



Preliminary Results

Operational Improvements from the In-Trail Procedure in the Pacific Organized Track System

Operational Improvements from the In-Trail Procedure in the Pacific Organized Track System

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February 2012



Outline

Operational Improvements from the In-Trail Procedure in the Pacific Organized Track System

- Reason for experiment
- Previous ITP experiments
- Experiment Design
- Comparison of Experiment baseline
- Experiment Results
- Questions



Reason for experiment

Operational Improvements from the In-Trail Procedure in the Pacific Organized Track System

- Under the FAA/NASA interagency agreement IA1-973
 - Technical Direction 7
- NASA is under contract to the FAA to complete the following
 - Analysis of current PACOTS traffic data
 - Conduct experiment review process on planned batch study
 - Enhance simulation software as required
 - Conduct batch simulation following the approved plan
 - Analyze and deliver data in the form of a presentation and white paper



Previous ADS-B ITP Experiments

Operational Improvements from the In-Trail Procedure in the Pacific Organized Track System

- Computerized Batch Study
 - Operational Improvements From Using the In-Trail Procedure in the North Atlantic Organized Track System (NASA/TM-2009-215939)
 - Focused on the NATOTS
 - Used the Traffic Manager (TMX)
- Human in the Loop
 - Enhanced Oceanic Operations Human-In-The-Loop In-Trail Procedure Validation Simulation Study (NASA/TP-2008-215313)
 - Focused on the NATOTS
 - Used the Airspace and Traffic Operations Simulation (ATOS)
 - In-Trail Procedure Air Traffic Control Procedures Validation Simulation Study (draft NASA/TM-2011)
 - Focused on Australian procedural airspace
 - Used The Australian Advanced Air Traffic System (TAAATS)
- Flight Trial
 - CRISTAL ITP (European consortium 2008)
 - Focused on Icelandic radar airspace



ADS-B ITP Experiment Overview

Operational Improvements from the In-Trail Procedure in the Pacific Organized Track System

- Evaluate flight level change opportunities
 - Standard flight level changes with restricted approval rate (baseline)
 - Standard flight level changes with ADS-B IN traffic display (IN)
 - Standard flight level changes with ADS-B IN traffic display and ITP (IN+ITP)
- Simulation tool: TMX
 - Joint NLR/NASA medium fidelity batch simulator
 - Includes BADA model, wind model, pilot model, ATC model, CPDLC model, ITP logic, cruise fuel flow model
- Focus is on Pacific Organized Track System (PACOTS)
 - Simulation of current day operations used as a baseline
 - Distribution of traffic and track loading based on current day PACOTS data
- Pilot model rules determine if a standard (non-ITP) request or an ITP request will be made
 - Non ADS-B IN equipped aircraft can make a request every 2.5 hours
 - ADS-B IN equipped aircraft can make a request every 10 minutes



Experiment Matrix

Operational Improvements from the In-Trail Procedure in the Pacific Organized Track System

- Design assumptions
 - All ADS-B IN equipped aircraft will also be ADS-B OUT equipped
 - 30% ADS-B OUT is approximately the 2006 level of equipage
 - 10% ADS-B IN approximates one large airline fleet being equipped
 - Equal ADS-B IN/ADS-B OUT equipage is not expected to be achieved within the time frame of the ITP trials
- Experiment ADS-B equipage environments
 - 1 baseline scenario
 - 0_0 (0% ADSB-OUT equipage_0% ADSB-IN equipage)
 - 6 experiment ADS-B equipage environments
 - 30_10, 60_10, 60_45, 90_10, 90_45, 90_80

ADS-B OUT	90		X	X	X
	60		X	X	
	30		X		
	0	X			
		0	10	45	80
		ADS-B IN			



Experiment Matrix

Operational Improvements from the In-Trail Procedure in the Pacific Organized Track System

- 3 traffic densities (times observed 2011 traffic level)
 - Current (1.0X, ~100 aircraft)
 - High (1.5X, ~150 aircraft)
 - Extra (2.0X, ~200 aircraft)
- 18 independent traffic flows per density
 - Initial traffic loading variations
 - Each variation is used for every experiment condition
- 2 procedural capability levels for ADS-B IN aircraft
 - ADS-B IN traffic display (IN)
 - ADS-B IN traffic display with ITP (IN+ITP)
- 2 Separation standards
 - 50 nmi
 - 30 nmi



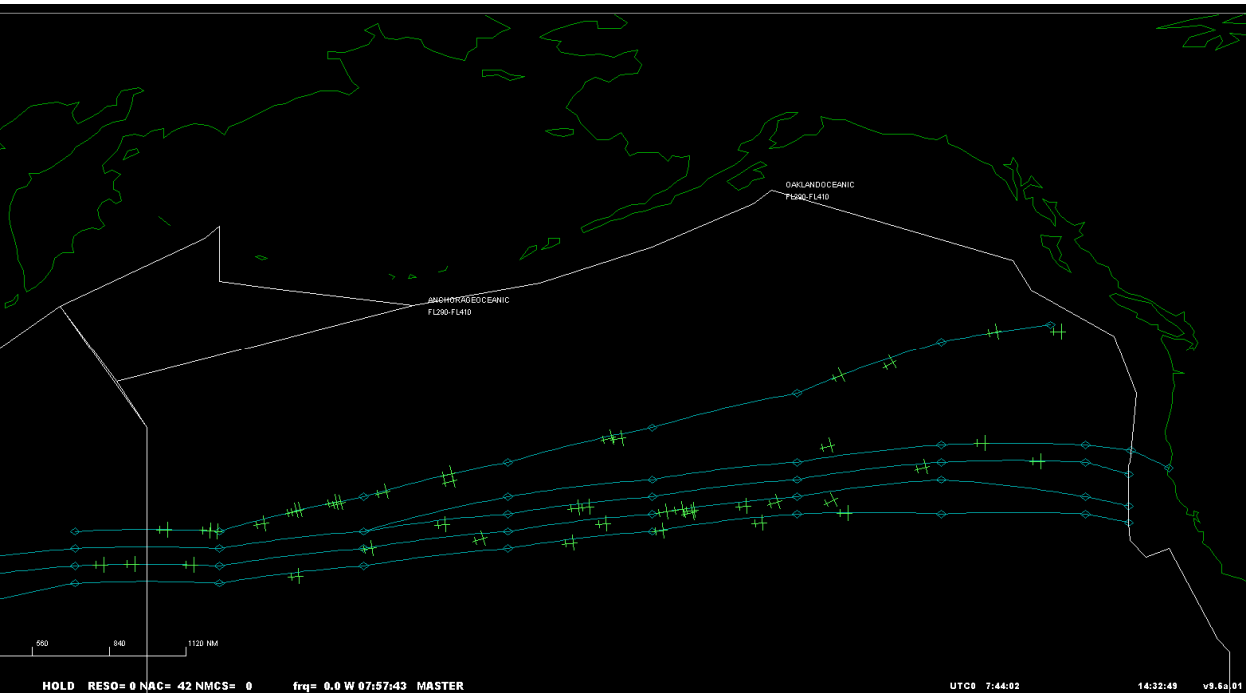
Experiment Matrix

Operational Improvements from the In-Trail Procedure in the Pacific Organized Track System

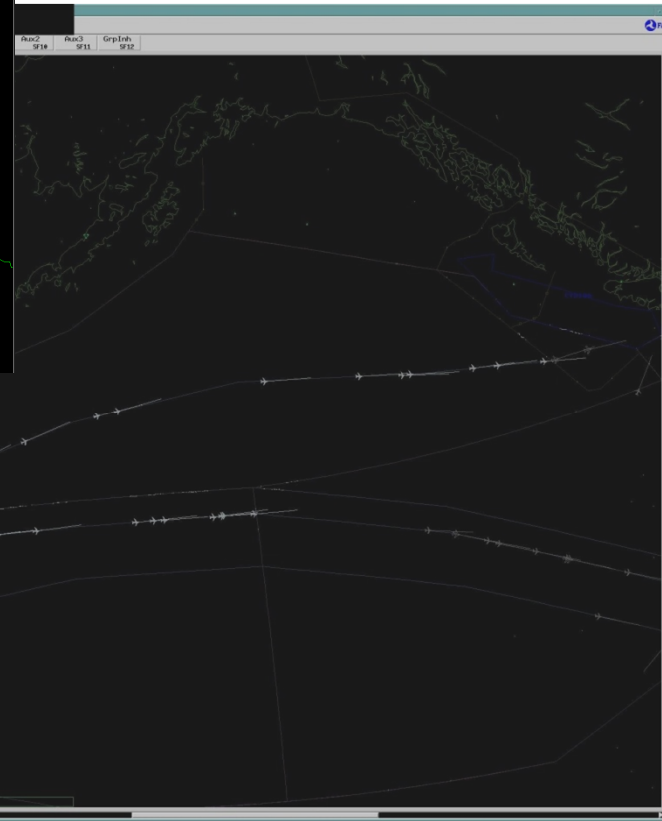
- 8 Aircraft Types (~77% of total pacific fleet)
 - B772 (47%)
 - B744 (31%)
 - A343 (8%)
 - B763 (8%)
 - A332 (3%)
 - A333 (1%)
 - B752 (1%)
 - B762 (1%)
- Baseline Climbs
 - ~70% of flights make at least one climb
 - (target request approval rate for baseline scenarios)
 - ~60% of climbs are 1000 foot
 - ~40% of climbs are in the range for the ITP

Simulation of Current Day

Operational Improvements from the In-Trail Procedure in the Pacific Organized Track System



Simulation of Current Day Operations using TMX



Screen shot from actual
PACOTS operations –
Oakland Center



Comparison of Experiment baseline

Operational Improvements from the In-Trail Procedure in the Pacific Organized Track System

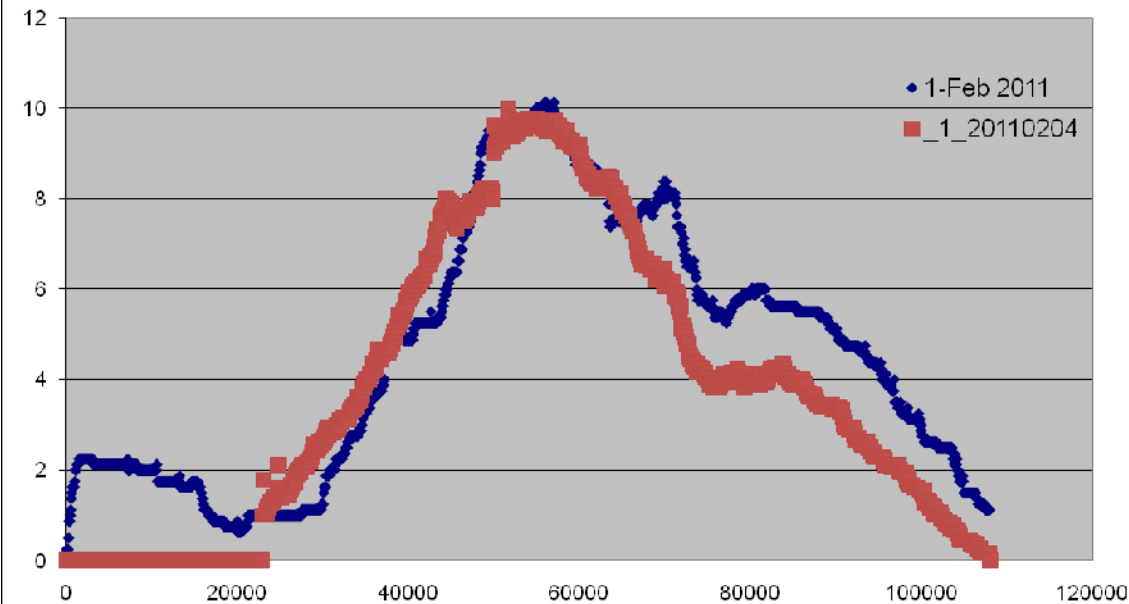
	Flight Data-Feb 2011	Experiment-Aug 2011
Traffic Count	65.1	68.9
% on Track 1	28.1	26.6
% on Track 2	30.8	29.4
% on Track 3	29.4	29.7
% on Track 14	11.7	14.2
% Altitude Requests		50 nmi / 30 nmi
1000 feet	61.0	61.4 / 61.5
2000 feet	34.6	28.6 / 28.4
3000 feet	2.6	8.4 / 8.2
4000 feet	1.5	1.6 / 1.9



