ГЕОЛОГІЧНА ІНФОРМАТИКА

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THE USE OF UNMANNED AERIAL VEHICLES FOR ORTHOPHOTO PLANS

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For many years, traditional aero photography has been an effective instrument to solve geodesic, geophysical, geological cartographic and monitoring tasks. However, the prime cost of usage of aviation carriers for local large-scale survey of the area is relatively high and has a number of limitations. That is why the actual task is to find the way to decrease prime cost of photographing. One of the promising approaches to get geodesic basis is method of remote cartographing using unmanned aerial vehicles (UAVs). In today's world aerospace has been developing rapidly with the help of UAVs, which proved to be extremely cost effective and convenient in terms of saving time and labor costs for photographing works. Aerial photography of the area, carried out with the help of UAV can be used in many fields and spheres, in particular in geodesy, topography and cartography.

The controlling of UAV is possible to execute with the help of a smartphone, tablet or software or satellite connection. UAVs can be launched using missiles, catapults or manually and are able to carry various types of materials, video equipment or even fertilizers for agricultural purposes.

The creation of an orthophoto plan that allows to accurate measure of territories, to establish or actualize the borders (boundaries) of any settlement (village, town, region), to execute environmental and agronomic land evaluation was considered in the article. On the basis of received orthophoto maps it is possible to conduct highly-precise topographic mapping and thus to create Master Plan and plan of territory development.

Algorithm UAV (air drones) data processing targeted to get orthophoto plan is described in the article. It is identical for the majority of software that is used for such purpose. The difference is only in peculiarity of work with each of it.

Keywords: unmanned aerial vehicles (UAVs), aerial photography, orthophoto plan.

Introduction. For maps and plans composition, investigated territory relief description people started to use aerial vehicles practically immediately after their creation. Initially these were primitive sketching of territory contours from balloons, then for photographing one started to use photo equipment and it was carried with the help of kites, observation balloons, dirigibles, pigeons, and later on with aerial vehicles which were heavier than the air. Aerial photography became the main method of creation and actualization of topographic maps and plans [6]. Materials were received with the help of analogous photo cameras which were installed on the planes. With time photographing became possible with digital cameras of aerial and later on space vehicles.

Today aerial photographing is developing quickly, which is based on usage of unmanned aerial vehicles (UAVs) and proved to be extremely cost effective and convenient in terms of time and labor costs for photographing works.

UAV – aerial vehicle with air-borne power unit for multiple use without crew, which rises up into the air with the help of aerodynamic power and executes flight in autonomous mode according to program or on remote commands of operators, and is able to bear effective load, equipment of reconnaissance and surface, air and water environment monitoring and is intended for getting back to aerodrome and for further usage. Other names of this class of carriers are unmanned aerial vehicles, unmanned aviation systems – UASs, drones, quadcopter, multicopter, UAVs as well. Existing classification and terminology creates certain difficulties in definitions, but this is not the subject of this research.

UAVs differ by size, productivity and type. They might be almost invisible as insects or be very much similar to piloted planes. They are able to hang in the air or develop speed up to 1000 km/h. UAV controlling is possible to do with smartphone, tablet or software of satellite connection. UAVs can be launched using missiles, catapults or manually and are able to carry various types of materials, video equipment or even fertilizers for agricultural purposes.

Modern technologies allow UAVs to fly on significant distance during long time; however, the majority does not go up more than 150 m above the ground. Air space at this height is mainly used for gliders and light aviation flights.

Usage of UAVs is more advantageous and quick for actualization of cartographic materials and receipt of reliable information comparing to usage of traditional or light aviation, results of photographing from UAVs is possible to process in automatic mode on regular computers. This allows executing non-uniformly scaled topographic photography with various levels of details with the help of the same equipment.

Subject of investigation is unmanned aerial vehicles with digital cameras.

Aim of the work is investigation of possibility to use UAVs for cartographic tasks, in particular for creation of orthophoto plans of the areas.

