NASA/CR–2015-218787

Annualized TASAR Benefit Estimate for Alaska Airlines Operations

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August 2015

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Prepared for Langley Research Center
under Contract NNL12AA06C

August 2015

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Preface

This document describes a simulation study to estimate annualized Traffic Aware Strategic Aircrew Requests (TASAR) benefits for Alaska Airlines operations. This document represents deliverable 41A for TASAR Analysis and Development.

This document was prepared by Engility Corporation, 900 Technology Park Dr., Billerica, MA under Contract No. NNL12AA06C with NASA Langley Research Center, Hampton, VA.

Abstract

The Traffic Aware Strategic Aircrew Request (TASAR) concept offers onboard automation for the purpose of advising the pilot of traffic compatible trajectory changes that would be beneficial to the flight. A fast-time simulation study was conducted to assess the benefits of TASAR to Alaska Airlines. The simulation compares historical trajectories without TASAR to trajectories developed with TASAR and evaluated by controllers against their objectives. It was estimated that between 8,000 and 12,000 gallons of fuel and 900 to 1,300 minutes could be saved annually per aircraft. These savings were applied fleet-wide to produce an estimated annual cost savings to Alaska Airlines in excess of $5 million due to fuel, maintenance, and depreciation cost savings. Switching to a more wind-optimal trajectory was found to be the use case that generated the highest benefits out of the three TASAR use cases analyzed. Alaska TASAR requests peaked at four to eight requests per hour in high-altitude Seattle center sectors south of Seattle-Tacoma airport.

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1. Introduction

The Traffic Aware Strategic Aircrew Request (TASAR) concept offers onboard automation for the purpose of advising the pilot of traffic compatible trajectory changes that would be beneficial to the flight. The TASAR onboard automation leverages surveillance information to increase the likelihood of air traffic control (ATC) approval of pilot-initiated trajectory change requests, thereby increasing the portion of the flight flown on or near a desired business trajectory. All automation and pilot procedures are fully dedicated to a single aircraft which allows tailoring of optimization criteria to the objectives of each flight and provides for timely responses to changing situations.

A preliminary fast-time simulation benefits assessment[1] estimated the benefits of three TASAR use cases: (1) lateral change after a reroute traffic management initiative (TMI) ends, (2) lateral change in the presence of convective weather, and (3) switch to a more wind-optimal trajectory (altitude, lateral, or combination). The agent-based simulation contained aircrew/TASAR agents that generate requests that improve on the efficiency of historical trajectories and controller agents that evaluate these TASAR requests against their objectives. The benefits of TASAR were assessed for generic network, low cost, regional, and business jet airspace users. Network carriers saved, on average, 543 lbs of fuel (about 80 gallons) per flight and about 3.6 minutes per flight. The rate of Automatic Dependent Surveillance-Broadcast (ADS-B) Out equipage among traffic aircraft did not significantly impact benefits but lower levels of ADS-B Out adoption caused controllers to receive more TASAR requests that may cause conflicts and therefore would not be immediately approveable.

This report builds on the preliminary benefits assessment by tailoring results to a specific airspace user, Alaska Airlines. It extends the previous study by developing estimates of annual fuel and time cost savings due to TASAR specifically for Alaska. Historical Alaska Airline trajectories are used as a baseline for comparison to simulated trajectories that consider potential TASAR requests. Also, peak requests by sector are studied in an attempt to further understand the impact of TASAR on ATC.

The document is divided into the following sections:

- Section 1 introduces the annualized benefits assessment
- Section 2 describes three use cases that were quantified
- Section 3 describes the simulation platform and method to quantify benefits
- Section 4 estimates annualized benefits results for Alaska Airlines
- Section 5 estimates impact of Alaska Airline TASAR requests on ATC
- Section 6 describes potential future refinements of the benefits assessment

2. TASAR Use Cases Analyzed

Benefits of three types of aircrew requests were quantified. Other types of aircrew requests that were not modeled have opportunities for benefits and therefore this analysis represents only part of the expected full benefit of TASAR. The benefits of the following three types of aircrew requests were quantified in this paper:

1) An aircraft is part of a reroute initiative to avoid convective weather or mitigate congestion. Aircraft in these initiatives are sometimes not shifted back to user-preferred routes after the initiative has ended. The aircrew requests a lateral trajectory change to a more efficient route.

2) An aircraft is impacted by convective weather, and there is sufficient lead time to the convective weather to allow a strategic route change rather than a tactical heading change. The aircrew requests a lateral trajectory change consisting of one or two named waypoints along the trajectory before reconnecting to the route.

3) The aircrew requests a trajectory change (lateral, altitude, or combination lateral and altitude) to switch to a more wind-optimal trajectory. This request for a more wind-optimal trajectory is intended to occur when the aircraft is not impacted by a reroute initiative or convective weather.

The following logic is used to classify flights into one of the three request types. If an aircraft is part of a reroute initiative that began before the aircraft departed, and the reroute initiative is cancelled or ended before the aircraft reached the arrival fix, then the aircraft is classified as aircrew request type (1) above (even if convective weather is present, since there may be overlap between the three request types). The data source for reroute initiatives is the National Traffic Management Log (NTML), available on the Federal Aviation Administration (FAA) Command Center website (www.fly.faa.gov). If at least one of the alternative routes of the aircraft is projected to enter convective weather, and the aircraft is not part of a reroute initiative that ends or is cancelled, then the aircraft is classified as request type (2). The data source for convective weather is Next-Generation Radar (NEXRAD) radar mosaic base reflectivity (www.ncdc.noaa.gov). Certain conditions allow aircraft to request a higher altitude to fly over convective weather, but this is not included as part of (2) and so convective weather tops data is not considered. All other aircraft are classified as request type (3). However, there is overlap between the aircrew request types since the aircrew seeks a wind-optimal solution in all cases, but aircrew request type (3) does not have a reroute initiative or severe convective weather impacting the aircraft.

3. Simulation Platform and Method to Quantify Benefits

An existing fast-time simulation platform that connects to the Future Air Traffic Management Concept Evaluation Tool (FACET) through an Application Programming Interface (API) was used to model trajectories and airspace structure such as routes and sectors. In the integrated platform, two instances of FACET were used. One instance of FACET, the simulator FACET, was used to model the current state (simulation clock time) of aircraft trajectories. The other instance of FACET, the predictor FACET, was used to model future states of aircraft trajectories to test TASAR aircrew requests for conflicts with surrounding aircraft, conflicts with airspace hazards, and to calculate the impacts of TASAR aircrew trajectory change requests on user time and fuel objectives. Both the simulator and predictor instances of FACET were updated at one minute increments.

Input files to the simulation platform contain flight plans as well as corresponding historically flown four-dimensional (4D) trajectories. Aircraft were modeled to follow their flown trajectory until an aircrew request is granted. Traffic information was obtained from historical Aircraft Situation Display to Industry (ASDI) data.

FACET was configured to predict future aircraft positions differently for historically flown 4D trajectories as compared to alternate trajectories generated by TASAR. Aircraft following their historically flown 4D trajectory did not use aircraft performance or atmospheric models and instead, arrived at the 4D waypoints as specified in the input file. For synthesizing alternate trajectories generated by TASAR, FACET converted the flight plan to a series of latitude and longitude waypoints that were simulated based on aircraft performance models. Wind modeling was based on historical Rapid Update Cycle (RUC) winds data that was read from outside of FACET and was used to update the aircraft groundspeed.

3.1 TASAR Alternative Trajectory Generation (Optimization Model)

In the simulation, TASAR evaluated alternative trajectories at five-minute intervals between the top-of-climb to 200 nmi from the destination airport. Trajectories were evaluated against a 50% fuel / 50% time objective and TASAR advisories were rejected if they increased fuel burned or flight time (i.e., tradeoffs between fuel burn and flight time were not considered).

The use of voice for aircrew requests limited the alternative lateral trajectories to changing one or two named waypoints before reconnecting to the original trajectory. A bounding box was created for each origin-destination airport pair. All navigation aids inside the bounding box were used to generate alternative trajectories. The bounding box was based on the geographical extent of the flown trajectories between each origin-destination airport pair.

Three alternate altitudes were considered at 2,000 feet above, 2,000 feet below, and 4,000 feet below the assigned altitude. Climbing was only permitted if the aircraft was at flight level (FL) 350 or below to be conservative since aircraft weight was not modeled in the simulation. Alternative trajectories consisted of lateral changes only, altitude changes only, and combination altitude and lateral changes. The aircraft in the simulation were modeled to follow their historical 4D trajectories once the aircraft were within 200 nmi of the destination airport.

3.2 TASAR Request Model

TASAR logic in the simulation implements filters to prevent the aircrew making requests that would be considered unacceptable to the controller. Requests were not made if any of the following conditions are true:

- Aircraft-aircraft conflict was predicted. The alternative trajectories generated by TASAR were probed to an eight-minute horizon to determine if there was a conflict with the surrounding traffic using a conservative ten nmi lateral and 1,000 ft vertical minimum separation shell. It was assumed that 100% of traffic was equipped with ADS-B Out since the earlier TASAR benefits study indicated that ADS-B Out equipage impacts ATC acceptability and workload but not user benefits since pilots could make a user request soon after a denied request. It was assumed that the conflict probe did not have access to flight plans and instead relied on state projections using current heading, vertical rate, and speed. Post-processing of simulation results to assess the impact of ADS-B Out equipage is discussed in Section 5.

- Aircraft-airspace hazard conflict was predicted. Alternative trajectories were also probed for conflicts with airspace hazards including special activity airspace (SAA) and severe convective weather. Airspace hazards, either weather or SAA, were defined as polygons with a floor, ceiling, and schedule for activation and deactivation. Polygons were dynamic in the sense that they are active for a defined period of time and then replaced by other polygons at different locations to mimic the motion of convective weather. If the aircraft was predicted (using the FACET predictor instance) to be inside an airspace hazard polygon, then the TASAR automation was modeled to be aware of the airspace hazard conflict.

- Aircraft had already made a request to current sector controller. Multiple requests in a sector are unreasonable and the aircrew waits until the next sector to make another request if the initial request is denied.

- Aircraft was estimated to be in handoff status once the aircraft was within approximately 20 nmi of the sector boundary. Any request received while the aircraft is in handoff status is likely to be met with the response to make the request to the next sector controller.

- Aircraft was on initial climb from origin airport and had not yet reached cruising altitude. Controllers are concerned about potential interference of the departure stream with the arrival stream, so requests are generally denied until the aircraft reaches cruising altitude.

- Aircraft is within 200 nmi of a large hub destination airport. Controllers indicated that aircraft must generally be on their assigned arrival route within 200 nmi of a large hub destination airport.

3.3 Controller Evaluation of TASAR Requests

The controller was modeled to reject an aircrew request if any of the following conditions exist.

- The aircrew request was projected to cause an aircraft-aircraft conflict. The controller had more information about the surrounding traffic than the TASAR-equipped aircraft including (1) the flight plans for all aircraft and (2) the ADS-B-equipped aircraft beyond the sixty nmi assumed ADS-B range.

- The aircrew request occurs in a sector that was experiencing traffic exceeding its monitor alert parameter value (i.e., a red sector). This was an attempt to model the phenomenon that, as traffic demand increases in their sector, controllers develop plans to cope with the rising traffic and, unless the request is consistent with the controller plan, the aircrew request is likely to be denied. Under higher traffic levels the aircrew request is less likely to be consistent with the controller plan

- The aircrew request was projected to enter an adjacent red sector. Controllers are generally not aware of red sectors elsewhere and will not consider traffic demand in other sectors when evaluating aircrew requests. However, the area manager may instruct the controller not to send traffic through an adjacent sector if the adjacent sector is currently experiencing high traffic.

