SFO Tailored Arrivals Environmental Analysis

by

Kevin Elmer, Rob Mead, Louis Bailey, Brad Cornell, Jesse Follet (Boeing)
Richard Lanier (NASA Ames Research Center / FAA)
San Francisco Aircraft Noise Abatement Office

JPDO Environmental Working Group
Operations Standing Committee
Georgia Tech Workshop
November 17-18, 2008

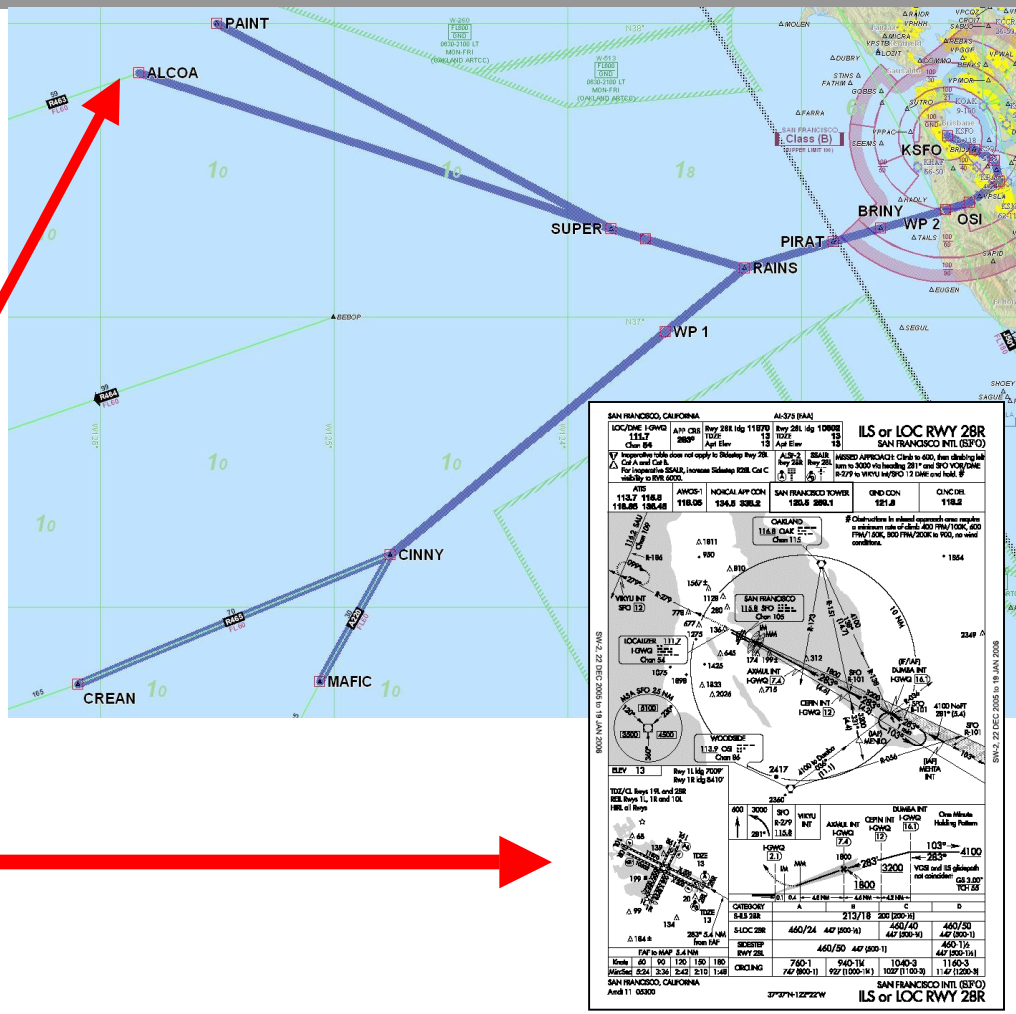
Background

- Oceanic Tailored Arrivals (OTA) field test with UAL B777 since 2005 - prediction accuracy (both EDA and FMS)
- Current Status
  - This is an operational implementation, not a trial
  - Both B777 and B747 aircraft are now participating
  - Not all flights requesting will get a full TA. Some will, but without the full automation (NASA's EDA), not all will get a full TA and the FAA is not promising they will. Rather, they get about 1/3 of the benefit by flying a partial TA (TA until broken off by ATC)
  - FAA has moved very quickly, leveraging a new system (Ocean21)
  - Recognize NASA's EDA role, and pioneering role
  - List of approved airlines (Number of flights per day) – UAL(12), ANZ(1), JAL(2), QAF(1), ANA(1)
  - Airlines looking to start very soon – NCA(2), SIA(2), NWA(1 A330), KAL(1), …
  - Other candidate airlines – AAR(1), EVA(2), CCA(1), …

