APPENDIX R

EFFECT OF THE NY/NJ/PHL METROPOLITAN AREA AIRSPACE REDESIGN ON AIRCRAFT FUEL CONSUMPTION

MP 070122

MITRE PRODUCT

Effect of the New York/New Jersey/Philadelphia Airspace Redesign on Aircraft Fuel Consumption

June 2007

Dr. Jonathan H. Hoffman

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MITRE Center for Advanced Aviation System Development McLean, Virginia



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Abstract

The New York/New Jersey/Philadelphia (NY/NJ/PHL) Airspace Redesign proposes substantial changes to aircraft routing and airport and airspace efficiency. As part of the process of developing a Final Environmental Impact Statement (EIS), aircraft fuel consumption in the Preferred Alternative and Mitigated Preferred Alternative is compared to that in the Future No Action Alternative. The Preferred Alternative airspace design would reduce fuel consumption in the study area by about 205 metric tons on the average day in 2011. Mitigation measures proposed to reduce noise exposure burn more fuel than the Preferred Alternative; the Mitigated Preferred Alternative would reduce fuel consumption by about 194 metric tons.

KEYWORDS: Airspace, Airspace Redesign, EDMS, Environmental Impact, Fuel Consumption, Mitigation, New Jersey, New York, Philadelphia, TAAM

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1 Introduction

The Integrated Airspace Alternative with Integrated Control Complex (ICC) has been identified by the Federal Aviation Administration (FAA) as the Preferred Alternative for the New York/New Jersey/Philadelphia (NY/NJ/PHL) Metropolitan Airspace Redesign project. This alternative, as described in Section 2.5 of the Draft Environmental Impact Statement (EIS),

"...involves full airspace consolidation, as well as modifications to multiple departure gates, additional arrival posts, and additional departure headings. This variation represents a full airspace consolidation and is a new approach to the redesign of airspace from NY to Philadelphia. Where current en route airspace separation rules of five nautical miles are typically used, this airspace redesign alternative would use three nautical mile terminal airspace separation rules over a larger geographical area and up to 23,000 feet MSL in some areas. The ICC airspace would be comprised of the majority of current NY TRACON and NY Center airspace, as well as some sectors from Washington Center and Boston Center. Boston Center could take the high-altitude parts of the current NY Center airspace structure."[1]

The Integrated Airspace Alternative with ICC makes some relatively high-altitude airspace design changes, as well as some low-altitude changes to maximize the use of the limited runway capacity available in the New York and Philadelphia metropolitan areas. These changes have an impact on aircraft emissions, because they change flying times and flight patterns.

Several dozen of the comments received on the Draft EIS raised the issue of aircraft emissions. Concern about emissions came from local elected officials, special interest groups, and other agencies of the federal government. In response to these comments, The MITRE Corporation's Center for Advanced Aviation System Development (CAASD) undertook a re-run of its operational efficiency simulations to obtain estimates of the impact on fuel consumption of the Preferred Alternative and the Mitigated Preferred Alternative.

Operational efficiency of an air traffic control system is typically measured in terms of time at a fixed level of traffic. Delay time, extra flying time, and time below a particular altitude have all been used in the operational analyses for the EIS. This paper presents the methods by which efficiency measured in time was converted to efficiency measured in fuel, and an estimate of the relative change in fuel consumption attributable to the two Alternatives. It is intended to accompany the Final EIS for the airspace redesign, so it does not restate the details of the redesign or mitigation measures. Details are available in the operational analyses that have been previously undertaken, which form appendices to the Draft EIS. [2]

2 Modeling Approach

Operational-efficiency simulations of the various Alternative airspace designs were built with the Total Airspace and Airport Modeller (TAAM) [3]. These simulations required minor changes to configuration and output settings to be used for fuel consumption analysis, as well as some additional parameters from two auxiliary models.

2.1 Operational Simulations

The operational and noise analyses of the Preferred Alternative required simulations of the annual-average day of traffic for 2011 in the study area. Two configurations of the five largest airports were included. The two configurations were combined to give an annual-average figure using the same weightings as they received in the operational analysis.

TAAM generates by default a measure of the total fuel consumption in the simulation. This fuel consumption measure takes into account:

- Distance flown by an unimpeded aircraft
- Extra time flown due to delays for sequencing to a runway
- Extra time flown due to delays for merging and spacing on an airway
- Climb and descent profiles

The first two items are by far the most important factors in a fuel consumption analysis.

Because the fidelity of the simulation is minimal outside a range of 200 miles from New York City, the absolute fuel consumption metric in any simulation by itself is not particularly meaningful. (For an extreme example, transatlantic traffic is not modeled beyond the entrance to the North Atlantic Track System.) Only the difference between the fuel consumption in two simulations is valid for assessing the impact of the redesign.

