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2011 Trajectory Based Operations Flight Trials

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***Abstract*— This paper presents findings from the Federal Aviation Administration (FAA) 2011 Trajectory Based Operations (TBO) flight trials, performed November 30, 2011 to December 22, 2011 at Seattle-Tacoma International Airport (KSEA). The flight trials evaluated the operational concept of meeting metering times into the terminal area using the Required Time-of-Arrival (RTA) function available in modern Flight Management Systems (FMSs). The trial objectives were to test the concept on a large scale, streamline the process of assigning an RTA, and facilitate an in-depth evaluation of the utility of RTA as a flow management tool for Air Traffic Control (ATC) and operators. Findings show that the Boeing 737 Next Generation (B737NG) aircraft equipped with GE Aviation FMSs are capable of meeting the technical performance expectations of RTA. A total of 833 Alaska Airline (ASA) revenue flights participated in the trials, with 595 aircraft (71%) executing an RTA to completion, and 575 of those 595 (96.6%) arriving within a 30 second tolerance. The trials identify several areas where additional research, standardization, and automation enhancements are needed for RTA to be operationally viable.**

Keywords - Trajectory Based Operations; flight trials; Required Time of Arrival; Flight Management System

I. INTRODUCTION

The Next Generation Air Transportation System (NextGen) and Single European Sky Air Traffic Management (ATM) Research (SESAR) programs aim to increase the safety, efficiency, and capacity of air traffic systems, while reducing the environmental impact of aviation [1], [2]. Four Dimensional (4D) Trajectory Based Operations (TBO) is a key component of these programs. TBO integrates advanced Flight Management System (FMS) capabilities with ground automation to manage aircraft trajectories in latitude, longitude, altitude, and time. Shifting from clearance-based to the trajectory-based traffic management of TBO is expected to increase the stability, predictability, and efficiency of the air traffic system [3].

In the 4DTBO concept, air and ground automation systems negotiate a trajectory consisting of lateral, vertical, and time constraints along the route. In the aircraft, many modern FMSs are equipped with Time of Arrival Control (TOAC) in the form of Required Time of Arrival (RTA) functionality [4]. The RTA function dynamically adjusts the aircraft speed schedule to arrive at a given fix at a specified time, while considering operator preferences. This accurate and precise time delivery has the potential to reduce controller intervention, such as holding, vectoring, and speed commands, thereby improving overall performance and efficiency of the air traffic system.

There are a number of open research areas regarding the use of RTA for TBO, including:

- Mixed equipage operations
- Pilot / controller workload impacts
- Automation requirements
- Standards, certification, and training needs
- Benefits assessment

The FAA has sponsored the 4D TBO using FMS RTA Program to validate the operational concept, demonstrate the benefits of FMS-based 4D TBO leveraging existing technology, assess the operational viability of a 2018 RTA-based operation, and inform on standards for TBO [5]. The research program has included several Human in the Loop (HITL) simulations [6], [7], [8], parametric simulation studies of FMS RTA performance [8], [9], [10], atmospheric modeling and analysis [8], [11], and two sets of TBO flight trials (2010 and 2011) [12], [13]. This research has provided valuable input for the development of FMS standards for TOAC and RTA functionality, and supports related standards work in the areas of data communications and trajectory information exchange.

A. Previous Work

There have been several prior flight trials exploring the use of RTA for trajectory management. In 2001, Scandinavian Airlines System (SAS) conducted a series of flight trials evaluating the performance of the Boeing 737 (B737) FMS in real world conditions. Results indicated that aircraft equipped with the existing generation of RTA technology could reliably predict and control to a trajectory [14], [15]. Studies in 2006 and 2007 demonstrated improved control accuracy using an updated RTA implementation [16], [17]. In November 2007, the Eurocontrol Partnership Project launched the Controlled Time of Arrival (CTA) ATM System Integration Studies (CASSIS) project, which evaluated the use of CTA in en route and terminal airspace, for 32 Boeing B737 revenue-service flights over 4 days in September 2008 [18]. Results indicated that the GE U10.7 FMS is capable of meeting metering times to within 5 seconds on approach.

More recently, SESAR has been moving towards a mid-term TBO implementation with the Initial 4D (I4D) project. I4D research has included a number of flight trials using an Airbus A320 equipped with a modified Honeywell FMS. These flight trials evaluate the benefits of initial TBO

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deployment in a mixed equipage environment [19], [20], [21]. In 2010, the FAA conducted an initial set of TBO flight trials [12]. These trials included 57 RTA revenue flights over 7 days. The 2011 TBO flight trials expanded upon these previous flight trials, providing a more extensive evaluation of the proposed TBO concept.

This paper is organized as follows. Section II provides an overview of the 2011 TBO flight trials, including scope and objectives, operational concept, and system automation. Section III presents detailed analysis and results. Section IV states conclusions and recommendations.

