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
- Technical Capability Level 1 (TCL1) Demonstration overview and results
- TCL2 Demonstration overview and results
- Next Steps

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?

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 **<u>are not required</u>** 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

UTM Research and Development

Operations Considerations

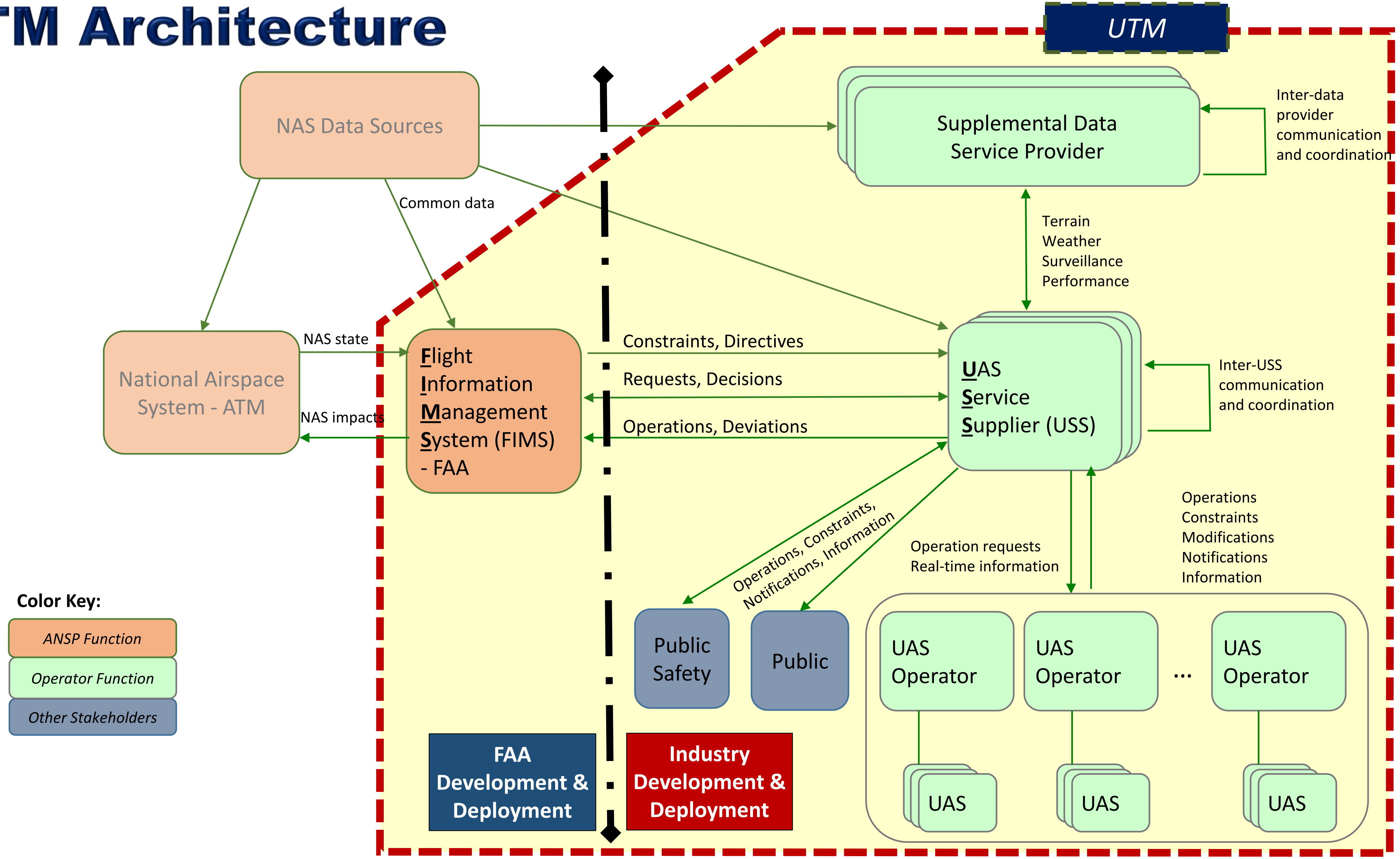
- Overarching architecture
- Scheduling and planning
- Dynamic constraints
- Real-time tracking integration
- Weather and wind
- Alerts:
  - Demand/capacity alerts
  - Safety critical events
  - Priority access enabling (public safety)
  - All clear or all land alerts
- Data exchange protocols
- Cyber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



UTM Approach and Schedule

UTM Progression

Goal:

Safely enabling large scale visual and beyond visual line of sight operations in the low altitude airspace

Risk-based approach along four distinct Technical Capability Levels (TCL)

UTM Progression

TCL1: ***multiple VLOS***

→ API-based networked ops

→ Info sharing

UTM Progression

TCL1: ***multiple VLOS***

→ API-based networked ops

→ Info sharing

TCL2: ***multiple BVLOS, rural***

→ Initial BVLOS

→ Intent sharing

→ Geo-fenced ops

UTM Progression

TCL1: ***multiple VLOS***

→ API-based networked ops

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TCL2: ***multiple BVLOS, rural***

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TCL3: ***multiple BVLOS, near airports, suburban***

→ Routine BVLOS

→ Airborne DAA, V2V

→ Avoid static obstacles

UTM Progression

TCL1: ***multiple VLOS***

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→ Routine BVLOS

→ Airborne DAA, V2V

→ Avoid static obstacles

TCL4: ***complex urban BVLOS***

→ BVLOS to doorstep

→ Track and locate

→ Avoid dynamic obstacles

→ Large scale contingencies

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 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 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 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

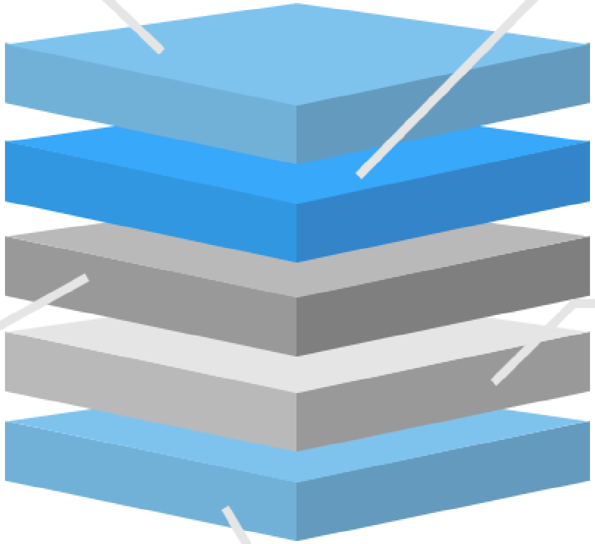
UTM TCL2: Scheduling and Executing Multiple BVLOS Operations

