Towards Unmanned Aerial Vehicle UTM-integration using mobile radio networks

K. Kainrath*,M. Gruber*, A. Hinze*, H. Fluehr* and E. Leitgeb **
* Institute of Aviation/FH JOANNEUM, Graz, Austria
** Institute of Microwave and Photonic Engineering/TU Graz, Graz, Austria
klaus.kainrath@fh-joanneum.at

***Abstract* - The Single European Sky ATM Research Joint Undertaking (SESAR JU) U-space research program proposed in 2017 a blueprint of UAV services along a timeline towards a fully autonomous Air Traffic and Unmanned Traffic Management (ATM and UTM), together named as U-space. The initial plan was to achieve this goal within four steps until 2035. Within the first phase the realization of UAV remote Identification (ID) and UAV tracking services as a basic prerequisite for a technical implementation of a UTM system was planned. Since there is still a lack of standardization in the field of UAVs, mobile radio technologies would be ideal for implementing phase one and further U-space services. In the following, the challenges for the mobile radio technology to be used in the U-space program will be considered.**

Keywords - UAV; UTM;mobile radio, SESAR

I. Introduction

The Single European Sky (SES) initiative has launched the Single European Sky ATM Research (SESAR) Programme as a critical part. Within this programme, the technological pillars of SES are represented. The focus is to modernize and introduce high-performance air traffic control infrastructure to the Air Traffic Management (ATM). This should lead to a safe and environmentally friendly development of air transport services.

Within SESAR there is a partnership of public and private sectors called the SESAR Joint Undertaking (SESAR JU, SJU). The members provide experience, expertise as well as funding for appropriate research.

As the market of Unmanned Aerial Vehicles (UAV) or commonly known as drones, is rapidly increasing in Europe and worldwide, a variety of new business cases emerge. According to the European drones outlook study [1], it is expected that by 2050 more than 400 000 UAVs will provide airborne services with a total market value of more than EUR 10 billion annually by 2035. Through this outlook, the European Commission launched the so-called U-space program in 2016. The goal of this initiative is to guarantee a safe and secure integration of UAVs into the airspace.

SESAR JU started in 2017 a number of exploratory research projects which should thematically explore the following topics for the future U-space Services: concept of operations (CONOPS) for drone operations, information management, ground-based technologies, critical communications, surveillance and tracking, cyber-resilience and geofencing. Figure 1 provides an overview of the partners and institutions involved in the program. In 2018 SESAR JU started the first demonstration projects.

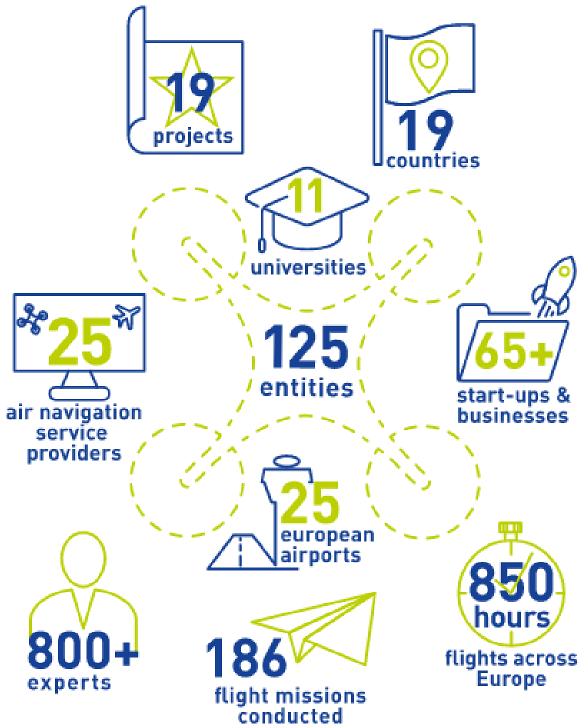

Figure 1: Numbers related to the U-space innovation and research [2]

For this reason, research projects such as CORUS, Gulf of Finland (GOF and GOF2.0), EuroDRONE and many more (see table II) have been or are currently carried out as part of the U-space Program, in which possible scenarios are being tested [2].

This work gives an overview about the current and upcoming challenges for mobile radio service providers as well as Unmanned Aerial Vehicle (UAV) operators to implement technologies for a possible integration of UAVs into the U-space. U-space is intended to be a set of services and procedures relying on a high level of digitalization and automation of functions to support a safe, efficient and secure access to airspace for a large number of drones [3]. These services should be implemented in four steps (U1 – U4) within a planned timeline until 2035. These four steps can be seen in figure 2.