This is an example Tailored Arrival Clearance via SUPER (8 Sept 2008)

- **From ALCOA, PAINT, DACEM, etc.**
- **Clearance includes published procedure, transition, and runway**
- **Clearance includes vertical, lateral, and speed constraints**
- **Clearance is from en route airspace through to destination**

- **PACIFIC ONE TA**
  At ALCOA cleared to
  - SUPER -----/21000A
  - RAINS -----/21000B
  - PIRAT 250/15000B
  - BRINY 250/12000B
  - N3722 W12223 -----/6000A
  - OSI
  - MENLO 210/4000A
  - ILS28R Approach
  - Runway 28R
- **Maintain FL370**

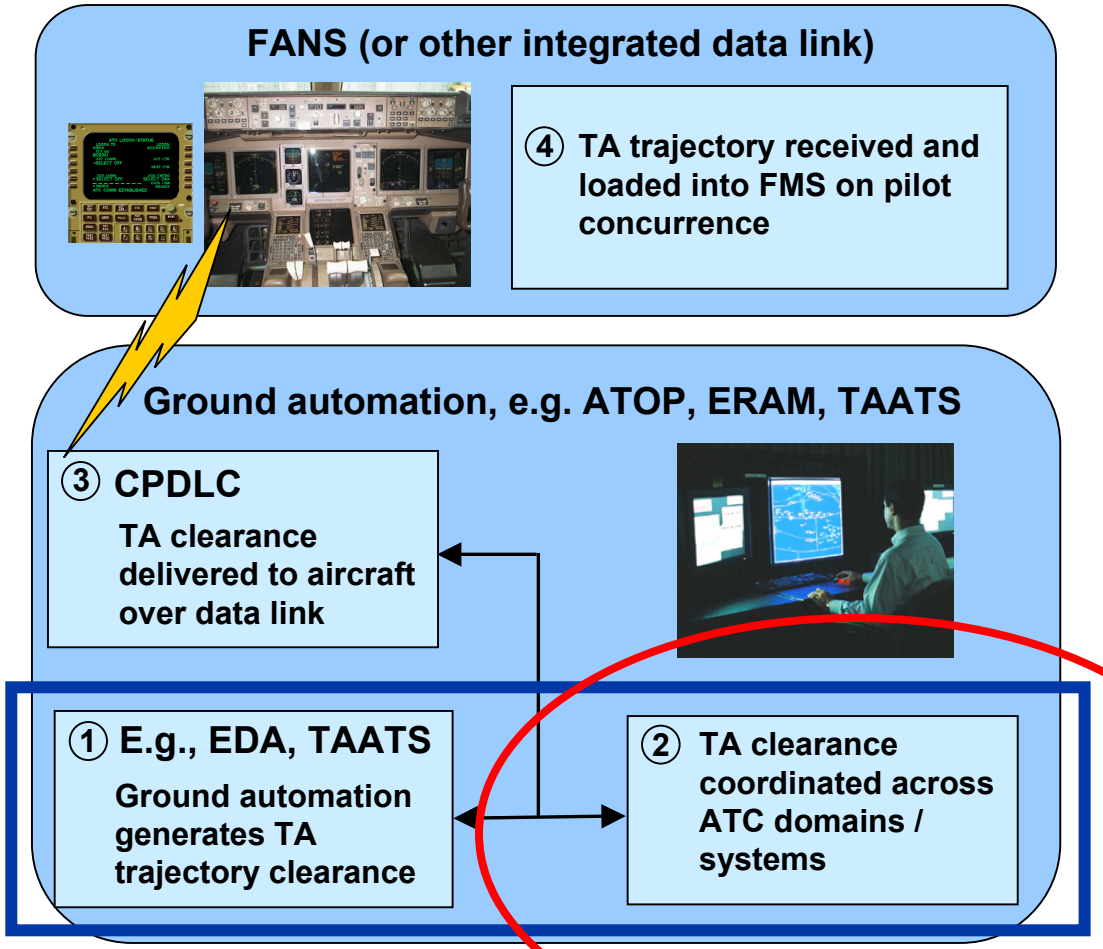


A smooth descent for multiple airframes, across multiple ATS facilities

Ground to Aircraft Trajectory Clearance

In the US, Data-link distinguishes Tailored Arrival only for programmatic separation with 3DPAM, whereas Voice Only has been used for the demonstrations in the Dutch and Australia Tailored Arrival Projects

End-to-end system context



⑤ **TA trajectory flown with FMS**

⑥ **Aircraft downlinks ETA information (at waypoints) along with other useful parameters for ATC trajectory confirmation and tuning**

⑦ **TA procedure broken off if trajectory cannot be continued for any reason**

The key hurdles

Tailored Arrival Environmental Assessment (1)

1. Data analysis included Tailored Arrivals flight candidates