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

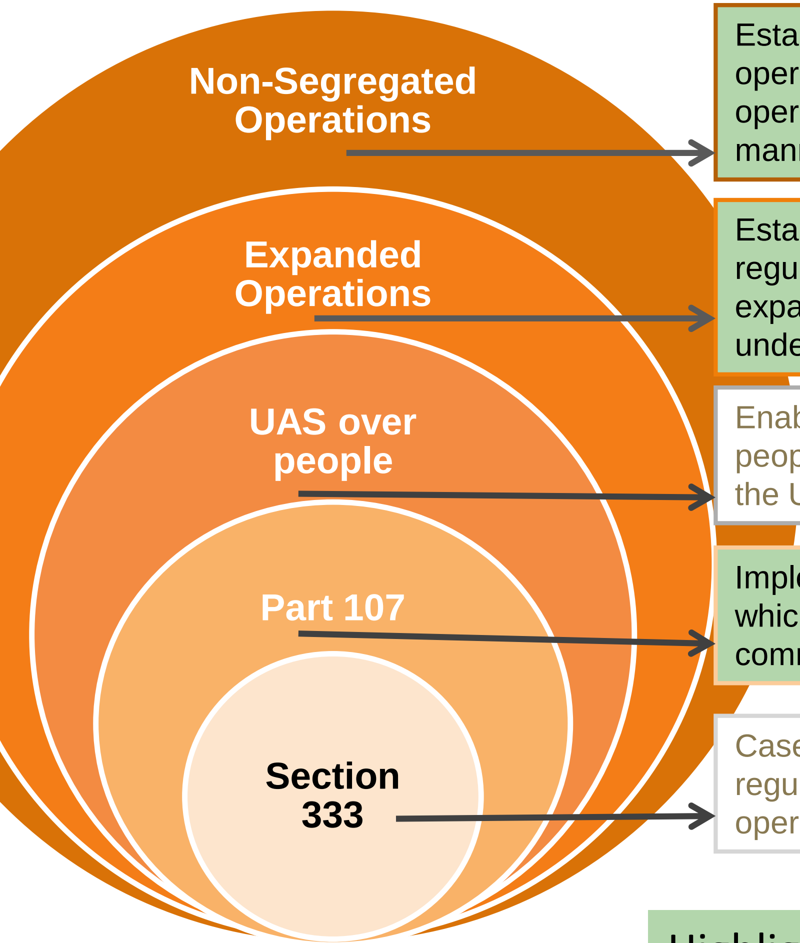
Alert triggered from departing from operational area and relayed to impacted operations

Priority Operations

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

Scheduling and tracking operations and contingency management

Contributions to FAA Decision-Making Process



FAA Decision-Making

- Establish appropriate regulations, infrastructure, and operational procedures to begin enabling UAS operations in existing airspace classes shared with manned aircraft
- Establish and implement an operational and regulatory framework for UAS operations which expands on Part 107 and enables UAS operations under a wider range of circumstances
- Enable operations for small UAS operating over people not directly participating in the operation of the UAS
- Implement an operational and regulatory framework which facilitates operations of small civil UAS for commercial and non-commercial/non-profit purposes
- Case-by-case exemptions granted to existing regulations to enable non-recreational UAS operations before Part 107 rulemaking was final

Highlighted boxes show NASA contributions

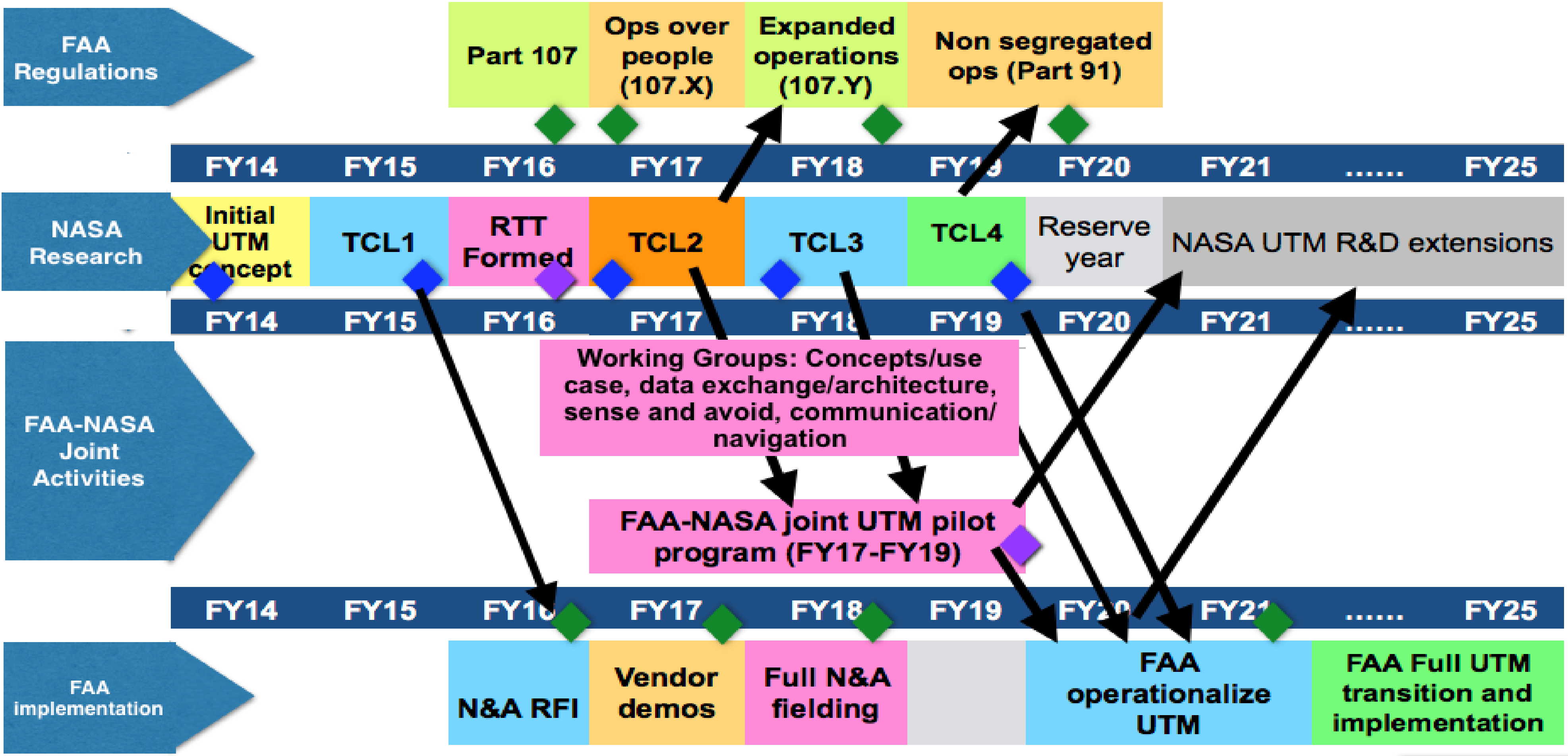
UTM R&D Contributions
(In collaboration with FAA)

