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A Predictive Model of User Equipage Costs for Future Air Traffic Services and Capabilities: An ADS-B Example

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Abstract

Many new technological solutions are considered in efforts to improve the efficiency and capacity of the National Airspace System (NAS). Most of these technologies require the addition or modification of equipment not only on the ground, but also in the aircraft that operate in the NAS. Because it is increasingly difficult for the Federal Aviation Administration (FAA) to justify mandates for forced aircraft equipage, it is often necessary to depend upon the aircraft owner/operators to voluntarily equip their aircraft with the needed technology. If these aircraft equipage costs are too high, the owner/operators may not equip their aircraft and the overall program might not proceed as desired.

Presented is a methodology that can be used to estimate the user equipage costs for future air traffic services and capabilities. Included is a forecast of future United States (U.S.) aircraft, broken down by model for Air Transport (AT) aircraft and by type for General Aviation (GA) aircraft. This forecast, when combined with model or type specific aircraft knowledge, provides an estimate of the future mix of aircraft capabilities, and can be utilized for any technology under study. The model considers aircraft classification and architecture to determine equipage states and identifies transition costs between each state. Also, methods for estimating owner/operator reactions and responses to the availability of the new technology, as well as the impact and cost of a possible equipage mandate, are presented.

An example of usage of the model is presented that analyzes Automatic Dependent Surveillance – Broadcast (ADS-B) equipage costs for the applications of broadcast surveillance and cockpit display of traffic information (CDTI) operational procedures. The presented methodology may also be used for other technological solutions, including navigation and communications.

Preface

The majority of this work was performed during the summer and fall of 2004. The fleet forecast shown in Appendix A was updated in 2005. The various analyses that have become superseded, such as Implementation Plan #1, were not updated with the newer forecast numbers, but remain informative and are thus included in this report.

The authors are using the updated forecast in their current analysis of different implementation plans in support of national ADS-B deployment decisions. The results of future analysis may be appropriate to publish as revisions to this report.

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1 Introduction

1.1 Purpose

As part of efforts to improve the efficiency and capacity of the NAS, many new technological solutions are considered. Most of these technologies require the addition or modification of equipment not only on the ground, but also in the aircraft that operate in the NAS. Since it is increasingly difficult to justify a mandate for forced aircraft equipage, the success of these technological solutions often depends upon the aircraft owner/operators to voluntarily equip their aircraft.

Before implementing a technological solution, it is prudent to analyze the solution's costs and probabilities for success. In the past, much attention has been paid to the ground infrastructure costs of new programs, but the cost to the aircraft owner/operators has not always been completely understood. If these aircraft costs are too high, the owner/operators may not equip their aircraft and the program might not succeed.

This paper presents a methodology that can be used to estimate the future user equipage costs for future air traffic services and capabilities. Two examples are presented that analyze Automatic Dependent Surveillance – Broadcast (ADS-B) equipage costs for the applications of broadcast surveillance and full cockpit display of traffic information (CDTI) operational procedures. However, a similar methodology may be used for numerous other technological solutions, including navigation and communications.

1.2 Background

MITRE's Center For Advanced Aviation System Development (CAASD) is often requested to provide estimates of the cost to implement varying technologies at differing points in the future. Since many of these technologies require equipment to be installed in aircraft as well as on the ground, it became necessary to develop a forecast of aircraft quantities that would allow for further classification of aircraft capability since the equipage costs for all aircraft would not be the same. For Air Transport and Regional aircraft, a bottom-up forecast was developed for each airline that was then summed to arrive at an aggregate. For GA, the forecast was based upon type of aircraft.

The FAA Safe Flight 21 Program Office asked CAASD for an analysis of potential future ADS-B equipage and the costs associated with modifying non-capable aircraft. The analysis was performed using the aircraft quantities from the previously developed forecast. The methodology followed is presented here as an example that can be used for other airborne equipment.

1.3 Scope and Audience

This paper describes the formulation of a future fleet-wide aircraft equipage cost estimation model. First presented is a forecast of future U.S. aircraft, broken down by model for Air Transport aircraft and by type for GA aircraft. When combined with model or type specific aircraft knowledge, this forecast is useful for understanding the future mix of aircraft capabilities and can be used regardless of the technology under study.

This paper describes how to: classify aircraft based upon current aircraft architecture; define avionics equipage states; and determine transition costs for moving between states based upon the technology under consideration. Also presented are methods for estimating owner/operator reactions and responses to the availability of a new technology. Finally, a process to analyze the impact and cost of a possible equipage mandate is explained.

Figure 1-1 illustrates the overall process and major elements used to develop the equipage model identified in this paper. This started with the development of an accurate forecast of aircraft operating in the United States of America (USA).

The left most block identifies the **fleets** and the taxonomy of the aircraft that were considered in the forecast. **Equipage** represents the parsing of the fleet forecast into aircraft classifications that can be used to describe the likely aircraft equipment and technology used for ADS-B. **Transitions** identifies both the quantities of aircraft by transition as well as the cost of the transitions.

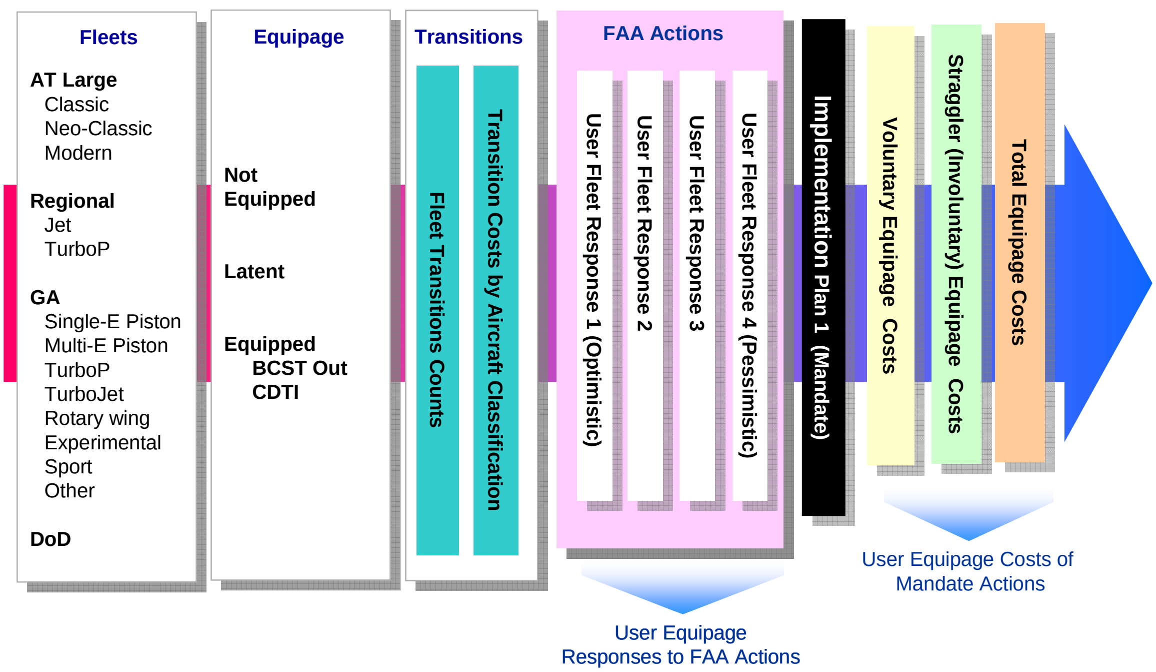

Figure 1-1. Model Process Diagram

The **FAA Actions** block identifies a set of four responses the industry could make based on the actions of the FAA. This ranges from an optimistic response of users to a pessimistic response of users. Finally, **Implementation Plans** are defined and costs are further allocated as either **voluntary** or **straggler** depending on the effective date for a mandate.

Anyone who is contemplating introducing a new technology into the NAS that involves aircraft equipage will benefit from considering the process described within.

1.4 Document Organization

Chapter 2 presents the forecast that was developed for use in multiple programs. Chapters 3–6 describe the different states of ADS-B equipage and the costs for transitioning between each state. Chapters 7–8 discuss the possible range of FAA actions in supplying the ABS-B ground infrastructure and the predicted owner/operator modifications and costs in reaction to the introduction of the capability. Chapters 9–10 investigate the effect of a possible mandate to avoid a mixed equipage scenario by forcing non-equipped aircraft to become ADS-B capable in a specified timeframe.

2 Fleet Forecast

2.1 Air Transport

2.1.1 Aircraft Model and Operator Categorization

Avionics modification costs are typically more dependent upon aircraft model type than the mode of aircraft operation. In other words, the cost to upgrade a B727 will be the same whether it is used as a Part 121 or Part 91 aircraft. It is recognized that certification costs are higher for Part 121 equipment, but it was assumed that the Part 91 market would be too small for specialized avionics, and that those aircraft would install the same avionics certified for the Part 121 operators. Also, it was assumed that all operators of B727s desire to use the same airspace. Therefore, it was decided that the Air Transport forecast would include all aircraft of a chosen type, regardless of the mode in which they were operated.

Similarly, Part 121 operators sometimes make use of smaller aircraft such as Falcons and Learjets. However, the quantity of these aircraft is quite small compared to their overall populations, so it was decided to include all quantities of these in the GA forecast.

Regional aircraft models were selected using similar logic and include regional jets and turboprop aircraft.

Thus, the aircraft models chosen for the Air Transport forecast include:

- A300, A310, A320 family, A330, A340 and A380
- B707, B717, B727, B737, B747, B757, B767, B777 and B787
- DC-8, DC-9 and DC-10
- L-1011
- MD-10, MD-11 and MD-80
- ATR42 and ATR72
- BAE 146, RJ70 and RJ85
- Beech 99 and Beech 1900
- CRJ100, CRJ200, CRJ440, CRJ700 and CRJ900
- DHC-8
- Do328 and Do328JET
- EMB-120, ERJ-135, ERJ-140/145, ERJ-170/175 and ERJ-190/195
- F28, F50, F70 and F100

- J31 and J41
- L188
- Metro
- Saab 340
- Shorts 360

2.1.2 Actual Fleet Counts

The AirCraft Analytical System (ACAS) database, produced by AvSoft[1] Limited of Rugby, England was utilized to determine the actual fleet counts of the models listed above as of December 31, 2004. These quantities were also supplied on an airline by airline basis.

A verification of these quantities was performed by reviewing the U.S. Securities and Exchange Commission (SEC) Form 10-K filings for all of the publicly traded carriers listed. Since these filings contain the latest factual information about an airline's fleet, slight adjustments were made to the ACAS data due to aircraft which had become parked or inactive and were soon to be decommissioned.

2.1.3 Firm Commitments

Since options can often expire, especially in the current airline business climate, it was decided to include only firm commitments in the airline specific forecasts. The firm commitments of each publicly traded airline were obtained from their SEC Form 10-K filings. For private carriers, press releases were used where available. Also, the Airbus and Boeing websites provided information.

2.1.4 Retirements

Information on aircraft retirements is not as readily obtainable as information on fleets and orders. For this model, it was assumed that an aircraft would retire from commercial passenger service in the year that it reached 25 years of age. Because of the low number of annual cycles seen by freighter aircraft, they can—and have—continued in service long past their economic life as a passenger aircraft. Therefore, it was decided that freighters would not retire in the forecast. This assumption is validated by the large amount of modification and re-engining performed by many cargo carriers during the conversion process.

A retirement age of 35 years was used for Northwest Airlines due to their history of re-investing in their aircraft and flying them for a longer period than other U.S. carriers. It was still necessary to assume a retirement progression for the Northwest DC-9 fleet since the majority are already greater than 35 years of age and would otherwise retire immediately in the model.

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[1] Avsoft in the USA, Contact Steve Longson, 1129 Royal Palm Beach Blvd., # 019, Royal Palm Beach, Florida 33411, phone 1-800-363-2568.

2.1.5 Cargo Conversions

History has shown that when an aircraft is retired from commercial passenger service that it does not necessarily leave the NAS. Many aircraft are converted to freighters and continue to provide a long service life because of the lower daily cyclic demand. Thus, it was assumed that half of B737, B757, B767 and B777 retirements would stay in the NAS as cargo conversion or charter aircraft.

A "dummy airline" named Cargo Conversions was created to accumulate the passenger to freighter conversions since it was unknown which current, or future, freight operator would purchase them. This dummy airline is then added with all of the other specific airline forecasts to determine fleet totals.

2.1.6 OEM Plug

A Preliminary Total Fleet Forecast was obtained by compiling all of the airline actual fleet counts, adding the firm commitments, subtracting the retirements and adding back in the cargo conversions. This yielded a forecast that declined over time since there are currently very few firm orders after 2011, but the retirements continue. It is realistic to assume that additional aircraft will be produced and operated in the future, but it is currently uncertain which airlines will do so. The Original Equipment Manufacturer (OEM) Plug was created as a collector for future aircraft production that was not yet allocated to a specific airline. It was then necessary to determine the size of this plug.

FAA forecasts were utilized to predict future total fleet sizes. The *FAA Aerospace Forecasts Fiscal Years 2005–2016* provided forecasts of quantities of 2 engine, 3 engine, and 4 engine large narrow body and wide body aircraft, regional jets, and turboprops. The *FAA Long-Range Aerospace Forecasts Fiscal Years 2015, 2020, 2025 and 2030* provided predictions of total large jets, regional jets, and turboprops. Quantities for the years not provided by the long range forecast were determined by straight line interpolation.

The Preliminary Total Fleet Forecast was compared to the FAA forecasts to determine the shortfall each year, which became the annual OEM Plug quantity. The OEM Plug for each category of aircraft was divided into a 50/50 split for Airbus and Boeing and a 50/50 split for Bombardier and Embraer. Within each manufacturer's allocation of future aircraft, model assignments were made based upon the mix in the current fleet. For example, no A340s or B737-600s were predicted since none are currently flown by U.S. operators. However, A380s and B787s were forecasted since there are currently quantities on firm orders. Once the OEM Plug was added to the Preliminary Total Fleet Forecast, the final forecast was created.

2.1.7 Total Forecast

The full model specific forecast was obtained by starting with the Actual Fleet Counts, adding the Firm Commitments, subtracting the Retirements, adding the cargo Conversions, and adding the OEM Plug. The full forecast is contained in Appendix A.

