UAS INTEGRATION INTO THE US NATIONAL AIRSPACE

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Consumer

Public Service

Commercial
Safety  Security  Privacy
What is a UAS?

- An Unmanned Aircraft System (UAS) historically has had various names
  - Drone, ROA, RPA, UAV, Model/R-C
- UAS come in all kinds of shapes & sizes
- UAS have many uses
  - Agricultural to Zoological
- UAS have many different users
  - Government entities
  - Universities
UAS come in all shapes and sizes
UAS Classifications

- By US Military Group
- By Location
- By Physical Size
- By Weight
  - Weight vs Altitude
- By Endurance
  - Endurance vs Weight
  - Endurance vs Altitude
  - Endurance vs Payload
- By Altitude
  - Altitude vs Speed
- By Wing Loading
- By Engine Type

- By Range/Altitude
- By Performance
- By Capabilities
- By Type
  - Micro
  - Small
  - Medium Altitude Long Endurance (MALE)
  - High Altitude Long Endurance (HALE)
- International Classifications
UAS is a “System”

Command, Control and Communication Links

Unmanned Aircraft and Payload

Ground Control Station
UAS Sensors and Payloads

- Electro Optical (EO)
- Infrared (IR)
- Infrared Linescan (IRLS)
- Multi Spectral Imaging (MSI)
- Hyper Spectral Imaging (HSI)
- Light Detection & Ranging (LIDAR)
- Laser Radar (LADAR)
- Chemical, Biological, Radiological & Nuclear (CBRN) Detection
- Synthetic Aperture Radar (SAR)
- Moving Target Indication (MTI)
- Signals Intelligence (SIGINT)
Why use a UAS?

• **Effective for missions that are Dull, Dirty or Dangerous**
  – Humans not put at risk
  – Continuous operations

• **Lower cost than manned aircraft**

• **Presents opportunity for a U.S.-based industry with significant growth and job potential**
  – Increasing Demand for UAS = jobs
  – Manufacturing, training, maintenance, software, etc.

• **United States is a global aerospace leader in terms of safety and technology**
  – Embracing UAS opportunities now will enhance our leadership position
  – Thoughtful, prudent integration will ensure integration risks are accurately identified and properly mitigated
Applications of Unmanned Aerial Systems

- Public Safety
- Deliveries
- Surveillance
- Weather Monitoring
- News Gathering
- Agriculture
- Mapping
- Disaster Relief
- Entertainment
- Spraying/Seeding
The National Airspace System

Class A
- Highly regulated airspace with jet routes
- UAS would share skies with airliners, military transport and general aviation
- UAS must carry a transponder and report location to ATC
- UAS will operate under Instrument Flight Rules (IFR) and communicate with ATC
- Detect and Avoid technologies are needed to avoid aircraft in an emergency
The National Airspace System

- Airspace that surrounds airports
- Two way communications are required with ATC
- Likely all UAS will have to take-off/land under ATC supervision in this airspace
The National Airspace System

- Above FL 600 holds promise for high altitude long endurance (HALE) UAS
- UAS performance differences above FL 600 may cause challenge for detect and avoid
- From 0-18,000 ft in Class E, detect and avoid is complicated by aircraft without transponders and UAS size, weight and power requirements
The National Airspace System

- Currently utilized by recreational UAS hobbyist (0-400 ft AGL) within line of sight
- Risk of colliding with helicopters, general aviation, and man-made objects
- Good starting point for UAS Traffic Management
Is there a legal way to fly UAS in the NAS?

**Civil UAS Operations**
- Type Certification, § 21.17(b) (Draft Advisory Circular)
- Experimental Airworthiness Certificates (Expanded DAR program)
- 333 Exemptions
- Certificate of Waiver or Authorization

**Public UAS Operations**
- Certificate of Waiver or Authorization (COA)
- Online application
- Most processed <60 days

**Model Aircraft Operations**
- Hobby or recreational use only
Public UAS Operations

Who is Operating UAS:
• Department of Agriculture
• Department of Commerce
• Department of Defense
• Department of Energy
• Department of Homeland Security
• Department of Interior
• Department of Justice
• NASA
• State Universities
• State/Local Law Enforcement

What are they doing with UAS?
• Border Patrol
• Firefighting
• Disaster Relief
• Search and Rescue
• Training for Ops Missions
• Operational Missions
• Research
• System Development
• Sensor Development & Testing
Civil UAS Operations

Who is Operating UAS:
• 4,731 petitions granted (as of 4/13/2016)

