IAM SYMPOSIUM 2025

5TH INNOVATIVE AIR MOBILITY SYMPOSIUM
17 – 18 NOVEMBER 2025 | GOETTINGEN (GER)

OVERCOMING CHALLENGES AND SHAPING THE FUTURE OF INNOVATIVE AIR MOBILITY

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German Society for Aeronautics and Astronautics
Lilienthal-Oberth e.V.

Agenda

17 NOVEMBER 2025 | SYMPOSIUM'S - DAY 1

09:30 CET Registration desk opens at 09:30 CET | FOYER GROUND FLOOR OF CONFERENCE CENTRE

10:00 CET Welcoming coffee available at 10:00 CET | FOYER

SCIENTIFIC SESSION 1: MARKET

Session chair: Lukas Asmer, *German Aerospace Center (DLR), Cologne, Germany*

NETWORKING LUNCH & POSTER SESSION

12:00 CET – 13:00 CET | FOYER

SCIENTIFIC SESSION 2: Public Acceptance / Noise

Session chair: Ole Bergmann, *German Aerospace Center (DLR), Göttingen, Germany*

14:50 CET | FOYER
NETWORKING BREAK

SCIENTIFIC SESSION 3: U-space

Session chair: Kristin Wendt, *German Aerospace Center (DLR), Hecklingen, Germany*

16:40 CET | FOYER
NETWORKING BREAK

SCIENTIFIC SESSION 4: Safe Autonomy

Session chair: Christoph Torens, *German Aerospace Center (DLR), Braunschweig, Germany*

18:30 CET
END OF SYMPOSIUM'S DAY 1

18 NOVEMBER 2025 | SYMPOSIUM'S - DAY 2

08:30 CET	Registration desk opens at 08:30 CET | FOYER GROUND FLOOR OF CONFERENCE CENTRE	Welcoming coffee available at 08:30 CET | FOYER
09:00 CET	SYMPOSIUM OPENING DAY 2 Daily welcome adress by the Symposium's chair	Bianca Schuchardt, *German Aerospace Center (DLR), Braunschweig, Germany*

SCIENTIFIC SESSION 5: Simulation

	Affordable or exclusive mobility? An applied cost model for Innovative Air Mobility (IAM) in Northern Germany	Jan Pertz, *German Aerospace Center (DLR), Hamburg, Germany*	

Session chair: Nabih Naeem, *German Aerospace Center (DLR), Hamburg, Germany*

10:30 CET I FOYER
NETWORKING BREAK

11:00 CET	KEYNOTE	Guillaume Soudain, *Programme Manager - Artificial Intelligence at EASA, Cologne, Germany*	
11:40 CET	PANEL DISCUSSION: Challenges of AI Certification	Panelists: Burak Ata, *Head of Certification and Assurance at Helsing* Konstantin Dmitriev, *Research Associate TUM & Senior Development Engineer at MathWorks GmbH* Umut Durak, *German Aerospace Center (DLR), Germany* Guillaume Soudain, *Programme Manager - Artificial Intelligence at EASA*	120

Moderation: Christoph Torens & Pranav Nagarajan, *German Aerospace Center (DLR), Braunschweig, Germany*

12:20 CET | FOYER
NETWORKING LUNCH & POSTER SESSION

SCIENTIFIC SESSION 6: Vertiport Design, Integration and Operations

13:30 CET	Research Questions on the Design and Operation of Vertiports: Possible Applications for the DLR Vertiport Demonstrator	Henry Pak, *German Aerospace Center (DLR), Köln, Germany*	125
	An Operational Perspective on Vertiport CONOPs – Weather-Driven Planning, Integration, and Flight Operation	Michael Anger, *Unisphere GmbH, Konstanz, Germany*	128
	Vertiport Integration into the European Airspace: A first glimpse into the EUREKA Whitepaper	Karolin Schweiger, *EUROCONTROL, Brétigny sur Orge, France*	130
	Launching the World's First Commercial eVTOL Operation – Challenges and Opportunities	Lukas Preis, *Skyports Infrastructure, München, Germany*	131

Session chair: Samiksha Rajkumar Nagrare, *German Aerospace Center (DLR), Braunschweig, Germany*

14:50 CET | FOYER
NETWORKING BREAK

SCIENTIFIC SESSION 7: Factors affecting Vertiport Design

15:20 CET	Risk Considerations for Vertiport Planning at Airports: An integrated Approach to Safety, Security, Environment, and Privacy	Paul David Lieten, *German Aerospace Center (DLR), Hecklingen, Germany*	133
	Effects of weather, delays, and technical disruptions on passenger satisfaction	Nirupama Vinayakumar Nair, *German Aerospace Center (DLR), Braunschweig, Germany*	136

Session chair: Bernd Bassimir, *German Aerospace Center (DLR), Braunschweig, Germany*

16:20 CET | FOYER
NETWORKING BREAK

16:45 CET
Stakeholder Forum 2025: Interactive workshop with short presentations

16:45 CET	2nd Stakeholder Forum for the research project VERTIFIED: Evaluation of the requirements for the planned vertiport demonstrators	Andreas Schaller, *German Aerospace Center (DLR), Hecklingen, Germany*	140
	Initial concept development for a vertiport demonstrator within project VERTIFIED	Nirupama Vinayakumar Nair, *German Aerospace Center (DLR), Braunschweig, Germany*	142
	Requirements for a modular vertiport design for project VERTIFIED	Samiksha Rajkumar Nagrare, *German Aerospace Center (DLR), Braunschweig, Germany*	145

Moderator: Samiksha Rajkumar Nagrare, *German Aerospace Center (DLR), Braunschweig, Germany*

18:45 CET
END OF SYMPOSIUM 2025

Welcome

Session Chair: Bianca I. Schuchardt, DLR


IAM SYMPOSIUM 2025
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17 – 18 NOVEMBER 2025 | GOETTINGEN (GER)
Overcoming Challenges and Shaping the Future of Innovative Air Mobility
Dr. Bianca I. Schuchardt
DLR Institute of Flight Guidance
DGLR
DLR


MENSA

Overcoming Challenges and Shaping the Future of Innovative Air Mobility

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Innovative Air Mobility (IAM) is “the safe, secure and sustainable air mobility of passengers and cargo enabled by new-generation technologies integrated into a multimodal transportation system”, as defined by the European Aviation Safety Agency (EASA) [1]. As such IAM is more than urban air mobility (UAM) or air taxi services. It extends into regional and multimodal use cases including cargo operations or emergency medical services. The concept of IAM is also known under the name advanced air mobility (AAM) established by NASA and widely used internationally. For example, the term AAM was adopted by the International Civil Aviation Organization (ICAO) for its AAM Study Group [2] as well as by the German Ministry for Digital and Transport (BMDV) in their national AAM strategy [3].

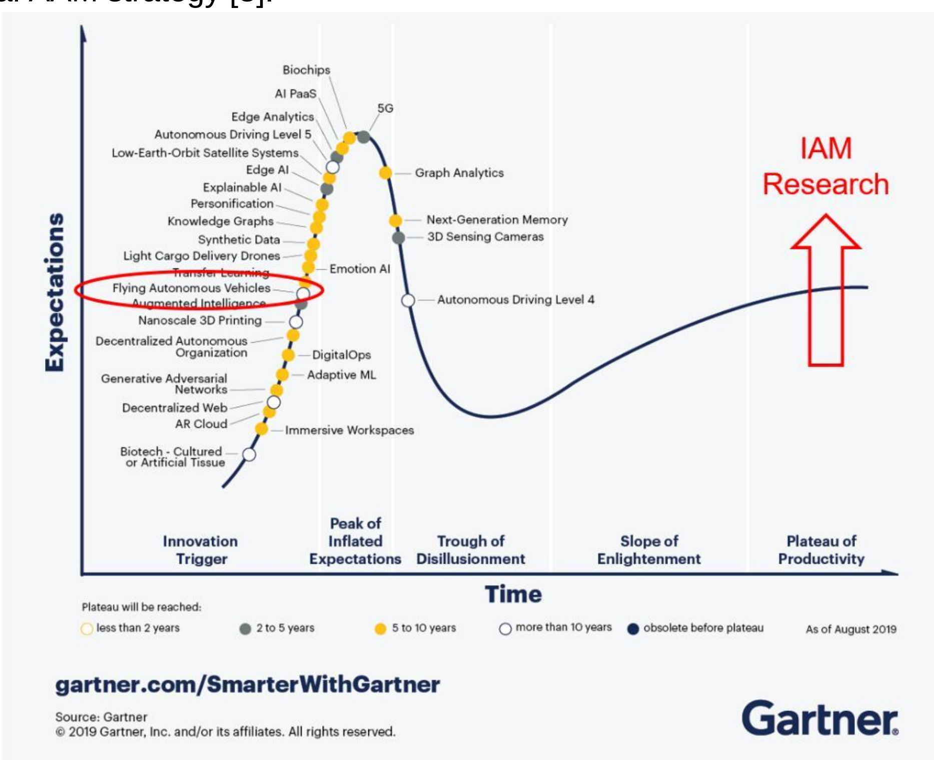

Figure 1: Hype cycle for emerging technologies, adapted from [4].

The recent hype about new air mobility concepts with autonomously flying aircraft was captured in Gartner’s hype cycle from 2019 [4], see figure 1. Since then the hype moved constantly onwards towards its peak. Today in 2025, we seem to have reached the point beyond the ‘peak of inflated expectations’ at least for Europe. IAM news earlier this year reveled several IAM start-ups being in financial crisis. However, according to Gartner, it is only a question of a few more years to overcome the 'trough of disillusionment' and to finally reach the 'plateau of productivity'. The overarching question is, how can we overcome remaining challenges and shape the future of IAM together?

This presentation will set the scene for the 5th IAM Symposium, organized jointly by German Aerospace Center (DLR) and German Society for Aeronautics and Astronautics (DGLR). The annual symposium originally started as DLR's UAM symposium in 2021 focusing on urban use cases, see also [5]. The 2025 event features presentations and posters on the following topics:

- How to overcome current challenges of IAM concepts?
- How can air mobility concepts be extended to smart inter-modal systems? Who are the stakeholders in IAM and what are their interests?
- How to take the next steps towards the safe introduction of air taxis or cargo drones and the necessary infrastructure in urban and regional areas?
- How does U-space play a role in IAM air traffic management?
- How to develop, construct and validate emerging new vertiport concepts?
- How can the gaps in the existing transportation system be identified and can IAM help?
- How can societal concerns such as safety, security, privacy, noise, and sustainability be addressed?
- What are recent advances in the simulation capabilities for IAM noise? How can the noise effect be assessed and what is the impact on humans?
- How can advances in autonomy and artificial intelligence be leveraged to enable IAM operations?

The aim of the symposium is to share research results and discuss recent developments and questions on current research activities and industrial developments in the field of IAM. It provides an opportunity for scientists and engineers from industry, research institutions and universities to exchange knowledge and findings of current studies, and to discuss directions for future research and development.

[1] EASA, IAM Hub, Drones & Air Mobility BasicsExplained, https://www.easa.europa.eu/en/domains/drones-air-mobility/drones-air-mobility-landscape/basics-explained, accessed 29.06.2025
[2] ICAO, Advanced Air Mobility Study Group (AAM SG), Fifth Meeting, Summary of Discussion, Montréal, Canada, 26-30 May 2025
[3] BMDV, Advanced-Air-Mobility-Strategie des BMDV, 2024.
[4] Gartner, Hype Cycle for Emerging Technologies, 2019.
[5] Pak, H., Asmer, L., Kokus, P. et al. Can Urban Air Mobility become reality? Opportunities and challenges of UAM as innovative mode of transport and DLR

contribution to ongoing research. CEAS Aeronaut J (2024). https://doi.org/10.1007/s13272-024-00733-x

Biography

Dr. Bianca I. Schuchardt

Dr. Bianca Schuchardt works as aeronautical research engineer at the DLR Institute of Flight Guidance in Braunschweig, Germany, and leads the research group on ‘Innovative Air Mobility Integration’. The group’s research focus is the safe and efficient integration of cargo drones and air taxis into the airspace.

Scientific Session 1: MARKET

Session Chair: Lukas Asmer, German Aerospace Center (DLR), Cologne, Germany

Multidisciplinary Analysis of 2025 Maturity Levels in the Overall IAM Ecosystem with Drones

DI Dr.-Ing. Holger Friehmelt, Arian Ghoddousi M.Sc., Tom Bruchmann M.Sc.
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With more than 2 million civilian drones in the EASA area of operation, the Austrian innovation laboratory AIRlabs Austria is also working on the overall ecosystem of unmanned aviation. With funding from the Austrian Ministry of Climate Protection BMK, the maturity levels (TRL) of the various disciplines required for successful civil UAV applications are systematically recorded and examined in order to provide a research and development roadmap and make recommendations for implementation. In doing so, AIRlabs Austria draws on a wide variety of reliable sources. On the one hand, the 25 AIRlabs consortium partners from industry, users and research should be mentioned here. Other valuable sources include the EU Drone Strategy 2.0 [1], the recommendations for action to the German federal government from December 2023 [2]and the Austrian Aviation Strategy (FTI) with a time horizon of 2030 [3], which was also published in 2023.

Quantitative statements are made with the help of **technology readiness levels** (TRL). A TRL is a scale for assessing the degree of maturity of a particular technology in its development life cycle. It ranges from TRL 1, where the basic principles are observed, to TRL 9, where the technology is fully operational and commercially viable. TRL is commonly used in industries such as aerospace and is therefore also very well suited to the UAS sector to guide decisions and recommendations for action.

A so-called **network diagram**, also known as a **spider web diagram** or **radar diagram**, is used as a form of **visualization**. It enables several data points or variables to be displayed on a two-dimensional graphic. It is therefore particularly useful for comparing the TRL of different areas of the UAS ecosystem. The visual representation allows strengths and weaknesses to be identified at a glance, making it a useful tool for analysis and presentation in the informative poster proposed here.

In addition to individual areas such as **certification, cross-border applications, business cases, training and the availability of specialist personnel**, the focus is on the following technical aspects of the UAS ecosystem: **propulsion systems** and, in particular, sustainable energy sources (such as batteries or fuel cells), automation through to **autonomous flight control systems**, including the necessary sensors, gyroscopes, accelerometers and control algorithms, **high-precision navigation systems** (including in GPS-restricted areas), and the use of the latest technology. navigation systems (including in GPS denied areas), **communication systems** both for the C2 link and for payload data (e.g. based on radio frequency (RF), Wi-Fi, LoRaWAN or mobile networks), **sensor technologies**, **artificial intelligence and machine**

learning for processing big data from sensor applications, but also for autonomous decision-making, object recognition, obstacle avoidance and adaptive flight planning and, last but not least, safety and anti-collision systems, for example to improve the **safety** of drones, their permissibility (e.g. through **obstacle detection and avoidance systems**, parachutes and "geofencing.
Finally, the graphical representation in the network diagram enables a Pareto analysis and the three most important recommendations for action are presented and discussed.

[1] European Commission: "A Drone Strategy 2.0 for a Smart and Sustainable Unmanned Aircraft Eco-System in Europe", Brussels, 29.11.2022 https://transport.ec.europa.eu/document/download/1cb5fb4f-4252-4f97-abf4-c4a167b1c7d2_en?filename=COM_2022_652_drone_strategy_2.0.pdf
[2] Bundesregierung Deutschland, Bundesministerium für Verkehr: "Unmanned Aircraft Systems and Innovative Aviation Strategies The Federal Government's Action Plan", 14.01.2022, https://www.bmv.de/SharedDocs/DE/Anlage/DG/aktionsplan-drohnen-englisch.pdf?blob=publicationFile
[3] Federal Ministry for Climate Protection, Environment, Energy, Mobility, Innovation and Technology: "RTI Strategy for Aviation 2040+", 2022, https://open4aviation.at/resources/pdf/RTI-Strategy-Austrian-Aviation-2040plus.pdf

Biography

DI Dr.-Ing. Holger Friehmelt

Dr. Holger Friehmelt has been Director of the Institute of Aviation at FH JOANNEUM Graz since 2017, overseeing Bachelor's and Master's programs. Previously, he held senior positions at RECARO Aircraft Seating in Germany, the USA, and South Africa. His research focuses on UAVs, system modeling, and flight testing and has been the founding father of AIRlabs. He has authored over 120 publications.

Demand Analysis of Regional Air Mobility Using an Agent-Based Demand Model

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[b]*Technical University of Munich*

Short-haul services with electric aircraft and Regional Air Mobility (RAM) have the potential to offer improved regional airport access and reduced emissions. This study investigates RAM demand in Germany and neighboring countries, focusing on 19-passenger hybrid-electric aircraft (HEA) with a range of up to 950 km. Unlike previous studies that focused on potential time savings and emissions or relied on secondary data (e.g., Grimme et al., 2020; Baumeister et al., 2020; Paproth et al., 2020; Justin et al., 2021), we incorporate survey-based passenger behavior findings into an agent-based demand model. Our adoption-aware framework, integrating a calibrated mode-choice model, simulates individual travel decisions, estimates potential market demand, and assesses the impacts of RAM.

The study area covers Germany and neighboring countries with 11,875 zones (11,717 in Germany and 158 in surrounding regions). A synthetic population of ~80 million individuals in 53 million households was generated (Pukhova et al., 2021), and a representative 5% sample was used for the initial analysis.

A multimodal network was developed, including door-to-door travel times and distances for car, rail, long-distance bus, conventional air, and HEA, which can operate from 54 IFR-capable airports or airfields in Germany and 341 in neighboring countries. Car and public transport were considered as the feeder modes. The HEA was projected to offer up to 82% CO_2-eq emission reduction compared to conventional aircraft configuration by 2050 and ticket prices between €0.45–€0.60 per revenue passenger kilometer, comparable to first-class train in Germany (Strathoff et al., 2022; Fu et al., 2025).

Travel demand was modeled with trip generation, destination choice, and mode choice components. (Pukhova et al., 2021) The mode choice model incorporated the stated-preference survey results analyzed by Fu et al. (2025). We assessed RAM's impact by quantifying demand-weighted changes in door-to-door travel time, door-to-door CO_2-eq emissions, and accessibility gains. The adoption-weighted benefits were estimated relative to current mode choices. Promising routes were identified considering both demand and benefit levels. Accessibility gains were monetized using logsum-based metrics and survey-derived value of time. Due to limited real market data of RAM, we defined both optimistic and conservative adoption scenarios. The former based on our model estimates, and the latter calibrated to a 5% market share based on prior studies (Spangenberg et al., 2020; Paproth et al., 2020).

On an average weekday, over 212,000 long-distance trips were generated by a 5% sample of the German population, with 90% occurring within Germany and 10% crossing borders. The majority (63%) were private or leisure trips, while 37% were business-related. In the optimistic scenario, the estimated RAM mode share reached 19% for non-business and 29% for business trips. Persisted under both optimistic and conservative scenarios, business travelers consistently showed higher adoption of RAM than non-business travelers. Adoption of RAM declined with lower income levels and was highest on routes connecting large cities, while rural connections had less uptake.

RAM offered time savings of 1.1 hours per trip on average compared to the fastest available mode on about half of all routes, and 1.3 hours compared to currently chosen modes on over 60% of routes. Routes with car-based feeder modes yielded greater time savings than those using public transport.

While RAM did not reduce the CO_2-eq emissions per trip compared to the currently chosen modes overall, it could potentially reduce CO_2-eq emissions by up to 16% on 59% of car routes and by up to 67% on 86% of routes currently served by conventional air.

Accessibility gains from RAM were positive across scenarios. In the conservative case, average generalized travel time per trip decreased by 2% (~€4). In the optimistic case, average generalized travel time savings per trip reached 15% (~€23) with car feeders and 13% (~€19) with public transport feeders. These benefits were higher for high-income and business travelers, and for routes connecting urban areas, with total accessibility improvements in the optimistic scenario roughly five times greater than in the conservative case.

The initial results suggest that RAM offers general benefits in travel time savings, emission reductions, and overall accessibility improvement. However, targeted policy support is needed to enhance access for lower-income groups and less-connected regions. Next steps include sensitivity analyses on time and cost parameters, as well as scaling the model to represent the full population for a comprehensive national assessment. Future work will also incorporate 2030 projections, accounting for anticipated socio-demographic developments.

[1] Baumeister, S., Leung, A., & Ryley, T. (2020). The emission reduction potentials of First Generation Electric Aircraft (FGEA) in Finland. Journal of Transport Geography, 85, 102730, from http://dx.doi.org/10.1016/j.jtrangeo.2020.102730.

[2] Fu, M., Othman, M.M., Moeckel, R., Hornung, M., & Antoniou, C. (2025). User preferences for regional air mobility: Insights from Germany. Journal of Air Transport Management (under revision).

[3] Grimme, W., Paul, A., Maertens, S., & van Wensveen, J. (2020). The prospects of hybrid-electric regional air transport - an assessment of travel time benefits of domestic short-haul flights in Germany with 19-seater aircraft. Transportation Research Procedia, 51, 199–207.

[4] Justin, C. Y., Payan, A. P., & Mavris, D. (2021). Demand Modeling and Operations Optimization for Advanced Regional Air Mobility. In AIAA Aviation 2021 Forum.

[5] Paproth, Y., Adam, F., Stich, V., & Kampker, A. (2020). Model for future thin-haul air mobility demand in Germany. In 2020 IEEE International Conference on Engineering, Technology and Innovation (ICE/ITMC). Piscataway, NJ: IEEE (Institute of Electrical and Electronics Engineers).

[6] Pukhova, A., Moreno, A. T., Llorca, C., Huang, W.-C., & Moeckel, R. (2021). Agent-Based Simulation of Long-Distance Travel: Strategies to Reduce CO2 Emissions from Passenger Aviation. Urban Planning, 6(2), 271–284.
[7] Spangenberg, M., Wellensiek, M., & Zhang, Q. (2020). D2.1 Economic Feasibility Study for a 19 PAX Hybrid-Electric Commuter Aircraft. ELICA (Electric Innovative Commuter Aircraft).
[8] Strathoff, P., Zumegen, C., Stumpf, E., Klumpp, C., Jeschke, P., Warner, K. L., et al. (2022). On the Design and Sustainability of Commuter Aircraft with Electrified Propulsion Systems. In AIAA Aviation 2022 Forum. Reston, Virginia, USA: AIAA (The American Institute of Aeronautics and Astronautics).

Biography

Mengying Fu

Mengying Fu is a Research Associate at Bauhaus Luftfahrt e.V. and a PhD candidate at the Technical University of Munich. Since 2019, her research has focused on travel behavior and the market development of emerging sustainable air transport, with a particular emphasis on urban and regional air mobility as a key application area.

NETWORKING LUNCH & POSTER SESSION

Extending the vertiport management tool VERTIGER for IAM scenarios: A drone-cage demonstration

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Innovative air mobility (IAM) is a novel concept that is designed to supplement the existing transport networks with safe, secure and sustainable air mobility. Among others, use cases of IAM include inner city and regional passenger transport, as well as cargo and medical operations. This novel concept needs to address many challenges, as it deals with a large number of aircraft and includes low-level airspace that was previously not considered for air traffic. To facilitate these new operations that involve the previously mentioned large number of new airspace participants, the concept of U-space is developed, as specified by the regulations of the European Union—see the CORUS-XUAM ConOps [1] for a detailed overview of U-Space.
One of the main stakeholders of IAM is the vertiport. A vertiport is a new infrastructure that is specifically designed for vertical take-off and landing operations of electric, vertical take-off and landing aircraft (eVTOL) or other similar aircraft. It serves as an entry and exit point to the new air traffic system, as well as a possible logistic hub for cargo operations. The vertiport can be placed at different locations ranging from dedicated areas in a city or a rural area, on rooftops of buildings to locations at an airport. All of these locations have their own challenges that need to be considered, especially in proximity to an airport, which requires a close interaction with conventional air traffic and air traffic control. While the design and the facilities that are part of the vertiport are still the topic of intense discussion, at a minimum the vertiport needs one final-approach and take-off zone (FATO) and a touchdown and lift-of zone (TLOF), which can be combined in a single location, as well as their respective safety areas—for definitions and regulations see PTS-VPT-DSN [2]. Similar to the existing airports, we need to manage the arrival and departure of aircraft, assign parking positions, and operate all facilities that are part of the vertiport. This is done by a vertiport operator; however, as the long-term goal of IAM is a highly automated system, this vertiport operator does not need to be a physical person but rather an autonomous software system that is optionally only supervised by an operator.
In this presentation, we will show an extended version of the vertiport operator tool for managing vertiport operations called VERTIGER - VERTIport manaGER [3] developed in the project HorizonUAM [4]. This extension provides the framework for more complex services provided at a vertiport, which are a topic of future research. Additionally, we will present a series of flight trials with three vertiports and three drones in a drone cage to showcase the functionality of the vertiport manager and the lessons learned from these trials. These scenarios represent simple use cases expected in IAM in an urban environment with a focus on the management of the vertiport's FATOs. We will further

highlight the interactions with a simple instance of U-space, which can serve as a baseline for more advanced U-space services that are provided at a vertiport in the future.

[1] EUROCONTROL: U-space conops and architecture (edition 4), CORUS-XUAM D4.2 (2023). [Online]. Available: https://ext.eurocontrol.int/ftp/?t=33e6e2c8e647e58310bb1eb79c1bb464
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[3] Schuchardt, B.I., Devta, A. & Volkert, A.: Integrating vertidrome management tasks into U-space. CEAS Aeronaut J (2024). https://doi.org/10.1007/s13272-024-00747-5
[4] Pak, H., Asmer, L., Kokus, P. et al.: Can Urban Air Mobility become reality? Opportunities and challenges of UAM as innovative mode of transport and DLR contribution to ongoing research. CEAS Aeronaut J (2024). https://doi.org/10.1007/s13272-024-00733-x

Biography

Bernd Bassimir

Bernd Bassimir is a scientific researcher at the DLR Institute of Flight Guidance with a focus on services provided at a vertiport. He studied computer science at the Friedrich-Alexander-Universität Erlangen-Nürnberg and is pursuing his Ph.D. with a focus on robust optimization in timetabling.

Cryogenic Hydrogen Cooling Concept for Sustainable Air Mobility

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This paper presents an innovative cooling concept for hydrogen-based air mobility propulsion systems. The system architecture is based on cooling an electrical motor by cryogenic hydrogen as sketched in Fig. 1. The nominal motor power is 300 [kW] at rotational speeds of maximum 2,500 rpm and compact design to fit into a lightweight airframe.

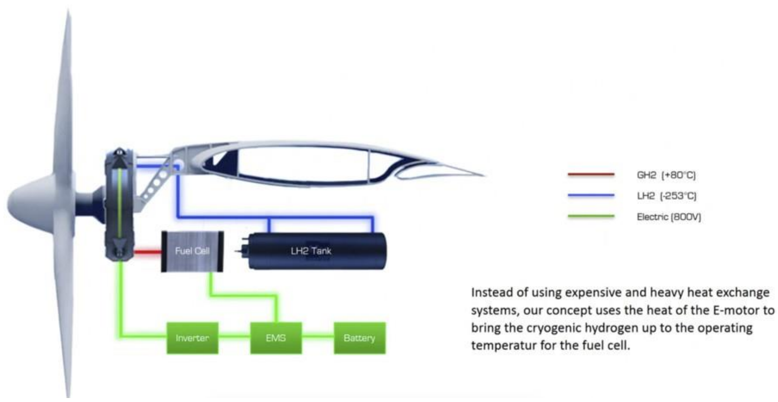

Fig.1: System layout of an electrical propulsion system cooled by cryogenic hydrogen.