2.2 General Aviation

The GA model is based on a three step process:

- Forecast the GA fleet's composition through the time period of the study.
- Determine current avionics equipage of the fleet.
- Project fleet avionics equipage for each year of the study based on re-equipage of existing fleet aircraft, retirement of older aircraft, and addition of new aircraft.

Forecasting GA fleet equipage is a complex, multi-step process. While the FAA has made efforts to predict raw GA aircraft counts through a portion of the study period, no such projection is available for avionics configuration, or for the flow of new aircraft into the fleet and retired aircraft out.

To allow these estimates to be made, the team used the following methodology:

- Identify current GA fleet count and composition.
- Estimate existing ADS-B avionics base, to include ADS-B data link, displays with the capability to display ADS-B applications, and Global Positioning System (GPS) navigation systems.
- Project fleet count and composition using FAA GA forecasts (2003–2014) and FAA long range forecasts (2015–2020).
- Determine new aircraft deliveries in each category for the 2003–2020 period using General Aviation Manufacturers Association (GAMA) and FAA projections, as well as historical trends based on GAMA new aircraft delivery statistics.
- Determine new aircraft ADS-B avionics configuration based on manufacturer-announced equipage and observed trends.
- Determine retirements in each category.
- Categorize each aircraft in the model by ADS-B equipage status.
- Estimate number of aircraft transitioning between ADS-B equipage states by year.
- Use fleet composition, estimated equipage, and yearly transition rates to determine total number of aircraft in each ADS-B equipage category by year.

The General Aviation forecast is contained in Appendix B.

2.2.1 Aircraft Model Categorization

The GA fleet is composed of well over 200,000 aircraft, and may be categorized in a number of ways, ranging from usage (e.g., charter, instruction, Emergency Medical Service, etc.) to purely physical characteristics, such as maximum take-off weight. The method chosen by the team reflects the FAA's GA Forecast and Fleet Count Categorization scheme, which is based on aircraft characteristics such as engine type, engine number, and airworthiness basis of issue. While not strictly in line with CFR 14 Part 1 definitions for category, these grouping, as shown in Table 2-1, provide a methodology to identify groups of similar aircraft that were judged by the team to share broad avionics equipage characteristics.

Table 2-1. GA Fleet Categorization

Category/Subcategory		Description
Piston	Single Engine	Primarily light airplanes (under 12,500 lb takeoff weight), single engine aircraft with gasoline or diesel piston engines (e.g., Cessna 172).
	Multi-Engine	Piston-powered airplanes with more than one engine (e.g., Beechcraft Baron).
Turbine	Turboprop	Single and multi-engine turboprop airplanes (e.g., Piper Meridian).
	Turbojet	Single and multi-engine jet airplanes (e.g., Gulfstream G400).
Rotorcraft	Piston	Single-engine piston helicopters (e.g., Robinson R-22).
	Turbine	Single and multi-engine turbine-powered helicopters (e.g., Boeing 234).
Experimental		Airplanes and helicopters registered as Experimental Category aircraft (e.g., Lancair Legacy).
Sport		Aircraft registered under the Sport Aircraft Category.
Other		Gliders, hot air balloons, other aircraft not falling under any category above (e.g., Scaled Composites SpaceShipOne).

2.2.2 Fleet Composition

The 2002 fleet composition is shown below in Table 2-2. As may be noted, the Sport aircraft reflects the pending nature of this rule-making in 2003. Also of note is the single engine piston fleet count – nearly two and a half times larger than all other categories combined.

Table 2-2. GA Fleet (2002)

Category/Subcategory		2002
Piston	Single Engine	144,550
	Multi-Engine	18,240
Turbine	Turboprop	6,600
	Turbojet	8,000
Rotorcraft	Piston	2,450
	Turbine	4,350
Experimental		20,400
Sport		0
Other		6,500
Total		

2.2.3 New Production Forecasts

One of the most difficult tasks facing the team was estimating the yearly delivery of new aircraft. Historically, new GA aircraft deliveries have been tied as much to the product liability environment as to economic factors. While new GA aircraft production has varied between almost 1,800 and under 1,000 aircraft per year, the reforms made to product liability laws during the late 1980's and early 1990's has resulted in a steady rate of growth in new aircraft deliveries since 1992. The team elected to use a linear projection of new aircraft deliveries for the 2003–2020 timeframe based on the observed trend between 1992 and 2002 as recorded by GAMA.

In the case of Sport aircraft, where no historical record exists to indicate likely future demand, the team used the FAA's forecast and industry expectations as a basis for estimating the impact of this type of aircraft on the total GA fleet count and ADS-B equipage profile.

2.2.4 Retirements

Given the fact that until the last few years, most small GA aircraft sold in the U.S. were based on 30 to 40 year old designs and 1940's vintage engine technology, there has been little interest in retiring aircraft due to a desire for greater efficiency or reduced cost of ownership. This situation is changing, due primarily to the development of new aircraft design and production technologies first used in the experimental aircraft fleet, but now adopted by companies such as Cirrus and Lancair to increase payload, cruise speeds, and safety. While not yet evident, it was judged likely that further improvements in new aircraft efficiency and safety, as well as the wide-spread availability of lower-cost Sport category aircraft will result in a growing number of retirements in the single and multi-engine piston category. These retirements were calculated based on total FAA fleet counts adjusted for new aircraft additions and the implied retirement of aircraft from the appropriate category. An example of this implied retirement rate is shown in Table 2-3, where a new aircraft forecasted delivery of 2045 aircraft would result in a 1,571 aircraft over-count if not for retirements.

Table 2-3. Single Engine Piston Fleet Count (2010–2011) Retirement Calculation

Fleet Count (2010)	New Aircraft Added to Fleet (2010)	Fleet Count (Without Retirements) (2011)	Fleet Count (2011)	Required Retirements (2010)
148,177	2045	150,222 (1,571 aircraft over FAA forecast)	148,651	1571

Retirement rates were applied to each category where a clear-cut new aircraft delivery model could be applied.

3 Aircraft Classification

3.1 Large Air Transport

Large Air Transport aircraft are considered to be aircraft traditionally in use by U. S. scheduled airlines. This would include aircraft with capacities of 70 or more passengers.

Three classifications were identified to characterize the equipage necessary to identify unique upgrade requirements for these aircraft to ADS-B capabilities.

Note that both Airbus and Boeing are, as of the beginning of 2004, delivering aircraft with the equipment capable of broadcast only (BCST) ADS-B in the form a compatible Mode-S transponder, and an installed GPS receiver with the capability of providing 1090 Extended Squitter.

3.1.1 Classic

The architecture of the Classic aircraft consists of mainly analog technology. These aircraft are referred to as “round dial” or “steam gauge” aircraft. The systems on this classification of aircraft are basically dedicated to single functions. This produces what is commonly referred to as federated systems that are not easily modified to accept new requirements. Examples of large air transport aircraft that fit into this classification are the B707, B727, B737-100/200, B747-100/200/300, A300/310, DC-8, DC-9, DC-10, MD-81/82/83, and L1011.

For an ADS-B system focus, Classic aircraft are considered to have older generation Mode-S transponders without extended squitter capability, no GPS navigation system or a multifunction display (MFD) capable of CDTI. To upgrade the Classic aircraft with a broadcast only ADS-B capability will require installing a new transponder and control and a GPS receiver. For a CDTI capability the Classic aircraft would require the installation of a GPS receiver with a capable MFD capable of displaying ownship position and uplinked traffic.

3.1.2 Neo-Classic

These aircraft are characterized by the introduction of ARINC 429 data buss architecture for avionics systems interconnection. This is a somewhat difficult class of aircraft as it includes aircraft designs starting with the Boeing 757 and 767 introduced in 1984 and continuing through this year with the A320 Airbus aircraft. Specific aircraft included in the neo-classic category include the B757-200/300, B767-200/300, B737-300/400/500/600, B747-400, MD-11, MD-87/88/90 and A319/320/321/340.

Many of these aircraft have a Flight Management System (FMS) but not all the FMSs have the same functionality or capability to support ADS-B applications and functions. These differences ion how to transition to ADS-B capability will be identified later.

Because this neo-classic aircraft spans such a wide time frame, most of the focus on identifying an ADS-B capability is limited to the last 8 years of production. The earlier production is more closely considered like the classic, especially as it relates to the capability of the installed Mode-S transponder to support 1090 Extended Squitter and GPS receiver installation.

3.1.3 Modern

These aircraft are defined by the introduction of an integrated avionics architecture which is significantly different from the traditional federated avionics architecture seen in the Classic and Neo-classic aircraft. These aircraft all have modern FMSs with heavily integrated functions that interface to one or more electronic cockpit displays, other systems and databases.

These aircraft, due to their newer age, are likely to have a newer Mode-S transponder that may be capable of upgrade to provide an extended squitter capability. These aircraft are most likely equipped with a GPS receiver or multimode receiver (MMR) that includes GPS. Therefore, these aircraft will be more easily modified to provide a broadcast only ADS-B capability as they already have most of the required equipage.

Aircraft types included in the modern classification include the B777, B737-700/800/900, B717, B767-400, and A318/330/380.

3.2 Regional

Regional aircraft are considered to be generally 70 seats or less. For this analysis regional aircraft have been classified into two categories, Jet and Turboprop. Most of the jet aircraft are of modern designs, but none of the current manufacturers of regional jets or turboprops provide, at this time, a production version of the aircraft with an ADS-B capability from the factory as a standard capability. Some assumptions on the availability of that capability are identified and included in the analysis described later.

3.2.1 Jet

Aircraft in this regional classification are generally of a modern architecture with respect to cockpit displays, FMS, autopilot, and flight controls functions. The other Communications, Navigation, and Surveillance (CNS) systems tend to remain a federated architecture, so the transponder and GPS are individual boxes. Aircraft types considered as jets are: BAE-146, RJ70 and RJ85 CRJ100, CRJ200, CRJ440, CRJ700, CRJ900, Do328JET, ERJ-135, ERJ-140/145, ERJ-170/175, ERJ-190/195, F28, F50, F70 and F100.

3.2.2 Turboprop

Aircraft types considered as turboprop in this analysis are: ATR42/72, Beech 99 and Beech 1900, DHC-8, Do328, EMB-120, Jetstream J31 and J41, L188, Metro, Saab 340, Shorts 360. These aircraft are considered architecturally similar to the jets for this analysis.

3.3 General Aviation

By strict definition "GA consists of all facets of aviation except air carriers holding a certificate of public convenience and necessity from the Civil Aeronautics Board and large commercial operators." (FAA Pilot/Controller Glossary, 8/4/05) In 1999 this air carrier exception constituted

19,145 aircraft comprised of scheduled domestic, flag, supplemental, cargo air carriers, commercial operators, commuters, and air taxis. The remaining aircraft registered in the U.S. are considered to belong to GA and in 1999 numbered 206,530, or over 90% of the U.S. aircraft. These GA aircraft cover the full gamut of aircraft types, sizes, and uses. The uses include but are not limited to personal and business travel, sightseeing tours, flight training, banner towing, pipeline and power line patrol, utility work, experimental aviation, and recreational and sport flying. Of these aircraft over 90% have a gross weight less than, usually much less than, 12,500 pounds and around 80% are powered by piston engines. The Aircraft Owners and Pilots Association (AOPA) states approximately 65% of GA operations are related to corporate and other business activities.

Given the large number and vast configuration differences of these aircraft, it is impossible to get an airframe by airframe accounting since the aircraft lack the homogeneity of the air carrier fleet. However, certain generalities can be applied to groupings of aircraft relative to the types of avionics they carry. We determined that the following classifications of Turbine Fixed Wing Turboprop, Turbine Fixed Wing Jet, and All Other would adequately address the avionics equipage issues. This was determined to be the right way to classify GA aircraft so that the assumptions on avionics needed becomes easier to estimate.

3.3.1 Turbine Fixed Wing Turboprop

This classification includes all GA aircraft equipped with turbine engines and driven by a propeller. Representative examples of these aircraft include the Raytheon Beech King Air, Cessna Conquest, Piper Cheyenne, Pilatus PC-12, and Socata TBM-700.

3.3.2 Turbine Fixed Wing Jet

These aircraft are all GA aircraft that are equipped with a turbojet engine and not driven by a propeller. Representative examples of these aircraft include the Lear 55, Global Express, Gulfstream 500, and the emerging new jets from manufacturers like Eclipse, Adam Aircraft and Swearingen.

3.3.3 All Other

This class of aircraft include all the other GA aircraft including piston aircraft, helicopters (piston or turbine), experimental aircraft, sport aircraft and any other GA class of aircraft. This list includes the vast majority of GA aircraft. It includes the ubiquitous Cessna 172 and Piper Cherokee along with numerous models from many other manufacturers, e.g., Bell, Mooney, Bellanca, Commander, Rockwell, Raytheon (Beech), Aerospatiale, Socata, Pilatus, Luscombe, Stinson, Cirrus, Lancair, Robinson, Waco, Swift, Navion, Grumman American, Aviat, Maule, American Champion, etc. The new breed of Sport aircraft adds many more to the list.

4 Equipage States

4.1 Not Equipped

An aircraft is considered not equipped if it requires major component additions or equipment replacement to make it capable of ADS-B functionality. For example, the aircraft is lacking at least two of the following: an upgradeable link, MFD capable of ADS-B, or acceptable GPS.

4.2 Latent

Latent is defined as an aircraft that can be made capable of ADS-B operation by adding link capabilities or interfacing to existing GPS equipment. Latent may also be defined as an aircraft with the necessary GPS interface and a display but needing a service bulletin to provide ADS-B link capabilities.

4.3 Latent for Broadcast Out

Latent for Broadcast out refers to an aircraft that is equipped with a Mode-S transponder that can be upgraded to extended squitter capability and can be interfaced to an existing GPS receiver providing the ADS-B broadcast out capability.

For Large Air Transport aircraft, this category includes aircraft retrofitted for European Elementary and Enhanced Surveillance since all these equipped aircraft have transponders capable of 1090 ES. Latent for BCST also includes aircraft with GPS and/or MMR.

For Regional aircraft, this category includes aircraft with transponders that can be upgraded to 1090 ES and are also equipped with GPS.

4.4 Latent for CDTI

These aircraft may be equipped with an upgradeable transponder for ADS-B reception, and already have an MFD display and an interface to the GPS.

