Oceanic Tailored Arrivals

*Project Overview*

*Environmental Work Group – CDA Workshop*
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Outline

- Concept Overview
- R&D Objectives
- SFO Field Trials Description
- Some Initial Findings
- Concluding Remarks
What is a Tailored Arrival?

An trajectory-based clearance that enables an efficient descent from cruise to landing

- Allows a continuous descent at low engine power
- Tailored to:
  - Avoid conflicts
  - Meet traffic-flow constraints
  - Avoid restricted airspace, weather, terrain
  - Accommodate specific aircraft constraints
- Given as a single clearance well prior to TOD
- Coordinated across airspace/facility boundaries
- Loaded into and flown using aircraft FMS
- Delivered by data-link for minimal workload
Why Tailored Arrivals?

- Reduced fuel burn
- Reduced noise
- Reduced emissions
- Improved engine life (due to fewer level-off power cycles)
- Reduced controller and pilot workload
- Improved arrival trajectory certainty and situational awareness
- Return on airline CNS avionics investment
Conduct R&D needed for Tailored Arrival CDA operations under all traffic conditions, regardless of congestion

Data-link and FMS technologies likely to remain core to long-term concept

Long-term concept will exploit ATC time-based metering and strategic conflict avoidance capabilities: e.g., EDA and TMA

NASA effort will be focused on foundational R&D:

- Develop and prove Tailored Arrival concept for congested ops
  - Maximize flight efficiency
  - Maximize throughput
- Extend TMA/EDA capabilities to support this concept
- Work in parallel with Boeing-led efforts to identify near-term opportunities
  - Obtain immediate benefits under accommodating conditions
  - Blaze a logical implementation path towards further-term concept
En Route/ Descent Advisor Automation

TMA plans sequence and schedule to TRACON meter fix

EDA generates advisories to meet TMA schedule (absorb delay)

Vertical advisories involve cruise and descent speed

Horizontal advisories involve path stretching
Tailored Arrival Specification

Basic TA clearance defines lateral routing and one or more crossing restrictions through IAF (e.g. Menlo)

Initial cruise/decent speeds and TOD will be dynamically controlled by EDA
Oceanic Field Trials: Scope

- Involved a single FANS-equipped Boeing 777 flight from HNL to SFO (UAL 76), on Central-East Pacific route structure
- Early morning arrival time chosen to minimize traffic interruptions
- Data-link communications provided through FAA’s newly deployed ATOP/Ocean-21 system at ZOA
- EDA prototype used to select upper-airspace speed profile to target arrival time at TRACON boundary
- Trials conducted in two phases: Aug-Sept, 2006; Dec-Jan, 2007
- 40 flight opportunities, 35 Tailored Arrival events
Trajectory Profile

- Lateral and vertical profile constraints developed through flight simulation at UAL, Boeing, NASA Ames
- Observed how pilots managed aircraft energy state in using FMS LNAV/VNAV to control path under various wind conditions

At COSTS cleared to:
- CINNY
- BRINY 11000/240kt
- OSI 7000A/210kt
- MENLO 4500A
- ILS28R Approach
- Runway 28R
Systems Involved

- UAL AOC
- NASA WX Server
- FANS 1/A B-777
- OTA Clearance Up-link
- ADS Down-link
- Controller Station
- ATOP
- Host
- EDA
- WX Interface
- RUC WX (Wind/Temp)
- WX for FMS Update
- Descent Speed Advisory
- Track and Flight Plan
- ZOA-Oceanic
- WX for FMS Update
Basic Event Series

1) Approx 2 hours prior to SFO arrival flight crew downlinks intent to participate in OTA trials
2) Controller modifies ADS-C reporting contract to capture data at 2-min intervals
3) Controller up-links Basic OTA clearance via CPDLC

- At [CINNY] cleared [ROUTE CLEARANCE]
- [ROUTE CLEARANCE] includes lateral route, crossing restrictions, approach procedure, and runway assignment
4) Flight crew loads Basic OTA clearance into FMS and reviews

• If acceptable, crew downlinks “wilco” and activates route in FMS

• If unacceptable, crew downlinks “unable”
5) Updated cruise/descent winds, based on CTAS/RUC, are sent to AOC by EDA test engineer for uplink and FMS auto-load

- Cruise wind @ CINNY
- Descent winds @ OSI for 100 ft, 10K ft, FL 180, FL 250
6) For EDA and scenarios, test engineer sets metering time at TRACON boundary

