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ADS-C CDP Benefits for New York and Oakland Oceanic Flight Information Regions

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Abstract

Automatic Dependent Surveillance – Contract Climb Descend Procedure (ADS-C CDP) provides oceanic controllers with an automation tool that enables aircraft to climb or descend around blocking aircraft. Aircraft operators are expected to benefit from the ability of aircraft to fly more frequently at fuel efficient altitudes. This analysis provides an estimate of the economic benefits of the fuel savings predicted to accrue to users operating aircraft within the FAA's New York and Oakland Oceanic Flight Information Regions (FIRs). The analysis covers the entire lifecycle of the program, which is expected to begin starting 2014 Q3 and extend through fiscal year (FY) 2035. It is based on simulation results published by MITRE in 2007 and 2011 that model average daily fuel savings across three assumed longitudinal separation standards (30 nm, 50 nm, and 10 minutes), for both a baseline Future Air Navigation System (FANS) equipage rate and a 100% equipage rate. In order to convert these simulation results to a stream of benefits across the program's lifecycle, the simulation results are interpolated using the projected FANS equipage rate for each year. The estimated fuel savings are converted from daily to annual fuel savings and are assumed to grow proportionally to the predicted activity in the FAA's oceanic FIRs. Savings in fuel quantities are monetized using an average projected unit cost of fuel. In the absence of data on changes in separation standards across time, a low and a high estimate are provided, by selecting the combination of separation standards that results in the lowest and highest monetary benefits throughout the lifecycle. The present value (PV) of the ADS-C CDP benefits is computed using a 7% discount rate, resulting in a benefits estimate ranging from a low of $12.8 million to a high of $15.2 million for a FY 2014-2035 lifecycle.

1 Introduction

This memorandum presents a rough order of magnitude (ROM) estimate of the economic benefits of the Automatic Dependent Surveillance – Contract Climb Descend Procedure (ADS-C CDP). The analysis in this report includes benefits for two Oceanic Flight Information Regions (FIRs) managed by the FAA: Oakland Oceanic FIR, operated by the Oakland Air Route Traffic Control Center (ZOA) and New York Oceanic FIR, managed by the New York Air Route Traffic Control Center (ZNY)[1]. While the forecast is limited to Oceanic FIRs managed by the U.S. government, user benefits are estimated for both U.S. and non-U.S. carriers.

The assumptions, background data, and methodology for the benefits analysis are discussed in detail in Sections 2 through 4, but a high-level overview is presented here. The starting point of the benefits analysis is a set of simulation results published by MITRE in 2007 [1] and 2011 [2]. The results consist of estimated average daily fuel savings for ZNY and ZOA, across three longitudinal separation standards: 30 nm, 50 nm, and, for ZNY only, 10 minutes (simulated as 80 nm). MITRE's results are presented both for the Future Air Navigation System (FANS) equipage rate in the baseline year and for an assumed 100% equipage rate. The ADS-C CDP capability will also be provided in the Anchorage Oceanic FIR (ZAN). However, due to partial availability of radar services in ZAN, the benefit is expected to be relatively small compared to ZNY and ZOA, which are dominated by oceanic airspace without radar coverage. Because of this, ZAN is not included in this benefits analysis. This is consistent with the analyses published by MITRE, which also do not include ZAN.

The simulation results are converted to a stream of benefits based on a forecast of FANS equipage rates for each year in the lifecycle. This equipage forecast is used to interpolate between the modeled average daily fuel savings at the baseline equipage rate and the savings at the 100% equipage rate. The interpolated results are annualized and scaled to take into account predicted growth in oceanic activity in ZNY and ZOA. The resulting fuel savings are then monetized using an average fuel unit cost provided by the FAA in its data package for investment analysis [4]. Fuel cost savings are estimated for each year in the lifecycle. This also allows the benefit estimate to be limited to a specific time period within the lifecycle, if needed (for example, ten years).

The average daily fuel savings modeled by MITRE depends on the minimum longitudinal separation required. Due to lack of data, the methodology described here does not try to estimate what share of flights is subject to a specific separation standard, or how this will change over time. Instead, a range of low and high benefit estimates is provided. The low end of the range is determined by selecting the combination of separation standards resulting in the lowest monetary benefit across the lifecycle, whereas the high end of the range is the combination with the highest estimated benefit.

[1] The acronyms ZNY and ZOA are used here to represent the New York and Oakland Oceanic FIRs, respectively, even though they normally apply to the entire Air Route Traffic Control Center.

2 Background

The ADS-C CDP procedure provides oceanic controllers with an automation tool that enables an aircraft to climb or descend around a blocking aircraft to reach its preferred altitude more efficiently [1]. Figure 1 shows how properly equipped aircraft can bypass blocking aircraft using ADS-C CDP to reach a new altitude. The main efficiency is a savings in fuel, since increased access to vertical maneuvers allow aircraft to fly atmospheric conditions that result in reduced fuel consumption.

