Overview of On-Going and Future R&D

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Ray Miraflor, NASA Ames Research Center
Outline

- JPDO and NGATS
- FAA - Aviation Environmental Design Tool
- NASA Research
  - Airspace Concept Evaluation System Simulations of CDA
  - CDA with Advanced Low Noise Guidance
  - Simulation Testing
  - Flight Validation
  - Tailored Arrivals Initiative
  - Trajectory Oriented Operations with Limited Delegation
- Industry Research – Boeing Aircraft Terminal Area Operations
- Partnership for AiR Transportation Noise and Emissions Reduction Research
  - Airports Study for Potential CDA Implementation
  - Southern California TRACON
NGATS and JPDO

- The Next Generation Air Transportation System (NGATS) is a national initiative that will address the civil aviation needs of the year 2025 while providing substantial near-term benefits.

- The Joint Planning and Development Office (JPDO) is the focal point for coordinating the research directed towards NGATS. Research described in this workshop is being coordinated through the JPDO Environment Integrated Product Team Operations Panel.

- More information may be found on [http://www.jpdo.aero](http://www.jpdo.aero).
AEDT is a comprehensive suite of software tools to assess the interdependencies between aviation-related noise and emissions.

Current Status:

- Incorporate into AEDT the ability to fly CDA procedures
  - Improved thrust and profile modeling
  - Development of larger RADAR track data sets for US airports
- Development of metrics relating traffic flow to ability to fly CDA during certain periods
Airspace Concept Evaluation System (ACES) Simulations of CDA throughout the NAS

- Fast-time airspace simulations to examine the impact on delays and throughput due to a change to CDA operations implemented throughout the NAS.

- CDA trajectory data is to be shared between panel member activities to develop input data for ACES.

Feedback to the NGATS Transformation Process
CDA with Advanced Low-Noise Guidance

- Optimized CDA eliminates the level flight segment at low altitude
- Advanced guidance computes a reference path including energy profile
  - Updated to reflect new speed, altitude or route
- Energy error is continuously updated to enable close conformance with the reference trajectory
- Enables delayed landing configuration
Simulation Testing

LNG 1.0 Experiment (2003)
- Single pilot test subjects
- Documented performance with optimized guidance

CDA Crew Procedures Study (2004)
- Two pilot crew procedures using standard FMS guidance.
- Documented performance and workload under varying levels of ATC interruptions during CDA operations.

LNG 2.0 Experiment (2005)
- Two pilot crew procedures using optimized guidance
- Documented improved performance using optimized guidance under high traffic density operations
Flight Validation

Validate simulation results using NASA B-757 aircraft in 2006.
Tailored Arrivals (TA)

Current Status:

- Current work is focused on preparing for oceanic TA field trials involving ZOA/NCT, scheduled to begin April 2006. This effort is being led by NASA with support from Boeing, UAL, FAA, and SFO airport.

- Above effort is progressing well:
  - This activity has received strong support and cooperation from the FAA at various levels.
  - An initial Test Plan that conveys procedures, CDA profile optimization, test matrix, and data collection/analysis is nearing completion.
  - Test will leverage the FAA’s ATOP/Ocean 21 system as a means of delivering TA clearances via data-link. A high-fidelity ATOP simulation capability has been developed at NASA Ames to support procedural development.
  - An important objective of this test is to include a prototype version of NASA’s En Route Descent Advisor (EDA) tool as a mechanism for dynamically “tailoring” the arrival in upper airspace. This clearly distinguishes this activity from past related CDA efforts, and provides a path for enabling TA/CDA procedures during congested traffic conditions.
  - A long-term CONOPS is under development that explores the feasibility and benefits of conducting TA operations under complex traffic/airspace constraints.
Tailored Arrivals (TA)  
Future Work

- Continue to develop and refine TA CONOPS and supporting benefit studies.
- Further define the role of TA in a larger system context (e.g., NGATS, GATI).
- Explore opportunities for follow-on field evaluations, with clear technical objectives in mind.
- Continue to develop ground automation required to “tailor” arrivals. This work will look into expanding the role of EDA into the lower altitude, TRACON airspace.
An Integrated Air/Ground Concept for Low Noise Operations

Trajectory Oriented Operations with Limited Delegation

**Goal**

Arriving aircraft descending on low noise continuous descent paths - merging with other aircraft and landing at the airport with high throughput.