- Requirements to operate within UTM environment
- Requirements to operate within ATM environment (UAS in the NAS project)
- Some vehicles will operate in both environments (Tweener)

- Multiple BVLOS operations – requirements
  - TCL2 flight test findings (e.g., wx, contingencies management)
  - Concept/use case work group
  - Data exchange standards through working group and simulations
  - Airspace scheduling through UTM
  - Navigation performance (geo-fence) through working group
- Heterogeneous manned/unmanned multiple operations requirements
  - TCL3 test findings and all of the above
  - DAA readiness assessment for small UAS through working group and tests
- Complex urban operations requirements
  - TCL4 test findings and All of the above
  - Contingency management (no GPS, cell, etc.)

Allowable Exceptions to Part 107 (above 400 ft., < 5 nm from airport) through data exchange and information architecture

UTM Development and Implementation



UTM research platform: cloud-based architecture, standard data exchange, connection through APIs to support scheduling, planning, and tracking of multiple operations in the airspace

- **TCL1:** Multiple operations with API, share information about area of operation and schedule
- **TCL2:** Multiple BVLOS operations with API, and cloud-based architecture
- **TCL3:** Multiple BVLOS operations with manned and unmanned operations
- **TCL4:** Multiple BVLOS operations in complex urban settings

Tech Transfer

- Information exchange standard
- Architecture
- Performance
- UTM Prototype

FAA milestones **NASA milestones** **Joint FAA-NASA milestones** **TCL: Technical Capability Level**

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

Partnerships and Collaboration Approach

- FAA and NASA are actively and closely collaborating
  - Over 200 collaborators: Gov't, industry, academia, FAA test sites, and FAA COE
- Industry is settling down: main players in commercial small UAS operators are emerging
- FAA and NASA will continue to collaborate to ensure agility and safety needs are balanced
- Other working groups
  - Information security group being formed
  - Weather group getting focused
  - Spectrum working group collaborating with CTIA

TCL1 & 2 Demo and Preliminary Results

UTM TCL1 and TCL2 Demonstration Objectives

TCL1

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

TCL2

Evaluate the feasibility of multiple BVLOS operations using a UTM research platform

TCL1: Multiple VLOS Operations

TCL1

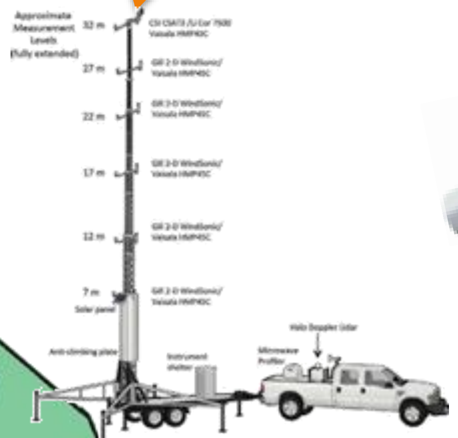
August 2015

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 TCL1 Demonstration Highlights

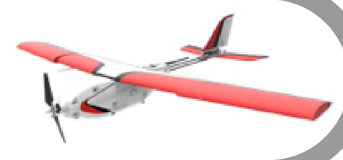
Days of Flight

8

11 Partner Organizations

2 Simultaneous VLOS Operations

10 UAS Platforms



4

Test Conditions

108

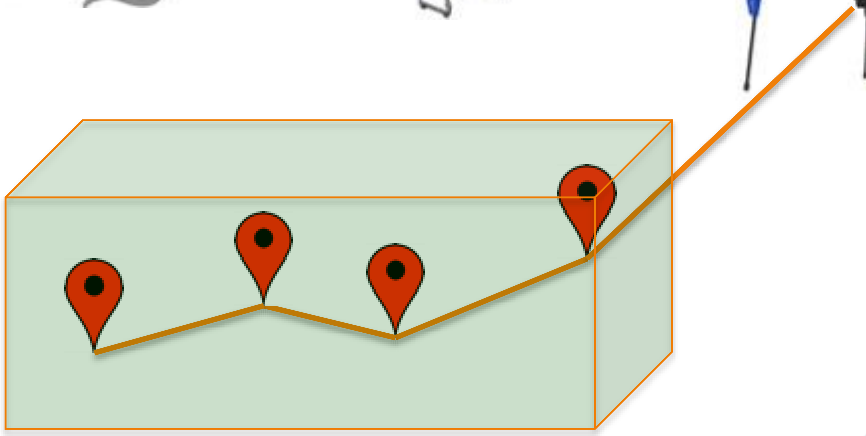
Flights

18

Flight Hours

TCL1 Demonstration Objectives

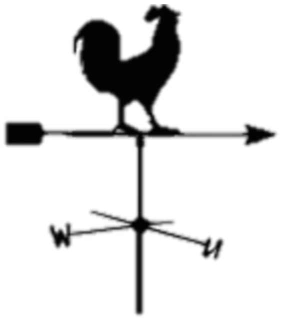
Objective 5: Collect Data on
Noise Signature of UAS Vehicles