The equipage for GA aircraft causes them to be latent for both BCST out and CDTI simultaneously, causing only one latent state for GA aircraft. The components of equipage are:

– Equipped with MFD/PFD & GPS or with FMS/EFIS & GPS

– Addition of ADS-B (UAT) transceiver required for CDTI capability

– Addition of ADS-B (Mode-S) transmitter required for Broadcast-Only capability.

5 Current Aircraft Equipage States

5.1 User Surveys

As part of the work on ADS-B equipage we conducted surveys of the top airlines to determine specifically how their fleets were equipped. This information along with data in the commercial ACAS database was used to identify capable and latent aircraft within each airline's fleets.

Surveys were provided to both the large air transport and regional carriers to determine the current configuration of the aircraft with respect to Mode-S transponders, GPS capability and installation capabilities to support ADS-B applications. Appendix C contains both the large air transport and regional carrier surveys that were sent out. Each of these surveys are different since the part numbers for transponders and GPS are different for the different types of aircraft.

MITRE CAASD developed the surveys and completed the identification of the equipment part numbers. Johns Hopkins University Applied Physics Laboratory actually sent out the surveys and followed up with each airline to get the responses. For the large air transport, of the 23 airlines sent surveys we received replies from all except one airline. For the regional carriers 20 surveys were sent out and responses were received from 13 airlines.

5.2 Commercial Databases

Until lately, commercial databases of aircraft equipage did not contain the details on avionics equipage by model or part number. The available databases focused on other aircraft components like engines, Auxiliary Power Units (APUs), seats, and other replaceable mechanical or electrical equipment. Avionics configurations were not generally included with any level of detail. However, one commercial database provider did begin to collect and report data on avionics configurations by specific aircraft tail numbers. AvSoft has begun to provide avionics equipage details on a tail by tail basis for airlines around the world.

The AvSoft database called ACAS was used in the MITRE analysis to determine the state of equipage for GPS or MMR capability. The ACAS provided the necessary equipage details for those aircraft identified in the airline surveys that are equipped with Mode-S transponders. This allowed us to estimate and group the number of aircraft with the necessary elements to achieve ADS-B either as latent, equipped or not equipped.

5.3 OEM Discussions

Several discussions were held with avionics OEMs to determine the specific details of their products as they apply to ADS-B. These conversations provided very useful information on the specific type and part numbers that are capable of or upgradeable to ADS-B functionality. This information was used in developing informational materials for the airline surveys so that adequate details about the equipment and capabilities were properly reported.

These discussions also provided information on upgrades to transponders and the current pricing for such upgrades. These discussions are valuable as they allow us to connect with actual equipment capabilities and to understand the upgrade capability and the likely costs.

6 Equipage State Transition Costs

6.1 Large Air Transport

As defined earlier in section 3.1 there are three classifications of large air transport aircraft. This section will identify how the transition costs were defined for each of these classifications of aircraft. The transition costs in this analysis were based on the FAA's ADS-B link decision cost benefit analysis (CBA) completed in October 2001. That CBA identified the same three classes of aircraft used in this study: classic, neo-classic and modern. This fact provided a consistent way to apply costs. ADS-B transition cost allocations were defined by examining each of the total costs in the October CBA by aircraft classification and proportioning the costs for each of the three key elements needed for ADS-B.

1. GPS and display costs
2. Link costs
3. Installation costs

Six transitions were considered for the analysis:

1. Not equipped to Latent (NE > L) (GA only transition)
2. Not equipped to cockpit display of traffic information (NE > CDTI)
3. Not equipped to broadcast only (NE > BCST)
4. Latent to CDTI (L > CDTI)
5. Latent to broadcast only (L > BCST)
6. Broadcast only to CDTI (BCST > CDTI)

The transition from not equipped to latent was not considered in the large air transport aircraft as it was determined that airlines would not invest in this path. It is, however, possible that GA might make this investment as they may upgrade their aircraft to MFDs which could make some aircraft latent. This upgrade would not be with the intent of using ADS-B directly, but for other reasons like alternative weather and navigation display uses. These costs are not considered in our analysis of ADS-B costs as these decisions are made separate from a decision that ADS-B is desired.

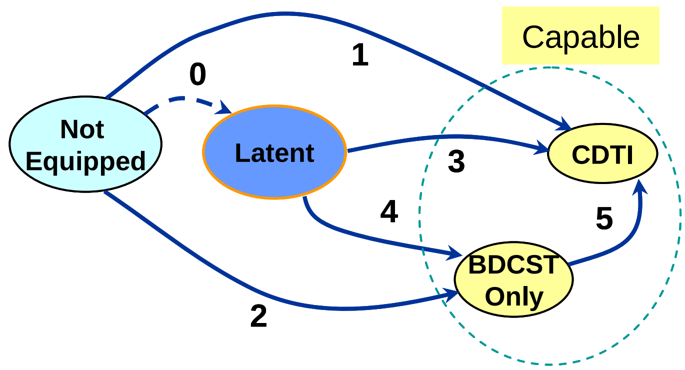


Figure 6-1. Identifies the Transitions Considered in the Analysis

The individual cost details that trace the CBA results to produce individual transition costs can be found in Appendix D. The chart has all five of the defined transitions identified in major sets of columns. The transitions are further divided by timeframes as identified in the Safe Flight 21 "Spirals" defined for the program as timeframes 2004–2006, 2007–2010, and 2011– 2016. Sets of rows in the chart are segregated by aircraft classification (classic, neo-classic and modern). Then, within each aircraft classification are rows that identify the elements required to complete the given transition (GPS & display costs, link costs, and installation costs).

Our assumption on large air transport aircraft is that the transition costs for each timeframe are constant over the time frame of the program Spirals. This can be readily seen in the chart in Appendix E.

6.1.1 Classic

Because classic aircraft have very little digital equipage, the task of integrating with existing avionics is minimal. This makes for possibly a simpler installation, but without many of the advantages of an integrated system. This results in a stand alone system with its own displays and minimal integration with other systems on the aircraft. These aircraft differ from neo-classic and modern in that they have no "glass" displays, so will require add on displays to achieve the needed ADS-B capabilities.

6.1.2 Neo-Classic

The neo-classic aircraft are all considered to be designed with ARINC 429 interfaces, but are not as completely integrated as are those considered modern. Costs for these aircraft may require upgrades to the displays and display processors along with likely replacement of the link if it is not capable of upgrade to ADS-B by the manufacturer. Transitioning these aircraft may involve one or more upgrades to individual LRUs (line replaceable units) to achieve the final functionality.

6.1.3 Modern

These aircraft offer considerable functional integration. The distinction between recent deliveries of neo-classic and modern aircraft begin to fade as the systems on these aircraft are designed to integrate more closely than in earlier neo-classic or classic aircraft avionics systems designs.

Transitioning these aircraft typically involve software upgrades to a central processor and possibly upgrades to an LRU. However the costs can be high for CDTI functionality because the development and recertification of the application software likely requires considerable recertification effort.

6.2 Regional

Regional turbo-jet aircraft are similar to the air transport modern aircraft avionics architecture and may use the same form factor sensors. However, most of the newer designs include sensors like the ATC transponder as part of a suite of LRUs specific for the avionics application in these aircraft. In either case the ATC transponder is still a federated box and not part of an integrated cabinet architecture.

Regional turbo-prop aircraft also fit this same architecture, therefore both the turbo-jet and turbo-prop aircraft types rely on upgrading an ATC transponder to 1090 ES through a service bulletin. In general the costs for the regional avionics are considered at 50% of the cost of the air transport avionics. This is possible as these sensors have fewer requirements than the similar air transport avionics equipment of similar function.

6.3 General Aviation

In order to simplify the analysis of the costs to equip the general aviation fleet, specific classes of GA aircraft were combined that are expected to have similar costs to upgrade. This resulted in the three classes of GA aircraft as fixed wing turboprop, fixed wing turbojet and all other. All other includes all piston aircraft and helicopters of either piston or turbine propulsion. This was determined as the right way to classify GA aircraft so that the assumptions on avionics needed becomes easier to estimate. The summary of transition costs is contained in Appendix F.

6.3.1 Turbine Fixed Wing Turboprop

This classification includes all GA aircraft equipped with turbine engines and driven by a propeller. Upgrading or adding ADS-B capabilities will likely be through individual components that provide the link as a separate component, and a display which may or may not be integrated with a GPS navigator. It is unlikely that a broadcast out only capability is economically viable as most systems have a display capability to provide area navigation capability through GPS.

6.3.2 Turbine Fixed Wing Jet

These aircraft are all GA aircraft that are equipped with a turbojet engine and not driven by a propeller. These aircraft are more likely to have an integrated cockpit display system. This may require some level of software update to make the system fully capable of ADS-B CDTI functionality.

6.3.3 All Other

This class of aircraft includes all the other GA aircraft including piston aircraft, helicopters (piston or turbine), experimental aircraft, sport aircraft and any other GA class of aircraft. With the addition of integrated GPS/VHF NAV and COMM systems in these aircraft for area navigation functionality, upgrading to CDTI capability can be achieved. Costs for upgrading these aircraft normally would include upgrading the GPS/NAV/COM unit and adding an ADS-B transceiver.

7 Possible FAA Actions

The FAA developed a program strategy (Appendix G) for the national deployment of ADS-B ground infrastructure and services that broke the implementation into three four-year Spirals, from 2005 to 2016. A business case was developed that required costs and benefits to the FAA and users to be calculated. The avionics costs described in this paper were a part of that effort.

The need was recognized to present FAA decision makers with a range of implementation options, especially considering the current constraints on the FAA budget. Therefore, four different FAA action plans were analyzed.

7.1 Per Current Plan (FAA_1)

This scenario assumes that FAA decision makers provide a solid commitment and all necessary funding for the implementation of the Spiral plan within the prescribed dates. This would result in full national deployment by 2016, including oceanic and Caribbean services.

7.2 4-Year Delay (FAA_2)

This scenario recognizes that even though the business case may show a positive return, the initial capital investment may not be readily available, resulting in Spiral 1 being completed in 2012 instead of 2008. This could be due to a delay in the start of Spiral 1 from 2005 to 2009, a start in 2005 with only half the rate of implementation each year, or a combination of initial delay and slower implementation. This 4-year delay in the completion of Spiral 1 would cause Spirals 2 and 3 to be completed in 2016 and 2020 respectively.

7.3 6-Year Delay (FAA_3)

This scenario builds in even more delay in the start date or rate of implementation, resulting in a completion of Spiral 1 in 2014, Spiral 2 in 2018, and Spiral 3 in 2022.

7.4 No Commitment (FAA_4)

This scenario allows for analysis of future implementation costs when no current commitment is made to the program. Any program delay of more than six years was felt to be a sign to the user community of a lack of commitment on the part of the FAA, and is included herein.

8 Predicted User Responses and Costs

Because of the wide variety of users in the NAS, it is expected that there would be a wide range of responses to any FAA implementation action. Since it is impossible to accurately predict the future, four responses were developed that describe possible user responses from the best to worst cases, allowing for a full range of analysis of potential costs and benefits. It was recognized that Air Transport and GA users have different needs and will respond differently, so the range of responses was created for each. This also allows for different combinations of responses to any one FAA action.

8.1 Air Transport

8.1.1 Extreme Joy (AT_1)

This scenario describes a highly optimistic user response to the FAA implementation of ADS-B infrastructure and services. In this case, the benefits of CDTI applications are readily apparent to all users, resulting in retrofits of all aircraft by 2016 (Figure 8-1). Because of the favorable user response, the large airframe manufacturers incorporate CDTI as a standard feature in production aircraft in 2008, with the regional manufacturers following suit in 2010. This response includes a near-term upgrade to broadcast only capability for those modern aircraft without such capability due to cost savings from transponder parts commonality for the users with mixed fleets. These aircraft then are further modified to include a CDTI along with all other aircraft as per the schedule. While this response may be too optimistic, it serves as an upper bound on expected equipage.

Response AT_1 Extreme Joy

- **AT CDTI STD in 2008; RJ CDTI STD in 2010**
- **Retrofit to CDTI**
  - **Classic 2008 – 2012; Neo-classic 2010 – 2016; Modern 2009 – 2013**
  - **RJ; jets 2009-2014; TurboP 2012-2014 (60%)**
- **Retrofit to BCST**
  - **Modern (parts commonality) 2006, 2007, 2008 (33% each)**
  - **RJ; Jets and TurboP none**

[Blue text is Regional (RJ) assumptions]

Figure 8-1. AT Response Equipage Definitions, Extreme Joy

8.1.2 Higher Equipage Realism (AT_2)

This response describes a scenario of high equipage but introduces a degree of realism by recognizing that not all users may anticipate the benefits of CDTI applications for various reasons, and would thus not retrofit their aircraft. For example, an airline may decide that an aircraft that is 5 years from retirement is not economically feasible for modification, yet this aircraft would continue to operate unmodified until its retirement date. Some users may make different assumptions for the costs of retrofits and the associated savings, causing them to decide against modifications. Additionally, some users may fly routes (e.g. short haul, low altitude, good weather, low density airports, etc.) where their benefits would be less, thus making retrofit less attractive for them. Because of the reduced amount of users planning retrofits, it is assumed that the large airframe manufacturers would only offer CDTI as an option in 2008, with the technology becoming standard equipment in 2012 (2014 for regional jets). Additionally, only certain percentages of aircraft are assumed to be modified (Figure 8-2).

Response AT_2 Higher Equipage Realism

CDTI Optional 2008, STD 2012; RJ FF in 2014

Retrofit to CDTI

- **Classic 75% 2012 – 2016; Neo-classic 60% 2014 – 2018; Modern 85% 2012 – 2016**
- **RJ; Jets 85% 2013-2018; TurboP 40% 2016-2018**

Retrofit to BCST

- **Modern 80% 2008 – 2010**
- **RJ; none**

[Blue text is Regional (RJ) assumptions]

Figure 8-2. AT Response Equipage Definitions, Higher Equipage Realism

8.1.3 Lower Equipage Realism (AT_3)

This response recognizes that even less users may anticipate the benefits of CDTI applications for various reasons, thus further reducing aircraft modifications. Because of the further reduced amount of users planning retrofits, it is assumed that the large airframe manufacturers would not offer CDTI as an option until 2012, with the technology becoming standard equipment in 2016 (2018 for regional jets). The A380 is assumed to be delivered with CDTI capability as has been previously stated by Airbus. Additionally, even lower percentages of aircraft are assumed to be modified (Figure 8-3).

