Unmanned Aircraft Systems Traffic Management (UTM)

SAFELY ENABLING UAS OPERATIONS IN LOW-ALTITUDE AIRSPACE

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Outline

• Overview
• Architecture
• Approach and schedule
• FAA-NASA Research Transition Team deliverables
• Progress and next steps
• Summary
Overview
Low Altitude UAS Operations

- 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 structures as needed
- Operational concept being developed to address beyond visual line of sight UAS operations under 400 ft AGL in uncontrolled airspace using UTM construct
What is UTM?

- 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 for enabling the management of low-altitude uncontrolled UAS operations

UTM addresses critical gaps associated with lack of support for uncontrolled operations

How to enable multiple BVLOS operations in low-altitude airspace?
• FAA maintains regulatory AND operational authority for airspace and traffic operations

• UTM is used by FAA to issue directives, constraints, and airspace configurations

• Air traffic controllers are not required to actively “control” every UAS in uncontrolled airspace or uncontrolled operations inside controlled airspace

• FAA has on-demand access to airspace users and can maintain situation awareness through UTM

• UTM roles/responsibilities: Regulator, UAS Operator, and UAS Service Supplier (USS)

• FAA Air Traffic can institute operational constraints for safety reasons anytime

Key principle is safely integrate UAS in uncontrolled airspace without burdening current ATM
UTM Principles and Services

Principles

- Users operate in airspace volumes as specified in authorizations, which are issued based on type of operation and operator/vehicle performance
- UAS stay clear of each other
- UAS and manned aircraft stay clear of each other
- UAS operator has complete awareness of airspace and other constraints
- Public safety UAS have priority over other UAS

Key UAS-related services

- Authorization/Authentication
- Airspace configuration and static and dynamic geo-fence definitions
- Track and locate
- Communications and control (spectrum)
- Weather and wind prediction and sensing
- Conflict avoidance (e.g., airspace notification)
- Demand/capacity management
- Large-scale contingency management (e.g., GPS or cell outage)
Defining Operator and Regulator/ANSP Roles

**UAS Operator**
- Assure communication, navigation, and surveillance (CNS) for vehicle
- Register
- Train/qualify to operate
- Avoid other aircraft, terrain, and obstacles
- Comply with airspace constraints
- Avoid incompatible weather

**Regulator/Air Navigation Service Provider**
- Define and inform airspace constraints
- Facilitate collaboration among UAS operators for de-confliction
- If future demand warrants, provide air traffic management
  - Through near real-time airspace control
  - Through air traffic control integrated with manned aircraft traffic control, where needed

Third-party entities may provide support services but are not separately categorized or regulated
Supporting Functions

**Wind & Weather Integration**

- Operator responsibility, may be provided by third party
- Actual and predicted winds/weather
- No unique approval required
UTM Research and Development

Operations Considerations
• Overarching architecture
• Scheduling and planning
• Dynamic constraints
• Real-time tracking integration
• Weather and wind
• Alerts:
  • Demand/capacity alerts
  • Safety critical events
  • Priority access enabling (public safety)
  • All clear or all land alerts
• Data exchange protocols
• Cyber security
• Connection to FAA systems

Vehicle Considerations
• Low SWAP DAA
• Vehicle tracking: cell, satellite, ADS-B, pseudo-lites
• Reliable control system
• Geo-fencing conformance
• Safe landing
• Cyber secure communications
• Ultra-noise vehicles
• Long endurance
• GPS free/degraded conditions
• Autonomous last/first 50 feet operations
Architecture
UTM Approach and Schedule
UTM Technical Capability Levels (TCLs)

**CAPABILITY 1: DEMONSTRATED HOW TO ENABLE MULTIPLE OPERATIONS UNDER CONSTRAINTS**

- Notification of area of operation
- Over unpopulated land or water
- Minimal general aviation traffic in area
- Contingencies handled by UAS pilot

