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# METHODOLOGY FOR CREATING A HIGH WORKLOAD SIMULATION EXERCISE FOR AIR TRAFFIC CONTROLLERS

**Summary.** The current article deals with the creation of a simulation exercise intended to train air traffic controllers at an unnamed airport. Simulation exercises enable air traffic controllers to practice possible scenarios that may occur in reality and to practice and improve previously acquired skills. Simulation exercises can be designed based on tasks that the manager has to attempt or complete. Air traffic controller training is usually designed so that their workload is gradually increased up to the highest adjustable threshold. It is important that each controller can handle the set number of aircraft declared by the airport operator and be trained for the possible maximum load that may occur. Air traffic control centers, thus, pay attention to the creation of simulations to induce a high workload for controllers. The goal is to present a methodology for the efficient and quick creation of simulation exercises with the possibility of evaluating their difficulty and creating an exercise that will put the air traffic controller under a high level of stress. Empirical measurements of the composition of aircraft types in the TMA for a specified period and measurements of the duration of individual tasks performed by air traffic controllers to control traffic were taken to indicate the number of possible variants for the creation of exercises. A proposal for exercises for the overload of air traffic controllers was also created.

## 1. INTRODUCTION

Air traffic controllers (ATCs) play a crucial role in ensuring the safe operation of airspace by maintaining appropriate distance between aircraft under their authority, using a combination of technology and international regulations [1]. As air traffic continues to grow, the importance of ATCs becomes even more significant. This growth in air traffic results in an increase in the number of aircraft operations within busy ATC sectors, which often have high air traffic density [2].

Given that safety is the top priority, the capacity of an ATC sector is defined as the maximum number of aircraft that can be effectively managed within a specified period while ensuring an acceptable level of controller workload. The following factors are important to better understand this concept [2]:

- controller workload,
- measurement of controller workload,
- acceptable level of controller workload.

In the current landscape of air transportation, the rapid increase in air traffic has led to airspace congestion, making it essential to carefully manage the workload of ATCs to ensure the continued safety and efficiency of the airspace system [2].

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According to Chatterji and Sridhars [3], the role of ATCs primarily involves a significant mental workload, as it consists mainly of tasks related to information interpretation and decision-making [3].

Consequently, several factors that influence the ATC workload include [4, 5]:

- Frequency of decisions required within a specific timeframe;
- Range of potential strategies for establishing priorities;
- Quality of information regarding signal clarity and data precision;
- Harmony among data, command, and control systems;
- Necessity to execute multiple tasks concurrently;
- Latency in air traffic data transmission or response;
- Volume of information that needs to be maintained in short-term memory;
- Volume of information that needs to be accessed from long-term memory;
- Gravity of the outcomes resulting from incorrect decisions;
- Degree of system error tolerance;
- Physical comfort provided by the air traffic control Workstation;
- Work environment, including shift management, overtime handling, and relationships with colleagues and supervisors.

ATCs must be able to handle a high workload and be sufficiently trained for demanding situations. Simulators are used for these purposes. The utilization of an ATC simulator is essential for training and enhancing the skills of ATCs in managing aircraft both in the air and on the ground. The ATC simulator boasts various features that make it an exceptionally effective training tool, enabling ATCs to prepare for real-world scenarios [6].

The goal of this article is to present a methodology for the efficient and quick creation of simulation exercises with the possibility of evaluating their difficulty and creating an exercise that will put ATCs under a high level of stress. The research question is “How can simulation exercises that evaluate the difficulty and induce high-stress levels in ATCs be created efficiently and rapidly?”

## 2. AIR TRAFFIC CONTROLLER WORKLOAD

The International Civil Aviation Organization defines "workload" as “mental or physical activity” and recognizes it is a potential cause of fatigue. However, workload is a complex concept with no universally accepted definition or standardized measurement method [7].

As previously mentioned, cognitive (or mental) workload lacks a universally agreed-upon definition and is often likened by analogy to physical workload. Generally, cognitive workload encompasses a range of mental activities such as decision-making, estimation, communication, identification, and searching. It can be understood as the relationship between the cognitive resources needed to perform a task and an individual's capacity to utilize these resources effectively [8].

Cognitive workload remains a subjective concept that cannot be directly measured or assigned an absolute value. However, considering that the human mind processes information at a limited rate, cognitive workload can be seen as the proportion of this processing capacity that is utilized at any given moment [8, 9].

For example, the cognitive process layer examines how controllers execute actions (the operational concept) and the associated cognitive processes. In psychology, cognitive processes encompass the full range of mental abilities and functions related to knowledge, including attention, memory (both short-term and working memory), judgment, reasoning, problem-solving, decision-making, language comprehension, and production, among others. In essence, these processes can be summarized as perception, central processing, and response.

The resulting framework for air traffic controller mental workload is based on three key concepts [10]:

- **Demanded mental resources (task load):** This encompasses the blend of physical and mental efforts needed to carry out perceptual, cognitive, and motor tasks. It is informed by empirical research and psychological theories on human cognitive processes. [11].