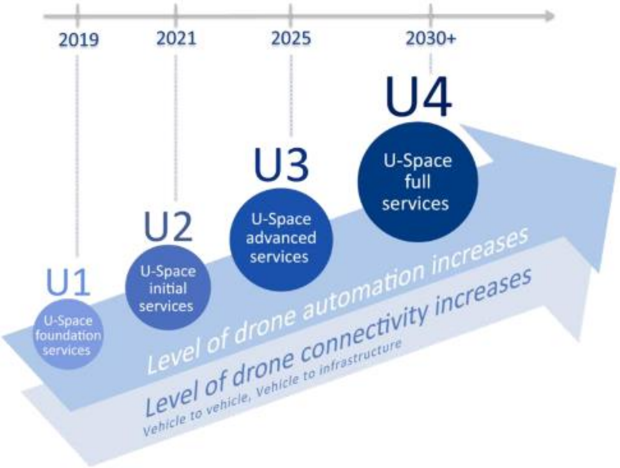

Figure 2: The planned U-space timeline [4]

An overview about the initial plan for the four phases of automation according to the SESAR U-space blueprint is given in table I:

TABLE I. THE INITIAL U-SPACE PLAN [5]

Phase	Planned U-space implementation grades	
	U-space service	***Planned technologies***
U1	Foundation service	e-registration, e-identification, geofencing
U2	Initial services	Management of drone operations that may includes flight planning, flight approval, tracking, airspace dynamic information, interfaces with ATM
U3	Advanced services	More complex operation in dense areas that may include capacity management, conflict detection, automated Detect and Avoid (DAA), advanced communication
U4	Full services	Integrated interfaces with manned aviation, support the full operational U-space, relys on high level of automation, connectivity and digitalisation

II. CURRENT STATUS

On the webpage of ATM Masterplan [6] hosted by SESAR it is mentioned, that the phase U1 is actually in its deployment phase which should be finished with the end of 2022. Unfortunately, the implementation is not carried out uniformly. This means that many countries implement the European Union Aviation Safety Agency (EASA) regulations differently. Furthermore, there are also significant differences to the implementation between Europe (EASA) and the USA where it is implemented by the Federal Aviation Administration (FAA).

In Austria and Germany, electronic registration (eID) works by registering the operator and the UAV with the authorities as part of the certification process in accordance with the EASA UAV regulations, which were introduced throughout Europe in January 2021. The regulations were developed by EASA and published under the designations (EU Regulations 2019/947 and 2019/945 [7]) as a uniform framework for the use of UAVs for implementation at the national aviation authorities. With these regulations, UAVs are now classified within three classes, OPEN (with three subgroups), SPECIFIC and CERTIFIED, according to the risk of the mission (operational area, mission height, BVLOS) and type of the UAV (e.g., weight). Figure 3 gives an easy overview on these classes:

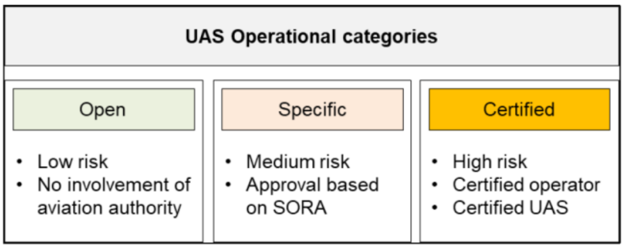

Figure 3: EASA UAV classification [8]

The following description of the approval process is according to the Austrian implementation of the EASA UAV regulation which can be found on the special UAV website of the Austrian authority called “dronespace” [9]. Most UAV applications in the private sector are covered by the OPEN category. Commercial UAV missions fall mostly into the SPECIFIC category. The highest class, CERTIFIED, is for very large UAVs and for very high-risk missions. For this, the requirements are tied to the safety requirements of civil aviation.

For the OPEN category, a corresponding e-registration with the authorities and the completion of a drone operator's license are currently sufficient. UAV use within the SPECIFIC category can only be carried out after a risk assessment. This risk analysis, also called "Specific Operation Risk Assessment" (SORA), is either carried out and published in advance by the competent authority or prepared by the operator. In the event of a successful application with a sufficient SORA, the authority will issue an operating license for the UAV mission applied for.

