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UAS Regulations in The Aspect of Unmanned Aviation Safety

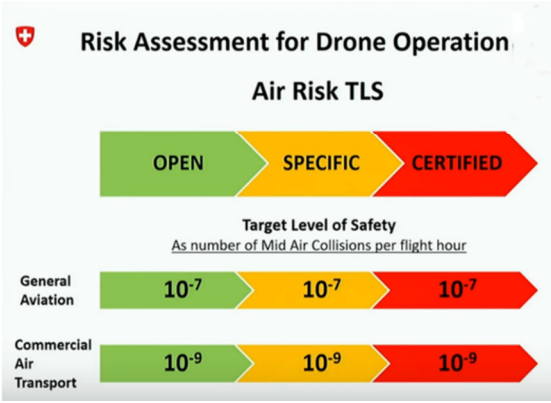
Abstract: The dynamic development of unmanned aviation forced the definition of the rules for performing UAS flight operations. The UAS regulations set the rules for the use of unmanned aerial vehicles and organize their functioning in integration with manned aviation. The paramount goal of the introduced regulations and provisions is to ensure an appropriate level of safety. Regulations should take into account both the current development needs of the industry and clearly defined safety objectives. It is important to all aviation stakeholders that, despite the shared use of a part of the airspace by both types of aviation, public recognition of the high level of aviation safety has not deteriorated. The introduced regulations had a direct impact on the safety of operations in both manned and unmanned aviation. The current experience of the impact of regulations in manned aviation is outlined and the current regulations in unmanned aviation, as well as safety and risk management, are discussed. The importance of the VLOS and BVLOS unmanned operations as well as the open, special and certified categories were discussed. In both types of aviation, one of the most significant factors influencing the level of safety is the human factor (HF). Therefore, the participation and importance of HF as an important component of the existing and implemented regulations was taken into account. Reference was made to the changes currently introduced at the national and European levels. The final conclusions are presented in the summary.

Keywords: UAS; Safety; Threats; Risk; Regulations; Safety management; SORA

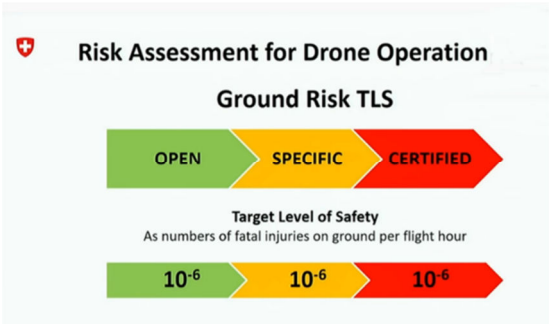
Introduction

The development of unmanned aviation was initially stimulated by military techniques and technologies, but currently, UAVs have a wide range of civil and recreational applications. Unmanned systems have been used in almost all sectors of the economy, in science, recreation, and in many areas of human activity. The observed development of UAV systems is enabled by advanced electronics, intelligent IT systems, satellite techniques, technologies, and several others. Military applications focus mainly on the effectiveness of the implementation of the tasks set. In civil applications, the most important component is to ensure the assumed level of security (TLS - Target Level of Safety) with the highest possible efficiency and low financial outlays. For all stakeholders in manned aviation, including governments, the safety of operations performed by unmanned aircraft is important. The level of UAV flight safety cannot differ significantly from the level of manned aviation. For over a hundred years, high trust in air transport has been developed. The assumptions and comparison of the safety level of UAV flights with manned aviation are presented in Figures **1** and **2** [1].

Integration in the conduct of air operations between unmanned and manned aircraft is a necessity due to the common use of part of the airspace, it is mainly airspace up to 150m AGL (VLL). To achieve the integration of manned and unmanned aviation, appropriate regulations are introduced, especially for UAV flights, which are aimed at ensuring an appropriate level of aviation safety.



