Unmanned Aircraft Systems Traffic Management (UTM)

SAFELY ENABLING UAS OPERATIONS IN LOW-ALTITUDE AIRSPACE

Jeffrey Homola and Dr. Brandon Owens

Cisco IoT SEVT

May 22, 2017

Acknowledgments

Dr. Thomas Prevot, Dr. Marcus Johnson,

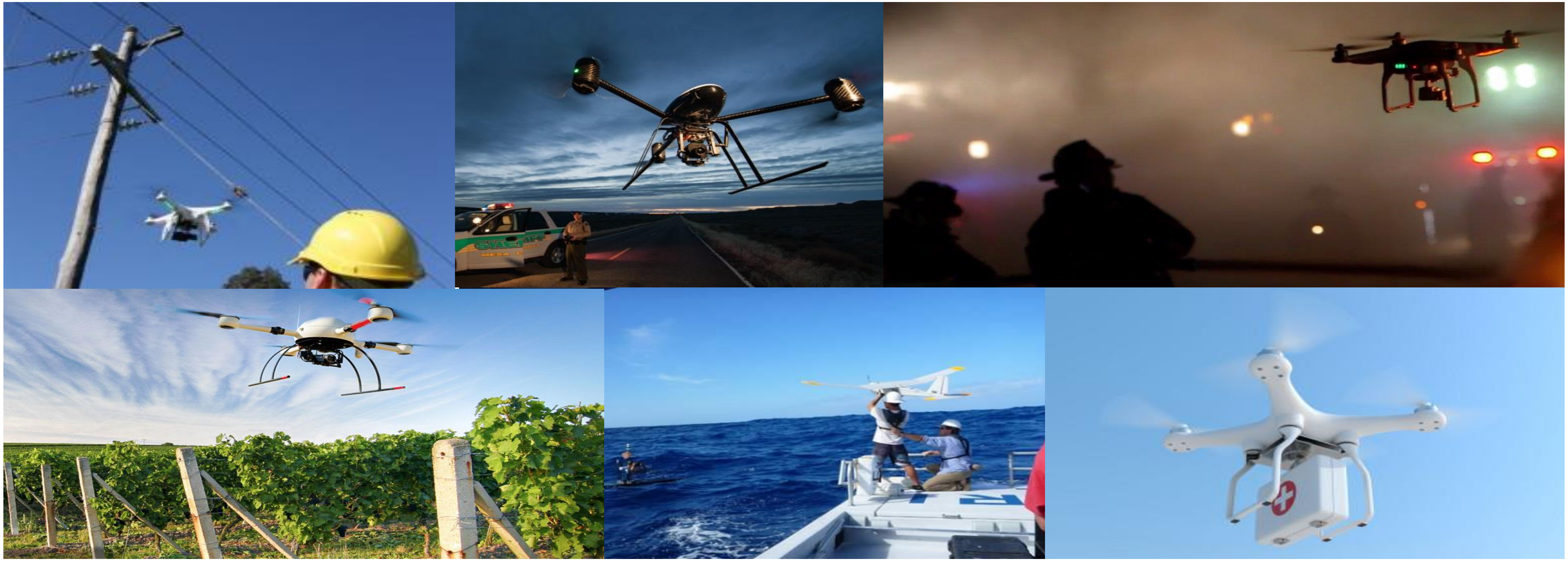
Dr. Joseph Rios and Dr. Parimal Kopardekar

Outline

- Overview
- Architecture
- Approach and schedule
- Technical Capability Level 1 (TCL1) Demonstration overview and results
- TCL 2 Demonstration overview and results
- Next Steps

Overview

UAS Traffic Management (UTM)



- Numerous types of UAS applications and use cases
- Many potential benefits and opportunities
- Consistent growth in demand for UAS and their operations

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 is a separate, but complementary system to the Air Traffic Management (ATM) system
- 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

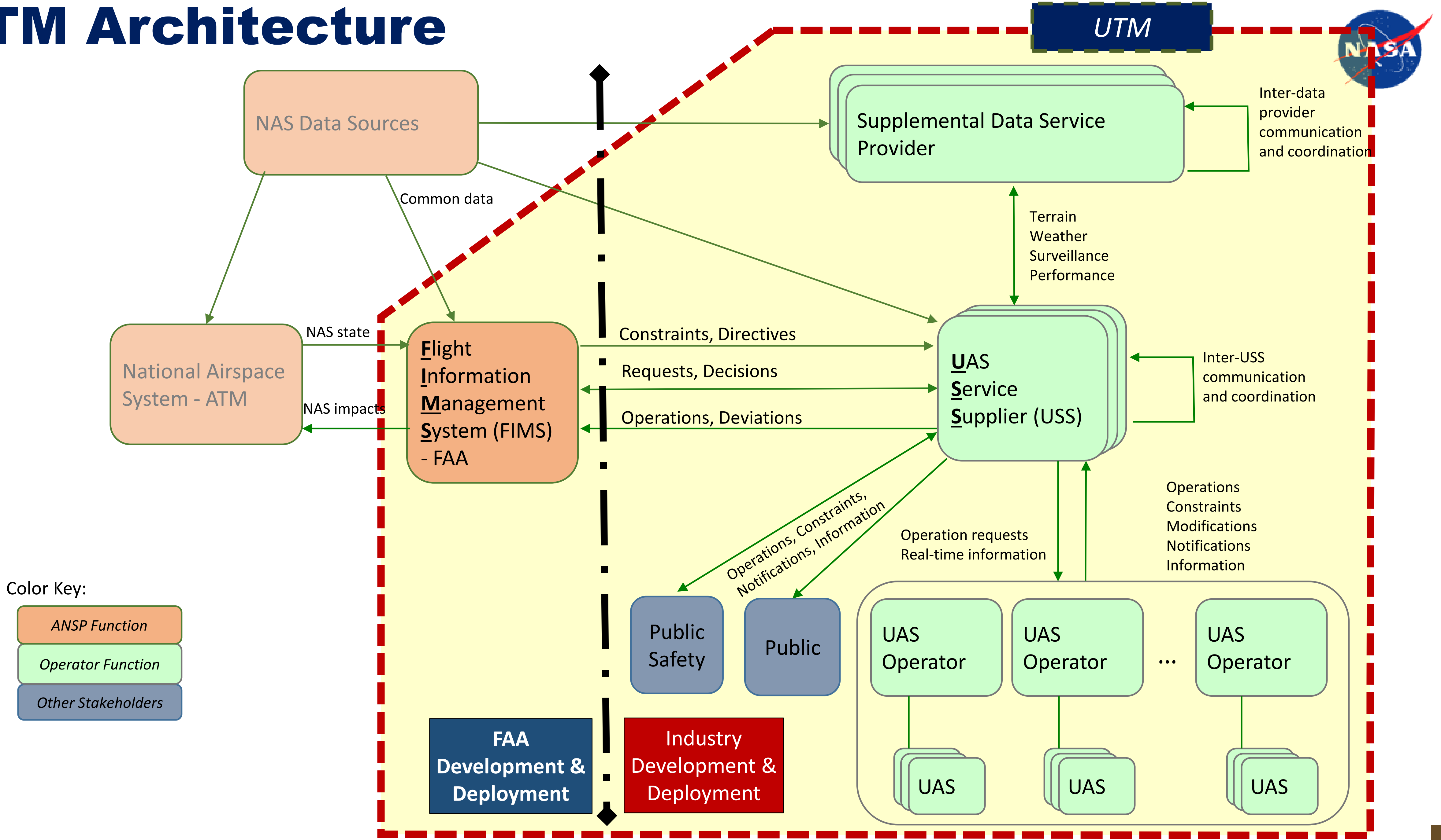
How to enable multiple BVLOS operations in low-altitude airspace?
UTM addresses critical gaps associated with lack of support for uncontrolled operations

