Airline Based En Route Sequencing and Spacing Field Test Results

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Interval Management

- Interval Management (IM) describes a set of applications to improve sequencing and spacing of converging flights
  - Automation supported speed management on ground and/or flight deck

![Diagram of Interval Management](image)
ABESS

• Airline Based En Route Sequencing and Spacing (ABESS) is a GIM-S application for airlines
  – Early version of IM, prior to ATC implementation
  – Development activity has been completed
  – Preconditioning of flights through the uplink of minor speed advisories
Related Concepts

• 3-D PAM

• Attila

• AMAN Products
  – Eurocontrol (2010), Arrival Manager: Implementation Guidelines and Lessons Learned

• Main differentiation with ABESS
  – ABESS is airline based
  – Extended metering horizon
ABESS Expected Benefits

• Increase in aircraft efficiency via use of early, minor speed adjustments that avoid costly, low altitude maneuvering

• Provide appropriate spacing for the initiation of new applications such as Flight-deck based Interval Management (FIM) and Optimized Profile Descents (OPDs)

• Realization of desired arrival sequences that are optimized for airline needs

• Reduce both ATC workload and radio frequency congestion
Information Exchange

Aircraft

- Wind Predictions
- Indicated Airspeed
- Advisory Acknowledgement
- Speed Advisories
- ATC Instructions
- Position Updates

AOC

- Filed Flight Plan
- Flight (Plan and Track) Information*
- ABESS Tool

FAA

*Contains:
- ETMS (approx 1 minute update rate)
- Radar data (as slow as 12 sec update rate)
- ASD-B data from ground-stations (up to once per sec)
ABESS User Interface
At Airline Operations Center
ABESS Concept Development

• Development started in 2005 with cooperation between FAA, NASA, MITRE, and UPS

• Concept development was embedded in a series of exploratory field tests with UPS:
  – October 2006
  – May / November 2008
  – Spring 2009
  – June 2010

- Objective of exploratory field tests was to develop procedures and functional requirements
  - Resulted in multiple iterations of the concept
Exploratory Test Environment

“Off-the-shelf” ground tools from NASA and MITRE were initially used and then refined

Field Test Participants
- UPS dispatchers
- Pilots
- Air traffic controllers
- Software engineering
- Human factors researchers

Field Test Traffic: UPS West Coast aircraft to UPS hub in Louisville
ABESS Aircraft Position Data Feeds

- Track data from Enhanced Traffic Management System (ETMS)
  - One minute updates
  - Lower (truncated) position precision
- ADS-B data
  - About 1 sec updates
- Radar data
  - About 12 sec updates
June 2010 Test

• June 7 – 9 and 14 – 16, 2010
  – ABESS testing during night

• Objectives
  – Measure ability to predict fix crossing times over extended look-ahead time periods (e.g. up to 80 min)
  – Measure accuracy of spacing problem resolution
  – Determine the operational acceptability of ABESS for controllers, pilots, and AOC personal
RESULTS
Results Overview

• Fix crossing time predictions
• Spacing predictions
• Metering conflict detections
  – True / missed detections
  – Nuisance detections
  – Causal factors
• Speed advisory determination
• Observed spacing at fix
Fix Crossing Time Predictions

Calculated at the time when the last aircraft entered the SAP

Only flights are shown here for which no speed advisories were executed as changes in speeds would have impacted the actual crossing times.
Average Fix Crossing Time Prediction Errors

- Calculated at the time when the last aircraft entered the SAP

<table>
<thead>
<tr>
<th></th>
<th>Signed (sec)</th>
<th>Unsigned (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>26</td>
<td>44</td>
</tr>
<tr>
<td>Median</td>
<td>16</td>
<td>27</td>
</tr>
<tr>
<td>Minimum</td>
<td>-62</td>
<td>1</td>
</tr>
<tr>
<td>Maximum</td>
<td>261</td>
<td>261</td>
</tr>
</tbody>
</table>

- Average prediction accuracy is similar to that found in previous tests (e.g. Moertl et al. 2009)* where average prediction errors were on average less than 30 sec for the last 100 minutes prior to the metering point

Spacing Predictions

- The correlation between actual versus predicted spacing is an indicator for the quality of spacing predictions.
- Correlation was calculated when the last aircraft in the flow entered the freeze horizon.

Correlation between predicted and actual spacing $r = 0.95$ over 4 days combined.
Metering Conflict Predictions

True Detections

• Over the 4 nights of regular ABESS operations, ABESS detected 142 “metering conflict” aircraft pairs
  – Aircraft were predicted to reach the metering point with less than the target spacing of 120 sec.

