Overview of **U**nmanned Aerial System **T**raffic **M**anagement (UTM)

Motivation

- Many applications of Unmanned Aerial System (UAS) have been proposed
  - Humanitarian
  - Package delivery
  - Precision agricultural
  - Infrastructure monitoring
- Worldwide interest is intense
- UAS will need to operate in uncontrolled airspace
- No infrastructure is available to support these new operations
  - Today's Air Traffic Management (ATM) started after mid-air collision over Grand Canyon in 1956
- The US needs a system for managing UAS operations in civilian low-altitude airspace

Sense of Urgency

- Business applications are emerging rapidly
- Low-altitude operations could become dominant aviation activity
- Vehicle designs are changing continuously
- Airworthiness certificate relief and Certificate of authorization (COA) are taxing processes
- Visual line of sight is limiting
- Several efforts to integrate civilian UAS into the National Airspace System are underway
- An automation system, operational procedures, flight rules, and regulations are urgently needed to enable the industry

Agenda

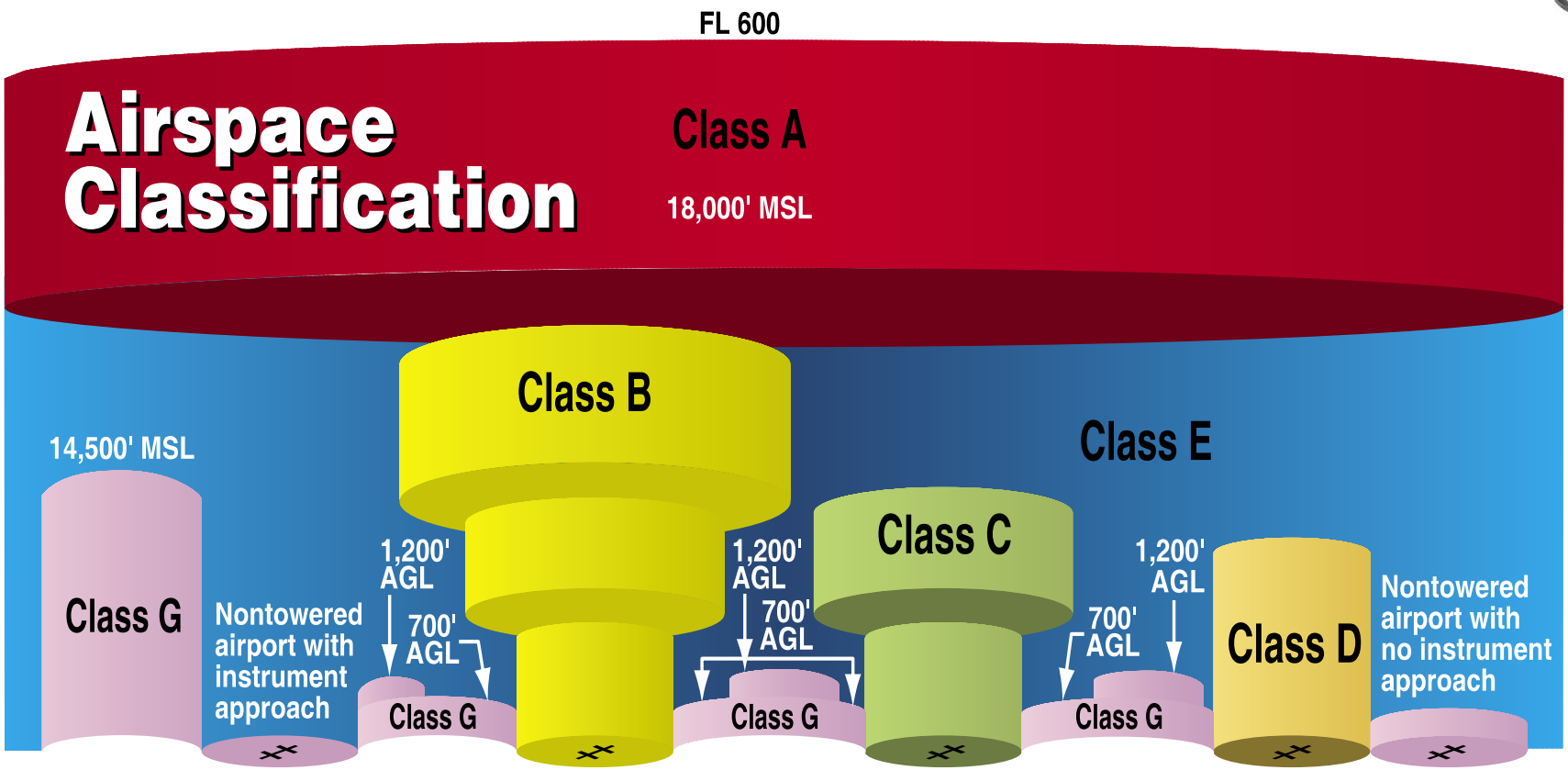
- Objectives
- Development Approach
  - Builds
  - Services
  - Simulation Capabilities
  - Field Tests
- UTM Build 1 Field Test Description
- Summary

Objectives

- Develop proof-of-concept UTM system to safely enable low-altitude small UAS operations
  - Automation system
  - Operational procedures
  - Flight rules