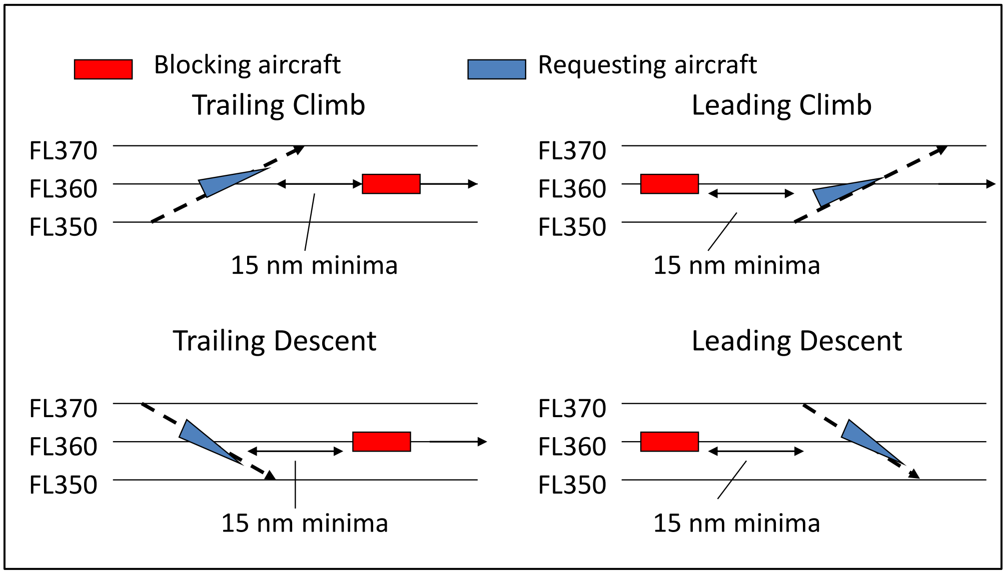

Figure 1: ADS-C CDP concept overview

ADS-C CDP will support improved climb and descent procedures only for properly equipped aircraft. The required equipage consists of advanced Communications, Navigation, and Surveillance (CNS) equipment, including Controller Pilot Data Link Communications (CPDLC) and ADS-C. FANS-equipped aircraft (more specifically, aircraft equipped with FANS 1/A) satisfy these equipage requirements.

Participating aircraft are also required to meet a figure-of-merit threshold of navigational performance. For the purpose of this analysis, it is assumed that FANS-equipped aircraft meet the required navigational performance. It is further assumed that FANS-equipped aircraft can achieve a Required Navigation Performance (RNP) standard of at least RNP-4, supporting 30 nm longitudinal separation, where implemented. Consequently, for the purpose of this benefits analysis, FANS equipage is assumed to be a sufficient equipment prerequisite to accrue ADS-C CDP benefits under all separation standards under consideration.

In 2007, MITRE prepared a business case analysis that included modeling of fuel savings attributable to ADC-CDP for ZNY and ZOA. The model results were developed using a traffic sample based on calendar year (CY) 2006 traffic densities [1]. The analysis calculated potential average daily fuel savings attributable to ADS-CDP for three separation cases: 30 nm separation (requiring RNP-4), 50 nm separation (requiring RNP-10), and, for ZNY only, 10-minutes longitudinal separation (simulated as 80 nm). The analysis was updated in 2011, using a 2010 traffic sample. The update was conducted only for ZNY and only for the 80 nm separation case [2]. The results from these analyses are incorporated into the methodology presented here. They are described in more detail in Section 3.1 below.

3 Data Sources and Previous Studies

This benefits analysis relies on data from three key sources:

- MITRE modeling results of ADS-C CDP in ZNY and ZOA
- FAA operations forecasts for ZNY and ZOA
- MITRE baseline FANS equipage statistics and equipage forecast for oceanic U.S. air carrier flights

The MITRE analyses provide estimated average daily fuel savings in a single baseline year, which are used in this analysis to evaluate the economic benefits of ADS-C CDP over its entire lifecycle. MITRE estimates fuel savings at two different levels of FANS equipage – the estimated equipage level in the base year and at 100%. The baseline equipage statistics and U.S. air carrier equipage forecast are used to predict equipage for each year in the lifecycle. The resulting equipage forecast, in turn, is used to compute an interpolated fuel savings from the two equipage data points provided in MITRE's modeling results. Finally, the operations forecasts are used to scale up the benefits values to take into account projected growth in oceanic activity. The data sources are described in greater detail in the Section 3.1, 3.2, and 3.3 below and the incorporation of the data into the benefits methodology is described in Section 4.

3.1 MITRE Modeling Results of ADS-C CDP in ZNY and ZOA

MITRE published a business case analysis for ADS-C CDP in 2007, which included modeling of average daily fuel savings benefits [1]. The modeling was based on 98 days of CY 2006 flight information including filed flight plan, aircraft location at time of altitude change request, and clearance responses. Average daily fuel savings for ZNY and ZOA were computed based on the CY 2006 traffic density.

Benefits were identified as fuel savings due to better aerodynamic efficiencies at higher altitudes. Parameters considered in the analysis included the location of the aircraft when the altitude change request was made, FANS equipage, longitudinal separation standards used (30 nm, 50 nm, and 80 nm), and timing of the altitude change request. Fuel savings were estimated for the baseline FANS equipage rate in effect for 2006 (15.0% for ZNY and 32.5% for ZOA), as well as a hypothetical 100% equipage rate representing the upper bound of benefits.

The study assumed FANS-equipped aircraft included CPDLC and ADS-C reporting capabilities. It was assumed that 30 nm separation required aircraft to be RNP-4 capable and that 50 nm separation required RNP-10 capability. The modeling allowed for a maximum of 2,000 feet in altitude change and specified that the requesting and blocking aircraft be on the same track. It also required a separation distance of at least 15 nm, to support a 30 minute look-ahead to conduct the ADS-C CDP maneuver, but no greater than the assumed longitudinal separation minimum (i.e. 30 nm, 50 nm, or 80 nm).

The potential location and timing of altitude changes for ADS-C CDP were determined in accordance with three hypothetical categories of altitude change requests. These altitude change request categories reflect the assumptions used to select the altitude changes considered eligible for an ADS-C CDP assisted maneuver. Fuel savings were estimated for each hypothetical category. The categories were defined as follows:

REQ	Actual altitude changes requested by the flight crew
FPL	Altitude changes filed in the flight plan, but not necessarily executed in flight
ACPref	Estimation of all theoretical altitude changes limited only by the aircraft's performance capabilities

In 2011, MITRE published an update of the ZNY ADS-C CDP benefits analysis using data from 109 days in January, February, July, and August of 2010 [2]. Again, results were presented both for the FANS equipage in the baseline year (i.e. 26.2% in 2010) and a hypothetical equipage level of 100%. The analysis used the same three altitude change categories defined above. The only separation standard included in the 2011 update was the 10 minute separation (again modeled as 80 nm separation).

