CENTER FOR ADVANCED AVIATION SYSTEM DEVELOPMENT (CAASD)

Analysis of Operational Impacts of Continuous Descent Arrivals (CDA) using *runway*Simulator

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Outline

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- Objective and Scope
- Study Approach
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Background

- **Continuous Descent Arrivals (CDA)**
  - Clears an aircraft to descend from cruise altitude to final approach
  - For maximum benefit, uses a best-economy power setting at all times
  - Allows level or shallow segments for deceleration (e.g., 250 knots at 10,000 feet)
  - Transitions to a final approach along a standard glideslope
  - Benefits include fuel savings, emissions and noise reduction
- **Impact of CDA at a given airport is based on multiple factors**
  - Application of CDA (% of CDA, time of day, approaches)
  - Traffic characteristics (equipment mix, traffic demand/pattern)
  - Airport configuration (runway dependencies)
  - Airspace constraints

Objective and Scope

- Analyze the operational impact of CDA at airport
  - Arrival delay/throughput and airport capacity (arrivals and departures)
  - Using the same airport/traffic setting used in the Dinges study of environmental impact of CDA [1,2]
  - Varying the percentage of CDA flights in multiple scenarios

Important Note

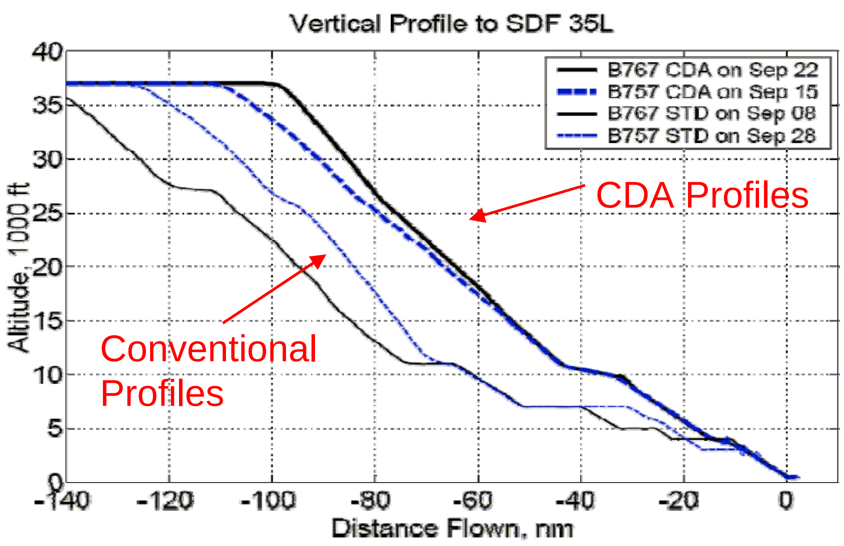
- **Scenario modeled maximized environmental benefits**
  - **Buffers were sufficient to assure 95% (i.e. 2σ) non-intervention on CDA aircraft**
  - **No advanced equipage was assumed to reduce open-loop uncertainty**
    - **E.g., Required Time of Arrival Function on Flight Management System, Cockpit Display of Traffic Information**
- **Alternate assumptions may produce less impact on capacity, but at reduced environmental benefit**

Study Approach

- Assumptions on CDA flights
- CDA settings in simulation model
- Other simulation settings
- Simulation cases
- Two simulation modes: Delay mode and Capacity mode

Assumptions on CDA Flights

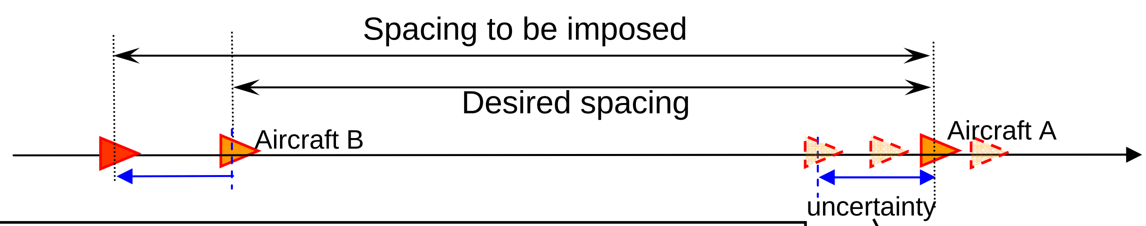
- **Aircraft are cleared at a specified location for CDA**
- **Aircraft spacing is adjusted by speed control or vectoring when flown by conventional method, but not while flying CDA**
- **Extra spacing is applied at the start of CDA to account for uncertainties due to wind, aircraft weight, equipment performance, and pilot actions**



