**Рецензент:** д.т.н., доц. Д.П. Пашков, кафедра керівництва військами (силами) в мирний час Національний університет оборони України імені Івана Черняховського, м. Київ.

## МЕТОДИЧЕСКИЙ АППАРАТ АНАЛИЗА РЕЗУЛЬТАТОВ ОБОРОННОГО ПЛАНИРОВАНИЯ

И. В. Лоза

*В статье рассмотрены методы исследований, которые могут использоваться при анализе результатов оборонного планирования в Вооруженных Силах Украины.*

***Ключевые слова:*** *оборонное планирование, методы исследования, анализ результатов, оценка программ и планов.*

## ANALYTICAL TOOLS IN THE ANALYSIS OF THE RESULTS OF THE DEFENCE PLANNING

I. Loza

*In the article the research methods are considered that can be used for analyze the results of defence planning in the Armed Forces of Ukraine.*

***Keywords:*** *defence planning, research methods, analysis of results, evaluation of programs and plans.*

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Y.Salnik, I.Matala, Y. Pashuk

*Army Academy, Lviv*

# MINI-UAV FLIGHT AND PAYLOAD AUTOMATED CONTROL SYSTEM

*This paper describes advanced control systems of miniature unmanned aerial vehicles (Mini-UAV, Small UAV, SUAV) in the world leading countries. It reveals composition and purpose of airborne equipment (hardware) and payload of mini-UAV for the Ukrainian Army.*

***Key words:*** *unmanned aircraft system, unmanned aerial vehicle, automated control system, payload.*

## Problem statement

Analysis of airborne hardware of modern tactical unmanned aircraft systems (UAS) [2-6, 11-14, 17] testifies that effectivness of their operations considerably depends on functional possibilities of UAV automated control systems. The recent experience of mini-UAS combat use in the Balkans, Afghanistan and Iraq [2-4, 8, 12-14] forces us to pay much attention on a role and place of SUAV flight and payload automated control systems for execution mini-UAS missions.

**The objective of this article** is to examine the perspective concepts of creation of mini-UAV flight and payload automated control systems (FPACS), development of FPACS general structure and setting of basic tasks for FPACS components.

## Main part

Small unmanned aircraft systems (SUAS) is a rapidly evolving area. As a rule, UAS consists of the unmanned aerial vehicle (without a human pilot on board), human element, control element, weapons systems platform, display, communication architecture, life cycle logistics, and other elements. UAV includes actually an unmanned aircraft, payload and airborne (highly integrated) equipment (aviation, navigation, radio-electronic and other equipment needed for flight) [2,6,8, 13-18].

A primary objective of mini-UAS operations is to increase the situational awareness of battlefield commanders and their staffs as they plan, coordinate, and execute operations (combat actions) through intelligence, surveillance, and reconnaissance (ISR) [1,11-14]. Small UAS can perform some or all of the following functions: enhanced targeting through acquisition, detection, designation, and battle damage assessment.

In spite of advanced achievements in sphere of automation and computerization, in developing of robot systems, use of mini-UAV is not independent and fully autonomous. It is in human operation-outer sphere, and still controlled and will be controlled by a man.

SUAS operations disclosed some significant limitations of these systems. The critical lesson to be learned from unmanned aircraft losses during the last decades distinguishes that most of mini-UAV crashes are more likely to result from a series of contributing factors and mainly considered as human-errors (type) accidents. Therefore FPACS is needed to free operators from monotonous and repeatable manual tasks, improve the navigation accuracy, autonomy and flight safety of mini-UAS [15-19].

A process of creation of mini-UAV flight and payload automated control systems follows after setting of tasks which small unmanned aerial vehicles carry out.

Essentially the sphere of mini-UAS operations is characterized by close range (less than 15 kilometers), short duration missions (1 to 2 hours) operating below the coordinating altitude and thoroughly integrating with the ground forces [2-4, 7, 12-14]. The main mission of SUAS is to provide air reconnaissance, first of all, NRT (near real time) combat information about terrain, enemy (disposition, strength, actions), and etc. The tactical unmanned aircraft systems give commanders a dedicated and rapidly taskable asset that can look wide as well as deep [13-14]. The key element of this asset is mini-UAV payloads (UAV can be treated as mobile platform for its usefull payload) which can be configured to accomplish a specific mission and include [2-7, 14, 17]:

sensors (electro-optical (EO), infrared (IR), synthetic aperture radar (SAR), signal intelligence (SIGINT),

Ground moving target indicator (GMTI)

communications relay (extend voice and data transmissions via the UAS);

weapons (lethal and non-lethal);

and other cargo, which may be internal or external to the UAV.

