A Controller-in-the-Loop Simulation of Ground-Based Automated Separation Assurance in a NextGen Environment

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San Jose State University | NASA Ames Research Center
Acknowledgments

NASA Airspace Program
Federal Aviation Administration (FAA)
NASA Langley Research Center’s Air Traffic Operations Laboratory (ATOL) team
The Problem

- NextGen is expected to accommodate a **threelfold (3X) increase** in air traffic demand compared to today’s levels.
- Cognitive resources of air traffic controllers are **limited**.
- Conventional clearance-based separation assurance (SA) is **not possible** in the envisioned high density environment.
The Approach

- "ground-based automated separation assurance"

- the ground-based automation manages the separation

- the operators manage the automation, provide additional services and make decisions
Beginning in 2007, a series of HITL simulations on ground-based automated SA have been conducted in the AOL.
SA1 (2007)

- Tested SA at three progressive levels of traffic density: 1X, 2X, 3X
- Varied levels of automated SA support across traffic levels: Manual, Interactive, Fully Automated
- Automation provided significant benefits in terms of safety and efficiency particularly at 2X and 3X. Significant reduction in workload. Resolutions provided by automation generally acceptable.


SA2 (2008)

• Tested ground-based automated SA at **2X and 3X** with tactical conflict and off-nominal situations

• Varied levels of TSAFE support across traffic levels

• Automation handled strategic conflicts. Participants handled conflicts deferred by automation, tactical conflicts, pilot requests, and emergencies.

• 98% of strategic and 75% of tactical conflicts resolved by automation, 95% of resolutions acceptable to flight crew participants, workload generally low.


SA3 (2010) Background

- NASA’s FY2010 ARMD Annual Performance Goal: “Conduct simulations of automated separation assurance with sequencing, spacing, and scheduling constraints.”
- JPDO concerns regarding the “lack of clarity” surrounding the functional allocation of new functions and responsibilities between the ground-based ATC and flight deck-based systems.
Two separate but collaborative studies on automated SA conducted from both the air- and ground-side perspectives in the ATOL and AOL.
Overall Experiment Design

**Short duration runs**

- Basic (STA)
- Dispersed (one every minute)
- Synchronous (all at 6 or 8 minutes)

<table>
<thead>
<tr>
<th>Timing of Arrival Time changes</th>
<th>S1</th>
<th>S2</th>
<th>S3</th>
</tr>
</thead>
</table>

**Medium duration runs**

- Arrival Time Constraints
  - No (Baseline)
  - Yes (STA)

<table>
<thead>
<tr>
<th></th>
<th>M1</th>
<th>M2</th>
<th>M3</th>
<th>M4</th>
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</thead>
<tbody>
<tr>
<td>NextGen (Traffic) Level</td>
<td>A</td>
<td>B</td>
<td></td>
<td></td>
</tr>
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</table>

**Exploratory Long duration runs**

- Level of Traffic with Arrival Time Constraints
  - Light
  - Heavy

<table>
<thead>
<tr>
<th>Level of Traffic with Arrival Time Constraints</th>
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<th>L3</th>
<th>L4</th>
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<tr>
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<tr>
<td>Heavy</td>
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</tbody>
</table>

**Convective Weather Patterns**

- Growing
- Decaying

ENRI International Workshop on ATM/CNS
Tokyo, Japan November 10-12, 2010
Experiment Design

**Short duration runs**

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<td>M4</td>
<td>M3</td>
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**Exploratory long duration runs**

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</thead>
<tbody>
<tr>
<td>Light</td>
<td>L1</td>
<td>L2</td>
</tr>
<tr>
<td>Growing</td>
<td>L3</td>
<td>L4</td>
</tr>
<tr>
<td>Growing</td>
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</tbody>
</table>

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Participants

- Six FAA front line managers staffed radar and area supervisor test positions. They were from different en route centers and current on radar.
- Four recently retired confederate controllers staffed remaining radar test sector positions.
- Four retired confederate “ghost” controllers controlled traffic outside of test area.
- Ten general aviation pilots served as pseudopilots for aircraft in the test scenarios.
Airspace

Separation Assurance 3

- 4 en route test sectors from ZKC and ZID centers
- Surrounding airspace controlled by confederates
- Flight Level 290 and above
- Mixture of overflight and transitioning aircraft to and from area airports
- All aircraft fully data comm and ADS-B equipped
Air Traffic

**NextGen Level A**

<table>
<thead>
<tr>
<th>Time (min)</th>
<th>ZID 80</th>
<th>ZID 81</th>
<th>ZKC 90</th>
<th>ZKC 98</th>
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</tr>
<tr>
<td>30</td>
<td>60</td>
<td>70</td>
<td>80</td>
<td>90</td>
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</table>

**NextGen Level B**

<table>
<thead>
<tr>
<th>Time (min)</th>
<th>ZID 80</th>
<th>ZID 81</th>
<th>ZKC 90</th>
<th>ZKC 98</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
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<td>0</td>
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<tr>
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<tr>
<td>30</td>
<td>50</td>
<td>60</td>
<td>70</td>
<td>80</td>
</tr>
</tbody>
</table>