Based on analytical pre-studies and a Model-Based Systems Engineering (MBSE) design approach, the relevant design steps including simulation, experimental testing and setup of the model functions will be described. The focus will be set on the experimental findings of cryogenic hydrogen fluid flow with thermal heat exchange [1]. Here, the thermodynamic and fluid dynamic behavior of hydrogen flowing through an electrically heated hollow conductor, acting as a cooling agent to maintain specified temperature and pressure ranges, will be highlighted. The test data evaluation revealed a strong dependency of the cooling power from the hydrogen mass flow at pressure levels above 4 [bar]. The hydrogen is assumed gaseous, but cryogenic, with no phase transition within the motor system. During the experimental testing, two types of hollow conductors were subjected to constant current, varying mass flows, and pressures. Two test series were conducted: the first analyzed a straight hollow conductor, while the second focused on a coiled hollow conductor. Uniform boundary conditions were maintained to ensure comparability, using consistent measurement points.
The overall system behavior is represented by an innovative Model-Based Systems Engineering approach [2] sketched in Fig. 2. By defining model functions representing the physical system behavior, a virtual model of the propulsion system has been set up to pre-test the system behavior and give evidence for scaling laws.

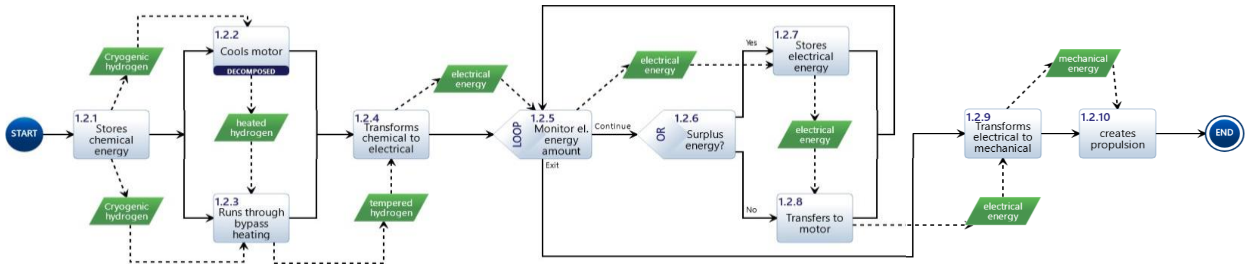

Fig.2: Model-Based Systems Engineering approach for the hydrogen-cooled power train.

Here, the correlations and interdependencies of the energy flow rates between the subsystems of the powertrain will be analyzed in detail. The model functions are based on analytical pre-calculations, experimental findings and simplified relations from thermodynamics and fluid mechanics.

Further, the quasi-static system behavior will be used to design a control loop for the propulsion system, representing the system dynamics when the aircraft is accelerating or decelerating. The response time of the hydrogen cooling system is very short, consequently the control loop shall be designed based on previously trained scenarios and fallback setting in case of a cooling system malfunction. This reinforcement learning framework, supported by the digital twin of the cooling system, provides a remarkable adaptability in optimizing mass flow rates according to varying thermal loads. This approach can outperform conventional control methods by dynamically managing complex nonlinear interactions within the system, thereby achieving enhanced energy efficiency and stable thermal regulation.

Finally, the validation of the virtual model of the propulsion system is carried out using test data from a representative model of the motor.

[1] Baeten, A., Barm, S., Fackler, M., Majic, N., Reitenberger, J., Guenther, T., Lohr, C., Sause, M., Trauth, A. and Weihrich, R. (2023a), Concept study of a lightweight high performance axial flux motor cooled with cryogenic hydrogen: SAMPE North America, Seattle, Washington, United States.

[2] Barm, S., Reitenberger, J., Bersiner, P., Baeten, A., Baeten, S., Fackler, M., Koerner, T. and Oblinger, C. (2024), “Design of a Cryogenic Airborne Hydrogen Cooling System for Electric Propulsion”, in AIAA SCITECH 2024 Forum, Orlando, FL, American Institute of Aeronautics and Astronautics, Reston, Virginia.

Biography
André Baeten

PhD in Mechanical Engineering, Technical University of Aachen (RWTH); 10 years R&D engineer flight physics at Airbus Military Air Systems, Munich; 2 years systems engineer air defense systems (MEADS) at MBDA, Munich; since 2009 Professor of lightweight construction and composite technology at Augsburg Technical University of Applied Sciences; scientific director of the Technology Transfer Center Hydrogen Technology, Lightweight Construction, and Digital Technologies.

Integrating Extended Reality in Air Traffic Control: innovative interfaces for drone monitoring at airports

Marzia Corsi, Sara Bagassi, Christophe Hurter, Antonio Esposito
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As unmanned aerial systems (UASs) continue undertaking a growing array of activities, the risk of encountering these vehicles is also rising. This poses potential threats to operational safety, including collisions with other aircraft or structures and unauthorised entry into restricted areas like airports. Furthermore, the expanding scope of UAS operations necessitates increased investment and research into monitoring and managing drone activity technologies, including future “air taxis” [1]. A key challenge is the identification of potential hazards posed by drones operating close to sensitive areas. This study focuses on the concern of drones intruding into restricted airport zones, requiring airport safety and security units and control tower operators to monitor and manage such airspace intrusions. In particular, this study endeavours to harness digital innovations to create and validate an XR-based Human Machine Interface tailored for Air Traffic Controllers (ATCOs) tasked with monitoring UAS traffic near airports.
This interface aims to facilitate a more intuitive and efficient interaction within the control tower, enhancing both performance and situational awareness for ATCOs who must navigate the integration of autonomous drones. The interface design draws inspiration from previous research on airport control towers [2-3], incorporating established concepts such as tracking labels, air gestures interaction, visual and aural cues for external elements, and safety net-based alert systems [4]. The presented concept [5] proposes including an on-demand semi-transparent augmented interface that live-streams the area surrounding the UAS ground infrastructure (vertiport) in the aerodrome area. To avoid the constant presence of an additional interface in the control tower, the ATCOs equipped with a see-through head-mounted display can visualise the HMI only when needed. The logic flow of the drone monitoring system is presented in Figure 1.
A case study was carried out to assess the proposed concept, with the interface developed and integrated into a control tower simulation platform. A human-in-the-loop real time validation exercise was conducted within the simulated environment of Toulouse Airport to validate the developed technical solution and evaluate the human performance of air traffic controllers.
The ATCOs were tasked with integrating drone monitoring duties into their ground control responsibilities, ensuring situational awareness and safe coexistence between conventional air traffic and drone operations. Additionally, they faced unexpected and

potentially hazardous events, requiring them to quickly assess and respond to emerging situations to maintain safety and operational efficiency.

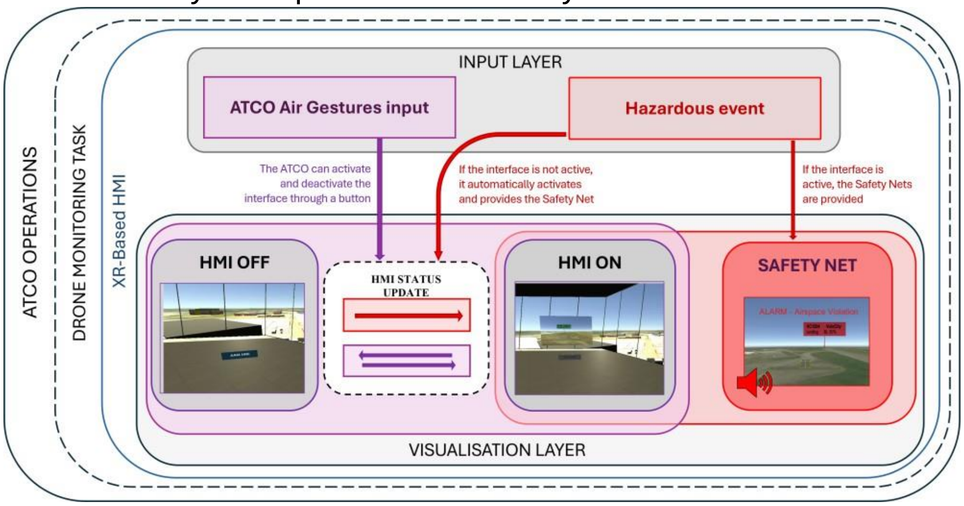

Figure 1: Logic flow of the drone monitoring XR-based HMI. During regular operations, the HMI can be activated and deactivated using air gestures. The closed interface allows for an unobstructed view of the airfield. When the interface is open, it displays drones' identification and tracking labels, providing real-time information for monitoring UAS traffic. When a hazardous event involving AAM traffic occurs, the safety net system is triggered. If the interface is closed, it automatically opens to ensure immediate situational awareness. The tracking label of the involved drone switches to red, a text clarifies the type of situation, and a directional acoustic cue drives the ATCO's attention toward the affected area.

The campaign assessed the technical solution: see-through head-mounted smart glasses designed to display the XR-based HMI within the real-world environment. This system provided the controllers with crucial information on drone traffic near the aerodrome, and its performance was evaluated against baseline equipment (Figure 2).

Figure 2: Baseline and Solution scenario equipment. The personal view of the controller in the solution scenario during the take- off and landing of the air taxi, and the emergency (safety net), is depicted in the 3 images on the right.

The validation campaign involved experienced, and student ATCOs and Aviation Engineering students with previous experience in ATC operations simulations. The

assessment focused on objective and subjective measures, data were collected through performance metrics, physiological measurements, and questionnaires to assess the workload, and situational awareness of the controllers and the system's usability. The results confirm that the proposed concept is technically and operationally viable, demonstrating its potential to support ATCOs in performing their tasks, reducing the workload while improving performance. The XR-based HMI proved to be an innovative tool, offering ATCOs an intuitive way to monitor UAS traffic, while the interface demonstrated significant potential to enhance safety and efficiency, certain limitations and opportunities for further optimisation have been identified, ensuring continued development towards an efficient and ergonomic ATC support system.
Future work should focus on developing an additional application that would enable a fully integrated air traffic management system capable of handling manned and unmanned traffic cohesively. A first step in this direction has already been taken by developing a proof of concept integrated into a real- time Augmented Reality (AR) interface for tracking airport traffic in the Bologna Airport Control Tower.

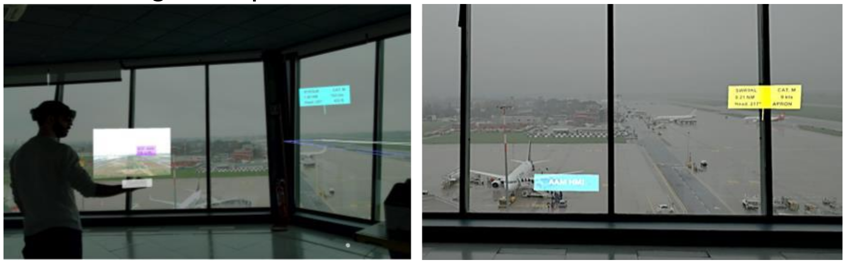

Figure 3: Integration of XR-based HMIs in the Bologna Airport scenario: Real-world implementation combining simulated ground infrastructure and unmanned traffic with a real-time AR interface for airport traffic monitoring, as viewed through a Microsoft HoloLens2.

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Biography

Marzia Corsi

Marzia Corsi is a Researcher in the UAS Department at the DLR Institute of Flight Guidance. With a background in HMI and ATC operations, her current research focuses on the integration of UAS into controlled and uncontrolled airspace. She is investigating concepts and technologies enabling IAM, including air taxis, vertiports, and U-space.

Potentials of Structure Integrated Flow Batteries in Aviation and Space Applications

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Funded by the Germany Space Agency, we developed an innovative flow reactor design that, thanks to its space-saving construction, aims to bring flow batteries one step closer to integration in aviation and space applications. The project was initiated by winning third place in the Europe-wide idea competition InnoSpace Masters 2021 and has already been showcased at the International Aerospace Exhibition ILA Berlin 2024. This achievement highlights not only the innovation of our design but also the growing interest in sustainable energy solutions in the aerospace sector.

Energy security plays a major role for aircraft and aviation applications due to their isolated and specific operating conditions. In modern aviation, the reliance on chemical energy sources, such as fossil fuels, poses significant challenges. These sources are subject to fluctuations in availability and price, along with environmental concerns related to carbon emissions. As the industry moves toward greener alternatives, the transition from traditional fuels to electrical energy sources becomes paramount.

For this transition to be successful, the necessary energy storage systems must possess a very long service life and high operational safety. This is crucial not only for ensuring the reliability of aircraft but also for minimizing the costs and environmental impact of maintenance operations as well as hazards for humans and equipment.

Flow batteries have emerged as a promising candidate to fulfill these requirements, particularly when utilizing higher energy density electrolytes. For example, zinc-polyiodide flow batteries have potential energy densities of up to 420 Wh/l, making them an attractive option for aviation applications. However, one of the main challenges we face is that current flow battery cells and stacks are too bulky and space-inefficient for direct integration into existing aviation module designs. The same challenge applies for other electrochemical reactors, like non-flow batteries and fuel cells.

To tackle this issue, we focused on developing contour-fitted flow battery cells. These cells are designed to be integrated directly into the support structures of aircrafts (shown in Figure 1). By doing so, we can optimize the use of available space, which is a critical factor in aviation design. This integration not only facilitates energy storage but also allows for the realization of additional functions such as module stiffening, thermal management, and radiation absorption.

The innovative aspect of our flow reactor design lies in its unique configuration, which maximizes energy storage while minimizing the footprint. The contour-fitted cells are engineered to match the structural contours of the aircraft, thereby reducing wasted space. This design philosophy is essential in aviation, where every kilogram and cubic meter counts.

In addition to space efficiency, we have prioritized safety in our design. The flow battery system incorporates advanced safety features that protect against potential failures, ensuring that the energy storage solution meets the rigorous standards required for aviation applications. These safety measures include robust containment systems, smart monitoring technologies, and fail-safe mechanisms that act proactively to mitigate risks.

Moreover, the thermal management capabilities of our flow battery design are noteworthy. Batteries generate heat during operation, which can affect performance and safety. By integrating the flow batteries into the aircraft's structural framework, we can effectively dissipate heat, maintaining optimal operating conditions and enhancing overall system efficiency. This dual functionality not only improves the performance of the energy storage system but also contributes to the overall capability and resilience of the aircraft.

The move toward electrical energy sources in aviation is not just a trend but a necessity driven by environmental concerns. The aviation industry is under increasing pressure to reduce its carbon footprint and comply with stringent regulations aimed at mitigating climate change. By developing flow battery technology that can be seamlessly integrated into aircraft, we are taking significant steps toward achieving sustainability goals.

The potential applications of our flow battery design extend beyond aviation. The principles and technologies being developed can also be applied to space applications, where energy storage solutions are critical for mission success. In space, energy sources are limited and often dependent on solar power, making efficient storage systems even more essential. Our innovative design could support long-duration missions and contribute to the reliability of space exploration initiatives.

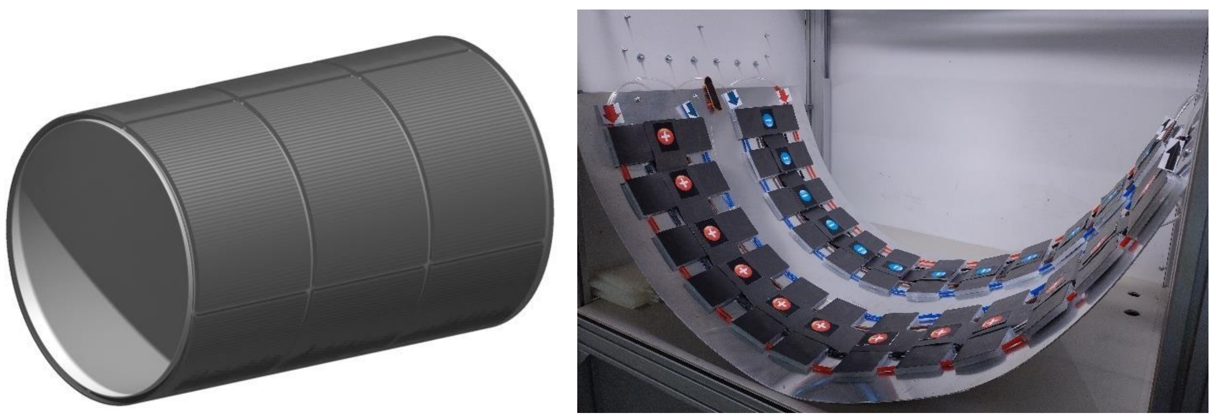

Figure 1: Structure integrated flow reactor cells

Biography

Jan Girschik

Jan Girschik heads the research group battery development at Fraunhofer UMSICHT in Oberhausen and focussed his research on innovative electrochemical reactor designs. After studying mechanical engineering at the University of Chemnitz, he made his PhD at the Ruhr University Bochum and was a research associate at the University of Calgary.

Assessment of Public Perception of Safety of Urban Air Mobility – Preliminary Results

1st Mrudul Chellapurath, 2nd James McLeod, 3rd Margarida Lopes, 4th Sofia Kalakou, 5th Raffaello Mariani
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4th ISCTE – Instituto Universitário de Lisboa, Sofia.Kalakou@iscte-iul.pt;
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Urban Air Mobility (UAM) is progressively being integrated, particularly in urban and suburban areas, providing services such as last-mile delivery of goods [1]. Pilot use-cases of emergency medical assistance by drones have been trialed [2], and feasibility studies of future passenger air-taxi passenger services have been studies [3,4]. As integration of these systems is expected to continuously increase, the assessing and understanding of public acceptance towards these new technologies has become a topic of interest in at research and agency level [5-7].

Within the frame of the European Union SESAR Joint Undertaking, a research project is ongoing to evaluate factors that influence citizens' acceptance of urban air mobility (UAM) in the European Union. This project, called ImAFUSa which stands for Impact and Capacity Assessment Framework for U-space Societal Acceptance, aims at delivering a framework that will help local authorities and other U-space stakeholders and users with the delivery of socially acceptable and beneficial UAM deployment in cities. One of the aspects investigated within ImAFUSA is the perception of safety of citizens when it comes to the operation of drones in urban areas.

Research was conducted by implementing virtual reality scenarios, which were all based on the same urban environment in which drones of a single type were flying, and drone parameters such as flight velocity and flight latitude were varied. All flights were structured, which means that the drones followed recognizable paths.

The scenarios were developed using Unity, and participants had an immersive experience – both visual and audio – using HTC Vive Focus 3 VR equipment, and a survey was conducted verbally as the participants experienced the scenarios.

Questions in the survey, which were kept consistent for each scenario, focused on the assessment of the perceived safety by the participants. Demographic information and familiarity with drones and virtual reality was also assessed to establish potential correlations with safety perception results.

Analysis of data focused on four pre-determined indicators: drones flight velocity; drones-to-observer distance; drones-to-bystander distance; drones-to-buildings distance. A fifth indicator surfaced from the responses, namely drone-to-drone path direction.
Overall, the results indicate that participants mostly showed a positive level of perceived safety. A common outcome from all four cases was the initial visual recognition of the drones rather than acoustic recognition, as many participants indicated that the expected noise of the drones was too low and overwhelmed by surrounding noise. It is possible that this factor skewed the perception of safety towards a favourable outcome.
Within these set-ups and acknowledged uncertainties, with regards to the first indicator, more than 50% of participants “felt safe” with drones flying to a velocity of up to 23m/s, with percentages progressively increasing to more than 80% when velocity was decreased to 15m/s and 7m/s whilst keeping flight altitude constant. Also, results from the drone-to-observer indicator (or flight altitude) showed that perceived safety increased from approximately 45% to over 75% with increasing flight altitude, as some participants indicated that they had more difficulties identifying the drones.
Results were less clear-cut when considering the fifth indicator of drones path direction, where a more even spread of data is visible. What is of interest is that, at the maximum flight altitude where participants perception of safety was lower as a result of seeing a more “densely populated” sky section.
Surveys are still ongoing to increase the number of participants and detailed anaylsis of the current data is ongoing, these initial results indicate a positive approach to the implementation of this new technology.

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Biography

Raffaello Mariani

Raffaello Mariani is Associate Professor at KTH Royal Institute of Technology, Stockholm, Sweden. He holds a PhD in Aerospace Engineering from The University of Manchester, Manchester, UK. Assoc. His work focuses on aircraft aerodynamics and novel configurations, with a strong emphasis on experimental work.

Development of a framework for the thermal modeling of an eVTOL

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The innovative idea of eVTOLs (electric vertical take-off and landing vehicles) aims to transport people autonomously over various distances in urban areas using an electrically powered aircraft. The range of the aircraft is limited by the available battery capacity, as electricity is required for the power electronics, drive components and the cabin. In this project, research is being conducted into optimizing the thermal management of the overall architecture of an eVTOL to optimize the efficiency and performance of these aircraft. A comprehensive framework for thermal modelling enables simulation-based optimizations based on a detailed modelling structure that considers both individual thermal subsystems and the overall system. The cabin, cockpit with dashboard zone, avionics bays and the battery bays were modeled as individual components. Each subsystem is analyzed considering its specific thermal properties and interactions with other components. The simulation of these subsystems is carried out using suitable thermodynamic and fluid dynamic models, with which the temperature distributions, heat transfers and heat dissipation can be predicted in realistic operating scenarios. When modeling the overall system of the eVTOL system architecture, the interactions between the subsystems are considered in order to obtain a comprehensive picture of the thermal processes. This makes it possible to identify and analyze the thermal challenges in different operating states and environmental conditions. To achieve this, the overall system is divided into 3 subsystems. One is an open air-circuit for cooling the cockpit, cabin and optionally the avionics compartment to create a comfortable indoor climate and to cool electrical components. On the other hand, the battery modules are cooled in an external liquid circuit. There is also a refrigerant cooling system that provides the required cooling capacity in the air or liquid circuit. The systems are illustrated in the figure 1.
An additional component of the framework is the identification of parameters that can be varied to optimize subsystems and the overall architecture. Therefore, the following parameters were identified:

- Subsystems
  - Thermal isolation (Cabin, Cockpit, Avionic Bay)
  - Heat load distribution
  - Permitted temperature ranges (Cabin, Cockpit, components)
- Overall system
  - Different system architectures
  - Massflow of the liquid cooling circuit/cooling circuit
  - Transfer surfaces of the heat exchangers
  - Valve control for air and refrigerant circuit

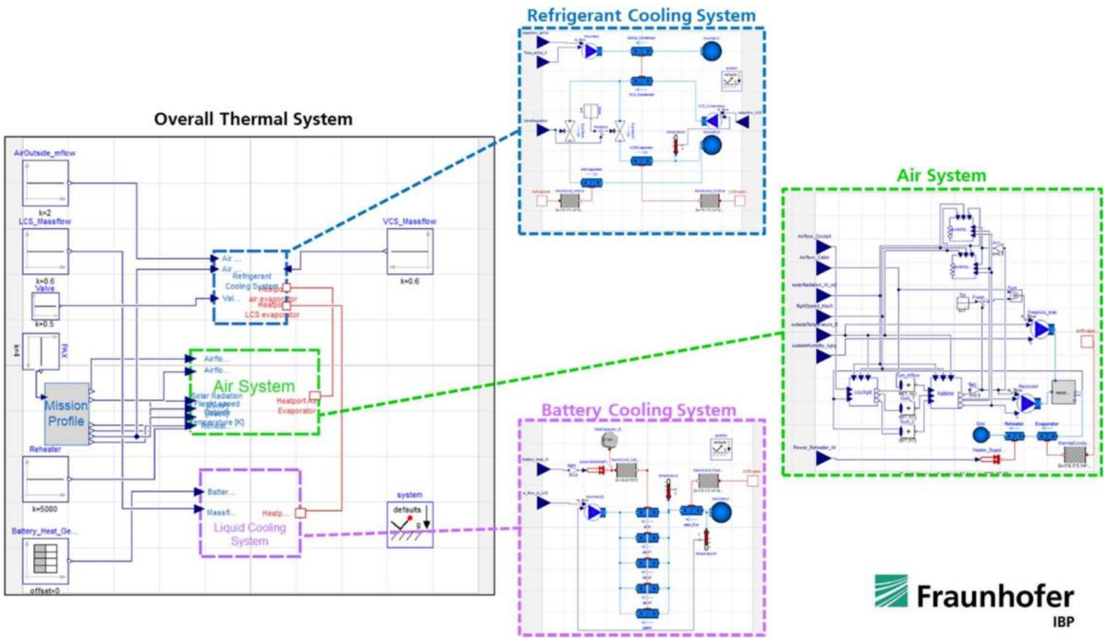

Figure 1: Modeling framework of the overall thermal system with its subsystems

The current model can be used to demonstrate that the temperature ranges in the cockpit and cabin can be maintained in accordance with FAR25 / ASHRAE161 between 18,3 °C and 26,7 °C. The batteries and the avionic bays do not exceed a temperature of 50 °C. The temperature distributions in the sub-compartments are shown in figure 2.

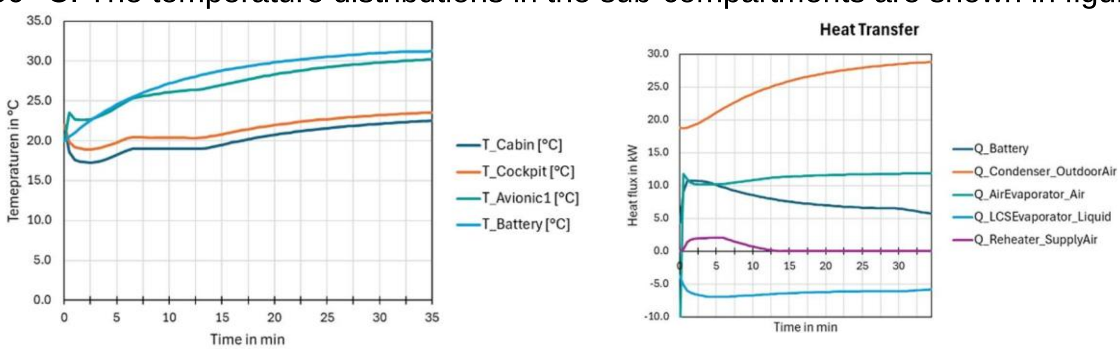

Figure 2: Temperature distributions (left) and heat transfer (right) in the overall thermal system of an eVTOL

The next step is to set up a test platform that allows the validation of the modeling framework. This will enable the model parameters to be set based on experimental data and real operating experience.

The developed framework is intended to provide a flexible platform for the thermal modelling of eVTOLs to carry out simulation-based optimizations. A comprehensive consideration of the overall thermal system architecture and parameter identification are key factors for the successful design and efficient operation of eVTOLs.

Biography

Christina Matheis

My name is Christina Matheis, M.Eng. and I am a research assistant and PhD student at the Fraunhofer Institute for Building Physics in Valley. I studied energy and building technology with a focus on energy efficiency and design. My research focuses on the development and validation of indoor climate simulation models as well as the planning and data analysis of indoor climate measurement experiments.

Evaluating IAM through the lens of System of Systems: Results and Next Steps

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Innovative Air Mobility refers to the safe, secure and sustainable mobility of passengers and cargo enabled by integrating new technologies (such as eVTOLs) into a multimodal transportation system. As such it involves numerous stakeholders with their own interest in the IAM System of Systems. IAM necessitates significant innovation and development to achieve the desired capabilities, relating to all aspects including aircraft, vertiport, airspace management and more.

