



# Unmanned Aircraft Systems Traffic Management (UTM)

## SAFELY ENABLING UAS OPERATIONS IN LOW-ALTITUDE AIRSPACE

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- 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

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- 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 **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



## 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

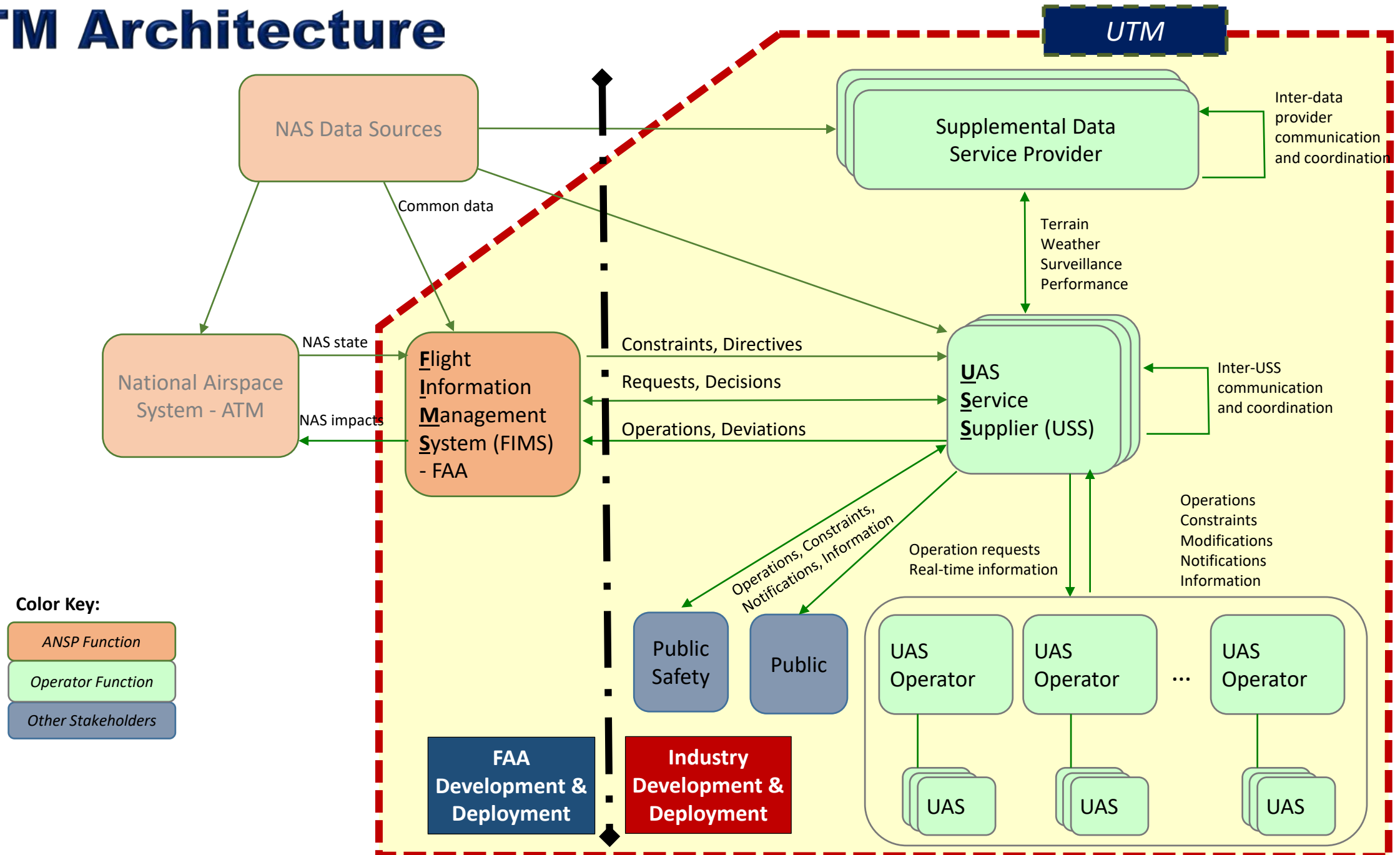
## Vehicle Considerations

- 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 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**