Response AT_3 Lower Equipage Realism

- **CDTI A380 only 2012 Option, 2016 STD; RJ FF in 2018**
- **Retrofit to CDTI**
  - **Classic 50% 2014 – 2018; Neo-classic 40% 2016 – 2020; Modern 65% 2014 – 2018**
  - **RJ; jets 65% 2015-2020; TurboP 20% 2018-2020**
- **Retrofit to BCST**
  - **Modern 50% 2008 – 2010**
  - **RJ; none**

[Blue text is Regional (RJ) assumptions]

Figure 8-3. AT Response Equipage Definitions, Lower Equipage Realism

8.1.4 Baseline (AT_4)

This response assumes that today's situation continues into the future. That is, new production large aircraft continue to deliver with broadcast only capability, but there are no CDTI retrofit or forward fit plans. Though they do not have the capability today, it is assumed that regional jets would begin to deliver with broadcast only capability in 2007 due to the avionics manufacturer's desire to standardize their production lines. No CDTI is planned for new regional jet production or retrofit. This is the worst case equipage response and is called the Baseline since it depicts the future that is expected without the influence of any FAA implementations (Figure 8-4).

Response AT_4 Baseline

- **BCST FF for RJ starts 2007**
- **No retrofits for AT or RJ**
- **No CDTI in FF for AT or RJ**

[Blue text is Regional (RJ) assumptions]

Figure 8-4. Response Equipage Definitions, Baseline

8.2 Air Transport Costs of Responses

One of the main reasons for this analysis is to identify the costs for equipping aircraft with ADS-B. The responses as defined in section 8.1 are based on a set of assumptions that define how the users would respond to the specific FAA actions. Each response defines a set of aircraft equipage forecasts which can then be priced by considering the number of aircraft that transition into each equipage configuration.

Cost computations for a selected period are made up of a quantity of aircraft multiplied by the cost to make the expected equipage transition. The result is the total cost to transition these aircraft for the period in question. This technique can be applied for any of the responses defined and for any defined period. The transition costs were discussed in section 6. Specifics for air transport, Regionals and GA will be discussed below.

As identified earlier there are four specific user responses that were defined. These responses result in an ADS-B equipage forecast which can be applied against the transition costs identified in Section 6. There is no forced equipage identified in any of these responses. The users are considered to respond to FAA actions to provide the necessary infrastructure to support the use of ADS-B. These four responses include an assumed baseline response, up to a high expectation of equipage by the users.

The following charts identify the summary of the costs that result from applying the aircraft forecast against the specific aircraft classification transition costs. The chart identifies the costs grouped by BCST and CDTI capabilities.

2004	Large AT			
Response 1	Voluntary			
	2004-2008	2009-2012	2013-2016	2004-2016
	STL Vol	STL Vol	STL Vol	TTL
BCST Only	$ 11.4	$ -	$ -	
	$ 64.9	$ 1,377.4	$ 302.6	**$ 1,744.9**
CDTI	$ 53.5	$ 1,377.4	$ 302.6	

Response 2	Voluntary			
	2004-2008	2009-2012	2013-2016	2004-2016
	STL Vol	STL Vol	STL Vol	TTL
BCST Only	$ 3.1	$ 6.0	$ -	
	$ 3.1	$ 98.4	$ 822.9	**$ 924.4**
CDTI	$ -	$ 92.4	$ 822.9	

Response 3	Voluntary			
	2004-2008	2009-2012	2013-2016	2004-2016
	STL Vol	STL Vol	STL Vol	TTL
BCST Only	$ 1.8	$ 3.9	$ -	
	$ 1.8	$ 3.9	$ 474.4	**$ 480.1**
CDTI	$ -	$ -	$ 474.4	

Response 4	Voluntary			
	2004-2008	2009-2012	2013-2016	2004-2016
	STL Vol	STL Vol	STL Vol	TTL
BCST Only	$ -	$ -	$ -	
	$ -	$ -	$ -	**$ -**
CDTI	$ -	$ -	$ -	

Figure 8-5. Voluntary AT Costs

In a similar manner to the Air transport costs identified above the Regional costs were also derived. Figure 8-6 identifies the Regional costs for BCST and CDTI.

2004	**Regional**			
Response 1	**Voluntary**			
	2004-2008	**2009-2012**	**2013-2016**	**2004-2016**
	STL Vol	**STL Vol**	**STL Vol**	**TTL**
BCST Only	$ -	$ -	$ -	
	$ -	$ 200.0	$ 170.7	**$ 370.7**
CDTI	$ -	$ 200.0	$ 170.7	

Response 2	**Voluntary**			
	2004-2008	**2009-2012**	**2013-2016**	**2004-2016**
	STL Vol	**STL Vol**	**STL Vol**	**TTL**
BCST Only	$ -	$ -	$ -	
	$ -	$ -	$ 213.2	**$ 213.2**
CDTI	$ -	$ -	$ 213.2	

Response 3	**Voluntary**			
	2004-2008	**2009-2012**	**2013-2016**	**2004-2016**
	STL Vol	**STL Vol**	**STL Vol**	**TTL**
BCST Only	$ -	$ -	$ -	
	$ -	$ -	$ 49.5	**$ 49.5**
CDTI	$ -	$ -	$ 49.5	

Response 4	**Voluntary**			
	2004-2008	**2009-2012**	**2013-2016**	**2004-2016**
	STL Vol	**STL Vol**	**STL Vol**	**TTL**
BCST Only	$ -	$ -	$ -	
	$ -	$ -	$ -	**$ -**
CDTI	$ -	$ -	$ -	

Figure 8-6. Voluntary Regional Costs

8.3 General Aviation

8.3.1 Rapid Transition to ADS-B (GA_1)

We expect the number of new GA aircraft with CDTI to be significant as services become available in Spiral 1 and Electronic Flight Information System (EFIS) becomes standard on most new aircraft. For turbine GA aircraft we expect to see the continued impact of the European transponder mandates as related to 1090ES new and retrofit equipage for high end users. For All Other GA aircraft, broadcast only equipage will taper to zero after the FAA begins implementing and supporting Spiral 1 applications and services.

8.3.2 Moderate Spiral 1 Delay (GA_2)

This would result in reduced new aircraft equipage with CDTI as services become available in Spiral 1 and EFIS becomes standard on new aircraft. Turbine GA aircraft would continue to experience the impact of European transponder mandates and related 1090ES for new and retrofit high end users. All of this works to further delay equipage of new and existing aircraft with CDTI. For All Other GA aircraft broadcast only rates would taper more slowly because of the reduced confidence in FAA further delaying new and existing aircraft equipage with CDTI.

8.3.3 Significant Spiral 1 Delay (GA_3)

A significant delay in Spiral 1 deployment and build-out of ground infrastructure would have the effect of further reducing user confidence in the ability of the FAA to provide promised services. The result of this delay in deployment would reduce new aircraft equipage rates with CDTI throughout the Spiral 1 build out period. Turbine GA aircraft would continue to experience the impact of European transponder mandates and related 1090ES for new and retrofit high end users. These factors work to further delay equipage of new and existing aircraft with CDTI in all groups versus GA_2. For the All Other group of GA aircraft, broadcast-only equipage rates would taper more slowly versus GA_1 or GA_2, once again due to reduced confidence in FAA ability to provide the upgraded broadcast services-based traffic information, versus the currently available but much more limited TIS service.

8.3.4 CDTI Only in Pockets (GA_4)

New aircraft equipage continues throughout the model (2004–2020). However, the sale of Traffic Information System (TIS)/1090ES capable transponders for All Other GA will continue, not because of a conscious desire for 1090ES, but because the function is packaged with TIS capability. The retrofit rate tapers to a fixed rate as early adopters complete their installations and the main body of the market responds to service limitations and coverage reductions. The impact of European mandates continues to affect the related 1090ES and retrofit equipage of the high end aircraft.

8.4 General Aviation Costs of Responses

Figure 8-7 is the costs for the four responses for all the GA aircraft. Using the number of aircraft in the forecast and the equipage rates of the model and the cost of the respective avionics, the total costs can be determined.

2004	GA			
Response 1	**Voluntary**			
	2004-2008	**2009-2012**	**2013-2016**	**2004-2016**
	STL Vol	**STL Vol**	**STL Vol**	**TTL**
BCST Only	$ 69.7	$ 1.6	$ 0.9	
	$ 472.1	$ 345.2	$ 240.9	**$ 1,058.2**
CDTI	$ 402.4	$ 343.7	$ 240.0	

Response 2	**Voluntary**			
	2004-2008	**2009-2012**	**2013-2016**	**2004-2016**
	STL Vol	**STL Vol**	**STL Vol**	**TTL**
BCST Only	$ 59.9	$ 2.9	$ 1.4	
	$ 322.6	$ 319.4	$ 256.2	**$ 898.2**
CDTI	$ 262.7	$ 316.4	$ 254.9	

Response 3	**Voluntary**			
	2004-2008	**2009-2012**	**2013-2016**	**2004-2016**
	STL Vol	**STL Vol**	**STL Vol**	**TTL**
BCST Only	$ 53.4	$ 2.9	$ 2.2	
	$ 230.2	$ 220.6	$ 209.5	**$ 660.3**
CDTI	$ 176.8	$ 217.6	$ 207.3	

Response 4	**Voluntary**			
	2004-2008	**2009-2012**	**2013-2016**	**2004-2016**
	STL Vol	**STL Vol**	**STL Vol**	**TTL**
BCST Only	$ 122.4	$ 58.7	$ 50.6	
	$ 122.4	$ 58.7	$ 50.6	**$ 231.7**
CDTI	$ -	$ -	$ -	

Figure 8-7. Voluntary GA Costs

8.5 Relationship between FAA Actions and User Responses

Due to the large variety of users and their operating environments, it is impossible to definitely predict the manner in which the user community will respond to any FAA action. In many cases several of the different responses may be realistically likely for any action. Tables 8-1 through 8-4 show the probable user responses to each of the four FAA actions. Once costs have been assigned to each response, it will be possible to describe a cost range associated with each FAA action.

Table 8-1. FAA_1 Action and Responses

FAA Action	OEM and User Responses	
	Air Transport	General Aviation
FAA_1 Per Plan – FAA fully funds ADS-B as a high priority – FAA demonstrates commitment to ADS-B • ADS-B Implementation and enhancements per Spirals • Capstone Phase 2 and 3 continues on schedule • EC[1] implemented on schedule • GOMEX commitment received • Commitment for National Deployment	**AT_1 Extreme Joy** – Confidence in future of ADS-B infrastructure and services from Spiral 1 results in voluntary retrofits and FF[2] to achieve benefits from Spiral 2 applications – See specific Response equipage definitions for AT_1	**GA1: Rapid Transition to ADS-B** – Significant new GA aircraft equipage with CDTI as services become available in Spiral 1 and EFIS becomes standard on most new aircraft – GA (All Other): BCST Only equipage tapers to zero after FAA begins implementing/supporting Spiral 1 apps and services – GA (Turbine): Continued impact of European transponder mandates and related 1090ES new and retrofit equipage for very high end users
	AT_2 Higher Equipage Realism – Not all airlines see value in retrofitting their entire fleets due to: • Cost of certain retrofits • Aircraft routing • Remaining expected aircraft life – See specific Response equipage definitions for AT_2	
	AT_3 Lower Equipage Realism – Less airlines than in AT_2 see value in retrofitting their entire fleets due to: • Cost of certain retrofits • Aircraft routing • Remaining expected aircraft life – See specific Response equipage definitions for AT_3	

[1]EC = East Cost
[2]FF = Forward Fit

Table 8-2. FAA_2 Action and Responses

FAA Action	OEM and User Responses: Air Transport	OEM and User Responses: General Aviation
FAA_2 4 year Delay Less prioritization for Spiral 1 results in 4 year delay to: – Ground infrastructure due to • Funding • Technical issues – Enhancements and operational approvals	**AT_2 Higher Equipage Realism** – Equipage delayed by 4 years and happens at a reduced level due to lowered confidence in program success – See specific Response equipage definitions for AT_2	**GA2: Moderate Spiral 1 Delay** – Reduced new GA aircraft equipage with CDTI as services become available in Spiral 1 and EFIS becomes standard on most new aircraft – GA (All Other): BCST Only equipage rates taper; reduced confidence in FAA reduces & delays CDTI retrofit rate increases until Spiral 2 – GA (Turbine): Continued impact of European transponder mandates and related 1090ES new and retrofit equipage for very high end users; delayed CDTI new and existing aircraft equipage
	AT_3 Lower Equipage Realism – Equipage delayed by 6 years and less airlines than in AT_2 see value in retrofitting their entire fleets due to: • Cost of certain retrofits • Aircraft routing • Remaining expected aircraft life – See specific Response equipage definitions for AT_3	

Table 8-3. FAA_3 Action and Responses

FAA Action	OEM and User Responses: Air Transport	OEM and User Responses: General Aviation
FAA_3 6 Year Delay Less prioritization for Spiral 1 results in 6 year delay to: – Ground infrastructure due to • Funding • Technical issues – Enhancements and operational approvals	**AT_3 Lower Equipage Realism** – Equipage delayed by 6 years and happens at a reduced level due to lowered confidence in program success – See specific Response equipage definitions for AT_3	**GA_3: Significant Spiral 1 Delay** – Significantly reduced new GA aircraft equipage with CDTI through Spiral 1 build out – GA (All Other): BCST Only equipage rates taper after Spiral 1 executes; reduced user confidence in benefits reduces & delays CDTI retrofit rates through end of scenario – GA (Turbine): Continued impact of European transponder mandates and related 1090ES new and retrofit equipage for very high end users; delayed CDTI new and existing aircraft equipage
	AT_4 Baseline – Delays in program implementation results in airlines waiting before responding with equipage – Due to delays, no voluntary equipage by airlines until sufficient benefits are demonstrated – See specific Response equipage definitions for AT_4	

Table 8-4. FAA_4 Action and Responses

FAA Action	OEM and User Responses	
	Air Transport	General Aviation
FAA_4 No Commitment – No firm commitment for ADS-B deployment • Insufficient ground infrastructure • Insufficient operational application approvals	**AT_4 Baseline** – No voluntary equipage by airlines until sufficient benefits are provided – See specific Response equipage definitions for AT_4	**GA_4: CDTI Only In Pockets** – Continued sale of TIS/1090ES capable transponders for 'GA-All Other'; no conscious desire for 1090ES, but function packaged with TIS capability – New aircraft equipage continues through model (2004–2020) – Retrofit tapers to fixed rate as early adopters completed and main body of market responds to service limitations and coverage reductions – Continued impact of European transponder mandates and related 1090ES new and retrofit equipage

9 Implementation Plans Defined

The user responses and the associated costs described in Chapter 8 assumed voluntary equipage actions on the part of operators and manufacturers. In several of those cases, aircraft will exist that do not have CDTI capability. Since many CDTI operational procedures require 100% equipage to achieve the expected benefits, it may be necessary to mandate compliance within a specific timeframe. An Implementation Plan defines a specific timeframe of implementation that can be applied to all of the user responses to determine the range of non-compliant aircraft and their associated costs of compliance. This provides for two different forms of cost accounting with respect to the costs attributable to the program; voluntary costs and involuntary costs.

