REPÜLÉSTUDOMÁNYI KÖZLEMÉNYEK
36. évfolyam (2024) 1. szám 97–108. • DOI: 10.32560/rk.2024.1.8

László Gajdács

The Potential Flight Safety Risks Associated with Unmanned Aerial Vehicles and the Importance of Ensuring their Visibility

In recent decades, the airspace has become increasingly congested due to the exponential growth in air traffic. Furthermore, the advent of unmanned aerial vehicles (UAVs) has introduced a new dimension to aviation safety. The integration of UAVs into the traditional aviation system presents a multitude of challenges, necessitating the development of appropriate legal regulations, innovative technical solutions, and the implementation of special procedures to mitigate flight safety risks. With the advent of sophisticated systems and equipment, even small UAVs can be effectively monitored and tracked during flight. This enables the immediate and indirect environment surrounding the UAV to be identified, enhancing situational awareness and reducing the risk of collisions. Such solutions include various existing identification systems, such as FLARM,[1] OGN,[2] ADS-B[3] and Remote ID.[4] Additionally, special lighting systems on board drones can be employed as a solution, particularly for visual recognition and identification. By utilising these systems, visual surveillance can be extended, and drones can be more easily detected by their surroundings. The simultaneous use of the aforementioned solutions can further enhance the safe integration of drones in traditional traffic [1].

Keywords: *drones, flight safety, risk, FLARM, ADS-B, OGN, Remote ID*

1. Introduction

In the field of aviation, it is of vital importance to adhere to the principle of maintaining visibility and awareness in order to ensure flight safety. This principle has been developed over the past decades through a series of research and development activities, with the objective of ensuring that different types of aircraft are "visible" to other aircraft in the airspace and to air traffic services.

Unmanned aircraft are defined as "flying robots" that exhibit a range of characteristics, including varying weights, designs, and purposes of use [12], [13]. In essence, there are three principal methods of control: manual mode, in which the drone operator directly controls

1 Flight Alarm.
2 Open Glider Network.
3 Automatic Dependent Surveillance-Broadcast.
4 Digital Registration Number of Drones.

the aircraft and maintains constant, direct contact with it; autonomous mode, in which the drone is programmed to navigate a pre-defined route without human intervention; and remote control mode, in which the operator controls the aircraft from a distance. The other mode is autonomous mode, in which the drone is capable of navigating a pre-programmed route without the need for human intervention [17]. The third mode is the combined mode, which permits the drone to undertake certain phases of the flight without human intervention, such as landing or take-off, while allowing it to operate autonomously in other respects [11]. All three modes may be flown in visual line of sight (VLOS) or beyond visual line of sight (BVLOS). The latter represents a significantly greater risk, as the device may be several kilometres away from the operator.

2. The role of flight safety in the utilisation of drones

A significant challenge in the design, ground and airborne operation of an unmanned aerial system (UAS) is ensuring flight safety and general safety [18], [20]. The operation of aircraft (including drones) and the safety of flights depend on reliability. Unlike traditional aircraft maintenance processes, unmanned aircraft maintenance personnel need to be familiar with the system as a whole, so reliability must cover the whole spectrum of the UAV, from the ground station to the communication equipment [19].

Conscious or "law-abiding operator behaviour" requires that those who fall into this user group are aware of the legislation that applies to them and the equipment they are using. Conscious behaviour can prevent potential damage to various personal and material assets.

In the context of unmanned aircraft operations, there are three main situations that should be avoided:

- a dangerous approach to another aircraft, which could result in a near miss or Airprox;[5]
- the causing of harm to people;
- of damage to property (including the various infrastructures) [2], [15].

2.1. The significance of safety in conventional air transport

Aviation safety can be defined as the management of aviation risk in practice. Aviation safety is a complex and multifaceted field, with each of its components serving a single objective: to avoid or minimise the number of aviation incidents or accidents. The effective operation of this system is governed by a combination of national and international legislation [3].

One of the primary objectives of the ICAO[6] is to reduce the number of fatal air disasters to zero by 2030. The objective is to achieve this through the intervention of some 193 countries. The common (international) rules serve as the foundation of aviation safety systems. They establish uniform requirements for operators, manufacturers and aircrew alike [4].

