Unmanned Aerial Systems Traffic Management (UTM)

SAFELY ENABLING UAS OPERATIONS IN LOW-ALTITUDE AIRSPACE

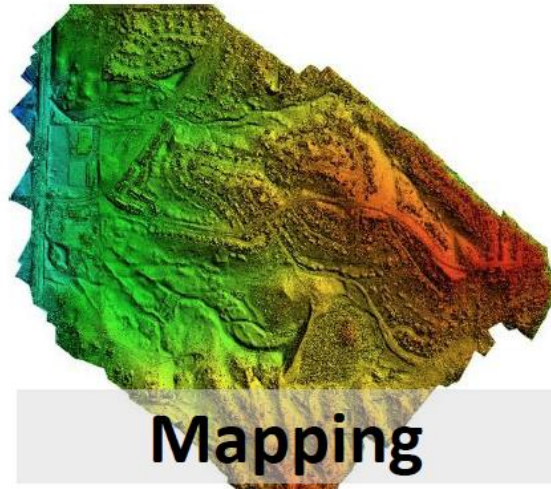NEXTGEN

NASA

http://www.utm.arc.nasa.gov

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Applications of Unmanned Aerial Systems

Public Safety

Deliveries

Surveillance

Weather Monitoring

Agriculture

Mapping

Disaster Relief

Entertainment

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Unmanned Aerial System Traffic Management (UTM)

Near-term Goal: Safely enable initial low-altitude UAS as early as possible

Long-term Goal: Accommodate increased demand with highest safety, efficiency, and capacity

Challenge and Opportunities

- Challenge: Acceptance of large-scale UAS operations in low altitude airspace
  - Airspace operations requirements: technology and procedures
  - Safety
  - Privacy policy
  - Security
  - Noise
  - Public perception

- Economics: Safe, secure, and scalable "Beyond visual line of sight" operations

- Opportunities: Technology advancements and new business models

UTM: Balancing Multiple Needs

NATIONAL AND REGIONAL SECURITY

Protecting key assets
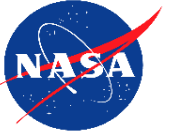
SAFE AIRSPACE INTEGRATION

Flexibility where possible and structure where needed

Geographical needs, application, and performance-based airspace operations

SCALABLE OPERATIONS FOR ECONOMIC GROWTH

Ever-increasing applications of UAS: Commercial, Agricultural, and Personal

What is UTM?

Research software prototype that

(1) Allows UAS operators to submit flight plans to execute a specific mission in low-altitude airspace, and

(2) Determines how to safely enable such single or multiple UAS operations either within visual line of sight or beyond visual line of sight
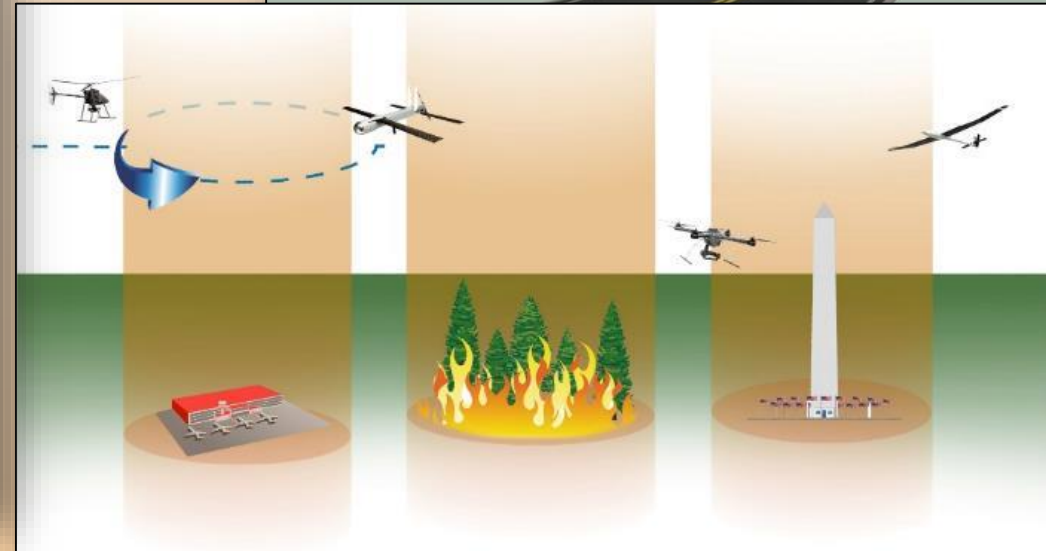
PRODUCT: Validated airspace operations requirements, prototype implementation

UTM Functions

AIRSPACE OPERATIONS & MANAGEMENT

- ~500 ft. and below
- Geographical needs and applications
- Rules of the airspace: performance-based
- Geofences: dynamic and static
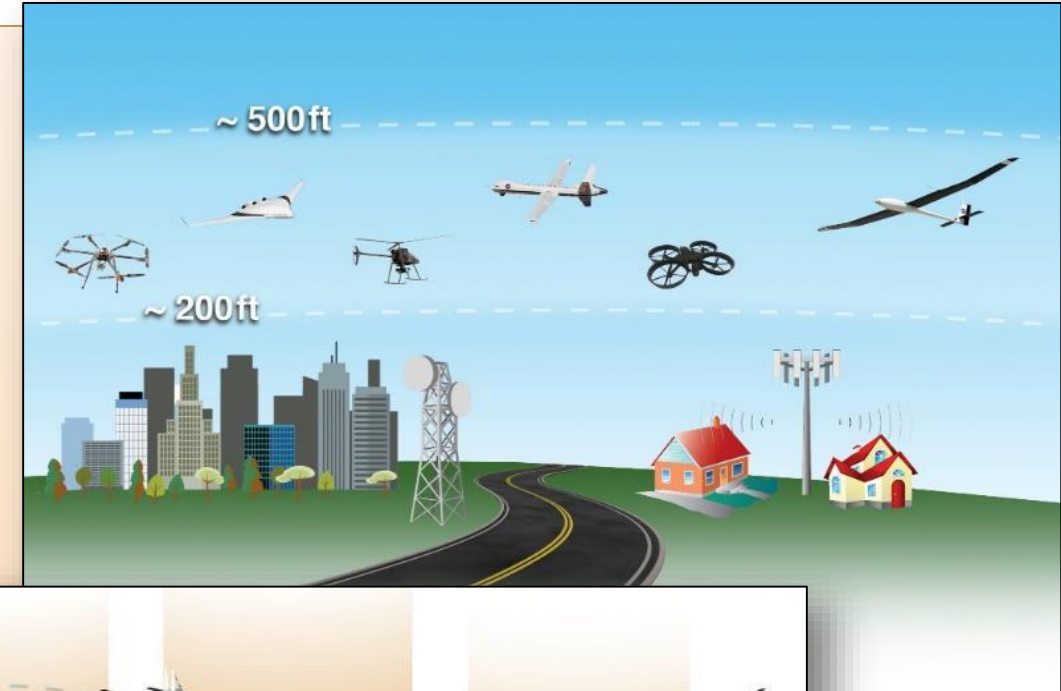
UTM Functions

WIND & WEATHER INTEGRATION

- Actual and predicted winds/weather

CONGESTION MANAGEMENT

- Demand/capacity imbalance
- Only if needed – corridors, altitude for direction, etc.