An application for an operating license can only be submitted using the application form provided for this purpose. The application must be accompanied by a risk assessment (SORA), details for the preparation of such a risk assessment can be found in the EASA Easy Access Rules.

To simplify the risk assessment, frequently occurring missions are treated as a standard scenario. If the operation falls under a so-called standard scenario, a risk assessment has already been carried out for the corresponding mission type and the necessary safety precautions and requirements have been defined. Therefore, the operator does not have to perform a risk assessment anymore, it is sufficient to declare the compliance of the operation with the corresponding scenario and the compliance with the established requirements.

In the certification process, the operator receives a sticker that must be prominently displayed on the UAV.

Electronic identification has already been evaluated within SESAR funded research projects. Technologies from aviation, such as Automatic Dependent Surveillance - Broadcast (ADS-B), FLARM (proprietary electronic system that can broadcast flight position data via Global Navigation Satellite System (GNSS) and barometric altitude), and mobile radio networks have been used. Within these projects the mentioned technologies were used and their functionality was demonstrated, but there is still a need for research in the field of interoperability of these technologies and urgent standardization of UAV hardware. The requirements increase especially when it comes to beyond-visual-line-of-sight (BVLOS) flights. Within the new UAV framework, UAV missions can now be performed within the visual-line-of-sight (VLOS) of the pilot, the extended-line-of-sight (EVLOS), which means the pilot has an assistant that monitors the UAV or BVLOS, where there is no visual contact to the UAV given. This is illustrated in the following figure 4:

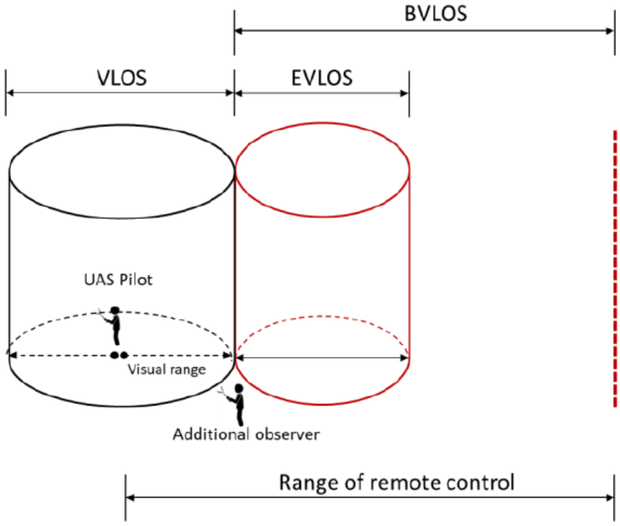

Figure 4: Separation of VLOS, EVLOS and BVLOS [9]

As seen in figure 4, the UAVs maximum operation range is the range of the remote control. This problem can be circumvented by using cellular radio. However, the problem here is that there is currently very little commercial hardware available for the use of mobile radio for UAVs, and else one has to rely on custom-developed solutions.

Thus, it can be stated that at the current time, no dedicated UAV hardware is used for UAV missions in the SPECIFIC category because it simply does not exist yet. Therefore, commercial products are used, which means that depending on the application, commercial UAVs are often utilized. UAV pioneers like DJI have a very advanced portfolio of UAV models that can be used for many use cases. Furthermore, there are also open UAV-platforms from many manufacturers, where in addition to the airframe and the flight controller, additional hardware for e.g., the data link or sensor technology can be installed. At present, it does not matter what is built in, because the authority decides according to the SORA conducted for the planned UAV mission whether a mission is approved or not.

This means that mobile radio is currently already being used as a data link. Since mobile communications technology was not primarily developed for use by UAVs, it is not easy to assume sufficiently good reception even in Very Low Level (VLL) airspace. In addition, there is a lack of appropriate Quality of Service (QoS) implementations in the mobile radio standard to ensure, for example, that there is a reserved bandwidth in the base stations used to guarantee that a Command and Control (C2) data link can always be maintained (e.g., handover).

III. Related Research

SESAR JU started exploratory research projects in 2017 that covered the research of different U-space services with a special focus on the concept of operation (CONOPS). In 2018 the SESAR U-space demonstration projects were launched, which, building on the previously collected results, should demonstrate U-space services.

