Aerodrome Controller's decision support for the approval of UAS operations

Tímea Vas
Aerospace Controller and Pilot Training Department
University of Public Service
Szolnok, Hungary
orcid.org/0000-0002-0082-0370

Miroslav Kelemen
Department of Flight Training, Faculty of Aeronautics
Technical University of Košice
Košice, Slovak republic
orcid.org/0000-0001-7459-927X

Róbert Rozenberg
Department of Flight Training, Faculty of Aeronautics
Technical University of Košice
Košice, Slovak republic
orcid.org/0000-0001-7133-4532

Csaba Fekete
Aerospace Controller and Pilot Training Department
University of Public Service
Szolnok, Hungary
orcid.org/0000-0002-1181-8276

Matej Antoško
Department of Flight Training, Faculty of Aeronautics
Technical University of Košice
Košice, Slovak republic
orcid.org/0000-0003-1951-9569

Matyas Palik
Aerospace Controller and Pilot Training Department
University of Public Service
Szolnok, Hungary
orcid.org/ 0000-0002-2304-372X

***Abstract*—Unmanned Aircraft System (UAS) may means potential benefit for airport operations but at the same time, they pose risks when interacting with manned aviation. Airports as potential sites for drone operations have been examined from several perspectives. Many of them in Europe and the United States are in use as test sites, and 10 years ago, a civil-military joint-use airport in Afghanistan allowed drone operations alongside with the civilian and military traffic. In both cases, the safe operation of unmanned and manned flights were solved by procedural separation - in the first case by designating a Special Use Airspace over the airfield dedicated for UAS flights, in the second case a safe distance was defined from a navigational reference point together with runway closure that served as a guarantee of separation. The European Union Aviation Safety Agency (EASA) considers UASs and their remote pilots as airspace users who should implement and apply the same rules and procedures that manned aviation does. At the same time, their management means high risk due to the lack of separation standards and procedures for air traffic control services. Our research focuses on the controlled aerodrome environment, within which we aim to develop a system to support the Aerodrome Controller (Aerodrome Controller; also referred to as Air Traffic Control Officer ATCO) decisions to issue clearances at an integrated model airport.**

Keywords—UAS, controlled aerodrome, ADC decision supporting, airspace class,

I. Introduction

The development of the use of unmanned aerial vehicles for civil and other special purposes creates space for the investigation and verification of operating procedures with the aim of safe and smooth flight operations. In general, one important work package consists of registered UAVs/UASs. The second work package consists of problems with the operation of unregistered UAVs/UASs. Our project focuses on the portfolio of problems of the first work package, in the subgroup of procedures and coordination over the airport and in its area of responsibility.

When researching selected topics for military purposes, researchers' findings in the field of civil operations and trends are also inspiring. For example, NASA is leading the nation rapidly ushering into this new era of air transportation called Advanced Air Mobility [1]. In the environment of the European Union, we find institutional knowledge at the level of EASA, or in various working platforms such as the Urban-Air-Mobility Initiative Cities Community of the EU's Smart Cities Marketplace etc. [2]. The trust and acceptance of citizens and future users of Urban Air Mobility (UAM) will also be critical to success [3]. The rapid rise of the number of Unmanned Aerial Vehicles and their integration into smart city initiatives has sparked a surge of research interest in a broad array of thematic areas [4]. The study of Patel et al. thoroughly reviews the literature to determine the most common cyber-attacks and the effects they have on UAV attacks on civil targets [5]. The military community finds perspectives on the issue of unmanned aerial systems within the so-called U-Space military concept [6] and the report as in [7].

The "European Standard Scene (STS)" is also a methodological guideline having a predefined operation described in Annex 1 to Regulation (EU) 2019/947, which will apply from 1 January 2024 [8]. It is one of the various options for operators to launch our operations within the airspace structure including the test airspace and airfield.