II. 2011 TBO Flight Trials Overview

The 2011 TBO flight trials evaluated the use of RTA to meet times for metering to the terminal area. The trials were conducted at Seattle-Tacoma International Airport (KSEA) between November 30, 2011 and December 22, 2011, using Alaska Airlines (ASA) Boeing 737 aircraft equipped with the General Electric (GE) Aviation FMS. Flights were issued specific arrival times at approximately 200 to 250 nautical miles (NM) from the Terminal Radar Approach Control (TRACON) boundary (Fig. 1). These arrival times were computed by the Traffic Management Advisor (TMA) system installed at the Seattle Air Route Traffic Control Center (ZSE ARTCC).

A. Scope and Objectives

Objectives for the 2011 TBO flight trials included:

- Increase exposure of RTA concepts and procedures to controllers and flight crews
- Increase acceptance and execution rate of RTA assignments (as compared to previous trials)
- Streamline the process for RTA assignment
- Facilitate an in-depth evaluation of the operational concept, and the utility of RTA

These trials significantly expanded upon the scope of the 2010 trials (Table I) to include the entire ASA fleet (B737-400, B737-700, B737-800, and B737-900 series aircraft), north and south flow airport configurations, additional meter fixes, air-ground data exchange, and additional automation capabilities for ATC including the display of FMS downlinked information at the Traffic Management Unit (TMU). While the preparations had provisions to include both metering and non-metering conditions, active metering at KSEA is very limited. As a result, no flights were assigned an RTA during metering operations. However, Seattle Center did use the times provided TMA even though metering was not active. Modifications to the TMA automation tools and RTA control algorithms were outside the scope of this research.

B. Operational Concept

Air traffic controllers at ZSE use the TMA ground automation system to assist in sequencing aircraft arriving into the KSEA TRACON. The TMA models the trajectory of each aircraft to provide an Estimated Time of Arrival (ETA) and Scheduled Time of Arrival (STA) to the metering fixes. During times of

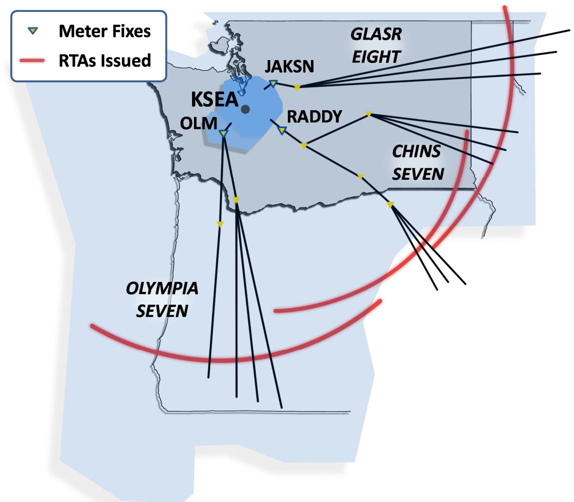

Figure 1. Flight Trials Overview

TABLE I. Comparison Between 2010 and 2011 Flight Trials

	2010 Trials	2011 Trials
Duration	7 days	23 days
Fleet	ASA subset	Entire ASA fleet
Metering Conditions	Non-metering	Metering and non-metering
Airport Configuration (Flow)	South only	North and South
Meter Fixes	OLM	OLM, RADDY, JAKSN
Flights Assigned an RTA	57	833
Wind Forecast Uplinks	Descent only	Cruise and Descent
Automation	Limited	Extensive using ACARS

low traffic, the ETA will typically match the STA. When demand exceeds capacity, metering takes effect and the TMA system optimally adjusts the STAs to manage the flow. ZSE controllers use a combination of speed control, vectoring, and occasionally holding patterns to achieve the STA. One mid-term operational concept for TBO is to use the FMS RTA functionality to meet the STA, reducing the need for controller intervention and more efficiently absorbing delay as aircraft approach the TRACON. This concept also enables more accurate and precise meter fix delivery times, potentially improving predictability inside the TRACON and enabling more throughput at the meter fix.

The operational concept for the flight trials was as follows. When the aircraft crossed a planning horizon of approximately 250 NM from the meter fix, the FMS initialized an automated configuration process, preparing the aircraft to receive an RTA. This process included uplinking cruise and descent winds, uplinking aircraft performance limits, and downlinking detailed trajectory information along with the earliest and latest possible RTA arrival times (the RTA Window) as calculated by the FMS. The performance limits ensured that the aircraft respected published speed and altitude constraints (Table II), and restricted the RTA speed envelope to stay within operator preferences. A custom web interface (Intent Display) visualized information downlinked from the aircraft (Fig. 2), indicating to ZSE when an aircraft was fully configured and eligible to participate in the trials. Each row corresponded to a separate Aircraft Identifier (ACID), providing a novel realtime monitoring capability to ATC. All RTA assignments were on the minute, with the FMS configured to a ± 20 second RTA tolerance.

