Theoretical and Terminological View of Unmanned Aircraft

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Abstract: *This paper represents a continuation of the ongoing research of authors who, in the framework of interdisciplinary scientific research, deals with several aspects of ensuring the safety of the Slovak Republic and the European Union in connection with aviation, aircraft, air traffic and airspace protection. In their current research, following these and constant developments in the field of innovation and introduction of new technologies in the field of aviation, the authors deal with unmanned aircraft, which are gradually used not only in the military, but are increasingly penetrating the commercial sphere of civil aviation. Due to the fact that the unmanned aircraft market is the fastest growing market of all categories of aviation, the authors in the article provide a theoretical and terminological view of the researched issues, including a brief historical view of the development of unmanned aircraft.*

Key Words: *Aviation, unmanned aircraft, development, theory, terminology*

1. INTRODUCTION

The dynamic development of human civilization and the closely related rapid development of new technologies at the end of the 20th and in the early decades of the 21st century brought a number of new challenges for all areas of human society. Despite the fact that today the majority of the population is born into a world in which things around us are evolving many times faster than a few decades ago, modern society has some problems not only with mastering many new achievements of modern science and technology, but also with their by understanding. One of the problems, for example, is that these new technologies or the achievements of the modern age do not wait for laws, regulations, directives or correct and uniform terminology, but on the contrary, they accelerate their intertwining with everyday life and use in practice. Their use subsequently disrupts the functioning of society at certain moments and creates problems (theoretical, terminological, practical, user-friendly, etc.)

which we have not yet faced and to which the current legislation may not provide a sufficient answer. A typical example of such technologies, resp. the achievements of modern science and technology are undoubtedly unmanned aircraft.

The use of drones for civilian purposes has only been a matter of the last few years, perhaps a little over a decade. Their frequent deployment in the military operations for which they were originally created gave rise to a public debate, which gradually aroused considerable interest not only from experts but also from the public. In addition, it was this interest of potential customers, together with the ever-decreasing production costs, that represented the opportunity for a completely new market.

The variability of modern drones almost knows no bounds. Today, a number of versions are available, from the smallest models measuring approx. 2cm × 2cm × 2cm with a weight of a few grams, to, for example, the Boeing Phantom Eye with a wingspan of 46 meters and a weight of almost 4,500 kg. In case of interest, it is now possible to buy an unmanned aircraft for several tens of euros. A slightly larger investment is required by a professional model with a built-in camera system, but even today, the price of purchasing such a device is also available to the average consumer.

The sum of all these factors has ultimately led to a huge increase in the number of private drones in many developed countries, including, of course, across the European Union, where the European Aviation Safety Agency (EASA) estimates that their share of the aviation market may to reach up to 10% of the total market in the next 10 years, around € 15 billion a year, and to create up to 150,000 jobs by 2050 [1]. Also in the United States, the market for civilian drones is expected to grow by up to 19% per year by 2020 and bring the US economy $ 82 billion and 100,000 new jobs by 2025 [2].

The rapid arrival of civilian drones can be observed in many areas, from their use in meteorology, cinematography, or journalism, to the recording of sporting or cultural events, building inspections, site protection, crop spraying or mail delivery, to their deployment as support stations for providing internet connection in remote locations. It is assumed that the next phase of their development will probably be the functional transport of people, which the developers are currently trying to achieve.

Also in the public sphere, we can see a rapid transition today from purely military to non-conflicting uses, such as geographical exploration, infrastructure control, monitoring of animal migration, monitoring of natural disasters or searching for missing persons. However, the focus of their public activities remains in the field of security and defence, such as protection of state borders or direct military deployment.

However, the era of drones does not only bring positive results, but also potential threats and challenges, such as their possible misuse for illegal surveillance and invasion of privacy in general, potential damage to property due to collisions with other aircraft, harassment of the population or smuggling of prohibited articles and substances. From the point of view of public safety, unmanned aircraft pose a risk, for example, to air traffic and the protection of military bases, cultural monuments, or nuclear power plants, etc [3].

In the Slovak professional literature, the topic of the legal regulation of the operation of unmanned aircraft is still insufficiently addressed. Recently, the first publications have begun to appear, but almost all of them deal with this issue from the point of view of public international law, especially in connection with their use in international conflicts. The area of their use for non-military purposes remains outside the interest of the domestic professional public. The very first comprehensive publication, dealing mainly with practical problems, but also marginally with legal regulation, was not published until 2016. The situation is different abroad and the topic of drones has already begun to gain in importance. This is also related to

the increase in publishing activities related to the issue of drones, which is an important source of this article. Documents of international and European organizations and institutions are also an important source, as well as various contributions from experts, especially in the field of aviation. Therefore, using relevant scientific research methods, the authors tried to develop this issue in the ongoing interdisciplinary research and bring readers from the ranks of academics, but also practitioners their theoretical-terminological view of the researched issues.