UTM Functions

SEPARATION MANAGEMENT

- Airspace reservation
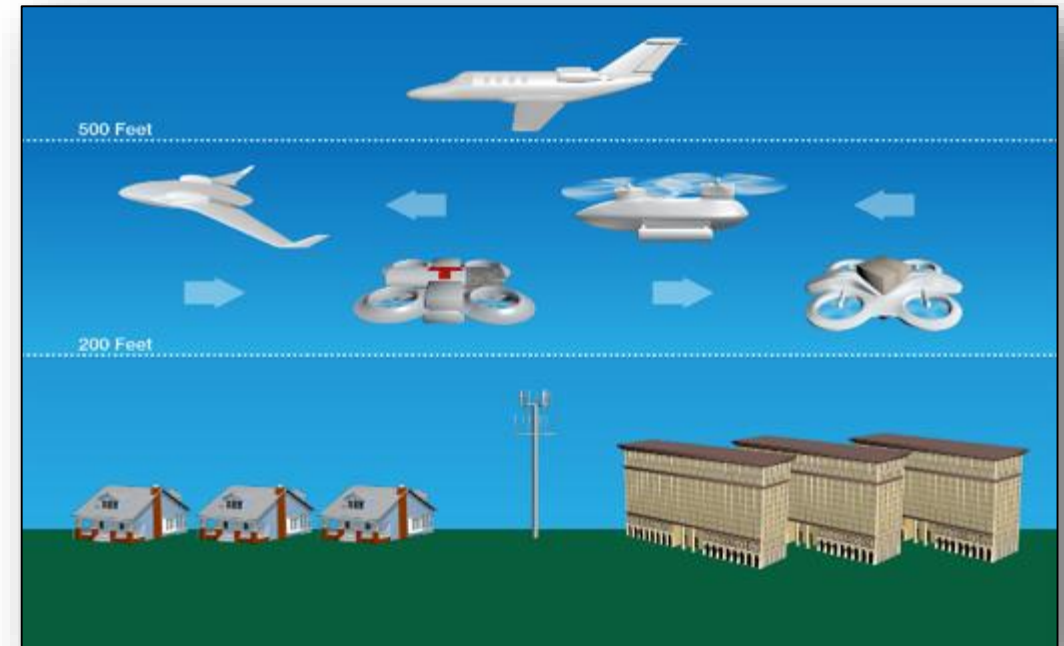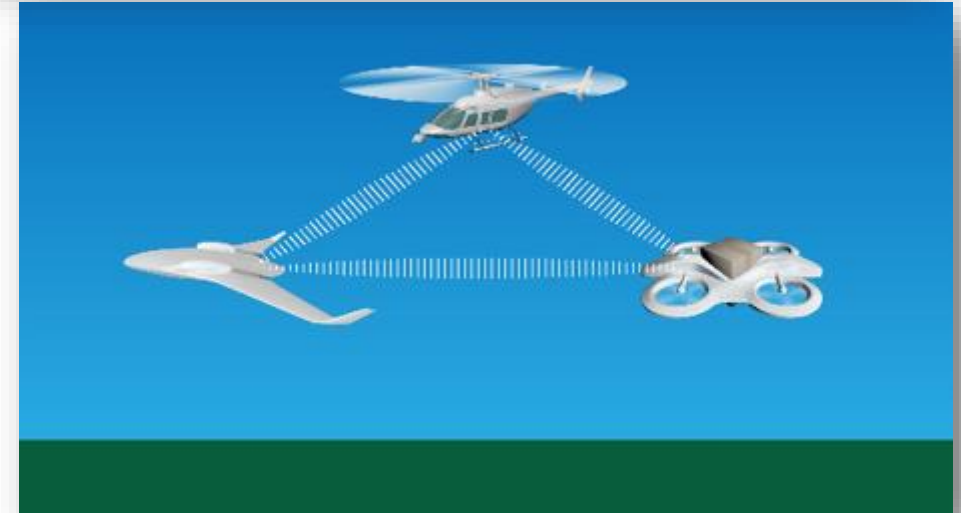- V2V and V2UTM
- Tracking: ADS-B, cellphone, & satellite based

CONTINGENCY MANAGEMENT

- Large-scale GPS or cell outage
- 9-11 like situations

Information Flow

Vehicle Performance Database

UTM Vehicles Registration

Check if UVIN is registered

Schedule delivery to …

Check static constraints

Area of Operation

Event

Hospital

Trajectory

Take-Off

Dynamic Constraints
- Weather
- Conflict Detection
- Feasibility

NOMADS

HRRR | GEFS | RAP | HIRESW | NAM

Real Time Data Access (GRIB/GRIB2 files)

Weather Forecast Variables

Model-Based Trajectory Constraint Check

Check dynamic constraints

UTM Services

Contingency Management
- Geo-fence breach
- Loss of C2
- Emergency responder

Operator submits operation (waypoints; vehicle info; operator data)

Operation completed

1
2
3
4
5
6

NASA UTM Simulation Capabilities

- Objectives
  - Validation and Verification of UTM research prototype functions
  - Develop, demonstrate, and evaluate advanced UTM services and operations
  - Develop tools and procedures to manage UTM ops
  - Accelerate and increase value of field tests and provide live virtual constructive (LVC) environments
  - Simulate complex operations that cannot be done in the field (e.g. urban ops, 911 type scenarios)

- Status
  - Simulation test bed in place
  - Simulations connect to UTM using TCL 1 and TCL 2 APIs
  - LVC environments fully functional and in use during field tests

