Emerging Aviation Markets
Proposed Crawl, Walk, Run Build-Up

**2020**
- Demonstration flights
  - Experimental flights
  - Establish community & user acceptance
  - Reduced payload and/or range
  - Modular energy storage solution

**2023**
- Commercial flights
  - All-electric on day 1
  - 60-mile range
  - Commercial pilot + 4 pax
  - Fleets with several manufacturers across 3+ cities

**2025**
- Early scaled operations
  - 5+ cities
  - 300-500 aircraft per city
  - 60,000+ passenger trips per day per city

**2030-2035**
- Fully-Scaled Operations
  - 12+ cities
  - 1000+ aircraft per city
  - 100,000+ passenger flights per day per city
  - No pilot in vehicle (5 pax per flight)
Airspace Operations Requirements

- Air-ground integrated concept of operations
- Roles/responsibilities
- Federated, networked, and interoperable data exchange
- Information architecture
- Airspace configuration (static and dynamic geo-fencing)
- Weather and wind (actual and predicted)
- Demand/capacity imbalance management
- 3D maps
- Track and locate (cell, ADS-B, satellite, pseudo-lites)
- Conflict (V2V, sense and avoid) and hazard avoidance
- Last and first 50 feet operation
- Contingency management
Research Platform that

(1) Gives situational awareness of all airspace constraints and info about other operations to UAS operators, support service suppliers, and regulators

(2) Allows to exchange data among UAS operators as well as regulator

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

(4) Determines how to safely enable such single or multiple UAS operations either within visual line of sight or beyond visual line of sight

(5) Integrates airspace and vehicle operations
Vehicle Technology Challenges

- Low Size, Weight, Power, and cost – Sense and avoid
  - Detection of obstacles such as wires as well as other moving objects
- Tracking: Cell phone, ADS-B, Satellite, pseudo-lite
- Reliable control system
- Safe landing under failure or safety under malfunction
- Long endurance (45 min current battery life)
- Cyber secure/spoof free vehicles
- Graceful landing in case of failure with low kinetic energy – safe flying around people
- Ultra-low noise vehicles
- Operations under GPS-free or degraded conditions
- Last/first 50 feet safe autonomous operation
System Wide Safety Strategic Thrust

• **Continuous System-wide Safety Awareness (Monitor)**
  Technical approaches and required architecture to support comprehensive safety monitoring through acquisition, integration and assurance of sensitive data from heterogeneous sources.

• **Safety Risk Identification and Evaluation (Assess)**
  Assured tools that improve the accuracy of real-time detection, diagnosis and prediction of hazardous states and the impact of these states on system safety.

• **Coordinated Prevention, Mitigation and Recovery (Mitigate)**
  Trusted methods for dynamic, multi-agent planning, evaluation, and execution of real-time risk mitigating response to hazardous events.

• **Experimentation, Demonstration and Assessment**
  Experimentation, demonstration, benefits analysis and transition of new RSSA technologies within all elements of the airspace.
Objectives:

- Apply PHM principles to safety within the UAM domain.
  - Identify relevant in-time risk assessment metrics
  - On-vehicle subsystems considered
    - Electrical powertrain
    - Positioning sensors
    - Communications equipment
- Integrate such a safety framework with the UTM architecture
  - Consider safety assessment a “service” within that architecture
- Conduct flight test to demonstrate feasibility of approach
  - Collect data and publish where possible
  - Flight test planned for Fall 2018
  - Plan to participate in UTM campaign
Objective:
- Predict effect of UAV system health on airspace safety in-time for decision-making

Approach:
- Leverage health management framework to predict faults in sub-systems of UAV electric powertrain
- Identify components within sub-systems that may affect its operation and airspace safety
  - Understand propagation timing of fault
    - Some faults progress over a single flight (fast),
      - battery state of charge (SOC)
      - Motor faults (some)
    - Some faults progress over several fights (slow),
      - battery state of health (SOH)
      - electronic speed controllers (ESC)
      - power conditioning circuits (PCC)
- Select type of sensors and determined needed data rates required for vehicle based on identified faults
- Model components, simulate, lab tests, flight tests

In case the SOC goes below a set low threshold and not able to do a safe landing, i) violate safety with crash landing/ ii) interfere in path of other UAV

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**Electric Powertrain Health (EPT)**

- **Battery**
- **Brushless DC Motor (BLDC)**
- **Electronic Speed Controller (ESC)**
- ** Conditioning circuit**

- **Safety Metrics**
  - rul_motor_battery
  - rul_motor
  - rul_esc
  - rul_ps

- **Effect**

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**Measured vs Estimated**

- **Voltage (V)**
- **Time (s)**

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**UAV Health**

- **State of Charge (SOC)**
- **State of Health (SOH)**
- **Bearing faults**
- **Low Insulation resistance**
- **MOSFET failure/degradation**
- **Logic Circuit malfunction**
- **Electronic components degradation**
Objective: (1) Test and evaluate baseline architecture and selected functional elements; (2) Collect data to support future development of envisioned capabilities

- Exercise use case scenarios for requirements discovery
- Test interfaces with remote ground systems and info services

Drivers:
- Consistency with UTM infrastructure
- Integrates relevant past research
- Begins spiral RDT&E for ISSA application to Emerging Ops domain

Status:
- Precursor tests conducted;
- Verification tests in fall

Baseline Capability Testing

Onboard ISSA-enabling Technologies

UAS Operator Station

Ground Infrastructure and ISSA-enabling Information Services (within UTM ecosystem)

On-board safety monitoring and contingency management algorithms

Interfaces for safety and mission awareness

Airspace Safety Margins Monitoring

Interaction with relevant ISSA monitoring services

Vehicle Systems Diagnostics and Prognostics

Environment Forecasting and Alerting

Onboard enabling Technologies

UAS Operator Station

Ground Control Station

Vehicle Systems Diagnostics and Prognostics

Environment Forecasting and Alerting

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