Integrated Pilot and Controller Procedures: Aircraft Pairing for Simultaneous Approaches to Closely Spaced Parallel Runways

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ATM 2011   Berlin, Germany
Outline

• Objective / Motivation
• Concept
• Experiment Plan
• Tools and Displays
• Results
  – Pilots
  – Controllers
• Summary
Objective

• To investigate integrated procedures for flight deck and air traffic control in the terminal area for simultaneous approaches
  – Levels of flight deck automation
  – Roles of the air traffic controller and the flight crew in pairing aircraft and monitoring their conformance
Motivation

• Significant efficiency and capacity are lost when poor weather conditions limit operations on parallel runways closer than 4300 ft

• NextGen and SESAR have a common goal to maintain visual capacities under all weather conditions on airports with parallel runways < 4300 ft apart

• Previous studies investigated roles of pilots and controllers separately, and examined aircraft that are already paired
  – This study examines the integrated dynamic role of pilots and controllers, as well as procedures and tools for the actual pairing
Concept

• Technology assumed
  – Differential Global Positioning System (DGPS)
  – Augmented Automatic Dependent Surveillance-Broadcast (ADS-B)
  – Augmented cockpit display
  – Datalink
  – Required Navigation Performance (RNP) 1.11

• Aircraft are provided 4D trajectories and managed simultaneously to the coupling point, 12 nmi from threshold
  – Coupling point is when the automation of the two aircraft are sharing data and are linked to one another through the aircraft automation

• Maintain precise time separation of 5-25 s

• Speed adjustments only to meet Required Time of Arrival (RTA)
San Francisco Arrivals

Point Reyes
Oceanic
Coupling point
Modesto
Yosemite
Big Sur
Experiment Plan
Experimental Conditions: Flight Deck

<table>
<thead>
<tr>
<th>Displays</th>
<th>Future Automation</th>
<th>Current Automation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Position Display</td>
<td></td>
<td></td>
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<tr>
<td>Predictive Display</td>
<td></td>
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</tbody>
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- Future Automation performs auto-speed control
- Current Automation is FMS with RTA guidance
- Position display: Distance error relative to a desired position in the profile
- Predictive display: ETA prediction based upon current ground speed
Experimental Conditions: ATC

- Three positions: 2 Sector Controllers and Area Coordinator
- Ground side automation provides optimal pairing with override capability
- Pairing allowed between aircraft from any stream but not the same stream
- Sector controllers are responsible for standard separation between pairs of aircraft and singles
- Sector controllers delegate separation to flight deck 4 nmi before the Coupling Point
- Sector controllers control leader aircraft directly
- Sector controllers will not try to space/control trailer aircraft normally, only by exception
Methodology

• Conducted in June/July 2010
• Our participants always flew in the trailing aircraft position
• Participants: 6 flight crews, 3 controller teams, 3 pseudo pilots
• Advanced Concept Flight Simulator (ACFS) – B757 performance with GE Smith’s FMS
• ATC simulator
• 54 total data collection runs
• Training and practice scenarios for participants
Tools and Displays
Controller Tools for Pairing

Pairs Table

Existing/Planned Aircraft Pairs

<table>
<thead>
<tr>
<th>LEADER</th>
<th>TRAILER</th>
</tr>
</thead>
<tbody>
<tr>
<td>UAL5678</td>
<td>AAL1234</td>
</tr>
<tr>
<td>AAL8765</td>
<td>AAL1234</td>
</tr>
<tr>
<td>UPS3456</td>
<td>USA2345</td>
</tr>
<tr>
<td>USA5432</td>
<td>AAL4365</td>
</tr>
<tr>
<td>EGL2938</td>
<td>SWA5647</td>
</tr>
</tbody>
</table>

Timeline

T

1. UAL746
2. SWA555
3. VRD751
4. AAL1415
5. VRD925
6. CDA1426
7. UAL961
8. CDA545
9. ACA578
10. AAL159
11. SWA554
12. AAL35
13. VRD265
14. AAL455
15. VRD267
16. VRD061
17. AWE557
18. BWA1230
19. EVA19
20. BFA118
21. BWA1157
22. CFA473
23. BWA6253
24. UAL1152
25. BUA1397
26. UAL173
Controller Tools for Pairing

If pair is acceptable, highlight pair in table and press “send”

