

ADS-B In-Trail Procedures

Enabling Climbs, Saving Fuel

From Concept to Flight

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Outline

- **Motivation and History**
- **Concept Description and Evaluation**
- **Operational Flight Evaluation**
- **Summary**



ADS-B In-Trail Procedures

Original NASA Objective and Rationale (2003)



Objective

Develop a near-term application of ADS-B that delivers immediate airline benefits through the introduction of more efficient oceanic operations

– **Develop ...**

- Conduct the research, simulations, safety analyses and flight tests required that lead to an implementation of a new oceanic capability

– **Near-Term Application of ADS-B...**

- ADS-B is a fundamental component of NextGen; near-term aspect helps get ADS-B out of the lab and into the real world

– **Immediate Airline Operational benefits ...**

- Airline operators benefit from their equipage investment; provides an incentive for operators to voluntarily equip with transformational technologies

– **More Efficient ... Operations**

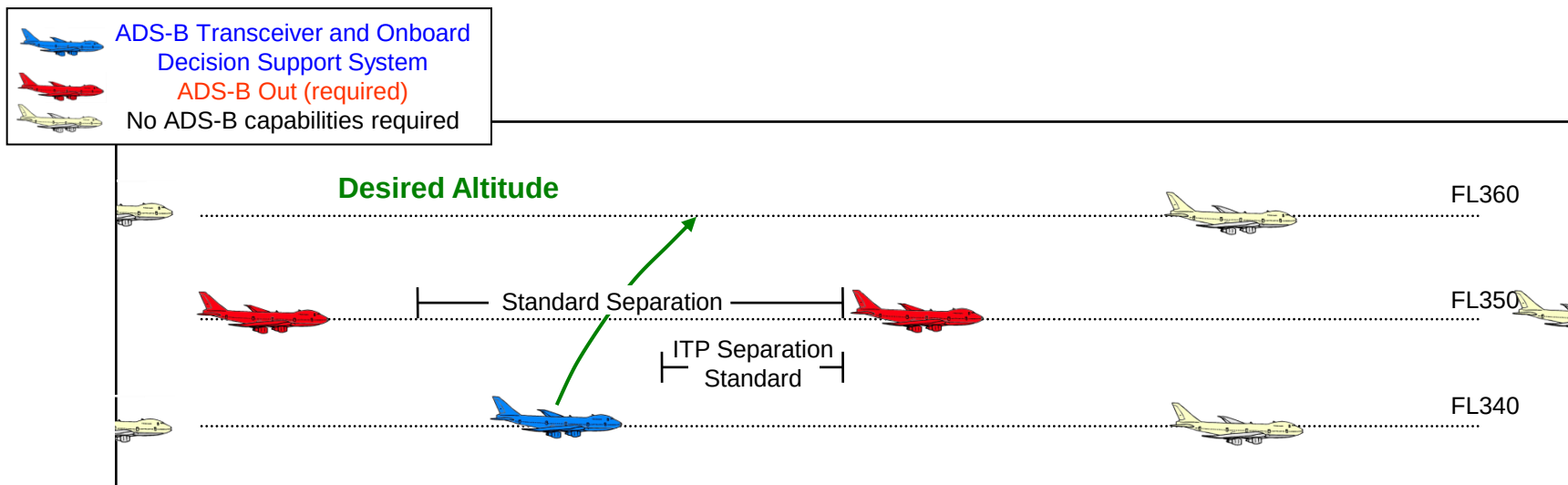
- Applications that enable aircraft to fly at optimal altitudes, tracks and speeds

– **Oceanic ...**

- Air traffic environment that is open to new technologies and procedures
- Provide tangible benefits by solving a significant problem (aircraft flying at inefficient altitudes) using relatively low cost technology



Motivation for ADS-B In-Trail Procedures



NEED → **CHALLENGE** = **OPPORTUNITIES**

➤ Altitude Changes required for better fuel economy, winds, and ride quality

➤ The combination of locally dense traffic and large separation minima limits altitude changes

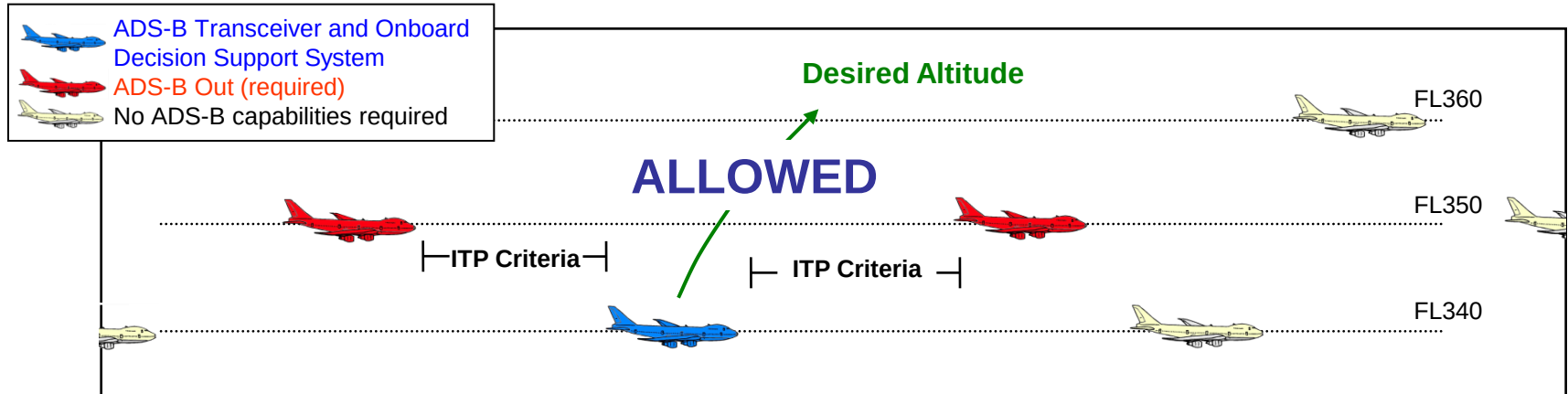
➤ Use airborne ADS-B applications to enable altitude changes otherwise blocked by conventional operations

ADS-B In-Trail Procedures

Sequence



ADS-B ITP Climb



Pilot Responsibility

Step 1: Pilot verifies ITP criteria

- ☒ ITP distance is greater than 15 NM
- ☒ Ground speed difference < 20 kts if 15 NM - 20 NM from reference aircraft or <30 kts if greater than 20 NM