Voluntary costs are defined within the implementation plan as the costs a user will assume on a voluntary basis. These are costs that a user would spend without any forcing event to equip with the desired avionics. The voluntary costs are not accounted against the program and are therefore considered borne by the user as the user has determined that these costs are justified for the benefits received by having the capability on the aircraft. These costs occur prior to the issuance of a mandate.

Any costs incurred after the identification of a mandate, or access denial if not equipped with the desired technology, are considered to be involuntary costs. These costs are all considered to be against any benefits defined for the system. The total equipage costs are the sum of the voluntary and involuntary costs accumulated to achieve the equipage.

9.1 Implementation Plan #1 (IP_1)

Spiral 3 of the FAA's plan is scheduled to end in December 2016, resulting in full provision of ADS-B services. Therefore, it was desired to investigate a mandate that would begin in January 2017 in order to achieve 100% equipage of the affected U.S. fleet by December 2020. This would allow for full use of CDTI procedures in 2021 above FL 100, in Class B airspace, and at the top ~70 airports. It was estimated that 10% of the GA aircraft would not need to meet this criteria and would thus not be required to equip.

This timing was applied to each of the possible user responses described in Chapter 8. Any aircraft that was equipped prior to 2017 was considered to be a "voluntary" equipage, as there was no forced equipage requirement at that time. Aircraft that needed to be modified after 2016 were considered to be forced into compliance, whether or not the user would have done so voluntarily anyway, since they are subject to the mandate and should be captured as a cost of the mandate. These aircraft are referred to as "stragglers" since they did not voluntarily equip prior to the mandate.

This Implementation Plan timing was analyzed for two types of rules; required broadcast only capability, and required CDTI capability.

9.2 Implementation Plan #2 (IP_2)

This Implementation Plan was conceived as a potential alternative surveillance program, and as such required broadcast only capability, but not CDTI procedures. The intended goal was to have 100% equipage in the intended airspace by December 2014. The implied requirement was that aircraft would be excluded from certain airspace if not equipped, so there was not a requirement for certain aircraft to comply. In order to allow for enough time to accomplish retrofits across the fleet, it was planned to make the potential rule effective in January 2007, yielding 8 years for compliance. Since large air transport aircraft are typically on a 6-year heavy maintenance cycle, it was assumed that modification would occur over the last six years, and not in 2007 or 2008. Any aircraft that was equipped prior to 2007 was not considered to be a cost for this plan. Additionally, aircraft delivered after 2007 that included broadcast only capability (air transport) were not considered to be a cost. The modification rate was assumed to be constant over the implementation timeline.

10 Implementation Plan Costs

The costs identified in this section are derived from examining the aircraft forecast by classification and the cost to transition those aircraft year by year based on the equipage expected and then totaling those costs over the complete timeframe of the specific Implementation Plan.

10.1 Implementation Plan #1 Costs

This section identifies the costs for each category of user by the capability of equipage (Broadcast Only and CDTI). Figure 10-1 identifies the Large Air Transport costs summary related to Implementation Plan 1.

Voluntary and Straggler Costs

2004	Large AT					
Response 1	Voluntary				Straggler	Total
	2004-2008	2009-2012	2013-2016	2004-2016	2017-2020	V+S
	STL Vol	STL Vol	STL Vol	TTL	TTL	TTL
BCST Only	$ 11.4	$ -	$ -		$ -	$ 1,744.9
	$ 64.9	$ 1,377.4	$ 302.6	$ 1,744.9		
CDTI	$ 53.5	$ 1,377.4	$ 302.6		$ -	$ 1,744.9

Response 2	Voluntary				Straggler	Total
	2004-2008	2009-2012	2013-2016	2004-2016	2017-2020	V+S
	STL Vol	STL Vol	STL Vol	TTL	TTL	TTL
BCST Only	$ 3.1	$ 6.0	$ -		$ 23.6	$ 948.0
	$ 3.1	$ 98.4	$ 822.9	$ 924.4		
CDTI	$ -	$ 92.4	$ 822.9		$ 565.3	$ 1,489.7

Response 3	Voluntary				Straggler	Total
	2004-2008	2009-2012	2013-2016	2004-2016	2017-2020	V+S
	STL Vol	STL Vol	STL Vol	TTL	TTL	TTL
BCST Only	$ 1.8	$ 3.9	$ -		$ 67.0	$ 547.1
	$ 1.8	$ 3.9	$ 474.4	$ 480.1		
CDTI	$ -	$ -	$ 474.4		$ 1,443.7	$ 1,923.8

Response 4	Voluntary				Straggler	Total
	2004-2008	2009-2012	2013-2016	2004-2016	2017-2020	V+S
	STL Vol	STL Vol	STL Vol	TTL	TTL	TTL
BCST Only	$ -	$ -	$ -		$ 141.3	$ 141.3
	$ -	$ -	$ -	$ -		
CDTI	$ -	$ -	$ -		$ 2,567.2	$ 2,567.2

Figure 10-1. Large Air Transport Implementation Costs

Figure 10-2 below identifies the Voluntary and Straggler costs for the Regional airlines from Implementation Plan 1.

Voluntary and Straggler Costs

2004	Regional					
Response 1	**Voluntary**				**Straggler**	**Total**
	2004-2008	2009-2012	2013-2016	2004-2016	2017-2020	V+S
	STL Vol	STL Vol	STL Vol	TTL	TTL	TTL
BCST Only	$ -	$ -	$ -		**$ 0.1**	**$ 370.8**
	$ -	$ 200.0	$ 170.7	**$ 370.7**		
CDTI	$ -	$ 200.0	$ 170.7		**$ 3.1**	**$ 373.8**

Response 2	**Voluntary**				**Straggler**	**Total**
	2004-2008	2009-2012	2013-2016	2004-2016	2017-2020	V+S
	STL Vol	STL Vol	STL Vol	TTL	TTL	TTL
BCST Only	$ -	$ -	$ -		**$ 6.4**	**$ 219.6**
	$ -	$ -	$ 213.2	**$ 213.2**		
CDTI	$ -	$ -	$ 213.2		**$ 189.8**	**$ 403.0**

Response 3	**Voluntary**				**Straggler**	**Total**
	2004-2008	2009-2012	2013-2016	2004-2016	2017-2020	V+S
	STL Vol	STL Vol	STL Vol	TTL	TTL	TTL
BCST Only	$ -	$ -	$ -		**$ 18.0**	**$ 67.5**
	$ -	$ -	$ 49.5	**$ 49.5**		
CDTI	$ -	$ -	$ 49.5		**$ 395.4**	**$ 444.9**

Response 4	**Voluntary**				**Straggler**	**Total**
	2004-2008	2009-2012	2013-2016	2004-2016	2017-2020	V+S
	STL Vol	STL Vol	STL Vol	TTL	TTL	TTL
BCST Only	$ -	$ -	$ -		**$ 32.9**	**$ 32.9**
	$ -	$ -	$ -	**$ -**		
CDTI	$ -	$ -	$ -		**$ 462.6**	**$ 462.6**

Figure 10-2. Regional Carrier Implementation Costs

Shown in Figure 10-3 is the voluntary and straggler costs for the GA fleet based on Implementation Plan 1.

Voluntary and Straggler Costs

2004	GA					
Response 1	Voluntary				Straggler	Total
	2004-2008	2009-2012	2013-2016	2004-2016	2017-2020	V+S
	STL Vol	STL Vol	STL Vol	TTL	TTL	TTL
BCST Only	$ 69.7	$ 1.6	$ 0.9		$ 275.9	$ 1,334.1
	$ 472.1	$ 345.2	$ 240.9	$ 1,058.2		
CDTI	$ 402.4	$ 343.7	$ 240.0		$ 1,466.5	$ 2,524.7

Response 2	Voluntary				Straggler	Total
	2004-2008	2009-2012	2013-2016	2004-2016	2017-2020	V+S
	STL Vol	STL Vol	STL Vol	TTL	TTL	TTL
BCST Only	$ 59.9	$ 2.9	$ 1.4		$ 353.8	$ 1,252.0
	$ 322.6	$ 319.4	$ 256.2	$ 898.2		
CDTI	$ 262.7	$ 316.4	$ 254.9		$ 1,730.2	$ 2,628.4

Response 3	Voluntary				Straggler	Total
	2004-2008	2009-2012	2013-2016	2004-2016	2017-2020	V+S
	STL Vol	STL Vol	STL Vol	TTL	TTL	TTL
BCST Only	$ 53.4	$ 2.9	$ 2.2		$ 548.0	$ 1,208.3
	$ 230.2	$ 220.6	$ 209.5	$ 660.3		
CDTI	$ 176.8	$ 217.6	$ 207.3		$ 2,301.9	$ 2,962.2

Response 4	Voluntary				Straggler	Total
	2004-2008	2009-2012	2013-2016	2004-2016	2017-2020	V+S
	STL Vol	STL Vol	STL Vol	TTL	TTL	TTL
BCST Only	$ 122.4	$ 58.7	$ 50.6		$ 676.0	$ 907.7
	$ 122.4	$ 58.7	$ 50.6	$ 231.7		
CDTI	$ -	$ -	$ -		$ 4,168.7	$ 4,400.4

Figure 10-3. GA Implementation Plan 1 Costs

The summary of the total Straggler and Voluntary costs for Implementation Plan 1 are identified in Figure 10-4.

Voluntary and Straggler Costs

2004	Large AT		Regional		GA		GA + All AT
Response 1	Straggler 2017-2020 TTL	Total V+S TTL	Straggler 2017-2020 TTL	Total V+S TTL	Straggler 2017-2020 TTL	Total V+S TTL	Total
BCST Only	$ -	$ 1,744.9	$ 0.1	$ 370.8	$ 275.9	$ 1,334.1	$ 3,449.8
CDTI	$ -	$ 1,744.9	$ 3.1	$ 373.8	$ 1,466.5	$ 2,524.7	$ 4,643.4
Response 2	Straggler 2017-2020 TTL	Total V+S TTL	Straggler 2017-2020 TTL	Total V+S TTL	Straggler 2017-2020 TTL	Total V+S TTL	Total
BCST Only	$ 23.6	$ 948.0	$ 6.4	$ 219.6	$ 353.8	$ 1,252.0	$ 2,419.6
CDTI	$ 565.3	$ 1,489.7	$ 189.8	$ 403.0	$ 1,730.2	$ 2,628.4	$ 4,521.1
Response 3	Straggler 2017-2020 TTL	Total V+S TTL	Straggler 2017-2020 TTL	Total V+S TTL	Straggler 2017-2020 TTL	Total V+S TTL	Total
BCST Only	$ 67.0	$ 547.1	$ 18.0	$ 67.5	$ 548.0	$ 1,208.3	$ 1,822.9
CDTI	$ 1,443.7	$ 1,923.8	$ 395.4	$ 444.9	$ 2,301.9	$ 2,962.2	$ 5,330.9
Response 4	Straggler 2017-2020 TTL	Total V+S TTL	Straggler 2017-2020 TTL	Total V+S TTL	Straggler 2017-2020 TTL	Total V+S TTL	Total
BCST Only	$ 141.3	$ 141.3	$ 32.9	$ 32.9	$ 676.0	$ 907.7	$ 1,081.9
CDTI	$ 2,567.2	$ 2,567.2	$ 462.6	$ 462.6	$ 4,168.7	$ 4,400.4	$ 7,430.2

Figure 10-4. Implementation Plan 1 Total Costs

10.2 Implementation Plan #2 Costs

This plan also relied on the user responses and the criteria identified in Chapter 8 for Implementation Plan 2 to determine the equipage costs. However due to the announcement of the equipage requirement and the timing for equipage all of these costs are considered straggler or involuntary.

The summary of the total costs for Implementation Plan 2 is identified in Figure 10-5.

