Enabling Civilian Low-Altitude Airspace and Unmanned Aerial System (UAS) Operations

By

Unmanned Aerial System Traffic Management (UTM)

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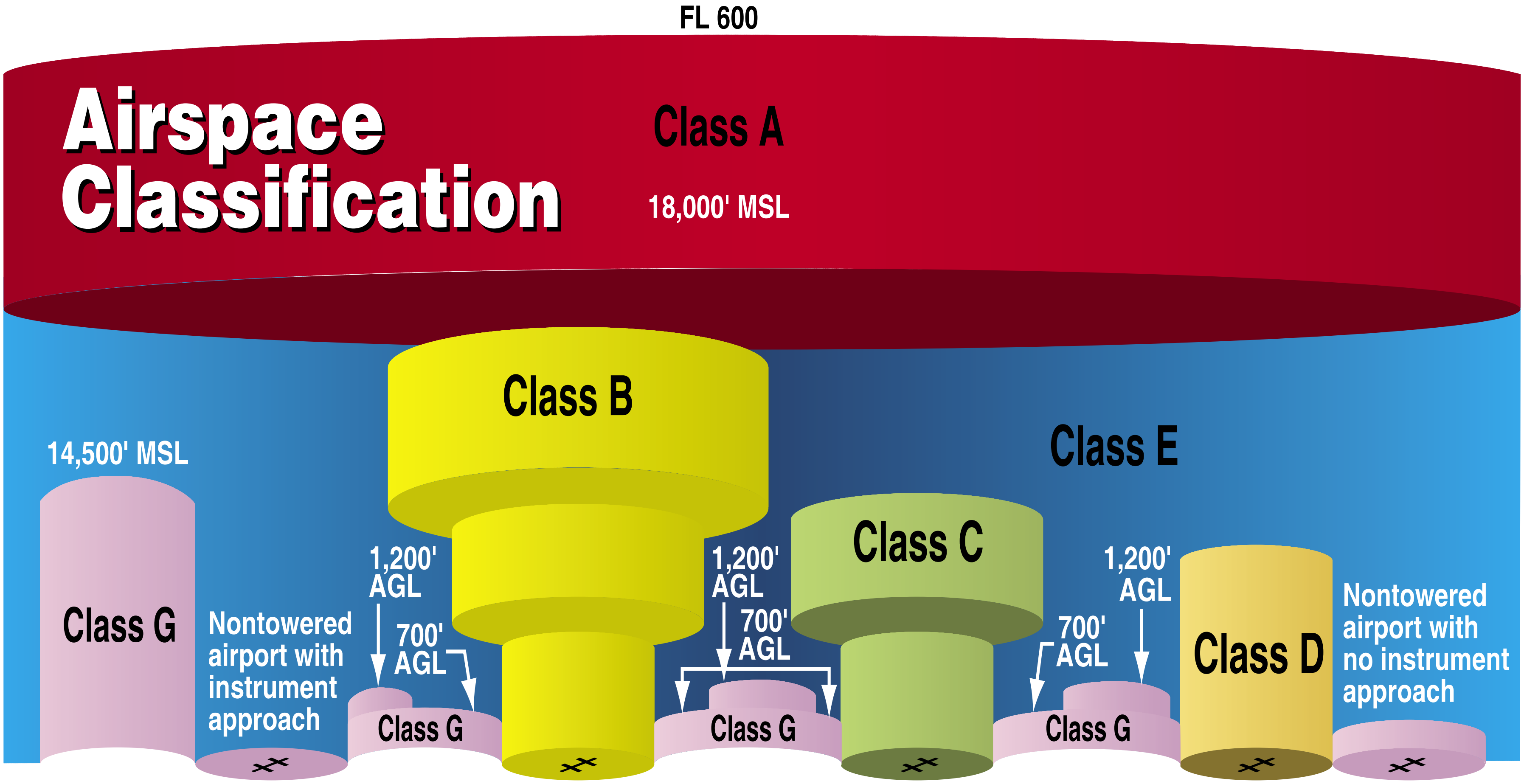
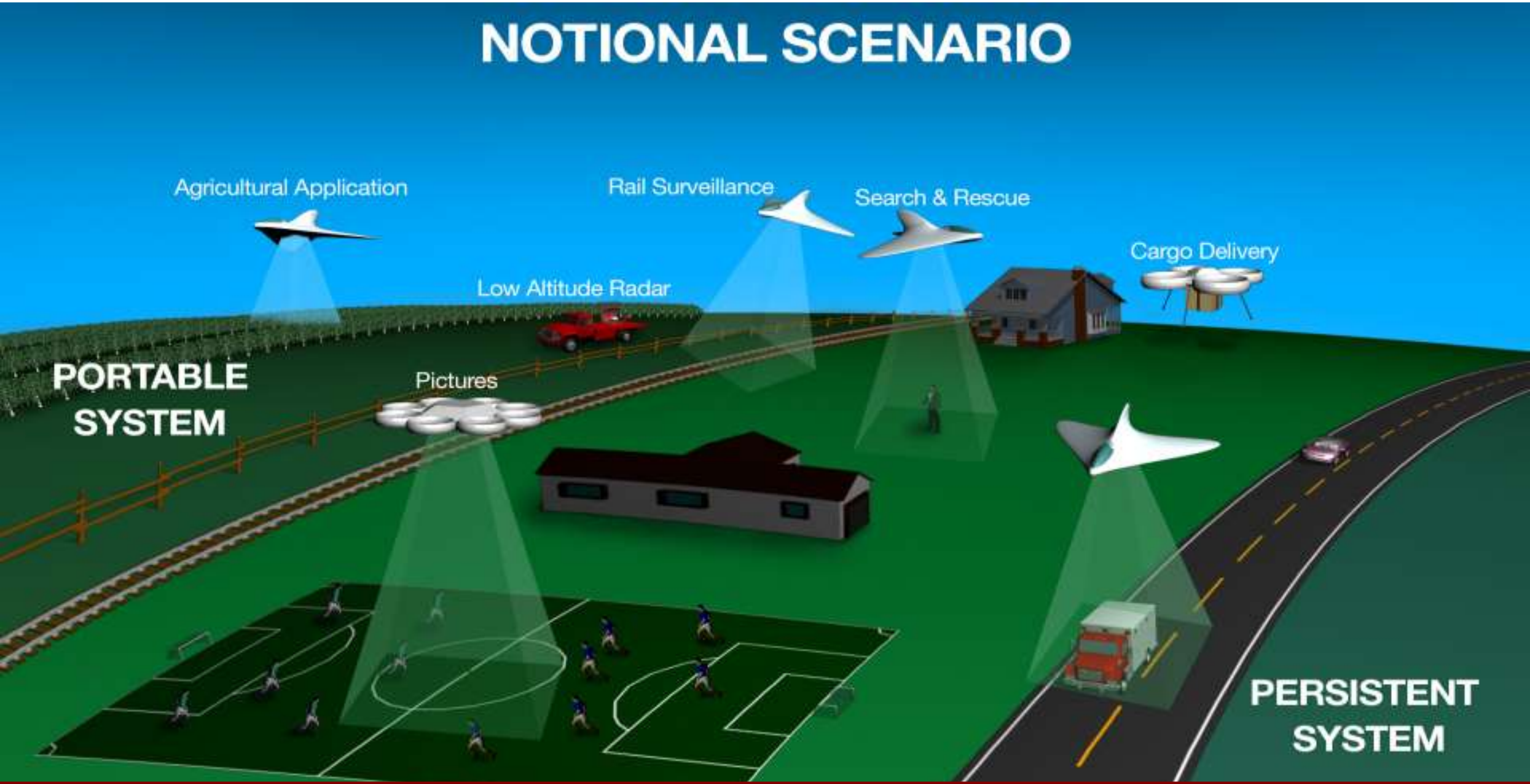
Airspace Classification



