Urban Air Mobility Traffic Analysis Tool

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1. Emerging challenges in Urban Air Mobility in near future
2. Urban Air Mobility Traffic and control risks
3. Potential solutions
4. UAV classifications
5. UAV classification implementation
6. Urban Air Mobility Traffic Analysis Tool
Emerging challenges in Urban Air Mobility in near future

Next Generation Air Transportation System (FAA)

Advanced Air Mobility (AAM)

Documents

- Part 107 - Small Unmanned Aircraft Systems
- In-Time Aviation Safety Management: Challenges and Research for an Evolving Aviation System
- Urban Air Mobility (UAM) Concept of Operations v1.0
- Unmanned Aircraft Systems (UAS) Traffic Management (UTM) Concept of Operations v1.0
- Unmanned Aircraft Systems (UAS) Traffic Management (UTM) Concept of Operations v2.0
- In-time System-wide Safety Assurance (ISSA) Concept of Operations and Design Considerations for Urban Air Mobility (UAM)
- Urban Air Mobility Concept (OpsCon) Passenger-Carrying operations

ARMD UAM-Related Projects

- Integrated Aviation Systems Program
  - Advanced Air Mobility
  - Flight Demonstrations & Capabilities
  - UAS Integration in the National Airspace System
  - UAS Traffic Management

- Advanced Air Vehicle Program
  - Revolutionary Vertical Lift Technology

- Airspace Operations & Safety Program
  - Air Traffic Management Exploration
  - System-Wide Safety
  - UAS Traffic Management

- Transformative Aeronautics Concepts Program
  - Transformational Tools & Technologies

AAM for FAA/NASA Research Roundtable
Emerging challenges in Urban Air Mobility in near future

U-space is a set of new services relying on a high level of digitalization and automation of functions and specific procedures designed to support safe, efficient and secure access to airspace for large numbers of drones.

**Documents**
- U-space Blueprint
- European ATM Master Plan
- European Drones Outlook Study
- Initial view in Principles for the U-space architecture
- CORUS U-space Concept of Operations
- U-space Drone Operations Europe
- EASA Opinion No 1/2020
- EU Commission Delegated Regulation 2019/945
UAM operating environment
UAM operations are performed through the use of UAM corridors. Strategic deconfliction and tactical separation in UAM corridors occur without direct ATC involvement.

UTM operating environment
In uncontrolled airspace below 400ft AGL UTM provides a cooperative traffic management for UAS and other aircraft.

ATM operating environment
Operations adhere to relevant ATM rules based on operation type, airspace class, and altitude.

Type X:
No conflict resolution service is offered.

Type Y:
Only pre-flight conflict resolution is offered.

Type Z:
Pre-flight conflict resolution and in-flight separation. Zu airspace controlled by UTM and Za controlled by ATM.

Two layers within VLL:
- High performance layer
- Standard performance layer

Dynamic corridors
Airspace structures

Along with new airspace structure, suitable ground infrastructure for UAM needs to be developed.

- Small airports for eVTOLs
- Pickup & Drop-Off sites
- Charging facilities
- MRO operations
- Parking spaces for longer-haul eVTOLS

Even though new airspace concepts are designed specifically to enable safe unmanned operations, once large-scale operations begin, it might be necessary to further redesign the airspace to adjust it to various types of vehicles and operations.
Urban Air Mobility Traffic and control risks

**MECHANICAL/TECHNICAL**
- Datalink loss
- Sensor failure
- Directional loss
- Flight controller failure
- Unintentional loss of altitude
- Total loss
- Loss of payload
- Erroneous data
- Latency
- Automation error

**ENVIRONMENTAL/METEOROLOGICAL**
- Animal collision
- Severe weather
- Icing
- Electromagnetic interference
- Corrosive environments
- Noise, pollution
- Sand or dust

**HUMAN/OPERATIONAL**
- Collisions
- VLOS loss
- Mission planning error
- Human error
- Insufficient understanding of advanced systems
- Obsolete equipment

**SECURITY**
- Intentional collision
- Intentional interference
- Trespassing
- Cyberattack

**UAM SERVICES**
- Lack of transactional integrity
- Datalink loss
- Loss of data, processing error latency
- Lack of available infrastructure
- Inadequate ground crew training
- Degradation of ground control station capability

Understood as a random situation that will make UAV not following the desired path

Change the weather logical errors implemented to simulation: i.e. wind 0 – 15 [m/s]

Understood as loss of control and geofencing is not working

Maybe random trajectories

Cyber security
Potential solutions

Adapting solutions from manned aviation

Integration of UAS/UAM into the future aviation system is a challenge. Dynamic development of unmanned aviation industry is outpacing existing regulations. Maintaining the current level of safety in the aviation sector is a priority.