- Functionality
  - Simulate multiple UAS clients in addition to live clients
  - Create and control UAS from multiple operator station in MACS
  - Visualize in Simulation Viewer
  - Communicate to UTM via UTM API
  - MACS Messaging Window to display UTM comm.
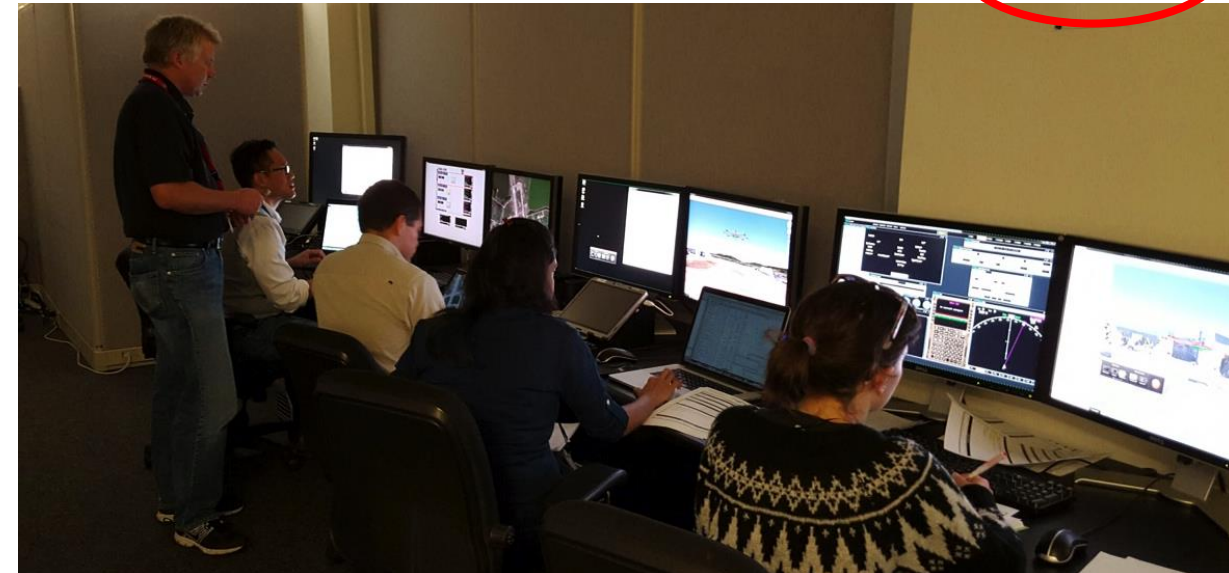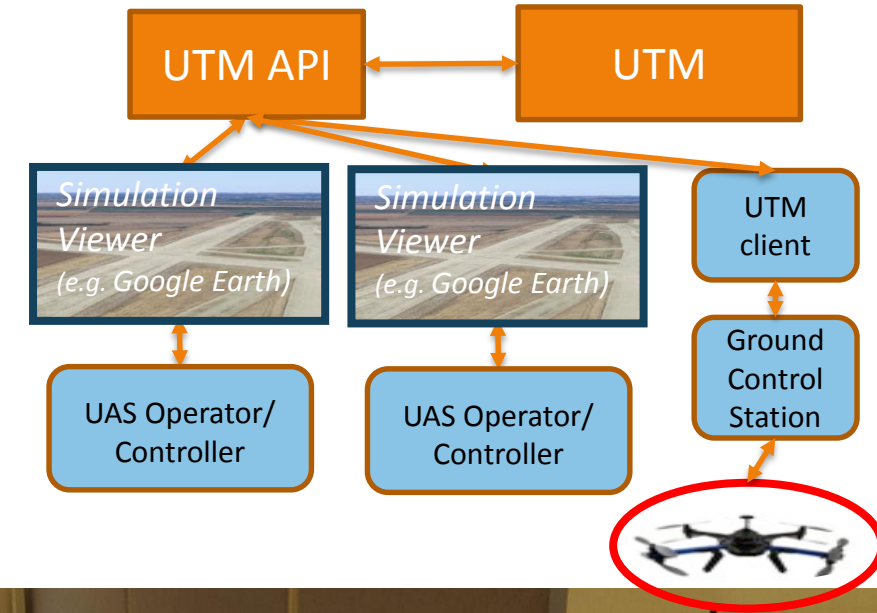
UTM Target Capability Level

Each capability is targeted to type of application, geographical area and uses risk-based approach

CAPABILITY 1 (AUGUST 2015)

- Reservation of airspace volume
- Over unpopulated land or water
- Minimal general aviation traffic in area
- Contingencies handled by UAS pilot
- Enable agriculture, firefighting, infrastructure monitoring

CAPABILITY 3 (JANUARY 2018)

- Beyond visual line of sight
- Over moderately populated land
- Some interaction with manned aircraft
- Tracking, V2V, V2UTM and internet connected
- Public safety, limited package delivery

CAPABILITY 2 (OCTOBER 2016)

- Beyond visual line-of-sight
- Tracking and low density operations
- Sparsely populated areas
- Procedures and "rules-of-the road"
- Longer range applications

CAPABILITY 4 (MARCH 2019)

- Beyond visual line of sight
- Urban environments, higher density
- Autonomous V2V, internet connected
- Large-scale contingencies mitigation
- News gathering, deliveries, personal use

Notional UTM Airspace

Multiple providers could offer some UTM services

Tailoring operational services based on geographical area needs

Vehicle performance could be different

SACRAMENTO INTL
CLASS C

McCLELLAN AFB
CLASS E

CLASS U1

CLASS U3

DOWNTOWN SACRAMENTO

SACRAMENTO MATHER
CLASS D

SACRAMENTO EXECUTIVE
CLASS D

CLASS U4

CLASS U2

Potential Users of UTM

Air Traffic Controllers

Hobbyists

Can use UTM information services for safety

Manned Aircraft Pilot

Reviews UAS operations prior to take off, maintains situation awareness for safety

General Public

Can use UTM information services for safety, privacy, and security concerns

UTM Manager

Makes strategic decisions to ensure safety, efficiency and equity of the UTM Airspace

UAS Controllers

Responsibly for the safe conduct of UAS vehicle(s)

UAS Operators

Legal entity that requests access to UTM airspace and manages UAS operations

UTM Services

TCL 1 Demonstration

What: Demonstrated concept for management of airspace in lower risk environments and multiple UAS operations

Where: Crows Landing, CA

Who: NASA and several flying, weather, surveillance partners

When: Aug 2015

Collected state data for operations, weather conditions, communications with UTM System, sound readings

Built foundation for future demonstrations with proposed increased capabilities

Showed that operations that could represent many business cases are already enabled with the initial concept

TCL 2 Demonstration

What: Extension of TCL 2 to BVLOS. Will exercise handling of off-nominal scenarios, altitude stratification, initial wx integration, surveillance data, and other services.

Where: Likely Reno-Stead, NV

Who: NASA and several flying, weather, surveillance partners

When: Oct 2016

Demonstrate efficient airspace use through multi-segmented plans, altitude stratification, and other procedures

Incorporate input from surveillance systems to share awareness with all stakeholders within UTM

Fly BVLOS with multiple vehicles procedurally separated supported by data from the UTM System

TCL 2 Operation area

Reno Stead Airport

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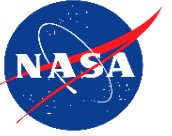
What: Demonstrate management of geographically diverse operations, 4 vehicles from each site flown simultaneously under UTM

Where: All 6 FAA UAS Test Sites

Who: NASA, Test Sites, support contractors

When: 19-21 April 2015

North Dakota Department of Commerce

Griffiss International Airport (NY)

