers will invest in equipping newly delivered aircraft after a federal commitment of two appropriation-funding cycles.
7. Manufacturers of large category turbojet or regional turboprop will start equipping ADS-B Out avionics on new aircraft deliveries in 2012[16] because it will be cheaper to purchase new aircraft with the avionics installed than to retrofit in 2020.
8. Large category turbojet and regional turboprop aircraft will start retrofitting active aircraft in 2013 in order to minimize costs associated with retrofitting the aircraft outside of its heavy maintenance cycle. All active large category turbojet and regional turboprop aircraft will be fully equipped with ADS-B Out by 2020.
9. GA aircraft and Rotorcraft will start equipping new aircraft deliveries in 2012 and retrofitting active aircraft in 2013. All active GA and Rotorcraft aircraft will be fully equipped by 2020.
10. All U.S.-certificated large category turbojet or regional turboprop passenger and cargo aircraft will equip with ADS-B Out because they will operate in the airspace required by this final rule.
11. Active U.S.-certificated GA aircraft and Rotorcraft currently equipped with transponder equipment[17] will equip with ADS-B Out equipment because they will operate in the final rule's affected airspace. Operators of GA aircraft without ADS-B Out transponder equipment could request ATC deviations prior to operating in the airspace affected by this final rule. Table 4 shows the current number of U.S.-certificated GA aircraft and Rotorcraft with transponder equipment:

Table 4

AIRCRAFT TYPE	TRANSPONDER EQUIPMENT	
	YES	NO
Fixed Wing - Piston	145,960	17,783
Fixed Wing - Turboprop	7,248	815
Fixed Wing - Turbojet	10,307	72
Rotorcraft	8,404	755

Source: 2006 FAA General Aviation and Airtaxi Survey

[15] http://www.faa.gov/news/speeches/news_story.cfm?newsId=7649
[16] 2013 is dependent on the appropriate funds being available from assumption 6.
[17] 2006 FAA General Aviation and Air Taxi Survey.

12. Experimental, Sport and Other aircraft will not equip with ADS Out. Operators of these aircraft could request ATC deviations prior to operating in the airspace affected by this final rule.[18]
13. Equipment costs are based on catalog pricing.
14. The analog/hybrid regional turboprop airplanes will not select an upgrade because the upgrade cost will be prohibitive.
15. We accept industry's performance-based cost estimates.
16. The FAA assumes that only 20% of analog large category transport turbojet airplanes will choose to equip with ADS-B Out capability because the upgrade cost will be prohibitive.

4.2.3.3 Fleet Discussion

This section discusses the fleets that will need to comply with the final rule in the future. The discussion draws upon forecasts covering the period from 2009 through 2025, as well as extended forecasts for 2026-2035. The section begins with a discussion of the expected affected airplanes, and then discusses in detail the derivation of the future affected fleet of large category turbojet, regional turboprop, general aviation and rotorcraft.

Large Category Turbojet Aircraft

The 2009 published FAA turbojet fleet annual unit forecast for 2009 to 2025 forms the basis for estimating the number of affected large category turbojet aircraft. This forecast covers wide body, narrow body and regional turbojet aircraft operated by US-certificated carriers and includes new deliveries and retirements. A bottom-up forecast was developed for each aircraft group and then summed to arrive at an aggregate. To estimate the large category turbojet fleet after 2025, we use the FAA long-term passenger turbojet fleet annual unit forecast for 2025-2035. These forecasts project the population of large category and regional turbojets to nearly double in the analysis interval.

Regional Turboprop Aircraft

The 2009 published FAA turboprop fleet annual unit forecast for 2009 to 2025[19] forms the basis for estimating the number of affected regional turboprop aircraft. This forecast categorizes regional turboprop aircraft by the number of airplane seats, operated by US-certificated carriers, and includes new deliveries and retirements. A bottom-up forecast was developed for each aircraft group by seat and then summed to arrive at an aggregate.

[18] ibid.
[19] FAA Aerospace Forecast 2009-2025, Table 21 & 21.

We estimated the regional turboprop fleet from 2026-2035 by using the 10-year average percent change from the 2010-2020 period. The FAA projects that the number of regional turboprop aircraft to decline about five percent from 2009 to 2035.[20]

General Aviation Aircraft

The 2009 published FAA general aviation fleet annual unit forecast for 2009 to 2025 forms the basis for estimating the number of affected general aviation aircraft. These forecasts cover fixed wing, rotorcraft, experimental, sport and other general aviation aircraft operated by US certificated carriers and includes new deliveries and retirements. We extended the general aviation fleet from 2026-2035 by using the 10-year average percent change from the 2010-2020 period.[21] We project the number of fixed wing general aviation aircraft will increase approximately 13 percent and the number of rotorcraft to nearly double.

4.2.3.4 Equipment Specifications

This section describes the new standards used herein to estimate the compliance cost for ADS-B Out avionics this final rule requires. The ADS-B Out system will consist of a position source, an ADS-B transmitter, altimetry sensors, flight crew interfaces and other avionics. This equipment will require integration to correctly transmit the ADS-B Out data.

In the United States, two different datalinks have been adopted for ADS-B Out:

- 1090 MHz Extended Squitter (1090 ES), and
- 978 MHz Universal Access Transceiver (978 UAT).

TSO-C166b defines the equipment requirements for 1090ES ADS-B equipment. TSO-C154c defines the equipment requirements for UAT ADS-B equipment. Future versions of these TSO's will be acceptable for rule compliance however, previous versions of the TSO's are not acceptable to operate in airspace defined by 14 CFR 91.225.

This is a performance-based rule, and thus there is no equipment requirement for the position source. Any position source meeting the accuracy and integrity requirements described in 14 CFR 91.227 is acceptable. Based on responses from industry, three types of position sources have been evaluated for costs including Global Navigation Satellite System (GNSS) equipment compliant with Technical Standard Order (TSO) C145a or TSO-146a, GNSS equipment compliant with TSO-C129a, and GNSS equipment compliant with TSO-C196.

[20] FAA Aerospace Forecast 2009-2025, Table 26. "U.S. Regional Carriers Passenger Aircraft".
[21] FAA Aerospace Forecast 2009-2025, Table 27. "Active General Aviation and Air Taxi Aircraft".

The minimum broadcast message element set for aircraft equipage for ADS-B Out used in the cost estimates defined below.[22]

Each aircraft must broadcast the following information, as defined in TSO–C166b or TCS–C154c. The pilot must enter information for message elements listed in (7) through (10) of this section during the appropriate phase of flight:
(1) The length and width of the aircraft;
(2) An indication of the aircraft's lateral and longitudinal position;
(3) An indication of the aircraft's barometric pressure altitude;
(4) An indication of the aircraft's velocity;
(5) An indication if TCAS II or ACAS is installed and operating in a mode that can generate resolution advisory alerts;
(6) If an operable TCAS II or ACAS is installed, an indication if a resolution advisory is in effect;
(7) An indication of the Mode 3/A transponder code specified by ATC;
(8) An indication of the aircraft's call sign that is submitted on the flight plan, or the aircraft's registration number;
(9) An indication if the flight crew has identified an emergency, radio communication failure, or unlawful interference;
(10) An indication of the aircraft's "IDENT" to ATC;
(11) An indication of the aircraft assigned ICAO 24-bit address;
(12) An indication of the aircraft's emitter category;
(13) An indication of whether an ADS–B In capability is installed;
(14) An indication of the aircraft's geometric altitude;
(15) An indication of the Navigation Accuracy Category for Position (NACP);
(16) An indication of the Navigation Accuracy Category for Velocity (NACV);
(17) An indication of the Navigation Integrity Category (NIC);
(18) An indication of the System Design Assurance (SDA); and
(19) An indication of the Source Integrity Level (SIL).

4.2.3.5 ADS-B Out Equipage Cost Estimate

We contacted manufacturers, industry associations, and ADS-B equipage providers and requested estimates for ADS-B equipage and installation costs. We requested estimates of airborne installation costs, by aircraft model, for the output parameters listed in the Equipment Specifications section. The manufacturers and industry associations we contacted were:

- Airbus,
- Aircraft Owners and Pilots Association,
- Aviation Communication and Surveillance Systems,
- Boeing,
- Free Flight Systems,
- Garmin,

[22] §91.227

- General Aviation Manufacturers Association,
- Honeywell,
- National Business Aviation Association,
- Raytheon, and
- Rockwell.

Not every manufacturer or ADS-B equipage provider we contacted responded to our ADS-B cost request. For those that did respond, each used a different methodology to develop their cost estimates. The differences in methodologies could be partially responsible for the variance in our cost estimates. These industry representatives have been actively involved in the performance requirements process. They are well aware of current and potential changes to the performance requirements.

For analytical purposes, we grouped aircraft types into classes with similar avionics architecture. The aircraft equipment classes potentially subject to the ADS-B Out performance requirements are:

- Large Category Turbojet Airplanes
  - Classic – B-707, B-727, B-737-100/200, B-747-100/200/300, A-300/310, DC-8, DC-9, DC-10, MD-80/81/82/83 and L-1011.
  - Neo-Classic – B-757-200/300, B-767/200/300, B-737-300/400/500/600, B-747-400, MD-11, MD-87/87/90 and A-319/320/321/340.
  - Modern – B-777, B-737-700/800/900, B-717, B-767-400, A-318/330/350/380.
  - New production aircraft.
- Regional Aircraft
  - Jet – BAE-146, RJ70 and RJ85, CRJ100/200/440/700, Do328JET, ERJ-135/130/145/170/175/190/195, and F28/50/70/100.
  - Turboprop – ATR42/72, Beech 99/1900, DHC-8, Do328, EMB-120, Jetstream J31/41/42, L-188, Metro Saab 340 and Shorts 330/360.
  - New production aircraft.
- GA
  - Single engine Piston - Airplanes with a maximum takeoff weight under 12,500 pounds.
  - Multi engine Piston – Piston powered airplanes with more than one engine.
  - Turboprop – Single and multi-engine turboprop airplanes.
  - Turbojet - Single and multi-engine jet airplanes.
  - Rotorcraft - Single and multi-engine helicopters.
  - New production aircraft.

For each aircraft class listed above, we categorized the aircraft's ADS-B equipage status into three distinct groups.

- Not Equipped – aircraft is not equipped for ADS-B Out functionality and requires major avionics component additions or equipment to make it capable of transmitting ADS-B Out information.
- Latent – aircraft that can be made capable of ADS-B Out operation by adding broadcast link capabilities or interfacing to existing Global Navigation Satellite System (GNSS) equipment.
- Equipped – aircraft that can be ADS-B Out capable with a software update.

We provide a low and high range of cost estimates associated with various operational and technical issues. The dollar value ranges consist of a wide variety of avionics within each aircraft group. The aircraft architecture within each equipment group can vary, causing different carriage, labor and wiring requirements for the installation of ADS-B Out equipment. Volume discounting versus single line purchasing also affects the dollar value ranges.

This rule does not require specific equipment; rather the equipment must meet certain performance specifications. Since this is a performance-based rule, industry may choose how to meet that performance standard with either a low or high cost of compliance alternative. A minimum equipment set that represents the expected minimum compliance may cost more in the future because it lacks upward compatibility. The low end estimate may include a minimum equipment option, a minor software upgrade, an Original Equipment Manufacturer (OEM) option change or a ground-based backup solution. The high end estimate includes the airborne design that integrates both ADS-B Out capability and provisions for future ADS-B and may also include a new or upgraded position source, a new installation or upgraded avionics system necessary to comply with the rule, or a system that will provide a cost-effective option for manufacturers and operators to integrate future GNSS [23] upgrades.[24] The base-case estimate represents a fleet where about half of the airplanes need only the low cost solutions and the other half of the airplanes are outfitted with the more expensive upgrades.

We did not include ADS-B Out operator training costs because we assumed the costs to be minimal.[25]

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[23] Future upgrades of GNSS might include greater availability or accuracy of the signals. These types of upgrades may enable additional applications, improved use of existing applications (such as increased efficiency or availability of ADS-B enabled operations) or a reduction in aircraft separation; but what those applications are will be difficult to ascertain at this point. Generically speaking, an incremental improvement in the performance of the position source could allow us to incrementally improve our air traffic control procedures and thereby improve efficiency and capacity.

[24] Even though this scenario is designed to look at ADS-B Out adoption in isolation, in practice the availability of equipment offering only ADS-B Out technology may be limited. Therefore, in practice the cost of adopting ADS-B Out may include the voluntary or unavoidable purchase of some functionality not strictly required by the ADS-B Out regulation.

[25] The FAA determined training costs will be minimal because no significant training will be required.

Large Category and Regional Turbojet ADS-B Out Equipment and Fuel Burn Costs

This section first covers the estimated ADS-B Out equipage costs plus the cost of additional fuel burn to large category and regional turbojets due to the added weight of ADS-B Out equipment.

The manufacturers provided us with ADS-B Out equipage costs estimates either by equipment type or for the following equipage types:

- Classic,
- Neo-classic, and
- Modern.

The manufacturers who provided costs by equipment groups either estimated a total cost of ADS-B Out hardware, included the costs of installation kits and installation, or provided detailed breakdowns of the various costs.

The ADS-B Out equipment costs for large category and regional turbojet airplanes are straightforward. Industry provided ADS-B Out unit costs by the equipment class units discussed in the Fleet Discussion section. The FAA assumes that only 20% of analog air transport turbojet airplanes will choose to equip with ADS-B Out capability because the upgrade cost will be prohibitive.

To satisfy the manufacturers' request to keep individual aircraft pricing confidential, we calculated a low and high range for unit costs by dividing the total low and high cost estimate by the number of affected large category turbojet airplanes. This range includes cost for all hardware and installation. The unit costs for large category turbojet airplanes range from about $19,000 to $1.7 million. The dollar value ranges consist of a wide variety of avionics within each aircraft group. The avionic costs vary based on the state of an aircraft's architecture, volume discounting, a minor software upgrade versus a major transponder or position source replacement, or an operator's decision to install avionics that take advantage of future GNSS upgrades.[26] We note that in the NPRM, our lower bound ADS-B Out cost estimate should have included the cost of aircraft manufacturer's service bulletins.

For 2012 through 2035 we estimated the newly delivered turbojet costs by multiplying unit costs by the annual number of new aircraft deliveries. Based on the FAA turbojet forecast, the retrofitting of aircraft in the current operating fleet as of 2013 was assumed to be uniformly distributed over 2013 through 2019. For each of the seven years, ADS-B Out retrofit costs for turbojets were estimated by multiplying unit costs by one-seventh of

[26]The result of these different compliance decisions was a wide range of cost estimates.

the active 2013 fleet. The new turbojet aircraft deliveries from 2012-2035 were assumed to have avionics component additions or equipment to make them capable of transmitting ADS-B Out information. The incremental costs we estimated for these new deliveries included either minor additional avionic or software upgrade.

The total cost to equip active and newly delivered turbojets from 2012 through 2035 ranges from about $1.0 billion to $2.4 billion with a base-case average of $1.7 billion. Table 5 summarizes the range estimate in constant dollars, and at three and seven percent present value rate for large category and regional turbojets.[27]

Table 5

Range of ADS-B Equipage Costs for Turbojet Airplanes			
	2009$ Millions		
	Low	Base-Case	High
Total	$1,023	$1,717	$2,412
3% Discount	$772	$1,292	$1,812
7% Discount	$557	$930	$1,303

The ADS-B Out equipage weight ranges from a low of three pounds to a high of 12 pounds.[28] The base-case assumes 7.5 pounds of added weight per turbojet aircraft. We used these weights to calculate a cost range for the average additional fuel burn for turbojet airplanes operating during the analysis period.

Given that fuel burn range, we used the methodology for incremental fuel burn, per flight, per pound of additional weight for turbojet aircraft from our published economic values.[29] We obtained the average annual cycles per turbojet aircraft from BACK Aviation Solutions. The gallons of additional fuel burn equals the incremental fuel burn per flight, per pound, multiplied by the average annual cycles (flights) multiplied by the low, base-case and high added weight estimates. Lastly, we multiply the estimated additional gallons of fuel burn by the jet fuel price forecast[30] to obtain a range of the annual cost of the added weight to the U.S. operated turbojet fleet.

A range of the estimated added fuel burn costs for the installation of ADS-B Out in US operated large category and regional turbojets for 2009 - 2035 is shown in the Table 6.

[27] Discussions with ADS-B Out providers. See section 4.2.3.5 ADS-B Out Equipage Cost Estimate for further detail.
[28]The manufacturer mentioned the worst case could be up to 200 additional pounds of weight for a minimally equipped, analog aircraft attempting to be fully compliant with future navigation and surveillance upgrades. It is highly unlikely that anyone will choose to invest the money to upgrade their aircraft to that level of capability when it is likely to be retired before an operator could recover the investment.
[29] "Economic Values for FAA Investment and Regulatory Decisions, A Guide", December 31, 2004.
[30] FAA Aerospace Forecast 2009-2025, Table 18. "U.S. MAINLINE AIR CARRIER FORECAST ASSUMPTIONS – Jet Fuel Prices".

Table 6

Additional Fuel Burn Costs on Turbojet Fleet			
	2009$ Millions		
	3 pounds	7.5 pounds	12 pounds
Total	$10.58	$26.45	$42.33
3% Discount	$7.22	$16.50	$25.79
7% Discount	$3.63	$9.07	$14.52

Regional Turboprop Aircraft ADS-B Out Equipment Costs

This section explains how the regional turboprop aircraft ADS-B Out equipment costs were estimated. We also explain why there is no additional fuel burn expense and why the costs to regional turboprops are lower than those estimated in the NPRM.

The manufacturers who responded with regional turboprop equipage costs provided us with costs estimates for the following equipage types:

- Saab 340,
- ATR,
- Regional Turboprop, and
- New Production Turboprop.

For these equipment groupings they provided the following detailed cost estimates by equipment class:

- Transponder and GPS Status,
- GNSS Equipage Cost,
- Datalink Equipage Cost,
- Installation Cost,
- Currently Installed Transponder upgrade cost,
- Installation Kit Cost, or
- Individual Component Cost.

The ADS-B Out equipment costs for regional turboprop airplanes are straightforward. Industry provided ADS-B Out unit costs by airplane equipment class units discussed in the Fleet Discussion section above.

To satisfy the manufacturers' request to keep individual aircraft pricing confidential, we calculated a low and high range for unit costs by dividing the total low and high cost estimate by the number of affected regional turboprop airplanes. This range includes cost for all hardware and installation. The unit costs for regional turboprop airplanes range from about $12,000 to $466,800. The dollar value ranges consist of a wide variety of avionics within each aircraft group. The avionic costs vary based on the state of an aircraft's architecture, volume discounting, a minor software upgrade versus a major transponder or position source replacement, or an operator's decision to install avionics that take advantage of future GNSS upgrades.

It is unlikely that the analog/hybrid regional turboprop airplanes will select an upgrade because the upgrade cost will be prohibitive. We consulted with industry about the active analog/hybrid regional turboprop fleet and were informed that these turboprops operated with less than 40 seats. Therefore, for the final rule, we assume active analog/hybrid regional turboprop aircraft, under 40 seats, will not upgrade with ADS-B Out and will retire early.

We consulted with appraisal companies[31] and determined the annual residual value of regional turboprop, under 40 seats, depreciate between seven to 14 percent, with a base-case of 10 percent. We obtained the current value of regional turboprop aircraft under 40 seats from our published economic values,[32] applied the residual value depreciation and included the costs of early retirement of the analog/hybrid regional turboprops to the costs of retrofitting and equipping regional turboprops for this final rule.

These costs included the early retirement of active analog/hybrid regional turboprop airplanes and the equipage of active and new production regional turboprop aircraft. The active aircraft in 2013, from the FAA turboprop forecast, were uniformly distributed over 2013 through 2019. For each of the seven years, ADS-B Out costs for regional turbojets were estimated by multiplying unit costs by one-seventh of the active 2013 fleet.

The manufacturers did not provide an equipage weight for ADS-B Out on regional turboprops. In the NPRM, we assumed the weight for an ADS-B Out transponder on regional turboprop aircraft will be about the same as weight as existing transponders and therefore the change will be negligible and there will be no additional weight or fuel burn costs. We received no comments about this assumption.

The total cost to equip and retire certain regional turboprop aircraft with ADS-B Out from 2012 through 2035 ranges from about $7.5 million to almost $41.6 million with a

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[31] Avitas, ACI

[32] "Economic Values for FAA Investment and Regulatory Decisions, A Guide", December 31, 2004.

base-case average of nearly $24.6 million. Table 7 summarizes the range estimate of constant dollars, three and seven percent present value rate.[33]

Table 7

Range of ADS-B Out Costs on Turboprop Fleet			
	2009$ Millions		
	Low	Base-Case	High
Total	$7.56	$24.57	$41.57
3% Discount	$5.08	$16.50	$27.92
7% Discount	$3.22	$10.48	$17.73

General Aviation Aircraft ADS-B Out Equipment Costs

This section explains how the final rule's general aviation aircraft base-case ADS-B Out equipment costs of $2.7 billion were estimated. We used general aviation industry equipment cost estimates, the FAA fleet forecast, and assumptions about the current fleet equipped with a transponder. We first discuss the industry cost estimates received. We then discuss our adjustments to the number of affected helicopters covered by the Memorandum of Agreement (MOA) between the FAA and the helicopter association (HAI) and operators. Once the foundation for the general aviation fleet is set, the ADS-B Out cost estimation is straightforward; multiply the number of affected general aviation aircraft by unit costs.

The manufacturers provided GA ADS-B Out equipage costs for the following equipage types:

- Single Engine Piston,
- Multi Engine Piston,
- Turbo Prop,
- Turbo Jet,
- Rotorcraft, and
- Experimental.

[33] Discussions with ADS-B Out providers. See section 4.2.3.5 ADS-B Out Equipage Cost Estimate for further detail.

For those equipment groups they provided costs for the following categories:

- Equipment Cost,
- Fleet Size,
- Installation Time,
- Installation Hourly Cost,
- Total Cost, and
- Total Fleet Cost.

There is currently a signed Memorandum of Agreement (MOA) between the FAA, the HAI, and helicopter operators for operation in the Gulf of Mexico. In this agreement, helicopter operators in the Gulf of Mexico agree to equip with "appropriate avionics and equipment to take advantage of FAA enhancements to the communications, weather reporting, and surveillance capabilities". The MOA has not yet been implemented, but with a compliance date of 2020 in the final rule, it is likely the helicopter operators will equip to be in accordance with the MOA before the required compliance date of this final rule. For this analysis, we are assuming that 9% of the active and newly delivered helicopter fleet will be operating in the Gulf of Mexico with ADS-B Out equipment voluntarily installed.[34] Therefore, we reason that this portion of the industry will equip without the rule and the compliance costs for the Gulf of Mexico-operated (nine percent of total rotorcraft fleet) rotorcraft will equal zero.

To satisfy the manufacturers' request to keep individual aircraft pricing confidential, we calculated a low and high range for unit costs by dividing the total low and high cost estimate by the number of affected general aviation airplanes. This range includes cost for all hardware and installation. The unit costs for general aviation aircraft range from about $5,000 to $20,000. We note that the unit costs for GA aircraft are less than those used in the NPRM because there are more ADS-B manufactures in the market place. The dollar value ranges consist of a wide variety of avionics within each aircraft group. The avionic costs vary based on the state of an aircraft's architecture, volume discounting, a minor software upgrade versus a major transponder or position source replacement, or an operator's decision to install avionics that take advantage of future GNSS upgrades.

The methodology to estimate ADS-B Out equipment costs for the GA fleet is based on the 2006 FAA General Aviation and Air Taxi Survey,[35] and we calculated the percentage of U.S. certificated GA aircraft and rotorcraft currently equipped with transponder equipment. We applied this percentage to the GA fleet from the Fleet Discussion section above to determine the number of newly delivered and active GA aircraft that will equip with ADS-B Out.

[34]Based on conversations with the Helicopter Association International (HAI) and FAA.
[35]http://www.faa.gov/data_statistics/aviation_data_statistics/general_aviation/

For 2012 through 2035 we estimated the newly delivered GA aircraft costs by multiplying unit costs by the annual number of new GA aircraft deliveries. The retrofitting of aircraft in the current operating fleet as of 2013, from the FAA GA forecast, was assumed to be uniformly distributed over 2013 through 2019. For each of the seven years, ADS-B Out retrofit costs, for active GA aircraft was estimated by multiplying unit costs by one-seventh of the active 2013 fleet.

The total cost to equip GA aircraft from 2012 through 2035 ranges from about $1.6 billion to about $3.9 billion with a base-case average of $2.7 billion. Table 8 summarizes the range estimate of constant dollars, three and seven percent present value rate.

Table 8

Range of ADS-B Out Costs on GA Fleet			
	2009$ Millions		
	Low	Base-Case	High
Total	$1,613	$2,734	$3,856
3% Discount	$1,258	$2,132	$3,006
7% Discount	$935	$1,584	$2,233

Table 9 shows the distribution of the constant GA costs by GA engine, turbojet and rotorcraft aircraft.

Table 9

2009$ Millions			
Aircraft	Low	Base-Case	High
GA Piston	$1,047	$1,611	$2,175
GA Turbine	$455	$877	$1,298
GA Rotorcraft	$111	$246	$383
Total	$1,613	$2,734	$3,856

In the NPRM, we assumed the weight for an ADS-B Out transponder, on a GA aircraft, will be about the same as weight existing transponders and therefore the change will be negligible and there will be no additional weight or fuel burn costs. We requested comments from industry on this assumption. Industry informed us the ADS-B Out equipage weight ranges from a low of three pounds to a high of five pounds.[36] The base-case assumes four pounds of added weight per turbojet aircraft. We accept those comments and used these weights to calculate a cost range for the average additional fuel burn for GA aircraft operating during the analysis period.

[36]The manufacturer mentioned the worst case could be up to 200 additional pounds of weight for a minimally equipped, analog aircraft attempting to be fully compliant with future navigation and surveillance upgrades. It is highly unlikely that anyone will choose to invest the money to upgrade their aircraft to that level of capability when it is likely to be retired before an operator could recover the investment.

We obtained the incremental fuel burn, per flight, per pound of additional weight and utilization for GA aircraft from our published economic values.[37] The gallons of additional fuel burn equals the incremental fuel burn per hour, per pound, multiplied by the average annual utilization, multiplied by the low, base-case and high added weight estimates. Lastly, we multiply this product by the jet fuel forecast[38] to obtain a range of the annual cost of the added weight to the U.S. operated GA fleet.

A range of the estimated added fuel burn costs for the installation of ADS-B Out in US operated GA fleet for 2009 - 2035 is shown in the Table 10.

Table 10

Additional Fuel Burn Costs on GA Fleet			
	2009$ Millions		
	3 pounds	7.5 pounds	12 pounds
Total	$19.75	$26.34	$32.92
3% Discount	$13.55	$16.84	$20.13
7% Discount	$6.81	$9.09	$11.36

4.2.3.6 ADS-B In –Turbojet, Turboprop and GA Aircraft Costs are Premature

An example of an ADS-B In application is United Parcel Service (UPS) and FAA working together to implement a system at Louisville, Kentucky (SDF) airport to increase airport capacity and efficiency while significantly reducing vulnerability to runway incursion events, both in terms of events and the damage sustained should an event occur. UPS and FAA have developed a concept to create a system that will use ADS-B surveillance at SDF, along with a Surface Management System and a scheduling and sequencing system to meet the demands of the future. UPS is also installing a Cockpit Display of traffic Information (CDTI) for certain proposed operational application such as merging and spacing, Surface Area Moving Management, and CDTI Assisted Visual Spacing capability in all of its B-757, B-767, B-747-400, A-300, and MD-11 fleets.

We have attempted to estimate the costs for equipping aircraft with the avionics necessary to perform the initial ADS-B In applications described in this rule. At the time of this analysis, there were no FAA specifications for ADS-B In. The FAA anticipates completing a TSO that outlines standards for the initial ADS-B In applications by the end of fiscal year 2010.

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[37] "Economic Values for FAA Investment and Regulatory Decisions, A Guide", December 31, 2004.
[38] FAA Aerospace Forecast 2009-2025, Table 18. "U.S. MAINLINE AIR CARRIER FORECAST ASSUMPTIONS – Jet Fuel Prices".

4.2.3.7 Learning Curve Efficiencies

In 1939,[39] T.P. Wright[40] recognized the repetition of the same operation results in reduced efforts expended on that operation.[41] Direct labor man-hours necessary to complete a unit of production will decrease by a constant percentage each time the production quantity is doubled. Learning or cost improvement occur due to workers increases in efficiency and implicit training. T.P. Wright found that an 80% learning efficiency has been a common occurrence in aircraft production. This section will estimate the learning efficiency[42] cost savings for the installation of ADS-B Out equipment in turbojet, turboprop and GA aircrafts for an 80% learning efficiency.[43]

We estimate the labor hour efficiencies for the production and installation of ADS-B Out on the xth set of airplanes (Y_x) as follows:

$Y_x = a * x^b$

Where Y_x = cumulative average time to produce and install a number of units,
a = time to produce and install the first unit by equipment group,
x = the sequential period of production and installation time,
b = index of learning (b = log (learning curve) / log (2)),
learning curve = 80.

In order to estimate the learning efficiency savings for providing and installing ADS-B Out on newly delivered and active aircraft, we used the industry-provided hours and Department of Labor[44] hourly labor rates, per equipment group, required to produce and install ADS-B Out. The learning efficiencies begin in 2013 and extend to 2035, the end of the analysis period. Table 11 shows the hours and hourly labor rates, per equipment group, required to install ADS-B Out.

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[39] The learning curve effect states that the more times a task has been performed, the less time will be required on each subsequent iteration. This relationship was first quantified in 1936 at Wright-Patterson Air Force Base in the United States. In the late 1960s Bruce Henderson of the Boston Consulting Group (BCG) began to emphasize the implications of the experience curve for strategy and in 1972 published "Perspectives on Experience". This book explains the experience curve effect, which is an observation that the costs of virtually every class of products decline by a constant and predictable percentage over time, as a function of experience. Recently, in 1991, Charles J. Teplitz published the "The Learning Curve Deskbook" which provides a basic understanding of the underlying theory of learning curves, as well as ready access to commonly used learning curve models, formulas, and tables.

[40] Theodore Paul Wright (May 25, 1895 – August 21, 1970) was a U.S. aeronautical engineer, educator, and served as administrator of the Civil Aeronautics Administration during 1944 – 1948.

[41] "American Methods of Aircraft Production", T.P. Wright, 1939.

[42] The rate of learning may be higher than the 80% presented in this regulatory impact analysis. If so, the learning efficiencies may be under estimated.

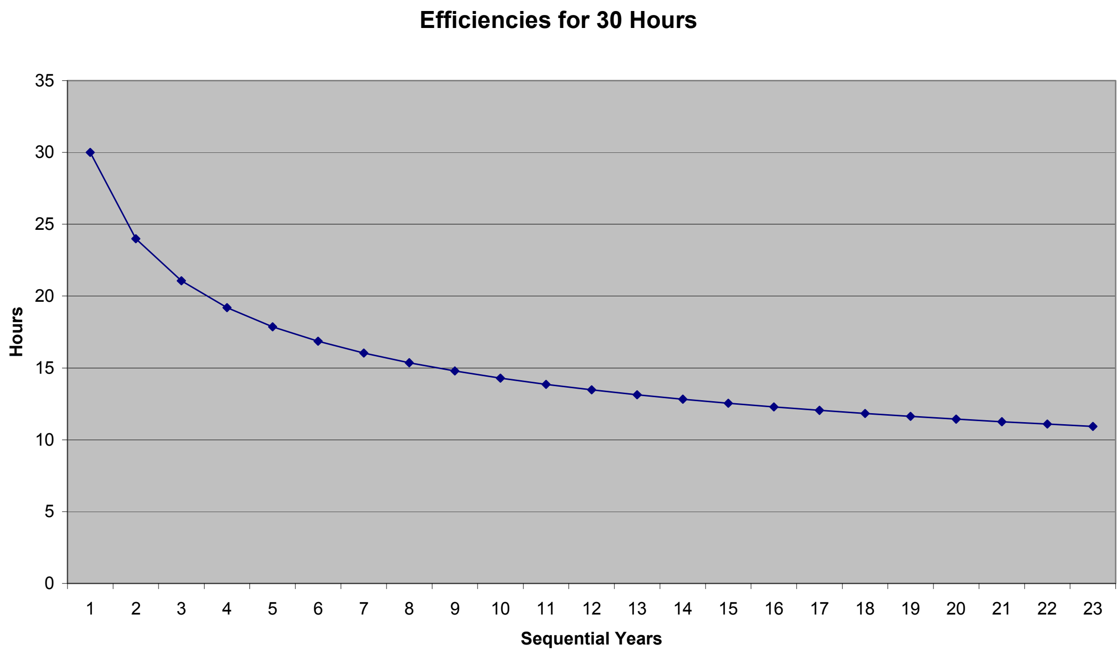
[43] 80% learning has been a common occurrence for over 65 years since T.P Wright recognized the concept in 1939.