The TASAR filters described previously, such as not making multiple requests to the same sector controller, were not applied again on the controller side since these types of requests would not reach the controller in the simulation.

4. Annualized TASAR Benefit Results for Alaska Airlines

The benefits analysis focused on Alaska operations in the continental United States. TASAR does not currently support oceanic operations and Alaska is not expecting to equip 737-400 aircraft operating in Alaska with TASAR. The focus is on 737-900ER, 737-900, 737-800, and 737-700 Alaska aircraft which are candidates to be equipped with TASAR.

4.1 Airport Pair Selected for Analysis

The Bureau of Transportation Statistics (BTS) T-100 Domestic Segment database[i] from April 2013 to March 2014 was used to determine the annual frequency of Alaska operations between airport pairs by aircraft type. The departures performed and aircraft type fields in the T-100 database were used to determine annual operations by aircraft type. These annual operations were then divided by the number of aircraft of each type to obtain the operations per aircraft shown in Table 1. The airport pairs that were analyzed are shown as shaded cells. Some of the airport pairs were selected since they are longer

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[i] http://www.transtats.bts.gov/Fields.asp?Table_ID=311

haul with a potential for higher TASAR benefits. The remaining airport pairs in the continental United States were not analyzed due to time constraints.

Table 1. Annual operations per aircraft by airport pair and aircraft type. Airport pairs analyzed are shaded.

Airport 1	Airport 2	Annual Operations per Aircraft			
		737-900ER	737-900	737-800	737-700
ANC	SEA	118	58	49	64
LAX	SEA	61	133	38	66
LAS	SEA	78	83	32	76
SAN	SEA	15	23	47	45
SEA	SFO	32	18	26	63
SEA	SNA	0	0	18	235
ANC	FAI	0	0	4	37
PHX	SEA	30	33	10	68
SEA	SJC	11	37	36	19
LAX	PDX	26	36	15	21
SEA	SMF	4	3	39	11
OAK	SEA	5	3	29	30
DEN	SEA	2	19	12	134
ANC	JNU	0	2	0	0
LAS	PDX	7	18	15	78
JNU	SEA	4	9	6	0
GEG	SEA	0	0	0	44
PDX	SAN	7	11	21	7
BUR	SEA	0	0	10	95
FAI	SEA	19	11	6	44
PDX	SNA	0	0	3	124
HNL	SEA	0	0	3	0
ANC	PDX	11	10	16	15
PDX	SFO	8	5	8	39
ONT	SEA	4	16	4	23
ORD	SEA	19	77	9	0
DFW	SEA	32	39	6	15
PDX	SJC	2	12	13	29
MSP	SEA	11	11	8	34
DCA	SEA	0	0	22	0
EWR	SEA	40	1	8	0
PSP	SEA	6	3	3	17
BOS	SEA	30	4	13	0
OGG	SEA	0	0	1	0
PSP	SFO	0	0	0	14
SEA	SLC	1	15	17	5
PDX	PHX	3	14	5	19
ATL	SEA	12	3	9	11
MCO	SEA	13	1	10	0
KOA	SEA	0	0	1	0
BLI	LAS	1	2	12	0

Airport 1	Airport 2	Annual Operations per Aircraft			
		737-900ER	737-900	737-800	737-700
BRW	SCC	0	0	1	0
SAT	SEA	4	8	9	0
AUS	SEA	8	36	2	0
SEA	TUS	12	8	6	0
IAH	SEA	31	1	1	0
MCI	SEA	9	9	7	0
ORD	PDX	5	12	2	25
PHL	SEA	16	3	5	0
SEA	STL	4	2	9	0
FLL	SEA	0	0	11	0
DCA	PDX	0	0	11	0
DCA	LAX	0	0	11	0
BOS	PDX	0	0	10	0
ANC	LAX	8	1	6	13
BOS	SAN	0	0	11	0
PDX	PSP	2	2	1	9
MCO	SAN	2	0	7	0
ANC	ORD	0	0	9	0
BRW	FAI	0	0	1	0
FAI	SCC	0	0	1	0
ATL	PDX	5	1	5	0
DFW	PDX	4	8	3	0
Total annual operations by aircraft type		720	802	712	1528

4.2 Simulation Fuel and Time Savings Estimates

Historical Alaska flights in July, August, and September 2012 were analyzed in the simulation platform to produce the simulation results detailed in Appendix A. The expired reroute initiative and convective weather use cases did not occur frequently (less than 5% of historical flights). This does not imply that 5% of flights were impacted by convective weather since flights may be delayed or cancelled at large hub airports until the convective weather passes and therefore TASAR would not interact with convective weather data. The expired reroute initiative had highest average benefit (103 gallons/operation, 7.8 min/operation) and the convective weather use cases had the lowest benefit (12 gallons/operation, 1.3 min/operation) with the wind use case falling in between (27 gallons/operation, 2.3 min/operation).

Due to the lower convective weather use case per operation benefit, the results are scaled without attempting to estimate the number of annual convective weather use cases. For example, 2 out of 29 historical 737-800 flights between Washington National (DCA) and Seattle (SEA) were classified as expired reroute initiative and each 737-800 operates between DCA and SEA an average of 22 times annually so (2/29)*22 = 1.5 annual cancelled expired reroute initiative use cases between DCA and SEA per 737-800. This will be a conservative underestimation since convective weather is more common in the months analyzed than other times of the year. The result of scaling the fuel and time results in Appendix A are show in Tables 2 to 5. Benefits are a function of both the benefit per operation and number of operations so that the Newark-Seattle (EWR-SEA) airport pair fuel benefit of about 2,200 gallons per aircraft per year is higher than the Los Angeles-Seattle (LAX-SEA) airport pair fuel benefit of about 900 gallons per aircraft per year even though there are about 50% more flights between LAX-SEA than EWR-SEA.

Table 2. Annual fuel and time benefits by use case for 737-900ER.

Apt 1	Apt 2	Annual Benefit Cancelled Initiative Use Case (1)			Annual Benefit Weather Use Case (2)			Annual Benefit Wind Use Case (3)		
		Num	Fuel (Gal)	Time (Min)	Num	Fuel (Gal)	Time (Min)	Num	Fuel (Gal)	Time (Min)
EWR	SEA	0.0	0.0	0.0	2.5	0.0	0.0	37.5	2267.9	325.8
BOS	SEA	0.0	0.0	0.0	0.0	0.0	0.0	30.0	1763.8	271.9
MCO	SEA	0.0	0.0	0.0	0.0	0.0	0.0	13.0	1550.3	143.0
LAS	SEA	0.0	0.0	0.0	0.0	0.0	0.0	78.0	1291.9	106.5
DFW	SEA	0.0	0.0	0.0	6.2	191.6	6.2	24.8	1119.7	148.8
LAX	SEA	0.0	0.0	0.0	0.0	0.0	0.0	61.0	902.6	87.6
ORD	SEA	2.1	561.6	52.8	2.1	72.7	8.4	14.8	616.6	84.7
MSP	SEA	0.3	6.8	0.9	0.6	7.1	0.6	10.1	535.0	35.2
PHX	SEA	0.0	0.0	0.0	0.0	0.0	0.0	30.0	433.6	40.0
SEA	SFO	0.0	0.0	0.0	0.0	0.0	0.0	32.0	293.9	28.8
SAN	SEA	0.0	0.0	0.0	0.0	0.0	0.0	15.0	179.1	15.0
SEA	STL	0.0	0.0	0.0	0.0	0.0	0.0	4.0	110.3	9.3
SEA	TUS	0.0	0.0	0.0	0.0	0.0	0.0	12.0	84.3	9.6
DEN	SEA	0.0	0.0	0.0	0.1	0.0	0.0	1.9	51.5	3.5
PDX	PHX	0.0	0.0	0.0	0.0	0.0	0.0	3.0	2.3	2.3
Sum			568.4	53.7		271.4	15.3		11202.7	1312.2

Table 3. Annual fuel and time benefits by use case for 737-900.

Apt 1	Apt 2	Annual Benefit Cancelled Initiative Use Case (1)			Annual Benefit Weather Use Case (2)			Annual Benefit Wind Use Case (3)		
		Num	Fuel (Gal)	Time (Min)	Num	Fuel (Gal)	Time (Min)	Num	Fuel (Gal)	Time (Min)
ORD	SEA	0.0	0.0	0.0	4.8	0.0	0.0	72.2	3011.9	413.9
LAX	SEA	0.0	0.0	0.0	0.0	0.0	0.0	133.0	1967.9	191.1
DFW	SEA	0.0	0.0	0.0	0.0	0.0	0.0	39.0	1760.8	234.0
LAS	SEA	0.0	0.0	0.0	0.0	0.0	0.0	83.0	1374.7	113.3
DEN	SEA	0.0	0.0	0.0	0.6	0.0	0.0	18.4	489.0	33.5
PHX	SEA	0.0	0.0	0.0	0.0	0.0	0.0	33.0	477.0	44.0
MSP	SEA	0.0	0.0	0.0	2.2	68.0	2.2	8.8	468.1	30.8
SAN	SEA	0.0	0.0	0.0	0.0	0.0	0.0	23.0	274.5	23.0
BOS	SEA	0.0	0.0	0.0	0.0	0.0	0.0	4.0	209.1	36.3
SEA	SFO	0.0	0.0	0.0	0.0	0.0	0.0	18.0	165.3	16.2
MCO	SEA	0.1	29.6	2.8	0.1	3.8	0.4	0.8	89.6	8.6

Apt 1	Apt 2	Annual Benefit Cancelled Initiative Use Case (1)			Annual Benefit Weather Use Case (2)			Annual Benefit Wind Use Case (3)		
		Num	**Fuel (Gal)**	**Time (Min)**	**Num**	**Fuel (Gal)**	**Time (Min)**	**Num**	**Fuel (Gal)**	**Time (Min)**
SEA	TUS	0.0	0.0	0.0	0.0	0.0	0.0	8.0	56.2	6.4
SEA	STL	0.0	0.0	0.0	0.0	0.0	0.0	2.0	55.1	4.7
EWR	SEA	0.0	0.6	0.1	0.1	0.6	0.1	0.9	54.4	7.9
PDX	PHX	0.0	0.0	0.0	0.0	0.0	0.0	14.0	10.8	0.0
Sum			30.2	2.9		72.5	2.7		10464.5	1163.6

Table 4. Annual fuel and time benefits by use case for 737-800.