This work presents the System of Systems approach to evaluating IAM/AAM following a product push paradigm, where the objective is to identify how a given aircraft can be embedded into the existing transport system while ensuring profitability, sustainability and value addition. Furthermore, through the use of Value/Business Models representing the satisfaction of each major stakeholder, this work evaluates how stakeholder satisfaction varies with the SoS design space. The SoS evaluation of the IAM is carried out using an Agent-Based Simulation of IAM built using the SoSID Toolkit [1–3] where the active stakeholders, their actions and interactions are modelled. Where possible, a parametric approach is adopted in the modelling to allow for broad design space exploration across all active stakeholders. The work carried out as part of the COLOSSUS Project [4], focuses on the integration of a fixed eVTOL concept into the existing Transport System.

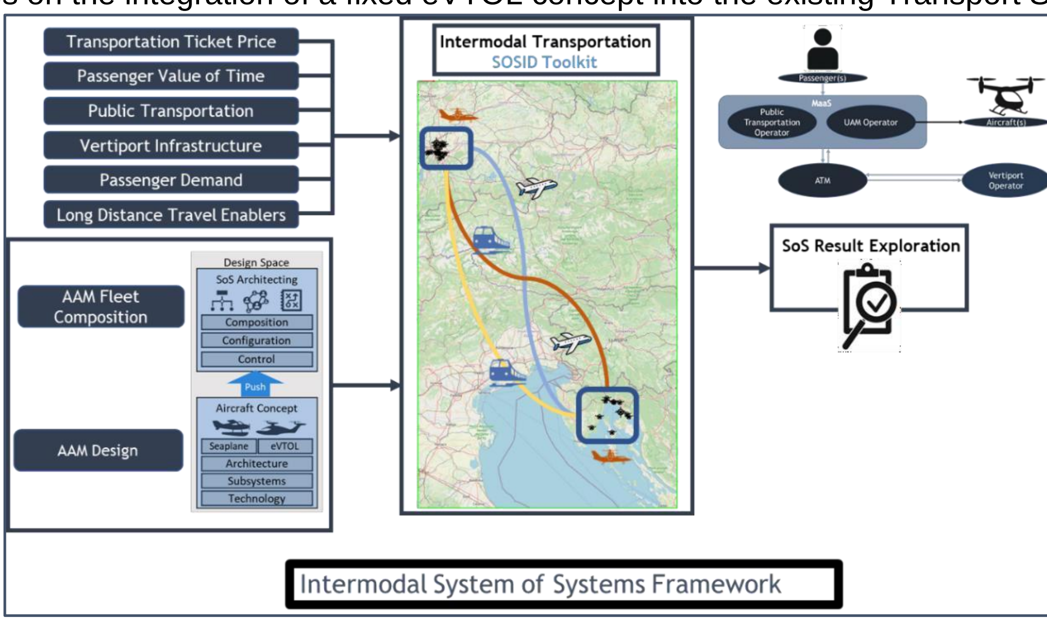

Figure 1 IAM SoS Framework

The research employs an Intermodal SoS analysis framework as depicted in Figure 1. The simulation model takes inputs of the aircraft and fleet composition, vertiport infrastructure, passenger demand and type, public transportation metrics, and long-distance travel enablers. Vehicle to passenger allocation model is based on a bidding algorithm where each aircraft agent estimates the earliest it can serve a passenger request. The bidding algorithm includes multiple factors, such as the load factor associated with the request, energy needed and time taken.

The study evaluates the Architecture choices of the SoS that lead to a profitable, sustainable and beneficial IAM. By varying the aforementioned model inputs, and evaluating against the Objective Functions and Value/Business Models; the best architecture can be identified. As the IAM SoS has diverse stakeholders with different interests in the SoS, a particular interest is given to how the stakeholder interests can be managed while also considering the overall effectiveness of the SoS. In this regard, multi-criteria decision making from the Stakeholder perspectives will also be carried out. It will explore how accounting for stakeholder preferences impact the best SoS architecture in contrast to considering only the objectives of the SoS.

A preliminary view of the stakeholder metrics that will be considered are as follows:

1. Passenger-Centric Metrics

These metrics measure how well the system meets individual travelers' needs and preferences:

Total Travel Time

- Sum of all journey segments including transfers and waiting. Reflects convenience and efficiency.

Number of Transfers per Journey

- Indicates complexity of the route. Lower values generally correspond to higher satisfaction.

Waiting Time

- Time spent at stations or vertiports before boarding the next mode. A proxy for system responsiveness.

2. Operator-Centric Metrics

These reflect vehicle and infrastructure efficiency, critical for IAM service providers:

Revenue

- Revenue generated by the IAM Operations.

Passengers Transported

- The number of passengers choosing IAM services and transported.

Deadhead Ratio

- Percentage of total flights without passengers (repositioning flights). Lower values imply better fleet planning.

Fleet Utilization Rate

- Ratio of active flight time to total available flight hours. High utilization indicates efficient deployment.

3. Environmental Metrics

These measure the ecological impact of different transport configurations:

Emission Savings from Modal Shifts

- Difference in emissions when passengers shift from higher-impact modes to lower ones (e.g., PT or AAM with clean energy).

Total Carbon Emissions

- Calculated using emission factors for each mode. Compared across scenarios (e.g., PT-only vs. PT+AAM).

Average Emissions per Passenger-Kilometer

- Standardized measure to account for travel distance and passenger load.

In future work, through the IAM-OSA project, the work will be extended with a deeper consideration of the active stakeholders such as vertiport operator, airspace management, passenger and more, by embedding expert knowledge through models into the established IAM Simulation.

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Biography

Nabih Naeem

Nabih Naeem is a researcher at the Institute of System Architectures in Aeronautics at the German Aerospace Center (DLR). His research focus is on System of Systems where Innovative Air Mobility and Aerial Wildfire Fighting use cases are evaluated with a holistic view point.

Separation Management with Detect-and-Avoid in Urban U-Space

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To integrate large numbers of small unmanned aircraft systems (sUAS) into the complex, obstacle-rich airspace found over modern cities, we adopt a two-tiered separation management approach under Europe's U-Space framework. Before any flight takes off, a strategic service computes and assigns each sUAS to one of two complementary airspace structures.

First, Corridors are established as one-way, tube-shaped routes at fixed altitude bands (e.g. 500 ft or 600 ft above ground level) with explicit minimum and maximum speed constraints; these "drone highways" are optimized to carry high-speed, long-distance traffic between urban nodes with minimal conflict potential. Second, Segments are provided as flexible, free-routing zones in which aircraft are not confined to pre-planned tracks but must instead execute their own Detect-and-Avoid (DAA) maneuvers in real time. This dual-structure design ensures that routine, predictable traffic benefits from tight geometric control, while irregular or non-nominal flights (e.g. emergency response, wind-diverted trajectories, or multi-drone inspections) can safely disperse into more open, self-managed airspace when needed.

Once airborne, tactical separation is enforced through a robust multisensor DAA fusion engine that combines both cooperative and non-cooperative data streams. Cooperative information-Remote ID broadcasts per ASTM F3411/EASA prEN 4709-002 and ADS-L (lightweight Air Data System) messages carrying identity, position, and intent-provides a persistent "friendly picture", while non-cooperative sensors (Frequency-Modulated Continuous Wave radar for all-weather range and velocity, infrared cameras for heat-signature detection in low light, and high-resolution optoelectric stereo cameras for fine classification and localization) fill in the rest of the environment.

An adaptive Kalman-filter framework continuously tunes sensor error covariances using pre-flight calibration and in-flight innovation residuals, applies Mahalanobis gating to reject outliers, and weights each measurement inversely to its estimated signal to noise ratio and latency.

By dynamically adjusting these fusion parameters to urban clutter, multipath, and visibility conditions, the system maintains high detection confidence and minimal latency in dense, obstacle-laden airspace.

To size both corridors and buffer zones in these structures, we derive performance- based separation minima tailored to each drone's flight capabilities and onboard DAA performance.

For every aircraft type, we gather its maximum climb and descent rates, turn radii, maximum acceleration/deceleration limits, sensors' field of view and update rate, and processing latency.

We then calculate the minimum horizontal and vertical distances required to guarantee an evasive turn, altitude change, or speed adjustment under worst-case reaction times. These values define both the width and vertical stacking of one-way Corridors and the maximum density of free-routing Segments, ensuring that even the least capable sUAS retains sufficient maneuvering room to avoid conflicts.

Using AirES, DLR's aircraft encounter simulator, we systematically compute, for each ordered pair of drone models and for discrete reaction-time intervals (e.g. 2, 3, 4 s), the minimal safety buffer needed to avoid a collision via one of three fixed avoidance maneuvers:

horizontal turn, vertical climb/descent, or speed change (brake or accelerate).

Each simulation assesses the worst-case initial geometry and relative velocities typical of urban operations, producing a matrix of separation distances.

To derive a global corridor separation standard, we take the maximum over all drone- pair combinations of the smallest distance across the three avoidance modes.

Finally, for real-time conflict resolution we compare two complementary approaches. ACAS sXu-a variant of the FAA's ACAS-X adapted for small drones-employs dynamic scaling of advisory sensitivity and response thresholds based on current local traffic density, altitude, and aircraft performance.

It computes an optimal avoidance trajectory (e.g. "climb at X ft/min") via pre-computed dynamic-programming tables.

While ACAS sXu yields tighter separation minima by optimizing every maneuver, the AirES approach offers computational simplicity and faster lookup.

In a hybrid implementation, sUAS could use ACAS sXu for critical, precision avoidance and fall back on the AirES tables as a computationally lightweight safety net.

Biography

Enno Nagel

Studies and PhD in Mathematics at the University of Münster, since 2024 researcher on flight guidance of unmanned air systems at the DLR.

Assurance Strategies for Safe AI Operation: Model-based Framework for the Development, Simulation and Monitoring of the Operational Design Domain

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There is a significant demand for the application of artificial intelligence in the aviation sector, to handle the ongoing traffic growth and solve scalability issues and thus increasing complexity. However, any utilization of AI must be trustworthy, and its integration into aircraft must never compromise safety. Current aviation is built upon deterministic systems that follow programmed “rules”, i.e., ones that behave predictably and can be verified through testing and certification. The existing framework for developing and certifying software systems in the aviation domain does not align with the development of AI systems, which utilize machine learning (ML) technology and neural networks. One of the core principles of such software is that training data defines the behavior. The same software can behave differently for different training, which completely challenges the existing standards and development practices in the aviation domain. To address this, EASA has developed first guidance on the certification of ML for aviation systems [1], and is continuing to work on the integration and safety of ML systems.

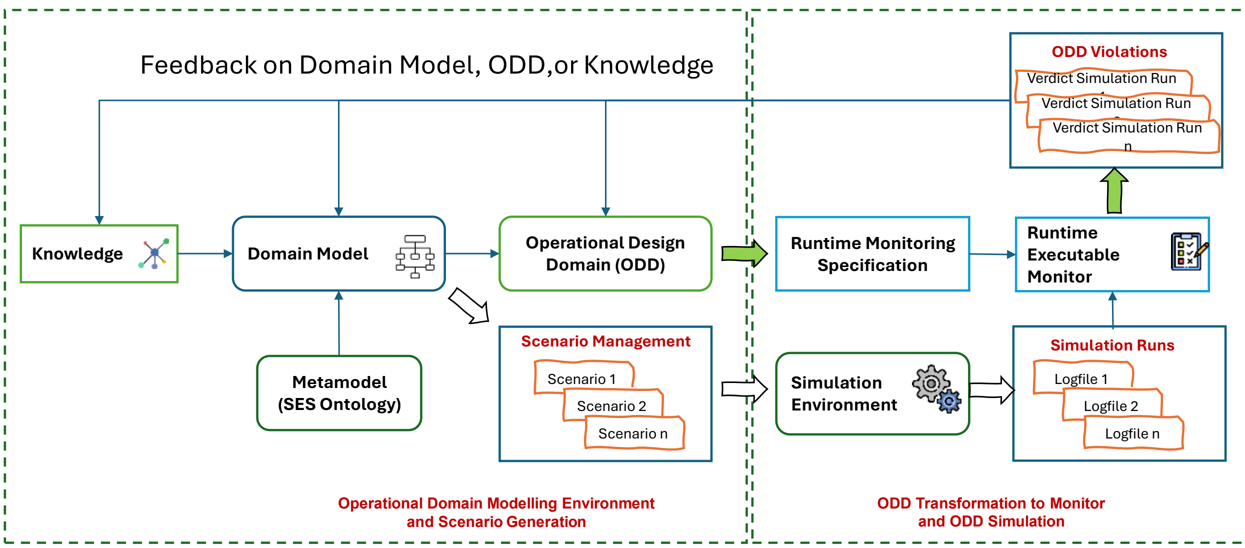

Figure 1: Overview of the model-based ODD framework.

One prerequisite is that the ML function is used only when it is safe to use. For ML systems this means that the environmental conditions during operation match Those represented in the training data. These operating conditions are formally defined as the operational design domain (ODD) of the system.

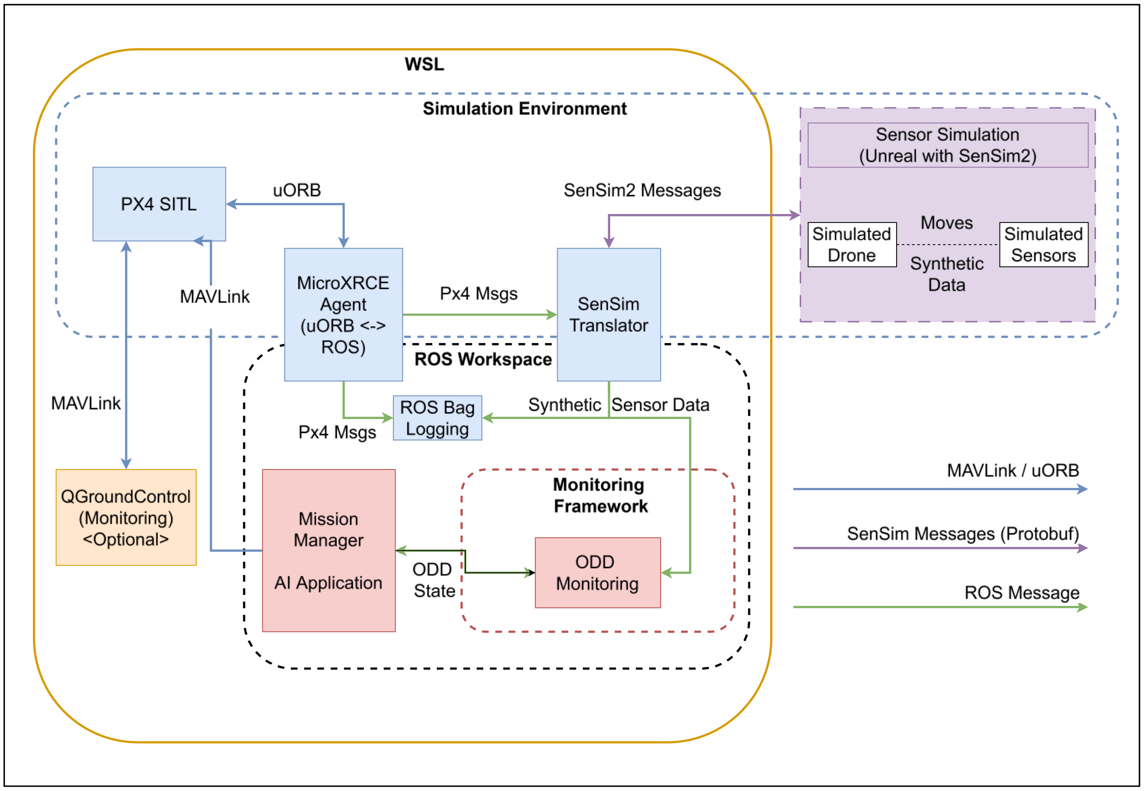

Figure 2: Overview of the IAM-OSA simulation setup, utilizing SenSim2 framework.

This work is the ongoing research of the project IAM-OSA and discusses the use of model-based approaches to define, test and supervise the ODD. We combine work on modeling the ODD, utilizing constraints and dependencies, for generating operational scenarios [1] with a further application of monitoring and safety supervision of the operation [2, 3].
We develop a model-based tool used to model the domain, refine and extract a formal model of the ODD, see figure 1. This ODD is then extracted, conforming to the ASAM OpenODD® standard. The standard was developed for the automotive domain, but can be adapted for the aviation domain, following a defined schema for syntax and taxonomy of the ODD. With this ODD, two goals are targeted to achieve. The first goal is to generate scenarios within and on the edges of the ODD, as well as evaluating the coverage of the scenarios. The second goal is to build a monitoring solution that can supervise the ODD and its properties, see figure 2. These goals are combined with the simulation framework SenSim2, which our Institute develops. The simulation framework is capable of simulating diverse ODD properties using the Unreal Engine 5, see figure 3. Using this strategy, we are developing a framework for the model-based development, extraction, simulation, and monitoring of ODD. With this framework, we aim to gain new insights into the concept of ODD, and its role in AI development and certification guidelines. The scenario simulation and monitoring framework can be utilized to test the edges of the ODD and refine its parameters.

Figure 3, a-f: Simulation of different ODD parameters utilizing the SenSim2 framework, showcasing effects of rain, snow, fog, and daylight.

[1] EASA, EASA Concept Paper: Guidance for Level 1 & 2 Machine Learning Applications, European Union Aviation Safety Agency (EASA), Mar. 2024
[2] Gupta, Siddhartha und Durak, Umut und Ellis, Oliver Simon und Torens, Christoph (2022) From Operational Scenarios to Synthetic Data: Simulation-Based Data Generation for AI-Based Airborne Systems. In: AIAA SciTech 2022 Forum. AIAA SciTech Forum 2022, 2022-01-03 - 2022-01-07, San Diego, CA. ISBN 978-162410631-6.
[3] Torens, Christoph und Gupta, Siddhartha und Roy, Nirmal und Sprockhoff, Jasper und Durak, Umut (2024) From Operational Design Domain to Runtime Monitoring of AI-Based Aviation Systems. In: 43rd AIAA DATC/IEEE Digital Avionics Systems Conference, DASC 2024, Seiten 1-9. AIAA DATC/IEEE 43rd Digital Avionics Systems Conference (DASC), 2024-09-29 - 2024-10-03, San Diego. ISBN 979-835034961-0. ISSN 2155-7195.

Biography

Christoph Torens

Christoph Torens is a researcher at the DLR Institute of Flight Systems, Department Unmanned Aircraft, Safe Autonomy Group. His research focuses on the connection of software standards, software certification, and the safe operation of autonomous unmanned aircraft systems.

Siddhartha Gupta

He is a researcher at the German Aerospace Center (DLR) and at TU Clausthal. He is working on the best practices for safety verification and validation practices to certify AI systems in aviation, focusing on modelling scenarios and operational design domain for such systems. He has demonstrated his modelling approach in many EU and German national projects.

Defining the Problem: An MBSE Approach to Stakeholder and Use Case Identification for Innovative Air Mobility as a System-of-Systems

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Innovative Air Mobility (IAM) is expected to complement the existing transportation system effectively by offering fast and safe travel options for passengers and cargo and providing benefits to citizens and communities. Enabled by recent technological advances - such as new concepts for VTOL-capable aircraft (VCA), advanced automation and increasing battery capacities - IAM aims to be an aerial addition to intermodal mobility networks, particularly in urban, suburban, and regional contexts. [1-4]

However, the successful integration of IAM requires more than just technical feasibility. A structured, system-oriented approach is essential to understand potential fields of application (use case), development pathways for IAM, and societal as well as technological impacts. For that reason, IAM is analyzed as a system-of-systems (SoS) [5], in which the different transport modes operate as integrated yet distinct constituent systems.

This contribution presents a methodological approach based on MBSE (Model Based Systems Engineering) that systematically frames the system-of-systems problem, with a particular focus on identifying use cases and development pathways for IAM. MBSE uses a formalized approach to define the problem space, explore and evaluate potential solutions, and provide continuous support throughout all phases of the system lifecycle. [6] The presented approach focuses on the user and their preferences, which serve as the basis for the user-centered development of IAM systems. The goal is to design systems that address the specific needs of potential user groups and can be seamlessly integrated into existing transportation systems. A key step in this process is systematically identifying relevant stakeholders and their specific needs. This considers not only the user perspective, but also the core IAM stakeholders who are significantly involved in development and implementation, as well as associated stakeholders who could be directly or indirectly affected by the new mode of transportation. Based on this identification, potential user groups are differentiated according to their mobility needs and reasons for travel to gain a comprehensive understanding of their requirements. These findings are used to derive user journeys that map various usage scenarios and transport-related requirements in detail. These user journeys then serve as the basis for deriving technical requirements for both the overall system-of-systems and its constituent systems. This ensures that technological development continuously aligns with identified user needs. The methodological framework is supplemented by the systematic analysis of potential development pathways for IAM. These development pathways describe possible technological solutions for fulfilling specific transport tasks and designing IAM systems.

The developed use cases and scenarios provide the foundation for an agent-based simulation [7] that depicts the system-of-systems. This simulation environment aims to analyze the complex interactions between aerial vehicles, ground-based infrastructure, air traffic management, and user behavior. Such simulations allow us to evaluate different IAM configurations, operational strategies, and regulatory framework. By modeling these elements together, we aim to generate robust insights into the scalability, interoperability, and impact of IAM on existing transport systems and the society.

In summary, the MBSE-driven SoS approach enables a holistic understanding of the IAM landscape. It bridges the gap between visionary concepts and practical implementation by systematically analyzing user needs, operational requirements, and the overall system behavior. The simulation results support IAM-stakeholders, city planners and policymakers in making informed decisions about the design, introduction, and scaling of IAM systems that are technically feasible, economically viable, and socially accepted.

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[3] Cohen, A.P., Shaheen, S.A., Farrar, E.M.: Urban air mobility: history, ecosystem, market potential, and challenges. IEEE Trans. Intell. Transp. Syst. 22(9), 6074–6087 (2021). https://doi.org/10.1109/Tits.2021.3082767

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Biography

Lukas Asmer

Lukas Asmer completed his Master's degree in Transport and Logistics at Ostfalia University of Applied Sciences in 2017. Since 2018 he has been working as a research associate at the DLR Institute of Air Transport in the department of Air Transport Development. Lukas Asmer is part of the unmanned aerial vehicles research group, which is investigating use cases and market potential for passenger and freight transportation using eVTOL aircraft. As part of various research projects, he is involved in estimating the potential global and regional demand for IAM and determining the systemic, technical and social factors that influence market development and the integration of UAM into intermodal transportation systems.

Concept of Operations for a Digital IAM Controller

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Innovative Air Mobility (IAM), particularly in the form of air taxis, has the potential to revolutionize urban and regional transportation by offering a faster, on-demand and more sustainable alternative to traditional transportation means. However, integrating IAM seamlessly within the existing air transport system, especially congested airspaces like control zones (CTR), presents significant challenges. Current air traffic control (ATC) systems are primarily designed for conventional aircraft, and the introduction of IAM vehicles, operating on diverse routes and schedules, can increase controller workload and compromise safety.

Studies conducted within the DLR project HorizonUAM have demonstrated the impact of air taxi integration on ATC. Simulations revealed a 44% increase in controller workload and an 18% decrease in situation awareness when air taxis were introduced into the control zone, operating on a fixed route network between vertiports. This workload increase is unsustainable, especially considering the projected growth in both conventional air traffic and IAM operations, coupled with the ongoing staffing challenges of air navigation service providers.

To address this issue, the DLR is developing a concept for a digital air traffic controller (ATCO) for managing IAM air taxi traffic operating in Visual Flight Rules (VFR) within control zones. This digital ATCO is designed to autonomously perform air traffic controlling tasks in safe, efficient and orderly manner within the predefined scope and can collaborate with human ATCOs.

The main functionalities of the digital controller for IAM are:

- **Conventional VFR services provision**: The digital ATCO will provide all the ATC services for air taxis operating in VFR. This includes issuing clearances for to enter/ exit the control zone, for landing and takeoff at vertiports of Hamburg, traffic information and advisories provision, weather information, guidance and separation for air taxis operating in SVFR.
- **Air taxi traffic monitoring:** The digital ATCO shall ensure that air taxis always have sufficient separation from other aircraft (both, other air taxis and conventional traffic) along their entire flight route. The digital ATCO will have access to real-time data on air taxis' positions, altitudes, speeds, and flight paths so that It can monitor their operation and highlight any deviation from the clearances, advisories or cleared route. In case of non-conformance to the clearance or non-adherence to the route, the digital ATCO will either solve the issue autonomously or handover the traffic to the human ATCO.

- **Flow management:** unlike commercial airlines, the air taxi services operate on flexible schedules allowing booking on short notice. The digital ATCO shall be then coordinating with the IAM Control Center in order to negotiate the arrival and departure target times for the air taxis on the basis of controller workload in order to enable among other last-minute service. It will be mainly supporting the flow management in tactical phase. The complete air taxi flow management will be performed either by a dedicated or an existing Flow Management Position.
- **Route Change & Specific Services:** changing the air taxi route could be either mandatory to solve a potential conflict or desired to save time or for sustainability reason. Short cuts were also considered when designing the air taxi fixed routes for making the whole traffic more efficient and sustainable. The digital ATCO shall be able to clear a new route for the air taxi as long as it has no impact on the other conventional traffic. It shall also make sure that the human ATCO is aware of it with an appropriate highlight on the air situation display. In case of a potential impact on the conventional traffic, the digital ATCO should handover the related air taxi to the human ATCO with a clear information about the reason of the requested change. The same principle is applicable to any specific service requested by air taxis.
- **Attention guidance:** The digital ATCO shall direct the human ATCO's focus to the most relevant information on their display. This is crucial for maintaining situational awareness.
- **Emergency Support:** The digital ATCO is not allowed to handle emergencies. It should only provide the human ATCO with advisories and with appropriate information about the flight and the related situation so that the ATCO save time and effort trying to make a clear picture of what happening. The digital ATCO should sort the relevant information to be displayed to the human ATCO.

This presentation will detail the concept of operations for the digital controller, focusing on its autonomous functionalities and its interaction with human controllers. We will also present the key findings from a workshop conducted with air traffic controllers, which gathered feedback on the digital controller concept and identified critical information needs. Finally, we will outline the planned development and validation activities for the digital air traffic controller, including future human-in-the-loop simulations to assess its effectiveness and safety.

Biography

Lukas Tyburzy

Lukas Tyburzy is a Computer Scientist and Research Associate at the German Aerospace Center, specializing in human-AI interaction for air traffic control. His research focuses on designing user-friendly interfaces for automated systems, improving air traffic controller workflow and safety.

Integrating Autonomous Drones in U-space

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U-space aims to facilitate safe and efficient drone flights. As it aims towards a high degree of automation, we investigate how autonomous drones can leverage and advance this ecosystem. We demonstrate how autonomous drones leveraging PX4 flight software can be enhanced with new capabilities to enable a seamless integration to the U-space. We focus on automatic flight authorization and traffic awareness. Furthermore, we highlight challenges and opportunities of increasing levels of autonomy and the use of drones as intelligent sensors in the U-space ecosystem.

U-space interaction is based on four mandatory U-space services (network identification, traffic awareness, flight authorization, geo- awareness) as outlined in EU 2021/664 and specified in EASA's means of compliance. All services are compulsory for a drone operator to use. The network identification service aims to inform authorized third parties about the U-space and its participants, whereas the traffic awareness service informs operators about both uncrewed and crewed air traffic. The flight authorization service is the most regulatory component of the U-space. It defines a process for filing, activating, and deactivating an authorization for every flight. The geo- awareness service provides information about relevant areas on ground.