**Concept**

- Use time-based flow management to regulate traffic density,
- Use trajectory-based operations to create efficient, nominally conflict-free trajectories that conform to traffic management constraints and,
- Maintain local spacing between aircraft with airborne separation assistance systems (ASAS).

**Addressed data link to communicate**

- Strategic information (e.g. 4D trajectory, RTA, spacing instructions)
- Routine messages (e.g. frequency changes)

**Data link broadcast of aircraft state**

- Short-term intent

**Trajectory planning tools**

**Scheduling tools**
Current Activities

Trajectory Oriented Operations with Limited Delegation

• Distributed Air-Ground Traffic Management (2000-2004) (HITL Sim)
  - En-route Trajectory Negotiation - demonstrated precise delivery of arrival aircraft on CDAs to a TRACON boundary meter fix
  - TRACON Merging & Spacing - demonstrated improved precision with airborne spacing guidance with mixed equipage

• Oceanic Tailored Arrivals at San Francisco (2005-2006) (HITL Sim & Field Eval)
  - Will demonstrate datalink delivery of a CDA arrival trajectory to FANS equipped oceanic arrivals to San Francisco (with Boeing & United)

• Merging and Spacing at Louisville (2005-2007) (HITL Sim & Field Eval)
  - Will demonstrate strategic arrival metering combined with airborne merging and spacing (with FAA, Langley, MITRE & UPS)

• Trajectory Oriented Operations with Limited Delegation (2006) (Fast Time & HITL Sim)
  - Will demonstrate TOOwiLD concept for en route and TRACON arrival operations with mix of datalink and/or spacing equipped aircraft
Aircraft Terminal Area Operations

OBJECTIVE:
Reduce Terminal Area Noise through low-noise operational procedure concepts

APPROACH:
• Integrated FMS/ATM design for low-noise operational procedure implementation
• Advanced flight deck for low-noise operational procedure acceptance
• Advanced tools for low-noise operational procedure design (B-Quiet, NMSim)
• Advanced Arrival and Departure demonstrations (Dutch Air Navigation Service, Orange County/Long Beach CDA)
• CDA design for Houston Bush Intercontinental Airport
• Simultaneous CDA operation to dual parallel runways
• Path options for CDA operation under medium to heavy traffic conditions

BENEFITS:
• Improved ability to implement low-noise operational procedures without increasing workload
• Improved ability to estimate benefit of low-noise operational procedures
• Low-noise operational procedure concepts validated by demonstration

SCHEDULE:

<table>
<thead>
<tr>
<th>Year</th>
<th>Procedure Development</th>
<th>SFO TA Trial</th>
<th>Advanced Flight Deck Demos</th>
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<tbody>
<tr>
<td>2004</td>
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<td>2007</td>
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<td>Dutch ATC Advanced Departure</td>
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2004 2005 2006 2007
Tailored Arrival Development at Boeing – Australia Example

General Format for development

• **Step 1**
  - Verify a/c capability to adhere to profiles and predicted times
  - Demonstrate a/c capabilities to Air Traffic Services, and build trust
  - Begin airspace integration
    - cross-center/sector clearance procedures and coordination

• **Step 2**
  - **Introduce procedures to routinely deliver pre-defined profiles**
    - Support requirements capture and provide early benefits
  - Design advanced ground tools for time-based sequencing and conflict avoidance, and profile clearance generation

• **Step 3**
  - Datalinked clearances are essential only at this point
  - Introduce advanced ground tools
  - Migrate to full Tailored Arrivals capability
  - Dynamically generate clearances in congested periods