Product: Overall con ops, architecture, and roles

**CAPABILITY 2: DEMONSTRATED HOW TO ENABLE EXPANDED MULTIPLE OPERATIONS**

- Beyond visual line-of-sight
- Tracking and low density operations
- Sparsely populated areas
- Procedures and “rules-of-the road”
- Longer range applications

Product: Requirements for multiple BVLOS operations including off-nominal dynamic changes

**CAPABILITY 3: FOCUSES ON HOW TO ENABLE MULTIPLE HETEROGENEOUS OPERATIONS**

- Beyond visual line of sight/expanded
- Over moderately populated land
- Some interaction with manned aircraft
- Tracking, V2V, V2UTM and internet connected

Product: Requirements for heterogeneous operations

**CAPABILITY 4: FOCUSES ON ENABLING MULTIPLE HETEROGENEOUS HIGH DENSITY URBAN OPERATIONS**

- Beyond visual line of sight
- Urban environments, higher density
- Autonomous V2V, internet connected
- Large-scale contingencies mitigation
- Urban use cases

Product: Requirements to manage contingencies in high density, heterogeneous, and constrained operations

Risk-based approach: depends on application and geography
FAA-NASA Research Transition Team (RTT) Deliverables
RTT Plan & Key Deliverables

• Near-term priorities
  – Joint UTM Project Plan (JUMP) – December 2016 (Completed)
  – RTT Research plan – January 2017
  – UTM Pilot project – April 2017-2019

• Execution
  – March 2016 – December 2020

Key RTT Deliverables (FAA needs)
- Tech transfer - to FAA and industry
- Concepts and requirements for data exchange and architecture, communication/navigation and detect/sense and avoid
  - Cloud-based architecture and Conops
  - Multiple, coordinated UAS BVLOS operations
  - Multiple BVLOS UAS and manned operations
  - Multiple operations in urban airspace
- Tech transfer to FAA
  - Flight Information Management System prototype (software prototype, application protocol interface description, algorithms, functional requirements)

FAA-NASA Key RTT Deliverable
- Joint FAA-NASA UTM Pilot Program

RTT will culminate into key technical transfers to FAA and joint pilot program plan and execution
Progress and Next Steps
UTM TCL 2 Demonstration (October 2016 at Reno-Stead)

Operational Area

Reno-Stead Airport

Live-Virtual Constructive Environment

Altitude Stratified Operations

Situation Awareness Displays

Critical alerts, operational plan information and map displays

Expanded

2

Flights up to 1.5 miles away from the pilot in command

Visual Line of Sight

3

Hypothetical missions based on industry use cases

Simultaneous Operations

5

SRHawk Radar
Used to detect small UAS

Weather Equipment
30 ft weather tower, sodar and lidar are used to measure atmospheric boundary layer

LSTAR Radar
Used to detect manned aircraft

Weather Equipment

30 ft weather tower, sodar and lidar are used to measure atmospheric boundary layer

Used to detect manned aircraft
TCL 1 and 2 Demo and Preliminary Results
UTM TCL 1 and TCL 2 Demonstration Objectives

TCL 1
Evaluate the feasibility of multiple VLOS operations using scheduling and planning through an API connection to the UTM research platform

TCL 2
Evaluate the feasibility of multiple BVLOS operations using a UTM research platform
TCL 1: Multiple VLOS Operations
UAS Range
Elevation: 166 feet MSL
Flat Agricultural Farmland
Operations at 2 Locations

Acoustic Sensors
Weather Sensors
100 ft Weather Tower
Radiosonde Weather Balloon
Remote Automated Weather Station

SRHawk Radar
Used to detect small UAS
UTM TCL 1 Demonstration Highlights

- Days of Flight: 8
- Partner Organizations: 11
- Simultaneous VLOS Operations: 2
- UAS Platforms: 10
- Test Conditions: 4
- Flights: 108
- Flight Hours: 18
Objective 1: Demonstrate UTM Prototype Features