2. A BRIEF HISTORICAL LOOK AT THE DEVELOPMENT OF UNMANNED AIRCRAFT

Unmanned aircraft are a phenomenon relatively well known in today's society, but still not very well understood. To better grasp this issue, it is therefore important to examine their historical development. As with many other historical issues, the origins of drone development are relatively unclear. Some authors consider the Archystas model of a mechanical pigeon to be the first prototype of an unmanned aircraft, which was manufactured around 246 BC as an aid to understanding the flight of birds [4].

However, other authors date them to 1849, when the Austrians used about 200 balloons to bomb Venice in an effort to occupy the city [5]. Although their use in this case has not been entirely successful, it is the first example of a long line of military drones for military purposes. Moreover, it is the possibilities of their use in military operations that will be the main reason for further development for a long time. Their services were used again in 1862 during the American Civil War by both the Confederacy and the Union for aerial reconnaissance [6]. The United States also used kites equipped with cameras for reconnaissance purposes during the Spanish-American War in 1898. These first forms of drones however, they are today not recognized by other authors due to their uncontrollability, which is considered one of the conditions for the operation of unmanned aircraft [7].

The First World War gave a new impetus to the development of drones and modern technologies contributed to a significant improvement in their usability, e.g. using the radio remote control. The possibilities of modern unmanned aircraft did not escape the attention of an inventor such as Nikola Tesla, who devoted himself intensively to their construction, improvement and use, and whose invention of radio-controlled devices from the late 19th century solved the problem of remote control [6]. The world's major powers, meanwhile, continued to experiment with their deployment in military operations. It was not only the United States, where in 1917 Elmer Sperry and Peter Hewitt designed a controllable Hewitt-Sperry Automated Airplane, which was able to fly at a distance of 80 km and carry up to 135 kg of explosives, but also Germany and Wilhelm von Siemens's attempts to use zeppelins as a launch base for special torpedoes [8]. In the United Kingdom, Archibald Low was responsible for building a prototype radio-controlled drone designed to dispose of German zeppelins, but which could also serve as a primitive form of guided missile [9].

The development of drones continued in the interwar period and their technology was constantly improving. The most famous model of this time is the DH.82B Queen Bee from 1935, which seems to have given its name to the modern common name of an unmanned aircraft - “drone” [10]. In the same year, private entrepreneur Reginald Denny demonstrated a prototype RP-1 modifications won the competition for the supply of drones for military purposes [7]. With some modifications, it was then used as the RP-4 model, known as the Radioplane OQ-2, used during World War II, when about 15,000 pieces were produced [11].

Development has not stopped in Germany either, where efforts to use drones for massive bombing in the form of Vergeltungswaffe 1 (V1), which carried up to 900 kg of explosives

programmed to explode after impact, have revived [12]. However, their use at the end of the war in 1944 eventually proved unsatisfactory [8].

During the Cold War, the reconnaissance and intelligence features of drones came to the fore. In particular, due to possible complications in the use of spy aircraft in enemy airspace [13], countries have sought to rapidly develop safe drones to obtain information in problem areas such as Cuba, North Korea or China. For this purpose, the 1951 Firebee model was modified to a more powerful Lightning Bug, which served the US military until the mid-1970s [12]. It also became a welcome means of obtaining information after the outbreak of the Vietnam War, especially for the subsequent bombing of enemy positions. Between 1964 and 1974, the Lightning Bug was deployed in nearly 3,500 operations in northern Vietnam [14], despite the fact that the quality of the images it took during its flights was woefully low compared to the resolution that modern drones can provide. The film also had to be sent back to the United States first, where it was professionally developed and then analysed before use [15].

While the United States has clearly kept not only statistics on the size of the drone arsenal, but also on the numbers of their uses, other states have also paid considerable attention to this area. Israel saw a significant shift, especially in the 1980s, many of which were later taken over by other states [12]. Among them was the Amber aircraft, which served as a model for the modern Predator [6], which gradually evolved into the Reaper, now one of the most famous drones. Nevertheless, from the Vietnam War, when their use was judged to be rather unsatisfactory, their deployment in military operations receded into the background until the Gulf War and Operation Desert Storm [16]. The Pioneer model was often used by both the Navy and the Marine Corps at that time to obtain information about enemy positions [17].