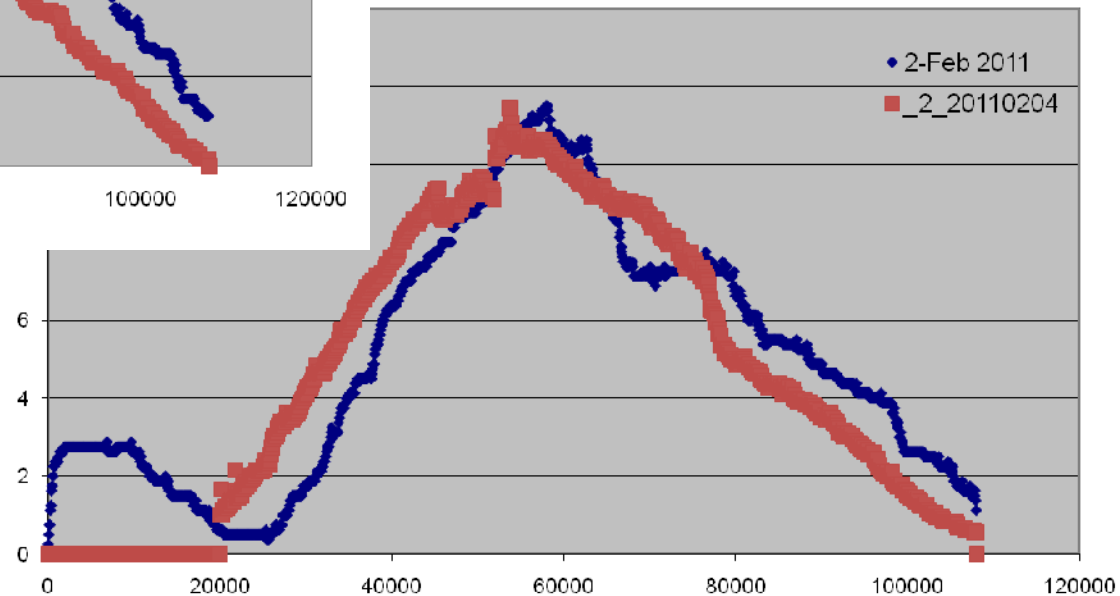
Comparison of Experiment baseline

Operational Improvements from the In-Trail Procedure in the Pacific Organized Track System

Track 1



Track 2

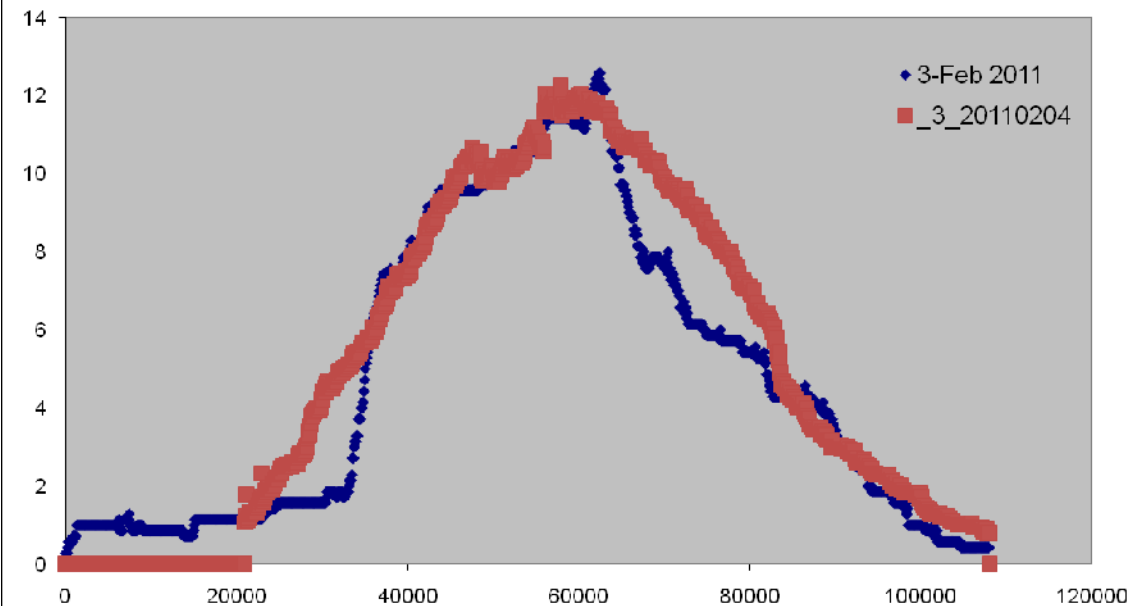




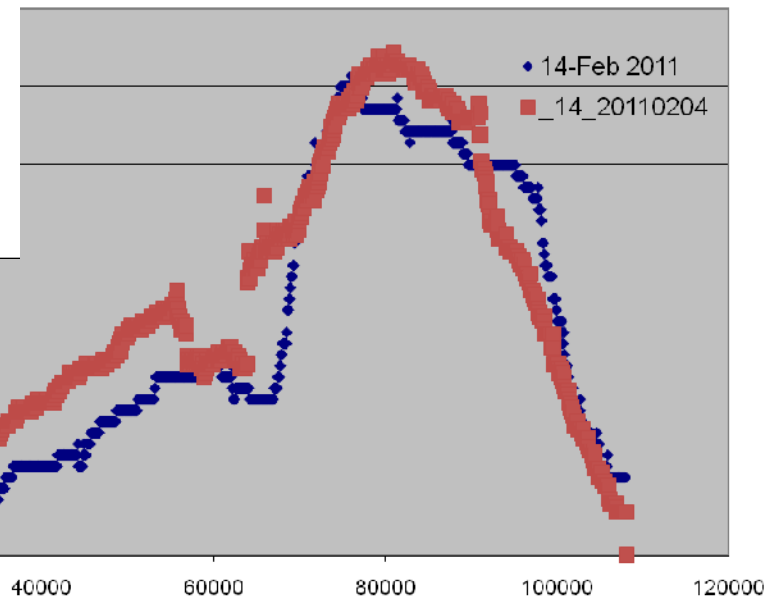
Comparison of Experiment baseline

Operational Improvements from the In-Trail Procedure in the Pacific Organized Track System

Track 3



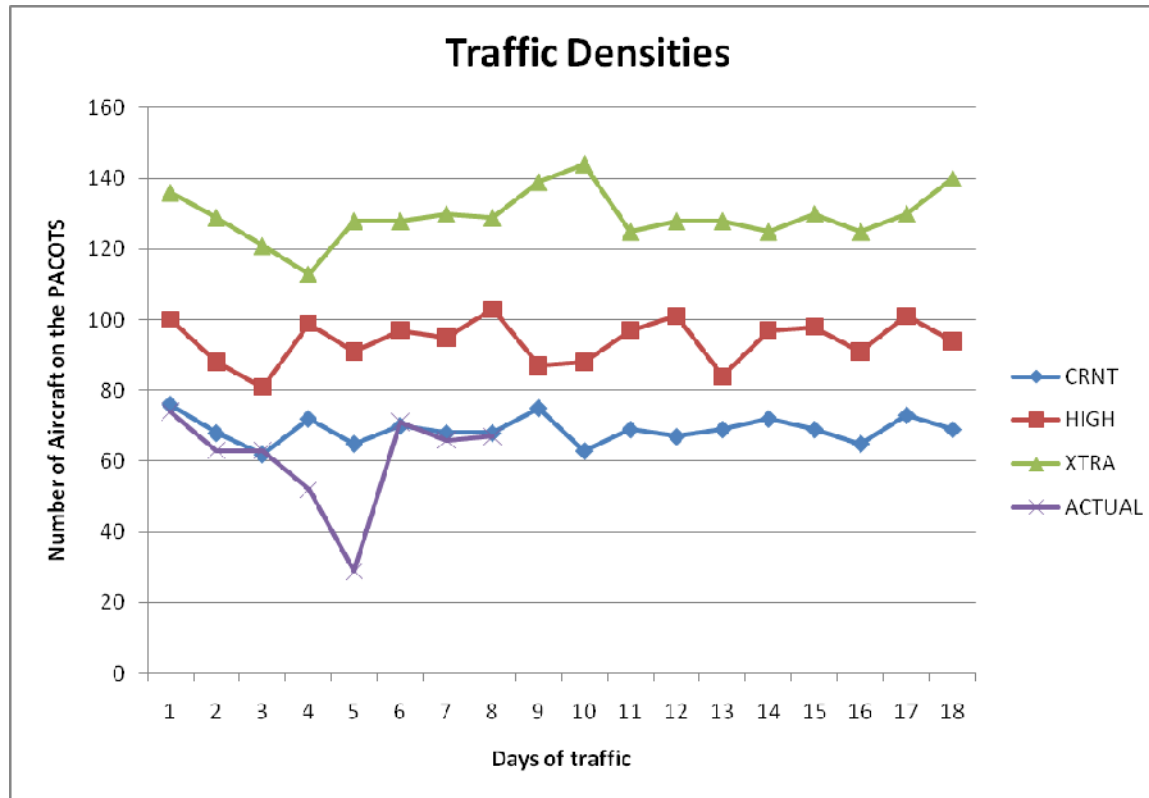
Track 14





Experiment Traffic Density

Operational Improvements from the In-Trail Procedure in the Pacific Organized Track System



Density Name	Average Number of Aircraft
ACTUAL	65.1 (60.6)
CRNT	68.9
HIGH	94.0
XTRA	129.3



Data Analysis Terms

Operational Improvements from the In-Trail Procedure in the Pacific Organized Track System

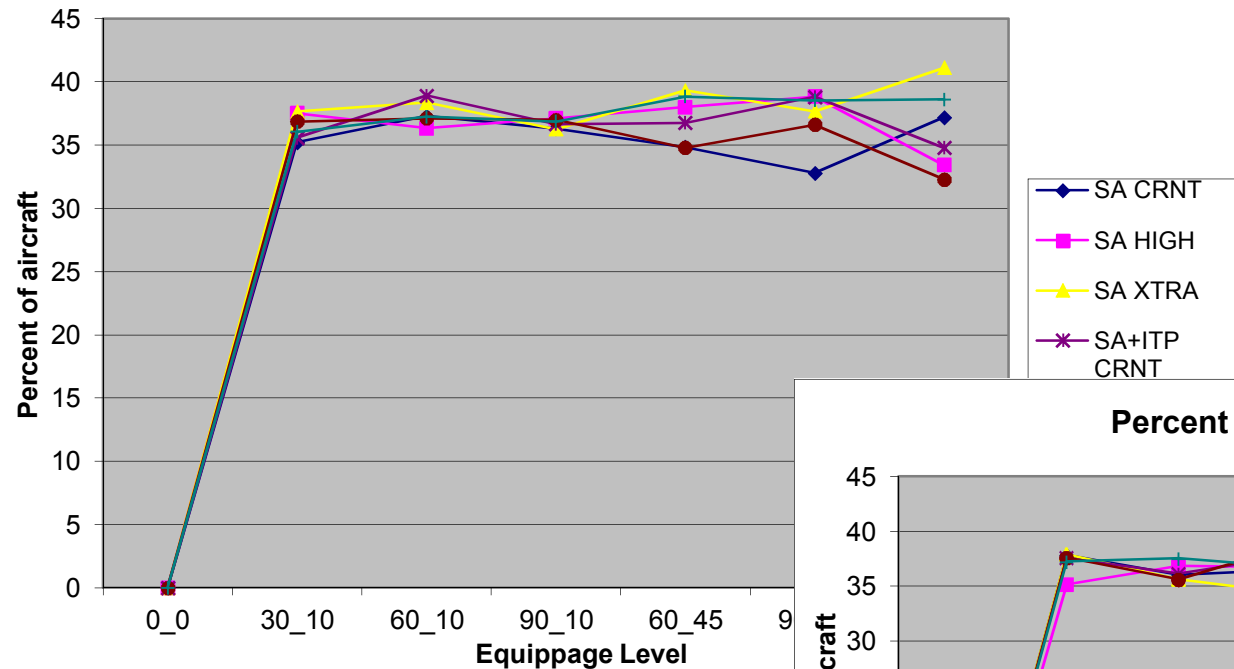
- **Altitude change request** – a request made by the aircraft to ATC for a change in the cruise altitude that the aircraft is cleared to fly at
- **Unequipped aircraft** – one or more aircraft that are not equipped with ADS-B IN or ITP technology
- **ADS-B equipped aircraft** – one or more aircraft equipped with ADS-B IN technology (this includes SA and SA+ITP aircraft)
- **SA aircraft** – one or more aircraft that is equipped with ADS-B IN and can make use of that information as a situation awareness tool to make more information altitude change requests
- **ITP aircraft** – one or more aircraft that is equipped with ADS-B IN and ITP technology. These aircraft can use this ability to make more informed standard or ITP altitude change requests (also referred to as SA+ITP)