State of Nevada

Virginia Polytechnic Institute & State University

University of Alaska Fairbanks

Texas A&M University Corpus Christi
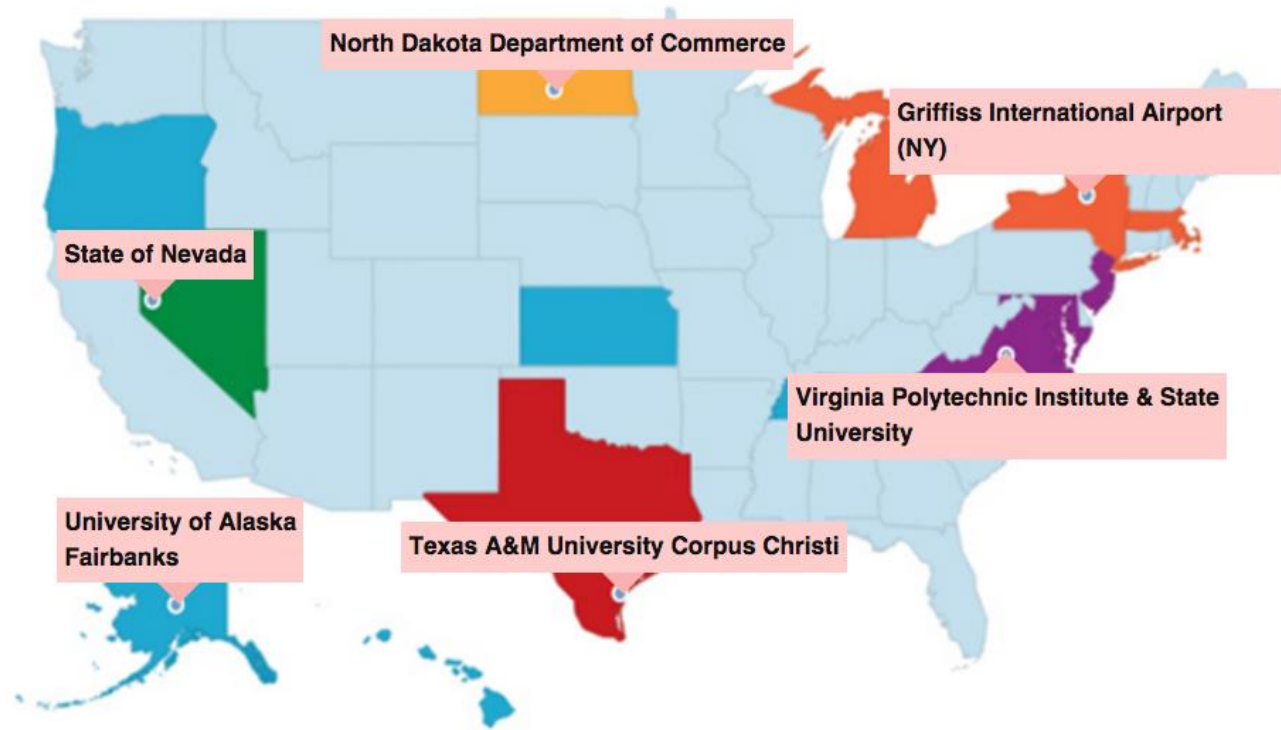
Obtain detailed feedback from the FAA Test Sites on the concept and operation of the UTM prototype

Introduce technology to the Test Sites for potential future use in airspace management

Learn what requirements might be needed for management of geographically diverse operations

Working Groups

- Collaborations in place with over 200 partners: industry, academia, and government are all represented
- Leveraging this by frequently meeting, obtaining solid stakeholder buy-in early and often on concepts
- Establishing semi-formal working groups to tackle specific issues, open to all of our collaborators to participate

Current Working Groups

Flight Planning

Ease use of the UTM System by developing services to bridge operators to UTM during flight planning. Additional services such as terrain checking, fleet optimization are possibilities

Conformance Monitoring

Ensure operations are staying where they said they would stay. Potential predictive capabilities to catch non-conformance as soon as possible.

Separation Assurance

Help monitor and alert for potential conflicts. Offer potential solutions to conflicts before vehicle to vehicle solutions are required.

Public Safety

Allow access to the airspace for public safety functions: police, fire, medical, national security, etc. Develop standards for prioritization of access.

MultiUTM

Develop concepts for enabling multiple UTM instances to communicate. Potentially allow for several different UTM Service Suppliers.

Progress

- Research Transition Team with FAA, DHS, and DoD

- 200+ industry and academia collaborators and increasing

- Initial UTM Concept of Operations: Industry, academia, and government

- Technical Capability Level 1 with 12 partners completed

- Technical Capability Level 2 in October 2016

- National Campaign with FAA Test Sites planned for April 2016

- Established several working groups to help develop the concept

- International interest

Opportunities: Research and Technology

- Beyond visual line of sight autonomous operations
- Tracking and locating every vehicle: Cooperative and non-cooperative
  - Cell/wireless, Automatic Dependent Surveillance, Satellite, localized beacon based systems
- Sense and avoid
  - Other vehicles (V2V) as well as objects such as wires
- Command, control, and communications without aviation certified systems: cell phone, etc.
- Last/first 50 feet: sensors, hardware, and software for autonomous operations
- Security
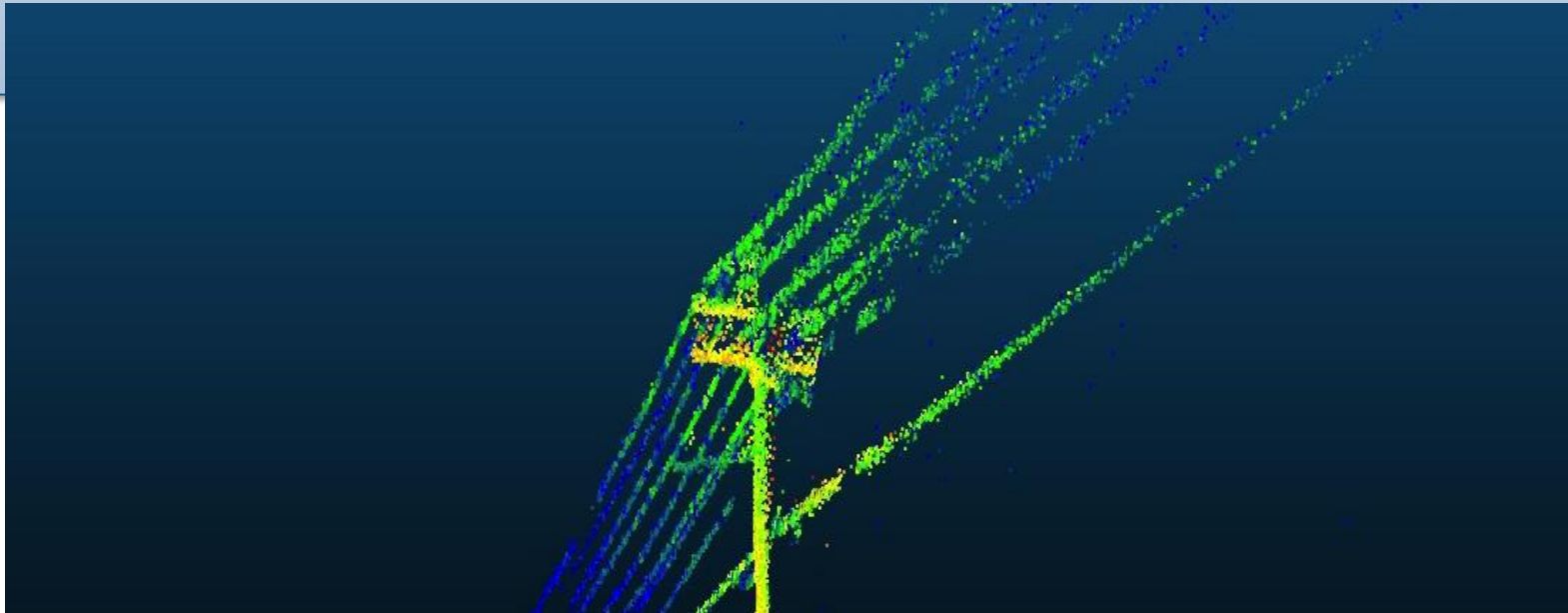
Policy and Public Acceptance