The TMC protocol was as follows:

- Monitor the Intent Display for eligible ASA flights:
  - Aircraft is at an appropriate distance (250 NM for OLM, 200 NM for JAKSN and RADDY)
  - Aircraft has accepted updated winds and performance limits
- Determine RTA time based on RTA window, TMA scheduling, and surrounding traffic
- Enter RTA assignment on the Enhanced Status Information System (ESIS) and place a call to Area Supervisor to coordinate the RTA assignment
- The minimum interval between in-trail RTA aircraft is 2 minutes

Controllers were instructed as follows:

- Monitor the ESIS display for incoming RTA assignments from TMC
- Issue the RTA using phraseology from training
- If the RTA is accepted, enter into datablock 4th row
- Vector or speed controls terminate the RTA

Flight Crew procedures were as follows:

- Review and accept uplinks of forecast wind, performance limits, and temporary RTA
- Manually enter RTA assigned by the controller
- Inform controller if the RTA is unachievable
- Check in on new frequency with RTA time

These procedures ensured safe operations during the flight trials. A Safety Risk Management Document was prepared prior to the flight trials according to the guidelines of the FAA Air Traffic Organization (ATO) Safety Management System Manual, v2.1 [22], identifying potential risks and appropriate mitigations.

TABLE II. SPEED AND ALTITUDE RESTRICTIONS

STAR	Flow	Restrictions
OLM7	North	250 KIAS / 12000 ft MSL for OLM
	South	270 KIAS / at or above 17000 ft MSL for OLM
CHINS7	North	250 KIAS / 12000 ft MSL for RADDY
	South	270 KIAS / 16000 ft MSL for RADDY
GLASR8	North	270 KIAS / 16000 ft MSL for JAKSN
	South	250 KIAS / 12000 ft MSL for JAKSN

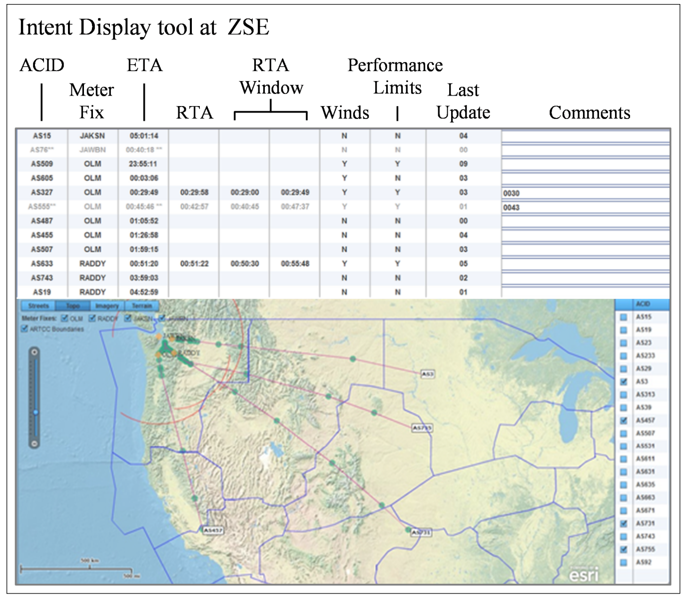

Figure 2. Intent Display for FMS downlink visualization.

C. System Automation

Aircraft configuration and data collection was automated using messages sent via the Aircraft Addressing and Reporting System (ACARS), with the format defined in ARINC standard 702A-1 [23]. The GE FMS has an onboard database, the Adaptable Datalink Data Base (ADDB) that defines custom message sets without modifying the FMS software release. The ASA fleet was programmed with a custom ADDB database to support the flight trials. Table III summarizes major operational issues and associated mitigations. Preparations involved significant custom software development.

A large amount of data was collected during the flight trials, including Rapid Update Cycle (RUC) numerical weather forecasts, ATC observation notes, ACARS messages (both uplinks and downlinks), Intent Display comments, and STA and ETA calculations from the TMA system. Additional data sources included flight records from the Extend Traffic Management System (ETMS) and fused radar track data available through the National Offload Program (NOP). All data sources were stored in a database and fused based on flight record information to create a composite set of information for each flight (Fig. 3). Pilot and controller surveys provided additional qualitative feedback.

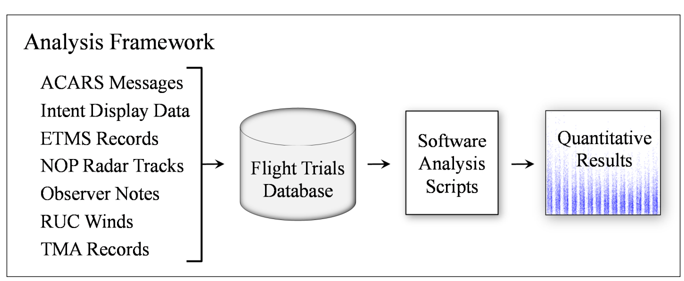

Figure 3. Data Analysis Overview

III. 2011 TBO Flight Trials Results

Fig. 4 summarizes results for the 833 flights issued an RTA to a meter fix. *Assigned, Accepted, Achieved (AAA)* signifies flights in which the RTA was completed and the aircraft crossed the meter fix within the ± 20 second tolerance. *Assigned, Accepted, Achieved Outside Tolerance (AAT)* signifies flights completing the RTA crossing outside the time tolerance. *Assigned, Accepted, Canceled (AAC)* were RTA clearances canceled by the controller, including cancellations due to nearby traffic. *Assigned, Accepted, Unachievable (AAU)* were RTAs reported unachievable by the pilot, including cancellations due to turbulence and direct clearances. *Assigned, Unable Immediately (AUI)* signifies flights in which the assigned time was outside the RTA window at the time of pilot entry. Appendix A provides a table of complete daily results. Of the 833 flights assigned an RTA, 595 (71%) fully executed the RTA to the meter fix, an increase over the 61% completion rate in the 2010 flight trials.