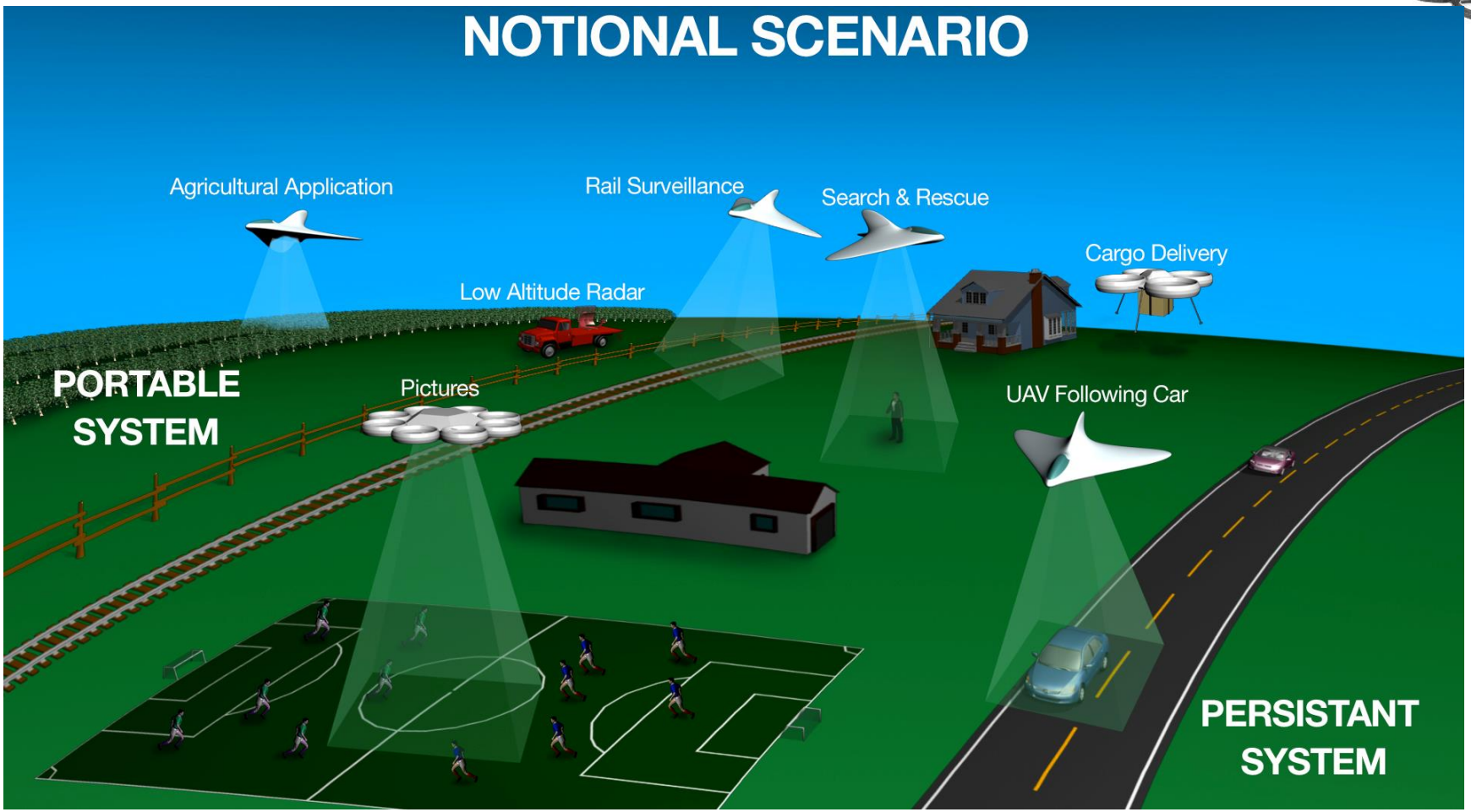
- Demonstrate UTM system in field tests in conjunction with a broad set of partners

US Airspace Classification



Source: Pilot's Handbook of Aeronautical Knowledge, FAA

UTM Applications



Notional UTM Scope

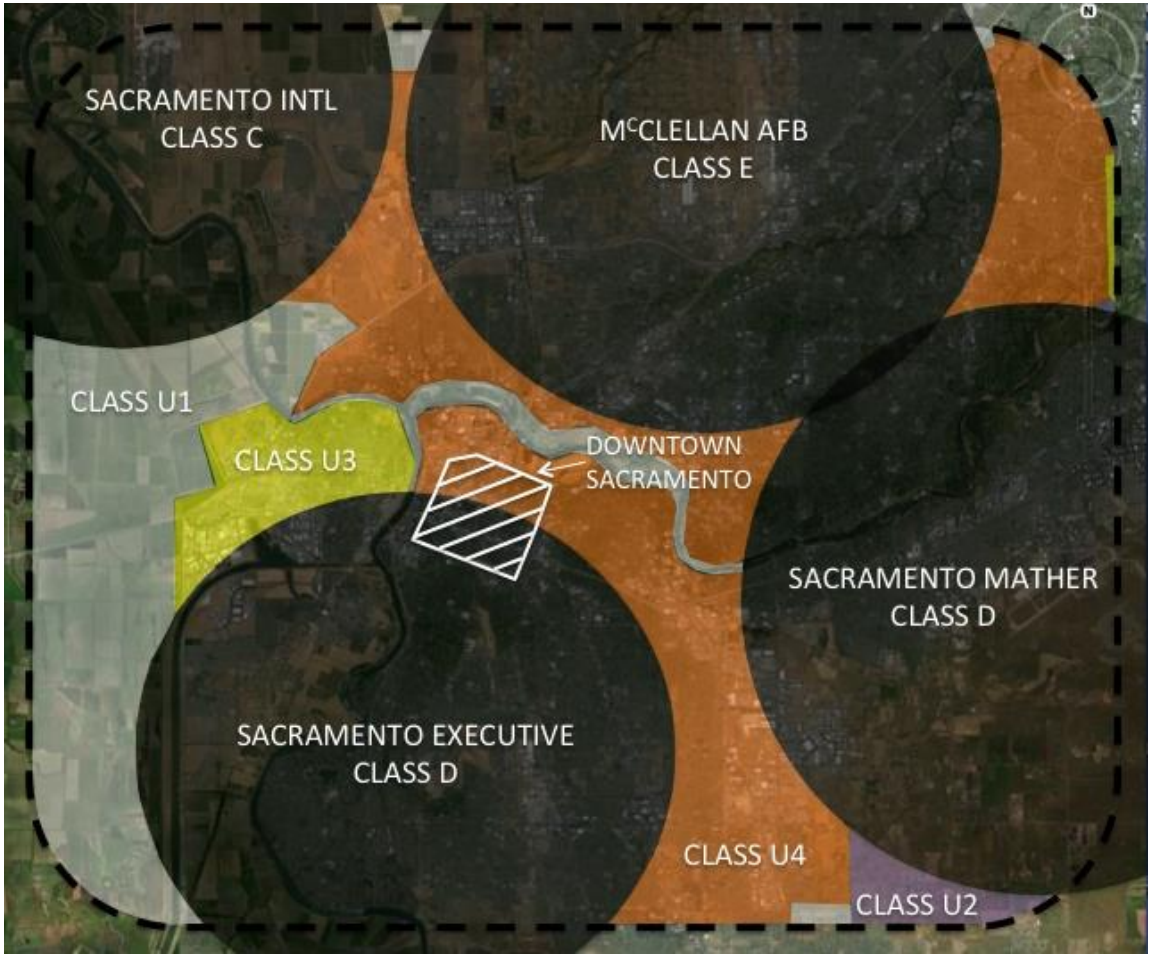
UTM Builds and Services

- Based upon four risk-based criteria:
  - Density of people on the ground
  - Number of structures on the ground
  - Likelihood of manned operations in close proximity
  - Number of UAS operations in close proximity
- Each build enables certain types of missions and provides certain services
- Each build includes supports the missions and services of the previous builds
- Builds are intended to be developmental milestones as well as self-contained systems.