- Policy
  - Acceptable noise
  - Privacy considerations
  - Transportation safety

- Public Acceptance
  - Humanitarian applications: Disaster relief, medicine delivery, etc.
  - Public safety: Traffic, bridge inspections
  - Agricultural: Large remote areas
  - Commercial: Cargo and package delivery
  - Personal applications: roof top inspection

- Crawl-walk-run strategy – from remote areas to urban areas

NuSTAR: Towards Self-Regulation

- Self-regulation: responsible, credible, collaborative

- National UAS Standardized Testing and Rating (NuSTAR)

- Parallel: Underwriter's Laboratory, Consumer Reports, JD Powers, Which?

- Credible test bed and scenarios

  – Urban, rural, atmospheric conditions (e.g., fog, smog, rain)

  – Simulated pets

  – Failure modes

  – Sub-system level performance: engine/propulsion, networking, battery, sensor systems, software systems

  – Cyber-security, GPS denied conditions, etc.

- Support UAS manufacturers, consumers, FAA, insurance companies, and public at large through objective assessments

- Forensics analysis: Re-creation of incidents and accidents

Questions

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Back-up

Next Steps

- Development, simulations, and testing of UTM Technical Capability Levels 2-4
- Safety analysis

- NASA will continue to work with industry, academia, and government groups
  - Refine operational requirements, system architecture(s), prototype, and conduct tests – Continue until safe airspace integration is proven!

- National initial safe UAS integration campaign: coordinated effort for data collection and demonstrations
  - Through FAA test sites and other approved locations

What is UTM?

Research software application prototype that (1) allows UAS operators to submit flight plans to execute a specific mission in low-altitude airspace, and (2) determines how to safely enable such single or multiple UAS operations either within visual line of sight or beyond visual line of sight

- Allows requester to create and submit one or more trajectories
- Shows all airspace constraints (dynamic and static geo-fences)
- Supports connection to external subsystems (e.g., 3D maps, weather data, etc.) through standardized interface protocols
- Assesses and advises for trajectory interference or constraint violations
- Provides multiple trajectories for the same UAS with rank ordering to seek the best available trajectory in presence of other operations and constraints
- Tracks vehicle position

Multiple customers with differing mission needs

LINE-OF-SIGHT TO BEYOND LINE-OF-SIGHT: PILOTED TO AUTONOMOUS
RANGE OF UAS EQUIPAGE AND DIVERSE MISSIONS

UAS 1   UAS 2   UAS 3   Fleet

Tracking
- ADS-B, cell, and satellite
- Low-altitude radar/sensors at key locations (uncooperative)

UTM SERVICES
- Authentication
- Airspace design and geofence definition
- Weather integration
- Constraint management
- Sequencing and

- spacing
- Trajectory changes
- Separation management
- Contingency management

Real-time Weather & Wind

Weather & Wind Predictions

Airspace Constraints

Other Low-altitude Operations

Transition between UTM and ATM airspace

Constraints: noise, sensitive areas, privacy, etc.

3D maps: terrain and human-made structures

Airspace Manager and UAS operators are primary users
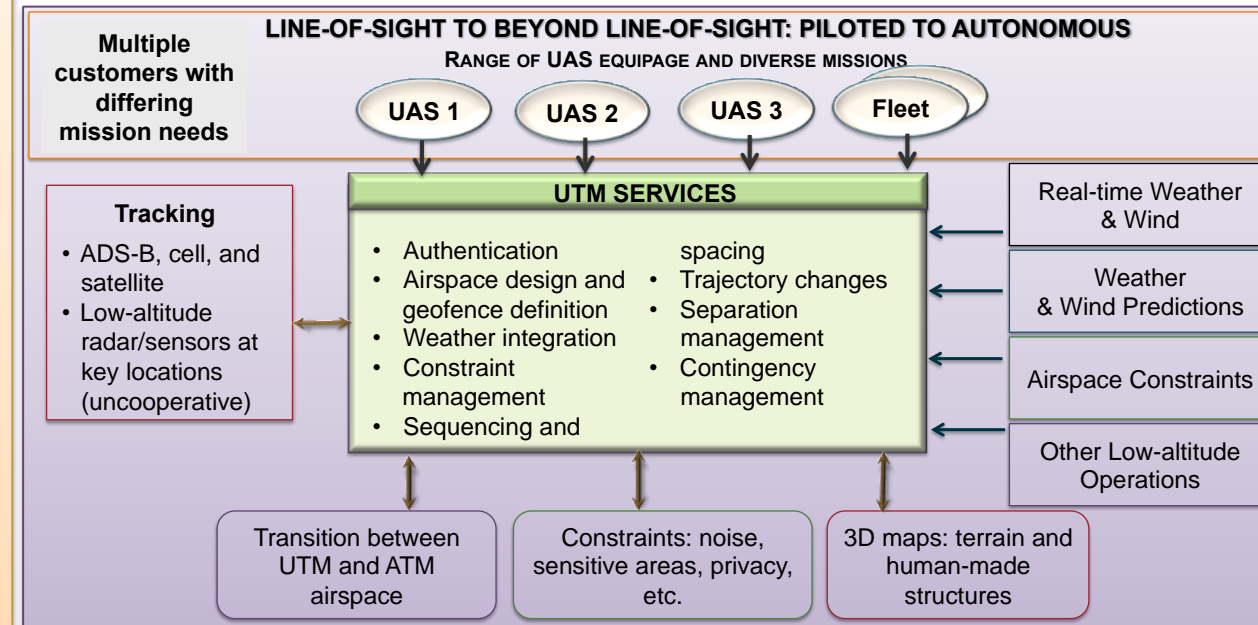
Cloud-based user access

UTM Design Functionality: Cloud-based

Self-driving car does not eliminate lanes and rules for efficient and safe operations

DIGITAL, VIRTUAL, & FLEXIBLE RISK-BASED APPROACH AND SERVICE INFRASTRUCTURE

- Safe low-altitude UAS operations with
  - Airspace management and geofencing
  - Weather and severe wind integration
  - Predict and manage congestion
  - Terrain and man-made objects: database and avoidance
  - Maintain safe separation (Airspace reservation, V2V, & V2UTM)
  - Allow only authenticated operations

LINE-OF-SIGHT TO BEYOND LINE-OF-SIGHT: PILOTED TO AUTONOMOUS
RANGE OF UAS EQUIPAGE AND DIVERSE MISSIONS

Multiple customers with differing mission needs

UAS 1 — UAS 2 — UAS 3 — Fleet

UTM SERVICES
- Authentication
- Airspace design and geofence definition
- Weather integration
- Constraint management
- Sequencing and
- spacing
- Trajectory changes
- Separation management
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Real-time Weather & Wind

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Airspace Constraints

Other Low-altitude Operations

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Constraints: noise, sensitive areas, privacy, etc.