What are they doing with UAS?
• Wide Range of Applications
  https://www.faa.gov/uas/legislative_programs/section_333/333_authorizations/
• Typical Operations:
  – visual line of sight
  – under 400 ft AGL
  – 2-5 miles away from airport/helipad
  – Daytime operations under visual flight rules
  – 55 lb aircraft and under
Model Aircraft Operations

• Fly below 400 feet and remain clear of surrounding obstacles
• Keep the aircraft within visual line of sight at all times
• Remain well clear of and do not interfere with manned aircraft operations
• Don't fly within 5 miles of an airport unless you contact the airport and control tower before flying
• Don't fly near people or stadiums
• Don't fly an aircraft that weighs more than 55 lbs
• Don't be careless or reckless with your unmanned aircraft
Integration Challenges

**Technology**
- Detect and Avoid
- Command and Control
- Human Factors / Autonomy
- Contingency Management
- Size, Weight, and Power
- GPS-Denied Environment
- Security

**Regulation**
- Airworthiness
- Certification
- Registration
- Safety Case
- Separation Standards
- Operational Flight Rules

**Public**

**Acceptance**
- Perception of risk, benefit and capability
- Privacy, Liability, Admissible Evidence (Legal)
- Ethics
- Noise/Environment
- Politics and Media

**Economics**
- Business Model
- Size of Market
- Volume and Demand
- Market Inertia
- Market Entry Strategies
- Return on Investment
Grand Canyon June 1956
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
UAS: 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
UTM Functions

AIRSPACE OPERATIONS & MANAGEMENT

- Geographical needs and applications
- Rules of the airspace: performance-based
- Geofences: dynamic and static
- Consider other traffic and underlying environment
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
Airspace Managed by UTM

Based upon four risk-based criteria:

- Population Density
- Density of Man-made Structures
- Likelihood of Manned Operations
- Number of UTM operations

Bounded by

- Jurisdiction and Airspace Management Authority
- UTM Connectivity
USS 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
TCL 1: August 2015
Line of Sight Operations
Low Risk Environment
Airspace Reservation
Geo-fencing for Separation
No Fly Zones
User Authentication

TCL 2: October 2016
Beyond Line of Sight Operations
Low Risk Environment
Segmented Flight Plans
Weather and Traffic Advisories
Altitude Stratification
Contingency Management (Alerting)
System Health Monitoring
TCL 3: January 2018
Beyond Line of Sight Operations
Suburban Environment
In-Flight Separation Provisions
Contingency Management (Resolutions)
On-demand Public Service Operations
Spectrum Management
Interacting UTMs
Limited Connections to ATM
Weather and Traffic Avoidance

TCL 4: March 2019
Beyond Line of Sight Operations
Urban Environment
Detect and Avoid
GPS-Denied Environments
Large Scale Contingency Management
Dynamic Airspace Reconfiguration
High Density Operations
TCL 1 UAS Operations

**Manufacturing**
- EM Tower Inspection
- Wind Turbine Inspection
- Bridge Inspection
- Power Line Inspection
- Solar Panel Inspection
- Rail Inspection
- Landfill Inspection
- Pipeline Inspection
- Dam Inspection
- Canal Inspection
- Waterway Inspection
- Water Tower Inspection
- Petroleum Spill Monitoring

**Farming**
- Aerial Application
- Precision Agriculture
- Livestock Monitoring
- Invasive Plant Monitoring

**Other**
- Forest Management
- Mosquito Monitoring
- Wildlife Conservation
- Archaeology
- Anthropology
- Prospecting

**Oceanic**
- Maritime Surveillance
- Maritime Scouting
- Ocean Research
- Anti-Piracy

**Recreation**
- Animal Spotting for Hunting
- Nature Photography
- Adventure Sports Photography

Typical Operation Limitations
- Line of Sight Operations
- Typically <400 ft AGL
- VMC Conditions & Daylight
- UAS < 55lbs
- 500 ft away from structures
1. UAS Operator submits operational plan

2. Vehicle registration checked

3. Static constraints are checked

4. Dynamic constraints are checked

5. UTM reports no issues and UAS operation begins

6. UTM Services are provided during operation

7. UAS operation completes

Schedule Crop Monitoring of Farm X
NASA UTM Project Objectives

- UAS Requirements
- Operational Rules and Guidelines
- CNS Requirements
- Airspace Management Requirements
- Data Services, Interfaces, and Architecture Requirements
Simultaneous UAS Operations