Value of UTM

- Higher density UAS operations
- Beyond visual light of sight (BVLOS) UAS operations
- Manned and unmanned vehicle operations coordination
- Unmanned vehicle operations coordination through agreed upon data/information exchanges about each others' operations and with FAA NAS systems
- Exceptions handling
- Beyond Part 107 operations– e.g. entry into controlled airspace

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

→ Info sharing

TCL2: *multiple BVLOS, rural*

→ Initial BVLOS

→ Intent sharing

→ Geo-fenced ops

TCL3: *multiple BVLOS, near airports, suburban*

→ Routine BVLOS

→ Airborne DAA, V2V

→ Avoid static obstacles

UTM Progression

TCL1: ***multiple VLOS***
- → API-based networked ops
- → Info sharing

TCL2: ***multiple BVLOS, rural***
- → Initial BVLOS
- → Intent sharing
- → Geo-fenced ops

TCL3: ***multiple BVLOS, near airports, suburban***
- → Routine BVLOS
- → Airborne DAA, V2V
- → Avoid static obstacles

TCL4: ***complex urban BVLOS***
- → BVLOS to doorstep
- → Track and locate
- → Avoid dynamic obstacles
- → Large scale contingencies

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
- FAA and NASA will continue to collaborate to ensure agility and safety needs are balanced
- Working groups
  - Information security group being formed
  - Weather group getting focused
  - Spectrum working group collaborating with CTIA
  - Concept and Use Cases
  - Communications and Navigation
  - Sense and Avoid

