UAS Service Suppliers

Development of specifications, tests, and implementations in parallel
Low Altitude UAS Operations

FAA small UAS forecast: 2.4M hobbyists, 450K commercial by 2022

Over 1M registered UAS Operators currently

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, not controlled by ATC/ATM
What is UAS Traffic Management?

UTM is an “air traffic management” ecosystem for small UAS in low altitude 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 UAS operations.
NASA UTM Concept and R+D...
एकांतवादिः सप्तांधपुरुषः
UTM core operating principles

- Green check marks indicating approved activities or principles.
- Red prohibition signs indicating prohibited activities or principles.
-符号 and other graphical elements are used to illustrate the concepts.
UTM Architecture
v2017.10.12 (reformatted for this presentation)

NAS Data Sources
Common data from FAA available to UTM components based on existing access mechanisms

National Airspace System

Flight Information Management System

Constraints, Directives
Requests, Decisions
Operations, Deviations

Supplemental Data Service Provider
Inter-USS communication and coordination
Terrain Weather Surveillance Performance

UAS Service Supplier
Inter-data provider communication and coordination
Operations, Constraints, Notifications, Information
Public Safety
Operation requests Real-time information
Operations Constraints Modifications Notifications Information

Public

UAS Operators
UAS Operators
UAS Operators

Color Key:
ANSP Function
Operator Function
Other Stakeholders

NAS Data Sources
NAS state
NAS impacts

Additional services and components that may have shared or TBD responsibilities
Discovery Registration Data/Services Authentication/Authorization

V2V Comm

UAS
UAS
UAS
<table>
<thead>
<tr>
<th>UTM Conflict Management Model</th>
<th>Strategic Separation</th>
<th>Tactical Separation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Strategic Conflict Management</td>
<td>Separation Provision</td>
</tr>
<tr>
<td>USS Function</td>
<td>Airspace Organization and Management Service</td>
<td>Conformance Monitoring Service</td>
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<td>SDSP or USS Function</td>
<td>Strategic Deconfliction Service</td>
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<td>Flight Planning Service</td>
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- **UTM Airspace Hazards**
- **UTM Airborne Hazards**
- **UTM Ground Hazards**

- **Visibility and Audibility Enhancements**
- **Geographic Flight Containment**
- **Position Broadcast**
- **Detect and Avoid**
- **Collision Avoidance**
- **Obstacle Avoidance**
## UTM Conflict Management Model

### Strategic Separation

<table>
<thead>
<tr>
<th>Function</th>
<th>Service</th>
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<tbody>
<tr>
<td>USS</td>
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### UTM or USS Function

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<tr>
<td>UAS</td>
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### UAS Operator / UAS Function

<table>
<thead>
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<td>Ground Surveillance</td>
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### Airspace Hazards

- Airspace Hazards
- Airborne Hazards
- Ground Hazards
### Technical Capability Levels (TCL)

**Risk-based development and test approach**

<table>
<thead>
<tr>
<th>TCL 1</th>
<th>TCL 2</th>
<th>TCL 3</th>
<th>TCL 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Traffic Density</td>
<td>Low-Mod Traffic Density</td>
<td>Moderate Traffic Density</td>
<td>High Traffic Density</td>
</tr>
<tr>
<td>Rural Applications</td>
<td>Rural / Industrial Applications</td>
<td>Suburban Applications</td>
<td>Urban Applications</td>
</tr>
<tr>
<td>Multiple VLOS Operations</td>
<td>Multiple BVLOS Operations</td>
<td>Mixed Operations</td>
<td>Dense BVLOS Operations</td>
</tr>
<tr>
<td>Notification-based Operations</td>
<td>Tracking and Operational Procedures</td>
<td>Vehicle to Vehicle Communication</td>
<td>Large Scale Contingency Management</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Public Safety Operations</td>
<td></td>
</tr>
</tbody>
</table>
TCL3 Field Testing...
TCL3 Flight Testing Overview
Executed February through May 2018
Technical Capability Level 3 Flight Tests
TCL 3 Flight Testing
UTM Requirements Development Process...
UtM USS Definition Process

Testing
Driven toward Collaborative Sims
Realized by Flight Tests

Concept Development
Formalized by Research Transition Team
Fortified by Industry Working Groups

Software Implementation
Guided by Use Cases
Solidified by APIs
For better or worse, the software development of USSs has been ahead of the other cycle elements for the majority of UTM development.
Process of formalizing a concept, feature, or service within UTM...

- Run through concept, dev, test cycles
- Internalize lessons, write initial requirements
- Survey partners
- Finalize requirements
Status of some example features/services...

Conformance Monitoring, Flight Notification, Flight Awareness, Dynamic Rerouting, etc.

USS Discovery Service, C2 Link Requirements

Strategic Deconfliction, Off-Nominal Situations
Example from Strategic Deconfliction Development...
Determinism was agreeable to respondents. Comments suggested additional requirements would harden this requirement. We add that given the same inputs, the results are the deterministic. We add a requirement that the results are the same for all USSs given the same inputs. This should preemptively close requirement loopholes. Some comments suggest that there are “corner cases” that may not fit this requirement. We argue that a well designed prioritization (as defined in lower level requirements) will form a strict total ordering, though this may require certain data elements in each operation plan.


[UTM-CM.30] The Prioritization scheme MUST be deterministically calculable by each USS given the same operation data.