Relevance of the investigation. For many years, traditional aerophotography has been an effective instrument of solving geodesic, geophysical, geological cartographic and monitoring tasks. However, the prime cost of usage of aviation carriers for local large-scale survey of the area is relatively high and has a number of limitations. This is why the actual task is to find the way to decrease prime cost of photographing. One of the promising approaches to get geodesic basis is method of remote cartographing using UAVs.

Analysis of recent researches. The following studies are dedicated to researches of UAVs usage for solving certain problems of civil sphere – works of V. Akulov, V. Alekseev, S. Halushko, V. Hlotov, A. Hunina, O. Zinchenko, M. Matiychyk, K. Meteshkin, O. Sechin, S. Stankevych, H. Trubnikov, V. Kharchenko, M. Shevni, J.D. Barton, J. Chen, D. Droeschel, R. Gini, G. Grenzdürffer, and others. But since one uses a very large number of UAVs of different classes and aerodynamic schemes with a wide range of technical and aerodynamic characteristics, various aerospace and navigation equipment, the analysis of the possibilities of their use to solve different tasks is still far from complete.

Presentation of the main part of material. From a practical point of view, aero-photography of the area done by UAVs today is relevant and profitable solution of majority tasks in sphere of aero-photography and geodesy, monitoring of environment and emergency situations, as well as agriculture.

The UAV performing a flight on a given route, both in automatic and semi-automatic mode, provides accurate and reliable photo and video materials about the area, monitoring of buildings and structures.

The use of small UAVs offers many advantages and surpasses traditional methods of shooting from an aircraft due to the possibility of rapid deployment of equipment and operational preparation for start (no need for special runways or platforms). UAVs make it possible to perform flights from minimum height of 100 m, and the drone aircrafts – even lower, which ensures the presence of the carrier under clouds at almost any time. A high resolution in area allows you to capture the smallest details of the area and objects with a centimeter accuracy. In addition, UAVs provide an opportunity to shoot small objects and areas, where usage of other types of aerial photography is unprofitable, and in some cases, is technically impossible.

The advantages of the UAV vs alternative types of obtaining photographs are as follows:

– The safety of filming. This is especially true within the city borders (compared to light aviation);

– higher accuracy and self-descriptiveness of the received data (in comparison with satellite images);

– high quality of the received photos;

– high frequency;

– significant time savings;

– low cost;

– resistance to weather conditions. Ability to take photos in cloudy weather;

– accuracy of surface modeling in plan: ± 5 cm.

The obtained data from the UAV are processed in specialized software and serve as the basis for the creation of digital and electronic maps, topographical plans of the area. They are used in the construction design, area monitoring, allow studying the relief, developing projects for the management of the territories taking into account rational use and environmental protection.

Most often UAVs are used to solve the following topographic and geodetic tasks [1–5, 7–13]:

– during mine surveying works – for the shooting and monitoring of the state of quarries, dumps, the determination of the scope of work in open-form development;

– in engineering geodesic surveys – for the creation of orthophoto plans and topographical plans of the area, where the use of traditional methods is not economically reasonable or is connected with a risk for personnel (shooting of hard-to-reach, impenetrable or extended objects);

– for land cadastral works – to determine the characteristic points of boundaries of land plots by photogrammetric method in small areas (village, settlement, garden cooperative), inventory of land and other real estate objects;

– for the control of the technical condition and safe usage of the objects of power and municipal economy (transmission lines, gas pipelines, heating roads), infrastructure objects, railway facilities.

The UAV has many advantages. An important factor is that there is constantly growing number of software that allows practically automated processing of data from UAVs in a short period of time with no need for significant computing resources. With data from UAV and with the help of ortho-transformation you can get an orthophoto plan, a 3D model of the area, maps of heights.

Under ortho-transformation one understands the process of geometric image correction during which perspective distortions, turns, distortions caused by the aberration of the optical system are eliminated. With it, the image is traced to the planned projection, i.e. such projection during which each point of the area is observed vertically, in nadir. To perform such a transformation, it is necessary to eliminate the distortions caused by the relief. Thus for transformation one needs a model of relief, one needs to know the height of the area for each point of the image.