5 Aircraft Proximity – Another Aircraft Dangerous Approach.
6 International Civil Aviation Organization.

The factors affecting aviation safety can be divided into three groups:

a) Objective factors:

- This encompasses factors that directly or indirectly impact aviation without the involvement of humans, such as material factors (aeronautical engineering) and

b) Subjective factors:

- This category encompasses human factors that may contribute to either a positive or negative change in aviation safety, to a lesser or greater extent.

c) Hidden or undisclosed factors:

- These are factors that, in many cases, cannot be identified in advance and are therefore almost impossible to predict. Consequently, the identification of these factors is unlikely to occur during the development of a potential aviation incident [5].

2.2. The significance of ensuring the safety of flight when utilising unmanned aircraft vehicles

The integration of unmanned aircraft into "conventional" aviation is still ongoing. In order to achieve this successfully and safely, there are three main objectives that must be met:

- it is of utmost importance that unmanned aircraft do not endanger other airspace users;
- furthermore, the ATM[7] procedures should mirror those applicable to drones;
- finally, air traffic services to unmanned aircraft should be transparent for ATC[8] controllers [5].

The utilisation of drones is associated with a multitude of potential safety hazards. It is of utmost importance to be aware of the potential risks associated with the use of drones, as any of them can occur during flight. Additionally, a number of hazards must be anticipated during the planning and execution phases of a drone flight, as well as during the flight itself. These include:

- inadequate pre-flight preparation, task planning;
- air traffic (other aircraft in the airspace);
- collision with another drone and/or piloted aircraft;
- weather conditions (high winds, gusts);
- human resources (required qualification, passing of examinations);
- lack of practical skill (little practical flying experience);
- occurrence of technical failures (electric motor failure, loss of drone control, etc.);
- changes in the flight environment (risk of possible collision with natural or artificial terrain);
- inappropriate choice of flight environment (obstacle environment);
- intentional drone interference, etc.

[7] Air Traffic Management.
[8] Air Traffic Control.

In order to be adequately prepared for potential risks, it is first necessary to be able to recognise the risk in question (see Figure 1).

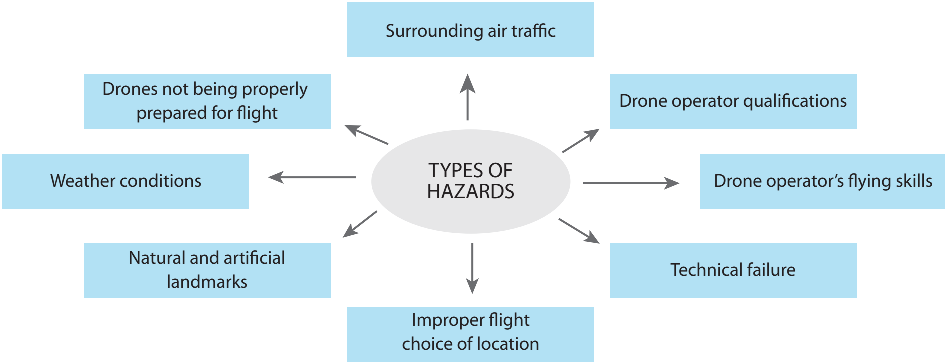

Figure 1.
Types of hazards associated with unmanned aircraft [the author]

What are risks? They are factors or circumstances that could lead to an accident. In aviation, these hazards can be obvious or hidden.

Knowledge of the various sources of hazards is not in itself sufficient to ensure safety. We need to know the magnitude and severity of the potential hazard, but also the likelihood of it occurring. Knowing the severity and the value of the probability of the event occurring enables us to manage the risk [9].

2.3. The role of the UAS safety risk assessment process

As in conventional aviation, the operation of unmanned aircraft is expected to be conducted in an optimal manner with regard to safety. A safety risk assessment can assist in the identification of potential safety hazards of varying severity and probability (frequency) that may arise during operations, along with the formulation of proposals and measures to mitigate them. The process is depicted in Figure 2.