The idea is to identify scalable aspects of airspace operations that could potentially be addressed by adapting safety guidelines existing in manned aviation or non-urban UAV operations.

- Aircraft classification
- Airspace classes
- Pilot/operator training and licensing
- Certification/registration
- Security systems
- Weather, icing
Potential solutions

In some cases, it is not reasonable to adapt already existing solutions.

Advanced technologies are outpacing development of the necessary infrastructure.

Adapting existing solutions can cause new risks to emerge.

- First cars (environment was not ready)
- Traffics in old cities where the infrastructure is inefficient
- Capacity of public transport
- Uncontrolled expansion of some elements (cars, traffic, data transfer etc.)

It is necessary to search for new solutions to address the risks and needs of new technologies.

E.g., Tesla autopilot performance can be affected by:
- poor visibility (heavy rain, snow, fog)
- bright light (oncoming headlights, direct sunlight)
- narrow, high curvature or winding roads
- interference from other equipment that generates ultrasonic waves
- extremely hot or cold temperatures

New traffic approach: tunnels providing stable conditions assuring high safety level

Roads suitable for horseback riding were too narrow for cars

Tesla tunnel under Las Vegas
UAV classifications: FAA, NASA

Table 1. FAA Categories of Permissible Operations over People

<table>
<thead>
<tr>
<th>Category</th>
<th>Performance-based requirements</th>
<th>Pilot Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Weight</td>
<td>Injury upon impact</td>
</tr>
<tr>
<td>1</td>
<td>≤ 0.55 lb</td>
<td>Not required</td>
</tr>
<tr>
<td>2</td>
<td>&gt; 0.55 lb ≤ 55 lb</td>
<td>No more severe than from 11 ft-lb rigid object impact (AIS level 3)</td>
</tr>
<tr>
<td>3</td>
<td>&gt; 0.55 lb ≤ 55 lb</td>
<td>No more severe than from 25 ft-lb rigid object impact (AIS level 6)</td>
</tr>
<tr>
<td>4</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 2. FAA UAS Categorization by Weight

<table>
<thead>
<tr>
<th>Category</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>sUAS Regular</td>
<td>MTOW &gt; 0.55 lb (250 g) but ≤ 55 lb (25 kg)</td>
</tr>
<tr>
<td>Under 0.55 lb</td>
<td>MTOW ≤ 0.55 lb (250 g)</td>
</tr>
<tr>
<td>Micro-/Ultra-Light UAS</td>
<td>MTOW &gt; 55 lb (25 kg) but ≤ 330 lb (150 kg)</td>
</tr>
<tr>
<td>Other UAS</td>
<td>MTOW &gt; 330 lb (150 kg)</td>
</tr>
</tbody>
</table>

Table 3. NASA UAS Classification Matrix

<table>
<thead>
<tr>
<th>Category</th>
<th>Type</th>
<th>Weight</th>
<th>Airspeed*</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Model or sUAS</td>
<td>≤ 55 lb</td>
<td>≤ 70 kt</td>
</tr>
<tr>
<td>II</td>
<td>sUAS</td>
<td>55 - 330 lb</td>
<td>≤ 200 kt</td>
</tr>
<tr>
<td>III</td>
<td>UAS</td>
<td>&gt; 330 lb</td>
<td>&gt; 200 kt</td>
</tr>
</tbody>
</table>

* In Europe sometimes speed is changed into kinetic energy that is a parameter
UAV classifications: levels of autonomy

Table 4. Levels of autonomy by NATO [1]