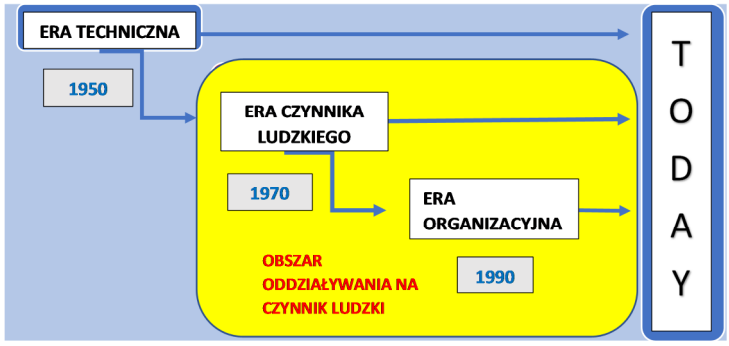
1. TLS comparison for airborne risk
Source: Methodology for the Specific Ops Risk Assessment (SORA) by JARUS - UAS Workshop 2018



2. Comparison of TLS for ground risk
Source: Methodology for the Specific Ops Risk Assessment (SORA) by JARUS - UAS Workshop 2018

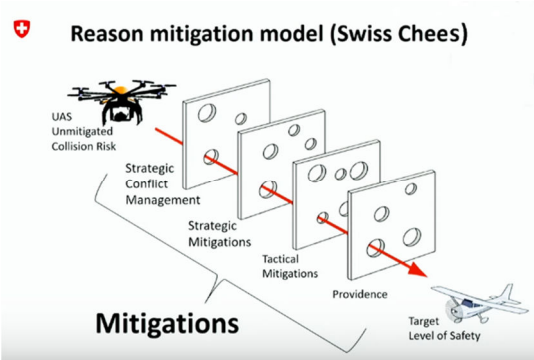
Aviation safety

Building a safety system in aviation is based on risk management and properly conducted risk analysis. Therefore, international aviation authorities introduce appropriate regulations concerning the possibly full scope of safety issues. In manned flights, the regulations followed the development of aviation and were often a reaction to tragic events. The main factor influencing the level of safety is the human factor (HF), which is responsible for the majority of air accidents. The established regulations do not always sufficiently take into account the importance of HF. This is clearly visible in the 118-year history of aviation. The evolution of aviation safety regulations includes several stages as shown in Figure **3**.



3. Evolution of aviation safety regulations
Source: own study

In scientific research, over time and gaining more and more experience, the concepts of the causality of air accidents, ways of preventing them, and managing the risk have also changed. One of the significant examples is the model of prof. J. Reason known as "Swiss cheese", which can be successfully used as a legitimate way of perceiving problems in the process of creating regulations in the field of unmanned flight safety.



4. J. Reason's model of airborne collision risk mitigation for SBSP
Source: Methodology for the Specific Ops Risk Assessment (SORA) by JARUS - UAS Workshop 2018 [12]

The changing aviation regulations became more and more effective in increasing the level of safety due to the rich database of past events. Concerning the SBSP, the database is very poor. Hence, setting the safety rules contained in the SBSP regulations requires the use of proactive and predictive methods.

The analysis of various concepts, theories, and models for solving aviation safety and risk management problems (5M, SHALL, HFACS, Practical Drift, and others) confirms that HF is at the heart of safety issues. Although the models take into account elements of the environment in which the pilot works, they make his actions, including errors, dependent on the relationship with the environment. Professor James Reason's theory situates human errors and violations as one of the elements of the security chain while emphasizing that human errors are active and result in immediate consequences. Nevertheless, the other barriers of Reason's theory also apply to the people in the environment, around the pilot. They are elements ranging from organization and management to training or regulations regarding the performance of operations.

SBSP regulations - world, Europe, Poland

International organizations and European and national aviation authorities introduce appropriate regulations to increase the level of UAS operation safety. ICAO in Circular No. 328 of 2011 [8] discusses UAS as a new component in the functioning of the aviation system in non-segregated airspace. The pillars of the circular are operations, equipment, and personnel. Point 2.7 of the circular assesses that UAVs will not carry passengers commercially (maybe in the distant future), which, compared to reality, shows an assumption error. The circular contains two concepts. One concept relates to the control of safety by the State Safety Program (SSP), and the other to the Safety Management System (SMS) [10], with responsibility for SMS assigned to air operators. Currently, on the international forum, ICAO introduces supplements to its appendices regarding UAVs, e.g. appendices 13 and 19 or in the Global Aviation Safety Plan GASP [9] ICAO Doc 10004 for the years 2020-2022.