An autonomous drone equipped with a PX4 flight controller already has the ability to fly a predefined route and ensure it stays within a defined inclusion geofence, as well as to avoid exclusion geofences. We utilize those abilities and extend them to take U-space requirements in the same manner into account as a human operator would. All U-space interfaces depend on the specific implementation of the respective U-space service provider. Arguably, the network identification service requires the drone to share its position over a specified interface. This interface could be a transponder on the drone, a connection to the U-space services via a ground control station or as in our case a direct connection from the drone to the U-space. The flight authorization service requires the formulation of a flight authorization, most likely based on 4D volumes with an real, height and time buffer the volume is planned to be occupied. They are currently presumably created via a web interface of the U-space provider. Immediately prior to the flight, the authorization must be activated and likewise deactivated after landing. Furthermore, the drone has to react to changes in the U-space during the flight. Namely, other drones deviating from their authorized flight path, new geo zones or a change in the flight authorization.

We aim to handle all U-space interactions on board, as displayed in Figure 1. Our drones connect directly via an accessible programming interface (API) over Internet Protocol (IP)-based connectivity to U-space service providers (USSPs). Our companion computer runs the additional U-space interaction software. It connects to the flight controller that, in turn, communicates with the ground control station (GCS) and potentially receives additional information about other participants via an ADS-B or FLARM receiver. In our experiments, we use a PX4 autopilot on a Pixhawk 6X and QGroundControl as our Ground Control Station.

Our concept has shown promising results in simulation and flight tests. We utilized self-hosted experimental U-space services based on RabbitMQ and MQTT communication interfaces. We demonstrated compliance with the traffic awareness service by sharing our position and receiving simulated traffic information on QGroundControl. We were able to comply with the flight authorization service in a nominal case by authorizing, activating, flying, and deactivating a mission designed in QGroundControl and an onboard planned mission.

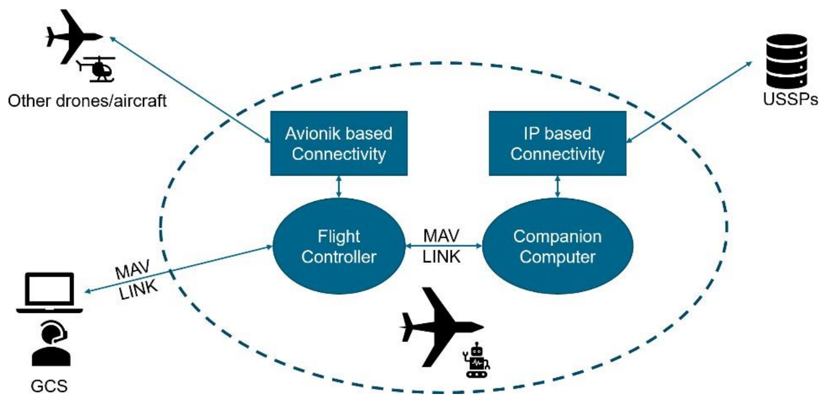

Figure 1 Drone to U-space interaction schema.

Additionally, we identified further challenges and opportunities related to autonomous drones in a U- space. First, filing an authorization in an off- nominal case is a non-trivial challenge, as further discussed in Strickert et. al. [1]. Especially if the change occurs in flight, induced by a mission correction or a dynamic no-fly zone created by the U-space in the flight path of the drone. Designing fitting 4D flight volumes is a further challenge that needs to be solved as a too-narrow volume could lead to frequent violations, and a too-broad volume limits the U-space for other participants. Second, in addition to the currently implemented mandatory services, there is a high potential for sharing additional information within the ecosystem. Especially Geo-awareness could entail not only static information based on regulatory limitations but also temporary changes and areas of potentially higher risk. For example, emergency operations, a construction site with a crane, or even a beach near a lake that could draw crowds during high temperatures. Furthermore, autonomous drones could act as intelligent sensors to provide recent and local information in the U-space that is otherwise not available. In a decentralized manner, the U-space ecosystem could also function as an exchange platform for all kinds of relevant information as a “To Whom It Concerns Service - TWICS” [2]. Lastly, information fusion on board the drone is crucial for making reliable decisions based on both communicated and intrinsically gathered information.

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Biography

Fabian Krause

Fabian Krause is working for DLR in the Department of Unmanned Aircraft Systems. He started at DLR after gaining insights in industry at BASF SE and public authorities alike at the German Federal Police to advance his skills as a software engineer and research scientist. His focus is in safe autonomy system design with a focus on uncertainty in information fusion, connectivity for UAVs and AI based decision and detection systems.

Implementation of U-space Test Environment at the National Experimental Test Center for Unmanned Aircraft Systems of the German Aerospace Center: Development of an Utilization Concept to Extend Testing Possibilities for Innovative Air Mobility

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U-space, as a digitalized ecosystem for unmanned air traffic, enables safe and secure integration of numerous Unmanned Aircraft Systems (UAS) into the existing airspace. To offer a testing environment for research as well as industrial partners the German Aerospace Center (DLR) initiated the internal research project AREA U-space (Air Space Research Area U-space) in order to implement a U-space sandbox at the National Experimental Test Center for Unmanned Aircraft Systems at DLR Cochstedt. Besides the integration of the four mandatory services being network identification, geo- awareness, flight authorization and traffic information service, services of higher U- space levels will be implemented as well. The higher levels of U-space, U3 - Advanced services and U4 - Full services, represent the evolution of U-space toward full integration with manned aviation. U3 introduces dynamic airspace management, tactical conflict resolution, and real-time data exchange with Air Traffic Control (ATC), enabling UAS to operate safely in increasingly complex and dense environments. U4 builds on this by incorporating full automation, advanced decision-making support, and seamless coordination with Air Traffic Management (ATM) systems. This level supports autonomous Beyond Visual Line of Sight (BVLOS) operations and scalable Innovative Air Mobility (IAM), making U-space a fully interoperable part of the broader airspace ecosystem. One of the higher U-space level services will be the collaborative interface with ATC developed by DLR. The collaborative interface with ATC is a core feature of U3 and U4 U-space levels, enabling shared situational awareness and dynamic airspace management between manned and unmanned traffic.

After end of project in 2026, the U-space environment should be available for UAS flight test campaigns conducted by DLR institutes and external industrial partners. In addition to flight test campaigns showing the readiness of U-space service capabilities, UAS flight trials with services offered by different U-space Service Providers (USSPs) are conceivable at DLR Cochstedt. By this, the planned U-space environment enables a wide range of testing possibilities with the scope of IAM and the opportunity to advance the U-space services and its environment at the DLR Cochstedt. To address the topic of the future use of the U-space sandbox by DLR-internal as well as external users of the test center, a long-term utilization concept will be developed. One part of this concept will be a collection of needs of potential users in the future. This research aims to give an overview on the identified research needs, interests and requirements from various stakeholders and different actors. Furthermore, an approach to identify needs of potential industrial end-users will be detailed and elaborated. In this context various methods for collecting input from interested users are being considered and evaluated in terms of their applicability. Hence, a long-term roadmap for the use of the implemented U-space environment at DLR Cochstedt will be detailed and used to ensure a long-term prospect of use for the U-space sandbox at the testing facility in Cochstedt. By this, one of the addressed aspects will be the integration of the U-space test environment into the existing as well as planned infrastructure at the test center. Due to the continuous development in the field of IAM, there is a need to extend testing possibilities as well. One example for a potential approach is to take the opportunity to enable UAS flight tests in combination with the vertiport demonstrators, which will be realized in the DLR internal research project VERTIFIED (Vertiport Research Infrastructure for Innovation Exploration and Demonstration) until 2028.

Biography

Kristin Wendt

Since 2021 Kristin Wendt is the acting head of the department "Projects and Cross-Divisional Topics" at the National Experimental Test Center for Unmanned Aircraft Systems of the German Aerospace Center (DLR). She starts her work at DLR in 2020 as project lead and as of 2023 she is the project leader of the DLR internal research project AREA U-space.

Infrastructure Research on Modular and Scalable Vertiports within the VERTIFIED Project

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Innovative Air Mobility (IAM) is set to transform future air transportation by enabling uncrewed and vertical take-off and landing (VTOL) operations. To support this vision, researching and developing dedicated infrastructure known as vertiports is crucial. The German Aerospace Center (DLR) addresses this through the internal research project VERTIFIED (Vertiport Research Infrastructure for Innovation Exploration and Demonstration), which aims to develop and evaluate two modular and scalable vertiport demonstrators at the National Experimental Test Center for Unmanned Aircraft Systems located at Magdeburg-Cochstedt Airport.

The infrastructure research within the project will focus on two primary configurations: an urban vertiport and an airport vertiport, each with unique infrastructure requirements shaped by their specific operational environments. This research will provide essential guidance for the planning and implementation of both demonstrators by examining which components of existing airport infrastructure can be integrated and identifying any additional elements required to support their operation.

To address these distinct use cases, this targeted implementation research will systematically investigate the specific infrastructure needs of each. This includes determining which critical systems such as fire protection infrastructure, weather monitoring, air traffic management integration and charging facilities are fundamental to the functionality of the demonstrators. Key modular zones and components, including touchdown and lift-off areas (TLOF), final approach and take-off areas (FATO), safety zones, parking stands, and safety installations will be flexibly configured to accommodate diverse operational demands. Furthermore, the study will explore how these elements can be effectively integrated into the overall vertiport architecture to ensure safe, efficient, and scalable operations.

While the urban vertiport will primarily focus on passenger and cargo transport use cases, the airport vertiport will emphasize seamless integration with existing airport infrastructure, including taxiways and aprons, as well as coordination with conventional aircraft operations. Both demonstrators will enable scaled testing and validation activities using unmanned aircraft systems (UAS) and will serve as platforms to explore a wide range of operational scenarios, such as airside procedures, arrival and departure coordination, and integration with U-space and air traffic management (ATM) systems.

The vertiport infrastructure will be developed in alignment with current prototypical design recommendations, including compliance with EASA Special Condition SC- VTOL-01 and the EASA Prototype Technical Specifications for Vertiport Design [1]. To enable digital and automated operations, the project will also develop and implement U- space services

at levels U3 and U4, fully aligned with the legal and operational requirements defined in EU Implementing Regulations.
The outcomes of VERTIFIED will offer valuable insights into the integration of vertiports within existing infrastructure and help identify their specific operational and technical requirements. The demonstrators will also serve as a testbed not only for internal DLR research activities but also for external users, supporting further development, validation and standardization of vertiport systems.

[1] EASA. “Prototype Technical Specifications for the Design of Vertiports,” European Union Aviation Safety Agency, 2022.

Biography

Oguzhan Nohutcu

Oguzhan Nohutcu earned a master’s degree in Aerospace Engineering from FH Aachen in April 2024. Since October 2024, he has been part of the scientific infrastructure team at DLR-Cochstedt as a research associate and is primarily responsible for the internal DLR project VERTIFIED, focusing on the implementation of two vertiport demonstrators at the Cochstedt site.

Wildlife Strike Prevention in the Context of Innovative Air Mobility

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Innovative Air Mobility (IAM) Operations are envisioned to perform their flights at low altitudes and as such in areas which are most abundant with wildlife [1]. Given the performance and structural characteristics of electric Vertical Takeoff and Landing (eVTOL) aircraft, high numbers of damaging collisions with animals are expected [2], [3]. To prevent such wildlife strikes, a system for collision avoidance between eVTOL and birds/bats was developed. The set-up of envelopes around the aircraft, where entering of opponents initiate different responses, was inspired by the concept of the Airborne Collision Avoidance System [4] used in conventional fixed-wing aviation and the “Well Clear” concept for Unmanned Aerial Vehicles (UAV) [5] (Figure 1). By addressing collisions between eVTOLs and animals, the focus of novel concepts for collision avoidance with non-collaborative airspace users [6] was extended to consider non-anthropogenic intruders.

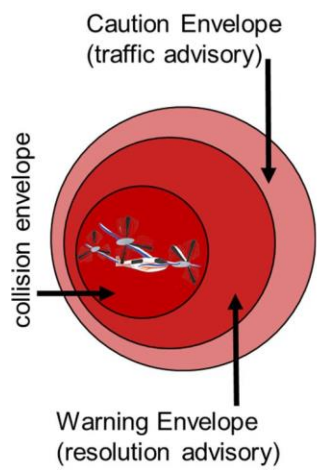

Figure 1: Envelopes around the eVTOL. Source: [7], used with permission

Using real-time information about wildlife movement, for example obtained by avian radar, a three-phase decision-tree to avoid collisions with animals was developed [7] (Figure 2). In the first, i.e. the strategic phase, the abundance of critical wildlife is evaluated and, if required, departure is rescheduled. During the flight, wildlife approaches towards the eVTOL trigger avoidance maneuvers. Depending on the intruded envelope, an automated tactical or manual emergency avoidance (sometimes referred to as “safety-net” or “collision avoidance”) maneuver is executed.

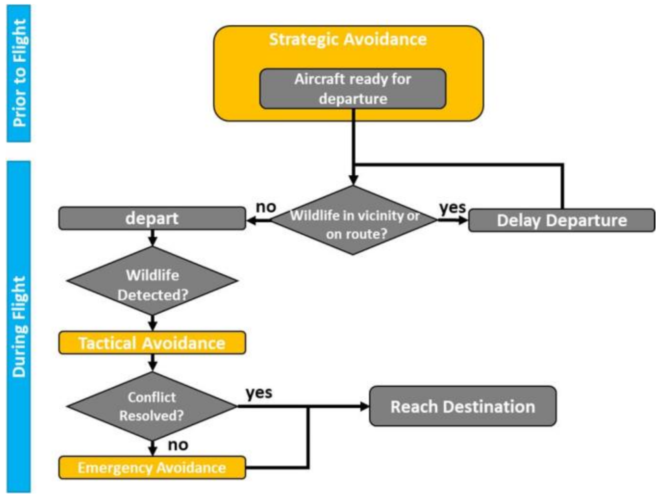

Figure 2: Phases of Collision Avoidance. Adapted from [7], with permission

Initial evaluations were performed with simulations for a sample route between the airport and the main railway station of Munich, Germany, for 13 variants of wildlife occurring prior or during the flight [8]. It was found that the proposed maneuvers could be successfully executed by the four representative eVTOL configurations considered (Multicopter, Lift to Cruise, Tilt Rotor and Vectored Thrust). On average, the Closest Point of Approach (CPA) with intruding wildlife was increased by 72%. The average airborne delay, when maneuvers were initiated, amounted to 107 seconds, corresponding to 15% of the assumed regular flight time of 692 seconds, which is considered reasonable to avoid potentially damaging strikes. Delays imposed in the strategic phase were higher, due to a conservative threshold of five minutes before re- evaluating departure.

In a second study [9], the simulation model of the system was enhanced to be applicable independent of location. It was validated for an airtaxi trajectory with continuous eVTOL traffic and real wildlife movements from all seasons of one calendar year collected at the location of Leeuwaarden airbase, the Netherlands. To reduce departure delays, a strategic envelope around the initial flight segment as well as a strategic avoidance parameter were introduced. The in-flight maneuvers and the geometric dimensions of the envelopes were optimized for performance and further reduction of delays. Finally, the manual emergency avoidance, which was performed by a human operator in the initial study, was modelled by assuming a successful conflict resolution to facilitate the execution of large-scale fast-time simulations. eVTOL traffic was simulated alongside 84 days of wildlife movements for the same four eVTOL configurations used for the initial study. The resulting 336 combinations were simulated twice, once with unimpeded air traffic and once with the UAM-CAS system activated. The simulations revealed that the UAM-CAS reduced the number of collisions per 10,000 flights by 62%. The average CPA was increased by 20%. With the incursions into the warning envelope being reduced by 61%, the need for human intervention to resolve conflict was substantially reduced. The adjustment of the strategic phase resulted in a substantial reduction in ground delays, with an average remaining delay of 14.4 seconds. In-flight delays amounted to 1.25

seconds on average. The total average delay corresponds to approximately 7.5% of the overall flight time. A small number of flights experienced delays of above 100 seconds. These consistently took place during peak wildlife activity during dawn and dusk.
Summarizing the findings of the two studies, it can be concluded that the implementation of a UAM-CAS system can substantially contribute to reducing wildlife strikes for eVTOL aircraft at the cost of reasonable delays. During peak activities, where delays are higher, a rescheduling of flights to avoid energy-intense avoidance maneuvers during the flight, is recommended. Since these periods are coupled to dawn and dusk, they are predictable and relatively short, which facilitates a timely rescheduling.
The wildlife strikes still experienced with an active UAM-CAS are most likely caused by missing reaction of the simulated animal targets, as already found in [10]. It is proposed that future studies implement wildlife behavior to evaluate the consequences on wildlife strike occurrences.

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Biography

Dr. Isabel C. Metz

Dr. Isabel C. Metz received her M.Sc. degree in Mobility and Transportation (cum laude) from the University of Technology in Braunschweig, Germany and her PhD degree from Delft University of Technology in the Netherlands. In her current position at the German Aerospace Center's Institute of Flight Guidance, she heads the institute's tower simulation facilities and investigates options to involve air traffic controllers and pilots in the process of operational wildlife strike prevention.

AGENT-BASED SIMULATION OF AIRBORNE OFFSHORE WIND FARM LOGISTICS AS A SYSTEM OF SYSTEMS

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The growing offshore wind energy capacity in the German North Sea and beyond requires efficient, cost-effective logistics for installation, maintenance and emergency response. Innovative solutions are therefore in demand to overcome the limitations and high costs of traditional Crew Transfer Vessels (CTVs) and helicopters. Uncrewed Aerial Vehicles (UAVs) are currently being explored for supplying wind turbines with maintenance tools and spare parts [7]. Agent-Based Modeling (ABM) is used to simulate airborne logistics and their interaction with offshore wind infrastructure. Based on these simulations, tailored TLARs for UAVs are developed to match the operational needs.

The DLR System of Systems Inverse Design (SoSID) Toolkit has already been successfully employed for the ABM of Urban Air Mobility networks, aerial wildfire suppression, and multimodal simulations [1][2][3][4]. Agent-based modeling has also enabled maritime applications such as search-and-rescue missions in the Barents Sea and piracy-risk simulations in the Arabian Sea [5][6].

To implement the new environment and scenario, the SoSID-Toolkit was extended with a helicopter agent model, since existing VTOL and fixed-wing agents did not capture their flight performance and fuel consumption precisely. An offshore weather modul based on the NORA3 dataset was integrated to reflect wind and sea conditions. An energy-production module quantifies wind turbine output and production loss scenarios, while enhanced dispatcher and maintenance-inspection modules dynamically generates task demands, including spontaneous fault responses and spare-part needs. Multimodal logistics with vessels, helicopters, and unmanned aerial vehicles should be simulated within realistic environmental and operational constraints.

Agent based modeling provides a framework for representing the diverse elements of offshore logistics, each endowed with localized decision making in response to environmental conditions. By specifying vehicle performance and operational rules at the agent level, ABM enables emergent behavior and uncovers inefficiencies invisible to vehicle-only approaches.

The simulations are expected to yield quantitative performance metrics at both the SoS level such as total energy generation and total energy consumption and the vehicle level, like the aircrafts deadhead ratios and load factors, leading to optimized TLARs and fleet compositions. These insights will support planning of resilient, cost-efficient, and fast logistics frameworks for the expanding offshore wind sector.

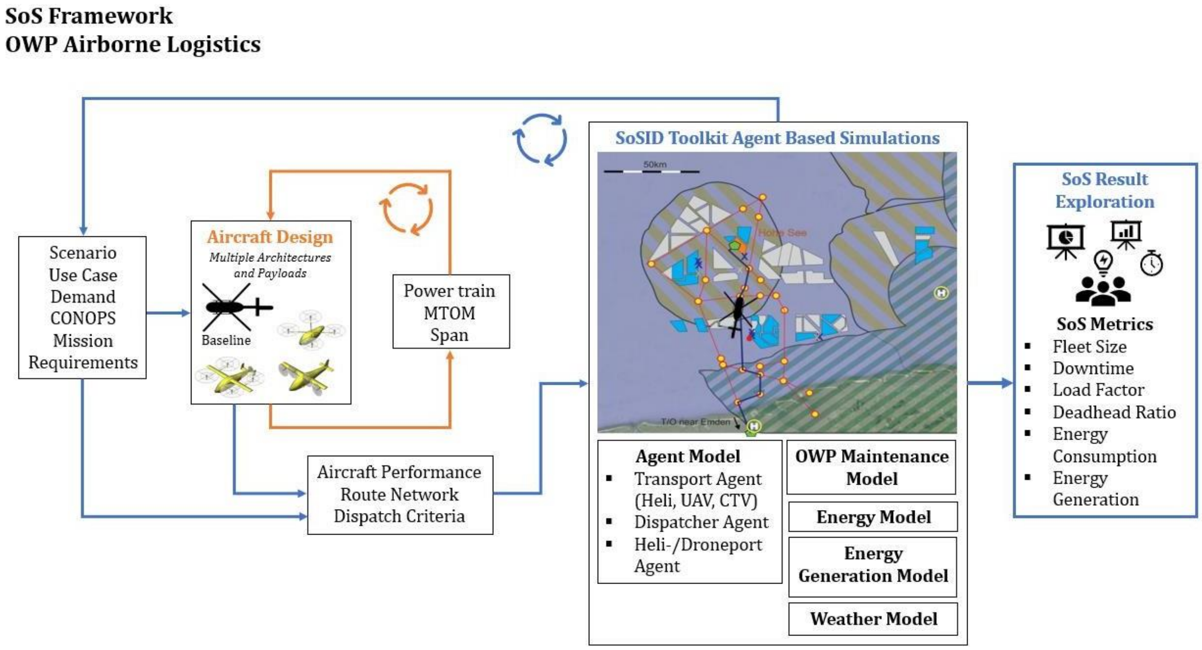

Figure 1: Adapted SoS Simulation Framework for Offshore Windpark (OWP) Logistics, map from [7]

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Biography

Nils Raaf

Nils Raaf is a Master's student in Aeronautical Engineering at HAW Hamburg. He is currently conducting his master's thesis at the German Aerospace Center (DLR), Institute of System Architectures in Aeronautics, Department of Aviation System Concepts and Assessment, focusing on agent-based simulations for drone-based offshore logistics applications, with prior experience in the wind energy industry and with uncrewed systems.

Holistic Modeling of Drone Behavior for Analyzing Safety and Security Aspects in Complex Environments

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Safe operation of drones in complex urban environments is a pivotal challenge for future innovative air mobility (IAM) solutions. Hence, analyzing and addressing associated safety and security aspects – while covering a wide range of use cases and misuse cases – is of major interest. The governance of complex systems and associated safety and security aspects requires a holistic approach [1]. Suitable modeling and simulation techniques are needed to support system design by representing real-world solutions and scenarios with sufficient fidelity to support the exploration and analysis of design decisions during the development process [2]. Conventional model-based system engineering (MBSE) concepts focus on modeling system behavior and architecture to define systems which meet stakeholder requirements, but they do not support model-based exploration of safety and security aspects in early stages of system design. More recently, approaches for integrating standardized risk analysis methods, such as fault tree analysis or failure mode and effects analysis, in early system design phases have been suggested [3], [4].
To operate IAM solutions in complex environments, sophisticated system architectures are needed which include peripheral subsystems such as

- Sensor subsystem(s) for situational awareness and collision avoidance, e.g., based on radar and/or lidar sensors,
- Navigation and cooperative localization subsystem(s), e.g., satellite-aided and/or transponder-based,
- Wireless communication subsystem(s) for drone-to-drone and/or drone-to-X communication, e.g. based on secure data exchange protocols [5].

In our contribution, we aim to adopt a holistic approach to modeling drone behavior in complex environments. We will use a generic drone architecture and consider the aforementioned three subsystems in detail. A central system model shall be digitally connected to partial models representing drone subsystems and the operating environment. To reflect the state of the art in multidisciplinary system development, partial models will be created in various modeling environments, and some of these models will only describe subsystem behavior, but do not necessarily contain any architectural description. For some subsystems, no dedicated models may be provided by the subsystem developers at all. Our holistic approach shall therefore be capable of integrating the heterogenous models as well as information on subsystems for which no models exist. The resulting federated model shall realistically represent the interactions of the drone subsystems with each other and with the environment. In this way, the drone behavior and its reactions to internal failures as well as to external threats can be continuously explored while its design is evolving. Fig.1 illustrates the projected reference implementation.

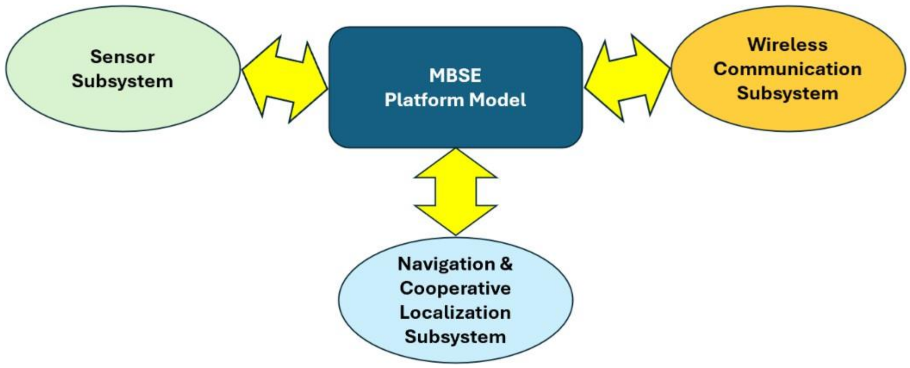

Fig. 1 – Drone behavior model composed of core MBSE platform model and three peripheral subsystems

In our contribution, we will present first results addressing two main challenges:

- A flexible modeling framework needs to be defined. It shall provide elements to holistically represent the overall system and associated threats. A capability is required to capture the behavior of subsystems which are not being developed with a model-based approach.
- Suitable bidirectional interfaces between the central system model and associated partial models of subsystems are required, to realistically represent the overall drone behavior. As all these models are created in different modeling environments (e.g., different tools, different modeling languages, different modeling methods), it is a major challenge to establish the required live bidirectional links. At the same time, the partial models need to be variable and parameterized to allow for the exploration of various system configurations.

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Biography

Jan Mietzner

Jan Mietzner was with Airbus DS (Ulm, Germany) from 2009 to 2017, where he was a technical project manager for radar developments. Since September 2017, he has been a full professor for communications engineering at the University of Applied Sciences (HAW) Hamburg. His research interests concern theoretical and practical issues of wireless communications, radar, and jamming systems.

Enhanced UAS Operation Risk Assessment for Drone Traffic Planning System: A Comprehensive SORA-EASA and LuftVO Compliant Framework with AI and GIS Powered

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Keywords: UAS, UTM, SORA, LuftVO, GeoPandas, AI detection, GIS-UAS analysis, Path planning, AI-powered UTM, Real-time zone data, PostGIS

The rapid expansion of commercial UAS operations has addressed a new flight analysis system, capable of processing complex spatial data in order to ensure regulatory compliance and operational safety. Traditional UAS flight planning tools often rely on simplified geographic models and limited data sources, resulting in suboptimal risk assessments and operational inefficiencies. Furthermore, the rapid development of machine learning methods rise hands to bring this concept to empower traditional methods in aviation and dealing with hi-tech drone traffic management and path planning system.