UTM TCL 1 and TCL 2 Demonstration Objectives

TCL1

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

TCL1

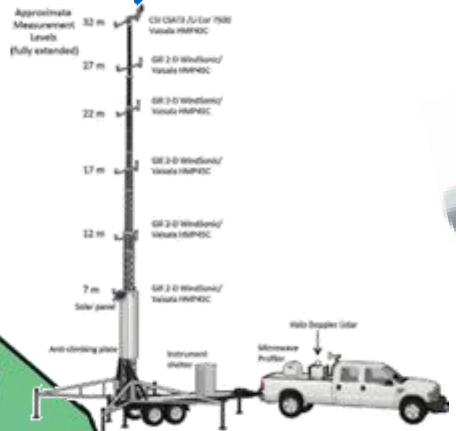
August 2015

UAS Range

Elevation: 166 feet MSL

Flat Agricultural Farmland

Operations at 2 Locations



Weather Sensors

100 ft Weather Tower

Radiosonde Weather Balloon

Remote Automated Weather Station

Acoustic Sensors

SRHawk Radar

Used to detect small UAS

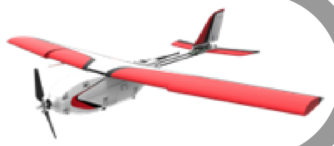
UTM TCL 1 Demonstration Highlights

Days of Flight
8

11 Partner Organizations

2 Simultaneous VLOS Operations

10 UAS Platforms



4
Test Conditions

108
Flights

18
Flight Hours

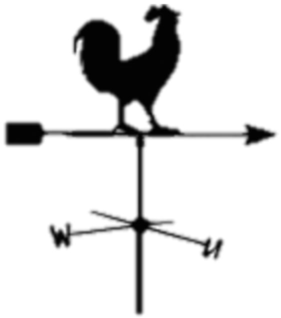
TCL 1 Demonstration Objectives

Objective 5: Collect Data on Noise Signature of UAS Vehicles

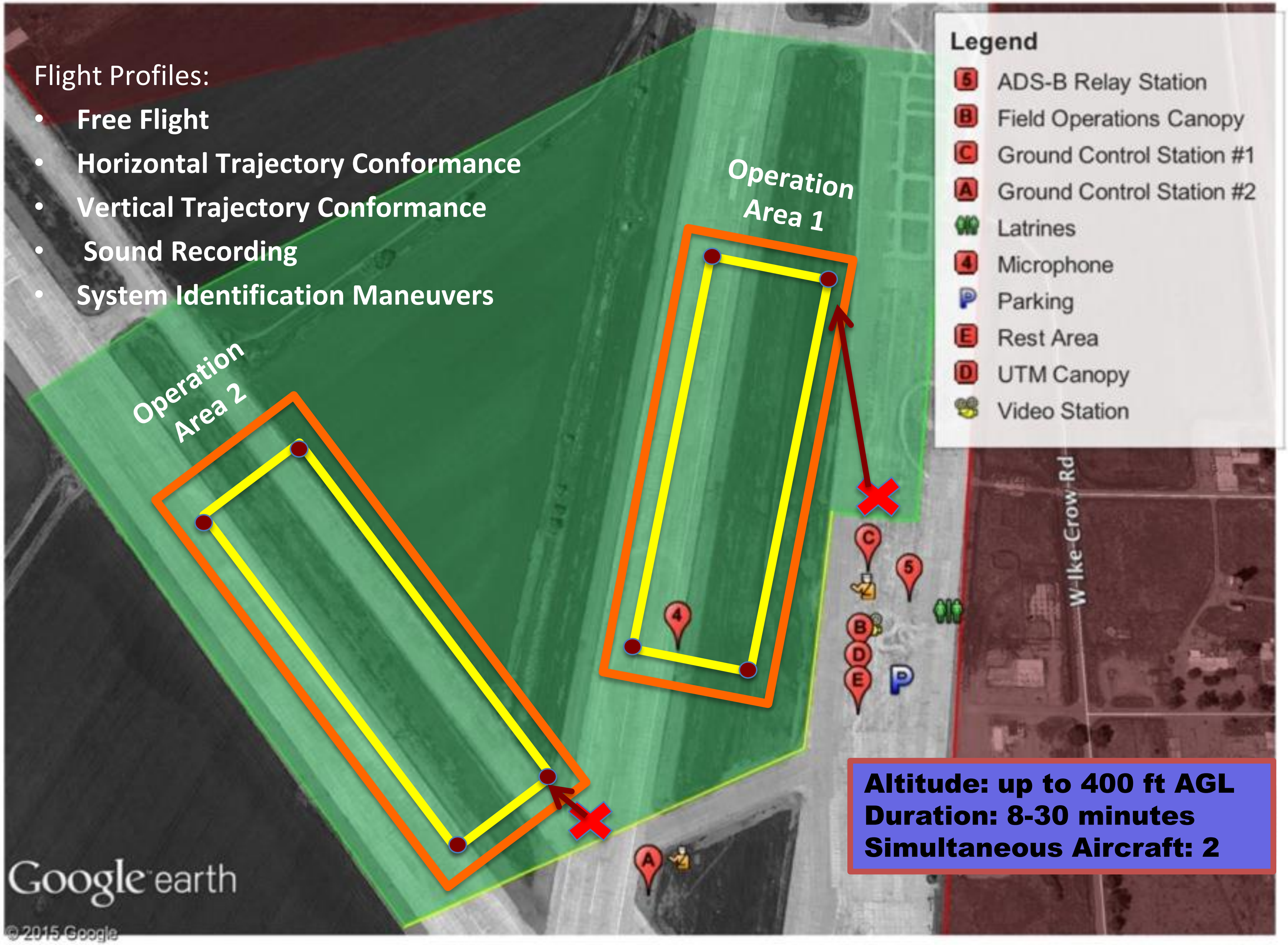
Objective 2: Collect Data on UAS Navigation Performance Error

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

23

TCL 1 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

TCL-1 National Safe UAS Integration Campaign

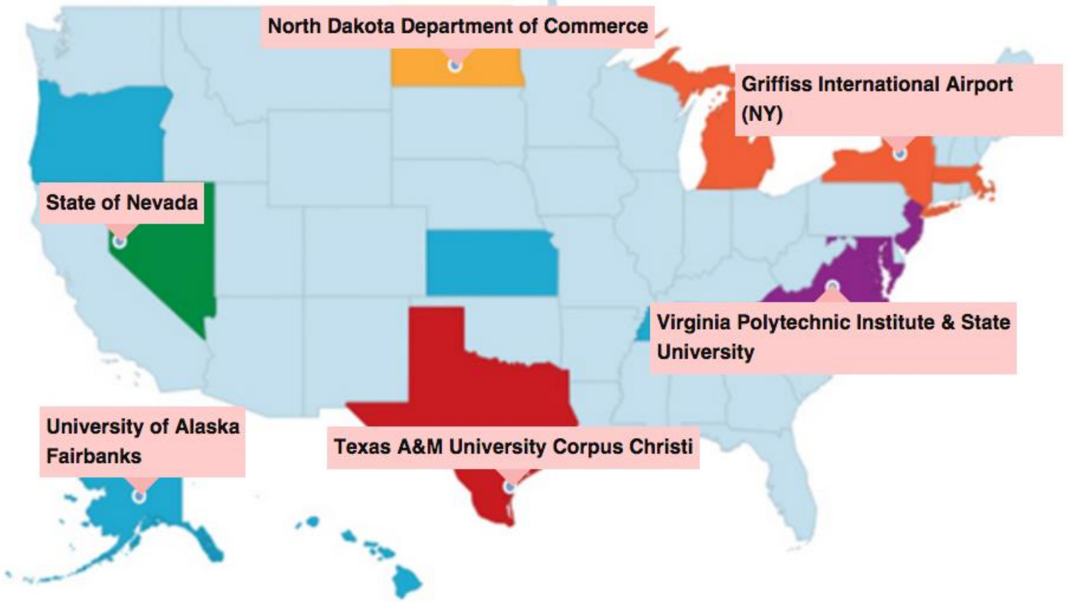
What: Demonstrated management of geographically diverse operations, 4 vehicles from each site flown simultaneously under UTM

Where: All 6 FAA UAS Test Sites

Who: NASA, Test Sites, support contractors

When: 19 April 2016

24 live vehicles, over 100 live plus simulated flights under UTM in one hour –Highly successful