Figure 2.
The process of risk assessment [6]

The security risk assessment process is comprised of four sub-processes:

- the assessment and identification of security threats;
- the undertaking of a risk assessment;
- the implementation of measures to mitigate potential risks;
- the documentation of risk assessment results.

The identification of potential hazards and factors that could affect aviation safety is a fundamental aspect of the identification process. The risk assessment determines the severity of the factors identified as hazards and their likelihood of occurrence. In order to reduce the potential risks, risk mitigation measures are identified. Finally, at the conclusion of the risk assessment process, a comprehensive documentation will be generated to validate the entire process from its inception to its conclusion [6].

3. The forms of unmanned aircraft detection and visibility implementations

The detection of unmanned aircraft can be achieved in a number of basic ways. Such aircraft can be detected by conventional radar systems. However, the efficacy of this approach is contingent upon a number of factors, including the dimensions of the aircraft to be identified, its structural composition, and other characteristics.

Furthermore, it is possible to detect them via on-board radiating devices (which can be transmitters or transceivers). These devices serve the basic function of providing information on the aircraft's position, altitude and planned course. Furthermore, the use of on-board lighting systems can also be employed to enhance their visibility.

Information regarding the detection and/or tracking of aircraft can be obtained through a variety of channels. An illustration of this phenomenon is presented in Figure 3.

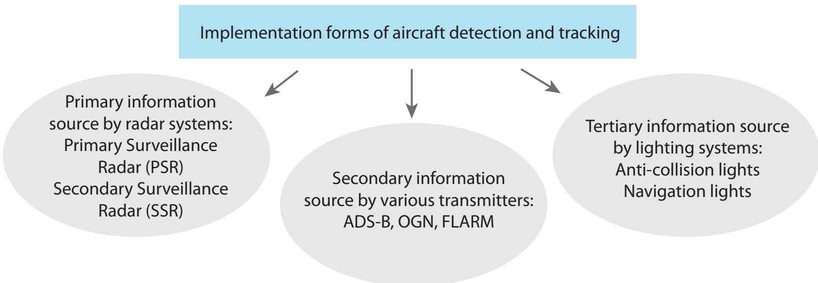

Figure 3.
Potential sources of information for the detection of aircraft (the author based on [1])

The objective of the data from the various sources is to provide as much information as possible about the spatial position of air transport users.

3.1. Primary source of information on unmanned aircraft

It is also possible to detect aircraft using conventional radar systems. However, the issue of their effective deployment is that drones have a considerably smaller size and therefore a smaller reflective surface than conventional aircraft. This prompts the question of the efficacy of obtaining information about them. A schematic of the radar measurement process is presented in Figure 4.

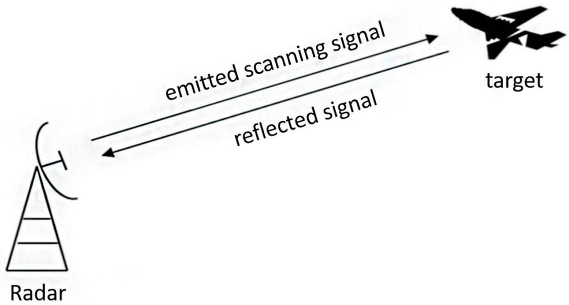

Figure 4.
Theoretical overview of radar measurement [14]

In the context of radar systems, it is possible to distinguish between active and passive radars. An active system is defined by the fact that the electromagnetic signal is emitted by the radar itself via a transmitter. In contrast to the active system, the passive system does not emit the illuminating signal required for target detection; instead, it utilises the signal sources in the target's environment for detection. The illuminating signals originate from transmitters associated with broadcasting or telecommunication systems. The aforementioned transmitters are referred to as illumination sources in the context of passive radar systems [14].

3.2. Secondary sources of information on unmanned aircraft

Flight and position data derived from secondary sources may be derived from the utilisation of the following system:

- FLARM;
- OGN;
- ADS-B;
- Remote ID.[9]

3.2.1. FLARM system

FLARM (Flight & Alarm) system is a technical solution designed to monitor air traffic and prevent collisions. The system was initially developed for glider pilots with the objective of preventing collisions in the air. Currently, approximately 50 000 conventional aircraft worldwide utilise this technology.

