

**AEROSPACE SYSTEMS FOR MONITORING AND CONTROL**

UDC 629.73:681.51 (045)

DOI: 10.18372/2306-1472.79.13825

**Alexander Lupp<sup>1</sup>**  
**Alexander Skivka<sup>2</sup>**  
**Victor Palamarchuk<sup>3</sup>**  
**Oleh Alexeiev<sup>4</sup>****THEORETICAL BASIS FOR CALCULATING THE WORKLOAD OF EXTERNAL PILOTS OF REMOTELY PILOTED AIRCRAFT**<sup>1</sup>National Aviation University

1, Kosmonavta Komarova ave., Kyiv, 03058, Ukraine

E-mails: <sup>1</sup>luppo.ae@ukr.net; <sup>2</sup>skivka@gmail.com; <sup>3</sup>vpalamar@ukr.net; <sup>4</sup>oalexiev@yahoo.com**Abstract**

*The article analyzes the existing methods of determining the workload level. On the basis of the analyzed material new methodological bases for calculating the workload level of external pilots of remotely piloted aircraft were created. While creating new methodological basis, all the relevant parameters that have an impact on the workload value were defined and grouped. The formulas for calculating these parameters were derived.*

**Keywords:** external pilot, remotely piloted aircraft, workload, fatigue, risk, theoretical basis**1. Introduction**

Nowadays aviation is developing rapidly and, although the world saw unmanned aviation not so long ago, it has already found a wide range of applications among both military and civil aviation. Along with the growing use of unmanned aviation, it has become necessary to create a legal and regulatory framework to regulate its operation.

Remotely piloted aviation systems, which are a part of the unmanned aviation, are a new component of aviation system, which is based on new developments in aerospace technology. These systems can open up new and expand existing opportunities for application, increase the level of flight safety and efficiency of aviation in general [1-3].

Previously, aviation activity was based on the concept that a pilot operates an aircraft, being on board, often together with passengers. Flight operations without a pilot on board touch upon a number of important technical and operational issues, which are currently being studied by aviation.

One such important issue is the definition of the external pilot workload, since the level of workload directly affects the safety and efficiency of the flight.

Insufficient workload (monotonous work) or heavy workload can lead to increased risk and reduced flight safety. It can also cause conflict situations, which in turn can lead to unforeseen and undesirable consequences, incidents, crashes, etc. That's why the definition of the external pilot workload is an urgent and important issue in the field of unmanned aviation.

That is why the creation of methodological basis for calculation will allow determining and giving an objective assessment of the pilot's workload, to foresee periods of monotony and overload in his work. In this way, it will be possible to provide an opportunity to take measures to optimize and create all the necessary conditions for the external pilot work when performing remotely operated flights.

**2. Problem statement**

First of all, to solve this problem it is necessary to analyze similar methods to determine the level of workload. This will allow forming the basic concept, requirements and building the basis for new theoretical bases. In the next stage it is necessary to analyze the constituent elements, their characteristics and features, which will indicate exactly what to pay attention to when determining

the constituent elements for the new theoretical basis.

The next step will be to identify the constituent elements that can affect the level of the external pilot workload. It is necessary to determine how and what they depend on, study their interaction and peculiarities; find the necessary distinguishing features, etc. Having received all the necessary data, it is possible to move on to deriving the theoretical bases - the creation of formulas, the order of calculation and description.

So, the issue of the creation of methodological bases for calculating the workload level of external pilots of remotely piloted aircraft (RPA) is very important, since the monitoring and control of the workload level will allow providing appropriate safety level, finding out weak points in the system and defining the ways to improve the system.

### 3. Review of existing solutions

One of the existing methods is the definition of the air traffic controller (ATC) workload [4]. Any wrong command or order of an air traffic controller can have incredible consequences on which will depend the fate of many people on board the aircraft and on the ground. Since this type of activity is related to great responsibility, the presence of such a technique is a vital condition for this profession.

**Air traffic control service (ATS).** Service provided for the following purposes:

- a) collision avoidance:
  - 1) between aircraft and
  - 2) aircraft and obstacles in the maneuvering area;
- b) air traffic control and its speeding up [5].