Source: Pilot’s Handbook of Aeronautical Knowledge, FAA

UTM Applications



- **Near-term Goal** – Enable initial low-altitude airspace and UAS operations with demonstrated safety as early as possible, within 5 years
- **Long-term Goal** – Accommodate increased UAS operations with highest safety, efficiency, and capacity as much autonomously as possible (10-15 years)

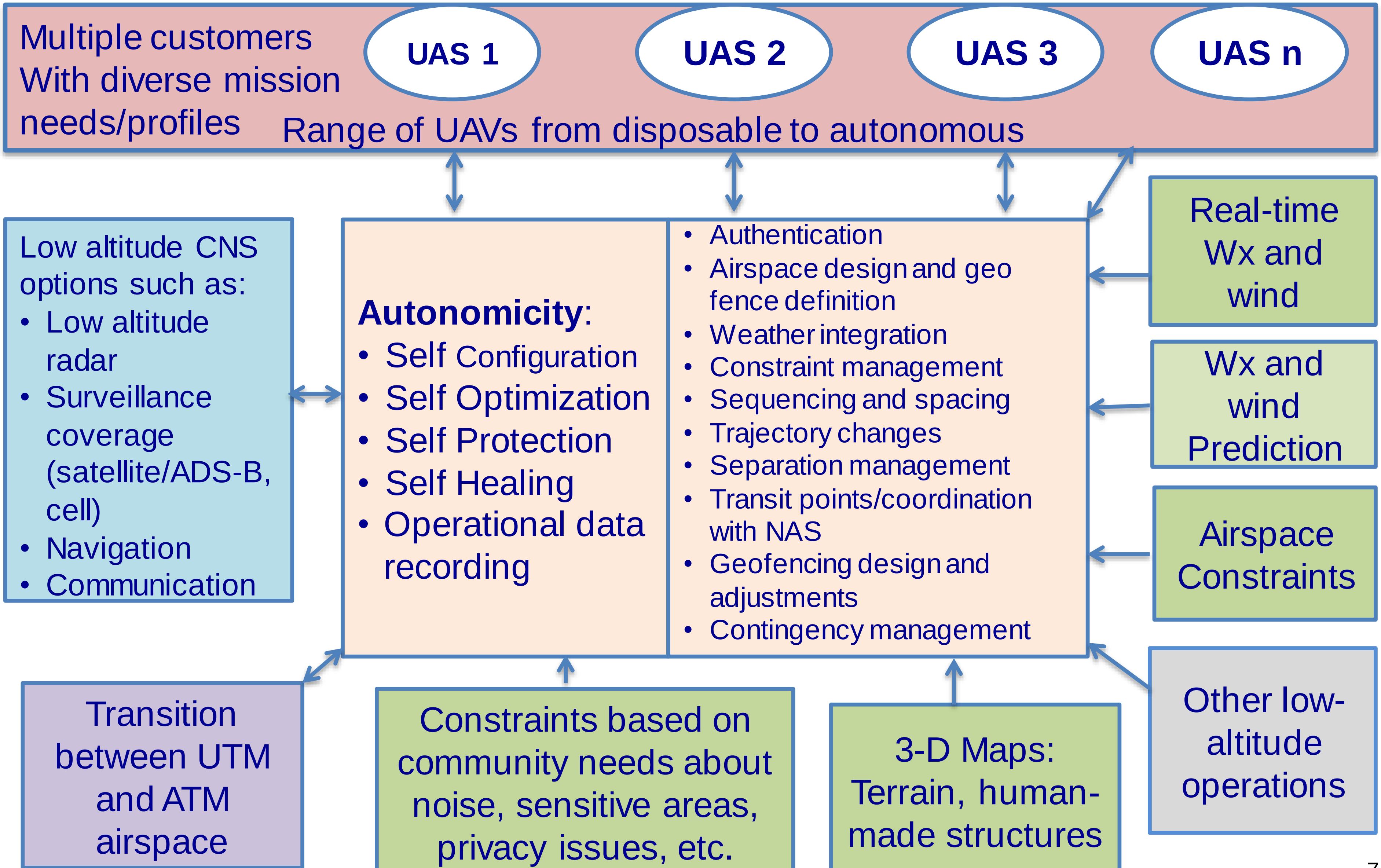
Operator Perspective: Low-altitude Airspace Operations

- Is airspace open or closed now and in the near-future?
- Which airspace they can operate, which airspace they should avoid?
- Will there be anyone else in the vicinity?
  - UAS, gliders, helicopters, and general aviation
- What should I do if I need to change my trajectory?
- How to manage a contingency?
- Who should operate the airspace and how?