This paper presents a novel comprehensive framework for Unmanned Aircraft System (UAS) operation risk assessment and path planning that integrates advanced spatial analysis technologies including 1.GeoPandas, 2.GIS spatial analysis, 3.high-resolution SRTM terrain model, 4.ESRI satellite image, 5.NOAA weather, 6.OpenStreetMap infrastructure data, 7.WorldPop demographic information, 8.population griding of flight zone and 9.Artificial intelligence-powered infrastructure detection to revolutionize aviation risk assessment for Unmanned Traffic Management (UTM) to manage drone traffic in uncontrolled airspace. The system implements full compliance with the European Union Aviation Safety Agency (EASA) Specific Operations Risk Assessment (SORA) methodology and German Aviation Regulations (LuftVO). This framework addresses critical limitations in existing UAS risk assessment systems by incorporating SOARA and LuftVO compliances with GIS and AI infrastructures.

A. Performance Analysis

1. **Spatial Accuracy:** GeoPandas and PostgreSQL/PostGIS integration provides geodesic precision with meter scale accuracy in spatial operations, compared to accuracy in traditional GIS systems.
2. **Processing Efficiency:** Dynamic weather updates enabled real-time flight plan modifications based on changing conditions.

3. **Infrastructure Detection:** AI-powered computer vision achieves 95%+ infrastructure detection accuracy compared to 60-70% in OSM-only systems.
4. **Regulatory Compliance:** Automated SORA and LuftVO compliance verification with 95.7% confidence level.
5. **Scalability:** The modular architecture enables deployment from single-user desktop applications to enterprise-scale cloud platforms.

B. Mathematical Framework:

- Enhanced GRC and ARC calculation with environmental modifiers
- Spatial risk propagation models
- Multi-criteria decision analysis with AHP weighting
- Risk-weighted path optimization algorithms

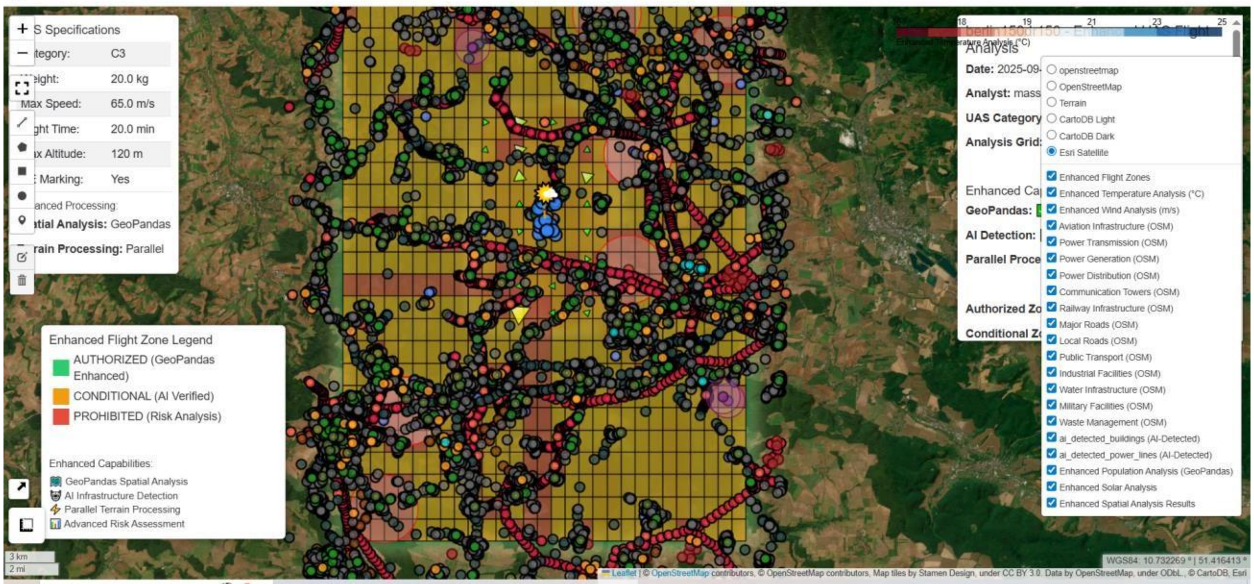

Fig.1- html output file

Input Data Layer
UAS Coordinates,UAS Specs,Terrain,Weather,Operation geography
Processing Engine Layer
GeoPandas Analysis,AI-openCV Infrastructure Detection,Parallel Processing, PostgreSQL/PostGIS
Risk Assessment Layer
SORA Compliance,LuftVO Compliance,Enhanced Weather,Population Analysis
Output Generation Layer
GeoJSON Data,Interactive HTML, CVS Report, Database Storage

Results: Key contributions include: (1) Implementation of geodesically precise spatial analysis using GeoPandas and PostgreSQL/PostGIS, (2) Integration of AI-powered infrastructure detection achieving 95%+ accuracy, (3) Comprehensive regulatory compliance (SORA and LuftVO) automation with 95.7% confidence level, and (4) Real-time spatial conflict detection and resolution capabilities.

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Biography

Masood Mayanbari

Ich studiere derzeit im Masterstudiengang Data Science an der Arden University. Zuvor habe ich einen Bachelorabschluss in Luft- und Raumfahrttechnik sowie einen Masterabschluss in Maschinenbau erworben.Ich habe Berufserfahrung als Design Engineer am BHRC. Aktuell arbeite ich an der Routenplanung von Drohnen in städtischen Gebieten basierend auf einer Hybridisierung von maschinellen Lernmethoden, GIS und Vorschriften zur betrieblichen Risikobewertung Vorschriften.

Collaborating towards the integration of aerial services in multimodal transportation solutions: The IDI Platform

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Traffic and city operations are evolving faster than ever, and the demand for innovative, efficient, and sustainable traffic solutions founded on Intelligent Transport Systems & Services (ITS) as well as effective city operations, are at an all-time high. There is an imperative for the interoperability and integration of air and ground traffic data and services. The **ITS-Driven Innovative aerial services (IDI) Platform** accelerates this transition by:

- Integrating Aerial & Terrestrial Transportation Infrastructure and Services: Harmonising drones and other emerging aerial services with existing transport and operational frameworks.
- Fostering Collaboration: Connecting public and private sectors, academia, and civil society to deliver next-gen solutions.
- Driving Innovation: Setting standards, addressing regulatory challenges, and promoting cross-sectoral initiatives to ensure safety, security, and sustainability.

Figure 1: Visual representation of the context and ambition of the IDI Platform

Members of the IDI work on the nexus of collaboration and innovation, focusing on the intersection of Intelligent Transport Systems (ITS) and cutting-edge aerial services, including drone technologies and autonomous systems. The IDI Platform has been founded on the multi-faceted quadruple helix model of innovation, engaging with the Public Sector/Government, Industry, Academia and Society. As such, IDI has adopted a holistic approach to fully integrate, in a responsible and sustainable manner, Innovative Aerial Services (IAS) into ITS-driven deployments within the transport, mobility and public services context. IDI focuses on key concepts such as Urban Air Mobility (UAM), Innovative Air Mobility (IAM), Advanced Aerial Mobility (AAM), Unmanned aircraft system Traffic Management (UTM) and U-space.

The IDI Platform merits society-driven innovation and deployment targeting to bridge cutting-edge aerial services with existing city operations and public services, including the bridging of aerial mobility solutions with existing transport networks. It safeguards generation of purposeful business opportunities and societal impact for diverse stakeholders across communities throughout Europe and globally.

Beyond its vision of unlocking latent demand and accelerating purposeful deployment towards more accessible and sustainable transport solutions and public services in urban and regional areas, the IDI Platform leverage synergies between the innovation and business ecosystems of ITS and IAS. As a new Innovation & Deployment Platform of the ERTICO – ITS Europe, the IDI Platform builds upon the collective expertise and resources of ERTICO’s Partnership to address emerging challenges and accelerate the development of ITS-Driven IAS. By leveraging synergies, the IDI Platform aims to unlock new opportunities for enhancing urban and regional, connectivity, accessibility and well-being in terms of mobility and critical public services.

The IDI Platform addresses a broad spectrum of services, from individual travel information and adaptive traffic management to city operations such as emergency medical services and surveillance of critical infrastructure, and connectivity of remote areas. It seeks to facilitate the sharing and protection of data, particularly in the realm of traffic management, and ensures convergence and alignment with cross-sectoral regulatory frameworks. A key focus is given on the adoption and development of standards and the integration of drones and aerial mobility into existing infrastructure.

Driving targets of the IDI Platform are summarised as to:

Facilitate multi-stakeholder collaboration to drive the deployment of ITS-driven IAS solutions.

- Address regulatory, technological, environmental, and societal challenges linked to aerial mobility by leveraging on ITS advances.
- Promote the harmonisation of cross-sectoral standards and multilevel governance frameworks to enable responsible and sustainable IAS growth.
- Explore and facilitate collaborative business innovation through public-private partnerships.
- Establish local living labs to serve as pre-commercial fieldwork for introducing and scaling commercial deployment of IAS.

Biography

Dr Vassilis AGOURIDAS

Dr. Vassilis AGOURIDAS is the Co-Chair of The IDI Platform (ITS-Driven Innovative aerial services) powered by ERTICO-ITS Europe. Previously, Dr AGOURIDAS had been with Airbus for 16 years, holding senior positions in Strategic Innovation and Corporate Development pioneering the Strategic Development of Urban Air Mobility.

Scientific Session 2: Public Acceptance / Noise

Session Chair: Ole Bergmann (DLR)

Challenges in Innovative Air Mobility Noise Prediction

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Innovative Air Mobility (IAM) covers a variety of applications and air vehicles. The field of IAM ranges from microdrones up to large helicopters, from unmanned to manned vehicles, and from urban to regional air mobility. The smallest vehicles perform reconnaissance missions in urban spaces, while the largest vehicles transport people within urban or regional areas. Most vehicles have in common that they feature vertical take-off and landing (VTOL) or at least short take-off and landing (STOL) capabilities. Moreover, most concepts use distributed propulsion, which is closely linked to the electrification of air mobility [1, 2].

All these types of vehicles and missions are restricted by noise emissions [3]. The propulsion and lift systems are the major contributors to the overall noise, as conventional engines are mostly replaced by electric motors, which produce significantly lower noise emissions.

Due to the variety of vehicles and missions, different kinds of propulsion systems are applied, and each propulsion system comes with its own challenges in noise prediction. As the propulsion system is often also used for VTOL operations, it not only overcomes drag during cruise conditions but also lifts the aircraft. Since the size of the vehicles differs, the type of propulsor ranges from small propellers to large helicopter rotors. The propulsors can be used for both horizontal flight and VTOL, or only for one mode of operation. They can be enclosed in ducts, shrouds, or wings, or they can be exposed. However, they all have in common that they use an electrically driven propeller or fan for thrust production.

One possible way to classify the type of thruster is through the analysis of disk loading (DL) [4, 5]. DL is defined as the ratio of thrust to the total disk area, as shown in eq. (1). The disk area (AP) is typically the sum of all rotor or propeller disk areas that contribute to the overall thrust (T).

$$DL = \frac{T}{A_P} \tag{1}$$

The DL is a measure of hover efficiency, but it also limits the maximum cruise speed of the vehicle. In addition, the disk area can be used to assess dominant noise sources, as higher DL values typically lead to increased tonal noise components from the thrusters.

The presentation highlights the challenges of IAM noise prediction depending on the mission profile and vehicle configuration. Therefore, relationships between disk loading and noise sources are derived and presented.

Noise predictions for different DL values at a constant thrust requirement under hover conditions are presented in detail. For this purpose, a blade element momentum theory is coupled with an acoustic model to predict tonal and broadband noise emissions. The

acoustic model combines Farassat's formulation 1A [6] for tonal noise and the Brooks, Pope, and Marcolini [7] (BPM) model for broadband noise. For each DL, a propeller is designed according to the minimum induced loss condition derived by Betz [8]. The models are implemented in the simulation tool PropCODE – "Propeller Comprehensive Optimisation and Design Environment" – and have been validated in Ref. [9, 10].
Finally, the paper presents the relationships between DL, achievable cruise speed, and noise emissions. These findings support the categorization of noise emissions based on vehicle configuration.

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Biography

Ole Bergmann

Completed Bachelor's and Master's degrees at FH Aachen University of Applied Sciences in 2019. From 2019 to 2025, pursued a cooperative PhD between FH Aachen and RWTH Aachen, focusing on the aeroacoustic design of propellers for Advanced Air Mobility (AAM) systems. Since June 2025, working at DLR in the field of AAM aeroacoustics.

Co-simulation of Urban Air Mobility for Pedestrian Spaces by Integrating AIRSIM and Unreal Engine with SUMO

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Drones are projected to be an integrated part of urban transportation systems and a preferred method for freight delivery in cities. This would then require these autonomous systems to cohabit and share space with humans in city centers. However mixing other modes of transport (like cars and cyclists e.t.c.,) with pedestrians in urban designs are known to cause safety concerns as noted in Shared Spaces [1] studies. In such mixed traffic environments, walking people are required to behave more cautiously when crossing paths with cyclists or vehicles mainly due to the fear of collisions. Due to lesser traffic infrastructure (e.g., bicycle lanes or signals) and reduced rules, people have to primarily negotiate their right of way and cross only after ensuring that vehicles will not cross first. This is stressful for elderly individuals considering their declining physical ability, psychological fears and reduced decision making ability for quick and dynamic environments. While they are expected to look around for crossing cars before making a decision; adding drones would further increase the cognitive overhead to the navigation task. Furthermore, noise levels that would result [2] due to autonomous drones and subsequent distractions to pedestrians due to their flights has been relatively less explored from a safety perspective that is important in this regard. This paper focuses on first completing a survey on current methods of simulating a traffic environment for flying drone in pedestrian populated spaces. Furthermore as noise is an inhibitor to navigation route choices of pedestrians, this work will demonstrate a co-simulation framework on how the SUMO traffic simulation engine can be integrated with AIRSIM. This framework will focus on generating synthetic noise data to model pedestrian behavior with drones sharing space. While SUMO will be used to model the path and movement of vehicles near pedestrian spaces, AIRSIM generates data for synthetic noise and drone flights in the presence SUMO simulated vehicle routes. Lastly as the noise level from autonomous drones highly rely on the chosen flight path along with wind-speeds, 3D sensor data that is required for safety critical route planning and perception algorithms (like object detection) will also be simulated by interfacing Unreal Engine with the co-simulation framework. The key contributions of this co-simulation framework is on identifying how noise and 3D sensor data (Pointcloud and Camera images) of autonomous drone sensors can be synthetically generated to model and influence navigation behavior of nearby walking pedestrians. The potential benefits of agent based modeling [4] , safety critical perception [5] and Augmented reality(AR) [3] to address the gaps in the above directions will be investigated. The results of this research and the co-simulation framework contributes to understanding how drone flights affect pedestrian navigation behavior in urban cities. This can then be used to devise methods to guiding pedestrians to navigate collectively when being projected with virtual walking paths using AR and drones [6].

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Biography

Vinu Kamalasanan

I am a postdoctoral researcher working at the institute of Informatics at TU Clausthal, Germany with the MEC Lab that focuses on mobility research. My key research focus is on how Augmented Reality (AR) influences navigation behavior in traffic environments like Shared spaces and its safety impacts.

How many flights in U-space are socially acceptable? Insights from an exploratory virtual-reality experiment*

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Over the years, various forms of pollution—such as air, water, and soil—have been extensively researched. However, other types, like visual pollution, have received comparatively less attention, particularly in urban settings. Visual pollution is the adverse effect that certain man-made structures, objects, or their movement can have on an individual's perception. The entities causing this undesirable effect are referred to as visual pollutants. Unmanned aerial vehicles (UAVs) are potential visual pollutants [1][2].

In the realm of Innovative Air Mobility (IAM), limited studies have examined the relationship between IAM and visual pollution. Yet, existing evidence suggests that visual pollution poses a significant obstacle to public acceptance. The introduction of IAM systems into complex landscapes requires a thorough assessment of their visual impact. Given that IAM is not yet widely deployed in real-world scenarios and that most existing studies rely heavily on quantitative methods, capturing meaningful citizen responses remains a challenge. To address this gap, a virtual reality (VR) experiment was developed and conducted. The resulting tool, known as the Visual Pollution Virtual Reality (VPVR) Tool, offers users an immersive, 3D experience simulating drone deployment scenarios. It enables participants to evaluate the perceived visual pollution caused by UAVs across different environments and drone configurations.

The VR environments enable the examination of the factors contributing to visual pollution through immersive, controlled scenarios. Throughout these simulations, the participants' responses to their virtual surroundings are recorded, providing data on which environmental aspects were deemed visually disruptive or acceptable. Feedback was gathered from 100 participants regarding their acceptance levels in both urban and rural settings, involving three types of vehicles used for sensing, cargo transport, and passenger services. The simulated environments were a combination of two main characteristics: drone type and environment type. Additionally, participants' audio-visual pollution perception was assessed to examine whether UAVs' audio input affects visual pollution perception. The experiment lasted approximately one hour. During the VR simulation, participants responded to smiley-based Likert scale questions every minute.

Finally, a surveyor asked verbal questions throughout the session and manually recorded the responses.

The analysis of the results reveals a marked difference in the average drone density threshold between urban and rural simulated environments. Sensing drones emerged as the most acceptable type. Cargo drones were generally more acceptable in rural areas, likely because participants recognized the tangible benefits of package delivery in regions where traditional logistics may be less efficient. An interplay between visual appearance and utility was found; smaller drones, such as sensing drones, enjoy overall higher acceptance, emphasizing how aesthetic and spatial considerations—beyond purely functional roles—affect public perceptions. The mission type significantly influenced acceptance. Although cargo drones were viewed positively for their potential utility, some participants questioned whether such benefits outweighed potential disturbances like noise and privacy concerns.

The collected information on the perceived acceptance levels was used to identify thresholds of U-space capacity and the equivalent values are presented. This exploratory research and its results can assist policy-makers and regulators on the design of U-space and its operations in such a form that enhances socially acceptable operations overcoming, hence, a major barrier in IAM diffusion.

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Biography

James McLeod

James McLeod is a research assistant at ISCTE University and is currently contributing to the ImAFUSA project. He holds a BSc in Mechanical Engineering and an MSc in Business Administration.

UAS - a new noise source from a noise protection perspective

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Current developments in the field of UAS (Unmanned Aircraft Systems) and the associated European legislation show that UAS will be increasingly used in the future. The UAS industry also has a great interest in starting regular operations, as ever longer flight times and larger payloads are possible. At present, they are mainly used in the service sector, e.g. for maintenance tasks or the transportation of medical goods, as well as in crisis management, e.g. for rescue missions. In the future, there will be so- called U-space airspaces in urban areas. The associated increase in UAS traffic raises the question of future noise pollution. This question needs to be investigated in more detail. UAS have their own, new noise characteristics, which are in addition to the conventional environmental noise in urban areas and also differ significantly from the known noise sources of general aviation. This special characteristic has not yet been sufficiently taken into account in the known noise metrics. It is therefore foreseeable that in future more and more people will feel disturbed by the noise of UAS flights or will at least be concerned about the expected noise pollution. This noise is often perceived as more disturbing than noise from other sources. This can affect public acceptance of the use of these aircraft in urban areas.

The presentation will show what the current legal noise assessment in Germany looks like for the open and special category over inhabited areas and what other questions are raised as a result. There are currently some unresolved issues in the application of § 21h (3) of the German Air Traffic Regulations (LuftVO) from a noise protection perspective, e.g. in the application of the Technical Instructions on Noise Abatement (TA Lärm). In addition, it has not yet been clarified how a noise assessment should be carried out when introducing a U-space. If TA Lärm is still to be applied, the following must be taken into account: The immission guide values of the TA Lärm represent a 16- hour level for the daytime period, i.e. all noise sources in this 16-hour period must be determined for an immission location and summarized to form a rating level. The U- space coordinator must carry out extremely forward-looking planning here, as the type and number of UAS will usually not be known when the application for a U-space is submitted. In addition, the prior exposure at the respective immission location must be known.

Furthermore, it will be shown how psychoacoustic parameters such as loudness, tonality and sharpness can at least provide an attempt at an effect-oriented consideration. Psychoacoustic parameters can help to better describe the actual perceived auditory impression and should be considered in addition to the purely physical parameter of sound pressure level. To this end, various measurement campaigns with different UAS models between 500 g and 10 kg were evaluated [1].

The results provide insights into the potential level of public annoyance and allow conclusions to be drawn for the assessment of UAS noise, which can be used for future regulations or standardization. In particular, the models that will be used for transportation

in the future due to their payload or are already used for inspection purposes have higher values for loudness and sharpness. However, these are not taken into account by the current noise indices. As a result, the characteristic UAS noise can only be inadequately assessed. Official noise assessment procedures must therefore be developed that take psychoacoustic effects into account, e.g. as a supplement. For example, it is conceivable that particularly conspicuous characteristics could be integrated into the usual noise assessment by means of a surcharge. This would certainly be possible via the TA Lärm and already exists in some cases, e.g. for tonality. The analyses also show that the psychoacoustic parameters investigated are dependent on the operating mode. Loudness and sharpness show a pronounced dependence on temporary load changes (e.g. during deceleration). In addition, fast overflights at high altitudes have a lower noise potential. It is therefore essential to adhere to the previous minimum flight altitude and possibly set minimum speeds for overflights.
With the current state of knowledge, it is quite possible to derive pragmatic solutions for noise protection that can be included in the official approval procedure for flight operations and thus mitigate the level of nuisance as a precautionary measure.

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Biography

Julia Treichel

Degree in media technology. Since 2011 working at the German Environment Agency in the field of noise abatement, noise impact. Thematically responsible for noise from UAS in the open and specific category. Further thematic focus on the Environmental Noise Directive and noise from leisure activities.

Scientific Session 3: U-space

Session Chair: Dr. Kristin Wendt (DLR)

Threat from Above: risks and opportunities of unmanned aerial systems in airspace G

Christian Holzer
ASO Airspace Surveillance S.R.L

Unmanned Aerial Vehicles (UAVs) — commonly referred to as drones — have evolved from niche technologies into a pervasive operational reality, creating both unprecedented opportunities and mounting security challenges. Today, drones pose a tangible threat to operators of critical infrastructure, industrial facilities, and public institutions. Acts of espionage, signal interference, and sabotage are no longer hypothetical scenarios; they are increasing in frequency, sophistication, and impact — often occurring without warning or detection.
At the same time, the economic potential of UAVs in logistics, urban mobility, and infrastructure management continues to accelerate, ushering in a transformative era of aerial innovation. This tension between technological progress and security vulnerability demands a fundamental redefinition of how the lower airspace is monitored, managed, and protected [1].

[1] www.asodronedetection.com

Biography

Christian Holzer

Christian Holzer — Technology & UAM Expert and CEO of ASO Airspace Surveillance S.R.L — examines the convergence of AI-driven optical drone detection, large-scale situational airspace awareness, and integrated Unmanned Traffic Management (UTM) systems. His perspective highlights how adaptive, data-driven counter-UAS technologies and vertically integrated infrastructures can build resilience and operational trust across the airspace ecosystem.
His call to action: We must transform the lower airspace from a zone of risk into an intelligent infrastructure of trust, awareness, and control.

Conceptual Development of a Collaborative Interface with Air Traffic Control for Integrated UAS Operations in Airport Environments

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The increasing demands of unmanned aircraft systems (UAS) for commercial, logistics, surveillance, medical delivery, and public safety purposes present significant challenges to the safety, security, and efficient use of airspace, particularly in and around airports where the airspace is controlled, and traffic density is high. To ensure reliable UAS operations in an airport, U-space is necessary to manage the increasing number of UAS at Very Low Level (VLL) altitude airspace safely. U-space offers a digital suite of services, including flight planning, geo-awareness, network identification, and real-time tracking. By integrating UAS into existing airspace, U-space helps prevent collisions, protects privacy, and supports the future of Innovative Air Mobility (IAM) and smart cities. As U-space services evolve toward higher maturity levels (U3 and U4), there is a growing necessity for a reliable and dynamic collaborative interface between U-space stakeholders and conventional Air Traffic Control (ATC) to enable integrated unmanned operations in complex airport environments [1]. This study proposes a conceptual framework for a high-level, data-driven collaborative interface between U-space participants and ATC designed to support real-time coordination and airspace management between manned and unmanned aircraft operating in shared airspace volumes. The proposed concept builds upon the SESAR Joint Undertaking's vision for interoperable U-space architecture, extending it to account for real-world airport constraints, legacy ATC systems, and the need for scalable, low-latency digital interfaces [2]. The interface concept involves a single Common Information Service Provider (s)CISP and U-space Service Providers (USSPs), enabling continuous bidirectional data exchange involving 4D trajectory data, airspace status, traffic information exchange, and emergency alerts. Emphasis is placed on the implementation of advanced U3-level services, such as a simplified version of a Dynamic Airspace Reconfiguration (DAR), coordinated with the ATC via Human- Machine Interface (HMI). The collaborative interface also introduces a DAR tool for shared airspace volumes, enabling the activation and deactivation of geo-zones during emergencies or system degradation. The developed interface supports both strategical and tactical collaboration by integrating UAS operational flight parameters through a user interface that enables interaction with the ATC, enhancing ATC situational awareness and facilitating joint decision-making in response to traffic density, severe weather events, or emergencies. Human factors considerations are taken into account in the user interface to ensure operational acceptance and safety. Simulation use cases for airport approach corridors, medical delivery scenarios, and dynamic no-fly zone activation and deactivation are proposed to

validate the operational feasibility. Furthermore, a modular validation roadmap is outlined, including software components, human-in-the-loop, and live UAS-ATC field trials, with a focus on harmonizing with the European Union Aviation Safety Authority (EASA) U-space regulatory framework (EU) 2021/664 [3] and future integration into the Digital European Sky services [4]. The study highlights the potential for the proposed collaborative interface to not only enhance operational safety and predictability in airport environments but also to unlock high-density, routine Beyond Visual Line of Sight (BVLOS) and IAM operations. Ultimately, the research contributes to the foundational architecture required to coordinate segregated UAS operations toward a fully integrated airspace system, where manned and unmanned aircraft safely coexist and operate collaboratively under a U- space ecosystem.

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[2] “SESAR Joint Undertaking | U-space,” Sesarju.eu, 2017. https://www.sesarju.eu/U-space
[3] “COMMISSION IMPLEMENTING REGULATION (EU) 2021/664 of 22 April 2021 on a regulatory framework for the U-space (Text with EEA relevance).” Available: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32021R0664
[4] “European ATM Master Plan.” Available: https://www.sesarju.eu/sites/default/files/documents/reports/SESAR%20Master%20Plan%202025.pdf

Biography

Praveen Kumar Selvam

Since 2023, Praveen Kumar Selvam has been working as a scientific employee in the Department of Unmanned Aircraft Systems at the German Aerospace Center (DLR) Institute of Flight Guidance in Braunschweig. His research interests include U-space Implementation, Innovative Air Mobility (IAM), Vertiports, and Beyond Visual Line of Sight (BVLOS) operations.

Full-Stack U-Space Airtaxi Path Planning with Microservice Architecture: Performance Analysis and Visualization

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The integration of airtaxis into urban airspaces demands robust, scalable, and modular path planning systems capable of handling the complexity of U-space environments. This ongoing master's thesis project presents the development of a full-stack path planning system based on a microservice architecture, aimed at enabling safe and efficient airtaxi operations in structured low-altitude corridors.

The architecture includes a global path planner using an A* algorithm to compute optimal 3D routes through predefined air corridors (Fig. 1). A local planner based on potential fields is also being considered to enable dynamic obstacle avoidance. The microservice-based approach promotes modularity and independent scalability of each functional component, enabling future extensions such as obstacle data fusion, adaptive replanning, or integration with real-time surveillance feeds without disrupting existing services.