Objective 2: Collect Data on UAS Navigation Performance Error

Objective 3: Collect Data on Aircraft Tracking Performance

Objective 4: Collect Weather Observations for Forecasting Models

Objective 5: Collect Data on Noise Signature of UAS Vehicles
Flight Profiles:

- Free Flight
- Horizontal Trajectory Conformance
- Vertical Trajectory Conformance
- Sound Recording
- System Identification Maneuvers

Altitude: up to 400 ft AGL
Duration: 8-30 minutes
Simultaneous Aircraft: 2
TCL 1 Observations
Observations:

1. **Ground equipment degraded performance and failed under high temperatures**
   High temperatures caused failures in ground control stations, routers, UTM computers, and Ethernet wiring.

2. **Spectrum interference from unknown sources causes lost link conditions**
   Lost link conditions were invoked due to spectrum interference. Local farming equipment was hypothesized to have contributed to the incidents.

3. **GPS degradation caused initiation of contingency management system**
   Inefficient satellites received during operations caused an aircraft to initiate a contingency management procedure and grounded another vehicle.

**UAS and ground equipment should be rated for use based on the operational environment**
Observations:

4. Atmospheric conditions on the ground were not indicative of conditions aloft. Despite flat terrain, wind and turbulence conditions varied on the ground as compared with 200—400 ft AGL.

5. Line of sight was often difficult to maintain when flying multiple aircraft. In the presence of other nearby operations, and raptors maintaining visual on aircraft was challenging for observers of the test.

6. Tracking information for UAS was provided at rate that was insufficient. The test used 5 second update rates for telemetry information which did not account for the dynamic changes in aircraft states, dropouts, quality of service connectivity, and human factors aspect of the displays. (Changed for TCL 2: 1 Hz or faster)

7. Lack of airspace and operations information caused conflicting planned operations. Flight crews had no airspace displays to allow them to de-conflict operations and this caused frequent operations that were in conflict.

All airspace users should have a common picture of the operating environment.
TCL 2: Multiple BVLOS Operations
UTM TCL2: Scheduling and Executing Multiple BVLOS Operations

Conflict Alerts
Alert triggered by proximity to other aircraft

Intruder Alerts
Alert triggered from radar submitted warning regions to UTM research prototype

Contingency Alerts
Simulated in-flight emergency reported to the UTM research prototype and relayed to impacted operations

Flight Conformance Alerts
Alert triggered from departing from operational area and relayed to impacted operations

Priority Operations
Users with special privileges are given priority of the airspace and impacted operations are informed of any conflicts

Scheduling and tracking operations and contingency management
State of Nevada Test Site

Operational Area

Reno - Stead Airport

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

SRHawk Radar
Used to detect small UAS

Weather Equipment
30 ft weather tower, sodar and lidar are used to measure atmospheric boundary layer

LSTAR Radar
Used to detect manned aircraft

Reno

October 2016
UTM TCL 2 Demonstration Flight Operations

Live-Virtual Constructive Environment

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

Expanded
Flights up to 1.5 miles away from the pilot in command

Visual Line of Sight
Hypothetical missions based on industry use cases

Simultaneous Operations

2 + 3 = 5
<table>
<thead>
<tr>
<th>SCENARIO</th>
<th>1 AGRICULTURE</th>
<th>SCENARIO 2 LOST HIKER</th>
<th>SCENARIO 3 OCEAN</th>
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Scenario 2: Lost Hiker

Critical Events (in approximate order):

- **GCS1** submits all plans while logged in as special user.
- **GCS3** sends message to RC “Reporting a lost hiker in area…” (once all GCS have launched).
- **ALL GCS** receive message from RC “Simulated lost hiker in area…” (once all GCS have launched).
- **GCS1** submits 2nd plan with special permissions *logged in as special user (after 2 minute hover & lost hiker message)*.
- **GCS3** receives UTM system message “first responder in proximity…” and ABORTS (after GCS1’s 2 min hover & lost hiker message).
- **GCS5** submits 2nd plan – REJECTED for special permissions operation – does not launch (after landing plan 1, while GCS1 is still flying).
UTM TCL 2 Demonstration Highlights