UTM Design Functionality

- UAS operations will be safer if a UTM system is available to support the functions associated with
  - Airspace management and geo-fencing (reduce risk of accidents, impact to other operations, and community concerns)
  - Weather and severe wind integration (avoid severe weather areas based on prediction)
  - Predict and manage congestion (mission safety)
  - Terrain and man-made objects database and avoidance
  - Maintain safe separation (mission safety and assurance of other assets)
  - Allow only authenticated operations (avoid unauthorized airspace use)
- Analogy: Self driving or person driving a car does not eliminate roads, traffic lights, and rules
- Missing: Infrastructure to support operations at lower altitudes

UTM – One Design Option



UAS 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

UTM Manager

- Airspace Design and Dynamic Adjustments
  - Right altitude for direction, geo-fencing definition, community concerns, airspace blockage due to severe weather/wind prediction or contingencies
  - Delegated airspace as the first possibility
- Support fleet operations as well as singular operators (analogy - airline operations center and flight service stations)
- Overall schedule driven system to ensure strategic de-conflictions (initially, overtime much more dynamic and agile)
- Management by exception
  - Operations stay within geo-fenced areas and do not interrupt other classes of airspace operations in the beginning stages
  - Supports contingency management

UTM System Requirements

- Authentication
  - Similar to vehicle identification number, approved applications only
- Airspace design, adjustments, and geo-fencing
  - Corridors, rules of the road, altitude for direction, areas to avoid
- Communication, Navigation, and Surveillance
  - Needed to manage congestion, separation, performance characteristics, and monitoring conformance inside geo-fenced areas
- Separation management and sense and avoid
  - Many efforts underway – ground-based and UAS based – need to leverage
- Weather integration
  - Wind and weather detection and prediction for safe operations

UTM System Requirements

- Contingency Management
  - Lost link scenario, rogue operations, crossing over geo-fenced areas
  - Potential “9-11” all-land-immediately scenario
- UTM Overall Design
  - Enable safe operations initially and subsequently scalability and expected massive growth in demand and applications
  - As minimalistic as possible and maintain affordability
- Congestion Prediction
  - Anticipated events – by scheduling, reservations, etc.
- Data Collection
  - Performance monitoring, airspace monitoring, etc.
- Safety of Last 50 feet descent operation
  - In presence of moving or fixed objects, people, etc.