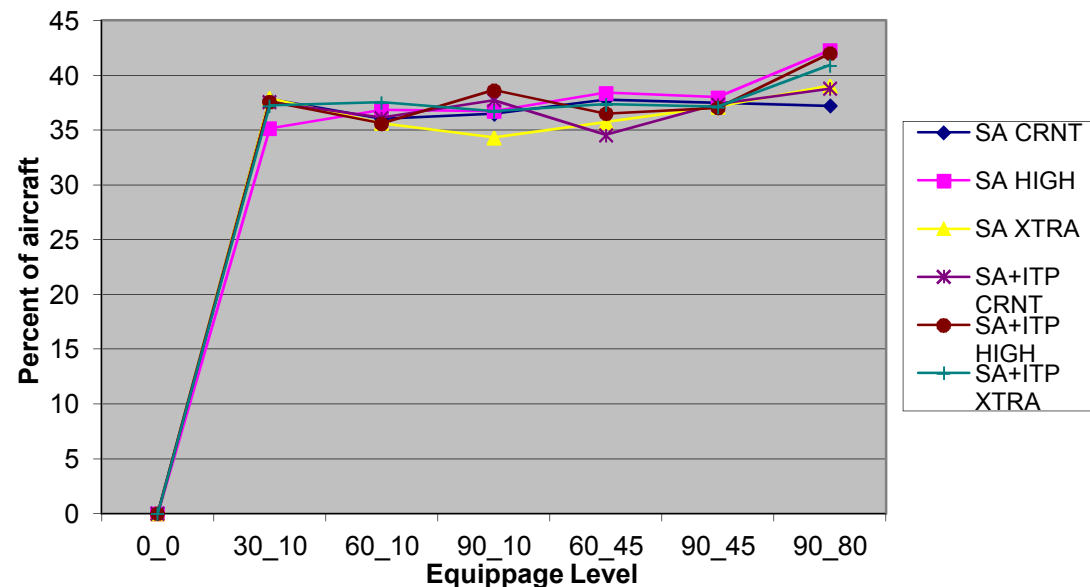
Unequipped aircraft

Operational Improvements from the In-Trail Procedure in the Pacific Organized Track System

Percent of unequipped aircraft with a savings



Percent of unequipped aircraft with a loss



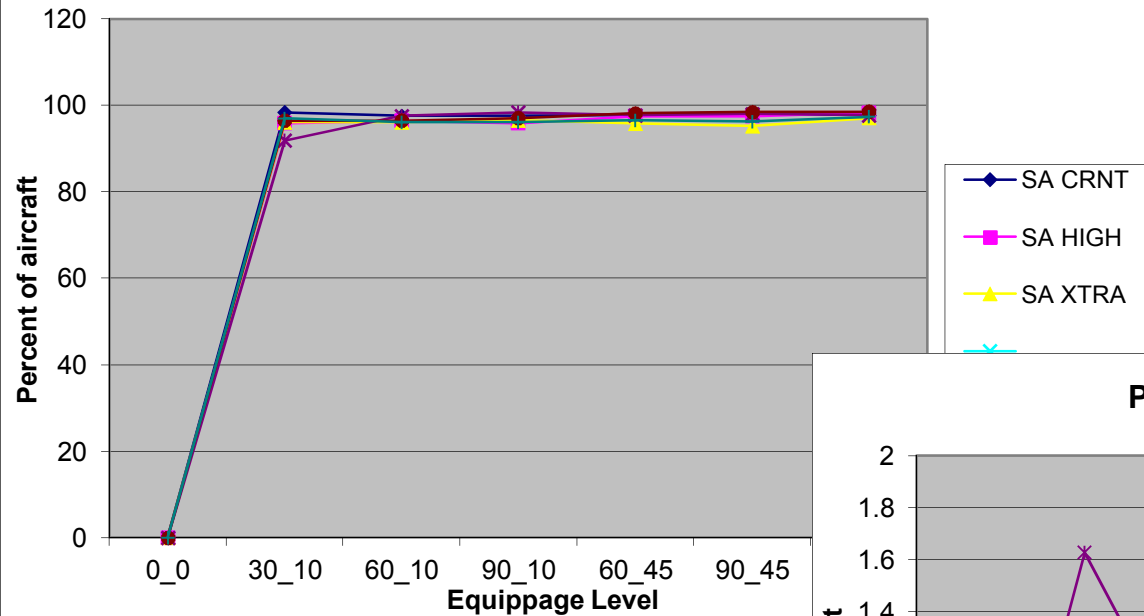
Unequipped aircraft are divided nearly equal between those with a savings, loss, and no change.



ADS-B equipped aircraft

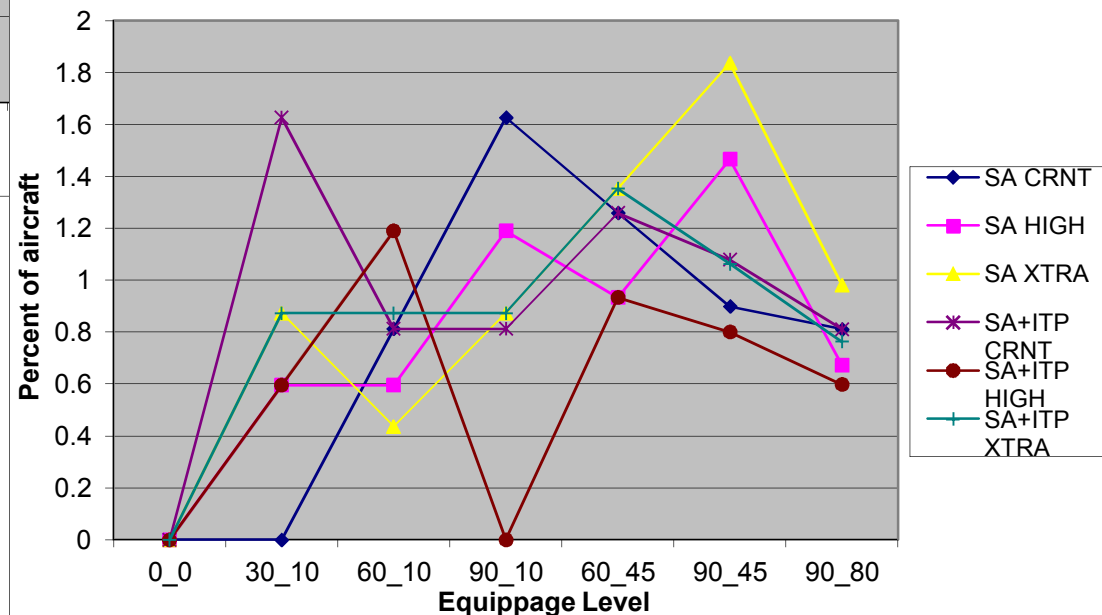
Operational Improvements from the In-Trail Procedure in the Pacific Organized Track System

Percent of equipped aircraft with a savings



Nearly all ADS-B equipped aircraft experience a savings, while only a minimal number are faced with a loss.

Percent of equipped aircraft with a loss



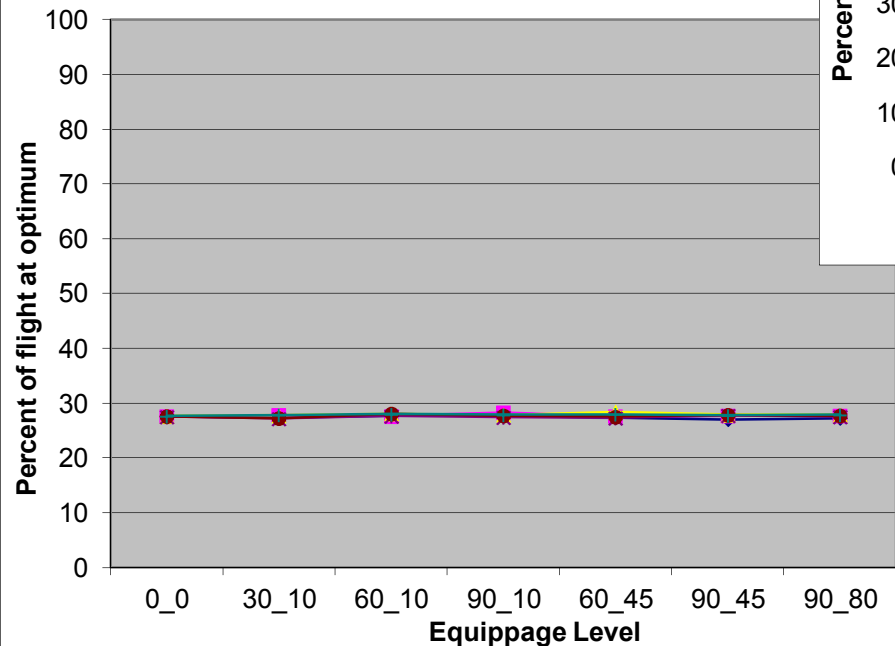


Percent of time on optimum FL

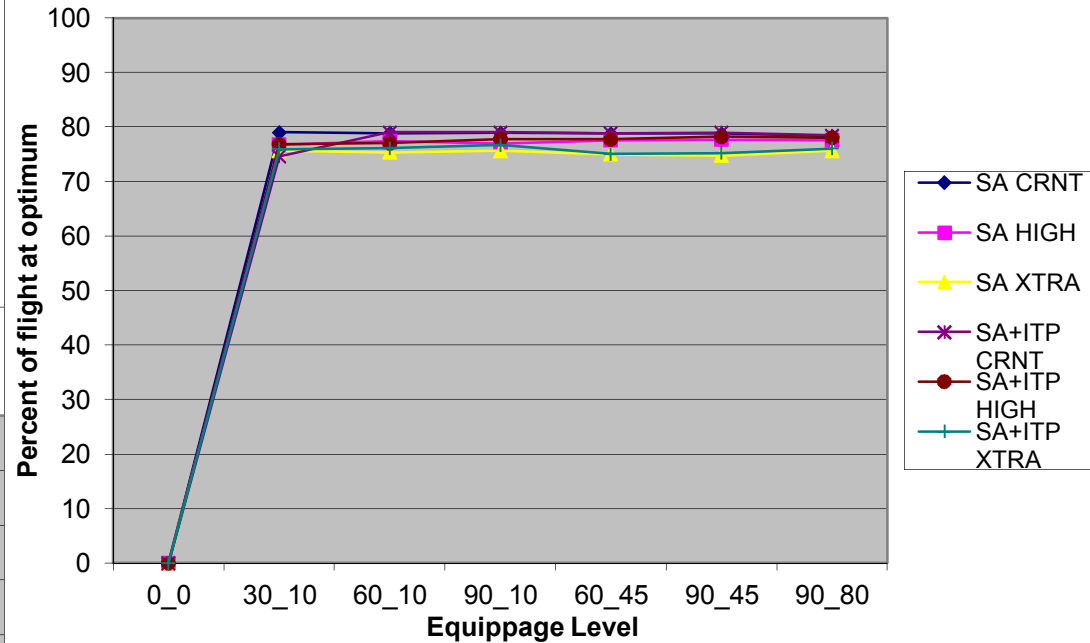
Operational Improvements from the In-Trail Procedure in the Pacific Organized Track System

ADS-B equipped aircraft on average spent nearly 50% more time at their optimum altitude than unequipped aircraft.