Visual Line of Sight (VLOS), Extended Visual Line of Sight (EVLOS) and Beyond Visual Line of Sight (BVLOS) are used regularly by the drone industry [9]:

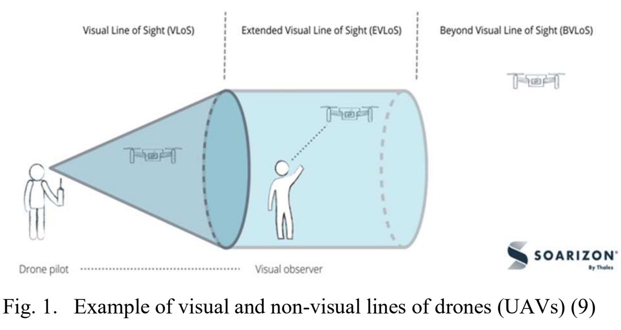

Fig. 1. Example of visual and non-visual lines of drones (UAVs) (9)

Two EU STSs have been published so far;

979-8-3503-7041-6/23/$31.00 ©2023 IEEE

STS 01 – VLOS over a controlled land area in an inhabited environment.
STS 02 – BVLOS with Airspace Observers over a controlled ground area in a sparsely populated environment [10].
Due to the project's goal, the primary scenario will be STS 01, on the research path leading to the STS 02 scenario in military and civil operations conditions.

The preliminary knowledge and the goal of our project, to develop a system to support the ADC (Aerodrome Controller) decisions to issue clearances at an integrated model airport, influenced the formulation of the research questions (RQ), to which the researchers are looking for verified answers:
RQ1: What is the sufficient level of detail about the operation of an unmanned vehicle between its operator and the air traffic controller for safe flight operations?
RQ2: Does 3D data visualization have the potential to improve the support of air traffic management decision-making processes at the airport and within its jurisdiction?
RQ3: Is it better to simplify ADC decisions regarding UAS to "Go" or "No go" for safe and smooth flight operations?

II. RESEARCH BACKGROUND

In the field of UAS flight integration, we have always focused on the aerodrome environment and its controlled airspace. That environment is the bottleneck of many different flight profiles and movements, and it has many decision-critical points, both from an ADC and Pilot in Command (PC) perspective. Procedures of fixed-wing UAS used at a controlled aerodrome and in a controlled airspace in Afghanistan and the incidents that happened during their operation raised a number of issues that are worth researching as they highlighted that ADC standard procedures are not always applicable. On radar and 3D tower simulator within a Hungarian military aerodrome environment we tested the UAS procedures that were used in Afghanistan [11]. The findings revealed:

- The UAS ground handling ramp should be separated from the manoeuvring area, but have a direct access to the runway in order to prevent from being blocked by the manned traffic flow.
- Standard procedures for departure and landing make UAS movements more predictable for ADC.
- We declared the significant points of coordination between ADC and Approach Controller (APC) during UAS operations.
- The priority issues of manned vs. unmanned traffic should be continuously revised in dependence on scenarios.
- Aviation radio phraseology should be enlarged with UAS-specific terminology for identification, taxiing, departure, and arrival procedures [12].

As the demand for experimental drone flights has increased, including the implementation of a drone-based atmospheric measurement system [13], our research focused on the ideal test airspace and airfield. Such a small country as Hungary where the airspace is similarly small, “multicolour”, fragmented, and more than 50% is controlled we should formulate suggestions about a test airspace structure which is scalable, does not constitute a significant obstacle to air traffic, is pre-tactically predictable, and designated over various topography and fauna [14].

The features of the airspace over the test site should draw each airspace user’s attention to the hazards that may occur with its activation. The test airspace, the ad-hoc segregated airspace, and the authorized UAS operation in uncontrolled airspace are similar in that they are used at the UAS operator's own risk. Within a controlled airspace, the responsibility is shared between UAS Remote Pilot (RP) and ADC to prevent collisions, establish separation, and ensure the rapid and regular flow of traffic.

International research groups also pay attention to issues on the safe integration of UAS traffic into controlled aerodrome environment. The FAA in cooperation with MITRE group conducted empirical research, carried out UAS traffic analyses in the National Airspace System (NAS), simulated complex and emergency traffic scenarios in ATC simulator lab in order to identify UAS impacts on ATC procedures and workload. Their findings revealed that five major areas should be focused on:

- UAS flight planning and automation.
- UAS control link.
- UAS specific information and procedures.
- ATC training.
- UAS interaction with the future NAS [14].