High-Level UTM Builds

- Build 1:
  - Within visual line-of-sight
  - Over unpopulated land or water
  - No manned aircraft
  - Geo-fences separate UAS
  - Contingencies handled manually by UAS pilot
- Build 2:
  - Beyond line-of-sight
  - Over sparsely populated land
  - Few manned aircraft
  - Procedures and rules-of-the road separate UAS
  - Contingencies alerted to UAS operator
- Build 3:
  - Beyond line-of-sight
  - Over modestly populated land
  - Some manned aircraft
  - In-flight separation of UAS
  - Some contingencies resolved
- Build 4:
  - Beyond line-of-sight
  - Urban environments
  - Manned aircraft commonplace
  - Autonomous separation of UAS
  - Large-scale system-wide contingencies resolved

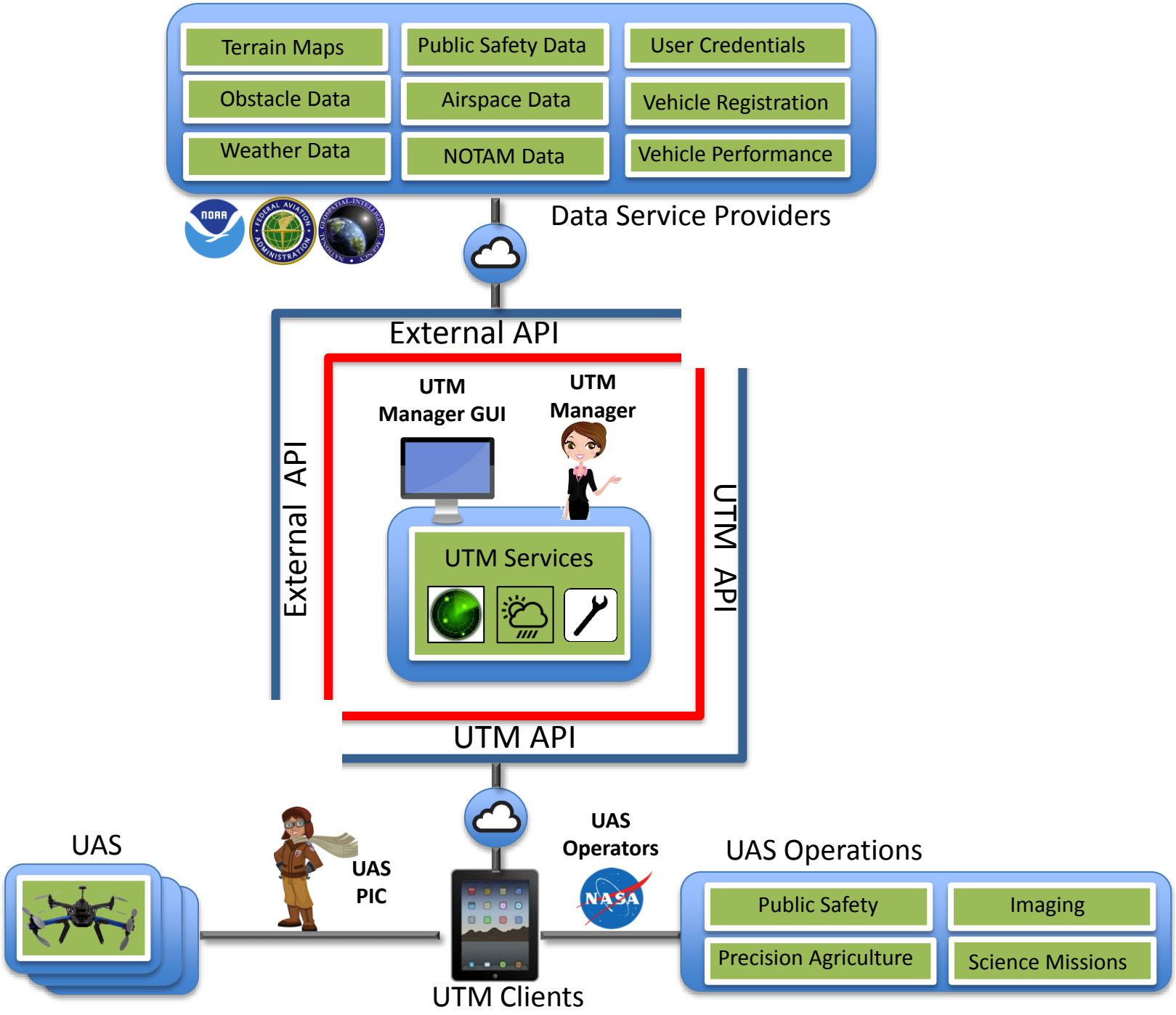
Notional UTM Airspace

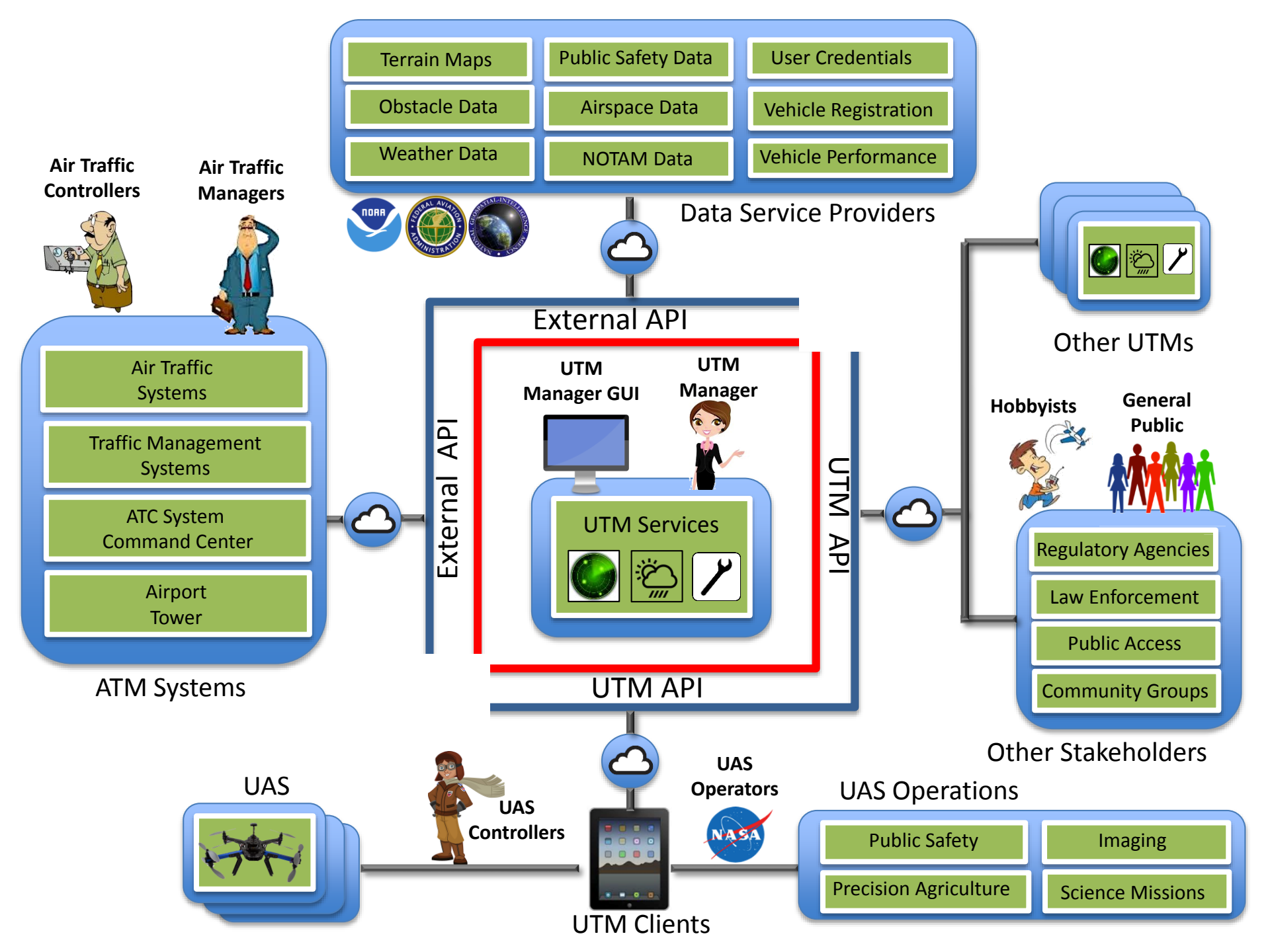


High-Level UTM Services

- Security Services:
  - System Health Monitoring
  - Vehicle Registration
  - User Authentication
  - Flight Monitoring
- Information Services:
  - Airspace Definition
  - Weather Information
  - Terrain and Obstructions
  - Traffic Operations
- Flight Services:
  - Flight Planning
  - Scheduling and Demand Management
  - Separation Assurance
  - Contingency Management

UTM System Architecture


Terrain Maps
Public Safety Data
User Credentials
Obstacle Data
Airspace Data
Vehicle Registration
Weather Data
NOTAM Data
Vehicle Performance
Data Service Providers
External API
UTM Manager GUI
UTM Manager
External API
UTM API
UTM Services
UTM API
UAS
UAS PIC
UAS Operators
UAS Operations
Public Safety
Imaging
Precision Agriculture
Science Missions
UTM Clients