The ortho plan is a photographic plan of the area on an accurate geodetic basis, obtained by aerial photography with the subsequent transformation of images from the central projection to the orthogonal. Transformation uses the ortho-transformation method.

Modern technologies for the creation of orthophoto maps widely use photogrammetric methods and are mainly aimed at obtaining images using large and medium-sized aircraft equipped with stabilization systems for aeronautical equipment (APA, digital photogrammetric cameras), control of elements of internal and external orientation, aerial photography elevation.

Typically, small-scale UAVs with a wingspan of up to 3 m are used to create orthophoto maps. The main problem with the use of such UAVs for terrestrial or water surface surveys are: use of non-metric professional, semi-professional and amateur digital cameras based on a CCD matrix (such as Samsung, Sony, Pentax or more "Serious" Canon or Nikon); lack of systems for stabilizing the UAV and control the elements of internal and external orientation; frequent deviation of optical axes from the vertical to several degrees, which complicates a lot the process of images primary processing.

The use of household cameras is associated with ease of control of them, and their benefits (low cost, ease of replacement when "hard landing").

However, the use of these cameras also has certain disadvantages. The main disadvantage is that household cameras are not initially calibrated – their exact focal lengths are unknown, the main point, distortion. In this case, the nonlinear distortion of optics (distortion), which is acceptable for household photography, can be up to several tens of pixels, which can lead to a reduction in the accuracy of the results of processing dozens of times. However, such cameras can be calibrated in laboratory conditions, which allows the accuracy of processing which differ little from professional small-format photogrammetric cameras [15].

In terms of traditional (classical) photogrammetry, the presence of these problems leads to the fact that the quality of the survey is likely to be treated as inappropriate.

However, the presence of modern photogrammetric software largely reduces these problems. Moreover, the development of digital photogrammetric processing methods has already led to the emergence of programs and software systems that can handle even such "poor" aerial photography in highly automated mode, with minimal operator involvement.

In this study, the process of creating an orthophoto map of the terrain based on the data obtained from the UAV Phantom 4 PRO DJI, is equipped with a nonparametric 20-megapixel camera with a 1-inch 20-megapixel sensor, which is capable of shooting 4K / 60fps video and 14 frames per second in serial mode, meeting the obstacles in 4 directions and staying in flight for up to 30 minutes.

Aerial photography from the UAV does not fundamentally differ from the shooting of "big airplanes", but has certain features. UAV flight, as a rule, is carried out with a cruising speed of 70–110 km/h (20–30 m/s) in the range of heights 300–1500 meters. Typically, non-metric household cameras with a matrix size of 10–20 megapixels are used for shooting. The focal length of the cameras is about 50 millimeters, which corresponds to the size of the pixel on the ground (GSD) from 7 to 35 centimeters.

Often images of UAVs are processed by simple non-destructive methods (affine transformation of images into a plan). As a result, the user receives overhead assemblies that, in addition to low accuracy, may contain contour ruptures at the junctions of neighboring images.

For strict photogrammetric processing of aerial photography and obtaining the most accurate results it is necessary that the images in one route have a triple overlap, and the overlap between the images of neighboring routes during plane shooting should be not less than 20 % [14]. In practice, when shooting from an UAV these parameters are not always met. UAV flight is not stable; it is influenced by wind gusts, turbulence and other excitation factors. If the shooting from conventional aircraft is planned with overlapping along the route 60 %, and between routes 20–30 %, then the projected shooting from the UAV requires overlap along routes 80 %, and between routes – 40 %, to exclude, if possible, gaps in the photo triangulation unit [15].

Aerial photography is flat and linear (route). In the plane shooting, in addition to the longitudinal overlapping of the photos, the transverse overlap has to be observed as well. The initial parameters of aerial photography with the UAV have the necessary spatial resolution, camera resolution, angle of view of the camera lens, the size of the overlap of frames. According to these data, the flight altitude, UAV speed and the shutter speed of the camera are calculated.