Unequipped aircraft % on Optimum



Equipped aircraft % on Optimum

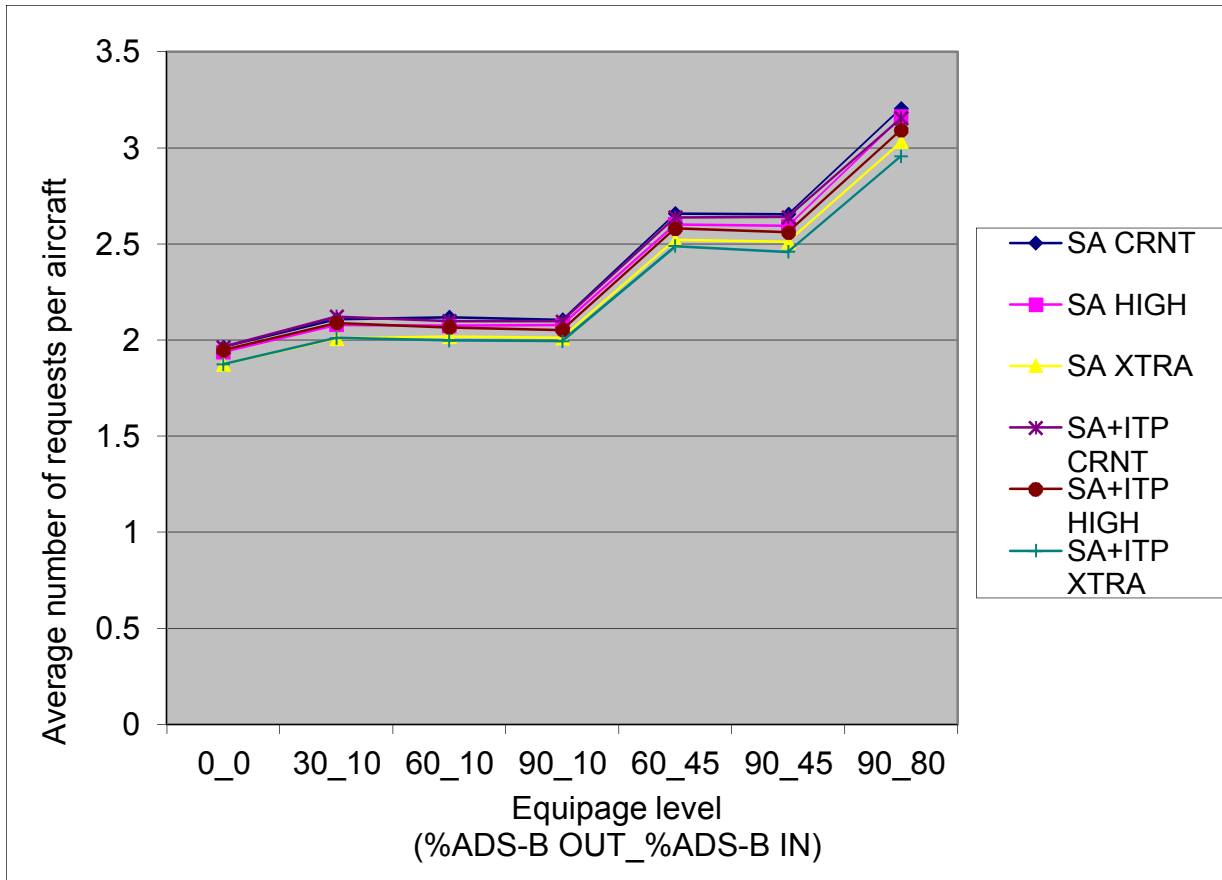


SA XTRA
SA+ITP CRNT
SA+ITP HIGH
SA+ITP XTRA



Aircraft Requests

Operational Improvements from the In-Trail Procedure in the Pacific Organized Track System



Aircraft on average made 2 requests during the crossing in the baseline.

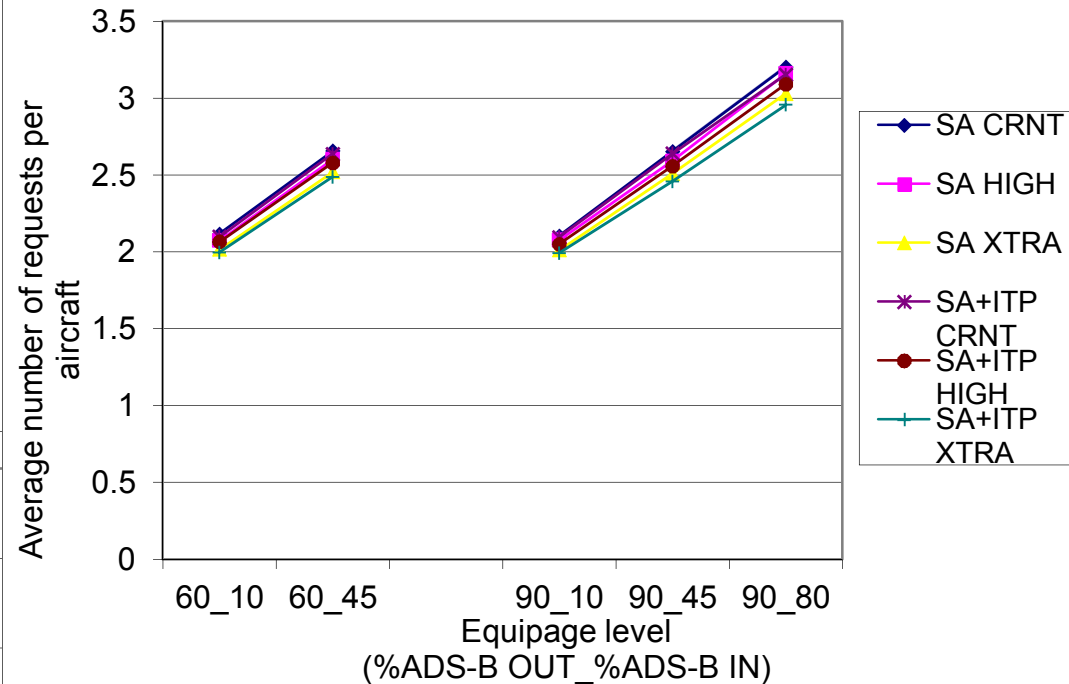
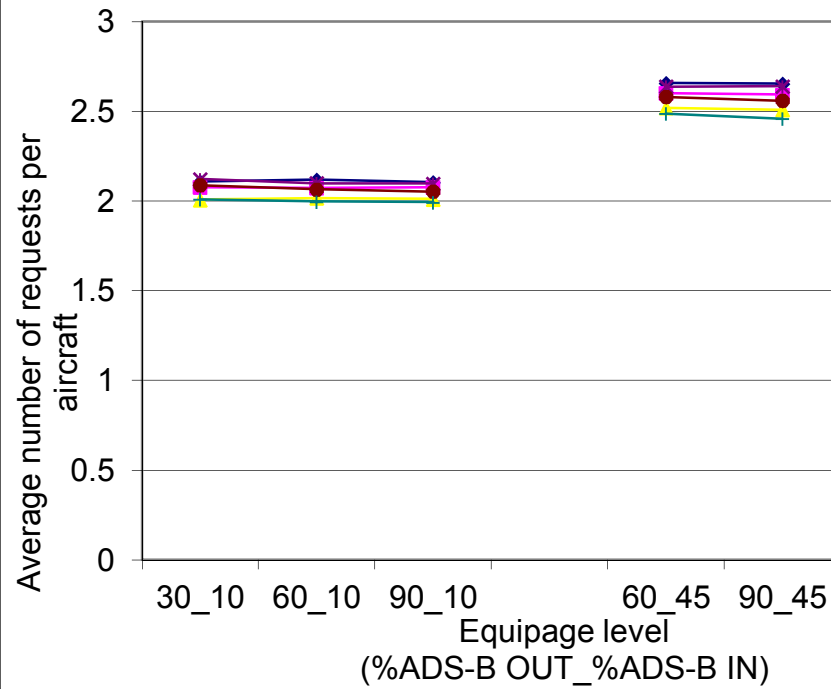
With ADS-B and ITP equipage that number rose to over 3 requests on average.



Aircraft Requests

Operational Improvements from the In-Trail Procedure in the Pacific Organized Track System

Grouping the results by ADS-B OUT equipage levels shows a consistent and direct effect of ADS-B IN equipage on the average number of requests an aircraft made.

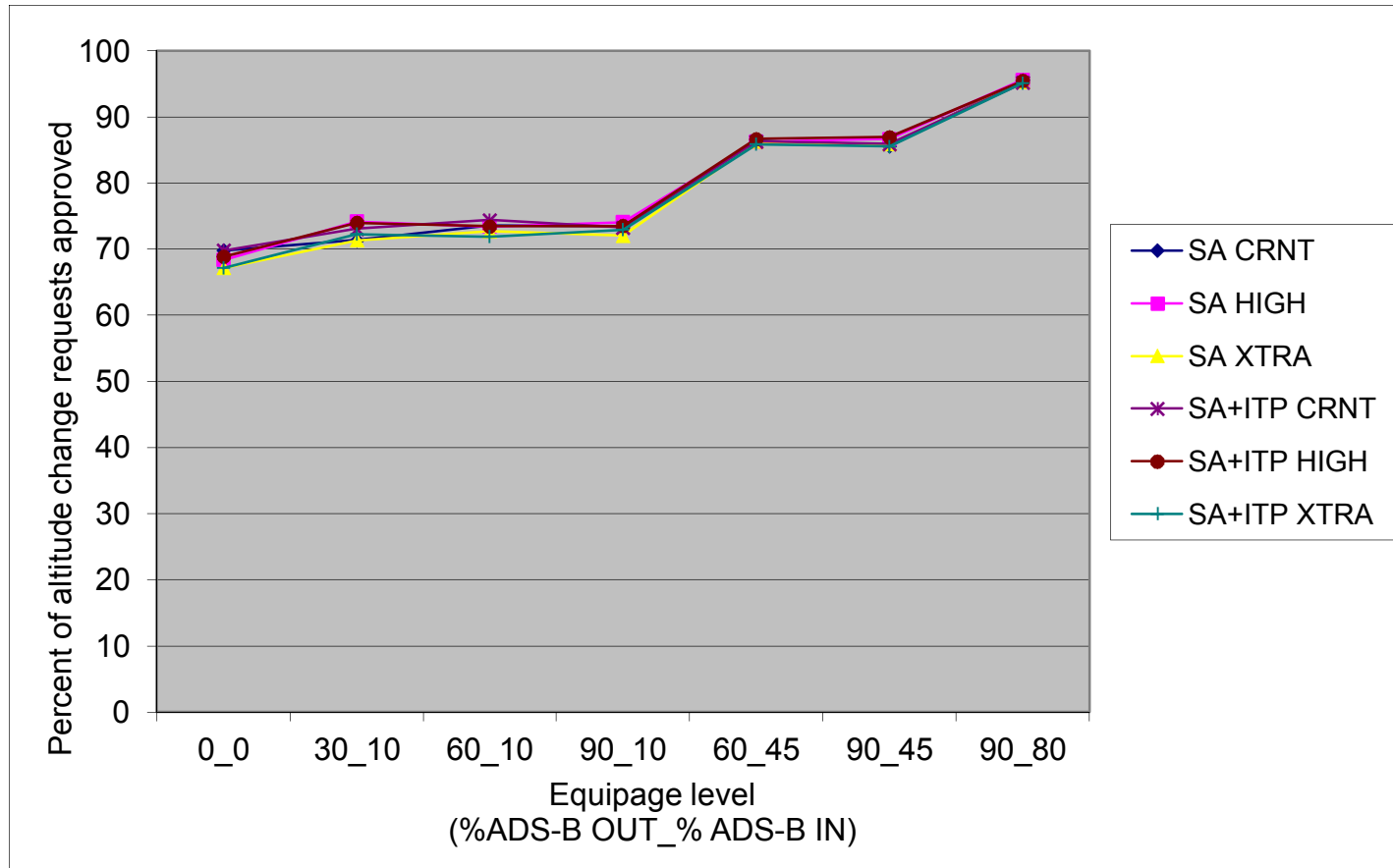


Grouping the results by ADS-B IN equipage levels shows that ADS-B OUT equipage has no significant effect on the average number of requests an aircraft made.



