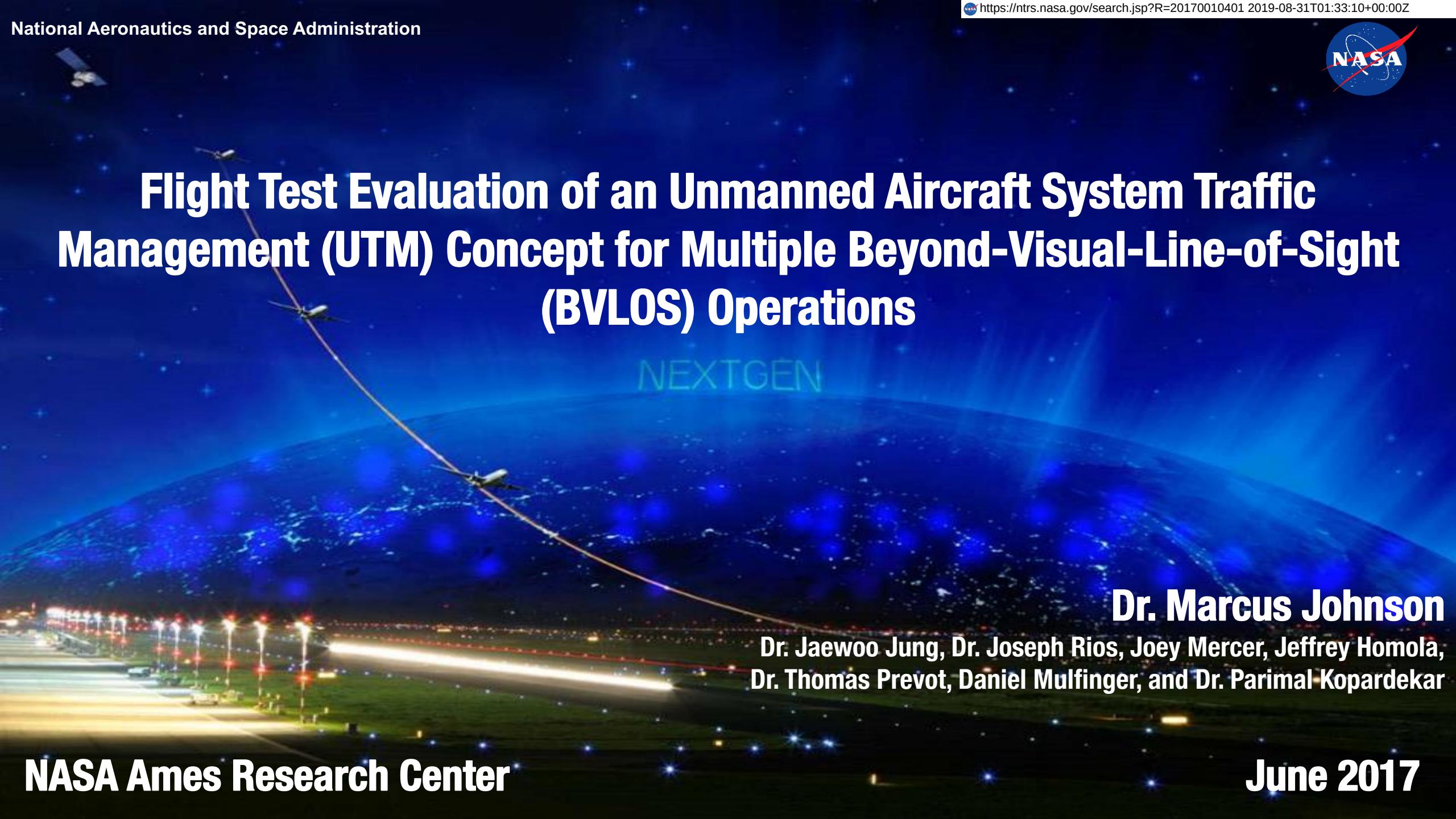
National Aeronautics and Space Administration



Flight Test Evaluation of an Unmanned Aircraft System Traffic Management (UTM) Concept for Multiple Beyond-Visual-Line-of-Sight (BVLOS) Operations

Dr. Marcus Johnson

Dr. Jaewoo Jung, Dr. Joseph Rios, Joey Mercer, Jeffrey Homola,
Dr. Thomas Prevot, Daniel Mulfinger, and Dr. Parimal Kopardekar

NASA Ames Research Center

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Low Altitude UAS Operations

FAA 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 safety structures in airspace

Operational concept being developed to address beyond-visual-line-of-sight (BVLOS) UAS operations at low altitude in uncontrolled airspace using UTM construct

Challenges with Expanding Operations

Visual Line of Sight
14 CFR Part 107

BVLOS

Separation

Weather

Command and Control

Awareness

Aircraft Performance

Operations over People

What is UAS Traffic Management?