[44] Department of Labor, Bureau of Labor Statistics. Occupational Employment and Wages

Table 11

	General Aviation						Transport Category	
	Single Engine	Multi Engine	Turbo Prop	Turbo Jet	Rotorcraft		Regional Turboprop	Large Turbojet
					Piston	Turbine		
Installation Time	30	36	57	65	44	44	125	60
Hourly Installation Cost	$76.21	$76.21	$76.21	$76.21	$76.21	$76.21	$76.21	$76.21

Next we summed the new aircraft deliveries for 2012 with the new deliveries and the one-seventh of the active fleet from 2013 to define the first period of our sequential periods of installation time, x. Our second period of installation time was defined as 2014, our third as 2015 and so on until 2035. The follow graph presents the 80% learning curve for a 30 hour time to produce and install the sequential units of newly delivered and active aircraft.



For each sequential period, we multiplied the number of ADS-B Out installations, by the labor cost, by the labor hours $a * x^b$. No efficiencies occur in year one because the learning has not yet begun. The majority of the learning efficiencies occur from 2014-2019, because during this period the active fleet was retrofitted.

Lastly, these labor learning efficiencies were subtracted from the labor costs we estimated in ADS-B Out Equipage Cost Estimate section.

Table 12 details the total ADS-B Out costs of this final rule, including learning efficiencies for labor, for large category turbojet aircraft in the 2009-2035 analysis interval. Learning curve efficiencies lowers the seven percent present value base-case estimate by approximately $100 million. When we queried industry for ADS-B costs associated with this final rule, the ADS-B out hardware costs resulted in a wide range with installation labor costs constant across all the cost ranges below.

Table 12

Total ADS-B Out Costs on Turbojets With Learning Curve Savings			
	2009$ Millions		
	Low	Base-Case	High
Total	$994	$1,738	$2,384
3% Discount	$710	$1,235	$1,690
7% Discount	$476	$825	$1,128

Table 13 details the total ADS-B Out costs of this final rule, including learning efficiencies for labor, for regional turboprop aircraft in the 2009-2035 analysis interval.

Table 13

Total ADS-B Out Costs on Turboprops With Learning Curve Savings			
	2009$ Millions		
	Low	Base-Case	High
Total	$4.73	$21.73	$38.74
3% Discount	$3.30	$14.72	$26.14
7% Discount	$2.19	$9.45	$16.70

Table 14 details the total ADS-B Out costs of this final rule, including learning efficiencies for labor, for GA aircraft in the 2009-2035 analysis interval.

Table 14

Total ADS-B Out Costs on GA Fleet With Learning Curve Savings			
	2009$ Millions		
	Low	Base-Case	High
Total	$1,365	$2,486	$3,607
3% Discount	$1,121	$1,952	$2,826
7% Discount	$833	$1,460	$2,109

4.2.3.8 ADS-B Out Maintenance Costs

In this section we discuss our assumptions and cost estimates for the maintenance and replacement intervals for the ADS-B Out equipment required by this final rule. As we received no comments on our modeling approach, the final rule is using the same approach to estimate maintenance and replacement costs as the NPRM. For the maintenance interval we use Mean Time To Repair (MTTR). For the replacement interval we use Mean Time Between Failure (MTBF).

Industry provided us with MTTR and MTBF times, in hours, for most large category turboprop and regional turboprop aircraft types. For other aircraft types we assumed MTTR and MTBF will be the same as an equivalent aircraft group and class. We used the individual original purchase prices provided by industry for cost of replacement avionics due to failure. For MTTR, we estimated the repair costs at three percent of the purchase price. We also assumed these replacement and repairs will occur at the aircraft scheduled maintenance checks and therefore will not generate aircraft downtime costs.

We assumed minimal incremental MTTR and MTBF costs for neo-classic and modern turbojet aircraft that could be made capable of ADS-B Out operation by adding data link capabilities, interfacing to existing Global Navigation Satellite System (GNSS) equipment, or that may need additional programming updates that could be upgraded at nearly no cost. These neo-classic and modern turbojet airplanes currently have transponders and position sources, so there is nearly no future incremental replacement or maintenance costs with this final rule.

We obtained estimates for the annual average hours flown by aircraft group from BACK Aviation Solutions. Table 15 shows the annual average hours by aircraft group estimates we will use to estimate when MTBF and MTTR will occur.

AVERAGE ANNUAL NUMBER OF HOURS FLOWN		
AIRCRAFT BODY	EQUIPMENT CLASSIFICATION	AVERAGE
Narrow Body	J2	2,857
Narrow Body	J3	1,677
Narrow Body	J4	1,500
Regional Jets	J2	2,003
Widebody	J2	3,101
Widebody	J3	2,529
Widebody	J4	3,307
Turboprops	TP, TP4	1,305

Table 15

We then estimated the replacement and maintenance interval, in years, for ADS-B Out equipment based on the average annual number of hours that aircraft operate. Table 16 shows the intervals, in years, for replacement and maintenance of ADS-B Out equipment.

Table 16

Replacement and Maintenance Intervals In Years									
MultiMode Receiver		Narrow J2	NarrowJ3	Narrow J4	Regional	WideJ2	WideJ3	WideJ4	TP
Analog	MTBF	7	12	13	10	6	8	6	15
Digital	MTBF	9	15	17	12	8	10	8	19
Analog	MTTR	3	6	7	5	3	4	3	8
Digital	MTTR	7	12	13	10	6	8	6	15

Tables 17 and 18 shows the estimated maintenance and replacement costs for ADS-B Out equipage in turbojet and turboprop aircraft during the 2009-2035 analysis interval.

Table 17

Large Category Turbojet Total MTBF and MTTR Costs $2009 Millions		
	MTBF Costs	MTTR Costs
Total	$62.55	$2.23
3% Discount	$41.61	$1.69
7% Discount	$24.89	$1.23

Table 18

Regional Turboprop Total MTBF and MTTR Costs $2009 Millions		
	MTBF Costs	MTTR Costs
Total	$7.06	$0.37
3% Discount	$3.48	$0.20
7% Discount	$1.40	$0.09

The manufacturers and vendors did not provide us with MTBF or MTTR details for GA aircraft. However, based on Table 1.7 of the 2006 FAA General Aviation and Air Taxi Survey, the following annual average hours flown by aircraft group is calculated as:

Table 19

GENERAL AVIATION AND AIR TAXI AVERAGE HOURS FLOWN - 2006					
Single Piston	Multi Piston	Turbo Prop	Turbo Jet	Rotorcraft	
				Piston	Turbine
96.4	136.3	268.2	392.8	281.2	428.8

The reason we assumed GA aircraft will not incur maintenance or repair cost is these aircraft have low utilization rates relative to commercial airplanes. Industry provided

MTBF and MTTR hours for Large Category and Regional Turbojet and Regional Turboprop aircraft in order to estimate ADS-B Out intervals. We assumed the Large Category and Regional Turbojet and Regional Turboprop aircraft MTBF and MTTR data will apply to the GA aircraft. The hourly MTBF estimates ranged from 20,000 to 45,000 hours depending on aircraft group. Because GA aircraft operate fewer hours than transport category aircraft, even at the bottom end of the range, the minimum replacement of an ADS-B Out unit on a GA aircraft will occur well beyond the analysis interval. Similarly, MTTR ranges fell between 10,000 to 15,000 hours, which again will occur outside of the analysis interval for a GA aircraft. Thus, for the GA aircraft analyzed within the analysis interval, the MTBF and MTTR costs will be minimal.

In the next section, these additional ADS-B Out equipage maintenance and replacement costs will be summed with the costs of additional fuel burn, purchasing and installing ADS-B Out, and upgrading avionic systems.

4.2.3.9 ADS-B Out Aircraft Equipage Cost Summary

The following tables summarize the range estimate of constant dollars, three and seven percent present value costs to industry over the 2009–2035 analysis interval. The low cost estimates represent the minimal compliance cost outcome or a programming compliance change. The high cost estimates means a transponder or position source replacement or an operator’s decision to install avionics that take advantage of future GNSS upgrades. The base case estimate represents a fleet where about half the airplanes are easily upgraded for future GNSS products and the other half meet the minimum requirements of the final rule.

These cost estimates include ADS-B Out equipage, installation, maintenance, additional fuel burn costs and learning curve savings. Based on our MTTR and MTBF assumptions stated earlier, maintenance and replacement costs for ADS-B Out for GA aircraft equals zero because the maintenance and replacement times will occur beyond 2035. The dollar value ranges consist of a wide variety of avionics within each aircraft group. The aircraft architecture within each equipment group can vary, causing different carriage, labor and wiring requirements for the installation of ADS-B Out equipment. Volume discounting versus single line purchasing also affects the dollar value ranges. We believe the base-case estimate is the most representative outcome. Table 20 shows the maintenance costs are included only in the base-case for the total cost calculation.

Table 20

Total Aircraft Cost of ADS-B Out 2009 $ Millions			
Constant Dollars	**Low**	**Base-Case**	**High**
With Learning Efficiencies	$2,363.84	$4,246.09	$6,030.27
Fuel Burn	$30.34	$52.79	$75.25
Mean Time Between Failure		$69.61	
Mean Time To Repair		$2.60	
Total	$2,394.18	$4,371.09	$6,105.53
3% Present Value	**Low**	**Base-Case**	**High**
With Learning Efficiencies	$1,834.15	$3,200.92	$4,542.29
Fuel Burn	$20.77	$33.34	$45.91
Mean Time Between Failure		$45.08	
Mean Time To Repair		$1.89	
Total	$1,854.92	$3,281.24	$4,588.20
7% Present Value	**Low**	**Base-Case**	**High**
With Learning Efficiencies	$1,311.18	$2,294.21	$3,253.60
Fuel Burn	$10.44	$18.16	$25.88
Mean Time Between Failure		$26.29	
Mean Time To Repair		$1.32	
Total	$1,321.62	$2,339.98	$3,279.48

4.2.4 Cost to FAA to Provide Surveillance Under the ADS-B Out Scenario

ADS-B Out implementation requires integration of four major components: ground infrastructure (ground based transceivers), automation, data[45] and avionics.[46]

The FAA has entered into a vendor contract with ITT to provide ADS-B surveillance uplink and downlink services, TIS-B and FIS-B services. The vendor will install and maintain the ground equipment necessary to provide ADS-B uplink and downlink services to air traffic control. The costs for ADS-B Out presented in this report are an estimate of what the contractor will charge the FAA to provide these services and also include the costs of automation interfaces and program office costs.

The costs of the ADS-B Out scenario also include radar costs, which include the cost to sustain existing radar until ADS-B Out is operational (sustain costs), the cost to operate backup radar (backup costs), and the cost to decommission some radar as ADS-B

[45] Integration of data is part of the ADS-B In ground costs.
[46] Exhibit 300 Attachment 2 Business Case Analysis Report for Future Surveillance JRC Phase 2a, pg. 12.

becomes operational (decommissioning costs). Under the radar baseline scenario, the FAA will incur costs of $2.9 billion over 27 years ($1.2 billion when discounted by 7%) as detailed in Table 2. Under the ADS-B Out scenario, the FAA will incur total legacy surveillance costs of $1.9 billion ($975 million when discounted by 7%). In other words, the FAA will spend $1 billion ($271 million when discounted by 7%) less on radar under the ADS-B Out scenario, because it will cut back on the number of radar. However, the FAA will incur $1.8 billion for the ADS-B Out surveillance services ($1.1 billion when discounted by 7%). Therefore, while the agency may be saving money on radar, it will be spending more on ADS-B services, so there will be no net cost savings to the FAA from the ADS-B Out program. Total costs to the FAA of the ADS-B Out scenario are higher than total costs of the radar baseline scenario.

The cost of the ground segment under the ADS-B Out scenario (not including Juneau, but including legacy surveillance costs) is estimated to be $3.7 billion ($2.0 billion) over 29 years as presented in Table 21. This includes total ADS-B Out ground costs of $1.8 billion ($1.1 billion when discounted by 7%), and total legacy surveillance costs of $1.9 billion ($974 million when discounted by 7%)[47].

Table 21
ADS-B Out Scenario Total Ground Costs: The Rule
(not including Low Altitude Operations in the Gulf of Mexico, Capstone or Juneau)
(2009K $)

Year	ADS-B Out Ground Costs	3% Discount Rate	7% Discount Rate	Total ADS-B Out Ground Costs Discounted at 3%	Total ADS-B Out Ground Costs Discounted at 7%	Total Legacy Surveillance - Sustain, backup, upgrade and decommission	Total Legacy Surveillance Discounted at 3%	Total Legacy Surveillance Discounted at 7%	Total ADS-B out Ground Costs and Legacy Surveillance	ADS-B Out Ground and Total Legacy Surveillance Discounted at 3%	ADS-B Out Ground and Total Legacy Surveillance Discounted at 7%
2009	$23,932	1.0000	1.0000	$23,932	$23,932	85,728	$85,728	$85,728	$109,660	$109,660	$109,660
2010	$202,435	0.9709	0.9346	$196,539	$189,192	61,559	$59,766	$57,532	$263,995	$256,306	$246,724
2011	$129,533	0.9426	0.8734	$122,098	$113,139	62,877	$59,268	$54,919	$192,410	$181,365	$168,059
2012	$139,275	0.9151	0.8163	$127,456	$113,690	134,504	$123,091	$109,796	$273,779	$250,547	$223,485
2013	$144,931	0.8885	0.7629	$128,770	$110,568	97,208	$86,368	$74,160	$242,140	$215,138	$184,727
2014	$136,411	0.8626	0.7130	$117,669	$97,259	107,617	$92,831	$76,729	$244,028	$210,500	$173,988
2015	$87,385	0.8375	0.6663	$73,184	$58,229	80,514	$67,429	$53,650	$167,900	$140,613	$111,879
2016	$87,184	0.8131	0.6227	$70,889	$54,294	80,188	$65,200	$49,937	$167,372	$136,089	$104,231
2017	$66,366	0.7894	0.5820	$52,390	$38,626	82,132	$64,836	$47,802	$148,499	$117,226	$86,428
2018	$59,279	0.7664	0.5439	$45,432	$32,244	77,504	$59,401	$42,157	$136,783	$104,833	$74,401
2019	$57,204	0.7441	0.5083	$42,565	$29,080	71,381	$53,114	$36,286	$128,585	$95,679	$65,366
2020	$57,259	0.7224	0.4751	$41,365	$27,204	63,998	$46,234	$30,405	$121,258	$87,599	$57,609
2021	$57,036	0.7014	0.4440	$40,004	$25,325	85,073	$59,669	$37,774	$142,109	$99,672	$63,098
2022	$46,321	0.6810	0.4150	$31,542	$19,222	64,821	$44,140	$26,899	$111,142	$75,683	$46,120
2023	$40,524	0.6611	0.3878	$26,791	$15,716	43,245	$28,590	$16,771	$83,768	$55,381	$32,487
2024	$40,556	0.6419	0.3624	$26,031	$14,699	62,789	$40,302	$22,758	$103,345	$66,333	$37,457
2025	$40,589	0.6232	0.3387	$25,294	$13,749	57,180	$35,632	$19,369	$97,769	$60,926	$33,118
2026	$40,589	0.6050	0.3166	$24,557	$12,850	57,180	$34,595	$18,102	$97,769	$59,152	$30,951
2027	$40,589	0.5874	0.2959	$23,842	$12,009	57,180	$33,587	$16,917	$97,769	$57,429	$28,926
2028	$40,589	0.5703	0.2765	$23,147	$11,223	57,180	$32,609	$15,811	$97,769	$55,756	$27,034
2029	$40,589	0.5537	0.2584	$22,473	$10,489	57,180	$31,659	$14,776	$97,769	$54,132	$25,265
2030	$40,589	0.5375	0.2415	$21,819	$9,803	57,180	$30,737	$13,810	$97,769	$52,556	$23,612
2031	$40,589	0.5219	0.2257	$21,183	$9,162	57,180	$29,842	$12,906	$97,769	$51,025	$22,068
2032	$40,589	0.5067	0.2109	$20,566	$8,562	57,180	$28,972	$12,062	$97,769	$49,539	$20,624
2033	$40,589	0.4919	0.1971	$19,967	$8,002	57,180	$28,129	$11,273	$97,769	$48,096	$19,275
2034	$40,589	0.4776	0.1842	$19,386	$7,479	57,180	$27,309	$10,535	$97,769	$46,695	$18,014
2035	$46,983	0.4637	0.1722	$21,786	$8,090	34,806	$16,140	$5,994	$81,790	$37,925	$14,084
Total	**1,828,508**			**1,410,679**	**1,073,833**	**1,867,742**	**1,365,176**	**974,856**	**3,696,250**	**2,775,855**	**2,048,690**

[47] The FAA developed these estimates internally.

The costs of this rule will be borne by both industry and the government, and benefits will accrue to industry and to the flying public, as discussed in the benefits section. Industry will incur costs ranging from $2.4 billion ($1.3 billion when discounted by 7%) to $6.1 billion ($3.3 billion when discounted by 7%). Estimated benefits accruing to industry and the flying public range from $6.8 billion ($2.1 billion when discounted by 7%) to $8.8 billion ($2.8 billion when discounted by 7%).

4.2.5 Benefits of ADS-B Out

ADS-B Out will enable improved surveillance services across the en route, terminal, and surface environments by providing a robust, highly accurate, timely four-dimensional surveillance data link, based on the downlink of the aircraft's Global Positioning System (GPS) parameters. ADS-B Out is designed to improve the capacity and efficiency of the NAS, maintain safety, and provide a flexible, expandable platform to accommodate future air traffic growth.

The FAA is not engaging in this rulemaking simply to meet the level of surveillance that exists in the current infrastructure, or to establish a new surveillance system that would only enable separation performance equivalent to that realized today. ADS-B Out performance is intended to go beyond today's standards for accuracy and provide a platform for the next generation air transportation system.

The following quantified benefit estimates apply to both domestic operators and foreign operators as they operate in U.S. controlled airspace. However, we did not break out benefits between domestic and foreign operators. Earlier we provided a separate cost estimate for foreign firms, which we did not include in the costs of the rule, but we do not provide a separate benefit estimate corresponding to those costs. Benefits are slightly overestimated because they include benefits to foreign operators but do not include the costs to foreign operators.

Quantifiable benefit areas and associated estimated benefits are presented in Table 22 below. Derivations of these estimates are described in the following sections.

Table 22
Quantified ADS-B Out Benefits
2009$ M

	Quantified ADS-B Out Benefits					
Benefit Area	Low Benefit 2009 M$	Discounted at 3%	Discounted at 7%	High Benefit 2009 M$	Discounted at 3%	Discounted at 7%
Total Benefits	$6,780.59	$3,976.83	$2,089.37	$8,477.56	$5,026.11	$2,739.18
Gulf of Mexico						
High Altitude Operations	$2,641.44	$1,476.72	$724.97	$2,641.44	$1,476.72	$724.97
More Efficient En-Route Separation	$2,257.08	$1,231.34	$581.15	$2,257.08	$1,231.34	$581.15
Delay Savings	$1,685.22	$945.55	$463.15	$1,685.22	$945.55	$463.15
Additional Flights Accommodated	$571.85	$285.79	$118.00	$571.85	$285.79	$118.00
Optimal and More Direct Routing	$384.37	$245.39	$143.82	$384.37	$245.39	$143.82
Improved En route Conflict Probe Performance	$266.89	$156.40	$81.52	$1,690.78	$990.77	$516.42
More Efficient Metering based on improved TMA accuracy	$1,365.61	$787.51	$398.07	$1,365.61	$787.51	$398.07
Increased ability to perform optimal profile descents	$2,479.93	$1,534.59	$863.21	$2,479.93	$1,534.59	$863.21
Value of Net Reduction in CO_2 Emissions [1]	$26.71	$21.60	$21.60	$299.79	$236.51	$236.51
[1] CO_2 Low benefits are discounted by 5%/ high benefits by 2.5%						

4.2.5.1 High Altitude Operations Over the Gulf of Mexico

Assumptions

- IOC for communications and weather over the Gulf of Mexico 9/2009,
- IOC for surveillance 12/09,
- Capacity benefits phase in beginning in 2012 and by 2019 100% of the active fleet is equipped, and
- Delays are limited to, or capped at 20 minutes.[48]

Delay Savings and Additional Flights Due to Increased Capacity over the Gulf of Mexico (Benefits of Reduced Delay and Value of Additional Flights Accommodated

We estimate that the benefit of increased capacity for high altitude operations that will be achieved with ADS-B Out over the Gulf of Mexico measured in reduced delays is $1.7 billion ($463 million at 7% present value). We also estimate that ADS-B Out will accommodate an additional 290,550 flights over the Gulf of Mexico during the period from 2017 through 2035. We estimate the benefit of these additional flights is $572 million ($118 million at 7% present value). Appendix B has details on the methods we used to estimate these benefits.

ADS-B Out can potentially decrease delays over the Gulf of Mexico by allowing air traffic controllers to separate traffic to radar standards rather than oceanic standards. While the rule does not mandate ADS-B Out performance requirements over the Gulf of Mexico beyond 12 miles from the U.S. shore, all high altitude aircraft that fly into and out of the U.S. over the Gulf of Mexico will have to be equipped to the standards of the rule because these aircraft will be traversing airspace that requires ADS-B performance. The FAA will provide ADS-B surveillance capability under the vendor service contract.

Currently, controllers need to build a margin of safety into airspace where there is no radar. In non-radar areas like the Gulf of Mexico controllers separate aircraft by 10 to 15 minutes, which is equivalent to 80 to 120 miles lateral separation. ADS-B Out

[48] "approximately 20 minutes represents the highest level of average delay realized in actual practice even at highly congested airports", FAA Airport Benefit Cost Analysis Guidance, page 16, FAA Airport Benefit Cost Analysis http://www.faa.gov/regulations_policies/policy_guidance/benefit_cost/media/faabca.pdf

surveillance in these areas will allow closer separation of aircraft because air traffic controllers will be able to see aircraft and achieve radar-like separation. This will lead to fewer delays and higher levels of traffic than would be the case without ADS-B Out.

Optimal Routing and More Direct Routing Over the Gulf of Mexico – Benefits of Decreased Flying Distance

Provision of ATC surveillance above FL240 for non-radar regions over the Gulf of Mexico will allow for optimal and more direct routing of flights. We estimate that $384 million ($144 million at 7% present value) might be achieved in time saved due to optimal routing and more direct routing over the Gulf. Details of how these benefits were estimated are shown in Appendix B.

Due to lack of surveillance and limited communication at high altitudes, non-radar separation procedures restrict aircraft flying high altitude operations over the Gulf to a limited number of routes or to a path avoiding the non-radar region completely. The introduction of radar-like separation attained by providing surveillance and improved communications services in the Gulf of Mexico will permit the creation of additional routes or the granting of more direct requests. This will allow for more efficient routes, which will result in decreased flying distance. Decreased flying distance can be translated into time saved, which can be valued in terms of aircraft direct operating costs and passenger value of time.

4.2.5.2 Improved En Route Conflict Probe Performance

Conflict Probe Benefits

The Conflict Probe is a tool designed to assist the air traffic controllers in their key role of ensuring the safe and expeditious movement of aircraft. It does this by constructing aircraft trajectories – the predicted flight path of aircraft in 3-D position and time -- based on detailed flight models, the aircraft's flight plan, and surveillance data. These trajectories are then continuously "probed" for possible separation violations between aircraft – i.e., "conflicts" -- and the controller is notified accordingly. The warning time for these conflicts is limited only by the trajectory accuracy, and thus strategic problem notification is supported for enhanced safety and efficiency. Controller action and pilot requests may also be checked before they are implemented with "trial" trajectories, further improving safety and facilitating the granting of these requests.

Assumptions

- The mean distance of prevented maneuvers = 1.04 NM.
- An average speed of 356 NM per hour per prevented maneuver will save .0029th of an hour (1.04 NM/356 nmph).[49]

[49] FAA (2003), "Controller-Pilot Data Link Communications (CPDLC Build 1A) Benefits Analysis."

- Given a value of time per IFR hour of $4,431[50] the average prevented maneuver will save $12.94($4,431 x .0029).
- Estimate 65% of the remaining conflicts are vector maneuvers.[51]
- The mean path length of vector maneuvers not eliminated with ADS-B is 4.01 NM.
- With ADS-B the efficiency of the remaining vector maneuvers will increase by 1/8 of the maneuver distance.
- Using an average speed of 356 NM per hour each vector maneuver made more efficient will save .0014th of an hour (4.01 NM /8 =.50 NM; convert to hours .50 NM/356 = .0014).
- Given a value of time per IFR hour of $4,431 each more efficient maneuver ($4,431 x .0014) will save $6.24.
- Conflict probe benefits begin in 2017.
- Controllers act on 10% [52] to 63.35% [53] of conflict alerts, with 10% giving a lower bound estimate and 63.35% giving an upper bound estimate.
- Slight discrepancies are due to round off error.

Controllers act on the knowledge that an aircraft on their display may have travelled for up to 12 seconds with no display update. To compensate for this less than precise radar surveillance information, the actual spacing between aircraft is usually larger than the minimum separation required. The minimum allowed en route separation is 5 nautical miles, but high performance aircraft can travel up to 1.5 nautical miles laterally during the time between updates on the radar display.[54]

With the greater precision of ADS-B, it is possible that controllers will put less of a buffer between aircraft in flight. With less of a buffer, there may be less maneuvering of aircraft and consequently less fuel consumed and less delays (less time spent in aircraft maneuvers). Because of the uncertainty of whether the knowledge that display data will be more precise with ADS-B will result in air traffic controllers actually reducing the buffer between aircraft, Mitre estimated the benefits that could result if their conflict probe tool alerted less frequently due to more precise ADS-B data. The Mitre study,[55] provides the basis for the methodology and some data for the benefits estimated here, but some of our assumptions differ from those in the study. Because the study was performed before the latest FAA forecast was released, the Mitre study does not use this latest forecast, while the estimates provided here do.

[50] Includes aircraft direct operating cost and passenger value of time and is based on the 2009 TAF and ATO-F FY09 economic values.

[51] "ADS-B Benefits Enabled from Improved En Route Conflict Probe Performance", The Mitre Corporation, August 27, 2007.

[52] Human Factors Research and Engineering Group AJP-61, FAA

[53] Subject matter experts in Air Traffic Organization – Finance, now called IP&A, Operations Research group

[54] Ibid.

[55] "ADS-B Benefits Enabled from Improved En Route Conflict Probe Performance"

According to Mitre's analysis, the excess separation can be reduced by at least .5 NM for each aircraft due to ADS-B, removing a total of 1 NM of excess separation due to the slower update rate of radar.[56] The total separation reduction from 8 to 7 NM allowed by ADS-B could support increased flight efficiency in two ways. First, some maneuvers are eliminated completely because of the reduction in the number of alerts. Without ADS-B, the conflict probe would issue an alert if two aircraft were going to lose 8 NM lateral separation. Two aircraft equipped with ADS-B would only set off a conflict probe alert if they were going to lose 7 NM lateral separation. Fewer maneuvers translate into a time savings, which translate into a cost savings. According to data from the FAA's Air Traffic Organization – Finance [57] (ATO-F) there would have been an added path distance of 1.04 NM per avoided maneuver, which translates into a time savings of .0029 hours.

Second, the lateral (vector maneuvers) that remain are expected to be more efficient due to the smaller separation distance that must be obtained as illustrated in the Mitre analysis. ATO-F estimated the mean path length of vector maneuvers not eliminated with ADS-B is 4.01 NM. These maneuvers could be made one eighth more efficient[58] eliminating .50 NM which translates to a time savings of .0014 hours.

To estimate the benefit of prevented maneuvers, Mitre estimated a conflict probe alert rate for both 8 NM and 7 NM separation by applying a URET-like conflict probe to recorded Base Year (2006) CONUS-wide data[59] with 8 NM separation to represent radar and 7 NM separation to represent ADS-B bounds. The analysis used a 10 minute look-ahead time and each alert occurred in en route airspace and would have been notified to an en route controller. Five days, each day being near the 90% busiest day in the NAS, were analyzed.

The measured alert counts at each separation value for each of the five days are presented in the table below. At an 8 NM separation, the average number of conflict probe alerts is 53,122 and at a 7 NM separation the average number of conflict probe alerts is 45,155.

Table 23
Measured Alert Counts

[56] Mitre estimated excess separation due to radar surveillance error. To estimate excess separation due to radar surveillance error they used "comparative studies of radar and Global Positioning System (GPS) data as recorded for actual flights (e.g. Paglione and Ryan, 2005) and other documented parameters such as wind prediction error, Flight Technical Error (FTE), and speed estimation error.
[57] The name of this FAA office has been changed to IP&A, Operations Research group, since they supplied the data.
[58]Mitre analysis, August 27, 2009, page 28.
[59]This is recorded CONUS-wide en route track and flight plans as generated by the Enhanced Traffic Management System (ETMS).

Date	Measured Alert Counts	
	8 nm Sep	7 nm Sep
3/17/2006	67,062	57,025
4/20/2006	52,384	44,517
5/04/2006	49,937	42,377
8/04/2006	48,616	41,346
12/19/2006	47,611	40,511
2006 Sample Average	**53,122**	**45,155**

To obtain alert rates, IFR handles[60] in the continental United States, for each of the five days were obtained from ATADS.[61, 62] Pairwise combination handles per day were calculated by subtracting the number of handles from the square of handles and dividing by two. This represents all possible combinations of handles over the continental U.S. for that day and is used as the denominator in the calculations of the alert rates.

Table 24
IFR handles over the continental U.S.

Date	User Groups					Pairwise Combination Handles Per Day
	Air Carrier	Air Taxi/ Commuter	General Aviation	Military	Sum	(h^2-h)/2
3/17/2006	69,637	27,560	27,251	14,537	138,985	9.66E+09
4/20/2006	69,093	27,231	28,002	15,077	139,403	9.72E+09
5/04/2006	68,017	27,629	27,343	15,149	138,138	9.54E+09
8/04/2006	71,976	29,014	24,913	12,097	138,000	9.52E+09
12/19/2006	73,253	28,987	23,911	11,554	137,705	9.48E+09
2006 Sample Average	**70,395**	**28,084**	**26,284**	**13,683**	**138,446**	**9.58E+09**
Source: ATADS						h = Handles per Day

Measured alert counts are taken as a percent of the pair-wise handle combinations per day for each of the two separation values (8 NM and 7 NM). This gives the percent of handle combinations that result in a conflict probe alert for each separation value according to the Mitre analysis; 5.54E-06 for 8 NM and 4.71E-06 for 7 NM separation.

Table 25
Alert Rate Per Pair-wise Handle for 8 NM and 7 NM Separation

[60] IFR Aircraft Handled. The number of ARTCC enroute IFR departures multiplied by two, plus the number of en route IFR overs. This formula assumes that the number of departures (acceptances, extensions, and organizations of IFR flight plans) is equal to the number of arrivals (IFR flight plans closed).
[61] http://aspm.faa.gov. # of handles is also available through Opsnet.
[62] Excludes Anchorage and Guam.

	Alert Rate for CONUS Centers						
				Measured Alert Counts			
Date	Handles per Day	Percent Combinations Ref Daily Avg	Pairwise Handle Combinations per Day	8 nm Sep	7 nm Sep	8 nm Alert Rate per Pair (Radar)	7 nm Alert Rate per Pair (ADS-B)
3/17/2006	138,985	151.0%	9.66E+09	67,062	57,025	6.94E-06	5.90E-06
4/20/2006	139,403	151.9%	9.72E+09	52,384	44,517	5.39E-06	4.58E-06
5/04/2006	138,138	149.2%	9.54E+09	49,937	42,377	5.23E-06	4.44E-06
8/04/2006	138,000	148.9%	9.52E+09	48,616	41,346	5.11E-06	4.34E-06
12/19/2006	137,705	148.2%	9.48E+09	47,611	40,511	5.02E-06	4.27E-06
2006 Sample Average	**138,446**	**149.8%**	**9.58E+09**	**53,112**	**45,155**	**5.54E-06**	**4.71E-06**

To forecast future conflicts these alert rates are applied to the forecast of daily pair-wise handle combinations over the continental U.S., which is computed from the number of IFR handles from the 2009 FAA Aerospace Forecast.[63] The table below illustrates how we estimated the number of prevented conflicts due to predicted fewer alerts with 7 NM separation rather than 8NM separation. We assume that the conflict probe increased accuracy benefit begins in 2017 [64] and continues through the lifecycle.