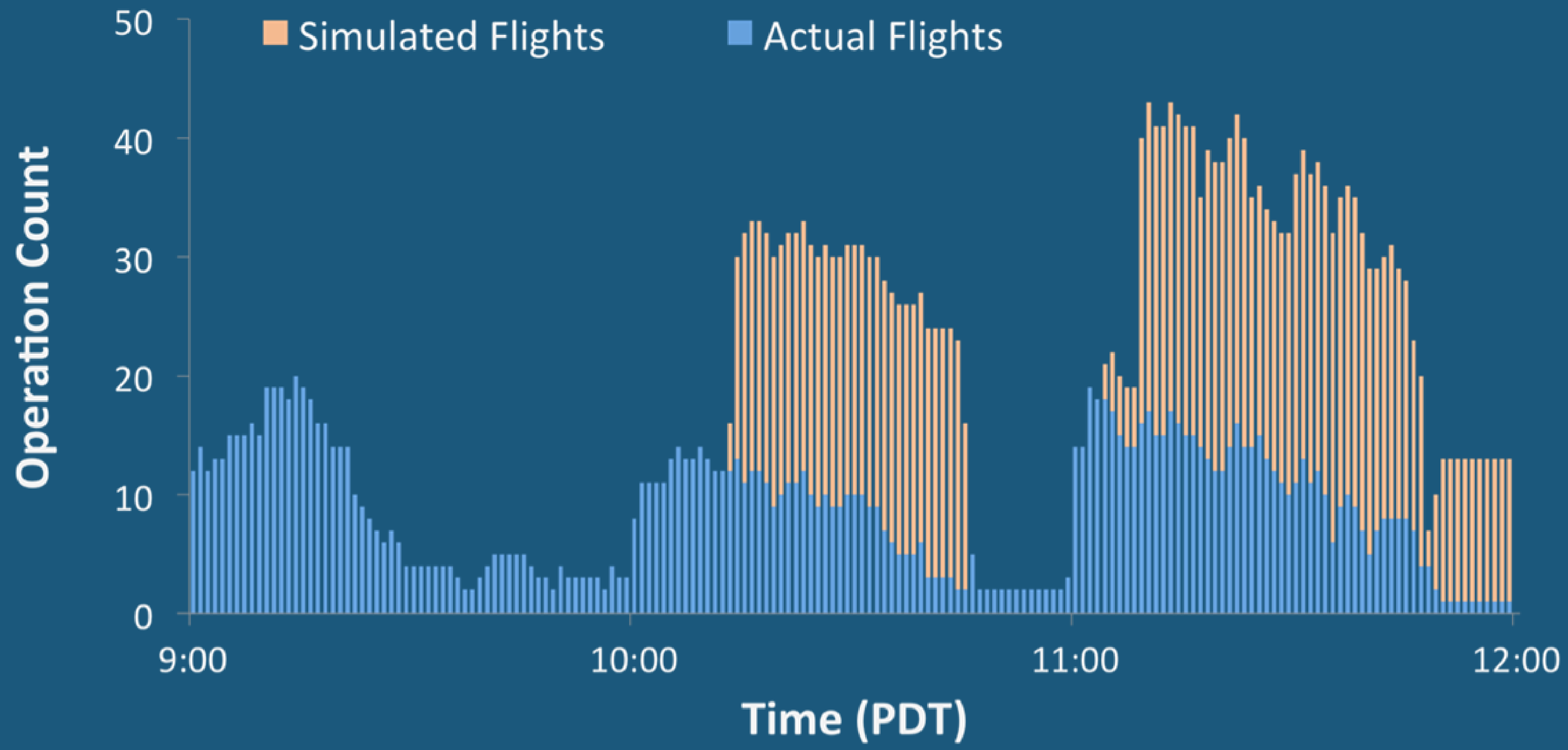
Received positive feedback from the FAA Test Sites on the UTM concepts, technologies and operations

API based model worked well – enabled operator flexibility, exchanged information, and maintained safe operations

TCL-1 National Safe UAS Integration Campaign

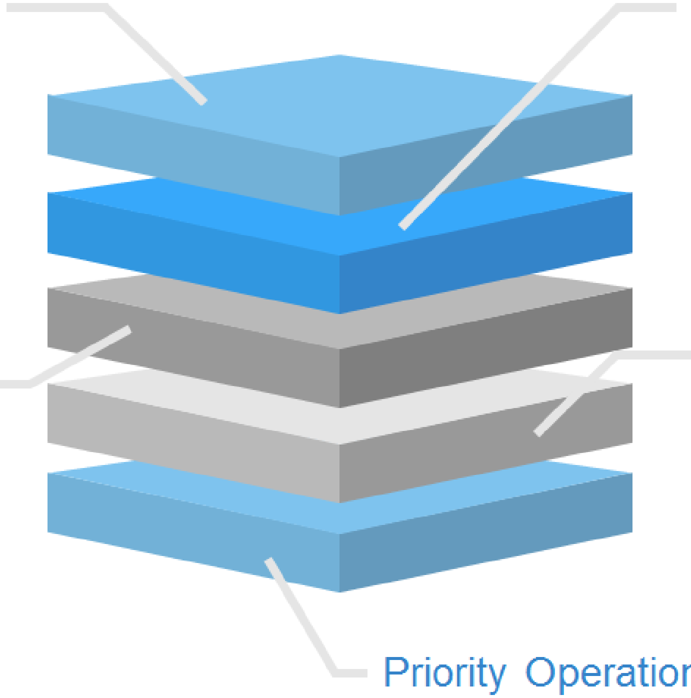
National Campaign Statistics:

- 3 Hours operational time with 31 hours of flight time
- 102 real, distinct flights plus 67 simulated operations
- 281.8 nmi flown under UTM System