Under the umbrella of CORUS project, an international research group developed the European Very-Low-Level (VLL) U-space concept. The VLL airspace normally is not used by general, manned aviation due to it is upper limit below 500’ AGL. The concept divides the airspace into four different classes namely *X*, *Y*, *Zu* and *Za* depending on the ground risks, air risks, and the UAS flight rule. The concept included a U-space safety assessment methodology (MEDUSA) based on Specific Operation Risk Assessment (SORA) providing a holistic approach to single mission risk assessment taking into consideration the RP’s viewpoint and airspace safety [15]. An interesting aspect for our research could be the *procedural and collaborative interface* which provides information or delegates the authorization right to the ATC to agree or deny planned UAS flights in a controlled airspace [16].

There are several ongoing projects dealing with U-space digitalization and UAS contingencies on ATC separation within shared airspaces. Among them, the objective of the Single European Sky ATM Research (SESAR) PJ34AURA is to identify requirements for U-space information exchange, and define concepts for UASs in a fully collaborative environment with ATM (Air Traffic Management). The Dynamic Airspace Reconfiguration (DAR) system supports manned and unmanned traffic integration into shared airspace environment. A new position defined within Airspace Management (ASM) namely DAR Manager (DARM) who is also an ATC and whose task is to tie and coordinate the continuous UAS airspace needs into ATC working interfaces. The experiments were conducted in a simulated environment with the participation of the Royal Netherland Aerospace Centre (NLR), and the German Aerospace Centre (DLR). Four different scenarios were tested in which the UAS traffic affected ADC or APC workload, traffic handling and coordination in some way. Each scenario ran the normal and contingency UAS flight path. Briefly their comments were:

- ATC was satisfied with the information provided by DARM, but expressed concerns about too many details in a limited area.
- Agreements were needed for the separation between U-space airspace and manned traffic.
- DARM location should be optimized.
- Negotiate communication and coordination procedures between DARM and ATC in offering different solutions for U-space airspace configuration.
- UAS emergency requires immediate action from ATC who should know what is expected to happen and how much time remains.
- Providing priority for UAS emergency traffic is not always necessary and it causes delays for manned traffic, which is incompatible with real life.
- In the absence of standards for separation of manned and unmanned, and unmanned and unmanned traffic, they have only assumptions.
- According to their assumptions, most commenters agreed that vertical separation should be 500' between UAS and manned VFR traffic, and 1000'between IFR traffic [17].

Our research group was thinking along similar lines when laying the foundations of LIND-A. LIND-A is a Hungarian acronym stands for Air Traffic Controller Decision supporting system within (AR) Augmented Reality. Many features of UAS operations altered and differ from manned flights in their flight dynamics, visibility, speed, size, and flight path. That is what makes ADC support necessary in issuing ATC clearances. Our assumptions are the following:

- Issuance of ATC clearance has a timely factor that is why it would be preferable to simplify ADC decisions in connection with UAS to a Go or No go choice.
- The 3D visualisation capabilities of AR offer many advantages for ADC in traffic management.
- To ensure the smooth flow of a mixture of unmanned and manned inbound or outbound traffic and those operating in manoeuvring area, horizontal time and/or distance-based separation should be considered.

III. LIND-A DECISION SUPPORT SYSTEM

Apart from the above-mentioned model aerodrome, there are those military ones that are offered for common civil and military use. In general, such aerodromes are available for General Air Traffic (GAT) and Operational Air Traffic (OAT) that come together on different fight paths and procedures. The military ATS is sometimes under-supported with digital technologies, at the same time we think the rising number of UAS activities can create anywhere – even at a test site or at fields of deployable operations – a complex traffic situation that may require controlled environment. The visualisation of traffic elements, airspace blocks, obstacles, and flight route profiles through VR glasses can provide the "augmented-window-view" for the ADC. The technical specifications of LIND-A framework are completed, the integration of data sources are ongoing, but testing has not started yet. According to our assumptions, generally known and used applications that increase the ADC Situational Awareness (SA) should be supplemented with different solutions for handling UAS together with conventional flight operation:

A. Meteorological data

The display of meteorological data is mandatory in an ADC working position. The monitor contains data required by the International Civil Aviation Organization (ICAO) and their changes, in addition to the forms of METAR, TAF and SPECI. The temperature or wind limits about which the ADC does not inform the manned traffic can affect UAS flights, particularly those whose Maximum Take Off Mass (MTOM) is below 25 kg. Our research project develops the model aerodrome's aero climatological description after analysing the METAR, TAF, and SYNOP database. At the same time, we set up an Unmanned Aircraft database (UA) considering the given type's limits. We are developing a UA-specific forecast to support the RP's preparation for flight, in order to choose the most reliable control mode, height or route, and support the ADC to provide flight information during UAS operations. [18]

B. Definition of decision-critical points

Decision-critical points and the issuance of ATC clearances are closely relating to each other. The issue has a timely manner because the issuance of a clearance should be early enough to ensure that the PC or RP has sufficient time and ability to comply with it. At the same time, the clearance should provide separation and expedition of the flow of traffic. Because the UAS we want to integrate into the daily routine of an airport has a lower-than-usual speed of traffic but more sensitivity in view of separation, delays are expected. The idea of ADC decision support system is to set the horizontal separation as safe as possible. In case the assumed distance of horizontal separation does not provide the adequate level of safety due to an emergency or reduced visibility conditions, the scale of vertical separation or other contingencies should set in force. Decision-critical points of clearance issuance should be declared separately in the aerodrome manoeuvring area and air operations. In the first case, we should take into account the airport layout, obstacles, stands, runway configuration, aircraft movements, and ground vehicles and the procedures in the Local Operational Procedures (LOA). In the second case, we should take into consideration the VFR and IFR procedures of the aerodrome, including:

- Departure traffic at the departure end of runway.
- Arrival traffic reaching Descending Point (DP) on ILS approach.
- Arrival traffic reaching the base turn of visual traffic circuit/radar pattern.
- Arrival traffic reaching the point on final should receive landing clearance.
- Arrival traffic landed.

According to our assumption, the UAS operations at the aerodrome always require a "safety-gap". The measure of this gap is in dependence on the manned aircraft's speed, position in the air and on the ground, and the wake turbulence behind them.

The ideal distance of the horizontal separation between a UAS and next arrival vs. departure or taxiing manned traffic can be more easily estimated if the ADC could see the UAS flight plan route, the endurance or the remaining time of the operation. A solution we would like to integrate and test in LIND-A is seen below (Fig.2.).

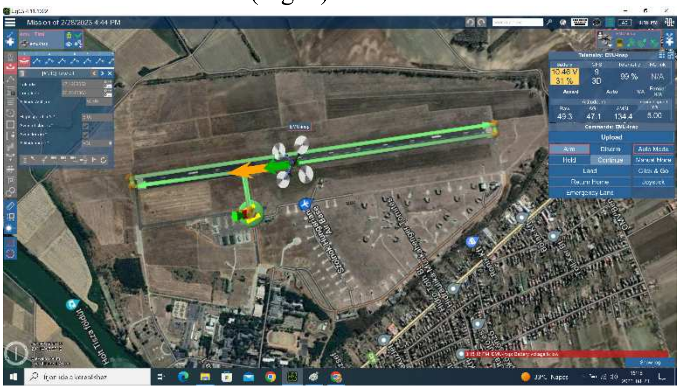

Fig. 2. Runway check route planner with UgCS [1]

