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Agenda Item 4: AI 17-5 ADS-B Implementation

AUTOMATIC DEPENDENT SURVEILLANCE – BROADCAST (ADS-B) IN-TRAIL OPERATIONAL PROCEDURES (ITP) OPERATIONAL FLIGHT TRIAL PROJECT OVERVIEW

Presented by the FAA

SUMMARY

The purpose of this working paper is to present the U.S. Federal Aviation Administration (FAA) activities associated with the ADS-B In-Trail Procedures (ITP) operational trial being conducted in the Pacific.

1. INTRODUCTION

1.1. The U.S. Federal Aviation Administration (FAA) created the Surveillance and Broadcast Services (SBS) Program in September 2005 to oversee and direct the acquisition of a number of surveillance and broadcast services in specified volumes of U.S. national airspace. These services are provided via a set of FAA-specified service volumes in en route airspace, terminal area airspace, and on airport surfaces.

1.2. The SBS Program Office is also developing a number of airborne Automatic Dependent Surveillance – Broadcast (ADS-B) applications that are expected to provide benefits to operators who choose to equip their aircraft with appropriate avionics, including "ADS-B In" (i.e. the ability to receive, process, and display ADS-B data from surrounding aircraft). In addition to providing benefits to operators who equip, these applications will help accelerate the understanding and acceptance of airborne ADS-B and provide an increased user-base of equipped aircraft that will support future applications. One such airborne ADS-B application being developed is ADS-B In-Trail Procedures (ITP).

1.3. Aircraft operating in oceanic airspace are, at times, held at non-optimal flight levels due to conflicting traffic either at the desired flight level or at flight levels between the existing flight level and the optimal flight level. The use of flight level changes enabled by ADS-B ITP can supplement existing oceanic procedures creating greater operational efficiency.

1.4. Due to significant interest by international partners, the United States, in collaboration with a number of other States, has been working over the past several years to develop procedures and standards for ADS-B ITP.

1.5. The FAA entered into an agreement with United Airlines for the purpose of performing an operational evaluation of ADS-B ITP in the Pacific Region on revenue flights. This agreement includes the development and certification of on-board systems that provide the ADS-B ITP criteria and display that information to the pilot.

1.6. The purpose of this paper is to provide an overview of the development of the ADS-B ITP and preliminary results from the operational trial that began in August 2011.

2. BACKGROUND

2.1. ADS-B ITP is comprised of a set of six flight level change geometries with each geometry dictated by whether the ITP aircraft desires to climb or descend and its proximate relationship with the other aircraft:

- Leading climb
- Leading descent
- Following climb
- Following descent
- Combined climb
- Combined descent

While there is no limit on the total climb authorized in the ADS-B ITP flight level change, the other aircraft cannot be more than 2,000 feet above or below the ADS-B ITP aircraft's altitude.

2.2. For ADS-B ITP, the maneuvering (trailing or leading) aircraft obtains the flight identification (ID), altitude, position and ground speed transmitted by proximate ADS-B equipped non-manuevering (leading or trailing) aircraft. Based on the ADS-B data from the non-maneuvering, or reference aircraft, a pilot can request clearance for an ITP altitude change to air traffic control (ATC). The controller verifies that the ITP and reference aircraft are same direction traffic and that the maximum closing Mach differential is less than or equal to a Mach Number of 0.06. If the controller determines that the requesting aircraft will maintain standard separation minima with all aircraft other than the ITP reference aircraft, a clearance for the climb or descent may be issued. After re-validating that the ITP initiation criteria are still valid, the maneuvering aircraft may then vertically transition through the altitude of the non-maneuvering aircraft.

2.3. To perform an ADS-B ITP, the aircraft desiring to climb or descend must be equipped with an ADS-B transceiver and an appropriate onboard decision support system, both of which have to be certified for this application. Aircraft operators choosing to equip in this manner would be able to take advantage of this procedure when operating in proximity to aircraft equipped with a suitable ADS-B transmitter ("ADS-B Out").

2.4. Aircraft operators who choose to equip with an ADS-B transceiver and on-board automation will benefit from the ability to perform in-trail maneuvers to achieve more time at optimum altitudes. This could result in more efficient and predictable flight profiles, thereby saving fuel and, in some cases, allowing operators to make operational decisions such as the opportunity to carry additional high value payload in lieu of additional contingency fuel. Aircraft operators have also indicated there may be other potential benefits associated with increased cockpit situational awareness resulting from ADS-B In traffic displays.