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 to enable the management of low-altitude uncontrolled UAS operations

UTM addresses critical gaps associated with lack of support for UAS operations in uncontrolled airspace

National Airspace System- ATM

Flight Information Management System (FIMS)

Supplemental Data Service Provider(s)

UAS Service Supplier(s) (USS)

Airspace Displays

Technical Capability Level (TCL) Progression

TCL1: *multiple VLOS*

- → Networked Operations
- → Info sharing

TCL2: *multiple BVLOS, rural*

- → Initial BVLOS
- → Intent sharing
- → Separation by geo-fencing

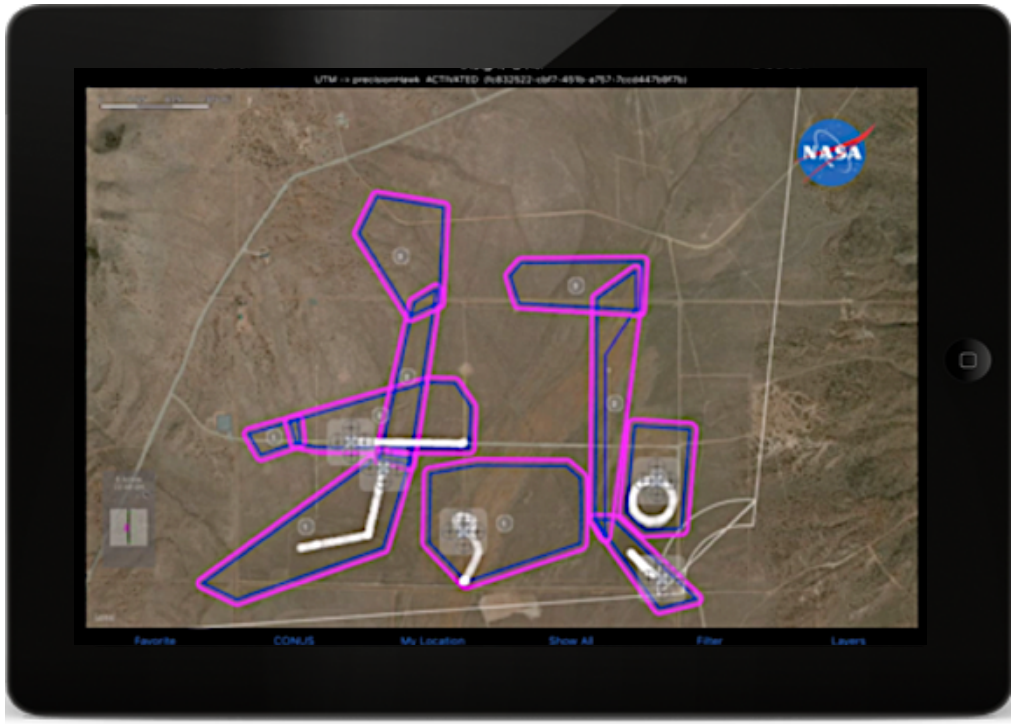
TCL3: *multiple BVLOS, near airports, suburban*

- → Routine BVLOS
- → Detect and Avoid (DAA) / Vehicle to Vehicle (V2V)
- → Avoid static obstacles