However, there is a type of FLARM system specifically designed for unmanned aerial vehicles (FLARM ATOM and FLARM AURORA), which also aims to provide a solution for drones to be seen and tracked during their flight (see Figure 5).

[9] Drone identification unit.

Figure 5.
FLARM Aurora modul [7]

The Aurora module, depicted in Figure 5, is also suitable for the transmission and broadcasting of the various types of data required by remote identification systems. The product is the smallest size transmitter available from the manufacturer, which has been specifically designed for unmanned aircraft.

3.2.2. Open Glider Network

The OGN system, similar to the FLARM system previously discussed, is designed to provide a solution for both piloted and unmanned aircraft, ensuring that those utilising the system are visible to their surroundings. The OGN system has been developed based on the FLARM system, and it currently has in excess of 20 000 registered users. The system's architectural framework is depicted in Figure 6.

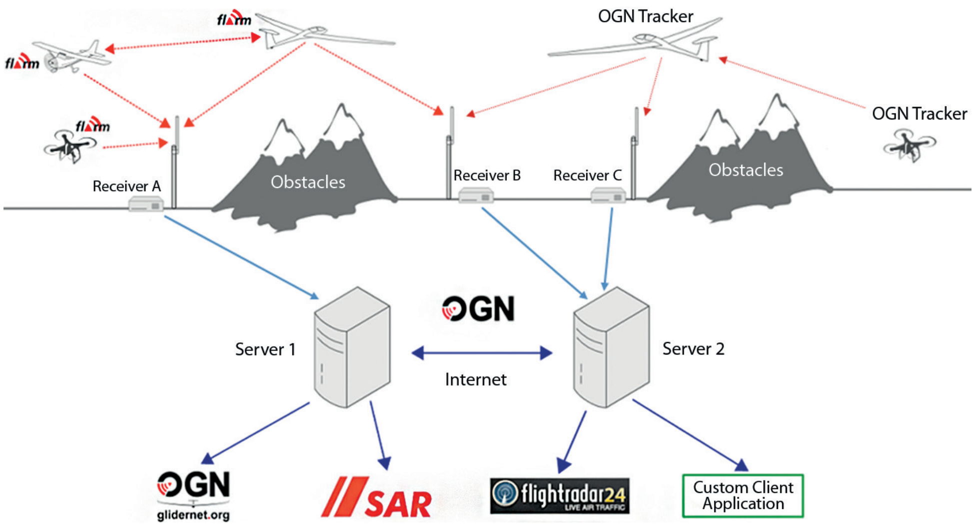

Figure 6.
Structure of the OGN system [16]

The following elements are integral to the functioning of the OGN system:

- OGN receiving stations (ground stations);
- on-board OGN transmitters (trackers);
- Automatic Packet Reporting System (APRS) Linux-based servers (receiving and sending data);
- websites and applications capable of processing and/or displaying data;
- human segment who use the system and the developers.

3.2.3. ADS-B system

Automatic Dependent Surveillance-Broadcast (ADS-B) is a sophisticated transceiver system. The system is designed to identify and track aircraft in flight for both airspace users and ground control units (Figure 7).