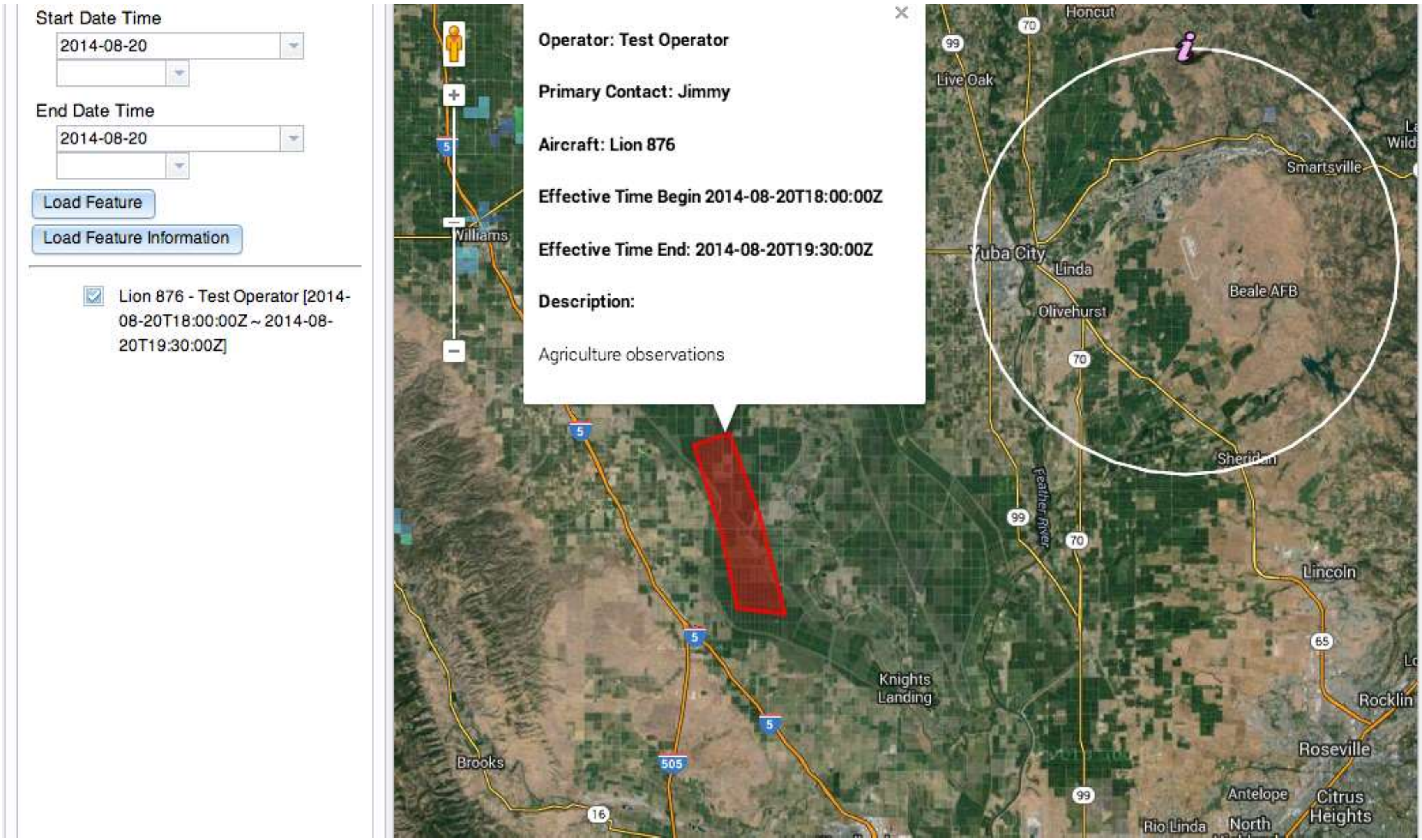
Near-term UTM Builds Evolution

UTM Build	Capability Goal
UTM1	Mostly show information that will affect the UAS trajectories • Geo-fencing and airspace design • Open and close airspace decision based on the weather/wind forecast • Altitude Rules of the road for procedural separation • Basic scheduling of vehicle trajectories • Terrain/man-made objects database to verify obstruction-free initial trajectory
UTM2	Make dynamic adjustments and contingency management • All functionality from build 1 • Dynamically adjust availability of airspace • Demand/capacity imbalance prediction and adjustments to scheduling of UAS where the expected demand very high • Management of contingencies – lost link, inconsistent link, vehicle failure