   - ANZ8, JAL2, UAL (34, 74, 76, 78, 830, 838, 852, 856, 858, 862, 870, 872, 886, 888, 892)
   - Most Flights from 12/4/07–5/27/08, UAL (78, 856, and 892) included after 3/23/08
   - Flights that arrived via Woodside (OSI)
2. Primary data source: radar data from the SFO ANOMS8 system
   - 5 days (1/3/08, 1/24/08-1/26/08, and 2/23/08) were missing due to ANOMS8 outages
3. Flights sorted by
   - Tailored Arrivals sort criteria using ATS clearances and ADS-C reports
   - Analysis of ANOMS8 radar data to verify and refine the initial sorting
4. Fuel consumption calculations based on prediction:
   - For low speed performance below 10,000 ft altitude, using the Boeing Climb-out Program (BCOP)
   - Above 10,000 ft altitude, using the Boeing INFLT tool for cruise & descent.
   - Vertical profile generated from BCOP and INFLT was matched to the mean descent paths of the collective ANOMS8 radar data
   - Common start point at cruise

Tailored Arrival Environmental Assessment (2)

5. Tailored Arrivals (TA) sort criteria, using ATS clearances and ADS-C data
   - Non participating - Opted out of procedure or were ineligible

     Note: As ineligible flights are included in the above statistics, numbers should not be interpreted as pilot participation in Tailored Arrivals
   - Partial Tailored Arrival – Met SOME of the TA criteria
   - Full Tailored Arrival – Met ALL of the TA criteria