Design of variants of interchangeable payload modules packaging is provided with taking into account the following special considerations for mini-UAS operations: weather, terrain, counteraction of adversary, time of day and year, etc. The analysis of SUAS operations testifies that their effectiveness can be increased by using multiplepayloads and integration of different types of sensors, for instance, camcorders and thermal cameras with providing of multispectral imagery [13, 14, 18].

The modern TV cameras provide NRT video information offering a familiar view of a scene for human eyes, stereoscopic viewing and system resolution unachievable in other optical systems or in thermal images and radars. At the same time these sensors have some disadvantages. They are restricted by weather conditions, terrain and vegetation, limited to daytime use only.

On the other hand the IR cameras are passive sensors which impossible to jam. They can easily penetrate light fog, but cannot penetrate heavy fog or clouds; provide good resolution and nighttime imaging capability, but cannot be effective during thermal crossover (1 to 1.5 hours after sunrise or sunset).

Moreover the use of SAR as variant of mini-UAV payload allows obtaining needed intelligence regardless of weather conditions and time of day.

Let’s examine the tentative composition and purpose of typical UAV flight and payload automated control system (Fig. 1).

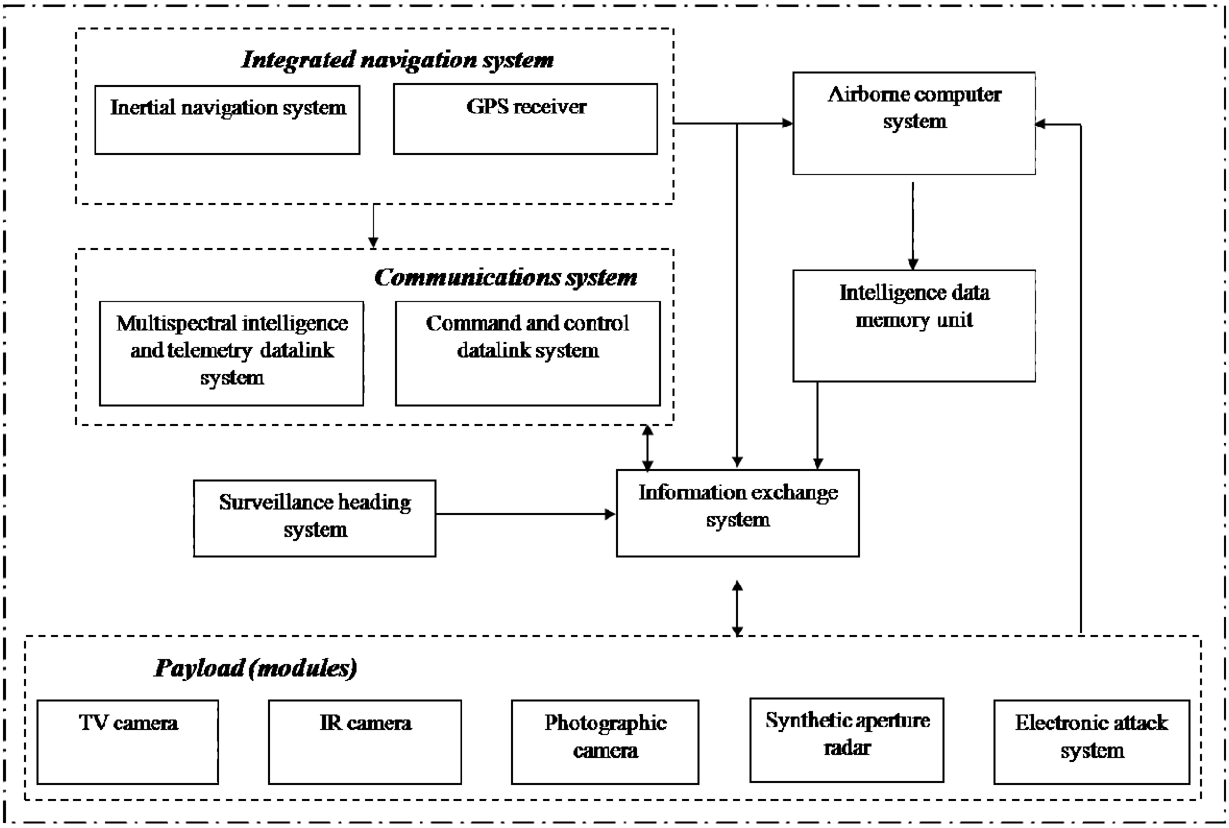

*Fig. 1.* **Functional structure of mini-UAV flight and payload automated control system**

***A mini-UAV flight and payload automated control system*** represents a main component of airborne equipment, which manages functioning of UAV integrated equipment and payload. It is a complex and multilevel microelectromechanical system (MEMS) consisting of both hardware and its supporting software. The main mission of FPACS is to provide autonomous (guided) flight of mini-UAV following desired (planned) path with prespecified altitude, velocity in order to arrive at the given target and complete the specified mission, as well as, to provide gathering and delivery (transmission) of air reconnaissance information to GCS.