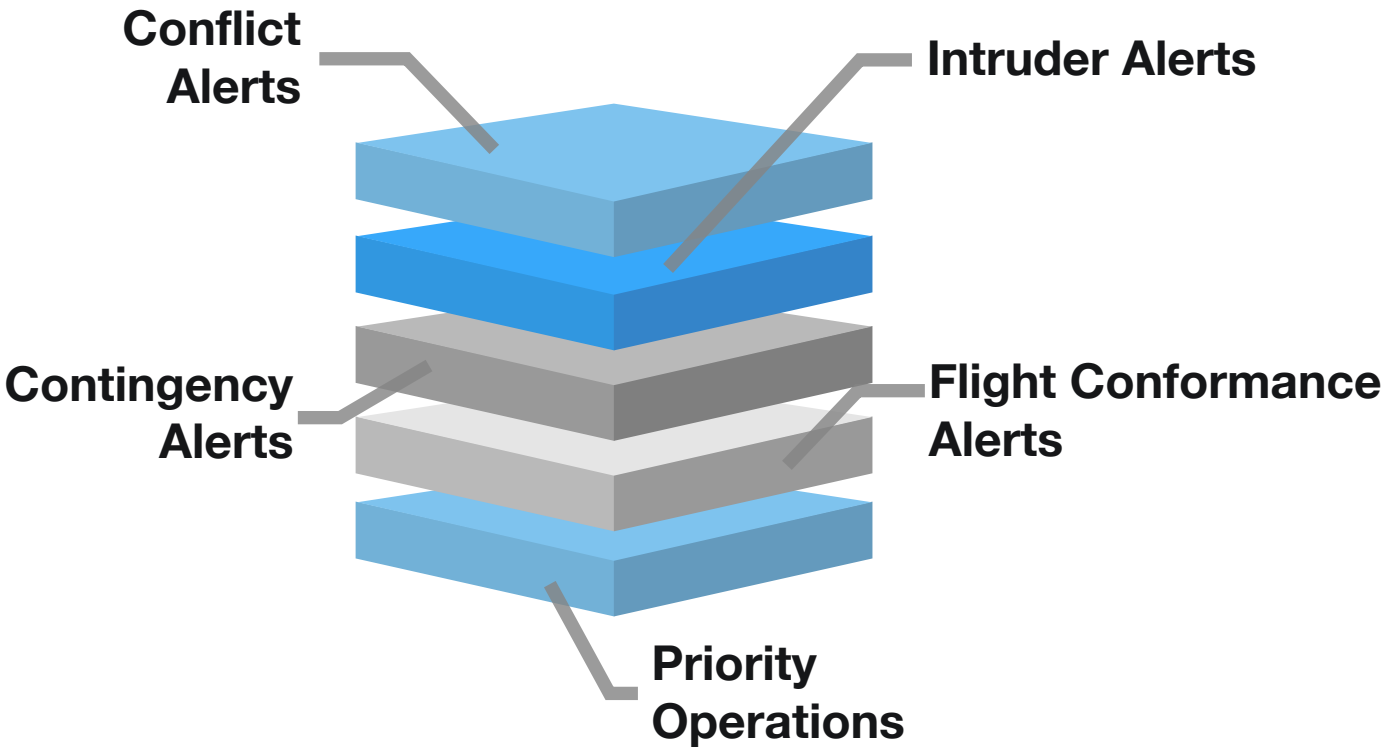
TCL4: *complex urban BVLOS*

- → BVLOS to doorstep
- → Track and locate
- → Avoiding dynamic obstacles
- → Large scale contingencies