C. *ATS airspace class related issues*

ATC's separation procedures are in close connection with ICAO ATS airspace classes. They clearly define the traffic in it, what flight rule can be used, and whether separation or flight information provided is in controlled airspace. Today, UAS flights under "specific" category cannot fully comply with IFR or VFR as written. Manned operations, according to IFR, are committed to comply with the required equipment list, to fly over minimum safety altitude, keep the operational restriction of the given procedure etc. and UAS may also be capable of meeting these requirements. Since the IFR infrastructure that provides safety for manned aviation was not designed for VLL airspace sectors, the performance of the UAS should be taken into account.[19] According to the Easy Access Rules of UAS (EAR), a BVLOS operation of a UAS is not considered maintaining VFR. [20] One of the basic principles of the research is to consider the model airport with its airspace structure, airspace class, and ATS infrastructure and procedures as a reference system. Pre-defined scenarios involved UAS traffic at it will be tested in the given reference system to identify hazards, UA and manned traffic visibility, UAS technical performance and EM procedures, communication lines, and usefulness of traffic information. The proposed system would be the same as the reference system but would be augmented with LIND-A supporting capabilities. We should also describe all aspects of the prosed system in order to develop LIND-A's safety enhancing capabilities. [21] The studies of UAV/UAS can help controllers to deal with complex air situations, provide reference for air traffic control services, reduce the workload of controllers, and ensure safe and efficient airspace operation. [22]

CONCLUSION

From the ATCO's perspectives, the UAS integration could raise a number of human performance problems. These include extreme workload or monitoring demands that distract attention from potential hazardous situations. Handling UAS traffic requires extra vigilance from an ATC and at same time, may cause his/her fearful resistance towards UAS integration. It can be also stated, that the automated or self-autonomous UAS operations and the digital U-space concept provide the ATC with solutions for handling increasingly complex traffic situations. All participants of aviation should be supportive in conflict management, assist the RP with solutions of U-space Service Provider (USSP), the PC with Automatic Dependent Surveillance and Broadcast (ADS-B) on board display – that does not provide compete safety, because UAS may equipped with other "hook on" devices – and the ATC in order to make decisions in the area of responsibility.

ACKNOWLEDGMENT

This work was supported by the National Research, Development and Innovation Fund (Thematic Programme of Excellence TKP2021-NVA-16 "Applied military engineering, military and social science research in the field of national defence and national security at the Faculty of Military Science and Officer Training").The project was funded by the Ministry of Innovation and Technology as the Sponsor and was carried out by the researchers of the Virtual Airport (VR_AD) research group of the Integrated-model airfield Priority Research Area.

REFERENCES

[1] „STEM LEARNING: Advanced Air Mobility: What is AAM? Student Guide.". National Aeronautics and Space Administration: Washington, DC. Available online: https://www.nasa.gov/sites/default/files/atoms/files/what-is-aam-student-guide_0.pdf

[2] „Urban Air Mobility and Sustainable Urban Mobility Planning – Practitioner Briefing.". UIC2 – UAM Initiative Cities Community, EU's Smart Cities Marketplace: Brussels, 2021. Available online: https://smart-cities-marketplace.ec.europa.eu/actionclusters-and-initiatives/action-clusters/sustainable-urban-mobility/urban-air-mobility-uam

[3] „Study on the societal acceptance of Urban Air Mobility in Europe.". McKinsey & Company. EASA: Brussels, 2021. Available online: https://www.easa.europa.eu/en/full-report-study-societal-acceptance-urban-air-mobility-europe

[4] K. AL-Dosari; Z. Hunaiti, and W. Balachandran. „Systematic Review on Civilian Drones in Safety and Security Applications.". Drones 2023, 7, 210. https://doi.org/10.3390/ drones7030210

[5] T. Patel, N. Salot, and P. Vrusha. „A Systematic Literature Review on the security of Unmanned Aerial Vehicle System.". arXiv, Corenell University, Dec. 2022. Available online: https://arxiv.org/pdf/2212.05028.pdf

[6] „Military and U-Space: Guidelines. Final report including D1/D2/D3 materials.". European Defence Agency: Brussels, 2023. Available online: https://eda.europa.eu/docs/default-source/documents/military-and-u-space---guidelines---final-report.pdf

[7] „Military and U-Space: Guidelines. SC3 report.". European Defence Agency: Brussels, 2023. Available online: https://eda.europa.eu/docs/default-source/documents/sc3-final-report-v1-0.pdf

[8] "Regulation (EU) 2019/947. Commission Implementing Regulation (EU) 2019/947 of 24 May 2019 on the rules and procedures for the operation of unmanned aircraft.". Available online: https://www.easa.europa.eu/en/document-library/regulations/commission-implementing-regulation-eu-2019947