Fig. 5 shows the corresponding radar tracks for the 833 participating flights. Flight distribution by meter fix was 619 (74%) OLM, 125 (15%) JAKSN, and 89 (11%) RADDY. Distribution by airport configuration was 653 (78%) south flow, 180 flights (22%) north flow. The majority of flights passed through OLM with a south flow configuration. The 2011 flight trials tested the TBO concept on a large scale, encompassing a range of operating conditions and facilitating an in-depth evaluation of the operational concept.

A. Time Performance

Flights met expectations for RTA time performance: 514 of the 595 (86.4%) aircraft that completed RTAs (*AAA* and *AAT*) met a 20 second tolerance (Fig. 6) and 575 of the 595 (96.6%) met a 30 second tolerance. This performance meets the European Organisation for Civil Aviation Equipment (EUROCAE) proposed standards for the use of RTA en route with 95% accuracy in meeting a time within 30 seconds [24]. These numbers do not include RTA flights canceled by either the controller or the pilot, since they did not complete the RTA. The positive bias in the distribution indicates that flights crossed the meter fix on average 8.9 seconds after the assigned time. This result contrasts with the results of the 2010 trials, in which flights predominantly crossed the meter fix early [12].

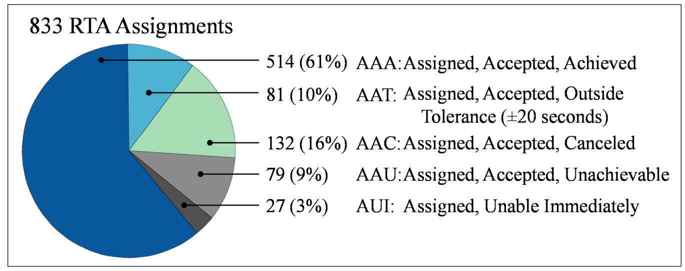

Figure 4. Outcome Summary

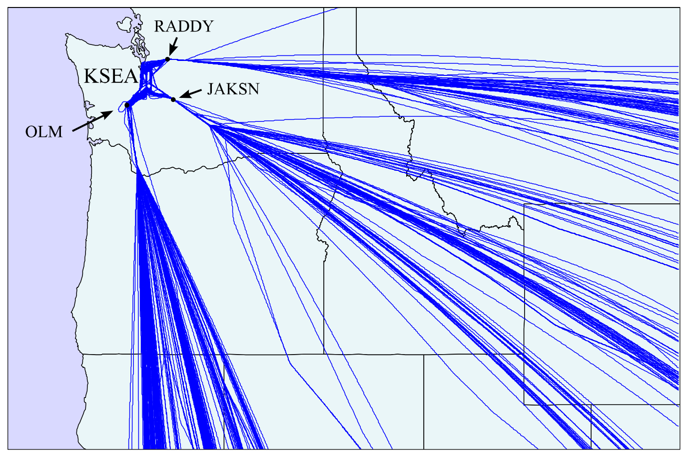

Figure 5. Radar tracks for the 833 participating flights.

TABLE III: Operational Issues and Mitigations

Issue	Mitigation
Difficult to detect "RTA Unable" events	Improved detection through ACARS message downlink.
Some flights missing downlink data	Extensive FMS ACARS automation to provide complete flight information, including both periodic and event-driven message downlinks. Dataset includes true airspeed, detailed trajectory predictions, RTA window and status, cost index, wind measurements, and event-acknowledgement messages.
Unexpected RTA window sizes	RTA Window periodically downlinked and displayed to ZSE prior to RTA assignment.
Missing or out of date FMS-entered winds, winds mismatch with the TMA system	FMS cruise and descent winds automatically uplinked via wind service, downlink to acknowledge pilot acceptance. Wind values interpolated from 2-hour Rapid Update Cycle data, the same source as TMA.
FMS Performance – speed fluctuations, low speeds, high deck angles, and buffet alerts observed during RTA HITLs [8]	Aircraft performance limits configured with minimum Climb, Cruise, and Descent Calibrated Air Speeds (CAS); Pilot to intervene in cases of inappropriate speeds, cancelling the RTA.
Speed, altitude constraints not honored by RTA	Performance limits automatically uplinked to aircraft based on planned trajectory.
RTA Window unavailable on the FMS downlink bus	Temporary RTA uplinked to aircraft FMS, triggering the FMS to calculate the RTA Window, window information subsequently available for downlink.
Limited support tools for RTA monitoring	Intent Display provides aircraft eligibility, diagnostics, and RTA status information. TMC communicates assignment to ATC via phone call.