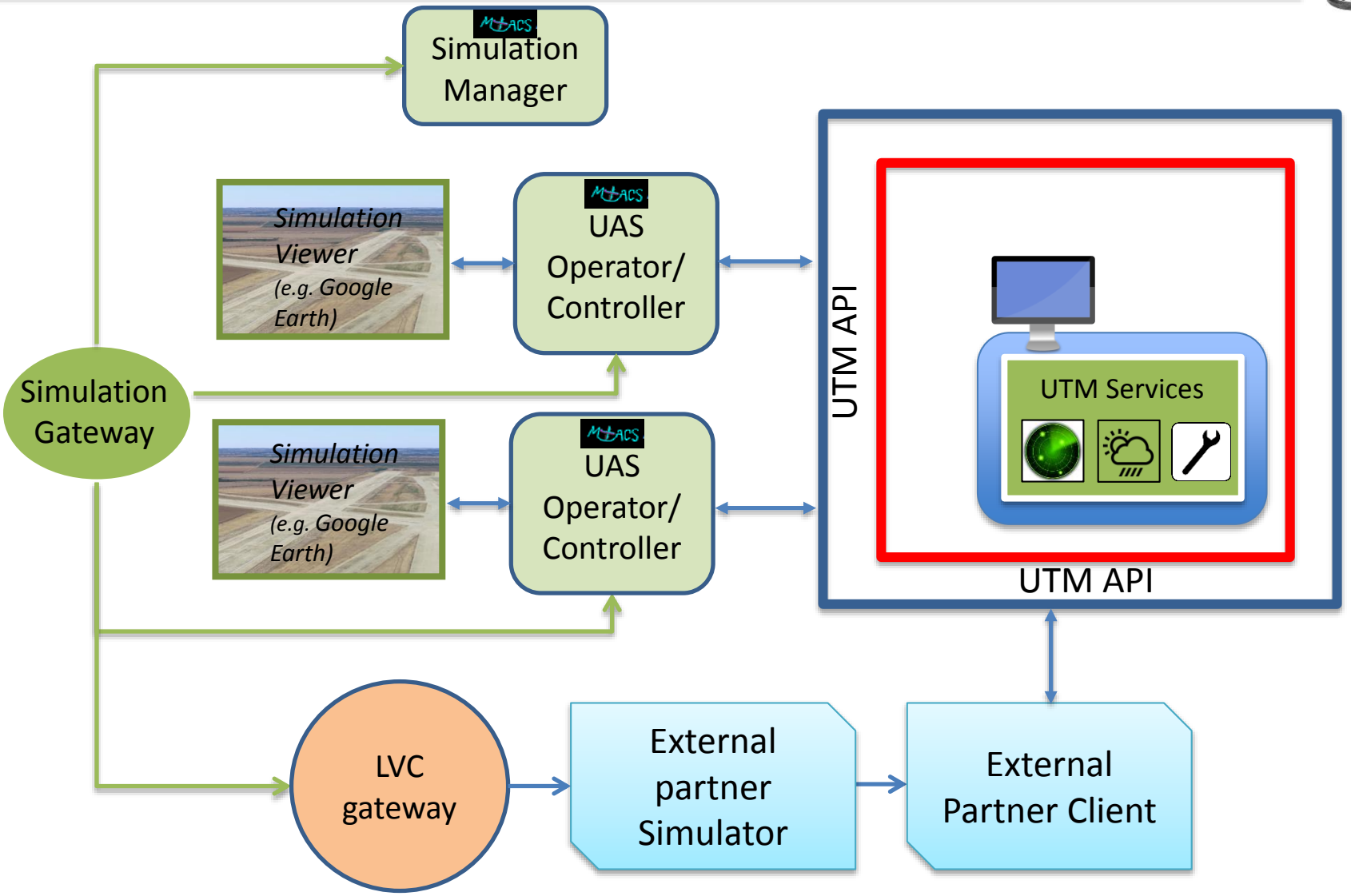

Terrain Maps
Public Safety Data
User Credentials
Obstacle Data
Airspace Data
Vehicle Registration
Weather Data
NOTAM Data
Vehicle Performance
Data Service Providers
Air Traffic Controllers
Air Traffic Managers
Air Traffic Systems
Traffic Management Systems
ATC System Command Center
Airport Tower
ATM Systems
External API
External API
UTM Manager GUI
UTM Manager
UTM Services
UTM API
UTM API
Other UTMs
Hobbyists
General Public
Regulatory Agencies
Law Enforcement
Public Access
Community Groups
Other Stakeholders
UAS
UAS Controllers
UAS Operators
UTM Clients
UAS Operations
Public Safety
Imaging
Precision Agriculture
Science Missions

UTM Simulations

- Demonstrate and evaluate advanced UTM services and UAS operations in high-fidelity human-in-the-loop simulations
- Define human's roles, responsibilities and procedures for managing UTM operations
- Perform verification and validation testing of UTM system prior to field tests
- Simulate complex operations that cannot be done during the field tests (e.g., urban operations, 9/11 type scenarios)

NASA Lab Test Bed

UTM simulator with access for external partners



UTM Field Tests

- Demonstrate, and evaluate current UTM services and UAS operations in conjunction with UTM stakeholders
- Verify tools and procedures to manage UTM operations
- Accelerate deployment of UTM System to FAA UAS test sites
- Validate assumptions made by the UTM Concept of Operations (e.g., vehicle performance, operational conditions, integration with real flight hardware and NAS systems)
- Provide tangible products for technology transfer of UTM requirements and capabilities to the FAA and UTM stakeholders

Build 1 Field Test Scenario

- Physical Location: Low Altitude Class G Airspace
  - Outside the Mode-C Veil
  - At least 3 nmi away from airports, helipads, etc.
  - 1,200 feet AGL or lower
- Risk Criteria
  - Population Density: Only people involved in operation
  - Structural Density: Only structures related to the operation
  - Manned operations: No non-participating aircraft expected
  - UAS Operations: Segregated by geo-fences or time
- Test Constraints
  - Within visual line-of-sight of Pilot-in-Command
  - During daylight hours
  - With visibility greater than 1 statute mile and clear of clouds

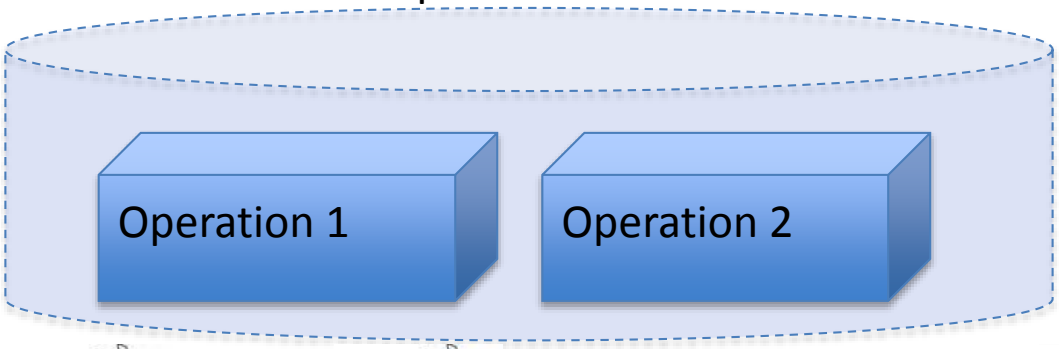
Build 1 Field Test Objectives

- Objective 1: Demonstrate UTM Build 1 capabilities and effectiveness under real world uncertainties

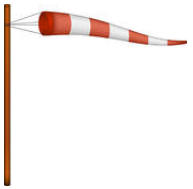
- Objective 2: Collect data to support Build 2 development