The countries of the European Union, which are also members of ICAO, have established the European Aviation Safety Agency (EASA) to harmonize regulations within the community and achieve a high level of safety in air operations. EASA has developed the

European Aviation Safety Program (EASP), which is equivalent to ICAO Annex 19. EASA has also produced a European roadmap for the safe integration of UAS in all classes of airspace [17], with VLOS and BVLOS out-of-sight flights and three categories of operations in terms of the magnitude of risk:

1. open - low risk;
2. specific - medium risk;
3. certified - (high risk).

EASA has also established guidelines for manufacturers and users regarding requirements for equipment up to 25 kg. SBSPs are divided into five classes from C0 to C4 (Class 0 - Class 4) and additionally, classes C5 and C6 have been established for STS. Unmanned aerial systems are intended to be operated by the rules and conditions applicable to open category and STS operations. The division of operations into VLOS and BVLOS determines the level of risk. Hence, the open category, in which only VLOS operations are allowed, is low-risk due to the constant presence of the UAV in the pilot's sight, which perceives hazards and avoids collisions in the air. In the special operation category, the UAV remains out of the pilot's visual range - BVLOS, the distance between the RPS and the UAV is increased and the pilot is assisted by DAA devices having an image from the UAV camera and possible help from observers.

Commission Regulations (EU) regarding the above regulations are:

- Commission Delegated Regulation (EU) 2019/945 of 12 March 2019 (amendment of Regulation 2020/1058) on unmanned aerial systems and third-country operators of unmanned aerial systems;[15]

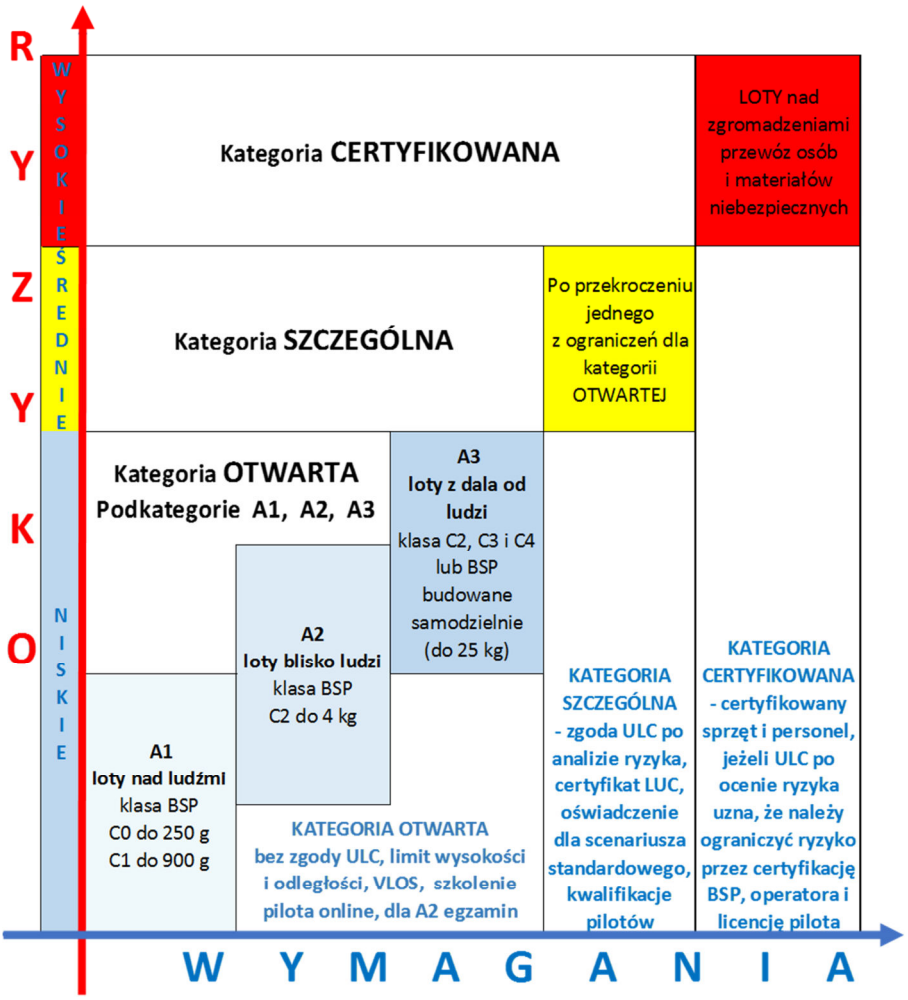
Commission Implementing Regulation (EU) 2019/947 of 24 May 2019 on the rules and procedures for the operation of unmanned aerial vehicles; [16].

