Modern technological trends in the development of the ecosystem of cargo UAVs

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Abstract. Trends in the development of the ecosystem of cargo UAVs are considered. This ecosystem has appeared in the aviation industry, including civil unmanned aerial systems manufacturers and their components, software developers, integrators, UAV-based service providers, insurance companies and trading platforms. The architectural concept of unmanned aircraft system traffic management is discussed.

1. Introduction

The world market of civil unmanned aerial systems (UAS), their components and services provided on their basis, is experiencing explosive growth. According to the results of statistical studies obtained from various sources, the global market for civilian UAS in 2017 amounted to about $ 4.0 billion and continues to grow rapidly. A new ecosystem has appeared in the aviation industry, including UAS manufacturers and their components, software developers, integrators, UAV-based service providers, insurance companies and trading platforms.

In this research, UAS will be defined \cite{1} as a set of interconnected elements, including one or more unmanned aircraft, means for providing takeoff and landing, means of flight control of one or more unmanned aircraft and flight control of one or more unmanned aircraft.

Estimates made by various research organizations show that the volume of the global UAS market, integrated solutions and services by 2035 will amount to more than $ 200 billion (at current prices) and will be subject to diversification of various sectors of the economy. Not only the market structure will change, but also the demands of consumers, which new leaders in global competition will have to adapt to. Russia's share in this emerging market may amount to more than $ 35–40 billion. Large domestic companies will emerge that will develop industry standards and new technologies in their segments.

However, the current practice, for example, in Russia at present, of the use of UAS is radically different from the projected scale. Analysis of public procurement for the period 2017-2019, accounting for the market for commercial orders, entertainment and educational services based on UAS gives a total market estimate in Russia of about 7.5 billion rubles over the past 2 years. The main factors hindering the large-scale use of civilian UAS in the domestic market are insufficient state support, imperfection of regulatory legal and technical regulation, as well as the apparent lag behind leading foreign countries in the technological development of safe and effective integration of UAS into the national airspace.
The use of UAS as a new category of air transport objectively creates new threats to national security, the air traffic safety of manned aviation, as well as new risks of harming the health of citizens, property of legal entities and individuals, violation of trade secrets and rights to protect personal life.

A key condition for the success of the introduction of unmanned aircraft in the economy of the Russian Federation is a joint and compromise achievement of the interests of the state in the face of regulatory regulators (federal executive authorities and certification bodies) and the business of developing a massive commercial market for the use of UAS, subject to established safety requirements. The implementation of safe and effective integration of UAS into the airspace of the Russian Federation will be a systematic and phased work, involving the participation of all interested parties in the development of regulatory legal and technical regulation, the creation and implementation of new technologies, the development and qualification of airborne and ground equipment, operational procedures for Air Traffic Control (ATC), training air traffic controllers, external pilots and personnel engaged in the technical maintenance of UAS.

Currently, there are ongoing discussions in the international organizations of ICAO, RTCA, EUROCONTROL, EASA, EUROCAE, as well as the Ministry of Transport of Russia, the Federal Air Transport Agency, the Union of Russian Aviation Manufacturers, aviation industry enterprises, research organizations, various business associations and non-profit associations about on the basis of which regulatory requirements and technological solutions to perform safe and effective integration of UAS into non-segregated airspace. There is currently no universally recognized, agreed upon and approved by state regulators decision in the Russian Federation.

In this regard, the urgent task is to analyze international and national programs, regulations and modern technological solutions related to the integration of UAS in a controlled and uncontrolled airspace, and develop proposals for their improvement in the interest of developing an agreed concept for UAS integration by all interested participants in the aviation industry into airspace and its approval by state regulators.

