

Identifying Potential Users and Their Requirements for a Virtual U-space Application

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Motivation: Within the AREA U-space project, the approach emerged to develop a Virtual U-space environment to address the current conceptual nature of U-space. Such a tool could enable the visualization, exploration, and testing of U-space concepts in a flexible, location-independent manner. By mapping 3D visualizations of urban areas, UAM infrastructure (e.g., vertiports), industrial sites, and residential zones onto real-world locations, it could support the development and validation of optimized U-space services, infrastructure decisions, and traffic management concepts. Additionally, it could facilitate the assessment of future traffic patterns and mobility solutions, as well as support applications such as urban planning, acceptance studies, and impact analyses. Mixed-reality testing, combining real and virtual elements, could further expand experimental possibilities. To explore the feasibility of this idea, research has been undertaken to identify potential users, their needs, and how they might interact with such a tool. Interviews with various stakeholders were conducted to derive initial persona profiles, providing insights into the potential user base and their requirements.

State of the Art: Current research on extended reality (XR) and digital-twin-based support systems for UAS operations primarily focuses on system architectures, prototypes, and technical validation. A prominent line of work explores augmented-reality aids for remote pilots to enhance situation awareness, integrating data such as flight parameters and safety zones into AR displays [1-3]. Additionally, digital twin frameworks are being developed to test UAS concepts and traffic management, ranging from co-simulation environments that bridge physical and virtual layers [4, 5] to multi-operator management systems [6] and crisis response tools [7]. Reviews also highlight the potential of digital twins for regulatory compliance [8]. Despite these technical advancements, empirical evidence regarding user involvement remains scarce. Existing studies predominantly evaluate technical feasibility or simulation accuracy, with limited formative research on operational users [3, 4]. Consequently, systematic knowledge about user needs, role-specific information requirements, and interaction preferences constitutes a significant gap. To address this, the present study investigates the specific requirements of potential users for a Virtual U-space through empirical interviews.

Method: The research employed a mixed-methods approach comprising expert interviews and a subsequent questionnaire survey. Between August and September 2024, online expert interviews were conducted with 17 stakeholders representing diverse

fields such as DLR, aviation authorities, industry, and start-ups. The primary objective was to elicit requirements for a Virtual U-space regarding visualization, system features, and interaction capabilities. Sessions lasted approximately two hours and employed a digital whiteboard to facilitate interactive discussions on professional backgrounds and specific use cases. The qualitative data were analyzed using standard content analysis techniques; interview statements were systematically coded, paraphrased, and condensed into core keywords.

Based on the interview results, persona profiles were developed and subsequently evaluated through an online questionnaire administered to ten DLR scientists. Participants assessed their identification with the derived persona profiles. Furthermore, they categorized specific requirements using a prioritization scale ranging from "must-have" to "nice-to-have."

Findings & Conclusion: Qualitative analysis identified five application domains, with "UAS operational support" and "Research" emerging as the most prominent categories, reflecting the specific focus of DLR experts. Requirements were consolidated into four thematic clusters: visualization, content/functions, interaction, and framework conditions. Visualization demands emphasized flexibility between 2D maps and 3D views. While operational scenarios prioritized technical precision and immersion, decision-making tasks required clearer presentation over high realism. Key information requirements included real-time drone positions, flight parameters, weather data, traffic flows, and ground risk zones. Interaction preferences highlighted the potential for VR/AR interfaces alongside standard desktop applications, featuring multi-user capabilities for collaboration and expert approval. Adaptability was crucial, with requests to integrate external simulation data (for research) and edit city models (for planning). General requirements stressed seamless integration into existing tools (e.g., Unreal Engine) and cost-efficiency. Based on the predominant use cases, two persona profiles, representing operational support and research, were derived. These profiles were subsequently validated by 10 DLR scientists via a questionnaire survey, with most participants confirming that they could identify with the presented user profiles. Prioritization ratings identified specific "must-have" features across visualization, information, and usability categories, narrowing down the extensive requirements to core functional priorities.

In conclusion, the derived persona profiles provide a valuable foundation for developing prototypes of a Virtual U-space by identifying key functional requirements and clarifying user expectations regarding utility and interaction patterns. However, the sample's heavy reliance on DLR experts represents a notable limitation. Future research must therefore incorporate a more diverse range of stakeholders to uncover broader use cases. Expanding the participant pool to include external industry partners or even the general public could further validate these findings, allowing for a deeper exploration of potential application scenarios and a refinement of persona profiles beyond the current scope.

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Biography

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Maria Stolz is a human factors researcher at the Institute of Flight Guidance of the German Aerospace Center (DLR) in Braunschweig. She absolved her Bachelor's and Master's Degree in Psychology at the University of Innsbruck. Her research focuses on the public acceptance of drones and autonomous transport systems.