In order to define air traffic controller workload, a few different quantitative and qualitative parameters related to the profession are considered. They are related to certain parameters of the area of responsibility, peculiarities of aircraft movement and air traffic controller workplace, which includes the procedures and instructions for the given workplace and the equipment with which he interacts.

**Air traffic controller workload** is a parameter that is determined by the ratio of the ATC controller's employment time to the total working time and can be determined by the formula 1:

$$K_{load} = \frac{T_{biz}}{T_{gen}}, \quad (1)$$

where  $T_{load}$  – ATC controller's employment time;

$T_{gen}$  – total working time.

ATC controller's employment time includes the time of communication with aircraft crew and coordination with ATC of neighboring sectors, the time of procedural operations (data entry with the keyboard, mouse, etc.), the time of operations with controls and the time required to make a decision and it is calculated by the formula 2:

$$T_{gen} = t_{pilot} + t_{nr} + t_{per} + t_{oper} + t_{dm}, \quad (2)$$

where  $t_{pilot}$  – time of communication with aircraft crew;  $t_{nr}$  – time of coordination with ATC of neighboring sectors;

$t_{per}$  – time of procedural operations;

$t_{oper}$  – time of operations with controls;

$t_{dm}$  – time required to make a decision.

Based on formula 1 and the information mentioned above, there are the following requirements for the level of workload (table 1):

Table 1

#### Workload requirements

Workload level value	Workload level description
$K_{load} \leq 0,2$	Monotonous level – insufficient workload
$K_{load} = 0,55$	Optimal level
$K_{load} \geq 0,75$	Prohibited (dangerous, exhausting) level – heavy workload

Thus, since the working conditions of an air traffic controller such as zone parameters (airspace structure, flight procedures) and equipment remain unchanged, the ATC controller's workload level depends directly on the number of aircraft under his control.

### 4. Theoretical basis for calculating the external pilot workload

In order to create the theoretical basis, first of all, it is necessary to determine all the parameters, the presence and value of which may in one way or another affect the workload level. When performing a remotely piloted flight by an external pilot, there are certain essential elements that are present in each system, namely:

- a) the time spent on control panel operations, i.e. the time required to perform certain

manipulations with the equipment or the RPA control system to perform a safe and controlled flight;

b) the time spent on monitoring, i.e. time needed to monitor the air situation, to ensure safe intervals between RPA and obstacles, between RPA and other air traffic (when flying in uncontrolled airspace), to monitor meteorological phenomena and flight conditions;

c) the time spent on monitoring flight parameters, i.e. the time required to continuously monitor flight parameters (flight speeds, flight course, flight path, altitude, distance, etc.).

There are also certain elements that may or may not be present depending on flight tasks, the number of flight participants, the structure of the airspace in which the flight takes place, etc. These elements should be included in the methodological basis for determining the workload, as they significantly affect its level. The main elements are listed below:

a) the time of communication (coordination) with ATS, i.e. the time required for radio telephony communication with ATS during the flight in the controlled airspace;

b) the time of communication (coordination) with other external RPA pilots, i.e. the time required for verbal communication, direct contact, radio telephony or other type of communication with other RPA pilots in the case of group flight, collective task, etc.;

c) the time of communication with a supervisor, i.e. the time required for coordination with a supervisor, getting his instructions, sending the reports, etc.;

d) the time for performing the task, i.e. the time required for performing the task successfully;

e) the time for making a decision, i.e. the time of an external pilot mental activity, required for analyzing and evaluating the situation, for conflict solving, making a right decision in emergency or other potentially dangerous circumstances.

In the following figure (Fig. 1) it is possible to see a schematic representation of the interaction of an external pilot with the integral and implicit elements that affect his workload level. External pilot A with the help of the control panel interacts with RPA via communication 1. During a remotely piloted flight, it is necessary to ensure aircraft separation with certain artificial and natural obstacles, threats and other air traffic (connections 2-6). Depending on the task an external pilot can interact with a command center D through

connection 7, interact with other external pilot B (connection 9) and perform the task directly, for example, it is necessary to detect enemy food storage E (connection 10 with RPA). Also, if RPA flight is performed in controlled airspace, an external pilot A has to interact and follow ATS instructions C through connection 8 [6].