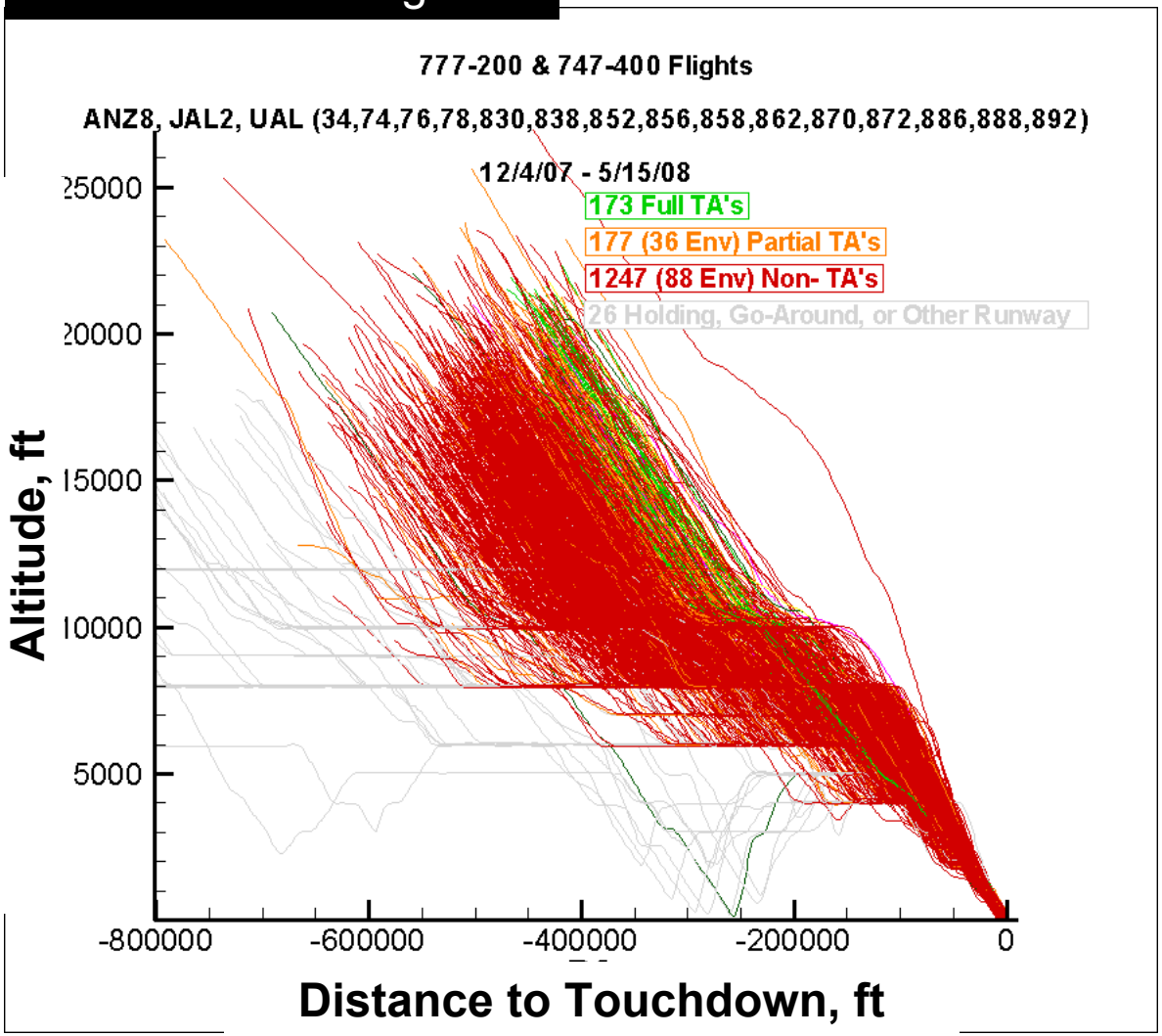
6. **Environmental Criterion: Radar data shows no more than ONE Level Flight Segment and that is no more than ½ Nmi.**