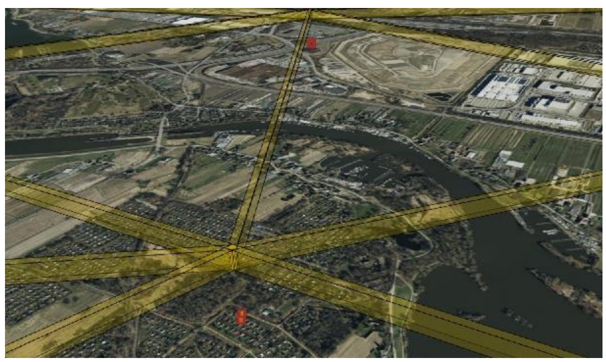

Fig. 1: Schematic of the air corridor network used for global path planning.

The system is implemented using Python and Java SpringBoot with standardized web interfaces. A key part of the evaluation involves analyzing system scalability and latency, including a breakdown of delays across different service stages.

A frontend developed using CesiumJS provides 3D visualization of the generated 4D trajectories. The project, expected to conclude by September 2025, aims to offer a scalable and transferable architecture for IAM stakeholders, including traffic managers, service providers, and municipalities.

By focusing on real-world deployability and integration with smart mobility infrastructure, this work contributes to bridging the gap between U-space theoretical frameworks and operationally viable airtaxi management systems. The architectural approach is inspired by prior work demonstrating the advantages of microservice architectures in UAV applications [1].

Keywords: U-space, airtaxi, microservices, path planning, urban air mobility, CesiumJS

[1] L. Matlekovic and P. Schneider-Kamp, “From Monolith to Microservices: Software Architecture for Autonomous UAV Infrastructure Inspection,” in Embedded Systems and Applications, Mar. 2022.

Biography

Sukhbir Singh

Sukhbir Singh is a master’s student at the Technical University of Munich specializing in flight system dynamics and aerial mobility. His thesis focuses on developing a microservice-based U-space path planning architecture for airtaxi operations, with an expected completion in September 2025.

Innovative Air Mobility - Control Center

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IAM-CC is a control center for managing fleets of highly automated or autonomous eVTOL air- craft in dense urban airspace under U-space/UTM rules.

It is projected to integrate 4D trajectory planning, strategic and tactical conflict management, geofence enforcement, vertiport slot scheduling, fleet health monitoring, and real-time visualization, with REST- based interoperability to U-space service providers.

It prospectively includes a simulation suite for aircraft, airspace, vertiports, passenger demand, booking, and U-space services to support validation, training, and demonstrations.

Front-end architecture:

- Cesium-powered 3D map.
  - Cesium World Terrain, OSM-derived layers, and configurable imagery.
  - GeoJSON/3D tiles overlays for dynamic/static geofences, no-fly zones, obstacles, and population-density heat maps.
- Interactive mission planning.
  - Rubber-band editor for drag-and-drop waypoints with time and altitude constraints.
  - On-map geofence drawing to publish or trial dynamic restrictions.
  - Color-coded trajectory compliance: green (nominal), yellow (caution), red (violation).
- Fleet and health dashboards.
  - Matrix view: columns per aircraft; rows for subsystems (battery, comms, propulsion health, proximity hazards, ground-risk density, vertiport congestion).
  - Color-coded icons highlight excursions from nominal.
  - Aviate panel on selection: attitude, ground speed, altitude, heading, and ranked conflict- resolution suggestions.
- Operator workflow panels.
  - Conflict Resolution panel with ranked mitigations: delay, expedite, reroute, altitude change, slot swap.
  - Vertiport Scheduler with slot availability, congestion forecasts, and automated relief proposals.

Back-end microservices:

- Path Planning Service.
  - REST endpoints produce candidate 4D trajectories along designated skyways.

    - Uses aircraft performance and energy models, wind and terrain, and integrates geofences and vertiport schedules.
- Conflict Detection Services.
    - Strategic (pre-flight): batch checks against active plans, static constraints, hazards, and demand-capacity rules.
    - Tactical (in-flight): streaming conformance monitoring on telemetry and dynamic geofences; detects trajectory conflicts and deviations.
- Conflict Resolution Service.
    - Generates and ranks deconfliction maneuvers: time shift, route diversion, altitude change.
    - Optimizes for safety, compliance, mission impact, and energy margins.
- Vertiport Management Service.
    - Tracks per-vertiport capacity, pad occupancy, charging resources, and turnaround pro- cesses.
    - Issues automated relief actions: delay, expedite, cancel, swap, or redirect to alternates.
- U-space/UTM integration.
    - REST connectors to USSP for mission management, flight authorization, and strategic deconfliction.
    - REST connectors to CIS/CISP for geo-awareness: static/dynamic geofences, NOTAMs, temporary segregated areas, terrain/obstacles, vertiport metadata, and event notifications.
    - Remote ID and identification/tracking data flows as applicable.
- Data and observability (implementation detail).
    - Time-series telemetry ingestion, eventing for alerts, audit logging for legal recording and incident reconstruction.

Simulation framework:

- UAS simulation.
    - Controlled Airtaxis Simulator: vehicle dynamics and onboard autonomy; accepts trajectory updates and resolution commands; streams telemetry including GPS and battery state.
    - Uncontrolled Traffic Simulator: non-cooperative manned/unmanned traffic on scripted or random routes; emits ADS-B-like or Remote ID-like tracks to tactical detection.
- Vertiport schedule simulation.
    - Time-indexed arrival/departure queues per vertiport in a database.
    - Charging stations, pad occupancy, and turnarounds modeled to predict congestion and trigger scheduler proposals.
- Passenger demand simulation.
    - Synthetic mission requests from temporal, geographic, and historical models.
    - Demand elasticity versus pricing, availability, weather, and events.

- Booking workflow simulator.
  - Emulates booking platforms and dispatch UIs; applies pricing, availability, and cancellation logic.
- U-space service simulators.
  - CISP simulator: registration, Remote ID streams, geo-awareness feeds, terrain/obstacles/vertiport metadata, and event alerts.
  - USSP simulator: mission planning and authorization, strategic deconfliction, dynamic geofence distribution, conformance monitoring, identification/tracking, and traffic information.
  - Optional services: dynamic capacity management, tactical conflict resolution, emergency and contingency management, legal recording, citizen reporting, procedural/col- laborative ATC interfaces, and drone AIM for 3D airspace structure governance.

Operational flow

- Intake mission requests from booking or dispatch.
- Generate candidate 4D trajectories and evaluate energy, time, and capacity constraints.
- Perform strategic deconfliction, obtain flight authorization via USSP, and ensure geo-awareness compliance via CISP.
- Reserve vertiport slots; publish conformance bounds and contingency plans.
- Execute missions with tactical monitoring and on-demand trajectory updates for conflicts, geofences, weather, or health alerts.
- Manage turnarounds and charging; adjust schedules and flows as conditions evolve.

Compliance and governance

- Align with U-space regulations for airspace designation, U-space services, and conformance monitoring.
- Maintain audit trails for authorizations, advisories, operator decisions, and telemetry for incident reconstruction.

Non-functional goals

- Scalability for city-scale operations with bursty demand.
- Low-latency decision loops for tactical deconfliction.
- High availability and graceful degradation with operator overrides.
- Configurability to regional U-space/UTM variants.

Biography

Enno Nagel

Studies and PhD in Mathematics at the University of Münster, since 2024 researcher on flight guidance of unmanned air systems at the DLR.

Scientific Session 4: Safe Autonomy

Session Chair: Christoph Torens (DLR)

Understanding the role of autonomy in aviation – why do planes need to fly themselves?

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The rise of innovative air mobility over the past decade and a half has been driven by significant leaps in two main areas of development – sustainable aviation and autonomous aviation. While sustainable aviation attempts to combat the challenges of climate change by innovating novel forms of propulsion with a focus on distributed electric powertrains, autonomous aviation offers a pathway to reduce the workload, training and qualification requirements of the flight crew on board the aircraft. Moreover, autonomous aviation offers an opportunity for newer forms of aviation to have a viable business case, e.g. cargo delivery drones or air taxis. However, the promise of autonomy in aviation is neither new nor unexplored.

Today, commercial transport aircraft ferry millions of passengers every day across the world but the pilots in command of these aircraft are only involved in critical phases of flight. Indeed, large portions of the flight are conducted by the flight computers onboard the aircraft. However, the human pilot in the cockpit is not only a source of confidence for passengers (although few ever see the pilots ferrying them), they also serve as the last line of defense in case a complex and thankfully improbable chain of failures should necessitate a manual intervention. However, as systems grow increasingly complex, so do the training and qualification requirements for the pilots supervising them. At the same time, there is a global shortage of pilots which does not seem to get better. Still, a future with an empty cockpit may be distant in commercial aviation as autonomous agents need to prove their robustness and resilience in challenging scenarios – for example similar to the Hudson River landing by Capt. Sullenberger and his copilot after a bird strike incapacitated both their engines.

An avenue with more potential for the introduction of autonomy may instead be in the realm of unmanned aircraft systems, where the lack of a pilot onboard the aircraft is not only acceptable but a premise to the operation and a technical (as well as regulatory) challenge to be solved. Already, drones deliver medical supplies to remote areas in different parts of the world and are being considered for such deliveries in densely populated urban centers of the world. The promise of delivery drones transporting our workday lunch or an urgently required spare part can only be fulfilled at scale if the need for human intervention from remote pilots can be eliminated. As regulatory advances allow for increasingly complex operations, the safety criticality of the autonomous systems flying these drones will also increase, particularly at the large scale these drones are expected to operate. For example, Roland Berger predicts that 160,000 commercial passenger drones will ply the skies by 2050 [1].

Drones play not only a useful role in the civilian sector, but they are also being increasingly deployed as a capable tool in military operations as evidenced by recent major conflicts in Europe and the Middle East. Ever more militaries and governments across the world are looking to drones to replace their aging aircraft fleets due to their promise of cost-effectiveness, rapid capability deployment as well as their ability to overwhelm enemy air defenses. Moreover, drones remove the risk to personnel on both sides, who would instead have to be deployed to these conflict zones.

Finally, the trickle-down effects of the successful development and integration of autonomous systems in aviation could mean that the dream of personal flight could come true. Hobbyists may be able to realize their pursuit of flight like birds without having to amass the high degree of skills needed to safely pilot an airplane. On the other hand, even experienced private pilots could benefit massively from the safety net potentially provided by autonomous systems in their general aviation aircraft, a domain where the safety record is orders of magnitude worse than that of commercial aviation.

The motivation to introduce autonomy in aviation is therefore quite clear. It is therefore important to understand its impact on aviation especially with regard to innovative air mobility. This paper attempts to address this topic by taking a holistic look at the history of autonomous systems development in aviation. It aims to also provide a classification of the different types of autonomous systems that have been introduced by domain and by level of functional responsibility, and identifies where there is still a significant need for development. It looks at concrete examples in industry and discusses potential challenges and opportunities for further development. A discussion of the technical aspects of autonomy would not be complete without a regulatory discussion. Therefore, this paper also looks at the key certification challenges and discusses potential regulatory pathways for the different technologies involved. While the discussion revolves around onboard autonomous systems, ground-based infrastructure elements are key to the success of autonomy in aviation and are also discussed to the extent possible. Through this contribution, the domain of autonomous aviation with its technical and regulatory challenges can be better understood and developers working in the field may have a bigger picture for where they could be headed. This enhanced technical comprehension, in turn, could accelerate the development of new regulations, and foster an informed discussion of the challenges and opportunities associated with autonomy in aviation.

[1] Hader, M. et.al. “Urban Air Mobility | USD 90 billion of potential: How to capture a share of the passenger drone market”, Roland Berger GmbH, November 2020.

Biography

Pranav Nagarajan

Pranav Nagarajan is a Research Scientist at the Institute of Flight Systems of the German Aerospace Center (DLR) in Braunschweig. There, he works in the Department of Unmanned Aircraft towards the development of safe autonomous systems for drones primarily in the EASA specific and certified categories.

Unmanned Cargo Transport in the EASA Specific Category – Insights from the DLR Projects ALAADy-CC (2022–2024) and Perspectives for KARGO (2026++)

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Unmanned aircraft systems (UAS) represent a key technology enabler for efficient, flexible, and cost-effective logistics – especially in remote areas or for time-critical deliveries. To realize this technology, at least three critical aspects are essential: the aircraft or the UAS, an operational concept which is acceptable to the regulator and molds to a deployable as well as profitable operating model. The project ALAADy- Demonstrator explored the feasibility of converting a manned gyroplane-based light aircraft to a low-cost cargo drone and successfully tested the concept in flight [1][2]. The project ALAADy-CC (Automated Low Altitude Air Delivery – Cross Country) aimed to identify the regulatory challenges and practical potential of operating robust low-cost cargo drones for unmanned cross-country flights in low-altitude airspace (< 500 ft). In particular, airdrop scenarios which eliminate the need for precise landing may enable economical operations, especially in humanitarian contexts. The regulatory domain for these challenges is given by the European Union Aviation Safety Agency (EASA), which regulates aviation safety for all European Member States.
A central aspect of the project ALAADy-CC was the application of the EASA SORA (Specific Operations Risk Assessment) framework to the proposed low-altitude cross-country cargo operations. During the flight testing of the converted UAS, operating procedures, testing protocols, and emergency concepts were developed and validated. From a technical perspective, it was shown that a modular conversion of the gyroplane into an unmanned transport platform equipped with autopilot, power supply, communication, and actuation systems is feasible. The integration of a safety concept, together with comprehensive risk analyses, formed the foundation for applying for a SORA 2.0 operational approval. By aiming for the lowest possible SAIL (Specific Assurance and Integrity Level) classification, operational costs can be significantly reduced while maintaining the required safety levels.
The following key challenges for the above operational concept have been identified in the course of workshops with German federal and European aviation authorities (LBA, EASA) as well as practical testing:

- Standardized and officially recognized methods for demonstrating risk mitigations are incomplete or inadequate.

- Conventional parachute systems are unsuitable for low-altitude operations, even though this airspace is ideally suited for drone use.
- Public and regulatory acceptance of airspace integration remains a critical issue.

Against this background, the proposed follow-up project KARGO – abbreviated in German for cost-efficient unmanned cargo transport – is intended to take the next step toward operational deployment and scalability. The project aims to establish an economically viable operating model with the following key features:

- Cargo flights at low altitudes in rural areas.
- One pilot supervising multiple aircraft (supervision instead of direct control).
- Minimization of maintenance and operational costs through robust, simplified technologies.

As in ALAADy-CC, the EASA SORA framework will also play a central role in KARGO – for both operational approval and the further development of standardized verification procedures. At the time of writing, the approval process for KARGO is in its final stages. Therefore, the presentation will not only summarize the findings from ALAADy-CC but also provide a cautious outlook on the goals and planned content of the upcoming KARGO initiative.

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[2] S. Benders, L. Goormann, S. Lorenz, and J.C. Dauer, “Softwarearchitektur für einen Unbemannten Luftfrachttransportdemonstrator,” 2018, doi: 10.25967/480238.

Biography

Dr.-Ing. Sven Lorenz

Dr.-Ing. Sven Lorenz is a Group Lead for the Unmanned Cargo and Passenger Transport research group within the Unmanned Aircraft Department at the Institute of Flight Systems of the German Aerospace Center (DLR) in Braunschweig and Cochstedt. His current work focuses primarily on realizing unmanned cargo drone operations in the EASA specific category by addressing both technical and operational challenges.

Pranav Nagarajan

Pranav Nagarajan is a Research Scientist in the Unmanned Aircraft Department at the Institute of Flight Systems of the German Aerospace Center (DLR) in Braunschweig. His primary goal is to enable the safe operational deployment of autonomous systems in aviation. His research focuses primarily on autonomous mission and contingency management for UAS in the EASA specific category.

Martin Laubner

Martin Laubner is a Research Scientist in the Unmanned Aircraft Department at the Institute of Flight Systems of the German Aerospace Center (DLR) in Braunschweig and Cochstedt. An avid pilot and passionate aviator, his research focuses on the development of novel solutions for the piloting, testing and evaluation of large and complex UAS configurations in flight, particularly for BVLOS operations.

Modelling of critical weather flight performance of multi-copter UAV for increased resilience controller design.

Arno Fallast, Samuel Lesak
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Aircraft icing has been identified as a major safety issue for manned urban air mobility (UAM) and unmanned aerial vehicles (UAV) likewise [1]. Restrictions imposed by the manufacturers and/or legislators regarding a UAV's tolerance to adverse weather conditions can reduce the availability. For UAV without specific adverse weather protection measures, the availability for legal flight is reduced even below 30% in the cold season for most regions of the world and is below 85% in the cold season in regions beyond 45°N or −45°S even for drones with enhanced weather resistance [2]. Emergency organizations experience a reduction in their operational capability as a result.


Figure 1: The 25 kg multi-copter UAV in the climatic wind tunnel.

To research on the capabilities of weather modelling and to increase accuracy of weather radar measurement interpretation, the collaborative research project IFIRE (Icing Forecast In Real Environment) is carried out [3]. To improve weather forecast models and calibrate data gathered from radar data, flight into known icing condition is intended to be performed in confined airspaces. These test flights are performed with a multi-copter UAV with a takeoff mass of up to 25 kg (shown in Fig. 1) equipped with specialized sensors for measurement of e.g. liquid water content (LWC) and droplet size.
Therefore, we aim at identifying prerequisites to ensure safe operation of multi-copter UAV under adverse weather conditions as a significant ice-accretion can occur within several minutes of operation (see Fig. 2). Developing flight controllers capable of handling degraded flight performance requires a simulation model for ice accretion and

performance degradation under icing condition on a powertrain for the UAV intended for flight experiments as the influence on lift and drag can be dramatical (see Fig. 3) Data are gathered at test campaigns for varying icing conditions within the CS25, Appendix C envelope in a climatic wind tunnel. A data driven approach (Dynamic decomposition with Control, DMDc [4]) is chosen for system identification. The high- fidelity simulation model allows future extension of UAV controller design for the flight under adverse weather conditions.

Figure 2: Severe ice accretion on a multi-copter propeller

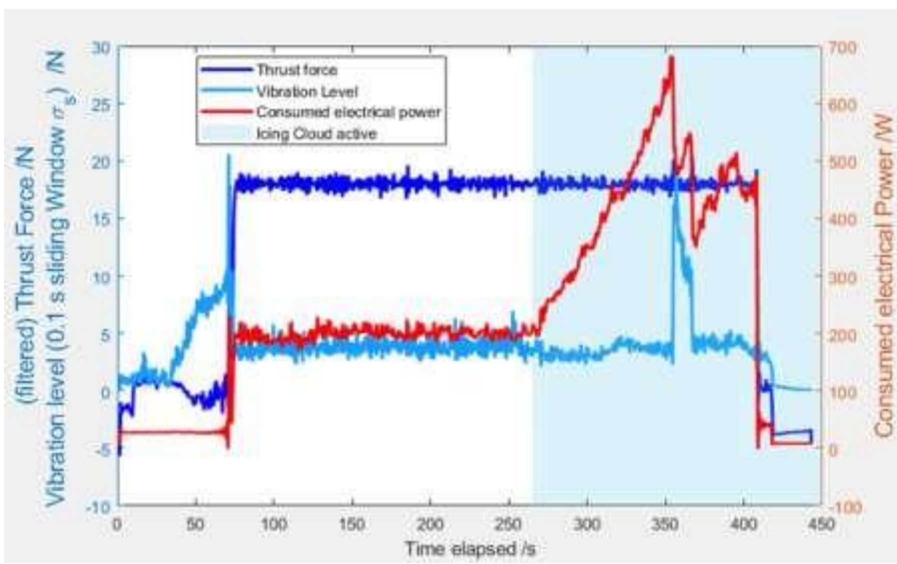

Figure 3: Increase of required electrical power to maintain the thrust force required to maintain cruise flight of the 25kg UAV under severe icing conditions.

It has been shown that commercially available UAV controllers are not fully capable of handling the challenges of degraded performance and increased time constants and inertia of ice accretion on the lift generating propellers in the flight regime they cover [5]. The current work investigates on limitations of conventional flight control methods such as full state feedback controller designed with LQR for various operating points such as hover flight or cruise flight. To overcome strongly varying operation points resulting from ice accretion on the propeller, gain scheduling can be implemented for various ice mass accreted on the propeller. This requires accurate knowledge of the ice mass currently on the propeller, that we achieve trough analysis of fight performance data. A long- short-

term-memory (LSTM) neural network is used to estimate the ice mass on the propeller and thus allows for selection of an appropriate gain parameter set. The LSTM model has shown to be capable of estimating the ice mass based solely on performance data (e.g. commanded thrust, RPM, consumed electrical Power) of a drive train [6].
We propose gain scheduling of controller gains adopted to the ice mass on the propeller estimated by interpretation of performance data. We show simulation results and show up a pathway to enhance resilience and safety margins for operation of UAM in adverse weather conditions.

[1] David Kozomara, Thomas Neubauer, Reinhard Puffing, Ingeborg Bednar and Wolfgang Breitfuss. "Experimental Investigation on the Effects of Icing on Multicopter UAS Operation," AIAA 2021-2676. AIAA AVIATION 2021 FORUM. August 2021.
[2] Gao, M., Hugenholtz, C. H., Fox, T. A., Kucharczyk, M., Barchyn, T. E., and Nesbit, P. R., “Weather constraints on global drone flyability,” Scientific Reports, Vol. 11, No. 1, 2021, p. 12092. https://doi.org/10.1038/s41598-021-91325-w, URL: https://doi.org/10.1038/s41598-021-91325-w.
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[4] Proctor, J. L., Brunton, S. L., and Kutz, J. N., “Dynamic mode decomposition with control”, 2014.
[5] Orchard, D., "Development of a Test Rig for the Assessment of Remotely Piloted Aircraft Systems (RPAS) in Icing," SAE Technical Paper 2023-01-1416, 2023, https://doi.org/10.4271/2023-01-1416.
[6] System Identification of a Multicopter Powertrain With Degradation for Simulation-Based Training of a Fault Detection Neural Network, A Fallast, A Ghoddousi, AIAA AVIATION FORUM AND ASCEND 2024

Biography

Speaker Given Name

A. Fallast is a researcher and senior lecturer at the Institute of Aviation at the University of Applied Sciences, Graz where he leads the research Group “Intelligent Systems”. He is a PhD Student at the Technical University Graz (Institute of Machine Learning and Neural Computation) researching Machine Learning methods for anomaly detection and data driven modelling. He received his bachelor’s degree and his master’s degree in aviation engineering from the FH JOANNEUM. For 12 years he has been working as a researcher and lecturer.

Creation of training data using data driven modeling for fault detection

Samuel Lesak, Arno Fallast
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Reliable fault detection is required to ensure the safe operation of future urban air mobility (UAM) vehicles. Realistic flight data is needed to test and evaluate fault detection algorithms, and many state-of-the-art methods in machine learning require large amounts of data. Operational data from existing systems are typically used to design such algorithms, but designing for systems that do not yet exist, such as UAM vehicles, presents specific challenges.

Traditional detailed system identification for unmanned aerial vehicles can be costly and requires expertise and resources. There are cases where a system is already in place, but the dynamics are not known in detail, like for a single prototype of a UAM. System identification and simulations can evaluate a system's performance and viability. A data-driven method is presented for approximating a multirotor unmanned aerial vehicles (UAV) system matrix using dynamic mode decomposition with control (DMDc) [1]. This approach is tested and verified by utilizing data collected from the sensors of a Pixhawk 4 from flight tests of a octocopter UAV with a maximum take-off mass of up to 25 kg. This method shall demonstrate the necessary sensors to approximate the dynamics of other systems like UAM vehicles.

This paper presents a method for creating a data set to aid the design of fault detection algorithms by simulating a UAM vehicle in Simulink. The vehicle is simulated in six degrees of freedom, applying the dynamics generated by DMDc and traveling autonomously using full-state feedback along a randomly generated route. In a Monte Carlo simulation, random faults, like drivetrain faults or excessive vibrations, are injected into the simulations via state machines. Additionally, performance degradation will be implemented for algorithms focusing on maintenance intervals. This includes modeling component wear, such as drivetrain wear and battery degradation.

The result is a dataset containing time-series flight data of the system states, labeled to indicate whether a fault occurred and the wear status of each component. The generated data is a basis for future work on designing fault detection using machine learning methods such as autoencoder-type neural networks and support vector machines. The generated data will be open source to encourage further research.

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Biography

Samuel Lesak

Samuel Lesak MSc is an aeronautical engineer with extensive knowledge of control engineering, flight mechanics, machine learning, and the application of MATLAB and Simulink. He completed his bachelor's and master's degrees in aeronautics at FH Joanneum in Graz. He gained professional experience in R&D simulation and control engineering, where he developed simulation models for urban air mobility (UAM) drones. He is currently working at FH Joanneum in Graz, Austria, as a researcher in the Intelligent Systems Lab research group.

Scientific Session 5: Simulation

Session Chair: Nabih Naeem (DLR)

Urban Air Mobility Traffic Analysis Tool

Antoni Kopyt, Mateusz Sochacki
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Growing complexity of advanced aviation systems brings new threats to safety and security and poses several regulatory and technical challenges. As Advanced Air Mobility (AAM), including Urban Air Mobility (UAM) and Unmanned Aircraft Systems (UAS), air traffic increases, it is important to ensure safe integration into an air traffic management system initially designed to support manned aircraft. The main challenge of integrating UAS into urban settings is that these environments are already densely used by ground traffic, people, and manned aircraft. Growing use of UAS in urban environments will increase the risks of potential collisions, various incidents and accidents that can result in serious losses or injury. Since the uses and applications of UAS are increasing and diversifying it is necessary to develop effective risk management practices, methodologies, and processes to ensure safety of operations. Identifying and understanding risk factors is a key step in developing risk mitigation and response measures for UAS operating in urban environments.

The purpose of this paper is to examine the most critical issues and challenges related to the rapid growth in UAS operations in urban environments. The goal of the research is to identify potential hazards and determine which safety regulations and procedures applied in manned aviation are scalable and can be implemented in the UAS domain. The paper will include analysis of existing risk prediction and mitigation technology, currently used in traditional aviation operations which can be used to develop in-time system-wide safety assurance of autonomous systems. However, special attention will be given to the challenges that are unique to the UAS domain for which new mitigation solutions need to be created.

This paper focuses on UAS integration in urban environments where their operations are currently greatly restricted by safety regulations. UAS are increasingly applied in other areas, such as international border patrol, forest surveillance, or precision farming. These missions are performed in non-urbanized areas and are less affected by the most challenging urban-related risks. In such applications the operations are safe, and UAS can be freely used and provide enhanced efficiency, major cost savings, and increased profitability. Even though, in most cases drone implementation and technological development relates to UAS operations and does not have a direct translation to UAM development, the applicable lessons learned and risk identification and mitigations capabilities will be discussed.

The Urban Air Mobility Traffic Analysis Tool was created in order to help with answering these questions. The dedicated software specifically for UAM solutions was developed. It is capable of simulating air traffic over specified area of interest, accounting for real population density data, airspace restrictions and daily traffic distribution. Aircraft

population is generated considering vehicles' parameters such as speed, ceiling, and range, as well as various levels of autonomy and cases of aircrafts' malfunctions. Both cargo- and passenger-oriented applications such as taxis and deliveries in point-to-point, hub-to-point and multipoint trips are considered.
The infrastructure (airports, zones, corridors etc.) is unready to gather such a high volume of UAS (commercial, private-use, service, etc.). Some of the adapted/proposed solution from commercial aviation in above mentioned reports seems to be inadequate and it is highly possible so they are not assuring sufficient safety. Thus, the novel approaches such as AI/ML in UAS traffic management seems to be a promising direction.