### Traffic level | Forecast for year | Test airspace capacity | Aircraft in ZKC-90

<table>
<thead>
<tr>
<th>Traffic level</th>
<th>Forecast for year</th>
<th>Number of aircraft</th>
<th>% of 2010 value</th>
<th>Number mean/peak</th>
<th>% of 2010 value</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>108</td>
<td>100%</td>
<td>15 / 18</td>
<td>100%</td>
<td></td>
</tr>
<tr>
<td>NextGen A</td>
<td>2025</td>
<td>162</td>
<td>150%</td>
<td>35 / 42</td>
<td>233%</td>
</tr>
<tr>
<td>NextGen B</td>
<td>2030+</td>
<td>216</td>
<td>200%</td>
<td>46 / 54</td>
<td>300%</td>
</tr>
</tbody>
</table>
## SA Functional Allocation

<table>
<thead>
<tr>
<th>Automation</th>
<th>Controller</th>
</tr>
</thead>
<tbody>
<tr>
<td>Detect Separation Conflicts</td>
<td>Supervise the automation</td>
</tr>
<tr>
<td>Resolve trajectory-based conflicts (if within tolerances)</td>
<td>Resolve trajectory conflicts flagged by the automation</td>
</tr>
<tr>
<td>Resolve all time-critical traffic conflicts</td>
<td>Monitor and maintain schedule compliance</td>
</tr>
<tr>
<td>Alert controller to urgent problems</td>
<td>Place aircraft back on trajectory following automated tactical maneuvers</td>
</tr>
<tr>
<td>Provide trajectory planning assistance</td>
<td></td>
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<tr>
<td>Use data comm to communicate</td>
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</tbody>
</table>
Apparatus

- MACS simulation platform
- Advanced controller displays
- 71 cm Barco displays
- DSR keyboards and trackballs
- Voice Switching and Comm. System (VSCS) emulation
- Wall projections of current and predicted traffic situations
Procedure

- Two week study
  - *Three days training*
  - *Five days data collection*
- 30-minute runs
- Participants divided into two teams
- Runs conducted simultaneously in two parallel “worlds”
- ZKC and ZID sectors divided within each world to ensure inter-facility coordination
- FAA test participants rotated through supervisor and radar positions for different perspectives
Results

— Airspace and traffic
— Workload
— Conflict detections and resolutions
— Losses of separation
— Subjective participant feedback
Airspace and Traffic

NextGen Level A

NextGen Level B
Workload

Workload by condition

- Workload significantly higher at Traffic Level B than Level A

- Scheduling constraints did not have an effect on workload

Workload by sector

- ZKC90 had significantly higher workload than ZID80 and ZID81 but not ZKC98
• Traffic Level B had significantly more conflicts predicted to lose separation in the test airspace than Level A

• STA scheduling condition had significantly fewer conflicts than the Baseline condition without scheduling constraints
Conflicts: Resolutions

- Majority of conflicts resolved by automation
- ATC involved resolutions increased with traffic levels
- TSAFE events increased with traffic levels
- ZKC98 required the greatest number of conflict resolutions issued
- ZKC98 required greater ATC involved resolutions and TSAFE clearances
• Traffic Level B resulted in greater numbers of separation events
• Baseline and STA conditions resulted in equal numbers of operational errors
• Baseline had overall greater number of separation events
• ZKC98 had the greatest number of separation events followed by ZKC90
Subjective Feedback:

- Spread of responses both between traffic levels and sectors
- "A little" attention demand
- "Average" supply of attention
- "Very good understanding" of situation
- "Reasonable situation awareness"
Subjective Feedback: Acceptability

• Questions on acceptability of operations aligned with Controller Acceptance Rating Scale (CARS)

• Acceptability of safety in Traffic Level A rated at 90.6% and Traffic Level B at 67.5%

• Volume of traffic not a concern but the greater complexity of the traffic and fewer resolution options were
Subjective Feedback: Impressions

• “…it seemed as if controller and automation fought against each other at times to resolve conflicts.”
• “it seems fairly natural, why not do it?”
• “You’re on the right track.”
• “It’s inevitable, I think the concept is strong, it needs work and testing, I think it’s the way we’re going to go.”
Summary

• Increase from Traffic Level A to B provided the most noteworthy results
• Mean workload, conflicts detected, and losses of separation counts were all higher in Level B
• “Reasonable situation awareness” was maintained at both traffic levels but Level B was rated as less safe (CARS) and more attention-demanding (SART) than A
• At the sector level, local complexity more of an issue than simple aircraft count (e.g., ZKC98)
Conclusion

• The functional allocation of separation assurance between controller and ground-based automation presented was well received and held promising results.

• An important component to being able to accommodate the envisioned future demand is the appropriate identification and handling of local complexities.
Questions?