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**Unmanned aerial system for agricultural**

*A brief history of the development of unmanned aircraft, terms, definitions, as well as the structure of an unmanned aerial system for agricultural are considered. Technical and regulatory barriers to the development of commercial unmanned aerial vehicles are discussed.*

**Background.**

Aviation of the XXI century is a century of unmanned aerial vehicle. The inducement for the intensive development of unmanned aircraft, as well as many other high-tech branches of engineering science, was the widespread use of unmanned aerial vehicles (UAVs) in the armed forces of the United States, Israel and other countries. More than 100 years ago Nikola Tesla developed and demonstrated a miniature radio-controlled vessel [1]. Since then, the theory and practice of unmanned aircraft has made a quantum leap from the unmanned aerial vehicle to the unmanned aerial complex and the unmanned aerial system.

UAVs are manufactured all over the world. USA, Israel, Germany, France, Japan, China and a number of other countries are leading in the production of UAVs. Since the beginning of the 2000s, UAVs developed for agriculture and forestry (monitoring crops, controlling pests and plant diseases) has assumed increasing importance. The pioneer in the application of UAVs for agricultural purposes is Japan, where currently 2,400 unmanned helicopters are used for spraying and sowing. Several UAV models have been developed, which are used for monitoring and spraying crops. In 1990, the unmanned helicopter Yamaha RMAX was developed [2]. A small, remotely controlled helicopter is equipped with a 2.4-liter two-stroke engine, capable of carrying a payload up to 28 kg and spraying chemicals at a velocity of about 24 km / h. The Japanese model of crop cultivation has obvious advantages. The main advantage is the accuracy of applying chemicals, which reduces both costs and pollution.

Ukraine is still lagging behind foreign UAV manufacturers, especially with regard to electronic devices, which make up the greater part of the cost of UAVs. The main problem of domestic manufacturers is insufficient element base. Therefore, foreign microcircuits and other elements for UAV manufacture are used in Ukraine.

Nevertheless, there are many examples of successful UAVs developments in Ukraine. For example, UAV DR-60 was developed and tested by Y. Pederi who is Head of AeroDrone company in Kiev. UAV DR-60 can be applied for detailed and regular monitoring of the state of farmland, controlling the crops growth, predicting and even managing yields. DR-60 is controlled from the ground using a laptop connected to the satellite navigation system. There is a battery, a digital camera and a navigation device on the drone board. The body of DR-60 is made of lightweight

materials, payload weight is 60 kg, the take-off weight is 150 kg, the flight speed is 100 km / h, the flight time without refueling is 90 minutes [3].

According to a new study by PwC on the commercial applications of drone technology [4], the emerging global market for business services using drones is valued at over $127 bn. And predicted global value of drone powered solutions in key industries) is: infrastructure – $45.2 bn.; agriculture – $32.4 bn.; transport – $13 bn.; security – $10 bn.; media & entertainment – $8.8 bn.; insurance – $6.8 bn.; telecommunication – $6.3 bn.; mining – $4.4 bn.

**Terms and definitions.**

*Unmanned aerial vehicle* is a pilotless aircraft, in the sense of Article 8 of the Convention on International Civil Aviation, which is flown without a pilot-in-command on-board and is either remotely and fully controlled from another place (ground, another aircraft, space) or programmed and fully autonomous [5].

*An unmanned aerial complex (UAC) is* a set of material and technical means necessary for the performance of certain functions [6]. The UAC includes one or more unmanned aerial vehicles, control, transport equipment, technical devices that form communication channels, transmissions and processing information devices, etc. The UAC is supplied from the manufacturing enterprise to the customer in the form of a complete complex fully ready for use. But, if necessary, this complex can be expanded, modified and integrated into other systems due to additional hardware and software. For example, the structure of the mobile UAC may include the following: unmanned aerial vehicles of various types, vehicles for transporting people and material resources, a vehicle with a control point, hangars for storing equipment, airfields infrastructure, including radar equipment, fronted antenna-feeder devices, including signal repeaters, spare parts kits, equipment for refueling or recharging batteries, etc. In addition to the basic facilities for UAC operation, additional support facilities will also be required to prepare the UAV for flight, to service the UAV after the flight, to conduct routine maintenance and repair, and to store the facilities of the complex. This group of funds is usually not part of the UAC; therefore, UAV is serviced by the customer's technical personnel.