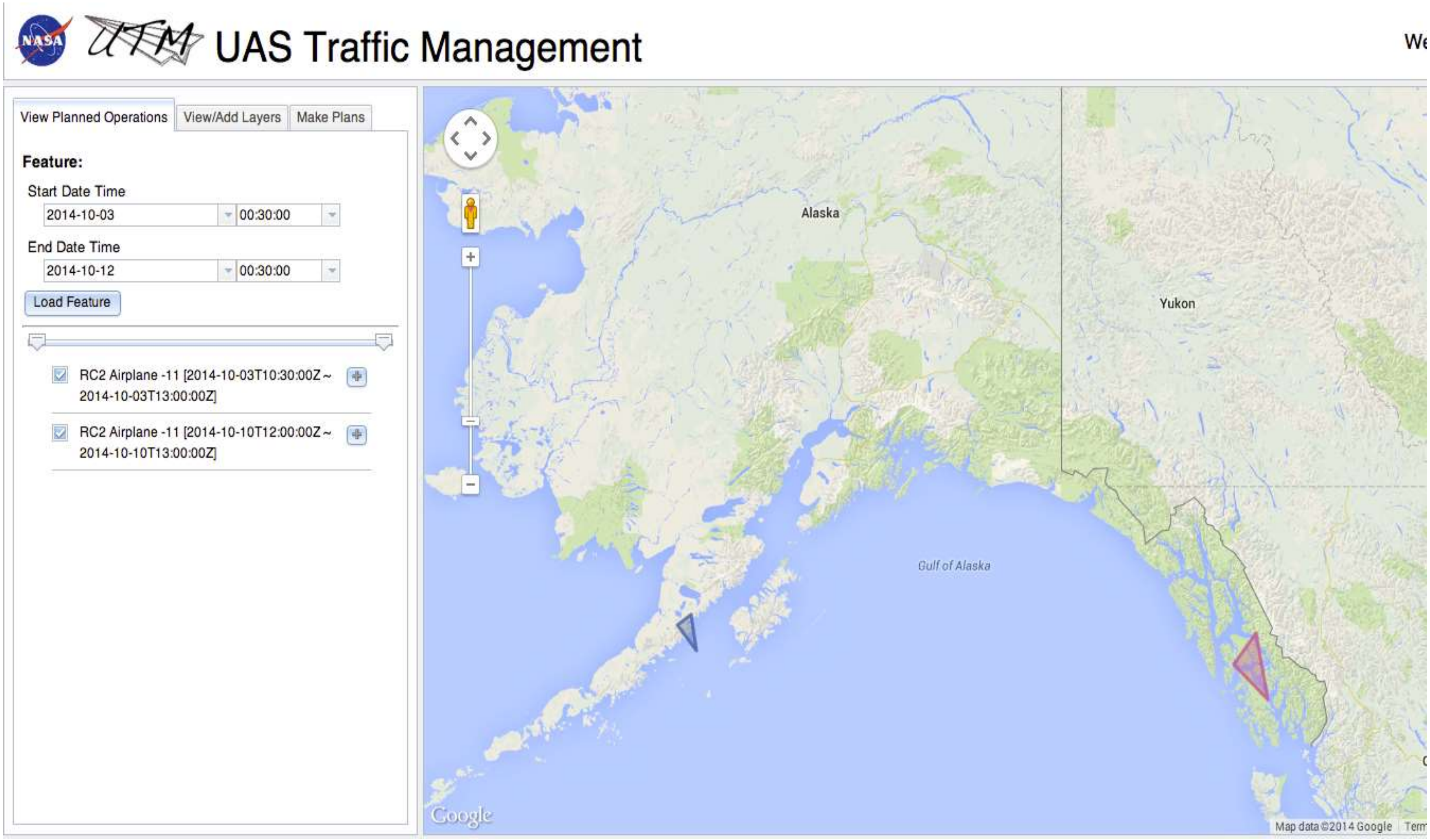
Near-term UTM Builds Evolution

UTM Build	Capability Goal
UTM3	Manage separation/collision by vehicle and/or ground-based capabilities • All functionality from build 2 • Active monitoring of the trajectory conformance inside geo-fenced area and any dynamic adjustments • UTM web interface, which could be accessible by all other operators (e.g., helicopter, general aviation, etc.) • Management of separation of heterogeneous mix (e.g., prediction and management of conflicts based on predetermined separation standard)
UTM4	Manage large-scale contingencies • All functionality of build 3 • Management of large-scale contingencies such as “all-land” scenario