Table 1 summarizes the average daily fuel savings estimated for all combinations of FIR, separation standard, FANS equipage as a share of flights, and altitude change request category. The relevant baseline year for the traffic density used in the analysis is shown, along with the FANS equipage rate (i.e. either the equipage rate for the relevant baseline year or 100%). While the model also included estimates of fuel savings outside of the FAA's oceanic FIRs, those results are not shown, as this benefits analysis is limited to airspace managed by the FAA.

The REQ category can be viewed as a lower bound on the benefits of the potential use of ADS-C CDP, since it does not take into account the likely increase in altitude change requests enabled by the ADS-C CDP capability. The ACPerf category, on the other hand, represents an upper bound, since it reflects the maximum theoretical use of the capability. The FPL category falls somewhere in between the two, as reflected by the results in Table 1. It represents a middle ground, since it can defensibly be argued that the ADS-C CDP capability will increase the frequency of altitude change requests over actual levels in the baseline year. The relevant column is highlighted in Table 1.

Table 1: Estimated fuel burn savings (lbs), daily average

FIR	Baseline Year	Separation (nm)	FANS Equipage	Altitude Change Request Category		
				REQ	FPL	ACPerf
ZNY	2006	30	15.0%	141	178	328
ZNY	2006	30	100.0%	1,481	2,375	4,817
ZNY	2006	50	15.0%	184	291	422
ZNY	2006	50	100.0%	2,278	3,481	6,945
ZNY	2010	80	26.2%	361	638	1,554
ZNY	2010	80	100.0%	1,606	2,777	7,451
ZOA	2006	30	32.5%	1,025	1,812	8,770
ZOA	2006	30	100.0%	2,871	5,008	19,216
ZOA	2006	50	32.5%	1,273	1,843	9,745
ZOA	2006	50	100.0%	4,121	5,568	23,587

The FPL category was selected for the computations performed for this benefits analysis. This choice was made in consultation with MITRE and the FAA's Oceanic Tactical Trajectory Management (OTTM) Program Office and represents a reasonable intermediate value between the lower and upper bounds. It should be noted that the results for the FPL category are consistently closer to the lower bound than to the upper bound, as shown by the data listed in Table 1. Accordingly, the choice of FPL is thought to represent a relatively conservative estimate of the total possible benefit.

In general, the opportunity for altitude change requests increases with required longitudinal separation distance. For example, as the results for ZOA shown in Table 1, the benefits are higher for 50 nm longitudinal separation than they are for 30 nm separation. This is because the minimum separation between requesting and blocking aircraft can be anywhere from 15 to 50 nm in the former case, as opposed to having an upper bound of 30 nm. Larger separation requirements create a greater chance of aircraft blocking each other, allowing for more ADS-C CDP opportunities. For ZNY, however, the benefits results for 80 nm separation are, in some cases, lower than those for 50 nm. A possible explanation is that the results for 80 nm separation are taken from the 2011 update, whereas the results for 50 nm are from the original 2007 business case analysis. Differences in traffic densities and in the methodology may have resulted in variations across the separate analyses that do not make the results directly comparable. This issue is discussed further in Section 6.

3.2 FAA Operations Forecast for ZNY and ZOA

The MITRE models of ADS-C CDP fuel savings are based on traffic densities in the baseline year (2006 or 2010, depending on the study). However, as traffic grows over time, the benefits are expected to increase at least in proportion to the change in activity. To estimate benefits over the entire 20-year lifecycle, the MITRE results shown in Table 1 were scaled by the relative growth in flight activity in ZNY and ZOA (see Section 4.3 for details). The basis for determining relative growth was either 2006 or 2010, depending on the baseline year used by MITRE for the benefits estimate.

An aircraft operations forecast prepared by the FAA NextGen System Analysis and Modeling Office [5] was used to estimate growth in oceanic flight activity. This forecast includes baseline activity data for ZNY and ZOA for 2010 and predicted daily traffic counts for the years 2020 and 2030. The forecast is shown in Table 2 below. Linear interpolation and extrapolation were used to extend the forecast to cover the full range from 2006 through 2035.

Table 2: Forecast of average daily oceanic operations

	Average Daily Ops	
Year	ZNY	ZOA
2010	485.8	591.6
2020	675.7	817.6
2030	917.7	1,069.0

3.3 FANS Equipage Forecast

The MITRE report *Oceanic Separation Standards and Aircraft Equipage for U.S. Oceanic Airspace* includes a FANS equipage forecast from 2011 to 2020 for aircraft in the U.S. oceanic air carrier fleet [3]. The forecast is reproduced in Table 3. For the purpose of this benefits analyst, this forecast was extended through 2035, through linear extrapolation. The extrapolated data is highlighted in Table 3.

A challenge in applying this FANS equipage forecast for the ADS-C CDP benefits analysis is that the forecast in Table 3 is expressed in terms of the share of the number of aircraft in the fleet that are equipped. In contrast, the average daily fuel savings estimates shown in Table 1 are based on equipage expressed as a share of the number of flights. The benefit of ADS-C CDP scales with the number of occurrences of aircraft blocking each other, which in turn is proportional to the number of oceanic flights. In order to apply the model results from Table 1 to the benefits analysis, ideally the FANS-equipage forecast should also be expressed as share of flights, not share of aircraft as is the case in the forecast shown in Table 3.

Table 3: U.S. oceanic air carrier fleet – FANS equipage forecast by aircraft

Year	U.S. Air Carrier Aircraft Oceanic FANS Equipage
2011	28%
2012	30%
2013	31%
2014	33%
2015	35%
2016	37%
2017	39%
2018	41%
2019	43%
2020	45%
2021	47%
2022	49%
2023	50%
2024	52%
2025	54%
2026	56%
2027	58%
2028	60%
2029	62%
2030	64%
2031	66%
2032	68%
2033	70%
2034	71%
2035	73%

Baseline ADS-C equipage data expressed both as share of flights and share of aircraft are available from a 2011 sample collected from the Ocean21 system [3]. Table 4 shows baseline equipage by share of flights, whereas Table 5 shows baseline equipage by share of aircraft. Note that for the purpose of this study, ADS-C equipped aircraft are assumed to also have CPDLC and therefore be FANS equipped.