For example in 2017, we project 129,100 IFR handles per day over the continental U.S. or 8.33 B pair-wise combination handles per day. To determine the number of URET conflict probe alerts expected under the baseline (8NM separation), we multiply pair-wise combination handles by the radar alert rate of 5.54E-06 to derive daily baseline conflicts of 46,192. This would represent the number of times per day the conflict probe would alert without ADS-B (8 NM separation). Similarly to obtain the number of URET conflict probe alerts expected with ADS-B we multiply pairwise combination handles by the 7NM separation alert rate of 4.71E-06 to derive 39,264 or the number of times per day the URET conflict probe would alert with ADS-B surveillance. The potential prevented maneuvers are 6,928 daily. However, experience indicates that controllers do not always act on the URET conflict probe alerts. Studies indicate that the number of times a controller acts on a conflict probe alert can be as low as 2% of conflict probe alerts to as high as 100%. The Mitre conflict probe analysis assumed that controllers would act on 100% of the conflict probe alerts. In the regulatory impact analysis of the NPRM, we assumed that controllers would have acted on 63.35% of these conflicts. In this final regulatory impact analysis, to be conservative, we add a lower bound estimate of conflict probe benefits that assumes that controllers only act on 10% [65] of conflict probe alerts. Table 26 uses 63.35% as the percent of conflict probe alerts that controllers

[63] Table 33, IFR Handled at FAA Air Route Traffic Control Centers, 2009 FAA Aerospace Forecast, less handles over Guam and Anchorage.

[64] The conflict probe is planned to be available to the R-side controller by 2016.

[65] Based on discussions with personnel in FAA's Human Factors Research and Engineering Group AJP-61. The lower bound number is also supported by studies including: **Adaptation and adoption of technologies: Examination of the User Request Evaluation Tool (URET),** Kevin Corker, Martin Howard, Martijn Mooij, San Jose Sate University, November 1, 2005, which indicated that about 2% of alerts are acted on and **Human Factors Analysis of Safety Alerts in Air Traffic Control,** Kenneth Allendoerfer, Human Factors Team – Atlantic City, ATO-P Ferne Friedman-Berg, Ph.D., Human Factors Team – Atlantic City, ATO-P Shantanu Pai, Engility Corporation November 2007 which concluded that 13%-19% of alerts are acted on.

act on. The number of actual prevented conflicts in the example is 4,389 in 2017 (6,928 times 63.35%). The dollar value of each prevented maneuver is $12.94 (see assumptions above for calculation) and the total dollar value of prevented maneuvers per day is $56,805.[66]

Table 26
Estimate of Prevented Conflicts and Savings for Prevented Maneuvers

Future years	Handles/day	Handle Pairs/day	Conflicts given 8 nm sepation	Conflicts given 7nm separation	Potential Prevented Conflicts	Actual Prevented Conflicts	Daily Savings for Prevented Maneuvers
2017	1.29E+05	8.33E+09	46,192	39,264	6,928	4,389	$56,805
2018	1.32E+05	8.74E+09	48,437	41,173	7,264	4,602	$59,566
2019	1.35E+05	9.14E+09	50,660	43,062	7,598	4,813	$62,300
2020	1.38E+05	9.56E+09	53,010	45,060	7,950	5,036	$65,189
2021	1.41E+05	1.00E+10	55,413	47,102	8,311	5,265	$68,145
2022	1.45E+05	1.05E+10	58,030	49,327	8,703	5,513	$71,363
2023	1.48E+05	1.10E+10	60,707	51,602	9,105	5,768	$74,655
2024	1.52E+05	1.15E+10	63,612	54,072	9,540	6,044	$78,227
2025	1.55E+05	1.20E+10	66,671	56,672	9,999	6,334	$81,989
2026	1.59E+05	1.26E+10	69,890	59,408	10,482	6,640	$85,948
2027	1.63E+05	1.32E+10	73,185	62,209	10,976	6,953	$90,000
2028	1.66E+05	1.38E+10	76,740	65,231	11,509	7,291	$94,371
2029	1.70E+05	1.45E+10	80,474	68,405	12,069	7,646	$98,963
2030	1.74E+05	1.52E+10	84,296	71,654	12,642	8,009	$103,664
2031	1.79E+05	1.59E+10	88,405	75,146	13,259	8,399	$108,717
2032	1.83E+05	1.67E+10	92,612	78,722	13,890	8,799	$113,890
2033	1.87E+05	1.75E+10	97,124	82,558	14,566	9,228	$119,439
2034	1.92E+05	1.84E+10	101,743	86,484	15,259	9,667	$125,119
2035	1.96E+05	1.92E+10	106,687	90,687	16,000	10,136	$131,199

In addition to eliminating potential conflicts that occur between 7 NM and 8 NM, ADS-B could make some maneuvers of aircraft that trigger an alert within the 7 NM separation more efficient. In 2017, we estimate 39,264 conflict probe alerts given a 7NM separation alert threshold (daily handle pairs of 8.33 billion times the 7 NM conflict probe alert rate 4.71E-06 = 39,264). If controllers acted on 63.35% of these conflict alerts, 24,874 potential conflicts would be maneuvered in 2017. Sixty-five percent of the remaining maneuvers (16,168) can be made more efficient because of ADS-B surveillance data. The dollar value of the increased efficiency is $6.24 per maneuver as explained under the

[66] Discrepancies due to round off error.

assumptions above. Savings for the remaining vector maneuvers is $100,827 per day in 2017.

Table 27
Estimates of Remaining Vector Maneuvers and Savings for Increased Efficiency of Some Remaining Maneuvers

Future years	Handle Pairs/day	Conflicts given 8 nm sepation	Conflicts given 7nm separation	7 nm URET Conflicts Acted On	# Conflicts requiring Vector Maneuvers	Daily Savings for Remaining Vector Maneuvers
2017	8.33E+09	46,192	39,264	24,874	16,168	$100,827
2018	8.74E+09	48,437	41,173	26,083	16,954	$105,727
2019	9.14E+09	50,660	43,062	27,280	17,732	$110,580
2020	9.56E+09	53,010	45,060	28,545	18,555	$115,709
2021	1.00E+10	55,413	47,102	29,839	19,396	$120,954
2022	1.05E+10	58,030	49,327	31,248	20,312	$126,666
2023	1.10E+10	60,707	51,602	32,690	21,249	$132,509
2024	1.15E+10	63,612	54,072	34,254	22,265	$138,851
2025	1.20E+10	66,671	56,672	35,902	23,336	$145,528
2026	1.26E+10	69,890	59,408	37,635	24,463	$152,554
2027	1.32E+10	73,185	62,209	39,409	25,616	$159,746
2028	1.38E+10	76,740	65,231	41,324	26,860	$167,506
2029	1.45E+10	80,474	68,405	43,334	28,167	$175,656
2030	1.52E+10	84,296	71,654	45,393	29,505	$183,999
2031	1.59E+10	88,405	75,146	47,605	30,943	$192,968
2032	1.67E+10	92,612	78,722	49,871	32,416	$202,151
2033	1.75E+10	97,124	82,558	52,300	33,995	$212,000
2034	1.84E+10	101,743	86,484	54,788	35,612	$222,083
2035	1.92E+10	106,687	90,687	57,450	37,343	$232,874

Table 28 shows annual savings in 2009 dollars given that controllers act on the alerts 63.35% of the time, the high benefit estimate. For example for 2017, we add savings from prevented maneuvers ($56,805) plus savings for more efficient vector maneuvers ($100,827) for daily total savings ($157,631) and derive an annual savings of $57.5 million. Since we estimate 78% equipage in 2017 we claim 78% of the $57.5 million savings in year 2017.

Table 28
Dollar Value of Conflict Probe Performance Benefits – High

Future years	Daily Savings for Prevented Maneuvers	Daily Savings for Remaining Vector Maneuvers	Daily Total Savings	Unadjusted Savings Per Year	Percent IFR Equipage	Adjusted Savings per Year	3% Discount Rate	High conflict Probe Benefits Discounted by 3%	7% Discount Rate	High conflict Probe Benefits Discounted by 7%
2017	$56,805	$100,827	$157,631	$57,535,451	0.78	$44,877,652	0.7894	$35,426,833	0.5820	$26,119,202
2018	$59,566	$105,727	$165,293	$60,331,764	0.87	$52,488,635	0.7664	$40,228,168	0.5439	$28,550,340
2019	$62,300	$110,580	$172,880	$63,101,048	1.00	$63,101,048	0.7441	$46,953,106	0.5083	$32,077,373
2020	$65,189	$115,709	$180,898	$66,027,921	1.00	$66,027,921	0.7224	$47,699,975	0.4751	$31,369,389
2021	$68,145	$120,954	$189,099	$69,021,143	1.00	$69,021,143	0.7014	$48,410,041	0.4440	$30,646,213
2022	$71,363	$126,666	$198,028	$72,280,386	1.00	$72,280,386	0.6810	$49,219,425	0.4150	$29,993,790
2023	$74,655	$132,509	$207,164	$75,614,816	1.00	$75,614,816	0.6611	$49,990,301	0.3878	$29,324,729
2024	$78,227	$138,851	$217,078	$79,233,493	1.00	$79,233,493	0.6419	$50,856,964	0.3624	$28,717,864
2025	$81,989	$145,528	$227,517	$83,043,797	1.00	$83,043,797	0.6232	$51,750,149	0.3387	$28,129,807
2026	$85,948	$152,554	$238,502	$87,053,184	1.00	$87,053,184	0.6050	$52,668,608	0.3166	$27,558,809
2027	$90,000	$159,746	$249,745	$91,157,091	1.00	$91,157,091	0.5874	$53,545,184	0.2959	$26,970,094
2028	$94,371	$167,506	$261,877	$95,585,152	1.00	$95,585,152	0.5703	$54,510,876	0.2765	$26,430,091
2029	$98,963	$175,656	$274,619	$100,235,840	1.00	$100,235,840	0.5537	$55,498,154	0.2584	$25,902,846
2030	$103,664	$183,999	$287,663	$104,996,995	1.00	$104,996,995	0.5375	$56,441,059	0.2415	$25,358,148
2031	$108,717	$192,968	$301,685	$110,115,100	1.00	$110,115,100	0.5219	$57,468,245	0.2257	$24,854,428
2032	$113,890	$202,151	$316,041	$115,354,996	1.00	$115,354,996	0.5067	$58,449,424	0.2109	$24,333,777
2033	$119,439	$212,000	$331,438	$120,975,039	1.00	$120,975,039	0.4919	$59,511,703	0.1971	$23,849,820
2034	$125,119	$222,083	$347,202	$126,728,748	1.00	$126,728,748	0.4776	$60,526,356	0.1842	$23,349,668
2035	$131,199	$232,874	$364,074	$132,886,907	1.00	$132,886,907	0.4637	$61,618,958	0.1722	$22,882,526
Total						**$1,690,777,940**		**$990,773,528**		**$516,418,914**

The analysis is repeated with a 10% rate of controllers acting on conflict probe alerts. The estimated dollar savings are presented below.

Table 29
Dollar Value of Conflict Probe Performance Benefits – Low

Future Years	Daily Savings for Prevented Maneuvers	Daily Savings for Remaining Vector Maneuevers	Daily Total Savings	Unadjusted Savings Per Year	Percent IFR Equipage	Adjusted Savings Per Year	3% Discount Rate	Low Conflict Probe Benefits Discounted by 3%	7% Discount Rate	Low Conflict Probe Benefits Discounted by 7%
2017	$8,967	$15,916	$24,883	$9,082,155	0.78	$7,084,081	0.7894	$5,592,239	0.5820	$4,123,000
2018	$9,403	$16,689	$26,092	$9,523,562	0.87	$8,285,499	0.7664	$6,350,145	0.5439	$4,506,762
2019	$9,834	$17,455	$27,290	$9,960,702	1.00	$9,960,702	0.7441	$7,411,698	0.5083	$5,063,516
2020	$10,290	$18,265	$28,555	$10,422,718	1.00	$10,422,718	0.7224	$7,529,593	0.4751	$4,951,758
2021	$10,757	$19,093	$29,850	$10,895,208	1.00	$10,895,208	0.7014	$7,641,680	0.4440	$4,837,603
2022	$11,265	$19,995	$31,259	$11,409,690	1.00	$11,409,690	0.6810	$7,769,444	0.4150	$4,734,616
2023	$11,784	$20,917	$32,701	$11,936,040	1.00	$11,936,040	0.6611	$7,891,129	0.3878	$4,629,002
2024	$12,348	$21,918	$34,266	$12,507,260	1.00	$12,507,260	0.6419	$8,027,934	0.3624	$4,533,207
2025	$12,942	$22,972	$35,914	$13,108,729	1.00	$13,108,729	0.6232	$8,168,926	0.3387	$4,440,380
2026	$13,567	$24,081	$37,648	$13,741,623	1.00	$13,741,623	0.6050	$8,313,908	0.3166	$4,350,246
2027	$14,207	$25,216	$39,423	$14,389,438	1.00	$14,389,438	0.5874	$8,452,278	0.2959	$4,257,316
2028	$14,897	$26,441	$41,338	$15,088,422	1.00	$15,088,422	0.5703	$8,604,716	0.2765	$4,172,074
2029	$15,622	$27,728	$43,349	$15,822,548	1.00	$15,822,548	0.5537	$8,760,561	0.2584	$4,088,847
2030	$16,364	$29,045	$45,409	$16,574,111	1.00	$16,574,111	0.5375	$8,909,402	0.2415	$4,002,865
2031	$17,161	$30,461	$47,622	$17,382,021	1.00	$17,382,021	0.5219	$9,071,546	0.2257	$3,923,351
2032	$17,978	$31,910	$49,888	$18,209,155	1.00	$18,209,155	0.5067	$9,226,428	0.2109	$3,841,164
2033	$18,854	$33,465	$52,319	$19,096,297	1.00	$19,096,297	0.4919	$9,394,113	0.1971	$3,764,770
2034	$19,751	$35,056	$54,807	$20,004,538	1.00	$20,004,538	0.4776	$9,554,279	0.1842	$3,685,820
2035	$20,710	$36,760	$57,470	$20,976,623	1.00	$20,976,623	0.4637	$9,726,750	0.1722	$3,612,080
Total						$266,894,702		$156,396,768		$81,518,376

Estimated conflict probe benefits range from $267 million ($82 million when discounted by 7%) to $1.7 billion ($516 million when discounted by 7%).

4.2.5.3 More Accurate Metering Because of Increased Accuracy

The improved accuracy and update rate of ADS-B position and speed information (over the accuracy, update rate, and information supplied by radar) will impact the capabilities of controller automation. One aspect of current automation is a metering capability called the Traffic Management Advisor (TMA). TMA is a decision support tool for en route controllers that optimizes arrival flows into busy airports. The controller display provides exact times for each aircraft to reach the arrival fix so that runway throughput is optimized. Because predictions of runway throughput and metering times are based on surveillance inputs, the increased accuracy and update rate of ADS-B, over radar, should allow better predictions, leading to an incremental increase in runway throughput.

TMA was developed by NASA as part of the Center TRACON Automation System (CTAS). Many NASA studies have examined the uncertainty in initial position, aircraft speed, aircraft weight, and winds, and how these uncertainties introduce errors into the CTAS calculations of meter fix arrival times. The study, "CTAS Error Sensitivity, Fuel Efficiency, and Throughput Benefits" (NASA 1996), compared the meter fix uncertainty of the current system, TMA (with the addition of weather information from the Integrated Terminal Weather System - ITWS) and a planned upgrade to TMA called the En route Descent Advisor (EDA). Table 30 presents a summary of the meter fix uncertainty information from the NASA paper. A further study comparing EDA and TMA, "EDA July 2004 Simulation Overview," (NASA 2004) presented similar results.

Table 30
Meter Fix Uncertainty from NASA Study

	Current Operations	TMA (with ITWS)	TMA/EDA (with ITWS)
Meter Fix Uncertainty (Standard Dev)	125 sec	55 sec	21 sec

ADS-B surveillance information should further reduce the uncertainty in initial position and speed allowing more accurate meter fix delivery. The "En route Descent Advisor Performance Analysis Final Report" (NASA, 2004) examined the CTAS input factors (e.g. position, speed, wind , weight, etc.) closely to determine the contribution of each to the meter fix uncertainty. They found that speed and initial position uncertainty account for approximately 40 percent of the remaining error. Table 31 repeats the information given in Table 30, but also applies the additional 40 percent reduction that would occur with no initial position and speed variance. Table 31 implies that if all position and speed error could be eliminated the remaining variance would be 13 seconds. If only half the variance could be eliminated the remaining would be 17 seconds. It is assumed in this estimate that the increased accuracy and update rate of ADS-B in the en route airspace, and the ability to downlink speed information directly into the automation (as opposed to the current method of estimating speed from multiple radar hits over time) will eliminate half the remaining variance due to speed and position uncertainty seen in the current system.

Table 31
Meter Fix Uncertainty with Increased Accuracy

	Current Operations	TMA (with ITWS)	TMA/EDA (with ITWS)	With Perfect Speed and Pos Accuracy	With Speed and Accuracy Twice as Certain as Radar
Meter Fix Uncertainty (Standard Dev)	125 sec	55 sec	21 sec	13 sec	17 sec
As a Percentage of Current Ops	100%	44%	17%	10%	14%

Table 31 also lists the meter fix uncertainty as a percentage of the uncertainty in current operations. TMA reduces the meter fix uncertainty by 66 percent (44 percent of the original); the addition of EDA should bring the total uncertainty reduction to 83 percent (17 percent of original). If the speed and position accuracy from surveillance information were twice as accurate as current information, the final reduction would amount to an 86 percent decrease in meter fix uncertainty (14 percent of original).

To translate the analysis described above into an economic benefit, we first examined the benefit of different arrival variance changes on airport delay using an equilibrium queuing model. The inputs for the model include current Future Airport Capacity Task (FACT 2) airport capacities, current demand profiles at each airport, and future projected operations from the Terminal Area Forecast (TAF). The model allows changes in the arrival variance that should reflect the changes in uncertainty described in Tables 30 and 31. The benefits of TMA, TMA plus EDA, and TMA plus EDA plus ADS-B increased accuracy were tabulated. The ratio of the incremental ADS-B increased accuracy benefits to the TMA benefits equaled approximately 0.05. This leads us to believe that the increased accuracy of ADS-B information should at least result in a 5 percent increase in benefits beyond current TMA projections. In reality this estimate is conservative, because it already assumes that the introduction of ADS-B information will be incremental to EDA, a program that is still in the planning stages but will most likely come to fruition before full ADS-B equipage.

The TMA Program Office completed a future benefits analysis in February 2007 that was submitted and approved within the FAA. The report presented yearly benefit results for 18 TMA airports through 2020. We leveraged these TMA results to estimate the additional benefit due to ADS-B. We first scaled the TMA results to reflect the current approved aircraft direct operating costs (ADOC) and value of passenger time (PVT) values. The ratio described in the previous paragraph was then applied to the TMA results in 2020 to estimate the additional benefits due to increased surveillance information. The benefits were assumed to begin by 2020 and continue through the SBS lifecycle. The 2020 benefit was extrapolated through 2035 using a linear scaling based on the growth in yearly operations at each relevant airport from the TAF.

The estimated benefits are $1.4 billion ($400 million when discounted by 7%).

4.2.5.4 Increased Ability to Allow Optimized Profile Descent Procedures

Optimized Profile Descents (OPDs)[67] are Area Navigation (RNAV) / Required Navigation Performance (RNP) terminal arrival procedures specifically designed to keep an aircraft at idle or near idle power from the Top of Descent (TOD) where descent begins, during the entire arrival until the Final Approach Fix (FAF). Thus, the aircraft can leave En Route airspace, enter Terminal airspace and descend smoothly to landing at the airport runway. The OPD eliminates step-down altitudes normally used and the associated inefficient power adjustments, whereby the aircraft must increase power at each step to level off. These procedures result in increased savings in fuel, and reduced noise and emissions. In addition, since little or no air traffic control vectoring of the aircraft is required during the procedure, the radio frequency is less congested.

OPDs are currently more feasible with RNAV[68] at low traffic densities and with similarly equipped aircraft. For multiple OPDs to occur, the aircraft must be sequenced and spaced accurately. Aircraft are normally sequenced to metering fixes using speed control and radar vectors. Radar is used to establish and monitor the separation interval between

[67] OPDs may also be referred to as continuous descent approaches or CDAs.
[68]And in the future will be feasible with RNP procedures.

arriving aircraft. The fidelity of the radar information directly impacts the air traffic controller's ability to maintain an appropriate interval.

As the amount of traffic increases, it becomes progressively more difficult for controllers to allow OPDs because of interfering flight paths from other arriving and departing traffic in the terminal, especially when more than one runway is in use. OPDs are often not used at very high traffic density situations.

Another factor limiting the use of OPDs is related to the inefficiencies involved in metering to the fix. OPD uses merging and spacing to bring aircraft to the TOD. In the Merging and Spacing (M&S) application, precise speed instructions are sent from the ground to en route aircraft to properly sequence aircraft approaching the terminal area.

The SBS program is developing both a ground and cockpit tool that can be used to optimize aircraft spacing to enable OPDs during increased levels of approach and departure activity than is currently feasible. A prototype tool is being developed for UPS to use in their Airline Operations Center. When this tool is mature it will be incorporated into FAA traffic flow management automation to allow FAA controllers to space aircraft from multiple carriers across multiple dependent merge fixes into an airport using future surveillance data.

The increased accuracy and fidelity of the ADS-B Out positioning solution, combined with the SBS merging and spacing tool provides a more sophisticated metering solution, allowing controllers to meter aircraft with varying performance characteristics to different merge points. Therefore, ADS-B has the potential to increase OPD usage.

Assumptions for OPD benefit estimates:

- OPD can save on average[69] 273 pounds of fuel per aircraft.
- Fuel cost per pound = $.291. Estimated fuel cost per gallon is $1.95[70] (2009 $) which converts to $.291 given 6.7 pounds per gallon of fuel.
- Benefit can only be achieved during visual meteorological conditions (VMC) conditions because reduced weather in the extended terminal area can hinder OPDs.
- NAS wide start year for OPD is 2014.
- OPDs can be accomplished without ADS-B Out at traffic densities[71] up to 40%.

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[69] The average of 181 lbs and 364 lbs saved per fight from "Continuous Descent FAA COE Noise Study Projects", Captain Bob Hilb, UPS Airlines, May 25, 2005.
[70] "Economic Information for Investment Analysis Data Package," 4/24/2009, Operations Research, ATO-Finance.
[71] We define traffic density as arrivals over capacity.

- OPDs at traffic densities from 40% to 70% cannot be accomplished without ADS-B Out and a spacing tool.[72]

- 50% of the fuel savings are attributed to ADS-B Out with spacing tool. We assume the rest is due to RNAV procedures.

- Spacing tool will be available at the Top 100 Airports.

- Only air carrier and commuter airlines will have sufficient economic incentive to apply OPDs on a day-to-day basis.

- Commuter operations comprise 66% of Air Taxi and Commuter operations.

The increased ability to allow OPD benefits were estimated by multiplying the average fuel savings per OPD arrival to the percent of flights that arrive at each of the top 100 airports during periods when demand is between 40 and 70 percent of VMC capacity. The benefit was only taken during VMC (good weather) because reduced weather conditions in the extended terminal area may hinder OPDs. Estimates were developed separately for the 100 busiest airports. The benefits were assumed to begin NAS-wide in 2014 (and 2009 for UPS airports) and only apply to air carrier and commuter aircraft. Additionally, we further degraded the benefit by attributing much of the savings for OPDs during the spacing tool regime to other necessary elements like RNAV/RNP. To take account of the additional necessary elements, the SBS program office only claimed one half of the final spacing tool regime OPD benefit.

We took all Air Carrier Operations and Commuter Operations from the 2008 TAF at the top 100 airports forecasted to the year 2035. Since operations include landings and takeoffs we divided operations by 2 to estimate landings which could benefit from OPD. Table 32 shows a sample of operations from the TAF.[73]

Table 32
Air Carrier and Commuter Operations

Airport	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
ABE	23,918	23,998	24,078	24,159	24,241	24,324	24,407	24,491	24,575	24,661	24,747	24,834
ABI	9,674	9,720	9,767	9,815	9,862	9,910	9,959	10,007	10,056	10,105	10,153	10,203
ABQ	95,937	97,614	99,322	101,059	102,830	104,632	106,467	108,335	110,238	112,176	114,150	116,160
ABY	4,025	4,042	4,061	4,079	4,097	4,115	4,133	4,152	4,170	4,189	4,208	4,227
ACK	86,230	87,926	89,660	91,426	93,228	95,066	96,941	98,853	100,803	102,792	104,820	106,890
ACT	6,634	6,775	6,918	7,064	7,213	7,366	7,522	7,682	7,844	8,011	8,180	8,354
ACY	17,014	17,174	17,335	17,498	17,661	17,826	17,994	18,163	18,334	18,506	18,680	18,856
ADM	2	2	2	2	2	2	2	2	2	2	2	2
ADQ	13,663	13,716	13,772	13,827	13,881	13,937	13,992	14,048	14,104	14,160	14,217	14,274
ADS	9,585	9,585	9,585	9,585	9,585	9,585	9,585	9,585	9,585	9,585	9,585	9,585
ADW	996	996	996	996	996	996	996	996	996	996	996	996
AFW	11,048	11,235	11,426	11,620	11,818	12,019	12,224	12,433	12,647	12,863	13,083	13,307

[72] With the exception of OPDs performed in Southern California.
[73] This table includes more than just the top 100 airports, but we only include top 100 in our calculations.

Benefits start to accrue in 2014, the year we expect the OPD procedures to be instituted NAS wide. Benefits increase with equipage which we assume is 27% in 2014 and grows to 100% by 2020. Below is the assumed ADS-B equipage rate.

Table 33
Percent of ADS-B Out Equipage

Year	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
% of Air Carrier & Commuter ADS-B Out equipped	0.2653	0.4066	0.5422	0.6688	0.7931	0.9022	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

Table 34 shows the percent of time that various weather conditions occur at a sample set of airports. We only take benefit for OPDs performed during visual meteorological conditions and as indicated in the table below, ABE experienced VMC conditions 71.7% of the time.

Table 34
Percent of Time Various Weather Conditions Occur

Wx_conditions	VMC	MVMC	IMC
ABE	71.7	15.3	13
ABI	86.1	8.2	5.7
ABQ	97.5	1.5	1
ABY	77.5	11.9	10.6
ACK	73	11	16
ACT	79	13.1	7.9
ACY	74.1	11.7	14.2
ADM	83	10.2	6.8
ADQ	74.3	16.1	9.6
ADS	81.5	10.8	7.7
ADW	79.4	11.6	9
AFW	81.5	10.8	7.7

Source: National Climatic Data Center
30 year average

Table 35 shows the percentage of flights that arrive during periods when the traffic density is between 40% and 70% of capacity.

Table 35
Percent of the Time that Demand is Between 40% and 70% of Capacity

Time	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
ABQ	0%	0%	0%	0%	0%	7%	7%	14%	14%	14%	21%	21%
ALB	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%	15%	15%
ANC	57%	57%	50%	50%	49%	40%	44%	39%	39%	39%	35%	26%
ATL	7%	8%	8%	8%	8%	8%	8%	3%	3%	3%	3%	0%
AUS	41%	41%	41%	48%	48%	48%	53%	61%	61%	71%	71%	71%
BDL	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	20%
BFL	51%	51%	51%	51%	51%	51%	51%	51%	51%	51%	51%	64%
BHM	24%	24%	24%	29%	29%	45%	52%	52%	62%	62%	62%	62%
BNA	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
BOI	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
BOS	81%	81%	81%	81%	81%	81%	81%	81%	81%	81%	86%	86%
BTR	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
BUF	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	2%
BUR	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
BWI	67%	21%	21%	21%	34%	39%	57%	57%	57%	63%	63%	63%
CHS	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

Source: ATO-Finance, Investment and Analysis Office

Calculation of benefits at ABQ in 2021 as an example:

Air Carrier and Commuter Operations = 108,335
Estimated Landings = (108,335)/2 = 54,168
Percent of Air Carrier and Commuter Aircraft that are ADS-B Out Equipped = 100%
Number of A/C and Commuter A/C ADS-B Equipped = 54,168
Percent of the time that ABQ has VMC conditions = 97.5%
Number of flights during VMC conditions = 97.5% x 54,168 = 52,813
Percent of flights that arrive during periods where demand is between 40 and 70% (medium density) = 14%
Number of flights arriving during medium density periods = 14% x 52,813 = 7,394
Estimated average fuel savings per airport = 272.7 pounds
Estimated fuel savings at ABQ in 2021 due to ADS-B = 7,394 x 272.7 = 2,016,300 pounds
Estimate average cost of fuel per pound = \$.291
Estimated monetized value of fuel savings due to OPD = 2,016,300 x \$.291 = \$586,743
Percent attributed to ADS-B with spacing tool = 50%
Monetized value of fuel savings due to ADS-B with spacing tool in millions of \$= (\$586,743 x 50%)/1,000,000 = \$.30 million.

Table 36
Estimated Dollar Benefits due to OPD by Airport by Year
2009$ M

By airport $M FY2009	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
ABQ	$0.00	$0.00	$0.00	$0.00	$0.00	$0.13	$0.15	$0.30	$0.30	$0.31	$0.47
ALB	$0.02	$0.03	$0.04	$0.04	$0.05	$0.06	$0.07	$0.07	$0.07	$0.07	$0.14
ANC	$0.45	$0.70	$0.85	$1.07	$1.28	$1.21	$1.52	$1.38	$1.42	$1.46	$1.33
ATL	$0.30	$0.48	$0.66	$0.84	$1.04	$1.24	$1.45	$0.58	$0.61	$0.64	$0.68
AUS	$0.21	$0.34	$0.46	$0.67	$0.81	$0.94	$1.18	$1.37	$1.40	$1.67	$1.70
BDL	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
BFL	$0.06	$0.09	$0.13	$0.16	$0.19	$0.22	$0.25	$0.25	$0.25	$0.26	$0.26
BHM	$0.05	$0.09	$0.12	$0.18	$0.21	$0.39	$0.50	$0.51	$0.62	$0.63	$0.65
BNA	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
BOI	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
BOS	$1.00	$1.55	$2.10	$2.62	$3.15	$3.63	$4.08	$4.13	$4.19	$4.24	$4.57
BTR	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
BUF	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
BUR	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
BWI	$0.72	$0.36	$0.49	$0.62	$1.18	$1.59	$2.64	$2.70	$2.77	$3.11	$3.18
CHS	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00

By airport $M FY2009	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
ABQ	$0.48	$0.76	$0.96	$1.35	$1.37	$1.40	$1.42	$1.62	$1.65	$1.80	$2.02
ALB	$0.14	$0.18	$0.19	$0.19	$0.31	$0.31	$0.32	$0.32	$0.33	$0.33	$0.34
ANC	$1.03	$1.06	$1.10	$1.13	$1.17	$0.88	$0.91	$1.25	$1.29	$1.06	$1.24
ATL	$0.00	$0.00	$0.00	$0.00	$0.46	$0.49	$0.51	$1.25	$1.32	$1.40	$1.48
AUS	$1.74	$2.07	$2.11	$2.16	$2.36	$2.41	$2.46	$2.61	$2.46	$2.28	$2.33
BDL	$0.32	$0.33	$0.34	$0.45	$0.62	$0.78	$0.90	$0.93	$1.09	$1.33	$1.36
BFL	$0.33	$0.34	$0.34	$0.35	$0.35	$0.39	$0.39	$0.40	$0.40	$0.41	$0.42
BHM	$0.66	$0.67	$0.68	$0.76	$0.77	$0.78	$0.83	$0.84	$0.86	$0.78	$0.87
BNA	$0.00	$0.00	$0.00	$0.00	$0.21	$0.22	$0.22	$0.23	$0.46	$0.47	$0.69
BOI	$0.00	$0.00	$0.00	$0.00	$0.11	$0.11	$0.23	$0.33	$0.44	$0.54	$0.55
BOS	$4.63	$4.69	$4.76	$4.82	$4.88	$4.95	$5.02	$5.08	$5.15	$4.81	$4.71
BTR	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
BUF	$0.03	$0.03	$0.03	$0.03	$0.03	$0.13	$0.13	$0.13	$0.13	$0.28	$0.28
BUR	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
BWI	$3.26	$3.57	$3.66	$4.04	$4.48	$4.59	$4.70	$5.17	$5.30	$5.42	$5.55
CHS	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00

Table 37
Total Estimated Benefits of Optimal Profile Descent

Year	Additional Fuel Savings from OPDs	3% Discount Rate	7% Discount Rate	Discounted by 3%	Discounted by 7%
2014	$31.04	0.8626	0.7130	$26.78	$22.13
2015	$47.00	0.8375	0.6663	$39.36	$31.32
2016	$64.61	0.8131	0.6227	$52.53	$40.23
2017	$80.81	0.7894	0.5820	$63.80	$47.03
2018	$98.57	0.7664	0.5439	$75.54	$53.61
2019	$112.82	0.7441	0.5083	$83.95	$57.35
2020	$126.31	0.7224	0.4751	$91.25	$60.01
2021	$125.93	0.7014	0.4440	$88.32	$55.91
2022	$125.01	0.6810	0.4150	$85.13	$51.88
2023	$128.94	0.6611	0.3878	$85.24	$50.00
2024	$126.67	0.6419	0.3624	$81.31	$45.91
2025	$125.67	0.6232	0.3387	$78.31	$42.57
2026	$126.55	0.6050	0.3166	$76.57	$40.06
2027	$122.92	0.5874	0.2959	$72.20	$36.37
2028	$128.15	0.5703	0.2765	$73.08	$35.43
2029	$128.96	0.5537	0.2584	$71.40	$33.32
2030	$129.78	0.5375	0.2415	$69.76	$31.34
2031	$131.09	0.5219	0.2257	$68.41	$29.59
2032	$127.09	0.5067	0.2109	$64.39	$26.81
2033	$129.18	0.4919	0.1971	$63.55	$25.47
2034	$131.25	0.4776	0.1842	$62.69	$24.18
2035	$131.59	0.4637	0.1722	$61.02	$22.66
Total	$2,479.93			$1,534.59	$863.21

4.2.5.5 Net Impact on Carbon Dioxide Emissions

ADS-B will result in both decreases and increases in carbon dioxide (CO_2) emissions, with a net reduction in CO_2 emissions, as explained below.