7. Evaluated all the ANOMS8 data to check if met **Environmental Criterion** including Non-Tailored Arrivals.

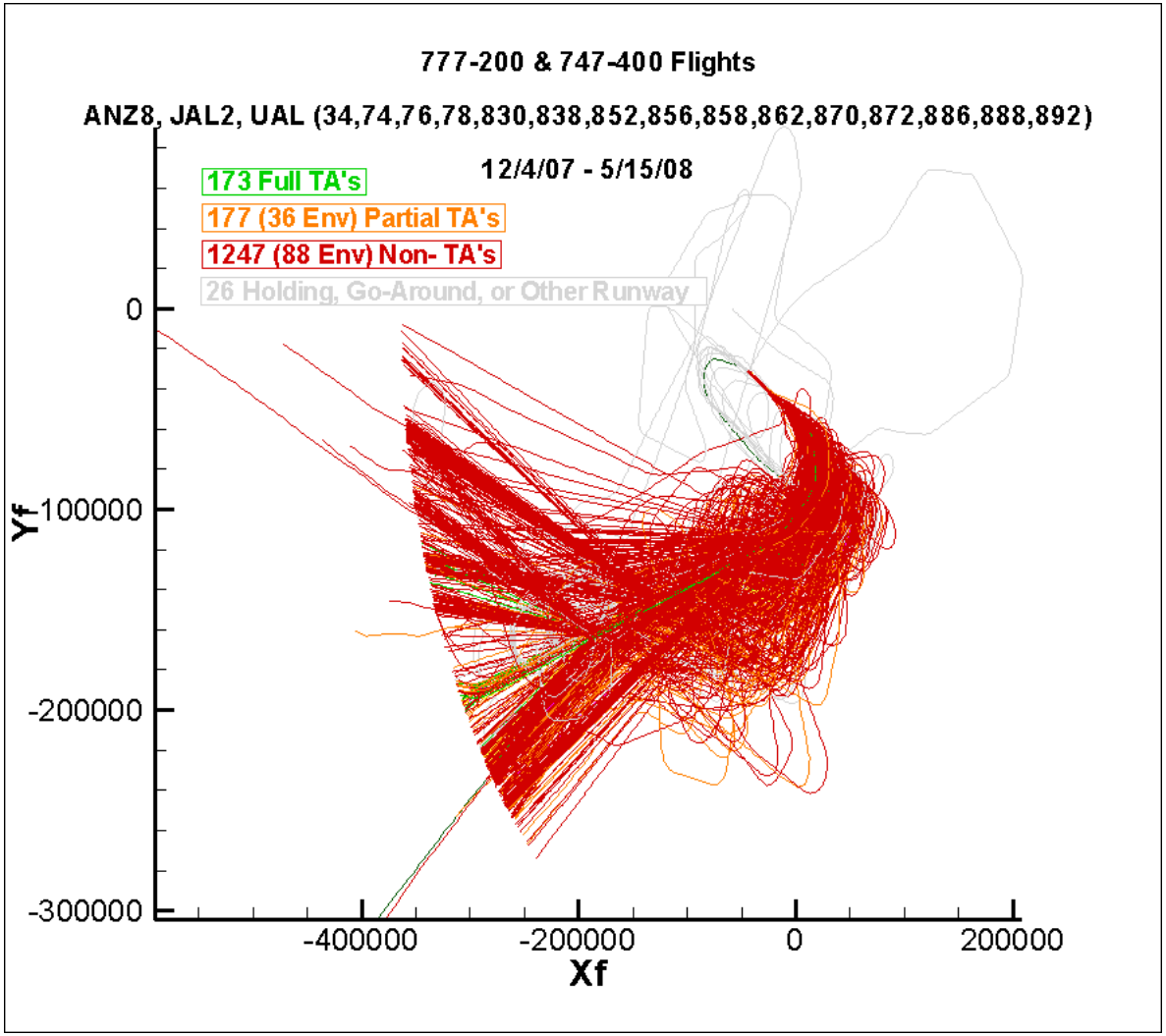
8. Noise Measurement Screening Criteria
   - Lateral offset angle < 60 degrees
   - Noise event less than 2 minute cutoff