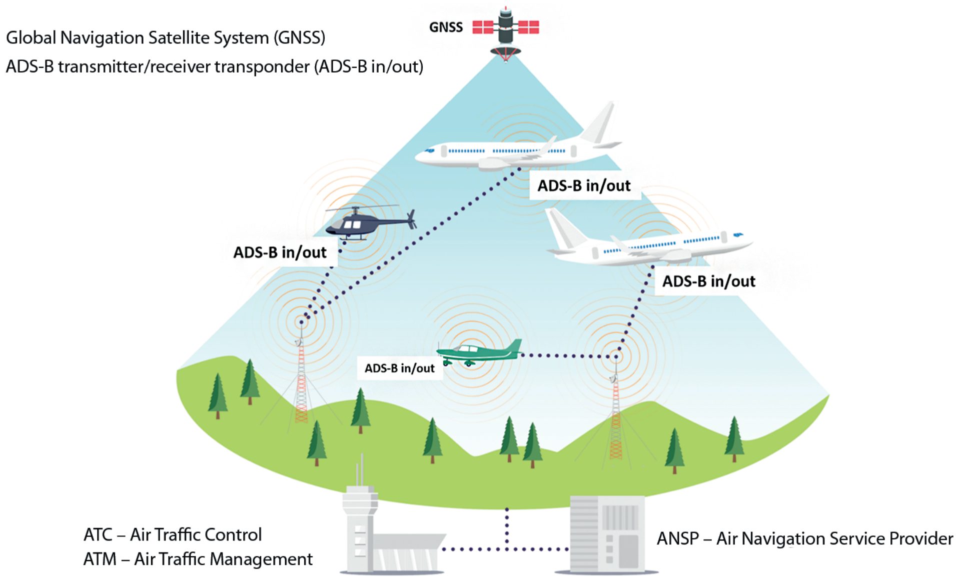

Figure 7.
ADS-B system architecture [8]

There are three main versions of ADS-B transceivers:

- ADS-B Out: capable of transmitting data to traffic control and aircraft;
- ADS-B In: capable of receiving position data from other aircraft;
- ADS-B In & Out: capable of sending and receiving its own data.

3.2.4. Remote ID

The Remote ID system was developed with the intention of enabling the identification of drones. It is currently still under development. It is, in essence, an identification data plate for the digital license plate of a drone. The purpose of the ID system is to facilitate remote identification of drones, including by authorities. This is done by transmitting data, as shown in Figure 8.

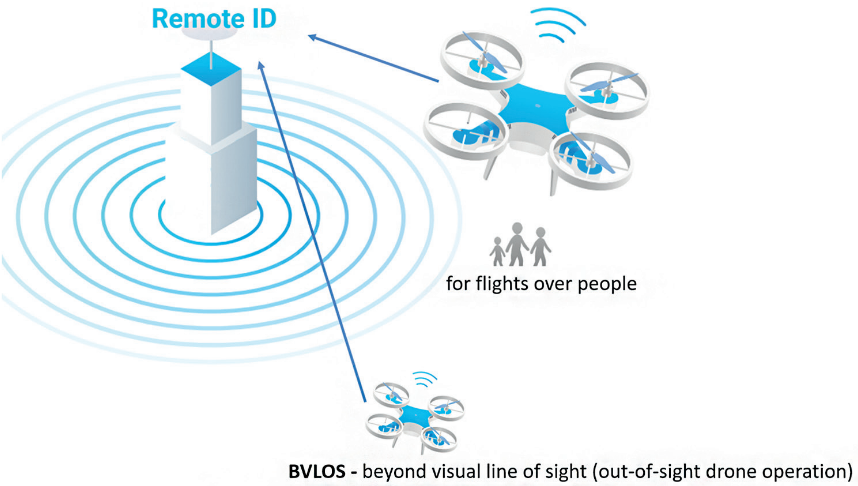

Figure 8.
Remote ID application overview [10]

In the European Union, the remote identification requirements, based on and largely applying FAA guidelines, require on-board transmitters to transmit the following data from the drone:

- the drone's unique serial number;
- the drone's registration number;
- the drone's geographic position and altitude relative to the location or take-off point;
- the drone's direction of travel and speed;
- geolocation of the operator or take-off point, etc.

3.3. A tertiary information source for unmanned aircraft

The third source of information is provided by the various navigation and anti-collision light sources installed on board unmanned aircraft. However, the regulations governing night operations are essentially universal. The use of drones is not exclusively limited to night-time operations; there is a greater need for them to be clearly visible in the sky during the day, irrespective of weather conditions. The application of "warning" lights, namely anti-collision lights, would reduce near miss to other aircraft and reduce the likelihood of potential collisions.

The functions and types of light sources on board unmanned aircraft are presented in Figure 9.

1. orientation, navigation function;
2. mode and system status indication function:
   - flight mode indication (P-mode, S-mode, A-mode);
   - low battery level;
   - data link between the drone and its remote control;
   - Return to Home Point (RTH) activation;
   - need for compass calibration;
   - Inertial Measurement Unit (IMU) failure, etc.
3. collision avoidance support function;
4. other additional functions [21].

