Major Gábor

DOES AN AUTONOMOUS DRONE RETURN HOME AT ALL TIME?

One of the aims of the introduction of unmanned aerial vehicles (UAV) was to protect the most valuable combat instrument, the human factor. Human life had to be protected and it also had to be protected against dangerous factors. For this purpose, in the beginning, robots for ground forces and later aerial robots were established. The aim was to deploy them in situations considered dangerous. Initially, this equipment was cable-operated, and then remotely controlled. Today, according to the fast evolution of IT and control technologies, intelligent autonomous systems have been promoted and taken their place. In this article, the author is introducing various types and forms of UAV control and will illustrate with examples the possibilities of their appearance in the field of an unmanned flight. With the assistance of a generic model system the reader can understand the basic on-board devices responsible for the flight of the UA[1]. Finally, the author is proposing suggestions with regard to the prevention and elimination of disclosed risks to have the drone return safely when its task has been already achieved.

***Keywords**: Unmanned aerial vehicle/system, drone, control, autonomous mode.*

INTRODUCTION

„Flight is as incredible as its past was....Soon there will be unmanned aerial vehicles patrolling the skies above our cities”
(Philip J. Jarret[2])

In the past few years, as a result of the rapid improvement of flight industry, IT and control technology, the use of such equipment by a small and specific fraction of the society has started to spread. Today, and not counting space instruments, improvement of unmanned aerial vehicles is the most dynamic among aircrafts. Hardly a day goes by when we cannot read topics about their innovations and innovative possibilities of their application. Evolution of unmanned aerial vehicles has been continuous in the past decades too, we can say stormy. Fixed wing, rotary wing and even flapping-wing (ornithopters) have been created. One type can fly faster than the speed of sound, another on weighs only a few grams and a third is capable to depart with several tonnes of take-off mass, another one can only fly few hundred meters from the base of its operation and there are types capable to fly across continents.

They can fly autonomously[3] or can be remotely controlled by a human being, or these two can be combined. Common features of these constructions: the necessary presence of human factor during their planning and construction period and their operations in the air and also on the ground all along their life cycle [4].

The improvement of UAV/UAS[4] technology applied in the civil sector with the ever decreasing size of control equipment and the decreasing construction costs, remote controlled and autonomous unmanned aerial systems are available to all. Civilians and companies widely

[1] Unmanned Aircraft (ICAO Circular 328)
[2] Philip J. Jarret: A repülés története page 140.
[3] Greek originated word to express individuality, independent, arbitrary (Bakos: Idegen szavak és kifejezések)
[4] Unmanned Aerial Vehicle/Unmanned Aerial System

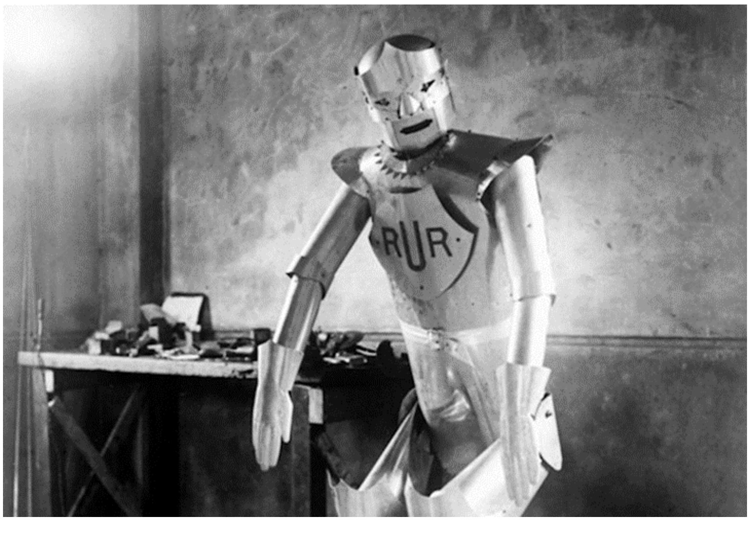
favour operations of UAVs to shoot pictures or videos or to deliver packages, not to mention military and disaster management tasks [14].

Is that true, that all that is needed is a decrease in the size of control tools and construction costs, and then anything can happen? Do we need human control if ability of self-control autonomy comes true? Is it not important to have the possibility of human intervention during the entire flight if needed?

