Human-in-the-Loop Experimentation for the Next Generation Air Transportation System

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NextGen

- FAA is predicting a substantial increase in the number of revenue passenger miles flown over the next 20 years.

- If left unmodified, the current air transportation system cannot indefinitely sustain this projected growth without inducing delays, inefficiencies, and environmental impacts.

- FAA’s NextGen concept envisions a comprehensive transformation of the National Airspace System to support this continued growth in a safe, reliable and efficient manner.

- NASA is collaborating with the FAA and industry partners to develop advanced technologies necessary for NextGen.
• Conditions in busy terminal areas today often result in inefficient arrivals

• More efficient arrivals are available, but current technology limits their use to periods of light to moderate traffic conditions

• New concepts and technologies are needed to make efficient arrival procedures feasible during heavy traffic

• NASA’s ATD-1 will operationally demonstrate the feasibility of efficient arrival operations combining ground-based and airborne NASA technologies

• This integrated arrival solution is being verified and validated in laboratories and transitioned to a field prototype
ATD-1 Integrated System

Flight Deck-based Interval Management (FIM) Equipped Aircraft

Controller Managed Spacing (CMS) in Terminal Airspace

Guidance for controllers to issue IM clearance to FIM aircraft

Guidance for controllers to issue speed commands to non-FIM aircraft

Traffic Management Advisor with Terminal Metering (TMA-TM)
Sequential Experiments

- Multi-year iterative experimentation process
- Batch computer simulations and Human-in-the-Loop (HITL) experiments in preparation for a flight demonstration
- Collaborative effort between NASA Langley and Ames Research Centers
## Batch and HITL Experiments

<table>
<thead>
<tr>
<th>Batch Computer Simulation</th>
<th>Human-in-the-Loop Experiment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fast-time</td>
<td>Real-time</td>
</tr>
<tr>
<td>Low / medium fidelity</td>
<td>Medium and/or high fidelity</td>
</tr>
<tr>
<td>Airborne technologies only</td>
<td>Integrated system of ground-based and airborne technologies</td>
</tr>
<tr>
<td>Scripted scenarios</td>
<td>Dynamic scenarios</td>
</tr>
<tr>
<td>Reduced realism</td>
<td>Realistic controller and pilot actions</td>
</tr>
<tr>
<td>Single facility and simulation environment</td>
<td>Multiple facilities and simulation environments</td>
</tr>
<tr>
<td>Lower cost, fewer resources, less time</td>
<td>Higher cost, more resources, more time</td>
</tr>
</tbody>
</table>
Sequential Experiments

- Multi-year iterative experimentation process
- **Batch computer simulations** and Human-in-the-Loop (HITL) experiments in preparation for a **flight demonstration**
- Collaborative effort between NASA Langley and Ames Research Centers

Diagram:
- IM-NOVA 2012
- IMSACE 2012
- ISIM 2013
- FIAT-4 2014
- RAPTOR 2014
- ABS-1 2013
- CA-5.3 2014
- ABS-2 2014
- EAGAR 2014
- Flight Test 2017
- IMAC 2015
- ABS-3 2015
Interval Management Alternative Clearances (IMAC) Human-in-the-Loop Experiment

Experiment Objective:
To explore the efficacy and acceptability of the ATD-1 Concept of Operations and the Interval Management procedures, and identify possible real-world implementation issues
Simulation Facilities

Desktop Pilot Interface

Full Mission Cockpit

Batch Aircraft

ATC Stations

Traffic Management Advisor

Pseudo-Pilot Interface
Participants

Subject air traffic controllers
- There were two groups of 4 subject controllers (a total of 8 subject controllers)
- The 4 subject controllers consisted of two ARTCC controllers and two TRACON controllers

Subject pilots
- There were two groups of 12 subject pilots (a total of 24 subject pilots)
- The subject pilots flew six two-crew simulators

Confederate air traffic controllers (data not collected and reported)
- 1 Ghost (ARTCC) and 1 Tower (TRACON) controller

Pseudo-pilots (data not collected and reported)
- 6 pseudo-pilots (one per controller)
Experiment Design

Operation

<table>
<thead>
<tr>
<th>BASELINE</th>
<th>CAPTURE</th>
<th>CROSS</th>
<th>MAINTAIN</th>
<th>MIXED</th>
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</thead>
<tbody>
<tr>
<td>Scenario A</td>
<td>Scenario C</td>
<td>Scenario E</td>
<td>Scenario G</td>
<td>Scenario I</td>
</tr>
<tr>
<td>Scenario B</td>
<td>Scenario D</td>
<td>Scenario F</td>
<td>Scenario H</td>
<td>Scenario J</td>
</tr>
</tbody>
</table>

- Two replicates of each operation type
  - One of each with Captain as PM
  - One of each with First Officer as PM

- Run order partially counterbalanced
  - Scenarios A – H counterbalanced
  - Scenarios I & J flown after A – H complete
Scenario Description

Denver International Airport

- Four landing runways
  - South-flow: 16L and 17R
  - North-flow: 35L and 35R
Scenario Description
**Flight Crew Acceptability**

**Hypothesis:** Pilots will report the mean acceptability of IM operations greater than or equal to 5

**Conclusion:** For all operations, the mean pilot acceptability ratings were significantly greater than 5 ($p \leq 0.006$)

<table>
<thead>
<tr>
<th>Operation</th>
<th>N</th>
<th>Mean</th>
<th>SD</th>
<th>Min</th>
<th>Median</th>
<th>Max</th>
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</thead>
<tbody>
<tr>
<td>BASELINE</td>
<td>48</td>
<td>6.8</td>
<td>0.6</td>
<td>5</td>
<td>7</td>
<td>7</td>
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<tr>
<td>CAPTURE</td>
<td>46</td>
<td>5.6</td>
<td>1.4</td>
<td>1</td>
<td>6</td>
<td>7</td>
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<tr>
<td>CROSS</td>
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<td>1.1</td>
<td>2</td>
<td>6</td>
<td>7</td>
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<tr>
<td>MAINTAIN</td>
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<td>5.8</td>
<td>1.5</td>
<td>1</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>MIXED</td>
<td>48</td>
<td>5.6</td>
<td>1.6</td>
<td>1</td>
<td>6</td>
<td>7</td>
</tr>
</tbody>
</table>
**Flight Crew Workload**

**Hypothesis:** Pilots will report the mean workload with IM operations less than or equal to 3

**Conclusion:** For all operations, the mean pilot workload ratings were significantly less than 3 ($p \leq 0.010$)

<table>
<thead>
<tr>
<th>Operation</th>
<th>N</th>
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<th>Min</th>
<th>Median</th>
<th>Max</th>
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</thead>
<tbody>
<tr>
<td>BASELINE</td>
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<td>1.4</td>
<td>1.3</td>
<td>1</td>
<td>1</td>
<td>10</td>
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<tr>
<td>CAPTURE</td>
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<td>2.3</td>
<td>1.4</td>
<td>1</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>CROSS</td>
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<td>2.4</td>
<td>1.9</td>
<td>1</td>
<td>2</td>
<td>9</td>
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<tr>
<td>MAINTAIN</td>
<td>42</td>
<td>2.5</td>
<td>2.5</td>
<td>1</td>
<td>2</td>
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</table>
Conclusions

- Overall both the concept and procedures were rated favorably in terms of acceptability.
- Based on controller and pilot feedback, IM operations did not significantly impact workload.
- Several critical issues were identified that must be resolved prior to real-world implementation.
- The experiment was successful and informative, and results are being used to prepare for flight test.