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

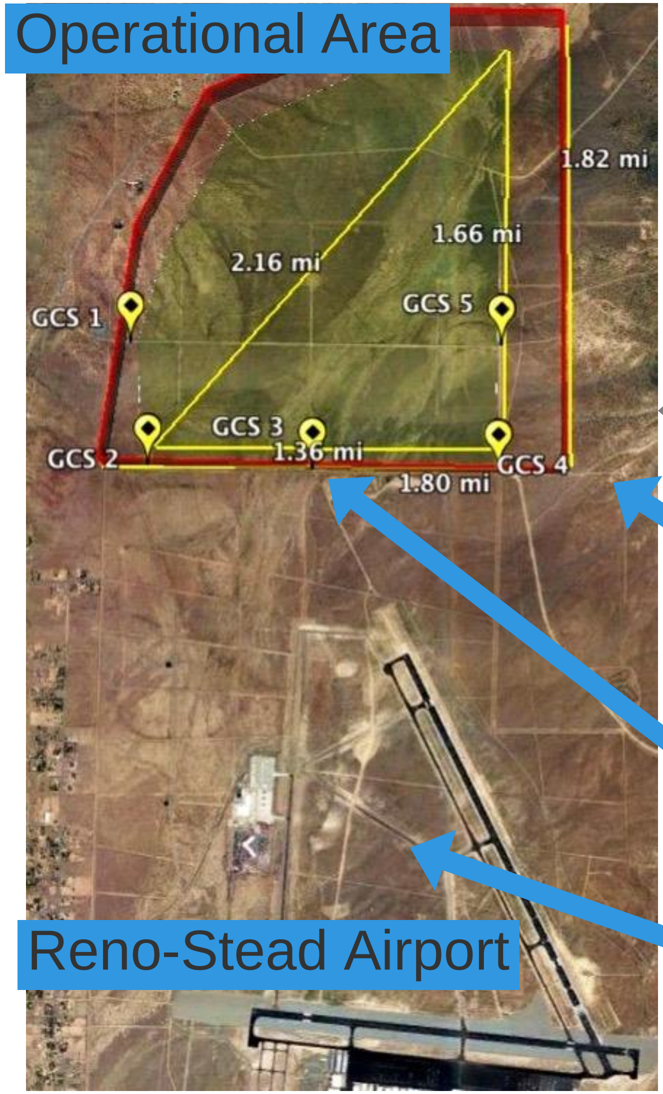
Users with special privileges are given priority of the airspace and impacted operations are informed of any conflicts

Scheduling and tracking operations and contingency management

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 TCL 2 Demonstration Flight Operations

Live-Virtual Constructive Environment

Altitude Stratified Operations

Situation Awareness Displays

Critical alerts, operational plan information and map displays

2 + 3 = 5

2 — Expanded

Flights up to 1.5 miles away from the pilot in command

3 — Visual Line of Sight

Hypothetical missions based on industry use cases

5 — 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		✓		✓

TCL 2 Preliminary Results

UTM TCL 2 Demonstration Highlights

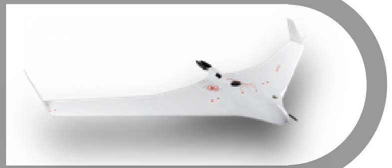
Days of Flight

5

14 Partner Organizations

2 Simultaneous Altitude Stratified Expanded Operations

11 UAS Platforms



30

Minutes per scenario

4

Scenarios

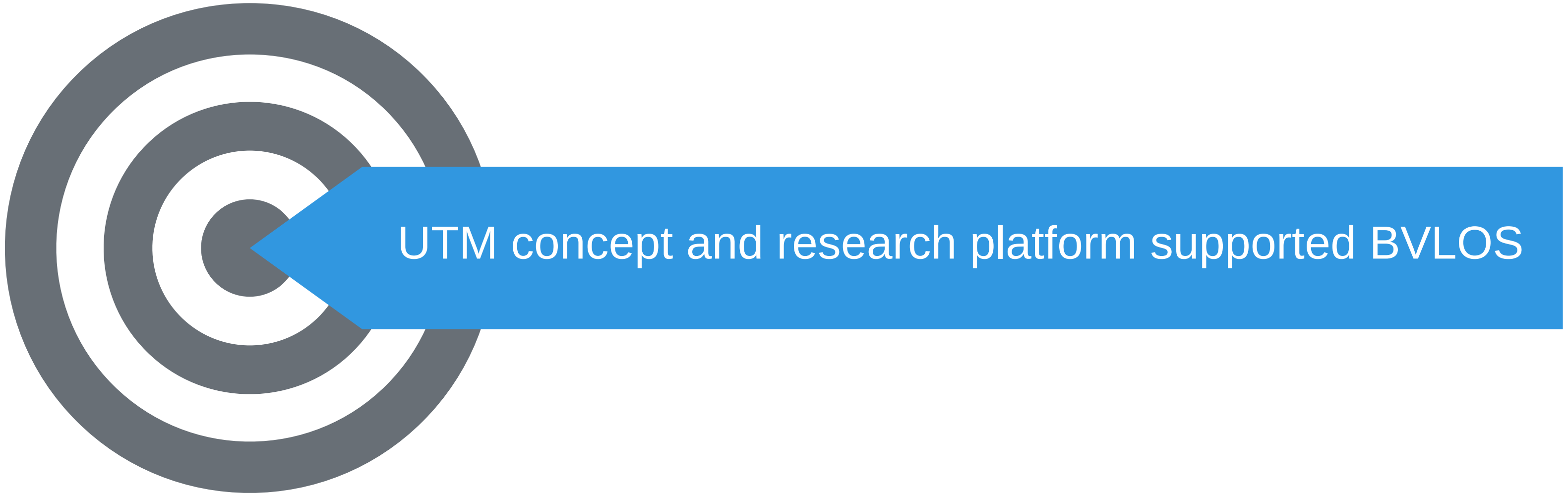
74

Flights

13.5

Flight Hours

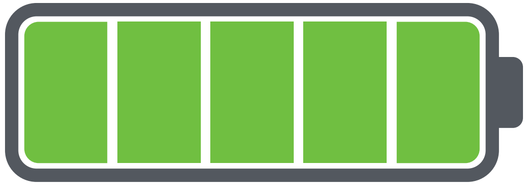
UTM Research Platform



UTM Core Principles and Guiding Tenet	Tested Feature
UAS should avoid each other	Scheduling and Planning Conformance Alerting Proximity Alerting Segregation in Space and Time (e.g. Geo-fencing)
UAS should avoid manned aircraft	Intruder Alerting Notification to manned (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