These included projects dealing with parcel deliveries between two densely populated cities, the transport of material for medical emergencies, police surveillance missions and even air cab trials in airport-controlled airspace. Scenarios were also shown for amateur UAV pilots on how private drone operators can benefit from U-space services. The projects aimed to demonstrate the different levels of automation possible, as well as the seamless exchange of information between multiple service providers in the same geographic area at the same time. Table II gives an overview of some of the ongoing SESAR U-space research, that were open at the SESAR WAVE3 call for very-large scale demonstration projects (VLD2):

TABLE II. SESAR U-space demonstration Projects [10]

Project Name	***Project Goal***
AMU-LED – Air mobility urban large experimental demonstrations (VLD02)	Development of CONOPS for urban air missions, performing simulations and a real flight demonstration
CORUS-XUAM – Concept of operations for European U-space service – extension for urban air mobility (VLD02)	Demonstration of support of U-space services and solutions to support urban air mobility (UAM)
GOF 2.0 – Integrated urban airspace very large-scale demonstration (VLD02)	Demonstration operational validity serving combined Unmanned aircraft System (UAS), electrical vertical take off and landing (eVTOL) and manned operations in a unified, dense urban airspace using current ATM and U-space services and systems
SAFIR-MED – Safe and flexible integration in advanced U-space and flexible services focusing on medical air mobility (VLD02)	Demonstration of the combined operation of UAV platforms with manned avioation in a real-life environment to validate the used technology

FH JOANNEUM is currently working on two research projects on this topic. In September 2018, an innovation lab under the title AIRlabs [19] was acquired through the Take Off funding program. The consortium around FH JOANNEUM is working together with renowned partners from industry and research on this project for 5 years.

It is planned to provide UAV operators with a test platform that on the one hand enables real operational environments and airspace for UAV flights and on the other hand also offers the possibility of indoor tests and simulations. In addition, a project called EMOTE (Evaluation of Mobile radio for UTM Systems) was launched in January 2022 to determine the special requirements in Austria for the use of mobile radio for UAVs. With regard to BVLOS UAV operations, the project will investigate how this technology can be used in remote mountain regions for rescue and search missions.

IV. TECHNOLOGICAL DEVELOPMENTS AND CHALLENGES

A large percentage of civil UAV applications will be assigned to the OPEN category in the future. This applies to hobby pilots with camera UAVs as well as commercial users who operate their UAVs in the visual range. In principle, the current technologies derived from model making would be sufficient for this, if it is purely a matter of controlling the UAVs. From the current point of view, there is no dedicated hardware for the data link for the SPECIFIC category. In addition to model-making components, special long-range radio modules are used that do not always comply with the legal framework, as they often operate with more transmitting power than is permitted by the authorities in order to cover the large ranges. This poses great risks for other services operating on these frequencies due to interference in these frequency bands.

In the SPECIFIC category, most of the time classic remote controller (RCs) are being used as the primary data link as well as third (3G, UMTS) and fourth (LTE) generation mobile radio as the secondary data link. Especially the combination of direct control via RC and fly-by-wire, or waypoint control via the cellular network is the most promising approach. This has already been proven in successful UAV test flights together with Austro Control as a partner [11].

In the meantime, various companies such as Botlink [12] Globe UAV [13], or DroneIQ [14] have already recognized the potential of mobile radio for UAVs and offer complete hardware packages, although this has not been officially recommended or approved by the authorities. Furthermore, there are companies like Dimetor [15], who are also involved in the SESAR GOF2.0 project, that in cooperation with mobile network operators can provide the status of the mobile network in graphical form for UAV operators. This will help operators to examine whether the signal quality on the planned route is sufficient before a UAV flight over the mobile network takes place.

Mobile communications in the current fourth and soon fifth generation also offer great potential for unmanned aviation. Mobile communications companies in particular are hoping for special use cases in order to generate new sources of revenue. In addition to high data rates, the new fifth-generation mobile communications standard (5G) should also enable very low latencies of less than 10 ms, which would be ideal for (UAV) control tasks in particular. Through Horizon2020, which was an EU-wide funding program for innovation (from 2014 to 2020), the 5G Drones platform was created. Through this program, use cases for 5G applications for UAVs are to be defined since June 2019 [16]. One use case, UAV Traffic Management using 5G networks is shown in figure 5.