Apt 1	Apt 2	Annual Benefit Cancelled Initiative Use Case (1)			Annual Benefit Weather Use Case (2)			Annual Benefit Wind Use Case (3)		
		Num	**Fuel (Gal)**	**Time (Min)**	**Num**	**Fuel (Gal)**	**Time (Min)**	**Num**	**Fuel (Gal)**	**Time (Min)**
DCA	SEA	1.5	213.4	20.5	2.3	27.1	3.8	18.2	1429.1	137.3
MCO	SEA	1.1	295.6	27.8	1.1	38.3	4.4	7.8	1010.5	85.6
SAN	SEA	0.0	0.0	0.0	1.7	5.2	1.1	45.3	790.6	59.7
BOS	SEA	0.0	0.0	0.0	0.0	0.0	0.0	13.0	763.9	117.8
ORD	SEA	0.0	0.0	0.0	0.0	0.0	0.0	9.0	538.1	64.0
LAS	SEA	0.0	0.0	0.0	0.5	5.7	0.5	31.5	526.0	39.8
DCA	LAX	0.3	14.4	1.7	0.3	3.9	1.7	10.3	500.4	59.9
EWR	SEA	0.2	4.9	0.7	0.5	5.1	0.5	7.3	495.1	63.5
FLL	SEA	0.0	0.0	0.0	0.9	53.8	7.8	10.1	483.7	99.0
LAX	SEA	0.0	0.0	0.0	0.6	0.0	0.0	37.4	447.2	36.3
DEN	SEA	0.0	0.0	0.0	0.2	2.7	0.2	11.8	317.8	28.0
DCA	PDX	0.0	0.0	0.0	0.0	0.0	0.0	11.0	238.5	33.0
DFW	SEA	0.0	0.0	0.0	0.1	0.0	0.0	5.9	231.0	24.0
MSP	SEA	0.0	0.0	0.0	0.7	3.0	0.7	7.3	223.9	27.6
PHX	SEA	0.0	0.0	0.0	0.0	0.0	0.0	10.0	148.9	15.1
SEA	SFO	0.0	0.0	0.0	0.0	0.0	0.0	26.0	102.6	10.4
SEA	TUS	0.0	0.0	0.0	0.3	0.0	0.0	5.7	20.6	2.4
SEA	STL	0.0	0.0	0.0	2.1	4.2	0.5	6.9	18.1	1.6
Sum			528.3	50.6		149.0	21.3		8286.0	905.2

Table 5. Annual fuel and time benefits by use case for 737-700.

Apt 1	Apt 2	Annual Benefit Cancelled Initiative Use Case (1)			Annual Benefit Weather Use Case (2)			Annual Benefit Wind Use Case (3)		
		Num	**Fuel (Gal)**	**Time (Min)**	**Num**	**Fuel (Gal)**	**Time (Min)**	**Num**	**Fuel (Gal)**	**Time (Min)**
DEN	SEA	0.0	0.0	0.0	0.0	0.0	0.0	134.0	5294.1	562.8

Apt 1	Apt 2	Annual Benefit Cancelled Initiative Use Case (1)			Annual Benefit Weather Use Case (2)			Annual Benefit Wind Use Case (3)		
		Num	Fuel (Gal)	Time (Min)	Num	Fuel (Gal)	Time (Min)	Num	Fuel (Gal)	Time (Min)
PHX	SEA	2.3	207.9	7.6	5.3	216.7	8.3	60.4	2497.8	100.5
SAN	SEA	0.0	0.0	0.0	0.0	0.0	0.0	45.0	1272.3	92.8
MSP	SEA	0.0	0.0	0.0	0.0	0.0	0.0	34.0	1050.0	104.6
DFW	SEA	0.0	0.0	0.0	0.0	0.0	0.0	15.0	830.2	74.5
LAX	SEA	0.0	0.0	0.0	6.2	193.8	20.6	59.8	302.2	35.1
SEA	SFO	0.0	0.0	0.0	3.0	36.5	3.0	60.0	284.5	25.5
PDX	PHX	0.0	0.0	0.0	3.2	12.0	0.8	15.8	81.0	6.3
Sum			207.9	7.6		459.0	32.7		11612.0	1002.1

4.3 Estimating Annualized Cost Savings

BTS Form 41[i] financial data was used to obtain fuel, maintenance, and depreciation costs in order to convert fuel and time savings to cost savings.

Form 41 Schedule P-12(a) reported $111,391,459 cost for 34,199,887 gallons of fuel for Alaska Airlines in March 2014 for an average cost of $3.26/gallon. This cost of $3.26/gallon was multiplied by the sum of fuel savings and the number of aircraft of that type to obtain a total annual savings of $3.39 million per year as shown in Table 6. The annual fuel savings column adds the fuel savings for the three use cases reported in Tables 2 to 5 and rounds down to the nearest 1,000 gallons. The 737-800 is shown producing the lowest fuel savings (8,000 gallons per aircraft per year) but this was caused by only simulating 289 of an estimated 712 operations rather than any specific reason that would cause the aircraft to experience lower benefits if equipped with TASAR. For all aircraft, the fuel savings in Table 6 represents a lower bound that most likely underestimates benefits since not all aircraft pairs shown in Table 1 were analyzed.

Table 6. Summary of fuel cost savings calculation.

Aircraft Type	Number of Aircraft of Type	Annual Ops Simulated / Estimated Annual Ops [ii]	Annual Fuel Savings per Aircraft (gallons)	Fuel Cost	Fuel Cost Savings for All Aircraft of Type
737-900ER	22	381/720	12,000	$3.26	$860,640
737-900	12	466/802	10,000	$3.26	$391,200
737-800	61	289/712	8,000	$3.26	$1,590,880
737-700	14	444/1,528	12,000	$3.26	$547,680
				Sum	$3,390,400

Form 41 Schedule P-5.2 reports the total maintenance, depreciation, and aircraft hours by aircraft type for Alaska Airlines and other large carriers. These figures were used to

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[i] http://www.transtats.bts.gov/Tables.asp?DB_ID=135

[ii] Already used in fuel savings column to the right. Shown to illustrate that different amount of operations for each aircraft type causes difference in benefits.

estimate maintenance and depreciation costs per minute by aircraft type. Alaska incurs other costs, including crew costs, but it was decided to exclude these from the analysis. The time savings may also result in increased customer satisfaction over time but no attempt was made to quantify that benefit.

Table 7. Summary of maintenance and depreciation savings calculation.

Aircraft Type	Number of Aircraft of Type	Time Savings per Aircraft (min)	Maintenance Cost per min	Maintenance Cost Savings for All Aircraft of Type	Depreciation Cost per min	Depreciation Cost Savings for All Aircraft of Type
737-900ER	22	1,300	$8.44	$241,384	$8.72	$249,392
737-900	12	1,100	$8.44	$111,408	$8.72	$115,104
737-800	61	900	$4.96	$272,304	$6.75	$370,575
737-700	14	1,000	$21.4	$299,600	$7.18	$100,520
			Sum	$924,696	Sum	$835,591

The fuel, maintenance, and depreciation costs are added which results in a total cost savings of about $5.15 million annually ($3,390,400 + $924,696 + $835,591 = $5,150,687).

These benefits were a result of lateral (44% of requests), vertical (5% of requests), and combination lateral and vertical TASAR requests (51% of requests). A breakdown of these percentages by aircraft type is included in Appendix B.

5. ATC Impacts

A total of 4,481 TASAR requests were simulated of which 285 (6%) were rejected due to conflicts (150) and other factors (135). Recall that it was assumed in the simulation that 100% of traffic aircraft was equipped with ADS-B Out. However, this did not result in TASAR detecting all conflicts since TASAR does not have as much information as the controller. A total of 5,342 requests which, if approved, would save fuel and time were not made by TASAR aircraft since they were predicted to be unapproveable to ATC including 971 due to conflicts.

If the surrounding traffic was not equipped with ADS-B Out or the TASAR ownship was not equipped with ADS-B In then this would imply that approximately (285 + 971) / (4,481 + 971) = 23% would reasonably expected to be rejected. The (285 + 971) includes the original 285 rejections and the 971 requests not made since they were predicted by TASAR to contain conflicts and, without both surrounding traffic being equipped with ADS-B Out and TASAR ownship being equipped with ADS-B In, these conflicts would not be known to TASAR and the requests would have been made. Therefore, while the previous benefit study indicated that ADS-B Out equipage rate and TASAR ownship ADS-B In equipage does not significantly impact benefits, they are important in reducing nuissance requests that increase controller workload. Also, while an attempt has been made to model controller behavior as closely as possible there is still uncertainty as to whether a controller will or will not grant a request. Even if a request would cause a conflict, the controller may hold onto the request and wait for the traffic to pass and be clear of projected conflicts before granting the request.

It was found that requests were concentrated in sectors south of SEA due to significant Alaska north-south traffic between SEA and airports to the south and east (e.g, SFO, LAX, DEN, PHX). 23% of requests were found to occur in four high altitude (FL 240+) sectors: ZSE46, ZSE13, ZSE14, and ZOA31.

Due to computational reasons, there was only one TASAR aircraft active in the simulation at once so the following procedure, which also takes into account that not all airport pairs were simulated, was used to estimate daily requests by sector across multiple simulation runs. The following statistics were used to derive (1) the expected daily TASAR requests per day and (2) TASAR requests not made due to conflicts: average daily Alaska flights between SEA and other continental US airports (192) derived from Table 1, the number of flights simulated (1,589), the number of TASAR requests by sector, and TASAR requests not made due to conflicts (i.e., filtered) by sector . For example, ZSE46 had 353 requests reported in the simulation so it was estimated that (353)(192/1589) = 43 requests per day occur in ZSE46. The requests not made (filtered) were used to approximate the number of requests if the aircraft was not equipped with ADS-B. These filtered requests were added to requests made to approximate the number of requests if the TASAR aircraft was not equipped with ADS-B In or traffic aircraft were not equipped with ADS-B Out. A summary of this calculation is shown in Table 8 for the ten sectors receiving the most TASAR requests.

Table 8. TASAR requests per day by sector where TASAR request occurs.

Sector where TASAR Request Occurs	TASAR Requests (1)	TASAR Requests not Made due to Conflicts (2)	Requests Made + Requests not Made: (1) + (2) = (3)	Requests per Day with ADS-B In: (1) * (192 / 1589)	Requests per Day without ADS-B In: (3) * (192 / 1589)
ZSE46	353	0	353	43	43
ZSE13	266	117	383	32	46
ZSE14	220	27	247	27	30
ZOA31	192	80	272	23	33
ZOA43	150	59	209	18	25
ZOA36	135	1	136	16	16
ZOA32	126	47	173	15	21
ZSE47	116	20	136	14	16
ZSE15	112	0	112	14	14
ZSE02	108	0	108	13	13

Requests per hour by sector was approximated by binning the TASAR request times into hours and scaling by requests per day (e.g., scale ZSE46 hourly results by 43/353) to account for the fact that flights were simulated across multiple days. Table 9 shows hourly results for the four sectors with the most requests which indicate that 4 to 8 requests per sector occur during the peak hours of about 8 AM, 2 PM, and 9 PM. If necessary, the peak requests of 4 to 8 requests per sector per hour could potentially be managed through coordination with dispatchers or another procedure.

Table 9. TASAR requests per hour by sector where TASAR request occurs.

Hour of Request (Pacific time)	ZSE46 Average Requests in Hour	ZSE13 Average Requests in Hour	ZSE14 Average Requests in Hour	ZOA31 Average Requests in Hour
0	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0
7	0.1	0.0	1.6	3.7
8	5.2	3.1	3.7	2.2
9	2.3	2.0	1.8	1.4
10	4.3	4.0	2.0	1.0
11	1.7	0.8	1.5	0.7
12	1.3	0.8	0.6	1.0
13	1.8	1.9	1.0	2.3
14	4.1	3.9	3.2	1.1
15	3.5	2.4	1.4	1.1
16	1.8	1.1	0.1	0.0
17	1.2	1.4	0.8	0.0
18	0.6	1.7	1.4	2.0
19	2.3	1.5	0.4	0.0
20	2.3	4.8	2.9	4.4
21	8.0	2.5	3.9	2.0
22	2.2	0.8	1.4	0.3
23	1.1	0.8	0.0	0.0

6. Future Work

A TASAR flight trial is planned for 2015 with one of the objectives to develop a methodology to verify the accuracy of the TASAR Traffic Aware Planner (TAP) software computed outcomes. This method could be applied to the simulation benefits results presented in this report to verify that benefits are not systematically being over or under reported. Following that flight test, it is expected that TASAR will be placed on an Alaska revenue flight so the method can be applied and suitable adjustments made to TAP and the benefits assessment.

Observations at ATC facilities are also planned which could be used to refine controller models in the simulation to better estimate the conditions under which a TASAR request is accepted or rejected.