The diagram of division into operation categories and UAV classes is shown in Figure **5**.

An important supplement to the EASA regulations is the risk analysis for specific operations developed by JARUS [6]. The JARUS organization (Joint Authorities for Rulemaking on Unmanned Systems) is the joint body responsible for creating regulations on unmanned systems), brings together world experts from 61 countries, EASA and EUROCONTROL, representatives of national aviation authorities, industry, and airlines.

The document submitted by the JARUS organization under the name "SORA v2.0" (Specific Operations Risk Assessment) [11] for unmanned systems presents a UAS operation risk management model for operators and aviation authorities. SORA is to be a solution to the inability to apply traditional risk management methods to SBSP. The study concerns the special category of SBSP flights. The model assumes the determination of the threat together with the suggestion of general countermeasures in such a way as to achieve the limits of safe operation performance. It takes into account the hazards of BVLOS flights and possible pilot errors. SORA focuses on establishing premises which, for safety purposes, are to create a framework and limitations for aviation entities. However, to a lesser extent, it focuses on the problems of managing the risk of threats at the operational level. Regulations concerning equipment, operators, pilots, or rules of operation do not take into account the safety of UAV flights comprehensively in the aspect of airspace management. In 2007, SESAR Joint Undertaking (SESAR - Single European Sky ATM - Air Traffic Management - Research) was established as a joint public-private venture, whose founding members are the EU and Eurocontrol as well as many aviation sector institutions (including PANSA). The document SESAR JU - European ATM Master Plan: "Roadmap for the safe integration of drones into all classes of airspace" addresses the issue of risk management at a high level of generality, defining risks, consequences, and mitigating actions. As part of the program, a concept regarding the safety of SBSP "U-space" flights is being implemented. As such, "U-space" is a

model designed to facilitate any type of UAS operation in any class of space and type of environment, even the most congested, as a combination of UAS with manned aviation and ATC.



5. Scheme of division into operation categories and SBSP classes
Source: own study

Until 2021, UAV flights in Polish regulations were treated separately based on exclusion from the provisions on manned aviation. From the beginning of 2021, EU Regulations 2019/945 and 2019/947 came into force. They significantly change the approach to UAS and safety issues, recognizing that unmanned flights are part of a joint aviation activity together with manned flights. The current national regulations are guidelines of the President of the Civil Aviation Authority No. 24 [3] and No. 7 [2] and guidelines No. 15 to 23 [4] containing nine NSTS scenarios. Polish aviation law is being amended. The draft amendments to the Act of 3 July 2002 - Aviation Law (Journal of Laws of 2020, item 1970, as amended), hereinafter referred to as "the Aviation Law Act" and some other acts, are intended to ensure the application of new European Union regulations on unmanned aircraft and unmanned aircraft systems [14].