[9] V. Villatte. „What are VLOS, EVLOS and BVLOS? Why do they affect drone operations?". Available online: https://www.scaleflyt.com/news/what-are-vlos-evlos-and-bvlos-why-do-they-affect-drone-operations

[1] Edited by the author using UgCS

[10] „Standard Scenario (STS).“. EASA: Brussels, 2019. Available online: https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX%3A32019R0947

[11] T. Vas, and Cs.Z. Fekete, “ UAV az ellenőrzött repülőtér forgalmában, avagy egy szimuláció tapasztalatai,” Repüléstudományi Közlemények (1997-TŐL) 25 : 2 pp. 371-383. , 13 p. (2013).

[12] M Palik, and T. Vas, “UAV operation in aerodrome safety and ACS procedures,” Defense resources management in the 21st century : the 7th scientific conference with international attendance organized by the Regional Department of Defense Resources Management Studies Brașov, Románia : National Defense University "Carol I" Publishing House (2012) 486 p. pp. 75-89. , 15 p.

[13] T. Vas, M.Palik, Z. Dudás, S.Simon, Zs. Bottyán, and Á. Fendrik, “The Flight Authorization of the Automatized VTOL UAS for Meteorological Sensor Measurement,” ACTA AVIONICA 23 : 2 pp. 1-11. , 11 p. (2021).

[14] M. Gajdos, Cs. Z. Fekete, and T. Vas, “Airspace structure for the drone test site activities,” unpublished

[15] J. Kamienski, J. Semanek, “ATC perspectives of UAS integration in controlled airspace,” 6th International Conference on Applied Human Factors and Ergonomics (AHFE 2015) and the Affiliated Conferences, AHFE 2015, doi: 10.1016/j.promfg.2015.07.169

[16] C. Brando, M. Boyero, L. Brucculeri, G. Ferrara, A. Hetelly, P. Hullah, D. Martin-Marrero, E.Pastor, A.P. Rushton, and A. Volkert, “U-Space Concept of Operations: A Key Enabler for Opening Airspace to Emerging Low-Altitude Operations” Aerospace 2019, 7, 24; doi:10.3390/aerospace7030024

[17] “AT-One - PJ.34 Solution 2 Exercise 5 Open Day - 12/20/2022” Available on line: https://bbb.nlr.nl/playback/presentation/2.3/76c8c315cdf9fd0d411faeb2fc9ec9061063768f-1671537581307

[18] Zs. Bottyán, Cs. Fekete, A. Z. Gyöngyösi, P. Kardos, Z. Tuba, T.Vas, “Rutinszerű légköri vertikális profilmérések végrehajtására alkalmas drón mérőhálózat kialakítása” KÖZLEKEDÉS ÉS MOBILITÁS 1 : 1 pp. 55-65. Paper: 16 , 11 p. (2022) https://doi.org/10.55348/KM.16

[19] A. C. Drumm, J. W. Andrews, T. D. Hall, V. M Heinz, J. K. Kuchar, S. D. Thompson, J. D. Welch, T Lincoln Laboratory, Lexington, M “Remotely piloted vehicles in civil airspace: requirements and analysis methods for the traffic alert and collision avoidance system (TCAS) and see-and-avoid systems” Digital Avionics Systems Conference, 2004. DASC 04. The 23rd Volume: 2, doi: 10.1109/DASC.2004.1390836

[20] “Easy Access Rules for Unmanned Aircraft Systems, C.3.3.”. Page 84 of 443| Sep 2022 Available on line:
https://www.easa.europa.eu/en/document-library/easy-access-rules/easy-access-rules-unmanned-aircraft-systems-regulations-eu

[21] “ICAO Doc. 9689 Manual on airspace planning methodology for the determination of separation minima”, First edition 1995.

[22] L. Yang, J. Huang, Q. Gao, Y. Zhou, M. Hu, H. Xie, “Dynamic Boundary Optimization of Free Route Airspace Sectors”. *Aerospace* **2022**, *9*, 832. https://doi.org/10.3390/aerospace9120832