7. References

[1] Henderson, J., Wing, D.J., and Idris, H., "Preliminary Benefits Assessment of Traffic Aware Strategic Aircrew Requests (TASAR)", *AIAA 12th Aviation Technology, Integration, and Operations Conference (ATIO)*, Indianapolis, IN, September 2012.

Appendix A: Simulation Fuel and Time Savings

This appendix includes fuel and time savings output from the fast-time simulation platform for each aircraft type. The simulation platform uses the same aircraft model for the 737-900 and 737-900ER so the results for these aircraft were not separated.

Table 10. 737-900, 737-900ER simulation results.

Airport 1	Airport 2	Use Case	Flights Simulated	Time Savings (min)	Fuel Savings (lbs)
KPHX	KSEA	Cx Reroute TMI	0	0.0	0.0
KPHX	KSEA	Weather	0	0.0	0.0
KPHX	KSEA	Wind	3	-1.3	-98.9
KPHX	KSEA	All	3	-1.3	-98.9
KSAN	KSEA	Cx Reroute TMI	0	0.0	0.0
KSAN	KSEA	Weather	0	0.0	0.0
KSAN	KSEA	Wind	5	-1.0	-81.6
KSAN	KSEA	All	5	-1.0	-81.6
KMSP	KSEA	Cx Reroute TMI	0	0.0	0.0
KMSP	KSEA	Weather	1	-1.0	-211.4
KMSP	KSEA	Wind	4	-3.5	-363.9
KMSP	KSEA	All	5	-3.0	-333.4
KDEN	KSEA	Cx Reroute TMI	0	0.0	0.0
KDEN	KSEA	Weather	1	0.0	65.3
KDEN	KSEA	Wind	33	-1.8	-181.4
KDEN	KSEA	All	34	-1.8	-174.1
KLAS	KSEA	Cx Reroute TMI	0	0.0	0.0
KLAS	KSEA	Weather	0	0.0	0.0
KLAS	KSEA	Wind	52	-1.4	-113.3
KLAS	KSEA	All	52	-1.4	-113.3
KPDX	KPHX	Cx Reroute TMI	0	0.0	0.0
KPDX	KPHX	Weather	0	0.0	0.0
KPDX	KPHX	Wind	2	0.0	-5.3
KPDX	KPHX	All	2	0.0	-5.3
KSEA	KSFO	Cx Reroute TMI	0	0.0	0.0
KSEA	KSFO	Weather	0	0.0	0.0
KSEA	KSFO	Wind	10	-0.9	-62.8
KSEA	KSFO	All	10	-0.9	-62.8
KLAX	KSEA	Cx Reroute TMI	0	0.0	0.0
KLAX	KSEA	Weather	0	0.0	0.0
KLAX	KSEA	Wind	87	-1.4	-101.2
KLAX	KSEA	All	87	-1.4	-101.2
KSEA	KSTL	Cx Reroute TMI	0	0.0	0.0
KSEA	KSTL	Weather	0	0.0	0.0
KSEA	KSTL	Wind	3	-2.3	-188.5
KSEA	KSTL	All	3	-2.3	-188.5

Airport 1	Airport 2	Use Case	Flights Simulated	Time Savings (min)	Fuel Savings (lbs)
KORD	KSEA	Cx Reroute TMI	0	0.0	0.0
KORD	KSEA	Weather	1	0.0	15.7
KORD	KSEA	Wind	15	-5.7	-285.4
KORD	KSEA	All	16	-5.4	-266.6
KDFW	KSEA	Cx Reroute TMI	0	0.0	0.0
KDFW	KSEA	Weather	0	0.0	0.0
KDFW	KSEA	Wind	3	-6.0	-308.8
KDFW	KSEA	All	3	-6.0	-308.8
KSEA	KTUS	Cx Reroute TMI	0	0.0	0.0
KSEA	KTUS	Weather	0	0.0	0.0
KSEA	KTUS	Wind	5	-0.8	-48.1
KSEA	KTUS	All	5	-0.8	-48.1

Table 11. 737-800 simulation results.

Airport 1	Airport 2	Use Case	Flights Simulated	Time Savings (min)	Fuel Savings (lbs)
KPHX	KSEA	Cx Reroute TMI	0	0.0	0.0
KPHX	KSEA	Weather	0	0.0	0.0
KPHX	KSEA	Wind	35	-1.5	-101.9
KPHX	KSEA	All	35	-1.5	-101.9
KSAN	KSEA	Cx Reroute TMI	0	0.0	0.0
KSAN	KSEA	Weather	3	-0.7	-21.4
KSAN	KSEA	Wind	82	-1.3	-119.3
KSAN	KSEA	All	85	-1.3	-115.8
KMSP	KSEA	Cx Reroute TMI	0	0.0	0.0
KMSP	KSEA	Weather	1	-1.0	-28.6
KMSP	KSEA	Wind	10	-3.8	-210.6
KMSP	KSEA	All	11	-3.5	-194.1
KDEN	KSEA	Cx Reroute TMI	0	0.0	0.0
KDEN	KSEA	Weather	1	-1.0	-78.6
KDEN	KSEA	Wind	50	-2.4	-184.8
KDEN	KSEA	All	51	-2.4	-182.7
KDCA	KSEA	Cx Reroute TMI	2	-13.5	-961.9
KDCA	KSEA	Weather	3	-1.7	81.5
KDCA	KSEA	Wind	24	-7.5	-536.9
KDCA	KSEA	All	29	-7.3	-502.2
KFLL	KSEA	Cx Reroute TMI	0	0.0	0.0
KFLL	KSEA	Weather	2	-8.5	-401.6
KFLL	KSEA	Wind	22	-9.8	-328.1
KFLL	KSEA	All	24	-9.7	-334.3
KDCA	KLAX	Cx Reroute TMI	1	-5.0	-295.4
KDCA	KLAX	Weather	1	-5.0	-79.3

Airport 1	Airport 2	Use Case	Flights Simulated	Time Savings (min)	Fuel Savings (lbs)
KDCA	KLAX	Wind	31	-5.5	-404.2
KDCA	KLAX	All	33	-5.5	-391.0
KEWR	KSEA	Cx Reroute TMI	1	-3.0	-147.9
KEWR	KSEA	Weather	2	-1.0	-76.7
KEWR	KSEA	Wind	32	-8.7	-463.0
KEWR	KSEA	All	35	-8.1	-431.9
KLAS	KSEA	Cx Reroute TMI	0	0.0	0.0
KLAS	KSEA	Weather	2	-1.0	-77.1
KLAS	KSEA	Wind	125	-1.3	-114.2
KLAS	KSEA	All	127	-1.3	-113.6
KBOS	KSEA	Cx Reroute TMI	0	0.0	0.0
KBOS	KSEA	Weather	1	4.0	437.2
KBOS	KSEA	Wind	31	-9.1	-401.9
KBOS	KSEA	All	32	-8.7	-375.7
KSEA	KSFO	Cx Reroute TMI	0	0.0	0.0
KSEA	KSFO	Weather	0	0.0	0.0
KSEA	KSFO	Wind	30	-0.4	-27.0
KSEA	KSFO	All	30	-0.4	-27.0
KMCO	KSEA	Cx Reroute TMI	1	-25.0	-1819.5
KMCO	KSEA	Weather	1	-4.0	-235.6
KMCO	KSEA	Wind	7	-11.0	-888.7
KMCO	KSEA	All	9	-11.8	-919.5
KLAX	KSEA	Cx Reroute TMI	0	0.0	0.0
KLAX	KSEA	Weather	1	0.0	0.0
KLAX	KSEA	Wind	67	-1.0	-81.7
KLAX	KSEA	All	68	-1.0	-80.5
KDCA	KPDX	Cx Reroute TMI	0	0.0	0.0
KDCA	KPDX	Weather	0	0.0	0.0
KDCA	KPDX	Wind	1	-3.0	-148.3
KDCA	KPDX	All	1	-3.0	-148.3
KSEA	KSTL	Cx Reroute TMI	0	0.0	0.0
KSEA	KSTL	Weather	4	-0.3	-13.6
KSEA	KSTL	Wind	13	-0.2	-17.9
KSEA	KSTL	All	17	-0.2	-16.9
KORD	KSEA	Cx Reroute TMI	0	0.0	0.0
KORD	KSEA	Weather	3	-2.0	40.3
KORD	KSEA	Wind	43	-7.1	-409.0
KORD	KSEA	All	46	-6.8	-379.7
KDFW	KSEA	Cx Reroute TMI	0	0.0	0.0
KDFW	KSEA	Weather	1	1.0	75.5
KDFW	KSEA	Wind	44	-4.1	-269.3
KDFW	KSEA	All	45	-4.0	-261.6
KSEA	KTUS	Cx Reroute TMI	0	0.0	0.0
KSEA	KTUS	Weather	1	0.0	2.7

Airport 1	Airport 2	Use Case	Flights Simulated	Time Savings (min)	Fuel Savings (lbs)
KSEA	KTUS	Wind	19	-0.4	-25.7
KSEA	KTUS	All	20	-0.4	-24.3

Table 12. 737-700 simulation results.

Airport 1	Airport 2	Use Case	Flights Simulated	Time Savings (min)	Fuel Savings (lbs)
KPHX	KSEA	Cx Reroute TMI	3	-3.3	-627.5
KPHX	KSEA	Weather	7	-1.6	-280.2
KPHX	KSEA	Wind	80	-1.7	-282.7
KPHX	KSEA	All	90	-1.7	-294.0
KSAN	KSEA	Cx Reroute TMI	0	0.0	0.0
KSAN	KSEA	Weather	0	0.0	0.0
KSAN	KSEA	Wind	16	-2.1	-193.4
KSAN	KSEA	All	16	-2.1	-193.4
KMSP	KSEA	Cx Reroute TMI	0	0.0	0.0
KMSP	KSEA	Weather	0	0.0	0.0
KMSP	KSEA	Wind	13	-3.1	-211.2
KMSP	KSEA	All	13	-3.1	-211.2
KDEN	KSEA	Cx Reroute TMI	0	0.0	0.0
KDEN	KSEA	Weather	0	0.0	0.0
KDEN	KSEA	Wind	5	-4.2	-270.2
KDEN	KSEA	All	5	-4.2	-270.2
KLAS	KSEA	Cx Reroute TMI	0	0.0	0.0
KLAS	KSEA	Weather	0	0.0	0.0
KLAS	KSEA	Wind	1	2.0	110.7
KLAS	KSEA	All	1	2.0	110.7
KPDX	KPHX	Cx Reroute TMI	0	0.0	0.0
KPDX	KPHX	Weather	4	-0.3	-26.0
KPDX	KPHX	Wind	20	-0.4	-35.0
KPDX	KPHX	All	24	-0.4	-33.5
KSEA	KSFO	Cx Reroute TMI	0	0.0	0.0
KSEA	KSFO	Weather	2	-1.0	-83.2
KSEA	KSFO	Wind	40	-0.4	-32.4
KSEA	KSFO	All	42	-0.5	-34.8
KLAX	KSEA	Cx Reroute TMI	0	0.0	0.0
KLAX	KSEA	Weather	3	-3.3	-214.2
KLAX	KSEA	Wind	29	-0.6	-34.6
KLAX	KSEA	All	32	-0.8	-51.4
KDFW	KSEA	Cx Reroute TMI	0	0.0	0.0
KDFW	KSEA	Weather	0	0.0	0.0
KDFW	KSEA	Wind	28	-5.0	-378.6
KDFW	KSEA	All	28	-5.0	-378.6

Appendix B: TASAR Request Trajectory Change Types

Table 13 summarizes the percentage of requests that are lateral, vertical, or combination lateral and vertical by aircraft type. The count of requests by aircraft type in the simulation are shown in the top half of the table and then shown as percentages in the lower half of the table.