• **Australia**
  - Air Traffic Alliance, Airservices Australia, Boeing, Qantas, Thales
  - Results being used in all three current streams
  - Development Step 1 completed

• **Development Step 2 just launched**
  - First flight 20 June 2005
    - routine availability of defined STARs uplinked via CPDLC
    - “reclearance” trials to be defined
  - Thales confirmed intent to provide ground tool prototype
Airports Survey for Potential CDA Implementation

- Long term Objectives
  - Enable widespread implementation of CDA procedures by identifying and resolving operational issues at airports where these procedures will be very beneficial
  - Develop cockpit and/or controller tools to enable traffic implementation at higher traffic level

- Near term Objective
  Determine airports where introduction of CDA would provide significant fuel burn, emissions, noise reduction
Approach

- Acquire aircraft trajectory (ACARS) and airport meteorological (NOAA) data and adjust aircraft altitude based on airport pressure

- Determine CDA opportunities

- Determine fuel burn, noise and emissions rankings

- Weigh other factors such as complexity of airspace and cooperation of airlines and airport authority
Southern California TRACON

• Enable Continuous Descent Approaches to all airports in the Southern California TRACON by:
  – Determining trade-off between throughput, noise, emissions and fuel burn as a function of initiation altitude and stringency of waypoint altitude crossing restrictions
  – Setting initiation altitude, initial separation and stringency of waypoint altitude crossing restrictions to meet desired throughput for each runway

• Analysis of CIVET and SEAVU arrivals to LAX are near completion
  – To be completed by 15 January 2006
Approach

For a given lateral profile

- Build wind model
  - Develop separate model for each definable subset of wind conditions

- Determine range of crossing altitudes (at each waypoint) for each aircraft type in unrestricted descent from cruise using Monte-Carlo simulation

- Develop (for each combination of aircraft type) set of scenarios with different initial altitudes and waypoint altitude crossing restrictions
  - Determine the required initial separation and throughput for each scenario using Monte-Carlo simulation
  - Determine fuel burn, emission and noise impact for each scenario using appropriate models

- Determine trade-off between throughput, noise, emissions and fuel burn (all as a function of initiation altitude and stringency of waypoint altitude crossing restrictions)
Summary

• Government agencies, industry, and academia are all engaged in CDA research and development.

• R&D spans procedural design, simulation testing, flight validation, and technology and tool development.

• Output from current and planned R&D will significantly contribute to the aviation needs of the future while providing substantial near-term benefits.
Supplemental Slides
Aviation Environmental Design Tool (AEDT)

- Assess interdependencies between aviation-related noise and emissions
- Incorporating today’s tools:
  - EDMS
  - SAGE
  - INM
  - MAGENTA
- In development from 2005 through 2010
- Funded by FAA Office of Environment and Energy
Airlines/Business Strategy

National Traffic Management

Regional Traffic Management

Local Approach & Departure Traffic Management

Airport & Surface Traffic Management

Thousands of participating agents:
National 1
Regional 20
Local 100s
Airports 100s
Aircraft 10,000s
Airlines 10s

Fast-time, nationwide gate-to-gate simulation of NAS operations

Full multi-day flight schedule with flight plans, 4-D gridded winds, gate-to-gate operations

Airspace Concept Evaluation System (ACES)

Fast-time, nationwide gate-to-gate simulation of NAS operations

Full multi-day flight schedule with flight plans, 4-D gridded winds, gate-to-gate operations
EDA Concept Overview

TMA plans sequence and schedule to TRACON meter fix

EDA generates advisories to meet TMA schedule (absorb delay)

Vertical advisories involve cruise speed, descent speed, and altitude

Horizontal advisories involve path stretching

- Cruise Speed
- Cruise Altitude
- Descent Mach
- Descent CAS
- BOD
- Meter Fix
- TRACON
- Runway
- TOD
- Capture way point
- Turn-back point