Table 4: 2011 Baseline ADS-C equipage by flights

User	ZNY	ZOA
U.S. airlines	15%	31%
Non-U.S. airlines	49%	74%

Table 5: 2011 Baseline ADS-C equipage by aircraft

User	ZNY	ZOA
U.S. airlines	19%	39%
Non-U.S. airlines	47%	70%

As shown, the equipage rate by flights is reasonably similar to the equipage rate by aircraft, but there are differences between the two different methods of calculating equipage rate. To illustrate these differences, it is useful to compute the ratio of the equipage rate by flights to the equipage rate by aircraft. This ratio is shown in Table 6.

Table 6: Ratio of 2011 baseline equipage by flights to equipage by aircraft

User	ZNY	ZOA
U.S. airlines	0.79	0.79
Non-U.S. airlines	1.04	1.06

The forecast of FANS equipage used for this study is expressed as a share of equipped aircraft instead of share of flights, which is the desired basis for computing equipage rate. As this was the only available FANS equipage forecast, it was adopted for this benefits analysis nonetheless. As the results in Table 6 indicate, this may result in overestimating the benefits for U.S. carriers and slightly underestimating the benefits for non-U.S. carriers.

These differences in equipage rates by aircraft vs. equipage rates by flights exist because the number of flights generated over a specified unit of time varies by aircraft. For example, if an air carrier assigns its FANS-equipped aircraft predominantly to long-range routes that generate relatively low number of flights per airframe, then its equipage rate by aircraft will be lower than its equipage rate by flight. As equipage increase over time, the difference between the two sets of equipage rates is expected to diminish and there is will be no distinction once equipage reaches 100%. Possible methods for adjusting the model to account for the difference in the basis for measuring FANS equipage are discussed in Section 6.

4 Methodology

Fuel savings attributed to ADS-C CDP for ZNY and ZOA are a function of FANS equipage levels, projected growth in operations, and assumed separation standards (30 nm, 50 nm, or 10 minutes, which is represented by 80 nm). The fuel savings also depend on the assumed altitude change request category. As described above, the FPL category was selected as an intermediate point between the lower and upper bounds on fuel savings. The sections below describe the remaining assumptions and methodology employed to compute the estimated annual economic benefit of ADS-C CDP.

4.1 Extended FANS Equipage Forecast

The average daily fuel savings for ZNY and ZOA shown in Table 1 are provided for two different FANS equipage rates: The rate measured for the baseline year and a hypothetical equipage rate of 100%. Obtaining an interpolated fuel savings between these two data points requires a year-by-year forecast of FANS equipage rates. This section describes the methodology and assumptions used to develop this forecast.

Because the forecast in Table 3 is limited to U.S. carriers, it was first necessary to extend the forecast to include non-U.S. carriers. As the data in Table 4 and Table 5 indicate, non-U.S. carriers feature higher equipage rates than U.S. carriers. Consequently, relying solely on a forecast limited to U.S. carriers would result in underestimating the economic benefits of ADS-C CDP.

In order to extend the forecast, a separate forecast for non-U.S. carriers was created, which was then combined with the forecast for U.S. carriers. This forecast was generated by adopting a simplifying assumption, namely that the growth rate in equipage for non-U.S. carriers matches the projected growth rate for U.S. carriers. In effect, this assumes that the gap in equipage between U.S. carriers and non-U.S. carriers will stay the same, measured in relative terms, until 100% equipage is reached. The resulting equipage forecast is shown in Figure 2, along with the combined forecast that includes both U.S. and non-U.S. carriers.

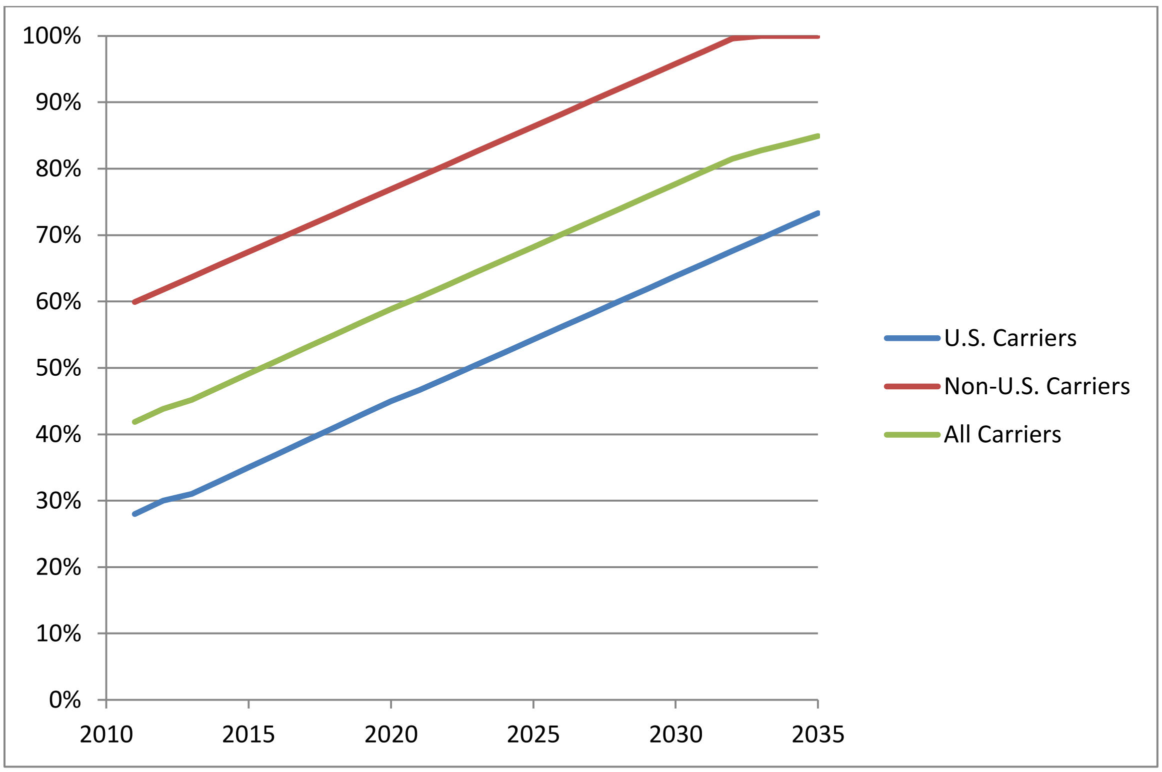

Figure 2: FANS equipage forecast

The combined forecast was computed as an average weighted by the respective shares of U.S. and non-U.S. carrier aircraft in the baseline sample used to survey equipage rates. Note that the forecast data provided by MITRE is based on manufacturer information on FANS equipage for new aircraft entering the fleet. The forecast does not include any retrofits and, consequently, it is possible that the equipage may increase faster than shown in Figure 2.