Figure 9.
A functional classification of on-board lighting systems for drones, as proposed [the author]

Currently, the majority of drones are equipped with on-board functions indicating mode and system status, as well as navigation lights. However, there is a growing need for collision avoidance lights. It is recommended that these features be incorporated into the drone during

4. Conclusion

As with conventional aviation, safety is a primary concern in the operation of unmanned aircraft. To ensure this, it is essential to adhere to the established framework of rules governing drone operations. Periodic reviews and amendments to these rules are necessary to maintain safety standards. Information on the position of aircraft can be obtained through various channels and systems, which are crucial for the safe transportation of airborne vehicles. Increasing the visibility of drones could be a potential solution to enhance flight safety.

References

[1] Gajdács L., "Látni és láthatóvá válni megoldások drónokhoz," *Hadmérnök,* Vol. 18, no. 4, pp. 5–17. 2023. Online: https://doi.org/10.32567/hm.2023.4.1
[2] EASA, *Concept of Operations for Drones, A Risk Based Approach to Regulation of Unmanned Aircraft.* EASA Brochure, 29 May 2015. Online: www.easa.europa.eu/en/document-library/general-publications/concept-operations-drones
[3] Wikipedia, *Aviation safety.* [s. a.]. Online: https://en.wikipedia.org/wiki/Aviation_safety
[4] ICAO, *Safety News.* [s. a.]. Online: www.icao.int/safety/Pages/default.aspx
[5] Gajdács L., Palik M., Dudás Z., "Drónok és hagyományos légi járművek közös légtérben történő alkalmazásának repülésbiztonsági kockázatai," *Repüléstudományi Közlemények,* Vol. 33, no. 1, pp. 157–170. 2021. Online: https://doi.org/10.32560/rk.2021.1.12
[6] J. Ferrigan, *Safety Risk Assessment for UAV Operation.* AeroTract Geospatial, April 2022.
[7] Airclip.de, *Flarm Module Aurora.* [s. a.]. Online: www.airclip.de/FLARM-module-Aurora
[8] ADS-B, *Introduction to ADS-B.* [s. a.]. Online: https://ads-b.aviation.govt.nz/introduction/#how-does-ads-b-work
[9] Dudás Z., "Repülésbiztonsági veszélyek és kockázatok," *Repüléstudományi Közlemények,* Vol. 15, no. 2, pp. 1–6. 2003. Online: www.repulestudomany.hu/kulonszamok/2003_cikkek/dudas_zoltan.pdf
[10] Elsight, *Compliance with FAA Remote ID Regulations.* White Paper, 2022. Online: https://lp.elsight.com/hubfs/Remote_ID_White_Paper-1.pdf
[11] Gajdács L., Major G., "Az UAV alkalmazásának kockázatai a biztonságtechnika területén," *Repüléstudományi Közlemények,* Vol. 30, no. 2, pp. 101–112. 2018. Online: www.repulestudomany.hu/folyoirat/2018_2/2018-2-09-0497_Major_Gabor-Gajdacs_Laszlo.pdf
[12] Békési B., Szilvássy L., Major G., Gajdács L., Jámbor K., "Munkadrónok egy modern légikikötő mindennapjaiban," *Honvédségi Szemle,* Vol. 151, no. 3, pp. 27–41. 2023. Online: https://doi.org/10.35926/HSZ.2023.3.3
[13] B. Békési, L. Szilvássy, G. Major, L. Gajdács, K. Jámbor, "Working Drones in a Modern Airport's Daily Life," in *Transport Means 2022 Sustainability: Research and Solutions, Proceedings of the 26th International Scientific Conference: Part II,* Ed., Ostaševičius, V., Kaunas: Leidykla Technologija, 2022, pp. 836–841.
[14] Gajdács L., "Pilóta nélküli légi jármű érzékelésének lehetséges megoldásai," *Hadmérnök,* Vol. 17, no. 4, pp. 17–28. 2022. Online: https://doi.org/10.32567/hm.2022.4.2
[15] International Civil Aviation Organization, *Doc 4444 ATM/501 Air Traffic Management.* Fifteenth Edition, 2007.
[16] The Open Glider Network's official website. Online: www.glidernet.org/
[17] M. Palik, G. Pongrácz, "Communication Issues of UAV Integration into Non Segregated Airspace," *Defense Resources Management in the 21st Century,* Brasov, Romanian National Defense University, Regional Department of Defense Resources Management Studies, 2012, pp. 69–74.
[18] Békési B., Major G., "A drónok konfigurációi, alkalmazási területei," in *Műszaki Tudomány az Észak-kelet Magyarországi Régióban 2022: Konferenciakiadvány,* Nyíregyháza, 2022. 06. 02. (Nyíregyházi Egyetem Műszaki és Agrártudományi Intézet, Magyar Tudományos Akadémia [MTA] Debreceni Területi Bizottság [DAB] Műszaki Szakbizottsága), Páy G. Ed., Nyíregyháza, Magyarország: Nyíregyházi Egyetem, 2022, pp. 301–307.

