



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

By

Unmanned Aerial System Traffic Management (UTM)

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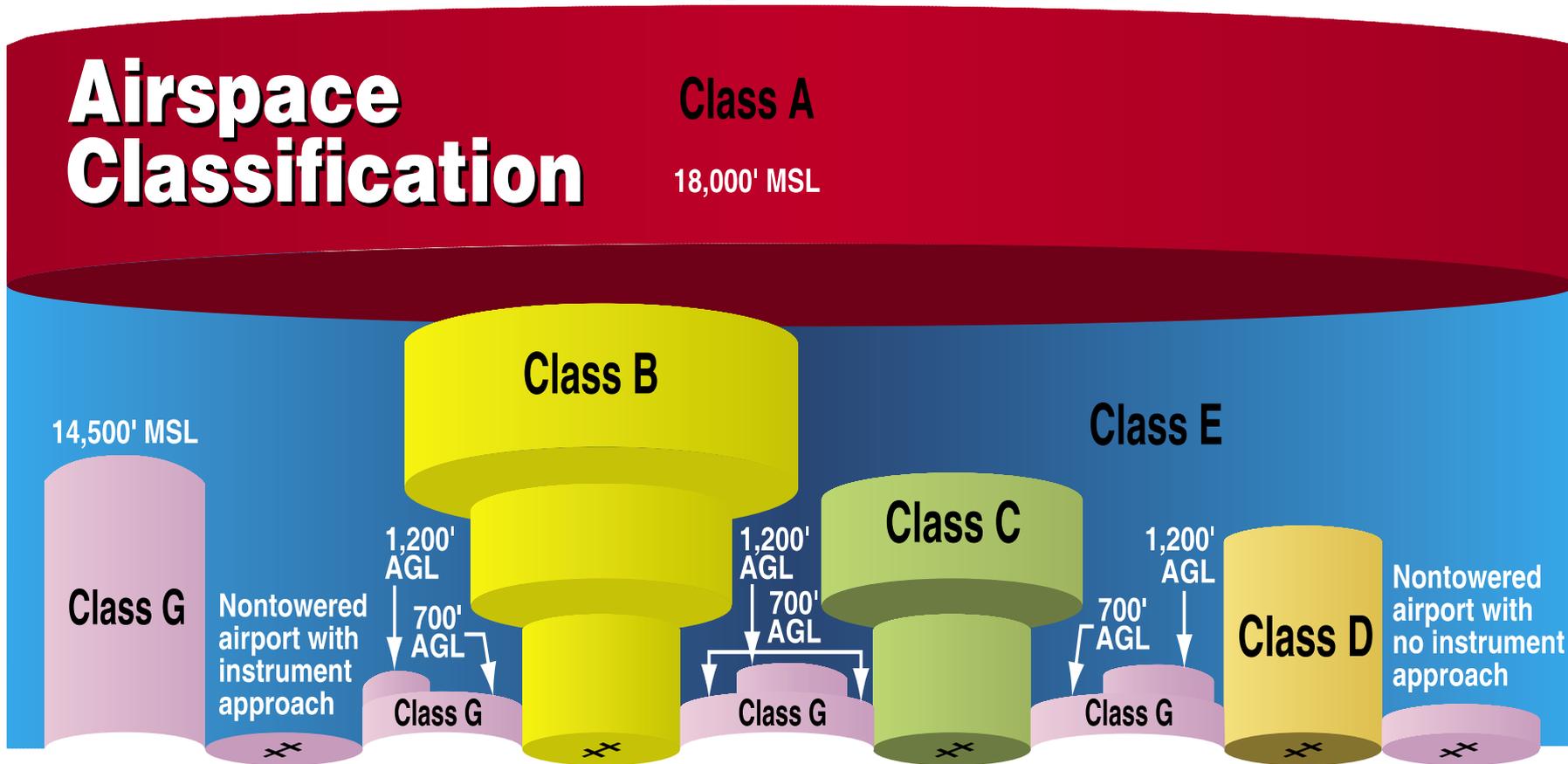
Airspace Classification