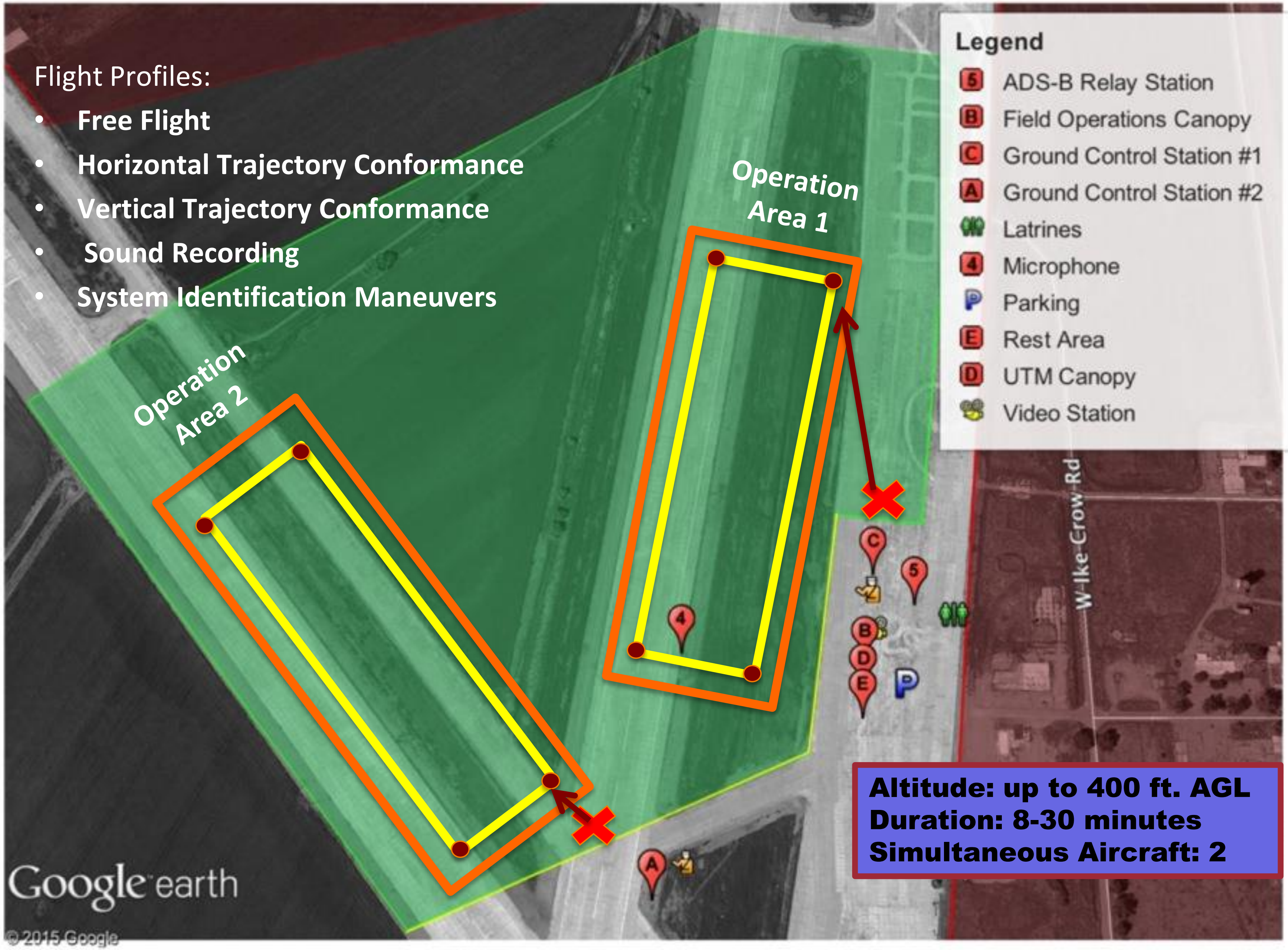
Objective 2: Collect Data on
UAS Navigation Performance Error

Objective 3: Collect Data on
Aircraft Tracking Performance

Objective 1: Demonstrate
UTM Prototype Features



Objective 4: Collect Weather
Observations for Forecasting Models



Flight Profiles:
• Free Flight
• Horizontal Trajectory Conformance
• Vertical Trajectory Conformance
• Sound Recording
• System Identification Maneuvers
Operation Area 1
Operation Area 2
Legend
ADS-B Relay Station
Field Operations Canopy
Ground Control Station #1
Ground Control Station #2
Latrines
Microphone
Parking
Rest Area
UTM Canopy
Video Station
W-Ike-Crow-Rd
Altitude: up to 400 ft. AGL
Duration: 8-30 minutes
Simultaneous Aircraft: 2
Google earth
© 2015 Google

TCL1 Safety-related 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

TCL2: Multiple BVLOS Operations

TCL 2

October 2016

Test Range

UAS Range

Elevation: 5050 feet

Desert Terrain

Missions up to 500 ft.