Reduced CO_2 Emissions

Assumptions and Conversion Factors

- Price per gallon of jet fuel = $1.95,
- Pounds of fuel per gallon = 6.7,
- Pounds per metric ton = 2204.6,
- 1 metric ton of fuel = 3.156 MT of CO_2,
- 2010 Global Social Cost of Carbon (SCC) per metric ton of CO_2 ranges from a low value of $4.88 to a high value of $36.46, expressed in 2009 dollars,
- SCC grows at the annual rates listed below

Average Annual Growth Rate(%)	5% Average	2.5 % Average
2010-2020	3.6%	1.7%
2020-2030	3.7%	1.8%
2030-2040	2.7%	1.6%
2040-2050	2.1%	1.1%

Some portion of the ADS-B Out benefits is reduced fuel consumption. Reduced cost of fuel benefits aircraft operators (and possibly consumers if reduced costs can be passed on). However, there is an additional environmental benefit to reducing fuel consumption and that is the benefit we present here. Fuel burn creates CO_2 emissions which remain in the atmosphere for long periods, becoming well-mixed throughout the earth's atmosphere, with long-term effects on the global climate.

To estimate the benefits of reduced CO_2 emissions we have to monetize the impact that changes in greenhouse gas (GHG) emissions will likely have on the environment. A first step in monetizing these benefits is to determine the incremental damage associated with changes in GHG emissions, in particular CO_2 emissions. These incremental or marginal damages are frequently described in the published literature[74] as the Social Cost of Carbon (SCC) and are measured as the net present value of climate change impacts over hundreds of years from an additional metric ton of CO_2 emitted to the atmosphere at a particular point in time. Based on an interagency report titled "Highlights of Appendix15A: Social Cost of Carbon for Regulatory Impact Analysis under Executive Order 12866", we use a set of range values for the social cost of carbon (expressed in terms of $/MT of CO_2) to monetize the reductions in CO_2 emissions. For 2010, the global social cost of carbon per metric ton of CO_2 ranged from $4.88 to $36.46, expressed in 2009 dollars.

[74] See Tol, Richard, 2005. *"The Marginal Damage Cost of Carbon Dioxide Emissions: an Assessment of the Uncertainties."* Energy Policy 33: 2064-2074.

It is widely believed that because GHGs tend to accumulate in the atmosphere and have very long residence time, future emissions are likely to produce larger incremental damages as physical and economic systems become more stressed. The IPCC Fourth Assessment Report estimated that climate-related economic damages resulting from an additional ton of carbon emissions are likely to grow at a rate between 2 and 4 percent annually. Consistent with the interagency guidance noted above, we allow the real global SCC to increase over time. By 2035, the range values reported above increased to \$11.63 and \$56.30, per metric ton of CO_2.

With ADS-B surveillance, we expect that less fuel will be burned because of fewer and more efficient en-route maneuvers, more efficient traffic management, increased use of optimal profile descent, more optimal and direct routing over the Gulf of Mexico and fewer delays on the ground for aircraft waiting for take-off over the Gulf of Mexico. In the benefit calculations (except the optimal profile descent benefit[75]) we estimated the number of hours saved due to ADS-B either in the air or on the ground and multiplied these hours by the appropriate aircraft direct operating cost (ADOC). The ADOC includes a fuel component. To estimate the fuel savings, the benefits were first re-estimated using only the aircraft direct operating cost of fuel. The estimated dollars saved on fuel are presented in the table below.

[75] The optimal profile descent benefit consists entirely of fuel savings.

Table 38
Dollar Value of Fuel Savings

Year	Gulf High Altitude Capacity	Gulf High Altitude Routes	Increased Accuracy Conflict Probe Low	Increased Accuracy Conflict Probe High	Increased Accuracy Metering	Optimal Profile Descent
2009	$0	$0	$0	$0	$0	$0
2010	$0	$0	$0	$0	$0	$0
2011	$0	$0	$0	$0	$0	$0
2012	$74,318	$1,007,010	$0	$0	$0	$0
2013	$153,119	$1,582,184	$0	$0	$0	$0
2014	$330,063	$2,188,627	$0	$0	$0	$31,044,408
2015	$567,876	$2,837,460	$0	$0	$0	$47,000,548
2016	$940,001	$3,502,195	$0	$0	$0	$64,607,570
2017	$1,535,019	$4,209,754	$2,225,633	$14,099,386	$0	$80,813,958
2018	$2,190,837	$4,951,879	$2,603,087	$16,490,558	$0	$98,568,690
2019	$3,368,845	$5,635,096	$3,129,392	$19,824,701	$0	$112,816,935
2020	$4,566,587	$6,356,590	$3,274,546	$20,744,248	$22,930,000	$126,309,558
2021	$5,614,744	$6,399,847	$3,422,990	$21,684,640	$23,390,000	$125,926,636
2022	$6,414,831	$6,502,972	$3,584,627	$22,708,609	$23,860,000	$125,014,080
2023	$7,466,560	$6,609,460	$3,749,992	$23,756,200	$24,350,000	$128,935,137
2024	$8,576,350	$6,696,653	$3,929,454	$24,893,094	$24,850,000	$126,671,880
2025	$10,054,708	$6,613,662	$4,118,420	$26,090,192	$25,360,000	$125,666,260
2026	$11,450,443	$6,588,165	$4,317,259	$27,349,837	$25,880,000	$126,552,263
2027	$12,979,466	$6,483,825	$4,520,786	$28,639,177	$26,410,000	$122,924,148
2028	$14,371,796	$6,379,804	$4,740,388	$30,030,358	$26,960,000	$128,147,875
2029	$16,260,079	$6,114,732	$4,971,031	$31,491,483	$27,530,000	$128,956,849
2030	$17,622,688	$5,746,458	$5,207,153	$32,987,314	$28,100,000	$129,777,244
2031	$18,873,470	$5,415,344	$5,460,977	$34,595,288	$28,700,000	$131,089,031
2032	$19,523,511	$5,066,040	$5,720,841	$36,241,527	$29,300,000	$127,087,792
2033	$20,604,966	$4,573,712	$5,999,558	$38,007,197	$29,930,000	$129,180,670
2034	$20,162,688	$4,376,493	$6,284,903	$39,814,863	$30,560,000	$131,249,860
2035	$19,271,160	$4,216,256	$6,590,307	$41,749,595	$31,220,000	$131,587,672
Total	**$222,974,124**	**$120,054,219**	**$83,851,345**	**$531,198,268**	**$429,330,000**	**$2,479,929,063**

To estimate fuel savings we divided the dollar value of fuel savings by $1.95,[76] to derive gallons of fuel saved. Gallons of fuel were converted to pounds of fuel saved (multiply by 6.7) and then to metric tons (divide by 2204.6). Metric tons of fuel consumed were converted to metric tons of CO_2 emissions (multiply by 3.156[77]). Table 39 shows these results.

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[76] FAA Forecast 2009-2025, Table 18, System Current $ converted to 2009 dollars and averaged for the years 2009-2025.
[77] IPCC, Aviation and the Global Atmosphere, Cambridge University Press, 1999, pg. 33.

Table 39
Total Metric Tons of CO_2 Abated

	Gulf of Mexico		Conflict Probe			
Year	High Altitude Capacity	Optimal Routes	High Estimate	Low Estimate	TMA	OPDs
2009	0	0	0	0	0	0
2010	0	0	0	0	0	0
2011	0	0	0	0	0	0
2012	366	4,953	0	0	0	0
2013	753	7,782	0	0	0	0
2014	1,623	10,765	0	0	0	152,697
2015	2,793	13,957	0	0	0	231,180
2016	4,624	17,226	0	0	0	317,783
2017	7,550	20,706	69,350	10,947	0	397,497
2018	10,776	24,357	81,112	12,804	0	484,827
2019	16,570	27,717	97,511	15,392	0	554,909
2020	22,462	31,266	102,034	16,106	112,785	621,275
2021	27,617	31,479	106,660	16,837	115,048	619,391
2022	31,552	31,986	111,696	17,632	117,359	614,903
2023	36,726	32,510	116,849	18,445	119,770	634,189
2024	42,184	32,939	122,441	19,328	122,229	623,057
2025	49,456	32,530	128,329	20,257	124,737	618,110
2026	56,321	32,405	134,525	21,235	127,295	622,468
2027	63,842	31,892	140,867	22,236	129,902	604,623
2028	70,690	31,380	147,709	23,316	132,607	630,317
2029	79,978	30,076	154,896	24,451	135,411	634,296
2030	86,680	28,265	162,254	25,612	138,215	638,331
2031	92,832	26,636	170,163	26,861	141,166	644,783
2032	96,030	24,918	178,260	28,139	144,117	625,102
2033	101,349	22,497	186,945	29,510	147,216	635,397
2034	99,174	21,527	195,836	30,913	150,314	645,574
2035	94,788	20,738	205,352	32,416	153,561	647,236
Total	**1,096,735**	**590,507**	**2,612,787**	**412,437**	**2,111,731**	**12,197,944**

<u>Increased CO_2 Emissions</u>

ADS-B Out will also result in some increased CO_2 emissions into the atmosphere; however the overall net result is a reduction in CO_2 emissions. We estimate the additional CO_2 emissions that will result from additional flights accommodated over the Gulf of Mexico, and from the additional fuel burn that will result from weight added to aircraft because of the avionics.

Additional Flights Over the Gulf of Mexico – CO_2 Emissions

Assumptions and Conversion Factors

- Average duration of additional flight over the Gulf – 4.33 hours, and
- ADOC per hour for fuel = $1,861.5.[78]

Table 40
Total Additional Metric Tons of Fuel Consumed and of CO_2 Produced Due to Additional Flights Over the Gulf of Mexico

Year	Additional flights	Additional flight hours	Additional Fuel Costs	Additional Gallons Consumed	Additional #'s of Fuel Consumed	Additional MT Fuel Consumed	Added MT of CO2
2009	0	0	$0	0	0	0	0
2010	0	0	$0	0	0	0	0
2011	0	0	$0	0	0	0	0
2012	0	0	$0	0	0	0	0
2013	0	0	$0	0	0	0	0
2014	50	217	$403,015	206,674	1,384,717	628	1,982
2015	50	217	$403,015	206,674	1,384,717	628	1,982
2016	200	866	$1,612,059	826,697	5,538,869	2,512	7,929
2017	400	1,732	$3,224,118	1,653,394	11,077,739	5,025	15,858
2018	600	2,598	$4,836,177	2,480,091	16,616,608	7,537	23,788
2019	1,000	4,330	$8,060,295	4,133,485	27,694,347	12,562	39,646
2020	1,400	6,062	$11,284,413	5,786,878	38,772,086	17,587	55,504
2021	2,250	9,743	$18,135,664	9,300,340	62,312,281	28,265	89,203
2022	3,150	13,640	$25,389,929	13,020,477	87,237,193	39,571	124,885
2023	4,450	19,269	$35,868,313	18,394,007	123,239,844	55,901	176,424
2024	5,750	24,898	$46,346,696	23,767,537	159,242,495	72,232	227,964
2025	7,800	33,774	$62,870,301	32,241,180	216,015,906	97,984	309,238
2026	9,500	41,135	$76,572,803	39,268,104	263,096,296	119,340	376,636
2027	11,900	51,527	$95,917,511	49,188,467	329,562,728	149,489	471,786
2028	14,800	64,084	$119,292,366	61,175,572	409,876,334	185,919	586,759
2029	17,950	77,724	$144,682,295	74,196,049	497,113,527	225,489	711,644
2030	21,550	93,312	$173,699,357	89,076,593	596,813,176	270,713	854,369
2031	26,450	114,529	$213,194,803	109,330,668	732,515,476	332,267	1,048,634
2032	31,300	135,529	$252,287,234	129,378,068	866,833,059	393,193	1,240,917
2033	36,900	159,777	$297,424,886	152,525,582	1,021,921,401	463,541	1,462,934
2034	43,250	187,273	$348,607,759	178,773,210	1,197,780,504	543,310	1,714,685
2035	49,850	215,851	$401,805,706	206,054,208	1,380,563,194	626,219	1,976,348
Total	**290,550**	**1,258,082**	**$2,341,918,712**	**1,200,983,955**	**8,046,592,499**	**3,649,910**	**11,519,117**

The FAA used the ETMS flight plan data and extracted origin and destination airports for all flights that included sectors ZHU72 or ZHU79 to create a unique list of origin destination pairs.

The flight time for flights between these city pairs was derived from the ETMS database and scheduled flight data (commercial) from OAG/Innovata. The average duration of

[78] Economic Information for Investment Analysis, Prepared for Operations Research/ATO-F, April 24, 2009, 50% of block hour variable cost for air carrier – TAF ($3,724) is attributed to fuel.

these flights was 4.33 hours.[79] Each additional flight was multiplied by 4.33 to obtain additional flight hours. These additional flight hours were multiplied by the fuel component of the aircraft direct operating cost per block hour ($1,861.5) to derive additional fuel costs. Additional fuel costs were divided by an average price per gallon of fuel ($1.95) to determine additional gallons of fuel consumed. Gallons of fuel consumed were converted to pounds of fuel consumed (multiply by 6.7) which were converted to metric tons (divide by 2204.6). Metric tons of fuel consumed were converted to metric tons of CO_2 by multiplying by 3.156.

Additional Weight of Avionics

ADS-B avionics can add from 3 to 12 pounds of weight to an aircraft which results in added fuel burn. We calculate the range of extra CO_2 emissions produced by the additional fuel burn. Total additional pounds of jet and GA fuel that would be consumed if ADS-B avionics added 3 pounds of weight and if ADS-B avionics added 12 pounds of weight to each aircraft are indicated in the table below. We convert pounds to metric tons (divide by 2204.6) and metric tons to CO_2 (multiply by 3.156). The additional metric tons of CO_2 produced would be 22,823 if ADS-B avionics added 3 pounds of weight and 56,613 if the avionics added 12 pounds of weight to each aircraft as displayed in the table below. Table 41 is an example that shows the high estimate of additional metric tons of fuel consumed.

Table 41
Additional Pounds of Fuel Consumed Due to Added Weight of Transponders

Year	Additional #'s of Jet Fuel Consumed - 3 # Transponder	Additional #'s of GA Fuel Consumed - 3 # Transponder	Total Added #'s of Fuel Consumed Low Estimate	Additional MT Fuel Consumed - Low Estimate	Added MT of CO_2 Due to Transponder - Low Estimate	Additional #'s of Jet Fuel Consumed - 12 # Transponder	Additional #'s of GA Fuel Consumed - 12 # Transponder	Total Added Pounds of Fuel Consumed - High Estimate	Additional MT Fuel Consumed - High Estimate	Added MT of CO_2 Due to Transponder - High Estimate
2009	0	0	0	0	0	0	0	0	0	0
2010	0	0	0	0	0	0	0	0	0	0
2011	0	0	0	0	0	0	0	0	0	0
2012	193,787	330,483	524,269	238	751	775,147	550,804	1,325,952	601	1,898
2013	191,203	339,426	530,628	241	760	764,810	565,710	1,330,520	604	1,905
2014	191,014	348,277	539,291	245	772	764,055	580,462	1,344,517	610	1,925
2015	189,906	356,619	546,525	248	782	759,624	594,364	1,353,988	614	1,938
2016	188,345	364,645	552,991	251	792	753,381	607,742	1,361,123	617	1,949
2017	187,827	372,483	560,311	254	802	751,310	620,805	1,372,115	622	1,964
2018	189,946	380,017	569,963	259	816	759,784	633,362	1,393,145	632	1,994
2019	192,528	387,709	580,237	263	831	770,112	646,182	1,416,294	642	2,027
2020	196,406	395,571	591,977	269	847	785,625	659,285	1,444,910	655	2,068
2021	201,002	403,688	604,690	274	866	804,009	672,813	1,476,822	670	2,114
2022	209,709	411,965	621,674	282	890	838,836	686,608	1,525,445	692	2,184
2023	217,647	420,274	637,921	289	913	870,586	700,457	1,571,043	713	2,249
2024	226,661	428,664	655,325	297	938	906,646	714,440	1,621,086	735	2,321
2025	222,430	437,080	659,510	299	944	889,721	728,467	1,618,188	734	2,317
2026	231,373	448,616	679,988	308	973	925,491	747,693	1,673,184	759	2,395
2027	241,306	460,151	701,457	318	1,004	965,222	766,919	1,732,141	786	2,480
2028	254,602	471,687	726,288	329	1,040	1,018,406	786,144	1,804,551	819	2,583
2029	264,866	483,222	748,088	339	1,071	1,059,463	805,370	1,864,833	846	2,670
2030	275,369	494,758	770,127	349	1,102	1,101,476	824,596	1,926,072	874	2,757
2031	284,155	506,293	790,448	359	1,132	1,136,618	843,822	1,980,440	898	2,835
2032	291,372	517,829	809,200	367	1,158	1,165,487	863,048	2,028,535	920	2,904
2033	299,012	529,364	828,377	376	1,186	1,196,050	882,274	2,078,323	943	2,975
2034	306,312	540,900	847,212	384	1,213	1,225,249	901,499	2,126,749	965	3,045
2035	313,992	552,435	866,428	393	1,240	1,255,970	920,725	2,176,695	987	3,116
Total	**5,560,769**	**10,382,156**	**15,942,925**	**7,232**	**22,823**	**22,243,078**	**17,303,593**	**39,546,671**	**17,938**	**56,613**

[79] MCR/SETA.

We added additional CO_2 produced by the additional flights over the Gulf of Mexico (11,519 K MT) to the additional CO_2 consumed by the added weight of the avionics (22.8 K MT for the low end of the range and 56.6 K MT for the high end of the range). The additional CO_2 produced ranges from 11,542 K MT to 11, 576 K MT.

To produce a range of net CO_2 savings we subtract the high net CO_2 produced (11,576 K) from the low net CO_2 saved (16,409) for the low estimate (4,833 K MT) and subtract the low net CO_2 produced (11,542K) from the high net CO_2 (18,610) saved for the high estimate (7,068 K MT) of net CO_2 savings.

Table 42
Total Metric Tons of CO_2 Saved

	Total metric tons of CO2 saved					
Year	Additional MT CO_2 Saved Low Estimate	Additional MT CO_2 Saved High Estimate	Additional MT CO_2 produced Low Estimate (Gulf and Wgt)	Additional MT CO_2 produced High Estimate (Gulf and Wgt)	Total Net MT CO_2 savings - Low	Total Net MT CO_2 Savings - High
2009	0	0	0	0	0	0
2010	0	0	0	0	0	0
2011	0	0	0	0	0	0
2012	5,318	5,318	751	1,898	3,420	4,568
2013	8,533	8,533	760	1,905	6,629	7,774
2014	165,084	165,084	2,754	3,907	161,177	162,330
2015	247,931	247,931	2,765	3,921	244,011	245,166
2016	339,629	339,629	8,721	9,878	329,751	330,908
2017	436,698	495,102	16,660	17,823	418,876	478,441
2018	532,762	601,070	24,603	25,782	506,980	576,467
2019	614,585	696,704	40,477	41,673	572,912	656,227
2020	803,890	889,818	56,352	57,573	746,318	833,466
2021	810,368	900,191	90,069	91,317	719,050	810,122
2022	813,435	907,499	125,775	127,068	686,366	781,725
2023	841,644	940,048	177,337	178,673	662,970	762,710
2024	839,743	942,856	228,902	230,285	609,459	713,954
2025	845,092	953,164	310,182	311,555	533,538	642,982
2026	859,722	973,011	377,610	379,031	480,690	595,402
2027	852,495	971,126	472,790	474,266	378,229	498,335
2028	888,314	1,012,707	587,799	589,343	298,971	424,908
2029	904,214	1,034,659	712,715	714,314	189,900	321,944
2030	917,098	1,053,739	855,472	857,126	59,971	198,267
2031	932,278	1,075,580	1,049,766	1,051,469	-119,192	25,814
2032	918,306	1,068,427	1,242,075	1,243,821	-325,514	-173,648
2033	935,968	1,093,403	1,464,120	1,465,909	-529,941	-370,717
2034	947,503	1,112,425	1,715,898	1,717,730	-770,227	-603,473
2035	948,738	1,121,675	1,977,589	1,979,464	-1,030,726	-855,913
Total	**16,409,348**	**18,609,698**	**11,541,940**	**11,575,730**	**4,833,618**	**7,067,758**

In Table 43, we convert the net reduction in CO_2 emissions into a dollar value by multiplying the net reduction by the social cost of carbon. We calculate results using a low and high social cost of carbon. Table 43 shows the result of using the low global SCC with the estimated low net reduction in CO_2 emissions and the high global SCC with the estimated high net reduction in CO_2 emissions to illustrate the low and high bounds. The benefit from a net reduction in CO_2 emissions ranges from \$27 million to a high of \$300 million, undiscounted.

Table 43 Benefit of Net Reduction in CO_2 Emissions

	Benefit of Net Reduction in CO2 Emissions									
Year	Total Net MT CO_2 savings - Low	Total Net MT CO_2 savings - High	SCC Per MT - Low	SCC Per MT- High	Low CO_2 Net Savings SCC	High CO_2 Net Savings SCC	5% Discount Rate	2.5% Discount Rate	Low - CO_2 Net Savings SCC D.R. 5%	High - CO_2 Net Savings SCC D.R. 2.5%
2009	0	0			$0	$0	1.0000	1.0000	$0	$0
2010	0	0	$4.88	$36.46	$0	$0	0.9524	0.9756	$0	$0
2011	0	0	$5.09	$37.08	$0	$0	0.9070	0.9518	$0	$0
2012	3,420	4,568	$5.30	$37.81	$18,127	$172,713	0.8638	0.9286	$15,659	$160,382
2013	6,629	7,774	$5.51	$38.43	$36,524	$298,746	0.8227	0.9060	$30,048	$270,664
2014	161,177	162,330	$5.71	$39.16	$920,320	$6,356,826	0.7835	0.8839	$721,071	$5,618,799
2015	244,011	245,166	$5.92	$39.89	$1,444,542	$9,779,691	0.7462	0.8623	$1,077,918	$8,433,028
2016	329,751	330,908	$6.13	$40.51	$2,021,374	$13,405,083	0.7107	0.8413	$1,436,591	$11,277,697
2017	418,876	478,441	$6.34	$41.24	$2,655,673	$19,730,908	0.6768	0.8207	$1,797,359	$16,193,156
2018	506,980	576,467	$6.54	$41.97	$3,315,651	$24,194,300	0.6446	0.8007	$2,137,269	$19,372,376
2019	572,912	656,227	$6.75	$42.59	$3,867,153	$27,948,710	0.6139	0.7812	$2,374,045	$21,833,532
2020	746,318	833,466	$7.06	$43.32	$5,269,002	$36,105,759	0.5847	0.7621	$3,080,786	$27,516,199
2021	719,050	810,122	$7.38	$44.15	$5,306,590	$35,766,871	0.5568	0.7436	$2,954,710	$26,596,245
2022	686,366	781,725	$7.69	$45.08	$5,278,158	$35,240,149	0.5303	0.7254	$2,799,007	$25,563,204
2023	662,970	762,710	$8.00	$45.91	$5,303,764	$35,016,024	0.5051	0.7077	$2,678,931	$24,780,840
2024	609,459	713,954	$8.21	$46.74	$5,003,654	$33,370,220	0.4810	0.6905	$2,406,758	$23,042,137
2025	533,538	642,982	$8.52	$47.68	$4,545,743	$30,657,386	0.4581	0.6736	$2,082,405	$20,650,816
2026	480,690	595,402	$8.83	$48.51	$4,244,494	$28,882,931	0.4363	0.6572	$1,851,873	$18,981,862
2027	378,229	498,335	$9.14	$49.34	$3,457,017	$24,587,859	0.4155	0.6412	$1,436,390	$15,765,735
2028	298,971	424,908	$9.45	$50.28	$2,825,277	$21,364,356	0.3957	0.6255	$1,117,962	$13,363,405
2029	189,900	321,944	$9.76	$51.11	$1,853,423	$16,454,551	0.3769	0.6103	$698,555	$10,042,213
2030	59,971	198,267	$10.08	$51.94	$604,508	$10,297,999	0.3589	0.5954	$216,958	$6,131,429
2031	-119,192	25,814	$10.39	$52.87	-$1,238,401	$1,364,782	0.3418	0.5809	-$423,285	$792,802
2032	-325,514	-173,648	$10.70	$53.70	-$3,483,005	-$9,324,890	0.3256	0.5667	-$1,134,066	-$5,284,415
2033	-529,941	-370,717	$11.01	$54.53	-$5,834,650	-$20,215,180	0.3101	0.5529	-$1,809,325	-$11,176,973
2034	-770,227	-603,473	$11.32	$55.47	-$8,718,973	-$33,474,641	0.2953	0.5394	-$2,574,713	-$18,056,221
2035	-1,030,726	-855,913	$11.63	$56.30	-$11,987,343	-$48,187,928	0.2812	0.5262	-$3,370,841	-$25,356,488
Total	**4,833,618**	**7,067,758**			**$26,708,625**	**$299,793,227**			**$21,602,064**	**$236,512,422**

4.3 Multilateration Alternative Scenario

4.3.1 Definition

Multilateration was one of the original technologies the FAA considered when exploring alternative surveillance sources in the early 1990s. The agency established several test-beds for multilateration. The incremental development of multilateration eventually led to the certification and deployment of ASDE-X and 3X systems for surface surveillance.

Multilateration functions by triangulating aircraft position based on time difference of arrival of signals to multiple ground stations. For multilateration surveillance, an aircraft must have at least 4 ground stations receiving its transponder information.[80] It can

[80] Exhibit 300 Attachment 2 Business Case Analysis Report for Future Surveillance, JRC Phase 2a, pg. 6.

function with both existing and future transponders such as Modes A/C, Mode S short and future extended squitter transponders. Multilateration is currently in use as a surface surveillance tool through the ASDE-X program, and has been tested for use in supporting the Terminal and En Route airspace domains.[81]

4.3.2 Cost to Industry

There are no costs to industry related to surveillance with multilateration because the current fleet is equipped with transponders, which will function with multilateration surveillance.

General aviation operators who aren't equipped for weather and traffic services in the cockpit could obtain these capabilities with multilateration by installing equipment on the aircraft and by subscribing to weather services. Accordingly, we did not include these costs in this analysis for either the multilateration scenario or the radar baseline scenario. We assume those operators would not willingly incur the costs of weather and traffic because for the most part they have not done so to date.

4.3.3 Cost to FAA

We estimate it will cost FAA $3.0 billion ($1.7 billion when discounted by 7%) to provide surveillance using multilateration over the 29 years. This will include facilities and equipment and operating and maintenance costs for multilateration ground facilities to provide core surveillance and the cost to sustain radar facilities until multilateration is operational. We do not include the cost of providing broadcast services with multilateration.

Included in the estimates of multilateration surveillance costs are costs of facilities and equipment, operations and maintenance costs, radar sustain costs and radar decommissioning costs. Multilateration does not require a separate backup system due to its built-in redundancies. Multilateration surveillance costs are presented in Table 44 below.

[81] Exhibit 300 Attachment 2 Business Case Analysis Report for Future Surveillance, JRC Phase 2a, pg. 10

Table 44
Cost to Provide Core Surveillance Using Multilateration
2009$ K

Year	Core Surveillance Facilities and Equipment Plus Caribbean and Gulf	Core Surveillance Operations and Maintenance Plus Caribbean and Gulf	Total Core Surveillance Plus Caribbean and Gulf - Multilateration	3% Discount Rate	7% Discount Rate	Total discounted at 3%	Total discounted at 7%	Total Legacy Sustain Costs	Total Core Surveillance and Sustain Costs	Total discounted at 3%	Total discounted at 7%
2009	$79,489	$0	$79,489	1.0000	1.0000	$79,489	$79,489	$85,728	$165,217	$165,217	$165,217
2010	$363,456	$869	$364,324	0.9709	0.9346	$353,713	$340,490	$61,559	$425,884	$413,479	$398,022
2011	$373,359	$1,982	$375,341	0.9426	0.8734	$353,795	$327,837	$56,654	$431,995	$407,197	$377,321
2012	$68,870	$1,452	$70,322	0.9151	0.8163	$64,355	$57,404	$57,901	$128,223	$117,343	$104,668
2013	$19,804	$6,295	$26,099	0.8885	0.7629	$23,189	$19,911	$54,814	$80,913	$71,890	$61,728
2014	$6,969	$12,931	$19,900	0.8626	0.7130	$17,166	$14,188	$54,795	$74,695	$64,432	$53,256
2015	$6,649	$18,811	$25,460	0.8375	0.6663	$21,322	$16,965	$54,777	$80,237	$67,197	$53,465
2016	$13,832	$50,951	$64,784	0.8131	0.6227	$52,675	$40,344	$54,035	$118,819	$96,610	$73,994
2017	$4,676	$52,312	$56,988	0.7894	0.5820	$44,987	$33,168	$60,040	$117,029	$92,383	$68,112
2018	$54,592	$52,312	$106,904	0.7664	0.5439	$81,933	$58,149	$51,731	$158,635	$121,580	$86,287
2019	$17,954	$52,312	$70,266	0.7441	0.5083	$52,284	$35,719	$45,042	$115,307	$85,800	$58,616
2020	$17,954	$52,312	$70,266	0.7224	0.4751	$50,761	$33,383	$37,302	$107,567	$77,709	$51,104
2021	$19,040	$52,475	$71,515	0.7014	0.4440	$50,159	$31,754	$32,900	$104,415	$73,234	$46,361
2022	$26,675	$52,475	$79,150	0.6810	0.4150	$53,897	$32,844	$28,505	$107,654	$73,307	$44,673
2023	$4,676	$52,475	$57,151	0.6611	0.3878	$37,784	$22,164	$24,116	$81,267	$53,727	$31,517
2024	$41,314	$52,475	$93,790	0.6419	0.3624	$60,200	$33,994	$0	$93,790	$60,200	$33,994
2025	$4,676	$52,475	$57,151	0.6232	0.3387	$35,615	$19,359	$0	$57,151	$35,615	$19,359
2026	$4,676	$49,073	$53,749	0.6050	0.3166	$32,519	$17,016	$0	$53,749	$32,519	$17,016
2027	$5,203	$49,073	$54,276	0.5874	0.2959	$31,882	$16,058	$0	$54,276	$31,882	$16,058
2028	$14,609	$48,719	$63,328	0.5703	0.2765	$36,115	$17,511	$0	$63,328	$36,115	$17,511
2029	$4,676	$48,719	$53,395	0.5537	0.2584	$29,564	$13,798	$0	$53,395	$29,564	$13,798
2030	$41,314	$48,719	$90,033	0.5375	0.2415	$48,397	$21,744	$0	$90,033	$48,397	$21,744
2031	$4,676	$44,963	$49,639	0.5219	0.2257	$25,906	$11,204	$0	$49,639	$25,906	$11,204
2032	$5,710	$44,963	$50,673	0.5067	0.2109	$25,675	$10,689	$0	$50,673	$25,675	$10,689
2033	$4,378	$44,963	$49,341	0.4919	0.1971	$24,272	$9,727	$0	$49,341	$24,272	$9,727
2034	$8,840	$44,963	$53,803	0.4776	0.1842	$25,697	$9,913	$0	$53,803	$25,697	$9,913
2035	$35,121	$43,711	$78,832	0.4637	0.1722	$36,554	$13,575	$0	$78,832	$36,554	$13,575
Total	**$1,253,189**	**$1,032,780**	**$2,285,969**			**$1,749,905**	**$1,338,397**	**$759,899**	**$3,045,868**	**$2,393,504**	**$1,868,932**

4.3.4 Benefits of Multilateration Surveillance

Our research did not identify any other feasible benefits of multilateration compared to radar. Multilateration may have the potential to improve accuracy but it would not be practical to do so, since it could require ground stations in locations where it may not be feasible. It is possible that in some locations multilateration could allow for tighter separation, but it might require too many multilateration ground stations for multilateration to be cost effective for reducing separation.