Graphic from Walton, J., "RNAV/CDA Arrival Design: 2004 Flight Test Trials, Louisville International Airport." *Optimized Vertical Descent Profiles – Near-term Implementation,* Atlanta, Georgia, January 2006.

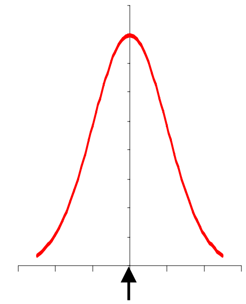
CDA vs. non-CDA
Larger uncertainty for CDA aircraft

- Regular aircraft



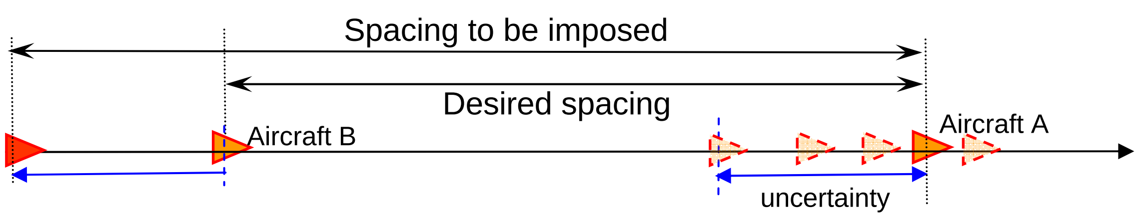
Due to wind, aircraft weight, aircraft equipment performance, pilot actions adjusted by speed control and vectoring

Uncertainty in aircraft separation when speed control and vectoring can be applied

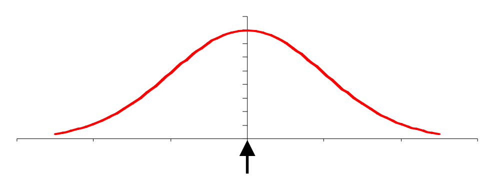


Aircraft separation can be maintained by vectoring or speed control

- CDA aircraft has larger degree of uncertainty



Uncertainty in aircraft separation in CDA where speed control and vectoring cannot be applied



Larger spacing is necessary to account for potential loss of separation

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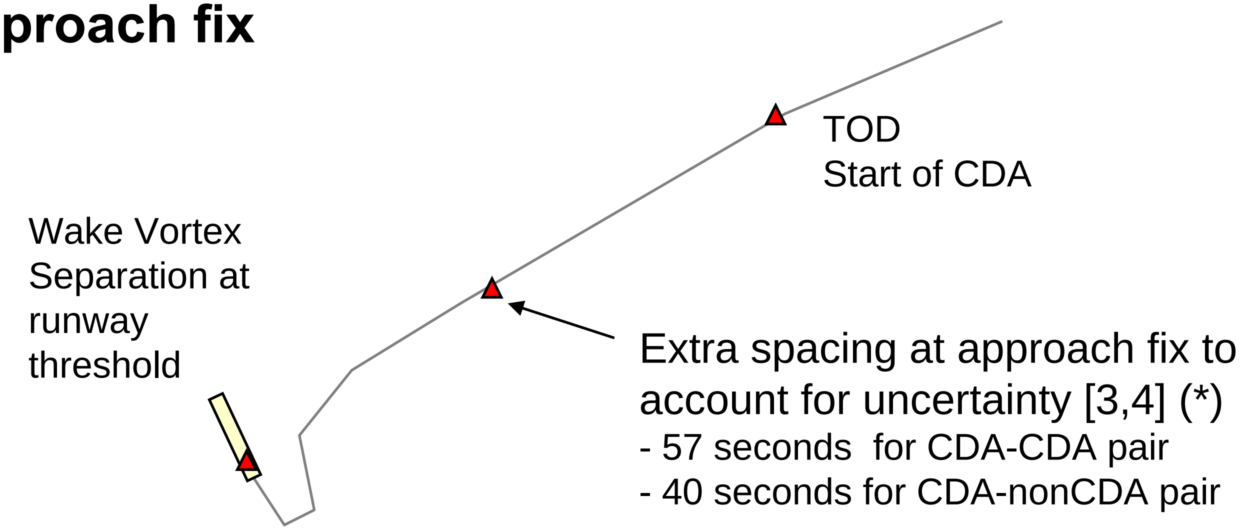
Accounting for CDA Uncertainties in Simulation Settings