Step 2: Pilot requests ITP climb from ATC

Step 5: Pilot revalidates ITP criteria

Step 6: Executes maneuver

Controller Responsibility

Step 3: Controller verifies:

- ☒ Altitude requested is available
- ☒ Closing Mach number difference between aircraft requesting ITP and reference aircraft ≤ 0.06

Step 4: Controller grants ITP climb

ADS-B In-Trail Procedures Maturity (~2008)

- **Concept Development (2004)**
- **Evaluation (2005-2007)**
 - **2005 - 2007** Batch simulations to evaluate ITP climb opportunities and efficiency gains
 - **2006** Experimental HITL evaluation of ITP and cockpit decision support tools: pilot perspective
 - **2007** Experimental HITL evaluation of ITP operations: controller perspective
- **Standards**
 - RTCA DO-312: ITP system level avionics standard (2008)
 - ICAO Separation and Airspace Safety Panel (SASP): ADS-B ITP Circular (panel approved ITP separation standard, 2009)
- **Next step – move from simulation to revenue service**
- **Transfer technology to the FAA**
 - FAA SBS had the mission and resources to implement this in revenue service



ITP Prototype Display (2006)
in NASA LaRC's Air Traffic Operations Lab

ADS-B In-Trail Procedures

Operational Evaluation

- **Goals**

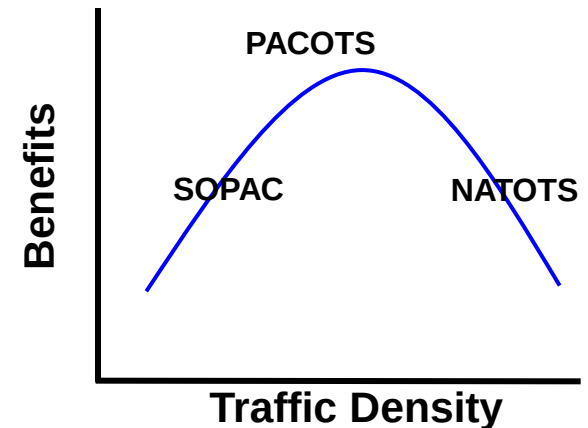
- Employ ADS-B ITP in limited, oceanic air carrier operations in 2011

- **Objectives**

- Validate operational performance of ADS-B ITP
- Validate economic benefits of ADS-B ITP
- Establish framework for global implementation of ADS-B ITP (ITP MOPS/TSO) and follow-on airborne ADS-B applications

- **Location**

- Potential locations include SOPAC, PACOTS, NATOTS
- SOPAC appears to be a good initial implementation region
 - Favorable business case
 - Straight forward implementation
- Future migration to other oceanic regions



ADS-B In-Trail Procedures

Operational Evaluation Partnership Agreements

- **Partnership**

- FAA and United Airlines agreement signed in April 2009
 - Additional partners include Honeywell and Goodrich



- **Scope**

- Retrofit 12 UAL 747-400 aircraft with certified ITP systems
- Gather data on use of systems in SOPAC for a year starting in 2011



- **Outcomes**

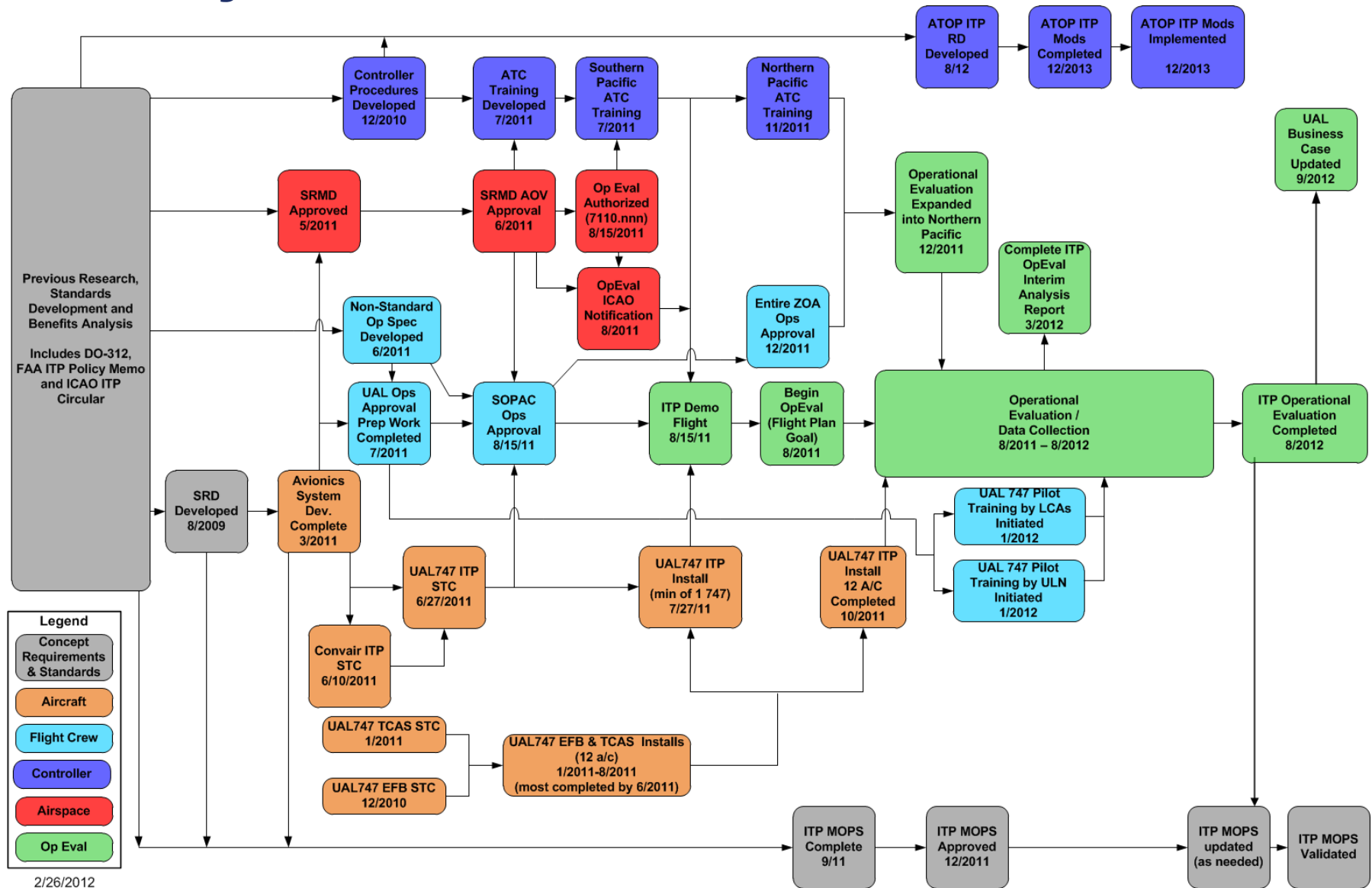
- Validate economic benefits of ADS-B ITP
- Validate operational performance of ADS-B ITP