2.2 Auxiliary Models

2.2.1 Fuel-Flow Integrator

CAASD's Integrated Terminal Research, Analysis and Evaluation Capabilities [4] include a "fuel-flow integrator" that is derived from the Eurocontrol Total Energy Model. The fuel-flow integrator is much more controllable via input configuration files than is TAAM, so it can give estimates of fuel consumption in cases where fine distinctions between air traffic control procedures are necessary.

2.2.2 Emissions and Dispersion Modeling System

The Emissions and Dispersion Modeling System (EDMS) "is one of the few air quality assessment tools specifically engineered for the aviation community."¹ It is used for local air quality analyses around airports. The modeling system is primarily concerned with ground operations of aircraft and other vehicles on the airport surface.

EDMS contains a database of most of the aircraft engines currently in use in the US. The database is coordinated with that of the Noise Integrated Routing System, so every flight in the 2011 forecast traffic could be directly related to an EDMS engine type. This database was used for taxi-out operations.

2.3 Corrections to TAAM Fuelburn Numbers

The default fuel consumption estimate in TAAM requires some correction in order to be useful in this context. First, for reasons of processing time, the full alternatives were simulated with no gate and taxiway modeling. Second, due to limitations in the structure of TAAM itself, as aircraft are sequenced for the runway, the fuel they consume is overestimated.

2.3.1 Taxi-Out Delay

The time taken and fuel consumed by aircraft as they taxi from their gates to the runway was not included in the operational analysis simulations. The delays aircraft could expect as they lined up for the runway was estimated, but an aircraft waiting at an airport with no taxiway structure does not consume fuel.

This was corrected by use of the EDMS fuel consumption database. That model converts time spent waiting (independent of cause) into fuel consumption for each aircraft, depending on engine type.

It is assumed for this analysis that gate allocation for aircraft is the same in all alternatives.

2.3.2 Delay by Speed Control

TAAM delays aircraft for sequencing to the runway or for spacing along a jet airway first by speed control. If the aircraft can not absorb enough time by slowing down, vectoring is the second choice. As the aircraft is flying under air traffic control instructions combining vectoring and speed control, TAAM does not change the fuel consumption. A real aircraft, when instructed to absorb delay, slows down to its minimum-fuel speed, so TAAM will overestimate fuel consumption when the aircraft is being sequenced.

¹ The official FAA information site for the model is at <u>http://www.faa.gov/about/office_org/headquarters_offices/aep/models/edms_model/</u>

The fuel-flow integrator, described above, can compensate for this over-simplification. Three different types of jets, a small regional jet, a Boeing 737-500, and a Boeing 747-400, were instructed to fly profiles that absorbed a fixed amount of time, first at their normal cruise speed, then at their minimum-fuel speed. The altitudes were chosen to match those of the most-used vectoring areas in the Future No Action and Preferred Alternative.

Aircraft Type	Delay Absorbed	Fuel Consumption Change
Embraer ERJ-145	2 min at 10,000 ft	22.7 kg
Boeing 737-500	2 min at 10,000 ft	45.5 kg
Boeing 747-400	2 min at 10,000 ft	0

Table 1. Fuel Corrections to Speed-Controlled Aircraft

Each aircraft delayed was matched to the most-similar type of aircraft. Delays up to the maximum speed-control plus vectoring time were credited with the appropriate amount of excess fuel consumption.

2.3.3 Delay by Holding

The aircraft performance model in TAAM has a holding speed, but not a holding fuel consumption. Holding fuel consumption will be less, by the same arguments as for speed control and vectoring.

In all cases, the holding speed matched the minimum-fuel speed calculated by the fuel-flow integrator, so the same method could be applied. The fuel-consumption changes in Table 1 were used for holding times up to 15 minutes.

2.3.4 Delay at Departure Airports

When an aircraft arriving at one of the modeled airports was delayed more than 15 minutes of holding, plus three minutes for speed control and (typically) four minutes absorbable via vectoring, it was assumed that traffic flow management programs would be initiated to moderate the volume at the destination.

These traffic flow management programs were not explicitly modeled in the operational simulations for the Draft EIS. Only the total delay was needed. When the volume of arrivals was too great for the airport to handle without large delays, arriving aircraft were held outside the simulated area. However, there is a substantial difference between ten minutes of fuel burned while holding and ten minutes of fuel burned while waiting to take off. Fuel consumed during the excess delays, therefore, was subtracted from the total for the simulation. Even if the aircraft engines were running during that delay, it was on the ground far from the study area, so it can be assumed not to affect the conclusions we wish to draw about the environmental consequences of this airspace redesign.

3 Results

3.1 Preferred Alternative versus Future No Action

The corrections to the fuel consumption calculated by TAAM typically amounted to about 3% of the total for departure delays (added to the default calculation) and 1-2% for arrivals (subtracted from the calculation).