FAA Investment for Equipage Constant Year 2004, $M	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*Total 2007-2014*
Air Transport + GA Total	**$163.8**	**$163.8**	**$206.2**	**$206.2**	**$206.2**	**$206.2**	**$206.2**	**$206.2**	**$1,565.0**
Air Transport Total	**$0.0**	**$0.0**	**$42.4**	**$42.4**	**$42.4**	**$42.4**	**$42.4**	**$42.4**	**$254.4**
_Classic	$0.0	$0.0	$18.0	$18.0	$18.0	$18.0	$18.0	$18.0	$107.8
Path 2 (NE -> Bcst)	$0.0	$0.0	$17.2	$17.2	$17.2	$17.2	$17.2	$17.2	$103.4
Path 4 (L -> Bcst)	$0.0	$0.0	$0.7	$0.7	$0.7	$0.7	$0.7	$0.7	$4.3
_Neo Classic	$0.0	$0.0	$13.2	$13.2	$13.2	$13.2	$13.2	$13.2	$79.3
Path 2 (NE -> Bcst)	$0.0	$0.0	$11.2	$11.2	$11.2	$11.2	$11.2	$11.2	$67.3
Path 4 (L -> Bcst)	$0.0	$0.0	$2.0	$2.0	$2.0	$2.0	$2.0	$2.0	$12.0
_Modern	$0.0	$0.0	$1.9	$1.9	$1.9	$1.9	$1.9	$1.9	$11.3
Path 2 (NE -> Bcst)	$0.0	$0.0	$1.5	$1.5	$1.5	$1.5	$1.5	$1.5	$9.0
Path 4 (L -> Bcst)	$0.0	$0.0	$0.4	$0.4	$0.4	$0.4	$0.4	$0.4	$2.4
_Regional - Turboprop	$0.0	$0.0	$6.0	$6.0	$6.0	$6.0	$6.0	$6.0	$36.0
Path 2 (NE -> Bcst)	$0.0	$0.0	$5.9	$5.9	$5.9	$5.9	$5.9	$5.9	$35.4
Path 4 (L -> Bcst)	$0.0	$0.0	$0.1	$0.1	$0.1	$0.1	$0.1	$0.1	$0.6
_Regional - Jet	$0.0	$0.0	$3.3	$3.3	$3.3	$3.3	$3.3	$3.3	$20.0
Path 2 (NE -> Bcst)	$0.0	$0.0	$2.0	$2.0	$2.0	$2.0	$2.0	$2.0	$11.9
Path 4 (L -> Bcst)	$0.0	$0.0	$1.4	$1.4	$1.4	$1.4	$1.4	$1.4	$8.1
	2007	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*Total 2007-2014*
General Aviation Total	**$163.8**	**$163.8**	**$163.8**	**$163.8**	**$163.8**	**$163.8**	**$163.8**	**$163.8**	**$1,310.6**
_Turbine Fixed Wing (Turboprop)	$7.7	$7.7	$7.7	$7.7	$7.7	$7.7	$7.7	$7.7	$61.2
Path 2 (NE -> Bcst)	$5.2	$5.2	$5.2	$5.2	$5.2	$5.2	$5.2	$5.2	$41.7
Path 4 (L -> Bcst)	$2.4	$2.4	$2.4	$2.4	$2.4	$2.4	$2.4	$2.4	$19.5
_Turbine Fixed Wing (Jet)	$10.6	$10.6	$10.6	$10.6	$10.6	$10.6	$10.6	$10.6	$84.5
Path 2 (NE -> Bcst)	$7.8	$7.8	$7.8	$7.8	$7.8	$7.8	$7.8	$7.8	$62.8
Path 4 (L -> Bcst)	$2.7	$2.7	$2.7	$2.7	$2.7	$2.7	$2.7	$2.7	$21.7
_All Other	$145.6	$145.6	$145.6	$145.6	$145.6	$145.6	$145.6	$145.6	$1,164.9
Path 2 (NE -> Bcst)	$120.4	$120.4	$120.4	$120.4	$120.4	$120.4	$120.4	$120.4	$963.6
Path 4 (L -> Bcst)	$25.2	$25.2	$25.2	$25.2	$25.2	$25.2	$25.2	$25.2	$201.3

Figure 10-5. Implementation Plan 2 Total Costs

11 Summary

The methodology described in this paper offers a realistic means of predicting a set of complex future cost ranges for user avionics equipage of various capabilities. Two examples were provided that described the range of costs for CDTI and BCST capabilities for ADS-B. A similar approach may be used for numerous other technological applications, including navigation and communications.

Appendix A US Fleet Forecast 2005 – 2030

A.1 US Fleet Forecast 2005 – 2009

AIRCRAFT MODEL	Act 2002	Act 2003	Act 2004	FC2005	FC2006	FC2007	FC2008	FC2009
360	16	16	0	0	0	0	0	0
A300	102	116	140	147	154	155	156	156
A310	51	51	51	53	53	53	53	53
A318	0	4	5	14	26	29	37	49
A319	221	243	259	290	317	341	363	386
A320	281	319	334	333	387	411	453	501
A321	31	31	35	36	40	43	52	64
A330	9	14	24	30	39	54	73	92
A380	0	0	0	0	0	0	0	7
ATR 42	58	49	29	36	36	36	36	36
ATR 72	64	64	61	61	61	61	61	61
B707	1	1	0	0	0	0	0	0
B717	85	95	107	121	123	123	123	123
B727	265	272	307	307	305	305	305	296
B737-200	143	144	98	99	97	101	90	69
B737-300	489	490	478	474	472	472	472	468
B737-400	88	90	88	88	88	88	88	88
B737-500	145	145	126	126	126	126	126	126
B737-700	198	222	272	320	368	412	441	467
B737-800	253	273	277	288	314	363	388	415
B737-900	18	23	24	25	33	39	59	82
B737BBJ	0	0	3	3	3	3	3	3
B747-100	30	28	19	20	20	20	20	20
B747-200	81	82	63	64	68	69	69	69
B747-300	8	8	1	1	1	1	3	3
B747-400	75	69	65	65	66	69	73	77
B757-200	588	607	608	608	608	607	603	597
B757-300	21	32	37	43	45	45	45	45
B767-200	108	85	81	84	80	81	83	81
B767-300	220	232	232	232	232	232	232	232
B767-400	37	37	37	37	37	37	37	37
B777-200	129	126	123	123	127	135	146	161
B787	0	0	0	0	0	0	0	1
BAE-146	52	52	52	52	52	52	52	52
BAE-J31	18	18	24	24	24	24	24	24
BAE-J41	54	49	25	25	25	25	25	25
BEECH 1900	186	185	179	179	179	179	179	179
BEECH-99	36	35	17	17	17	17	17	17
CRJ100	121	121	100	100	100	100	100	100
CRJ200	343	478	507	575	585	595	604	609

A.1 US Fleet Forecast 2005 – 2009 (continued)

AIRCRAFT MODEL	Act 2002	Act 2003	Act 2004	FC2005	FC2006	FC2007	FC2008	FC2009
CRJ440	20	43	43	73	93	113	123	130
CRJ700	45	87	128	179	211	243	265	285
CRJ900	1	6	24	68	105	135	155	173
DC-10	108	111	98	97	93	87	81	81
DC-8	105	113	97	97	97	97	97	97
DC-9	267	262	246	226	217	207	195	181
DHC8	197	154	125	125	125	125	125	125
Do328Jet	63	63	10	10	10	10	10	10
EMB-120	131	123	79	79	79	79	79	79
ERJ-135	75	89	86	90	90	90	90	90
ERJ-140	58	74	74	108	128	148	162	172
ERJ-145	316	366	448	503	531	551	566	577
ERJ-170	0	0	33	73	113	138	153	166
ERJ-175	0	0	0	26	51	76	91	104
ERJ-190	0	0	0	7	25	47	77	111
ERJ-195	0	0	0	0	0	4	16	28
F100	57	47	0	0	0	0	0	0
F27	12	12	0	0	0	0	0	0
F28	1	1	0	0	0	0	0	0
L1011	18	11	5	5	3	0	0	0
L188	13	13	13	13	13	13	13	13
MD-10	32	32	39	39	39	39	39	39
MD-11	82	86	73	79	79	79	79	79
MD-81	21	21	14	12	2	2	2	2
MD-82	328	321	275	275	268	263	228	209
MD-83	139	140	137	137	137	137	137	137
MD-87	2	2	2	2	2	2	2	2
MD-88	124	124	124	124	124	124	124	124
MD-90	16	16	16	16	16	16	16	16
METRO	69	69	14	14	14	14	14	14
SAAB 340	225	174	164	164	164	164	164	161
Forecast NB Total	3886	4037	3969	4071	4240	4407	4542	4686
Forecast WB Total	1090	1088	1051	1076	1091	1111	1144	1188
Forecast Large Total	4976	5125	5020	5147	5331	5518	5686	5874
Forecast RJ Total	1094	1379	1505	1857	2069	2251	2371	2468
Forecast TP Total	1067	949	730	737	737	737	737	734
Forecast All Total	7137	7453	7255	7741	8137	8506	8794	9076

A.2 US Fleet Forecast 2010 – 2017

AIRCRAFT MODEL	FC2010	FC2011	FC2012	FC2013	FC2014	FC2015	FC2016	FC2017
360	0	0	0	0	0	0	0	0
A300	157	157	157	151	145	145	142	140
A310	53	53	53	53	53	53	53	53
A318	64	81	99	117	135	154	172	189
A319	415	450	485	522	559	596	632	667
A320	554	601	639	675	694	723	749	762
A321	80	98	116	134	152	171	188	206
A330	106	118	129	145	158	171	186	199
A380	18	36	51	67	80	94	109	122
ATR 42	36	36	36	36	36	36	54	61
ATR 72	61	61	61	61	61	61	79	87
B707	0	0	0	0	0	0	0	0
B717	123	123	123	123	123	123	123	123
B727	287	283	283	283	283	283	283	283
B737-200	56	56	61	61	61	61	61	61
B737-300	437	398	358	319	302	288	287	285
B737-400	88	88	88	87	80	69	65	60
B737-500	126	126	126	126	126	119	106	101
B737-700	499	536	574	610	647	684	720	755
B737-800	448	486	521	570	619	668	715	750
B737-900	113	148	185	222	259	296	332	367
B737BBJ	3	3	3	3	3	3	3	3
B747-100	20	20	20	20	20	20	20	20
B747-200	64	59	57	56	56	56	56	56
B747-300	3	3	3	3	3	3	3	3
B747-400	81	83	83	83	79	75	73	71
B757-200	586	575	564	558	548	526	499	467
B757-300	45	45	45	45	45	45	45	45
B767-200	79	75	74	74	74	72	72	72
B767-300	232	230	228	217	216	212	201	189
B767-400	37	37	37	37	37	37	37	37
B777-200	173	185	197	215	230	245	261	274
B787	8	20	34	50	63	76	91	104
BAE-146	48	46	41	39	36	35	35	35
BAE-J31	24	24	24	24	24	24	24	24
BAE-J41	25	25	25	25	25	25	25	25
BEECH 1900	179	179	179	176	176	175	174	171
BEECH-99	17	17	17	17	17	17	17	17
CRJ100	100	100	100	100	100	100	100	100
CRJ200	609	609	609	609	609	609	609	609
CRJ440	135	135	135	135	135	135	135	135
CRJ700	302	324	345	364	380	396	410	431

A.2 US Fleet Forecast 2010 – 2017 (continued)

AIRCRAFT MODEL	FC2010	FC2011	FC2012	FC2013	FC2014	FC2015	FC2016	FC2017
CRJ900	190	211	232	252	268	283	297	319
DC-10	81	81	79	77	77	77	77	77
DC-8	97	97	97	97	97	97	97	97
DC-9	165	147	131	116	98	98	98	98
DHC8	122	119	119	118	106	93	89	85
Do328Jet	10	10	10	10	10	10	10	10
EMB-120	79	78	74	71	67	62	62	58
ERJ-135	90	90	90	90	90	90	90	90
ERJ-140	178	178	178	178	178	178	178	178
ERJ-145	583	583	583	583	583	583	583	583
ERJ-170	180	202	223	242	258	274	288	309
ERJ-175	118	139	160	180	196	211	225	246
ERJ-190	150	178	204	231	258	285	312	338
ERJ-195	49	74	100	127	154	181	208	234
F100	0	0	0	0	0	0	0	0
F27	0	0	0	0	0	0	0	0
F28	0	0	0	0	0	0	0	0
L1011	0	0	0	0	0	0	0	0
L188	13	13	13	13	13	13	13	13
MD-10	39	39	39	39	39	39	39	39
MD-11	79	79	79	79	79	79	79	79
MD-81	2	2	2	2	2	2	2	2
MD-82	178	141	125	86	58	23	6	6
MD-83	133	129	103	94	84	73	63	47
MD-87	2	2	2	2	0	0	0	0
MD-88	124	124	112	93	74	55	30	12
MD-90	16	16	16	16	16	16	16	16
METRO	14	14	14	10	10	10	10	10
SAAB 340	157	153	146	138	129	114	74	68
Forecast NB Total	4840	5007	5162	5319	5477	5639	5812	5974
Forecast WB Total	1230	1275	1320	1366	1409	1454	1499	1535
Forecast Large Total	6070	6282	6482	6685	6886	7093	7311	7509
Forecast RJ Total	2543	2627	2706	2782	2843	2904	2960	3045
Forecast TP Total	727	719	708	689	664	630	621	619
Forecast All Total	9340	9628	9896	10156	10393	10627	10892	11173

A.3 US Fleet Forecast 2018 – 2025

AIRCRAFT MODEL	FC2018	FC2019	FC2020	FC2021	FC2022	FC2023	FC2024	FC2025
360	0	0	0	0	0	0	0	0
A300	140	140	140	140	140	140	140	140
A310	53	53	53	53	53	53	53	53
A318	205	219	233	248	263	283	308	334
A319	698	727	755	785	812	826	828	818
A320	778	789	806	827	850	868	888	905
A321	221	236	250	265	280	300	325	350
A330	212	222	234	250	268	287	308	326
A380	134	144	155	171	189	208	229	253
ATR 42	72	84	101	124	139	152	153	161
ATR 72	89	97	109	133	148	160	161	169
B707	0	0	0	0	0	0	0	0
B717	123	123	123	123	123	123	114	92
B727	283	283	283	283	283	283	283	283
B737-200	61	61	61	61	61	61	61	61
B737-300	278	269	257	246	239	240	240	240
B737-400	57	54	54	54	52	47	46	46
B737-500	88	77	71	71	64	56	56	56
B737-700	786	815	843	873	903	922	940	970
B737-800	781	810	838	868	899	926	947	969
B737-900	398	427	456	485	516	556	605	656
B737BBJ	3	3	3	3	3	3	3	3
B747-100	20	20	20	20	20	20	20	20
B747-200	56	56	56	56	56	56	56	56
B747-300	3	3	3	3	3	3	3	3
B747-400	70	69	69	68	66	65	65	65
B757-200	450	439	428	415	400	388	360	339
B757-300	45	45	45	45	45	45	45	45
B767-200	71	71	71	71	71	71	71	70
B767-300	179	178	174	173	168	159	151	146
B767-400	37	37	37	37	37	37	37	29
B777-200	286	296	304	316	327	341	347	357
B787	116	126	138	154	173	191	212	236
BAE-146	35	35	35	35	27	17	7	0
BAE-J31	24	24	24	24	24	24	24	24
BAE-J41	25	25	25	25	25	25	25	25
BEECH 1900	165	151	115	72	66	66	66	39
BEECH-99	17	17	17	17	17	17	17	17
CRJ100	91	80	77	60	50	35	23	4
CRJ200	609	609	609	608	584	550	505	453
CRJ440	135	135	135	135	135	135	135	135
CRJ700	455	479	501	531	570	621	680	750