ROBOTS AND THEIR IMPLEMENTATION METHODS

Before the examining its control possibilities, it is appropriate to review fields and forms of this technical solution and it is worth to review the world of ROBOTS referred to in the introduction. The aggregation motive of the appearance of unmanned aerial vehicles was to protect the life of the most valuable combat asset, the life of human beings, to protect them in danger. In the beginning, the intention was to first create ground robots and then aerial robots to deploy them to avoid risks of human loss in dangerous situations.

The expression of robots or, rather Robotics is originated from Asimov[5]. He used these words not knowing that he created them, he thought that this was the summary expression for hydraulics, mechanics and other related sciences. The original word robot is rooted in the Czech language, where the meaning is forced labour, and it was first applied by a novelist Karel Čapek in his book R.U.R. (**R**ossum's **U**niversal **R**obots).



Picture 1. ERIC[6] the first robot [6] in 1928

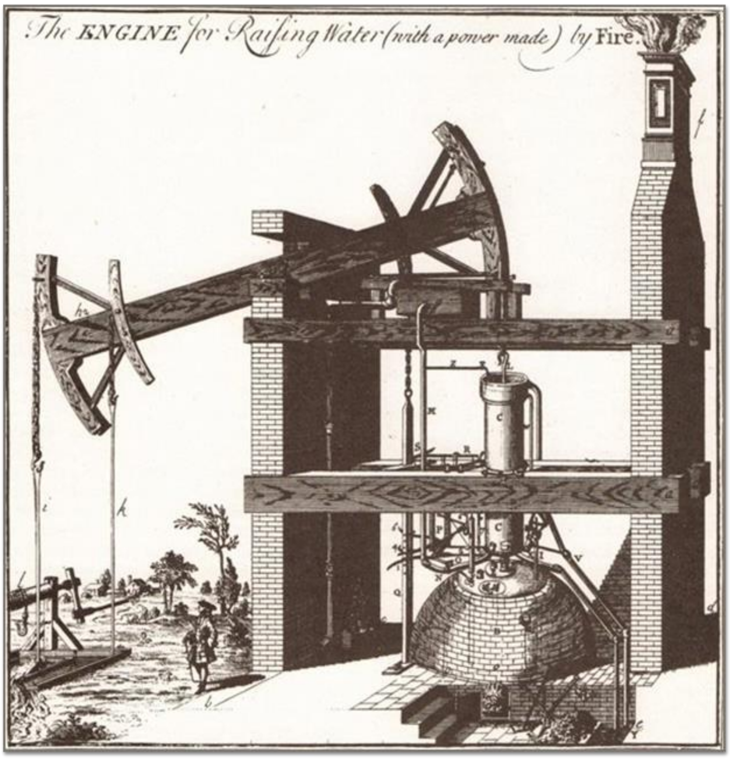
In literature, also in engineering and technical literature, the meaning of this word is a tool or piece of equipment that conducts physical or intellectual work similar to human activities. Therefore, we expect such properties in robots applied in production and in scientific researches

[5] Isaac Asimov (2 January 1920 Petrovicsi, Russia – 6 April 1992 New York, USA) Russian originated but american writer and biochemist. His science fiction novels and his science popularize made him well known. He was really famous and an exceptionally prolific writer.

[6] This 45 kg weigh humanoid aluminium robot was created by two British, Captain William H Richards and Alan Reffell. It could stand and could move its limbs and also could turn its head and speak. It could not perform useful work, just appeared as a display item. It disappeared in 1930. The Science Museum in London has launched a project in 2016 to reconstruct it. The planned budget exceeded the amount of 35.000 Pounds [16]

that make them capable to correct or supervise their own activities in greater or lesser extent. In other words, they have to fulfil the basic requirements of intelligence, e.g. perception, information processing, knowledge and memory, learning skills and communication-based activities [1].

In a different approach, robots are controlled mechanic systems that can be re-programmed between two projects. Remote programming can be also executed while the equipment is in deployment. It can move on pre-programmed routes and all along it can execute its tasks.



Picture 2. Outline [17] of the first steam engine by Thomas Newcomen[7]

Looking back in history, we can see that mankind has always tried to avoid doing dangerous and unpleasant tasks and to have them carried out by others. During the first Industrial Revolution in the 18th century, machines have appeared. From this point on, mankind gradually withdrew itself from executing hazardous and monotonous tasks.

