Controller and Pilot Evaluation of a
Datalink-Enabled Trajectory-Based
Operations Concept

Eric Mueller
Outline

• Background
• Objectives
• Trajectory-Based Operations Concept
• Simulation Plan
• Results
• Conclusions and Next Steps
• Trajectory-Based Operations (TBO) definition
  • The air and/or ground use of 4D aircraft trajectory prediction to detect, analyze and resolve ATC problems

• Benefits
  – Studies indicate reduced voice congestion from datalink saves hundreds of millions of dollars via increased sector capacities*
  – Direct savings to airspace users for datalink TBO largely unmeasured, though widely assumed

Subject of this presentation

Controller and pilot evaluation of voice/datalink procedures and weather avoidance

Field trials of integrated system

Controller and pilot evaluation of basic datalink TBO

Pilot evaluation of TBO procedures

Voice procedures for TBO

FAA Technical Center simulation of field test architecture

Pilot evaluation of negotiations and off-nominal conditions
Objectives

• Obtain feedback on feasibility of datalink TBO concept
• Investigate user and system benefit mechanisms
• Quantify benefit of increased system-wide percentage of datalink-equipped aircraft
Near-Term TBO Concept

Existing Functions

- Controller responsible for separation
- Aircraft Flight Management System (FMS) integrated with datalink using FANS-1/A

New Trajectory Functions

- Trajectory-based clearance advisories
  - Wind-favorable routes
  - Minimum-delay conflict resolutions
- Integrated datalink messaging

New Controller Functions

- Rapid-feedback trial-planner on radar (R-side) traffic display
- Clearance advisories integrated with trial planner, optional, fully controller-adjustable
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Datalink Trajectory Exchange Example
Simulation Architecture

737 Cab 747-400 Cab

FANS-1/A Encoding/Decoding

Trajectory Automation

Pseudo-Pilot Stations

Voice

R-Side Sector Positions
## Experiment Matrix

<table>
<thead>
<tr>
<th>Traffic Condition</th>
<th>Datalink Equipage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0%</td>
</tr>
<tr>
<td>Typical busy day (1x)</td>
<td>(3)</td>
</tr>
<tr>
<td>Very busy day (1.5x)</td>
<td>(3)</td>
</tr>
</tbody>
</table>

Three (3) scenarios per experimental condition
Scenarios and Participants

• Three participant teams
  – Four recently retired Fort Worth Center controllers
  – Two current flight crews
    • 747-400 crews familiar with FANS1/A
    • 757, 767 crews unfamiliar with FANS1/A
  – Eight pseudo-pilots

• Scenarios
  – Six sectors combined into three, one controller each
  – Altitudes above 18,000 ft (high altitude sectors)
  – Controllers never work the same traffic recording from the same sector
  – 30 minute scenarios
  – 28 hours of total simulation time with all teams

Eastern Dallas-Fort Worth Center Airspace
Flight Plan Amendments

Total flying time differences for lateral flight plan amendments

28 simulation hours, 84 controller sector-hours
### Direct-to Amendment Summary

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0%</td>
</tr>
<tr>
<td># Direct-to’s</td>
<td>212</td>
</tr>
<tr>
<td>Mean time saved (min)</td>
<td>0.77</td>
</tr>
<tr>
<td>Total time saved (min)</td>
<td>163.5</td>
</tr>
</tbody>
</table>

5 to 12 minutes flying time saved per hour in six-sector area over voice condition
Controller Workload

- Workload decreases at high datalink equipage levels
- Workload more dependent on traffic level and sector than datalink %
Voice comm. reductions alone do not dramatically reduce controller workload.
Voice requests more likely to be accepted than datalink requests.
Datalink requests more likely to be approved at high datalink equipage.
Controller workload not a key factor in approval/rejection of requests at these workload levels.
Qualitative Feedback

• Avoiding voice transfer-of-communications is an important benefit of datalink

• Major pilot and controller concern was “is the other guy actually working on my request/instruction?”
  • May want to initiate non-routine clearances with verbal instruction
  • May want most pilot requests to be made with voice

• Datalink should not be used to replace every voice transaction
  • Goal is to find the right mix of voice and datalink

• Automatic datalink message construction from flight plan amendments beneficial

• Weather could be a good application for datalink TBO
Conclusions

• Five to twelve minutes flying time saved per hour in datalink conditions over voice-only condition