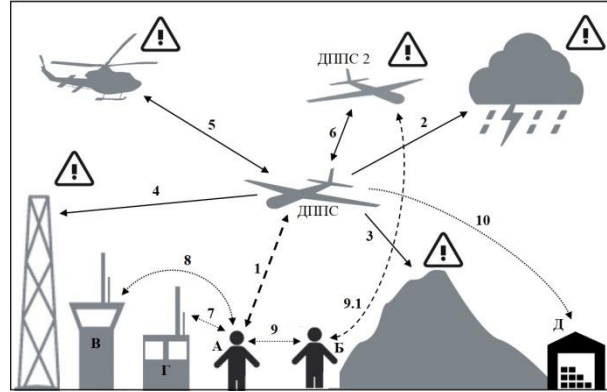


Fig.1. External pilot interaction with the elements that affect his workload level

Having defined all the necessary basic parameters that affect the workload level, we can derive the main formula. This formula for determining the workload factor is somewhat similar to the formula for determining the ATC controller workload. So, for determining the external pilot workload factor it is necessary to find the ratio of external pilot employment time to his total working time, which is shown in the following formula (3):

$$K_{load} = \frac{T_{biz}}{T_{gen}}, \quad (3)$$

where  $T_{biz}$  – external RPA pilot employment time;

$T_{gen}$  – total working time.

The external RPA pilot employment time includes some other elements, as opposed to the ATC controller's employment time. This time consists of the sum of obligatory elements and conventional elements (marked with an asterisk), if these elements are present, which is shown in the following formula (4):

$$T_{biz} = t_{mon} + t_{mn} + t_{cp} + t_{atc}^* + t_{pilot}^* + t_{con}^* + t_{task}^* + t_{dm}^*, \quad (4)$$

where obligatory elements:

$t_{mon}$  – time spent on control panel operations;

$t_{mn}^*$  – time spent on monitoring the air situation;

$t_{cp}^*$  – time spent on monitoring flight parameters;

and conventional (marked with an asterisk):

$t_{atc}^*$  – time of communication (coordination) with ATS;

$t_{pilot}^*$  – time of communication (coordination) with other external RPA pilots;

$t_{sw}^*$  – time of communication with a supervisor;

$t_{pt}^*$  – time for performing the task;

$t_{dm}^*$  – time for making a decision.

The values of each obligatory or conventional elements are calculated according to their own formulas given below.

The time on control panel operations depends on the time needed to perform one particular RPA operation (maneuver), i.e. the time spent on certain control panel operations to perform this operation (maneuver), and depends on the number of such actions (maneuver) during the flight. This time can be determined by formula (5):

$$t_{dk} = N_{pt} \times t_{0dk}, \quad (5)$$

where  $N_{pt}$  – number of actions (maneuvers) during the flight;

$t_{0pt}$  – time on control panel operations needed to perform RPA operation (maneuver).

Since air situation monitoring is carried out periodically during the entire flight, the monitoring time equals to the product of total flight time and the factor of monitoring the air situation, its value depends on flight conditions and automation level, and calculated by formula (6):

$$t_{mon} = T_{gen} \times k_{mon}, \quad (6)$$

where  $T_{gen}$  – total working time;

$k_{mon}$  – factor of monitoring the air situation;

Flight parameters monitoring and air situation monitoring is carried out periodically during the entire flight. The time of flight parameters monitoring equals to the product of total flight time and the factor of monitoring flight parameters, its value depends on RPA performance and automation level, and calculated by formula (7):

$$t_{cp} = T_{gen} \times k_{cp}, \quad (7)$$

where  $T_{gen}$  – total working time;

$k_{cp}$  – factor of monitoring flight parameters;

The time of communication (coordination) with ATS is presented only in the case of flight in controlled airspace. It equals to the product of one radio telephony communication time and the number of ATS sectors where the RPA flight is taken. The second value is multiplied by two, since in every ATS sectors an external pilot has to communicate with ATS at least twice – entering and leaving ATS sector. This time can be calculated by formula (8):

$$t_{atc}^* = 2N_{secatc} \times t_{0atc}, \quad (8)$$

where  $N_{secatc}$  – number of ATS sectors where the RPA flight is taken;

$t_{0atc}$  – time of one communication (coordination) with ATS.