The result of the digital aerial photography of the terrain are digital aerial photographs, as well as external orientation elements recorded in the flight (linear XS, YS, ZS – coordinates of the center of photography, angles α, β, γ – orientation of the camera relative to the coordinate axes.

In accordance with the laws of central design, which is based on the image of the terrain aerospace contains a number of distortions, the magnitude of which are determined by the angle of inclination of the optical axis of the aerial camera and fluctuations in terrain.

The process of creating an orthophoto map implies:

– uploading pictures;

– formation of a point surface model;

–- optimization of the model and construction of a dense cloud of points;

– construction of a polygonal surface model;

– Generation and editing of the orthophoto map.

When the data is received after shooting, each photo has its own coordinates of the centers, as well as the altitude mark. At the first stage, the uploaded footage is being uploaded to the project, and the construction of an approximate, "rough" model of the terrain. The coordinates of the centers (fig. 1) and the height mark are used for this purpose.

When used, automatic definition of common points in overlapping photographs, determination of the coordinates of the centers of photographing and elements of mutual orientation of the photographs.

There are occasional cases where, for technical reasons, some photographs do not include coordinates of centers and altitude. In this case, the program can automatically find their position by the method of finding common points. But of course, if it's a small number of photos.

As a result of the first alignment of images, a sparse cloud of points is constructed, where each point is the result of finding common points in adjacent photos. On this model you can see the overall image of the terrain, but this is only the first approximation to the desired result (fig. 2).

Fig. 1. Coordinates position marks of photo centers

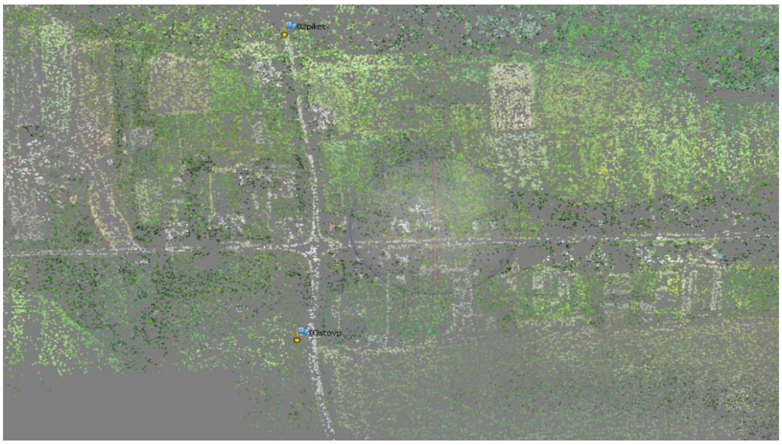

Fig. 2. Spilled cloud of points

Next step is optimization of the model. Here one should connect received model to ground points of anchorage. Which means that coordinates of point of details are uploaded into project and these coordinates are used to execute visual alignment of the model. As a rule, on such points of details one places identification marks that are easy to recognize on photos.

If operator finds out difference between certain identification mark and point of detail, he himself is able to correct the situation. In case identification marks are not visible, e.g. due to trees crowns or it was point of water cut, then such points should be excluded from the process of visual alignment of the model connection. Thus, deviation will be minimal. After above mentioned actions the process of model optimization starts correspondingly.

Next stage is building a dense point cloud on the basis of already created and leveled model where every point is a result of minimum 3 pixels on closely-spaced photos. This process takes a lot of time as all photos are analyzed and mutual points are searched. As a result, one gets dense point cloud which graphically represents working model. (fig. 3).

The stage of building a dense point cloud will not work without the operator's supervision. This is because there might be cases where some points are not correctly defined according to their high-altitude parameters (Fig. 3), that is, either they are located above or under the main cloud of points. These incorrectly defined points should be manually deleted, as they can negatively affect the quality of the results at subsequent stages. However, at the same time one should be very careful since under some angles, not all the points are visible and one may accidentally delete several kilometers of the processed area.