B. Aircraft Configuration

Table IV summarizes the configuration steps required for flight trials eligibility. The diminishing eligibility is attributable to several factors:

- A small number of aircraft were not programmed with the custom ADDB database due to maintenance schedules
- Pilot workload may have been high, resulting in timed-out wind, performance limit, or RTA uplinks
- The controller may have been uncomfortable issuing the RTA given surrounding traffic and workload
- The flight may have occurred near the boundary of the hours of operation, and hence not assigned

The lesson learned is that the aircraft configuration and RTA assignment process is complicated, even with automation in place, and it will require further streamlining and tool development prior to widespread deployment.

C. Speed and Altitude Restriction Compliance

RTA aircraft met published speed and altitude restrictions similarly to non-RTA aircraft. Table V shows detailed compliance rates for each meter fix, flow configuration, and RTA outcome. There was no significant difference in restriction compliance for RTA flights between the north and south flow. For the flights that did not meet the speed and/or altitude restrictions, a number of these flights were likely cleared by ATC to cross the meter fix outside of published restrictions.

D. RTA Speed Profiles

Fig. 7 shows a scatter plot of speed and Cost Index (CI) (ratio of time cost/hr to fuel cost/lb) changes immediately following RTA assignment. The FMS uses the CI to determine speed schedule; increases in CI are associated with speed increases since time costs are more important. During the execution of an RTA, the FMS adjusts the CI to manage aircraft speed and consequently the arrival time. This plot shows the impact of enabling RTA mode, with points in the top right quadrant corresponding to speed increases, points in the bottom left associated with speed decreases. The outliers indicate that some flights experienced significant increases or decreases in speed due to RTA assignment. The skew to left indicates that aircraft had more capacity to slow down than speed up. The distribution also indicates that for most aircraft in the flight trials, the immediate speed change associated with enabling RTA was less than 15 knots.

Additional observations from the radar track analysis indicate that many flights experienced a sharp increase in speed during descent. This was likely due to a switch from Mach to Indicated Airspeed (IAS). Fig 8. shows the distribution of speed changes as a function of time absorbed. Overall trends indicate that as the amount of delay assigned to the aircraft increased, there was a decrease in the speed at RTA assignment, as is expected. These results also indicate that aircraft had more capacity to slow down than to speed up.

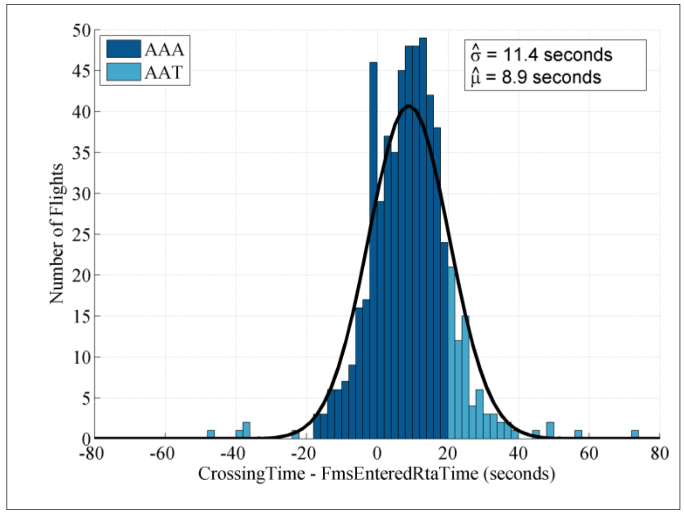

Figure 6. Crossing Time Distribution

TABLE IV. AIRCRAFT CONFIGURATION RESULTS

Configuration Step	Aircraft	% Total	%Previous
Eligible Meter Fix	1532	100%	-
Requested Descent Winds	1423	92.9%	92.9%
Sent Descent Winds	1357	88.6%	95.4%
Accepted Descent Winds	1281	83.6%	94.4%
Accepted Cruise Winds (if Sent)	1258	82.1%	98%
Accepted Performance Limits	1205	78.7%	95.8%
Accepted Temporary RTA	731	47.7%	60.7%
Issued RTA	833	54.4%	69.1% †

† As percentage of *Accepted Performance Limits.*

TABLE V. SPEED AND ALTITUDE COMPLIANCE RATES

% Within Compliance		OLM		JAKSN		RADDY	
		North	***South***	***North***	***South***	***North***	***South***
AAA	***Spd***	89.1	92.0	75	95.8	100	90.4
	Alt	83.6	100	100	87.5	100	100
AAT	***Spd***	83.3	78.0	100	100	100	87.5
	Alt	83.3	96	100	100	100	100