While multilateration could provide radar-like separation in some parts of the Gulf of Mexico, it is not feasible to provide radar like services throughout the entire area of the Gulf. This is due to limitations in the number and location of platforms, which would house the ground stations. We assume that multilateration surveillance would provide the same functionality as radar, and we have estimated no benefits from multilateration surveillance beyond those achieved by the current radar system.

5.0 Summary Comparison of Costs and Benefits

The costs of the ADS-B Out, multilateration, and the radar baseline scenarios are summarized in Table 45 below with present values displayed in Tables 46 and 47. Estimated FAA surveillance costs are $3.7 billion ($2.05 billion when discounted by 7%) and exceed the radar baseline by $810 million ($800 million when discounted by 7%).

Avionics costs in these tables are presented at the midpoint between the high and low estimates. In later tables, we will present the avionics costs as a range. The midpoint of estimated user costs to equip is $4.37 billion ($2.12 billion when discounted by 7%).

Table 45
Summary of Costs of Multilateration, Radar Baseline and ADS-B Out Scenarios
2009$ B

	Multilateration	Radar Baseline [1]	ADS-B out	ADS-B out incremental costs & benefits [2]
FAA SURVEILLANCE COSTS	**$3.05**	**$2.88**	**$3.70**	**$0.82**
ADS-B Ground Segment			$1.83	
Multilateration Ground Segment [3]	$2.29			
Radar Replace and Sustain		$2.88		
Legacy Sustain	$0.76		$0.76	
Backup (Radar)			$0.81	
Surface			$0.00	
Airborne			$0.81	
Radar Decommission			$0.04	
Legacy Upgrade ASDE-3			$0.25	
USER COSTS [4]			**$4.37**	**$4.37**
Total Cost	**$3.05**	**$2.88**	**$8.07**	**$5.19**

[1] Detail on the costs of the radar baseline may be found in Table 2.
[2] Difference between the costs of the ADS-B out scenario and the radar replace scenario.
[3] Includes radar decommissioning costs.
[4] Avionics cost baseline which is the midpoint between avionics low and high estimates.

Table 46
Summary of Costs of Multilateration, Radar Baseline and ADS-B Out Scenarios
2009$ B at 3% Present Value

	Multilateration	Radar Baseline	ADS-B out	ADS-B out incremental costs & benefits [1]
FAA SURVEILLANCE COSTS	$2.39	$1.94	$2.78	$0.84
ADS-B Ground Segment			$1.41	
Multilateration Ground Segment [2]	$1.75			
Radar Replace and Sustain		$1.94		
Legacy Sustain	$0.64		$0.64	
Backup (Radar)			$0.49	
Surface			$0.00	
Airborne			$0.49	
Radar Decommission			$0.03	
Legacy Upgrade ASDE-3			$0.20	
USER COSTS [3]			$3.28	$3.28
Total Cost	$2.39	$1.94	$6.06	$4.12

[1] Difference between the costs of the ADS-B out scenario and the radar replace scenario.
[2] Includes radar decommissioning costs.
[3] Avionics cost baseline which is the midpoint between avionics low and high estimates.

Table 47
Summary of Costs of Multilateration, Radar Baseline and ADS-B Out Scenarios
2009$ B at 7% Present Value

	Multilateration	Radar Baseline	ADS-B out	ADS-B out incremental costs & benefits [1]
FAA SURVEILLANCE COSTS	$1.87	$1.25	$2.05	$0.80
ADS-B Ground Segment			$1.07	
Multilateration Ground Segment [2]	$1.34			
Radar Replace and Sustain		$1.25		
Legacy Sustain	$0.53		$0.53	
Backup (Radar)			$0.26	
Surface			$0.00	
Airborne			$0.26	
Radar Decommission			$0.02	
Legacy Upgrade ASDE-3			$0.16	
USER COSTS [3]			$2.34	$2.34
Total Cost	$1.87	$1.25	$4.39	$3.14

[1] Difference between the costs of the ADS-B out scenario and the radar replace scenario.
[2] Includes radar decommissioning costs.
[3] Avionics cost baseline which is the midpoint between avionics low and high estimates.

Table 48 summarizes the costs and benefits and shows the difference between the ADS-B Out scenario and the radar baseline scenario. Tables 49 and 50 present the same costs and benefits discounted by 3% and 7% respectively. Avionics costs range from a low of $2.5 billion ($1.4 million when discounted by 7%) to a high of $6.2 billion ($3.3 billion when discounted by 7%) over the time horizon of the analysis. The total incremental cost of the ADS-B Out scenario (including government costs) ranges from $3.3 billion ($2.2 billion when discounted by 7%) to $7.0 billion ($4.1 when discounted by 7%) more than the radar baseline scenario.

We estimated that benefits range from $6.8 billion ($2.1 billion when discounted by 7%) to $8.5 billion ($2.7 billion when discounted by 7%). These are incremental to the radar baseline.

If benefits are high and costs are low (best case scenario), we estimate $5.2 billion ($590 million when discounted by 7%) of net benefits. If benefits are low and costs are high, we estimate negative net benefits.

Table 48
Summary of Costs and Benefits
2009$ B

	Multilateration	Radar Baseline	ADS-B out		Difference between ADS-B out low costs and Radar	Difference between ADS-B out high costs and Radar	Midpoint [3]
FAA Ground Costs	$3.05	$2.88	$3.70		$0.81	$0.81	$0.81
			Low	High	Low Cost	High Cost	
Avionics Costs			$2.47	$6.18	$2.47	$6.18	$4.37
Total Cost	$3.05	$2.88	$6.16	$9.87	$3.28	$6.99	$5.18
			Low	High			
Total Benefits			$6.78	$8.48			
Gulf High Altitude Operations			$2.64	$2.64			
Delay Savings			$1.69	$1.69			
Additional Flights Accommodated			$0.57	$0.57			
Optimal and Direct Routing			$0.38	$0.38			
Improved En route Conflict Probe Performance			$0.27	$1.69			
More Efficient Metering (improved TMA accuracy)			$1.37	$1.37			
Increased Ability to Perform OPD			$2.48	$2.48			
Value of Reduced CO2 Emissions			$0.03	$0.30	High benefit	Low Benefit	
Total Incremental Benefits [3], [4]			$6.78	$8.48	$8.48	$6.78	$7.63
					High benefit/low cost	Low benefit/high cost	
Net Benefits					$5.20	($0.21)	$2.45

[1] Total Incremental Benefits are Relative to the Radar Baseline.
[2] The benefits of radar are not estimated. We assume they far exceed the cost of radar. We look at the benefits of ADS-B relative to radar.
[3] The midpoint of the high and low.

The bulk of the ATC efficiency benefits from ADS-B Out are expected to occur after the compliance date of the rule. However, the FAA's deployment strategy for surveillance equipment has the potential to allow benefits to be realized earlier than this conservative estimate. For example, if FAA decided to roll out ADS-B surveillance coverage regionally, aircraft operating primarily in the covered region may choose to equip faster than the rule mandates. A higher density of equipped aircraft in specific regions could permit increased use of procedures that yield benefits.

Table 49
Summary of Costs and Benefits
2009$ B at a 3% Present Value

	Multilateration	Radar Baseline	ADS-B out		Difference between ADS-B out low costs and Radar	Difference between ADS-B out high costs and Radar	Midpoint [3]
FAA Ground Costs	$2.39	$1.94	$2.78		$0.84	$0.84	$0.84
			Low	High	Low Cost	High Cost	
Avionics Costs			$1.90	$4.64	$1.90	$4.64	$3.28
Total Cost	$2.39	$1.94	$4.68	$7.41	$2.74	$5.47	$4.12
			Low	High			
Total Benefits			$3.98	$5.03			
Gulf High Altitude Operations			$1.48	$1.48			
Delay Savings			$0.95	$0.95			
Additional Flights Accommodated			$0.29	$0.29			
Optimal and Direct Routing			$0.25	$0.25			
Improved En route Conflict Probe Performance			$0.16	$0.99			
More Efficient Metering (improved TMA accuracy)			$0.79	$0.79			
Increased ability to perform CDA			$1.53	$1.53			
Value of Reduced CO2 Emissions			$0.02	$0.24			
					High benefit	Low Benefit	
Total Incremental Benefits [1], [2]			$3.98	$5.03	$5.03	$3.98	$4.50
					High benefit/low cost	Low benefit/high cost	
Net Benefits					$2.29	($1.49)	$0.39

[1] Total Incremental Benefits are Relative to the Radar Baseline
[2] The benefits of radar are not estimated. We assume they far exceed the cost of radar. We look at the benefits of ADS-B relative to radar.
[3] The midpoint of the high and low

Table 50
Summary of Costs and Benefits
2009$ B at a 7% Present Value

	Multilateration	Radar Baseline	ADS-B out		Difference between ADS-B out low costs and Radar	Difference between ADS-B out high costs and Radar	Midpoint [3]
FAA Ground Costs	$1.87	$1.25	$2.05		$0.80	$0.80	$0.80
			Low	High	Low Cost	High Cost	
Avionics Costs			$1.35	$3.31	$1.35	$3.31	$2.34
Total Cost	$1.87	$1.25	$3.40	$5.36	$2.15	$4.11	$3.14
			Low	High			
Total Benefits			$2.09	$2.74			
Gulf High Altitude Operations			$0.72	$0.72			
Delay Savings			$0.46	$0.46			
Additional Flights Accommodated			$0.12	$0.12			
Optimal and Direct Routing			$0.14	$0.14			
Improved En Route Conflict Probe Performance			$0.08	$0.52			
More Efficient Metering (improved TMA accuracy)			$0.40	$0.40			
Increased ability to perform OPD			$0.86	$0.86			
Value of Reduced CO2 Emissions			$0.02	$0.24			
					High benefit	Low Benefit	
Total Incremental Benefits [1], [2]			$2.09	$2.74	$2.74	$2.09	$2.41
					High benefit/low cost	Low benefit/high cost	
Net Benefits					$0.59	($2.02)	($0.73)

[1] Total Incremental Benefits are Relative to the Radar Baseline
[2] The benefits of radar are not estimated. We assume they far exceed the cost of radar. We look at the benefits of ADS-B relative to radar.
[3] The midpoint of the high and low

Even though the quantitative benefits of the ADS-B Out rule do not always exceed the costs, the FAA has made a reasoned determination that the quantitative and the qualitative benefits exceed the costs. The bulk of the costs are incurred from the effective date of the rule (2010) to the compliance date (2020), while most of the benefit from ATC efficiencies occur after the compliance date. The FAA is mandating ADS-B Out because we view ADS-B Out as a springboard to NextGen which could lead to further benefits in the future; some of the benefits have yet to be identified and some have not yet been quantified. Also, as explained in the market failure section, there is a lack of incentive for operators to voluntarily equip with ADS-B Out. Once all the aircraft within an airspace are equipped with ADS-B Out, operators who also equip their aircraft with ADS-B In can begin to accrue benefits such as continuing visual approaches in marginal conditions or reduced aircraft to aircraft conflicts. The FAA views ADS-B as a means to accommodate the expected increase in demand for surveillance and separation services with less delay than would be possible with the current radar system. As mentioned in the preamble, "to accommodate the projected level of traffic without adding delay, more comprehensive surveillance in the NAS, including more radar sites in certain areas, would be necessary." However, increasing the number of radars in the NAS does not solve the inherent limitation of radar technology, and would not enable the FAA to eventually reduce current separation standards. Also, radar does not provide the capability to provide services on the flight deck as ADS-B does.

6.0 Additional Programmatic Benefits of ADS-B Out

In addition to the rule-oriented benefits of ADS-B discussed above, there are additional benefits of ADS-B associated with the overall ADS-B program. These include increased ability to conduct operations at low altitudes over the Gulf of Mexico, enhanced search and rescue capability, and enhanced surveillance where radar is currently weak. These benefits are discussed below.

6.1 Increased Ability to Conduct Operations at Low Altitudes over the Gulf of Mexico

There is currently a signed Memorandum of Agreement (MOA) between the FAA, the Helicopter Association International (HAI), helicopter operators, and oil and gas platform owners to improve low altitude service in the Gulf of Mexico. In this MOA, helicopter operators agree to equip with appropriate avionics and equipment to take advantage of FAA enhancements to communications, weather reporting, and surveillance capabilities. In this regulatory impact analysis we reason that, since helicopter operators in this region would equip with or without the rule, the associated benefits and costs are attributable to the overall ADS-B program but not the rule itself.

6.2 Enhanced Search and Rescue Capability

One of the objectives of the ADS-B program is to make techniques and services associated with radar surveillance also available for non-radar airspace through use of

ADS-B, including enhanced search and rescue (SAR). While ADS-B should not be considered a replacement for Emergency Locator Transmitters (ELTs), when an aircraft is reported missing, ADS-B can enhance SAR operations by providing the last known surveillance position. The new 406MHz ELT has an activation rate of 81-81 percent in actual accidents but the ELTs in most General Aviation aircraft have an activation rate of 73 percent. The benefit of enhanced SAR operations is an increased likelihood of survival for those involved in aviation accidents. When radar coverage is not available and an aircraft is reported missing, SAR teams most often don't know where to start looking. Also, even when an accident doesn't directly result in fatalities, many people who survive the accident die of exposure because they cannot be found quickly. SAR activities, however, can be better focused if surveillance data is available for a flight presumed missing. By knowing the position of the aircraft prior to the accident, the time duration of the search operation can be greatly reduced. By reducing the search times and locating the accident site quickly, the cost and resources to conduct the operations are also greatly reduced. According to a published report from the Alaska Wing Civil Air Patrol, in 2008, there were 211 SAR missions in Alaska, totaling 705 flight hours. Aircraft used vary from single-engine ($150-$500 per hour), multi-engine ($6,500 per hour), and helicopters ($2,500-3,200).

The anticipated SAR benefits from having ADS-B surveillance coverage in non-radar inter-mountain areas like in the Rocky Mountains of Colorado can best be understood by looking at the benefit Alaska has realized as a result of their Capstone project and how their SAR operations have been affected. FAA Capstone avionics continuously broadcast the GPS-based position of the aircraft and other information through ground stations to Anchorage Center and other aircraft, and is available to operators for flight following. The potential for monitoring the location of FAA Capstone-equipped aircraft, and having the capability to note the loss of ADS-B data from an aircraft, could benefit the SAR process when an aircraft is overdue or reported missing, whether or not the aircraft's onboard Emergency Locator Transmitter (ELT) functions. The track data can also be retrieved by the Anchorage Center if the aircraft is reported missing or overdue, to determine the last known position.

To fully understand how ADS-B technology can augment ELT information for SAR, it is important to understand the mechanism of the ELTs, their reliability, and advances in technology and their associated costs. Currently General Aviation aircraft are required (by Congressional mandate in 1972) to equip with an ELT that is battery powered and activates upon severe impact. It is supposed to emit a signal on a specified radio frequency. The original ELTs manufactured to FAA specifications emitted a signal on the 121.5/243 MHz frequency. However, they had an activation rate of less than 25% in actual crashes and a 97% false-alarm rate, i.e., sending SAR teams on missions where a signal was heard but no aircraft accident occurred. In 1985, a newer version became available that improved the activation rate to 73% in actual crashes but at a $200-500 cost plus cost of installation. In February 2009, however, the 121.5 frequency was no longer being monitored for distress signals because of the high rate of false alarms. Recently, an even more advanced model has been developed (406 MHz) and it activates 81-83% of the time but they are relatively expensive.

Additionally, hand-held, portable versions of an ELT called Emergency Position Indicating Radio Beacon (EPIRB) have become available. These types of tracking and alerting devices and services are growing in number and sophistication so it is only a matter of time until they will most likely leap-frog 406 ELTs in reliability and functionality. For comparison of ELTs, see Table 52.

Table 52
Comparison of Emergency Locator Transmitters

Emergency Locator Transmitters (ELTs) – All are battery powered			
	ELT Cost to Operator in addition to avionics	Activation rate in actual accidents	Comments
Original mandated (1973) 121.5/243MHz ELT TSO-C91	Approx. $100	Less than 25%	False alarm rate 97%
Improved ELT (1985) 121.5/243MHz TSO-C91A	$200-500 cost including installation	73%	February 1, 2009, the satellite system discontinued monitoring of 121.5/243 distress signals due to poor accuracy and high no. of false signals
ICAO int'l required 406MHz ELT TSO-C126 (uses digital technology); voluntary in US	$1,000 cost not including installation	81-83%	More accurate and near instantaneous; Allows SAR personnel to have vital information specific to operator and aircraft
Emergency Position Indicating Radio Beacon (EPIRB).	Variable cost; hand-held (no installation)	Depends on the selected option	EPIRBs are battery-powered, very portable, completely waterproof, and they float. They have signal options.

However, ADS-B has the potential to be used to provide continuous positioning information, while also providing other services, such as weather and traffic information. This is especially useful if an aircraft is reported overdue or missing, yet no ELT signal has been observed. ADS-B does not depend on battery-powered emission of a signal to indicate the last known position. It has been tested and, in fact, used for rescue purposes in Alaska. A Capstone SAR example occurred in 2002 when a pilot flew from Bethel 75 miles north to the village of Marshall, Alaska. He didn't return. As a National Guard helicopter prepared to launch for search and rescue operations, rescue organizers turned to air traffic controllers, who called upon the aircraft's ADS-B track and were able to vector the rescue helicopter directly to the aircraft's last known position. Barely two and a half hours after he was reported missing, the pilot had been picked up, alive.

More recently, in December 2008, in Colorado, where the installation of a wide-area multilateration (WAM) system was being tested, a glimpse of the benefit from having flight tracking data for SAR was realized. WAM is a surveillance system that is less robust and less sophisticated than ADS-B but it can be used for tracking flights. It is important to note that in this instance, WAM was not being used for air traffic operations. However, when an aircraft was reported missing, which was not under ATC radar surveillance, WAM data was reviewed to locate the last tracked position of the aircraft. In this type of terrain, if the estimate of the location of an accident is off by one valley, a day can be added to any search effort. The WAM data in this test-environment instance reduced the search area from what would have been approximately a 30 by 30-mile area to a 1 by 1-mile area. The site was located within 3.5 hours of the accident. Unfortunately, there were no survivors but if there were, the likelihood of survival would have been greater since the threat of death from exposure to the elements would not have been a factor.

6.3 Enhanced Surveillance Where Radar is Currently Weak

The FAA's ADS-B rule is designed to replicate the coverage of FAA's current alignment of surveillance radars. The degree to which actual ADS-B coverage may exceed this requirement is currently unknown. Since ADS-B ground stations are smaller, cheaper, and more flexibly deployed than conventional radar installations, it will be easier for the FAA to expand surveillance coverage and broadcast services than it is today. The effective range of ADS-B ground stations is still limited by line of sight considerations, but can extend down to the ground and can receive ADS-B signals from over 200 miles away. The relatively small size of ADS-B ground stations should enable greater scalability of NAS surveillance, even in areas with challenging terrain such as the Rocky Mountains. An ADS-B compatible multilateration system designed to provide surveillance to mountainous airports is already under development in the state of Colorado. Opportunities for expansion of NAS surveillance capability will be examined on a case-by-case basis. Surveillance can also be established through parties entering into agreements with the FAA that provide ADS-B services given considerations such as future ADS-B applications testing, early equipage of ADS-B avionics, or cost-sharing.

The FAA's SBS office has supported analysis of this additional service coverage at airport locations below the current minimum radar coverage. FAA estimates that there are potentially 1048 airports which may benefit from this coverage. The maximum potential aggregate national benefit, based on standard ASR benefit criteria, is projected to have a net present value (NPV) of $610 million but this does not account for any marginal costs for extending the currently proposed ITT ADS-B laydown and is not currently part of the proposed investment program.

Additionally, various states including Minnesota and Wisconsin are contemplating piggy backing onto FAA's ITT ADS-B implementation contract to expand the coverage beyond the current laydown to fill in gaps. For instance 5 airports in Minnesota will gain coverage under the ITT laydown that are not currently covered down to 2000' AGL. Minnesota is examining a supplementary purchase of ADS-B receivers to fill gaps in its coverage for another 16 airports and Wisconsin is contemplating purchasing two receivers to cover 13 airports.

Appendix A Legacy Infrastructure Costs

Table A.1

Legacy Sustain Costs Under ADS-B Out Scenario 2009 $

	Legacy Sustain Airborne	Legacy Sustain Surface	Total Legacy Sustain	3% Discount Rate	7% Discount Rate	Legacy Sustain Discounted at 3%	Legacy Sustain Discounted at 7%
Total	**$588,393**	**$171,506**	**$759,899**			**$643,599**	**$530,535**
Year							
2009	$61,644	$24,084.52	$85,728	1	1	$85,728	$85,728
2010	$42,336	$19,223.37	$61,559	0.9709	0.9346	$59,766	$57,532
2011	$40,600	$16,054.30	$56,654	0.9426	0.8734	$53,402	$49,484
2012	$40,580	$17,320.57	$57,901	0.9151	0.8163	$52,988	$47,264
2013	$40,561	$14,252.63	$54,814	0.8885	0.7629	$48,702	$41,817
2014	$40,543	$14,252.63	$54,795	0.8626	0.7130	$47,267	$39,068
2015	$40,524	$14,252.63	$54,777	0.8375	0.6663	$45,875	$36,500
2016	$40,507	$13,528.50	$54,035	0.8131	0.6227	$43,935	$33,650
2017	$40,489	$19,551.44	$60,040	0.7894	0.5820	$47,396	$34,944
2018	$39,425	$12,306.07	$51,731	0.7664	0.5439	$39,647	$28,138
2019	$38,362	$6,679.76	$45,042	0.7441	0.5083	$33,515	$22,897
2020	$37,302	$0.00	$37,302	0.7224	0.4751	$26,947	$17,722
2021	$32,900	$0.00	$32,900	0.7014	0.4440	$23,075	$14,608
2022	$28,505	$0.00	$28,505	0.6810	0.4150	$19,410	$11,828
2023	$24,116	$0.00	$24,116	0.6611	0.3878	$15,944	$9,353
2024	$0	$0.00	$0	0.6419	0.3624	$0	$0
2025	$0	$0.00	$0	0.6232	0.3387	$0	$0
2026	$0	$0.00	$0	0.6050	0.3166	$0	$0
2027	$0	$0.00	$0	0.5874	0.2959	$0	$0
2028	$0	$0.00	$0	0.5703	0.2765	$0	$0
2029	$0	$0.00	$0	0.5537	0.2584	$0	$0
2030	$0	$0.00	$0	0.5375	0.2415	$0	$0
2031	$0	$0.00	$0	0.5219	0.2257	$0	$0
2032	$0	$0.00	$0	0.5067	0.2109	$0	$0
2033	$0	$0.00	$0	0.4919	0.1971	$0	$0
2034	$0	$0.00	$0	0.4776	0.1842	$0	$0
2035	$0	$0.00	$0	0.4637	0.1722	$0	$0

Table A.2

Legacy Backup Cost for ADS-B Out Surface and Airborne Backup (2009 K$)

	Legacy Backup Surface	Legacy Backup Airborne	Total Legacy Backup	3% Discount Rate	7% Discount Rate	Total Legacy Backup discounted at 3%	Total Legacy Backup discounted at 7%
Total	**$0**	**$812,255**	**$812,255**			**$487,113**	**$263,286**
Year							
2009	$0	$0.00	$0	1	1	$0	$0
2010	$0	$0.00	$0	0.9709	0.9346	$0	$0
2011	$0	$0.00	$0	0.9426	0.8734	$0	$0
2012	$0	$0.00	$0	0.9151	0.8163	$0	$0
2013	$0	$0.00	$0	0.8885	0.7629	$0	$0
2014	$0	$18,423.60	$18,424	0.8626	0.7130	$15,892	$13,136
2015	$0	$18,423.60	$18,424	0.8375	0.6663	$15,429	$12,276
2016	$0	$18,423.60	$18,424	0.8131	0.6227	$14,980	$11,473
2017	$0	$18,423.60	$18,424	0.7894	0.5820	$14,544	$10,723
2018	$0	$18,988.94	$18,989	0.7664	0.5439	$14,553	$10,329
2019	$0	$19,554.28	$19,554	0.7441	0.5083	$14,550	$9,940
2020	$0	$20,119.62	$20,120	0.7224	0.4751	$14,535	$9,559
2021	$0	$22,332.81	$22,333	0.7014	0.4440	$15,664	$9,916
2022	$0	$24,546.00	$24,546	0.6810	0.4150	$16,715	$10,186
2023	$0	$8,604.32	$8,604	0.6611	0.3878	$5,688	$3,337
2024	$0	$54,134.42	$54,134	0.6419	0.3624	$34,747	$19,621
2025	$0	$54,134.42	$54,134	0.6232	0.3387	$33,735	$18,337
2026	$0	$54,134.42	$54,134	0.6050	0.3166	$32,752	$17,138
2027	$0	$54,134.42	$54,134	0.5874	0.2959	$31,798	$16,016
2028	$0	$54,134.42	$54,134	0.5703	0.2765	$30,872	$14,969
2029	$0	$54,134.42	$54,134	0.5537	0.2584	$29,973	$13,989
2030	$0	$54,134.42	$54,134	0.5375	0.2415	$29,100	$13,074
2031	$0	$54,134.42	$54,134	0.5219	0.2257	$28,252	$12,219
2032	$0	$54,134.42	$54,134	0.5067	0.2109	$27,429	$11,419
2033	$0	$54,134.42	$54,134	0.4919	0.1971	$26,631	$10,672
2034	$0	$54,134.42	$54,134	0.4776	0.1842	$25,855	$9,974
2035	$0	$28,935.91	$28,936	0.4637	0.1722	$13,417	$4,983

Table A.3
Radar Decommissioning Costs (2009 K$)

	Decommissioning	3% Discount Rate	7% Discount Rate	Decommissioning Costs Discounted at 3%	Decommissioning Costs Discounted at 7%
Total	**$42,589**			**$29,636**	**$18,663**
Year					
2009	$0	1	1	$0	$0
2010	$0	**0.9709**	0.9346	$0	$0
2011	$0	**0.9426**	0.8734	$0	$0
2012	$0	**0.9151**	0.8163	$0	$0
2013	$0	**0.8885**	0.7629	$0	$0
2014	$0	**0.8626**	0.7130	$0	$0
2015	$0	**0.8375**	0.6663	$0	$0
2016	$416	**0.8131**	0.6227	$338	$259
2017	$623	**0.7894**	0.5820	$492	$363
2018	$3,740	**0.7664**	0.5439	$2,866	$2,034
2019	$3,740	**0.7441**	0.5083	$2,783	$1,901
2020	$3,532	**0.7224**	0.4751	$2,551	$1,678
2021	$8,726	**0.7014**	0.4440	$6,120	$3,874
2022	$8,726	**0.6810**	0.4150	$5,942	$3,621
2023	$7,479	**0.6611**	0.3878	$4,945	$2,901
2024	$5,609	**0.6419**	0.3624	$3,600	$2,033
2025	$0	**0.6232**	0.3387	$0	$0
2026	$0	**0.6050**	0.3166	$0	$0
2027	$0	**0.5874**	0.2959	$0	$0
2028	$0	**0.5703**	0.2765	$0	$0
2029	$0	**0.5537**	0.2584	$0	$0
2030	$0	**0.5375**	0.2415	$0	$0
2031	$0	**0.5219**	0.2257	$0	$0
2032	$0	**0.5067**	0.2109	$0	$0
2033	$0	**0.4919**	0.1971	$0	$0
2034	$0	**0.4776**	0.1842	$0	$0
2035	$0	**0.4637**	0.1722	$0	$0

Table A.4
Other Legacy Costs for ADS-B Out Scenario (2009 K$)

	Legacy Upgrade Remaining ASDE-3 Surface	3% Discount Rate	7% Discount Rate	ASDE-3 Discounted at 3%	ASDE-3 Discounted at 7%
Total	**$252,998**			**$204,828**	**$162,372**
Year					
2009	$0.0	1	1	$0	$0
2010	$0.0	0.9709	0.9346	$0	$0
2011	$6,222.9	0.9426	0.8734	$5,866	$5,435
2012	$76,603.5	0.9151	0.8163	$70,103	$62,531
2013	$42,394.2	0.8885	0.7629	$37,667	$32,342
2014	$34,398.0	0.8626	0.7130	$29,672	$24,525
2015	$7,313.5	0.8375	0.6663	$6,125	$4,873
2016	$7,313.5	0.8131	0.6227	$5,947	$4,554
2017	$3,045.1	0.7894	0.5820	$2,404	$1,772
2018	$3,045.1	0.7664	0.5439	$2,334	$1,656
2019	$3,045.1	0.7441	0.5083	$2,266	$1,548
2020	$3,045.1	0.7224	0.4751	$2,200	$1,447
2021	$21,115.2	0.7014	0.4440	$14,810	$9,375
2022	$3,045.1	0.6810	0.4150	$2,074	$1,264
2023	$3,045.1	0.6611	0.3878	$2,013	$1,181
2024	$3,045.1	0.6419	0.3624	$1,955	$1,104
2025	$3,045.1	0.6232	0.3387	$1,898	$1,031
2026	$3,045.1	0.6050	0.3166	$1,842	$964
2027	$3,045.1	0.5874	0.2959	$1,789	$901
2028	$3,045.1	0.5703	0.2765	$1,737	$842
2029	$3,045.1	0.5537	0.2584	$1,686	$787
2030	$3,045.1	0.5375	0.2415	$1,637	$735
2031	$3,045.1	0.5219	0.2257	$1,589	$687
2032	$3,045.1	0.5067	0.2109	$1,543	$642
2033	$3,045.1	0.4919	0.1971	$1,498	$600
2034	$3,045.1	0.4776	0.1842	$1,454	$561
2035	$5,870.5	0.4637	0.1722	$2,722	$1,011

Appendix B – Reduced Delay over Gulf of Mexico

Increased Capacity over the Gulf of Mexico - Benefits of Reduced Delay

Current non-radar separation in the Gulf of Mexico constrains the number of flights that can operate in each of the Air Route Traffic Control Center Gulf (ARTCC) sectors (ZHU79 and ZHU72). According to ZHU controllers many flights experience ground or air delay because of this constrained airspace. Currently delay only occurs during highly seasonal peak traffic days.[82] As demand increases we expect days with delays to increase.