- **ASPIRE Agreement Partners**

- Air Services Australia
- Airways Corp. New Zealand

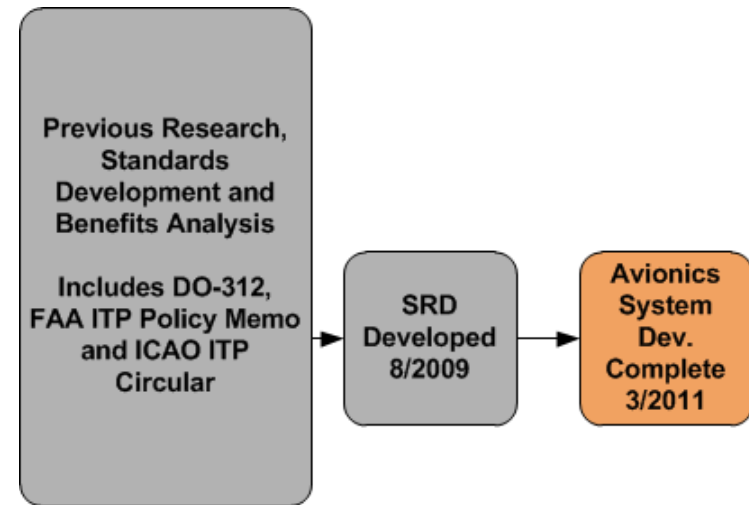
ITP Key Activities



SRD/Avionics Systems Development

- **System Requirements Document**

- Defines requirements for the system
- Based on DO-312, initial MOPS material, previous research (NASA)
 - Pilot focus group, simulator evaluations, test flights

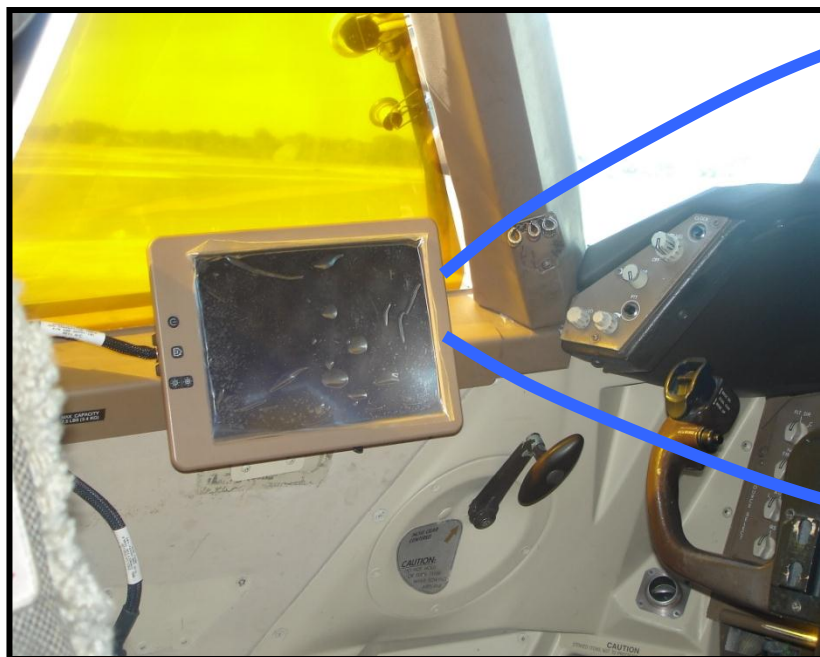


- **Systems Development**

- System architecture design and development
- Traffic computer design and development
- Electronic Flight Bag (EFB) development and design
- Display design
 - Pilot focus group, simulator evaluations, test flights

Flight Crew Interface

- ADS-B-In requires hardware, software and crew interface
- EFB (side mounted display) solution chosen as a retrofit option
- Based on NASA's ITP Prototype