Unmanned aircraft gradually experienced a transition from use exclusively for reconnaissance purposes and began to be deployed as a direct means of combat, e.g., in Iraq, Afghanistan or Pakistan [18]. Since then, there has been only a small step towards their use in the targeted disposal of dangerous persons, which is now generally considered to be their main purpose and rightly provokes many controversies [19]. In response to the 9/11 attacks, the Predators were armed and deployed to hunt Osama bin Laden [15]. Since 2010, the United States has been gradually moving to a more modern model, the so-called Reaper, which is probably the busiest type of drone today. Its increasing use reflects the fact that the United States administration has increased the number of unmanned aerial vehicles from 2,100 in 2010 to 9,500 in 2017 [16].

Although it is quite clear that in the past, drones were predominantly used for military purposes, we can also find examples from the civilian sphere, where they are gaining in importance today. These examples can be found in the scientific field and data collection.

The U.S. Weather Office [20] used an unmanned aircraft to collect meteorological data in dangerous storms in 1946 [8]. The National Aeronautics and Space Administration (NASA) also recognized possible opportunities and developed the Pathfinder, a solar-powered drone, in the 1980s. Due to technological shortcomings, its development was interrupted until 1993. After renewal, however, the findings of its development served as the basis for Pathfinder Plus and Helios [21]. In Australia, in 1998, the AAI Aerosonde Laima model was designed to collect meteorological data capable of one tank to fly over the Atlantic Ocean [12].

3. TERMINOLOGICAL BACKGROUND

Unmanned aircraft, which are the subject of research by the authors in this work, have been referred to by different names since the very beginning, and even today there is still no

universal consensus on the definition of what is most referred to as a drone. One of the main problems of finding a unified, generally accepted definition is the inability to agree on what should actually be the object of the definition, whether only the aircraft itself or possibly other elements associated with it, e.g., control station.

Despite the fact that the name drone is used to a large extent in common social interaction, this term is almost never used in professional literature and especially in legal documents. The reason is primarily the negative connotations that have been associated with drones in recent years, especially in connection with targeted airstrikes as part of their military use. They have become the main symbol of their use today. That is why states in their legislation and international organizations in official documents use a rather technical definition [22]. As a result, the term "Unmanned Aerial Vehicle" (UAV), which has been used by the general public as well as in some professional publications, has come to the fore for some time [23]. Even today, we can still encounter its use in some publications and official written materials, for example in documents of the United States Ministry of Defence [24]. Gradually is being replaced by new terms. The International Civil Aviation Organization (ICAO) considers it completely obsolete today [25].

The Convention on International Civil Aviation from 1944 (hereinafter referred to as the "Chicago Convention"), for example, uses the term "Pilotless Aircraft" in Article 8. However, this name has not been established in practice and is no longer used at all. In its scope, the term - Unmanned Aerial Vehicle (UAV) was developed, which under Art. 8 was included by the Eleventh Air Navigation Conference in 2003. At that time, UAV was understood as "an aircraft not controlled by a pilot, within the meaning of Article 8 of the Convention on International Civil Aviation, which flies without a pilot on board and is either remotely and completely controlled from another location (on ground, from another aircraft or space), or programmed and fully autonomous" [26]. This interpretation was later confirmed by the 35th Session of the ICAO Assembly in 2004 and added to official documents [27]. However, this designation was eventually abandoned and is no longer used today [28].

Today, therefore, ICAO does not use the term pilotless aircraft or UAVs but works with the general term Unmanned Aircraft (UA), which means "aircraft intended to operate without a pilot on board" [29]. Second used term is the Unmanned Aircraft System (UAS), which is defined as "an aircraft and its attached components operated without a pilot on board" [25].

However, developments have gradually necessitated the introduction of new terms, namely Remotely Piloted Aircraft (RPA), which ICAO has described as "a pilot-operated aircraft located different from the aircraft (i.e., on the ground, ship, in another aircraft or in space), which monitors the aircraft at all times [...] and has direct responsibility for the safe control of the aircraft during flight" [25]. Later, a simple definition was established that it is "an unmanned aircraft that is controlled from a remote-control station" [27].

However, when RPA refers to the whole system, both the aircraft and the control station, together with other control and monitoring elements and components, the term Remotely Piloted Aircraft System (RPAS) is used. It is defined by ICAO as "the remotely piloted aircraft, the relevant remote piloted station(s), the necessary command and control links and any other components specified in the type design" [27].