Results - Baseline and TA Flights

ANOMS 8 Tracking Data



ANOMS 8 Tracking Data – Lateral Path



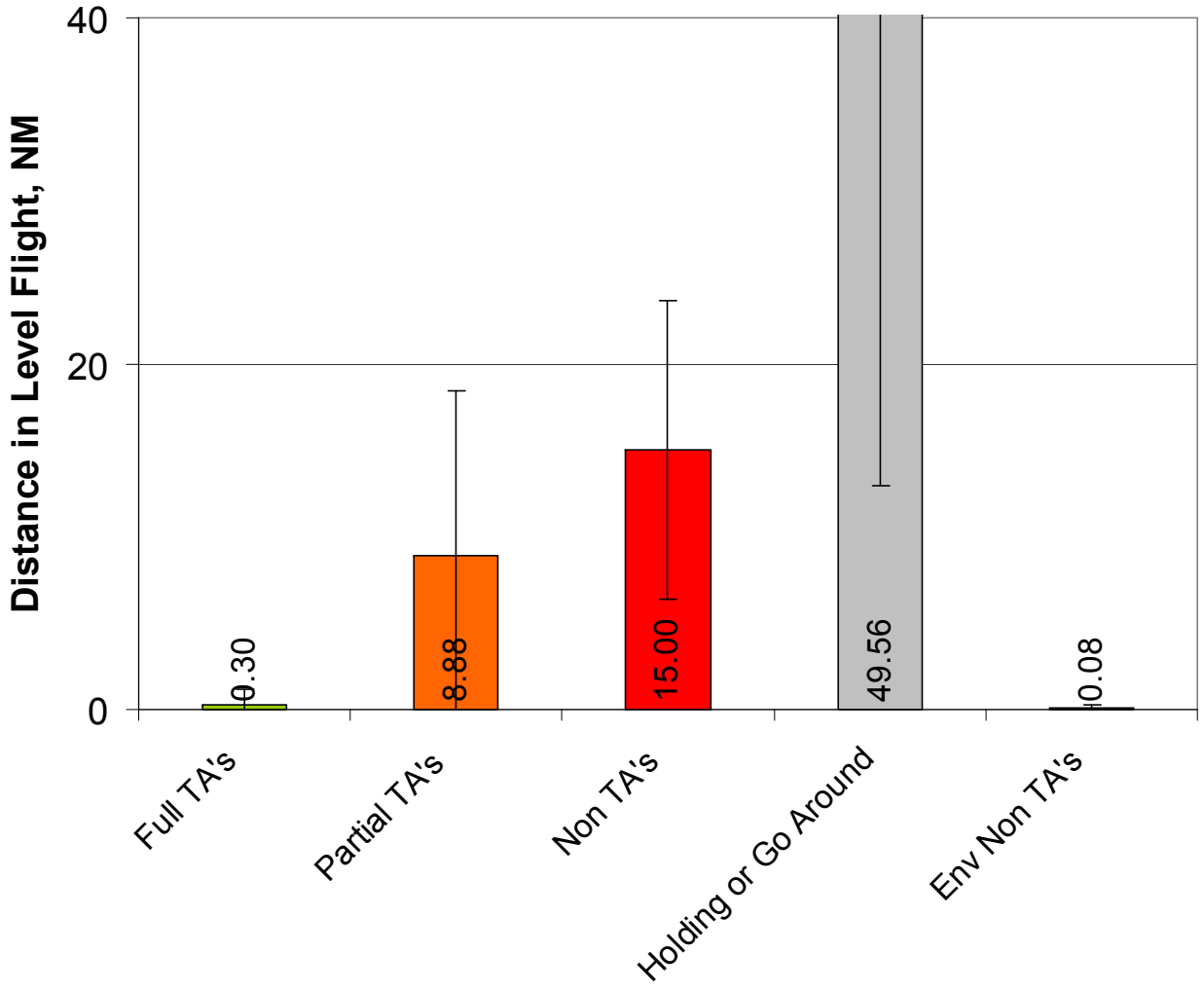
SFO Tailored Arrival Environmental Statistics

Data Collected	Total Flights*	% of Total Flights
Non-TA**	942	76%
Partial TA	177	14%
Tailored Arrival	89	7%
Bad-Holding or Wrong Runway	39	3%

* ANOMS8 Data collected for **1247** Total Flights from December 4, 2007 to May 27, 2008

** Non-TA included non-participating flights and data collected prior to TA start date

Low Altitude Level Flight (Mean & Std Dev)



Fuel Consumption from Top of Descent Cruise to Landing

	777-200	747-400
Non-TA	3,410 lbs	6,470 lbs
Partial TA	2,900 lbs	5,650 lbs
Full TA	1,980 lbs	3,670 lbs

Fuel Saving from Tailored Arrival per Flight

	777-200	**747-400**
Full TA	**1,430 lbs**	**2,800 lbs**
Partial TA	**510 lbs**	**820 lbs**

- Fuel consumption was calculated using the Boeing Climb-out Program (BCOP) for low speed performance below 10,000 ft altitude.
- Fuel consumption above 10,000 ft altitude was calculated using the Boeing INFLT tool for cruise and descent.
- The vertical profile generated from BCOP and INFLT was matched to the mean descent paths of the collective ANOMS8 radar data.