Side mounted display installed in a B747

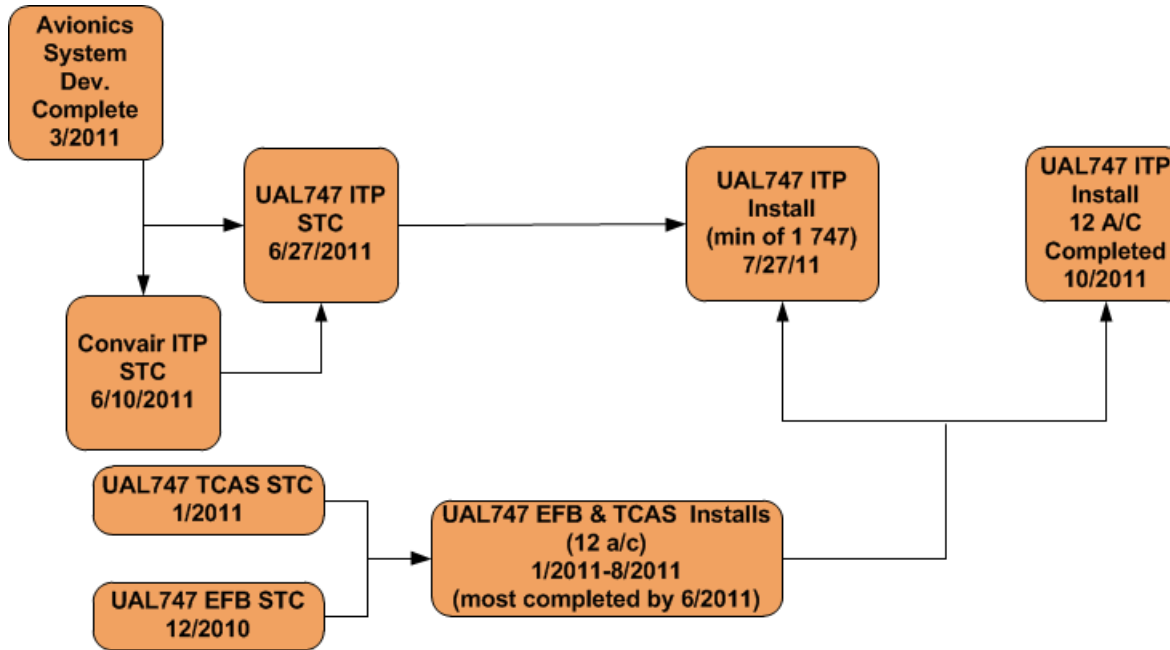


Plan View



ITP Data View

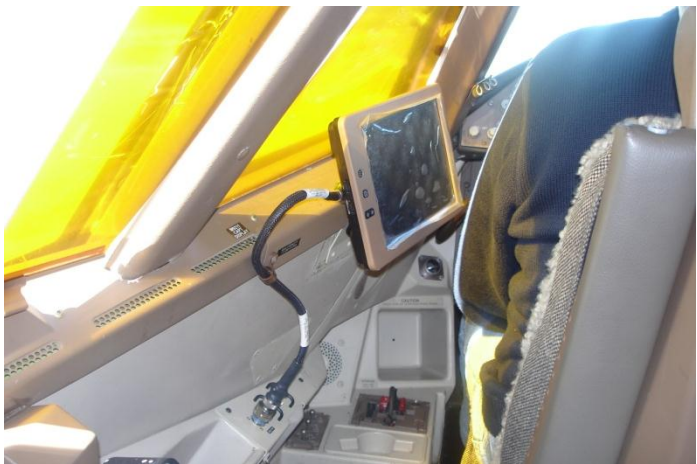
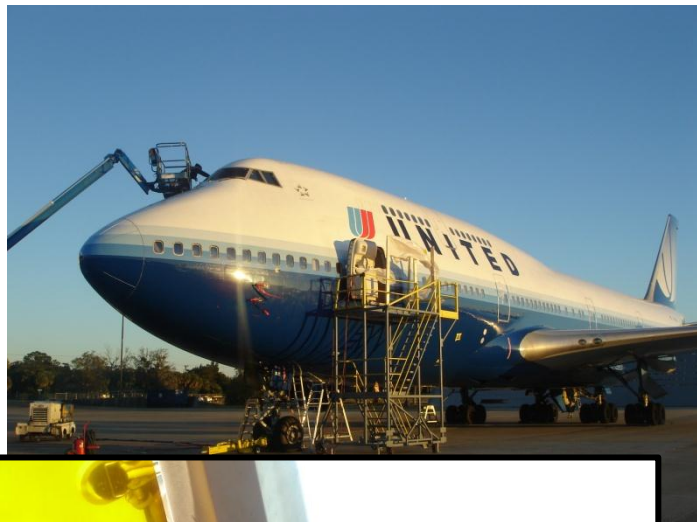
Certification and Installation Approach



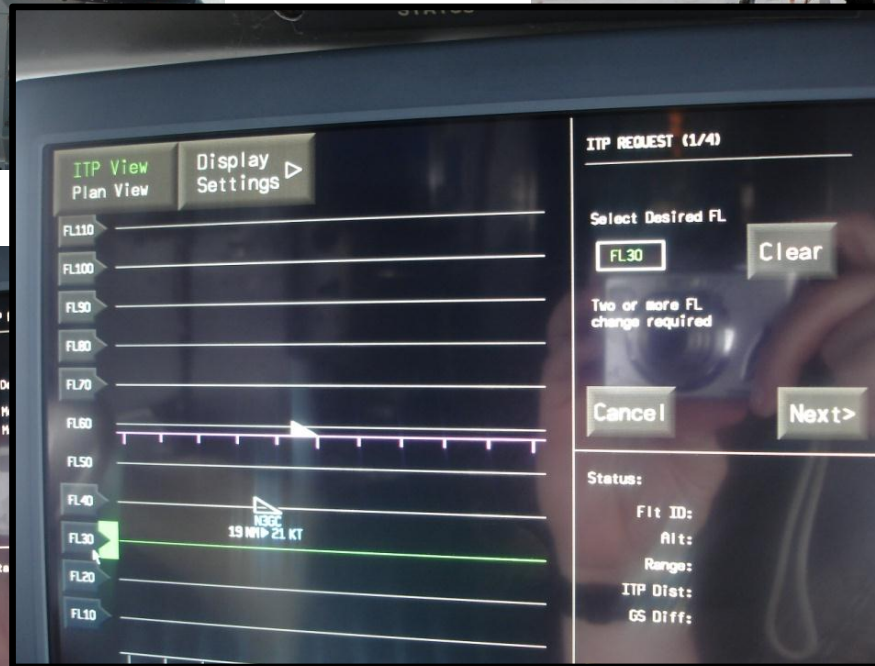
- **Obtained a total of four Supplemental Type Certificates (STCs) for the project**
 - Two STCs for non-ITP components to facilitate efficient installation of hardware (Honeywell TCAS system and Goodrich EFB) on the aircraft
 - Third STC was for Convairs equipped with an ITP system
 - Fourth STC was for a 747s equipped with an ITP system