TCL 2 Safety-related Observations

Impact of Weather



<u>Nominal Aircraft Endurance</u>

Multi-Rotors: 20-40 minutes

Fixed-Wing: 45-200+ minutes

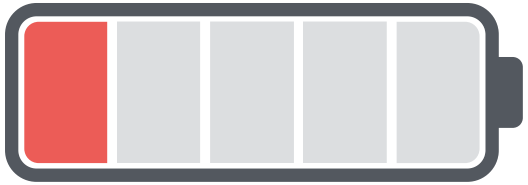
Reno-Stead Elevation: 5,050 ft

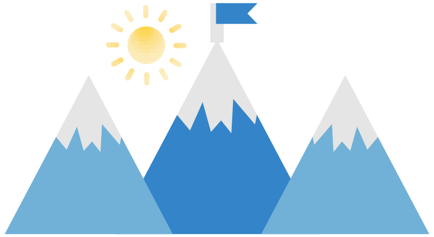
<u>Cool Temperatures</u>

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





<u>Warm Temperatures</u>

Density Altitude: 9,000+ ft

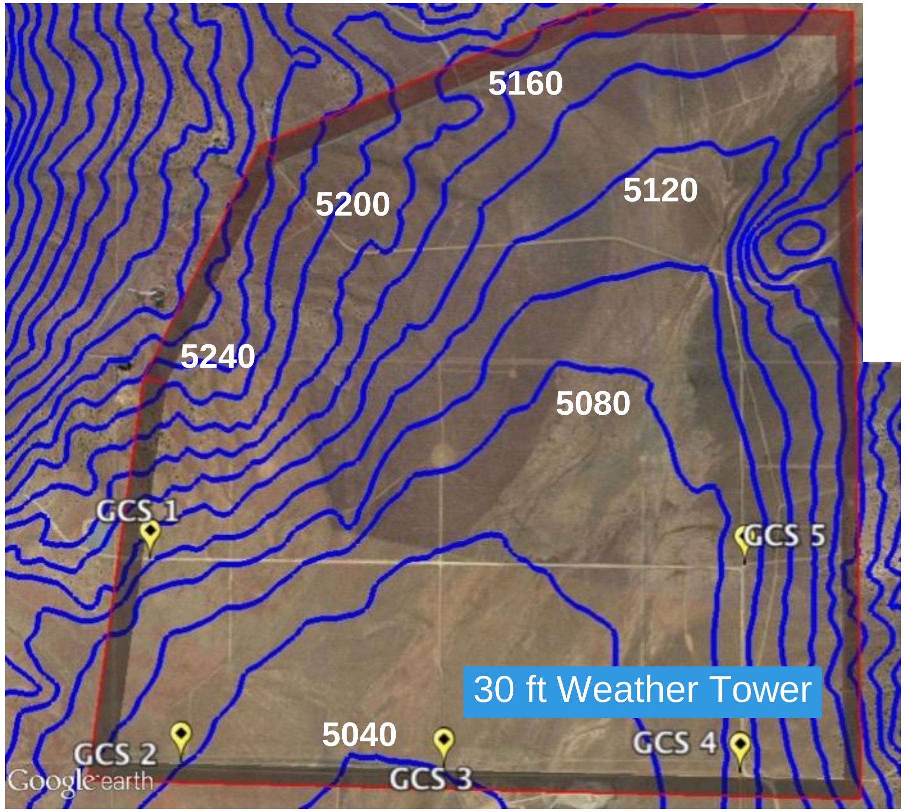
Winds: 5-15 knots

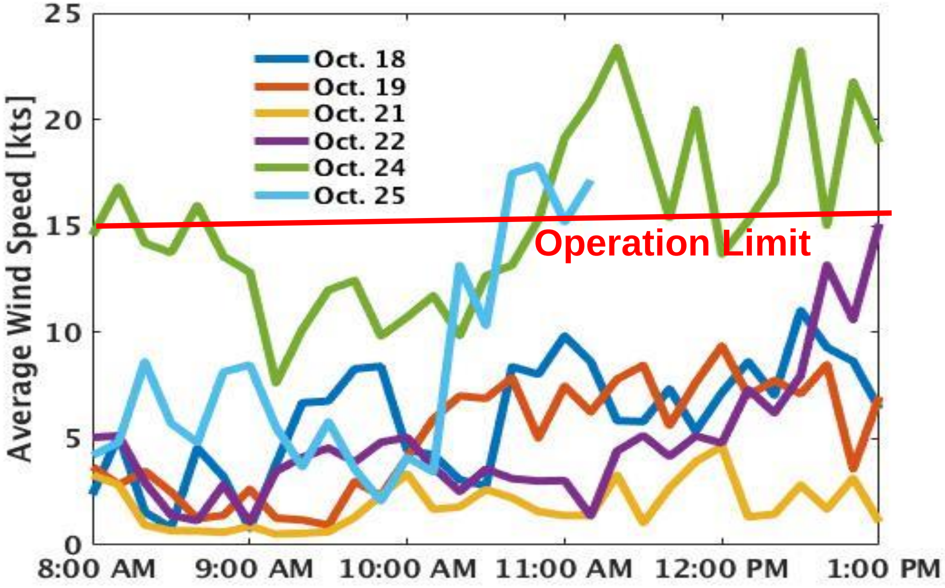
Aircraft experienced substantially **shorter endurance**