<table>
<thead>
<tr>
<th>Level</th>
<th>Description</th>
<th>Capability</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Remote control</td>
<td>No tactical behavior.</td>
</tr>
<tr>
<td>2</td>
<td>High-level human input</td>
<td>Low-level tactical behavior in simple environment.</td>
</tr>
<tr>
<td>3</td>
<td>Mid-level human input</td>
<td>Multi-functional missions in moderate environment.</td>
</tr>
<tr>
<td>4</td>
<td>Low-level human input</td>
<td>Collaborative, high-complexity missions in difficult environment.</td>
</tr>
<tr>
<td>5</td>
<td>No human input</td>
<td>All missions in extreme environments.</td>
</tr>
</tbody>
</table>

Table 5. Levels of autonomy by National Institute of Standards and Technology [2]

<table>
<thead>
<tr>
<th>Level</th>
<th>Description</th>
<th>Capability</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Remotely controlled system</td>
<td>Actions depend on operator input.</td>
</tr>
<tr>
<td>2</td>
<td>Automated system</td>
<td>Actions depend on fixed built-in functionality (preprogrammed).</td>
</tr>
<tr>
<td>3</td>
<td>Autonomous non-learning system</td>
<td>Actions depend upon a fixed set of rules.</td>
</tr>
<tr>
<td>4</td>
<td>Autonomous learning system with the ability to modify rules</td>
<td>Actions depend upon a set of rules that can be modified for continuously improving goal directed reactions.</td>
</tr>
</tbody>
</table>

UAV classification implementation

Table 7. Proposed UAS classification

<table>
<thead>
<tr>
<th>Level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Full manual</td>
</tr>
<tr>
<td>1</td>
<td>Automatic Flight Control (waypoint navigation: A -&gt; B)</td>
</tr>
<tr>
<td>2</td>
<td>Relatively small UAS: Automatic Flight Control + Collision Avoidance</td>
</tr>
<tr>
<td>3</td>
<td>Large cargo UAS: Automatic Flight Control + Collision Avoidance</td>
</tr>
<tr>
<td>4</td>
<td>Fully Autonomous</td>
</tr>
</tbody>
</table>

Table 8. UAS use cases

<table>
<thead>
<tr>
<th>Level</th>
<th>Use cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Hobby, personal usage, photography, video production</td>
</tr>
<tr>
<td>1</td>
<td>Small delivery (one task, one trajectory, e.g. package, food), media, surveillance operation, traffic monitoring</td>
</tr>
<tr>
<td>2</td>
<td>Small delivery (package, food, post), multiple trajectory, inspections</td>
</tr>
<tr>
<td>3</td>
<td>Packages hub to Person H2P or H2H, multiple packages, larger cargo</td>
</tr>
<tr>
<td>4</td>
<td>Air taxi, medical transport</td>
</tr>
</tbody>
</table>
# UAV classification implementation

## Table 9. Proposed UAS classification

<table>
<thead>
<tr>
<th>Level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Hobby, personal usage</td>
</tr>
<tr>
<td>1</td>
<td>Small delivery (package, food, medical supply) one task, one trajectory</td>
</tr>
<tr>
<td>2</td>
<td>Small delivery (package, food, post), multiple trajectory</td>
</tr>
<tr>
<td>3</td>
<td>Packages hub to Person H2P or H2H, multiple packages, larger cargo</td>
</tr>
<tr>
<td>4</td>
<td>Fully Autonomous, human taxi</td>
</tr>
</tbody>
</table>

## Various UAV levels:
- different starting points/destinations:
  - L1 - from any place to any place
  - L3 - H2P, H2H
- different routes:
  - L3 - bypass not to disturb
  - L1 - need to deliver package to people
- different time of operating:
  - L3 - night shift opposite to daylife
  - L1, L2 - along the daylife
- different operating areas:
  - business district
  - commercial districts
  - residential area
  - parks/open fields
- on-demand & scheduled routes
Urban Air Mobility Traffic flight rules

Number of systems but all of them are centralized alike

But all of those solutions are short in future thinking.

Drone and pilot registration is crucial and important – such systems already exist and function – drone deploy i.e.