2. Analysis of ICAO documents related to the use of airspace by unmanned aircraft systems

Currently, much attention is paid to the use of airspace and the integration of unmanned aerial systems into it. In international organizations ICAO, RTCA, EUROCONTROL, EASA, EUROCAE, as well as in the Ministry of Transport of Russia, the Federal Air Transport Agency, the Union of Aircraft Manufacturers of Russia, various business associations and non-profit associations, there are ongoing discussions, on the basis of which regulatory requirements and technical solutions should BSS flights be performed in an unsegregated airspace. There is currently no universally recognized, agreed upon and approved by state regulators decision in the Russian Federation. In this regard, the urgent task is to analyze ICAO documents related to the use of airspace by unmanned aerial systems and justify the need to improve regulatory regulation at the national level and harmonize it with international regulation in the interests of developing a concept for the integration of UAS into the airspace of the Russian Federation.

2.1. Airspace structure and classification

The widespread use of UAS inevitably actualizes the problem of organizing air traffic and air navigation services for UAV flights in non-segregated airspace together with manned aircraft. In the interests of rational use, creation of favorable conditions for planning, coordination, provision and execution of aviation flights of all departments, as well as operational air traffic services, the airspace of states is divided into separate volumes, the totality of which forms its structure.

The basis for building the airspace structure is the criteria for the required throughput of the air traffic organizations (ATO), the economy and regularity of air traffic, while ensuring the level of flight safety.

When constructing the airspace (AS), ICAO recommends that the following key factors be given in Appendix 11 to the Convention on International Civil Aviation. “Air traffic services” [3]:

- type of air traffic services provided (dispatch, flight information, emergency alert service);
- flight rules;
- intensity and type of air traffic (regular or occasional);
- technical characteristics of aircraft (AC);
- performance characteristics of radio navigation aids and ATO;
- air traffic services dispatcher capabilities.

Based on these criteria, the airspace in which international air traffic services are provided can be classified and designated as airspace of classes A, B, C, D, E, F, G. Requirements for aircraft flying in different classes of aircraft spaces are defined and represented by regulatory documents of ICAO [2, 3].

Thus, the airspace of classes A, B, C, D, and E is controlled airspace, and the airspace of classes F and G is uncontrolled airspace. Moreover, the ICAO classification is advisory in nature, and the states themselves determine the structure of the national airspace.

The ICAO recommendations regarding airspace structuring are most fully implemented in the US Air Force. In accordance with the Code of Federal Rules 14 CFR “Aeronautics and Space” [3] in cases where the aircraft is not in classes A, B, C, D, restricted or restricted areas, it is in class E or class G.

**Class A.** Class A airspace covers the entire country and has a lower border of 18,000 ft. MSL (relative to mean sea level). In this class of airspace, the air traffic control service has a fairly good understanding of the air situation through the use of mandatory air traffic control. Class A space begins at an altitude of 18,000 ft. MSL and extends to a height of 60,000 ft. MSL.

**Class B.** Class B airspace surrounds national airports and typically extends up to 10,000 feet. MSL, and in some cases, higher. Class B airspace can extend horizontally with a radius of up to 15 miles from the airport tower. More precisely, it is determined specifically based on the conditions of air traffic intensity, geographical or other conditions of a particular airport. Unlawful entry into Class B space is a very serious violation that puts at risk the lives of many people flying large passenger airplanes. If penetration into spaces of classes D or E entails only a serious warning, then penetration into class B or C entails severe punishment.

**Class C.** The height separation shows the upper and lower bounds, as well as in the class B space. Also, as in the class B space, flights without coordination with ATC are possible above and below the ledges of space C. For general aviation flights inside this space requires permission from the Air Traffic Control Authority (ATC), which can be obtained by telephone (some ATC units may receive applications by radio).

**Class D.** Class D, usually refers to the airspace of small urban airports with a control tower. Typically, the upper class D boundary is at 2,500 feet. AGL above the airport, but this height may be different. Some boundaries of the space D can have, for example, an elongated shape, this is due to the peculiarities of passing the take-off or landing routes of the airport.