~ 108 Flights
~18 Flight Hours
Duration: 2-38 minutes
Avg. Flight Time: ~ 11 min

Crows Landing, CA

Weather Sensors

Acoustic Sensors

Surveillance Sensors

LONE STAR UAS
CENTER OF EXCELLENCE & INNOVATION

CALIFORNIA

San José State UNIVERSITY

Airware ne3rd

PRECISIONHAWK

UNMANNED
EXPERTS

SKYSCS

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Demonstration Objectives

Objective 1: Demonstrate UTM Capabilities

Objective 2: Collect Data on UAS Navigation Performance Error

Objective 3: Collect Data on Aircraft Tracking Performance

Objective 4: Collect Weather Observations for Forecasting Models

Objective 5: Collect Data on Noise Signature of UAS Vehicles
UTM Vehicles

8 multi-rotors and 2 fixed wing

Maximum Take-off Weight

~ 4 lbs

~ 40 lbs

Endurance

15 min

60 min
UTM Manager Displays

Java-based Desktop Display

iOS Application
UTM Field Equipment: Weather

Data Collected
- Temperature
- Pressure
- Wind Direction
- Wind Speed
- Altitude
- Turbulent Kinetic Energy

Remote Automated Weather Station

Weather Tower

Approximate Measurement Levels
- 32 m (fully extended)
- 27 m
- 22 m
- 17 m
- 12 m
- 7 m

Solar panel

Anti-climbing plate

Radiosonde Weather Balloon

CSI CSAT3 / CI Cor 7500
Vaisala HMP45C

Gill 2-D WindSonic
Vaisala HMP45C

Gill 2-D WindSonic
Vaisala HMP45C

Halo Doppler Lidar

Microwave Profiler

Instrument shelter

UTM Field Equipment: Weather

Data Collected
- Temperature
- Pressure
- Wind Direction
- Wind Speed
- Altitude
- Turbulent Kinetic Energy

Remote Automated Weather Station

Weather Tower

Approximate Measurement Levels
- 32 m (fully extended)
- 27 m
- 22 m
- 17 m
- 12 m
- 7 m

Solar panel

Anti-climbing plate
UTM Field Equipment: Surveillance and Acoustics

Short Range Radar

Cellular Network Tracking

Data Collected:
- Latitude
- Longitude
- Altitude
- Sound magnitude and frequency

Ground Situation Awareness Display (ADS-B In, En Route radar, Terminal Radar, ASDE-X, ASSC)

Acoustic Measurement:
- Nicolet Vision XP
- B&K Nexus 4-Ch Power Supply
- ½” B&K Microphone + Wind Screen
Flight Profiles:
- Free Flight
- Horizontal Trajectory Conformance
- Vertical Trajectory Conformance
- Sound Recording
- System Identification Maneuvers

Altitude: up to 400 ft AGL
Duration: 8-30 minutes
Simultaneous Aircraft: 2
Observations of Operational Use

• **New Airspace Users will require training and UTM needs to be intuitive**
  - **Observation:** UAS Operators submitting an operational plan to the system that differs from what was input into the GCS or a willingness to violate an operational plan.
  - **Recommendation:** Operator training and integration of flight planning and traffic management services into ground control stations

• **The right equipment for the operational environment**
  - **Observation:** High temperatures had impact on ground equipment. C2 interference occurred with local farming equipment. Degradation of GPS signals impacted flight operations.
  - **Recommendation:** UAS and ground systems and instruments are “qualified” by operational environment and performance.

• **Situation awareness is key for safe operations**
  - **Observation:** sUAS varies with size and line of sight (LOS) can be easily lost (e.g. sUAS looked like birds during operation). Weather reported on the ground isn’t always indicative of weather experienced at operational altitude. Tracking of sUAS needs to occur at sufficiently fast update rates.
  - **Recommendation:** Improvements are needed in weather forecasting, modeling, and sensing at low altitudes. Tracking UAS infrastructure will need to be built to scale and with sufficient bandwidth. Airspace users should be given a common picture of their environment for safe operations.
Questions

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System Error

Conformance buffer
Sample Results: Conformance to Flight Plan
Sample Results: Determination of Buffer for Operational Area
Sample Results: Weather Comparison to HRRR

Temperature

Wind Speed

Wind Direction

Turbulent Kinetic Energy
Sample Results: Vehicle Sound Profile

- Scaled to 10 m AGL.
- Plotted as a function of \( \text{MTOW} \rightarrow \) not weight as tested!
- Under 10 lb group clusters around 60 – 65 dB
- Over 10 lb group has no definitive trend with MTOW
- Fixed-wing DragonEye has comparable noise level as the quads. Surprised!
Sample Results: Relative Sound Footprint

- Sound Exposure Level (SEL) scaled to 500-ft AGL.
- UAV data plotted as a function of MTOW \(\rightarrow\) not weight as tested!
- UAVs cluster around 40 – 50 dB \(\rightarrow\) below conversation level
- FAA data for light helos are 30 – 40 dB higher