Assessment of Air Traffic Control for Urban Air Mobility and Unmanned Systems

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Emerging Low Altitude Airspace Operators

Unmanned Aircraft Systems (UAS)
- Hobbyist and commercial use
- Typically <55 lbs
- 900K UAS registered since 2015
- Potentially 4 million by 2021
- Remotely piloted or fully automated

Urban Air Mobility (UAM)
- Passenger carrying operations in a metropolitan area
- Potentially 27,000 operations per deployed city by 2025
- Human piloted, remotely piloted, or fully automated

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• UAS operations are increasingly common in urban areas and large-scale package delivery is in the works

• Over 75 UAM developers anticipate commencing operations within a decade

• Dozens of novel ATC systems for low altitude airspace management have been proposed

UAS Developers

UAM Developers

UTM Developers

Dramatic Industry and Research Growth
Research Objectives

• Address the following:
  – what challenges exist for Air Traffic Control (ATC) to support these new operators and operations
  – how may the response by ATC to maintain safety and efficiency hinder UAS or UAM deployment
  – what approaches may exist to overcome these challenges
Research Approach

1. Identify ATC challenges that result from large-scale UAS and UAM deployment
2. Project potential limitations imposed on operators by ATC to abate challenges
3. Decompose ATC challenges to identify the mechanisms that drive them
4. Evaluate opportunities that influence these mechanisms and relieve the ATC challenge
Case Study Approach to Identify Constraints in UAM/UAS System Operations (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

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

4. Identified Operational Challenges in Missions
ATC Challenges from UAM/UAS Operations

1. Increased Number of Operations
   - The NAS supports 200,000 GA and 7,000 commercial aircraft annually
     - UAS and UAM fleets are projected to be 20x larger than this by 2021
     - The ATO supports 44,000 flights per day nationally
     - Uber predicts it will conduct up to 27,000 flights daily in a single city by 2025

2. Increased Density of Operations
   - Voice communication untenable at such densities (workload, spectrum, tail #)
   - Datacomm communications would likely require automated handling
   - Primary/secondary radar systems (including ADS-B) will become saturated
   - Separation minima or see and avoid requirements may not support flight densities

3. Lower Altitude Operations (<3000ft)
   - Surveillance and navigation systems provide poor coverage
   - GPS vulnerable to multipath, urban canyon impacts and jamming

4. Heterogeneity in Pilots, Automation, and Aircraft
   - Increasing pilot automation challenges interface with ATC
   - Mixed levels of equipage, aircraft performance, and pilot training
ATC Challenges from UAM/UAS Operations

- Significantly increased number of operations
- Significantly increased density of operations
- Operations at altitudes below 3000ft
- Heterogeneity in equipage, piloting, and automation

Challenge for current-day ATC
ATC Challenges from UAM/UAS Operations

- Significantly increased number of operations
- Operations at altitudes below 3000ft
- Heterogeneity in equipage, piloting, and automation

Challenge for current-day ATC

ATC limitations on UAM/UAS operations

What limitations may ATC impose on UAM and UAS operators in order to avoid safety or efficiency impacts from these challenges?
Preliminary ATC Limitations for UAM/UAS Operations

- An ATCo will seek to resolve overcapacity issues from UAM and UAS either by reducing demand or increasing capacity.
- Both approaches, or inaction, imply a set of limitations for UAM and UAS operators.

If ATC implements **demand adjustments**, UAM and UAS operators may:

1. **Experience ground delay**
   - Nearly all Traffic Management Initiatives (TMIs) can cause ground delay if implemented before takeoff.
   - UAM and UAS operations are especially susceptible to ground delays due to the short range of their missions.

