HorizonUAM: Safety and Security Consideration for Urban Air Mobility

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3rd OPTICS2 Workshop:
Towards SAFE and SECURE Urban Air Mobility
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HorizonUAM Project Framework

- Urban Air Mobility (UAM) research, focus on urban air taxi services
- DLR internal research project, initiated by DLR executive board
- 07/2020 – 06/2023
- 10 DLR institutes and facilities involved
  - Flight Guidance
  - Combustion Technology
  - Flight Systems
  - Air Transport and Airport Research
  - Communications and Navigation
  - Air Transportation Systems
  - Aerospace Medicine
  - System Architectures in Aeronautics
  - Atmospheric Physics
  - Unmanned Aircraft Systems
- Project budget 9.0 M€
Project Content

- UAM system simulation
  - Scenarios, demand forecast, economy
- Vehicle
  - Vehicle family concepts, system technology, cabin
- Safety/Security
  - Autonomy, multi sensor navigation and communication, risk assessment, U-space concept
- Vertidrome
  - Infrastructure, flight guidance, UAM network management, airport integration
- Acceptance
  - Acceptance of civil drones and air taxis, citizen participation
- Demonstration/Assessment
  - UAM cabin simulator, tower simulator, scaled flight guidance/ navigation demonstrations
UAM as a System

Further reading:
• Schuchardt et al., Urban Air Mobility Research at the DLR German Aerospace Center – Getting the HorizonUAM Project Started, AIAA Aviation 2021, 08.2021
• L. Asmer et al., Urban Air Mobility Use Cases, Missions and Technology Scenarios for the HorizonUAM Project, AIAA Aviation 2021, 08.2021
Vehicle Family Concepts

<table>
<thead>
<tr>
<th>Aircraft architecture</th>
<th>Multirotor</th>
<th>Quadrotor</th>
<th>Lift+Cruise</th>
<th>Tiltrotor-wing</th>
<th>Vectored Thrust</th>
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<tr>
<td>Disc loading</td>
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<td>Hovering efficiency</td>
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<td>Downwash speed &amp; noise</td>
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<td>Forward flight speed &amp; efficiency</td>
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<td>Gust resistance and stability</td>
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<td>Preferred use case</td>
<td>Air taxis (inner-city point-to-point services)</td>
<td>Air taxis and airport shuttles</td>
<td>All</td>
<td>All</td>
<td>Airport shuttles and intercity</td>
</tr>
</tbody>
</table>

Further reading:
- P.S. Prakasha, et al., Towards System of Systems driven Urban Air Mobility Aircraft Design, DICUAM, 03.2021

Figure based on: Roland Berger GmbH, "Urban Air Mobility the Rise of a New Mode of Transportation," Nov. 2018.
Vertidrome

Further reading:
- K. Schweiger et al., UAM Vertidrome Airside Operation: What needs to be considered?, DICUAM, 03.2021
- K. Schweiger et al., Urban Air Mobility: Vertidrome Airside Level of Service Concept, AIAA Aviation 2021, 08.2021
- F. Naser et al., Air Taxis vs. Taxicabs: A Simulation Study on the Efficiency of UAM, AIAA Aviation 2021, 08.2021
- K. Schweiger, UAM Vertidrome Operationen - Vision als Treiber der aktuellen Forschung, to be presented at DLRK 2021, 09.2021
Public Acceptance

• Analysis of public acceptance towards civil drones and air taxis
• Participatory noise measurements
• Perception of drones and air taxis by pedestrians
• Air taxi passenger interaction and comfort

Further reading:
• A. End et al., Gender differences in noise concerns about civil drones, ICBEN Congress on Noise as a Public Health Problem, 06.2021
• I. Moerland-Masic, et al., Urban Mobility: Airtaxi Cabin from a Passengers Point of View, Comfort Congress 2021, 9.2021
Demonstration and Assessment

- Tower simulation for integration of UAM at airports
- Scaled flight demonstrations for showing communication, navigation and flight guidance concepts with drones in model city
- Final assessment of chances and risks associated with UAM
- Annual HorizonUAM Symposium
Safety and Security Overview

- Challenges, gaps, and research outline on safety and security
  - Safe Autonomy
  - Reliable Multi-Sensor Navigation
  - Robust and Efficient Communication
  - U-space and Safe Air Traffic
  - Cyber-Physical Safety and Security