ADS-B In-Trail Procedures

First of Type Installation (First two STCs) – Nov 2010

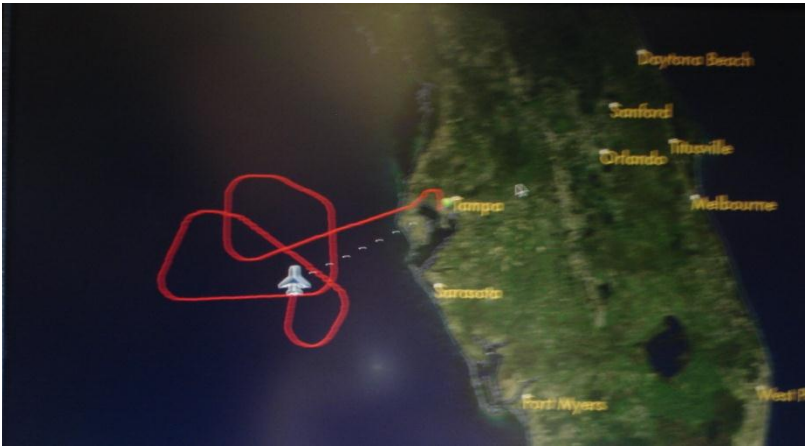


Convair ITP Flight Testing

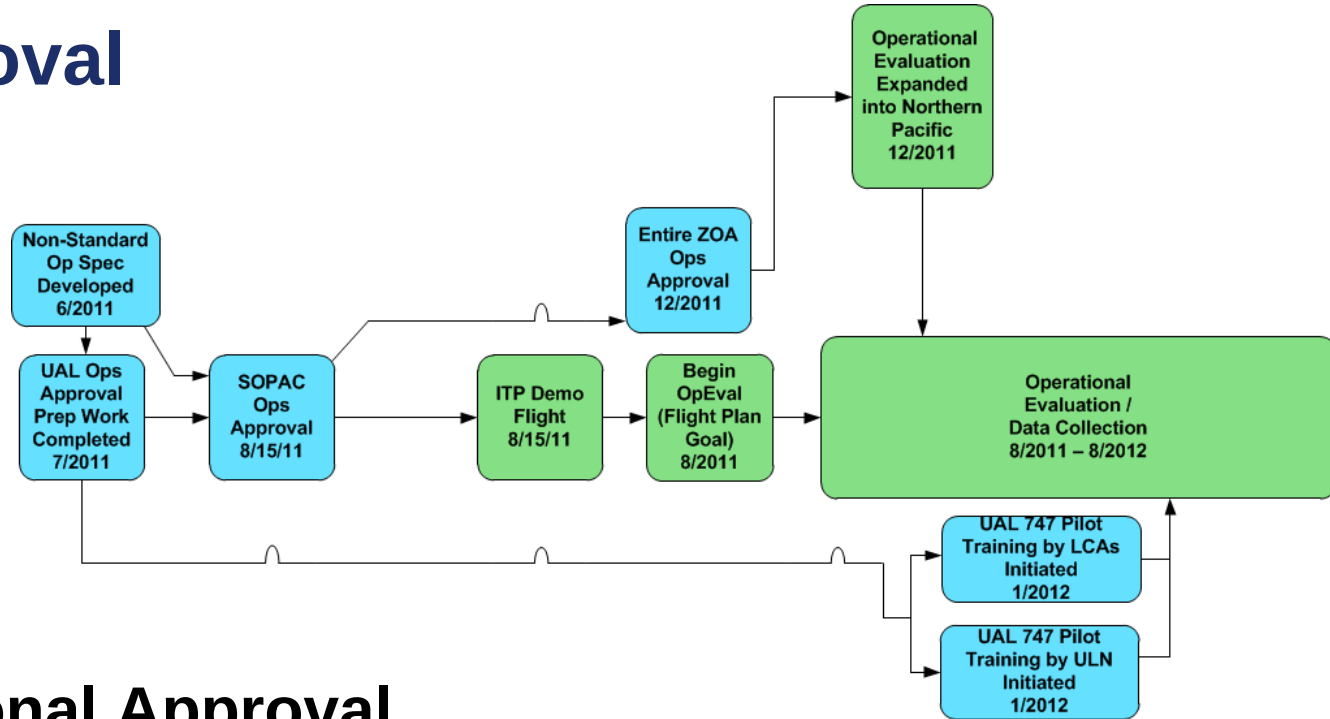


ADS-B In-Trail Procedures

Final ITP STC Flight Testing – May 2011



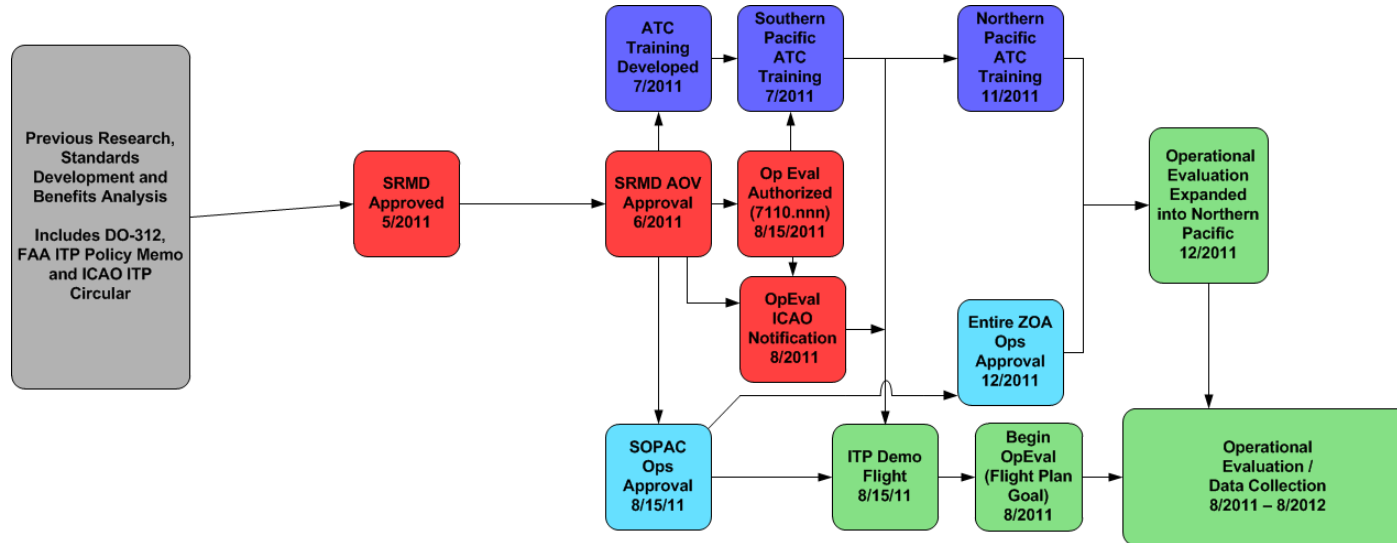
Ops Approval



- **Operational Approval**

- Required to operate certified ADS-B ITP system in flight
- FAA developed a non-standard Operational Specification for ITP
- United's role was to demonstrate how they met the standard and requirements
 - Addressed training materials, airworthiness requirements, maintenance program, ITP equipment requirements, flight manual, flight crew/dispatch training, etc.