As shown in Table 4 and Table 5, there are also significant differences in FANS equipage between aircraft operating over the Atlantic and those operating over the Pacific. Aircraft operating in ZOA are generally better equipped, with equipage rates roughly double those measured in ZNY. Since the average daily fuel savings shown in Table 1 were modeled separately for ZNY and ZOA, with significant differences in the results, separate equipage forecasts for ZNY and ZOA are needed to obtain a robust estimate of the combined benefit.

In order to take into account these geographical differences, the FANS equipage forecasts for U.S. and non-U.S. carriers shown in Figure 2 were subdivided into separate forecasts for ZNY and ZOA. The first year of the forecast was estimated by applying the proportion in FANS equipage between ZNY and ZOA from the baseline survey to the 2011 forecast for U.S. and non-U.S. carriers shown in Figure 2. Subsequent years in the forecast were obtained by applying the proportion in equipage between ZNY and ZOA, scaled by the year-over-year change in the ratio of projected flight activity in ZNY to that in ZOA (see Table 7). This last step takes into account that oceanic flight activity in ZNY is predicted to increase at a higher rate than the activity in ZOA [5]. This increased activity is expected to cause the equipage rate in ZNY to converge towards the equipage rate in ZOA. This effect is relatively minor, however, since the predicted growth rate in ZNY is only slightly higher than that for ZOA. The equipage forecast that results from this analysis is shown in Table 8.

Since the interpolation of modeled average daily fuel savings requires a combined equipage rate for U.S. and non-U.S. carriers, an aggregate rate for all carriers was computed for ZNY and ZOA. The combined equipage rate was computed as an average weighted by the respective shares of U.S. and non-U.S. carrier aircraft in the baseline and forecast. The combined FANS equipage rates for ZNY and ZOA, respectively, are shown in the last two columns in Table 8.

Note that the projected 2011 equipage rates shown in Table 8 are slightly higher than the 2011 baseline equipage reported in Table 5. This is because the overall U.S. carrier oceanic equipage rate reported for 2011 in MITRE’s forecast is greater than the actual overall rate in the 2011 baseline data collected from Ocean21. The difference exists because the data was generated by two different methodologies: The underlying FANS equipage forecast that drives the results shown in Table 8 was based on information provided by aircraft manufacturers on the equipage of new aircraft predicted to be assigned to the U.S. oceanic air carrier fleet. The baseline data shown in Table 5, on the other hand, was based on actual equipage reported in Ocean21. Overall, conformance between the two methods is good, with an overall difference of approximately two percentage points.

Table 7: ZNY to ZOA ratios of activity

	ZNY:ZOA Activity Ratio	
Year	U.S. Carriers	Non-U.S. Carriers
2011	1.89	1.72
2012	1.89	1.72
2013	1.89	1.72
2014	1.89	1.72
2015	1.90	1.72
2016	1.90	1.73
2017	1.90	1.73
2018	1.90	1.73
2019	1.90	1.73
2020	1.90	1.73
2021	1.91	1.74
2022	1.92	1.75
2023	1.93	1.75
2024	1.94	1.76
2025	1.94	1.77
2026	1.95	1.77
2027	1.96	1.78
2028	1.96	1.79
2029	1.97	1.79
2030	1.97	1.80
2031	1.98	1.80
2032	1.99	1.81
2033	1.99	1.81
2034	2.00	1.82
2035	2.00	1.82

Table 8: FANS equipage forecast by aircraft carrier type and oceanic region

Year	U.S. Carriers		Non-U.S. Carriers		All Carriers	
	ZNY	ZOA	ZNY	ZOA	ZNY	ZOA
2011	21%	42%	51%	76%	33%	57%
2012	22%	45%	52%	78%	35%	60%
2013	23%	47%	54%	80%	36%	62%
2014	24%	50%	56%	83%	38%	64%
2015	26%	53%	57%	85%	39%	67%
2016	27%	56%	59%	87%	41%	70%
2017	29%	59%	61%	90%	42%	73%
2018	30%	62%	62%	92%	44%	75%
2019	32%	65%	64%	94%	45%	78%
2020	33%	68%	65%	97%	47%	81%
2021	34%	70%	67%	99%	48%	83%
2022	36%	73%	70%	100%	50%	85%
2023	37%	75%	73%	100%	52%	87%
2024	39%	78%	76%	100%	55%	88%
2025	41%	81%	79%	100%	57%	90%
2026	42%	84%	82%	100%	59%	91%
2027	44%	86%	85%	100%	61%	93%
2028	45%	89%	88%	100%	63%	94%
2029	47%	92%	91%	100%	65%	96%
2030	48%	95%	93%	100%	67%	97%
2031	50%	97%	96%	100%	70%	99%
2032	51%	100%	99%	100%	72%	100%
2033	54%	100%	100%	100%	74%	100%
2034	57%	100%	100%	100%	75%	100%
2035	60%	100%	100%	100%	77%	100%

The assumptions that were employed in order to derive the FANS equipage forecasts shown in Table 8 represent the best judgment of the benefits team, but are subjective in nature. Alternative sets of assumptions and scenarios are possible. For example, the North Atlantic oceanic environment is subject to a possible equipage mandate, which could significantly increase the rate of equipage over time, especially in the intermediate future. Possibilities for risk adjusting the choice of assumptions are discussed in Section 6.