Example Interface



Alaska's UTM

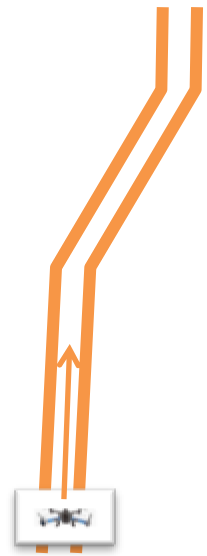


https://tmiserver.arc.nasa.gov/UTMWebApp/

Geo-fenced Areas

UAS area of operations geo-fence

Operators may request an area of operation. If granted, a geo-fence is implemented wherein other requests that intersect spatially and temporally with the operation could be denied.



UAS trajectory geo-fence

Operators may request specific trajectory for an operation. If granted, a geo-fence based on the vehicles operating parameters will be created to keep other vehicles within the UTM system from intersecting.

Airspace constraint geo-fence

Airspace that is off limits to UAS operations (airports, TFRs, etc.) will have a geo-fence prohibiting acceptance of plans that intersect.

Types of UTM

- Portable UTM System: Set up, operate, and move
  - Support humanitarian, agricultural and other applications and be able to move from one location to another
- Persistent UTM System: Sustained, real-time, and continuous operations
  - Denali National Park
  - Between mega-cities
  - Urban areas
- Number of alternative options to design, architect, and operate UTM
  - All ideas are welcome

Consideration of Business Models

- Single service provider for the entire nation such as a government entity
- Single service provider for the entire nation provided by a non-government entity (for-profit, or not-for-profit entity)
- Multiple service providers by regional areas where UTM service could be provided by state/local government entities
  - Need to be connected and compatible
- Multiple service providers by regional areas where UTM service could be provided by non-government entities
  - Need to be connected and compatible
- Regulator has a key role in certifying UTM system and operations

Example Research and Development Needs

- Minimum UTM system design and requirements
- Minimum vertical and horizontal separation minima among UAS and other operations (gliders, general aviation, helicopters)
  - Static or dynamic
  - Analytical, Monte Carlo or other types of modeling
- Tracking accuracy and separation minima trade-off
  - Oceanic separation vs en route aircraft separation
- Trajectory models for better prediction of different UAS
- Vehicles and wind/weather related considerations – modeling and prediction of winds, eddies, and weather at low altitudes
  - May need to enhance weather prediction capabilities
- Classification of UAS – bird strike example

Example Research and Development Needs

- Contingency procedures: large-scale and individual vehicle
- Sense and avoid – many products, research activities, and NASA UAS challenge
- Human computer interface design options for UTM manager
- Human computer interaction options for UAS ground control station
  - How many UAS can a ground control station operator manage
- Type of UAS and minimum autonomy capabilities
  - Humans can't operate two rotor failure mode for a multi-rotor vehicle
- Last/first 50 feet operations landing and safety
  - Various sensor pack and networked options for all weight classes
- Vehicle risk category
- Minimum equipage requirements

Example Student Projects

- Overall UTM design
- UTM interface
- Ground control station interface for multiple vehicle control
- Separation minima analysis (beyond well clear)
- Trajectory definition of UAS
- Wind/weather as related to geo-fencing
- Noise impact modeling
- Highways in the sky design (rules of the road)
- UAS trainer – who is qualified to operate? How quickly you can train?
- Wireless infrastructure (e.g., CDMA, LTE, etc.)
- Affordable and light weight sensors for sense and avoid
- Requirements on UAS – communication, latency, lost communication, energy depletion, etc. - Minimum
- Last/first 50 feet technology options (sensors, architecture, human-autonomy role, manual input, auto abort, etc.)
- Business case for private industry

Summary

- Near-term goal is to safely enable initial low-altitude operations within 1-5 years
- Longer-term goal is to accommodate increased demand in a cost efficient, sustainable manner
- Strong support for UTM system research and development
- Collaboration and partnerships for development, testing, and transfer of UTM to enable low altitude operations
- Step towards higher levels of autonomy

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Flight Situation Awareness