
Dr. Marcus Johnson
Dr. Jaewoo Jung, Dr. Joseph Rios, Joey Mercer, Jeffrey Homola, Dr. Thomas Prevot, Daniel Mulfinger, and Dr. Parimal-Kopardekar

NASA Ames Research Center

June 2017
Low Altitude UAS Operations

FAA Small UAS forecast – 7M total, 2.6M commercial by 2020

Vehicles are automated and airspace integration is necessary

New entrants desire access and flexibility for operations

Current users want to ensure safety and continued access

Regulators need a way to put safety structures in airspace

Operational concept being developed to address beyond-visual-line-of-sight (BVLOS) UAS operations at low altitude in uncontrolled airspace using UTM construct
Challenges with Expanding Operations

Visual Line of Sight
14 CFR Part 107

BVLOS

Command and Control

Separation

Weather

Awareness

Aircraft Performance

Operations over People
UTM is an “air traffic management” ecosystem for uncontrolled airspace

UTM utilizes industry’s ability to supply services under FAA’s regulatory authority where these services do not exist.

UTM development will ultimately identify services, roles/responsibilities, information architecture, data exchange protocols, software functions, infrastructure, and performance requirements to enable the management of low-altitude uncontrolled UAS operations.

UTM addresses critical gaps associated with lack of support for UAS operations in uncontrolled airspace.
Technical Capability Level (TCL) Progression

**TCL1:** multiple VLOS
- Networked Operations
- Info sharing

**TCL2:** multiple BVLOS, rural
- Initial BVLOS
- Intent sharing
- Separation by geo-fencing

**TCL3:** multiple BVLOS, near airports, suburban
- Routine BVLOS
- Detect and Avoid (DAA) / Vehicle to Vehicle (V2V)
- Avoid static obstacles

**TCL4:** complex urban BVLOS
- BVLOS to doorstep
- Track and locate
- Avoiding dynamic obstacles
- Large scale contingencies
TCL 2 UTM Functionality

Scheduling and Planning, Tracking, and Contingency Management

UTM Mobile Application

Conflict Alerts

Intruder Alerts

Contingency Alerts

Flight Conformance Alerts

Priority Operations
Evaluate the feasibility of multiple BVLOS operations using a UTM research platform
Flight Test Overview

Operational Area

Reno-Stead Airport

UAS Range
- Elevation: 5050 feet
- Desert Terrain
- Missions up to 500 ft
- Operations at 5 Locations

SRHawk Radar

Weather Equipment

LSTAR Radar

Nevada UAS Test Range

October 2016
Flight Test Highlights

- **Situation Awareness Displays**
  - Critical alerts, operational plan information and map displays

- **Altitude Stratified Operations**

- **Live-Virtual Constructive Environment**

---

**BVLOS + Visual Line of Sight = Simultaneous Operations**

- 2 BVLOS Flights
- 3 Visual Line of Sight Flights
- 5 Simultaneous Operations

- 74 Flights
- 11 UAS Vehicles
- 14 Partnerships
- 5 Days of Flight (30 Minutes per Scenario)
Scenario 2: Lost Hiker

1. Dynamic Re-Routing
2. VLOS Altitude Stratification
3. Priority Operation
4. Constraint Notifications
TCL 2 Flight Test Lessons Learned
Use of the UTM Research Platform

Areas for improvement:
- Spectrum Usage
- Contingency Management Actions
- User reported information (e.g. UREP)
- Integrated Airspace Display

Observations

Few flight crews had experience flying amongst other operations.

Due to differences in the equipment and practices of other operators, information sharing was critical for safety.

Flight crew progressed from reluctance to acceptance to endorsement of shared airspace information.

UTM provided situation awareness with respect to other operations that was generally accepted by operators.
Inconsistent Altitude Reporting

Increased risk of controlled flight into terrain and airborne collision hazard

Altitude reporting should be consistent or translatable across airspace users
Weather Impact on UAS

Nominal Aircraft Endurance
- Multi-Rotors: 20-40 minutes
- Fixed-Wing: 45-200+ minutes
- Reno-Stead Elevation: 5,050 ft

Cool Temperatures
- Density Altitude: 4,000 ft
- Winds: 5-35 knots
- Aircraft encountered thermals, microbursts and high winds which resulted in reduced endurance and degraded flight plan conformance

Warm Temperatures
- Density Altitude: 9,000+ ft
- Winds: 5-15 knots
- Aircraft experienced substantially shorter endurance

UAS should be tested and rated against different operational environments
Basin and range topography yielded local micro-climates with observably different wind conditions.

Local weather and national forecasts not indicative of observed conditions on site.

Ground reports were not indicative of conditions UAS experienced aloft.

Ground reports local to GCS location was not indicative of conditions UAS experience while BVLOS.

Improvements in weather products are needed to support BVLOS.
Operators should **display airspace information** and have access to other operator’s operational intent and contingency actions in off-nominal conditions.

Altitude reporting should be **standardized** and consistent/translatable to current airspace users.

In the absence of acceptable weather products, **atmospheric conditions** should be **self-reported from GCS and UAS**.

Initial BVLOS should **avoid altitude stratification**, until improved position sharing (e.g. V2V) and weather products.

**Flight trajectories** should be **contained within geo-fence boundaries** that are shared with the UTM research platform to support separation.
Next Steps
May 15th – June 9th 2017

- ~40 partners total across 6 testing locations
- 6 USS Implementers (Amazon Prime Air, Google Project Wing, Airmap, Simulyze, ANRA, NASA)
- NASA USS and FIMS run in the cloud
- Data feeds monitored in UTM lab and at each location
- Multiple Media days

<table>
<thead>
<tr>
<th>Test Sites</th>
<th>USS Technology</th>
<th>Geofence Technology</th>
<th>Ground-based Sense &amp; Avoid</th>
<th>Airborne Sense &amp; Avoid</th>
<th>Communication, Surveillance</th>
<th>Human Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alaska</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Nevada</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>New York</td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>North Dakota</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Texas</td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Virginia</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
</tbody>
</table>
TCL 3: Multiple BVLOS operations near airports and suburban areas
Parcel Delivery

Real Estate Photography

Operations near airports

Weather Services

Operations over populated areas

Infrastructure Inspection

Cell Tower Inspection

Traffic Monitoring

Contingency Management

Remote Identification

Airspace / Ground Constraints

Real Estate Photography
Summary

**TCL 2 Demonstration** successfully showed the feasibility of supporting multiple BVLOS operations in a rural environment and highlighted areas of future research.

**TCL 2 National Campaign** successfully demonstrated the UTM architecture, collected data to support the NASA-FAA UTM Research Transition Team, and engaged industry to contribute to the development of UTM.

**TCL 3 Demonstration** will evaluate the effectiveness and interoperability of technologies to support separation, communication, navigation, data-exchange, and airspace management in a complex operational environment.
Questions?