FL 600

Airspace Classification

Class A

18,000' MSL

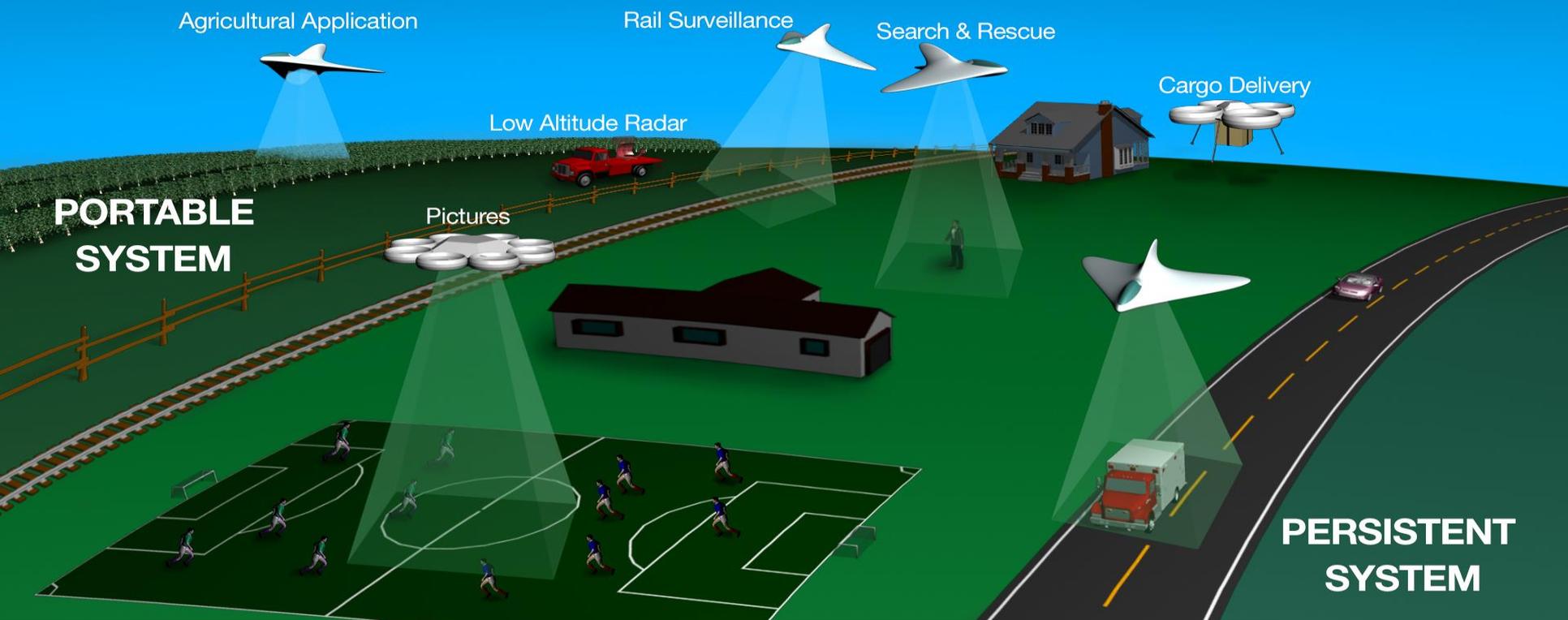


Source: Pilot's Handbook of Aeronautical Knowledge, FAA



UTM Applications

NOTIONAL SCENARIO



- **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?