TCL 2 UTM Functionality



UTM Mobile Application



Scheduling and Planning, Tracking, and Contingency Management

TCL 2 Flight Test Objective

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

Flight Test Overview

UAS Range

Elevation: 5050 feet

Desert Terrain

Missions up to 500 ft

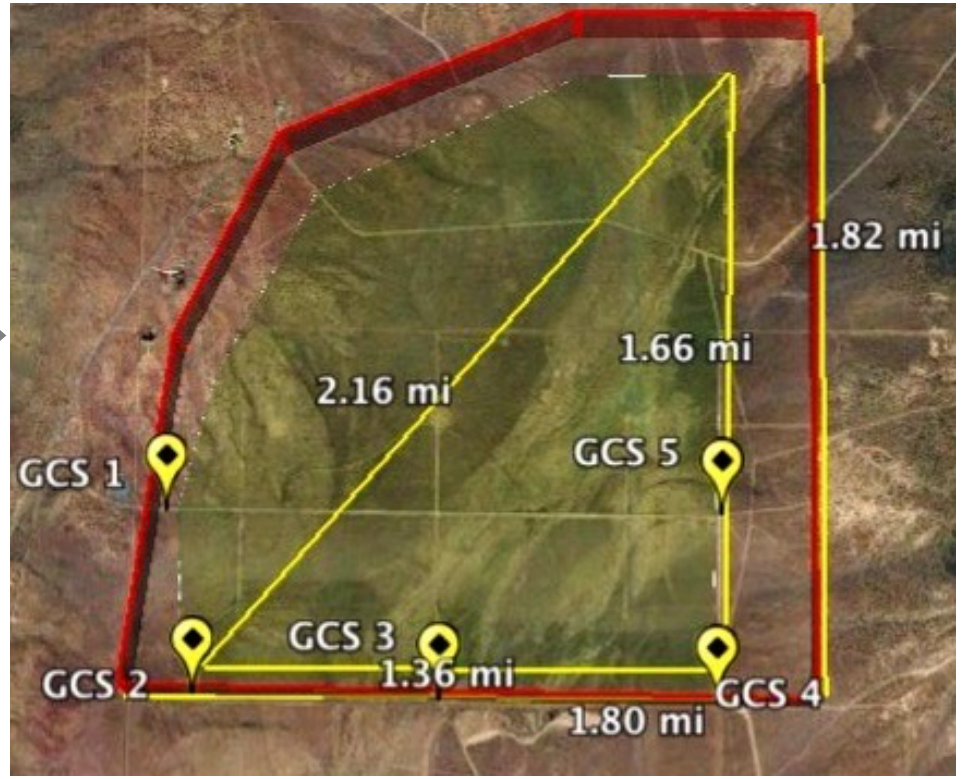
Operations at 5 Locations

SRHawk Radar

Weather Equipment

LSTAR Radar

Nevada UAS Test Range



October 2016

Flight Test Highlights

Situation Awareness Displays

Critical alerts, operational plan information and map displays

Altitude Stratified Operations

Live-Virtual Constructive Environment

BVLOS 2 + Visual Line of Sight 3 = Simultaneous Operations 5

Flights: 74

UAS Vehicles: 11

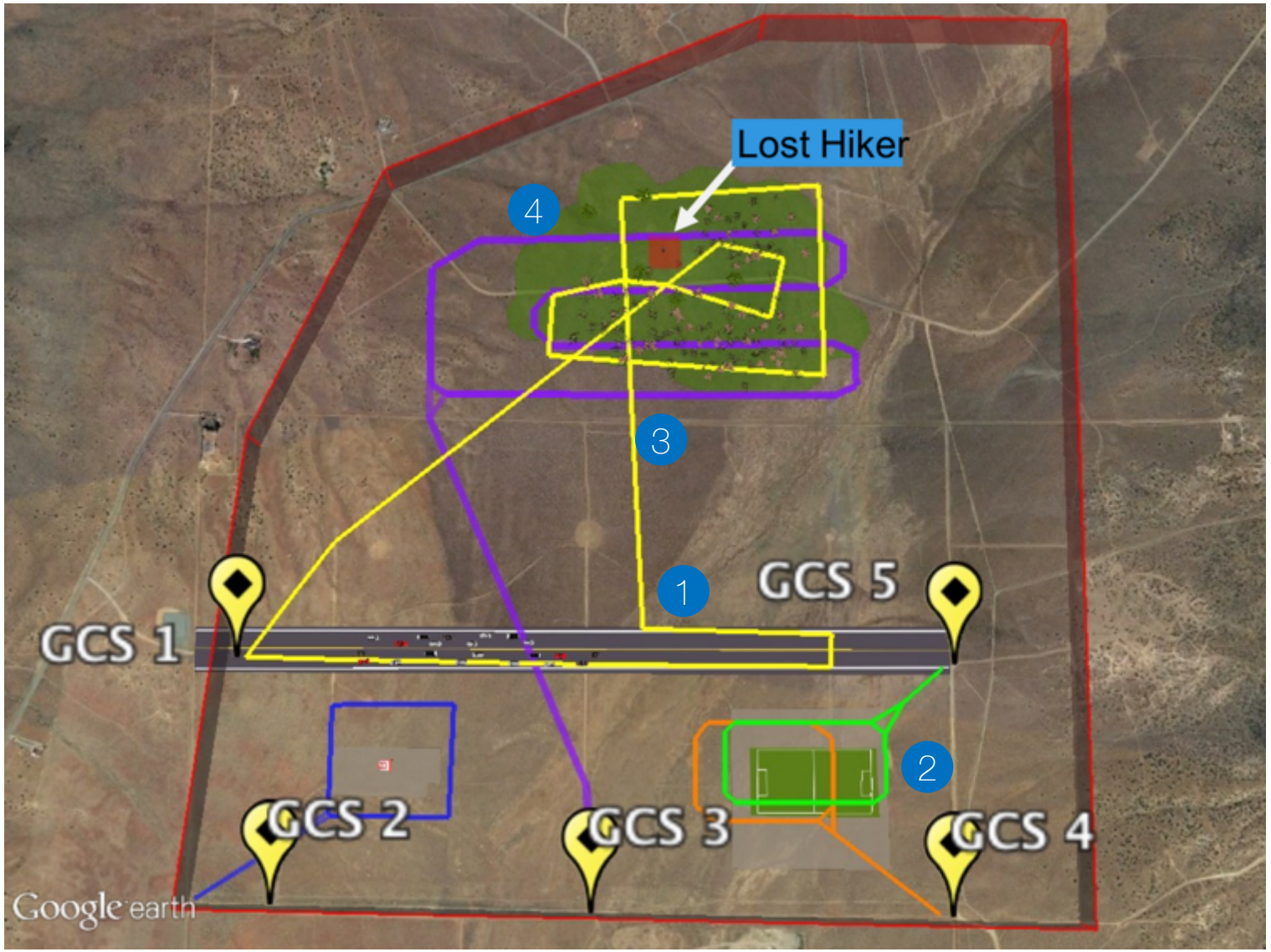
Partnerships: 14

4 Scenarios

30 Minutes per scenario

Days of Flight: 5

Scenario 2: Lost Hiker

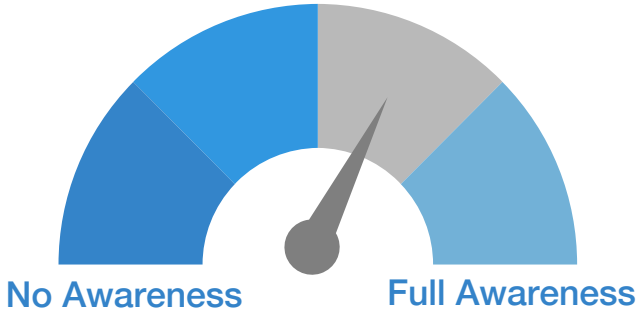


1. Dynamic Re-Routing
2. VLOS Altitude Stratification
3. Priority Operation
4. Constraint Notifications

TCL 2 Flight Test Lessons Learned

Use of the UTM Research Platform

Awareness of proximity to nearby operations



Areas for improvement:

Spectrum Usage

Contingency Management Actions

User reported information (e.g. UREP)