A.3 US Fleet Forecast 2018 – 2025 (continued)

AIRCRAFT MODEL	FC2018	FC2019	FC2020	FC2021	FC2022	FC2023	FC2024	FC2025
CRJ900	342	366	388	419	459	509	569	638
DC-10	77	77	77	77	77	77	77	77
DC-8	97	97	97	97	97	97	97	97
DC-9	98	98	98	98	98	98	98	98
DHC8	96	109	126	139	137	138	136	145
Do328Jet	10	10	10	10	10	10	10	10
EMB-120	50	43	31	18	15	2	0	0
ERJ-135	90	90	90	90	90	90	75	40
ERJ-140	178	178	178	178	178	178	178	178
ERJ-145	583	583	583	579	562	520	464	399
ERJ-170	333	357	379	409	449	499	558	628
ERJ-175	269	293	315	346	386	436	496	565
ERJ-190	361	382	403	425	449	476	512	546
ERJ-195	257	278	299	321	344	372	408	442
F100	0	0	0	0	0	0	0	0
F27	0	0	0	0	0	0	0	0
F28	0	0	0	0	0	0	0	0
L1011	0	0	0	0	0	0	0	0
L188	13	13	13	13	13	13	13	13
MD-10	39	39	39	39	39	39	39	39
MD-11	79	79	79	79	79	79	79	79
MD-81	2	2	2	2	2	2	2	2
MD-82	5	5	5	5	5	5	5	5
MD-83	41	37	32	30	21	15	0	0
MD-87	0	0	0	0	0	0	0	0
MD-88	2	2	2	2	2	2	2	2
MD-90	15	14	5	0	0	0	0	0
METRO	10	10	10	10	10	10	10	10
SAAB 340	56	42	42	36	15	0	0	0
Forecast NB Total	6133	6292	6449	6632	6811	6994	7173	7359
Forecast WB Total	1572	1610	1649	1707	1766	1826	1887	1949
Forecast Large Total	7705	7902	8098	8339	8577	8820	9060	9308
Forecast RJ Total	3130	3215	3300	3400	3500	3600	3700	3800
Forecast TP Total	617	615	613	611	609	607	605	603
Forecast All Total	11452	11732	12011	12350	12686	13027	13365	13711

A.4 US Fleet Forecast 2026 – 2030

AIRCRAFT MODEL	FC2026	FC2027	FC2028	FC2029	FC2030
360	0	0	0	0	0
A300	140	140	140	140	140
A310	53	53	53	53	53
A318	360	382	399	418	432
A319	828	832	853	883	911
A320	927	938	947	957	985
A321	352	369	390	409	424
A330	345	362	377	386	402
A380	274	293	312	331	348
ATR 42	163	163	163	163	163
ATR 72	170	170	170	170	170
B707	0	0	0	0	0
B717	64	44	38	31	31
B727	283	283	283	283	283
B737-200	61	61	61	61	61
B737-300	240	240	240	240	240
B737-400	46	46	46	46	46
B737-500	56	56	56	56	56
B737-700	1010	1051	1082	1093	1123
B737-800	984	1019	1045	1080	1108
B737-900	702	748	788	827	855
B737BBJ	3	3	3	3	3
B747-100	20	20	20	20	20
B747-200	56	56	56	56	56
B747-300	3	3	3	3	3
B747-400	65	64	64	64	64
B757-200	331	330	330	330	330
B757-300	41	34	29	27	27
B767-200	66	66	66	66	66
B767-300	143	141	134	134	134
B767-400	25	19	19	19	19
B777-200	370	388	407	426	443
B787	257	276	295	314	331
BAE-146	0	0	0	0	0
BAE-J31	24	24	24	24	24
BAE-J41	25	25	25	25	25
BEECH 1900	36	36	36	36	36
BEECH-99	17	17	17	17	17
CRJ100	0	0	0	0	0
CRJ200	361	269	149	130	109
CRJ440	135	115	92	92	92
CRJ700	820	872	925	965	995

A.4 US Fleet Forecast 2026 – 2030 (continued)

AIRCRAFT MODEL	FC2026	FC2027	FC2028	FC2029	FC2030
CRJ900	718	806	892	942	973
DC-10	77	77	77	77	77
DC-8	97	97	97	97	97
DC-9	98	98	98	98	98
DHC8	135	135	135	135	135
Do328Jet	10	10	10	10	10
EMB-120	0	0	0	0	0
ERJ-135	21	18	4	4	4
ERJ-140	156	120	104	104	104
ERJ-145	325	261	207	137	135
ERJ-170	708	795	889	923	954
ERJ-175	646	734	828	893	924
ERJ-190	590	624	654	684	705
ERJ-195	486	520	551	581	602
F100	0	0	0	0	0
F27	0	0	0	0	0
F28	0	0	0	0	0
L1011	0	0	0	0	0
L188	13	13	13	13	13
MD-10	39	39	39	39	39
MD-11	79	79	79	79	79
MD-81	2	2	2	2	2
MD-82	5	5	5	5	5
MD-83	0	0	0	0	0
MD-87	0	0	0	0	0
MD-88	2	2	2	2	2
MD-90	0	0	0	0	0
METRO	10	10	10	10	10
SAAB 340	0	0	0	0	0
Forecast NB Total	7568	7784	7999	8213	8426
Forecast WB Total	2012	2076	2141	2207	2274
Forecast Large Total	9580	9860	10140	10420	10700
Forecast RJ Total	3900	4000	4100	4200	4300
Forecast TP Total	593	593	593	593	593
Forecast All Total	14073	14453	14833	15213	15593

Appendix B GA Forecast 2003 – 2020

			2003	2004	2005	2006	2007	2008	2009	2010	2011
Piston											
	Single Engine		144,550	144,900	145,363	145,829	146,295	146,763	147,233	147,704	148,177
	Multi-Engine		18,204	18,167	18,131	18,095	18,058	18,022	17,986	17,950	17,914
Turbine											
	Turboprop		6,692	6,813	6,925	7,039	7,155	7,272	7,392	7,514	7,637
	Turbojet		8,200	8,397	8,723	9,063	9,415	9,782	10,162	10,557	10,968
Rotorcraft											
	Piston		2,470	2,500	2,529	2,558	2,587	2,616	2,646	2,676	2,707
	Turbine		4,352	4,374	4,395	4,417	4,439	4,460	4,482	4,504	4,526
Experimental			20,400	20,451	20,549	20,648	20,747	20,846	20,947	21,047	21,148
Sport (Sport Acft Cat)			0	1,000	2,300	2,600	3,100	3,600	4,100	4,600	5,000
Other			6,500	6,520	6,539	6,559	6,578	6,598	6,618	6,638	6,658
		Total	**218,189**	**219,996**	**222,379**	**223,781**	**225,400**	**227,037**	**228,694**	**230,371**	**231,968**

			2012	2013	2014	2015	2016	2017	2018	2019	2020
Piston											
	Single Engine		148,651	149,127	149,604	150,008	150,413	150,819	151,226	151,635	152,044
	Multi-Engine		17,878	17,843	17,807	17,771	17,736	17,700	17,665	17,630	17,594
Turbine											
	Turboprop		7,763	7,890	8,020	8,133	8,246	8,362	8,479	8,598	8,718
	Turbojet		11,395	11,838	12,298	12,667	13,047	13,439	13,842	14,257	14,685
Rotorcraft											
	Piston		2,738	2,769	2,800	2,820	2,840	2,860	2,880	2,900	2,920
	Turbine		4,548	4,571	4,593	4,616	4,639	4,662	4,686	4,709	4,733
Experimental			21,250	21,352	21,454	21,497	21,540	21,583	21,626	21,670	21,713
Sport (Sport Acft Cat)			5,400	5,800	6,200	6,550	6,900	7,250	7,600	7,950	8,300
Other			6,678	6,698	6,718	6,731	6,745	6,758	6,772	6,785	6,799
		Total	**233,586**	**235,226**	**236,888**	**238,229**	**239,585**	**240,955**	**242,340**	**243,741**	**245,158**

Appendix C Surveys

C.1 Large Air Transport Airline Survey

Airline Name	Total Aircraft
Large AT Airline	A/C #

Current transponder/GPS aircraft capability

Aircraft Type	Quanity	Transponder Manufacturer	Transponder Model Number	Transponder Part Number	MMR Manufacturer	MMR Model Number	MMR Part Number
A/C Type	A/C #						
A/C Type	A/C #						
A/C Type	A/C #						
A/C Type	A/C #						
A/C Type	A/C #						
A/C Type	A/C #						
A/C Type	A/C #						
A/C Type	A/C #						

Retrofit Plans for European Transponder Mandate (March 2005) or other retrofit plans

Aircraft Type	Quanity	Transponder Manufacturer	Transponder Model Number	Transponder Part Number	MMR Manufacturer	MMR Model Number	MMR Part Number	Upgrade Year
A/C type 1								
A/C type 2								
A/C type n								

Future Purchase Plans

Aircraft Type	Quantity
A/C type 1	
A/C type 2	
A/C type n	

General Survey

In the future, if the ground infrastructure/operational procedures supporting ADS-B is available, would you equip?

Will not equip	Likey to equip	Undecided

Tell us about your future plans.

Notes:

Known Equipment capable of ADS-B Capability (Air Transport)

Transponder (Mode-S)

Equipment/Mfgr.	Model Number	Part Numbers			
Rockwell-Collins	TPR-901	822-1388-003	822-1388-xxx		
Honeywell	TRA-67A *(any PN is upgradeable)*	066-01127-1402	066-01127-1602	***<-- both these PN are ES capable***	
ACSS	XS-950	7517800-10005	7517800-10004	7517800-10003	7517800-10002

MMR (Multi-mode receiver)

Rockwell Collins	GLU-9xx	822-1158-xxx	822-1152-xxx	822-1153-xxx	822-1154-xxx
Rockwell Collins	GNLU-9xx	822-1235-xxx	822-1236-xxx	822-1237-xxx	822-1238-xxx
Honeywell	RMA-55B	066-50029-1101	066-50029-1161		

C.2 Regional Carrier Survey

Operator Name	**Total Aircraft**
Regional Airline	# A/C

Current transponder/GPS aircraft capability

Aircraft Type	Quanity	Transponder Manufacturer	Transponder Model Number	Transponder Part Number	MMR Manufacturer	MMR Model Number	MMR Part Number
A/C type 1	# A/C						
A/C type 2	# A/C						
A/C type n	# A/C						

Retrofit Plans for European Transponder Mandate (March 2005) or other retrofit plans

Aircraft Type	Quanity	Transponder Manufacturer	Transponder Model Number	Transponder Part Number	MMR Manufacturer	MMR Model Number	MMR Part Number	Upgrade Year
A/C type 1	# A/C							
A/C type 2	# A/C							
A/C type n	# A/C							

Future Purchase Plans

Aircraft Type	Quantity	Year
A/C type 1		
A/C type 2		
A/C type n		

General Survey

In the future, if the ground infrastructure/operational procedures supporting ADS-B is available, would you equip?

Will not equip	Likey to equip	Undecided

Tell us about your future plans.

Notes:

Known Equipment capable of ADS-B Capability (Business/Regional)

Transponder (Mode-S)

Equipment/Mfgr.	**Model Number**	**Part Numbers**			
Rockwell-Collins	TDR-94/94D	622-9210-006			
Honeywell	TRA-67A (any PN is upgradeable)	066-01127-1402	066-01127-1602	***<-- both these PN are ES capable***	
	XS-852				
ACSS	XS-950	7517800-10005	7517800-10004	7517800-10003	7517800-10002
	RCZ-852	7510700-850			

MMR (Multi-mode receiver)

Rockwell Collins	GLU-9xx	822-1158-xxx	822-1152-xxx	822-1153-xxx	822-1154-xxx
Rockwell Collins	GNLU-9xx	822-1235-xxx	822-1236-xxx	822-1237-xxx	822-1238-xxx
Rockwell Collins	GPS-4000A	822-1377-xxx			
Honeywell	RMA-55B	066-50029-1101	066-50029-1161		

Known Equipment capable of ADS-B Capability (Air Transport)

Transponder (Mode-S)

Equipment/Mfgr.	**Model Number**	**Part Numbers**			
Rockwell-Collins	TPR-901	822-1388-003	822-1388-xxx		
Honeywell	TRA-67A *(any PN is upgradeable)*	066-01127-1402	066-01127-1602	***<-- both these PN are ES capable***	
ACSS	XS-950	7517800-10005	7517800-10004	7517800-10003	7517800-10002

MMR (Multi-mode receiver)

Rockwell Collins	GLU-9xx	822-1158-xxx	822-1152-xxx	822-1153-xxx	822-1154-xxx
Rockwell Collins	GNLU-9xx	822-1235-xxx	822-1236-xxx	822-1237-xxx	822-1238-xxx
Honeywell	RMA-55B	066-50029-1101	066-50029-1161		

Appendix D AT Transition Costs

D.1 AT Classic

		NE --> CDTI (ATc1)			NE --> BDCST Out (ATc2)		
		2004-2006	2007-2010	2011-2016	2004-2006	2007-2010	2011-2016
Display & GPS	**% of install $**						
Display	40%	37,800	37,800	37,800	-	-	-
GPS	25%	52,725	52,725	52,725	52,725	52,725	52,725
Link Cost							
Transponder	20%	62,340	62,340	62,340	62,340	62,340	62,340
Upgrade	2%						
Control	8%	20,400	20,400	20,400	20,400	20,400	20,400
1090 Mhz RCV link	5%	15,000	15,000	15,000	-	-	-
Installation		63,200	63,200	63,200	33,496	33,496	33,496
Total		**251,465**	**251,465**	**251,465**	**168,961**	**168,961**	**168,961**
GPS & Display		**90,525**	**90,525**	**90,525**	**52,725**	**52,725**	**52,725**
Link Cost		**97,740**	**97,740**	**97,740**	**82,740**	**82,740**	**82,740**