2.5. Detailed benefits analyses for ADS-B ITP have focused on savings that could be achieved in the North Atlantic Organized Track System (NATOTS), Pacific Organized Track System (PACOTS) and in the South Pacific (SOPAC) airspace, including flights that operate between the west coast of the United States and Australia or New Zealand.

2.6. A summary of the ITP criteria are as follows:

- Maximum of two reference (target) aircraft; +/- 2000 feet from ITP aircraft altitude
- Reference aircraft can be any combination of ahead of or behind the ITP aircraft
- ITP aircraft can climb or descend at no less than 300 feet per minute
- Initiated with no closer than 15 NM and no more than 20 knots of closure. *Note: for the purposes of the initial phase of the operational evaluation the criteria has been modified to be 18 NM and no more than 20 knots of closure.*
- The closing Mach number difference must be less than or equal to Mach Number of 0.06
- ITP aircraft must maintain Mach number in climb
- Reference aircraft must be level and non-maneuvering
- ITP aircraft must have certified ITP equipment onboard as well as CPDLC
- Reference aircraft must have valid ADS-B Out signal

3. FAA ADS-B ITP PROJECT

3.1. ADS-B ITP has been under development for over eight years. The work supporting the development of ITP has ranged from batch simulations to human-in-the-loop experiments and has included avionics and separation standards development. Some of these activities included: development and approval of an ICAO Separation and Airspace Safety Panel (SASP) ITP Circular; ADS-B ITP Safety, Performance and Interoperability Requirements (SPR) Documents DO-312 and ED-159; U.S. National

Aeronautics and Space Administration (NASA) report detailing results from a human-in-the-loop experiment that investigated the viability of ADS-B ITP from a cockpit prospective; and a NASA report detailing results from a joint Airservices Australia and NASA validation experiment of the ATC procedures associated with ADS-B ITP.

3.2. In 2008, the FAA SBS program established a project for the purpose of enabling an operational evaluation of ADS-B ITP by aircraft operating in revenue service. The objectives of the project were to a) validate the operational performance and economic benefits of ITP; and b) develop and validate ADS-B ITP Minimum Operational Performance Specifications (MOPS).

3.3. As a part of this project, the FAA established agreements with United Airlines and Honeywell to accomplish the work necessary for the development, certification and installation of onboard systems for 12 United Airlines Boeing 747-400s. Goodrich Aerospace was selected by the partners to be the project's Electronic Flight Bag (EFB) supplier. These onboard systems calculate the ADS-B ITP criteria and display that information to the pilot. Honeywell was primarily responsible for the development of the traffic computer and traffic computer software, as well as the ITP display software. Goodrich Aerospace was responsible for the EFB hardware and operating system software. United Airlines has been responsible for overall coordination and installation of ITP equipment, obtaining operational approval and conducting the flight evaluation.

3.4. The entire ITP system was certified for use on a United Boeing 747 in June 2011. United Airlines subsequently received Operational Approval from FAA Flight Standards to commence ITP operations on 15 August 2011.

3.5. The FAA developed ATC procedures and conducted the safety analyses that were required to support the flight evaluation. The ATC procedures were developed and tested using the FAA's Dynamic Simulation (DYSIM) simulation system. Safety analyses for the operational flight evaluation were completed following the FAA's Safety Management System procedures and resulted in an ITP Safety Risk Management Document that was approved by the FAA's safety regulator in June 2011.

3.6. FAA En Route and Oceanic Safety and Operations Support authorized Oakland Air Route Traffic Control Center (KZAK) to initiate the operational evaluation in the SOPAC airspace on 15 August 2011. This authorization was expanded to include the entire KZAK managed oceanic airspace in December 2011.

4. ADS-B ITP OPERATIONAL EVALUATION

4.1. As stated previously, the goal of the FAA ITP project is to enable an operational evaluation of ADS-B ITP in revenue service. Details of the operational flight evaluation are outlined below.

4.2. Scope:

a. The operational evaluation is being conducted using ITP system equipped United Airlines Boeing 747-400's operating in the Oakland Oceanic FIR.

b. There is a comprehensive designated data collection activity for both United Airlines and ZOA. Any significant adverse operational issues that are discovered (such as communication or workload) will result in an immediate suspension of all operational evaluation activity.

c. The data collected is being used to enhance the understanding of the economic, safety and operational impact of ADS-B ITP.

d. All pilots and air traffic controllers authorized to participate have completed approved training.

e. The operational evaluation flights will be conducted for a period of at least one year.

