

Abstract

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 areal, 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.

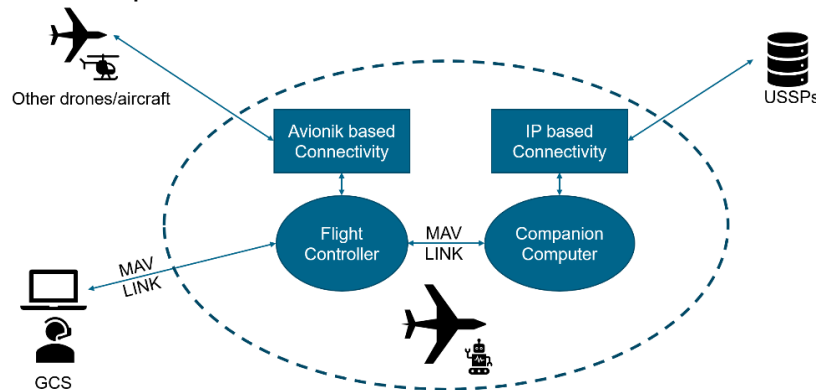


Figure 1 Drone to U-space interaction schema.

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.

[1] G. Strickert, S. Schopferer, F. Krause, P. Nagarajan, „Automatische Verhandlung zwischen U-Space und unbemannten Luftfahrzeugen“, DLRK 2024, 2024 ,Hamburg

[2] F. Krause, P. Nagarajan “U-space TWICS: A meta U-space service concept to aid developing communications between autonomous uncrewed systems”. In: Drones and Unmanned Systems, 1, Seiten 108-113. IFSA Publishing, DAUS 2025, Granada, Spanien. doi: 10.13140/RG.2.2.18747.94240.

Biography

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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.