The first step in the analysis was to estimate the increase in capacity that might reasonably be achieved by radar-like separation. Discussions with representatives from Houston Center revealed that the monitor alert parameter (MAP) value [83] is 12 for Sector ZHU 72and 18 for sector ZHU 79, the two sectors comprising the high altitude airspace over the Gulf of Mexico. The average time an aircraft spends in the region (both sectors) is 32 minutes. Combining these gives an hourly capacity of 56 aircraft in today's environment. Once ADS-B Out is implemented in the Gulf of Mexico and assuming a 5 mile separation standard is approved based on ADS-B Out data being available for separation purposes, the hourly capacity for sectors in the Houston CTA[84]/FIR [85] is estimated to increase from 56 to 84 aircraft. This capacity is higher than that used in the NPRM due to the following recently planned enhancements not originally known: Houston Center is now planning a 3rd GOMEX high altitude sector raising the combined MAP value for all 3 sectors to an estimated 45; second, a new RNP-10 route structure will add to the number of routes available and thereby add to the capacity of the airspace; third, Merida Center plans to add an additional high altitude sector to increase Mexico's capacity in receiving and transferring aircraft across the common boundary with Houston, and lastly, additional capacity at key airports in Mexico is expected to be complete soon, further alleviating the constraints built into the original capacity estimates for Mexico.

We started with actual operations over the Gulf of Mexico for each day in 2008. This data was obtained from the FAA Air Traffic Data Activity System (ATADS) Houston Oceanic operations counts for each day in 2008. [86]

For example, on December 31, 2008, there were a total of 308 oceanic operations tracked by the Houston Center (ZHU). This represents the number of operations over the Gulf of Mexico on that day as displayed in Table B.1 below.

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[82] ATO En Route Services, Surveillance and Broadcast Services Benefits Basis of Estimate, June 2006, FAA ATO, pg. 41.
[83] The MAP value is the maximum number of aircraft that can be managed by a sector simultaneously with the exception that the MAP value can be exceeded for brief intervals.
[84] Control Area: A control area is airspace wholly contained beyond the 12 mile limit whereby an ICAO state has been designated as the ATS authority for the control of air traffic
[85] Flight Information Region: FIR's designate regions for informational service's only, not ATC control.
[86] Available on the FAA Office of Policy and Plans (APO) website: http://www.apo.data.faa.gov/

Table B.1
Number of Flights over the Gulf of Mexico on 12/31/2008
CENTERS: Oceanic

	Oceanic									
	Departures				Overflights					
Date	Air Carrier	Air Taxi	General Aviation	Military	Air Carrier	Air Taxi	General Aviation	Military	Total	Total
12/31/2008	0	0	0	0	267	4	18	19	308	4,702
Total:	**0**	**0**	**0**	**0**	**267**	**4**	**18**	**19**	**308**	**4,702**

In this way, we collected the number of operations over the Gulf of Mexico for every day in 2008. The second column of Table B.2 (highlighted in yellow) gives a snapshot of the number of actual operations organized from high to low for the 31 days in 2008 with the highest number of operations. The highest operation day in 2008 was 616. Then we reduced the number of operations by 10% to account for operations that only made small incursions into oceanic sectors. The third column in Table B.2 is a snapshot of the starting point from which we forecast operations to represent future years.

Table B.2
Estimated Number of Flights Per Day

	ATADS 2009	ATADS reduced by 10%	1.4%	4.3%	5.2%	5.8%	5.5%	4.5%	4.2%	4.1%	4.1%	Start of 4% growth	
Day	**2008**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
1	616	554	562	586	616	652	688	719	749	780	812	844	878
2	572	515	522	544	572	606	639	668	695	724	754	784	815
3	567	510	517	540	567	601	634	662	689	718	747	777	808
4	539	485	492	513	539	571	602	629	655	682	710	739	768
5	532	479	485	506	532	563	594	621	647	674	701	729	758
6	530	477	484	504	530	561	592	619	644	671	698	726	755
7	525	473	479	500	525	556	587	613	638	665	692	720	748
8	511	460	466	486	511	541	571	597	621	647	673	700	728
9	505	455	461	481	505	535	564	590	614	639	666	692	720
10	500	450	456	476	500	530	559	584	608	633	659	685	713
11	490	441	447	466	490	519	547	572	596	620	646	672	698
12	488	439	445	464	488	517	545	570	593	618	643	669	696
13	483	435	441	460	483	512	540	564	587	611	637	662	688
14	473	426	432	450	473	501	528	552	575	599	623	648	674
15	469	422	428	446	469	497	524	547	570	594	618	643	669
16	465	419	424	442	465	493	520	543	565	589	613	637	663
17	464	418	423	442	464	491	518	542	564	587	611	636	661
18	464	418	423	442	464	491	518	542	564	587	611	636	661
19	461	415	421	439	461	488	515	538	561	584	608	632	657
20	458	412	418	436	458	485	512	535	557	580	604	628	653
21	457	411	417	435	457	484	511	533	556	579	602	626	651
22	453	408	413	431	453	480	506	529	551	574	597	621	646
23	451	406	412	429	451	478	504	526	548	571	594	618	643
24	450	405	411	428	450	477	503	525	547	570	593	617	641
25	449	404	410	427	449	476	502	524	546	568	592	615	640
26	449	404	410	427	449	476	502	524	546	568	592	615	640
27	445	401	406	423	445	471	497	519	541	563	586	610	634
28	444	400	405	422	444	470	496	518	540	562	585	609	633
29	435	392	397	414	435	461	486	508	529	551	573	596	620
30	431	388	393	410	431	457	482	503	524	546	568	591	614
31	430	387	392	409	430	455	480	502	523	544	567	589	613

To forecast operations for years out to 2035, we derived total operations for the U.S. to and from Latin America using several forecasts from the 2009 FAA forecast. [87] We multiplied the average seats per aircraft (international) [88] by the scheduled passenger capacity and load factors [89] to obtain passengers per aircraft. Then we divided the total passenger traffic to and from the U.S. from Latin America [90] by the average passengers per aircraft[91] to derive the estimated total flights and computed the percent change in operations from year to year, as presented in Table B.3.

[87] FAA Aerospace Forecasts, Fiscal Years 2009-2025, U.S. Department of Transportation, Federal Aviation Administration, Office of Policy and Plans.
[88] Table 9 FAA Aerospace Forecasts, Fiscal Years 2009-2025
[89] Table 13 FAA Aerospace Forecasts, Fiscal Years 2009-2025
[90] Table 8 FAA Aerospace Forecasts, Fiscal Years 2009-2025
[91] Table 9 FAA Aerospace Forecasts, Fiscal Years 2009–2025

Table B.3
Forecast of High Altitude Operations in Gulf of Mexico

Calendar Year	Total Passenger Traffic To and From the United States (Millions) Table 8 Total Passengers To and From U.S. from Latin America [a]	Average Seats Per Aircraft Table 9 International (Seats)	Scheduled Passenger Capacity and Load Factors Table 13 % Load Factor (Latin America)	Average Seats/A/C Times Load Factor Passengers Per Aircraft	Total Passengers Divided by Passengers per A/C Flights	% Change in Flights
Historical*						
2000	40.8	230.6	69.0	159.1	256,393	
2001	38.8	226.9	69.2	157.0	247,174	-3.60%
2002	36.9	221.5	66.5	147.2	250,394	1.30%
2003	39.1	220.2	69.3	152.6	256,440	2.41%
2004	42.7	218.7	70.4	153.9	277,259	8.12%
2005	44.2	217.1	72.2	156.7	281,981	1.70%
2006	47.1	215.0	74.9	160.9	292,826	3.85%
2007E	48.6	215.9	76.9	166.1	292,644	-0.06%
Forecast						
2008	49.3	217.5	79.3	172.4	285,880	-2.31%
2009	48.9	217.0	77.8	168.8	289,870	1.40%
2010	51.1	217.5	77.8	169.2	302,243	4.27%
2011	54.0	218.1	77.9	169.8	317,893	5.18%
2012	57.3	218.6	77.9	170.3	336,450	5.84%
2013	60.6	219.0	78.0	170.7	354,900	5.48%
2014	63.4	219.4	78.0	171.0	370,804	4.48%
2015	66.2	219.8	78.0	171.4	386,213	4.16%
2016	69.1	220.4	78.0	171.8	402,148	4.13%
2017	72.1	220.9	78.0	172.2	418,616	4.10%
2018	75.2	221.4	78.0	172.6	435,713	4.08%
2019	78.4	221.9	78.0	173.0	453,462	4.07%
2020	81.8	222.4	78.0	173.4	471,823	4.05%
2021	85.3	222.9	78.0	173.8	490,952	4.05%
2022	89.0	223.3	78.0	174.1	510,884	4.06%
2023	92.8	223.8	78.0	174.5	531,604	4.06%
2024	96.7	224.2	78.0	174.8	553,134	4.05%
2025	100.8	224.7	78.0	175.2	575,491	4.04%

Using the estimated growth in operations up to year 2018 as presented in the last column of Table B.3 and derived from the FAA forecast [92] and an assumed 4% growth rate after 2018, we increased each daily number of flights starting in the third column of Table B.2 out to the year 2035. The percent change in operations (shown in the last column of Table B.3) is indicated on the top row of Table B.2 above (which shows a snapshot of flights growing per year). The specific tables from which the numbers in Table B.3 originate in the FAA forecast are indicated in the top row of Table B.3.

Next we took our forecast (Table B.2 – Estimated Number of Flights per Day) and counted the number of days for each year that would experience operations falling into various daily demand groupings. Table B.4 presents a snapshot of these groupings for selected years. For instance, we estimate that in 2015 there will be four days during which high altitude operations will be less than 200, 33 days with operations from 200 to 249, 42 days with 250 to 299 operations and so on.

[92] FAA Aerospace Forecasts Fiscal Years 2006-2017, U.S. Department of Transportation, Federal Aviation Administration Office of Policy & Plans.

Table B.4
Unconstrained Daily Demand [93]

	Number of Days Per Year					
Daily Demand Groupings	2008	2015	2020	2025	2030	2035
Less Than 200	58	4	1	0	0	0
200 to 249	88	33	3	1	0	0
250 to 299	113	42	27	3	1	0
300 to 349	51	89	36	16	1	1
350 to 399	27	86	62	33	12	0
400 to 449	18	45	78	32	23	3
450 to 499	7	26	57	61	26	13
500 to 549	2	18	36	65	24	22
550 to 599	1	12	21	48	49	20
600 to 649	0	6	16	30	55	15
650 to 699	0	3	14	21	48	30
700 to 749	0	1	6	15	35	49
750 to 799	0	0	4	12	23	52
800 to 849	0	0	3	14	12	34
850 to 899	0	0	0	4	16	25
900 to 949	0	0	1	4	11	24
950 to 999	0	0	0	3	8	17
1000 to 1049	0	0	0	2	8	10
1050 to 1099	0	0	0	0	4	10
1100 to 1149	0	0	0	1	2	10
1150 to 1199	0	0	0	0	4	6
1200 to 1249	0	0	0	0	1	9
1250 to 1299	0	0	0	0	1	3
1300 to 1349	0	0	0	0	0	4
1349+	0	0	0	0	1	8
Total	**365**	**365**	**365**	**365**	**365**	**365**

In order to estimate the delay for each level of operations under the base case scenario (no surveillance over the Gulf) and under the ADS-B Out scenario (ADS-B surveillance over the Gulf) a queuing model developed by MCR Federal was used.

To run the queuing model with hourly capacities, we needed an hourly demand profile. ZHU ARTCC provided the hourly demand profile based on the four busiest days in 2003. This profile was applied to the midpoint of each of the daily operations groupings to derive an hourly demand profile for each level of operations. Table B.5 displays the hourly demand profile for a day for 675 flights (representing the midpoint of operations from 650 to 699). For example, 12.8% of the 675 operations or 86 operations occurs at 10 a.m.

93 A complete table of unconstrained daily demand showing number of days for each year from 2009 to 2035 in each daily demand group can be found in Table B.14 below.

Table B.5
Hourly Demand Profile on Peak Days

Time	% of Operations	# of Operations
6	1.4%	9
7	2.4%	16
8	3.2%	22
9	10.7%	73
10	12.8%	86
11	8.7%	59
12	9.3%	63
13	6.8%	46
14	8.1%	55
15	7.9%	53
16	9.8%	66
17	5.7%	38
18	7.0%	47
19	3.2%	22
20	2.1%	15
21	0.8%	5
22	0.0%	0
	Total	**675**

This hourly demand distribution for the midpoint of each daily demand grouping was input into the queuing model. The queuing model was then run for the base case capacity (56 aircraft per hour) and the surveillance capacity (84 aircraft per hour). The queuing model produced a probability distribution of delay minutes for each grouping.

We assume that delays beyond 20 minutes per flight are not acceptable [94] and we will not accommodate demand for flights if the delay is expected to surpass 20 minutes. According to the queuing model 20-minute delays are encountered at daily flight levels of 675 under the baseline and 1025 under the surveillance case. We therefore constrain demand at 675 for the baseline and at 1025 for the surveillance case. Table B.6 shows demand constrained at 675 flights for the baseline and Table B.7 shows demand constrained at 1025 flights for the surveillance case.

[94] "approximately 20 minutes represents the highest level of average delay realized in actual practice even at highly congested airports, FAA Airport Benefit Cost Analysis Guidance, page 16, FAA Airport Benefit Cost Analysis http://www.faa.gov/regulations_policies/policy_guidance/benefit_cost/media/faabca.pdf

Table B.6
Daily Demand Constrained at 675 Flights [95] – Baseline

	Number of Days per Year					
Daily Operations	2008	2015	2020	2025	2030	2035
Less Than 200	58	4	1	0	0	0
200 to 249	88	33	3	1	0	0
250 to 299	113	42	27	3	1	0
300 to 349	51	89	36	16	1	1
350 to 399	27	86	62	33	12	0
400 to 449	18	45	78	32	23	3
450 to 499	7	26	57	61	26	13
500 to 549	2	18	36	65	24	22
550 to 599	1	12	21	48	49	20
600 to 649	0	6	16	30	55	15
650 to 699	0	4	28	76	174	291
700 to 749	0	0	0	0	0	0
750 to 799	0	0	0	0	0	0
800 to 849	0	0	0	0	0	0
850 to 899	0	0	0	0	0	0
900 to 949	0	0	0	0	0	0
950 to 999	0	0	0	0	0	0
1000 to 1049	0	0	0	0	0	0
1050 to 1099	0	0	0	0	0	0
1100 to 1149	0	0	0	0	0	0
1150 to 1199	0	0	0	0	0	0
1200 to 1249	0	0	0	0	0	0
1250 to 1299	0	0	0	0	0	0
1300 to 1349	0	0	0	0	0	0
1349+	0	0	0	0	0	0
Total	**365**	**365**	**365**	**365**	**365**	**365**

[95] A complete table of daily demand constrained at 675 flights showing number of days for each year from 2009 to 2035 in each daily demand group up to and including 675 can be found in Table B.22 below.

Table B.7
Daily Demand Constrained at 1025 Flights – Surveillance Case

Daily Operations	Number of Days per Year					
	2008	2015	2020	2025	2030	2035
Less Than 200	58	4	1	0	0	0
200 to 249	88	33	3	1	0	0
250 to 299	113	42	27	3	1	0
300 to 349	51	89	36	16	1	1
350 to 399	27	86	62	33	12	0
400 to 449	18	45	78	32	23	3
450 to 499	7	26	57	61	26	13
500 to 549	2	18	36	65	24	22
550 to 599	1	12	21	48	49	20
600 to 649	0	6	16	30	55	15
650 to 699	0	3	14	21	48	30
700 to 749	0	1	6	15	35	49
750 to 799	0	0	4	12	23	52
800 to 849	0	0	3	14	12	34
850 to 899	0	0	0	4	16	25
900 to 949	0	0	1	4	11	24
950 to 999	0	0	0	3	8	17
1000 to 1049	0	0	0	3	21	60
1050 to 1099	0	0	0	0	0	0
1100 to 1149	0	0	0	0	0	0
1150 to 1199	0	0	0	0	0	0
1200 to 1249	0	0	0	0	0	0
1250 to 1299	0	0	0	0	0	0
1300 to 1349	0	0	0	0	0	0
1349+	0	0	0	0	0	0
Total	365	365	365	365	365	365

Table B.8 shows the results of the queuing model when run for a daily demand level of 675. The results show that at 675 daily flights there will be 13500 minutes of total delay for the base case capacity and 86 minutes total delay for the surveillance capacity at the 50th percentile. This works out to 20 minutes per flight under the base case and .13 minutes per flight under the surveillance scenario. The daily savings in hours between the base case and surveillance case is estimated to be 224 at a daily flight level of 675 ((20-.13) x 675/60).

Table B.8
Delay for Baseline (56/hour) and Surveillance (84/hour) Scenarios at a Daily Flight Level of 675

Percentiles	56 aircraft/hour Delay (min)	84 aircraft/hour Delay (min)
0%		0
10%		3
20%		14
30%		31
40%		56
50%	13,500	86
60%		124
70%		175
80%		252
90%		394
100%		1,722
Average Delay (min)	20.00	0.13
Delay Savings (hours)		224

At daily demand levels beyond 675, for the base case since we capped flights at 675 we calculate delay of 20 minutes for each of the 675 flights ((20 x 675)/60=225 hours). Then we subtract the surveillance delay which is (.41 x 725)/60 = 4.95) and subtract from the baseline delay (225-4.95 =220 hours) for the net savings in hours with ADS-B.

Table B.9
Results of Queuing Model for Base Case and Surveillance Case at 725 Daily Flights

Percentiles	56 aircraft/hour Delay (min)	84 aircraft/hour Delay (min)
0%		0
10%		44
20%		93
30%		160
40%		223
50%	14500	297
60%		381
70%		484
80%		626
90%		906
100%		2624
Average Delay (min)	20.00	0.41
Delay Savings (hours)		220.05

The daily delay in minutes at each demand level for the baseline and surveillance is presented in Table B.10. For instance, at a demand level of 675 we estimated delays of 20 minutes per aircraft under the baseline and .13 minutes with surveillance using the queuing model. We then convert to total delay hours per year by multiplying the delay times the midpoint of the daily flights (or demand) grouping times the number of days that we have forecast for that grouping divided by 60. So for a demand level of 675, under the baseline, the delay is calculated as follows: (20 x 675 x 76)/60 = 17,100.

For the ADS-B surveillance case, delays of 20 minutes occur at 1025 flights. We do not accommodate flights beyond that level and calculate delay hours per year as we did for the baseline. So for a demand level of 975 under the ADS-B surveillance case, the delay is calculated as follows: (13.31 x 975 x 3)/60 = 649.

Total delay in hours under the baseline is 22,680 and under the surveillance case it is 2,977. The surveillance case results in a savings of 19,703 hours relative to the baseline in 2025 as illustrated in the table below.

Table B.10
Delay Savings for Daily Flight Levels of Demand

Midpoint	Daily demand	Baseline Delay Per Aircraft (minutes)	Surveillance Delay Per Aircraft (minutes)	Baseline 2025 # Days Per bin	Baseline 2025 Delay Per Bin in hrs.	Surveillance 2025 # Days Per bin	Surveillance 2025 Delay Per Bin in hrs.
175	Less Than 200	0.00	0.00	0		0	
225	200 to 249	0.00	0.00	1		1	
275	250 to 299	0.00	0.00	3		3	
325	300 to 349	0.00	0.00	16		16	
375	350 to 399	0.00	0.00	33		33	
425	400 to 449	0.08	0.00	32	18	32	
475	450 to 499	0.43	0.00	61	208	61	
525	500 to 549	1.37	0.00	65	779	65	
575	550 to 599	3.92	0.00	48	1803	48	
625	600 to 649	8.87	0.00	30	2772	30	
675	650 to 699	20.00	0.13	76	17100	21	31
725	700 to 749		0.41	0		15	74
775	750 to 799		0.93	0		12	144
825	800 to 849		1.91	0		14	368
875	850 to 899		4.13	0		4	241
925	900 to 949		7.22	0		4	445
975	950 to 999		13.31	0		3	649
1025	1000 to 1049		20.00	0		3	1025
1075	1050 to 1099			0		0	
1125	1100 to 1149			0		0	
1175	1150 to 1199			0		0	
1225	1200 to 1249			0		0	
1275	1250 to 1299			0		0	
1325	1300 to 1349			0		0	
1375	1350+			0		0	
	Total			**365**	**22680**	**365**	**2977**

We assume that capacity would be phased in starting in year 2012 to reach full compliance by 2020 as presented in Table B.11. [96] Therefore, the full amount of delay savings cannot be achieved until 2020. Table B.11 summarizes annual delay savings in hours and indicates phasing in of equipment with the resulting hours that we estimate will be saved under the surveillance case relative to the baseline. It then computes an economic value of the delay hours saved. The factors used in computing the economic value of delay savings benefits are in Table B.13.

[96] The phasing depends on estimated Gulf equipage and allocation of ADS-B separation to more altitudes over time.

Table B.11
Annual Delay Savings in Hours, Capacity Phasing, Hours Saved and Economic Value of Delay Savings (2009 M$)

Year	Delay Savings in Hours	Capacity Phasing	Hours Saved	$ per hour (2009$)	Economic Value (2009$M)	PV factor 3%	PV factor 7%	Discounted Value 3%	Discounted Value 7%
2009	95.57	0%	0	$3,857	$0.00	1	1	$0.00	$0.00
2010	146.92	0%	0	$3,857	$0.00	0.9709	0.9346	$0.00	$0.00
2011	317.24	0%	0	$3,857	$0.00	0.9426	0.8734	$0.00	$0.00
2012	728.16	20%	145.6325	$3,857	$0.56	0.9151	0.8163	$0.51	$0.46
2013	1000.17	30%	300.0513	$3,857	$1.16	0.8885	0.7629	$1.03	$0.88
2014	1616.98	40%	646.7917	$3,857	$2.49	0.8626	0.7130	$2.15	$1.78
2015	2225.62	50%	1112.808	$3,857	$4.29	0.8375	0.6663	$3.59	$2.86
2016	3070.04	60%	1842.025	$3,857	$7.10	0.8131	0.6227	$5.78	$4.42
2017	4297.17	70%	3008.02	$3,857	$11.60	0.7894	0.5820	$9.16	$6.75
2018	5366.45	80%	4293.16	$3,857	$16.56	0.7664	0.5439	$12.69	$9.01
2019	7335.09	90%	6601.583	$3,857	$25.46	0.7441	0.5083	$18.95	$12.94
2020	8948.68	100%	8948.675	$3,857	$34.51	0.7224	0.4751	$24.93	$16.40
2021	11002.64	100%	11002.64	$3,857	$42.44	0.7014	0.4440	$29.76	$18.84
2022	12570.49	100%	12570.49	$3,857	$48.48	0.6810	0.4150	$33.01	$20.12
2023	14631.46	100%	14631.46	$3,857	$56.43	0.6611	0.3878	$37.31	$21.89
2024	16806.20	100%	16806.2	$3,857	$64.82	0.6419	0.3624	$41.61	$23.49
2025	19703	100%	19703.19	$3,857	$75.99	0.6232	0.3387	$47.36	$25.74
2026	22438	100%	22438.27	$3,857	$86.54	0.6050	0.3166	$52.36	$27.40
2027	25435	100%	25434.54	$3,857	$98.10	0.5874	0.2959	$57.62	$29.02
2028	28163	100%	28162.95	$3,857	$108.62	0.5703	0.2765	$61.95	$30.03
2029	31863	100%	31863.22	$3,857	$122.89	0.5537	0.2584	$68.04	$31.76
2030	34533	100%	34533.39	$3,857	$133.19	0.5375	0.2415	$71.60	$32.17
2031	36984	100%	36984.42	$3,857	$142.64	0.5219	0.2257	$74.45	$32.20
2032	38258	100%	38258.24	$3,857	$147.56	0.5067	0.2109	$74.77	$31.13
2033	40377	100%	40377.45	$3,857	$155.73	0.4919	0.1971	$76.61	$30.70
2034	39511	100%	39510.77	$3,857	$152.39	0.4776	0.1842	$72.78	$28.08
2035	37764	100%	37763.73	$3,857	$145.65	0.4637	0.1722	$67.54	$25.08
Total					$1,685.22			$945.55	$463.15

Table B.12
Passenger Value of Time [97], [98] [99]

	Passenger Capacity	Load Factor	Passenger per Aircraft	Hourly Values of time $ Per Passenger	Hourly Value of Passenger Time
Air Carrier - TAF	107.4	79.20%	85.0608	$28.60	$2,432.74
Air Taxi - TAF	30.7	73.30%	22.5031	$28.60	$643.59
GA	4	52.70%	2.108	$37.20	$78.42
Military	N/A	N/A	N/A	N/A	N/A

Source: Economic Information for Investment Analysis, Prepared for Operations Research/ATO-F, 04/24/2009

[97] Source for Passenger Capacity and Load Factor is "Supporting Documentation for the Economic Factors Used in Investment Analysis," pg. 17, Federal Aviation Administration, December 7, 2006, Final.
[98] Source for Hourly Values of Time 2000 U.S. $ Per Passenger is "Economic Values for FAA Investment and Regulatory Decisions, A Guide, Draft final Report, December 31, 2004, Prepared for FAA Office of Aviation Policy and Plans.
[99] GDP Chained Price Index, Budget of the United States Government, Fiscal Year 2007, Table 10.1—Gross Domestic Product and Deflators Used in the Historical Tables: 1940-2011.

Table B.13
Factors Used to Compute Economic Value

Hourly value of time used in High Altitude Gulf Analysis				
Type of Operations	% TRAFFIC	ADOC Ground 2009 $	Avg PVT	Total Weighted Value
Air Carrier and Commuter -TAF	85.36%	2,037.14	$2,432.74	$3,815.49
Air Taxi - TAF	1.08%	533.14	$643.59	$12.76
GA	7.63%	296.68	$78.42	$28.63
Military	5.86%			
Total Weighted		$ 1,879	$ 2,221	$ 3,857

The dollar value of one hour of delay savings was calculated using the factors in Table B.13. The distribution of traffic among air carrier and commuter, air taxi, GA and military was computed using the oceanic overflight data from ATADS. This provided a weighting for the hourly costs of delay.

Aircraft direct operating costs (ADOC) are estimated per hour on the ground as $2,037 for air carriers TAF, $533 for air taxis and $297 for general aviation.[100] Average passenger value of time is derived by multiplying passenger capacity by load factor [101] to derive passengers per aircraft and multiplying passengers per aircraft by the hourly value of passenger time[102]. These values are presented in Table B.13. Values used to calculate hourly passenger value of time per aircraft is found in Table B.12.

The value of $3,857 per one hour of delay savings was derived by taking a weighted average of the sum of ADOC ground operating costs and the average passenger value of time for each type of operations, weighted by the percent of traffic accounted for by each type. This value was then multiplied by the hours saved (Table B.11) each year to derive an economic value of delay savings. These delay savings were then discounted at 3% and 7%. The analysis did not take into account any downstream delay savings that might be achieved due to ADS-B. Downstream delay occurs when an aircraft that is delayed causes further delays in the system. Therefore, the benefits are underestimated.

We estimated the benefits of avoiding delays that would be encountered by high altitude operations are $1.7 billion or $946 million when discounted at 3% and $463 million when discounted at 7%. These results are presented in Table B.11.

[100] Economic Information for Investment Analysis Data Package, Prepared for Operations Research/ATO-F, pg. 6, Federal Aviation Administration, April 24, 2009.
[101] Economic Information for Investment Analysis Data Package, Prepared for Operations Research/ATO-F, pg. 7, Federal Aviation Administration, April 24, 2009.
[102] Source for Hourly Values of Time 2000 U.S. $ Per Passenger is "Economic Values for FAA Investment and Regulatory Decisions, A Guide, Final Report, October 3, 2007, Prepared for FAA Office of Aviation Policy and Plans.

Additional Flights Accommodated by ADS-B

As mentioned above, our analysis assumes that flight delays in excess of 20 minutes will not be tolerated. Demand levels that could result in flight delays above 20 minutes are not accommodated. The queuing analysis indicated that without surveillance over the Gulf, delays of 20 minutes occur at a level of operations of 675 per day. If there is surveillance, (as would be the case with ADS-B) delays would occur at daily flight levels of 1025. On days that we anticipate demand in excess of 675, ADS-B technology would accommodate more flights. Starting in 2014 we forecast that there will be days on which daily flight demand will exceed 675 as indicated in Table B.15. In this analysis we assume that with ADS-B surveillance flights between 675 and 1025 per day will be accommodated, as explained below.

Table B.14
Unconstrained Daily Demand

	Number of Days Per Year																											
Daily Demand Groupings	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Less Than 200	58	51	44	27	18	10	4	4	2	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
200 to 249	88	85	60	58	49	48	42	33	20	17	13	7	3	2	1	0	1	1	1	1	1	1	0	0	0	0	0	0
250 to 299	113	115	131	116	89	65	48	42	45	43	37	36	27	17	15	9	3	3	1	1	0	0	1	1	1	1	1	0
300 to 349	51	58	62	78	99	108	107	89	76	53	40	32	36	41	33	34	27	16	15	8	3	3	1	0	0	0	0	1
350 to 399	27	28	30	40	50	58	73	86	93	93	87	76	62	39	35	26	33	33	28	27	18	14	12	7	3	2	1	0
400 to 449	18	18	24	20	25	31	35	45	51	66	73	83	78	78	68	59	36	32	25	27	31	27	23	14	14	11	6	3
450 to 499	7	7	7	16	21	19	24	26	29	33	46	45	57	70	75	76	68	61	51	30	26	22	26	29	26	20	12	13
500 to 549	2	2	6	7	7	16	18	18	20	19	22	29	36	41	46	50	70	65	61	60	52	36	24	20	20	24	26	22
550 to 599	1	1	1	2	4	6	7	12	16	19	18	18	21	23	30	34	38	48	60	64	60	55	49	36	25	14	19	20
600 to 649	0	0	0	1	2	3	4	6	6	11	15	17	16	15	17	25	29	30	34	41	51	60	55	57	50	35	24	15
650 to 699	0	0	0	0	1	1	2	3	4	5	5	11	14	17	16	13	15	21	25	30	33	40	48	49	49	51	47	30
700 to 749	0	0	0	0	0	0	1	1	2	3	5	4	6	9	13	14	16	15	18	20	24	29	35	41	48	51	42	49
750 to 799	0	0	0	0	0	0	0	0	1	1	2	3	4	5	5	11	10	12	13	16	17	19	23	26	28	39	50	52
800 to 849	0	0	0	0	0	0	0	0	0	1	1	2	3	4	4	5	8	14	11	12	11	14	12	21	25	27	27	34
850 to 899	0	0	0	0	0	0	0	0	0	0	0	1	0	2	3	5	4	4	9	9	10	12	16	15	17	22	25	25
900 to 949	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	1	4	4	5	7	13	9	11	9	13	12	19	24
950 to 999	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	2	3	4	5	5	11	8	12	8	12	15	17
1000 to 1049	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	1	3	3	3	8	9	10	9	10	10
1050 to 1099	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	1	4	3	4	6	10	9	9	10
1100 to 1149	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	0	4	2	4	6	11	6	10
1150 to 1199	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	1	4	3	4	3	11	6
1200 to 1249	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	3	2	4	3	9
1250 to 1299	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	3	2	4	3
1300 to 1349	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	3	2	4
1349+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2	3	6	8
Total	**365**	**365**	**365**	**365**	**365**	**365**	**365**	**365**	**365**	**365**	**365**	**365**	**365**	**365**	**365**	**365**	**365**	**365**	**365**	**365**	**365**	**365**	**365**	**365**	**365**	**365**	**365**	**365**

The difference in number of flights that would be accommodated given ADS-B surveillance in the Gulf of Mexico are presented in Table B.15 below. For each demand level above 675, the difference in flights between that level and the next (50 flights) is multiplied by the number of days that we expect that level of demand according to our forecast.