FPACS normally includes integrated navigation system (inertial and satellite units), central processing unit (CPU), power supply module and other systems (Fig. 2).

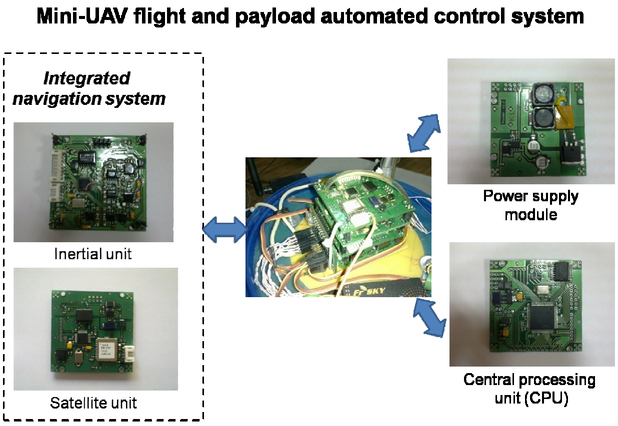

*Fig. 2.* **Basic elements of mini-UAV FPACS**

***An integrated navigation system*** provides optimal processing of navigation information from the inertial navigation system (INS, inertial unit) and GPS receiver (satellite unit).

The key element of FPACS for achieving of its autonomy is an inertial unit which integrated with the GPS/GLONASS receiver and guarantees high accuracy of UAV navigation and control. Usually it is a strapdown inertial navigation system (SINS) which uses motion sensors (accelerometers), rotation sensors (gyroscopes), barometric altimeter and triaxial magnetometer to continuously integrate the vehicle's attitude changes in pitch, roll and yaw, as well as gross movements, and calculate the position, orientation, and velocity of SUAV, and maintain the required navigation solution after comparison of information from above-mentioned sensors with GPS receiver information.

Satellite unit supplies accurate position and velocity information using GPS satellite signals to correct/calibrate a navigation solution from INS and provide coordinates of UAV and ISR objects

***An airborne computer system*** is a high performance hardware and software package (information processing, storage and transmission equipment), which is intended for converting of input data into output data, collection and processing of information from measuring subsystems in accordance with the given tasks [16-20]. The airborne computer system is multilevel, hierarchical, heterogeneous system. At the lower level of hierarchy the specialized digital prosessing systems provide preprocessing of information from one or group of homogeneous sensors. The middle level of hierarchy uses more powerful universal digital prosessing systems which carry-out central functional tasks on basis of integrated data processing of information from the large number of sensors. The top level hierarchy utilises universal digital prosessing systems, which are intended to carry-out management, control, indication and communication tasks.

Modern airborne computer systems are built around powerful microcontrollers and complete optimal estimation of diverse parameters and their correction, navigation, orientation and vectorial gravimetry and other tasks.

***An intelligence data memory unit*** accumulates of air reconnaissance information from taking-off to landing of mini-UAV and allows to conduct more detailed analysis of this information after completing of unmanned vehicle's flight. This system can be removable or built-in.

***A surveillance heading system*** provides vision-based tracking necessary for mission-control UAV and normally includes a TV camera with wide-angle lens. The system is interchangeable and can be supplemented with infrared/thermal imager or digital camera, or radar depending on the UAV tasks. Information from surveillance system is transmitted to the UAV operator and used for SUAV flight and payload control.

***A multispectral intelligence and telemetry datalink system*** (radio transmitter and antenna-feeder device) transfers the real-time intelligence and telemetry data to the ground control station (GCS) through a line of sight (LOS) communication data link.

***A command and control datalink system*** (radio receiver and antenna-feeder device) provides command and control information from the ground control station (UAS operator) to the UAV using the command link.

***An information exchange system*** provides distribution of intelligence between onboard imaginary sources, transmitter of intelligence and telemetry datalink system, and onboard intelligence data memory unit. Input of flight mission information and UAV pre-flight test is conducted through the external interface ports of this system.

***A narrow-beam antenna control system*** supports stable, uninterrupted communication with GCS and transmitting of real-time air reconnaissance information from mini-UAV to its operator. Use of narrow-beam aerial systems both on the GCS and on mini-UAV is reasonable.