To transfer data between the aircraft and the control station, the so-called a Command-and-Control link (C2 link) which serves for the technical connection of the station to the aircraft. The pilot can control the RPA by means of a Remote Pilot Station (RPS). This can exist both in the form of a small manual control and a very complex station with many elements, which can have a static or mobile form. Other components of RPAS in addition to RPA, RPS and C2 link can be e.g., navigation equipment, launching and interception devices,

autopilot, or a system to ensure safe termination of the flight in the event of an emergency [27].

Ultimately, therefore, ICAO uses the terms UA and UAS as general terms, which fall under Pilotless Aircraft under Art. 8 of the Chicago Convention and replace the now obsolete UAVs. RPA is a special subcategory of UA [25], always controlled by the pilot, while RPAS includes RPA and other elements necessary for operation. However, there are also special types of drones that operate completely independently without the control of a particular pilot, only on the basis of a pre-programmed system. Therefore, they cannot be controlled in real time at all during the flight. In this case, it is referred to as Autonomous Aircraft [27].

All the categories of unmanned aircraft explained above – UA, RPA, but also autonomous aircraft, fall under Art. 8 of the Chicago Convention [27] and are now commonly used in the scientific literature. You have mastered them e.g., also the US Federal Aviation Administration [30]. However, the introduction of these terms does not in any way change the current legislation on model aircraft, which are intended for non-commercial use only and which generally do not fall within the scope of the Chicago Convention [25].

4. THE TERM OF UNMANNED AIRCRAFT IN EUROPEAN LEGISLATION

The European Union (EU) is aware of the growing importance of the UA, and it is therefore not surprising that its legal acts also deal with a certain terminology that largely reflects international law. However, as will be explained below, they face several problems.

Of course, the EU had to react to ICAO developments and quickly adopted the term UAS, which it similarly understood as an umbrella term for RPAS, which are controlled manually by a pilot, as semi-autonomous aircraft operating according to a pre-programmed system, but allowing pilot intervention during flight, and fully autonomous aircraft , which are able to independently collect data from the surrounding environment, analyse them, evaluate and possibly adjust their flight without external intervention [31]. Nevertheless, the term unmanned aircraft has not been formally defined in any legislation. Appropriate terminology and its specific definition have therefore continued to be the subject of various considerations. Even in 2015, EASA proposed to use the term drone because of its general reputation [32]. However, it did not work out in the end, and discussions on the applicable terminology continued.

Unfortunately, it must be stated that we do not find a legal definition of UA or UAS in European law today [33]. The only mention is in Regulation (EC) No 1049/2001 of the European Parliament and of the Council. Regulation (EC) No 216/2008 of 20 February 2008 on common rules in the field of civil aviation and establishing a European Aviation Safety Agency and repealing Council Directive 91/670 / EEC; 1592/2002 and Directive 2004/36 / EC [34]. In Annex II. of that Regulation, in point i) merely states that according to Art. 4 par. 4, this Regulation does not apply to "drones with an operating mass of 150 kg or less" and therefore remain governed by national law. Unmanned aerial vehicles over 150 kg fall within the scope of the Regulation and are fully covered by the legislation. With this adjustment, the EU has essentially completely abandoned the regulation of UA, as almost no commercial UA reaches 150 kg, in practice most are below 20 kg.

However, this inappropriate legal situation was finally decided by the European Commission as part of a comprehensive civil aviation arrangement in 2015. In particular, the Proposal for a Regulation of the European Parliament and of the Council on common rules in the field of civil aviation and establishing a European Union Aviation Safety Agency repeals

Regulation (EC) No 1049/2001 of the European Parliament and of the Council 216/2008 [35]. Article 3 contains two basic definitions, one for the drone and the second for its accessories.

Article 3 (29) defines an unmanned aircraft as "any aircraft operated or intended to be operated without a pilot on board". The EU will therefore have a new understanding of this concept very similarly to ICAO, differing only in the fact that, in addition to unmanned aircraft, it complements de facto unmanned aircraft. On the other hand, the proposal in Art. 3 (30) differently regulates the concept of equipment for the remote control of an unmanned aircraft (hereinafter referred to as "equipment") as "any equipment, apparatus, accessory, software or equipment necessary for the safe operation of an unmanned aircraft". In essence, it is now an internationally defined UAS, but without the aircraft itself. Interestingly, the proposal does not speak of the UAS as an umbrella term at all, but only of its components.

In parallel with this proposal, EASA also published in the summer of 2016 its prototype regulation on unmanned aerial operations [36], in which it adopts the European Commission's terminology in the case of the definition of an unmanned aircraft but approaches the whole UAS differently. In Art. 2 par. 1 letter (v) the term unmanned aircraft system is used to refer to the combination of an aircraft and its equipment, what ICAO commonly refers to as the UAS and which is completely missing in the Commission proposal.