**Class E.** Class E is a huge controlled airspace that is not defined as classes A, B, C, D, G. It fills the gap between the other classes. In it you can fly within limits not limited to other spaces. Class E always has one of four lower boundary values: surface, 700 AGL (height above ground), 1,200 AGL, 14,500 MSL. Most of the E space has a height limit of 1,200 AGL. The height limit of 700 AGL is indicated on the maps by a wide purple line with a blurred border. The blurred boundary is on the side where the lower boundary of the 700 AGL space is introduced.

**Class G.** This class is located under the remaining spaces and starts from the surface of the earth. It covers the entire surface of the earth, repeating the relief. In remote areas, it has a height of 14500 MSL. The upper boundary of class G is usually the lower boundary of space E. Class G is completely uncontrolled and is most suitable for general aviation and unmanned aerial vehicles (UAVs). Class G ends where it intersects with classes B, C, D, E.

In EU countries, airspace classification is established by national aviation authorities. For example, in the United Kingdom, the classes of controlled airspace A, C, D, E and the class of uncontrolled airspace G are established. In Germany, the classes of controlled airspace C, D, E and the class of uncontrolled airspace G are installed. In Spain, all classes of airspace from A to G in accordance with the classification of ICAO. Classes A to E are for controlled airspace, classes F and G are for uncontrolled.
3. Towards the ecosystem of cargo UAVs

One of the actively discussed trends in the development of the UAS market is the concept of UTM (Unmanned aircraft system traffic management) [4-16]. The experts of the Aeronet Association [5] prepared analytical material on the UTM concept, its capabilities and limitations.

The increasing use of civilian unmanned aerial systems leads to the need to make their movement safe at any point, and at any given time. Finding yourself like yourself in the sky, determining the relative position to prevent a possible collision should be instant and absolutely accurate. The world scientific community continues to search for methods to solve this problem associated with the organization of the joint use of "small", passenger and cargo UAVs. One of the concepts proposed in the USA is called Unmanned aircraft system traffic management - UTM [5].

The UTM concept was proposed in 2014 by the National Aeronautics Agency NASA (National Aeronautics and Space Administration) [8]. Declaring UTM as a new era in aviation, NASA launched an initiative project, and organized tests of the prototype system in 2015. During the tests, an attempt was made through the UTM system to inform external pilots about the exit beyond the planned geofence, as well as about manned aircraft approaching the airfield.

Parimal Kopardekar, chief technologist and author of the NASA UTM concept, noted [4] that UTM is designed to ensure the safety of civil aviation at low altitudes by providing pilots with the information necessary to ensure separation from other aircraft by reserving zones for specific routes, taking into account limited airspace and adverse weather conditions.

An analysis of the results of the first tests showed that the new era of aviation in the form of the UTM concept has a significant limitation. The data transfer technologies proposed for use, such as mobile communications and the Internet, are not approved by civil aviation, which means that the UTM system will not solve the issues of safe joint flights between military aircraft and manned aircraft.

The next pilot work on the UTM system for the FAA [3] began about two years ago, when an agreement was reached with NASA [8] on cooperation in space SAA (Space Act Agreement), aimed at automating the air traffic control service.

It should be noted that interest in the UTM project has been shown by many private companies and research and educational institutions, including large technology companies that have invested heavily in the project. In particular, in July 2016 in Switzerland (Lausanne), the International Association for Air Traffic Management BVS - GUTMA (Global UTM Association) was created. Currently, the Association has about 70 members, from 27 countries, including Russia. Russia has joined the Association represented by NP GLONASS and Azimut JSC.

So, the main functions of UTM are defined today. The FAA web-site [7] gives the following definition. UTM is a “traffic management” ecosystem for uncontrolled operations that is separate from, but complements, the Air Traffic Management - ATM (ATM) air traffic management system.

Thus, the UTM is designed to define services, roles and responsibilities, information architecture, communication protocols, software features, infrastructure and performance requirements to enable uncontrolled unmanned operations at low altitudes. That is, in essence, UTM is a set of reference and information services that provide users with information about flight plans, but not about the actually reliable position of aircraft.