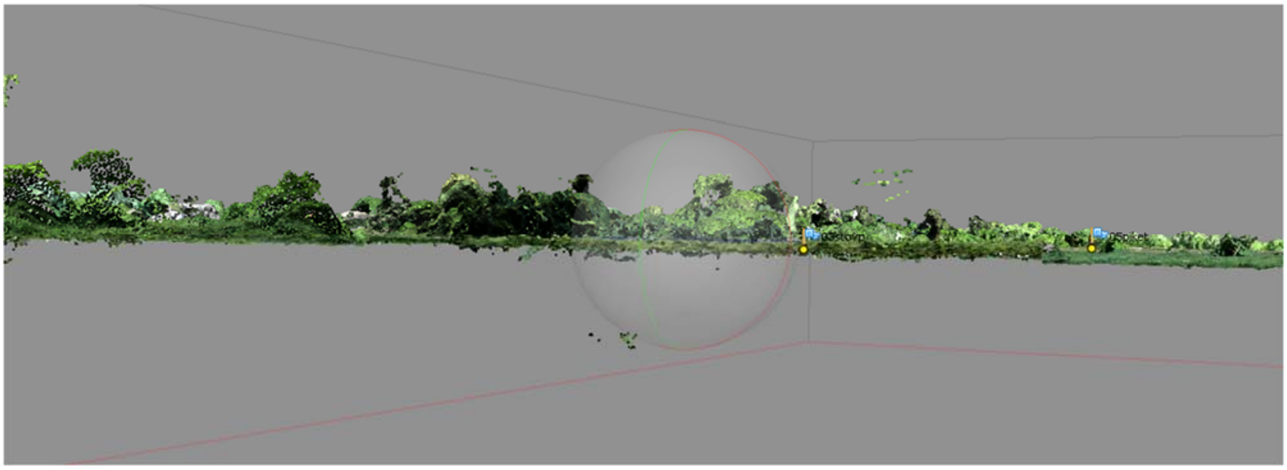

Fig. 3. Dense point cloud

On this stage it is possible to execute points classification. It can be executed either in automatic mode (the program will split available points into classes defined by default) or operator can nominate classes on his own and name them. This classification is used on next stage of processing.

After building of dense point cloud, next step is building of polygonal model of area (fig. 4).