Table B.15
Additional Flights Accommodated Because of Surveillance

Daily Flights	2014	Add'l Ops	2015	Add'l Ops	2016	Add'l Ops	2017	Add'l Ops	2018	Add'l Ops	2019	Add'l Ops	2020	Add'l Ops	2021	Add'l Ops	2022	Add'l Ops
Less Than 200	4		4		2		1		1		1		1		1		1	
200 to 249	42		33		20		17		13		7		3		2		1	
250 to 299	48		42		45		43		37		36		27		17		15	
300 to 349	107		89		76		53		40		32		36		41		33	
350 to 399	73		86		93		93		87		76		62		39		35	
400 to 449	35		45		51		66		73		83		78		78		68	
450 to 499	24		26		29		33		46		45		57		70		75	
500 to 549	18		18		20		19		22		29		36		41		46	
550 to 599	7		12		16		19		18		18		21		23		30	
600 to 649	4		6		6		11		15		17		16		15		17	
650 to 699	2		3		4		5		5		11		14		17		16	
700 to 749	1	50	1	50	2	100	3	150	5	250	4	200	6	300	9	450	13	650
750 to 799	0		0		1	100	1	100	2	200	3	300	4	400	5	500	5	500
800 to 849	0		0		0		1	150	1	150	2	300	3	450	4	600	4	600
850 to 899	0		0		0		0		0		1	200	0	0	2	400	3	600
900 to 949	0		0		0		0		0		0		1	250	0	0	2	500
950 to 999	0		0		0		0		0		0		0		1	300	1	300
1000 to 1049	0		0		0		0		0		0		0		0		0	
1050 to 1099	0		0		0		0		0		0		0		0		0	
1100 to 1149	0		0		0		0		0		0		0		0		0	
1150 to 1199	0		0		0		0		0		0		0		0		0	
1200 to 1249	0		0		0		0		0		0		0		0		0	
1250 to 1299	0		0		0		0		0		0		0		0		0	
1300 to 1349	0		0		0		0		0		0		0		0		0	
1349+	0		0		0		0		0		0		0		0		0	
Total		50		50		200		400		600		1000		1400		2250		3150

For instance, according to our forecast, in 2016 there will be 2 days, during which demand will reach 725 flights per day and one day during which it will reach 775 flights. ADS-B technology will allow an additional 50 flights above the level that will be tolerated without surveillance for each of 2 days ((725-675) x 2 = 100) and an additional 100 flights (775-675 x 1 =100) for the one day with 775 flights. The technology will allow for the accommodation of 200 more flights in 2016 than the base case.

Consumer Surplus Analysis

Assumptions

- Over the time horizon there will be no change in the size of the airplane, no change in the load factor and no change in the current way goods are delivered.
- Elasticity of demand $\beta = -1$ [103].

[103] To better capture aggregate consumer responses to a change in federal policies, FAA frequently adopts a unitary elastic demand curve, for example, see FAA's 1995 Cost Allocation Study. Estimates of the own-price elasticity of demand typically range between -0.7 to 1.5. The lower bound of -0.7 is frequently cited as an estimate for short-haul business travel while the upper bound is an estimated for long-haul domestic travel. In a book titled *"Straight and Level: Practical Airline Economics"*(2008), Stephen Holloway reports other own-price elasticities including a -1.04 for long-haul international business travel and a -1.15 for long-haul domestic business. Similarly, if one considers the meta-study conducted in 2002 by Gillen, Morrison, Stewart, *Air Travel Demand Elasticities: Concepts Issues and Measurement,* a -1 own-price elasticity clearly falls within the interval estimates reported in that study.

To estimate the economic benefit associated with the additional passengers as a result of implementing ADS-B, a consumer surplus approach was adopted. For the purpose of calculating the net surplus triangle it is assumed that the demand curve over the relevant range of aircraft operations can be approximated by a constant elasticity of demand curve, i.e, $P(q) = aq^{-1}$, with the price elasticity of demand equal to -1. The following formula is then used each year to calculate the consumer surplus associated with the additional passengers:

$$\textit{Incremental Passenger Benefit} = \int_{Q1}^{Q2} P(q)dq - P(Q2)[(Q2 - Q1)],$$

where P(q) is the unit elasticity demand curve, Q1 is the number of passengers without ADS-B, Q2 is number of passengers with ADS-B.

Figure 1 graphically illustrates this calculation for a given year. The net economic benefit associated with serving additional passengers is represented by the shaded area. The vertical axis measures the natural log of average air fare; the horizontal axis measures the natural log of average seats.

Figure 1

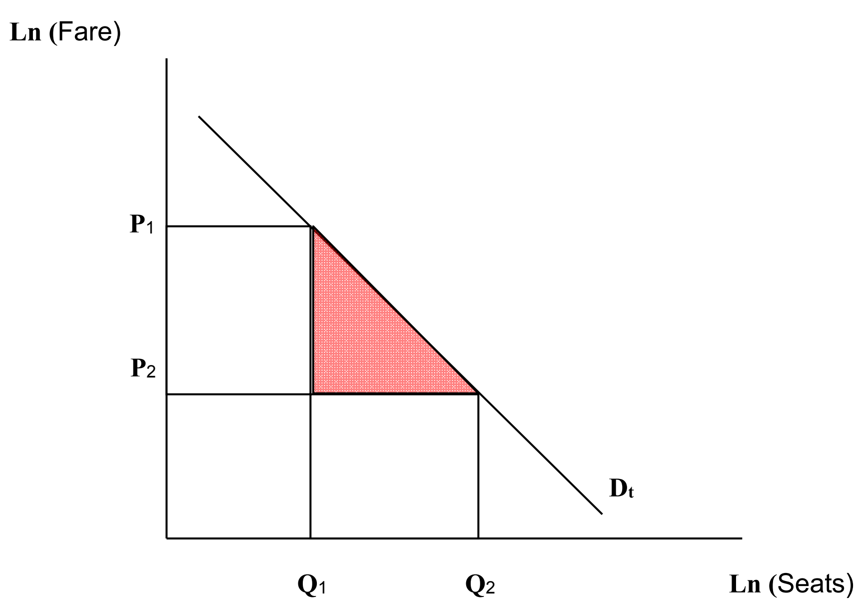


Table B.16 displays the data for each year used in the consumer surplus.

Table B.16 Consumer Surplus Estimates

Benefit of Additional Flights - Estimate of Consumer Surplus								
Year	Q_1 (1)	Q_2 (2)	P_1 (3)	Net change in Consumer Surplus (4)	3% Discount Rate	7% Discount Rate	Discounted by 3%	Discounted by 7%
2009	14,095,031	14,095,031	$242	$0	1	1	$0	$0
2010	14,735,128	14,735,128	$240	$0	0.9709	0.9346	$0	$0
2011	15,581,843	15,581,843	$238	$0	0.9426	0.8734	$0	$0
2012	16,544,694	16,544,694	$236	$0	0.9151	0.8163	$0	$0
2013	17,416,818	17,416,818	$236	$0	0.8885	0.7629	$0	$0
2014	18,296,946	18,303,996	$236	$320	0.8626	0.7130	$276	$228
2015	19,103,915	19,110,984	$236	$309	0.8375	0.6663	$259	$206
2016	19,907,966	19,936,320	$237	$4,768	0.8131	0.6227	$3,877	$2,969
2017	20,780,121	20,836,984	$237	$18,365	0.7894	0.5820	$14,498	$10,689
2018	21,642,503	21,728,033	$237	$39,920	0.7664	0.5439	$30,595	$21,714
2019	22,523,585	22,666,524	$238	$106,940	0.7441	0.5083	$79,573	$54,363
2020	23,409,149	23,609,809	$238	$202,452	0.7224	0.4751	$146,256	$96,184
2021	24,349,498	24,672,864	$238	$502,534	0.7014	0.4440	$352,467	$223,131
2022	25,164,905	25,618,846	$238	$953,008	0.6810	0.4150	$648,952	$395,465
2023	26,078,289	26,721,306	$239	$1,830,812	0.6611	0.3878	$1,210,382	$710,020
2024	27,097,656	27,930,762	$239	$2,935,537	0.6419	0.3624	$1,884,209	$1,063,974
2025	28,034,963	29,168,129	$239	$5,191,282	0.6232	0.3387	$3,235,035	$1,758,467
2026	28,894,962	30,277,322	$239	$7,434,831	0.6050	0.3166	$4,498,195	$2,353,677
2027	29,786,049	31,519,956	$240	$11,224,620	0.5874	0.2959	$6,593,281	$3,320,960
2028	30,664,826	32,824,166	$241	$16,706,494	0.5703	0.2765	$9,527,480	$4,619,485
2029	31,502,015	34,124,443	$242	$23,705,745	0.5537	0.2584	$13,125,296	$6,126,015
2030	32,158,464	35,311,040	$242	$33,063,145	0.5375	0.2415	$17,773,070	$7,985,182
2031	32,977,686	36,852,244	$244	$47,916,724	0.5219	0.2257	$25,007,379	$10,815,436
2032	33,498,278	38,089,394	$246	$65,184,461	0.5067	0.2109	$33,028,429	$13,750,459
2033	34,056,855	39,476,577	$248	$87,706,360	0.4919	0.1971	$43,145,717	$17,291,012
2034	34,528,554	40,889,368	$250	$116,623,546	0.4776	0.1842	$55,700,055	$21,487,792
2035	34,846,755	42,187,952	$252	$150,502,488	0.4637	0.1722	$69,787,210	$25,915,850
Total				$571,854,660			$285,792,492	$118,003,277

(1) Q_1= Passengers without rule

(2) Q_2= Passengers with rule

(3) P_1 = Real average fare without rule (2009$)

(4) Consumer Surplus benefit of additional flights

Source: Passenger and average fare data based on Latin America Traffic Statistics (2000-2040)

Optimal and More Direct Routing Benefits

The FAA examined the top twenty city pairs from the US to Mexico and south whose direct paths crossed the non-radar region for April 2003 and estimated savings in nautical miles (NM-I) that could result with radar-like separation. Appendix C describes in more detail how these savings were estimated. Table B.17 shows the savings in NM for the month of April 2003 for twenty city pairs over the Gulf that could have been achieved with the creation of more efficient routes. [104] There were a total of 4,063 flights between the twenty city pairs in April 2003. Of these flights, 1,105 were flights that flew through the non-radar region that could have benefitted from optimal routing. The table shows how much savings in NM could be achieved through optimal routing for flights between each city pair. For instance, direct routing could save 18.3 NM for flights operating between Miami (MIA) and Mexico City (MMMX). A potential average savings of 15 NM could be achieved by flights that operate between the twenty city pairs.

We estimate the number of flights per year that fly through non-radar regions and could potentially save 15 NM per flight with more optimal routing. In April of 2003 there were 1105 of these flights. April represents about 9% of the yearly traffic load. We estimate that in 2003 there were about 12,266 flights through the non-radar regions that could have derived benefit from optimal routing. We estimate that these flights will grow at about 4% a year. Optimal routing could save each of these flights 15 NM each. Table B.20 below indicates the annual number of flights and total savings each year that might be achieved from optimal routing.

Another 756 flights avoided the non-radar region either because the aircraft or crew may not be certified to fly that far from shore or because of limited capacity along the non-radar routes because of traffic. Some of these flights could be granted a more direct route with the advent of surveillance. We estimate that flights that could benefit from direct routing through the Gulf is equal to about 10.8% of the number of flights through the Gulf. [105]

Table B.17 shows how much savings in NM could be achieved if these flights could fly through the non-radar area. For instance, flying through the non-radar region could save a flight between Miami (MIA) and Mexico City (MMMX) 30.8 NM. We estimate that direct routing could save these flights on average 67.8 NM per flight.

[104] ATO En Route Services, Surveillance and Broadcast Services Benefits Basis of Estimate, June 2006, Federal Aviation Administration, Air Traffic Organization, pg. 53
[105] These flights that currently avoid the non-radar regions of the Gulf are not included in the count of flights that fly through the Gulf.

Table B.17
Optimal Route Savings Between Selected City Pairs Based on April 2003 Flights

City 1	City2	Number of Flights	Count of flights already on optimal route or weather related	Count of current non-radar flights	Savings per flight current non-radar routes (nmi)	Count of flights that avoided region	Savings per flight that avoided non-radar route (nmi)	Total savings (nmi)
MIA	MMMX	574	0	292	18.3	282	30.8	14,030
IAH	MMUN	338	183	155	12.4			1922
DFW	MMUN	292	156	136	2.6			354
ATL	MMMX	271	152	119	5.8			690
MSP	MMUN	215	215					0
ATL	MMUN	219	122	97	30.6			2968
ORD	MMUN	212	169	10	30.6	33	82.3	3022
JFK	MMMX	217	118	99	5.8			574
CLT	MMUN	198	6	8	30.6	184	82.3	15,388
EWR	MMUN	185	73	61	30.6	51	82.3	6064
IAH	MZBZ	183	183					0
DTW	MMUN	168	117	17	30.6	34	82.3	3318
EWR	MMMX	158	91	67	5.8			389
DEN	MMUN	137	66			71	133.3	9464
IAH	MROC	126	126					0
STL	MMUN	130	130					0
IAH	MGGT	116	111					0
IAH	MSLP	111	111					0
PHL	MMUN	108	24	9	30.6	75	82.3	6448
JFK	MMUN	105	44	35	30.6	26	82.3	3211
TOTAL		**4063**	**2197**	**1105**	**264.9**	**756**		**67,842**

Table B.18
Dollar Value of an Hour Saved with Optimal and More Direct Routing

Type of Operations	% TRAFFIC	ADOC Airborne 2007 $	Avg PVT	Total Weighted Value
Air Carrier and Commuter -TAF	85.36%	4,044.83	$2,432.74	$5,529.25
Air Taxi - TAF	1.08%	1,058.58	$643.59	$18.45
GA	7.63%	589.06	$78.42	$50.95
Military	5.86%			
Total Weighted				$ 5,599

Table B.19
Daily Demand Constrained at 625

	Number of Days per Year																							
Daily Operations	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Less Than 200	18	10	4	4	2	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
200 to 249	49	48	42	33	20	17	13	7	3	2	1	0	1	1	1	1	1	1	0	0	0	0	0	0
250 to 299	89	65	48	42	45	43	37	36	27	17	15	9	3	3	1	1	0	0	1	1	1	1	1	0
300 to 349	99	108	107	89	76	53	40	32	36	41	33	34	27	16	15	8	3	3	1	0	0	0	0	1
350 to 399	50	58	73	86	93	93	87	76	62	39	35	26	33	33	28	27	18	14	12	7	3	2	1	0
400 to 449	25	31	35	45	51	66	73	83	78	78	68	59	36	32	25	27	31	27	23	14	14	11	6	3
450 to 499	21	19	24	26	29	33	46	45	57	70	75	76	68	61	51	30	26	22	26	29	26	20	12	13
500 to 549	7	16	18	18	20	19	22	29	36	41	46	50	70	65	61	60	52	36	24	20	20	24	26	22
550 to 599	4	6	7	12	16	19	18	18	21	23	30	34	38	48	60	64	60	55	49	36	25	14	19	20
600 to 649	3	4	7	10	13	21	28	38	44	53	61	76	89	106	123	147	174	207	229	258	276	293	300	306
650 to 699	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
700 to 749	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
750 to 799	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
800 to 849	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
850 to 899	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
900 to 949	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
950 to 999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1000 to 1049	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1050 to 1099	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1100 to 1149	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1150 to 1199	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1200 to 1249	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1250 to 1299	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1300 to 1349	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1349+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365

Table B.20
Value of Optimal and More Direct Routing Over the Gulf of Mexico
(2009 $M)

Year	Number of flights affected - growth of 4% per year	Potential optimal non-radar route savings (nmi) - 15 nmi per flight savings	Number of Additional Flights that had been avoiding non-radar regions	Potential additional flight savings from flights previously avoiding non-radar areas 67.9 (nmi) savings per flight	High Altitude Capacity Phasing	Total Savings (nmi)	Total Savings (Hours)	Benefit ($M BY07)	Discounted by 3%	Discounted by 7%	3% Discount Rate	7% Discount Rate
2009	15,520	232,800	10,976	745,236	0%	0	0	$0.00	$0.00	$0.00	1.0000	1.0000
2010	16,140	242,100	11,435	776,403	0%	0	0	$0.00	$0.00	$0.00	0.9709	0.9346
2011	16,790	251,850	12,050	818,202	0%	0	0	$0.00	$0.00	$0.00	0.9426	0.8734
2012	17,460	261,900	12,679	860,918	20%	224,564	576	$3.22	$2.95	$2.63	0.9151	0.8163
2013	18,160	272,400	13,306	903,450	30%	352,755	905	$5.06	$4.50	$3.86	0.8885	0.7629
2014	18,880	283,200	13,797	936,816	40%	488,007	1,251	$7.01	$6.04	$5.00	0.8626	0.7130
2015	19,640	294,600	14,302	971,099	50%	632,850	1,623	$9.09	$7.61	$6.05	0.8375	0.6663
2016	20,420	306,300	14,656	995,115	60%	780,849	2,002	$11.21	$9.11	$6.98	0.8131	0.6227
2017	21,240	318,600	15,058	1,022,431	70%	938,722	2,407	$13.48	$10.64	$7.84	0.7894	0.5820
2018	22,090	331,350	15,449	1,049,014	80%	1,104,291	2,832	$15.85	$12.15	$8.62	0.7664	0.5439
2019	22,970	344,550	15,487	1,051,581	90%	1,256,518	3,222	$18.04	$13.42	$9.17	0.7441	0.5083
2020	23,890	358,350	15,598	1,059,097	100%	1,417,447	3,634	$20.35	$14.70	$9.67	0.7224	0.4751
2021	24,850	372,750	15,528	1,054,331	100%	1,427,081	3,659	$20.49	$14.37	$9.10	0.7014	0.4440
2022	25,840	387,600	15,652	1,062,764	100%	1,450,364	3,719	$20.82	$14.18	$8.64	0.6810	0.4150
2023	26,880	403,200	15,773	1,071,014	100%	1,474,214	3,780	$21.16	$13.99	$8.21	0.6611	0.3878
2024	27,950	419,250	15,825	1,074,497	100%	1,493,747	3,830	$21.44	$13.76	$7.77	0.6419	0.3624
2025	29,070	436,050	15,301	1,038,931	100%	1,474,981	3,782	$21.18	$13.20	$7.17	0.6232	0.3387
2026	30,230	453,450	14,958	1,015,648	100%	1,469,098	3,767	$21.09	$12.76	$6.68	0.6050	0.3166
2027	31,440	471,600	14,351	974,399	100%	1,445,999	3,708	$20.76	$12.19	$6.14	0.5874	0.2959
2028	32,700	490,500	13,732	932,416	100%	1,422,916	3,649	$20.43	$11.65	$5.65	0.5703	0.2765
2029	34,010	510,150	12,571	853,584	100%	1,363,734	3,497	$19.58	$10.84	$5.06	0.5537	0.2584
2030	35,370	530,550	11,057	750,736	100%	1,281,286	3,285	$18.39	$9.89	$4.44	0.5375	0.2415
2031	36,780	551,700	9,661	655,955	100%	1,207,655	3,097	$17.34	$9.05	$3.91	0.5219	0.2257
2032	38,250	573,750	8,189	556,040	100%	1,129,790	2,897	$16.22	$8.22	$3.42	0.5067	0.2109
2033	39,780	596,700	6,234	423,309	100%	1,020,009	2,615	$14.64	$7.20	$2.89	0.4919	0.1971
2034	41,370	620,550	5,235	355,477	100%	976,027	2,503	$14.01	$6.69	$2.58	0.4776	0.1842
2035	43,030	645,450	4,342	294,795	100%	940,245	2,411	$13.50	$6.26	$2.32	0.4637	0.1722
Total	**730,750**	**10,961,250**	**343,200**	**23,303,260**		**26,773,149**	**68,649**	**$384.37**	**$245.39**	**$143.82**		

We estimated total savings in nautical miles that could be achieved by more direct routes through the Gulf by estimating the number of flights that could fly these routes (10.8% of the number of flights over the Gulf) and multiplying that by an average savings of 67.8 NM per flight. Because adding these additional flights into the Gulf would also add demand to the High Altitude capacity model, we decided that the benefit would only accrue on days where there is little to no delay and we chose days with a demand level of less than 625. To estimate number of flights per year we multiplied the number of days that we expected demand to be at various levels times that level and times 10.8% and summed all the levels. Table B.19 shows number of days each year that we would encounter various daily demand levels. For instance, in 2015 we expect there will be 42 days when there will be an average demand for 275 flights. We multiply 42 by 275 and by 10.8% and do this for all the daily demand bins up to, but not including 675, and sum the results for an estimated 14,302 flights that could benefit from more direct routes over the Gulf. We then multiply the number of flights by the average savings per flight (14,302 x 67.8) to derive a total potential savings for 2015 of 971,099 NM. These benefits are achieved as capacity is phased in, beginning in 2012, based on industry equipage. We computed total savings (NM) (632,850 for 2015) by adding potential optimal non-radar route savings (294,600 for 2015) to potential additional flight savings (971,099 for 2015) and multiplying the sum by the percent capacity phasing (50% for 2015)
.

To monetize these savings we converted total savings into hours saved by dividing total savings (NM) by an average airspeed of 390 (632,850 divided by 390 for 2015). We then converted hours saved to value of hours saved by multiplying hours saved by the sum of the weighted averages of aircraft direct operating costs airborne and the passenger value of time as presented in Table B.18 ($5,599). Refer to Table B.20 for potential savings in miles, savings converted to total savings in miles, total savings in hours and total savings converted to dollars (benefits) and discounted benefits.

The result was an estimated benefit of $384.37 million dollars ($245.39 million when discounted by 3% and $143.82 million when discounted by 7%) as indicated in Table B.20.

Table B.21

Unconstrained Daily Demand

Daily Demand Groupings	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Less Than 200	18	10	4	4	2	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
200 to 249	49	48	42	33	20	17	13	7	3	2	1	0	1	1	1	1	1	1	0	0	0	0	0	0
250 to 299	89	65	48	42	45	43	37	36	27	17	15	9	3	3	1	1	0	0	1	1	1	1	1	0
300 to 349	99	108	107	89	76	53	40	32	36	41	33	34	27	16	15	8	3	3	1	0	0	0	0	1
350 to 399	50	58	73	86	93	93	87	76	62	39	35	26	33	33	28	27	18	14	12	7	3	2	1	0
400 to 449	25	31	35	45	51	66	73	83	78	78	68	59	36	32	25	27	31	27	23	14	14	11	6	3
450 to 499	21	19	24	26	29	33	46	45	57	70	75	76	68	61	51	30	26	22	26	29	26	20	12	13
500 to 549	7	16	18	18	20	19	22	29	36	41	46	50	70	65	61	60	52	36	24	20	20	24	26	22
550 to 599	4	6	7	12	16	19	18	18	21	23	30	34	38	48	60	64	60	55	49	36	25	14	19	20
600 to 649	2	3	4	6	6	11	15	17	16	15	17	25	29	30	34	41	51	60	55	57	50	35	24	15
650 to 699	1	1	2	3	4	5	5	11	14	17	16	13	15	21	25	30	33	40	48	49	49	51	47	30
700 to 749	0	0	1	1	2	3	5	4	6	9	13	14	16	15	18	20	24	29	35	41	48	51	42	49
750 to 799	0	0	0	0	1	1	2	3	4	5	5	11	10	12	13	16	17	19	23	26	28	39	50	52
800 to 849	0	0	0	0	0	1	1	2	3	4	4	5	8	14	11	12	11	14	12	21	25	27	27	34
850 to 899	0	0	0	0	0	0	0	1	0	2	3	5	4	4	9	9	10	12	16	15	17	22	25	25
900 to 949	0	0	0	0	0	0	0	0	1	0	2	1	4	4	5	7	13	9	11	9	13	12	19	24
950 to 999	0	0	0	0	0	0	0	0	0	1	1	1	2	3	4	5	5	11	8	12	8	12	15	17
1000 to 1049	0	0	0	0	0	0	0	0	0	0	0	1	0	2	1	3	3	3	8	9	10	9	10	10
1050 to 1099	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	1	4	3	4	6	10	9	9	10
1100 to 1149	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	0	4	2	4	6	11	6	10
1150 to 1199	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	1	4	3	4	3	11	6
1200 to 1249	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	3	2	4	3	9
1250 to 1299	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	3	2	4	3
1300 to 1349	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	3	2	4
1349+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2	3	6	8
Total	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365

Table B.22

Daily Demand Constrained at 675 Flights

	Number of Days per Year																							
Daily Operations	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Less Than 200	18	10	4	4	2	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
200 to 249	49	48	42	33	20	17	13	7	3	2	1	0	1	1	1	1	1	1	0	0	0	0	0	0
250 to 299	89	65	48	42	45	43	37	36	27	17	15	9	3	3	1	1	0	0	1	1	1	1	1	0
300 to 349	99	108	107	89	76	53	40	32	36	41	33	34	27	16	15	8	3	3	1	0	0	0	0	1
350 to 399	50	58	73	86	93	93	87	76	62	39	35	26	33	33	28	27	18	14	12	7	3	2	1	0
400 to 449	25	31	35	45	51	66	73	83	78	78	68	59	36	32	25	27	31	27	23	14	14	11	6	3
450 to 499	21	19	24	26	29	33	46	45	57	70	75	76	68	61	51	30	26	22	26	29	26	20	12	13
500 to 549	7	16	18	18	20	19	22	29	36	41	46	50	70	65	61	60	52	36	24	20	20	24	26	22
550 to 599	4	6	7	12	16	19	18	18	21	23	30	34	38	48	60	64	60	55	49	36	25	14	19	20
600 to 649	2	3	4	6	6	11	15	17	16	15	17	25	29	30	34	41	51	60	55	57	50	35	24	15
650 to 699	1	1	3	4	7	10	13	21	28	38	44	51	60	76	89	106	123	147	174	201	226	258	276	291
700 to 749	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
750 to 799	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
800 to 849	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
850 to 899	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
900 to 949	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
950 to 999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1000 to 1049	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1050 to 1099	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1100 to 1149	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1150 to 1199	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1200 to 1249	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1250 to 1299	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1300 to 1349	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1349+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365

Table B.23
Daily Demand Constrained at 1025 Flights

Daily Operations	Number of Days per Year																							
	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Less Than 200	18	10	4	4	2	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
200 to 249	49	48	42	33	20	17	13	7	3	2	1	0	1	1	1	1	1	1	0	0	0	0	0	0
250 to 299	89	65	48	42	45	43	37	36	27	17	15	9	3	3	1	1	0	0	1	1	1	1	1	0
300 to 349	99	108	107	89	76	53	40	32	36	41	33	34	27	16	15	8	3	3	1	0	0	0	0	1
350 to 399	50	58	73	86	93	93	87	76	62	39	35	26	33	33	28	27	18	14	12	7	3	2	1	0
400 to 449	25	31	35	45	51	66	73	83	78	78	68	59	36	32	25	27	31	27	23	14	14	11	6	3
450 to 499	21	19	24	26	29	33	46	45	57	70	75	76	68	61	51	30	26	22	26	29	26	20	12	13
500 to 549	7	16	18	18	20	19	22	29	36	41	46	50	70	65	61	60	52	36	24	20	20	24	26	22
550 to 599	4	6	7	12	16	19	18	18	21	23	30	34	38	48	60	64	60	55	49	36	25	14	19	20
600 to 649	2	3	4	6	6	11	15	17	16	15	17	25	29	30	34	41	51	60	55	57	50	35	24	15
650 to 699	1	1	2	3	4	5	5	11	14	17	16	13	15	21	25	30	33	40	48	49	49	51	47	30
700 to 749	0	0	1	1	2	3	5	4	6	9	13	14	16	15	18	20	24	29	35	41	48	51	42	49
750 to 799	0	0	0	0	1	1	2	3	4	5	5	11	10	12	13	16	17	19	23	26	28	39	50	52
800 to 849	0	0	0	0	0	1	1	2	3	4	4	5	8	14	11	12	11	14	12	21	25	27	27	34
850 to 899	0	0	0	0	0	0	0	1	0	2	3	5	4	4	9	9	10	12	16	15	17	22	25	25
900 to 949	0	0	0	0	0	0	0	0	1	0	2	1	4	4	5	7	13	9	11	9	13	12	19	24
950 to 999	0	0	0	0	0	0	0	0	0	1	1	1	2	3	4	5	5	11	8	12	8	12	15	17
1000 to 1049	0	0	0	0	0	0	0	0	0	0	0	1	1	3	4	7	10	13	21	28	38	44	51	60
1050 to 1099	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1100 to 1149	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1150 to 1199	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1200 to 1249	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1250 to 1299	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1300 to 1349	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1349+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365

Table B.24
Additional Flights

Daily Flights	2014	Add'l Ops	2015	Add'l Ops	2016	Add'l Ops	2017	Add'l Ops	2018	Add'l Ops	2019	Add'l Ops	2020	Add'l Ops	2021	Add'l Ops	2022	Add'l Ops
Less Than 200	4		4		2		1		1		1		1		1		1	
200 to 249	42		33		20		17		13		7		3		2		1	
250 to 299	48		42		45		43		37		36		27		17		15	
300 to 349	107		89		76		53		40		32		36		41		33	
350 to 399	73		86		93		93		87		76		62		39		35	
400 to 449	35		45		51		66		73		83		78		78		68	
450 to 499	24		26		29		33		46		45		57		70		75	
500 to 549	18		18		20		19		22		29		36		41		46	
550 to 599	7		12		16		19		18		18		21		23		30	
600 to 649	4		6		6		11		15		17		16		15		17	
650 to 699	2		3		4		5		5		11		14		17		16	
700 to 749	1	50	1	50	2	100	3	150	5	250	4	200	6	300	9	450	13	650
750 to 799	0		0		1	100	1	100	2	200	3	300	4	400	5	500	5	500
800 to 849	0		0		0		1	150	1	150	2	300	3	450	4	600	4	600
850 to 899	0		0		0		0		0		1	200	0	0	2	400	3	600
900 to 949	0		0		0		0		0		0		1	250	0	0	2	500
950 to 999	0		0		0		0		0		0		0		1	300	1	300
1000 to 1049	0		0		0		0		0		0		0		0		0	
1050 to 1099	0		0		0		0		0		0		0		0		0	
1100 to 1149	0		0		0		0		0		0		0		0		0	
1150 to 1199	0		0		0		0		0		0		0		0		0	
1200 to 1249	0		0		0		0		0		0		0		0		0	
1250 to 1299	0		0		0		0		0		0		0		0		0	
1300 to 1349	0		0		0		0		0		0		0		0		0	
1349+	0		0		0		0		0		0		0		0		0	
Total		**50**		**50**		**200**		**400**		**600**		**1000**		**1400**		**2250**		**3150**

Appendix C Optimal Routing

Details on Optimal Routing of High Altitude Operations Over the Gulf of Mexico

Optimal Routing Of High Altitude Operations Over the Gulf of Mexico

Problem: Due to the lack of surveillance and limited communication at high altitudes, non-radar separation procedures restrict aircraft to the available airways.

Capability/Direct Impact: By providing surveillance and improved communication services, radar-like separation can be applied which enables enhanced dynamic air traffic management. Enhanced dynamic traffic management can, in effect, increase the number of available airways by granting directs.

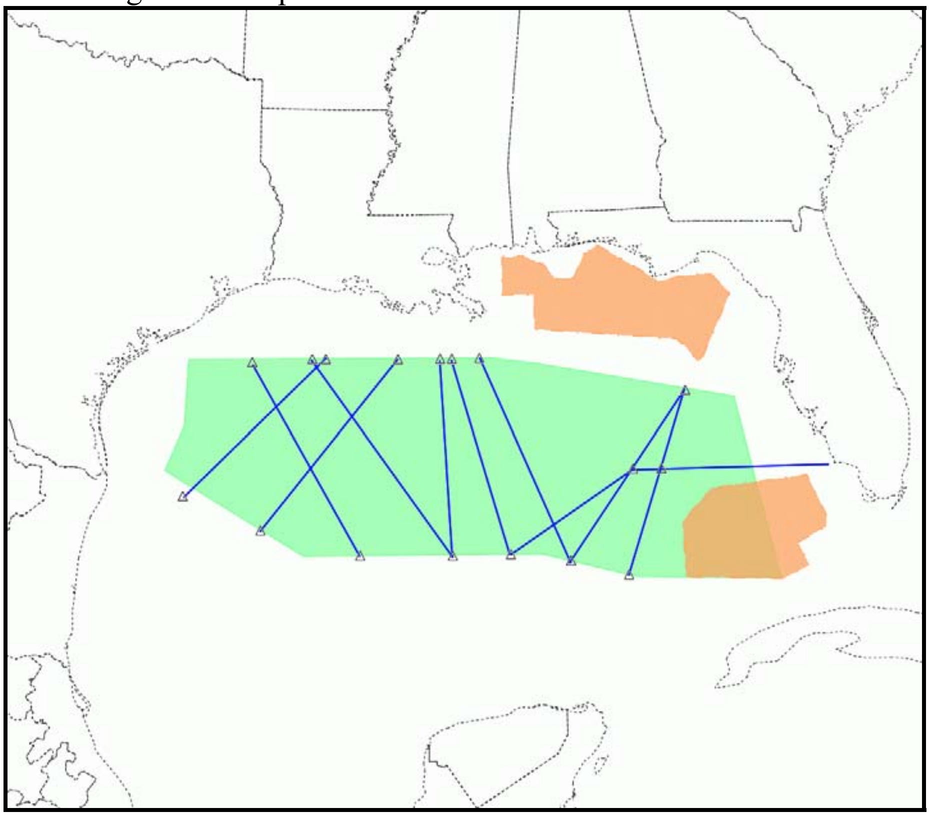
Outcome/Benefit: Enhanced dynamic air traffic management increases direct routing, which should lead to a reduction in flight distances and times. Reduction in flight distances and times translates to savings in aircraft direct operating costs and passenger value of time.