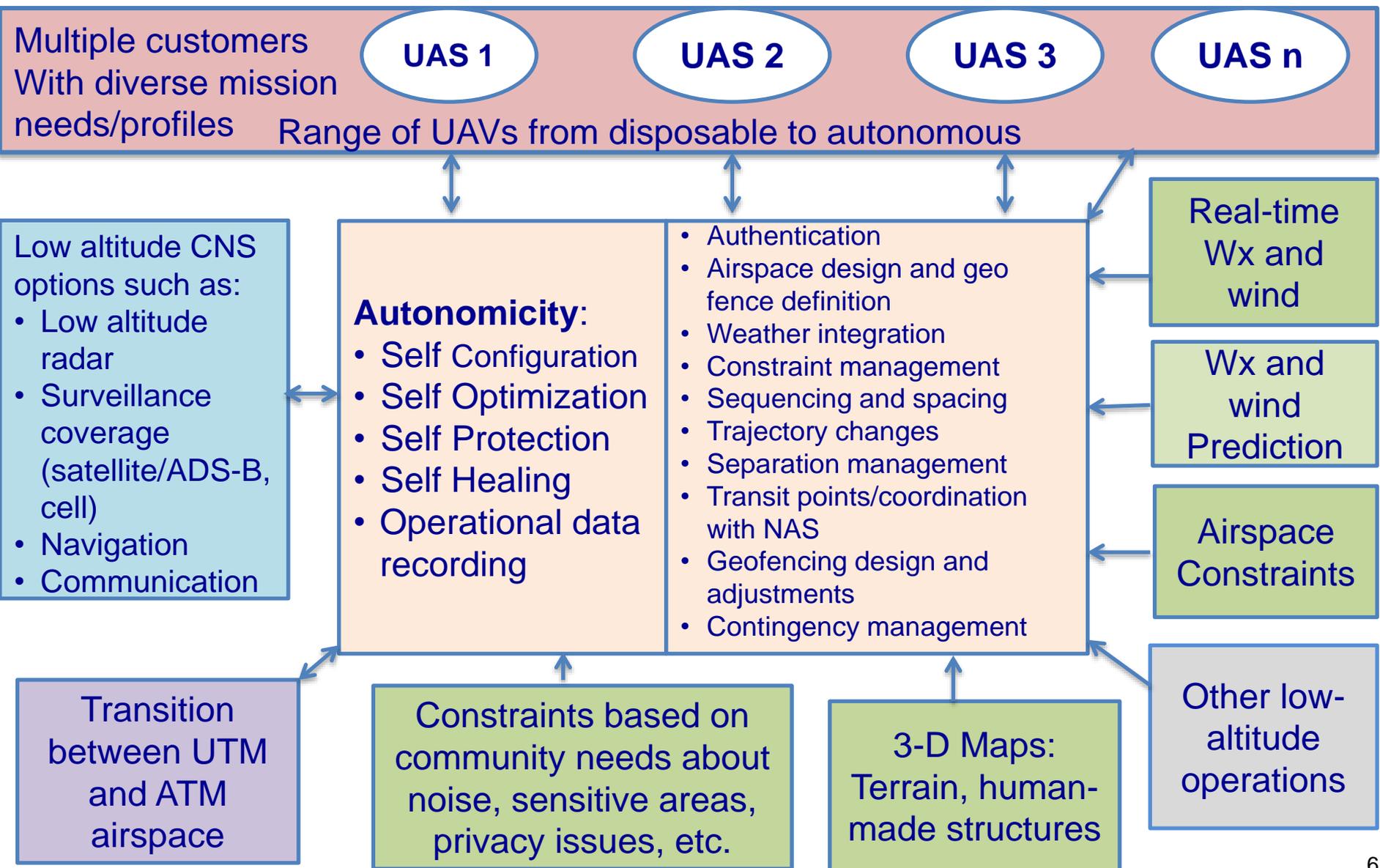


UTM Design Functionality

- 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





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: Initial Thoughts



- 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	<p>Mostly show information that will affect the UAS trajectories</p> <ul style="list-style-type: none">• 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	<p>Make dynamic adjustments and contingency management</p> <ul style="list-style-type: none">• 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	<p>Manage separation/collision by vehicle and/or ground-based capabilities</p> <ul style="list-style-type: none">• 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	<p>Manage large-scale contingencies</p> <ul style="list-style-type: none">• All functionality of build 3• Management of large-scale contingencies such as “all-land” scenario

Example Interface

Start Date Time
2014-08-20

End Date Time
2014-08-20

Load Feature

Load Feature Information

Lion 876 - Test Operator [2014-08-20T18:00:00Z ~ 2014-08-20T19:30:00Z]

Operator: Test Operator

Primary Contact: Jimmy

Aircraft: Lion 876

Effective Time Begin 2014-08-20T18:00:00Z

Effective Time End: 2014-08-20T19:30:00Z

Description:
Agriculture observations



Alaska's UTM

NASA UTM UAS Traffic Management

We

View Planned Operations View/Add Layers Make Plans

Feature:

Start Date Time
2014-10-03 00:30:00

End Date Time
2014-10-12 00:30:00

Load Feature

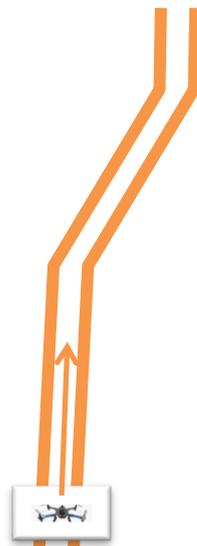
- RC2 Airplane -11 [2014-10-03T10:30:00Z ~ 2014-10-03T13:00:00Z]
- RC2 Airplane -11 [2014-10-10T12:00:00Z ~ 2014-10-10T13:00:00Z]

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

Example Research and Development Needs



- Many research and development needs – near-term and long-term growth-oriented implementation
- 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 50 feet operations landing and safety – vehicle and receiver interface
 - Various sensor pack and networked options for all weight classes
- Vehicle risk category
- Minimum equipage requirements (standards are being developed)



Example Student Projects

- Overall UTM design
- UTM interface
- Ground control station interface for multiple vehicle control
- Separation minima analysis
- 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.)
- Requirements on UAS – communication, latency, lost communication, energy depletion, etc.
- 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