[UTM-CM.32] The Prioritization scheme MUST be equivalently calculable by each USS given the same operation data.
A UTM Operation should be free of 4-D intersection with all other known UTM Operations prior to departure and this should be known as “Strategic Deconfliction” within UTM. The Strategic Deconfliction scheme:

- [UTM-CM.05] MUST have the 4-D non-intersection of operations as its primary objective.
- [UTM-CM.10] MUST be well-documented for the understanding of operators.
- [UTM-CM.12] MUST allow for inspection of decisions by operators upon request from operators to their supporting USS.
- [UTM-CM.15] MUST be supported by all USSs
- [UTM-CM.20] MUST be mandated by the airspace regulator.

Strategic Deconfliction needs a prioritization scheme for operations within UTM. The Prioritization scheme:

- [UTM-CM.25] MUST allow for preemption of operations with lower priority by those with higher priority.
- [UTM-CM.30] MUST be equivalently calculable by each USS given the same operation data.
- [UTM-CM.35] MUST be efficiently calculable by each USS given the same operation data.
- [UTM-CM.37] MUST be independently calculable by USSs given the same operation data.
- [UTM-CM.40] SHOULD be a function of operator, operation, airspace, and vehicle parameters.

Strategic Deconfliction needs an allowance for negotiating deconfliction of UTM operations. The Negotiation scheme:

- [UTM-CM.50] MUST be facilitated via USSs.
- [UTM-CM.55] MUST be a finite process.

Strategic Deconfliction needs an allowance for intersecting UTM operations. Intersecting operators, via their USSs:

- [UTM-CM.60] MUST have preceded the decision to intersect with a negotiation process.
- [UTM-CM.65] MUST each provide explicit acknowledgement to each other of the planned intersection of operation volumes when intersection is mutually decided.
- [UTM-CM.70] MUST each provide details to each other on the approach to a separation provision while in intersecting operation volumes when intersection is mutually decided.

Note: Requirement labels likely to change during harmonization with other documentation. Labels to be only considered for consistency within this document.
USS Development Process for TCL4...
<table>
<thead>
<tr>
<th>Date Range</th>
<th>Sprint</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>15-Jun-2018 to 20-Jul-2018</td>
<td>Sprint 0 Validation</td>
<td>Enable minimal impact on-ramping of new entrants. Provide initial validation of updated APIs. Assure base level compliance of USSs to new API. Establish baseline for future feature development and collaborative simulation.</td>
</tr>
<tr>
<td>12-Nov-2018 to 06-Dec-2018</td>
<td>Sprint 4 FIMS, USS Handoffs, DRs and Priority Ops</td>
<td>Test interaction between dynamic restrictions and priority operations. Develop use cases for FAA requests to USSs via FIMS. Implement and test a scenario for FIMS&lt;-&gt;USS data exchange. Develop the concept of USS to USS handoff. Discuss and document concept for self-policing of USS Network (Online Compliance Monitoring Services).</td>
</tr>
<tr>
<td>Late January?</td>
<td>USS Super Sim</td>
<td>High density, high tempo, long duration simulation with various elements (DRs, Rogues, etc.) introduced throughout.</td>
</tr>
</tbody>
</table>

Ongoing discussions regarding services: Discovery, Strat Deconflict, Conform monitoring, Flight Awareness/Notification, etc.
TCL4 General Sprint Milestones

Day 0

- Sprint retrospective
- Sprint kickoff
- Discuss schedule/goals

API update
- Tests established
- Simulation plan finalized

Automated testing
- Simulation walkthrough
- General debugging

Simulation execution
- Data collection
- 2hr of rest before next cycle

Day 30-50
Testing Partner USSs

A test suite written using JUnit is called pointing at partner systems. A series of “unit tests” each exercising a single aspect of the API models hits their endpoints looking for the expected HTTP response.

Gradle is integrated with JUnit to produce reports as as a zipped set of browser-readable files sent to partners.

Currently we run the full suite against all partners once daily. Previously we manually did it on demand. We are moving toward automated on-demand testing so partners can test their system based on their needs.

This process may form the basis of operational USS vetting and continuous compliance monitoring.
NASA UTM Technology Choices...
“Individuals and interactions over tools and processes”...
but tools really help
### NASA USS and FIMS research platform ecosystem

| **Runtime** | Cloud deployment  
Well-known frameworks  
Geo-enabled RDBMS  
Service-based architecture, API driven |
|-------------|---------------------------------------------------------------|
| **CI/CD**   | Code generation from APIs  
Code quality and code coverage metrics  
Scripted builds, infrastructure as code  
Automated REST API testing |
| **Source Control** | Access-controlled repositories  
Publicly available APIs  
Version controlled database schema  
Formal API and model definitions |
| **Cybersecurity** | Shift left philosophy  
Secure coding practices  
Threat modeling  
Vetted libraries over custom code |
| **Teaming** | Agile development  
Issue and progress tracking  
Daily scrums, 2-3 week sprints  
Leverage external partners |
<table>
<thead>
<tr>
<th>Component and Service Requirements</th>
<th>UTM ConOps</th>
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<tbody>
<tr>
<td>USS Specification</td>
<td>UTM APIs</td>
</tr>
<tr>
<td>USS Testing Approaches</td>
<td>Testing Results and Analysis</td>
</tr>
</tbody>
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Example SDOs

Regulator/ANSP

Industry

Example SDOs
The UTM Project is successfully developing the framework and related requirements for large scale, small UAS traffic management.

Processes for testing partner systems is evolving and may form the basis for future checkout requirements in an operational UTM System.

Completed TCL 1, 2, and 3 Demonstrations including many testing organizations, industry, and academia partners that are crucial to validating requirements and investigating technology solutions.

NASA and the FAA are closely collaborating to ensure appropriate regulatory and operational requirements are included and that technology transfers support the development of future operational systems.
Bibliography (images)

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- New York by anbileru adaleru from the Noun Project
- Alaska by anbileru adaleru from the Noun Project
- Texas by anbileru adaleru from the Noun Project
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