Simulations of Continuous Descent Operations with Arrival-Management Automation and Mixed Flight-Deck Interval Management Equipment

Todd J. Callantine, Michael Kupfer, and Lynne Martin
San Jose State University/NASA Ames Research Center

Thomas Prevot
NASA Ames Research Center
Research Team

Nancy Bienert
Connie Brasil
Chris Cabrall
Ashley Gomez
Sarah Hunt
Kim Jobe
Vick Kelkar
Joey Mercer
Susan Morey
Faisal Omar
Terry Smith

Jessica Ciotti
Brian Donnelly
Chuck McAleavy
Danny Vincent
Victoria Dulchinos
John Kaneshige
Sandy Lozito
Shivanjli Sharma
Overview

- NASA Air Traffic Management Technology Demonstration-1 (ATD-1)
- ATD-1 Concept of Operations
- Controller-Managed Spacing (CMS) Tools
- Prior CMS ATD-1 (‘CA’) Simulations
- CA-4 Simulation
- CA-4 Results
- Conclusions and Future Research
Demonstrate NextGen Performance-Based Navigation arrival-management methods to save fuel, reduce noise, and maximize the use of existing capacity

- Schedule arrivals for de-conflicted Continuous Descent Operations (CDOs)
- Use ADS-B-enabled Flight-Deck Interval Management (FIM) for increased inter-arrival precision
- Accelerate transfer of NASA-developed technologies
- Collect operational data and provide to partners and stakeholders
ATD-1 Concept of Operations

TMA-TM assigns runways, computes schedules for meter-fixes, terminal-area fixes, runways

Controllers use speed, path assignments to adjust aircraft toward frozen schedule

Controllers issue ‘descend via’ CDO clearances, FIM clearances to equipped aircraft

Controllers use CMS tools to issue speeds to unequipped aircraft, monitor FIM operations

<table>
<thead>
<tr>
<th>Clearance Type</th>
<th>ATC Phraseology</th>
</tr>
</thead>
<tbody>
<tr>
<td>CDO Initiation with Runway Assignment</td>
<td>&lt;CALLSIGN&gt;, DESCEND VIA THE MAIER THREE ARRIVAL, BOULDER CITY TRANSITION, TO RUNWAY TWO-SIX.</td>
</tr>
<tr>
<td>FIM Clearance Availability</td>
<td>&lt;CALLSIGN&gt;, INTERVAL SPACING AVAILABLE, ADVISE WHEN READY TO COPY.</td>
</tr>
<tr>
<td>FIM Initiation</td>
<td>&lt;CALLSIGN&gt;, FOR INTERVAL SPACING, CROSS JIFFY AT 1432:30Z. WHEN ABLE, SPACE NINE-ZERO SECONDS BEHIND DELTA EIGHT-SEVEN-SEVEN ON THE BONHAM FIVE ARRIVAL, FORT SMITH TRANSITION.</td>
</tr>
<tr>
<td>CDO Speed Adjustment</td>
<td>&lt;CALLSIGN&gt;, DESCEND VIA THE MAIER THREE ARRIVAL, EXCEPT MAINTAIN TWO-ZERO-ZERO-KNOTS.</td>
</tr>
<tr>
<td>CDO Termination</td>
<td>&lt;CALLSIGN&gt;, DESCENT CLEARANCE CANCELLED, FLY HEADING TWO-ZERO-ZERO, MAINTAIN SEVEN THOUSAND FEET</td>
</tr>
<tr>
<td>FIM Suspension</td>
<td>&lt;CALLSIGN&gt;, SUSPEND INTERVAL SPACING, SLOW TO TWO-THREE-ZERO KNOTS.</td>
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</table>
Controller-Managed Spacing Tools

- Timelines show current schedule
- Slot markers translate temporal STA information to spatial target
- Early/late indicators put timeline STA – ETA error in aircraft data block
- Speed advisories suggest speed to fly in order to get on schedule
Prior CMS-ATD1 Research

- Successful initial integration of ATD-1 simulation components
- Controllers generally receptive to ATD-1 mixed-FIM-equipage arrival operations
- Tools, workload, and proposed phraseology acceptable

CA-1

CA-2

CA-3

- Improved operations via en-route pre-conditioning of all aircraft
- Workload in ATD-1 conditions significantly lower than for current-day operations
- Tool ratings consistent with prior studies

- Experienced DFW controllers with no prior exposure found ATD-1 operations acceptable
- Greater familiarity with tools, operations, and phraseology is needed