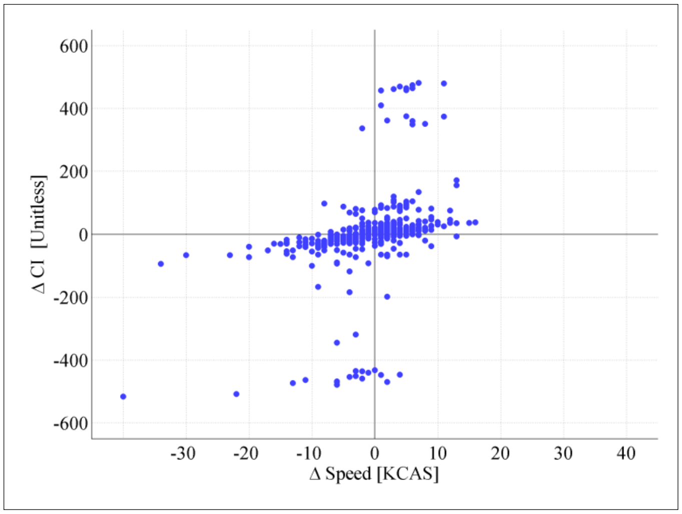

Figure 7. Speed and Cost Index changes at RTA assignment

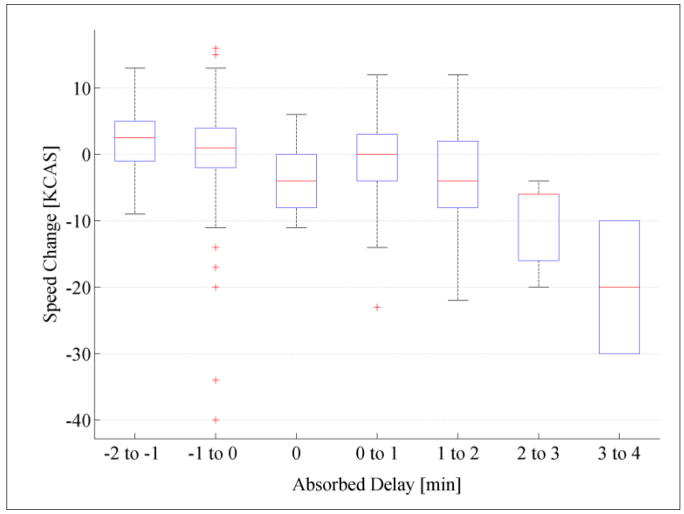

Figure 8. Speed Change vs. Absorbed Delay

E. *Spacing Between Flights During RTA Execution*

Table VI shows the spacing analysis results. This includes flights having another flight within 50 NM at the time of RTA assignment, and also having a flight within 20 NM when crossing the meter fix. There appear to be no significant differences in spacing trends between RTA and non-RTA flights. However, it was observed that controllers were accommodating RTA flights by issuing speed commands to surrounding traffic. The arrival routes and flow directions appear to have little impact on spacing.

F. *Impact of Improved Wind Information*

The 2010 TBO flight trials indicated that updated winds are an important factor when executing an RTA [12]. For the 2011 flight trials, an experimental wind service was developed to provide timely and accurate wind forecast uplinks to the aircraft just prior to RTA assignment [11]. Prior to takeoff, the aircraft FMS was loaded with a single wind value for the entire flight, referred to as the Flight Plan Wind. The wind service provided a one-time uplink of wind values as the aircraft entered the TMA planning horizon for each remaining waypoint in the flight plan (Cruise Wind), and wind values for three flight levels in descent (Descent Wind). Fig. 9 compares FMS wind representation against aircraft measured winds. The comparison uses a nearest neighbor interpolation in the time dimension and 3D-linear interpolation in space. Quality control data (including bank angle) was unavailable for the aircraft wind measurements, and the analysis does not consider the effects of FMS wind blending between measured and forecast winds. Results highlight the importance of providing Cruise Wind and Descent Wind uplinks. Furthermore, results show the potential for improvement in FMS wind representation. Further research is needed to consider the impact of wind blending.

TABLE VI. SEPARATION COMPARISON BETWEEN SURROUNDING LEADING AND TRAILING FLIGHTS

Relative Position	Lead Flight		Trail Flight	
Flight Type	RTA	Non-RTA	RTA	Non-RTA
Number of Flights	76	38	72	34
Average Seperation at Assignment NM)	30.6	28.9	-26.3	-23.7
Average Separation at Meter Fix (NM)	11.6	12.4	-12.5	-12.1
Average Distance Gained (NM)	19.0	16.5	-13.8	-11.6

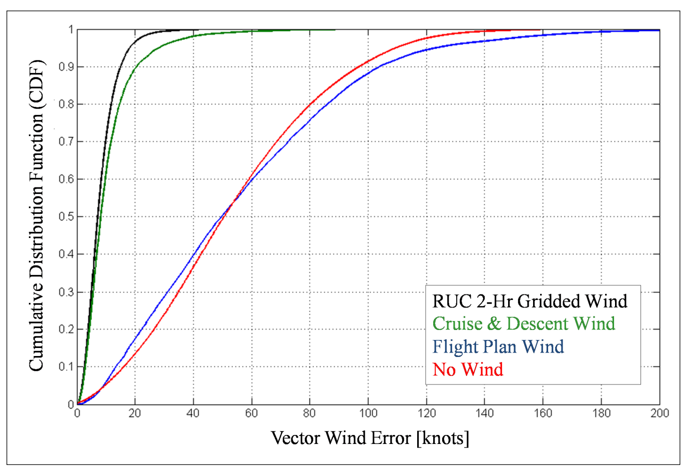

Figure 9. Wind error distributions

G. Air-Ground Trajectory Comparison

Fig. 10 compares ZSE TMA ETA predictions against downlinked FMS ETA predictions at the region of RTA assignment. The flights without a wind update had only a single Flight Plan Wind entry from prior to takeoff. Results show that wind uplinks significantly improve air-ground trajectory synchronization, reducing the mean error from 24 seconds (without wind update) to 8 seconds (with wind update). Reducing discrepancies between air and ground systems remains an open area of research [25], [26], with significant potential for improvement. Beyond technical issues, there are also a number of open policy issues related to trajectory synchronization, including defining roles, responsibilities, and methodology for ensuring air-ground trajectory synchronization.