This operational evaluation has additionally been adopted as an initiative within the Asia and South Pacific Initiative to Reduce Emissions (ASPIRE) program. The ASPIRE program is a cooperative agreement between the FAA, Airservices Australia and Airways Corporation New Zealand which will allow the organizations to share data and provide a mechanism for providing mutual support of the operational evaluation.

4.3. Objectives

a. Validate that air traffic controllers applying ADS-B ITP find it a useful tool.

b. With data collected from United Airlines, validate the impact on contingency fuel loading by dispatch and flight crews when they are aware that the aircraft will be ITP capable.

c. From post flight surveys, determine the significance and value of increased situation awareness for the flight crew.

d. Determine how often the ADS-B ITP is requested, and how often an ITP clearance is issued.

e. Determine a measurable reduction in fuel burn on flights with the combined benefit of situation awareness and ITP climbs.

f. Validate SPR assumptions and gather data to support validation of the MOPS currently under development for ADS-B ITP.

4.4. A copy of the Controller Pilot Data Link Communications (CPDLC) messages that are being used during the operational trail is included in Attachment A. Until ITP message sets are built into airborne and ground based communication platforms, standardized free text messages (developed and endorsed by ICAO) and concatenated with standard CPDLC vertical request clearances, will be used.

4.5. The FAA is currently in discussions with the air navigation service providers (ANSPs) for New Zealand and Fiji about expanding the ITP operational evaluation into the Nadi FIR and the Auckland Oceanic FIR. The FAA has also held discussions with the Japan Civil Aviation Bureau about the potential for offering ITP in the Fukuoka FIR at some point in the future.

5. OPERATIONAL EVALUATION PRELIMINARY RESULTS

5.1. A comprehensive data collection and analysis process was developed for the operational evaluation. This data will be used to validate operational performance and economic benefits of ITP, validate safety requirements and assumptions and monitor operational hazards that could lead to suspension of the operational flight trial.There are seven different types of data being collected during the operational flight evaluation. The seven type of data are:United Airlines computer data – supports analysis of the economic benefits of ITP

- Dispatch comment sheet – captures comments from dispatchers about fuel planning and consumption from pre-flight planning to arrival
- CPDLC messages – captures ITP events and related messages
- ADS-C position reports – capture position information of aircraft involved in an ITP event
- Controller comment sheet – provides an opportunity for controllers to provide feedback on ITP events
- Pilot comment sheet – captures pilots comments on subjects including fuel planning, situation awareness, operational impacts and comments on human factors aspects of ITP
- Pilot data sheet – captures information about the change of ITP distance during an ITP event and the duration of the flight level change

5.2 This data is collected, analyzed and used to address key higher level metrics and hazard tracking. Attachment B includes a table of the key metrics that are being tracked and the summary of results from ITPs performed in August 2011.

5.3. The data contained in the tables involved two ITP equipped United Airlines Boeing 747s flying on the same day in the same airspace (one flight operated from LAX-SYD flight and the other flight from SFO-SYD). Most of the ITPs performed that evening were between the two United Airlines aircraft. They were valid operational ITPs performed in non-radar airspace applying the ITP separation standard, but United Airlines intentionally conducted extra climbs and descents to allow the partners an opportunity to gather additional data on ITP. United Airlines also routed the aircraft so the flight paths would facilitate ITP events. As a result, the business case numbers were not valid for these series of flights. All other data is valid and provides insight

into the application of ADS-B ITP in the SOPAC airspace.

6. SUMMARY

6.1. The FAA began an operational evaluation of ADS-B ITP along SOPAC routes in August 2011 which has been expanded to all oceanic airspace controlled by Oakland Air Route Traffic Control Center (KZAK) in December 2011. The FAA established agreements that led to the development and certification of onboard systems that provide the ADS-B ITP criteria and display that information to the pilot. The FAA has also performed all required safety management system processes and analyses.

6.2. For additional information on the operational evaluation, please contact Mr. Ken Jones at Kenneth.M.Jones@nasa.gov or +1 (757) 864-5013.

7. ACTION BY THE MEETING

7.1 The meeting is invited to:

a) Note the information presented in this paper; and

b) Support the ADS-B ITP operational trials in the Pacific.