Biography

Antoni Kopyt

Antoni Kopyt is an Assistant Professor at Warsaw University of Technology, Poland. Received a PhD diploma with honors in 2016 in Automatics and Robotics. During studies, he spent one year at the L'Institut Polytechnique des Sciences Avancées, Paris, France. In 2013, he went to NASA Langley Research Center, VA, USA, for a scholarship, researching Adaptive automation. His professional interests are computer simulations, automation, human–operator modeling, biofeedback, human-in-the-loop, UAV, and UAM. Dr. Kopyt participated in several projects funded by the European Commission, such as ACROSS, TALOS, NEFS, NICETRIP, and several nationally funded projects. He is strongly engaged in numerous R&D projects in Urban Air Mobility (UAM) that focus on the area of multi-variate sensor data. He also received a faculty grant for a young scientist to research his PhD thesis. He supported the teaching process at FPAE in several subjects at the Bachelor's and Master's levels. He published several papers in scientific and technical journals and actively presented multiple speeches at international and national conferences. Currently, he is a subcontractor for NASA LaRC in the System Wide Safety program, researching Urban Air Mobility. The study's primary goal is to develop a simulator of an urban area and test various methods and risks in ATM. AIAA SSIF TC member, DASC TC member.

AI-Based Adaptive Drone Flight Path Optimization in Urban Environments

Michael Gruenewald
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Technical progress on the development of suitable air vehicles flying in urban environment is fast and potential applications are manifold. Though the acceptance of such systems could be a major obstacle to its operations. Resistance could come from affected people who do not directly benefit from the application of such systems. Increasing acceptance by minimizing the environmental impact such as pollution and noise as well as reducing risk and improving performance to increase the economic benefit should be a valid approach.

The integration of AI-driven techniques for optimizing drone flight paths in urban environments offers significant benefits, particularly in enhancing performance and minimizing environmental impact. This is especially relevant for applications such as delivery and security operations, where safety and public acceptance are critical and urban air systems are a game changer providing the biggest advantage as compared to existing transport systems.

The models considered in the study can take dynamically into account for urban environment regulations from authorities, traffic situation, temporary inaccessible areas, critical infrastructure, the noise situation and other parameters.

In this study, we present two complementary optimization approaches. The first employs regression trees to quantitatively assess and compare segmented flight paths, enabling data-driven route selection. The second approach utilizes artificial potential fields to define a parameterized flight space based on mission objectives and operator preferences, allowing for gradient-based path optimization.

These methods support dynamic adaptation by enabling the tuning of parameters such as time-to-target, energy consumption, noise emission, avoidance of sensitive zones (e.g., hospitals, power plants, military areas) and reducing risk based on flight physics parameters. Crucially, the framework supports both offline mission planning and real- time adjustments, ensuring robust operations in rapidly changing environments.

The decision tree method uses the assumption that the drone follows predefined flight path sections which all have their known beneficial and detrimental parameter values characterizing their section. The optimized flight path is found by integrating over the different sections from start to target and identifying the one with minimum impact. Impact criteria can be prescribed by the user and can be obtained – time dependent – from digital databases.

The artificial potential method calculates a multidimensional grid of values for each point in the urban space based on the user provided criteria – similar as the decision tree model. Here at every point of the potential flight path the next point along the path is determined by a local gradient search. No predefined path sections exist in this case.

Based on the drone type the urban environment and the weather conditions flight physics parameters can be included in both methods for the path generation, the lift off and the landing situation. This is especially useful for emergency scenarios, where rapidly changing and crucial conditions can endanger the system.
Using a case study centered around a hospital in Munich, we demonstrate how optimized noise corridors can be identified—either adaptively for individual missions or as standardized offline routing parameters.
Our results highlight the potential of AI-based path planning to improve the efficiency, safety, and societal integration of urban drone operations.

Biography

Michael Gruenewald

Dr. Michael Gruenewald, a physicist from the University of Karlsruhe and UCLA, has extensive experience in aerospace and technology management. He led simulation and method development at Daimler and Airbus. As a VP at Airbus, he significantly impacted the company's research strategy. He co-founded SRITec and also lectures at Munich's Technical University.

Transportation system for IAM: application of a demand model to study areas

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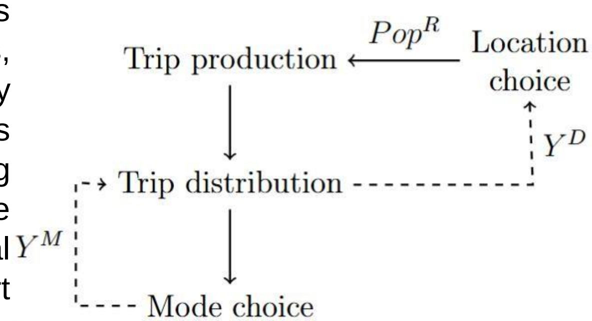
This work focuses on modelling a transportation system for Innovative Air Mobility (IAM). It builds upon the specification, still carried out and yet published, of a demand model for IAM named "IAM-DeMo" (Innovative Air Mobility DEmand MOdel). The IAM-DeMo was based on discrete choice theory and comprises four sub-models interconnected by satisfaction variables. It includes the mode choice model (the core), as well as those modelling levels needed to study the impacts of IAM on the population: location choice, trip production, and trip distribution. It is developed at both national and regional scales, which makes it possible to assess accessibility effects on remote areas. The use cases considered are tourism-related and commuting mobility. As a further step on top of the specification, in this study, we: a) define spatial dimensions (study areas, zoning, and transport network); b) project required input data to future scenarios; and c) identify demand model parameters.



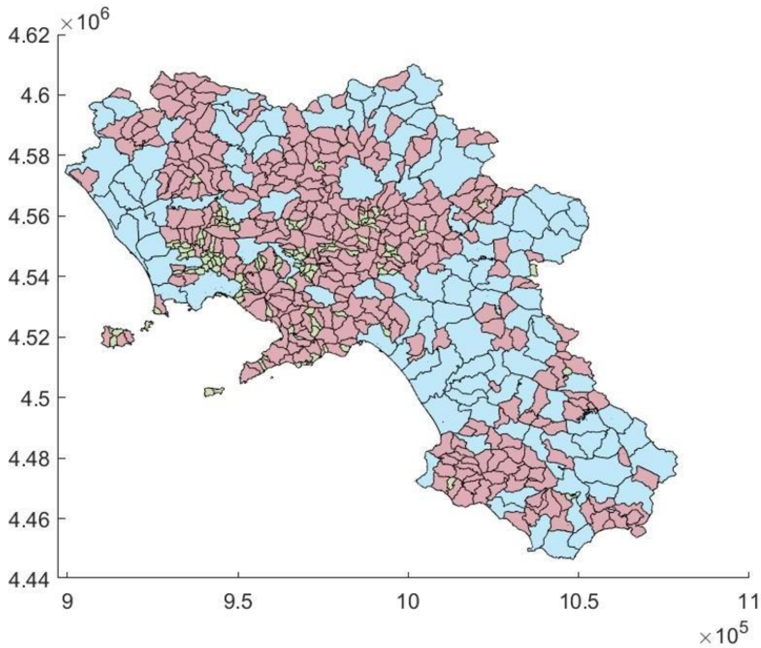
Architecture of IAM-DeMo

Spatial dimensions include the study areas, their zoning, and the transport network. Trips may start and end at many different points thus the study areas are divided into zones (zoning) and analyse only the trips between the centroids of each zone [1]. We have applied IAM-DeMo to Italy at the national level and the Campania region at the regional level. We have built thematic maps and indicators to carry out zoning. The result was a coarser level of zoning based on areas and land uses. At the regional scale, zones approximately correspond to municipalities: large municipalities are subdivided by land use; small ones are aggregated; medium-sized are standalone zones. At national scale, metropolitan areas are used.

Regarding the **projection of input data into future scenarios,** the target years are selected as 2035 and 2050, aligned with European Commission sustainability objectives [2]. Projection was based on statistical studies and academic literature. The studies provide:

- Sociodemographic data from ISTAT (Italian National Institute of Statistics) to estimate decision-makers, utility function attributes, and weights for satisfaction variables.
- Transport and territorial data (ISTAT) to describe modal attributes (costs, time intervals) and future infrastructures.
- Planning documents to identify future transport networks and infrastructures, and new attraction areas.

The transport network comprises the primary links (ground transport infrastructures, air routes…) and a detailed access/egress network. The IAM-DeMo considers 15 transport modes, including IAM. In this study, construction of new vertiports has not been considered but only existing airfields and heliports have been included.



Regional study area "Campania Region". Large municipalities in blue, medium ones in red, small ones in green

The IAM-DeMo features a highly articulated architecture, capable of accounting for multiple use cases, decision- makers, trip purposes, and time slots, to capture the diverse transport phenomena stemming from the introduction of IAM. Our primary objective is to establish a methodological framework that enables the interrelations between IAM and travellers' behaviour. For this reason, we **define all parameters for IAM-DeMo** combining academic literature and expert judgment, rather than calibrating the model with a disaggregate likelihood approach, which would have required the creation and administration of a survey, and subsequent analysis of the data. We adapt parameters (e.g., partitioning coefficients and trip rates) from calibrated models found in the literature. When we are unable to find suitable literature sources, we rely on expert judgment (we rely on the Delphi method, along with other techniques, to minimize bias and perform reasonableness checks).

Conclusions. This study provides a comprehensive methodological framework for assessing the potential impacts of IAM on future mobility, especially in remote and underserved areas. The IAM-DeMo model demonstrates the feasibility of integrating IAM into multi-modal transport systems at different spatial scales. Initial application to Italian national and regional case studies highlights how IAM could complement existing transport infrastructure, particularly by improving accessibility in low-density zones. The projected scenarios for 2035 and 2050 show that IAM has the potential to influence mode choices, particularly for specific trip purposes such as tourism and resident mobility. While quantitative outputs remain indicative, this work contributes a structured basis for future scenario analysis, policy support, and investment planning in IAM. The framework and assumptions presented here can be used to guide subsequent model calibration and data collection efforts.

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[2] Erbach, G., 2021. European climate law. Regulation (EU) 1119.

Biography

Valeria Cosenza

2021 Master's degree in Building Engineering-Architecture. Thesis in Urban Planning [a]
2022 – 2023 Scholarship for research purposes “Definition and evaluation of parameters for the assessment of the resilience of transport networks” [a]
2023 - ongoing PhD "Evolving mobility under new air transport modes" [a, b]
CIRA supervisor: Ing. Lidia Travascio
University supervisor: Prof. Ing. Gennaro Nicola Bifulco; Prof. Ing. Luigi Pariota

Affordable or exclusive mobility? An applied cost model for Innovative Air Mobility (IAM) in Northern Germany

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In the IAM industry and literature, diverse vehicle configurations and different values for estimated ticket prices per kilometre circulate. At this moment, these numbers are fixed values without any link to a business model, including a fleet assignment and vehicle allocation to demand scenarios. Therefore, this research focuses on an applied cost model to calculate the direct operating cost of potential IAM businesses based on demand scenarios for the metropolitan area of Hamburg. For this purpose, the study considers commuters, business travellers and airport shuttles going to the Hamburg Airport, which contain about 9500 IAM passengers per day in total [1,2,3]. The cost model itself is a derivative of a consisting cost estimation, which is used for initial cost evaluation for different IAM activities [4]. For multicopter configurations, the model uses a fixed fare per kilometre of 5 €/km, for vectored thrust configurations of 1.5 €/km. Existing assumptions of the initial cost estimation will be substituted by various inputs which are generated by an operating IAM business model. An operating platform is needed to serve the demand requests, to estimate the needed fleet size as well as the number of revenue flights and empty flights that in turn influence occurring operating costs. Therefore, this study uses a vehicle allocation model to calculate the required operation inputs [5].
In a first step, the ticket price for an IAM flight scales linearly with the flight distance, similar to a ticket fare in traditional transport systems. The fare per kilometre is derived from the initial direct operating cost estimation [cite]. First results indicate an unbalance of ticket prices for different flight distances. When using fixed fares per kilometre for multicopter configurations on short-haul and vectored thrust configurations on long-haul, the existing model considers two different subsystems with individual fares per km. Whenever the flight distance exceeds the maximum range of the multicopter, the model operates with a vectored thrust configuration, designed for longer ranges. Here, the value for the fare per kilometre changes as well, which could lead to significantly lower total ticket prices on longer flights with the currently used fares when switching from multicopter to vectored thrust configurations. Itineraries with a long flight distance for the multicopter receive an above-average ticket price, which then leads to an underestimation of potential demand. In the same way, short flights with vectored thrust configurations are offered with below-average ticket price that lead to an overestimation of potential demand. Figure 1 shows two different ticket fare structures.
While a fixed fare value leads to a linear function for each configuration, there is a ticket price jump when switching from multicopter to vectored configurations. In comparison, the orange fit shows an exponential function with saturation as an alternative ticket structure. Differences in the total ticket price are marked with green and red areas to

illustrate potential over or underestimations of the associated demand of IAM. Parameters of the alternative fare structure must be linked to airlines operations data to achieve a profitable business model. When considering different flight distances, thus varying operating costs, the model has to observe the demand and frequency of the flights on certain flight distances. In the end, an IAM business has to set the parameters for the exponential function to serve a potential demand that leads to a profitable business.

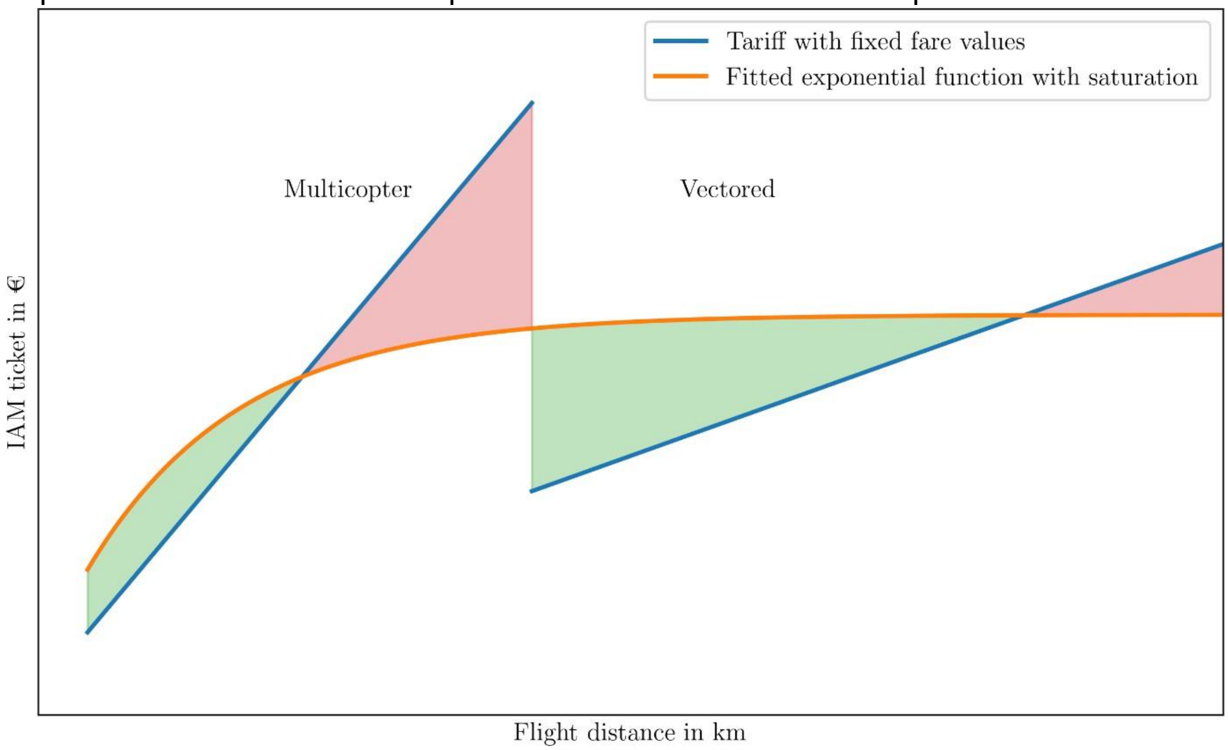

Figure 1 Comparison of different ticket structure for IAM flights

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Biography

Jan Pertz

After finishing his Master in Mechanical and Process Engineering at the TU Darmstadt, he joined the DLR in 2019. Since then, his focus has been on the operations and business modelling of drone applications. In particular, he investigates potential IAM passenger demand and occurring costs.

Panel Discussion: Challenges of AI Certification

This panel is targeted towards the certification challenges of AI systems for aviation. The panel will invite speakers on the topic of AI certification and the challenges regarding that topic. Targeted topic areas include: gaps of existing standards, standardization groups and efforts towards new standards, research perspectives on trustworthy AI, safety monitoring and assurance of AI systems, environmental conditions and operational design domain of AI systems, and more.

Panelists:

Burak Ata, Head of Certification and Assurance at Helsing

Konstantin Dmitriev, Research Associate TUM & Senior Development Engineer at MathWorks GmbH

Umut Durak, German Aerospace Center (DLR), Germany

Guillaume Soudain, Programme Manager - Artificial Intelligence at EASA

Moderator: Christoph Torens & Pranav Nagarajan, German Aerospace Center (DLR), Braunschweig, Germany

Panel: Challenges of AI Certification

Christoph Torens, Pranav Nagarajan
DLR Institute of Flight Systems
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The utilization of artificial intelligence (AI) is growing throughout all domains. There is strong demand for the use of AI in the aviation domain. With AI, there is a huge potential for automating complex tasks, e.g., vision-based tasks to support the landing operation. The overall goal is to improve the performance of operations, and increase the number of operations, while at the same time reducing the cost of operation, and also maintain and increase safety [1]. This implies following rigorous certification standards. This is a challenge, because traditional standards and processes for certification do not fit the new paradigm of data-driven designs of AI components [2]. In traditional software, the behavior is determined by software design and software algorithms. This enables a coherent and bidirectional traceability from requirements, over design, to software source code, executable code and tests [3, 4]. However, with AI systems the behavior is determined to a large degree by the data that was used for training. Using different data results in different behavior. As a result, the same rigor that is used for software development is also required for the data handling. The requirements for data quality, the characterization of the data, as well as the overall development lifecycle needs to be considered [5, 6]. This is just one of the challenges that emerge with the AI software.
This panel is targeted towards the certification challenges of AI systems for aviation. The panel will invite speakers on the topic of AI certification and the challenges regarding that topic. Targeted topic areas include: gaps of existing standards, standardization groups and efforts towards new standards, research perspectives on trustworthy AI, industry perspectives on AI utilization, safety monitoring and assurance of AI systems, environmental conditions and operational design domain of AI systems, and more. The authors of this abstract will be the moderators of the panel. As invited panelists, we are proud to present our highly valued guests: Guillaume Soudain (EASA), Burak Ata (Helsing GmbH), Konstantin Dmitriev (TUM), and Umut Durak (DLR). We kindly refer to the biography for further information.

[1] EASA, Artificial Intelligence Roadmap 2.0: Human-centric approach to AI in aviation, European Union Aviation Safety Agency (EASA), May 2023.
[2] EASA, EASA Concept Paper: Guidance for Level 1 & 2 Machine Learning Applications, European Union Aviation Safety Agency (EASA), Mar. 2024
[3] Torens, Durak, and Dauer. (2022) Guidelines and Regulatory Framework for Machine Learning in Aviation. In: AIAA Science and Technology Forum and Exposition, AIAA SciTech Forum 2022. AIAA SCITECH 2022 Forum, 2022-01-03 - 2022-01-07, San Diego, California. ISBN 978-162410631-6.
[4] Dmitriev, Schumann and Holzapfel, "Towards Design Assurance Level C for Machine-Learning Airborne Applications," 2022 IEEE/AIAA 41st Digital Avionics Systems

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[5] Kaakai, Adibhatla, G. Pai, and E. Escorihuela, “Data-Centric Operational Design Domain Characterization for Machine Learning-Based Aeronautical Products,” in Proc. of SafeComp, Toulouse, France, Sep. 2023, pp. 227–242.
[6] Kaakai, Fateh, et al. Toward a machine learning development lifecycle for product certification and approval in aviation. SAE International journal of aerospace, 2022, 15. Jg., Nr. 01-15-02-0009.

Biography
Panelists

Guillaume Soudain

Guillaume Soudain has been working for EASA since 2006, first as ‘Software and Airborne Electronic Hardware Expert’ in the Agency's Certification Directorate. In 2014, he was appointed ‘Software Senior Expert’, in charge of the coordination of software aspects of certification within the Agency, before taking his current role of ‘EASA AI Programme Manager’ in 2022. Since 2018, he has been at the forefront of driving innovation and ensuring safe deployment of AI in aviation through his leadership of EASA's AI Roadmap. He also represents EASA in the joint EUROCAE WG-114 / SAE G-34 working group on AI. Before joining EASA, Guillaume worked for 5 years, from 2001 to 2006, as a ‘Software Engineer’ in the development of automatic flight control systems in the European rotorcraft industry.

Burak Ata

Burak Ata serves as the Head of Certification and Assurance at Helsing. His primary areas of expertise encompass airworthiness certification and quality assurance within both civilian and military programmes. In addition to his role at Helsing, Burak Ata co-chairs EUROCAE WG-117, which focuses on Aviation Software standards.

Konstantin Dmitriev

Konstantin Dmitriev is a Research Associate at the Technical University of Munich and a Certification Engineer at MathWorks. He is a member of the SAE G-34 / EUROCAE WG-114 working group developing the ARP6983 standard for AI certification. His professional interests include the safety and certification of artificial intelligence and machine learning systems.

Umut Durak

Umut Durak is the deputy head of the Safety Critical Systems and Systems Engineering Department at the German Aerospace Center (DLR) Institute of Flight Systems. He also holds a professor title from the Institute of Informatics at the Clausthal University of Technology. His research focus lies in software intensive airborne systems.

Moderators

Christoph Torens

Christoph Torens is a researcher at the DLR Institute of Flight Systems, Department Unmanned Aircraft, Safe Autonomy Group. His research focuses on the connection of software standards, software certification, and the safe operation of autonomous unmanned aircraft systems.

Pranav Nagarajan

Pranav Nagarajan is a Research Scientist at the Institute of Flight Systems of the German Aerospace Center (DLR) in Braunschweig. There, he works in the Department of Unmanned Aircraft towards the development of safe autonomous systems for drones primarily in the EASA specific and certified categories.

Scientific Session 6: Vertiport Design, Integration and Operations
Session Chair: Samiksha Rajkumar Nagrare, German Aerospace Center (DLR), Braunschweig, Germany

Research questions on the design and operation of vertiports: Possible applications for the DLR Vertiport Demonstrator

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The presentation provides an overview of research topics that are well suited to being addressed by the DLR Vertiport Demonstrator, which is currently under development. The DLR Vertiport Demonstrator can be regarded as an experimental process environment that can be utilized to simulate and investigate the interaction between aircraft, infrastructure, and processes at a vertiport under various conditions.

A vertiport is a specialized type of airfield designed for the operation of novel aircraft types that do not fall within the conventional categories of fixed-wing aircraft or helicopters, among others. These novel categories of aircraft, designated as eVTOLs, encompass a diverse array of vehicles capable of vertical takeoff and landing (VTOL), with the capability of operating in unmanned mode where applicable. In addition to the prevailing perspective that a vertiport is intended for the takeoff and landing of VTOL-capable aircraft, it can be regarded as a component of further systems. Therefore, a vertiport is a component of not only the UAM/IAM transport system, but also of the ground and conventional air transport network, as well as its environment. The ground, air, and UAM/IAM transportation systems collectively constitute the overall transportation system.

Vertiports are comparable to conventional airports or airfields in terms of their purpose and their transportation and operational functions. From the higher perspective of the overall transport system, vertiports function as links between the ground and air transport systems and the UAM/IAM transport system. From the perspective of an UAM/IAM system, vertiports function as both sources and sinks of UAM/IAM traffic, thereby constituting an essential system component for flight operations. The central function of vertiports is to provide the necessary organizational, technical, and operational infrastructure in the form of facilities, equipment, and personnel required to carry out flight operations, passenger and cargo handling, and aircraft handling. Consequently, a vertiport can be regarded as a distinct "process environment."

The topographical features in the vicinity of a vertiport and the associated airspace largely determine the possibilities and restrictions for UAM/IAM traffic taking place there. In many cases, the location of the vertiport is associated with specific patterns of traffic demand that place particular demands on the respective vertiport. In particular, vertiports in urban areas and vertiports situated at airports have to operate under challenging conditions due to limited ground and airspace.

The term "vertiport topology" refers to the configuration of pads and stands, as well as their connection via designated taxi routes. When designing a vertiport topology, the objective is to provide a specified capacity with the lowest possible land consumption and to achieve the highest possible capacity for a given area, respectively. Vertiport topology, operating mode, and processes together have a major impact on vertiport capacity.

The design of the airside is significantly influenced by binding regulations based on technical specifications, standards, and recommendations from national and international aviation authorities. Initial drafts for the design guidelines for vertiports with pilots on board were presented by the Federal Aviation Administration [1] and EASA [2]. There is a need to review these guidelines under practical conditions and to develop them further if necessary.

The vision of UAM/IAM includes new types of aircraft that can also be operated without a pilot on board. The absence of pilots on board requires the establishment of additional regulations organizational frameworks. To ensure the seamless integration of Uncrewed Aerial Systems (UAS) into the airspace, a high degree of automation and digitalization is paramount. To accomplish these tasks, U-space [3] and xTM (Extensible Traffic Management) [4] are being developed in Europe and the US. These concepts are designed to facilitate the integration of cooperative operating environments within the existing framework of traditional air traffic services (ATS). The implementation of these concepts necessitates the development of novel technologies and procedures for flight operations to ensure the safe and orderly operation of both unmanned and manned aircraft in parallel.

Based on the analysis of current design guidelines, future operational concepts, and the environmental, capacity, and space requirements for vertiports, five domains for research in the context of vertiports were identified, for which the DLR Vertiport Demonstrator can provide valuable services (Figure 1). The relevance of these domains is explained, and examples of specific research questions and studies are provided. The DLR Vertiport Demonstrator can be used as a valuable tool for reviewing design guidelines and adapting them to the aircraft's technical capabilities, testing communication, navigation and surveillance (CNS) technologies — especially for unmanned operations — and examining flight operations processes in more detail with regard to the vertiport's safety, capacity and space requirements.

Figure 1: Domains of vertiport research

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[2] EASA, Vertiports: Prototype Technical Specifications for the Design of VFR Vertiports for Operation with Manned VTOL-Capable Aircraft Certified in the Enhanced Category (PTS-VPT-DSN), EASA, Editor. 2022.
[3] CORUS-XUAM, U-space ConOps and architecture (edition 4). 2023.
[4] Federal Aviation Administration, Urban Air Mobility (UAM): Concept of Operations. 2023.

Biography

Henry Pak

Henry Pak graduated from RWTH Aachen University in 1988 with a degree in mechanical engineering. He joined DLR in 1991. Since 2002, he has been working at the predecessor institute of the Institute of Air Transport. He has been working in the field of unmanned air systems and urban air mobility since 2016. His research focuses on the analysis of the UAM/IAM system, use cases, and the market potential for passenger transport.

An Operational Perspective on Vertiport CONOPs – Weather-Driven Planning, Integration, and Flight Operation

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The integration of vertiports into urban environments is a critical enabler for the successful deployment of advanced air mobility (AAM) systems. However, the lack of operational experience and the complexity of urban constraints pose significant challenges—not only to site selection and infrastructure design, but also to the reliable and safe operation of vertiports. These challenges are further compounded by the need to ensure seamless interoperability between vertiports, U-space services, and classical air traffic management (ATM) systems within existing airspace structures. Addressing these interdependencies is essential to enable scalable, safe, and sustainable AAM operations in complex urban environments.