Average Throughput During 10-minute Windows

CA-4 Simulation

• Continue investigation of issues identified in CA 1, 2, and 3
  – Quantify effects of ‘imprecise’ (< 2 mins MF delay) vs. ‘precise’ (< 1 min MF delay) flow preconditioning
  – Refine FIM status designators
  – Compare full CMS toolset to slot markers and timelines only

• Continue to focus on IM-TAPSS and ATD-1 laboratory integration
  – Adapt simulated airspace, traffic scenarios, and TMA-TM for PHX west-flow operations
  – Integrate B744 simulator
  – Integrate realistic winds
Airspace/Routes/Winds
**Meter List and FIM Clearance**

<table>
<thead>
<tr>
<th>ATC</th>
<th>Flight Crew</th>
</tr>
</thead>
<tbody>
<tr>
<td>DAL808, INTERVAL SPACING AVAILABLE, ADVISE WHEN READY TO COPY</td>
<td>DAL808 READY TO COPY</td>
</tr>
<tr>
<td>DAL808, FOR INTERVAL SPACING, CROSS SCADE AT ONE NINER, ONE FIVE PLUS TWO FOUR ZULU. WHEN ABLE, SPACE ONE-THREE-ZERO SECONDS BEHIND UNITED SEVEN-FOUR-ONE ON THE GEELA SIX ARRIVAL, BLYTHE TRANSITION</td>
<td>SCHEDULED TIME AT SCADE IS 1915 PLUS 24, SPACE AT SCADE 130 SECONDS BEHIND UAL741 ON BLYTHE GEELA SIX, DAL808</td>
</tr>
</tbody>
</table>
Center FIM Status Designators and Speed Advisories

- GIM speed advisory available
- FIM Equipped
- Advised GIM speed
- FIM Clearance Issued
- RTA Mode Reported
- Paired Spacing Mode Reported
FIM status designators override CMS early/late indicators or speed advisories
Participants

- Controllers
  - Experimental subjects
    - 2 Feeders and 2 Finals
    - 4 Center
    - Retired controllers, most with CMS tool and/or AOL experience
  - Confederates
    - 1 Center, 1 Tower

- Pilots
  - 8 ASTOR pilots with glass-cockpit experience
  - 10-12 Regional jet pilots and SJSU aviation students as pseudo-pilots
  - B744 crews
Traffic Scenarios

• Traffic mixes derived from PHX recorded traffic

• Similarly balanced meter-fix loading

• Meter-fix delay: ~2-4 min

• Target throughput: ~42-44 ac/hr per runway (0.3 nmi scheduling buffer)

• FIM-equipped desktop simulators inserted on EAGUL and KOOLY routes

• B744 inserted on MAIER and EAGUL routes
Flow Preconditioning

![Graph showing MF Schedule Error (s) for Early and Late phases.](image-url)

- Early Phase:
  - Precise: [Data Points]
  - Imprecise: [Data Points]

- Late Phase:
  - Precise: [Data Points]
  - Imprecise: [Data Points]
Example Tracks and Profiles
Precise vs. Imprecise Flow Preconditioning

(tracks, profiles shown separately on next four slides)
Example Tracks: Imprecise
Example Profiles: Imprecise
Flow Preconditioning Effects on Lateral Route Conformance
Addendum: B744 Workload Ratings

![Bar chart showing WAK Rating for Imprecise and Precise conditions for Captain and First Officer.](chart.png)
Subjective Results

- TMA-TM schedules mostly rated as achievable, stable, and accurate
- En-route speed advisories rated only ‘moderately’ accurate and stable
- Controllers largely successful in maintaining scheduled throughput levels
- All CMS tools rated acceptable, but slot markers rated less stable than timelines; controllers expressed a desire to flexibly control when slot markers are displayed for particular aircraft
- No significant differences in ratings for slot markers and timelines only, versus full toolset with third-line information
- FIM clearances rated between ‘moderately manageable’ and ‘very manageable’; controllers gave high ratings for read-back clarity, accuracy, and timeliness
- FIM status designators rated favorably; Center controllers rated status-updating task ‘very acceptable,’ TRACON controllers ‘reasonably acceptable’
- FIM operations ‘increased task complexity,’ but not excessively
Conclusions and Future Research

- Successful adaptation of IM-TAPSS for PHX, compatibility/operational need verified
- Importance of tool familiarity verified
- Importance of ‘involving en-route controllers in arrival management’ demonstrated

- CA-5 simulation begins July 2013
  - Compare baseline and ATD-1 performance measures for realistic PHX traffic and winds