4.2 Additional Assumptions

A number of additional assumptions were adopted in order to estimate and monetize the economic benefit of ADS-C CDP fuel savings over the program lifecycle. These assumptions follow generally accepted practices. They are listed below, with citations to the reference documents that provide the sources for the assumed values in question:

- All amounts are specified in fiscal year (FY) 2012 dollars, unless otherwise specified.
- Jet fuel density is constant at 6.7 lbs per gallon [6].
- Average fuel cost across the lifecycle is valued at $2.47 per gallon [4].
- The Initial Operating Capability date is 2014 Q3 [7]. The benefits are phased in to reflect the mid-year IOC, with 50% of benefits realized in FY 2014 and 100% in FY 2015. The lifecycle is then assumed to extend for 20 years, ending in FY 2035.
- The model uses a 7% discount rate for calculating the present value (PV) of the benefits over the lifecycle [4].

4.3 Fuel Savings Estimates

The model results shown in Table 1 for the FPL category at the baseline equipage level and the 100% level were interpolated using the equipage levels for all carriers shown in Table 8. This computation was carried for each modeled separation standard for ZNY (i.e. 30 nm, 50 nm, and 80 nm) and for ZOA (i.e. 30 nm and 50 nm). As described earlier, the ZNY model results for 80 nm separation are based on 2010 data and traffic densities, while model results for all other scenarios are based on 2006.

Since the fuel savings opportunities created by ADS-C CDP occur when there is a chance of aircraft blocking each other, the benefit is expected to grow as oceanic traffic increases. In order to take this into account, the interpolated average daily fuel savings was scaled up by the relative growth in activity over the baseline year (i.e. 2006 or 2010, depending on the scenario). The results were then annualized by multiplying by 365.25. The resulting savings in fuel consumption were converted to fuel cost savings using an average fuel cost of $2.47 per gallon, in order to monetize the benefits as an economic value. The results are discussed in Section 5 below.

5 Results

The monetary value of the fuel savings benefits was computed for each separation standard supported in the modeling. Annual fuel and cost savings for each year in the lifecycle for ZNY are shown in Table 9 for 30 nm, 50 nm, and 80 nm separation. The fuel and cost savings for ZOA are shown in Table 10 for 30 nm and 50 nm separation.

Generating a combined benefits value requires an estimate of how the separation requirements will change over time in both the Pacific and the Atlantic airspace, and what share of aircraft will be able to make use of reduced separations. The Pacific currently features both 30 nm and 50 nm separation, whereas the Atlantic primarily features 10 minutes separation (modeled here as 80 nm) [3]. The goal in both the Atlantic and the Pacific oceanic region is to reduce separation requirements further, but the timing of such reductions is difficult to predict, in part due to the international coordination required. Moreover, even when reductions in separation standards are implemented, not all aircraft are able to benefit due to the presence of mixed equipage and limitations on the CNS infrastructure [3].

Due to the difficulty in predicting changes in separation standards and the lack of specific forecasts on which flights can operate under reduced separation, low and high estimates of the economic benefit of ADS-CDP were calculated. This range in benefits describes the uncertainty in predicting potential reductions in separation standards over the course of the lifecycle. The fuel savings presented in Table 9 and Table 10 allow for six possible ways of combining the three separation scenarios for ZNY (30 nm, 50 nm, and 80 nm) with the two separation scenarios for ZOA (30 nm and 50 nm). The low end of the estimate was created by picking the combination that resulted in the lowest overall benefit over the 20-year lifecycle, whereas the high end was given by the combination that resulted in the highest benefit. The combination resulting in the lowest total oceanic benefit is 30 nm separation for ZNY and 30 nm separation for ZOA. The highest estimate is the combination of benefits for 50 nm separation for ZNY and 50 nm separation for ZOA. The resulting total low and high estimates, along with the discounted, present value of the benefits are shown in Table 11. The present value of the low and high benefit estimates through FY 2035 is shown graphically in Figure 3.

Table 9: ZNY annual fuel savings and fuel cost savings

	FANS	Fuel Savings (lbs)			Fuel Cost Savings (FY 2012 $)		
Year	**Equipage**	**30 nm**	**50 nm**	**80 nm**	**30 nm**	**50 nm**	**80 nm**
2014	38%	190,898	285,327	204,554	$70,273	$105,035	$75,301
2015	39%	415,322	619,886	442,443	$152,889	$228,193	$162,873
2016	41%	450,201	671,080	477,056	$165,729	$247,039	$175,615
2017	42%	486,432	724,237	512,948	$179,066	$266,607	$188,827
2018	44%	524,014	779,358	550,119	$192,901	$286,898	$202,511
2019	45%	562,949	836,441	588,568	$207,234	$307,912	$216,665
2020	47%	603,235	895,487	628,296	$222,064	$329,648	$231,289
2021	48%	649,551	963,438	674,172	$239,114	$354,662	$248,177
2022	50%	703,967	1,043,152	727,710	$259,146	$384,007	$267,886
2023	52%	764,671	1,131,994	787,195	$281,492	$416,711	$289,784
2024	55%	827,704	1,224,219	848,884	$304,696	$450,661	$312,492
2025	57%	893,067	1,319,827	912,776	$328,757	$485,857	$336,013
2026	59%	960,760	1,418,818	978,872	$353,676	$522,298	$360,344
2027	61%	1,030,783	1,521,192	1,047,172	$379,453	$559,984	$385,487
2028	63%	1,103,136	1,626,949	1,117,676	$406,088	$598,915	$411,441
2029	65%	1,177,818	1,736,089	1,190,384	$433,580	$639,092	$438,206
2030	67%	1,254,831	1,848,611	1,265,295	$461,930	$680,514	$465,782
2031	70%	1,334,173	1,964,517	1,342,410	$491,138	$723,181	$494,170
2032	72%	1,416,570	2,084,858	1,422,414	$521,470	$767,481	$523,621
2033	74%	1,496,446	2,201,537	1,500,033	$550,874	$810,433	$552,195
2034	75%	1,571,825	2,311,689	1,573,400	$578,623	$850,983	$579,202
2035	77%	1,648,973	2,424,408	1,648,439	$607,022	$892,477	$606,826
	Total	**20,067,326**	**29,633,114**	**20,440,820**	**$7,387,215**	**$10,908,587**	**$7,524,706**