• Controller workload decreases with higher datalink equipage

• Aircraft request approval rate independent of controller workload
  – Voice requests for simple route changes more likely to be approved than datalink requests

• Mixed-equipage TBO in domestic airspace feasible
Next Steps

• Controller- and pilot-in-the-loop simulation, 8/2011
  – Weather avoidance concept
  – Mix of datalink and voice procedures

• Architecture construction for field test evaluation, 9/2011
  – Amend flight plans in and receive track updates from ERAM
  – Exchange datalink messages with properly equipped aircraft flying in domestic US airspace

• FAA Technical Center and field test evaluations, 2012+
Backup Slides
Works Cited

  - Calculated benefit of $99.5M

  - Modeled benefit of $654M

  - Calculated benefit of $483.8M
Next Steps: Field Trial Architecture

Integrate CTAS Trajectory Automation with Data Comm & ERAM for operational trials

Equipped Aircraft

Lockheed Martin

ERAM

Route & altitude amendments

Radar tracks, flight plans

Boeing Gateway

FANS-1/A Processing

AOC Processing

Clearance uplinks, request downlinks

Aircraft state data

Controller User Interface

CTAS Trajectory Automation

NASA Field Test System
Trajectory Exchange Screenshot 1
Trajectory Exchange Screenshot 2
Trajectory Exchange Screenshot 3
Trajectory Exchange Screenshot 5
Trajectory Exchange Screenshot 6

MOD RTE 1 LEGS 1/2

122°  26NM
TXK03  .826/FL330
068°  24NM
TXK05  .826/FL330
129°  30NM
BEKEN  .826/FL330
107°  73NM
SWB    .825/FL330
105°  130NM
MCB    .824/FL330

<ERASE RTE DATA>

20:43:10.08
Trajectory Exchange Screenshot 7
Trajectory Exchange Screenshot 8
Data Collection Metrics

• Objective data
  – Conflict parameters
    • Time to first LOS, geometry
    • Separation violations
  – Trajectory prediction comparisons
  – Flying time differences as a function of equipage level
    • For conflict resolution
    • For weather avoidance
  – Overall flying times by experiment configuration (all aircraft)
  – Controller activity
    • number of datalink messages,
    • keystrokes,
    • time on voice channel transmitting, receiving
  – Voice reversion frequency for datalink aircraft
Data Collection Metrics

• Objective data (continued)
  – Frequency of user request approval
  – Pilot response times for datalink messages
  – Direct-to usage
    • Proportion of available D2s actually sent
    • D2s with conflicts are revised with an aux waypoint and issued to get most of original time savings, presumably only to datalink aircraft
  – Auto-resolution suggestions
    • Used with or without modification, or ignored

• Subjective data
  – Direct self-selection of controller workload during sim
  – Usability and benefit of key features
  – End-of-scenario workload ratings using NASA TLX
Experiment Matrix with Rationale

- **Datalink (DL) equipage**
  - Expected initial equipage of 20%
  - Around 50% of fleet could “reasonably” equip by 2020
  - Higher equipage may provide greater system-wide benefits

- **Traffic density**
  - Predictions suggest up to 50% increase over next 10 years
  - Workload improvements and per-aircraft benefits may be greater with more a/c

<table>
<thead>
<tr>
<th>DL equipage → Traffic Condition ↓</th>
<th>0%</th>
<th>20%</th>
<th>50%</th>
<th>80%</th>
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80% datalink condition has lowest percentage of high workload scores
90% of accepted clearances have response times under 75 seconds

A gamma cumulative distribution function should be used to model response times
Flight Deck Procedure

• Aural/Visual Alert

• PNF indicates a new message has arrived

• PNF accesses the message in FMC/CDU (do not print)

• PNF reads the message aloud

• PNF accesses the relevant page in the FMC/CDU for loading the message elements (e.g., altitude or waypoint)

• PNF selects the LOAD prompt to bring the trajectory up on the Navigation Display

• PF checks for problems (e.g., discontinuities) with new clearance

• PNF checks the Navigation Display to insure that there is time to execute clearance

• If no issues, PF & PNF should both indicate that the clearance is acceptable

• PNF selects the ACCEPT button

• PNF selects the EXECUTE button, saying that he is executing the clearance

• PNF selects the WILCO/RESPONSE SEND button