Build 1 Field Test Approach

Demonstration Airspace



Surveillance
Weather



NASA Flight
Support Crew

Partner(s) Flight
Support Crew

Visual Observers

Range Safety
Officer

Mission
Manager

NASA
GCS/Display

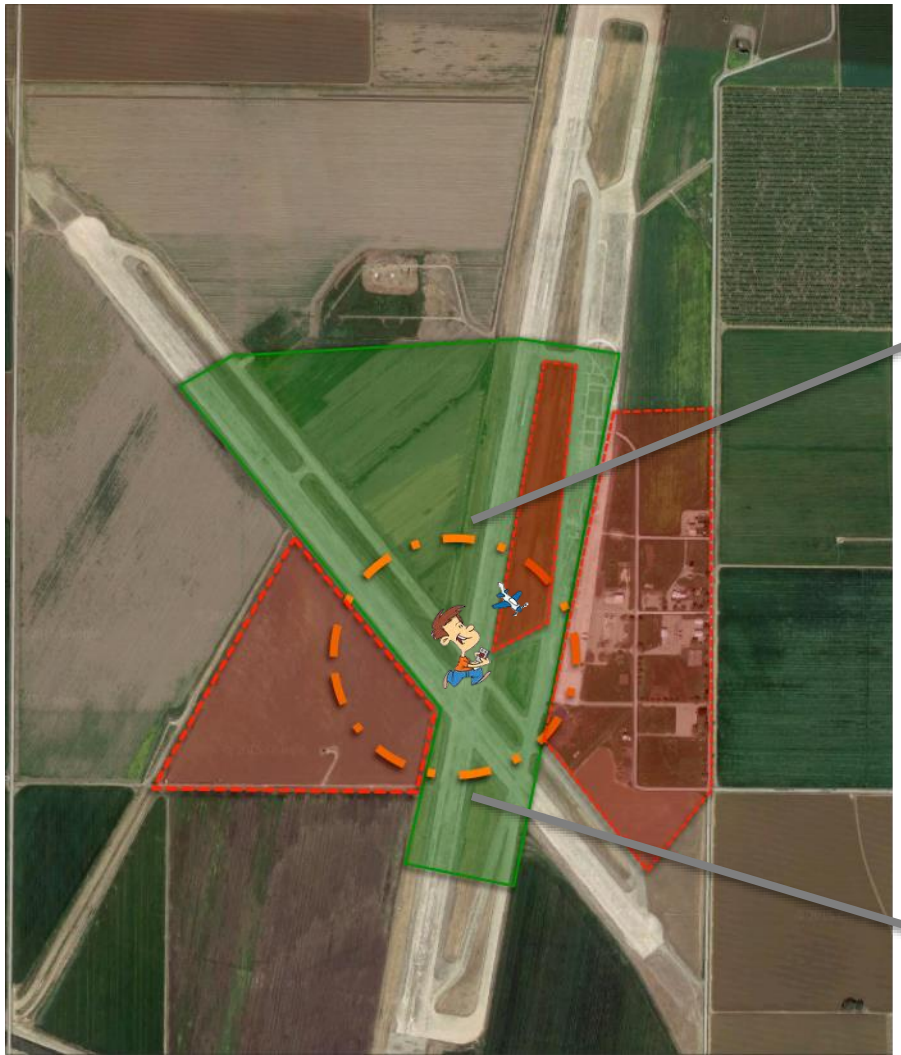
Partner(s)
GCS/Display

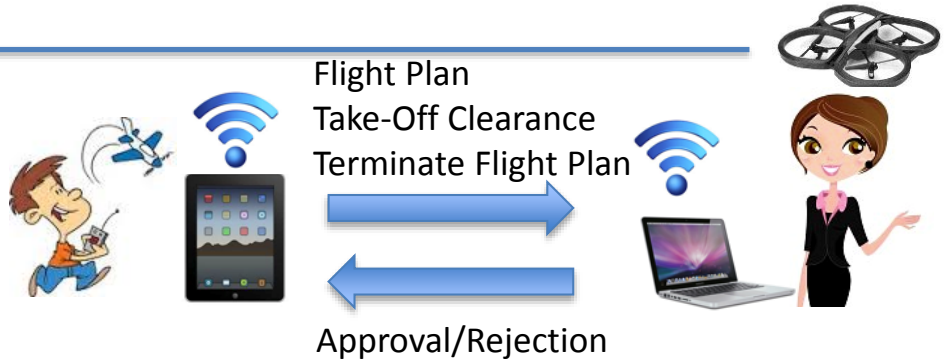
Ad-hoc network

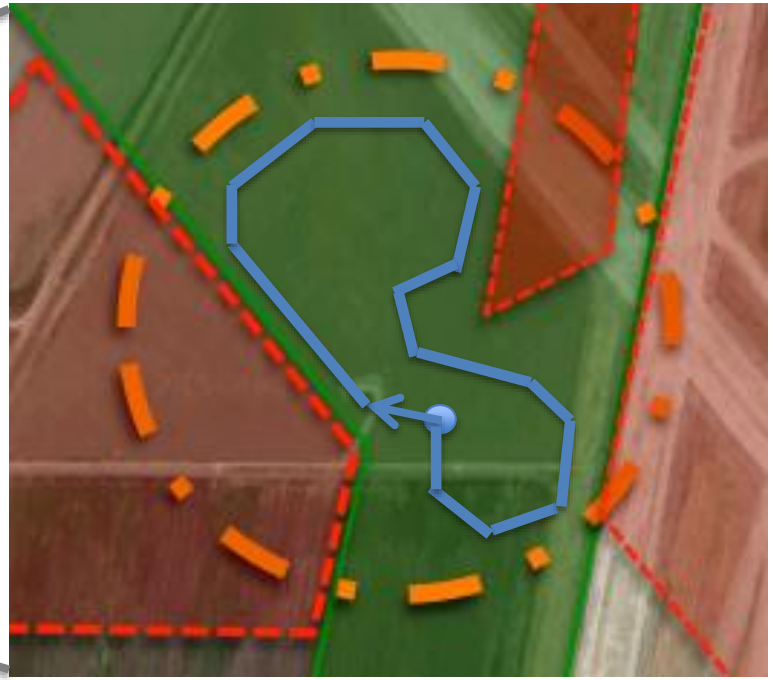
UTM System

UTM Manager

Build 1 Field Test Example







Summary

- UTM is a unique and necessary effort to enable safe operations
- Collaboration is welcome: private sector, university, and government agencies
- Field testing and simulations will demonstrate UTM feasibility

Backup Slides

UTM Services: Security Services

- System Health Monitoring
  - Monitors the status of the internal subsystem and external system components required to provide each UTM service
- Vehicle Registration
  - Ensures that only registered vehicles are approved for operations within UTM airspace and receive the appropriate UTM services
- User Authentication
  - Ensures that only credentialed users can access the system and are provided the appropriate UTM services
- Flight Monitoring
  - Monitors both UAS and non-UAS operations within the UTM airspace in terms of their safety and security risk to each other