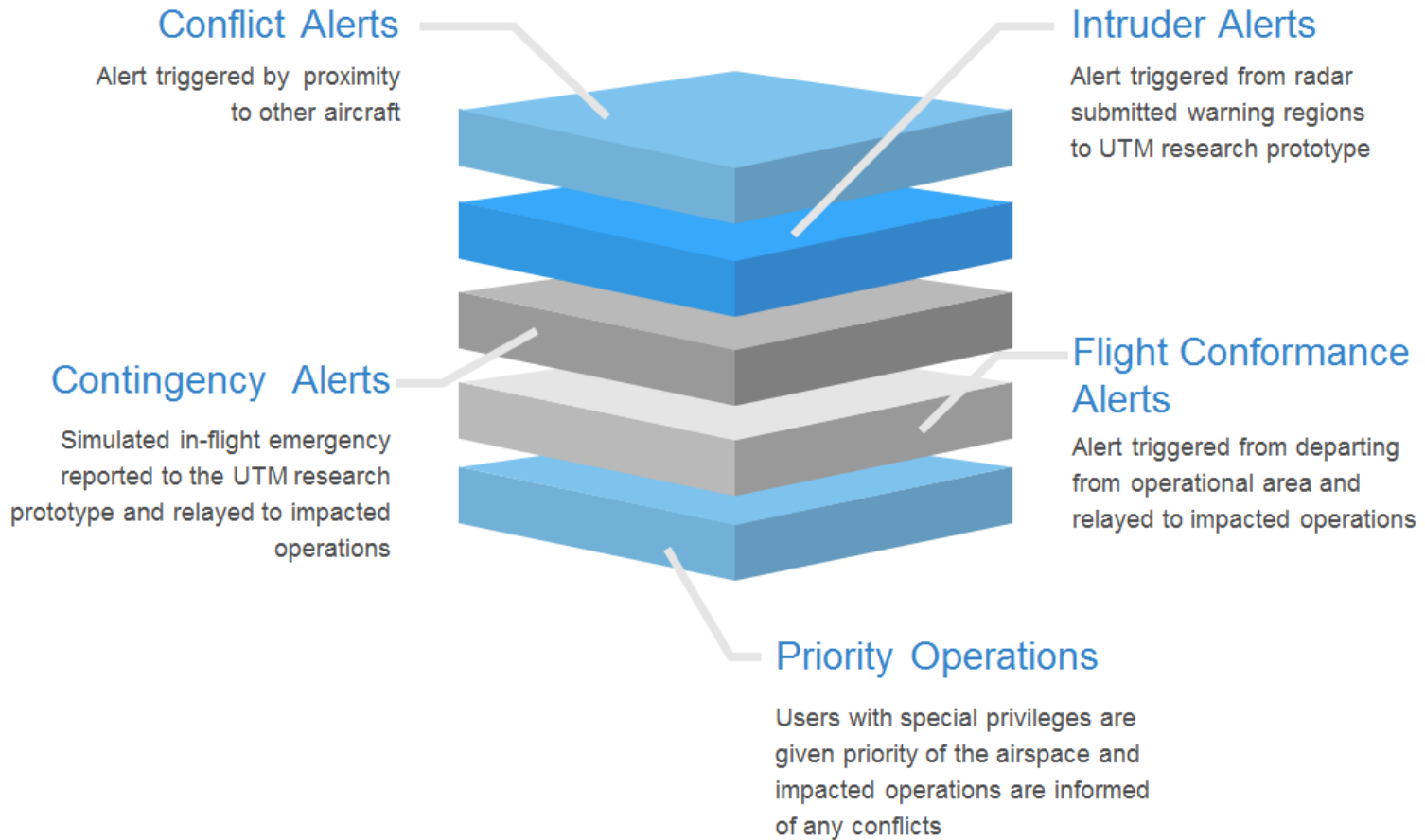
## CAPABILITY 4: FOCUSES ON ENABLING MULTIPLE HETEROGENEOUS HIGH DENSITY URBAN OPERATIONS

- 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



Scheduling and tracking operations and contingency management



# 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

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- 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

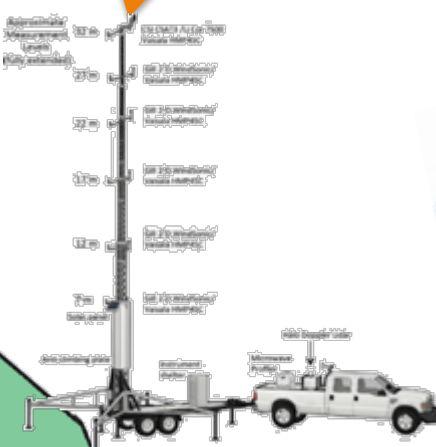

Elevation: 166 feet MSL

Flat Agricultural Farmland



Operations at 2 Locations



**Crows Landing, CA**



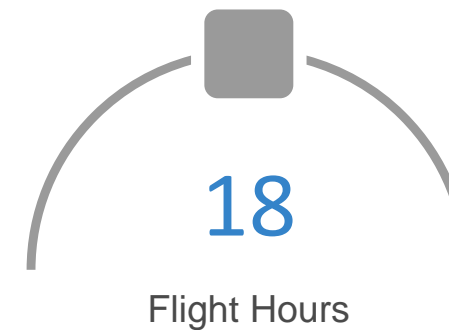
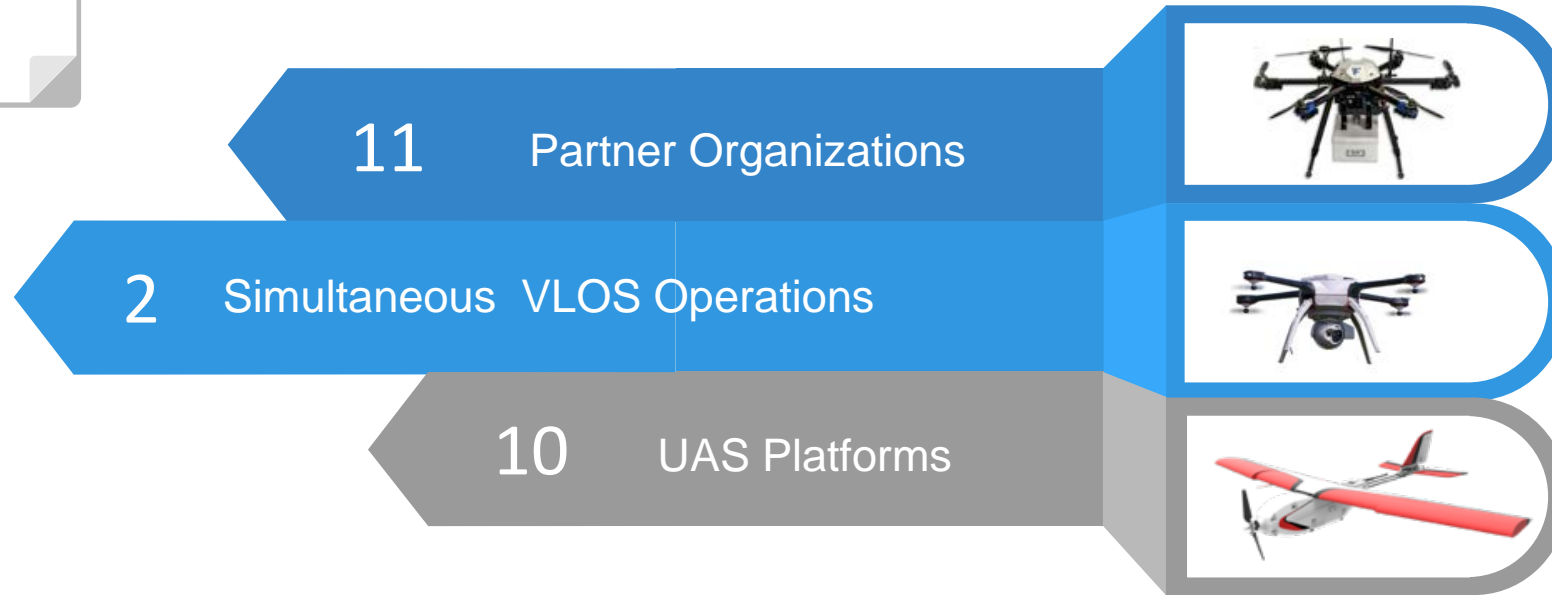
**Acoustic Sensors**



