

Abstract

Communication in U-space: Results and Lessons Learned from the mFund Project SKADRO

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The integration of uncrewed aerial vehicles (UAVs) into U-space requires communication and surveillance systems that can reliably support the exchange of aircraft state and traffic information as well as telemetry under diverse operational conditions. The mFund Project SKADRO (Scalable Drone Communication Systems for U-space Areas) investigated the practical requirements for scalable UAV communication and cooperative surveillance. Emphasis was placed on the use of LTE as communication backend, complemented by Software-Defined and ultra-wideband radios as redundant means of communication. The project focused on the practical evaluation of these technologies under realistic operating conditions and on identifying the arising challenges when integrating them into U-space.

A central result of SKADRO was the successful use of LTE as a communication link for UAVs. Flight tests were conducted in rural, urban, and mixed-airspace environments, covering different propagation and operational conditions. Throughout the tests, the LTE connection remained stable and available, demonstrating the feasibility of commercial cellular infrastructure for U-space operations. This is particularly relevant, since LTE can provide connectivity using existing infrastructure and does not rely on dedicated communication infrastructure in the flight area. Beyond the exchange of surveillance and telemetry data, LTE was also successfully used for video transmission and beyond-visual-line-of-sight (BVLOS) UAV control, demonstrating its capability to support both high-bandwidth payload data as well as operational control functionality.

The project also investigated cooperative surveillance using Automatic Dependent Surveillance – Light (ADS-L). An implementation of the official EASA Standard based on software-defined radios was integrated into the system. Additionally, an original contribution was the development of an extended ADS-L message structure capable of transmitting raw Global Navigation Satellite System (GNSS) measurement data. Instead of only transmitting a processed position solution, raw GNSS observations provide additional information that can be used for high precision relative navigation and separation assurance applications.

The flight testing revealed that the main challenges were not associated with the LTE communication link, but with the integration of other surveillance technologies. Issues were encountered with Automatic Dependent Surveillance – Broadcast (ADS-B) in urban environments and with the SDR-based ADS-L system. These issues were independent

of the LTE communication link and were primarily related to the respective receiver and radio implementations. These experiences highlight that the successful deployment of a U-space communication architecture highly depend on radio-frequency constraints, hardware implementation, interoperability, and the characteristics of the surveillance technology itself.

The results obtained in SKADRO consequently provide a systems-level perspective on U-space communication. The flight test campaign demonstrated that LTE provides robust and continuous connectivity across different operating environments, including the support of surveillance, telemetry, video transmission, and BVLOS control, while the practical limitations encountered with ADS-B and ADS-L shifted the focus toward receiver availability and radio frequency implementations of these technologies.

Overall, SKADRO demonstrates the feasibility of LTE-based communication for scalable UAV operations and contributes an experimentally validated ADS-L implementation with extended messaging capabilities for raw GNSS measurement data.

The project also provides practical lessons on the integration of cooperative surveillance technologies into U-space environments. These results underline the importance of evaluating communication, surveillance, and implementation aspects as a full integrated system accounting for the requirements of all stakeholders.

The findings provide a foundation for the design of future U-space communication architectures in which reliable cellular connectivity can serve as communication backbone for a range of operational and safety-relevant applications.

Biography

Fabian Frickenstein



Fabian Frickenstein holds Bachelor's and Master's degrees in Mathematics and worked at Zuse Institute Berlin during his studies, focusing on the verification of mixed-integer programming results. He later joined the Chair of Flight Guidance and Air Transport as a research assistant and PhD student, where he is responsible for the mFund project SKADRO and focuses on UAV information exchange and navigation.