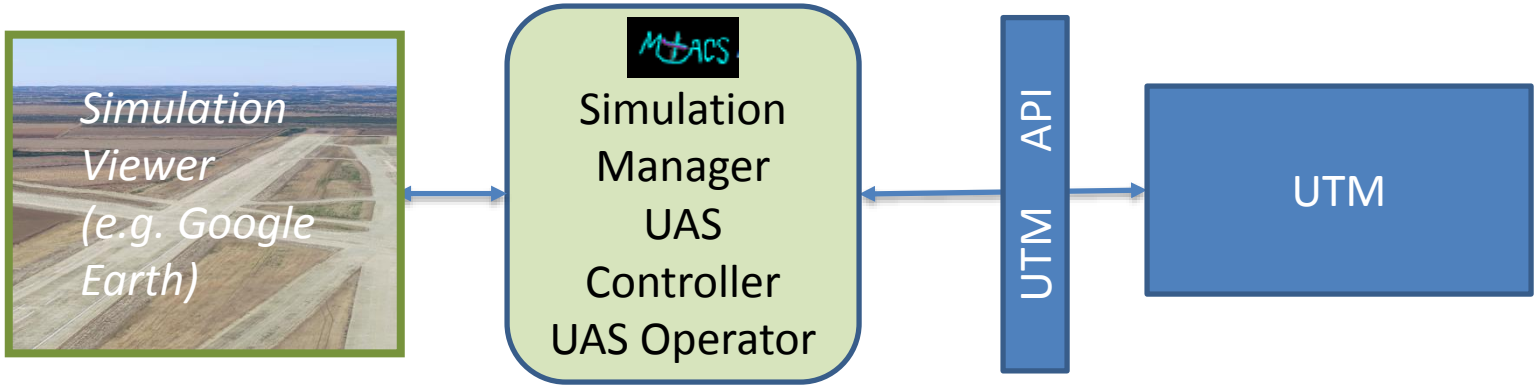
UTM Services: Flight Services

- Flight Planning
  - Assesses proposed UAS operations against airspace availability and operational constraints
- Scheduling and Demand Management
  - Schedules UAS operations to reduce congestion, conflicts, and improve overall safety as traffic demand increases
- Separation Assurance
  - Provides temporal, procedural and in-flight separation services from other traffic, weather, terrain, and vertical obstructions
- Contingency Management
  - Resolves off-nominal conditions that occur during an operation such as flight non-conformance and lost communication

UTM Services: Information Services

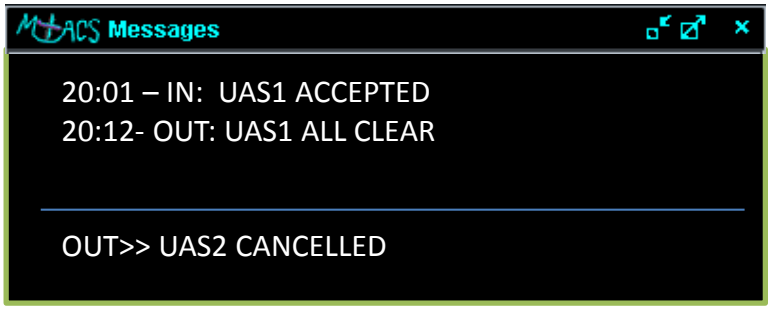
- Airspace Definition
  - Provides users with the physical extents of its UTM airspace as well as regions within that airspace where operations are not permitted – either permanently or temporarily
- Weather Information
  - Provides users with information about the current and predicted weather conditions in the UTM airspace
- Terrain and Vertical Obstructions
  - Provides users with information about the terrain, man-made structures, and vertical obstacles in the UTM airspace
- Air Traffic Operations
  - Provides users with information about the planned and current UAS operations in the UTM airspace

Standalone Testbed: UTM-PS
Personal Simulator for UTM



Functionality

- Create and control UAS scenarios in MACS
- Visualize in Simulation Viewer
- Communicate to UTM via UTM API
- MACS Messaging Window to display UTM comm.



Automated messages:

- MACS flight plan->Operational plan
- ALL CLEAR (TBD sec) before activating aircraft
- MACS flights state -> UTM position updates
- CLOSED message ->UTM (landed)

Manual messages

- UTM messaging window in MACS for viewing UTM messages and sending responses from MACS

NASA Lab test bed: UTM-LS

Lab Simulator for UTM

Simulation Manager

Simulation Viewer (e.g. Google Earth)

UAS Operator/ Controller

Simulation Viewer (e.g. Google Earth)

UAS Operator/ Controller

Simulation Viewer (e.g. Google Earth)