Request approvals

Operational Improvements from the In-Trail Procedure in the Pacific Organized Track System



Baseline approval rate is just under 70 percent as desired.

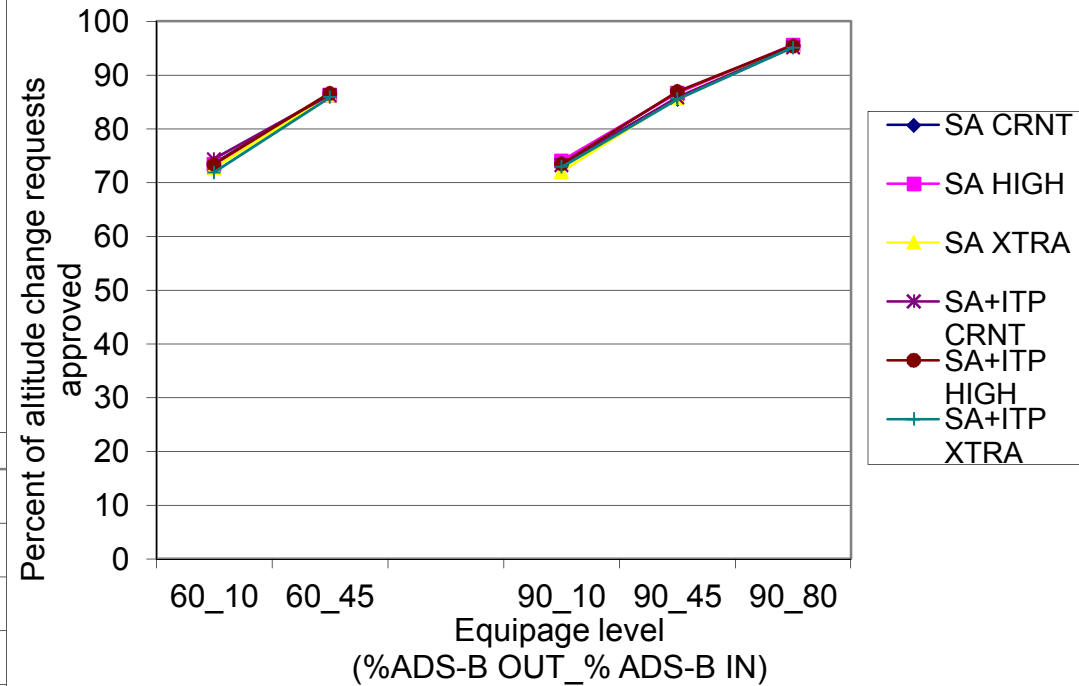
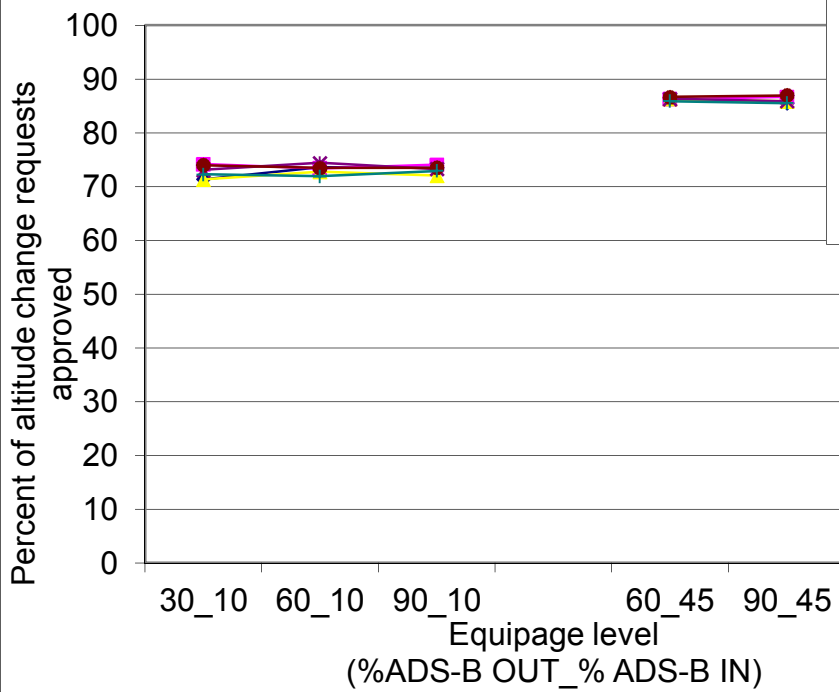
That increases by over 25% as aircraft are equipped with ADS-B.



Request approvals

Operational Improvements from the In-Trail Procedure in the Pacific Organized Track System

Grouping the results by ADS-B OUT equipage levels shows a consistent and direct effect of ADS-B IN on the percent of altitude change requests that were approved.



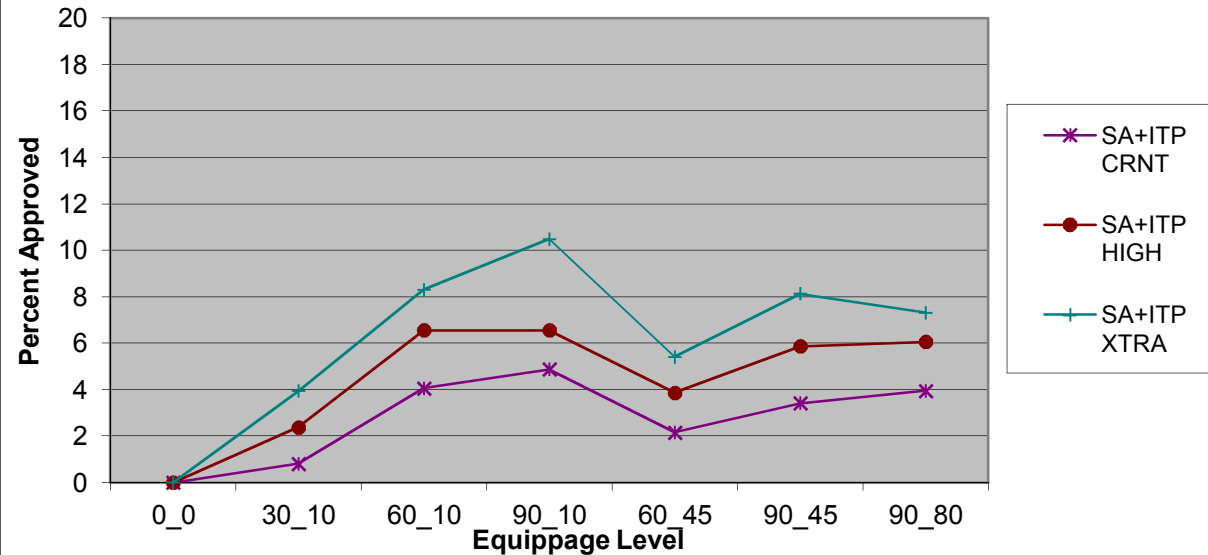
Grouping the results by ADS-B IN equipage levels shows that ADS-B OUT equipage has no significant effect on the percent of altitude change requests that were approved.



ITP use in 50/50

Operational Improvements from the In-Trail Procedure in the Pacific Organized Track System

Percent of ITP/STD Approvals per Equipped Aircraft

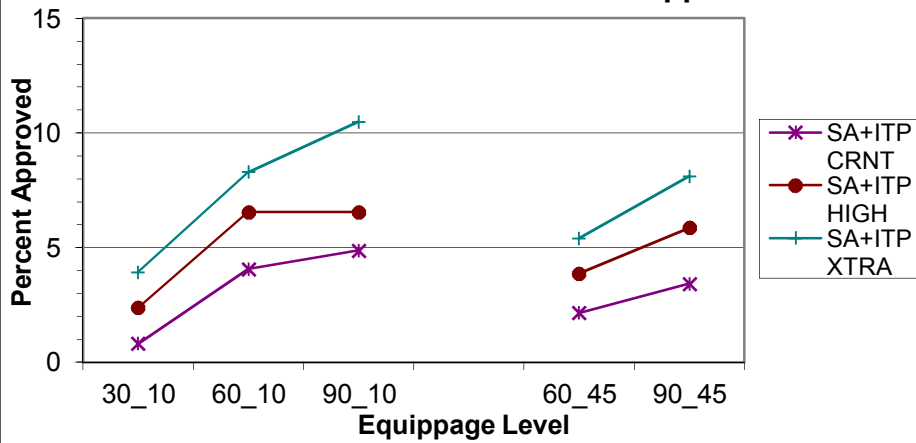


ATC could determine that an ITP request is not necessary and issue a standard clearance.

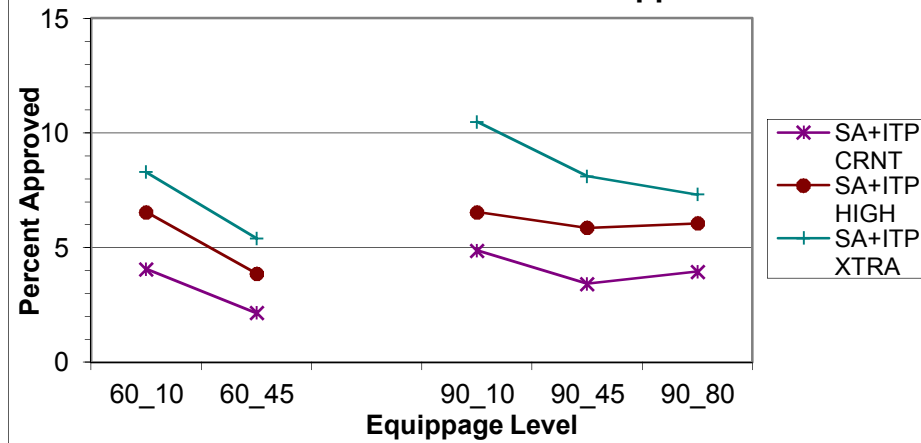
ADS-B OUT equipage shows a direct relationship with the percent of ITP/STD approvals. (bottom left)

ADS-B IN equipage shows an inverse relationship to the percent of ITP/STD approvals. (bottom right)

Affect of ADS-B OUT on ITP/STD Approvals



Affect of ADS-B IN on ITP/STD Approvals

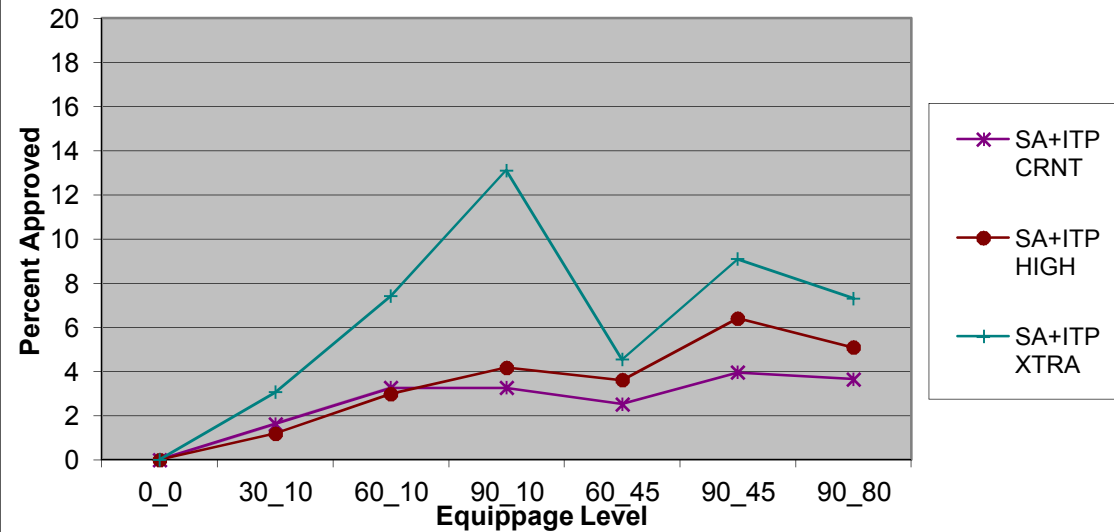




ITP use in 50/50

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Percent of ITP Approvals per Equipped Aircraft

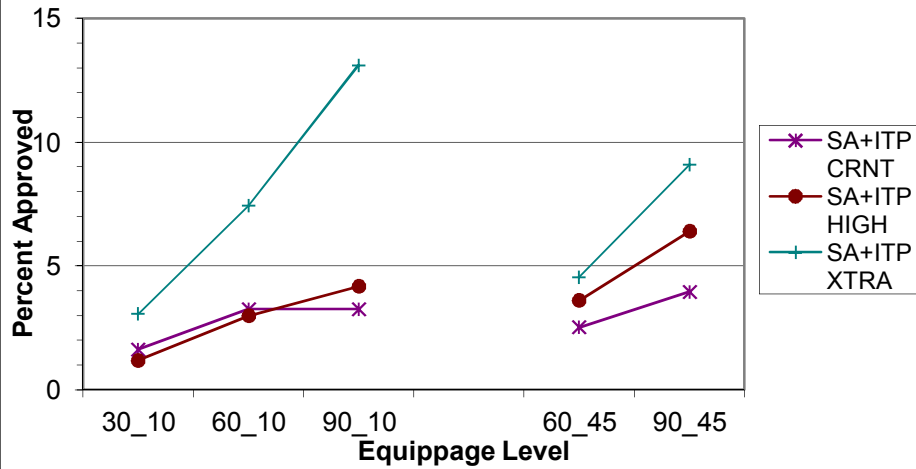


ATC could determine that an ITP request is valid and issue an ITP clearance.