- **Start time of each aircraft may be delayed to ensure separation**
  - **At runway threshold (wake vortex separation)**
  - **Extra spacing applied to pairs involving CDA aircraft at approach fix**

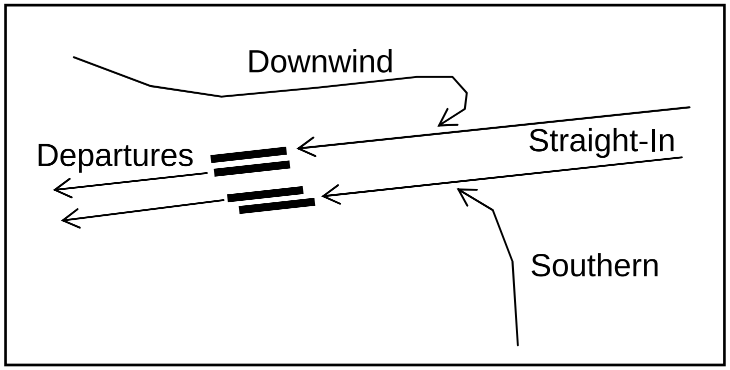


(*) Previous analysis used 40 seconds for CDA-nonCDA pair and 80 seconds for CDA-CDA pair, which was overestimating the uncertainty on both ends. Also, we had additional spacing requirements of 85 to 130 seconds that was derived from the data obtained at an airport in the east coast, that was not applicable to other airports.

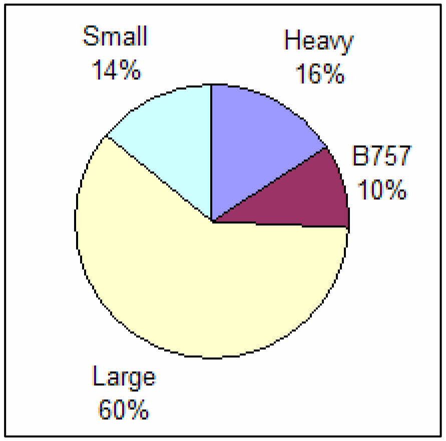
Other Simulation Settings

- **Airport/airspace**
  - **Two parallel independent departure runways**
  - **Three arrival streams to land on two parallel independent runways**
- **Input traffic**
  - **Based on Dinges study [1, 2] traffic file and ETMS data**
  - **Assume that metering mechanism is available to determine the order of arrival at metering fix**
- **Separation minima (*)**
  - **IFR separation at runway threshold**
  - **Minimum radar separation (3 NM) at arrival fix**

Arrivals and Departures



Composition of Input Traffic
Wake Vortex Classification



(*) Previous analysis used IFR separation for CDA flights and VFR separation for non-CDA flights. In this analysis, threshold separation was set to IFR to isolate the impact of CDA

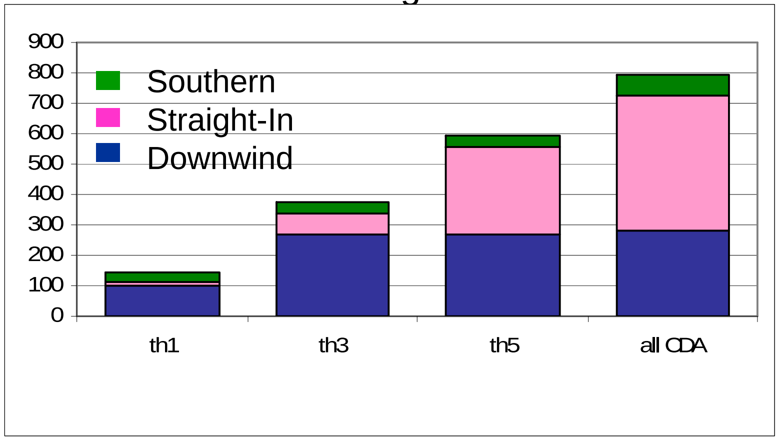
Simulation Cases

- **Five levels with different percentages of CDA usage**
- **Actual CDA % is slightly different from that of environmental analysis [1,2]**
  - **Inclusion of "Small+" aircraft (14% of total) to account for operational impact**
- **CDA % varies by approach for each threshold level**
  - **Assignment of CDA based on the arrival volume on approach**