Integrated Airspace Display

Observations

Few flight crews had experience flying amongst other operations

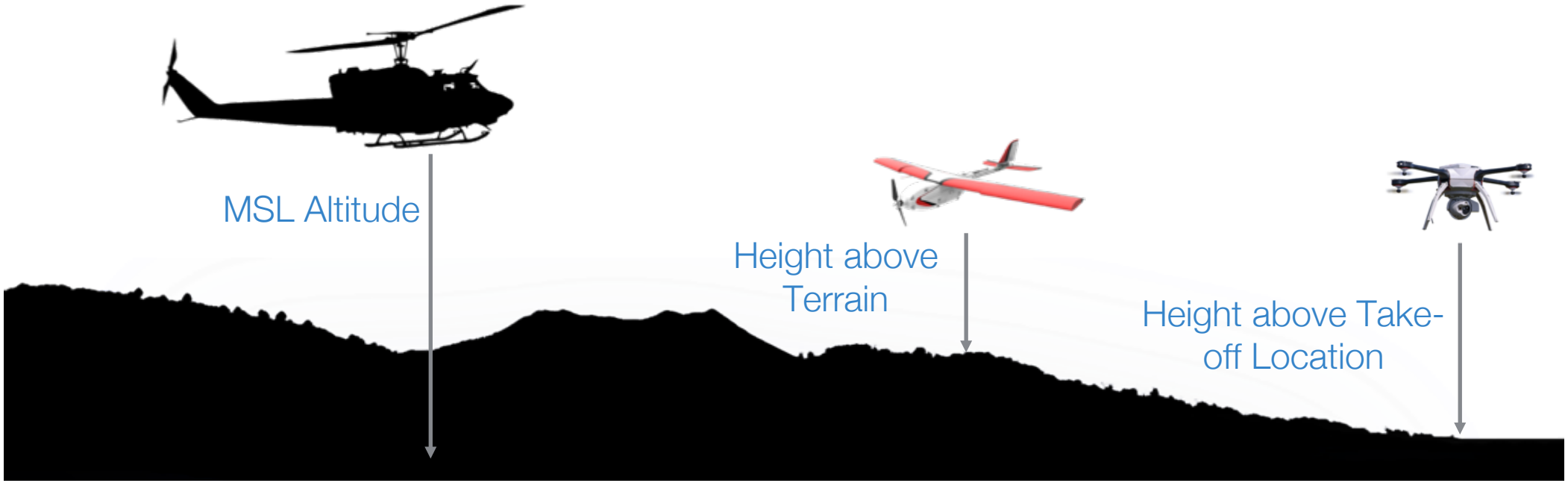
Due to differences in the equipment and practices of other operators information sharing was critical for safety

Flight crew progressed from reluctance to acceptance to endorsement of shared airspace information

UTM provided situation awareness with respect to other operations that was generally accepted by operators