Table 10: ZOA annual fuel savings and fuel cost savings

Year	FANS Equipage	Fuel Savings (lbs)		Fuel Cost Savings (FY2012 $)	
		30 nm	50 nm	30 nm	50 nm
2014	64%	826,615	896,607	$304,295	$330,060
2015	67%	1,773,889	1,929,415	$653,007	$710,259
2016	70%	1,898,769	2,070,536	$698,978	$762,209
2017	73%	2,027,870	2,216,576	$746,502	$815,969
2018	75%	2,161,191	2,367,536	$795,581	$871,541
2019	78%	2,298,734	2,523,416	$846,213	$928,924
2020	81%	2,440,497	2,684,214	$898,400	$988,117
2021	83%	2,582,170	2,844,409	$950,552	$1,047,088
2022	85%	2,717,997	2,997,791	$1,000,553	$1,103,551
2023	87%	2,843,326	3,138,937	$1,046,689	$1,155,510
2024	88%	2,971,236	3,283,091	$1,093,776	$1,208,577
2025	90%	3,101,728	3,430,255	$1,141,813	$1,262,751
2026	91%	3,234,801	3,580,427	$1,190,800	$1,318,032
2027	93%	3,370,456	3,733,608	$1,240,737	$1,374,422
2028	94%	3,508,692	3,889,798	$1,291,625	$1,431,918
2029	96%	3,649,510	4,048,996	$1,343,463	$1,490,523
2030	97%	3,792,909	4,211,203	$1,396,251	$1,550,235
2031	99%	3,938,889	4,376,419	$1,449,990	$1,611,054
2032	100%	4,085,056	4,541,851	$1,503,797	$1,671,953
2033	100%	4,176,815	4,643,871	$1,537,576	$1,709,509
2034	100%	4,268,575	4,745,892	$1,571,354	$1,747,065
2035	100%	4,360,335	4,847,912	$1,605,133	$1,784,621
	Total	**66,030,057**	**73,002,759**	**$24,307,086**	**$26,873,887**

Table 11: Low and high estimates of combined annual economic benefits

	Low Estimate (FY 2012 $)		High Estimate (FY 2012 $)	
Year	Total	PV	Total	PV
2014	$374,568	$327,162	$435,095	$380,029
2015	$805,896	$657,851	$938,453	$766,057
2016	$864,706	$659,680	$1,009,248	$769,950
2017	$925,568	$659,917	$1,082,577	$771,862
2018	$988,482	$658,667	$1,158,439	$771,917
2019	$1,053,447	$656,034	$1,236,835	$770,239
2020	$1,120,463	$652,120	$1,317,765	$766,951
2021	$1,189,666	$647,099	$1,401,750	$762,459
2022	$1,259,699	$640,367	$1,487,558	$756,199
2023	$1,328,181	$631,009	$1,572,222	$746,951
2024	$1,398,472	$620,938	$1,659,238	$736,722
2025	$1,470,570	$610,234	$1,748,607	$725,610
2026	$1,544,476	$598,975	$1,840,330	$713,712
2027	$1,620,191	$587,232	$1,934,405	$701,117
2028	$1,697,713	$575,074	$2,030,833	$687,913
2029	$1,777,043	$562,566	$2,129,614	$674,181
2030	$1,858,182	$549,769	$2,230,748	$659,998
2031	$1,941,128	$536,738	$2,334,235	$645,435
2032	$2,025,267	$523,367	$2,439,434	$630,396
2033	$2,088,449	$504,388	$2,519,942	$608,599
2034	$2,149,977	$485,278	$2,598,047	$586,414
2035	$2,212,155	$466,647	$2,677,097	$564,725
Total	$31,694,300	$12,811,115	$37,782,475	$15,197,438