Table 2 shows the results of the fuel calculation. To simplify the data analysis and validation, the simulation was broken up into sections corresponding to each major airport. "Internals" are flights that both depart from and arrive at one of the simulated airports. Consumption of fuel in the Preferred Alternative is reduced by 205 metric tons (204,920 kg) compared to the Future No Action Alternative, or 66,840 gallons per (average) day.²

Airport	Future No Action Fuel Consumption	Preferred Alternative Fuel Consumption	Preferred Alternative Benefit
EWR	6,640,480	6,583,252	57,229
PHL	4,743,119	4,686,764	56,355
JFK	8,328,735	8,287,755	40,980
LGA+HPN	2,874,567	2,841,432	33,135
Internals	57,175	42,943	14,232
ISP	278,473	265,729	12,745
TEB+MMU	527,269	537,024	-9,755
Total	16,809,338	16,661,646	204,920
	10,009,000	10,001,010	

Table 2. Fuel Consumption by Airport (kg/annual average day)

Several qualitative features visible in Table 2:

- The overall conclusion of the operational analysis is repeated here. Many flights must fly more miles of ground track, but on balance the reduction in delay is worth the extra miles, in fuel as in delay.
- Fuel savings to EWR traffic are diminished because the arrival delay benefits are accomplished by opening a new runway, which entails longer flying distances.
- EWR and PHL traffic see the biggest benefit in terms of fuel consumption because they have the most traffic.

² Specific gravity of jet fuel was obtained from the Material Safety Data Sheet at http://www.chevronglobalaviation.com/docs/aviation_turbine_fuel.doc

- JFK has the highest absolute numbers because it has the highest percentage of international flights by heavy jets, but its benefit are smaller than those at EWR or PHL because of lower overall traffic.
- Delay savings at LGA are large, but the overall savings are smaller than at JFK because the jets that fly there are smaller.
- TEB and MMU flights actually see a small penalty. The low-altitude portions of the arrival and departure procedures are longer to separate them from EWR traffic to the greatest extent possible. Traffic at these airports in Future No Action does not experience the large runway delays seen at the larger airports, so the only delay savings at these airports come from the airway congestion.
- Internal flights show a much larger benefit, compared to the total fuel consumption, than any other sub-simulation. This is because very short flights are usually the most delayed long-haul flights have generally reserved all the landing slots before the internal flight is ready to take off, so the internal flight goes to the back of a very long line. Any improvement in delay, therefore, will be felt most by the internal flights.

3.2 Effect of Mitigation

The differences between the Preferred Alternative and the Mitigated Preferred Alternative [5] do not affect delays to any great extent [6]. They tend to be routing decisions made on a case-bycase basis, so fuel consumption for the Mitigated Preferred Alternative was calculated via perturbations of the Preferred Alternative. That is, each flight changing its track as a result of the mitigation (these flights were previously identified for the noise analysis) is updated in the fuel consumption analysis according to the mitigated track.

Table 3 shows the effect of each mitigation measure on all traffic. In this table, a positive number is an increase in fuel consumption; a negative number denotes a decrease. Note that only one of the impacts is of the same order of magnitude as the benefits of the Preferred Alternative. The "weighted effect" column gives the annualized impact of each mitigation measure that applies only to one airport configuration, taking into account the frequency with which that configuration is used.

Airport	Mitigation	Fuel Consumption Increase (kg)	Weighted Effect (kg)
PHL	3 West Headings	3,330	2,498
	4 East headings	690	173
	River Departures at Night	371	278
	River Approach	-1,727	-432
	Night-time CDA	-165	-165
EWR	Night Ocean Routing	13,306	7,318
	22R Departure Headings	1,595	877
	Raised Downwind Legs	0	0
	Night-time CDA	-65	-65
LGA	Reduced Headings from 31	0	0
	LDA approach to 22	0	0
HPN	Northwest departure track	0	0
Total		19,062	10,482

 Table 3. Fuel Consumption Impact of Mitigation Measures

Most mitigation measures increase fuel consumption, since the Preferred Alternative favored minimum-time tracks at low altitudes, and the shortest-time track is usually the minimum-fuel track. Many mitigation measures sacrificed the shortest-time track for some flights in order to reduce noise exposure. A reduction in the number of departure headings could have either a positive or a negative impact. Reducing headings from one-per-gate to a smaller set increases track length, and therefore fuel consumption, for some flights while reducing it for others. The net effect is a small increase at EWR and PHL, zero at LGA.

PHL departures over the Delaware River at night causes only a small increase, since only a few flights are affected. Implementation of a river approach creates a shorter flight track for flights from the south side of the approach control. Flights from the north side do not use the river approach (that would increase noise exposure), so net fuel consumption is reduced.