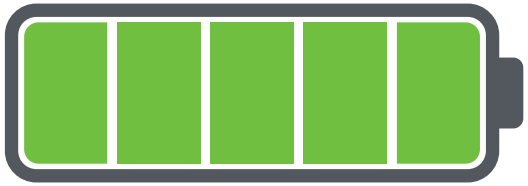
Inconsistent Altitude Reporting

Increased risk of controlled flight into terrain and airborne collision hazard



Altitude reporting should be consistent or translatable across airspace users

Weather Impact on UAS



Nominal Aircraft Endurance

Multi-Rotors: 20-40 minutes

Fixed-Wing: 45-200+ minutes

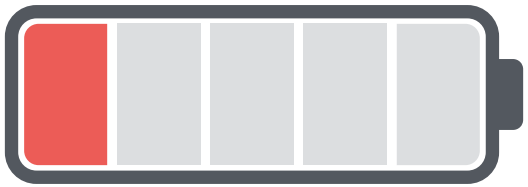
Reno-Stead Elevation: 5,050 ft

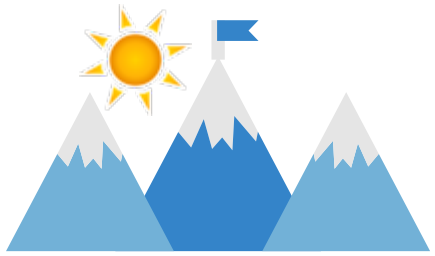
Cool Temperatures

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

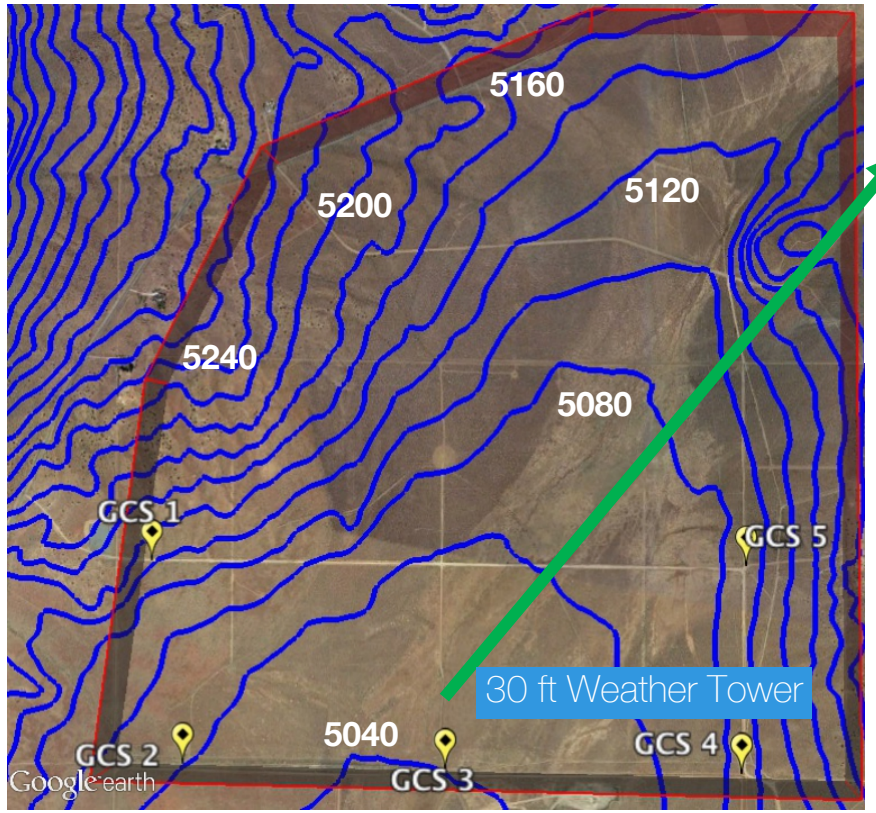
Winds: 5-15 knots

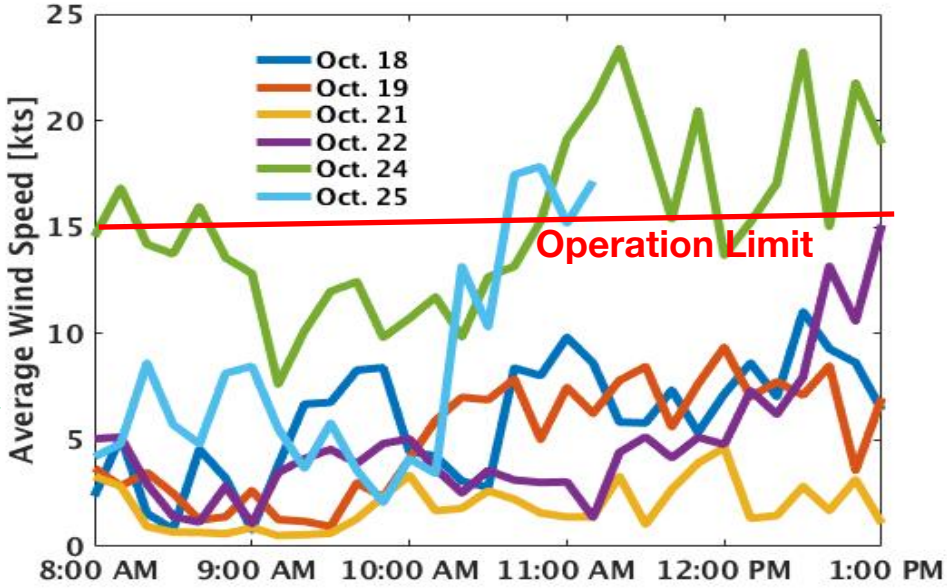
Aircraft experienced substantially **shorter endurance**

UAS should be tested and rated against different operational environments

Locality Impact on Operations

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

Recommendations for BVLOS Operations

1. Operators should **display airspace information** and have access to other operator's operational intent and contingency actions in off-nominal conditions

2. **Altitude reporting** should be **standardized** and consistent/translatable to current airspace users

3. In the absence of acceptable weather products, **atmospheric conditions** should be **self-reported from GCS and UAS**

4. Initial BVLOS should **avoid altitude stratification**, until improved position sharing (e.g. V2V) and weather products

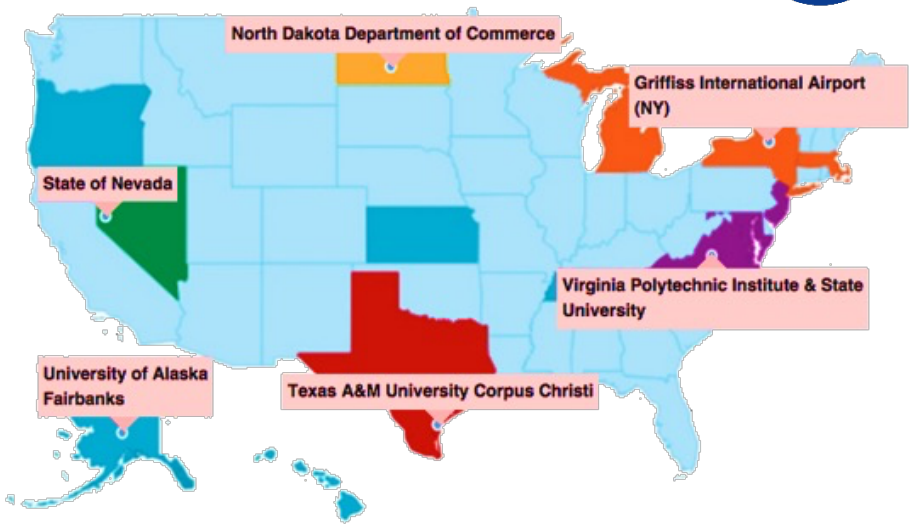
5. **Flight trajectories** should be **contained within geo-fence boundaries** that are shared with the UTM research platform **to support separation**