• There were 32 true conflict aircraft pairs
  – ABESS successfully identified all of these, except 3
  – 92% of conflict aircraft detection
Metering Conflict Predictions

Nuisance Detections

• Nuisance detections should be kept to a minimum
  – likely to reduce the tool’s usefulness and may reduce operator trust in the tool

• Calculation of nuisance detections:

\[
\text{# predicted conflict aircraft} \quad - \quad \text{# true conflict aircraft} \quad - \quad \text{# successful speed advisories}^* \\
\hline
\text{# predicted conflict aircraft}
\]

• Resulted in 75% nuisance detections
  – Only 25% of ABESS identified conflicts were “true”

* Successful speed advisories removed the conflict spacing that caused the speed advisory to be given.
Identified Contributors to Nuisance Rate

• Data instability
  – Variability of groundspeed (see Moertl et al. 2009)
  – Requires heuristics to correctly “smooth” data

• Wind prediction inaccuracy
  – Contributions of error sources to overall nuisance rate remain to be determined

• ATC clearances
  – Unforeseen trajectory changes
Observed Variability of Speed Reports

- Ground Speed in Knots (refers to right index)
- Trajectory Modeled Airspeed in Mach (refers to left index)
- Indicated Airspeed down linked via ACARS in Mach (refers to left index)
- Altitude
Working Around Variability of Speed Reports

• To account for the variability in ground speed, the ABESS trajectory modeler uses the speed that is filed in the flight plan

• Once non-conformance between trajectories and true position reports is detected, the trajectories are updated with consideration of reported ground speed
  – However, even in cases of non-conformance, the modeled speed is still strongly influenced by filed speed
  – This work-around procedure delays the modeler’s ability to detect speed changes for a flight
    • This is graphically shown on the next slide
Effect of Speed Report Variability

The trajectory modeler is delayed in picking up the increase in airspeed.

Once the modeler detects the (unexpected) increase in speed, the fix crossing time errors decrease.
Speed Advisory Determination

• Two alternatives for speed advisories
  – “Global” speed advisory solutions resolved not only the conflict between two aircraft but also between all other aircraft in that stream
    • The ABESS tool created global solutions that consisted of multiple speed advisories, thereby resolving each conflict
  – “Non-global” speed advisory solutions resolved only individual conflict pairs
    • Sometimes “global” solutions required aircraft to fly speeds outside their allowable speed envelope
      – In that case, the operator selected the speed advisory that resulted the most in the desired change
  • Required repetitive user actions for each conflict
Process for Speed Advisory Determination

ABESS detects spacing conflict

1. Global Solutions

ABESS provides speed advisory that resolves conflicts for ALL aircraft in stream

Operator selects appropriate speed advisory

Operator assesses speed advisory feasibility based on flight’s speed envelope and indicated airspeed

Operator communicates speed advisory to dispatcher

2. Non-Global Solutions

ABESS does NOT provide speed advisory

Operator views list of possible speed advisories and associated predicted meter time changes

Operator selects speed advisory with predicted meter time that resolves conflict

Repeat for every conflict pair

Next Slide
Comparison with Indicated Airspeed

• Knowledge of indicated airspeed would have allowed the ABESS operator to determine speed advisory feasibility
  – No indicated airspeeds were available to the ABESS operator
    • Even if indicated airspeed had been available, instantaneous readouts (e.g. all 9 min at UPS) fluctuate considerably such that they can be confusing

• Operator had two ways to estimate speed advisory feasibility
  1. Request readout of indicated airspeed from dispatcher
     • Workload intensive and sometimes inaccurate
  2. Rely on ABESS “modeled” indicated airspeed
     • Not always reliable
• Complex process of speed advisory communication resulted in average duration of 12 minutes, ranging between 4 to 31 minutes
  – Uplink path + feedback path combined
Observed Spacing at Fix

*Slow Downs*

Aircraft Spacing-Slow Downs

Sequencing (seconds)

Predicted
Actual
Goal

UPS921 UPS903 UPS957 UPS945 UPS941 UPS905 UPS921 UPS913 UPS907 UPS857 UPS921 UPS973 UPS941

-0.01 -0.03 -0.01 -0.02 -0.02 -0.02 -0.02 -0.02 -0.02 -0.04 -0.02 -0.02 -0.03 -0.02

0 60 120 180 240 300
Observed Spacing at Fix

*Speed Ups*

Aircraft Spacing - Speed Ups

- **Predicted**
- **Actual**
- **Goal**

Sequencing (seconds)

<table>
<thead>
<tr>
<th>Aircraft</th>
<th>Predicted</th>
<th>Actual</th>
<th>Goal</th>
</tr>
</thead>
<tbody>
<tr>
<td>UPS913</td>
<td>+0.01</td>
<td></td>
<td></td>
</tr>
<tr>
<td>UPS921</td>
<td>+0.04</td>
<td></td>
<td></td>
</tr>
<tr>
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<td>+0.01</td>
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<td></td>
</tr>
<tr>
<td>UPS919</td>
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<td>+0.02</td>
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</table>
Summary

• Exploratory field test results indicate promise and limitations for using speed advisories during extended metering
  – Average (signed) fix crossing time prediction errors were 26 sec for up to 80 min prior to the metering fix
  – Actual and predicted spacing correlates at $r = 0.95$
  – 92 % conflict detection rate
  – 75 % nuisance detection rate
  – 17 % success rate for spacing achievement

• Further research and development for extended metering algorithms
  – Development of data processing heuristics
    • Utilization of indicated airspeed information
      – E.g. facilitate detection and correction of wind prediction errors
  – Speed advisory algorithm refinement
    • Achieve acceptable balance between missed / nuisance advisories