Table 13. Percentage of lateral, vertical, and combination lateral and vertical by aircraft type.

Trajectory Change Type	737-900/ER	737-800	737-700	All
Lateral	323	1268	71	1,866
Vertical Lower	4	102	0	109
Vertical Higher	2	79	3	88
Lateral and Lower	78	602	212	1,120
Lateral and Higher	73	509	214	1,013
Sum	480	2560	500	4,196
Lateral (%)	67.3%	49.5%	14.2%	44.5%
Vertical Lower (%)	0.8%	4.0%	0.0%	2.6%
Vertical Higher (%)	0.4%	3.1%	0.6%	2.1%
Lateral and Lower (%)	16.3%	23.5%	42.4%	26.7%
Lateral and Higher (%)	15.2%	19.9%	42.8%	24.1%
Sum	100.0%	100.0%	100.0%	100.0%

Appendix C: Summary Presentation

The following presentation summarizes the Alaska Airlines annualized benefit estimation. Data in tables and figures are the same as that found in other areas of the report. Data values were rounded for presentation purposes.

Alaska Airlines Traffic Aware Strategic Aircrew Requests (TASAR) Benefits Assessment

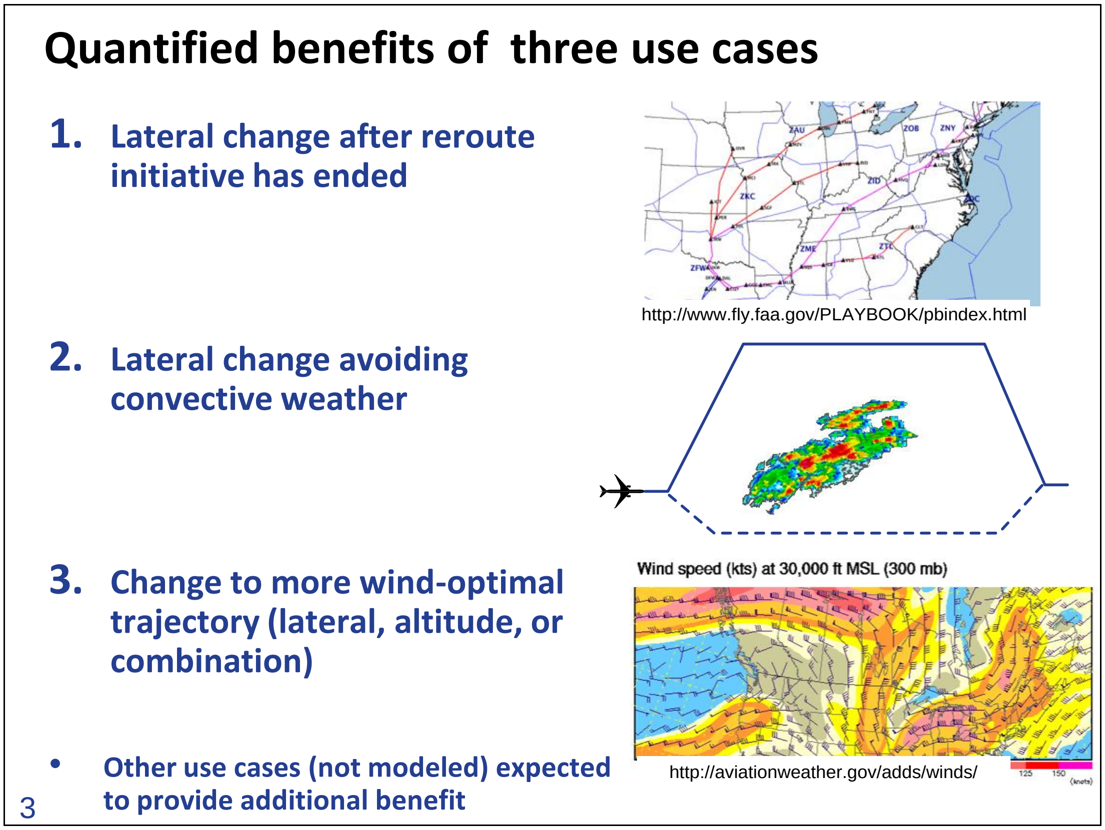
Jeff Henderson
Engility Corporation

David Wing
NASA Langley

Seattle, WA
October 2014

Overview of benefits assessment

- **TASAR use-cases analyzed**
- **Method used to estimate fuel and time benefits**
- **Results**
  - *Benefits for Alaska routes*
  - *ATC impacts*
- **Future work**
  - *Flight test to validate methodology*



Quantified benefits of three use cases

1. **Lateral change after reroute initiative has ended**

http://www.fly.faa.gov/PLAYBOOK/pbindex.html

2. **Lateral change avoiding convective weather**

3. **Change to more wind-optimal trajectory (lateral, altitude, or combination)**

Wind speed (kts) at 30,000 ft MSL (300 mb)

http://aviationweather.gov/adds/winds/

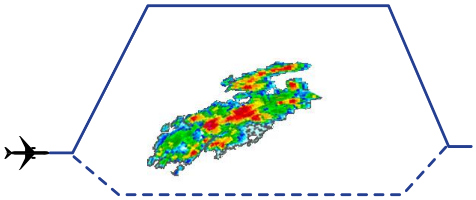
- **Other use cases (not modeled) expected to provide additional benefit**

Quantified benefits of three use cases

1. Aircraft part of re-route initiative that has ended classified as (1).

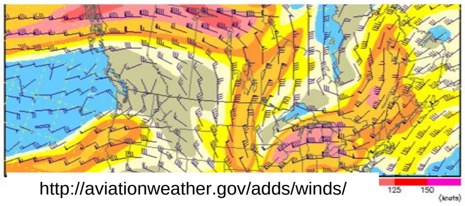
http://www.fly.faa.gov/PLAYBOOK/pbindex.html

2. Aircraft with alternative route through convective weather classified as (2) if not part of (1).



3. Remaining aircraft not in (1) or (2) classified as (3). TASAR uses RAP predicted winds. Aircraft flies historical sensed (e.g., aircraft report) winds that have been fused into RAP analysis winds.

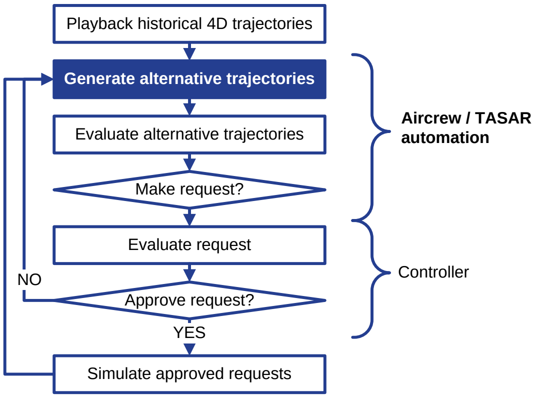
Wind speed (kts) at 30,000 ft MSL (300 mb)



http://aviationweather.gov/adds/winds/

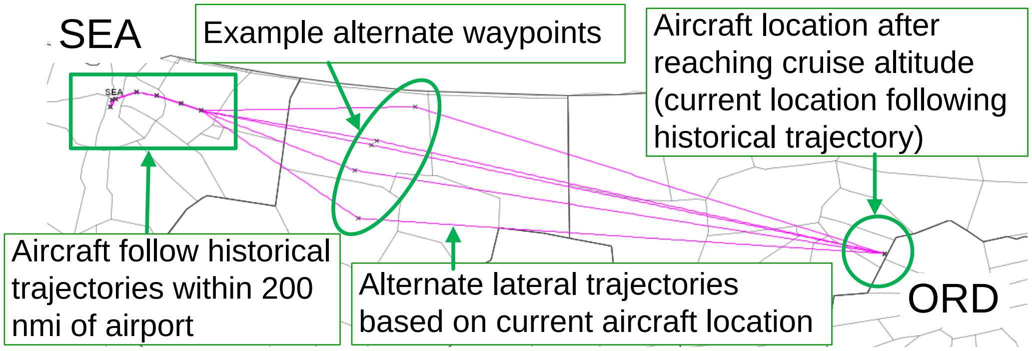
Method to estimate fuel and time benefits

- **Baseline**
  - *Aircraft follow historical 4D trajectories derived from ASA radar tracks*
- **With TASAR**
  - *Aircraft follow historical 4D trajectories until TASAR request granted*
  - *Aircrew model uses TASAR to consider fuel, time, and ATC acceptability*
  - *Controller model evaluates request using more traffic info*



Aircrew generates request according to their objectives

- **Objective used in simulation: 50% fuel, 50% time**
  - *Constraint: fuel and time savings both ≥ 0 (i.e., exclude solutions that decrease fuel burned but increase flight time and vice versa)*
- **Voice communication limits requests to two named waypoints**
- **Considered lateral, altitude, and combination lateral and altitude trajectory changes**



Example alternate waypoints

Aircraft location after reaching cruise altitude (current location following historical trajectory)

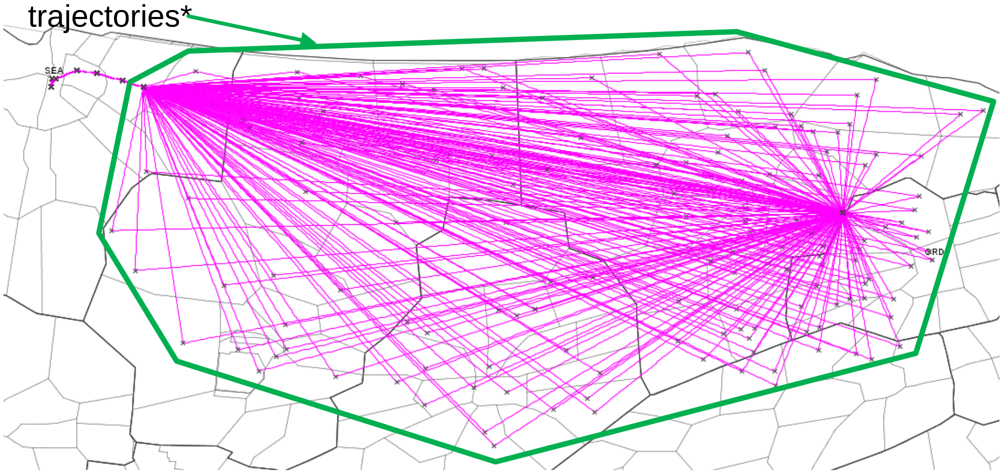
Aircraft follow historical trajectories within 200 nmi of airport

Alternate lateral trajectories based on current aircraft location

Alternative waypoints limited for computational reasons

- **Bounding box used to limit alternative trajectories**
- **Box limits based on historical tracks between airport pair**

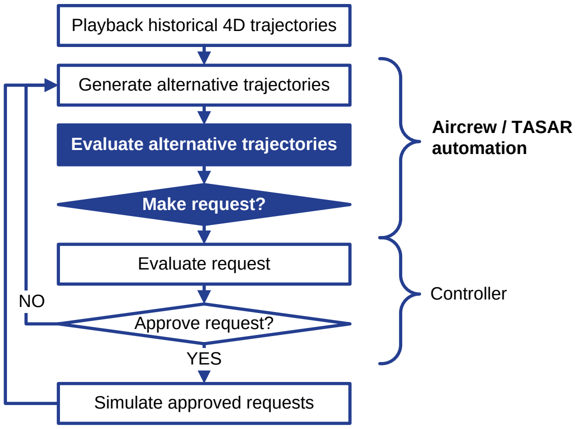
All named waypoints inside bounding box used to generate alternative trajectories*



*** Note: Additional alternative waypoints not shown in figure.**

Aircrew decides whether to make request based on estimate of controller acceptability

- **Aircrew request withheld if:**
  - *Aircraft-aircraft conflict (depends on ADS-B equipment)*
  - *Aircraft-airspace hazard conflict*
  - *Already made request to current controller*
  - *Request has no impact on current sector*
  - *Aircraft in handoff status – 20 nmi from sector boundary*
  - *Aircraft on initial climb – potential interference with arrival traffic*
  - *Aircraft within 200 nmi of large hub destination airport*



Playback historical 4D trajectories

Generate alternative trajectories

Evaluate alternative trajectories

Make request?