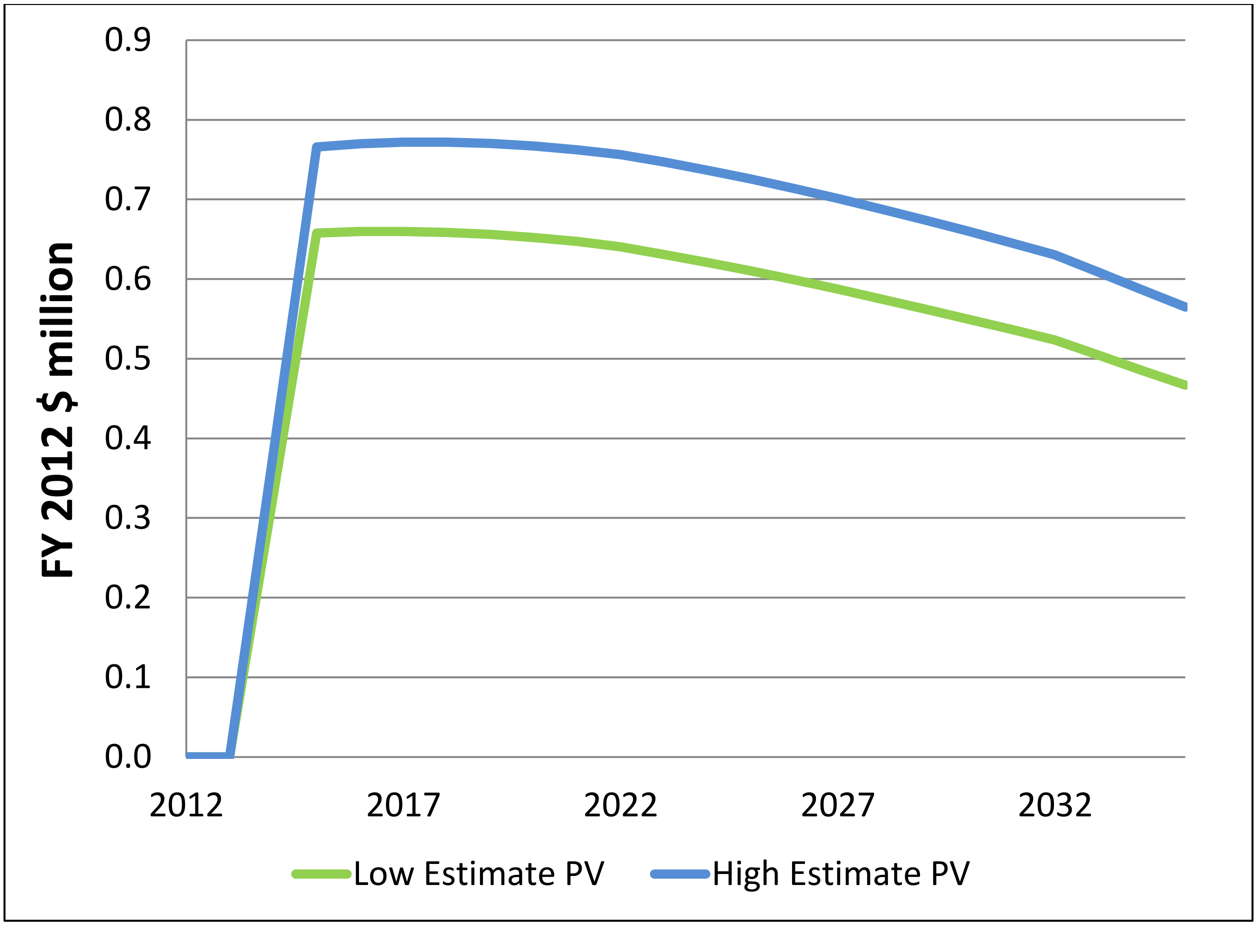

Figure 3: Present value of annual ADS-CDP benefits through FY 2035

6 Summary and Recommendations for Future Work

The above analysis presents a low and high estimate for the lifecycle economic value of predicted fuel savings attributable to the implementation of ADS-C CDP. The analysis results in a benefits estimate ranging from PV $12.8 to $15.2 million dollars over the program lifecycle. The analysis is based on MITRE's modeling of fuel savings for a range of equipage rates, separation standards, and altitude change request categories. A set of assumptions, documented above, were employed to select from or interpolate between the range of parameters used in MITRE's modeling in order to create benefit streams across the FY 2014-2035 timeline that represents the lifecycle.

As described in this memorandum, there are a number of uncertainties inherent in developing the benefits analysis. These uncertainties, and possible methods for improving the model to account for them, include:

- The forecasts for FANS equipage are based on the share of aircraft equipped in the fleet, whereas the benefits methodology calls for equipage data based on the share of flights. One possible method to address this discrepancy would be to apply a scaling factor to the FANS equipage forecasts based on the ratios shown in Table 7.

- The forecasts for FANS equipage are based on manufacturer information on equipage of new aircraft entering the fleet. They do not take into account the possibility of retrofitting aircraft. This may result in underestimating the economic benefit of ADS-C CDP. One possible method to adjust for this is to use survey data or input from subject matter experts to specifically estimate the likelihood of retrofitting existing aircraft with FANS equipment.

- The assumptions used to extend the FANS equipage forecast to non-U.S. carriers and to divide it into forecasts specific to ZNY and ZOA represent the best judgment of the benefits team, but other sets of assumptions and scenarios should be considered. For example, the current set of assumptions does not take into account plans for implementing an equipage mandate in the Atlantic region. One possible solution would be to adopt a range of assumptions. This could include a high-growth case where equipage is assumed to accelerate due to new mandates and a low-growth case where growth in equipage rates is assumed to be relatively flat.

- The FANS equipage assumptions cover air carrier aircraft only, but are applied to model results that incorporate other user categories, notably general aviation and military flights. The impact of this approach and the need for developing FANS equipage forecasts for user categories other than air carrier aircraft should be reviewed.

- As currently implemented, the benefits analysis mixes modeling results from two different years, 2006 and 2010. This results in the combination of data which may not be completely compatible in regards to the underlying assumptions used to derive them. This issue should be reviewed and the possibility of updating the ZNY and ZOA modeling with a common set of assumptions should be considered.

- The modeling prepared by MITRE includes a range of possible longitudinal separation standards. In the absence of a forecast of the implementation of reductions in separation and the share of aircraft able to use reduced separation, this analysis adopts a forecast range. The range is based on the lowest and highest possible combinations of the modeling results. The impacts of using this approach should be reviewed and alternative approaches should be considered.

- The benefits analysis should be risk adjusted in order to take into account uncertainties in the inputs and assumptions. A typical approach for implementing risk adjustment is to perform a Monte Carlo analysis, where input variables are replaced with probability distribution functions. A conservative benefits estimate based on the twentieth percentile of the resulting risk-adjusted benefit is usually recommended for benefits analysis in support of FAA investments.

References

1. Arthur, B., D. Maroney, and G. Taylor, *FY07 ADS-C In-Trail Procedure Business Case Analysis*, MITRE Corporation, McLean, VA, August 2007.
2. Arthur, W. C., *Estimated Benefits of ADS-C Climb-Descent Procedures in New York Oceanic Airspace*, Mitre Product 100447, MITRE Corporation, McLean, VA, January 2011.
3. Chàvez, P. G., et al., *Oceanic Separation Standards and Aircraft Equipage for U.S. Oceanic Airspace*, Mitre Product 120028, Mitre Corporation, McLean, VA, February 2012.
4. Federal Aviation Administration, *Economic Information for Investment Analysis*, data file, March 16, 2011.
5. Federal Aviation Administration, *NextGen System Analysis and Modeling Office: Oceanic Flight Time Distance Summary*, data file, 2012.
6. Federal Aviation Administration, *Aviation Maintenance Technician Handbook: General*, FAA Handbook FAA-H-8083-30, 2008.
7. Federal Aviation Administration, *Oceanic Tactical Trajectory Management (OTTM) Overview and Timelines*, May 25, 2011.