Weather is a critical component in the assessment, operation, and integration of vertiports. It directly influences track usability, service availability, and safety margins, and must be considered in both strategic planning and real-time operational decision-making. Unisphere GmbH has developed a simulation-based methodology to support vertiport planning and operations, leveraging historical weather data, regulatory frameworks, and digital infrastructure. The Smart 4D Trajectory technology, originally inspired by the Solar Impulse project, enables evaluation of vertiport usability under varying meteorological and airspace conditions. This includes automated risk assessment, wind pattern analysis, and service availability forecasting based on high-resolution weather data.

Unisphere is actively providing vertiport analysis tools today and is engaged in three ongoing vertiport projects. One of these is part of the SESAR EUREKA initiative in Rome, where Unisphere is conducting detailed usability assessments for the vertiports at Fiumicino and Piccolomini. A key outcome of this work is the development of a track analysis framework that evaluates approach and departure track usability based on wind limits, airspace restrictions, and eVTOL performance parameters. This framework, developed under the EUREKA project, supports regulatory compliance with EASA's requirement of >95% track usability and informs infrastructure design decisions.

In parallel, the presentation outlines the evolving regulatory landscape for vertiports in Europe. While VFR operations are currently governed by national regulations based on EASA's prototype specifications (PTS-VPT-DSN), a comprehensive EU-level framework for IFR vertiports is under development, with finalization expected in 2026. The NOVA Vertiport solution is introduced as a digital platform that integrates real-time weather data, METAR/TAF, and sensor fusion to support safe and efficient vertiport operations. NOVA combines aviation-grade weather sensors with cloud-based data management and API-driven distribution to ensure situational awareness and operational continuity.

The presentation will provide detailed insights into vertiport assessments, weather information, and the technologies applied to support operational decision-making. It will also actively explore the fine line between high-resolution micro weather forecasting and more pragmatic, operationally viable approaches to weather integration at vertiports. Key findings include the identification of optimal track orientations, quantification of weather-induced constraints, and the role of digital infrastructure in enabling safe and scalable vertiport operations.

This work contributes to the development of scalable solutions for vertiport integration, addressing both technical and regulatory challenges in the evolving landscape of urban air mobility.

Biography

Michael Anger

Michael Anger is Co-Founder and CTO of Unisphere GmbH, a German start-up developing smart software for automated drone and air taxi operations. An aerospace engineer and former Flight Director for Solar Impulse, he now leads innovation in simulation-based flight management and weather analytics for urban air mobility.

Vertiport Integration into the European Airspace: A first glimpse into the EUREKA Whitepaper

Karolin Schweiger
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The successful deployment of Innovative Air Mobility (IAM) in Europe depends on the seamless integration of vertical take-off and landing capable aircraft (VCA) and vertiports into existing airspace structures. A Whitepaper, developed by the EUREKA consortium, critically examines the regulatory, operational, and infrastructural challenges associated with vertiport integration within the 500–2000 ft altitude band, an airspace layer that is currently underserved by both traditional Air Traffic Management (ATM) and U-space frameworks. Through a thorough examination of current European and international regulations, the Whitepaper highlights key inconsistencies and governance gaps that impede the entry of and hinder the scalability of IAM operations. Focusing on operational vertiport research, the EUREKA project evaluates the emerging roles of IAM operators, vertiport managers, the local vertiport network, ATM and U-space Service Providers (USSP) in coordinating IAM traffic in low-level airspace. The findings emphasize the need for a harmonized regulatory baseline, clear understanding of roles and responsibilities, and local operational governance to ensure safety, efficiency, and interoperability. This presentation will summarize the Whitepaper's core insights so far, with the aim of accelerating IAM readiness across Europe.

Biography

Karolin Schweiger

Karolin Schweiger is an aerospace engineer at the EUROCONTROL Innovation Hub and contributes to EUREKA as a U-space and Vertiport Specialist. Previously, she worked for almost 4 years as an Urban Air Mobility researcher focusing on vertiport airside operations, the evaluation of vertiport designs using fast-time simulation and the definition of operational requirements. Karolin is currently finalizing her Ph.D. at the Technical University of Berlin.

Launching the World's First Commercial eVTOL Operation - Challenges and Opportunities

Lukas Preis
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Skyports Infrastructure will help launch an aerial taxi service in Dubai in 2026. As vertiport operator we work closely with Joby Aviation as aircraft operator and Dubai's Road and Transport Authority. The unique challenge of this project is twofold: it is the first of its kind, which makes reliance on best practices difficult. And it requires the transfer of much research and technology into the real world with all it’s no-technical constraints (political, societal, market, customer behavior).

In the presentation Skyports will give an introduction to the project scope and specifically focus on the development and design of its flagship vertiport, DXV. This vertiport is located outside the Dubai International Airport and its airfield consists of 2 FATOs serving simultaneous as stands. EIS is planned for 31 March 2026 and construction is under way, which allows for a unique real-time view into the construction progress.

We will elaborate on the various challenges that vertiport design in the real world bring. One is streamlining check-in. Our goal is to make this process as seamless and fast as possible, while reducing operational costs. This requires a mix of smart facility design, deployment of tech and re-thinking of requirements and processes. In a similar fashion, security screening needs to be fast and seamless, creating a pleasant passenger experience.

Beyond the individual vertiport, Skyports is actively working on topics relevant for the network of vertiports. With short flights (< 10 minutes) and a single vertiport operator across all four vertiports in Dubai, new opportunities and challenges arise. We need to think through flight routes, demand, accessibility and demand. All of this work is conducted to launch a vertiport network in Dubai in 2026, while allowing for scale-up of volume into profitable operations within a few years.

Biography

Lukas Preis

Lukas Preis oversees business intelligence and operations research at Skyports. After finishing his PhD on vertiport design and operations at the Technical University of Munich in 2022, he now applies his methodological expertise to the emerging AAM industry. He has a passion for simulation and helping both business and academia make data-driven decisions.

Scientific Session 7: Factors affecting Vertiport Design
Session Chair: Bernd Bassimir, German Aerospace Center (DLR)

Risk Considerations for Vertiport Planning at Airports: An integrated Approach to Safety, Security, Environment, and Privacy

Paul David Lieten, Samiksha Rajkumar Nagrare, and Nirupama Vinayakumar Nair
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The integration of vertiports at existing airports represents a key challenge for the innovative air mobility (IAM) of the future. Safety-related, infrastructural and operational risks must be systematically identified and assessed in the early planning phase in order to ensure safe and efficient integration into airport operations.

Four key focus areas are essential for safe, sustainable, and socially accepted vertiport operations: Safety (SF), Security (SC), Environment (EN), and Privacy (PV). Based on these areas, a qualitative risk assessment was conducted, with key risk indicators (KRIs) defined for each category to identify representative hazards relevant to vertiport safety, environmental impact, security, and data protection.

Each KRI is assessed in terms of its probability of occurrence and extent of possible damage. The results are then classified using the ICAO risk matrix, which enables a transparent prioritization of mitigation measures and supports informed decision-making in the vertiport planning process [1]. The following ten indicators were initially examined.

The safety-related KRIs address key operational hazards associated with vertiport integration. SF1 (see Table 1) considers the risk of crashes, both midair and on the ground, which, although extremely improbable, could have catastrophic consequences. SF2 covers physical interferences on the ground, such as conflicts with infrastructure or personnel, posing a high risk due to their frequency and severity. SF3 highlights GPS jamming as a growing threat to navigation reliability in dense airspace environments. SF4 evaluates the importance of maintaining obstacle clearance to ensure safe take-off and landing procedures within constrained airport surroundings.

Environmental risks, though not predominant, are relevant in vertiport planning. EN1 addresses weather hazards like high winds, fog, and icing, which can impair the performance of an electric vertical take-off and landing (eVTOL) aircraft by reducing visibility and affecting flight stability. While infrequent, these conditions have operational implications. EN2 evaluates pollution risks such as noise emissions and potential chemical leaks from charging or maintenance as extremely improbable with negligible severity. In contrast, EN3 highlights animal strikes involving birds or wildlife as more significant, with remote probability but major severity, potentially damaging rotors or sensors and requiring evasive action.

Security risks address potential disruptions to vertiport operations through unauthorized access (SC1) or cyberattacks on digital systems (SC2). Although these events are considered improbable, their potential impact ranges from hazardous to catastrophic,

especially in highly automated environments [2]. Early implementation of physical and digital safeguards is therefore essential.
Privacy concerns focus on data theft (PV1), involving unauthorized access to passenger or operational data. While the severity is assessed as minor, such incidents can undermine user trust and regulatory compliance.

Table 1: Risk Assessment of Vertiport Hazards Based on ICAO Matrix [1]

Probability of occurrence	**Extent of possible damage**				
	Catastrophic A	Hazardous B	Major C	Minor D	Negligible E
Frequent 5					
Occasional 4			**SF2**	**PV1**	
Remote 3			**EN3**	**EN1**	
Improbable 2		**SC1**	**SF3**		
Extremely Improbable 1	**SF1** **SC2**	**SF4**			**EN2**

The assessment demonstrates that a wide range of potential hazards spanning safety, environmental, security, and privacy domains can significantly influence the future operation of vertiports. Addressing these risks early in the planning phase is essential to ensure not only operational safety, but also regulatory compliance, environmental sustainability, and public acceptance. Future work will incorporate qualitative and quantitative risk analysis validation to assess the effectiveness of mitigation strategies at an early stage.

[1] INTERNATIONAL CIVIL AVIATION ORGANIZATION (2013), “Safety Management Manual (SMM)” (Third Edition). Quebec, Canada
[2] BUNDESAMT FÜR SICHERHEIT IN DER INFORMATIONTECHNIK (2024) “IT-Grundschutz-Profil für kleine und mittlere Flughäfen”. Bonn, Germany

Biography

Paul David Lieten

I studied Safety and Hazard Defense in Magdeburg and currently work as a research assistant at the German Aerospace Center (DLR) in Cochstedt. My work focuses on operational safety and risk assessment in the context of new aviation technologies, including vertiport integration and unmanned aircraft systems.

Effects of weather, delays, and technical disruptions on passenger satisfaction

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As Innovative Air Mobility (IAM) systems move towards reality, a need arises to focus not only on operational metrics but also on passenger-centric service quality. Passenger satisfaction influences user adoption, operational efficiency, and long-term success of any transportation system, boosting its environmental impacts and helping the country's economic development. When passengers embark with positive satisfaction, it encourages the use of multimodal systems. In that way, the transportation system is seen as reliable and convenient, heading toward broader acceptance. The satisfaction feedback from the passengers also helps the transport providers refine schedules, infrastructure, and digital services for the betterment of the system.

While existing frameworks evaluate vertiport performance, they lack the resolution to capture the diverse perceptions of individual passengers undergoing delays and disruptions. In this brief abstract, we aim to present a satisfaction model that bridges this gap by combining operational simulation with behavioral sensitivity by simulating vertiport scenarios under varying environmental and technical disruptions, delays and cancellations due to miscellaneous factors.

In this work, we introduce a metric-based satisfaction level of the passengers using the vertiport facilities. Our work is based on the HorizonUAM project [1-2] from the German Aerospace Center (DLR). Within this, our abstract addresses the effect of vertiport operations, weather conditions, and associated eVTOL cancellations and delays on passenger satisfaction. The level of passenger satisfaction is determined by developing a hybrid passenger satisfaction model that integrates dynamically weighted sensitivities, disruption penalties, and tolerance-based emotional classifications. In a vertiport simulation environment, an agent-specific satisfaction score was generated by considering the aforementioned factors.

The vertiport operations are frequently subject to non-nominal events, such as operational disruptions (missed vertiport slots /cascading delays), specific environmental conditions (particularly wind intensity and snowstorms), infrastructural failures (blocked gates / pad unavailability), or other vehicle related issues (technical faults/cancellations). These disruptions affect not only system-level performance but also have varying impacts on the passenger experience. While frameworks like Vertidrome Airside Level of Service (VALoS) [3] provide a threshold-based method for assessing operational acceptability (e.g., average delay, punctuality, cancellations), they are inherently binary and system-oriented. VALoS classifies each day or simulation run as either "acceptable" or "non-acceptable," based on global metrics, and lacks importance at the individual passenger level. As in Figure 1, passengers would prefer a smooth and ideal travel over severe delays and cancellations.

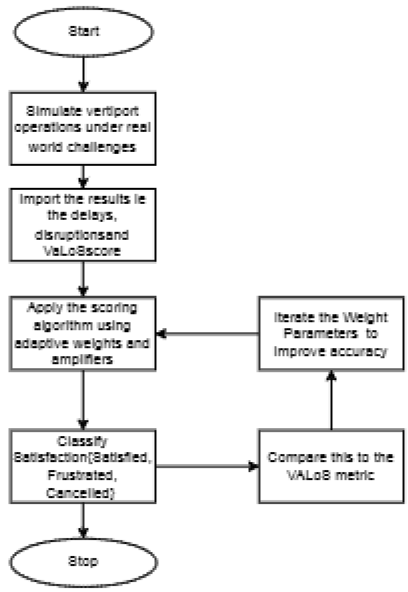

Figure 1 Framework for passenger satisfaction model

The core of our approach lies in a scoring algorithm that deducts penalties from a basis score based on the disruption data. Two types of penalties are applied, first one is the independent penalties for each disruption (e.g., delay minutes, missed slot, snowstorm), and the other are the amplifier penalties applied when disruptions that are known to interact negatively from a passenger's perspective (e.g., delay, cancellation, or snowstorm). The final satisfaction score is then evaluated against the agent's personal tolerance threshold to determine their emotional state. If the score ≥ tolerance, then the passenger is satisfied, if score < tolerance the passenger is frustrated. To validate the accuracy of our model, we compare the classifications to benchmark outputs derived from the VALoS framework.

Finally, the framework conducts a weight calibration mechanism. Using a feedback loop, we iteratively rectify the penalty weights and amplifier coefficients to minimize the mismatch between our predicted agent states and the VALoS benchmark. The result is a calibrated, validated, and personalized satisfaction model that transforms coarse system-level disruptions into nuanced, stakeholder-aware evaluations.

To add more accuracy to the algorithm, the ground truth must come from real data sources. Therefore, as a part of the future work, we further research into satisfaction data from public transport platforms such as railways (Deutsche Bahn), airports, trams and buses in Germany.

[1] Schuchardt, B. I., Becker, D., Becker, R.-G., End, A., Gerz, T., Meller, F., Metz, I. C., Niklaß, M., Pak, H., Schier- Morgenthal, S., et al., “Urban Air Mobility Research at the DLR German Aerospace Center– Getting the HorizonUAM Project Started,” AIAA Aviation 2021 Forum, 2021, p. 3197.
[2] Schweiger, K., König, A., Metz, I. C., Naser, F., Swaid, M., Abdellaoui, R., and Schuchardt, B. I., “HorizonUAM: Operational Challenges and Necessary Frameworks to Ensure Safe and Efficient Vertidrome Operations,”CEAS Aeronautical Journal, 2024, pp. 1–16.
[3] Schweiger, K., and Knabe, F., “Vertidrome Airside Level of Service: Performance-based evaluation of vertiport airside operations,” Drones, Vol. 7, No. 11, 2023, p. 671.

Biography

Nirupama Vinayakumar Nair

Nirupama completed her masters in Embedded systems engineering from the University of Freiburg and is currently working at DLR Institute of Flight guidance as a researcher. Her research includes Vertiport placements and operations.

Stakeholder Forum 2025: Interactive workshop with short presentations
Moderator: Samiksha Nagrare, German Aerospace Center (DLR), Hecklingen, Germany

2nd Stakeholder Forum for the research project VERTIFIED: Evaluation of the requirements for the planned vertiport demonstrators

Andreas Schaller[1], Samiksha Nagrare[2], Oguzhan Nohutcu[1], Kristin Wendt[1]
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The German Aerospace Centre (DLR) has already demonstrated first concepts of flight guidance of air taxis at vertiports in a scaled manner in the DLR internal research project HorizonUAM [1], which ended in 2023. Based on these results, the internal follow-up research project VERTIFIED (Vertiport Research Infrastructure for Innovation Exploration and Demonstration) was initiated to develop a concept for two vertiport demonstrators and build them up at DLR's National Experimental Test Center for Unmanned Aircraft Systems in Cochstedt. While one of these demonstrators will be developed as an “urban vertiport” to enable flight tests with Unmanned Aircraft Systems (UAS) to simulate a vertiport in urban environment, the second one will be realized as "vertiport at an airport” to facilitate UAS flight trials at a vertiport in airport environment.

After the end of the ongoing project in 2028, the vertiport demonstrators will be available to use for interested external users such as industrial partners of the test center or other research organizations. Thus, project VERTIFIED aims to extend the testing possibilities in Cochstedt for internal as well as external users of the testing facility. Therefore, the involvement of both kinds of stakeholders, internal as well as well as external from research, industry and authorities, in the early planning phase is of particular importance due to the necessity of the identifications of requirements for the demonstrators in an early stage.

By offering vertiport demonstrators as testing infrastructure to interested user groups as e.g. manufacturers of air taxis, service providers or providers of necessary hardware, the project makes a significant contribution to the commercialisation of Innovative Air Mobility (IAM). The validation and further steps in the requirements management process should lead to the realisation of the two demonstrators, which are closely oriented to the needs of the future.

While first requirements on the demonstrators were collected in the kick-off stakeholder forum in 2024, the second stakeholder forum in November 2025 will focus on the evaluation of the requirements for the demonstrators developed based on the outcome of first stakeholder event. By collecting direct feedback from later potential users of the vertiport demonstrators, the catalogue of requirements in its current version will be evaluated and completed to reach the next milestone of the project: a finalized design concept for the demonstrators.

[1] Schuchardt, B.I., Becker, D., Becker, R.G., End, A., Gerz, T., Meller, F., Metz, I.C., Niklaß, M., Pak, H., Schier-Morgenthal, S. and Schweiger, K., 2021. Urban air mobility research at the DLR German aerospace center–getting the HorizonUAM project started. In AIAA Aviation 2021 Forum (p. 3197).

Biography

Andreas Schaller

Andreas Schaller is a research assistant at the DLR internal VERTIFIED project and is one of the moderators of the stakeholder forum. He works with DLR in Cochstedt and manages supervision of the stakeholder forum. Before he started his work at DLR, he worked on headlight development projects at Capgemini Engineering for six years.

Initial concept development for a vertiport demonstrator within project VERTIFIED

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The increasing interest in the development of Innovative Air Mobility (IAM) concepts requires dedicated ground infrastructure like vertiports to support safe, efficient, and scalable operations. Recent studies have emphasized that integrating vertiports into the urban and airport environment requires careful consideration of space constraints, system interoperability, and infrastructure, particularly in dense metropolitan areas [1]. To support this development, two representative vertiport demonstrators are being conceptualized within a project from the German Aerospace Center (DLR) titled Vertiport Research Infrastructure for Innovation Exploration and Demonstration (VERTIFIED). One vertiport is aimed to be integrated into an airport environment, and the other one is located in an urban setting. The goal is to create a conceptual design to enable the implementation and assessment of different operational and technical configurations for unmanned aircraft systems (UAS) operations under realistic conditions.
The designs are developed under consideration of the current regulatory framework, like the European Union Aviation Safety Agency (EASA) [2] and stakeholder needs collected from a designated list of operators, users, and aircraft manufacturers via held stakeholders forums. The conceptual development of the vertiport demonstrators is based on a detailed requirements analysis covering operational, spatial, technical, and safety-related criteria. For the conceptual design, these requirements are then translated into categories such as physical layout, component specifications, process flow, simulation planning, and system variants. Both demonstrators aim to reflect use-case-specific requirements for infrastructure, layout, vehicle handling, turnaround procedures, and passenger flows.
At the airport site, approximately 160 hectares of fenced land are available for development. The layout planning excludes operationally sensitive zones such as runways and critical taxi areas, leaving sufficient space to design a scalable and regulation-compliant vertiport. As shown in Figure 1, the airport demonstrator plans to include 1 Touchdown and Liftoff Area (TLOF) pad, 3 adjacent parking stands equipped with high-capacity charging systems, taxiways, a terminal zone for passenger processing, emergency areas, and an approximately 1200 m² model city simulation environment, which could be scaled upon demand in future simulations.
The urban vertiport, designed for more spatially constrained conditions, proposes a compact layout that is potentially located on or adjacent to public infrastructure, such as rooftops or parking zones. The urban design incorporates features like vertical circulation

for passengers, integrated multimodal access, emergency egress systems, and noise-buffering elements. Emphasis is placed on modularity and adaptability for different regulatory or vehicle requirements.
Process flow for both demonstrators outlines a complete Vertical Takeoff and Landing (VTOL) operation cycle: arrival, landing, taxi, passenger offboarding, parking and charging, boarding, and departure. These flows are designed to ensure spatial separation between critical aircraft paths and passenger movements. Emergency procedures and ground crew logistics are also mapped into the layout. This forms the foundation for the next project phase, where both vertiport concepts will be evaluated through simulations. The simulation activities will assess the energy demand, delay propagation, and pad configuration efficiency. Supported by U-space services, the simulation framework will enable the modelling of airside processes and air taxi operations like vehicle approach and take-off procedures, ground handling, and their interaction with passenger movement.

Figure 1: Placement of the vertiport layout for airside and urban side at the Cochstedt airport [1]

The simulation framework will be used to explore operational resilience, flexibility, scalability, stress-test different traffic scenarios, and assess how vertiport configurations affect turnaround time and throughput. Scenarios involving varying demand levels and emergencies will be modelled to ensure the adaptability of the designs. These design principles are consistent with insights from [3], whose systematic review highlights essential aspects of vertiport planning such as flexible infrastructure modules, integration into existing transportation ecosystems, standardization across layouts and operations, and compliance with safety and environmental regulations.
Finally, feedback from stakeholders will be systematically integrated to refine the designs and operational procedures. This ensures that the demonstrators are optimized not only for technical performance but also for stakeholder expectations and regulatory

compliance. The validated designs will be used as blueprints for the scalable implementation of vertiports in both urban and airport environments and to support future regulatory frameworks for IAM infrastructure deployment.

[1] Schweiger, Karolin, et al. "Horizonuam: Operational challenges and necessary frameworks to ensure safe and efficient vertidrome operations." CEAS Aeronautical Journal (2024): 1-16.
[2] EASA, Vertiports Prototype Technical Specifications for the Design of VFR Vertiports for Operation with Manned VTOL-Capable Aircraft Certified in the Enhanced Category (PTS-VPT-DSN), Cologne, Germany: European Union Aviation Safety Agency, 2021
[3] Schweiger, Karolin, and Lukas Preis. "Urban air mobility: Systematic review of scientific publications and regulations for vertiport design and operations." Drones 6.7 (2022): 179). https://doi.org/10.3390/ drones6070179

Biography

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Nirupama completed her masters in Embedded systems engineering from the University of Freiburg and is currently working at DLR Institute of Flight guidance as a researcher. Her research includes Vertiport placements and operations.

Requirements for a modular vertiport design for project VERTIFIED

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An interdisciplinary project at the German Aerospace Center (DLR) titled Vertiport Research Infrastructure for Innovation Exploration and Demonstration (VERTIFIED) deals with building a vertiport concept, realizing and validating it at the National Experimental Test Center for Unmanned Aircraft Systems located in Cochstedt. Within the project, two vertiport locations will be considered: one at the airport and one in the urban area. One important aspect of the said work is to develop requirements for flexible, modular vertiport research infrastructure to plug and play with various vertiport configurations for its physical realization. This abstract encapsulates these requirements for building a 1:5 scaled vertiport for a small Unmanned Aircraft System (UAS) with a 2-meter wingspan (tip to tip). It has the characteristics of a Vertical Takeoff and Landing (VTOL) vehicle.

The regulations to be followed to build this vertiport are the European Union Aviation Safety Agency (EASA) regulations, specifically the EASA Special Condition SC-VTOL-01 [1] and the prototype technical specifications for the design of vertiports document [2]. These regulations are developed with the objective of defining dimensions, characteristics, applicability and location for the design of the vertiports where the Visual Flight Rules (VFR) are applicable. Furthermore, these vertiports will also utilize U3/U4 services provided by U-space, which are defined in EU Implementing Regulations 2021/664 [3], 2021/665, and 2021/666. With these regulations in place, the requirements for a modular vertiport that involves various components are described.

The focus of having a modular vertiport stems from having a cost-effective, stable infrastructure that is scalable in the future to hold an eVTOL for cargo delivery and passenger delivery use cases. A model city is also aimed to develop as a part of the experimentation that replicates an urban environment. Within this environment, a modular Final-Approach and Takeoff area (FATO), where the UAS takes off and lands from, will be installed on a wooden structure on a scaled building made from steel maritime containers. These containers also offer modularity when rearranging the urban area. The FATO markings will be painted on, and several omnidirectional white lights on the FATO will be installed according to the PTS- VPT-DSN specifications from EASA (given in [2]). In the case of the vertiport at the airport, the FATOs will be placed at the ground level, marked with a luminescence paint, making the FATO visible to the pilot during the day and at night. Furthermore, fencing must be installed in the airport vertiport to distinguish between the security-restricted areas, accessible airside areas, and general passenger-side areas. This fencing could be made up of steel wire rope mesh, which is flexible to install and easy to place at different locations within the scope of the distinction area.

Other modular facilities, such as the passenger terminal areas, are to be built with unhinged accordion folding partitions or walls made up of a series of panels that fold in on themselves and are bifold. The passenger terminal would also include foldable chairs for passengers to sit and a screen to display the UAS schedule. Similarly, a room for building the operations centre for the vertiport to manage, and another room is built as the same structure as a passenger terminal. This operation centre will include foldable chairs, tables, monitors, a Central Processing Unit (CPU), a mouse, a keyboard, and communication devices to communicate with the pilot, U-space Service Provider (USSP) and the Air Traffic Control (ATC) centre for manned aviation, and a radar system to locate the said UAS. Furthermore, in both these vertiports, it is essential to have a wind direction indicator in the shape of a truncated cone of lightweight fabric installed horizontally on a vertical shaft with orange and white stripes.

The aforementioned details enclosed some modular aspects for the desired vertiport. The painted FATO design could always be repainted at the airport vertiport to form an FATO for a bigger UAS or a full-scale Vertical Takeoff and Landing Capable Vehicle (VCA). Similarly, more containers can be placed together to increase the size of the FATO at the urban vertiport, thereby accommodating various VCA/UAS sizes. Hence, the modular design will bring the possibility of expansion at DLR for future VCA operations.

[1] EASA, "Special Condition Vertical Take-Off and Landing (VTOL) Aircraft," SC-VTOL-01, 2019.
[2] EASA, Vertiports Prototype Technical Specifications for the Design of VFR Vertiports for Operation with Manned VTOL-Capable Aircraft Certified in the Enhanced Category (PTS-VPT-DSN), Cologne, Germany: European Union Aviation Safety Agency, 2021.
[3] EASA, "AMC and GM to Regulation (EU) 2021/664 on a regulatory framework for the U-space," 2022.

Biography

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Dr. Samiksha Rajkumar Nagrare is a researcher at the German Aerospace Center (DLR) with a primary focus on vertiport operations and integrating them in conjunction with U-space and drones. Earlier she was with the Indian Institute of Science (IISc), Bangalore for her PhD specializing in the area of Unmanned Aerial Vehicle (UAV) Traffic Management (UTM). She is also an avid drone pilot.