Safety Risk Management Document (SRMD)

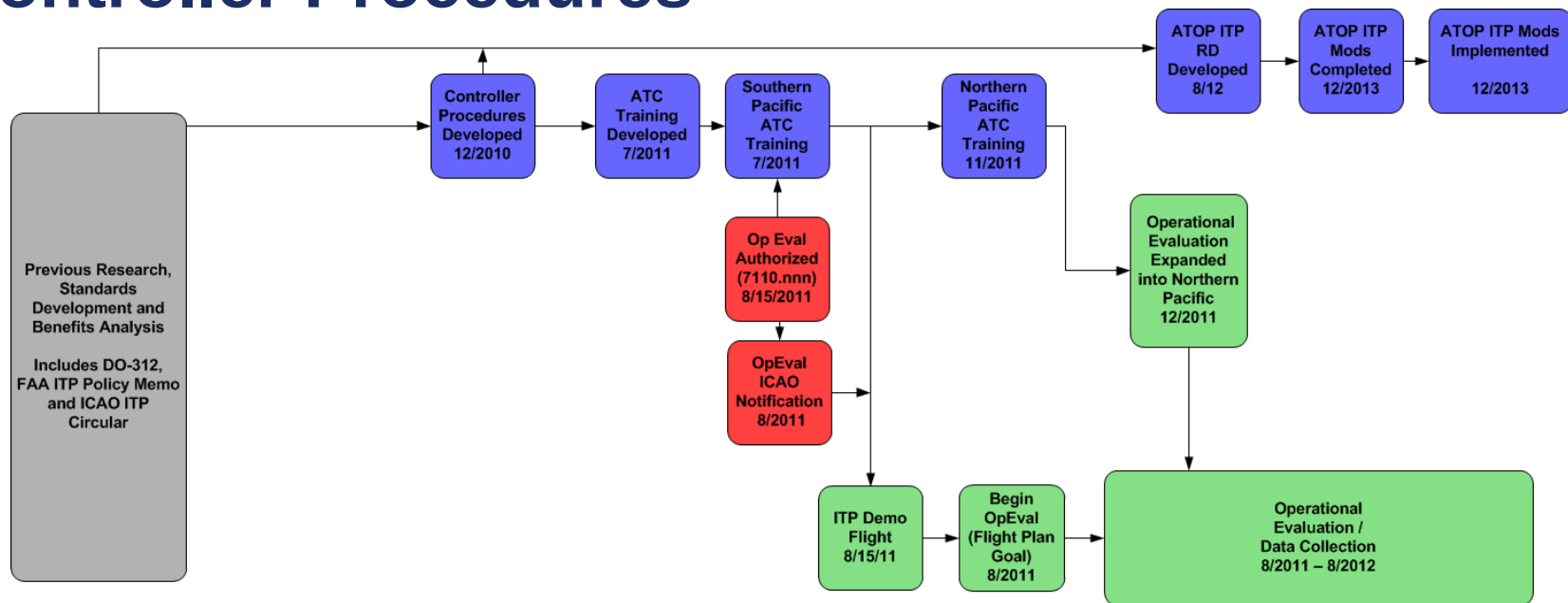


- **SRMD required when introducing a new procedure into the airspace**

“Safety Risk Management is a methodology applied to all NAS changes that ensures that hazards are identified and unacceptable risk is mitigated and accepted prior to the change being made”

- **ITP SRMD based on DO-312/ED-159, ICAO SASP developed ITP Circular and an FAA ITP Safety Risk Management Panel**

Controller Procedures



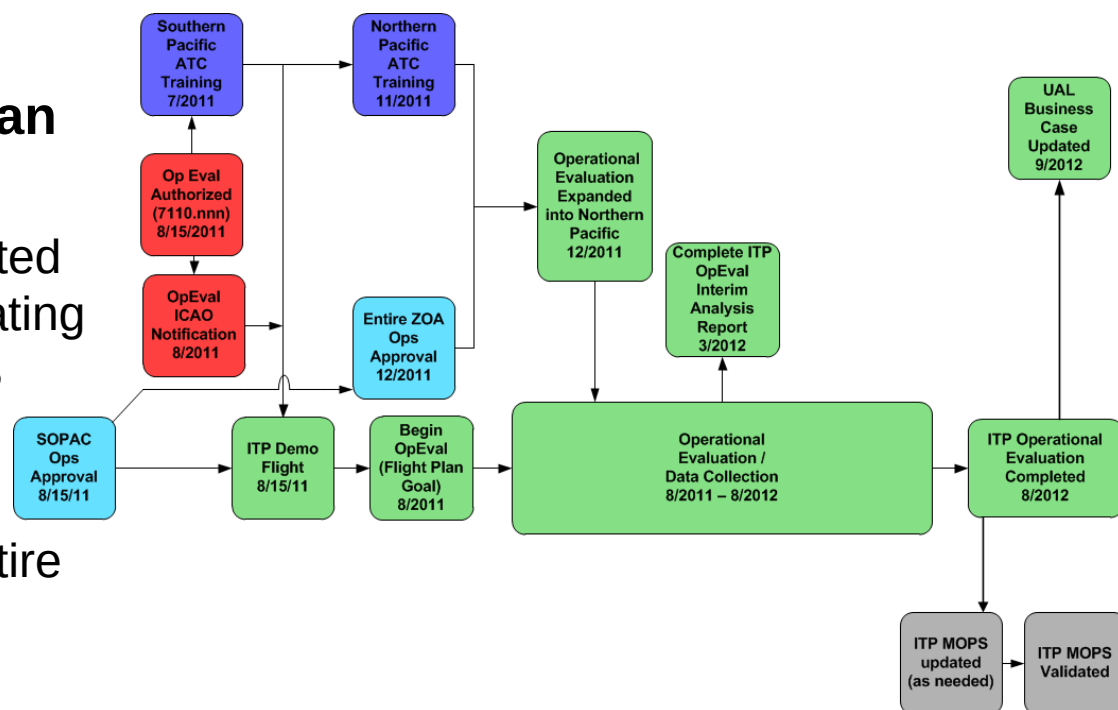
- **Controller Procedures and Training**

- Established the procedures the controller employs when assessing and approving an ITP request
- Based on safety analysis, ICAO SASP ITP Circular and previous NASA research
- Evaluated using Dynamic Simulator (DYSIM) simulations; DYSIM simulations also used in training