Baseline Information: Current flights between Gulf city pairs either file one of the 10 available non-radar routes, or file a path that avoids the non-radar region completely. Figure 1 displays the non-radar region, the non-radar routes, and two important SUAs that constrict traffic.

Flights crossing the non-radar region of the Gulf of Mexico are constrained to routes with set entry and exit fixes. Because of spacing restrictions and arrival/departure stream flows, controllers sometimes treat routes as one-way corridors. The addition of surveillance across the gulf would provide more optimal routing to flights that already file within the non-radar region in two ways. First, it would allow new entry/exit locations on the U.S. side of the region. The ability to allow new entry/exit points on the U.S. side should allow controllers to grant more directs from U.S. locations to the fixes on the Mexican airspace border. Second, it would allow controllers to build additional routes. Although the necessity of creating one-way routes for separating arrival and departure streams will still exist, controllers can build these routes much closer together than is possible with the current non-radar separation standards. This addition of airways should allow both inbound and outbound traffic to fly paths closer to the optimal route.

Flights that avoid the non-radar region may do so because the aircraft or crew may not be certified to fly that far away from shore, or the capacity along the non-radar routes may be limited due to traffic or weather [flights that are constrained due to capacity or lack of surveillance accounts for 10.8% of flights between city pairs]. Added surveillance should increase capacity along current non-radar routes and allow addition of available routes, and assumed equipage of these flights should allow them to take the more optimal routes through the Gulf.

Figure 1. Airspace and routes in the Gulf of Mexico.



The light shaded region is the non-radar airspace. The dark shaded regions are two Special Use Airspace (SUA) areas. The lines in the light shaded region are the current routes through the region.

We first examined the top twenty city pairs from the US to Mexico and south whose direct paths crossed the non-radar region for April 2003. We chose to examine savings in terms of excess distance between current routes and more direct routes, where possible. The data source was ETMS-recorded filed flight paths. We considered savings from the two general categories mentioned in the previous paragraphs.

For flights that already fly through the non-radar region, we explored if the current route was the most optimum of the available routes to the destination. If not, we assumed the addition of surveillance would increase capacity along the more optimum route and additional parallel routes would be created to allow more direct paths between entry and exit points. In some situations, we also examined if directs from US locations to current fixes on the Mexican border would save distance.

We also investigated savings for flights that avoided the non-radar region. An attempt was made to determine if these circuitous routes around the region were weather-related. If a route between city pairs was filed more than 20% of the time, we assumed that it was not weather-related, but involved either capacity or equipage considerations. We removed routes filed less than 20% of the time from the analysis. Savings for this second category focused on allowing these flights to take the more optimal non-radar region route.

Table C-1 displays the excess distance data for the top twenty city pairs. The savings are broken into columns for flights that took routes through the non-radar regions and those who avoided the non-radar region.

Table C-1

Optimal route savings between selected city pairs

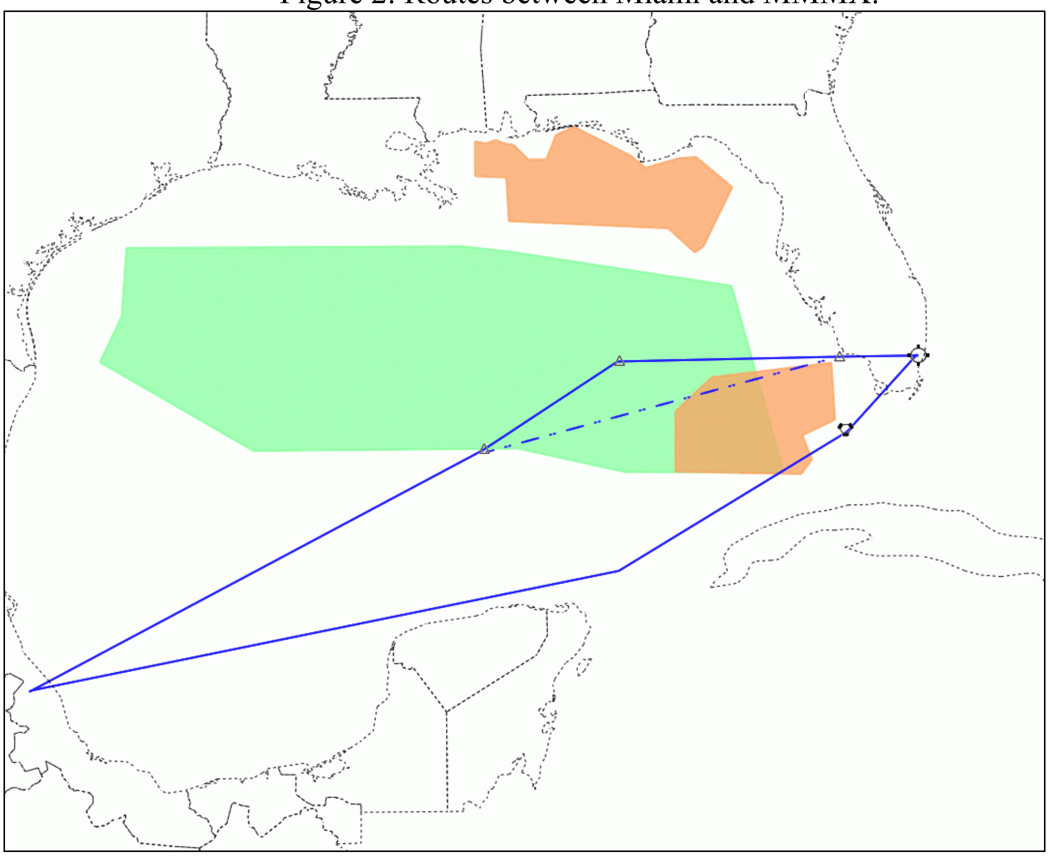
City 1	City2	Count	Count of flights already on optimal route or weather related	Count of current non-radar flights	Savings per flight current non-radar routes (NM)	Count of flights that avoided region	Savings per flight that avoided non-radar route (NM)	Total savings (NM)
MIA	MMMX	574	0	292	18.3	282	30.8	14,030
IAH	MMUN	338	183	155	12.4			1922
DFW	MMUN	292	156	136	2.6			354
ATL	MMMX	271	152	119	5.8			690
MSP	MMUN	215	215					0
ATL	MMUN	219	122	97	30.6			2968
ORD	MMUN	212	169	10	30.6	33	82.3	3022
JFK	MMMX	217	118	99	5.8			574
CLT	MMUN	198	6	8	30.6	184	82.3	15,388
EWR	MMUN	185	73	61	30.6	51	82.3	6064
IAH	MZBZ	183	183					0
DTW	MMUN	168	117	17	30.6	34	82.3	3318
EWR	MMMX	158	91	67	5.8			389
DEN	MMUN	137	66			71	133.3	9464
IAH	MROC	126	126					0
STL	MMUN	130	130					0
IAH	MGGT	116	111					0
IAH	MSLP	111	111					0
PHL	MMUN	108	24	9	30.6	75	82.3	6448
JFK	MMUN	105	44	35	30.6	26	82.3	3211
TOTAL		4063						67,842

Using only these twenty city pairs and the fact that April represents 9% of the yearly traffic load, we estimate savings of approximately 750,000 NM a year from more optimal routes.

MIA-MMMX

While most routes across the non-radar region are already direct, there is one notable exception. The most travel in the non-radar region takes place between Miami and Mexico City (574 flights in April 2003). The northern route (292 flights April 2003) between Miami and Mexico City has a turn in the gulf designed to avoid an SUA just west of the Florida Keys. With better surveillance, a new route, or a direct could be granted that would cut 18 NM off the current route and still avoid the SUA. This new route would also be 31 NM less than the current southern route (282 flights April 2003) that does not penetrate the non-radar region. See Figure 2.

Figure 2: Routes between Miami and MMMX.



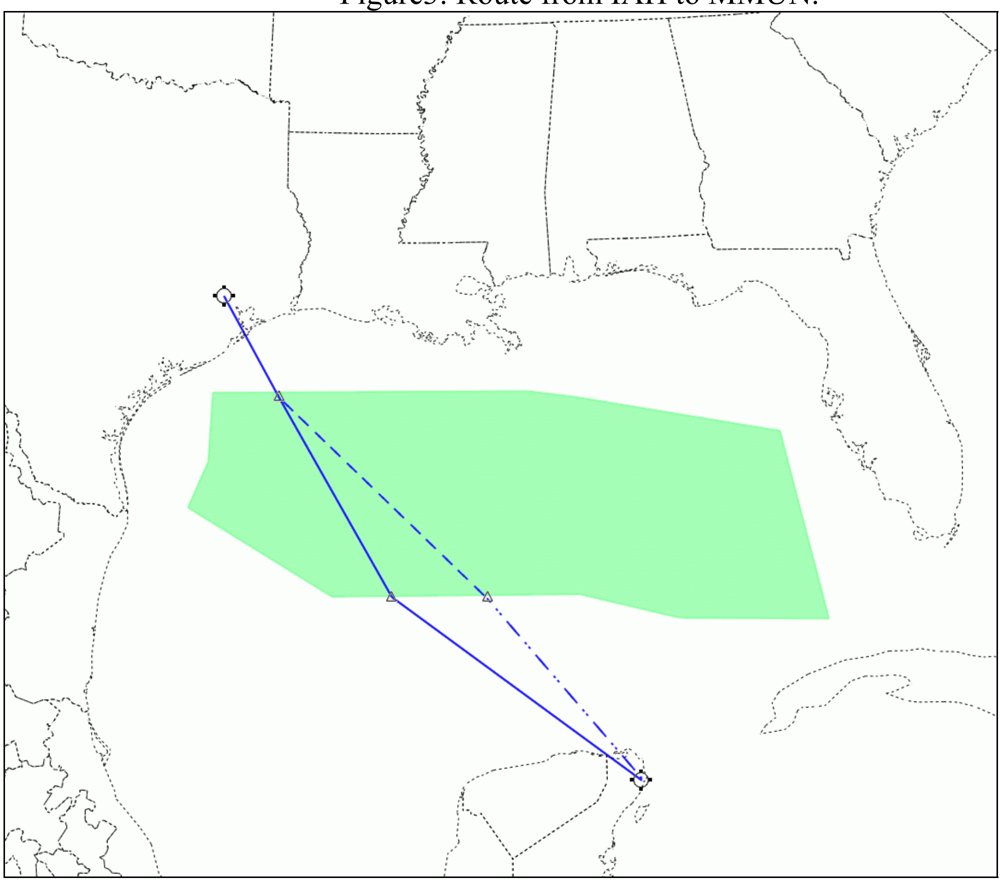
The light shaded region is the non-radar region and the dark shaded regions are two SUA areas. The solid lines are common northern and southern routes. The dashed line is the proposed shorter route.

IAH-MMUN

The current route structure includes non-radar routes that are close to the optimum path between major city pairs (e.g. IAH-CUN, IAH- MID). However, many times one of these routes is used as a one-way corridor causing flights in the opposite direction to use a non-optimum route. Although the necessity of creating one-way routes for separating arrival and departure streams may still exist, controllers can build these routes much closer together than is possible with the current non-radar separation standards. This addition of airways should allow both inbound and outbound traffic to fly a route closer to the optimal route.

During April 2003 there were 338 flights between IAH and MMUN. Half the flights (nearly all from IAH to MMUN) flew on the solid path flown in Figure 3. If we assume the same departure path (which ends on the MUSYL fix), we find that the dotted path (not a current route) is 12 NM shorter than the flown route. Most of the flights from MMUN to IAH already go on a very direct route. There were very few flights that did not cross the non-radar region between these cities, and their path may be weather related.

Figure3: Route from IAH to MMUN.



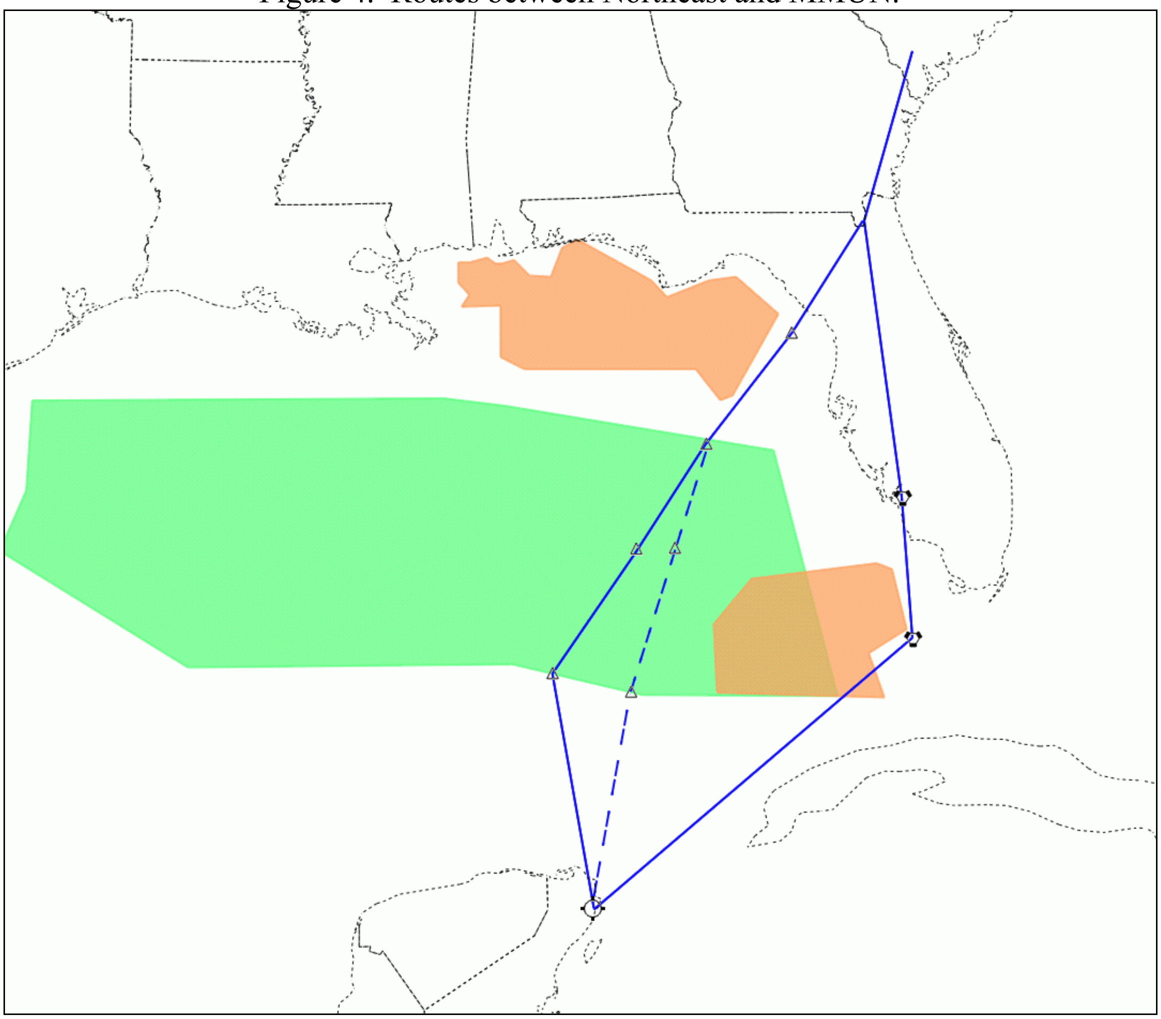
The solid line is most common route April 2003; the dashed line is shorter route by 12 miles. The light shaded region is the non-radar region.

Northeast-MMUN

Most of the flights during April 2003 from CLT, JFK, and EWR to MMUN and back generally followed one of the three paths seen in Figure 4. Most flights from ATL to MMUN and some from both DTW and ORD also took similar routes to MMUN with some variation at the extreme North of Figure 4. Between all of these city pairs there are more routes that avoid the non-radar region (Florida route) than can be explained because of weather.

If capacity were to increase because of surveillance, then most of these flights could take a route close to the optimum middle route (dashed path in Figure 4) saving 30.6 NM over the western case and 80.2 NM over the Florida route.

Figure 4. Routes between Northeast and MMUN.

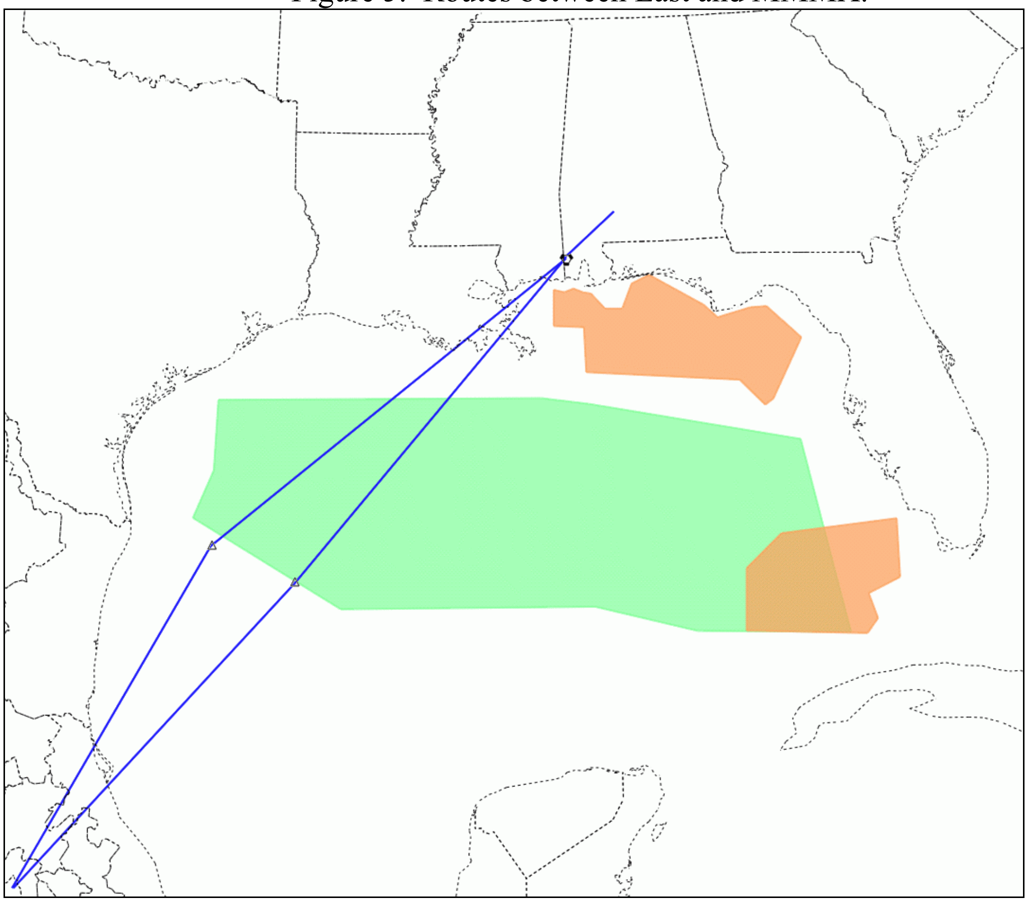


All lines are common routes (April 2003). The dashed line is most optimum route. The light shaded region is the non-radar region and the dark shaded regions are two SUA areas.

East-MMMX

Flights from JFK, EWR, and ATL to MMMX during April 2003 generally took one of the two routes shown in Figure 5. The southern route is more direct by 5.8 NM. If capacity were to increase, more of these flights could take a route closer to the southern route. A few of the recorded flights took routes that did not penetrate the non-radar region. There were so few of these that we assume these deviations were weather related.

Figure 5. Routes between East and MMMX.



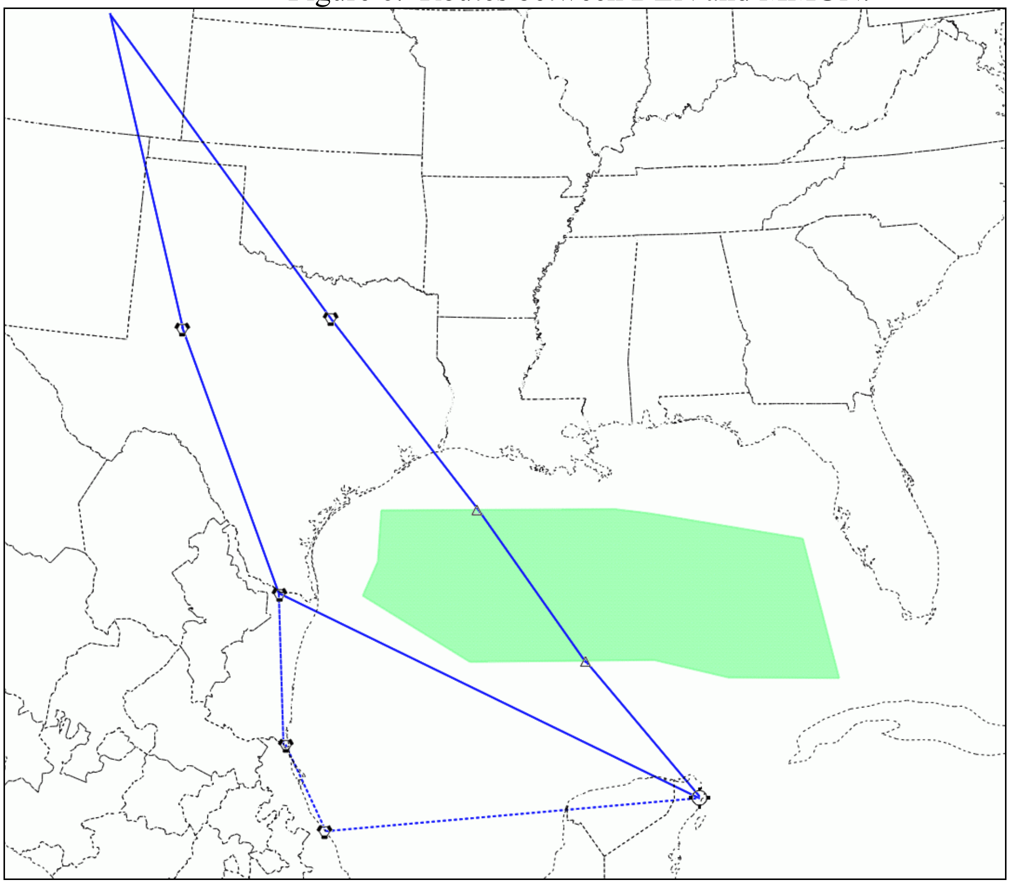
The solid lines are common routes. The light shaded region is the non-radar region and the dark shaded regions are two SUA areas.

DEN-MMUN

Flights from DEN to MMUN in April 2003 took one of two routes. Over half filed a southern route that entered Mexico near McAllen, Texas and hugged the coast before flying to MMUN (dotted path in Figure 6). The more direct filed route through the non-radar region is over 400 NM shorter than the southern route.

Over half the return flights from MMUN to DEN have filed routes that start with a NAVAID directly across from McAllen, Texas. We suspect that these flights also followed a route similar to those on the trip from DEN to MMUN and ETMS truncates the data when the flight is passed to the US. However, to be conservative, we use the direct path from MMUN to McAllen to estimate all the southern routes between DEN and MMUN. Using this route we find that flights that use the non-radar region route save 133 NM each.

Figure 6. Routes between DEN and MMUN.



Lines are common routes. The dark shaded region is the non-radar region.

Other flights:

Midwest-MMUN: Flights between STL and MSP in April 2003 generally took one of two routes across the non-radar region. The flights picked up both of these routes near New Orleans. The distance difference was negligible. Most flights from ORD and half the flights from DTW also take these paths. The other ORD and DTW flights take an eastern route that coincides with the traffic from the Northeast to MMUN.

IAH-other cities: Nearly all the flights from IAH to Central or South American cities in the top twenty follow a single path that already exits at the most direct point available on the Mexican border (fix MARTE).

DFW-MMUN: These flights are already generally direct. We could calculate a slight savings of 2.6 NM a flight by sending planes going from DFW to MMUN direct from the end of the departure path from DFW (BILEE fix) to the exit point on the Mexican border (KEHLI fix) instead of going first to the entry point on the U.S. side of the current non-radar area (KLAMS fix). The return flights (also on A766) were already optimum. This gives a total savings in April 2003 of 354 NM.

Appendix D Conflict Probe Sensitivity Analysis

The conflict probe benefit area was one of the two benefit areas for which we estimated a range of low and high benefits. There is some amount of uncertainty regarding how frequently air traffic controllers act on URET alerts. As explained above, studies and subject matter expert judgment indicate that air traffic controllers may not use conflict probe as frequently as originally assumed. In the regulatory evaluation we estimated results assuming controllers act on 10% of the URET conflict probe alerts for the low benefit estimate and 63% for the high benefit estimate.

In this section we estimate net benefits for 4 different controller act on rates: 63%, 30%, 10% and 2% holding all other variables constant. The highlighted lines show results from the regulatory evaluation. The conclusion that we draw is that the act-on rate does not have much of an impact on the final conclusions. Regardless of the rate that controllers act on conflict alerts, given our assumptions, if all other benefits are high and costs are low, the rule will be cost beneficial. If all other benefits are low and costs are high the rule will not be beneficial at any of the act-on rates considered when the results are discounted.

	Low Benefits/High Costs		
	Net Benefits		
Conflict Probe Act On Rate	Not discounted	3% discount rate	7% Discount Rate
63%	$1.21	($0.66)	($1.59)
30%	$0.32	($1.18)	($1.86)
10%	($0.21)	($1.49)	($2.02)
2%	($0.42)	($1.62)	($2.09)
	High Benefits/Low Costs		
	Net Benefits		
Conflict Probe Act On Rate	Not discounted	3% discount rate	7% Discount Rate
63%	$5.20	$2.29	$0.59
30%	$4.31	$1.77	$0.32
10%	$3.78	$1.45	$0.15
2%	$3.56	$1.33	$0.09
Yellow highlighted rows were the results presented in the regeval.			

Appendix E A Timeline of ADS-B Out Costs and Benefits

Timeline of ADS-B Out Costs (millions of undiscounted 2009 $)

Year	Total ADS-B out Ground Costs and Legacy Surveillance	GA Avionics Low	GA Avionics High	Turbojet Avionics low	Turbojet Avionics High	Turboprops Avionics Low	Turboprops Avionics High	ADS-B Avionics Costs Low	ADS-B Avionics Costs High	Total ADS-B Costs Low	Total ADS-B Costs High
2009	$110							$0	$0	$110	$110
2010	$264							$0	$0	$264	$264
2011	$192							$0	$0	$192	$192
2012	$274	$9.5	$24.7	$31.4	$46.9	$0.0	$0.0	$41	$72	$315	$345
2013	$242	$166.6	$435.8	$113.7	$266.5	$0.7	$2.6	$281	$705	$523	$947
2014	$244	$166.5	$435.4	$111.0	$261.5	$0.7	$2.7	$278	$700	$522	$944
2015	$168	$166.3	$434.8	$102.6	$251.5	$0.7	$2.8	$270	$689	$438	$857
2016	$167	$166.3	$434.9	$100.7	$246.7	$0.7	$2.7	$268	$684	$435	$852
2017	$148	$166.6	$436.1	$98.2	$251.3	$0.7	$2.6	$265	$690	$414	$839
2018	$137	$167.0	$438.3	$97.1	$241.9	$0.7	$2.7	$265	$683	$402	$820
2019	$129	$167.5	$440.0	$102.1	$246.8	$0.8	$3.0	$270	$690	$399	$818
2020	$121	$10.9	$30.8	$19.9	$25.6	$0.3	$1.2	$31	$58	$152	$179
2021	$142	$11.6	$33.0	$20.4	$25.8	$0.3	$1.3	$32	$60	$174	$202
2022	$111	$12.1	$35.1	$23.9	$30.6	$0.4	$1.4	$36	$67	$148	$178
2023	$84	$12.5	$36.6	$22.8	$28.0	$0.3	$1.2	$36	$66	$119	$150
2024	$103	$12.9	$38.3	$26.2	$55.2	$0.3	$1.0	$39	$95	$143	$198
2025	$98	$13.2	$40.0	$32.1	$61.1	$0.3	$1.3	$46	$102	$143	$200
2026	$98	$13.5	$34.6	$16.2	$34.7	$0.5	$1.9	$30	$71	$128	$169
2027	$98	$13.5	$34.6	$18.5	$44.2	$0.5	$1.9	$33	$81	$130	$178
2028	$98	$13.5	$34.6	$18.4	$37.7	$0.5	$1.9	$32	$74	$130	$172
2029	$98	$13.5	$34.6	$16.1	$37.8	$0.5	$1.9	$30	$74	$128	$172
2030	$98	$13.5	$34.6	$17.8	$51.5	$0.5	$1.9	$32	$88	$130	$186
2031	$98	$13.5	$34.6	$17.1	$51.3	$0.5	$1.9	$31	$88	$129	$186
2032	$98	$13.5	$34.6	$14.9	$42.2	$0.5	$1.9	$29	$79	$127	$177
2033	$98	$13.5	$34.6	$16.3	$50.3	$0.5	$1.9	$30	$87	$128	$185
2034	$98	$13.5	$34.6	$15.7	$49.8	$0.5	$1.9	$30	$86	$128	$184
2035	$82	$13.5	$34.6	$16.4	$52.2	$0.5	$1.9	$30	$89	$112	$171
Total	$3,696	$1,385	$3,640	$1,069	$2,491	$12.2	$46.2	$2,466	$6,177	$6,163	$9,873

Notes: Avionics costs include equipment acquisition, installation costs, fuel burn, mean time between failure and mean time to repair.

Timeline of ADS-B Out Benefits (millions of undiscounted 2009 $)

Year	GoMex Delay Savings	GoMex Additional Flights Accommodated	Gomex Optimal and More Direct Routing	Improved EnRoute Conflict Probe High	Improved EnRoute Conflict Probe Low	More Efficient Metering due to Improved TMA Accuracy	Optimal Profile Descents	Value of CO2 Emissions High	Value of CO2 Emissions Low	Low Benefits	High Benefits
2009	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
2010	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
2011	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
2012	$1	$0	$3	$0	$0	$0	$0	$0	$0	$4	$4
2013	$1	$0	$5	$0	$0	$0	$0	$0	$0	$6	$7
2014	$2	$0	$7	$0	$0	$0	$31	$6	$1	$41	$47
2015	$4	$0	$9	$0	$0	$0	$47	$10	$1	$62	$70
2016	$7	$0	$11	$0	$0	$0	$65	$13	$2	$85	$96
2017	$12	$0	$13	$45	$7	$0	$81	$20	$3	$116	$171
2018	$17	$0	$16	$52	$8	$0	$99	$24	$3	$143	$208
2019	$25	$0	$18	$63	$10	$0	$113	$28	$4	$170	$247
2020	$35	$0	$20	$66	$10	$73	$126	$36	$5	$270	$356
2021	$42	$1	$20	$69	$11	$74	$126	$36	$5	$280	$369
2022	$48	$1	$21	$72	$11	$76	$125	$35	$5	$288	$379
2023	$56	$2	$21	$76	$12	$77	$129	$35	$5	$303	$396
2024	$65	$3	$21	$79	$13	$79	$127	$33	$5	$312	$408
2025	$76	$5	$21	$83	$13	$81	$126	$31	$5	$326	$422
2026	$87	$7	$21	$87	$14	$82	$127	$29	$4	$342	$440
2027	$98	$11	$21	$91	$14	$84	$123	$25	$3	$355	$453
2028	$109	$17	$20	$96	$15	$86	$128	$21	$3	$378	$477
2029	$123	$24	$20	$100	$16	$88	$129	$16	$2	$400	$499
2030	$133	$33	$18	$105	$17	$89	$130	$10	$1	$421	$519
2031	$143	$48	$17	$110	$17	$91	$131	$1	-$1	$446	$542
2032	$148	$65	$16	$115	$18	$93	$127	-$9	-$3	$464	$555
2033	$156	$88	$15	$121	$19	$95	$129	-$20	-$6	$496	$583
2034	$152	$117	$14	$127	$20	$97	$131	-$33	-$9	$523	$605
2035	$146	$151	$13	$133	$21	$99	$132	-$48	-$12	$550	$625
Total	$1,685	$572	$384	$1,691	$267	$1,366	$2,480	$300	$27	$6,781	$8,478