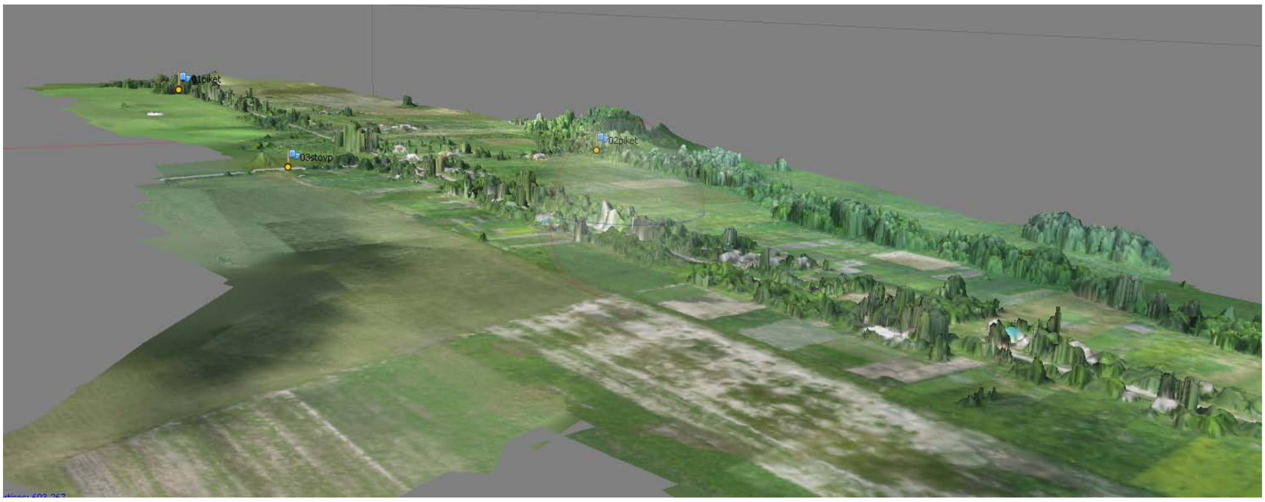

Fig. 4. Polygonal model of area

Here for operational efficiency of the model one should set the number of loops for certain area (square), as in case of standard settings usually there will be a big number of loops built and this will significantly slow down the further work with a model. Making the polygon model is done with triangulation.

In case classification of points is built on preliminary stage, the creation of polygonal model is possible only according to classes defined by operator. After polygonal model creation operator has a possibility to edit and correct the result.

Next step is generation of orthophoto map. All images are projected onto polygonal model of the location (geographic area). It is necessary to pay attention to editing of received orthophoto map. In mosaic mode it is seen that on joints of neighboring photos there might be discrepancies and one object will be reflected on several photos.

For correction of the situation, it is necessary to delete mistaken area and define a unique photo which is in the closest position to nadir position (fig. 5 and 6).

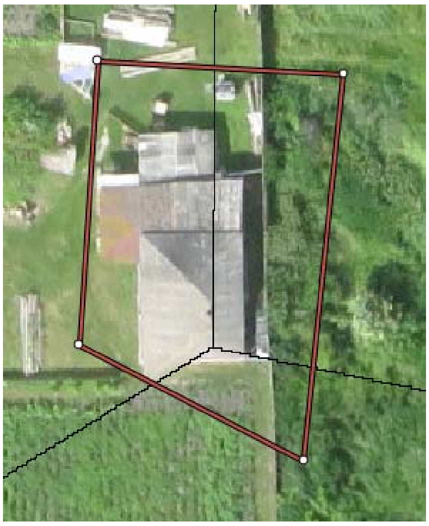

Fig. 5. Discrepancies in the result of joining different images

Fig. 6. Corrected situation

After gradual editing of the orthophoto map as indicted one should export it and start the work this orthophoto map was designed for.

After all stages of processing input data the orthophoto map is created. Observational error while conducting observation on land points of junctions indicates that it does not exceed 0,1 mm in the map scale, which means to fulfill projects in scale 1 : 2000. It is not more than 20 cm.

Orthophoto map created this way allows:

– executing exact measuring of the territory square footage;

– setting or actualizing borders of any residential area (village, city, region);

– executing ecological and agro-technical evaluation of the lands.

It is also possible to use orthophoto map for:

– constructing and projecting;

– renovation and specification of existing cadastral maps as well as creation of new maps;

– creation of 3-D models;

– creation of rainwater run-off map;

– development of advertising materials.

On the basis of received orthophoto maps one is able to conduct highly-precise topographic mapping and thus to create Master Plan and plan of territory development.

Described process of UAV (air drones) data processing targeted to get orthophoto plan is identical for the majority of software that is used for such purpose. The difference is only in specifics of work with each of it.

Conclusions. As human pressure on the natural surroundings is not possible to decrease or slow down it is crucial to look for innovative technologies for monitoring of natural surroundings and potentially insecure (unsafe) objects, for actualization of cartographic application. Such technologies may become use of UAV (air drones).

The advantages of UAV (air drones) for cartographic purposes are relatively low cost of work, urgency (it is always possible to get information on latest conditions of the matter), objectivity (orthophoto plan (plan developed with method of differential orthophoto-transformation) is developed without detachment, it is possible to check it any time again) and operational efficiency as for acceptable survey (photo) accuracy.

Digital orthophoto maps received in the result of aerial photography (scanning) from UAV (air drones) with full vector data and links with external data bases might be successfully used as finished product in GIS, as well as planimetric base for creation of digital and topographic maps.