The time of one contact (coordination) with other external RPA pilots is presented in the case of group flight or the flight when the contact (coordination) with other pilots is needed. This time is the product of the time of one contact and the number of contacts with other pilots. This time can be determined by formula (9):

$$t_{pilot}^* = N_{out} \times t_{0pilot}, \quad (9)$$

where  $N_{out}$  – number of contacts with other pilots;

$t_{0pilot}$  – time of one contact (coordination) with other pilot.

The time of communication with a supervisor is involved only in the case, if the flight performed requires prompt issuance of new tasks, update the tasks, prompt reporting of progress or report the results to the supervisor (e.g. prompt transmission of search and rescue flight results). This time depends on the time of one contact with a supervisor  $t_{0sw}$  and the number of contacts with a supervisor and calculated by formula (10):

$$t_{sw}^* = N_{com} \times t_{0sw}, \quad (10)$$

where  $N_{com}$  – number of contacts with a supervisor;

$t_{0sw}$  – time of one contact with a supervisor.

The time for performing the task is involved only in the case, if a specific task is performed during the flight. This time depends on the type of the task, the number of tasks, flight conditions, RPA performance, automation and etc. This time can be determined by formula (11):

$$t_{task}^* = N_{task} \times t_{0task}, \quad (11)$$

where  $N_{task}$  – number of tasks;

$t_{0task}$  – time for performing one task;

The time for making a decision  $t_{dm}^*$  cannot have a definite formula for calculation, since its value totally depends on the circumstances and conditions of the situation. This value can be affected by weather conditions, flight conditions, RPA performance, external pilot's qualifications and experience, automation level, facilities and equipment, etc.

This time can be used during the investigation of aviation events, when modeling different non-standard situations. It best reflects the human factor and its impact on the development of events.

## 5. Conclusions

The method of determining the level of ATC controller workload and its components, their features and characteristics were analyzed. Then the elements of the theoretical basis for calculating the workload of an external pilot were defined; how and what they depend on; their interaction and peculiarities were also studied. Having received all necessary data, the methodological basis was created; calculation order and formulas were created and described.

Thus, the created methodological basis is the way to solve the problem of defining the workload of RPA external pilot which will allow us to give an objective assessment of the workload level, to foresee the periods of monotony and congestion in work. All this information is rather crucial for taking optimization measures, control and creation of necessary conditions for external pilot's work during remotely controlled flights.

**О. Є. Луппо<sup>1</sup>, О. В. Сківка<sup>2</sup>, В. С. Паламарчук, О. М. Алексєєв**

**Теоретичні основи розрахунку навантаження зовнішніх пілотів дистанційно пілотованих літальних апаратів**

<sup>1</sup>Національний авіаційний університет, просп. Космонавта Комарова 1, Київ, Україна, 03058  
E-mails: <sup>1</sup>luppo.ae@ukr.net; <sup>2</sup>skivka@ukr.net; <sup>3</sup>vpalamar@ukr.net; <sup>4</sup>oalexiev@yahoo.com

У статті аналізуються існуючі методи визначення рівня навантаження на зовнішніх пілотів. На основі проаналізованого матеріалу створено нові методичні основи для розрахунку рівня навантаження зовнішніх пілотів дистанційно пілотованих літальних апаратів. При створенні нової методологічної основи були визначені і згруповані всі відповідні параметри, які впливають на значення робочого навантаження. Отримано формули для розрахунку цих параметрів.