% of CDA aircraft in each case

CDA level	Operatioinal Analysis	Environmental Analysis
no-CDA	0.0	0
Threshold 1	15.5	16.3
Threshold 3	40.7	47.8
Threshold 5	64.6	78.8
all-CDA	86.0	100

Total # of CDA flights in Simulation



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Simulation Modes

Use *runway*Simulator both in "Delay" and "Capacity" modes

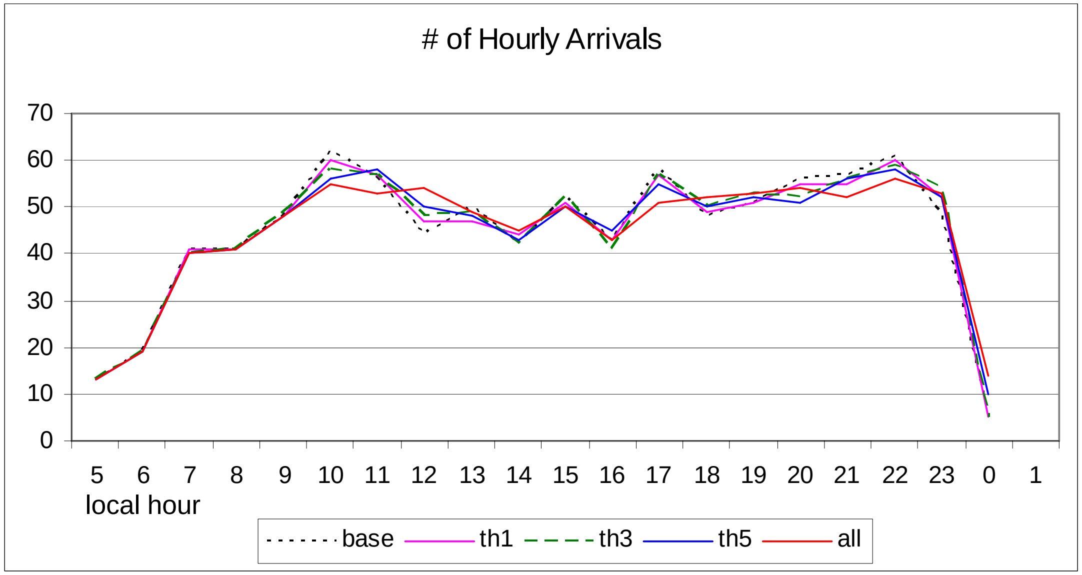
- **Delay mode**
  - **Estimated differences in delay and throughput using realistic schedule of arrivals derived from ETMS data**
  - **Simulation period: 24 hours, no warm-up**
  - **Compared arrival throughput and delay among cases**
- **Capacity mode**
  - **Estimated differences in airport capacity assuming continuous high demand for both arrivals and departures using the fleet mix derived from the traffic file used in delay mode**
  - **Simulation period: 400 hours, 5 hour warm-up**
  - **Compared estimated airport capacity (arrivals and departures)**

Results – Arrival Throughput

- **As the percentage of CDA flights increases, throughput decreases**
  - **In the Threshold1 case (15% CDA), the reduced throughput (by 3) is recovered during the next one to three hours**
  - **In the Threshold3 case (40% CDA), the reduced throughput (by 4) is recovered over the next two to three hours**
  - **In the Threshold5 and All-CDA cases (CDA = 65%, 86%), the reduced throughput (more than 5) is recovered over the next two to three hours**