[19] Békési B., Papp I., Szegedi P., "UAV-k légi és földi üzemeltetése," *Economica,* Vol. 6, no. 2, pp. 99–117. 2013. Online: https://doi.org/10.47282/ECONOMICA/2013/6/2/4422

[20] Békési B., Novák M., Kárpáti A., Zsigmond Gy., "Investigation of the Reliability of UAVs," *Proceedings of the 16th International Conference Transport Means 2012.* Kaunas, Lithuania, 2012, pp. 101–103.

[21] Gajdács L., "A drónok vizuális láthatóságának jelentősége," *Repüléstudományi Közlemények,* Vol. 35, no. 2, pp. 157–168. 2023. Online: https://doi.org/10.32560/rk.2023.2.17

Pilóta nélküli légi járművek repülésbiztonsági kockázatai, láthatóságuk jelentősége

Napjainkban egyre zsúfoltabb a légtér a növekvő számú légi forgalom miatt. Emellett az elmúlt évtizedekben egyre nagyobb számban jelennek meg a pilóta nélküli légi járművek is. Integrálásuk a hagyományos légi közlekedési rendszerbe számos kihívást fogalmaz meg. A repülésbiztonsági kockázatok csökkentésére megfelelő jogi szabályozásra, új műszaki megoldásokra és speciális eljárások kombinált alkalmazására van szükség. Különböző rendszerek és berendezések segítségével a kis méretű drónok is megfigyelhetővé válnak repülésük folyamán a közvetlen és a közvetett környezetük számára egyaránt. Ilyen megoldások a már meglévő különféle azonosító rendszerek, mint a FLARM, az OGN, az ADS-B és a Remote ID. Továbbá megoldást jelenthetnek – elsősorban a vizuális felismerés és azonosítás érdekében – a drónok fedélzetén elhelyezett speciális fénytechnikai rendszerek is. Ezek használatával kiterjeszthető a vizuális megfigyelés, könnyebben észlelhetők a drónok a környezetük számára. A fenti megoldások egyidejű használata tovább javíthatja a drónok biztonságos integrálását a hagyományos forgalomba [1].

Kulcsszavak: *drónok, repülésbiztonság, kockázat, FLARM, ADS-B, OGN, Remote ID*

Gajdács László	László Gajdács, MSc
százados, tanársegéd, PhD-hallgató	Captain, Assistant Lecturer, PhD student
Nemzeti Közszolgálati Egyetem	Ludovika University of Public Service
Hadtudományi és Honvédtisztképző Kar	Faculty of Military Science and Officer Training
Repülőfedélzeti Rendszerek Tanszék	Department of Aircraft Onboard Systems
gajdacs.laszlo@uni-nke.hu	gajdacs.laszlo@uni-nke.hu
orcid.org/0000-0003-2334-6859	orcid.org/0000-0003-2334-6859

TKP2021-NVA-16 has been implemented with the support provided by the Ministry of Culture and Innovation of Hungary from the National Research, Development and Innovation Fund, financed under the TKP2021-NVA funding scheme.

Nemzeti Kutatási, Fejlesztési és Innovációs Hivatal

AZ NKFI ALAPBÓL MEGVALÓSULÓ PROGRAM