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

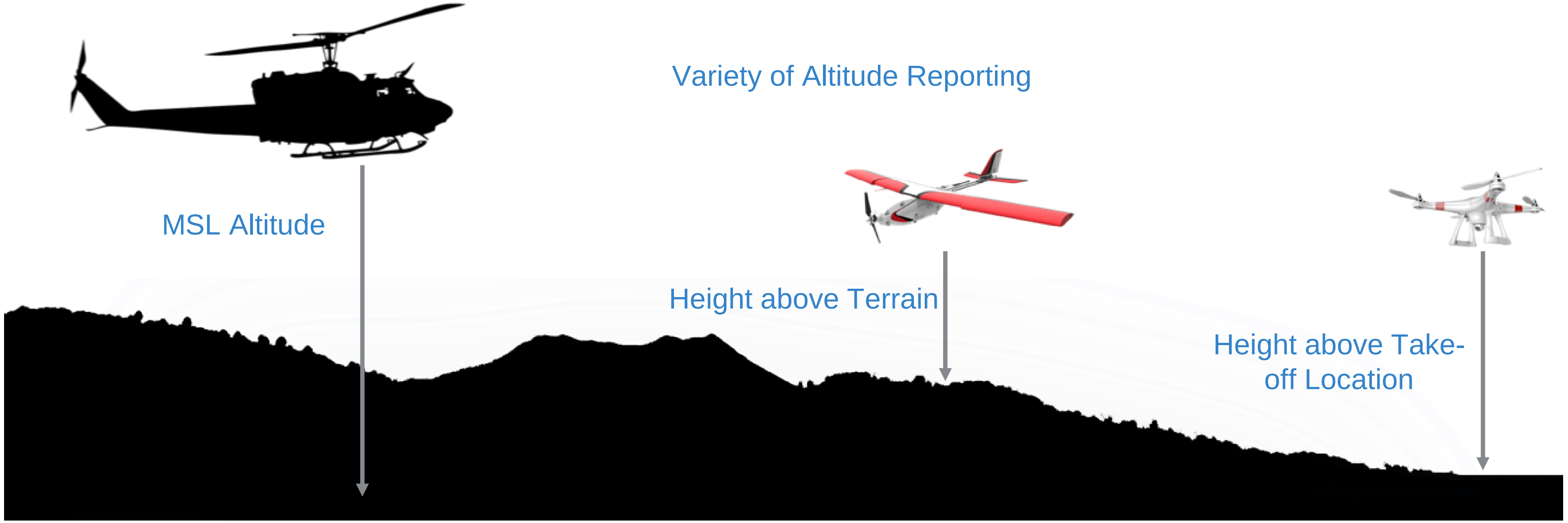
Ground reports were not indicative of conditions UAS experienced aloft

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

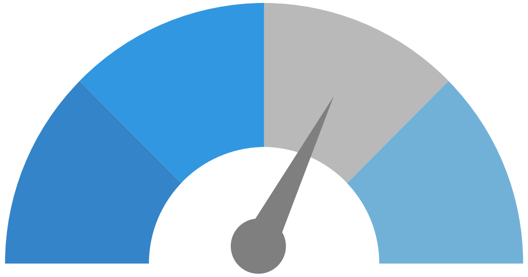
Increased risk of controlled flight into terrain and airborne collision hazard



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.

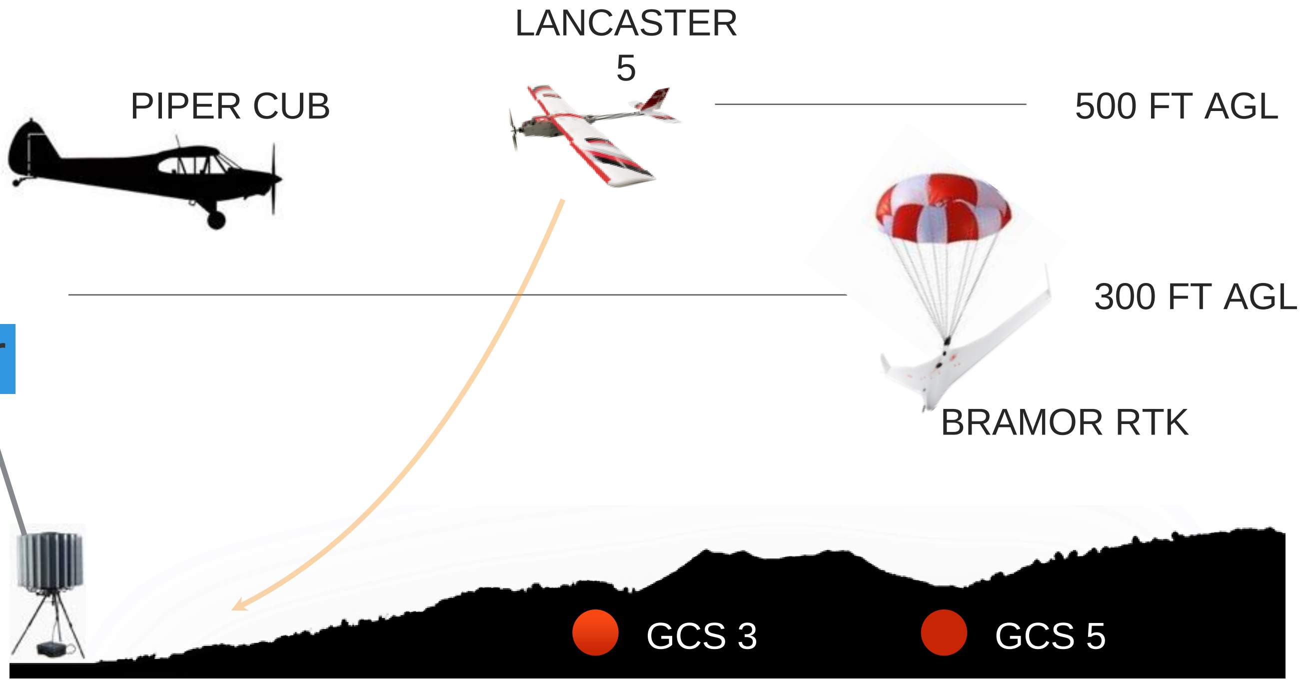
Industry standardization can reduce risk for BVLOS Operations

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 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

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**

Use of Cisco Products in Field Testing

Background

- For UTM TCL1 field testing, the UTM server was deployed to the field & connected to its clients via a Wireless Local Area Network

- The server was on a computer underneath a canopy

- Client stations were positioned up to a few hundred yards from the server & were also under canopies

- “Everyday” consumer electronics (i.e., non-industrial routers, access points, Ethernet cables, etc.) were used to implement the network at a different frequency from those used by the UAS to avoid interference

Background

- The routers & access points used for UTM TCL1 field testing proved to be unreliable in the outdoor environment
- Connection dropouts were frequent & seemed to correlate with the ambient temperature & equipment exposure to direct sunlight
- For TCL 2 field testing, the UTM server would be located at NASA Ames & clients would connect to it over the Internet
- Thus, a new (& better) network architecture was needed for UTM TCL 2 field testing