UAS Operator/ Controller

ADRS

UTM API

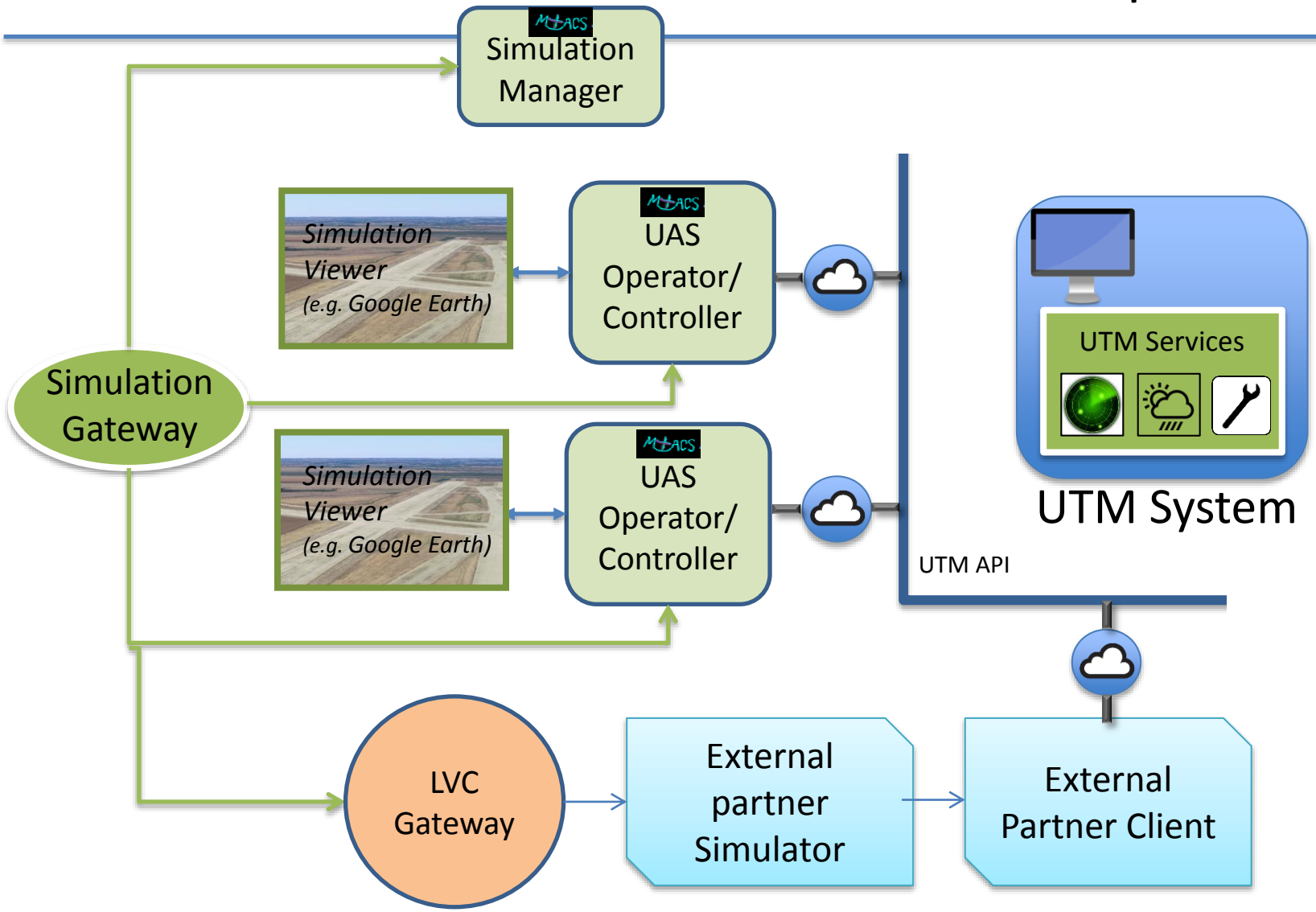
UTM

Functionality

- Simulate multiple UAS 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.

NASA Lab Test Bed

UTM simulator with access for external partners



Build 1 Location and Layout

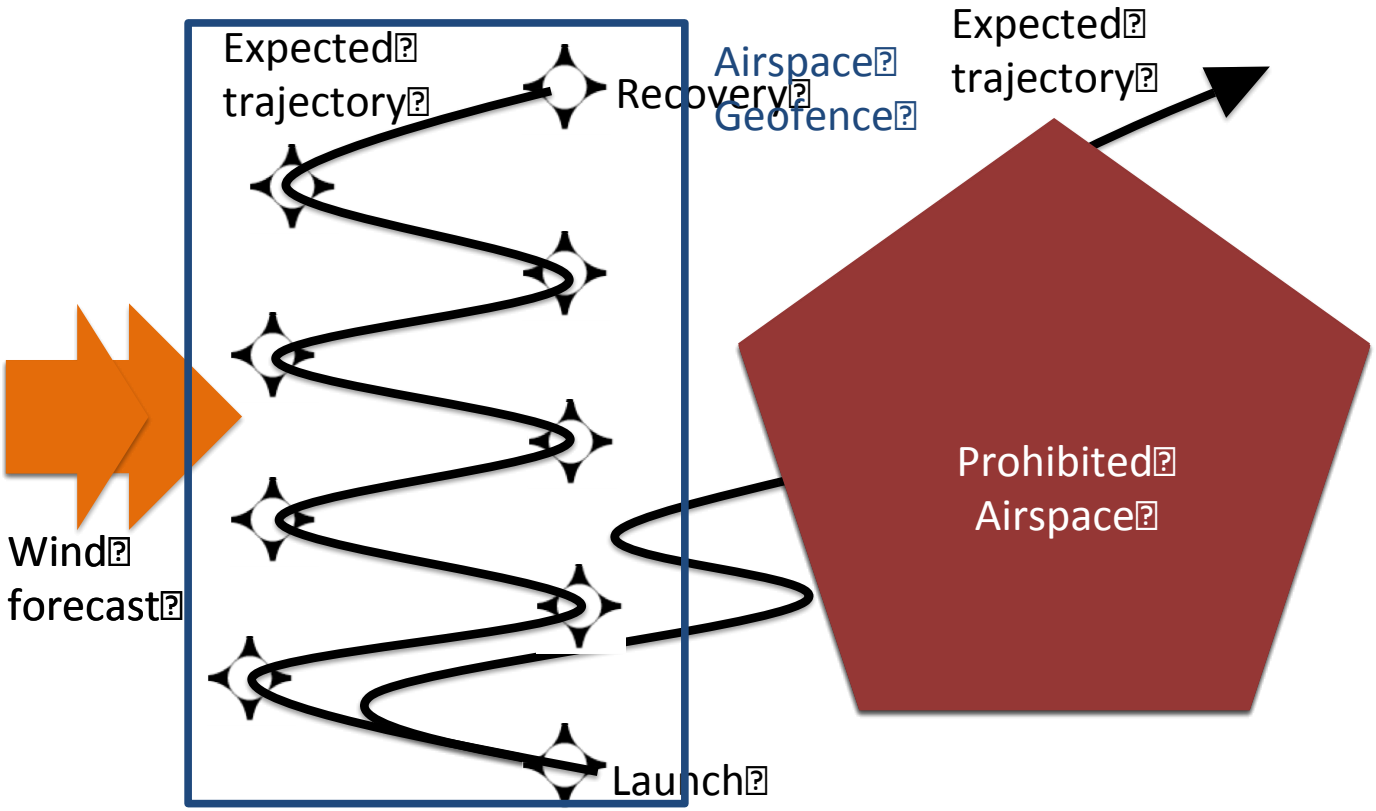
- Test Location: Crows Landing Airfield
  - 35 miles east of Moffett Field, CA
  - NASA Ames Research Center has a Use Agreement with Stanislaus Co. which owns most of the property.
  - Vehicles would be operating under a NASA MOA*
  - There are no usable facilities or services at Crows Landing. Users must be 100% self-sufficient and bring all their own equipment, power, bathrooms, shade, water, and food.
  - There are services several miles away in the towns of Crows Landing or Patterson.
- Test Duration: 1 Week
  - Dates: TBD (August 17-20th 2015)

Build 1 Flight Test Scope

- Block A: Singleton Operations
  - Testing UTM Services in Nominal Conditions
  - Testing Operational Procedures in Nominal Conditions
  - Testing Vehicle Conformance
  - Data Collection: Vehicle and Surveillance Performance
- Block B: Sequential Operations
  - Testing UTM Services in Nominal and Off-Nominal Conditions
  - Testing Operational Procedures in Nominal and Off-Nominal Conditions
  - Testing Vehicle Conformance
  - Data Collection: Vehicle and Surveillance Performance
- Block C: Coincidental Operations
  - Testing UTM Services in Nominal and Off-Nominal Conditions
  - Testing Operational Procedures in Nominal and Off-Nominal Conditions
  - Testing Vehicle Conformance
  - Data Collection: Vehicle and Surveillance Performance

UTM Constraint Checking

Operation plan approved



- Trajectory conformance depends on:
  - Aerodynamic characteristics
  - Vehicle performance (e.g. thrust)
  - Automatic flight control

- Three ongoing efforts:
  - Vehicle modeling with available data
  - Model validation with field tests
  - Assessing feasibility of wind tunnel tests