- **Available mental resources:** These represent the physical and mental capacities—encompassing perceptual, cognitive, and motor skills – that an ATCs possesses to provide effective control services.
- **Threshold:** This is the point at which the demanded mental resources (task load) surpass the available mental resources. It signifies the value beyond which the workload becomes excessive for the ATCs to manage effectively.

In essence, this framework helps to assess and manage the mental workload of ATCs by comparing the demands placed on them during their tasks to their available cognitive and physical capacities [10].

Task demands associated with cognitive work often increase the level of complexity within cognitive systems. When the cumulative effect of these task demands and complexities exceeds the capacity of the human thinking system, it can lead to workload, particularly mental workload [12].

High levels of mental workload, or moderate levels sustained over extended periods, can result in fatigue, particularly mental fatigue [13, 14]. Research has indicated that a primary trigger for mental fatigue is the duration of time spent on tasks, known as time-on-task (TOT) [15]. For instance, continuous mental demands experienced for two hours can lead to mental fatigue, potentially slowing down work processes and resulting in increased reaction times [14, 15].

In summary, cognitive workload encompasses various mental activities and is inherently subjective, lacking a universally accepted definition. For ATCs, cognitive workload can be assessed by comparing task demands to their available mental resources. High levels of mental workload, especially when sustained over time, can lead to mental fatigue, highlighting the importance of managing cognitive demands to maintain effective performance and safety in air traffic control.

### 2.1. Workload assessment

ATC workload measures commonly rely on subjective ratings provided by controllers either during air traffic control operations or shortly afterward. However, these subjective ratings can interfere with controllers' activities, influencing their perceived workload; they are also susceptible to errors [16].

In response, objective workload estimates are being developed as alternatives to subjective ratings. These estimates are derived from routinely recorded ATC data that detail both aircraft and controller activities. Previous studies in the field of ATC have utilized various task parameters – either individually or in combination – to create a realistic workload index. These parameters may include the number of aircraft under control, the duration or content of radio communications, or assessments made by experienced observers [16].

The workload of ATCs can be assessed directly by observing their work and measuring the time required to complete all tasks. This method allows the percentage of time spent managing aircraft within an hour to be determined. However, this method can be used to investigate the ATCs workload only for the existing airspace organization, departure and arrival routes layout, etc. [17].

Three task categories are defined [17]:

- Routine tasks,
- Level change monitoring tasks,
- Conflict monitoring tasks.

For each task, the following data is needed [18]:

- Task duration: the time (in seconds) required to execute the task,
- Task occurrences: the number of routines, climbs/descents, and conflict tasks.

The equation for determining the workload level is:

$$WL=t_{Fl}*O_{Fl}+t_{Cnf}*O_{Cnf}+t_{Cl}*O_{Cl}. \tag{1}$$

where [17]: $O_{Fl}$, $O_{Cnf}$, and $O_{Cl}$, respectively, are the occurrences of routine tasks, climbs/descents, and conflict tasks during a given period and $t_{Fl}$, $t_{Cnf}$, and $t_{Cl}$, respectively, are the durations of routine tasks, climbs/descents, and conflict tasks.

Table 1 shows the recorded working time of one hour for an ATCs and the associated workload. If the controller talks on the frequency or during coordination for more than 42 minutes out of the hour, it is considered overload, and a loss of situational awareness may occur, meaning the controller stops knowing about current aircraft positions and flight plans and predicting future states to detect possible conflicts [18].

Table 1

Workload and recorded working times of ATCs [17]

| Threshold | Interpretation | Recorded Working Time during 1 hour |
|---|---|---|
| 70% or above | Overload | 42 minutes + |
| 54–69% | Heavy load | 32–41 minutes |
| 30–53% | Medium load | 18–31 minutes |
| 18–29% | Light load | 11–17 minutes |
| 0–17% | Very light load | 0–10 minutes |

## 3. SCENARIO CREATION

ATCS must maintain their acquired experience while constantly improving their skills and acquiring new ones. For this purpose, a controller is constantly subjected to training such as periodic and improvement training. Periodic training primarily aims to maintain the competencies required to provide ATC services, while improvement training focuses on practicing new procedures, implementing changes, and applying these updates in real-world scenarios. For these levels of training, new exercises and scenarios need to be created [19]. The process of scenario generation begins by defining simulation objectives, which involves understanding the operational environment and gathering input from stakeholders. The next step typically involves acquiring operational and aircraft traffic data as a foundation for the scenario. This data is then modified to fit the specific requirements of the desired scenario [20]. Scenarios often start with current data as a baseline, as this ensures a reasonable level of realism that would be challenging to achieve from scratch. Once the initial data is obtained, the focus shifts to manipulating flight data to create the desired scenario. This involves defining the simulation and operational parameters for each flight, including the simulation start time, altitude, position, direction of flight, and cruising speed. Additionally, the initial version of the flight route for each simulation flight is determined during this phase [20].