Network Architecture for UTM TCL2 Field Testing

- Over the course of 5 field test deployments, we built up a network architecture that supported Internet or cellular “point-to-point” connections for:
  - UTM UAS Clients at 5 Ground Control Stations (GCSs) located kilometers apart
  - 1 UTM Research Coordinator Station
  - 1 UTM Surveillance Client that received & forwarded data from two radar deployed in the area

Network Architecture for UTM TCL2 Field Testing

- Internet connections in the field were facilitated by:
  - 8 Cisco IR829 Integrated Services Routers with Cellular Data Plans
  - To keep track of these routers we named them: Peter, Lois, Brian, Chris, Meg, Stewie, Cleveland, & Quagmire

Network Architecture for UTM TCL2 Field Testing

- The routers utilized the following Cisco antennas:
  - Multiband Omnidirectional Stick Antennas (ANT-4G-OMNI-OUT-N=)
  - 4G LTE Articulating Dipoles (4G-LTE-ANTM-D=)
  - Multiband Panel Outdoor 4G Antenna (ANT-4G-PNL-OUT-N=)
- Internet connections were also provided by various USB cellular modems & equipment supplied by our UAS Operator partners
- We encouraged our UAS Operator partners to use whatever field networking equipment they were comfortable with rather than forcing them to use our equipment
- The Cisco IR829 routers were available to them as backup options

Router in its natural habitat

Cisco IR829 Router

The Cisco 829 Routers were used because:

- We wanted a device that would work reliably in extreme temperatures & direct sunlight
- We wanted a device that could take a beating
- We wanted a device that could serve as an access point for the WLAN in case we decided to revert to a WLAN architecture for testing
- We wanted a device that could use the cellular network to create virtual private networks (“cellular point-to-point”)
- We needed a device that was in our agency’s catalogue of items approved for purchase

Cisco IR829 Router

How did the routers do?

- There were still some connection dropouts anecdotally linked to exposure to direct sunlight, but that could have been due to the Ethernet cables we were using at the time (eventually we upgraded to Cat 7 nylon-braided cables)
- One of the routers survived being dragged ~20 feet along with a canopy that was blown over by a wind gust (it was more or less unscathed while the canopy was destroyed)
- It took non-trivial effort to get the routers properly configured to work properly in our architecture, but they ultimately performed the functions that we had planned for them once that was settled
- We ended up getting more use out of them than we expected (we almost exceeded the data plan limits that we purchased for them)

The Cisco IR829 routers were critical pieces of hardware for UTM TCL2 field testing & a significant upgrade over the equipment that was used for UTM TCL1 field testing

Next Steps

Next Planned Evaluations

- Additional TCL2 multiple BVLOS tests at all FAA test sites in May/June 2017
  - Strong industry participation (many operators, multiple USS, many use cases)
  - Focus Areas:
    - UAS Service Supplier technologies and procedures
    - Geofencing technologies/conformance monitoring,
    - Ground-based surveillance/sense and avoid,
    - Airborne sense and avoid
    - Communication, navigation, surveillance
    - Human factors related to UTM data creation and display
- TCL3 preparations ongoing, testing period end FY17/FY18

TCL 2 National Safe UAS Integration Campaign

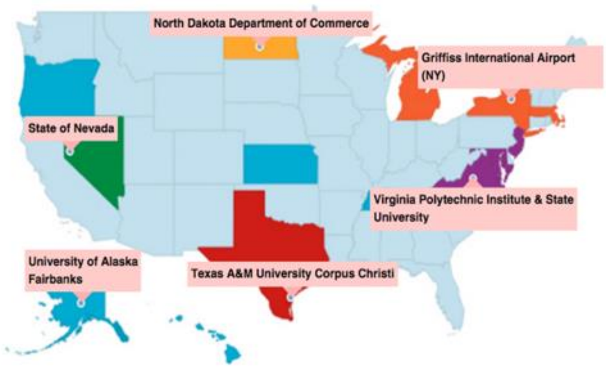
What: Demonstrate and evaluate critical elements of diverse multiple BVLOS operations, 4 different vehicles from each site flown under UTM

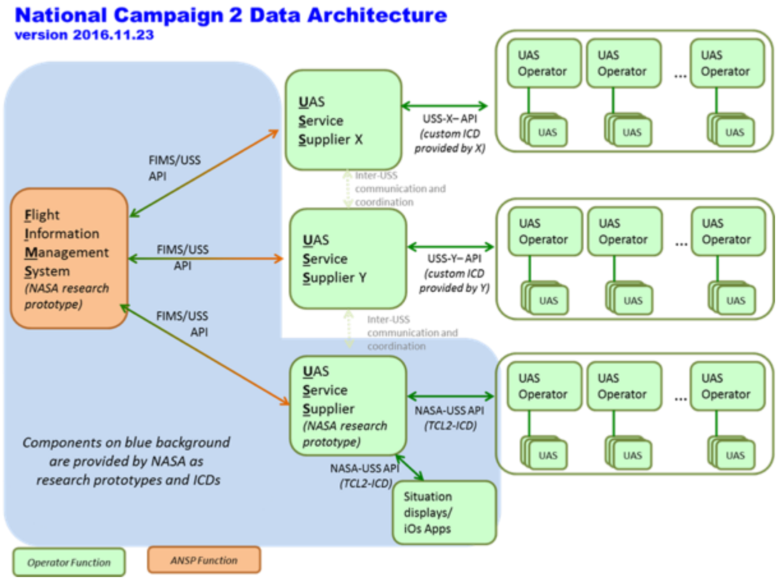
Demonstrate architecture with multiple Operators, UAS Service Suppliers and Flight Information Management System (FIMS)

Where: 6 FAA UAS Test Sites

Who: NASA, Test Sites, partners

When: 15 May – 9 June 2017





Test Site	USS Tech	Geofence Tech	Ground-based SAA	Airborne SAA	CNS	Human Factors
Alaska		X			X	
Nevada	X	X	X	X	X	X
New York	X	X			X	
North Dakota	X	X	X		X	X
Texas				X		
Virginia	X			X		

The UTM concept and research platform is exercised by all industry and FAA test sites

QUESTIONS?

Embracing innovation in aviation while respecting its safety tradition