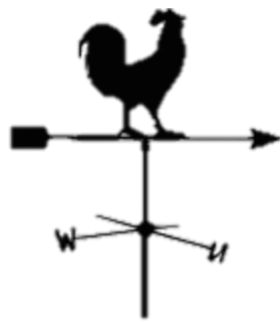
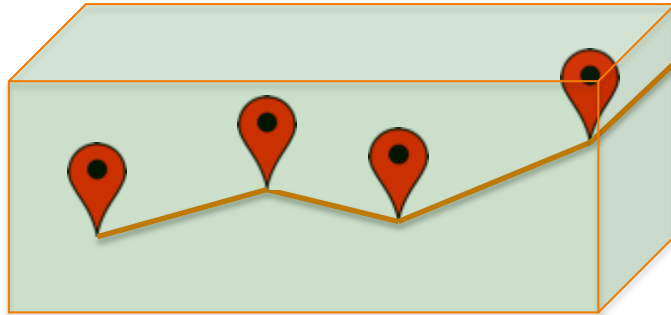
**Weather Sensors**  
100 ft. Weather Tower  
Radiosonde Weather Balloon  
Remote Automated Weather Station

**SRHawk Radar**  
Used to detect small UAS

# UTM TCL1 Demonstration Highlights



# 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

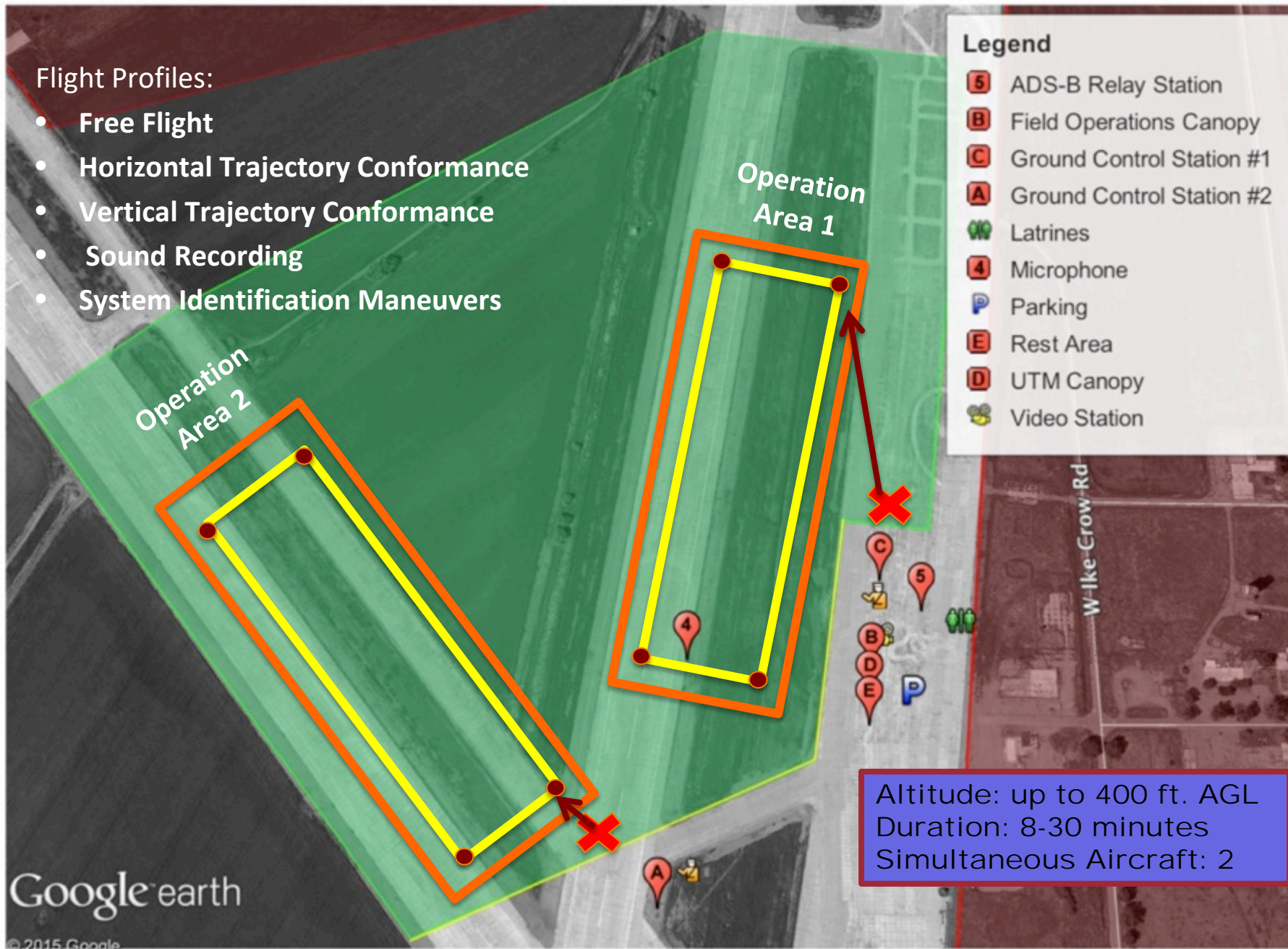


Flight Profiles:

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

Legend

- 5 ADS-B Relay Station
- B Field Operations Canopy
- C Ground Control Station #1
- A Ground Control Station #2
- Latrines
- 4 Microphone
- P Parking
- E Rest Area
- D UTM Canopy
- Video Station



Altitude: up to 400 ft. AGL  
Duration: 8-30 minutes  
Simultaneous Aircraft: 2



# TCL1 Safety-related Observations

## Observations:

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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:

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- 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