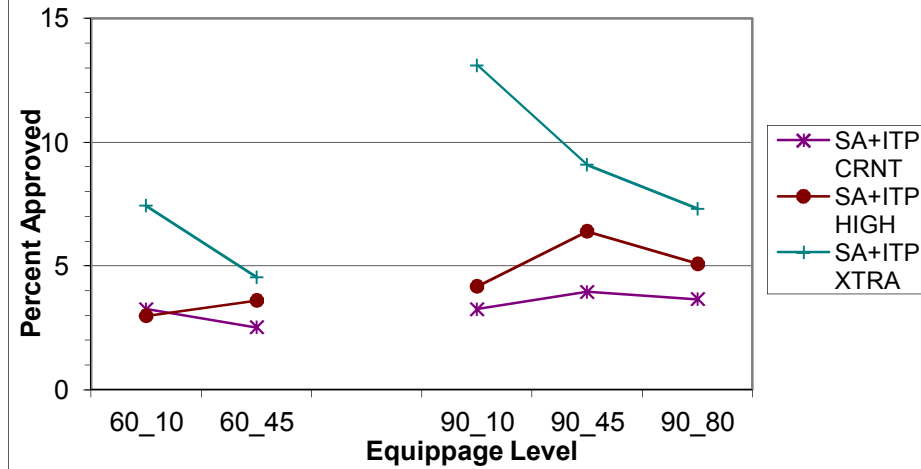
ADS-B OUT equipage shows a direct relationship with the percent of ITP approvals. (bottom left)

ADS-B IN equipage shows a general inverse relationship to the percent of ITP approvals. (bottom right)

Affect of ADS-B OUT on ITP Approvals



Affect of ADS-B IN on ITP Approvals

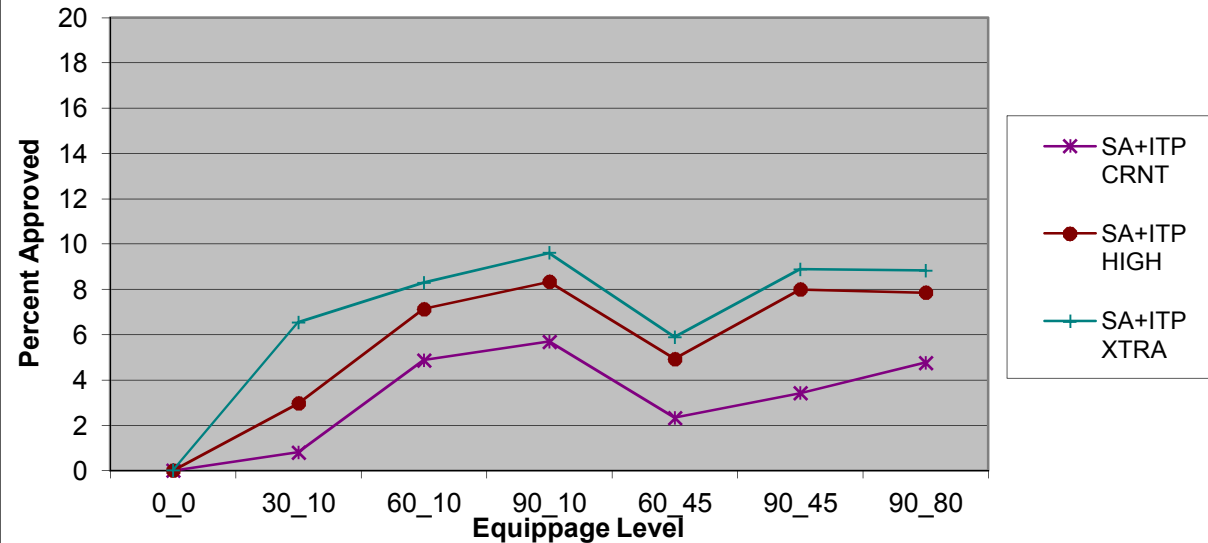




ITP use in 30/30

Operational Improvements from the In-Trail Procedure in the Pacific Organized Track System

Percent of ITP/STD Approvals per Equipped Aircraft

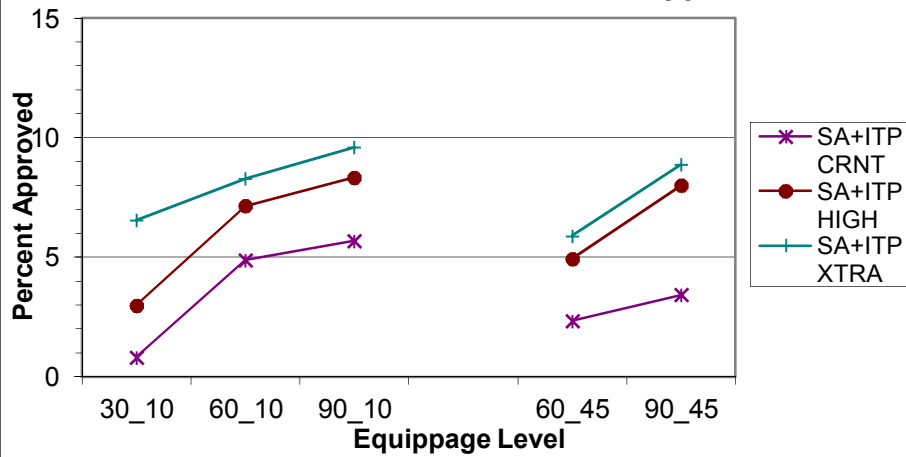


Approvals rates for the ITP/STD are slightly lower in 30/30 than in 50/50, due to there being less need for ITP since the separation standard is less.

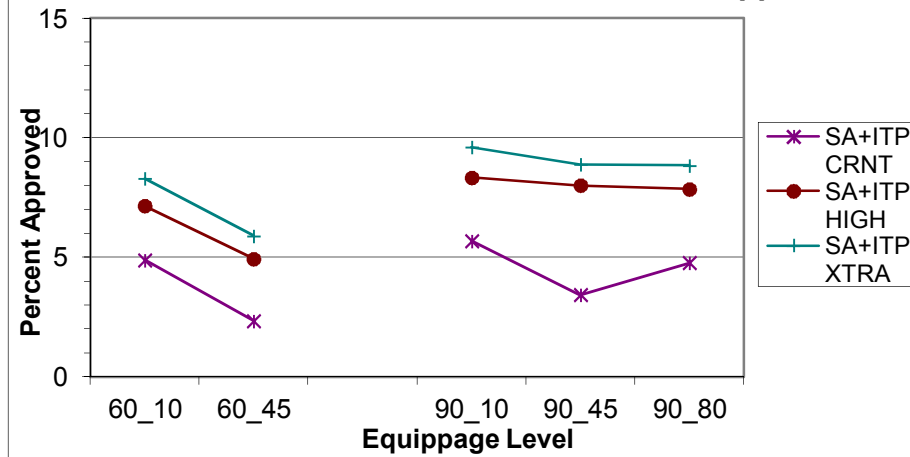
ADS-B OUT equipage shows a direct relationship with the percent of ITP/STD approvals. (bottom left)

ADS-B IN equipage shows a general inverse relationship to the percent of ITP/STD approvals. (bottom right)

Affect of ADS-B OUT on ITP/STD Approvals



Affect of ADS-B IN on ITP/STD Approvals

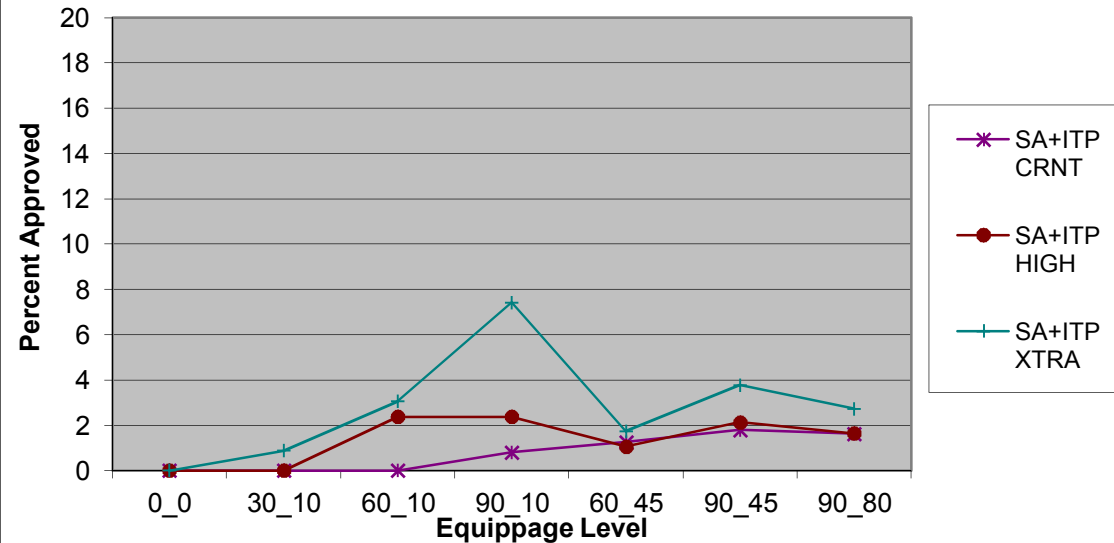




ITP use in 30/30

Operational Improvements from the In-Trail Procedure in the Pacific Organized Track System

Percent of ITP Approvals per Equipped Aircraft

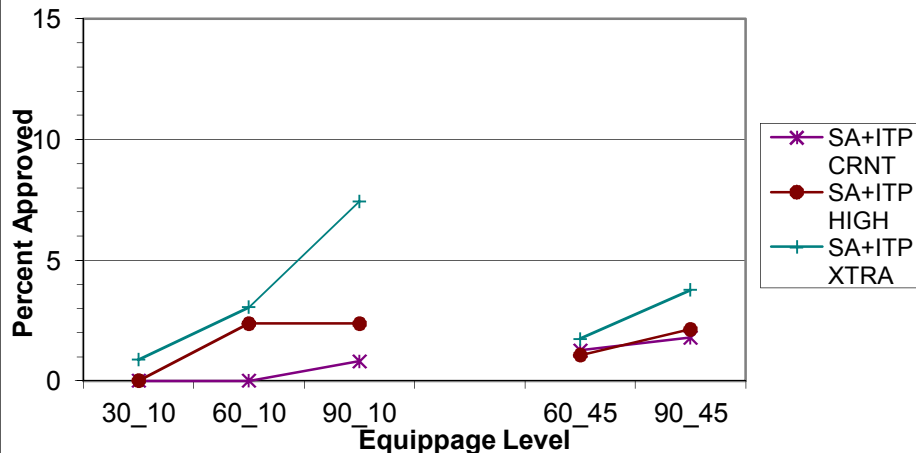


Approvals rates for the ITP are slightly lower in 30/30 than in 50/50, due to there being less need for ITP since the separation standard is less.