Whereas the first machines, such as the steam engine shown in picture 2, were producing textile, machines today are produced by machines. To reach this possibility, the mechanical device is not enough anymore on its own, a control unit is needed. With pre-programmed data, machines are even capable to execute different tasks autonomously. It can be the construction of a vehicle, opening a door, hovering, cutting grass or taking off to execute different aerial assignments. They can work under human supervision or under the control of a computer [18].

The aim of this article is not to explain in detail the evolution and development of ground robots, because it can be in itself the subject of a separate study, but to introduce the control procedures of aerial vehicles and to highlight the possibilities of their supervision.

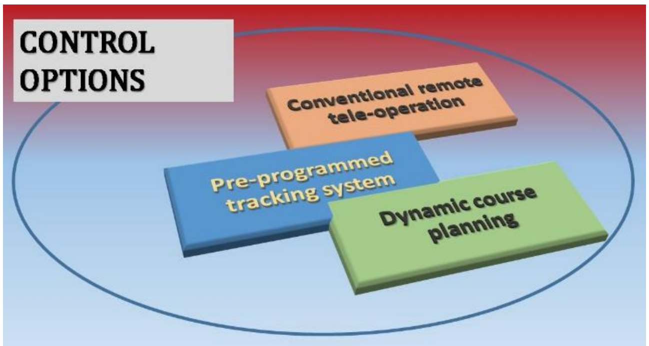
[7] Thomas Newcomen (Darthmouth, United Kingdom, 24 February 1664–5 August 1729). He was a smith, a plumber, a crimper and a laic Baptist preacher and an inventor. He invented the first operable steam engine in 1711.

ROBOT CONTROL

According to their movement competencies robots can be divided into two main groups:

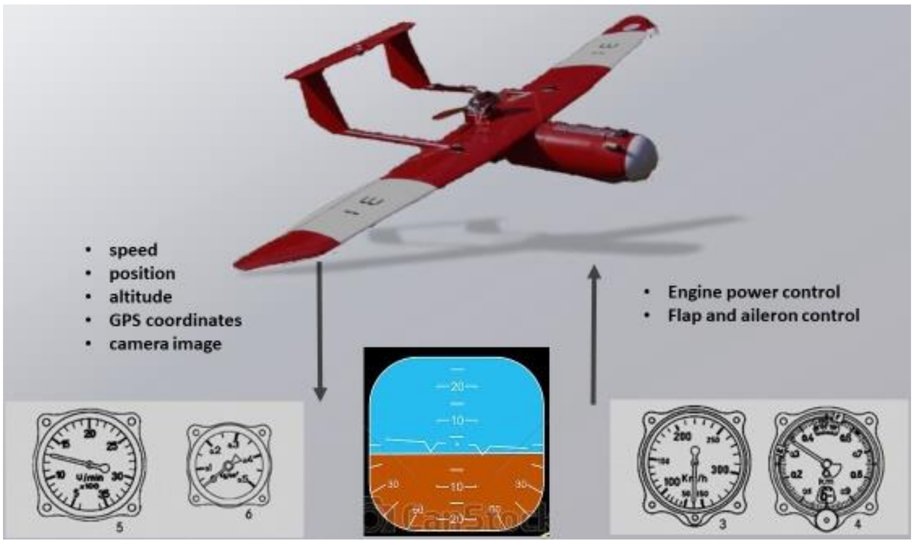
- Fixed (immobile, standing);
- Mobile (capable of movement).

Control of fixed robots is easily achievable via cable control, whereas with mobile robots it can be complicated because of the complex transmission between their applied system elements.



Picture 3. Control possibilities (edited by the author)

Mobile robots which are capable to change their position, such as ground wheeled vehicles or airborne moving drones are controlled by a specific computer and able to execute autonomous movements. These help those in the implementation of control possibilities as is highlighted in picture 3.



Picture 4. Schematic illustration of conventional control (edited by the author) [19]

During the application of conventional remote control tele-operation the movement of the equipment is controlled under visual signals by an operator. It can be executed in two forms. In the first form, our equipment may not leave the visual range[8,] in the second form the equipment is applied with imaging and image transmission systems, which are essential for the safe control[9]. In this case, we may not talk of autonomous robots, because these are controlled via