Operational Evaluation

- **Operational Evaluation began on August 15, 2011**

- Demonstration flight conducted using two United 747s operating in revenue service; UAL 863 and UAL 869 had qualified aircraft and flight crews
- Expanded to encompass entire ZOA FIR December 2011

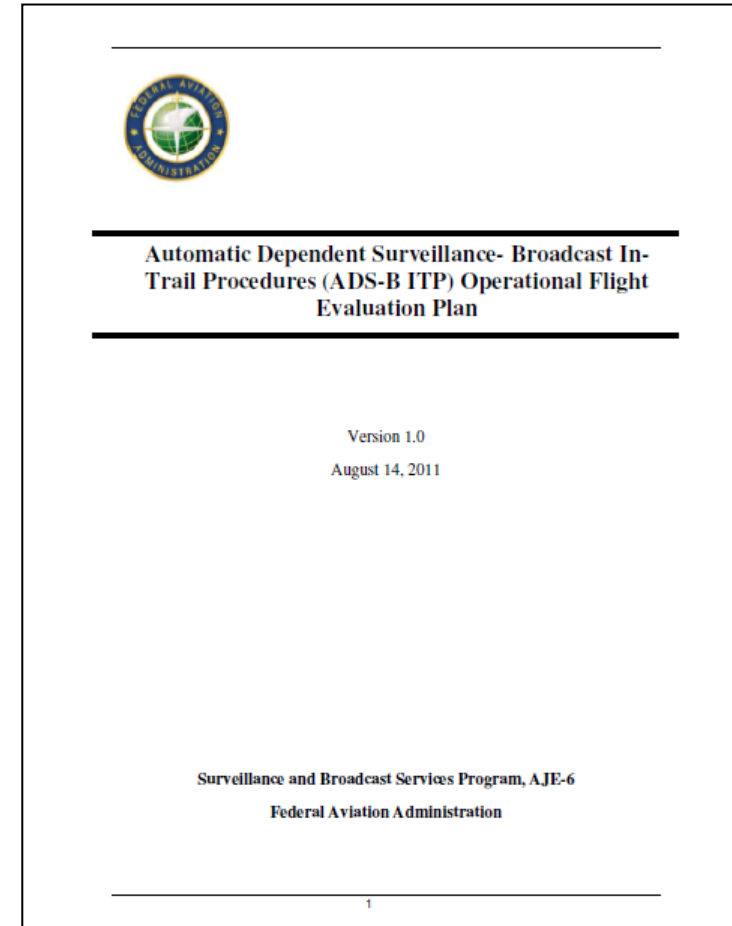


- **Op Eval will take place for at least a two year period**

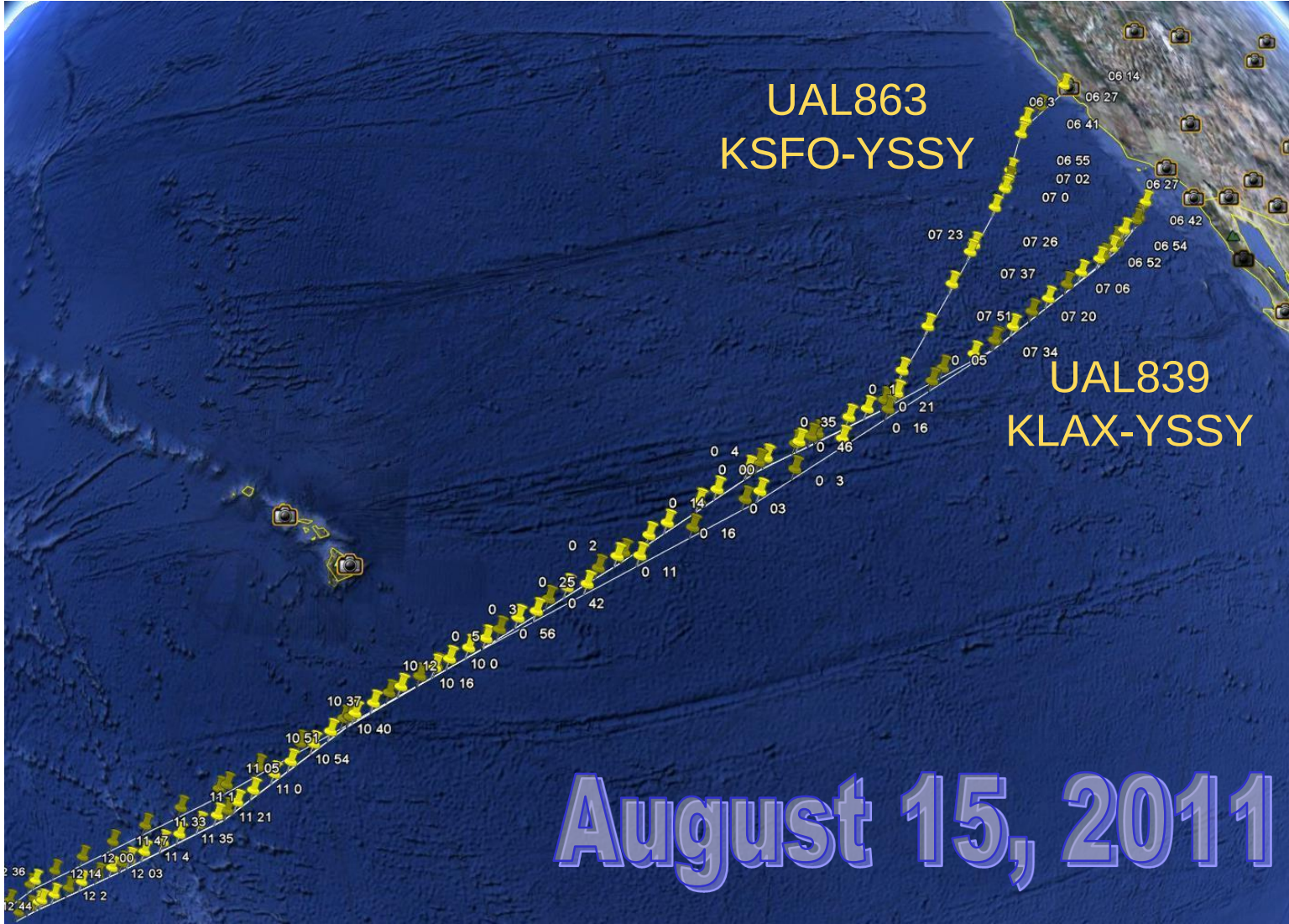
- Data will be collected and analyzed
- Data used to validate safety assumptions and will gather data on operational performance and economic benefits

Operational Evaluation

- **Data is being collected from the following sources**
 - Dispatch
 - United Airlines computer data
 - Dispatch Comment Sheet
 - Controller/Oceanic Center
 - CPDLC messages
 - ADS-C position reports
 - Controller Comment Sheet
 - Cockpit
 - Pilot Comment Sheet
 - Pilot Data Sheet
- **Data from all sources is correlated and de-identified**
 - Data associated with a given flight assigned a random identifier and all identifying information is removed from the data



ADS-B ITP Demonstration Flight



ADS-B ITP is Operational!