Evaluate request

NO

Approve request?

YES

Simulate approved requests

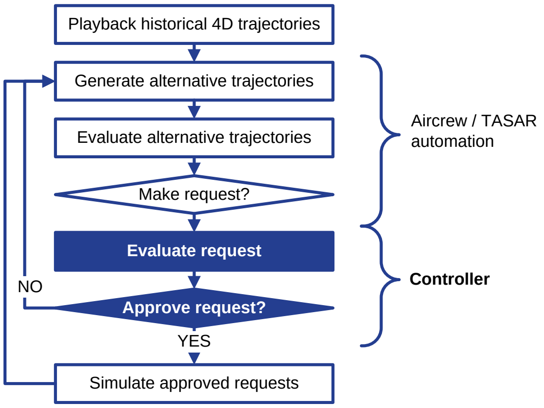
Aircrew / TASAR automation

Controller

- **Benefit results assume 100% ADS-B OUT equipage**
  - *Earlier study indicated that ADS-B OUT equipage impacts ATC acceptability but not TASAR benefits*
  - *ATC impacts included later in presentation*

Controller evaluates requests against ATC objectives using ATC knowledge

- **Additional ATC knowledge**
  - *Aircraft intent (flight plans)*
  - *ADS-B Aircraft outside 60 nmi assumed ADS-B range*
  - *Demand exceeding monitor alert parameter (MAP) – red sectors*



Playback historical 4D trajectories

Generate alternative trajectories

Evaluate alternative trajectories

Make request?

Evaluate request

NO

Approve request?

YES

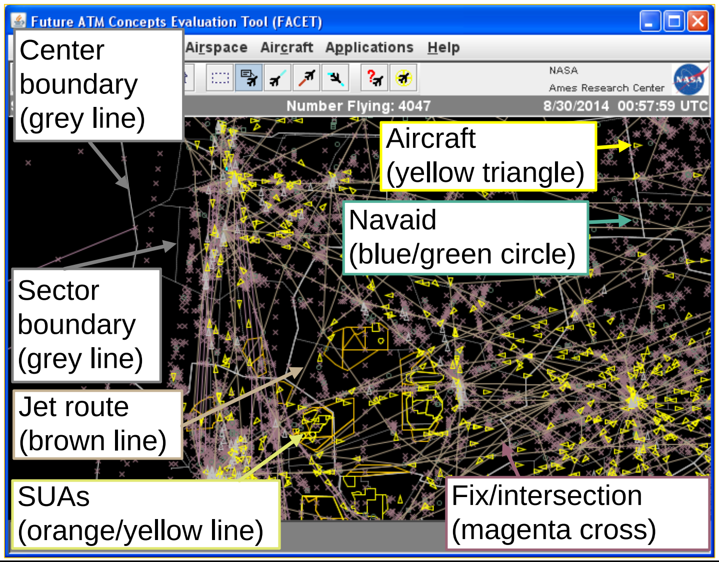
Simulate approved requests

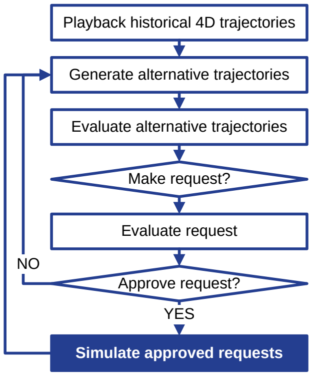
Aircrew / TASAR automation

Controller

Fast-time simulation used for both baseline and TASAR scenarios

- **Platform leverages Future ATM Concept Evaluation Tool (FACET)**
  - *Aircraft performance model*
  - *Airspace*




Playback historical 4D trajectories

Generate alternative trajectories

Evaluate alternative trajectories

Make request?

Evaluate request

Approve request?

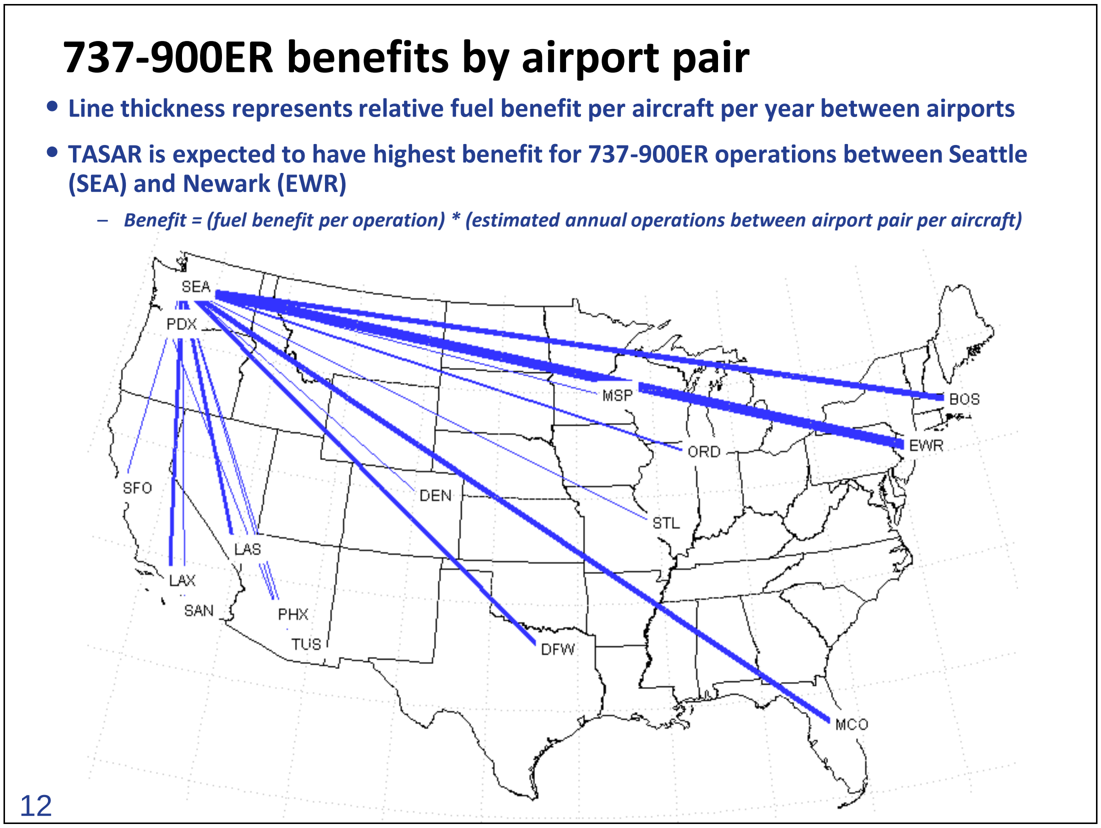
NO

YES

Simulate approved requests

Results overview

- **Fuel and time benefits for airport pairs by aircraft type shown in following order**
  - *737-900ER*
  - *737-900*
  - *737-800*
  - *737-700*
- **Summary of annual fuel and time benefits:**
  - *by aircraft type, and*
  - *across all 737s (excluding 737-400s)*



737-900ER benefits by airport pair

- Line thickness represents relative fuel benefit per aircraft per year between airports
- TASAR is expected to have highest benefit for 737-900ER operations between Seattle (SEA) and Newark (EWR)
  - *Benefit = (fuel benefit per operation) * (estimated annual operations between airport pair per aircraft)*

Airport pairs with highest expected annual fuel benefits for 737-900ER when using TASAR

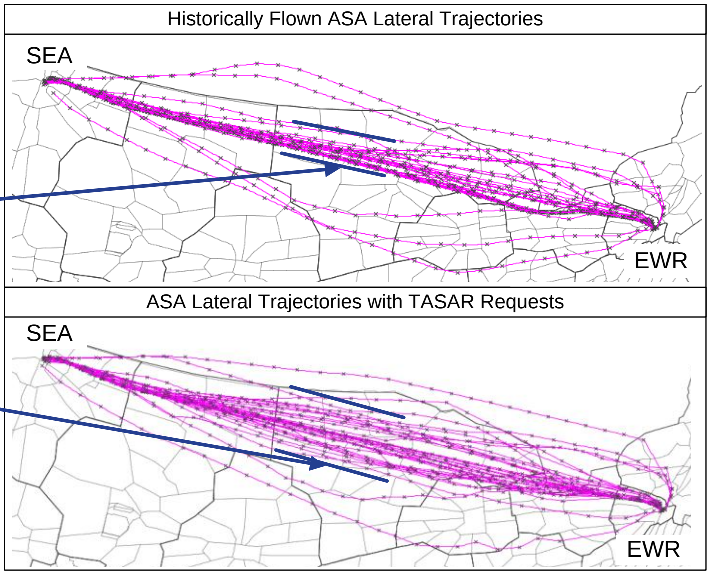
- Data source for annual operations: BTS T100 database derived from Form 41 air carrier reported operations (divide annual ops by number of aircraft to obtain ops per aircraft)
- Table shows results for wind use case which occurs most frequently
- Convective weather and expired TMI use cases included for completeness

Airport 1	Airport 2	Per Operation Benefit		Annual Benefit		
		Fuel (gal)	Time (min)	Ops per 737-900ER	Fuel (gal)	Time (min)
Newark (EWR)	Seattle (SEA)	60.5	8.7	38	2,268	326
Boston (BOS)	Seattle (SEA)	58.8	9.1	30	1,764	272
Orlando (MCO)	Seattle (SEA)	119.3	11.0	13	1,550	143
Las Vegas (LAS)	Seattle (SEA)	16.6	1.4	78	1,292	107
Dallas (DFW)	Seattle (SEA)	45.1	6.0	31	1,120	149
Los Angeles (LAX)	Seattle (SEA)	14.8	1.4	61	903	88
Chicago (ORD)	Seattle (SEA)	41.7	5.7	19	617	85
Total Annual Benefit (Wind Use Case)				381*	11,203	1,312
Total Annual Benefit (Wind, Convective Wx, and expired TMI)				381*	12,042	1,381

TASAR fuel savings is at least 12,000 gal per 737-900ER per year

* Note: Underestimates annual benefit since typical aircraft can perform at least 700 ops per year. Not all airport pairs shown.

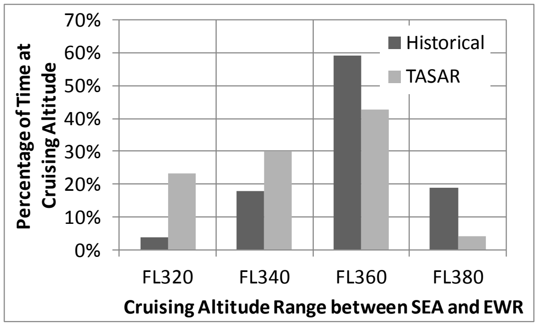
Trajectories between SEA and EWR (highest annual 737-900ER TASAR fuel benefit)

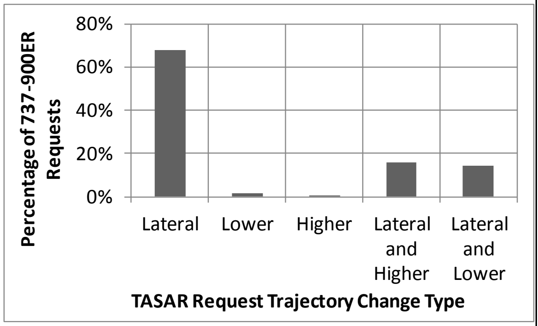


TASAR requests not simple directs. Larger spread result of TASAR taking advantage of changing atmospheric conditions and ATC restrictions.