[8] Visual Line Of Sight (VLOS) operations

[9] Beyond Visual Line Of Sight (BVLOS or BLOS) operations

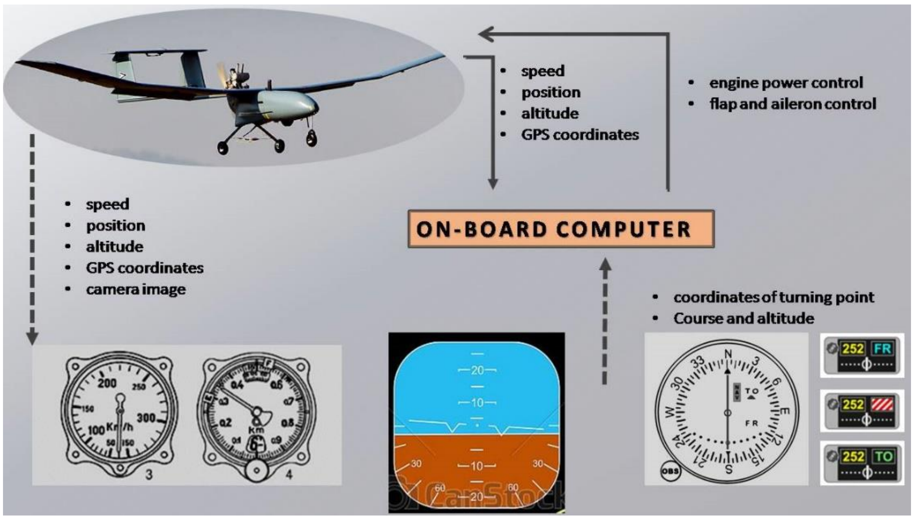
an open system. Control of this kind requires professional knowledge and continuous attention from the operator. During the management of the drone, the operator has to be continuously informed on the current position and flight parameters of the aerial vehicle. It is also important to know that in practice, the operator controls the UAV from a cockpit deployed on the ground.

Online operational processes of current flight parameters are usually carried out by a sensor operator who is sitting in a separate workplace, and not by the flight operator. Processing the data received from the UAV and its flight requires continuous connection and requires the full attention of the operators. The conventional model of this operation method is highlighted in picture 4.

Pre-programmed flight path: the UAV has to pass pre-programmed ground or three-dimensional points in its duty environment. It occurs by point to point regulation or by path tracking method on pre-planned turning points. During the execution of these tasks it is required to apply a barrier detection system on the UAV such as ultrasound or proximity sensors to avoid without problem any unforeseen barriers.

Control-based on dynamic path planning essentially requires the exact coordinates of the target. Application of an on-board computer on the UAV significantly changes the control situation. During its path from the take-off point to the destination it identifies the terrain and sets up its own orbit. Camera, image processing, ultrasound or laser rangefinder, digital course meter, and currently measured GPS coordinates support its navigation and sensing. It is significant to program the take-off point just the same as the destination point. Target is just an intermediate location. In case we can dynamically upload target coordinates during the execution of the exercise, there is no need for concordant take-off and destination points.

The evolution of IT, control and production technologies have made it possible to create smaller and smaller computers and miniaturisation was also feasible. Programming of small UAVs was not a problem anymore. On-board flight data transmission between the UAV and the ground control are mostly to inform the operator and not to confirm the control itself. It can occur because orders of the operator are simplified and consist of flight direction only and the desired target coordinates. Such a computer system is highlighted in the following picture.



Picture 5. Schematic illustration of computer-based control (edited by the author) [19]

Thanks to this scheme we can avoid a number of difficulties. From now on, UAV operators should execute the tasks of a flight controller and not the tasks of a pilot. Because of the stormy evolution of related technologies the UAV is now capable to execute take-off and landing procedures individually. The operator sitting in a distant and safe control station introduces only the flight path and monitors the execution of the mission. If these criteria are met, one operator will be capable to control the flight of several UAVs simultaneously. On-board computers will be responsible for the security of the airborne UAV and will manage the correct maneuvers.

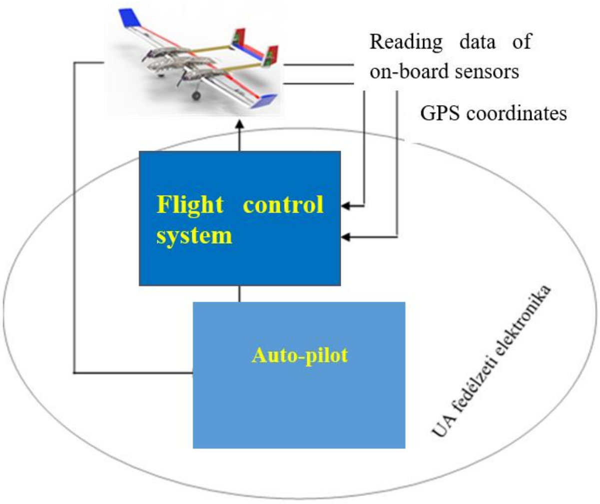
It is essential to gain concordance among the ground sub-systems and the aerial sub-systems. To achieve this goal, continuous and standing communication is needed to ensure efficient cooperation [15]. In the next chapter I will introduce the possibilities of control and I will examine how parameter influencing affects on-board devices.