Small UAVs normally have two control modes: manual and autopilot control mode. FPACS allows human pilots to manage mini-UAV in the manual mode from standard radio remote through radio signals. While autopilot control mode can automatically keep the unmanned aircraft at the desired state, a semiautonomous control mode (mixed control mode) is provided when the human operator controls the flight path and the FPACS controls the altitude.

The use of mini-UAV FPACS allows to minimize time for UAS personnel (operators) training and involve for UAV control a wide spectrum of skilled and unskilled users. Also this system provides implementation of given missions for SUAS on considerable distance from the deployment position, when no communications with GCS, in any weather and at any time of day.

Let us consider the use of mini-UAV (for instance, RQ-11 Raven) during air reconnaissance on “serpent” route (interval between the lines 50-70 meters) in order to better understand the importance of FPACS for improving efficiency of SUAS operations (Fig. 3).

*Fig. 3.* **Mini- UAV trajectory during air reconnaissance**

In this case (wind less than 20 knots) the FPACS provides accurate flight control of UAV in autopilot control mode with heading hold (max deviation from the route 7-12 meters), altitude hold (±5 m) that allows to execute designated tasks, namely, to provide a close observation on low altitude (less than 1000 m) and ensure the assigned level of flight safety [13, 14, 17].

The basic requirements for mini-UAV FPACS are [10-12,16-19]:

low cost;

miniaturization (small sizes and light weight);

declining of energy consumption;

accurate flight control of UAV in all control modes, in all stages, including take-off, ascent, descent, trajectory following, and landing;

the UAV operator can seamlessly switch between manual control and autopilot control;

PID (proportional-integral-differential) gains can be changed during flight through the ground station;

design uses inexpensive, commercially available hardware and own innovative software;

increasing of volume of memory of CPU,

comprehensive set of waypoint commands which provide the user with a variety of navigation commands;

communication protocol permits access to all internal FPACS variables via the GCS;

sensor packages should guarantee a good performance in hard conditions, especially in a mobile and temperature-varying environment;

improving jam-protection etc.

## Conclusions

1. SUAS play an important role in supporting battlefield commanders primarily through ISR.

2. The main problem of mini-UAS is to provide stable, uninterrupted, efficient and concealed control of integrated equipment and payload of UAV in different terms (weather, terrain, jam, and other).

3. Upgrading of mini-UAV flight and payload automated control systems is one of the foreground tasks in creation of advanced SUAS that allow to decrease the losses of mini-UAVs and provide effective use of their payloads.

4. This paper presented general structure of typical mini-UAV flight and payload automated control system.

5. The article revealed composition and basic tasks of SUAV airborne equipment and payload.

6. The paper examined possible variants of interchangeable payload modules packaging for SUAS in order to increase their operations effectiveness.

7. The article was based on typical mini-UAS missions and the Ukrainian defense-industrial sector possibilities.

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## СИСТЕМА АВТОМАТИЗОВАНОГО УПРАВЛІННЯ ПОЛЬОТОМ І КОРИСНИМ НАВАНТАЖЕННЯМ БЕЗПІЛОТНИХ ЛІТАЛЬНИХ АПАРАТІВ ПОЛЯ БОЮ

Ю.П. Сальник, І.В. Матала, Ю.М. Пащук

*Проведено аналіз сучасних систем управління безпілотними літальними апаратами поля бою (міні-БпЛА) провідних країн світу. Розглядається склад та призначення бортового обладнання і корисного навантаження міні-БпЛА для Сухопутних військ Збройних Сил України.*

***Ключові слова:*** *безпілотний авіаційний комплекс, безпілотний літальний апарат поля бою, система автоматизованого управління, корисне навантаження.*

## СИСТЕМА АВТОМАТИЗИРОВАННОГО УПРАВЛЕНИЯ ПОЛЕТОМ И ПОЛЕЗНОЙ НАГРУЗКОЙ БЕСПИЛОТНЫХ ЛЕТАТЕЛЬНЫХ АППАРАТОВ ПОЛЯ БОЯ

Ю.П. Сальник, И.В. Матала, Ю.М. Пащук

*Проведен анализ современных систем управления беспилотными летательными аппаратами поля боя (мини-БПЛА) ведущих стран мира. Рассматривается состав и назначение бортового оборудования и полезной нагрузки мини-БПЛА для Сухопутных войск Вооруженных Сил Украины.*

***Ключевые слова:*** *беспилотный авиационный комплекс, беспилотный летательный аппарат поля боя, система автоматизированного управления, полезная нагрузка.*