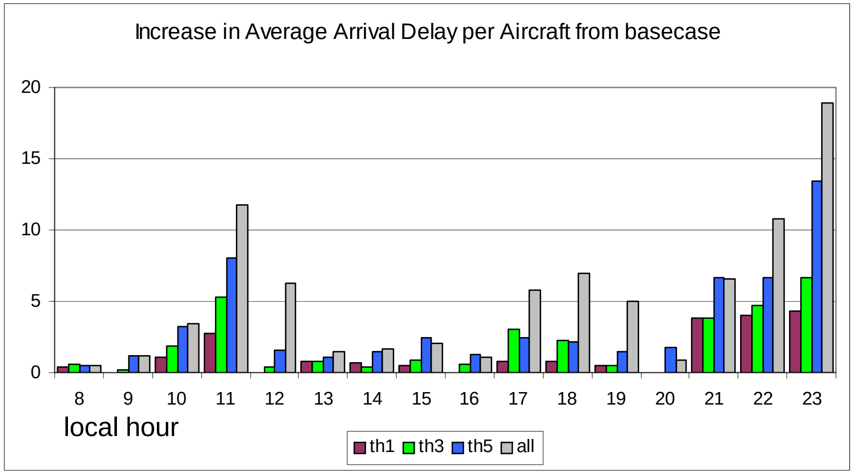
Reduction in Hourly Throughput and
Time to Recover

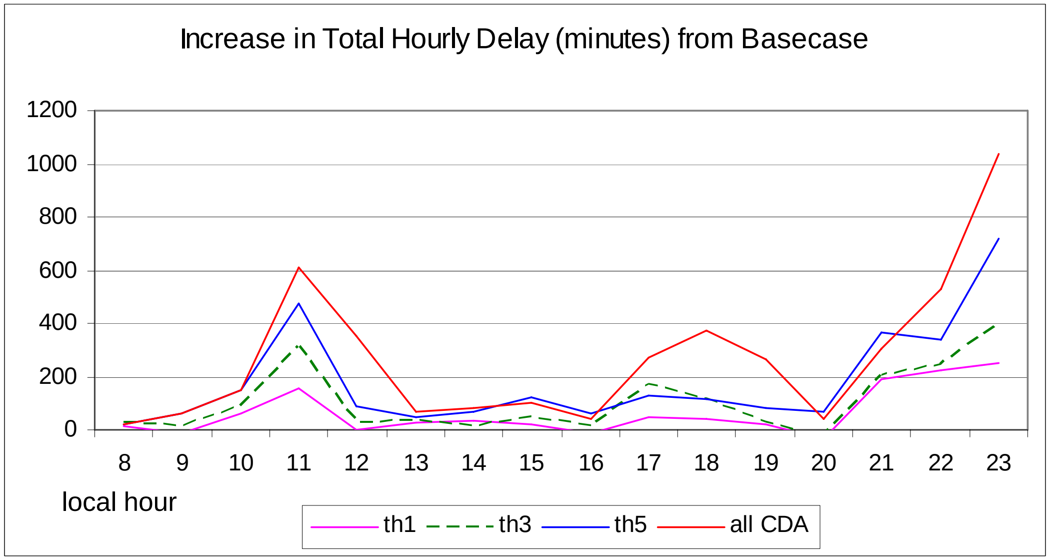
	Th1	Th3	Th5	All CDA
Isolated peak demand time	3 / hour 1 hour	4 / hour 2 hours	6 / hour 2 hours	7 / hour 2 hours
Sustained peak demand time	2 / hour 3 hours	4 / hour 3 hours	5 / hour 3 hours	7 / hour 3 hours



Results – Arrival Delay

- **Total hourly delay increases as the percentage of CDA increases**
- **Increase in average arrival delay exceeds 5 minutes when more than 40% of aircraft are assigned to CDA (Threshold3) during high demand periods (*)**