2. **Experience airborne delay**
   - Numerous TMIs can cause holding, rerouting, or reduced speed flight.
   - Due to short range of operations, UAM and UAS operations are unlikely to experience significant airborne delay as planning horizons and uncertainty are small.
If ATC implements capacity adjustments, UAM and UAS operators may:

3. Increase financial burden on ANSPs and operators
   - An ANSP can increase airspace capacity through a variety of staffing, airspace redesign, and technological means
   - These may result in additional aircraft equipage, or higher fees for service

4. Experience rationing of ATC services to prioritized users
   - Aircraft with higher performance levels and equipage effectively increase ATC capacity
   - ATC may resort to a best equipped, first served model
   - CFR §107.37 already gives all other airspace users total priority over small (<55lb) UAS
If ATC fails to effectively balance demand and capacity, UAM/UAS operators may:

5. Be unable to access controlled airspace

43% of the densely populated LA Basin is beneath surface level ATC (yellow)

TFRs for sporting events prohibit flights in Boston for up to 100 days a year

6. Experience a reduction of flight safety where ATC services are not provided

Over the Hudson, Good Views, Difficult Flying

By RUSS BUETTNER
Published: August 11, 2000
Summary of Potential ATC Limitations for UAM/UAS Operations

- Significantly increased number of operations
- Operations at altitudes below 3000ft
- Heterogeneity in equipage, piloting, and automation

Challenge for current-day ATC

ATC Limitations on UAM/UAS Operations

- Inability to access airspace
- Airborne delay
- Increased financial burden
- Rationed ATC services
- Reduction of flight safety
- Ground delay

Increased financial burden
Decompose ATC Challenges to Identify Mechanisms that Drive Them

- The main, high-level ATC challenge UAM and UAS operations create is a scalability challenge
- Scalability in this presentation refers to the ability of ATC to provide efficient services to increasingly more aircraft in a region
Practical capacity is the number of operations that can simultaneously be accommodated within an airspace sector while accruing no more than a specified amount of average delay (i.e. a carrying capacity)
Airspace Practical Capacity
Influence Diagram

Each orange “factor” acts through a blue “mechanism” to influence the practical capacity of an airspace, and thus the scalability of ATC.
Each factor was evaluated to identify opportunities that may influence the mechanisms and increase ATC Scalability.

- **Airspace and Route Design**
  - Special Use Airspace
  - Airspace Geometry
  - Community Acceptance

- **Separation Standards**
  - Traffic Mix & Sequencing
  - Weather

- **Controller and Pilot Workload**
  - Staffing
  - Decision Support automation

- **CNS Capabilities**
- **ATC ConOps routes, procedures**
• Some airspace may not be accessed by en-route UAM aircraft due to:
  – Protected airport/TOLA procedures and airspace
  – Building/terrain obstacle clearance requirements
  – TFR/geofence airspace
  – Inclement weather

Central Boston Helicopter Chart

Available Airspace Mapping 800-1000ft
Creation of non-serviced airspace “cutouts” from controlled airspace has been shown to support high densities of VFR operations.
Airspace Geometry and SUA
FAA Low Altitude Advanced Notification Capability (LAANC)

Boston FAA LAANC Facility Map UAV Authorization from Airmap.io

No Flight

<50 ft

<100 ft

<150 ft
Airspace Geometry and SUA

- Sector capacity is typically limited by controller workload, so smaller sectors are designed to increase regional capacity.

- Dynamic sectorization schemes have limited benefits for UAM/UAS as the number of operations is likely to surpass the pooled capacity of all sectors in the region.
Evaluate Opportunities to Influence Mechanisms and Increase ATC Scalability

Each factor was evaluated to identify opportunities that may influence the mechanisms and increase ATC Scalability.
Community Acceptance

- Aircraft noise the primary community acceptance issue
- Can limit airspace and route design (i.e. Sky Harbor, Logan)
- Technological, operational and public relations opportunities exist to boost acceptance

```
Local Government
\hspace{1cm} \text{zoning, acquisition, funding}

Federal Aviation Administration
\hspace{1cm} \text{procedure design, funding}
\hspace{1cm} \text{aircraft certification, ATC}

Court System
\hspace{1cm} \text{legal action}

\text{community action}

Local Community
\hspace{1cm} \text{noise exposure}

Aircraft Operations
\hspace{1cm} \text{curfews}
\hspace{1cm} \text{noise abatement procedures}
\hspace{1cm} \text{noise charges}
\hspace{1cm} \text{quotas/slots}
```

Airports, Heliports, and other TOLAs
Evaluate Opportunities to Influence Mechanisms and Increase ATC Scalability

Each factor was evaluated to identify opportunities that may influence the mechanisms and increase ATC Scalability:

- **Airspace and Route Design**
  - Special Use Airspace
  - Airspace Geometry
  - Community Acceptance

- **Separation Standards**
  - Traffic Mix & Sequencing
  - Weather

- **Controller and Pilot Workload**
  - Staffing
  - Decision Support automation

- **CNS Capabilities**
  - ATC ConOps routes, procedures

These factors were evaluated to identify opportunities that may influence the mechanisms and increase ATC Scalability.
Communications

• Data Communications
  – Reduce pilot and controller workload
  – VDL link limited to line of sight communications

• Cellular Network Communications
  – Near ubiquitous urban-area coverage
  – Handle traffic orders of magnitude above aviation networks
  – Long distance line-of-sight signal propagation challenge
  – Insufficient availability, integrity, and infrastructure hardening
Navigation

- Performance Based Navigation (PBN)
  - Enables closer route spacing, point to point nav, and operations nearer to obstacles
  - High integrity requirement ($10^{-5}$ excursions per hour) may remove controller surveillance workload
  - High costs of equipping aircraft and implementing infrastructure
  - Potential for GPS jamming and spoofing at low altitudes

Communication, Navigation and Surveillance
Potential Benefits of Aircraft Routing through PBN-Inspired Capabilities

Simultaneous helicopter and airport arrivals not possible due to large required containment boundaries.

VFR Heli Route Centerline

Non-RNP AR Containment Boundaries

Approach Centerline
Reduced containment boundaries of RNP AR, as well as support for precision turns may better contain commercial operations and provide ATC with flexibility to support ODM operations.
Surveillance

- Particularly challenging for UAS and UAM operations

- Primary radars
  - Line of sight limitations limit coverage in many regions of interest
  - Resolution of small UAS targets

- Transponders
  - Insufficient channels to function as secondary radar source

- ADS-B
  - Potential signal saturation
  - Opportunity for non-participation
  - Vulnerable to jamming, insertion, deletion
  - Relied upon by UAM operators and Google Project Wing
Each factor was evaluated to identify opportunities that may influence the mechanisms and increase ATC Scalability.
# ATC Separation Requirements
## For IFR Terminal Area Operations

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<th>Aircraft Involved</th>
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<th>Vertical Separation Req.</th>
<th>Longitudinal Separation Req.</th>
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<td>1.5 3 NM</td>
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</table>
Separation Standards

- Separation minima for IFR operations prohibit high density UAM operations in Boston.
- Current IFR Boston MedFlight operations into Mass General shut down Logan operations.
Separation minima avoid aircraft conflicts by allowing for inaccuracies in the navigation system and surveillance, the pilot or autopilot, and the communication system.
Separation Standards

Separation minima were developed based on radar accuracy/resolution (e.g. 1950s for en route radar)

GPS and improved radar (CNS) have reduced position and timing uncertainty (e.g. modern en route radar)

A constant separation standard

CNS has improved, but separation minima have not changed; the procedural safety buffer has therefore implicitly increased and become embedded.
Each factor was evaluated to identify opportunities that may influence the mechanisms and increase ATC Scalability.
Controller Workload

- São Paulo “helicontrol” area was limited to 6 simultaneous helicopter operations until April, 2018
  - Contains over 200 heliports and conducts on average 800 movements per day
- Boston helicopter traffic is primarily managed as a secondary responsibility of a local tower controller.
  - Impact of Medevac in low IFR Conditions
Staffing and Decision Support

- Airspace capacity is highly sensitive to controller staffing and decision support
- Oshkosh and Silverstone provide evidence of super-high throughput VFR operations
- Challenges include cost and a potential reduction of safety
• The anticipated scale of UAM/UAS operations is unsupportable through the current ATC ConOps

• ATC may hinder UAM/UAS operations through delays, fees, rejected entry, discontinued service, and other actions

• Three key mechanisms determine ATC capacity in an airspace
  – Separation Standards: restrictive in IMC, for airport procedures, and aircraft with large wake vortex separation
  – Airspace and Route Design: restrictive at low altitudes in proximity to TFRs, SUAs, obstructions, or geofences
  – Controller and Pilot Workload: restrictive in controlled airspace or uncontrolled, congested airspace

Summary
Thank You

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