3D maps: terrain and human-made structures

What is UTM?

- Research prototype that allows examination of how to safely enable single or multiple UAS operations in low-altitude airspace either visual line or sight or beyond visual line of sight

  - Shows all airspace constraints (dynamic and static geo-fences)

  - Allows to create trajectory or send in trajectory

  - Allows to connect external subsystems (e.g., 3D maps, weather data, etc) through standardized interface protocols

  - Allows to assess trajectory overlaps or constraint violations

  - Will allow to provide multiple trajectories for the same UAS with rank ordering to seek the best available trajectory in presence of other operations and constraints

User Access to UTM

- Cloud-based: user accesses through internet

- Generates and files a nominal trajectory

- Adjusts trajectory in case of other congestion or pre-occupied airspace

- Verifies for fixed, human-made, or terrain avoidance

- Verifies for usable airspace and any airspace restrictions

- Verifies for wind/weather forecast and associated airspace constraints

- Monitors trajectory progress and adjust trajectory, if needed (contingency could be someone else's)

- Supports contingency – rescue

- Allocated airspace changes dynamically as needs change

Approving UTM Operations

UTM Airspace

- Population Density
- Structure Density
- UTM Operation Density
- Likelihood of Manned Operation
- UTM Connection Coverage

Airspace Classifications

Airspace Constraints

- Airspace Restrictions by FAA Rules
- Airspace Prohibited for Security
- Noise Sensitive Areas
- Privacy Sensitive Areas

UTM Constraints

UAS Mission

- Operational Area
- Contingency Management
- Weather Conditions
- Spectrum Availability
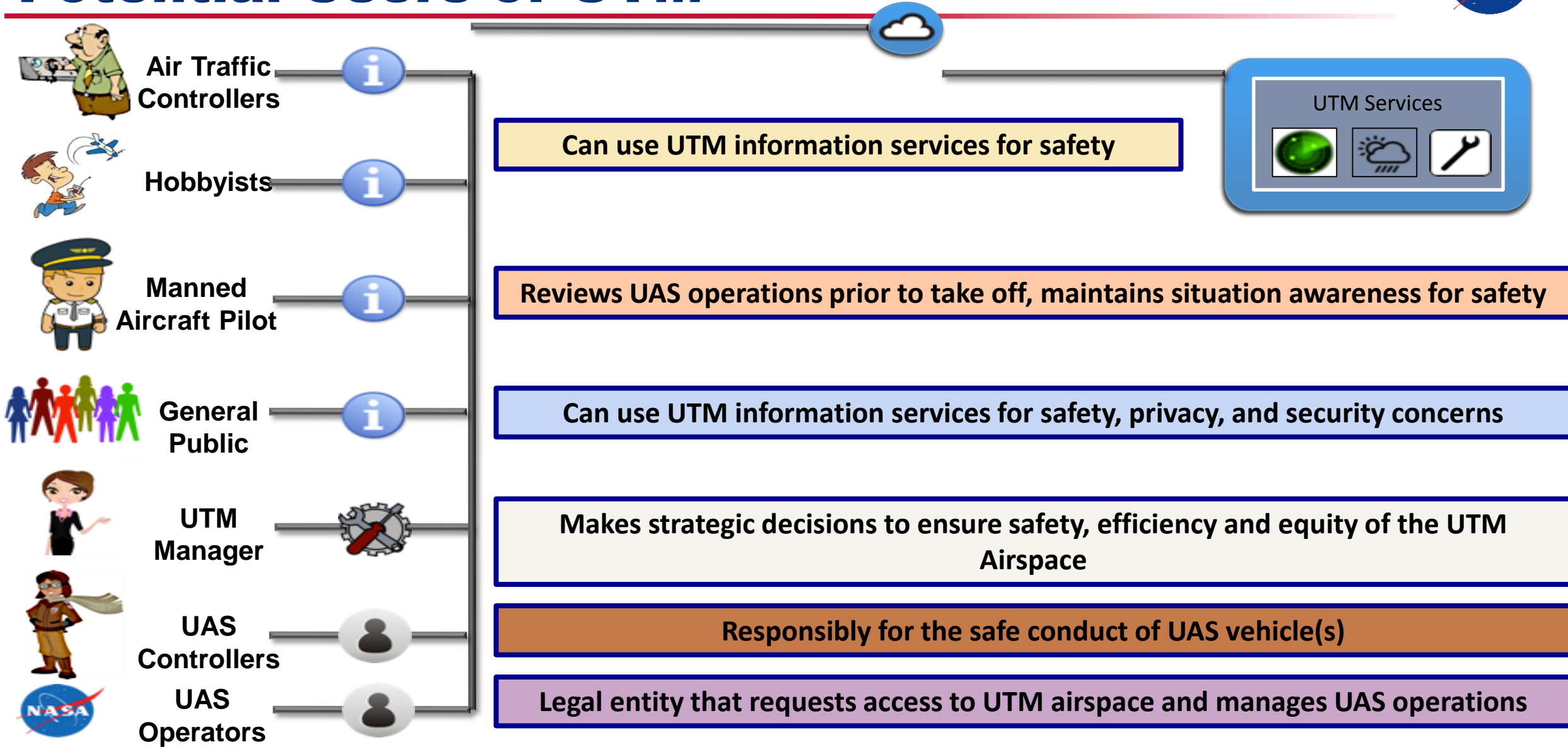- Supporting Infrastructure
- Available UTM Services