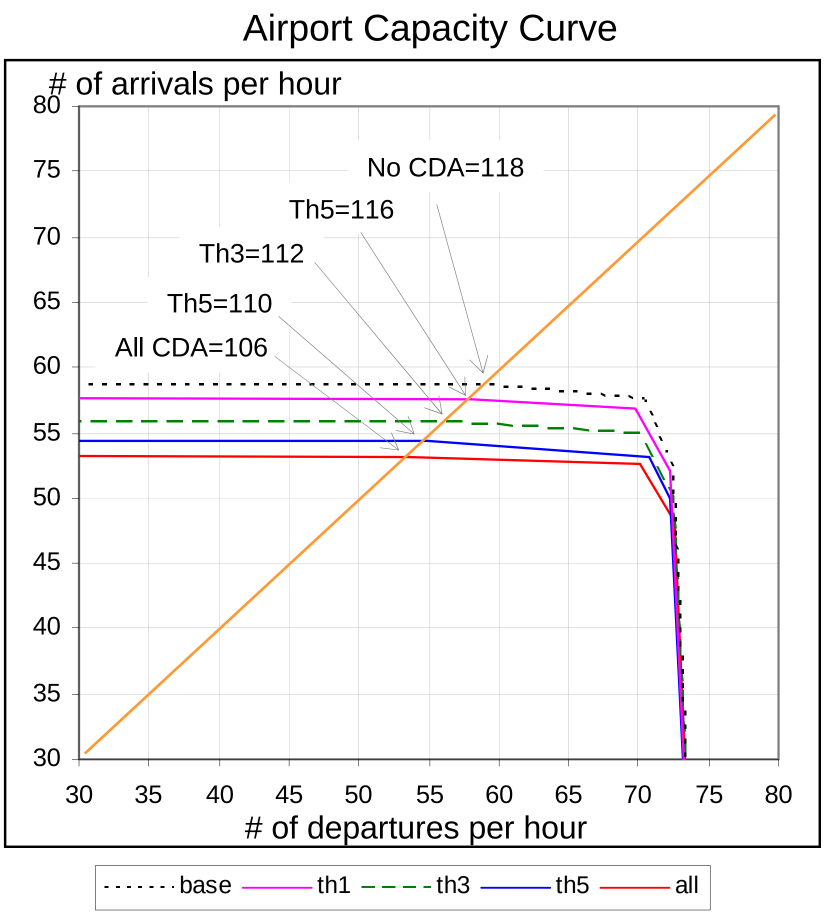




(*) Previous analysis compared the average arrival delay per aircraft. In this analysis, the difference between average arrival delay per aircraft in basecase and that in each threshold is compared.

Results – Airport Capacity

- **Total capacity drops as the percentage of CDA flights increases**
  - **118/hr at non CDA**
  - **106/hr at All CDA**
- **Maximum (arrival-priority) arrival rate drops linearly with increasing percentage of CDA flights**



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Summary

- **Based on the assumptions and airport/traffic setting of this analysis,**
- **Impact of CDA on arrival throughput/delay**
  - **CDA percentage progressively reduces arrival throughput and increases delay**
  - **Impact is seen first in the time periods when the arrival demand stays high. As the percentage of CDAs increases, the impact spreads into other periods when the demand in more isolated**
  - **As the percentage of CDAs exceeds 40%, the impact becomes more prominent**
- **Impact of CDA in airport capacity**
  - **CDA percentage progressively reduces airport capacity**
  - **As percentage of CDA flights increases from 0% (no CDA) to 86% (all CDA), airport capacity (arrival and departure) decreases from 118/hour to 106/hour**

Future Work

- The study focused on the operational impact of various percentage of CDA flights at an airport
- CAASD's work continues in FY08 with extended scope in assessing the operational impact of CDA
  - Factors to be examined may include
    - Traffic characteristics
    - Equipment performance
    - Airport configuration
    - Airspace constraints
  - NAS-wide impact of CDA will be assessed
- These analyses will support development of general guidelines on how and when to apply CDA at a given airport

List of References

[1] Dinges, Eric," Continuous Descent Approach (CDA) Capability Demonstration," *CDA Workshop*: NASA Ames Research Center, Moffett Field, CA, June 2007.

[2] Dinges, Eric, "Determining the Environmental Benefits of Implementing Continuous Descent Approach Procedures," *7th USA/Europe Air Traffic Management R&D Seminar:* Barcelona, Spain, 2007.

[3] Dijkstra, Ferdinand, "Assessing Predictability for Tailored Arrivals," *Boeing Tailored Arrivals Symposium*: Seattle, WA, March 2007.

[4] Coppenbarger, Rich, "Oceanic Tailored Arrivals," Boeing *Tailored Arrivals Symposium*: Seattle, WA, March 2007.

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