Flights assigned an RTA time in the middle to mid-late portion of the RTA window were most likely to successfully execute the RTA. The RTA window information was found to be very helpful to the TMU in assigning the RTA times. RTA window accuracy was found to be an issue, leading in many cases to RTAs which were close to the window edges becoming unachievable.

The FMS downlinks exhibited a positive ETA error bias (i.e., flights crossed the meter fix later than the FMS predicted), which is different from the 2010 trials. This finding needs further investigation.

H. Controller Feedback

There were 38 surveys submitted during the trials, with controllers indicating they worked approximately 241 RTA flights. Feedback from ATC (both the TMU and Radar controllers) show that controllers were generally positive about the concept (Fig. 11, Fig. 12), but indicated there would need to be improved processes, separation procedures, and automation. In particular:

- Display of RTA times at the control position
- Separation between RTA aircraft and between RTA and non-RTA aircraft
- Indication that flights are executing RTAs as they enter new sectors
- Ability to freeze times for individual flights

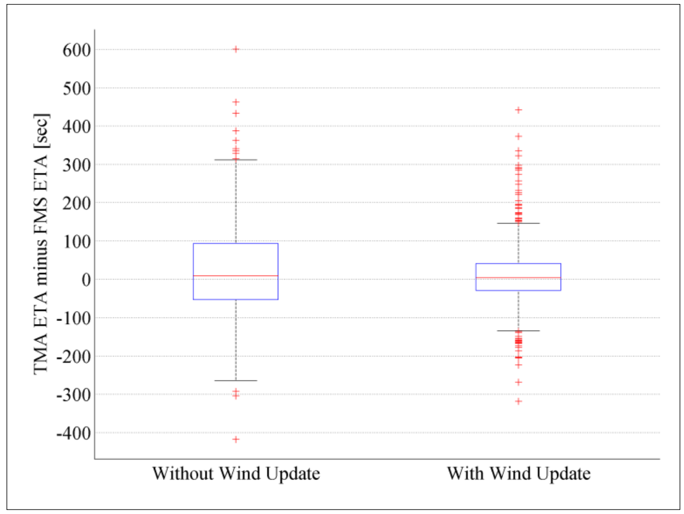

Figure 10. Air-ground trajectory harmonization

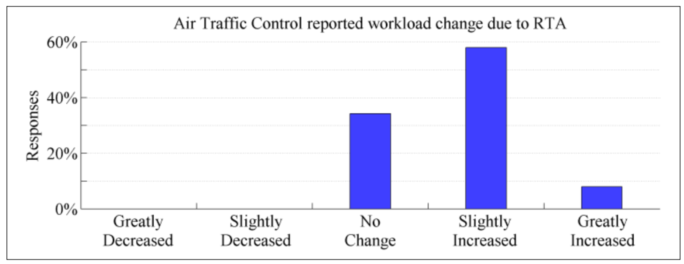

Figure 11. ATC reported workload

I. Pilot Feedback

Pilot feedback was sparse but generally positive. Approximately two thirds of the 16 respondents indicated that there was no increase in pilot workload. However, half noted that speed control was an issue during RTA execution, particularly dealing with auto-throttles during descent. During a Vertical Navigation Mode (VNAV PATH) descent, the auto-throttles will not advance unless the actual indicated airspeed is less than the commanded speed by more than 15 knots. This functionality can potentially result in the aircraft flying slower than the preferred speed in descent. ATC also reported observing this same effect. The flight trials communications phraseology was noted to be acceptable to pilots.