Operations at 5 Locations

State of Nevada Test Site

Reno

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

UTM TCL2 Demonstration Flight Operations

Live-Virtual Constructive Environment

Altitude Stratified Operations

Situation Awareness Displays

Critical alerts, operational plan information and map displays

2 + 3 = 5

Expanded

Flights up to 1.5 miles away from the pilot in command

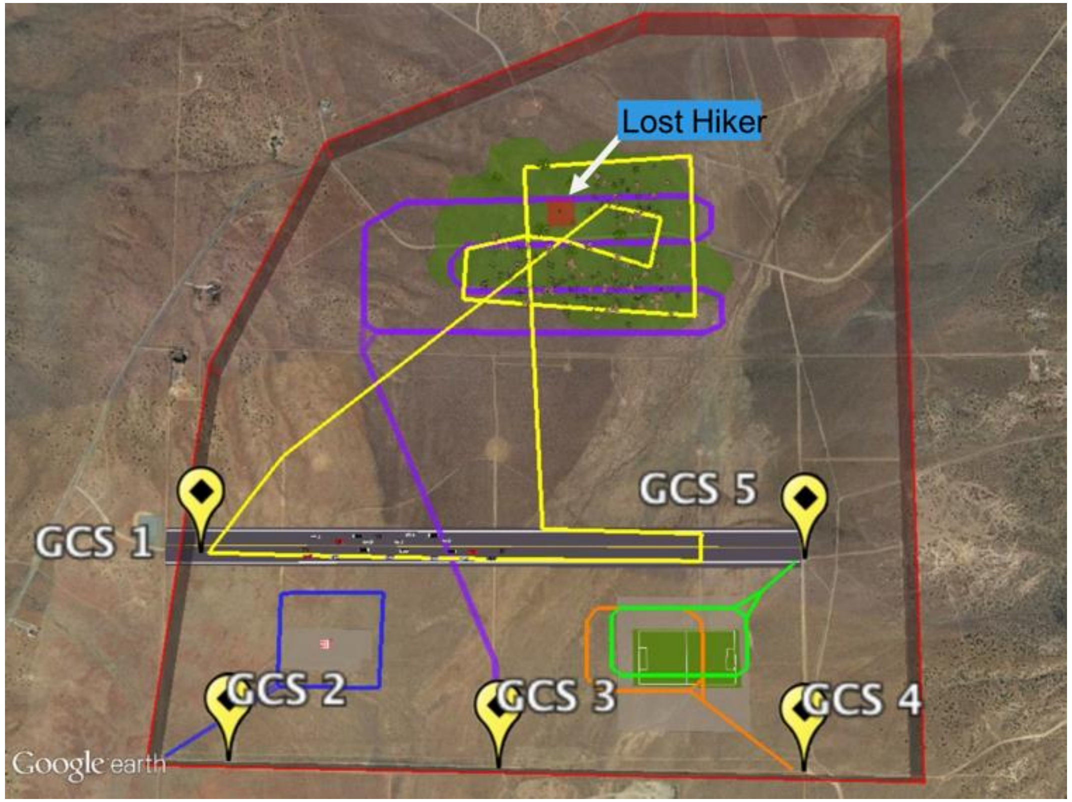
Visual Line of Sight

Hypothetical missions based on industry use cases

Simultaneous Operations

	SCENARIO 1 AGRICULTURE	SCENARIO 2 LOST HIKER	SCENARIO 3 OCEAN	SCENARIO 4 EARTHQUAKE
BVLOS	✓	✓	✓	✓
MULTIPLE BVLOS	✓		✓	
ALTITUDE STRATIFIED VLOS	✓	✓		✓
ALTITUDE STRATIFIED BVLOS			✓	
INTRUDER AIRCRAFT TRACKING	✓		✓	
INTRUDER AIRCRAFT CONFLICT ALERTS	✓		✓	
ROGUE AIRCRAFT CONFLICT ALERTS	✓			
DYNAMIC RE-ROUTING		✓		✓
CONTINGENCY MANAGEMENT CONFLICT ALERTS			✓	✓
PUBLIC SAFETY PRIORITY OPERATION		✓		
SIMULATED VIRTUAL AIRCRAFT		✓		✓

Scenario 2: Lost Hiker



Critical Events (in approximate order):

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

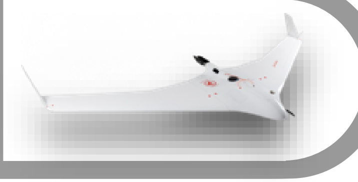
UTM TCL 2 Demonstration Highlights

Days of Flight
5

14 Partner Organizations

2 Simultaneous Altitude Stratified Expanded Operations

11 UAS Platforms



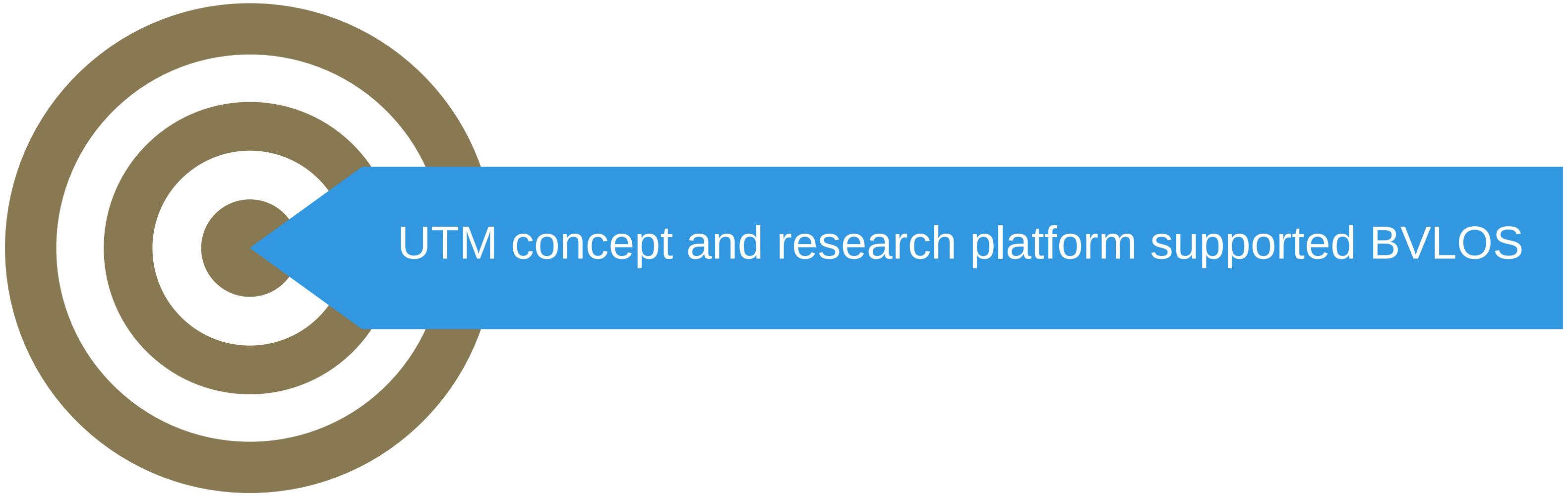
30
Minutes per scenario

4
Scenarios

74
Flights

13.5
Flight Hours

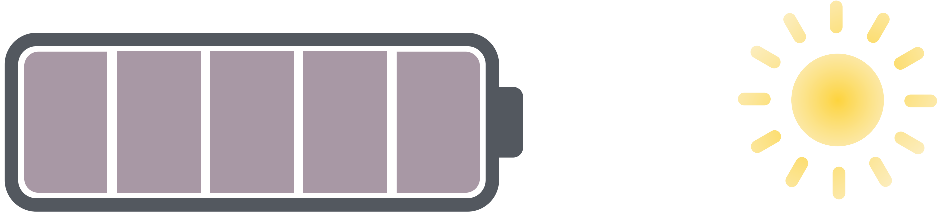
UTM Research Platform



UTM Core Principles and Guiding Tenet	Tested Feature
UAS should avoid each other	Scheduling and Planning Conformance Alerting Proximity Alerting Separation by Segregation (e.g. Geo-fencing)
UAS should avoid manned aircraft	Intruder Alerting Separation by Notification (e.g. NOTAM)
UAS operators should have complete awareness of all constraints in the airspace	UTM Mobile Application Contingency Management Alerts
Public safety UAS have priority within the airspace	Priority Operations
Flexibility where possible and structure where necessary	Altitude Stratification Dynamic Re-routing 4D Segmented Flight Plans