		Latent --> CDTI (ATc3)			Latent --> BDCST Out (ATc4)			BCST Out --> CDTI (ATc5)		
		2004-2006	2007-2010	2011-2016	2004-2006	2007-2010	2011-2016	2004-2006	2007-2010	2011-2016
Display & GPS	**% of install $**									
Display	40%	37,800	37,800	37,800	-	-	-	37,800	37,800	37,800
GPS	25%	-	-	-	-	-	-	-	-	-
Link Cost										
Transponder	20%	-	-	-	-			-	-	-
Upgrade	2%	15,400	15,400	15,400	-	-	-	-	-	-
Control	8%	20,400	20,400	20,400	20,400	20,400	20,400	-	-	-
1090 Mhz RCV link	5%	15,000	15,000	15,000	-	-	-	15,000	15,000	15,000
Installation		34,760	34,760	34,760	5,056	5,056	5,056	28,440	28,440	28,440
Total		**123,360**	**123,360**	**123,360**	**25,456**	**25,456**	**25,456**	**81,240**	**81,240**	**81,240**
GPS & Display		**37,800**	**37,800**	**37,800**	**-**	**-**	**-**	**37,800**	**37,800**	**37,800**
Link Cost		**50,800**	**50,800**	**50,800**	**20,400**	**20,400**	**20,400**	**15,000**	**15,000**	**15,000**

D.2 AT Neo-Classic

		NE --> CDTI (ATn1)			NE --> BDCST Out (ATn2)		
		2004-2006	2007-2010	2011-2016	2004-2006	2007-2010	2011-2016
Display & GPS	**% of install $**						
Display	45%	375,000	375,000	375,000	-	-	-
GPS	30%	52,725	52,725	52,725	52,725	52,725	52,725
Link Cost							
Transponder	18%	62,340	62,340	62,340	62,340	62,340	62,340
Upgrade	2%						
Control	0%	-	-	-	-	-	-
1090 Mhz RCV link	5%	15,000	15,000	15,000	-	-	-
Installation		59,200	59,200	59,200	28,416	28,416	28,416
Total		**564,265**	**564,265**	**564,265**	**143,481**	**143,481**	**143,481**
GPS & Display		**427,725**	**427,725**	**427,725**	**52,725**	**52,725**	**52,725**
Link Cost		**77,340**	**77,340**	**77,340**	**62,340**	**62,340**	**62,340**

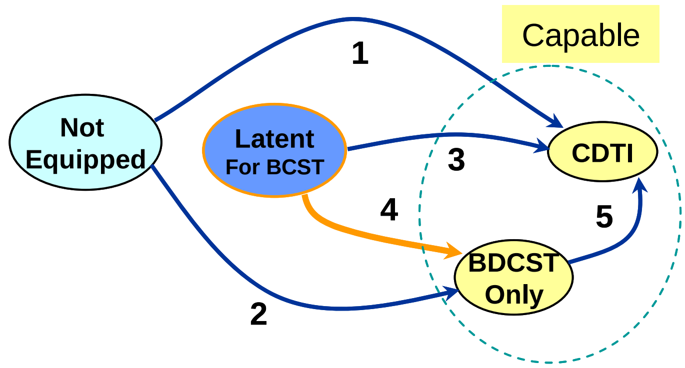
		Latent --> CDTI (ATn3)			Latent --> BDCST Out (ATn4)			BCST Out --> CDTI (ATn5)		
		2004-2006	2007-2010	2011-2016	2004-2006	2007-2010	2011-2016	2004-2006	2007-2010	2011-2016
Display & GPS	**% of install $**									
Display	45%	375,000	375,000	375,000	-	-	-	375,000	375,000	375,000
GPS	30%	-	-	-	-	-	-	-	-	-
Link Cost										
Transponder	18%	-	-	-	-			-	-	-
Upgrade	2%	15,400	15,400	15,400	15,400	15,400	15,400	-	-	-
Control	0%	-	-	-	-	-	-	-		
1090 Mhz RCV link	5%	15,000	15,000	15,000	-	-	-	15,000	15,000	15,000
Installation		30,784	30,784	30,784	1,184	1,184	1,184	29,600	29,600	29,600
Total		**436,184**	**436,184**	**436,184**	**16,584**	**16,584**	**16,584**	**419,600**	**419,600**	**419,600**
GPS & Display		**375,000**	**375,000**	**375,000**	**-**	**-**	**-**	**375,000**	**375,000**	**375,000**
Link Cost		**30,400**	**30,400**	**30,400**	**15,400**	**15,400**	**15,400**	**15,000**	**15,000**	**15,000**

D.3 AT Modern

		NE --> CDTI (ATm1)			NE --> BDCST Out (ATm2)		
		2004-2006	2007-2010	2011-2016	2004-2006	2007-2010	2011-2016
Display & GPS	**% of install $**						
Display	45%	172,000	172,000	172,000	-	-	-
GPS	30%	52,725	52,725	52,725	52,725	52,725	52,725
Link Cost							
Transponder	18%	62,340	62,340	62,340	62,340	62,340	62,340
Upgrade	2%	-	-	-	-	-	-
Control	0%	-	-	-	-	-	-
1090 Mhz RCV link	5%	15,000	15,000	15,000	-	-	-
Installation		55,500	55,500	55,500	26,640	26,640	26,640
Total		**357,565**	**357,565**	**357,565**	**141,705**	**141,705**	**141,705**
GPS & Display		**224,725**	**224,725**	**224,725**	**52,725**	**52,725**	**52,725**
Link Cost		**77,340**	**77,340**	**77,340**	**62,340**	**62,340**	**62,340**

		Latent --> CDTI (ATm3)			Latent --> BDCST Out (ATm4)			BCST Out --> CDTI (ATm5)		
		2004-2006	2007-2010	2011-2016	2004-2006	2007-2010	2011-2016	2004-2006	2007-2010	2011-2016
Display & GPS	**% of install $**									
Display	45%	172,000	172,000	172,000	-	-	-	172,000	172,000	172,000
GPS	30%	-	-	-	-	-	-	-	-	-
Link Cost										
Transponder	18%	-	-	-	-	-	-	-	-	-
Upgrade	2%	15,400	15,400	15,400	15,400	15,400	15,400	-	-	-
Control	0%	-	-	-	-	-	-	-		
1090 Mhz RCV link	5%	15,000	15,000	15,000	-	-	-	15,000	15,000	15,000
Installation		28,860	28,860	28,860	1,110	1,110	1,110	27,750	27,750	27,750
Total		**231,260**	**231,260**	**231,260**	**16,510**	**16,510**	**16,510**	**214,750**	**214,750**	**214,750**
GPS & Display		**172,000**	**172,000**	**172,000**	**-**	**-**	**-**	**172,000**	**172,000**	**172,000**
Link Cost		**30,400**	**30,400**	**30,400**	**15,400**	**15,400**	**15,400**	**15,000**	**15,000**	**15,000**

Appendix E Airport Transport Aircraft Transition Costs



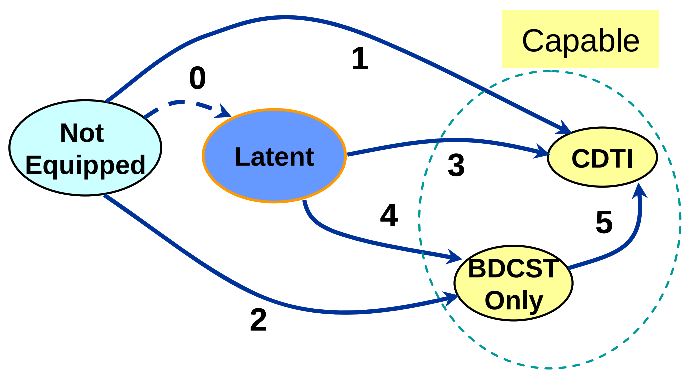
E.1 Air Transport Aircraft

Constant Year (2004) Unit Cost ($K)	2004 - 2008	2009 - 2012	2013 - 2016	2017 - 2020
Classic				
Path 1 (NE -> CDTI)	$251.5	$251.5	$251.5	$251.5
Path 2 (NE -> BCST	$169.0	$169.0	$169.0	$169.0
Path 3 (L -> CDTI)	$123.4	$123.4	$123.4	$123.4
Path 4 (L -> BCST)	$ 25.5	$ 25.5	$ 25.5	$ 25.5
Path 5 (BCST -> CDTI)	$ 81.2	$ 81.2	$ 81.2	$ 81.2
Neo-Classic				
Path 1 (NE -> CDTI)	$564.3	$564.3	$564.3	$564.3
Path 2 (NE -> BCST	$143.5	$143.5	$143.5	$143.5
Path 3 (L -> CDTI)	$436.2	$436.2	$436.2	$436.2
Path 4 (L -> BCST)	$ 16.6	$ 16.6	$ 16.6	$ 16.6
Path 5 (BCST -> CDTI)	$419.6	$419.6	$419.6	$419.6
Modern				
Path 1 (NE -> CDTI)	$357.6	$357.6	$357.6	$357.6
Path 2 (NE -> BCST	$141.7	$141.7	$141.7	$141.7
Path 3 (L -> CDTI)	$231.3	$231.3	$231.3	$231.3
Path 4 (L -> BCST)	$ 16.5	$ 16.5	$ 16.5	$ 16.5
Path 5 (BCST -> CDTI)	$214.8	$214.8	$214.8	$214.8
Regional – Jet and TurboProp				
Path 1 (NE -> CDTI)	$178.8	$178.8	$178.8	$178.8
Path 2 (NE -> BCST	$70.9	$70.9	$70.9	$70.9
Path 3 (L -> CDTI)	$115.6	$115.6	$115.6	$115.6
Path 4 (L -> BCST)	$ 8.3	$ 8.3	$ 8.3	$ 8.3
Path 5 (BCST -> CDTI)	$107.4	$107.4	$107.4	$107.4

E.2 Major Assumptions

- Display costs derived from Oct CBA less other components (GPS, GPS I/O, Xpndr, Control)
- Apply 25% discount to all AT equipment costs
- Installation cost is from CBA and is proportioned based on equipment to be installed (by % of Install)
- Use 2004 average catalog price for components from all vendors
- Modern aircraft have capable transponders, controls and GPS w/I/O
- No controls needed for Neo-classic or Modern retrofits
- Equipment and installation certification costs are included in the manufacturer estimates
- Consider Dual Transponder equipage
- 10% costs for spares of transponders, controls and GPS
- For not equipped transitions single GPS is included

Appendix F General Aviation Transition Costs



F.1 General Aviation

Constant Year (2004) Unit Cost ($K)	2004 - 2006	2007 - 2010	2011 - 2020
Turbine Fixed Wing (TurboProp)			
Path 0 (NE -> L)	$34.0	$30.5	$26.9
Path 1 (NE -> CDTI)	$147.3	$131.4	$115.6
Path 2 (NE -> BCST	$40.6	$36.2	$32.2
Path 3 (L -> CDTI)	$113.5	$101.1	$88.5
Path 4 (L -> BCST)	$6.6	$5.7	$5.3
Path 5 (BCST -> CDTI)	$109.4	$97.4	$85.2
Turbine Fixed Wing (Jet)			
Path 0 (NE -> L)	$63.4	$57.1	$50.8
Path 1 (NE -> CDTI)	$282.1	$253.9	$225.7
Path 2 (NE -> BCST	$71.7	$64.6	$57.4
Path 3 (L -> CDTI)	$218.1	$196.3	$174.5
Path 4 (L -> BCST)	$8.3	$7.5	$6.6
Path 5 (BCST -> CDTI)	$209.8	$188.8	$167.8
All Other			
Path 0 (NE -> L)	$4.5	$3.8	$3.0
Path 1 (NE -> CDTI)	$12.5	$8.8	$5.5
Path 2 (NE -> BCST	$9.5	$7.8	$7.0
Path 3 (L -> CDTI)	$9.0	$6.0	$ 2.5
Path 4 (L -> BCST)	$5.0	$4.0	$4.0
Path 5 (BCST -> CDTI)	$9.0	$6.0	$2.5

F.2 Major Assumptions

Unit costs include costs of display, GPS, link and installation, depending on path chosen.

“All Other” Category Assumptions:

- Paths 3 and 5 costs are for software upgrades only.
- Only 50% of the display and GPS cost is allocated to ADS-B functionality (costs are shown with reduction)
- Display and GPS costs are based on the average list price from vendors. The list price includes installation. Future year costs include development costs and de-escalation based on historical data
- GA link costs are based on the list price of one major vendor. The list price includes installation. Future year costs were calculated based on vendor predictions, assesment of market, and engineering judgement
- “Turbine Fixed Wing” Category Assumptions:
- “Jet” costs were derived by taking a percentage of the Air Transport Neo Classic aircraft
- “Turboprop” costs were derived by taking the average of the “Jet” and “All Other” costs

Appendix G Spiral Chart

Spiral 0 1999 - 2004	Spiral 1 2005 - 2008	Spiral 2 2009 - 2012	Spiral 3 2013 - 2016
All new Boeing/Airbus aircraft deliver with BCST only Xponder Large base of MFD equipped GA aircraft DoD aircraft commit to Xponders Australia announcement stimulates global interest in ADS-B	East Coast services stimulate GA Availability of Services drives conversion to CDTI European Mandate drives Latent aircraft Electronic Flight Bag (EFB)/ Wide Format CDTI More manufacturers announce new products	Terminal Services begins to stimulate AT and DoD equipage GA continues to upgrade and equip More manufacturers introduce new and upgrade products CDTI becomes desired capability	En-route Services continues interest in all users ATC services continue equipage stimulation CDTI enables expanded ATC services

Glossary

ACAS	AirCraft Analytical System
ADS-B	Automatic Dependent Surveillance – Broadcast
APU	Auxiliary Power Unit
ARINC	Aeronautical Radio Incorporated
ATC	Air Traffic Control
BCST	Broadcast Only
CAASD	Center for Advanced Aviation System Development
CBA	Cost Benefit Analysis
CDTI	Cockpit Display of Traffic Information
CNS	Communications, Navigation, and Surveillance
EFIS	Electronic Flight Information System
FAA	Federal Aviation Administration
FMS	Flight Management System
GA	General Aviation
GAMA	General Aviation Manufacturers Association
GPS	Global Positioning System
LRU	Line Replaceable Units
MFD	Multi-Function Display
MMR	Multimode Receiver
NAS	National Airspace System
OEM	Original Equipment Manufacturer
SEC	Securities and Exchange Commission
STL	Sub-total
TIS	Traffic Information Service
TTL	Total
U.S.	United States
USA	United States of America
VOL	Voluntary