Altitudes between SEA and EWR (highest annual 737-900ER TASAR fuel benefit)

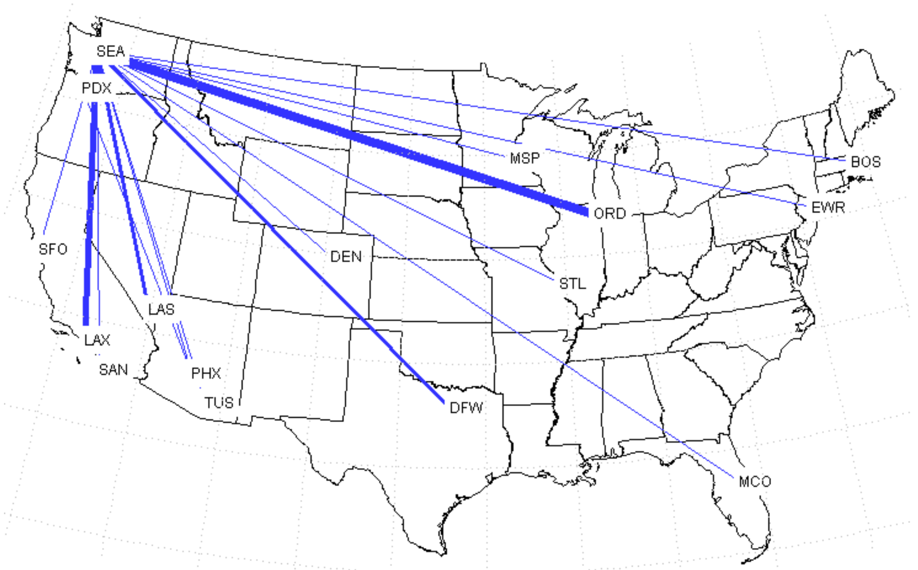
- **On average TASAR requests result in aircraft cruising at lower altitudes between SEA and EWR**
- **Pure altitude changes are least frequent TASAR solution**
  - ***TASAR requests generally lateral or combination lateral and vertical***
  - ***Similar results for other airport pairs***





737-900 benefits by airport pair

- **Line thickness represents relative fuel benefit per aircraft per year between airports**
- **TASAR is expected to have highest benefit for 737-900 operations between Seattle (SEA) and Chicago (ORD)**
  - ***Benefit = (fuel benefit per operation) * (estimated annual operations between airport pair per aircraft)***

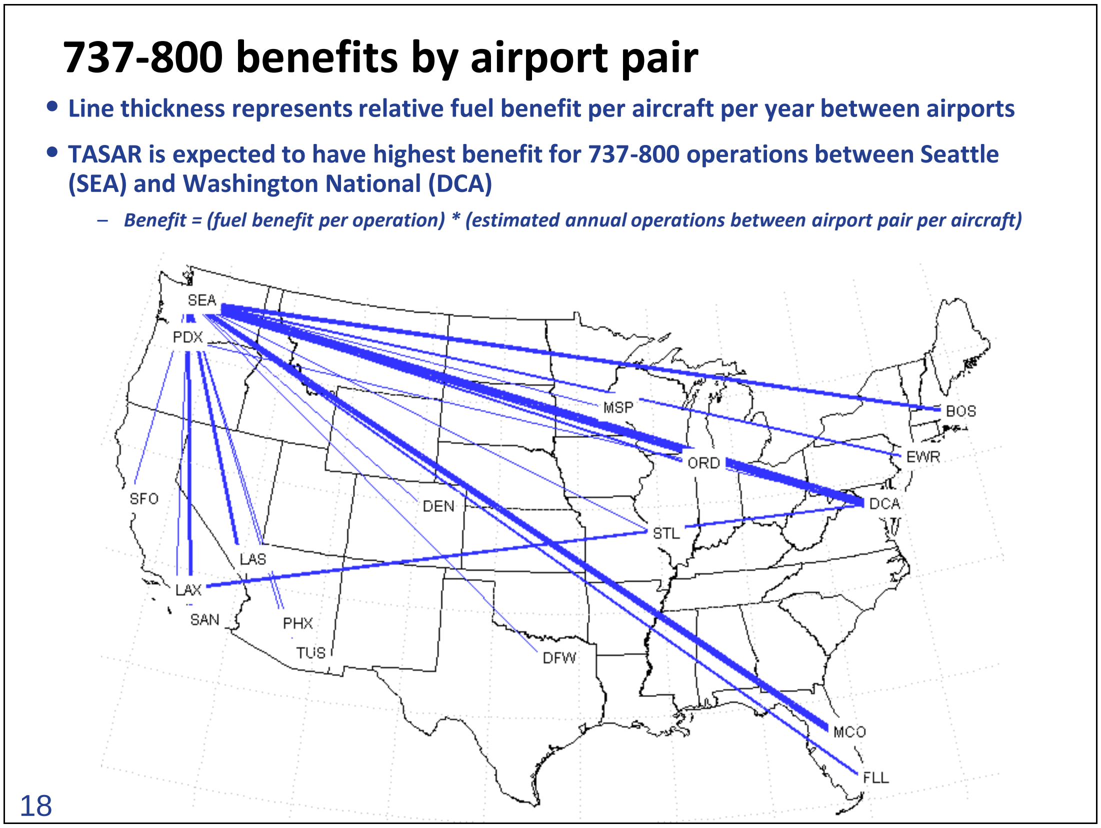


Airport pairs with highest expected annual fuel benefits for 737-900 when using TASAR

Airport 1	Airport 2	Per Operation Benefit		Annual Benefit		
		Fuel (gal)	Time (min)	Ops per 737-900	Fuel (gal)	Time (min)
Chicago (ORD)	Seattle (SEA)	41.7	5.7	77	3,012	414
Los Angeles (LAX)	Seattle (SEA)	14.8	1.4	133	1,968	191
Dallas (DFW)	Seattle (SEA)	45.1	6.0	39	1,761	234
Las Vegas (LAS)	Seattle (SEA)	16.6	1.4	83	1,375	113
Denver (DEN)	Seattle (SEA)	26.5	1.8	19	489	34
Phoenix (PHX)	Seattle (SEA)	14.5	1.3	33	477	44
Minneapolis (MSP)	Seattle (SEA)	53.2	3.5	11	168	31
Total Annual Benefit (Wind Use Case)				466*	10,465	1,164
Total Annual Benefit (Wind, Convective Wx, and expired TMI)				466*	10,567	1,169

TASAR fuel savings is at least 10,000 gal per 737-900 per year

* **Note: Underestimates annual benefit since typical aircraft can perform at least 700 ops per year. Not all airport pairs shown.**



737-800 benefits by airport pair

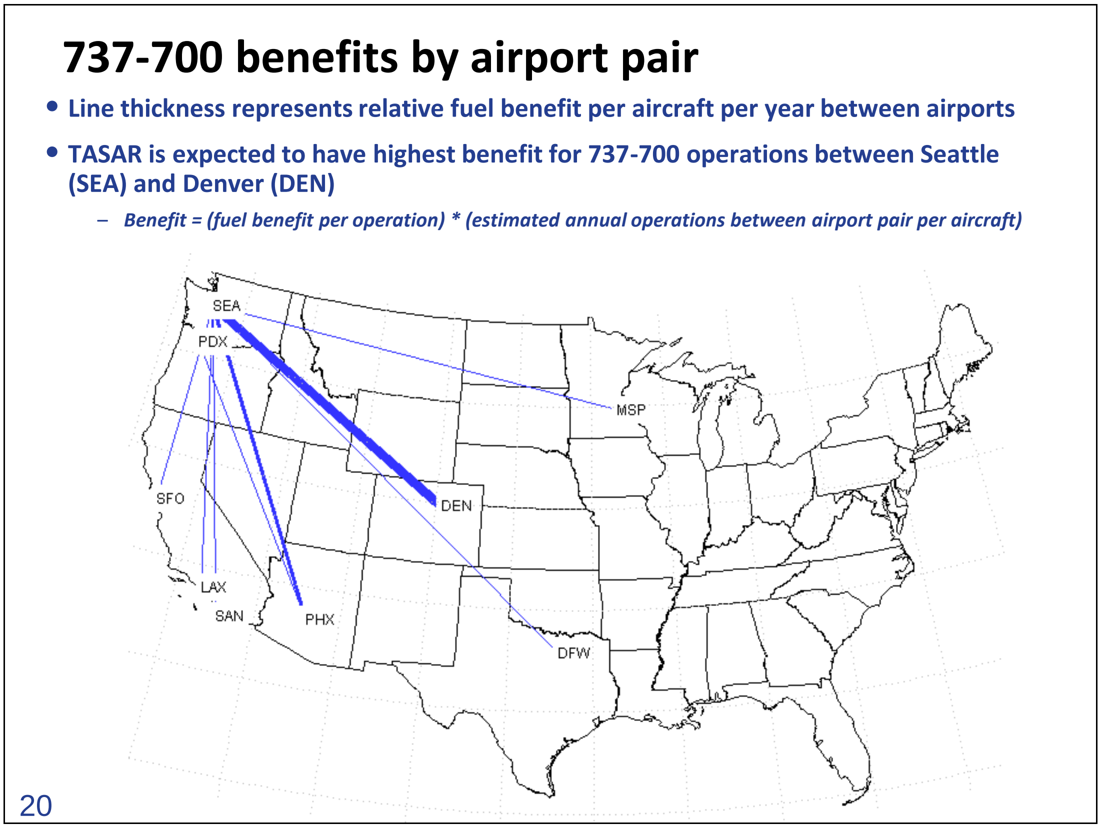
- Line thickness represents relative fuel benefit per aircraft per year between airports
- TASAR is expected to have highest benefit for 737-800 operations between Seattle (SEA) and Washington National (DCA)
  - *Benefit = (fuel benefit per operation) * (estimated annual operations between airport pair per aircraft)*

Airport pairs with highest expected annual fuel benefits for 737-800 when using TASAR

Airport 1	Airport 2	Per Operation Benefit		Annual Benefit		
		Fuel (gal)	Time (min)	Ops per 737-900	Fuel (gal)	Time (min)
Washington (DCA)	Seattle (SEA)	78.5	7.5	18	1,429	137
Orlando (MCO)	Seattle (SEA)	129.9	11.0	8	1,010	86
San Diego (SAN)	Seattle (SEA)	17.4	1.3	45	791	60
Boston (BOS)	Seattle (SEA)	58.8	9.1	13	764	118
Chicago (ORD)	Seattle (SEA)	59.8	7.1	9	538	64
Las Vegas (LAS)	Seattle (SEA)	16.7	1.3	31	526	40
Washington (DCA)	Los Angeles (LAX)	48.4	5.8	10	500	60
Newark (EWR)	Seattle (SEA)	67.7	8.7	7	495	64
Total Annual Benefit (Wind Use Case)				289*	8,286	905
Total Annual Benefit (Wind, Convective Wx, and expired TMI)				289*	8,963	977

TASAR fuel savings is at least 8,000 gal per 737-800 per year

* Note: Underestimates annual benefit since typical aircraft can perform at least 700 ops per year. Not all airport pairs shown.