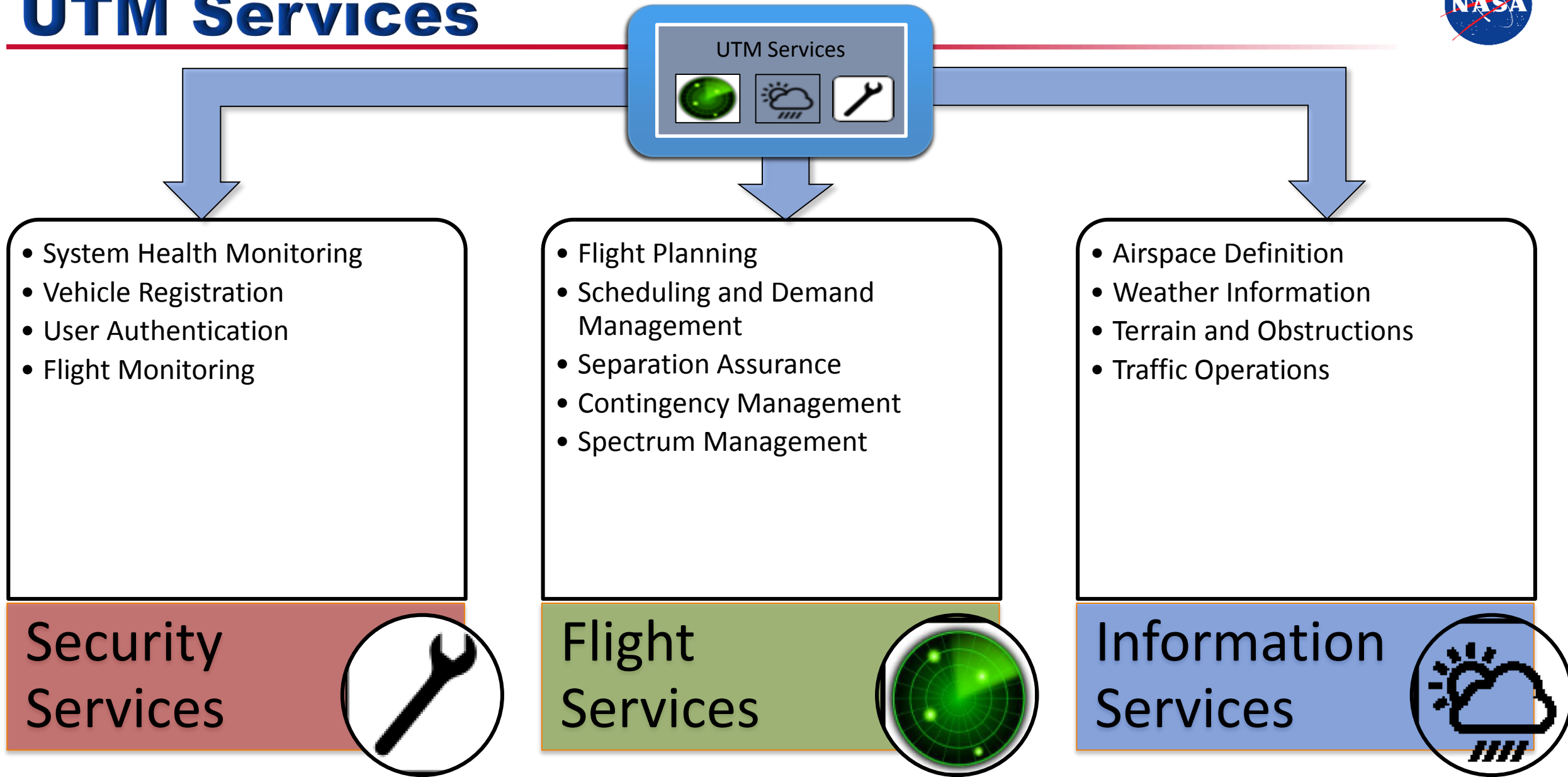**UTM Operational Plan**

UAS Vehicle

- Equipage
- Capabilities
- Performance
- Payloads
- Command and Control Coverage
- GCS Location
- Operator Training
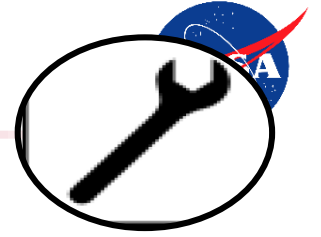
Vehicle Classifications

Potential Users of UTM

Air Traffic Controllers

Hobbyists

Can use UTM information services for safety

UTM Services

Manned Aircraft Pilot

Reviews UAS operations prior to take off, maintains situation awareness for safety

General Public

Can use UTM information services for safety, privacy, and security concerns

UTM Manager

Makes strategic decisions to ensure safety, efficiency and equity of the UTM Airspace

UAS Controllers

Responsibly for the safe conduct of UAS vehicle(s)

UAS Operators

Legal entity that requests access to UTM airspace and manages UAS operations

UTM Services

UTM Services

Security Services
- System Health Monitoring
- Vehicle Registration
- User Authentication
- Flight Monitoring

Flight Services
- Flight Planning
- Scheduling and Demand Management
- Separation Assurance
- Contingency Management
- Spectrum Management

Information Services
- Airspace Definition
- Weather Information
- Terrain and Obstructions
- Traffic Operations

# UTM Services: Security

System Health Monitoring:

- Status of internal subsystems/services

- Status of external system components

  – Surveillance Systems, Weather Stations

- Performance of communication channels

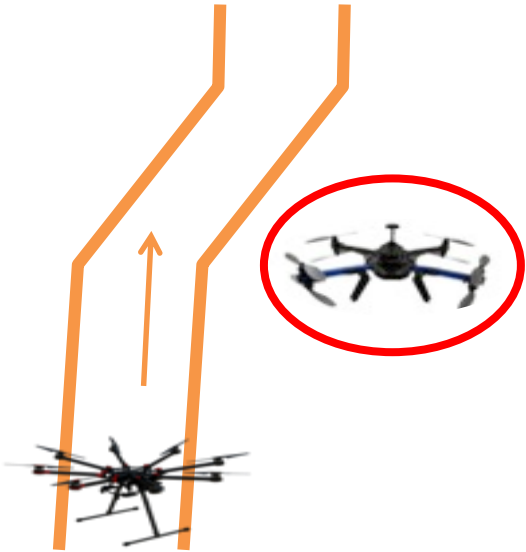- Reports failures

Vehicle Registration and Authentication:

- Ensures registered vehicles are allowed to operate and receive services

- Vehicle performance data and models

UTM Services: Security
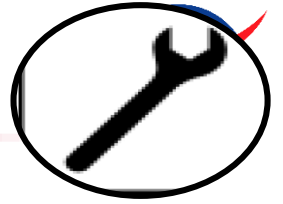
User Authentication and Authorization:

- Users require authenticated credentials
- UTM Clients capabilities, UTM service, and Training Information
- Different Types of Users (and different levels of access):
    - UTM Manager / Administrator
    - UAS Operators
    - non-UAS Operators
    - General Public

Flight Monitoring:

- Identifies and tracks aircraft in the UTM Airspace
    - May use multiple surveillance sources
- Monitors flight status and conformance of UTM operations
- Identifies rogue and intruder operations
- Reports failures in operations and assesses impacts to airspace use.