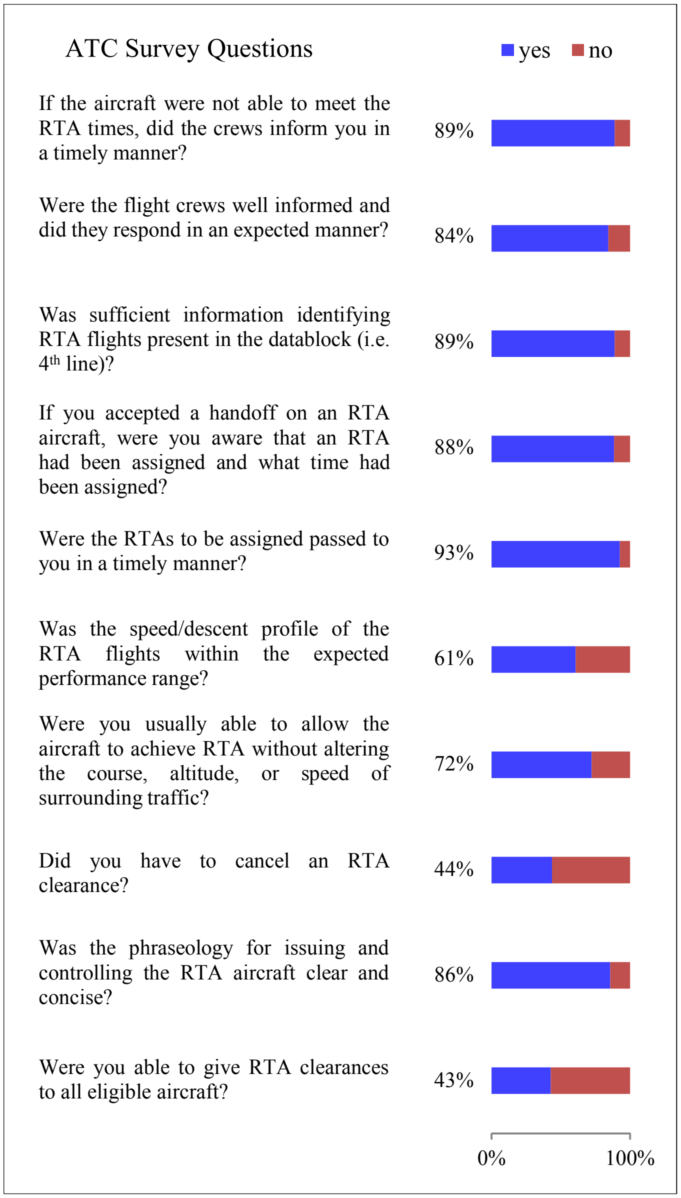

Figure 12. ATC Survey Results

IV. Conclusions

The first two stated objectives for the flight trials were to increase exposure of the RTA concept and procedures to controllers and flight crews and to improve acceptance and execution rate of RTA assignments from the previous flight trials. The 2011 flight trials included 833 RTA assignments, as compared to 57 RTA assignments in the 2010 trials. This is a significant increase in exposure to the RTA concept for controllers and flight crews. Of the 833 flights assigned RTAs, 595 (71%) fully executed the RTA to the meter fix, an increase over the first flight trials where 61% of assigned aircraft fully executed RTAs.

The third objective was to streamline the process of RTA assignment. Processes on the ground, data link, and automated flight preparations of eligible aircraft for the expanded flight trials greatly increased the ability for data collection and reduced unknowns in the flight deck. While all of these processes were successful in meeting the needs of the flight trials, some hardening and formalization would be needed in order to make the concept of using RTAs to meet TMA STAs a viable operation in domestic airspace by 2018. These issues and proposed modifications to processes and automation will be addressed in future work.

The fourth objective of the flight trials was to facilitate a more in-depth evaluation of the operational concept and the utility of RTA as a useful tool for ATC and operators. Several issues were identified for both ATC and the operators concerning the utility of RTA and the operation as defined for the flight trials. Of the flights that were issued RTAs, 16% had their RTAs canceled, either due to ATC or pilot concerns. The RTA concept was an involved process and there were instances where coordination procedures, outlined in the Expanded Flight Trials Plan [5], were not followed by either controllers or pilots. Familiarity with the RTA concept could reduce some of these instances, but additional concerns and streamlining of procedures still need to be addressed.

In conclusion, the 2011 TBO flight trials demonstrated that aircraft can meet desired RTA time performance, however a number of operational issues need addressing before widespread deployment. These issues include controller and pilot concerns with RTA speed profiles, pilot workload in managing RTA speeds and auto-throttles in descent, controller workload in managing spacing in heavy traffic, roles and responsibilities associated with providing updated wind forecasts, and the overall fragility of RTA under current operating conditions. These issues make RTA unlikely for mid-term implementation. The results from these trials were used to inform standards committees, manufacturers, and other TBO stakeholders in order to mature RTA for future operational use.

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APPENDIX A: DAILY OUTCOME TOTALS

	11/30	12/01	12/02	12/03	12/04	12/05	12/06	12/07	12/08	12/09	12/10	12/11
AAA	7	10	14	29	26	21	26	19	18	38	34	20
AAT	1	1	4	3	2	0	2	7	2	1	4	7
AAC	5	4	3	1	5	1	2	7	14	2	4	7
AAU	5	2	6	8	6	2	1	3	3	2	2	8
AUI	2	1	4	0	0	1	1	0	0	0	1	0
Total	20	18	31	41	39	25	32	36	37	43	45	42

	12/12	12/13	12/14	12/15	12/16	12/17	12/18	12/19	12/20	12/21	12/22	Total
AAA	19	30	32	22	33	33	25	17	14	17	10	**514**
AAT	2	5	3	1	6	3	6	3	16	2	0	**81**
AAC	12	7	6	10	5	8	6	8	3	9	3	**132**
AAU	8	0	3	5	4	2	2	1	0	4	2	**79**
AUI	1	1	1	4	0	0	2	0	1	5	2	**27**
Total	42	43	45	42	48	46	41	29	34	37	17	**833**