737-700 benefits by airport pair

- Line thickness represents relative fuel benefit per aircraft per year between airports
- TASAR is expected to have highest benefit for 737-700 operations between Seattle (SEA) and Denver (DEN)
  - *Benefit = (fuel benefit per operation) * (estimated annual operations between airport pair per aircraft)*

Airport pairs with highest expected annual fuel benefits for 737-700 when using TASAR

Airport 1	Airport 2	Per Operation Benefit		Annual Benefit		
		Fuel (gal)	Time (min)	Ops per 737-900	Fuel (gal)	Time (min)
Denver (DEN)	Seattle (SEA)	39.5	4.2	134	5,294	563
Phoenix (PHX)	Seattle (SEA)	41.3	1.7	60	2,498	100
San Diego (SAN)	Seattle (SEA)	28.3	2.1	45	1,272	93
Minneapolis (MSP)	Seattle (SEA)	30.9	3.1	34	1,050	105
Dallas (DFW)	Seattle (SEA)	55.3	5.0	15	830	74
Los Angeles (LAX)	Seattle (SEA)	5.1	0.6	60	302	35
San Francisco (SFO)	Seattle (SEA)	4.7	0.4	60	284	26
Total Annual Benefit (Wind Use Case)				444*	11,612	1,002
Total Annual Benefit (Wind, Convective Wx, and expired TMI)				444*	12,279	1,042

TASAR fuel savings is at least 12,000 gal per 737-700 per year

* Note: Underestimates annual benefit since typical aircraft can perform at least 700 ops per year. Not all airport pairs shown.

Fuel and Time Savings Summary

Aircraft Type	Annual TASAR Fuel Benefit	Annual TASAR Time Benefit	Airport Pair with Highest TASAR Benefit
737-900ER	12,000 gallons/aircraft	1,300 min/aircraft	EWR – SEA
737-900	10,000 gallons/aircraft	1,100 min/aircraft	ORD – SEA
737-800	8,000 gallons/aircraft	900 min/aircraft	DCA – SEA
737-700	12,000 gallons/aircraft	1,000 min/aircraft	DEN – SEA
All aircraft types excluding 737-400s	1,040,000 gallons*	110,700 min*	ORD – SEA

* **Assumes 22 737-900ERs, 12 737-900s, 61 737-800s, 14 737-700s as of August 2014. Additional 737-900ERs on order.**

Estimated Cost Savings Summary

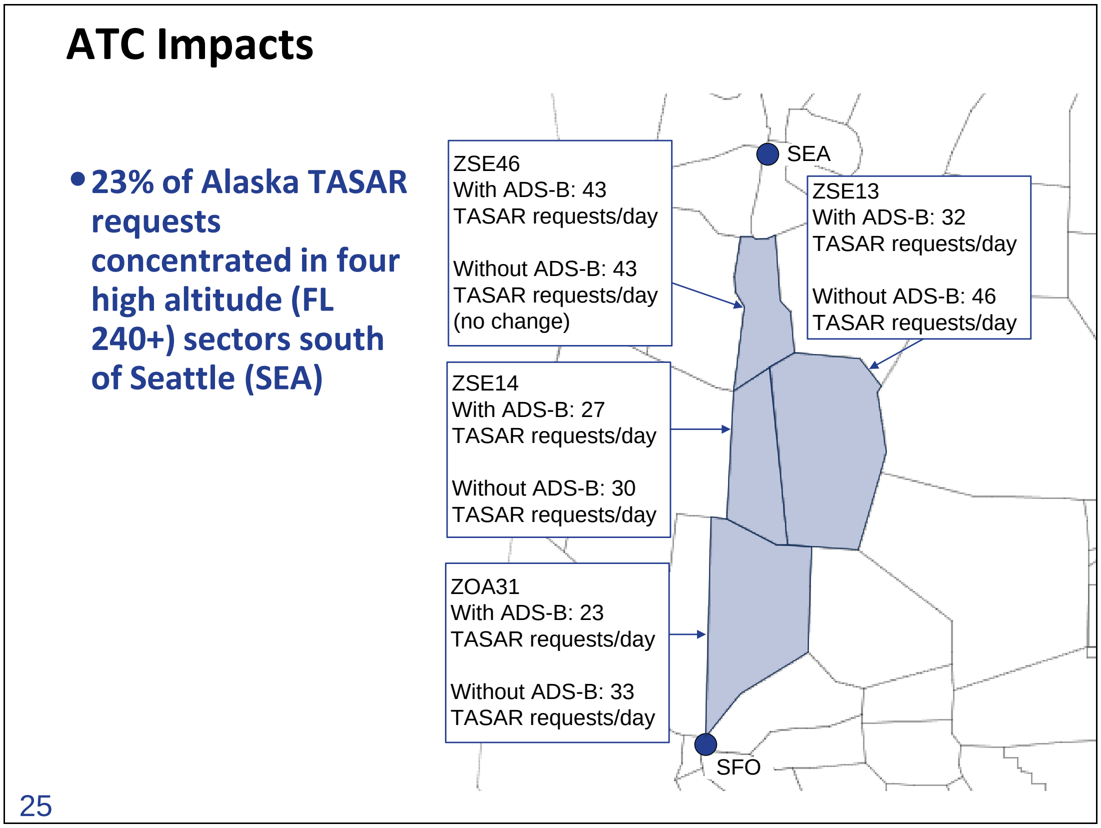
Aircraft Type	Fuel Cost/Gallon (March 2014)*	Maintenance Cost/min (2013)*	Depreciation Cost/Min (2013)*
737-900ER	$3.26	$8.44	$8.72
737-900	$3.26	$8.44	$8.72
737-800	$3.26	$4.96	$6.75
737-700	$3.26	$21.40	$7.18
Total Cost Savings by Category	$3,390,000/year**	$924,000/year**	$835,000/year**
Total Cost Savings for all Categories	$5,150,000/year**		

* **Obtained from BTS Form 41 data**

** **Applies fuel and time savings from previous slide.**

ATC Impacts

- **Average of 3.4 requests per flight**
  - *Without ADS-B IN – 23% of requests rejected due to conflicts or other reasons*
  - *With ADS-B IN – 6% of requests rejected due to conflicts or other reasons*
  - *Request rejections do not significantly impact benefits – aircrew waits until next sector then makes same or similar request*



ATC Impacts

- **23% of Alaska TASAR requests concentrated in four high altitude (FL 240+) sectors south of Seattle (SEA)**

ZSE46
With ADS-B: 43 TASAR requests/day

Without ADS-B: 43 TASAR requests/day (no change)

ZSE13
With ADS-B: 32 TASAR requests/day

Without ADS-B: 46 TASAR requests/day

ZSE14
With ADS-B: 27 TASAR requests/day

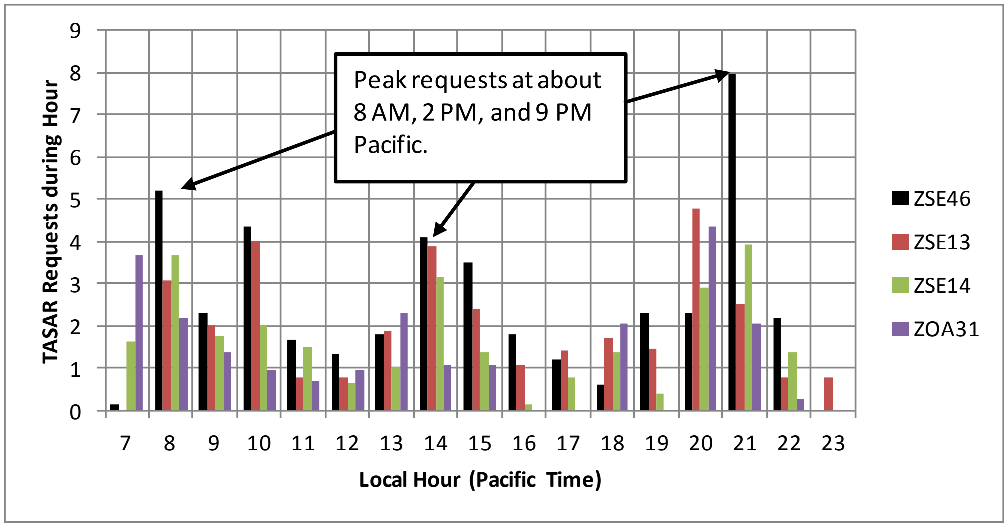
Without ADS-B: 30 TASAR requests/day

ZOA31
With ADS-B: 23 TASAR requests/day

Without ADS-B: 33 TASAR requests/day

ATC Impacts

- **Peak Alaska TASAR requests are about 4 to 8 requests per hour per sector**
- **Could be managed through dispatcher coordination or other procedure**



Peak requests at about 8 AM, 2 PM, and 9 PM Pacific.

Future Work

- **Second TASAR flight trial planned for 2015**
  - ***Generating method to validate TAP computed outcomes is an objective of the flight trial***
  - ***Controller observations to better understand TASAR request acceptability***
- **Expected TASAR to be placed on an Alaska revenue flight after flight trial**
- **Validation method, controller observations, and Alaska revenue flight data could be used to refine benefits estimated by simulation**

REPORT DOCUMENTATION PAGE	*Form Approved* *OMB No. 0704-0188*

1. REPORT DATE *(DD-MM-YYYY)* 01- 08 - 2015	**2. REPORT TYPE** Contractor Report	**3. DATES COVERED** *(From - To)*

4. TITLE AND SUBTITLE Annualized TASAR Benefit Estimate for Alaska Airlines Operations	**5a. CONTRACT NUMBER** NNL12AA06C
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S) Henderson, Jeffrey	**5d. PROJECT NUMBER**
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER 330693.04.30.07.05
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) NASA Langley Research Center Hampton, Virginia 23681-2199	**8. PERFORMING ORGANIZATION REPORT NUMBER**
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) National Aeronautics and Space Administration Washington, DC 20546-0001	**10. SPONSOR/MONITOR'S ACRONYM(S)** NASA
	11. SPONSOR/MONITOR'S REPORT NUMBER(S) NASA/CR-2015-218787

12. DISTRIBUTION/AVAILABILITY STATEMENT
Unclassified
Subject Category 03
Availability: NASA STI Program (757) 864-9658

13. SUPPLEMENTARY NOTES

Langley Technical Monitor: David J. Wing

14. ABSTRACT

The Traffic Aware Strategic Aircrew Request (TASAR) concept offers onboard automation for the purpose of advising the pilot of traffic compatible trajectory changes that would be beneficial to the flight. A fast-time simulation study was conducted to assess the benefits of TASAR to Alaska Airlines. The simulation compares historical trajectories without TASAR to trajectories developed with TASAR and evaluated by controllers against their objectives. It was estimated that between 8,000 and 12,000 gallons of fuel and 900 to 1,300 minutes could be saved annually per aircraft. These savings were applied fleet-wide to produce an estimated annual cost savings to Alaska Airlines in excess of $5 million due to fuel, maintenance, and depreciation cost savings. Switching to a more wind-optimal trajectory was found to be the use case that generated the highest benefits out of the three TASAR use cases analyzed. Alaska TASAR requests peaked at four to eight requests per hour in high-altitude Seattle center sectors south of Seattle-Tacoma airport.

15. SUBJECT TERMS

Alaska airlines; Benefits; Electronic flight bag; Route optimization; Traffic aware strategic Aircrew request; User requests

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON**
a. REPORT	**b. ABSTRACT**	**c. THIS PAGE**			STI Help Desk (email: help@sti.nasa.gov)
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