- EDA cruise/descent speeds are computed and up-linked, e.g. FMC SPEED SCHEDULE: CRZ [.83], DES [.83/286]
- Upon acceptance, flight crew enters EDA instruction into FMS
7) OC4 hands-off to ZOA Sector 35
   • CPDLC services drop off
   • ATOP ADS contract automatically terminated upon hand-off
Controller issues pilot discretionary descent clearance down to 8,000 ft along OTA profile
9) NCT controller clears aircraft to continue OTA descent and provides approach clearance
10) Localizer intercept, glide-slope capture, and landing
# Data Collection (Quantitative)

<table>
<thead>
<tr>
<th>Source</th>
<th>Elements</th>
<th>Frequency</th>
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<tbody>
<tr>
<td>ADS-C</td>
<td>• Position group (lat/long, altitude, time stamp)</td>
<td>1/ (2 min)</td>
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<tr>
<td></td>
<td>• Weather group (wind speed, wind direction, temperature)</td>
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<tr>
<td></td>
<td>• Earth reference group (ground speed, vertical rate, track angle)</td>
<td></td>
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<tr>
<td></td>
<td>• Air reference group (Mach, heading)</td>
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<tr>
<td></td>
<td>• Projected intent (ETAs at all downstream waypoints)</td>
<td></td>
</tr>
<tr>
<td>ZOA Host Track and FP</td>
<td>• Position</td>
<td>1/ (12 sec)</td>
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<tr>
<td></td>
<td>• Ground speed, track heading</td>
<td></td>
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<tr>
<td>NCT ARTS Track and FP</td>
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<td>1/ (5 sec)</td>
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<tr>
<td></td>
<td>• Ground speed, track heading</td>
<td></td>
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<tr>
<td>EDA outputs</td>
<td>• Trajectory predictions</td>
<td>Event based</td>
</tr>
<tr>
<td></td>
<td>• Advisories</td>
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</tr>
<tr>
<td>RUC</td>
<td>• Grid wind speed/direction</td>
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<td></td>
<td>• Grid T, P</td>
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<tr>
<td>SFO Microphone</td>
<td>• Noise level</td>
<td>10 Hz</td>
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Microphone Deployment

Permanent noise monitor sites

Deployed portable noise monitors

Courtesy SFO Noise Abatement Office
Some Initial Findings
Example Vertical Profiles

OTA flight conducted 8/29/2006

EDA-assigned speed schedule = .84 M, 295 kt CAS

Baseline UAL 76 flight captured 8/19/2006, showing 5-min level-off at 8,000 ft and a 1-min level-off at 4,000 ft.
All B-777 CEP Track C Vertical Tracks

Dec 9 – Jan 6, 2007

Altitude, ft

Track Distance, ft

Early morning (4am - 5am)
Morning (7am - 11am)
Early Evening (5pm)
Evening (7pm - 10pm)
All B-777 CEP Track C Lateral Tracks
Dec 9 – Jan 6, 2007

Early morning (4am - 5am)
Morning (7am - 11am)
Early Evening (5pm)
Evening (7pm - 10pm)
FMS Trajectory Prediction

FMS Predictions Captured 8/31/06

Wind Uplink

Time to Runway (Minutes)
FMS Trajectory Prediction
FMS and EDA Time Prediction Comparison

FMS Time Prediction at CREAN to BRINY:
Mean = 3 seconds early
Max Early = 35 seconds
Max Late = 38 seconds
Std Dev = 20

EDA Time Prediction at CREAN to BRINY:
Mean = 9 seconds late
Max Early = 34 seconds
Max Late = 38 seconds
Std Dev = 22
Summary

➔ Tailored Arrivals has potential for economic and environmental benefits: fuel, noise, and emissions reduction through CDA

➔ Challenge is to plan and execute CDA trajectories in congested traffic conditions. *This is where the benefits are!*

➔ Problem requires predictive, ground-based automation for generating conflict-free, flow-conformant trajectory solutions

➔ EDA automation is a start, but further capabilities needed to support further-term Tailored Arrivals concept

➔ Air/ground oceanic infrastructure has provided excellent environment for validating Tailored Arrivals procedures, communications and system interoperability

➔ SFO results analysis in progress to validate benefit assumptions and establish operational feasibility

➔ Success of SFO trials has provided NASA the incentive needed to continue R&D efforts in this important area