UTM Services: Flight Services
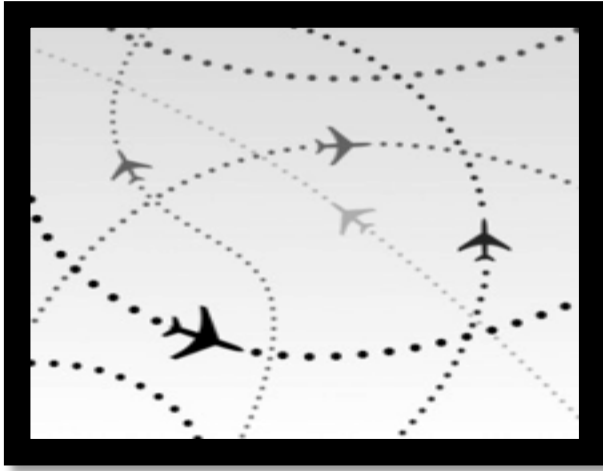
Flight Planning:

- Assess proposed operation against:
  - Airspace availability and Operational Constraints
- Operational plan could be
  - 2-D or 3-D Airspace, 3-D or 4-D Trajectory, or combination
- Plans are checked, approved/denied, and can be amended during flight
- Constraint info is available to UTM clients for flight planning

Scheduling and Demand Management:

- Resolves competition for airspace resources by multiple operations
- Risk-based metrics used to approve/deny/modify operations plans
- Rescheduling is based on demand
- Operator can propose several alternate operational plans in order to resolve competition.
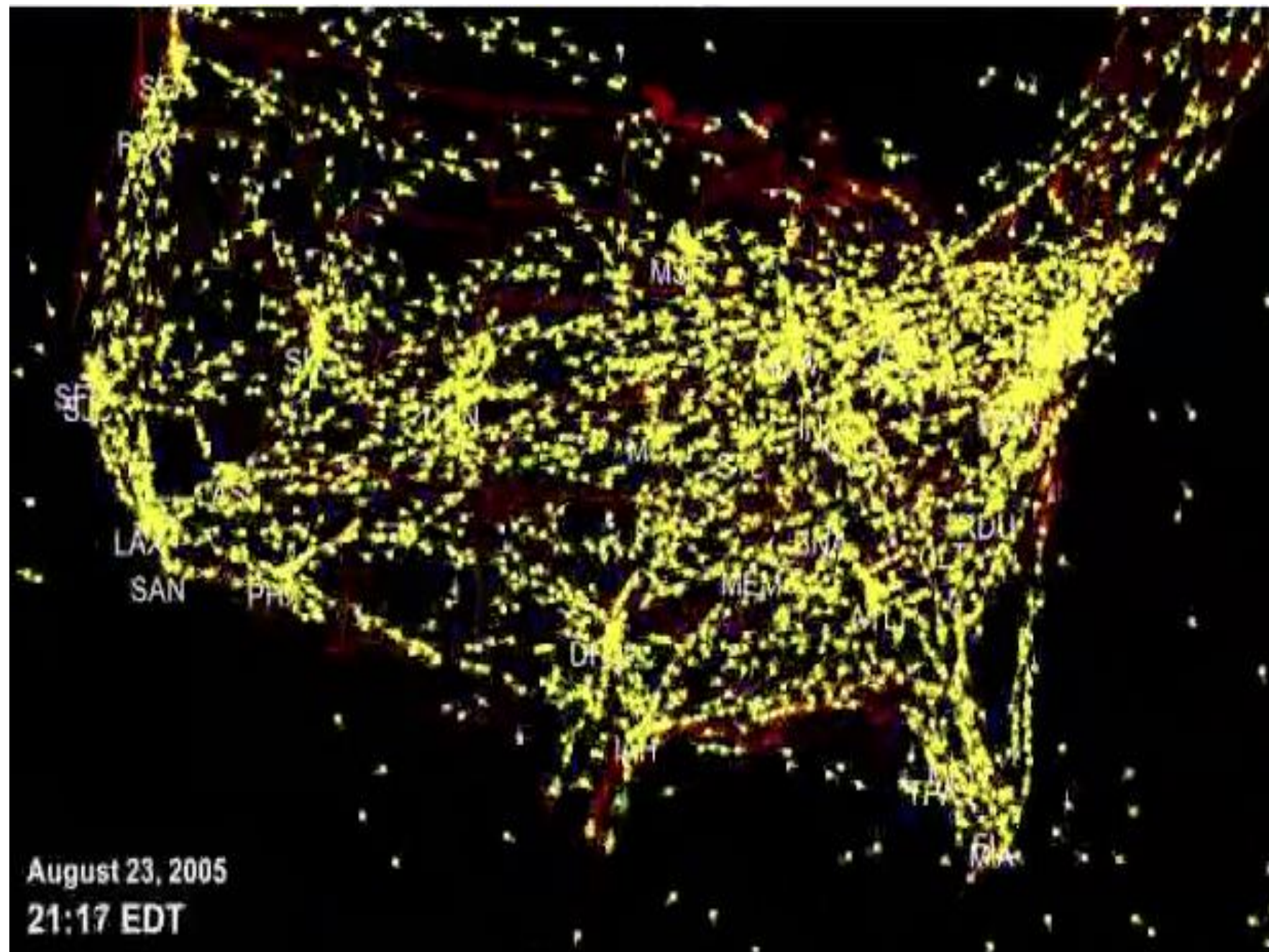
UTM Services: Flight Services
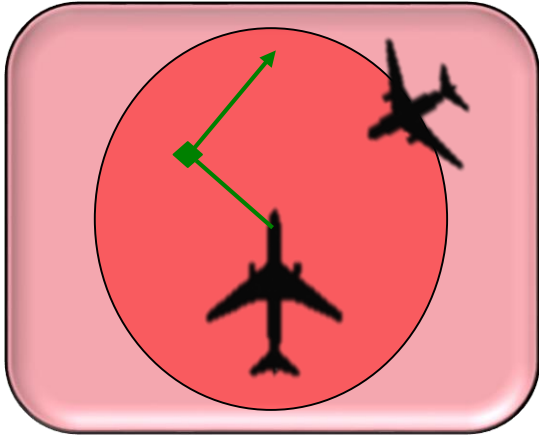
Separation Assurance:

- Multiple methods of separation provided: spatial, temporal, procedural, geographic, and in-flight separation

- Service provides separation from: UAS, intruder aircraft, weather, terrain, and vertical obstructions

- Operational environment, UAS and UTM Capabilities, Mission, and available data dictates the nature of the service (method of separation).

Contingency Management (CM):

- UTM is notionally a manage-by-exception system

- Methods of CM include: manual actions by UTM manager and UAS operator, automated decision making by UTM system, autonomous capabilities by UAS and/or a combination of these methods.

- CM determines what actions are taken when failures occur with other services

- The objective of CM is to minimize disruptions and maintain safety in off-nominal conditions (non-conformance, unavailable services/data, intruder aircraft, rogue vehicles, lost link conditions, communication failures, etc.)

August 23, 2005
21:17 EDT

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Consideration of Business Models

Single service provider: government entity

Traditional ANSP, like the FAA

UTM POTENTIAL BUSINESS MODELS

Single service provider: a non-government entity

Web services - General Aviation flight service station model

Each state may implement or delegate to counties/cities

Regional implementations by various companies - customized

Multiple service providers: state/local government entities

Multiple service providers: non-government entities

**Regulator has a key role in certifying UTM system and operations.
All UTM systems must interoperate.**