### Operational Area



### 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



### Expanded

Flights up to 1.5 miles away from the pilot in command



### Visual Line of Sight

Hypothetical missions based on industry use cases

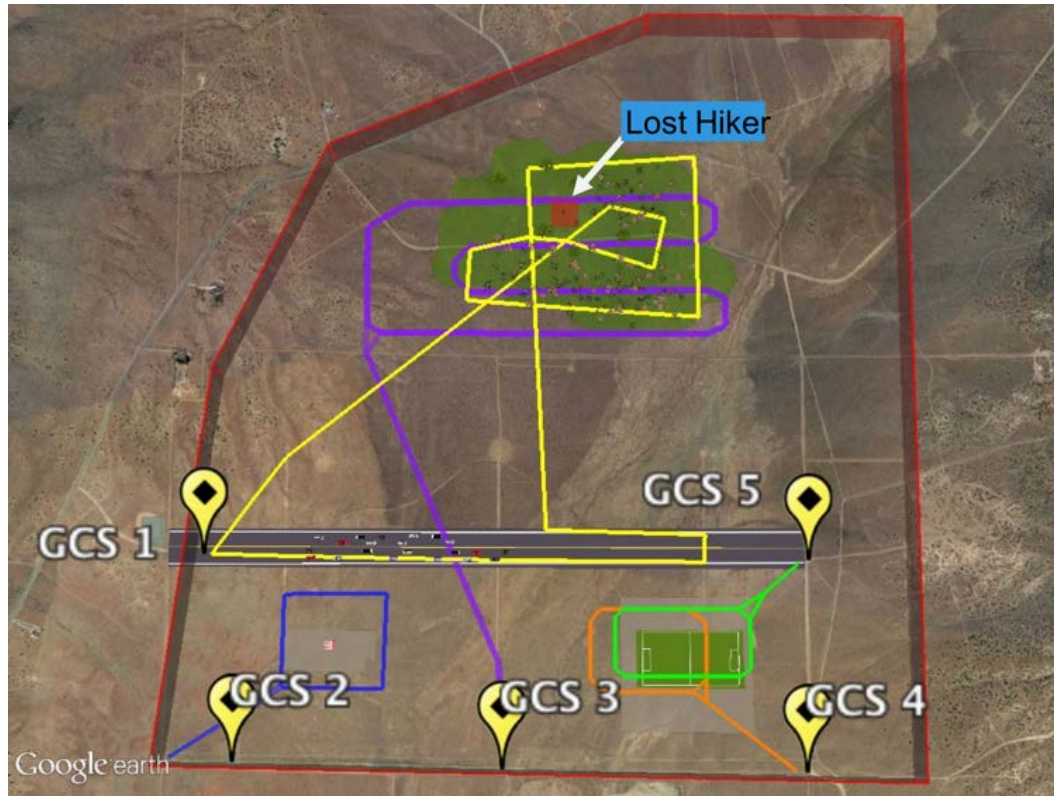


### Simultaneous Operations

|  | SCENARIO<br>1<br>AGRICULTURE        | SCENARIO<br>2<br>LOST HIKER         | SCENARIO<br>3<br>OCEAN              | SCENARIO<br>4<br>EARTHQUAKE         |
|--|-------------------------------------|-------------------------------------|-------------------------------------|-------------------------------------|
| BVLOS  | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> |
| MULTIPLE BVLOS                               | <input checked="" type="checkbox"/> |                                     | <input checked="" type="checkbox"/> |                                     |
| ALTITUDE STRATIFIED<br>VLOS                  | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> |                                     | <input checked="" type="checkbox"/> |
| ALTITUDE STRATIFIED<br>BVLOS                 |                                     |                                     | <input checked="" type="checkbox"/> |                                     |
| INTRUDER AIRCRAFT<br>TRACKING                | <input checked="" type="checkbox"/> |                                     | <input checked="" type="checkbox"/> |                                     |
| INTRUDER AIRCRAFT<br>CONFLICT ALERTS         | <input checked="" type="checkbox"/> |                                     | <input checked="" type="checkbox"/> |                                     |