- **Days of Flight**: 5
- **Partner Organizations**: 14
- **Simultaneous Altitude Stratified Expanded Operations**: 2
- **UAS Platforms**: 11
- **Minutes per scenario**: 30
- **Scenarios**: 4
- **Flights**: 74
- **Flight Hours**: 13.5
### UTM Core Principles and Guiding Tenet

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<tr>
<th>Tested Feature</th>
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<td>Scheduling and Planning</td>
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<td>Proximity Alerting</td>
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<td>Separation by Segregation (e.g. Geo-fencing)</td>
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<td>Intruder Alerting</td>
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<td>Separation by Notification (e.g. NOTAM)</td>
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<td>UTM Mobile Application</td>
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<td>Contingency Management Alerts</td>
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<td>Priority Operations</td>
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<td>Dynamic Re-routing</td>
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<td>4D Segmented Flight Plans</td>
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<tr>
<th>UAS should avoid each other</th>
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<td>UAS should avoid manned aircraft</td>
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<td>UAS operators should have complete awareness of all constraints in the airspace</td>
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<td>Public safety UAS have priority within the airspace</td>
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<td>Flexibility where possible and structure where necessary</td>
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**UTM concept and research platform supported BVLOS**
TCL 2 Findings
Impact of Weather

**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
Inconsistent Altitude Reporting

Increased risk of controlled flight into terrain and airborne collision hazard

Altitude Reporting should be consistent or translatable across airspace users
Surveillance may not be a requirement in all TCL 2 environments, however for areas with increased manned air traffic, surveillance provided increased situation awareness and should be required.
Preliminary Recommendations for Initial Multiple BVLOS Operations (based on TCL-2 evaluations)

01. Operators need to **display airspace information** and have access to other operator’s operational intent and contingency actions in off-nominal conditions (common UTM picture was useful)

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

03. Initial BVLOS should **avoid altitude stratification**, until altitude standard, V2V

04. **Altitude reporting** should be **standardized** and consistent/translatable to current airspace users
Next Steps
TCL 2 National Safe UAS Integration Campaign

What: Demonstrate and evaluate critical elements of diverse multiple BVLOS operations, 4 different vehicles from each site flown under UTM

Demonstrate architecture with multiple Operators, UAS Service Suppliers and Flight Information Management System (FIMS)

Where: 6 FAA UAS Test Sites

Who: NASA, Test Sites, ~40 partners

When: 15 May – 9 June 2017

The UTM concept and research platform is exercised by all industry and FAA test sites.
High level objectives of TCL 3 evaluations

- **System Level Evaluation**
  - Contingency Management /Off-Nominal Conditions
  - Priority Operations and Airspace and Ground Constraints

- **Separation**
  - Non-cooperative aircraft
  - Cooperative Aircraft
  - Ground Obstacles

- **Communication and Navigation**
  - Direct Communication and Control (e.g. radio controlled)
  - Distributed Communication (e.g. cellular network, mesh networks)

- **Navigation** (close to people and buildings, terrestrial and satellite-based)
  - Data gathering for modeling, measurement and forecasting of weather
  - UAS/USS weather integration

TCL 3 Evaluations will include testing at Crows Landing, CA in Fall 2017 using COA 2016-WSA-46 that authorizes NASA to conduct BVLOS operations with small UAS at Crows Landing, CA using a radar for separation (instead of visual observers).
Summary

• Very active collaboration with FAA and industry
• UTM construct is adopted globally (e.g., J-UTM, K-UTM, SESAR, etc.)
• FAA-NASA UTM RTT construct has been very productive
• Next big impact will be UTM pilot and path towards initial operations
Embracing innovation in aviation while respecting its safety tradition