Next Steps

TCL 2 National Campaign

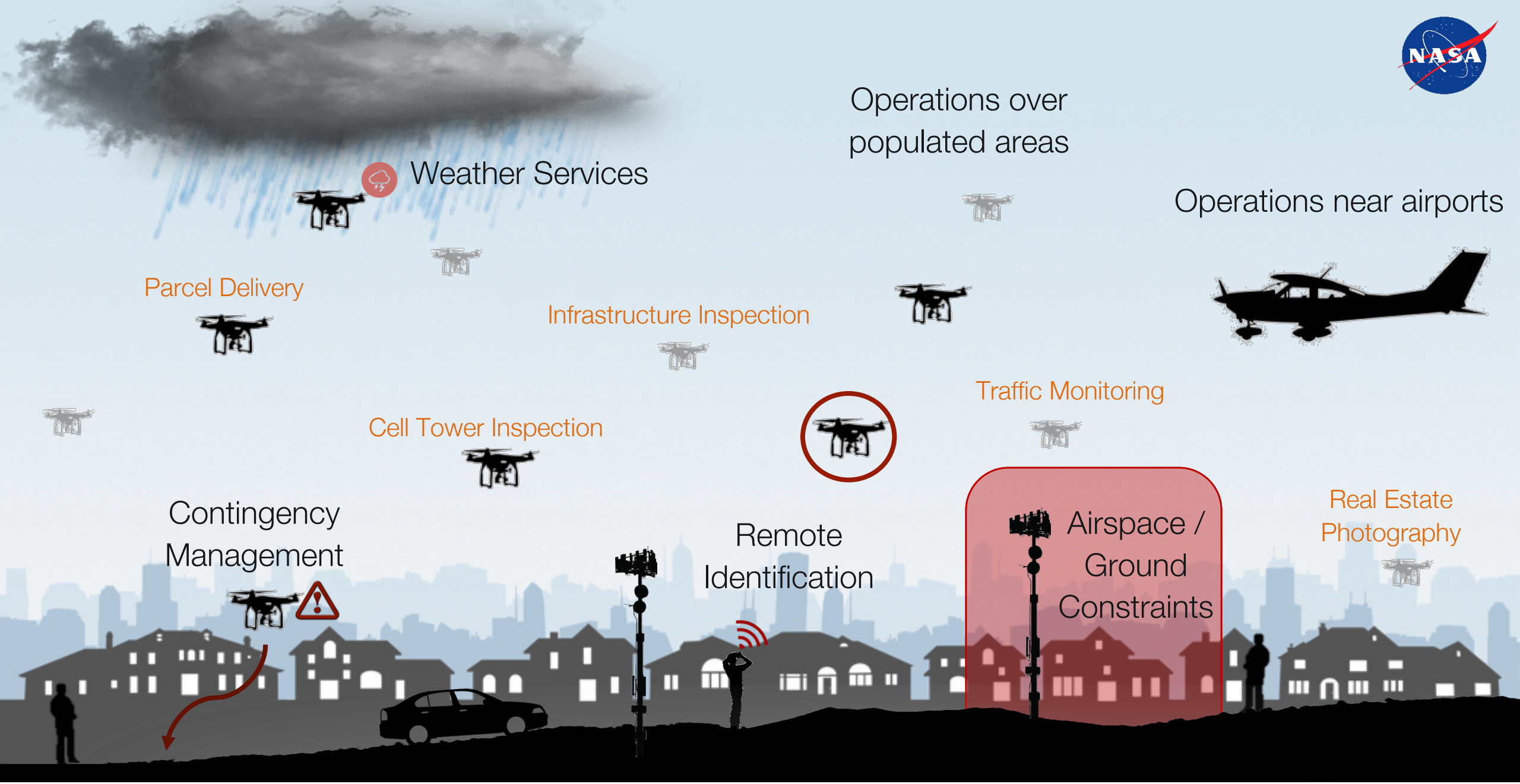
May 15th – June 9th 2017

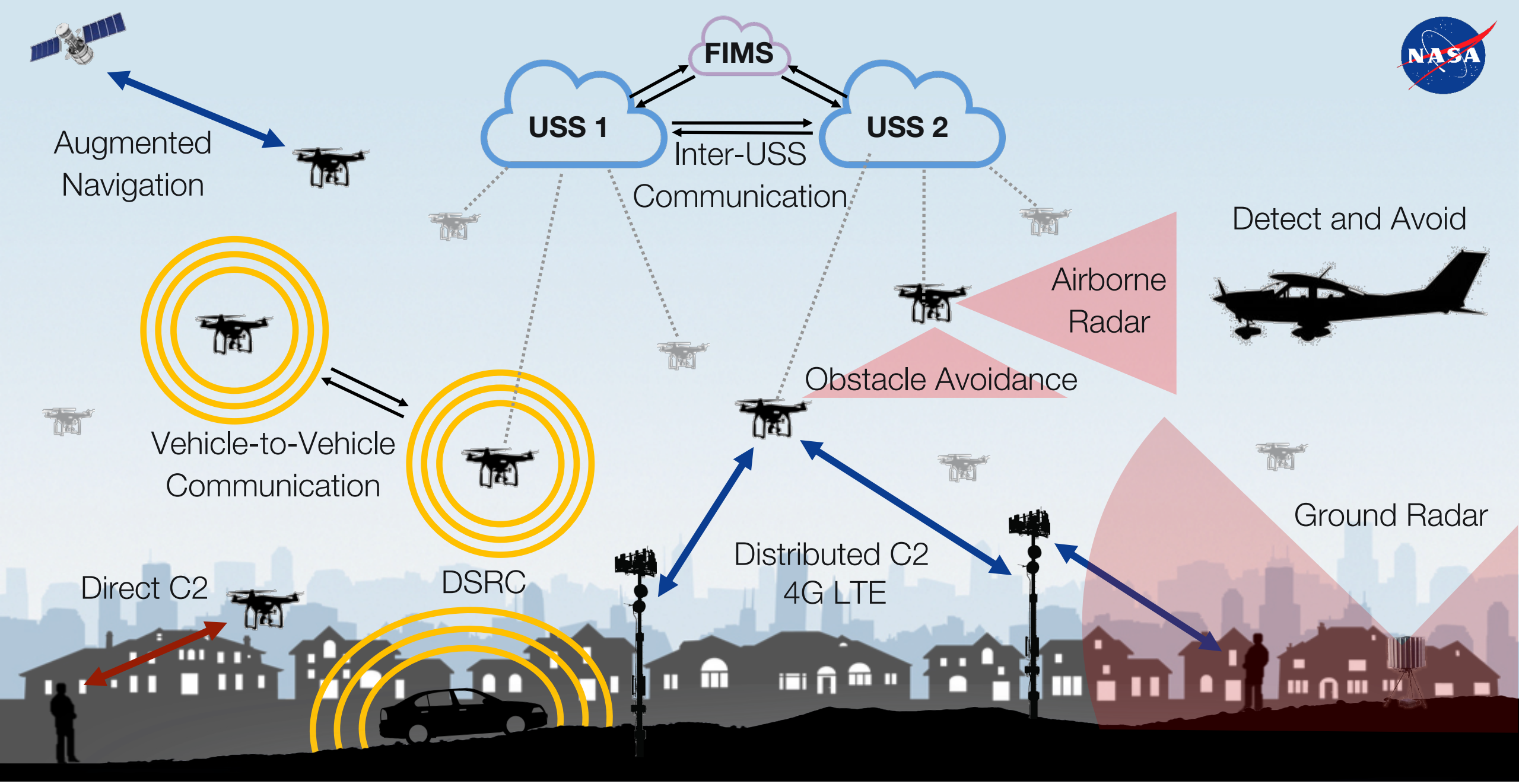
- ~40 partners total across 6 testing locations
- 6 USS Implementers (Amazon Prime Air, Google Project Wing, Airmap, Simulyze, ANRA, NASA)
- NASA USS and FIMS run in the cloud
- Data feeds monitored in UTM lab and at each location
- Multiple Media days



Test Sites	USS Technology	Geofence Technology	Ground-based Sense & Avoid	Airborne Sense & Avoid	Communication, Navigation, Surveillance	Human Factors
Alaska	✓	✓	✓	✓	✓	✓
Nevada	✓	✓	✓	✓	✓	✓
New York		✓			✓	
North Dakota	✓	✓	✓		✓	✓
Texas				✓		
Virginia	✓		✓	✓		✓

TCL 3: Multiple BVLOS operations near airports and suburban areas


Weather Services
Operations over populated areas
Operations near airports
Parcel Delivery
Infrastructure Inspection
Traffic Monitoring
Cell Tower Inspection
Contingency Management
Remote Identification
Airspace / Ground Constraints
Real Estate Photography


FIMS
USS 1
USS 2
Inter-USS
Communication
Augmented
Navigation
Detect and Avoid
Airborne
Radar
Obstacle Avoidance
Vehicle-to-Vehicle
Communication
DSRC
Direct C2
Distributed C2
4G LTE
Ground Radar

Summary

TCL 2 Demonstration successfully showed the feasibility of supporting multiple BVLOS operations in a rural environment and highlighted areas of future research

TCL 2 National Campaign successfully demonstrated the UTM architecture, collected data to support the NASA-FAA UTM Research Transition Team, and engaged industry to contribute to the development of UTM

TCL 3 Demonstration will evaluate the effectiveness and interoperability of technologies to support separation, communication, navigation, data-exchange, and airspace management in a complex operational environment

Questions?