Most important common features:

- Operator and Drone Registries
- Flight Requests and Approvals
- Real-Time Traffic Monitoring
- SORA (Specific Operation Risk Assessment)
- Geofencing/restricted areas
Urban Air Mobility Traffic Analysis Tool

Current status
- Simulations of drone traffic over specified area with defined no-fly-zones and restricted traffic zones
- UAV modeled as a point with no dynamics
  - Specified size (collision radius)
  - Limited range
  - Specified cruise speed
  - Division into UAV autonomy levels
  - Assigned waypoints
  - Families: commuters, parcel deliveries
- Departure and destinations points determined based on UAV type/application based on real world population density and hub locations

Close next steps
(couple of weeks)
- Outcome of a close encounter based on UAVs’ autonomy levels
  - two low autonomy level drones -> collision
  - at least one high autonomy level drone -> collision avoidance

Long perspective
- Additional done families
  - Recreational/loiter
  - Food (ad-hoc) deliveries
- More realistic modelling of deliveries destination selection
  (multipoint destinations within the same area)
- More advanced start and landing modelling
- Risks and managing the risks by different class of UAVs
- Traffic rules
  - Corridors, zones, etc.
Urban Air Mobility Traffic Analysis Tool

Population density distribution
Statistics Poland (Central Statistical Office)

Airspace restrictions
Polish Air Navigation Services Agency
Urban Air Mobility Traffic Analysis Tool

Daily traffic distribution – Municipal Road Administration

Source: Warsaw Municipal Road Administration, https://zdm.waw.pl
**Urban Air Mobility Traffic Analysis Tool**

### UAV population definition
- Drone families and their parameters (e.g. cruise speed, range, level of autonomy, daily traffic distribution, hubs)
- Population density
- Route/waypoints assignment

### Route planning
- Airspace restrictions
- No-fly zones
- Restricted fly zones (drones may only enter the zone if its departure or destination point lies within that zone, drone must fly along shortest path)
- Assignment of flight altitude

### Traffic simulation
- Simulation of air traffic
- Each drone flies to its destination(s) via waypoints specified during route planning
- Detection of required collision avoidance manoeuvres (traffic advisories) and collisions (in case of non autonomous drones)

### Traffic report
- Traffic animation
- Traffic density map
- Collisions density map
- Traffic advisories density map
- Number of collisions per drone
- Number of traffic advisories per drone
Urban Air Mobility Traffic Analysis Tool

Loiter drones

- 550,000 UAV operations in 2022 in Poland
  - 0.01456 UAV operations per capita (per year, assuming population of 37.766M)
  - 95 UAV operations per day in Warsaw area (assuming population of 2.384M)


Commuter drones (taxi)

- 111.5M taxi rides in 2022 in Poland (app based)
  - 2.95 taxi rides per capita (per year, assuming population of 37.766M)
  - 19,270 taxi rides per day in Warsaw area (assuming population of 2.384M)

Source: https://www.transport-publiczny.pl/pdf/TAXI_raport_CS6-min.pdf
Urban Air Mobility Traffic Analysis Tool

Departure, destination and waypoints selection

Departure times distribution
Urban Air Mobility Traffic Analysis Tool

Traffic simulation

Traffic density map
Urban Air Mobility Traffic Analysis Tool

Traffic distribution

Simulation report

Simulation was started at: 2023.04.20 09:50:16.
Simulation time at the start was: 00:00:00.
Simulation duration was: 24:00:00.

Total number of drones in the simulation was: 3000, including:

<table>
<thead>
<tr>
<th>Autonomy</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 0</td>
<td>100</td>
</tr>
<tr>
<td>Level 1</td>
<td>100</td>
</tr>
<tr>
<td>Level 2</td>
<td>600</td>
</tr>
<tr>
<td>Level 3</td>
<td>1200</td>
</tr>
<tr>
<td>Level 4</td>
<td>1000</td>
</tr>
</tbody>
</table>

Total number of collided drones was: 18.
Total number of collision avoidances was: 2076.
UAV classification implementation

**Simulation tool allows to:**

- Drones’ data generation: each drone is assigned with randomly drawn speed, take-off and landing points’ location and time,
- Hub locations and numbers
- Drone population generator
- drone’s path is adjusted in such a way that it avoids restricted airspaces
- Air traffic simulation based on the generated data the traffic simulation is conducted taking into account the drones’ parameters
- Data analysis: traffic animation, traffic density map generation
- Heat map of airborne
- Heat map of drones’ Collision
- Heat map of collision avoidance