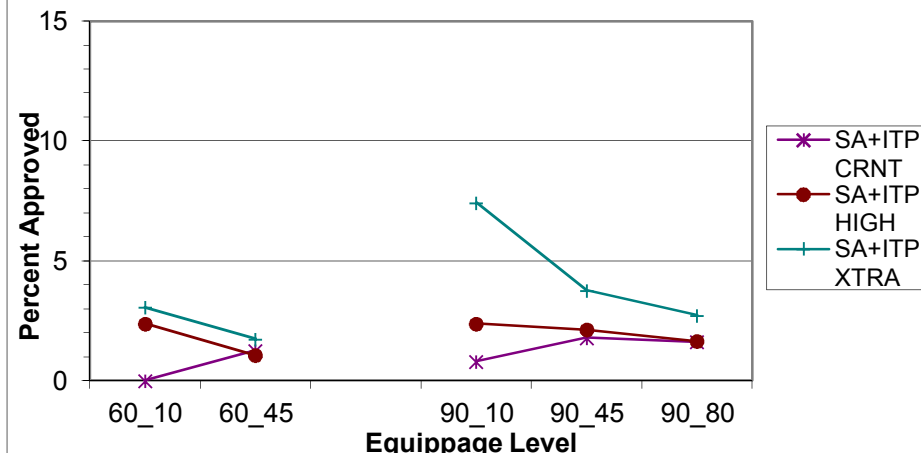
ADS-B OUT equipage shows a direct relationship with the percent of ITP approvals. (bottom left)

ADS-B IN equipage shows a general inverse relationship to the percent of ITP approvals. (bottom right)

Affect of ADS-B OUT on ITP Approvals



Affect of ADS-B IN on ITP Approvals





Fuel Savings in 50/50

Operational Improvements from the In-Trail Procedure in the Pacific Organized Track System

The equipped aircraft experienced significantly larger fuel savings than the unequipped aircraft.

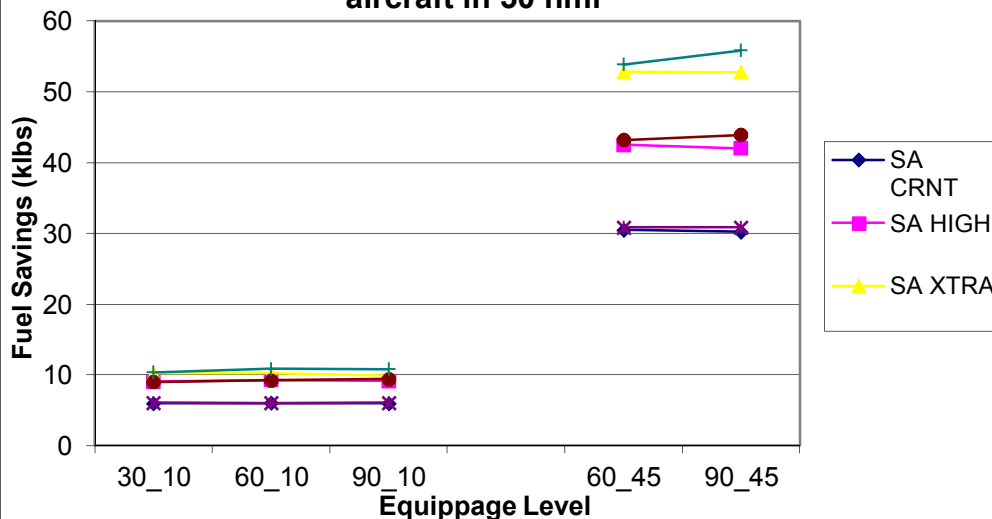
The unequipped aircraft fuel savings showed no consistent trends and were not significant.

ADS-B OUT did not show a significant affect on the system savings.

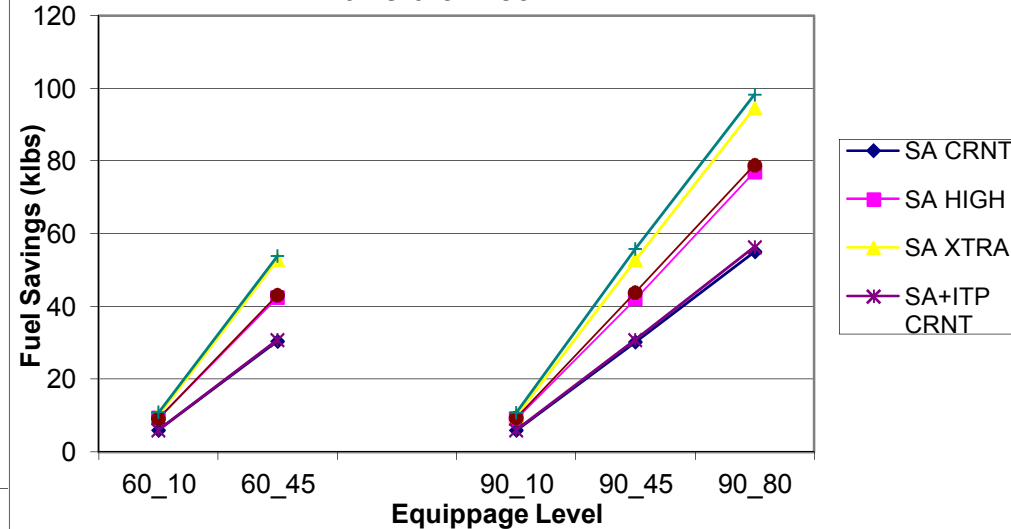
ADS-B IN showed a direct and positive trend with the system savings.

This again is due to the fact that ADS-B OUT mainly changed the type of requests being made and ADS-B IN changed the number of requests.

ADS-B OUT affect on System Savings for Equipped aircraft in 50 nmi



ADS-B IN affect on System Savings for Equipped aircraft in 50 nmi



Example of current density with the SA+ITP at 60_45:

Equipped aircraft saved 30,828 pounds
With 55 aircraft that is an average of 560 pounds

Unequipped aircraft saved 174 pounds
With 14 aircraft that is an average of 12 pounds



Fuel Savings in 30/30

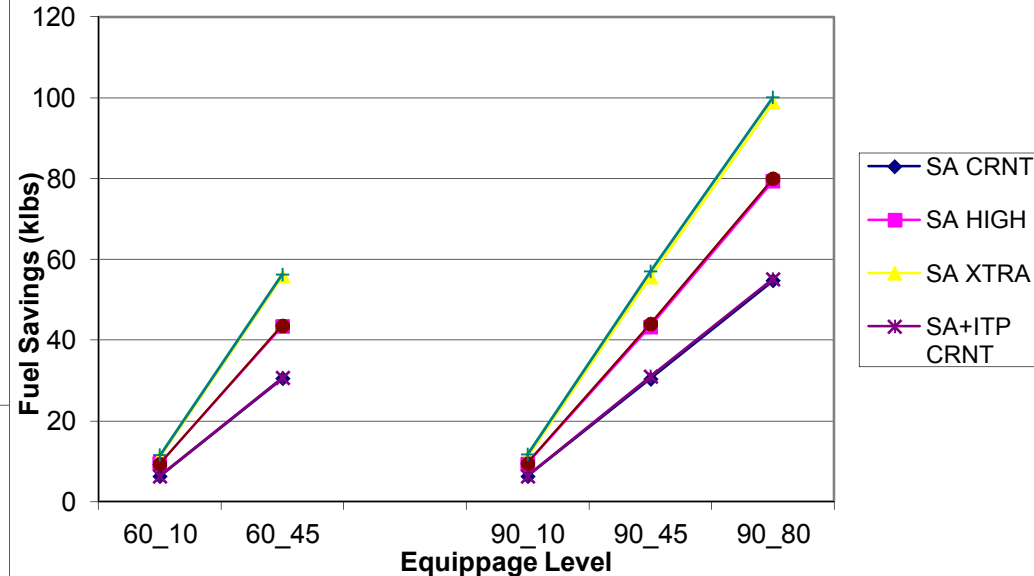
Operational Improvements from the In-Trail Procedure in the Pacific Organized Track System

The equipped aircraft experienced significantly larger fuel savings than the unequipped aircraft.

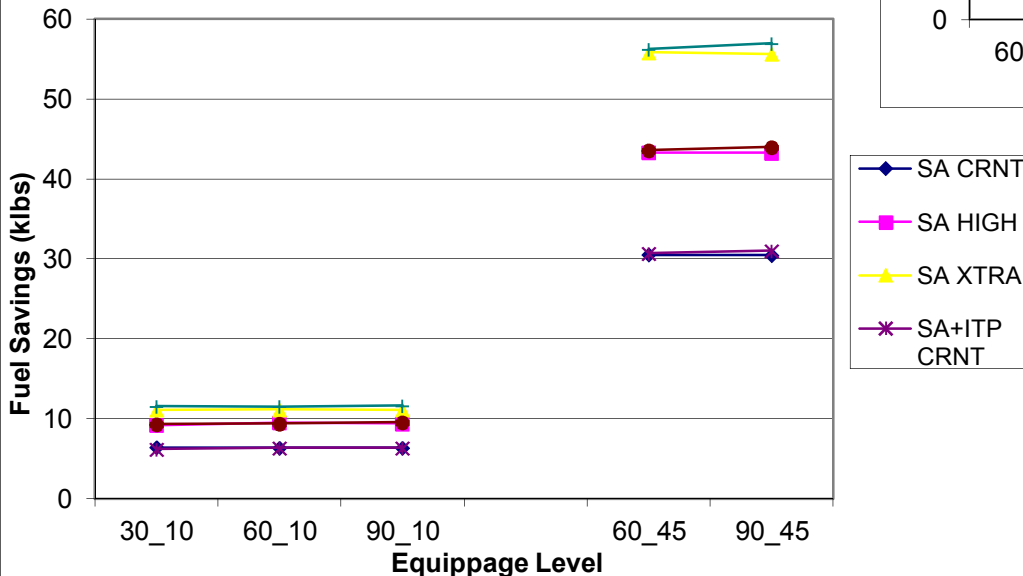
The unequipped aircraft fuel savings showed no consistent trends and were not significant.

System savings and trends are very similar in 30/30 as they were in 50/50 and for the same reasons.

ADS-B IN affect on System Savings for Equipped aircraft in 30 nmi



ADS-B OUT affect on System Savings for Equipped aircraft in 30 nmi



Example of current density with the SA+ITP at 60_45 (same example as in 50/50):

Equipped aircraft saved 30,695 pounds
With 55 aircraft that is an average of 558 pounds

Unequipped aircraft saved -740 pounds
With 14 aircraft that is an average of -53 pounds



ITP aircraft Fuel Savings Summary

Operational Improvements from the In-Trail Procedure in the Pacific Organized Track System

		ADS-B equipage					
		30_10	60_10	90_10	60_45	90_45	90_80
Separation	Density	(average fuel savings per flight in pounds)					
30/30	Current	900.6	926.3	931.3	995.1	1005.1	1009.4
	High	1001.2	1008.8	1023.3	1041.8	1051.3	1075.4
	Extra	911.8	904.7	916.6	979.2	991.5	984.3
50/50	Current	885.6	878.0	885.2	998.3	999.6	1029.2
	High	965.1	987.3	1007.7	1032.4	1049.8	1059.4
	Extra	817.0	854.7	853.1	935.4	971.3	965.2

The savings of the ITP aircraft were significant. On average, the flights equipped with both the ITP equipment and the ability to use the ITP saved between 800 and 1,000 pounds of fuel per flight.

For reference the average number of aircraft per scenario density were 68.7 (current), 93.7 (high), and 128.4 (extra).



Operational Improvements from the In-Trail Procedure in the Pacific Organized Track System

Questions?



