Opportunities and Challenges for Urban Air Mobility

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Urban Air Mobility

- On Demand Air Mobility motivated by growing surface congestion, success of TNCs and perceived technology transfer from electric vehicles, UAVs and automation
Urban Air Mobility

- UAM Markets
  - Intra-Urban
  - Inter-Urban
UAM Vehicles

VS.
UAM Vehicles

VS.
Over 200\(^1\) announced vehicle concepts (of varying credibility)

**Example Flying Full-Scale Prototypes**
- Airbus A^3 Vahana
- Opener Blackfly
- Vertical Aerospace Seraph
- eHang 216
- Volocopter 2x
- Astro Aerospace Elroy
- Kitty Hawk Heaviside
- Beta Technologies Ava XC
- Joby Aviation S4
- Workhorse Surefly
- Kitty Hawk Cora
- Boeing PAV
- Lilium Lilium Jet
- LIFT HEXA

**Other Advanced Developments**
- Karem
- Rolls-Royce
- Pipistrel
- Embraer
- Jaunt Air Mobility

**Many Additional Vehicle Concepts**

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Case Study Approach to Identify UAM Operational Constraints (LAX, BOS, DFW)

1. Identified Promising Markets
   - Current helicopter charter services
   - US census and commuting data
   - Housing market data

2. Defined Reference Missions

3. Applied Notional ConOps* to Each Mission
   - Customer request
   - Customer first-mile travel
   - Dispatch to customer
   - TOLA Takeoff and Landing Area
   - Customer pre-flight
   - Flight
   - Customer last-mile travel
   - Land and disembark
   - Route to alternate

*ConOps assessed conventional technologies as well as electric propulsion and pilot automation

4. Identified Operational Challenges in Missions

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Data LDEO Columbia, NSF, NOAA
SID, NOAA, U.S. Navy, NGA, GEBCO
Image Landsat/Copernicus
## UAM Operational Constraints Identified from City Case Studies

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**Summary of Case Study Results:**

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**Summary of Case Study Results:**

Challenge to Site Infrastructure Near Demand
Existing aviation infrastructure in Boston
UAM Operational Constraints
Identified from City Case Studies

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Summary of Case Study Results:
Current ATC Procedures Will Not Scale Controller Workload Constraint

**São Paulo “helicontrol” Area**
- limited to 6 simultaneous helicopter operations\(^\text{15}\)
- designated entry points and routes

**Boston Logan Controlled Airspace**
- additional controller staffed for >3 operations
- designated helicopter routes
ATC Surface Controlled Airspace BOS
Special Use Airspace
Red Sox Game Example
<table>
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<tr>
<th>Aircraft Involved</th>
<th>Lateral Separation Req.</th>
<th>Vertical Separation Req.</th>
<th>Longitudinal Separation Req.</th>
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<tr>
<td>IFR to IFR All classes</td>
<td><img src="image1" alt="Lateral Separation" /> 3 NM</td>
<td><img src="image2" alt="Vertical Separation" /> 1000 ft</td>
<td><img src="image3" alt="Longitudinal Separation" /> up to 8 NM</td>
</tr>
<tr>
<td>IFR to VFR Class: B,C</td>
<td><img src="image4" alt="Lateral Separation" /> 3 NM</td>
<td><img src="image5" alt="Vertical Separation" /> 500 ft</td>
<td><img src="image6" alt="Longitudinal Separation" /> up to 8 NM</td>
</tr>
<tr>
<td>IFR to Obstruction</td>
<td><img src="image7" alt="Lateral Separation" /> 3 NM</td>
<td><img src="image8" alt="Vertical Separation" /> 1000 ft</td>
<td><img src="image9" alt="Longitudinal Separation" /> N/A</td>
</tr>
<tr>
<td>Tower or Pilot Visual Separation Class: B,C,D</td>
<td>“pass well clear” “see and avoid”</td>
<td>“pass well clear” “see and avoid”</td>
<td>“see and avoid”</td>
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BOS Runway 4R IFR Separation Zone
Controlled Airspace Cutout Example
New York SFRA Example

New York Airspace Cutout

Teterboro Controlled Airspace
LaGuardia Controlled Airspace
Newark Controlled Airspace

Kearny Heliport
Teterboro Airport 170,000 annual flights
Hudson River SFRA >60,000 annual flights

Newark Airport
Linden Airport 55,000 annual flights
Hudson River SFRA >60,000 annual flights
Impact of ATC Scenarios on Magnitude of Constraint
San Francisco MSA

**Fully Segregated**
Accessible Population: 48%
Accessible Commuter Residences: 57%
Accessible Commuter Workplaces: 24%

**Static VFR Cutout & SUA Access**
Accessible Population: 86%
Accessible Commuter Residences: 90%
Accessible Commuter Workplaces: 86%
ATC Restriction Analysis of US Major Metropolitan Statistical Areas

Seattle, Portland, Sacramento, San Francisco, Los Angeles, San Diego, Riverside, Las Vegas, Denver, Minneapolis, St. Louis, Detroit, Cleveland, Pittsburgh, Indianapolis, Kansas City, Columbus, Cleveland, Chicago, Cincinnati, Buffalo, Baltimore, New York, Philadelphia, Washington, Boston, Charlotte, Dallas, Austin, Houston, Orlando, Tampa, Miami
ATC Restriction Analysis of US Major Metropolitan Statistical Areas

Population Coverage

- Baseline
- Access to Special Use Airspace
- Access to Low-Traffic Contr. Airspace
- Access to VFR Cutouts
- Access to All Three

Workplace Coverage

PhD Thesis of Parker Vascik
## Constraint Identification

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Multirotor and DEP Powered Lift most widely proposed for UAM applications
# Certification Challenges for Electric UAM Configurations

**Risk Severity = Probability x Consequence**

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<tr>
<th>Hazard Description</th>
<th>Multirotor</th>
<th>DEP Powered Lift</th>
<th>Rotorcraft</th>
<th>Fixed Wing</th>
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<tbody>
<tr>
<td>Common Mode Power Failure (Low-/High-Altitude)</td>
<td>High/High</td>
<td>High/Medium</td>
<td>Medium/Medium</td>
<td>Medium/Medium</td>
</tr>
<tr>
<td>Battery Thermal Runaway</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Battery Energy Uncertainty</td>
<td>High</td>
<td>High</td>
<td>Medium</td>
<td>Medium</td>
</tr>
<tr>
<td>Fly-By-Wire System Failure</td>
<td>High</td>
<td>High*</td>
<td>Low**</td>
<td>Low</td>
</tr>
<tr>
<td>Bird Strike</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
</tr>
<tr>
<td>High-Level Autonomy Failure</td>
<td>High</td>
<td>High</td>
<td>High</td>
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The severity of some challenges changes with configurations.
Hybrid Electric SSTOL Alternative

30% scale flight demonstrator of a 4 passenger, 2700 lb blown wing aircraft with <100 ft takeoff/landing distance

Takeoff Landing Distance < 100 ft

Unblown Stall Speed < 60kts

Distributed Electric Propulsion
Blown Wing for High $C_L$

Hybrid Electric
Batteries Sized for TO&L Surge
Engine Sized for Cruise
MIT Beaverworks Prototype

Vehicle designed and built by 16.82 class in SY 2018-2019
Flight demonstrator shows that high lift ($C_L > 10$) is achievable in real-world flight environment but that there are control challenges to be addressed.