The most important change proposed in the draft is the introduction to the Aviation Law of a new section dedicated to unmanned aerial vehicles. The draft section VIa "Unmanned aircraft" of the Act has been divided into 6 chapters regulating: performing operations with the use of unmanned aircraft systems, geographical zones for unmanned aircraft systems, register of operators of unmanned aircraft systems, designated entities, and

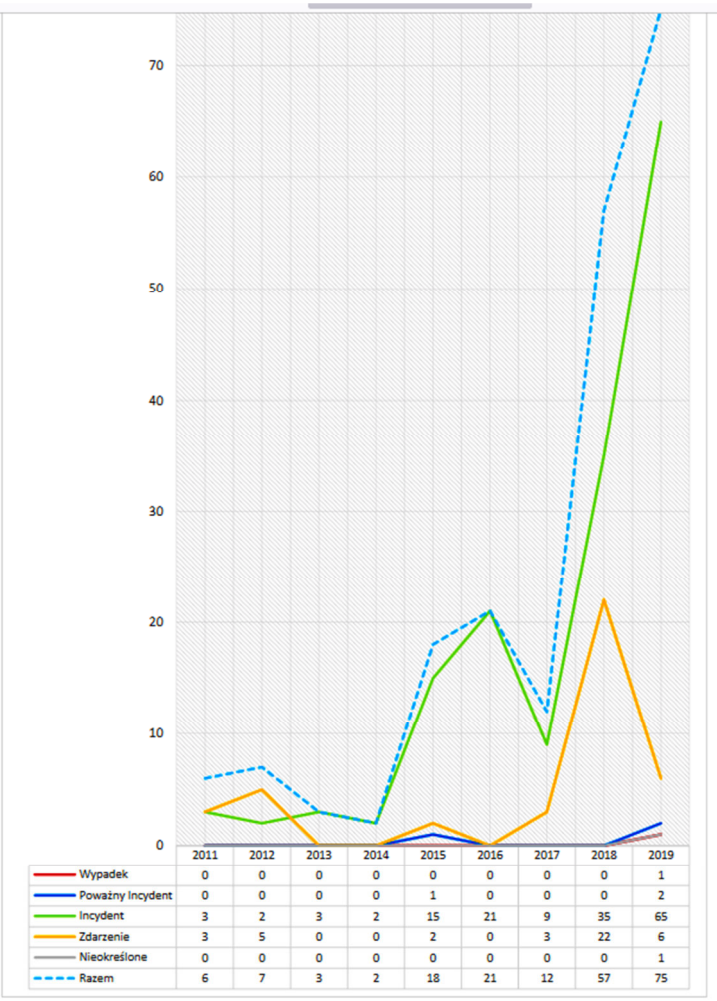
recognized entities, documents confirming qualifications, training, and examinations, and preventing the unlawful use of unmanned aerial vehicles. The Aviation Law is to be accompanied by a regulation specifying the conditions for operations in the open and special category, as well as a regulation on geographical zones.

The most important changes in the aviation law affecting safety concern many issues. The draft assumes that the provisions regulating the principles of performing operations using unmanned aerial vehicle systems for civil use will, in principle, also apply to operations performed by entities whose statutory task is to provide all kinds of services performed in the public interest. The justification for this position of the legislator is that the principles of performing operations using UAS and the level of qualifications of persons performing them for state services should be the same as for all airspace users. An important element is the registration of operators and certified UAVs. Responsibility for the tasks of the competent authority (Article 18 of Regulation 2019/947) has been assigned to ULC and PANSA, respectively. Among other things, the Agency is to ensure the maintenance, operation, and development of the ICT system used to provide services related to the performance of tasks by the Agency. Changes in the aviation law are to enable the control not only of members of aviation personnel but also of persons conducting theoretical training and examinations as well as practical training and assessment of practical skills. A solution has been adopted for NSTS, according to which confirmation of receipt and completeness of declarations will be forwarded to operators of unmanned aerial vehicle systems without the need to issue administrative decisions. Members of model aircraft clubs or associations will be able to perform operations in the "special" category after obtaining permission from the President of the CAO. The third-party liability policy will be obligatory for UAS with MTOM over 250g. In addition to the criminal provisions of the Act and the sanctions contained therein, Annex 5c to the Act proposes a long list of relatively high fines for failure to comply with formalities on the part of pilots and operators.