DESIGN OF ON-BOARD SYSTEM

As is clear from the overview of devices of unmanned aerial vehicles, I will summarise functions of flight related on-board instruments and their operational creditability.

The design, number and quality of on-board instruments can differ significantly by category. In the following case, quality means system security established by redundant elements.

When we speak about unmanned aerial vehicles we should not forget that referring to pilot-controlled aircrafts and their operations, we already have a mature technical manual and regulation, however, not for drones. During the planning phase and the construction phase of UAVs, regulations approved for the operation of conventional aircrafts must be fundamentally applied.



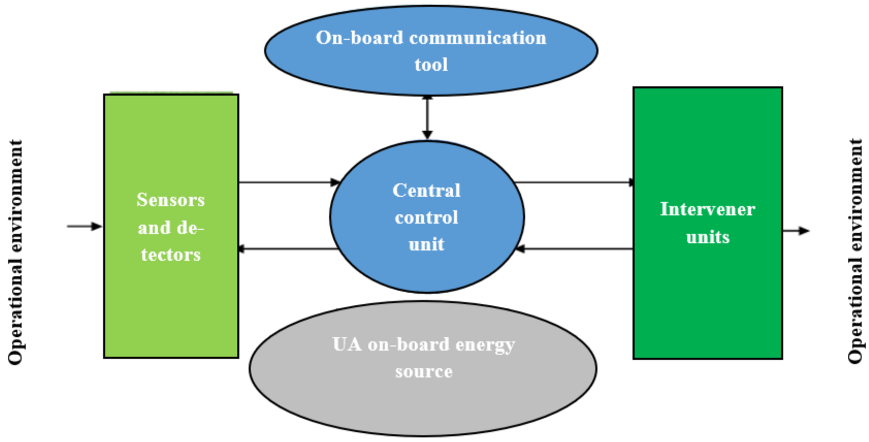
Picture 6. Simplified on-board system model [5]

In the general design system, electronic components responsible for the flight of a UAV can be divided into three main blocks. These are the equipment itself with the applied sensors and interveners, the flight control unit and the auto pilot. The simplified system consists of two tied circuits as highlighted in picture 6. The inner tied circuit ensures the stability of flight characteristics like altitude and flight positions like pitch angle. This circle is responsible for flight control. Furthermore, its task is to avoid the consequences of disturbances which appear during the flight like, turbulence, gusts and shifts in density. Flight data, like speed and altitude is measured by sensors and transmitted as electronic signal to the electronic process circuit. The flight control system transmits the setpoint generated by the auto pilot and the actual sensor data to the intervener units. After the shift in the course of the feedback, measurement result is provided by the intervener units [4].

Reliable and persistent operations of the aerial vehicle are determined by many features such as its airframe, engine, certain interveners, on-board electronics and the reliability of electric supply circles. Flight parameters and location of the UAV is measured by several sensors. Data received from the sensors are stored in the central control unit. This data is autonomously compared with the setpoint (desired basic flight data) and then considering the system`s characteristics the intervener sign will be calculated. According to their function, on-board electronics responsible for automatization can be divided into two groups. Flight control circles are responsible for the stability of the flight, for the desired altitude and its holding. They are also responsible for proper turning and angle. The signal transmitted to the interveners is produced by the auto-pilot module. At present, decisions are taken in accordance with the standing task and the data, mainly position coordinates, measured [5].

To proceed in the presentation of on-board systems in picture 7 I highlight the connection between certain blocks. This should help to understand the complete structure and the main operational functions. We can conclude, that partial or complete malfunction of certain components might cause complete dysfunction.

If the operation of a component is limited, for example because of a malfunction, control of the UAV can be lost. It is expedient to minimize the probability of the complete malfunction of certain units. There are some very important criteria in regard with the planning, construction and operations period of a UA. On the one hand, complete failure of sensors, detectors and the auto-pilot is not permitted. On the other hand, reduced functionality is acceptable in case of a malfunction and certain functionalities have to be interchangeable.