| ROGUE AIRCRAFT<br>CONFLICT ALERTS            | <input checked="" type="checkbox"/> |                                     |                                     |                                     |
| DYNAMIC RE-<br>ROUTING                       |                                     | <input checked="" type="checkbox"/> |                                     | <input checked="" type="checkbox"/> |
| CONTINGENCY<br>MANAGEMENT<br>CONFLICT ALERTS |                                     |                                     | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> |
| PUBLIC SAFETY<br>PRIORITY OPERATION          |                                     | <input checked="" type="checkbox"/> |                                     |                                     |
| SIMULATED VIRTUAL<br>AIRCRAFT                |                                     | <input checked="" type="checkbox"/> |                                     | <input checked="" type="checkbox"/> |



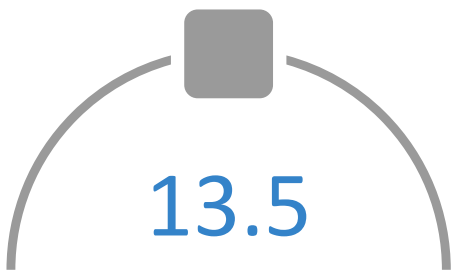
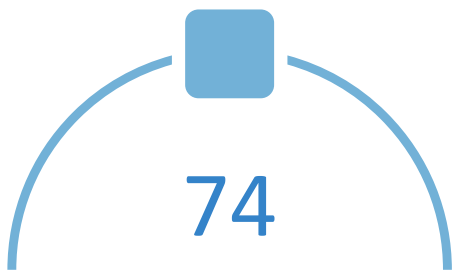
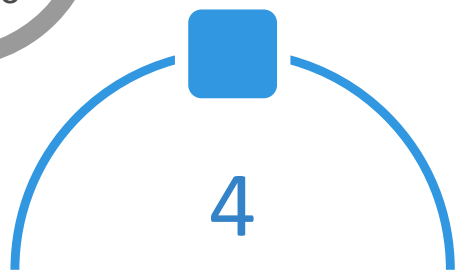
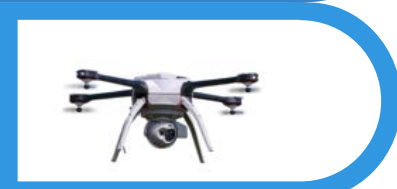
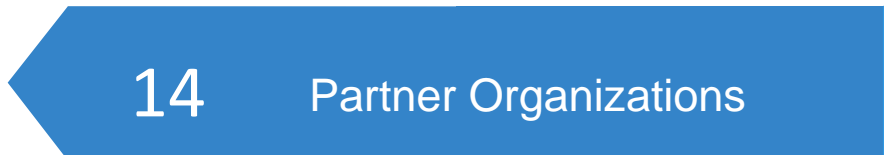
# Scenario 2: Lost Hiker



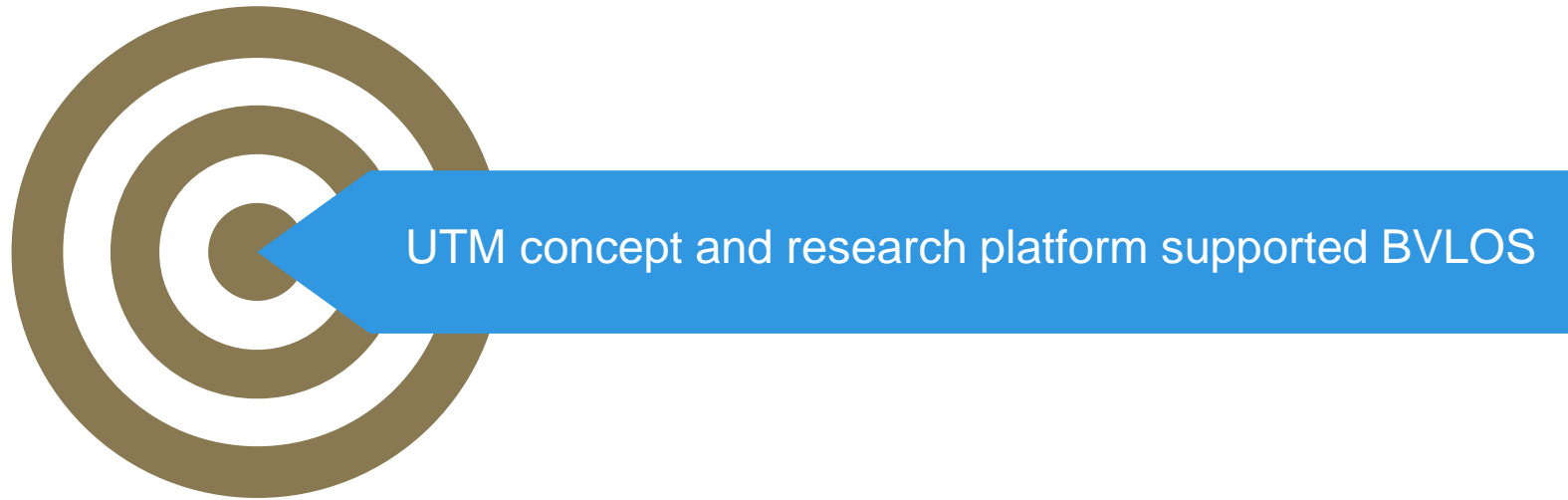
- Critical Events** (in approximate order):
- **GCS1** ( submits all plans while logged in as special user
  - **GCS3** sends message to RC "Reporting a lost hiker in area..." (once all GCS have launched)
  - **ALL GCS** receive message from RC "Simulated lost hiker in area..." (once all GCS have launched)
  - **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)

