Investigation of Communications Involved in Near-term UAM Operations

Jillian Keeler, Savita Verma, and Tamsyn Edwards
• Air passenger transportation
• Using electric vertical takeoff and landing vehicles (eVTOLS)
• VFR operations in Classes B, C, and D around urban areas:
  – San Francisco, Detroit, New York City [1]
  – Reduces travel time and road congestion
• Coordinating with local / tower controllers

• In addition to current roles with traditional IFR/VFR traffic, controllers coordinating UAM traffic would need to:
  – Handle UAM clearances for departures, arrivals, and general airspace usage
  – Perform UAM hand-offs to other facilities
• Already burdened in current NAS
• Significant risk to safety and efficiency of UAM operations
• Future UAM infrastructures should not increase current workload levels for air traffic controllers [2, 3]

Near-term Solution to the Communication Issue?

- Implementation of a letter of agreement (LOA)
  - Outline regulatory conditions
  - Delegate individual responsibilities
  - Detail specific, pre-authorized UAM routes
  - Identify operational restrictions
  - Pre-assign beacon codes
  - Implicit Class B clearance for departure
Objectives

• Examine whether a near-term solution for UAM operations could alleviate communication-associated workload for controllers
  – Conduct human-in-the-loop (HITL) study using present day helicopter routes with communication and procedural requirements outlined in a letter of agreement
• Two Class B Airports
  – Dallas-Fort Worth International Airport (DFW)
  – Dallas Love Field Airport (DAL)

• One Class D Airport
  – Addison Airport (ADS)
# Experimental Matrix

<table>
<thead>
<tr>
<th>Experimental Blocks</th>
<th>Low (1)</th>
<th>Moderate (2)</th>
<th>High (3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline without LOA (C)</td>
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<td>C2</td>
<td>C3</td>
</tr>
<tr>
<td>Current Routes with LOA (CL)</td>
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<td>CL3</td>
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## Experimental Matrix

<table>
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<th>UAM Traffic Levels</th>
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Baseline without LOA – Class B Clearance

**UAM Pilot**

“DFW Tower, UAM422, approaching [waypoint along route] at 1100 ft, request Bravo clearance via Highway 121, Route I-35 East, Vista Ridge, and Spine Road with information Whiskey.”

**DFW Controller**

“UAM422, DFW Tower, cleared to enter class Bravo. Squawk 4043. [Additional instructions (e.g., descend for traffic separation)].”
Baseline without LOA – Departure Clearance

UAM Pilot

“DFW Tower, UAM422, ready for takeoff.”

DFW Controller

"UAM422, DFW Tower, wind calm, departure from vertiport will be at your own risk.”
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Letter of Agreement (LOA)

• Meant to reduce verbiage
• Defined routes (e.g., cruise altitude, name/code)
• Documented communication procedures for Class B and D airspaces
• Provided sector transition waypoints
• Pre-assigned beacon codes
• ATIS broadcast including advisories for UAM traffic
• Automatic frequency changes for exiting Class B
• Outlined point outs between facilities
Current Routes with LOA – Class B Clearance

UAM Pilot

“DFW Tower, UAM422, approaching CYOTE via Dallas Three.”

DFW Controller

“UAM 422, DFW Tower, cleared via Dallas Three.”
Current Routes with LOA – Departure Clearance

"DFW Tower, UAM422, ready for takeoff, Love One."

"UAM 422, DFW Tower, cleared via Love One."
### Modified Routes with LOA

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• Assumed same communication procedures
• Made changes to routes based upon SME feedback
• Maximize separation and route efficiency
Participants

• Retired air traffic controllers \((N = 6)\)
• Primary positions
  – Served as DFW LE-3, DAL Helo, or ADS Local
• Secondary positions
  – Served as DFW LE-1, DAL Local, or DFW West
• Used stations simulating STARS through the Multi Aircraft Control Simulator (MACS)
- eVOTLs
- VFR conditions
- Routes ranging 25 - 50 miles
- Cruise speed 130 knots
- 1100’ to 1600’ MSL
- Routes simulated using the Multi Aircraft Control Simulator (MACS)

<table>
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<th>Characteristic</th>
<th>Low</th>
<th>Moderate</th>
<th>High</th>
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<tbody>
<tr>
<td><strong>En Route Temporal Spacing in Seconds</strong></td>
<td>90 s</td>
<td>60 s</td>
<td>45 s</td>
</tr>
<tr>
<td><strong>En Route Spacing in Miles</strong></td>
<td>3.75 mi</td>
<td>2.50 mi</td>
<td>1.86 mi</td>
</tr>
<tr>
<td><strong>Total Number of Flights</strong></td>
<td>115</td>
<td>167</td>
<td>225</td>
</tr>
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</table>

UAM Traffic Levels
• **Average percentage of time spent communicating**
  - Total time spent communicating in seconds divided by total run time (~40 minutes)
  - Proportion converted to percentage
  - Averaged by position (e.g., DFW LE-3, DAL Helo, and ADS Local)

• **Post-block questionnaire**
  - Subjective feedback on experience handling UAM (e.g., task load, interference with IFR traffic communication)
Average Communication Percentage - DFW LE-3
With low UAM traffic:
- Conditions with LOA featured significant communication load reduction
- Almost half the percentage of time seen in the **Baseline** condition (35.57%)
Average Communication Percentage – DFW LE-3

With moderate UAM traffic:
- Communication load still reduced with introduction of LOA in **Current** and **Modified Routes** conditions, around 10% decrease
- No additional benefit for communication load from modified versions of routes
With high UAM traffic:
- Smaller benefit of LOA seen, only 10% decrease going into conditions with LOA
- Modifications to routes did not produce an additional reduction in communication load
Average Communication Percentage - DAL Helo
Average Communication Percentage – DAL Helo