Security and industry development

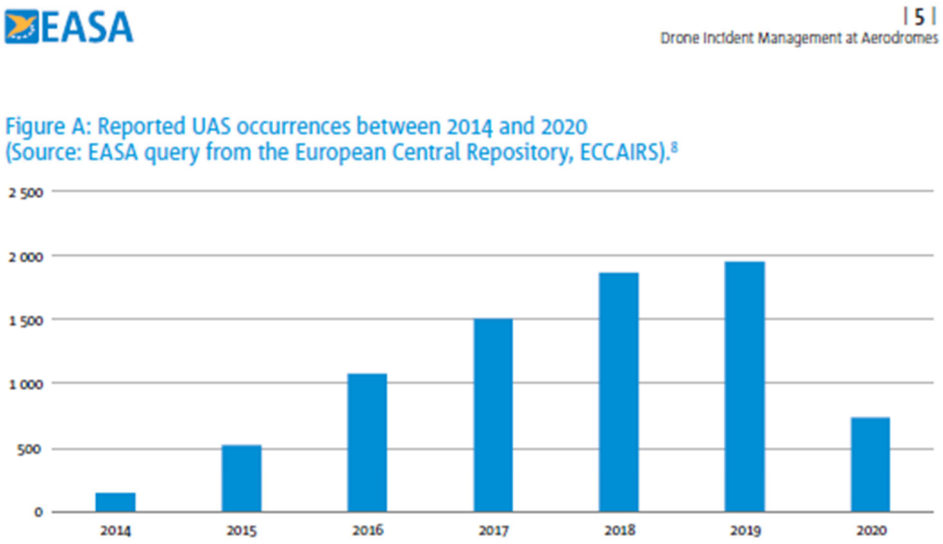
The developing unmanned industry forces the creation of new and modifications of existing regulations and activities to achieve the assumed level of safety with the smallest possible restrictions for its development. The decisive indicator of the level of safety is accidents and incidents involving the SBSP. Data on incidents involving the SBSP in Poland are registered in the CBZ (Central Reporting Database) maintained by the Civil Aviation Authority. In the annex to the National Civil Aviation Safety Program - National Safety Plan 2020-2023, in the National Register of Threats point 3. c - Operations of unmanned aerial vehicles (UAV/RPAS), indicators presenting accidents and incidents involving UAVs are presented - Figure **6**.

NAAs submit their data to ECCAIRS (European Co-ordination center for Accident and Incident Reporting Systems) of the European Coordination Center for Accident and Incident Reporting Systems. The EASA report presents a summary of UAV events in the years 2014-2020 at airports - Figure **7** [5]. A significant decrease in events is recorded in 2020.



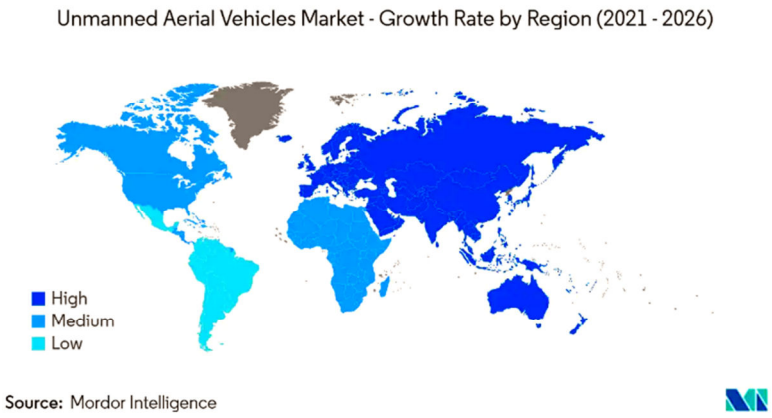
	2011	2012	2013	2014	2015	2016	2017	2018	2019
Wypadek	0	0	0	0	0	0	0	0	1
Poważny incydent	0	0	0	0	1	0	0	0	2
Incydent	3	2	3	2	15	21	9	35	65
Zdarzenie	3	5	0	0	2	0	3	22	6
Nieokreślone	0	0	0	0	0	0	0	0	1
Razem	6	7	3	2	18	21	12	57	75