Additional Slides

Operational Improvements from the In-Trail Procedure in the Pacific Organized Track System



ADS-B In-Trail Procedure

Operational Improvements from the In-Trail Procedure in the Pacific Organized Track System

- Region of applicability:
 - Non-radar procedural airspace
- Restrictions on use:
 - ITP aircraft must be
 - Equipped with ADS-B IN
 - Equipped with ITP onboard tools
 - Receiving a qualified ADS-B signal from each reference aircraft
 - Reference aircraft must be within 2,000 feet vertically of the ownship
 - Maximum of two reference aircraft can be selected
 - Must maintain more than 300 fpm climb/descent rate and current Mach
 - Controller Pilot Data Link Communication (CPDLC) must exist



ADS-B In-Trail Procedure

Operational Improvements from the In-Trail Procedure in the Pacific Organized Track System

- Initiation Criteria:
 - Evaluate prior to an ITP request and prior to acceptance of an ITP clearance
 - ITP distance ≥ 15 nmi with ground speed difference ≤ 20 kts
 - ITP distance ≥ 20 nmi with ground speed difference ≤ 30 kts
- Controller Criteria:
 - ITP aircraft is not currently a reference aircraft
 - Standard separation exists at the requested flight level
 - ITP and reference aircraft
 - May not be closing at more than 0.06 Mach
 - Are classified as same track
 - Have no more than 2,000 feet vertical separation
 - Are not currently maneuvering
 - Are not expected to maneuver prior to the ITP being completed



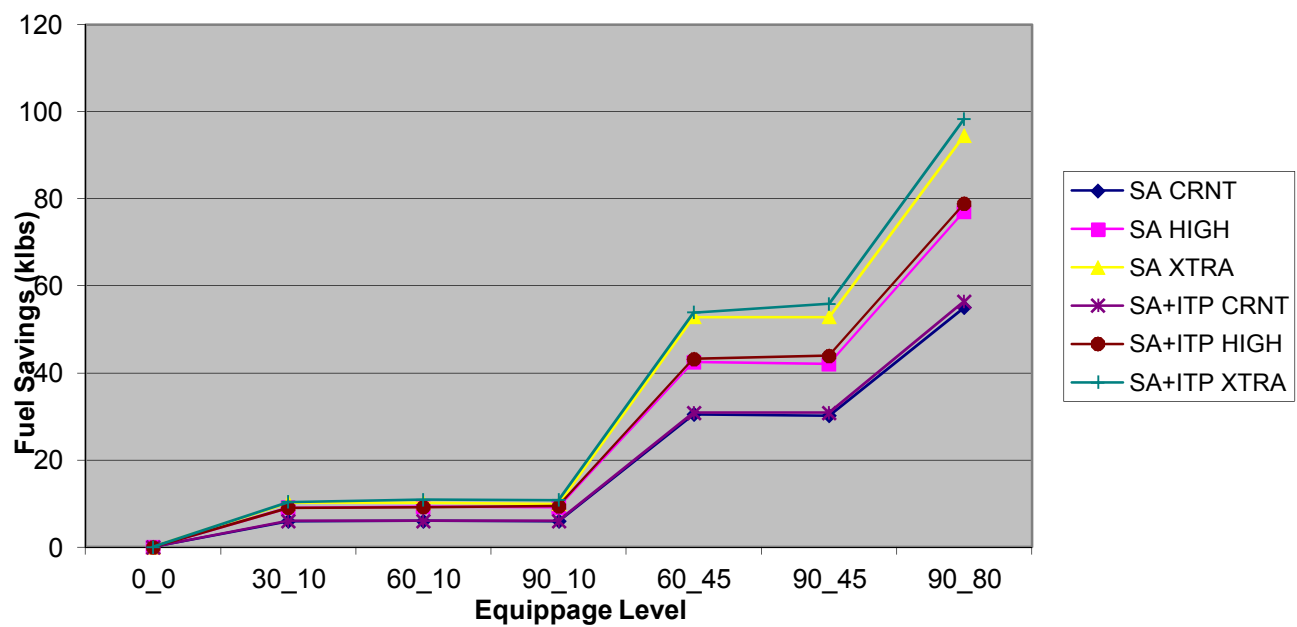
Fuel Savings in 50/50

Operational Improvements from the In-Trail Procedure in the Pacific Organized Track System

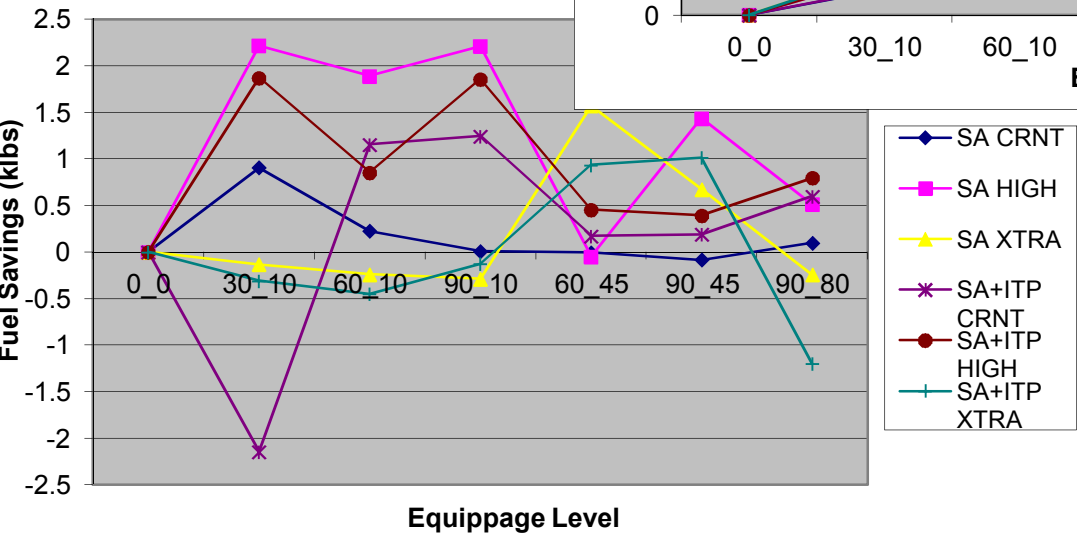
The equipped aircraft experienced significantly larger fuel savings than the unequipped aircraft.

Note the difference in scale between the equipped and unequipped aircraft.

System Savings for Equipped aircraft in 50 nmi



System Savings for Unequipped aircraft



Example of current density with the SA+ITP condition:

Equipped aircraft saved 56,400 pounds
With 55 aircraft that is an average of 1,025 pounds

Unequipped aircraft saved 600 pounds
With 14 aircraft that is an average of 43 pounds



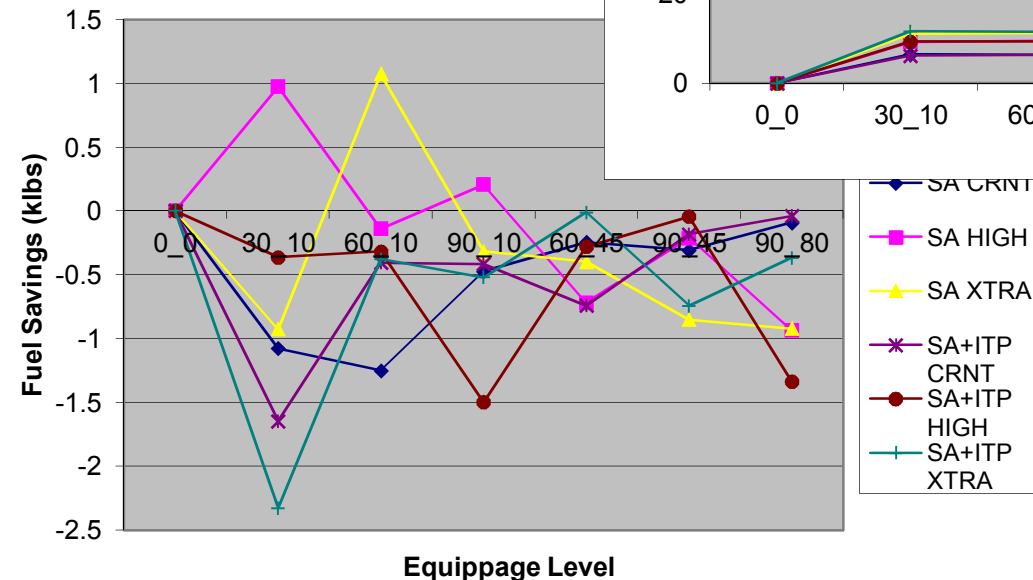
Fuel Savings in 30/30

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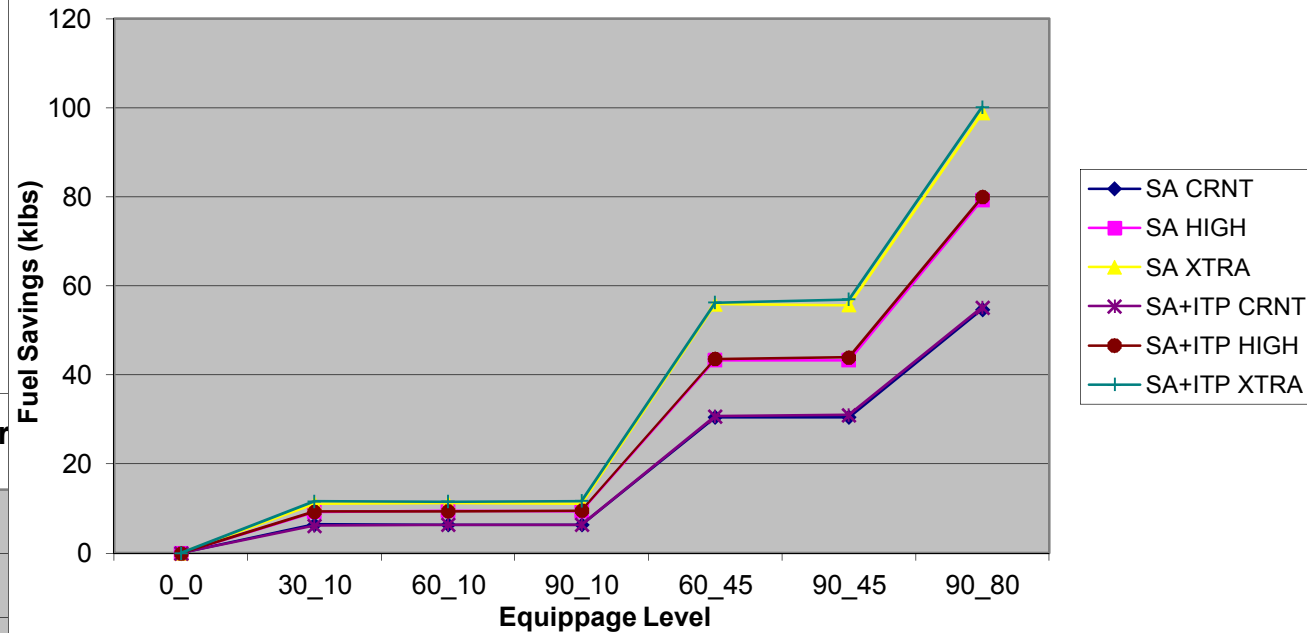
The equipped aircraft experienced significantly larger fuel savings than the unequipped aircraft.

Note the difference in scale between the equipped and unequipped aircraft.

System Savings for Unequipped aircraft



System Savings for Equipped aircraft in 30 nmi



Example of current density with the SA+ITP condition:

Equipped aircraft saved 55,000 pounds
With 55 aircraft that is an average of 1,000 pounds

Unequipped aircraft saved -38 pounds
With 14 aircraft that is an average of -2.7 pounds



ITP System Fuel Savings Summary

Operational Improvements from the In-Trail Procedure in the Pacific Organized Track System

		ADS-B equipage					
		30_10	60_10	90_10	60_45	90_45	90_80
Separation	Density	(average fuel savings in pounds)					
30/30	Current	6171.3	6333.0	6367.6	30695.2	31000.0	55189.0
	High	9333.5	9411.7	9537.2	43588.7	43973.7	79948.9
	Extra	11572.9	11500.4	11644.0	56236.4	56953.3	100144.3
50/50	Current	6043.5	5992.6	6042.2	30827.6	30859.9	56403.6
	High	9005.5	9214.4	9401.0	43200.4	43905.0	78870.6
	Extra	10363.9	10839.7	10816.1	53884.2	55865.0	98285.1

The savings of the ITP aircraft were significant. On average, the flights equipped with both the ITP equipment and the ability to use the ITP saved between 6,000 and 100,000 pounds of fuel.

For reference the average number of aircraft per scenario density were 68.7 (current), 93.7 (high), and 128.4 (extra).