And one should pay attention to the fact that the FAA talks about organizing only unmanned operations. This aspect is the main disadvantage and limitation of the UTM concept, as it requires airspace segregation for the safe operation of the air handling system. This is, in fact, “buffering” in the form of a zone of demarcation between the military aircraft and the air defense forces, however, the complete isolation of unmanned and manned aircraft in different layers of the airspace only exacerbates the problem.

Further plans for the development of UTM and U-Space [16] provide for the joint implementation of BVS and PVS flights, including for mass joint flights in cities within the framework of the concept of urban air mobility. However, the ways in which this will be ensured are not explained.
In the roadmap [6], a forecast is given that, provided that all levels of UTM development are realized in 2035 over Paris, it is expected that flights of 156 commercial aircraft, 2,500 UAVs carrying passengers and cargo, and 16,667 small UAVs delivering parcels, 58 UAVs making inspections and 44 recreational UAVs are expected.

The public-private partnership for the implementation of the UAM program will be supported by the European Commission and will bring together cities and regions, investment, industry and research companies and organizations. The first city to join the initiative on 05/30/2018 was Geneva, followed by Hamburg, Ingolstadt, Ghent, Plovdiv, Brussels, Enschede, Munster and Antwerp. A similar project in the United States started in 2018 as part of aeromobility research programs conducted by the NASA National Aerospace Agency in conjunction with the FAA. In May 2018, NASA signed a partnership agreement with Uber Technologies to explore concepts and research on technologies related to urban air mobility in order to create a safe and efficient ecosystem of future passenger and cargo flights operated by manned and unmanned aircraft in cities and towns. Pilot urban air mobility projects involving Airbus [6] are also underway in Singapore, Brazil and Japan.

Currently, there are several categories of air transport proposed for the implementation of the UAM concept, each of which has clear characteristics and potential uses:

- traditional aircraft piloted by a licensed pilot used as air taxi (the use of helicopters with a capacity of 2-6 passengers is more appropriate due to lower minimum requirements for landing sites located in cities and suburban settlements), the average range is 100-300 km;
- unmanned aircraft (UAV) for the transport of passengers and goods - multicopters with vertical take-off and landing (VTOL) with electric (hybrid) engines will optionally be piloted in the traditional way by licensed pilots on board, remotely licensed by an external pilot or will be fully autonomous vehicles, short range up to 120 km;
- flying cars (vehicles that the driver/pilot can drive in the vehicle’s configuration to the airport or landing pad, reconfigure the car to aircraft mode, and then fly to the destination airport) designed to transport people over medium distances (100-300 km), in the near future, are likely to become capable of VTOL;
- promising transport unmanned aircraft, which will combine the characteristics of unmanned and manned aircraft, can take off and land almost anywhere, with a high speed and range of more than 300 km, which have VTOL advanced capabilities and do not require a fixed take-off and landing airport, will initially be piloted by a licensed pilot, but over time will be able to become fully autonomous unmanned aerial vehicles.

From the point of view of technological readiness, the urban air mobility industry is at a high stage of development, and if the existing safety problems and regulatory issues are eliminated, passenger unmanned vessels will be used in pilot projects in the early 2020s, flying cars in 2020-2022, while promising aircraft can only come into reality by 2025-2030.

4. Conclusion

Thus, the analysis of the ongoing international programs and legal regulations [7-16] related to the use of UAS airspace in the EU countries allows us to conclude that in this area European states strive to achieve leadership on a par with the United States Authorized by the European Parliament organizations (EASA, EUROCONROL, EUROCAE, JARUS) provides a phased, systematic, harmonized with ICAO international regulation integration of UAS of all types into the airspace system of the European Union b Without reducing the existing air traffic management system performance, lowering flight safety and an unacceptable increase in risk for all airspace users, as well as people and property on the ground.

In order to achieve these goals, the EU is actively cooperating with a wide range of stakeholders, including manufacturers of UAS and equipment, commercial suppliers, business associations, technical standardization organizations, research institutions, research centers, government institutions and other regulatory bodies.
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