Aircraft pair turns amber and data link message is sent to both aircraft

Call signs of both aircraft turn green after acknowledge is received
PAIRING CONTROL

Lead aircraft UAL459 (B747-400)
Current speed = 320 knots
Planned approach speed = 134 knots
ETA at couple point ROMEO = 17:50:25

Ownership ETA at couple point LEEMA = 17:50:42

Required spacing interval = 15sec (+/-10s)
Current spacing error = +2 sec
Coupling status = ON TIME

Pair-Dependent Speed

Pair-Coupled Speed
Position and Predictive Displays: Conformance Bars on the Navigation Display

Position Display - Nav

Predictive Display - Nav

In conformance

Out of conformance – early
Position display – Conformance Bars
Around the Aircraft

Primary Flight Display  Navigation Display

FMS annunciation after pairing

On-time window markers
Aircraft position indicator

On-time window
Longitudinal Situation Indicator

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ETA at couple point ROMEO = 17:50:25
Ownship ETA at couple point LEEMA = 17:50:42
Required spacing interval = 15 sec (=/– 10 sec)
Current spacing error = +2 sec
Coupling status = ON TIME
Conformance Monitoring – Controller Tool

Select “Show Conformance”
Or
Dwell on any aircraft in a pair

Conformance bars on the follower aircraft

If out of conformance, then aircraft pairing may be canceled
Results
Pilot Results
Pilot Results

• Independent Variables
  – Future v. Current automation
  – Position v. Predictive displays

• Metrics
  – Pairing Performance
  – Workload
  – Situation Awareness
  – Pilot Feedback
Pairing Performance for Simulator Crews (The Trailing Aircraft)

- The participant crews were able to successfully pair in all cases
- Our crews did not cancel any pairs
- There were no losses of separation
Pilot Workload

- Crews conducting pairing procedures indicated relatively low workload levels
  - Mean of about 3, with scale of 1-7
Pilot Workload (By Condition)

- Predictive display had low workload under Current automation
- Position display had low workload under Future automation
Pilot Situation Awareness

• Situation Awareness measures revealed medium to high situation awareness for pilots across all variables examined in this study
  – There were no significant differences for automation levels or conformance monitoring display types
  – Trend and pilot feedback showed
    • Better Situation Awareness with Position Display
    • Poor Situation Awareness with Current Automation
Pilot Feedback

- Procedures were feasible and safe

- Display Findings
  - Position Display was more accurate
  - Predictive Display was confusing to interpret, also predictive data caused display features to change too rapidly

- Concerns with Situation Awareness when lead aircraft was in different sector

- Infrequency of use of the procedures may lead to problems with training and implementation
Controller Results
Controller Results

• Independent Variables
  – Positions: Area Coordinator, Niles, Boulder

• Metrics
  – Pairing Performance
  – Workload
  – Situation Awareness
  – Controller Feedback
Pairing Performance for Controllers

- Controllers were able to successfully pair the flight simulator in all cases
- Controllers cancelled some pairs but not the pair including the flight simulator
- There were no losses of separation
Pairing Performance for Controllers (Per Run)

- Number of Pairs Created: 14.7
- Number of Pairs Canceled: 0.8
- Number of Singles: 5.5
Controller Workload (By Position)

Mean Workload

Very High

Very Low

*\(p<0.06 \text{ (marginal)}\)

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<thead>
<tr>
<th>Controller Position</th>
<th>Boulder</th>
<th>Coordinator</th>
<th>Niles</th>
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</thead>
<tbody>
<tr>
<td>Workload (WAK)</td>
<td>1.4</td>
<td>1.5</td>
<td>1.3</td>
</tr>
</tbody>
</table>
Controller Situation Awareness

• Situation awareness measures revealed medium to high situation awareness for controllers
  – There were no significant differences among the three controller positions for situation awareness
Controller Feedback

• Managing inter-pair spacing was hard if the lead aircraft was not in their sector
• Controllers would like to have direct control over the trailing aircraft as well
• They said that they did not cancel the pair where pilot participants were involved because the pilots never expressed inability to continue
Summary

• Pilots preferred the Position display over the Predictive display

• Pilots had similar levels of workload and SA for the two automation types

• Controllers had manageable workload and adequate Situation Awareness across positions

• Need to improve integrated procedures
  – To address the issue of controllers managing the leaders and automation or pilots managing the followers
Thank You!!

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