At the same time, EASA also adds a new subcategory for part of the equipment in Art. 2 par. 1 letter r), namely the remote pilot station (RPS) as "part of a UAS containing equipment intended to control an unmanned aircraft". The RPS will therefore be considered as one of the components of the UAS [37]. The reason for this special allocation of the RPS is the effort to simplify the certification process. Indeed, if the control station were not legally separable from the UAS and the UA, there would in some cases be unnecessary control of the RPS even if the conditions apply only to the UA as a separate object [38].

5. CONCLUSIONS

Any progress, inventions or innovations of the modern world are created in order to facilitate our daily life, work, to move one step further. Unmanned aircraft are one example of such progress and innovation. Until a few years ago, drones were used only in the military field, now they are also used in the civilian sector to solve various tasks that were previously solved using manned aircraft. The dynamic development of new technologies allows the use of drones in various spheres of society. The new generation of digital technologies such as artificial intelligence, machine vision, processing of large amounts of data make it possible to qualitatively expand the range of tasks and possibilities of using drones.

The expansion of the possibilities of using these aircraft also results from the fact that today we already have different types of unmanned aircraft, which can be divided into several classes depending on various criteria, such as range, endurance, maximum take-off weight, number of engines, wing load, use etc.: unmanned aerial vehicles with fixed air foils, movable air foils, rotating air foils, waving air foils or aerostatic-type drones [39]. In addition to these groups, there are various mixed types of drones that cannot be unambiguously assigned to any of these groups.

Progress in this area is closely linked to the continuous growth in demand for the use of drones, even though a few years ago they were only considered toys. Today, drones are used not only for entertainment, to create nice photos or videos, but also to perform work in several industries. For example, in agriculture, they are used for: aerial survey of land; flying around fields to control the work of hired personnel; monitoring of animal identification fields; monitoring the location and use of agricultural machinery; grazing cattle, finding animals that

have been detached from the herd and directing them back; identification of sick animals in the herd using a drone equipped with a thermal imager and the necessary software; list of crops and fields, etc [40].

Another area of use of drones is search and rescue. The use of unmanned drones for search and rescue can be divided into four main groups: emergency detection, participation in liquidation, search and rescue of victims and assessment of damage caused. They work quickly and accurately, without endangering the lives of ground rescue teams. In order to broadcast the image and coordinate the work of ground teams, rescuers will install the necessary equipment on drones. The most often used are a video camera and a thermal imager. The thermal imager helps to detect people at night, in smoky areas or under treetops. Video broadcasting allows you to coordinate the work of the rescue team [41].

Also, drones can be used for amateur and professional filming and photography. The use of drones simplifies, reduces the cost of this process, and gives more options for different shots. For professional filming, film studios do not have to rent helicopters and cranes, as a modern unmanned aerial vehicle for professional filming, along with complete hanging accessories and a camera, costs about the same amount of money, but it is only a one-time investment [42].

Of course, increasing safety has become an indivisible and extremely important factor in the drone industry due to the growing number of machines used. Improper operation, often under the influence of the so-called human factor, can cause a collision with another drone or even an aircraft. The safety of others and property may (and does) compromise. Therefore, drone companies are developing new technologies [43] and ways to increase flight safety, for example through parachute systems. Safety still needs to be maintained in the aviation industry, and therefore more effective ways of maintaining safety need to be devised in the drone industry as well.

An important security issue that needs to be addressed as soon as possible is the cyber security of drones. We encounter news and information as hackers have taken control of drones, including military aircraft, to steal them for sale or use them for their own purposes. They use new methods. There are not many such cases at the moment, given the number of devices sold, but it is only a matter of time. It is therefore a serious task for developers to devise effective ways to protect against similar acts in the near future. In the context of drone progress and security, it is therefore necessary to constantly monitor and respond immediately to new threats, to take measures to ensure the safety of citizens, the protection of their health and their property, and not to infringe on their privacy.

In general, in conclusion, it can be stated that every year all technologies are modernized or replaced by others, more efficient, effective, more economical, etc. Therefore, we will certainly have new materials, technologies, systems that will increase safety in the future, which will be used in the construction of drones. Those that reduce equipment weight, increase strength, have more powerful and efficient batteries to improve endurance and performance are being explored, and other ways of building drones may emerge. In any case, developments in the field of innovation and the introduction of new technologies will continue in all areas of human society, including aviation, and will therefore be immediately reflected in the category of unmanned aircraft. The new development will undoubtedly bring other new challenges, which will be the content of further research by the authors in the subject matter.

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