TCL2 Safety-related Observations

Impact of Weather

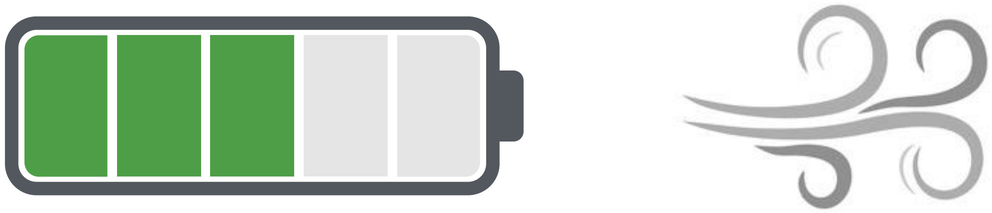


Nominal Aircraft Endurance

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

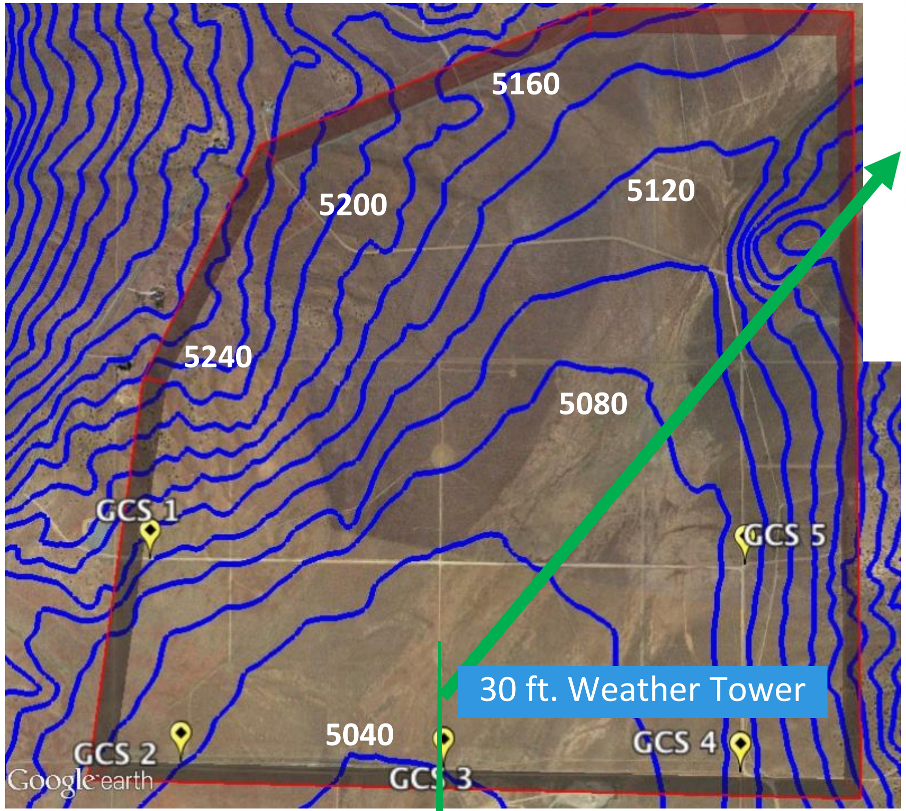
Winds: 5-15 knots

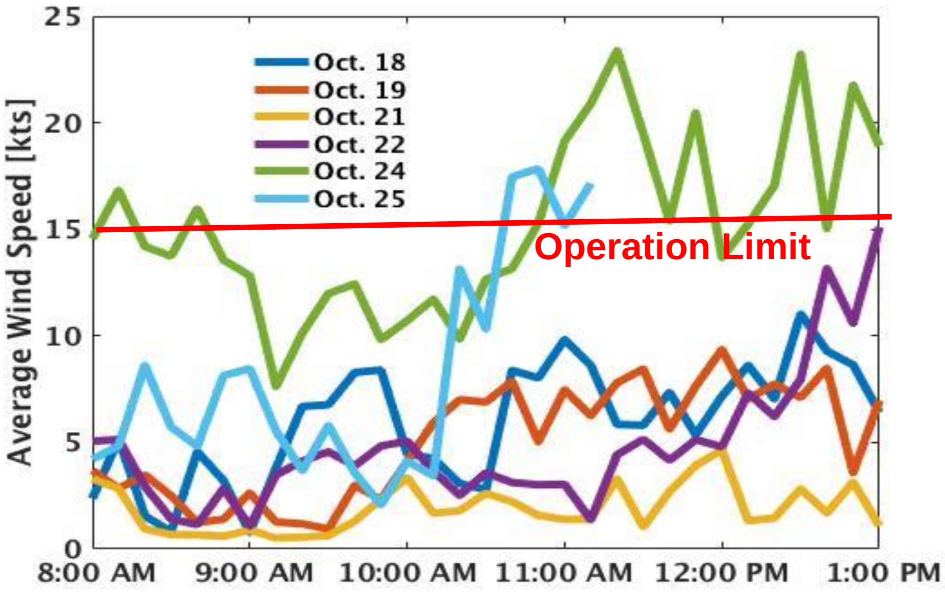
Aircraft experienced substantially **shorter endurance**