Picture 7. Hardware system – feasibility model [4]

Flight safety shall not be violated, conditions must be harmonized accordingly. We cannot expect full functionality from the UAV in case of an unexpected malfunction. It may mean that the UA is not capable to achieve its current task, but still capable to avoid crash. It also can perform emergency landing with maximum security and can activate the operator`s remote control option too. The establishment of a temporary security status may also be configured like circling in a given altitude.

CONCLUSIONS

At the beginning of this article I have attempted to find answers to the following questions: what happens in case of the malfunction of certain sensors required for safe flight? What happens with our unmanned system in case of an enemy or allied interference or jamming?

In the light of the above, it was clearly visible and understandable that in the case of malfunction of an essential flight system like altimeter, the autonomous UA must be able to hand over its control to the ground control unit. It may mean a safe option for the ongoing operation. It also reflects to that fact, that this kind of aerial vehicle can be deployed only within the visibility of the control personnel. However, if the deployment of the equipment is required beyond the visibility, we have to forget this kind of error management. When facing larger expectations, the critical systems of the deployed equipmenthave to be equipped with parallel units, which are capable to substitute each other.

During its flight, a system of this kind is much better protected against temporary malfunction of the transmission channel. The on-board computer can be prepared by pre-processed algorithms on how to act in case of an enduring loss of communication. We can also refer to an additional problem, the security of terrain-following and low-altitude flights. Because of the much shorter reaction time, the possibility of an unexpected injury is much larger during the execution of these tasks.

Nevertheless, in accordance with the stormy evolution of unmanned aerial systems their operation is in a shift in the direction of individual decision making. It does not only apply to the selection of their flight course, but also for their combat application.

Instead of answering we may form another question. Namely, how wide autonomy can be given to robots and what kind of conditions do we have to establish for their use of weapons and for their rules of engagement? It is impossible to find the correct and exact answer today and it also might be irresponsible. Certainly, human beings will use all advantages of privilege services and improvements in the IT section provided by robotic appliances. Such a case can be to leave our UA in autonomous mode while deployed. Therefore, the operator of the UA will be able to operate several UAs in line, because thealready "grown-up" aerial vehicle will not require permanent supervision.

Finally, it is useful to think about the questions, when can we completely release our ground or aerial robot to control itself? When can we let it live its independent life?

We can also compare the above mentioned capabilities with artificial intelligence researches. Can we implement these autonomous characteristics into our equipment as discussed earlier? It is still a complicated task and really difficult to achieve. However, there are progressive improvements in ethology, genetics, neurobiology, evolution biology, anthropology and robotics. For the time being, science is not capable to create the robot with individual thought and reasoning. The lack of analytic and assessment capabilities is also an ongoing barrier. Although, we have achieved very good results in the above mentioned sciences, but we still cannot implement human conscience, perception, faith, desire and will or intention.

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AZ AUTONÓM DRÓN[10] MINDIG HAZATÉR?

A pilóta nélküli járművek megjelenésének egyik előidézője az a tézis volt, hogy a legdrágább „harci eszközt”, az embert, annak az életét, miként lehet megóvni a veszélyes körülményektől. Ennek érdekében sorra készültek különböző földi-, majd később légi robotok, amelyeket egy-egy veszélyesnek ítélt helyzetben bevethettek. Ezeknek a szerkezeteknek az irányítása a kezdetekben vezetékes-, majd a vezeték nélküli távirányítással történt. A számítás- és irányítástechnika rohamos fejlődése következtében napjainkra az autonóm, intelligens rendszerek kerültek előtérbe. Az alábbi publikációban a szerző az irányítás különböző formáit, területeit mutatja be, majd ezek előfordulási lehetőségeit példák segítségével illusztrálja a pilóta nélküli repülésben. A cikkből az olvasó megismerheti az UA[11] repüléséért felelős, alapvető fedélzeti berendezéseket egy általános rendszermodell segítségével. Végezetül a feltárt kockázatok elhárítására, kiküszöbölésére tesz javaslatot a cikk szerzője, azért, hogy a drónunk mindig biztonságosa térjen vissza a számára meghatározott feladat végrehajtását követően.

***Kulcsszavak**: pilóta nélküli légijármű rendszerek, drón, irányítás, autonóm üzemmód.*

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