The consortium is very large and includes mobile operators as well as companies, for example, Frequentis AG from Austria, which is heavily involved in the topic of Unmanned Traffic Management (UTM) services [17]. In the future, a UTM system will also be a fixed component of the U-space program, since it will use the services developed within the framework of U-space.

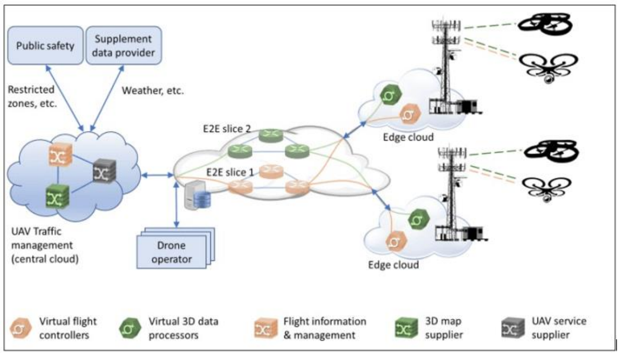

Figure 5: UAV Traffic Management using 5G networks [16]

Mobile technology will definitely be the key to the implementation of U-space services in the near future. This is also shown by the large number of scientific publications in this area, which have been steadily increasing since 2017 [18]. Table III shows planned phase U2 U-Space services and their potential implementation via mobile technology:

The biggest challenges for mobile operators will be Quality of Service (QoS), dedicated bandwidths, multiprovider applications and antennas optimized for VLL. A QoS must guarantee that control commands (C2) can always arrive at the UAV even in the case of a heavily loaded network. Bandwidth within cells should also always be reserved for UAVs. This is the only way to ensure that in handover scenarios, when UAVs switch from one base cell to another, they again have resources for the data link.

It must also be possible for all available providers to be accessed immediately via an electronic SIM card (eSIM), for example. In this way, it is possible to switch seamlessly from one provider to another in the event of a poor connection. Blockchain technology would offer a possible implementation for this.

Ultimately, it will also be necessary to use optimized antennas on future optional UAV routes in the VLL, which will also be able to connect the VLL space appropriately well with a mobile network coverage.

TABLE III. U-SPACE TECHNOLOGIES IMPLEMENTED VIA MOBILE RADIO

U-space U2 service	***Requirements***
Tracking (position report submission)	Tracking via assisted GNSS (triangulation of base stations in addition to traditional GNSS data) is already possible on mobile end devices. Commercial hardware for UAVs have to be implemented.
Surveillance data exchange	Automated GNSS information can be broadcasted over the mobile radio network (IP based). This data can be easily transferred to any desired network location.
Geo-fence (inc. dyn. Geo-fencing)	A definition of an interface between UTM service and flight controllers has to be implemented. Dynamic updates of geofencing may be actualized via the mobile radio data link to the flight controller.
Incident/Accident reporting	Can be coupled with tracking data. If no data is sent anymore, the last known position will be retransmitted. Also a mobile radio emergency transponder can be installed.
Monitoring	Can be implemented according to the tracking service.
Communication infrastructure monitoring	Preflight route planning; observation, if there are possible radio dead spots on the planned route (e.g., by services of companies like Dimetor).
Overall information service	If operators, UAVs and UTM service providers are all within an IP based network, then any data exchange can easily be realized.

V. CONCLUSION AND OUTLOOK

For the use of mobile radio in UAVs, it applies that this technology can be used in principle, but not without redundancies. This means that RCs from the model-making industry should be used for take-off and landing operations, as these have been tried and tested in the line-of-sight (LOS) range and function perfectly. In the flight phases, a flight controller can be used to control the UAV autonomously via mobile radio using waypoints on the one hand, or via a ground station and a control device (e.g., joystick) using fly-by-wire on the other. It should be considered that not only one provider is used and that external antennas are attached to optimize the reception quality. Furthermore, emergency scenarios should always be implemented in the flight controller for BVLOS applications. This can be a "Hold Position" or "Return Home" algorithm.

First and foremost, it will be crucial to standardize the communication hardware for UAVs, on the ground as well as for the UAVs themselves. Furthermore, the development and implementation of the 5G standard must be examined. At present, the fourth mobile communications standard still lacks essential technical requirements for a corresponding U-space service implementation.

Mobile radio providers, UAV authorities as well as UAV operators will have to develop solutions for QoS, reserved bandwidth, multiprovider SIM, optimization of antennas as well as a network interface to implement U-space data services over the mobile radio network.

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