UAS should be tested and rated against different operational environments

Impact of Weather

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

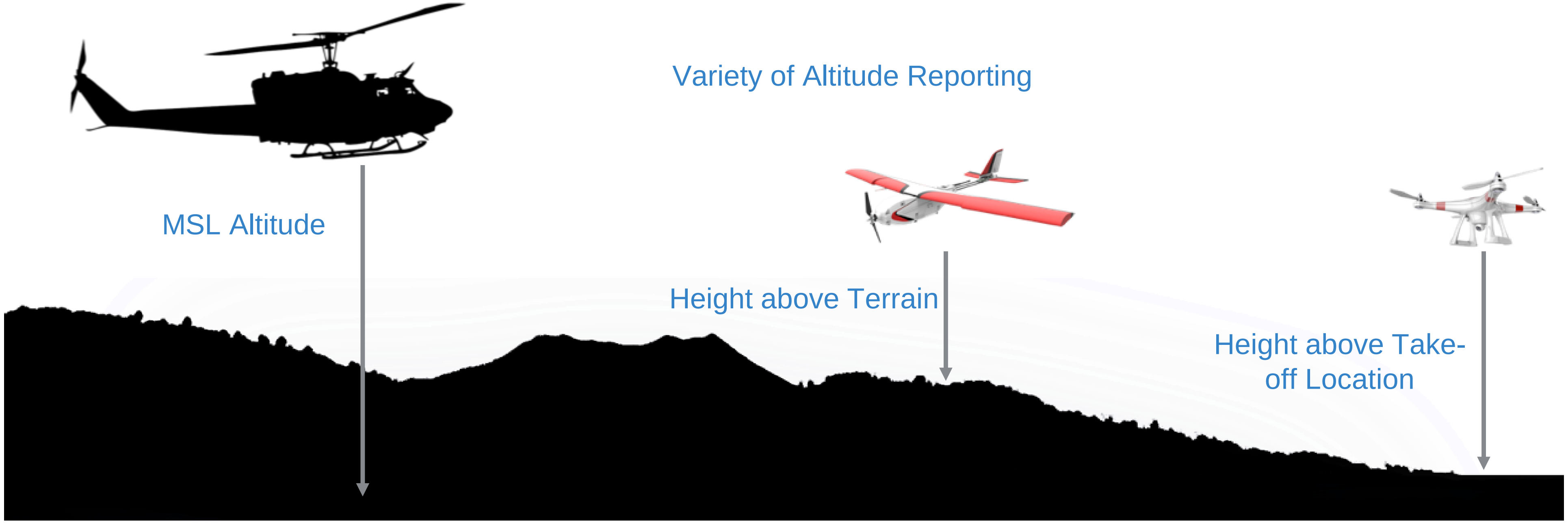
Ground reports were not indicative of conditions UAS experienced aloft

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

Improvements in weather products are needed to support BVLOS

Inconsistent Altitude Reporting

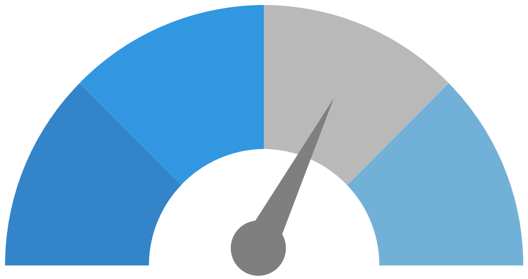
Increased risk of controlled flight into terrain and airborne collision hazard



Altitude Reporting should be consistent or translatable across airspace users

Use of the UTM Research Platform

Awareness of proximity to nearby operations



No Awareness Full Awareness

Medium Awareness

<u>Areas for improvement</u>:

Spectrum Usage

Contingency Management Actions

User reported information (e.g. UREP)

Integrated Airspace Display

Notifications and Alerts

- Operation plan violation alerts need to be clear and informative
- Levels of alerting and severity should be included in messages and displays
- Procedures are needed for returning to normalcy from an operational plan violation

UTM improved awareness, however additional information should be shared between operators

Key Findings using UTM to support Expanded Operations

1 Information sharing provided situation awareness of airspace constraints

UTM clearly raised situation awareness and shifted flight crew's perspective of safety from a self-centered view to an airspace view.

2 Informative weather products are lacking

The test used numerous weather sensing equipment and weather products for forecasting, however the differences in local conditions and when the aircraft was aloft were dramatic.

3 User reported information enhanced safety

When users had the ability to communicate conflicts, like RF interference or weather conditions, it improved the safety and confidence in conducting operations. This was especially true in aggressive weather conditions.

4 Alerting is useful but alerting criteria is needed

Operators benefited from raised situation awareness due to notifications and alerts, but the frequency and severity diluted the usefulness for some operators.

A common awareness of all airspace constraints and hazards is essential for safe BVLOS operations

Key Findings using UTM to support Expanded Operations

5

Minimum set of GCS information is required

Mixed operations require additional information to maintain situation awareness. A minimum set of required display information and common units are needed to ensure each operator has a common dialect to communicate hazards in the airspace.

6

Differences reporting in altitude pose a hazard

A common altitude measure for information sharing and reporting, common units of measure, and an acceptable error tolerance for each measurement are needed.

7

Reliable and Redundant C2 Links

Even in favorable radio line of sight conditions lost link conditions occur and when operating in close proximity of other operations interference when aloft is an issue.

8

Vehicle performance should be rated by environment

Several vehicles greatly underperformed from what was listed by the manufacturers due to the environmental conditions. More uniformity and transparency as to how UAS are tested and at what conditions, is needed.

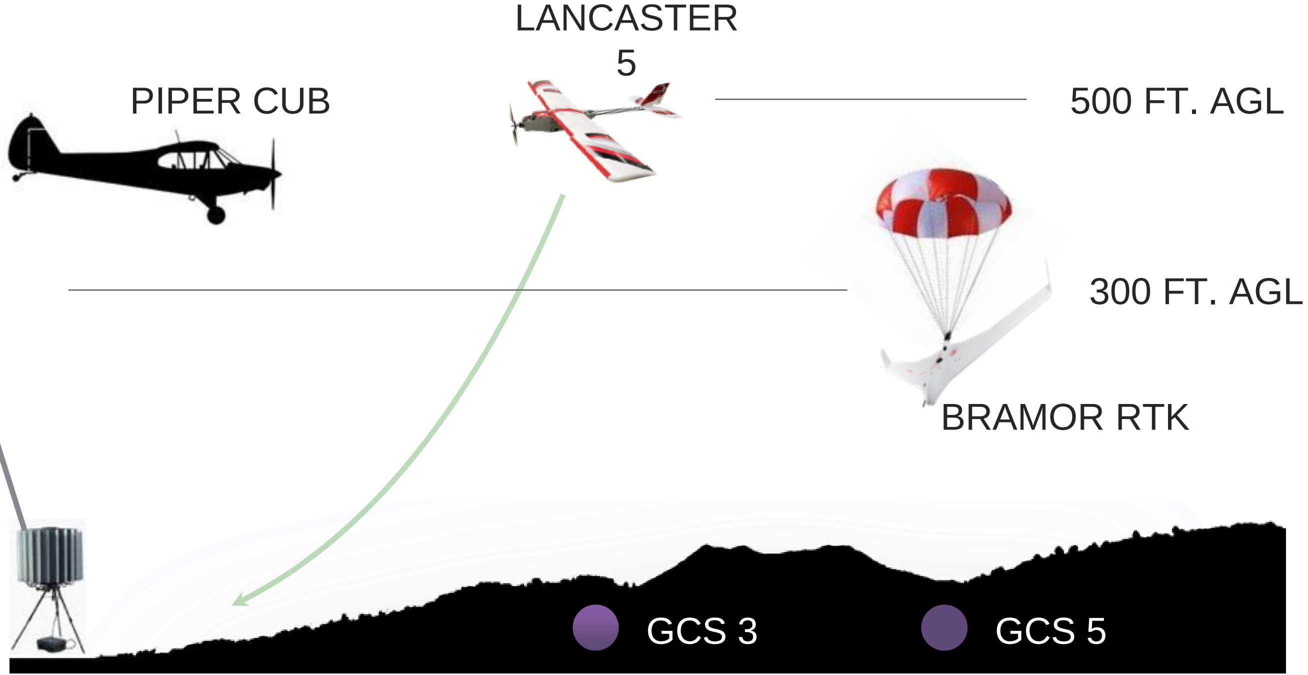
Industry standardization can reduce risk for BVLOS Operations