With low UAM traffic:
- Communication load reduced by almost half with introduction of LOA
- Modified versions of the routes added to the communication load (~11%)
With moderate UAM traffic:
- Smaller difference going into conditions with LOA from the **Baseline** condition
- Modified versions of routes slightly added to communication load, despite usage of LOA
With high UAM traffic:
- Introduction of LOA alleviated communication load for **Current Routes** (~11%)
- Communication load with **Modified Routes** was not significantly reduced (difference of ~6% from **Baseline** condition)
Average Communication Percentage - ADS Local
With low UAM traffic:
- Similar, low communication levels across all three conditions
- Ranged from 30.68% to 37.93% on average
With moderate UAM traffic:
- No benefit of LOA in reducing communication load with **Current Routes**, produced higher communication averages
- **Modified Routes** had a small benefit of communication reduction than just the LOA
With high UAM traffic:
- No significant impact of LOA or modifications to routes on communication load
- Similar average percentages of communication, ranging from 30.68% to 37.93%
Post-Block Questionnaire – IFR Communications
To what extent did the UAM communications interfere with IFR communications?

1 = Not at all interfered, 4 = Moderately, 7 = Interfered very much

For DFW LE-3 controllers:
- Similar ratings across all three conditions, indicating moderate interference with IFR comms
- High variability in responses for **Baseline** condition

<table>
<thead>
<tr>
<th>Condition</th>
<th>DFW LE-3</th>
<th>DAL Helo</th>
<th>ADS Local</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline, No LOA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Current Routes, LOA</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Modified Routes, LOA</td>
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To what extent did the UAM communications interfere with IFR communications?
1 = Not at all interfered, 4 = Moderately, 7 = Interfered very much

For DAL Helo controllers:
- No significant benefit of LOA or modifications to routes
- Responses for Baseline and Current Routes conditions indicated almost non-existent levels of interference
- Modified Routes condition had an almost moderate level of interference with IFR comms
For ADS Local controllers:

- Rated IFR comm interference as being almost non-existent across the **Baseline** and **Current Routes with LOA** conditions
- Modified versions of routes presented more interference with IFR comms (at least somewhat moderate)
Post-Block Questionnaire – Task Load
For DFW LE-3 controllers:

- More likely to perceive some task interference in all conditions regardless of the presence of LOA or modifications made to routes.
UAM communications slowed me down in my tasks.
1 = Strongly Disagree, 4 = Neutral, 7 = Strongly Agree

For DAL Helo controllers:
- Reported task interference in **Baseline** condition
- Introduction of LOA reduced task interference for some (greater variability in responses)
- Some task interference reported when modified versions of routes used with LOA
For ADS Local controllers:

- More inclined to report task interference in the **Baseline** condition
- Less task interference reported in conditions that featured a LOA
- **Modified Routes** condition provided no additional benefit in task interference reduction
Summary

• Explored whether the implementation of a LOA would reduce controller-associated workload
• Current helicopter routes, including modified routes, and communication procedures outlined in the LOA would be feasible for near-term operations
• Presents issues of limitations for ability to scale
  – Higher traffic loads shown to have a negative impact, especially for DFW
• Future research needs to examine alternative methods for voice comms
  – Controller-pilot data link communications
  – Changes in controller’s roles and responsibilities for expected UAM operations
  – Additional infrastructure options (e.g., frameworks used in unmanned aircraft system traffic management)
Questions?

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Thank you!
Back-up Slides
What level of pilot voice communications did you have this run?

1 = Very low level, 4 = Comfortable level, 7 = Unmanageably high level
What level of pilot voice communications did you have this run?
1 = Very low level, 4 = Comfortable level, 7 = Unmanageably high level

- Baseline, No LOA
- Current Routes, LOA
- Modified Routes, LOA
What level of pilot voice communications did you have this run?
1 = Very low level, 4 = Comfortable level, 7 = Unmanageably high level
What level of ground communications (ATC to ATC) did you have this run?
1 = Very low level, 4 = Comfortable level, 7 = Unmanageably high level

<table>
<thead>
<tr>
<th>Condition</th>
<th>Average Response</th>
</tr>
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<tbody>
<tr>
<td>Baseline, No LOA</td>
<td>3.5</td>
</tr>
<tr>
<td>Current Routes, LOA</td>
<td>4.2</td>
</tr>
<tr>
<td>Modified Routes, LOA</td>
<td>6.5</td>
</tr>
</tbody>
</table>

Low UAM  
Moderate UAM  
High UAM
What level of ground communications (ATC to ATC) did you have this run?
1 = Very low level, 4 = Comfortable level, 7 = Unmanageably high level
What level of ground communications (ATC to ATC) did you have this run?

1 = Very low level, 4 = Comfortable level, 7 = Unmanageably high level

- Baseline, No LOA
- Current Routes, LOA
- Modified Routes, LOA
<table>
<thead>
<tr>
<th>Flight Type</th>
<th>Airport</th>
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<tbody>
<tr>
<td></td>
<td>DFW</td>
<td>DAL</td>
<td>ADS</td>
</tr>
<tr>
<td>Total IFR Flights – Arriving</td>
<td>54</td>
<td>16</td>
<td>6</td>
</tr>
<tr>
<td>Total IFR Flights – Departing</td>
<td>50</td>
<td>20</td>
<td>1</td>
</tr>
<tr>
<td>Total VFR Flights – Arriving &amp; Departing</td>
<td>0</td>
<td>1</td>
<td>11</td>
</tr>
<tr>
<td>Grand Total of Flights</td>
<td>104</td>
<td>36</td>
<td>18</td>
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