Further reading:
- P. Nagarajan et al., ASTM F3269 - An Industry Standard on Run Time Assurance for Aircraft Systems, AIAA Scitech 2021, 01.2021
- S. Schopferer, et al., ML Applications in Unmanned Aviation: Operational Risks and Certification Considerations, Machine Learning in Certified Systems - DEEL Workshop, 01.2021
- Becker et al., Approach for Localizing Scatterers in Urban Drone-To-Drone Propagation Environments, EuCAP European Conference on Antennas and Propagation, 03.2021
- C. Torens et al., HorizonUAM: Safety and Security Considerations for Urban Air Mobility, AIAA Aviation 2021, 08.2021
Safe Autonomy

- Challenges related to safe autonomy
  - Missing pilot is equivalent to a missing fallback layer
  - Artificial intelligence (AI) and machine learning as new technologies
  - Verification aspects and achieving a high level of safety for autonomous functions

- Discussion / Gaps
  - Regulatory, standards and certification aspects of AI
    - Regulation and standardization efforts ongoing

- Research on increasing safety of autonomous operations
  - Literature study, categorization of verification methods
  - Establish toolchain for assessment of the safety of autonomous functions
  - Automation of supervision tasks and self-awareness
Reliable Multi-Sensor Navigation

- Challenges for reliable urban navigation
  - Strong GNSS multipath in urban environment
  - Non-line-of-sight (NLOS) to some satellites
  - GNSS interference
  - Constraints from cost and size requirements

- Discussion / Gaps
  - Certification process for multi-sensor solutions
  - Required performance for UAM navigation
    - Accuracy, integrity, continuity, availability

- Research of a multi-sensor navigation system
  - Airborne equipment (multi-sensor onboard unit)
  - Ground infrastructure (differential GNSS augmentation, visual cues)
  - Innovative multi-sensor solution leading to integrity-monitoring architecture
Robust and Efficient Communication

- Challenges for robust communication
  - No existing system for UAM
  - High mobility of vehicles in 3D plane
  - Non-line-of-sight (NLOS) conditions
  - Strong multipath propagation
  - Efficient usage of shared resources

- Discussion / Gaps
  - Requirements for collision avoidance
  - Latency, bandwidth, availability, …

- Research on communication concepts
  - Channel model for UAM scenarios
    - Air to air (A2A)
    - Air to infrastructure (A2I)
  - Propagation characteristics in urban environments
U-Space and Safe Air Traffic

- Challenges for U-space and Safe Air Traffic
  - U-space services not yet available
  - Currently time plan delayed
  - Low-altitude bands frequented by birds / drones

- Discussion / Gaps
  - Required U-space services
  - On-board sensor requirements to detect and identify birds and drones

- Research supporting U-space development and birds / drones collision avoidance
  - Flight demonstrations evaluate and identify required information from U-space
  - Requirements of impact resistance to avoid damage in case of collision
  - Filling the gaps
    - Prototype U-space services: Vertidrome management
    - Collision avoidance and flight path prediction of birds and drones
Cyber-Physical Safety and Security

- Challenges for cyber-physical safety and security
  - Prevention, detection, response and mitigation of diverse attack vectors (see figure)
  - Shared situational awareness for efficient crisis resolution

- Discussion / Gaps
  - Adapted definition of “Aviation Security”
  - Switch from transport system users being attackers to attackers acting remotely from anywhere

- Research and analysis of overall system
  - Critical operation procedures (e.g. take-off / landing)
  - Physical and cyber attacks and combinations
Conclusions

• Focus of the DLR’s HorizonUAM project lies on urban air taxi services, including
  • Vehicle design
  • Vertidrome infrastructure
  • Airspace integration and operation
  • Public acceptance

• Identification of challenges in safety and security for UAM in the discussed categories
  • Discussion of gaps and open questions for implementing UAM
    • Trust, standardization and regulation for increasing degrees of autonomy
    • Navigation performance requirements in urban environments
    • Communication performance requirements, specifically for collision avoidance
    • Required U-space services and level of automation and connectivity
    • Holistic approach for cyber-physical safety and security

• Project is in an early phase, work ongoing…
Join us at https://dlr.expert/horizonuam2021
Virtual symposium, free to register

Thank you for your attention!