* Estimates derived from GE90-85B and PW4056 engine data

Airline Fuel Consumption from Top of Descent Cruise to Landing

Estimated Actual Fuel & CO2 Savings from SFO Tailored Arrivals*

Airline	Airplane	Potential Fuel & CO_2 Savings**	Actual Fuel & CO_2 Savings	% Realized Potential
Air New Zealand	777-200ER	**Fuel: 215,930 lbs** **CO_2: 681,480 lbs**	**Fuel: 84,020 lbs** **CO_2: 265,170 lbs**	**39%**
United Airlines	777-200ER	**Fuel: 739,310 lbs** **CO_2: 2,333,270 lbs**	**Fuel: 99,930 lbs** **CO_2: 314,870 lbs**	**14%**
United Airlines	747-400	**Fuel: 1,556,800 lbs** **CO_2: 4,913,290 lbs**	**Fuel: 152,200 lbs** **CO_2: 480,340 lbs**	**10%**
Japan Airlines	747-400	**Fuel: 64,400 lbs** **CO_2: 203,240 lbs**	**Fuel: 7240 lbs** **CO_2: 22,840 lbs**	**11%**

* From December 4, 2007 to May 27, 2008

** Potential Fuel Savings based on Total number of flights recorded by ANOMS8 per Airline

dBA_{max} Noise Contours for Representative Daily Oceanic Arrivals into SFO - 20 747/ 777 flights

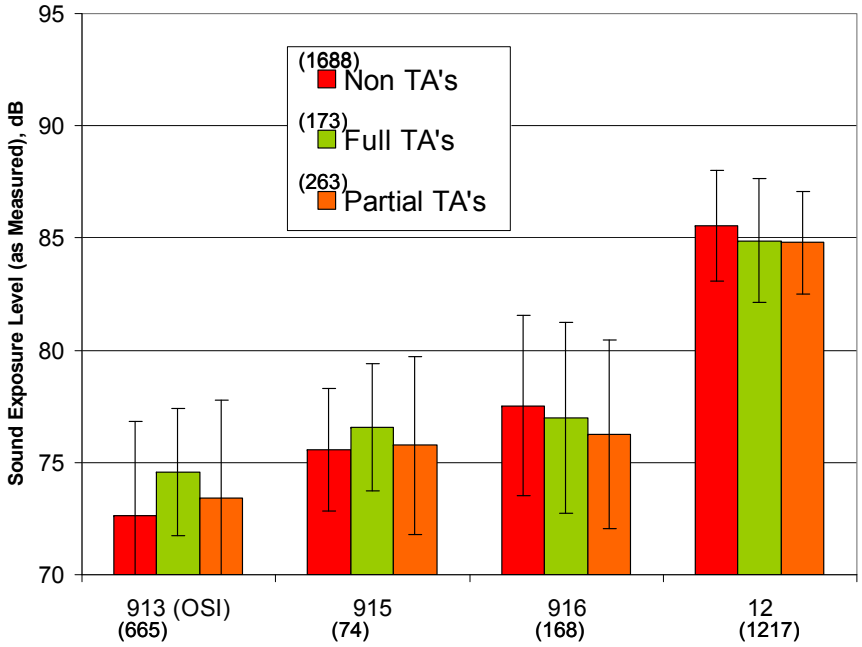
Boeing Technology | **Phantom Works**

Non Tailored Arrival

Partial Tailored Arrival

Tailored Arrival

Noise Measurement Comparison



No statistically significant change in noise at four measurement locations

Conclusions

- Tailored Arrival eliminated the level off segments observed in standard SFO arrivals.
- 21% of the flights collected from the ANOMS8 data participated in a Tailored Arrival
- 33% of the participating Tailored Arrival flights saved significant amount of fuel along with reducing environmental impacts from noise and emissions.
- The remainder saved some reduced amount of fuel and reduced environmental impact.
- Tailored Arrivals participation resulted in better chances of reduced environmental impact. After 15 March
  - For non-participating flights, only 13% of flights would be considered green
  - For Tailored Arrival participants, 63% would be considered green.
- No Significant Change in Noise at four measurement locations
- Significant reduction in noise contours

Final Environmental Update
Due out in Dec 08

Percentages as of Sep 27th, 2008

Candidate Flights	27-May	27-Sep		F/P	F/(F+P)
Full	**89**	**286**	% flights performing full TAs	**24%**	**35%**
Partial	**177**	**532**	% flights performing partial TAs	**44%**	**65%**
Not requested/Denied		**384**			
Not Granted		**5**			
Candidate Flights		**1202**	Total % flights requesting TAs	**68%**	