**Ключові слова:** зовнішній пілот; дистанційно пілотований літальний апарат; робоче навантаження; втома; ризик; теоретичні основи

**А. Е. Луппо<sup>1</sup>, А. В. Скивка<sup>2</sup>, В. С. Паламарчук, О. Н. Алексеев**

**Теоретические основы расчета загрузки внешних пилотов дистанционно пилотируемых летательных аппаратов**

<sup>1</sup>Национальный авиационный университет, просп. Космонавта Комарова 1, Киев, Украина, 03058  
E-mails: <sup>1</sup>luppo.ae@ukr.net; <sup>2</sup>skivka@ukr.net; <sup>3</sup>vpalamar@ukr.net; <sup>4</sup>oalexiev@yahoo.com

## References

[1] International Civil Aviation Organization (2015) *Manual on Remotely Piloted Aircraft Systems*. Doc ICAO 10019. First edition. – Montreal. – 166 p.

[2] Ministry of Defense of Ukraine (2016) «Pro zatverdzhennya Pravyl vykonannya pol'otiv bezpilotnymi aviatsiynymi kompleksamy derzhavnoyi aviatsiyi Ukrainy». Order No. 661 of December 08, 2016. – Kyiv. – 32 p. (In Ukrainian)

[3] International Civil Aviation Organization (2011) *Unmanned Aircraft Systems*. ICAO Cir 328. Montreal. – 54 p.

[4] Kharchenko V., Chynchenko Y. (2017) Models of Air Traffic Controllers Errors Prevention in Terminal Control Areas under Uncertainty Conditions. *Proceedings of the National Aviation University*, No. 1, pp. 7-13.

[5] International Civil Aviation Organization (2016) *Procedures for Air Navigation Services – Air Traffic Management*. Sixteenth edition. ICAO Doc 4444. – Montreal. – 464 p.

[6] Wickens C., Dixon S. (2002) Workload Demands of Remotely Piloted Vehicle Supervision and Control: (I) Single Vehicle Performance. Aviation Human Factors Division, Institute of Aviation, USA. – Illinois, September 2002. – 39 p.

[7] Lуппо А., Алексєєв О., Лохачева К., Серhieieva Н. (2017) Procedure of implementation of arrival and departure manager system in Ukrainian airspace. *Systemy obrobky informatsiyi. Zbirnyk naukovykh prats' Kharkivs'koho universytetu povitryanykh syl (no. 4(150))*.

В статье анализируются существующие методы определения уровня нагрузки на внешних пилотов. На основе проанализированного материала созданы новые методические основы для расчета уровня загрузки внешних пилотов дистанционно пилотируемых летательных аппаратов. При создании новой методологической основы были определены и сгруппированы все соответствующие параметры, которые влияют на значение рабочей нагрузки. Получены формулы для расчета этих параметров.

**Ключевые слова:**внешний пилот; дистанционно пилотируемый летательный аппарат; рабочая нагрузка; усталость; риск; теоретические основы

**Alexander Luppo.** Candidate of Pedagogical Sciences.

Associate Professor of Air Navigation Systems department of Institute of Air navigation in National Aviation University.

Education: Faculty of Air Traffic Services, OLAGA, Leningrad (SU).

Research area: improvement and automation of a professional selection system and development of professional-major.

Publications: 70

E-mail: luppo.ae@ ukr.net

**Alexander Skivka.** (1990) Applicant at the Department of Air Navigation Systems, National Aviation University, Kyiv, Ukraine.

Education: Institute of Air Navigation Services, National Aviation University (2013).

Research area: free flight aircraft and resolution of conflict situations in a free flight.

Publications: 18.

E-mail: skivka@ukr.net

**Victor Palamarchyuk.** (1987) Applicant at the Department of Air Navigation Systems, National Aviation University, Kyiv, Ukraine.

Education: Institute of Air Navigation Services, National Aviation University (2010).

Research area: free flight aircraft and resolution of conflict situations in a free flight.

Publications: 5

E-mail: vpalamar@ ukr.net

**Oleh Alexeiev.** (1978). Candidate of Technical Sciences.

Associate Professor of Air Navigation Systems department of Institute of Air navigation in National Aviation University, doctoral student.

Education: Faculty of Air Traffic Services, State Flight Academy of Ukraine, Kirovograd, Ukraine (2000).

Research area: improvement and automation of a professional selection system and development of professional-major.

Publications: 41.

E-mail: oalexiev@yahoo.com