Night-time ocean routing causes a large increase in fuel consumption. Almost a quarter of the fuel savings at EWR attributable to the Preferred Alternative would be offset by increased fuel consumption of ocean-routed flights.

Raising the downwind leg from 6,000 to 8,000 ft at EWR has no measurable impact on fuel consumption. The distance flown by the flight remains the same, the airspeed is not affected, and most jet aircraft consume fuel at the same rate at the higher altitude as they do at the lower.

Continuous-descent arrivals decrease fuel consumption. However, at the low altitudes where they are possible in this airspace, the benefit is inconsequential. Almost all of the fuel benefits of continuous-descent arrivals occur in the vicinity of the top-of-descent point. The low-altitude portion of a continuous descent approach benefits noise exposure only.

The two remaining mitigation measures are small lateral displacements of the trajectory in the Preferred Alternative. These displacements shorten some flight tracks and lengthen others, but none by more than a mile or two. The impact on fuel consumption is invisibly small.

3.3 Fuel Consumption in the Mitigated Preferred Alternative

Subtracting the bottom line of Table 3 from the bottom line of Table 2, we find that the Mitigated Preferred Alternative saves 194.4 metric tons of fuel on an average day. Annually, the savings in 2011 would total 71,000 metric tons of fuel, or 23.4 million gallons. This is slightly less than the fuel consumption savings of 24.6 million gallons per year in the Preferred Alternative.

4 Conclusion

The NY/NJ/PHL Airspace Redesign has been shown in previous work to increase the efficiency of air traffic control operations in the study area. The flight-time and delay savings described in the Operational Analysis appendix to the EIS relate directly to reductions in fuel consumption, and the related emission of pollutants. This paper has estimated the effect on fuel consumption of the Preferred Alternative and the Mitigated Preferred Alternative. Table 4 summarizes the qualitative effects of each part of the Alternatives that affects fuel consumption.

Airport	System Change	Preferred Alternative	Mitigated Alternative	Emissions Impact vs. Future No Action
	Realigned airways and			Mixed increases and
All	fixes	Х	Х	decreases
	Delay Reduction	Х	Х	Decrease
LGA	Departure Headings	Х		Decrease
			Х	Reduction of decrease
	Expanded LDA			
	approach		Х	Near zero
EWR	Dual Arrivals	Х	Х	Decrease
	Departure Headings	Х		Decrease
			Х	Reduction of decrease
	Raised Downwind		Х	Near zero
	Midnight Ocean			
	Routing		Х	Increase
	CDA		Х	Decrease
	Improved Runway			
JFK	Usage	Х		Decrease
ISP	Shorter air routes	Х		Decrease
PHL	Departure Headings	Х		Decrease
			Х	Reduction of decrease
	River RNAV Approach		Х	Decrease
	Night River Departure		Х	Near zero
	CDA		Х	Decrease
	Northwest departure			
HPN	track		Х	Near zero

Table 4. Summary of Fuel Consumption Impacts

Fuel consumption was estimated by using a trio of computer models: Overall aircraft performance while airborne was determined in a TAAM simulation. Fuel consumed on the ground was estimated via data adapted from the EDMS. Corrections to the fuel consumption due to expanded use of speed control in the Preferred Alternative were obtained from the Fuel Flow Integrator.

The Preferred Alternative would reduce fuel consumption on an average day in 2011 by almost 205 metric tons, compared to the Future No Action Alternative. Mitigation measures to reduce noise exposure cause more fuel to be burned, compared to the Preferred Alternative, though it still represents a saving over No Action. The Mitigated Preferred Alternative would reduce fuel consumption by just over 194 metric tons per day.

4.1 Limitations of the Study

Only differences among the alternatives are valid in this study. Absolute numbers are not operationally meaningful, since flights are not modeled in great detail anywhere more than 200 miles from New York City. Traffic at smaller airports in the study area is held constant across the alternatives, so it was excluded from the calculations.

This study did not attempt to distinguish fuel burned below the mixing layer at each airport from fuel burned above. Over such a large study area, the total fuel consumed was a more appropriate metric.

Fuel burned by service vehicles on the airport surface is typically part of an airport emissions analysis. It is not included here. Service vehicle emissions are assumed constant over all alternatives in this study because the flight schedules do not change.

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Glossary

CAASD	Center for Advanced Aviation System Development
EDMS	Emissions and Dispersion Modeling System
EIS	Environmental Impact Statement
EWR	Newark Liberty International Airport
FAA	Federal Aviation Administration
HPN	Westchester County Airport
ICC	Integrated Control Complex
ISP	Long Island MacArthur Airport
JFK	John F. Kennedy International Airport
LGA	LaGuardia Airport
MMU	Morristown Municipal Airport
NJ	New Jersey
NY	New York
PHL	Philadelphia
TAAM	Total Airspace and Airport Modeller
ТЕВ	Teterboro Airport