Key Findings using UTM to support Expanded Operations

Manned Aircraft Test Range Incursion on 10/22/2016

9 Surveillance enhanced situation awareness

Surveillance may not be a requirement in all TCL2 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

01 Operators need to **display airspace information** and have access to other operator’s operational intent and contingency actions in off-nominal conditions

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

05 **Operator training**, **UTM information integrated with GCS**, displaying airspace constraints, and procedural guidance are needed to support **separation provision**

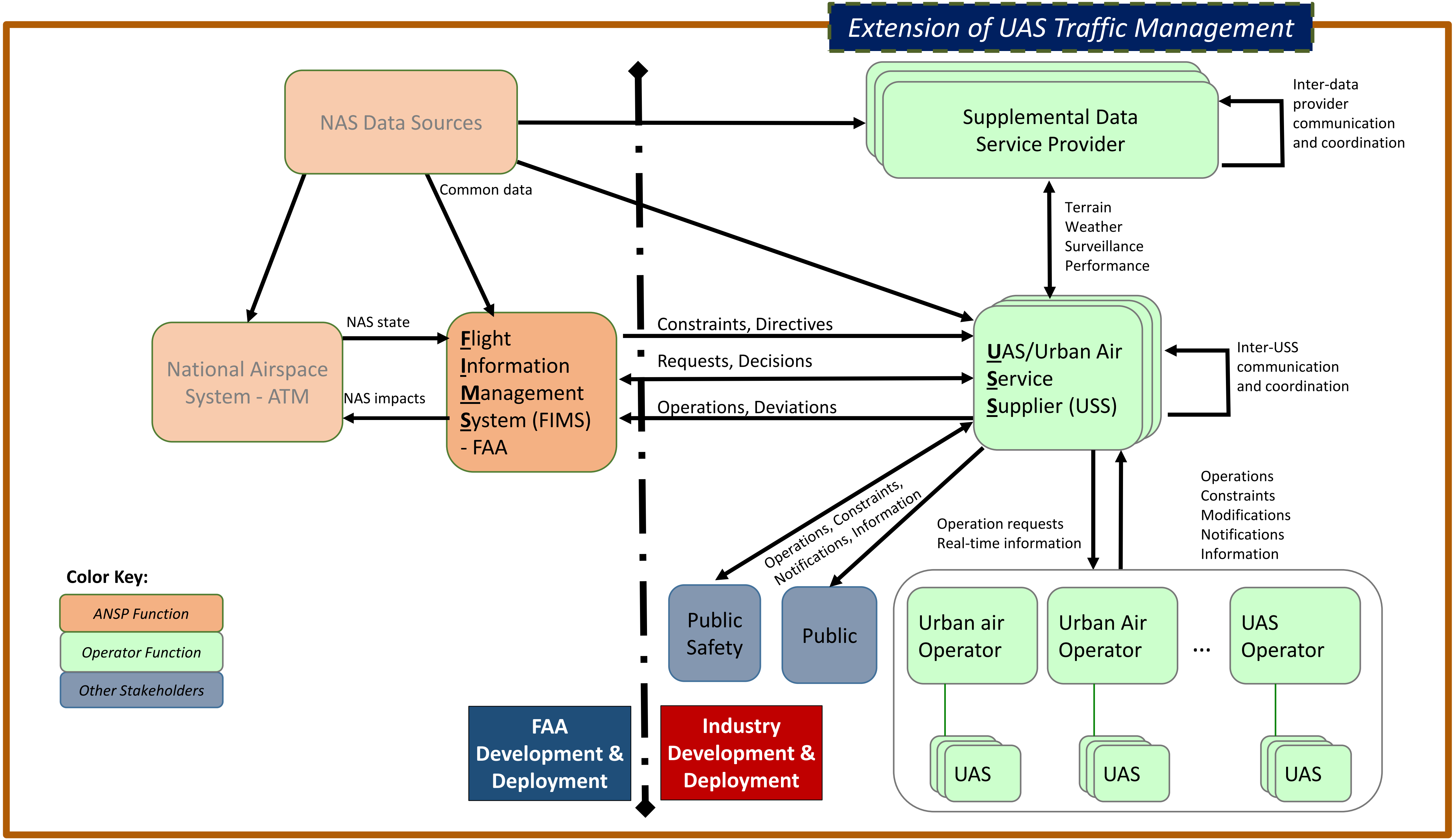
Summary/Next Steps

Next Steps

- Additional TCL2 multiple BVLOS tests at all FAA test sites
  - Released statement of work recently
- TCL3 preparations ongoing
- Working groups continue: Join the collaborative innovation
- Continue to work closely with FAA on UTM pilot project

QUESTIONS?

Embracing innovation in aviation while respecting its safety tradition



Extension of UAS Traffic Management
NAS Data Sources
Supplemental Data Service Provider
Inter-data provider communication and coordination
Common data
Terrain
Weather
Surveillance
Performance
National Airspace System - ATM
NAS state
NAS impacts
Flight Information Management System (FIMS) - FAA
Constraints, Directives
Requests, Decisions
Operations, Deviations
UAS/Urban Air Service Supplier (USS)
Inter-USS communication and coordination
Operations, Constraints, Notifications, Information
Operation requests
Real-time information
Operations
Constraints
Modifications
Notifications
Information
Color Key:
ANSP Function
Operator Function
Other Stakeholders
Public Safety
Public
Urban air Operator
Urban Air Operator
...
UAS Operator
UAS
UAS
UAS
FAA Development & Deployment
Industry Development & Deployment