6. Operations of unmanned aerial vehicles
Source: ULC



7. Recorded events of unmanned aerial vehicles in 2014-2020
Source: EASA

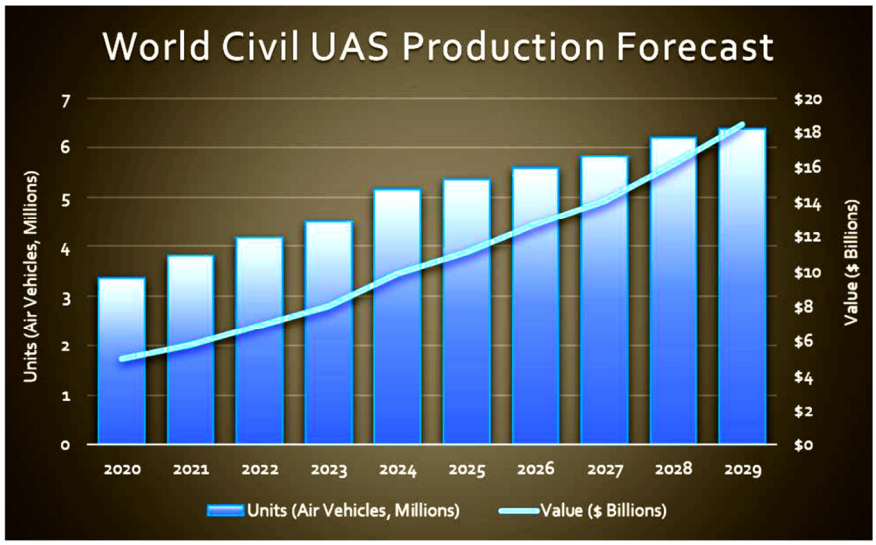
Eurocontrol also presents a summary of SBSP events in EVAIR (Voluntary ATM Incident Reporting) Bulletin No 22 2015 - 2019 Summer periods 10 May 2021[7]. After a significant increase in 2018, EVIAR recorded a decrease in drone events in 2019. The data shows that in the summer of 2019, the most affected flight phase was the approach phase about the previously monitored period. Most of the occurrences were reported by air operators (AOs) during good visibility conditions and on approach, but events at higher altitudes were also reported. About 15% of meetings with BSP can be classified as serious incidents.
To find the degree of dependence of the level of security on the applicable regulations, data on development trends in the industry should also be taken into account. According to Mordor Intelligence, the growth rate of the UAS market in the world by region is distributed as shown in Figure **8** [13].



8. Growth rate of the UAS market in the world by region
Source: Mordor Intelligence

Mordor Intelligence predicts that the unmanned aerial vehicle market in the forecast period (2021-2026) will register a CAGR (Compound Annual Growth Rate) of 8.48%, and the civil and commercial segment will dominate the market during the forecast period. Teal Group releases 2020/2021 world civil UAS market profile and forecast [18], in turn, takes into account the impact of the pandemic, suggesting that it is changing the structure of growth in the industry, increasing support for delivery drones, while hurting investments in some long-term applications. Teal Group forecasts that non-military unmanned aerial vehicle production will reach $108 billion over the next decade, rising from $5 billion globally in 2020 to $18.4 billion in 2029, Figure **9**, representing 15.6% of the total annual growth rate.

Comparing the systematic growth of the unmanned industry market in comparison with the decreasing number of events involving UAVs, it can be concluded that globally, unmanned operations are performed with a lower level of risk. This is due to better-adapted regulations and increased general awareness of the safe conduct of UAS flights. This gives grounds to conclude that the actions taken to ensure the assumed level of safety in unmanned flights bring positive results.