August 16, 2011, 8:01 Z: United 839 requests an ITP climb ahead of United 863

SECTOR QUEUE				
NM	CPD	UAL839	08:01:34	CWP15
DL : REQUEST CLIMB TO F320 DUE TO AIRCRAFT PERFORMANCE ITP 22NM AHEAD OF UAL863				



August 16, 2011, 8:06 Z: Oakland Oceanic grants United 839 an ITP climb to FL320!

(169)	(free text)	ITP AHEAD OF UAL863
(20)	CLIMB TO AND MAINTAIN {alt}	F320
Probing : ITP AHEAD OF UAL863, CLIMB TO AND MAINTAIN F320 [UAL839]: Conflict with 1 aircraft, 0 airspace within VSP. IMMINENT		

Op Eval Results

FAA Project Perspective



- **A total of 9 ITPs have been performed in an operational environment**
 - Conducted by two different United airplanes using each other and one other airline as ITP traffic aircraft
 - Controllers and pilots thought the procedure was straight forward
 - Pilots were particularly impressed with the increased situation awareness
 - Data collected during the flights and initial data analysis has been performed

Event	Geometry	Climb or Descend	ITP Distance
1	following	climb 3000 ft (FL270-FL300)	82nm
2	leading	climb 2000 ft (FL300-FL320)	22nm
3	leading	descend 2000 ft (FL320-FL300)	24nm
4	following	descend 2000 ft (FL310-FL290)	22 nm
5	following	climb 3000 ft (FL290-FL320)	23nm
6	combined leading/following	climb 2000 ft (FL310-FL330)	26nm/77nm behind
7	following	climb 2000 ft (FL320-FL340)	26nm
8	leading	climb 2000 ft (FL330-FL350)	34nm
9	following	climb 2000 ft (FL340-FL360)	34nm

Operational Evaluation Metrics

August 2012

Application Validation Metric	Southern Pacific		Northern Pacific	
	Expected Measurement	Actual Measurement	Expected Measurement	Actual Measurement
Number of trained and approved pilots (actuals are for entire 747 subfleet)	598 (Expected) /81 (Actual)			
Number of ITP capable flights per month (ITP aircraft, pilot and airspace)	60	8	120	21
Number of ITP requests per month	2	3	30	5
Number of ITP maneuvers performed per month	1	1	3	1
Number of "standard" flight level changes resulting from an ITP request per month	1	2	24	2
Avg amnt of reduced discretionary extra fuel for ITP capable aircraft per flight	300 lbs		0	
Avg amnt of increased payload for ITP capable aircraft per flight	150 lbs		0	
Average fuel burn reduction for ITP capable aircraft per flight	60 lbs		800	

Safety measurements

Parameter to be Monitored	Expected Avg. Measurement	Actual Measurements			Explanation of Deviation	Corrective Action Required?
		Min	Mean	Max		
ITP Initiation Distance	20 nm	19.2	39.2	59.1		
ITP Distance at Co-altitude	18 nm	18.9	39.3	59.7		
Time From ITP Initiation to Level Off at New Altitude	7 min	3	4	5		
Percentage of ITP maneuvers where a wake encounter occurred and a wake turbulence incident was reported	2%					
Wake Turbulence Incident Severity (5-1)**	5					

** 5 is minimal, 1 is catastrophic



Summary of August ITP requests

Event ID	Own Alt	Request	SOPAC (S) or Northern Pacific (P)	Clearance	Altitude Change
1044	36,000	REQUEST CLIMB TO F380. ITP 31NM BEHIND ERR145	P	CLIMB TO REACH F380 BY 1320 REPORT LEVEL F380	2000
114	28,000	REQUEST CLIMB TO F310. ITP 21NM BEHIND URE15	S	ITP BEHIND URE15 CLIMB TO AND MAINTAIN F310 REPORT LEVEL F310	3000
4136	31,000	REQUEST CLIMB TO F330. ITP 42NM AHEAD OF ORR968	P	UNTIL WE RECEIVE OFFICIAL CONFIRMATION THAT ADS AND CPDLC ARE BACK UP.I AM UNABLE TO USE THE REDUCED SEPARATION.	0
513	31,000	REQUEST CLIMB TO F330. ITP 35NM AHEAD OF ERR1915	S	CLIMB TO REACH F330 BY 0930 REPORT LEVEL F330	2000
540	31,000	REQUEST CLIMB TO F330. ITP 56NM AHEAD OF ORR968	P	ITP AHEAD OF ORR968 CLIMB TO AND MAINTAIN F330 REPORT LEVEL F330	2000
7110	33,000	REQUEST CLIMB TO F350. ITP 17NM AHEAD OF ERR008 AND 77NM BEHIND ERR0815	P	UNABLE.DUE TO TRAFFIC	0
8910	34,000	REQUEST CLIMB TO F360. ITP 33NM AHEAD ERR082	S	CLIMB TO AND MAINTAIN F360 REPORT LEVEL F360	2000
986	35,000	REQUEST CLIMB TO F370. ITP 57NM BEHIND ERR0815	P	CLIMB TO AND MAINTAIN F370 REPORT LEVEL F370	2000

ADS-B ITP Summary

- **ADS-B In-Trail Procedures (ITP) is Operational**
 - First operational ITP flights conducted August 15, 2011; expanded to the entire ZOA region in December 2011
- **Data collection is ongoing**
 - Evaluating operational performance and economic benefit of ITP
- **ATOP ITP updates**
 - ITP modifications for ATOP are being developed
- **ADS-B In-Trail Procedures is an example of an idea of going from concept to flight**
 - NASA research was foundational
 - Required significant collaboration and coordination
- **ADS-B ITP “lessons learned” will drive development and transition of future applications**

Questions?

