The Future of Aviation: A Paradigm for Unmanned Aviation Systems and Urban Air Mobility

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NOTE: All presentations will undergo a review by the MDL and then by ITAR/EAR.
Topic Overview

- Air Traffic Management (ATM)
- Unmanned Aircraft System Traffic Management (UTM)
- Urban Air Mobility Operations
- Paradigm for Beyond
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
Key Operational Assumptions

- 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
**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

<table>
<thead>
<tr>
<th>UAS Operator</th>
<th>Regulator/Air Navigation Service Provider</th>
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<tbody>
<tr>
<td>- Assure communication, navigation, and surveillance (CNS) for vehicle</td>
<td>- Define and inform airspace constraints</td>
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<td>- Register</td>
<td>- Facilitate collaboration among UAS operators for de-confliction</td>
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<td>- Train/qualify to operate</td>
<td>- If future demand warrants, provide air traffic management</td>
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<td>- Avoid other aircraft, terrain, and obstacles</td>
<td>- Through near real-time airspace control</td>
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<tr>
<td>- Comply with airspace constraints</td>
<td>- Through air traffic control integrated with manned aircraft traffic control, where needed</td>
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<td>- Avoid incompatible weather</td>
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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 Architecture
### 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

### 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

### 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
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.
<table>
<thead>
<tr>
<th>UTM Core Principles and Guiding Tenet</th>
<th>Tested Feature</th>
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<tbody>
<tr>
<td>UAS should avoid each other</td>
<td>Scheduling and Planning</td>
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<td>Conformance Alerting</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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<tr>
<td>UAS should avoid manned aircraft</td>
<td>Intruder Alerting</td>
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<td>Separation by Notification (e.g. NOTAM)</td>
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<td>UAS operators should have complete awareness of all constraints in the airspace</td>
<td>UTM Mobile Application</td>
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<td>Contingency Management Alerts</td>
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<td>Public safety UAS have priority within the airspace</td>
<td>Priority Operations</td>
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<td>Flexibility where possible and structure where necessary</td>
<td>Altitude Stratification</td>
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<td>Dynamic Re-routing</td>
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<td>4D Segmented Flight Plans</td>
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TCL 3 Evaluations (preparations underway)

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)
Connected System for Scalability

- Cloud-Based Services (Weather, Tracking, Trajectory)
- Demand/Capacity Coordination
- Scheduling
- Spacing
- Separation
- Airspace and Traffic Constraints

User Demand

Aircraft

UTM System

Support Services Supplier

Air Mobility Operations Center

Air Navigation Service Provider
Research Approach

CRAWL-WALK-RUN APPROACH

Low-density: Initial Operational Capability
- Helicopter routes using today’s procedures
- Clearance into controlled airspace (UTM - authorization and notification)
- User created conflict-free trajectories and own tracking

Medium-density: Interim Operational Capability
- User creates conflict-free trajectories
- Interoperable, cooperative, intent sharing through UTM
- Self-managed operations (e.g., detect and avoid, contingency management)

High-density: Mature Operational Capability
- Fully-autonomous planning, scheduling, separations, entry/exit controlled airspace, interoperability, and contingency management
- Multiple, simultaneous take-offs and landings

Research needed to identify requirements for scaled operations
Future Paradigm for Airspace Operations

Uncontrolled Airspace High-Altitude Unmanned and Manned Traffic Management

Uncontrolled Airspace: Class G
(ceiling varies, typically 1200 AGL)

PAVs

Supersonic Trajectories

Controlled Airspace: Class A, B, C, D, E

GA

Terminal / Metroplex

ODM

2.7M UAS at low alt

Low Altitude Urban

Swarms

Pocket Airports

Airport

Alt: 120K & Up
10s to 100s Ops

Alt: 60K & Up
Supersonics: 10s to 100s
Commercial: 25K

Top of Class G
PAVs and ODM: 1K to 37K
UAS: 10K - Millions
GA: 3K+
Current ATM

All services are provided by the FAA
- Traffic flow management
- Airspace directives/constraints
- Scheduling, sequencing and spacing
- Separation management
- Off-nominal management
- Every vehicle interaction in real-time

FAA Systems

Humans address off-nominal and contingencies

Very little interaction among users, and 3rd party services

- Human in the epi-center of information integration
- Every data moves through FAA systems for every vehicle
- Each change focused in on domain-specific FAA system

UTM-inspired-ATM

Some services are provided by FAA
- Airspace directives/constraints
- Resource availability and changes to resources (e.g., arrival/departure rates, resource schedules)
- Separation

FAA Systems

User or third party services
- Flow management
- Sequencing, and spacing
- User participation strategic separation

Automation addresses off-nominal and contingencies

Users collaborate/cooperate for efficiency, intra-user preferences for flights into constrained resources

- Automation in the epi-center of information integration
- New paradigm: digital and connected ecosystems - outside apps, scalability

NASA Unique Role: Architecture, data exchange, service allocation/roles/responsibilities, rules of engagement, service performance requirements, automation for contingency management and disruption handling, machine learning environment and algorithms for continuous improvement, certification/acceptance approaches, and technology transitions
# Rationale for Change

## Current State of the Art
- Not scalable due to human-centric decisions and actions
- Virtually all interactions/data goes through FAA systems
- Does not leverage industry capabilities

## Results In
- Does not accommodate new users and higher density of current users
- Modernization becomes slow process
- All costs are borne by government

## Change is needed/Redefine
- Methods and techniques
- Interactions among operators and FAA system
- Service-oriented architecture
- Safety systems – increasing airspace access while ensuring safety

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If we don’t change now, US global leadership will suffer
Big Picture – What’s next?

- High altitude UTM – cooperative among operators above FL60,000 (Google Loon, Facebook Aquila, Aerovironment)
  - Cooperation through data exchanges, contingency management procedures and technologies

- Urban air mobility: Extension of UTM – cooperation through data exchange, regulator provides constraints and operator plans their own operation and avoids others and constraints

- Service-oriented architecture for current ATM operations – what can we learn from UTM for ATM
Summary

- Very active collaboration with FAA and industry
- UTM construct is adopted globally (e.g., J-UTM, K-UTM, SESAR, ICAO, etc.)
- FAA-NASA UTM RTT construct has been very productive
- Next steps will be UTM pilot and path towards initial operations
- Opportunity to extend UTM paradigm as appropriate
The End

THANK YOU FOR YOUR PARTICIPATION!

NOTE: This presentation will be accessible through the Industry Day website.