*An unmanned aerial system* (UAS) includes not only the UAC, but also additional components that form various types of connections between its elements. These components are technical personnel, software, means of integration with other systems, allowing to combine several UACs into a system with unified management; technical and regulatory documentation [6]. UAVs that are part of the UAS and equipped with the appropriate target load determine its specialization. Among civil systems, the most common are information receiving in-flight video and photo data, and transferring them to ground-based equipment for processing. To do this, software that implements the appropriate algorithms is needed. Start and landing facilities may include vehicles, launchers, as well as equipment for pre- and post-flight control of the UAV. This part of the complex is serviced by technical staff of UAS.

*Flight control centres* (FCCs) operate using control calculations and include staff of relevant specializations. FCCs combine the devices and equipment for the development of UAV flight programs, flight control of UAV technical condition, radio command control of flight missions, as well as for data collection, processing and transmission. FCCs differ in organization and execution depending on the

system tasks. Thus, applying fixed FCC is advisable for agrarian UAS control on a regional or district scale. Mobile platforms (on cars) for FCC is advisable for UAS control at the farm level. In order to control copters, performing work in small areas, portable consoles are often used by the operator. The UAV control system is the brain of the UAV, its artificial intelligence, which is being improved using as robotics and mechatronics. Today, it is common to distinguish three types of UAV control systems:

1) *manual actuation* from a remote-control panel within the optical visibility (Visual Line Of Sight) *by external pilot* (or remote pilot control) or extension of the visibility range using the observer and the radio links for control of visual information coming from the front-view camera (Extended Visual Line of Sight operations). An external pilot solves the problem of piloting primarily: the desired course, altitude support, etc.;

2) *automatic control* beyond the limits of visibility, using only the instruments of the ground control station (Beyond Visual Line of Sight), provides the possibility of a fully autonomous UAV flight along a given trajectory at a given altitude with a given speed and with stabilization of the orientation angles. Automatic control is carried out using on-board software devices;

3) *manual-automatic control* (or distant control) – the flight is carried out automatically without man intervention using the autopilot according to the originally specified parameters, but the external pilot can make changes to the route in an interactive mode. Thus, the external pilot can influence the result of the operation, without being distracted by the piloting tasks.

Automatic and semi-automatic control are currently most demanded by the UAV operators, because such control less training needed and provide safe and efficient operation of the UAV. Fully automatic control can be the optimal solution for aerial photography tasks of a predetermined agricultural area, when it is necessary to photograph at a great distance from the base location outside the contact with the ground station.

To use the UAV in agriculture, it should be considered in conjunction with its instrumentation equipment and payload. Agrarian UAV, in addition to unmanned aerial vehicles, consists of an on-board control complex, payload, FCC and a ground-based analysis and decision-making unit.

**The main barriers to the development of the UAV market**

***Regulatory barriers.***

To date, the development of the civilian UAV market, including for agriculture, is hampered by a regulatory barrier to the integration of UAV into a single airspace. This problem is not completely solved in any country in the world. In Ukraine only the first steps have been taken in this direction. In 2018, In 2018, to ensure safe flight operations of general-purpose drones within Ukrainian airspace the State Aviation Service of Ukraine published a new concept draft. The introduction of electronic registration and certification, registration, the right to unmanned systems control depending on their size and destination is considered for the first time. Those measures should greatly simplify the fly-over permission. However, this document should be supplemented by a number of accompanying documents containing detailed rules and instructions. For now, unmanned systems are purchased by structures that

have special powers (border guards, army, the Ministry of Emergency Situations) without waiting for the creation of a regulatory framework. Currently, the responsibility for UAVs flying for commercial purposes lies with the operator. The issues of certification, insurance, registration have not yet been fully resolved.

***Technical barriers.***

Most UAVs are not equipped with a system of obstacle recognition and avoidance of collisions, which led to an increased accident rate of the UAV. Autopilots of some UAV models are less than perfect but used for the sake of economy in cost and weight of the onboard equipment. There is one vulnerable link in the UAV control system. This is a necessity for constant information exchange with ground control points. A large volume of transmitted data is very difficult to provide a high level of reliability. In the simple version, they can simply be suppressed by interference.

## Conclusion

We are witnesses to the beginning of a new round of technological progress. The precedent has already been created, UAVs are already being used for aerial works and services. But before this expected future comes, it is necessary to solve many problems. The most important of which is to find a balance of interests of all parties to which the use of UAVs can in one way or another influence. Business is interested in effective agricultural technologies, citizens need a comfortable environment, the state needs to maintain the country's security. Only if this balance is maintained the desired efficiency of UAVs can be attained.

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