ATTACHMENT A – CPDLC Messages

Use of downlink pre-formatted free text messages

The airborne system will append the vertical request message element with a free text message dM67.

When a vertical request for climbing (resp. for descending) has been prepared as part of an In Trail Procedures transaction, the aircraft shall send a downlink message containing dM9 REQUEST CLIMB TO [level] (resp. dM10 REQUEST DESCENT TO [level]) concatenated with message element dM67 containing the following text:

ITP procedure type (number and relative position of reference aircraft)	**dM67 Message Element content**
1 reference aircraft (ahead)	"ITP [Distance] BEHIND [Aircraftflightidentification]"
1 reference aircraft (behind)	"ITP [Distance] AHEAD OF [Aircraftflightidentification]"
2 reference aircraft (both ahead)	"ITP [Distance] BEHIND[Aircraftflightidentification] AND [Distance] BEHIND [Aircraftflightidentification]"
2 reference aircraft (both behind)	"ITP [Distance] AHEAD OF [Aircraftflightidentification] AND [Distance] AHEAD OF [Aircraftflightidentification]"
2 reference aircraft (one ahead and one behind)	"ITP [Distance] BEHIND [Aircraftflightidentification] AND [Distance] AHEAD OF [Aircraftflightidentification]"

Example of ITP request message:
REQUEST CLIMB TO FL360
ITP 25NM BEHIND SIA228 AND 21NM AHEAD OF AFR008

Use of uplink pre-formatted free text messages

The controller will append the vertical request message element with a free text message uM169.

When a vertical clearance for climbing (resp. for descending) has been prepared as part of an In Trail Procedures transaction, the ground system shall send an uplink message containing uM20 CLIMB TO [level] (resp. uM23 DESCEND TO [level]) concatenated with message element dM169 containing the following text:

ITP procedure type (number and relative position of reference aircraft)	**uM169 Message Element content**
1 reference aircraft (ahead)	"ITP BEHIND [Aircraftflightidentification]"
1 reference aircraft (behind)	"ITP AHEAD OF [Aircraftflightidentification]"
2 reference aircraft (both ahead)	"ITP BEHIND [Aircraftflightidentification] AND BEHIND [Aircraftflightidentification]"
2 reference aircraft (both behind)	"ITP AHEAD OF [Aircraftflightidentification] AND AHEAD OF [Aircraftflightidentification]"
2 reference aircraft (one ahead and one behind)	"ITP BEHIND [Aircraftflightidentification] AND AHEAD OF [Aircraftflightidentification]"

Example of ITP clearance message:
ITP BEHIND SIA228 AND AHEAD OF AFR008
CLIMB TO FL360
REPORT LEVEL FL360

ATTACHMENT B - Preliminary Operational Evaluation Results

Operational and Economic Metrics

Application Validation Metric	Expected Measurement	Actual Measurement	Explanation of Deviation	Corrective Action
Number of ITP maneuvers performed per month	4	9	intial test and demo	
Average amount of reduced discretionary extra fuel for ITP capable aircraft per flight	300 lbs	N/A	extra fuel boarded to facilitate test	
Average amount of increased payload for ITP capable aircraft per flight	150 lbs	N/A		
Average fuel burn reduction for ITP capable aircraft per flight	60 lbs	N/A	slight increase in burn probably due to special routing and extra vertical maneuvers	
Percentage of flight crew requests for ITP, that result in controller clearances granted for ITP	85%	100%	excellent controller support for demo	
Percentage of flights with ITP capableaircraft, where crews report using the plan view display to make a flight path decision that they wouldn't have otherwise made	50%	50%	crews gave specific use for planning enhancement in arrival environment	

Safety related metrics

Parameter to be Monitored	Expected Avg. Measurement	Actual Measurements			Explanation of Deviation	Corrective Action Required?
		Min	Mean	Max		
ITP Initiation Distance	20 nm	23.1	33.5	88.4		
ITP Distance at Co-altitude	18 nm	23.8	34.5	88.5		
Time From ITP Initiation to Level Off at New Altitude	7 min	3	5.3	8	about 50% @ 300fpm	
Percentage of ITP maneuvers where a wake encounter occurred and a wake turbulence incident was reported	2% *		0			
Wake Turbulence Incident Severity (5-1)**	5					

– END –