|               |                                |                                  |
|---------------|--------------------------------|----------------------------------|
| <b>GCS 1:</b> | Traffic Monitoring @ 300 ft    | Medical Supply Delivery @ 300 ft |
| <b>GCS 2:</b> | Cell Tower Inspection @ 200 ft |                                  |
| <b>GCS 3:</b> | Forest Ranger @ 500 ft         |                                  |
| <b>GCS 4:</b> | News Reporter @ 500 ft         |                                  |
| <b>GCS 5:</b> | News Reporter @ 300 ft         |                                  |

# UTM TCL 2 Demonstration Highlights



# UTM Research Platform



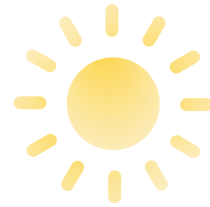
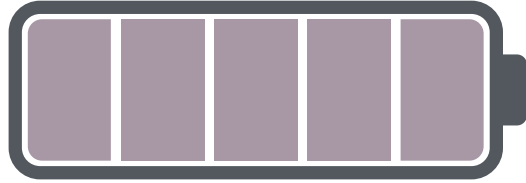
| UTM Core Principles and Guiding Tenet  | Tested Feature   |
|--|--|
| <p align="center"><b>UAS should avoid each other</b></p>   | <p align="center">Scheduling and Planning<br/>Conformance Alerting<br/>Proximity Alerting<br/>Separation by Segregation (e.g. Geo-fencing)</p> |
| <p align="center"><b>UAS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



# TCL2 Safety-related Observations

# Impact of Weather

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## Nominal Aircraft Endurance

Multi-Rotors: 20-40 minutes

Fixed-Wing: 45-200+ minutes

Reno-Stead Elevation: 5,050 ft

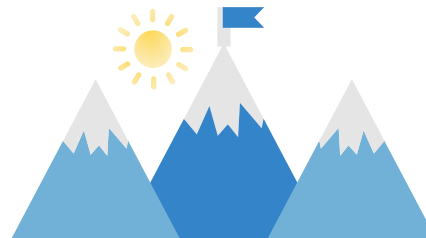
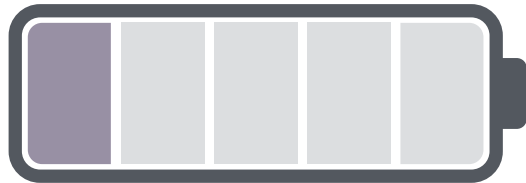