9. Growth forecasts for the UAS market in the world
Source: Teal Group

Summary

The safety of UAS flights depends on many factors. The most important include the technical and technological level of unmanned systems and activities affecting the efficiency of the broadly understood human factor. In both cases, the fundamental role is played by the regulations that affect the level of both safety and efficiency. With regard to unmanned flights, the concept adopted by the international aviation authorities ICAO and EASA assumes the level of risk as the basis for the introduction of flight division and related regulations. Thus, it eliminates errors and weaknesses in actions used to control the level of safety in the development of manned aviation. In the technical and technological aspects, the regulations introduced take into account current achievements and solutions regarding both unmanned systems and airspace management and control. The weakest link of the safety system under construction in unmanned flights is the impact on the human factor. The increase in the number of negative events related to UAV flights results from the scale effect of the UAVs used. At the same time, with the rapid increase in the number of UAS operations in the last two years, a significant decrease in incidents involving UAS has been recorded. Since the broadly understood HF has a decisive impact on the level of safety, there is a basis to conclude that the recorded decrease results both from the modified old and new more effective regulations affecting HF as well as from gaining experience and building awareness and safety culture among the personnel of operators and pilots as well as other users unmanned aerial vehicles.

The analysis of the presented data points to a number of areas and problems that can be used to ensure a higher level of security. The most important ones include:

- Specialization of regulation adapted to different types of flights and tasks performed; e.g. recommendations for the management of UAVs delivering and performing other commercial services (as in manned aviation regulations for commercial air transport and GA)
- Introducing regulations for UAVs while taking into account adequate changes regarding manned aviation;
- Development of airspace traffic management systems for UAVs enabling full integration with manned aviation;
- Including in the regulations unavoidable UAV flights with people on board in the near future and the issue of autonomous flights.

Parallel development of UAS technical and technological solutions, management of airspace for joint use by UAVs and manned aviation, building awareness of human factor safety, and adapting regulations to changing conditions may ensure that safety is maintained at the assumed level.

List of the most important acronyms and abbreviations

AGL (Above Ground Level) - height above ground level
ATC (Air Traffic Control) – air traffic control
ATM (Air Traffic Management) - air traffic management system
BSP - unmanned aerial vehicle
BVLOS (Beyond Visual Line of Sight) - operations beyond the line of sight of the unmanned aerial vehicle operator
DAA - Detect And Avoid - systems that allow you to see or detect hazards and take action to comply with acceptable flight rules
EASA (European Union Aviation Safety Agency) - the European Union Aviation Safety Agency, until 2018 EASA (European Aviation Safety Agency)
HF (Human Factor) - human factor
ICAO (International Civil Aviation Organization) - International Civil Aviation Organization
JARUS (Joint Authorities for Rulemaking on Unmanned Systems) - joint authorities responsible for creating regulations on unmanned systems
MTOM – maximum take-off mass; the maximum mass specified by the manufacturer or developer of the unmanned aircraft
NSTS (Natiponal Standard Scenario) - National Standard Scenario
PANSA (PANSA - Polish Air Navigation Services Agency) - Polish Air Navigation Services Agency
RPS (Remote Pilot Station) - controller for remote control of BSP
SBSP – unmanned aerial vehicle system
SESAR Joint Undertaking (SESAR - Single European Sky ATM - Air Traffic Management - Research), European air traffic management system)
SMS (Safety Management System) – safety management system
SORA (Specific Operations Risk Assessment) - Risk assessment for SBSP operations in a specific category
Geographical zone - a part of the airspace designated by the competent authority that facilitates, restricts or excludes operations with the use of unmanned aerial systems in order to eliminate risks related to safety, privacy, personal data protection, security or the environment resulting from operations with the use of these systems
STS (Standard Scenario) – standard SBSP flight scenarios
TLS (Target Level of Safety) - assumed security goal
UAS (Unmanned Aerial System) – unmanned aerial system
CAA - Civil Aviation Authority
VLL (Very Low-Level Airspace) – low-altitude airspace
VLOS (Visual Line of Sight) - Operations within the line of sight of the unmanned aerial vehicle operator

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