The results of conducted experimental researches and practical works confirmed that aerial photography (scanning) from UAV (air drones) may successfully change traditional aerial photography and earth-based methods of special data collection aimed at creation and actualization of topographic and cadastral plans of large scales.

However, taking into account that small UAV (air drones) usually do not have hydro-stabilizing platforms, due to limitations of actual load the strict requirements appear regarding weather conditions for photographing, i.e. conditions under which it is possible to execute aerial photographing and acquiring of certain standard material.

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ЗАСТОСУВАННЯ БЕЗПІЛОТНИХ ЛІТАЛЬНИХ АПАРАТІВ ДЛЯ СКЛАДАННЯ ОРТОФОТОПЛАНІВ

Протягом багатьох років традиційне аерофотознімання є ефективним інструментом для розв'язання геодезичних, геофізичних, геологічних, картографічних і контрольних задач. Проте собівартість використання авіаносіїв для локального крупномасштабного дослідження району є відносно значною і має ряд обмежень. Тому акутуальним завданням є пошук способа зменшення собівартості фотографування. Одним із перспективних підходів до отримання геодезичної бази є метод дистанційного картографування з використанням безпілотних літальних апаратів (БПЛА). Сьогодні у світі швидкими темпами розвивається аерозйомка за допомогою БПЛА, які виявилися надзвичайно рентабельними і зручними в плані економії часу і трудовитрат на знімальні роботи. Аерофотозйомка місцевості, здійснювана за допомогою БПЛА, може використовуватись у багатьох галузях і сферах, зокрема в геодезії, топографії і картографії.

Управління БПЛА може здійснюватись за допомогою смартфона, планшета або програмного забезпечення супутникового зв'язку. БПЛА можуть запускатись за допомогою ракет, катапульт або вручну і переносити різні види матеріалів, відеоапаратуру або навіть добрива для сільськогосподарських потреб.

Розглянуто створення ортофотоплану, який дозволяє виконувати точний обмір площі територій, встановлювати або актуалізувати межі (кордони) будь-якого населеного пункту (села, міста, області), здійснювати екологічну і агротехнічну оцінку земель.

Ключові слова: безпілотні літальні апарати (БПЛА), аерознімання, ортофотоплан.

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ПРИМЕНЕНИЕ БЕСПИЛОТНЫХ ЛЕТАТЕЛЬНЫХ АППАРАТОВ ДЛЯ СОСТАВЛЕНИЯ ОРТОФОТОПЛАНОВ

На протяжение многих лет традиционная аэрофотосъемка является эффективным инструментом для решения геодезических, геологических, геофизических, картографических и контрольных задач. Однако себестоимость использования авианосителей для локального крупномасштабного картографирования района является относительно высокой и имеет ряд ограничений. Потому актуален поиск способа уменьшения себестоимости фотографирования. Одним из перспективных подходов к получению геодезической базы является метод дистанционного картографирования с использованием беспилотных летательных аппаратов (БПЛА). Сегодня в мире быстрыми темпами развивается аэросъемка с помощью БПЛА, которые оказались чрезвычайно рентабельны и удобны относительно экономии время- и трудозатрат на съемочные работы.

Аэрофотосъемка местности, осуществляемая с помощью БПЛА, может использоваться во многих отраслях и сферах, в частности в геодезии, топографии и картографии.

Управление БПЛА может осуществляться с помощью смартфона, планшета или программного обеспечения спутниковой связи. БПЛА могут запускаться с помощью ракет, катапульт или вручную и переносить различные виды материалов, видеоаппаратуру или даже удобрения для сельскохозяйственных нужд.

Рассмотрен процесс создания ортофотоплана, позволяющий осуществлять точный обмер площади территории, устанавливать или актуализировать границы любого населенного пункта (села, города, области), осуществлять экологическую и агротехническую оценку земель.

Ключевые слова: беспилотные летательные аппараты (БПЛА), аэросъемка, ортофотоплан.