## Cool Temperatures

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

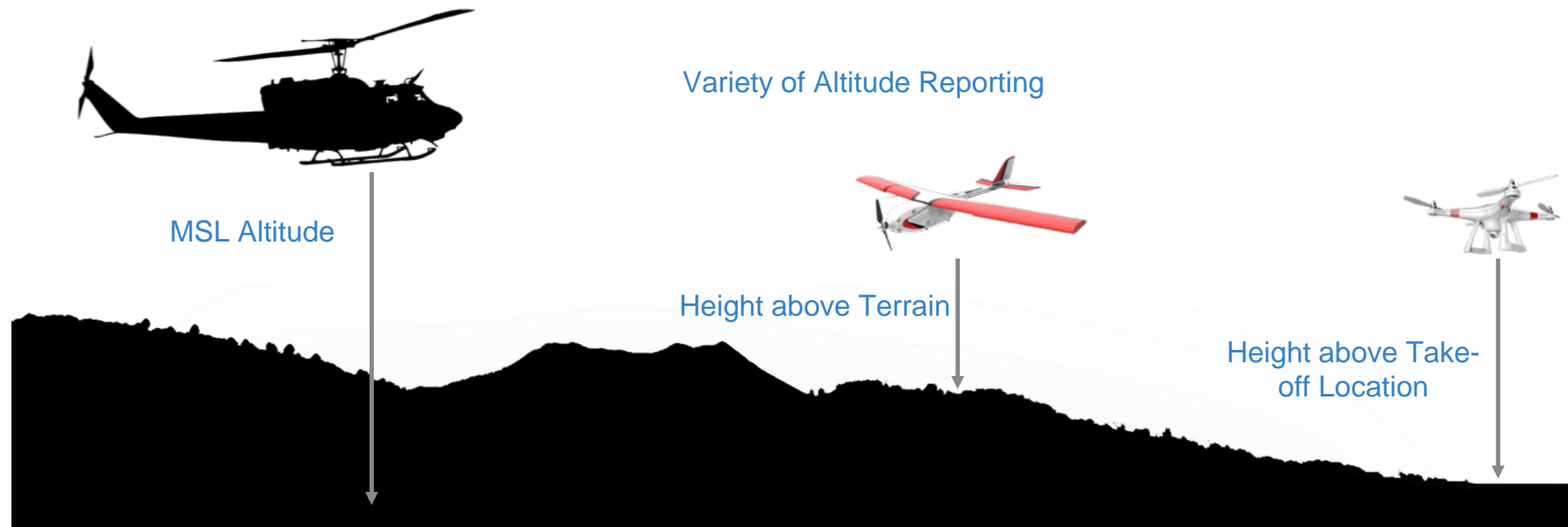
Winds: 5-15 knots

Aircraft experienced substantially **shorter endurance**

UAS should be tested and rated against different operational environments

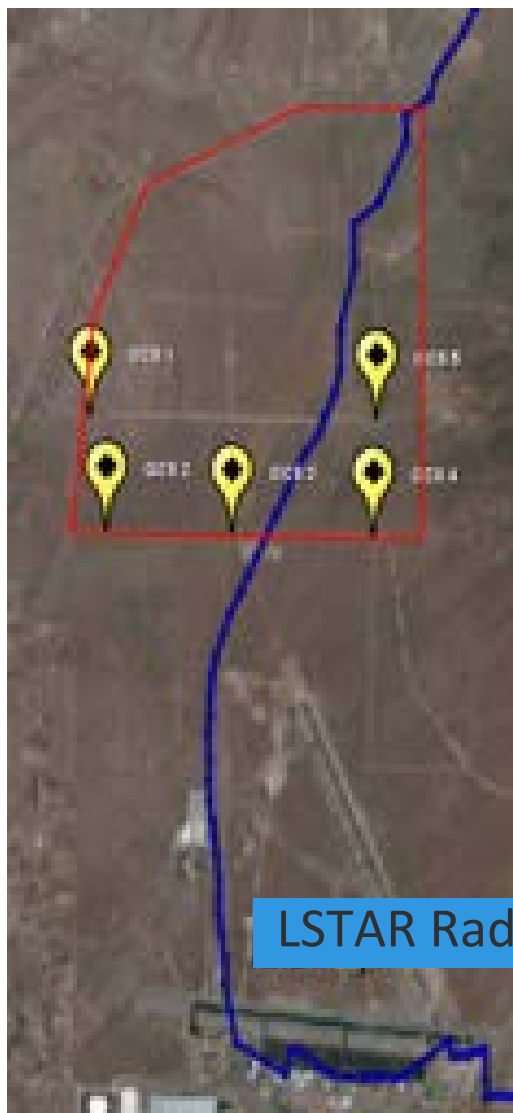
# Inconsistent Altitude Reporting

**Increased risk of controlled flight into terrain and airborne collision hazard**



Altitude Reporting should be consistent or translatable across airspace users

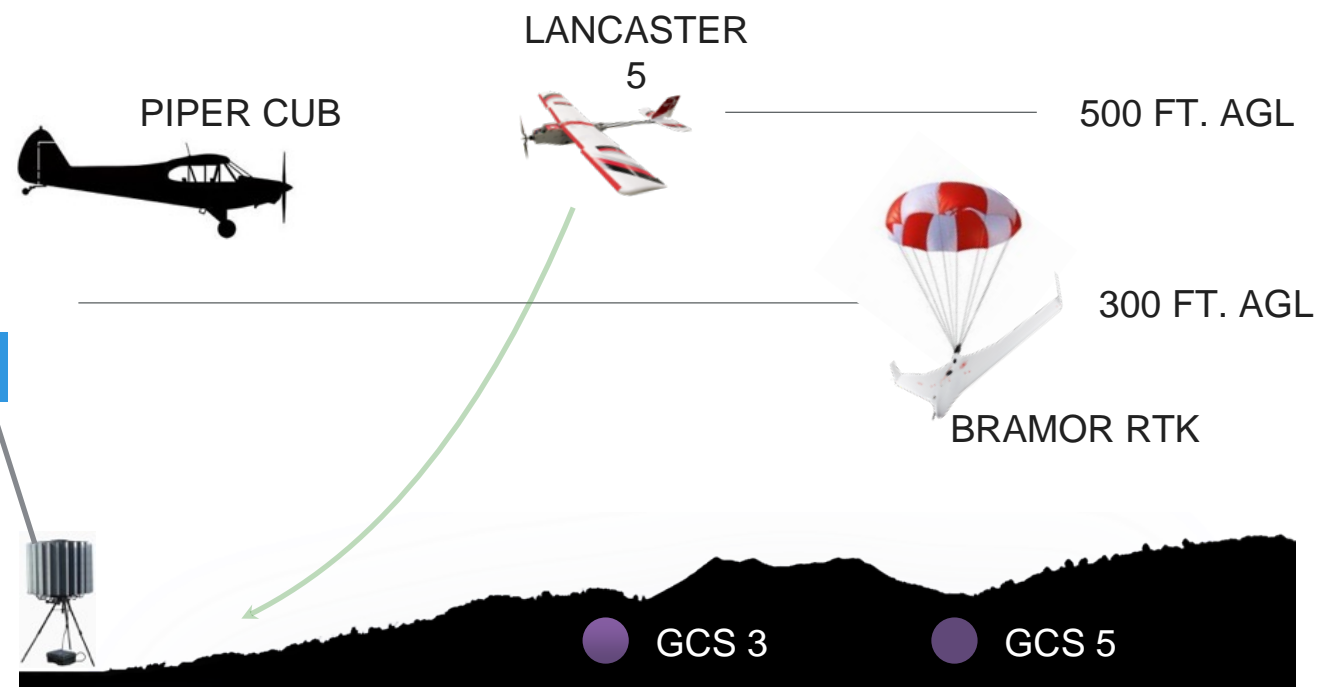
# Key Findings using UTM to support Expanded Operations



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**





# Acceptance



- National UAS Standardized Testing and Rating (NUSTAR)
- Current State of the Art
  - Many performance measures are considered for UAS
  - Capability to assess and certify performance benchmarking is a huge gap
- Proposed Solution
  - Responsible, credible, collaborative tests and data
  - Parallel: Underwriter's Laboratory, Consumer Reports, JD Powers
- Approach
  - Drop tests
  - Urban, rural, atmospheric conditions (e.g., fog, smog, rain, winds)
  - Sense and avoid, Simulated obstructions, GPS denied conditions, etc.
  - Cyber security
- Data oriented rating, acceptance, and assurance
- Every UAS vehicle model goes through
- Support UAS manufacturers, consumers, FAA, insurance companies, and public at large through objective assessments



# Summary/Next Steps

# Next Steps

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- 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

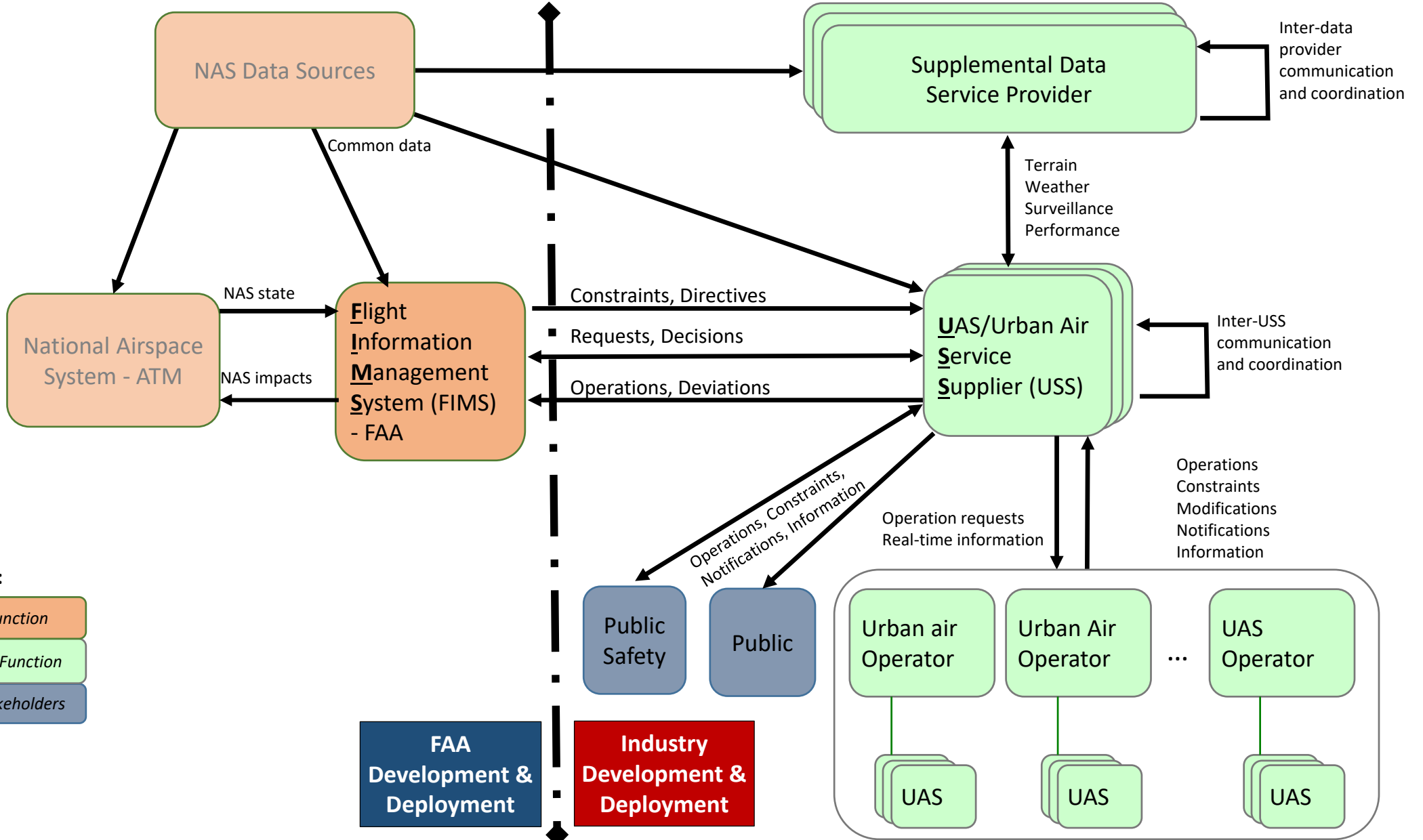
# QUESTIONS?

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*Embracing innovation in aviation while respecting its safety tradition*

# Extension of UAS Traffic Management



**Color Key:**

- ANSP Function
- Operator Function
- Other Stakeholders