## 4. MATERIALS AND METHODS

Empirical methods were employed to design a simulation exercise for air traffic control operators at an undisclosed air traffic control station to subject the operators to high workload and overload. The simulation is intended for an Approach (APP) radar (surveillance) simulator environment that is a replica of the actual approach control station equipped with functions as a training vehicle for the approach area providing radar (surveillance) services [6]. Over 60 days, the movements of aircraft within the terminal maneuvering area (TMA) were meticulously recorded by built-in clock functions within the voice communication system used by the ATCs at the unit.

The primary objectives were to ascertain:

1. The most prevalent types of aircraft within the TMA,
2. The amount of time aircraft spent within the TMA,
3. The duration of the following tasks:
   - Routine tasks,
   - Level change monitoring tasks,
   - Conflict monitoring tasks.

Task durations were analyzed to facilitate the structuring of the simulation exercise. Each task was categorized to ensure that during the one-hour exercise session, ATCs engaged in dialogue for more than 42 minutes, adhering to Eurocontrol methodologies. Routine tasks were defined as follows [21]:

1. Aircraft entry into the sector: Identification of the aircraft and establishment of communication with the ATC.

2. Flight monitoring: Periodic checking of aircraft parameters such as location, speed, direction, and flight level throughout its passage through the sector. The ATC assesses the sector situation and takes necessary actions.
3. Adjustment of flight parameters: Granting permission to change flight parameters based on decision-making processes or pilot requests, coordinated with neighboring sectors.
4. Exit from the ATC sector: Radio communication upon reaching the sector border, where the pilot contacts the sector controller of the adjacent unit and transfers control.
5. Speed adjustment: Ensuring the aircraft arrives at a navigation point within a specific time for safe separation.
6. Transponder code change: Modification of the aircraft's transponder code to resolve conflicts when two aircraft within the sector share the same code.

   Furthermore, it was established that every five minutes, controllers must achieve a workload value (WL) ranging from 50 to 70. Tasks were sequenced accordingly to maintain intervals within this workload range; the main exercised items are shown in Table 2.

Table 2

Status of traffic and exercised items

| **Traffic** | **Rules** | **Exercised items** |
|---|---|---|
| **DEP, ARR** | **VFR, IFR** | Radar identification, landing instruction, sequence arrangement, horizontal and vertical separation, departure and arrival procedure, coordination, traffic information |

The periods necessary for reciting the individual basic phrases needed for basic air traffic control at the approach station were determined. The approximate length of the phrases was determined according to EUROCONTROL, with a standard speech rate of 100 words per minute [22]. The individual periods for the standard phrases intended for the creation of the simulation exercise are shown in Table 3.

Table 5 shows the average times of individual activities performed by the air traffic controller. When the routine task takes 4 s on average, the level change monitoring task takes 13 s, and the conflict monitoring task takes 25 s. It was determined that the air traffic controller must reach a workload (WL) at a level between 50 and 70 every five minutes during the simulation exercise according to Equation 1. Based on this assumption, the activities shown in Table 5 can be organized into 40 different variants within five minutes.

Table 3

Main phrases used to control air traffic

| **Phrase** | **Approximate time [s]** |
|---|---|
| Climb Flight Level 120 ($t_1$) | 3.6 |
| Descend Flight Level 120 ($t_2$) | 3.6 |
| Turn left heading/turn right heading … ($t_3$) | 1.8 |
| Vectoring for ILS Approach for RWY … track distance to touchdown … ($t_4$) | 6 |
| Contact unnamed tower … ($t_5$) | 4.8 |
| Identified ($t_6$) | 0.6 |
| Report level ($t_7$) | 1.2 |
| Traffic, 12 o´clock, 5 miles, altitude 3500 feet, crossing left to right, C-172 ($t_8$) | 9.6 |
| Report in sight ($t_9$) | 1.8 |
| Report established on localizer ($t_{10}$) | 3.4 |
| Go around ($t_{11}$) | 1.2 |
| Follow OKM 4 arrival/departure ($t_{12}$) | 3.6 |

## 5. RESULTS

Table 3 and 4 display the data collection results. Three main types of aircraft controlled in the area of responsibility were identified by controllers (named X, Y, and Z to preserve the anonymity of the

ATC unit). These three types made up almost 95% of the air traffic, with type X making up more than 50%. Based on Equation 1, it was established that the air traffic controller's workload (WL) should reach a level between 50 and 70 every five minutes during the simulation exercise. With this requirement in mind, the activities listed in Table 5 can be arranged into 40 different sequences or variants within a five-minute period.

Table 4

Traffic in TMA

| Aircraft type | Percentage occurrence in TMA | Average Flight time in TMA [s] |
|---|---|---|
| Type X | 53% | 795.21 |
| Type Y | 28% | 589.92 |
| Type Z | 14% | 552.34 |
| Other types (OT) | 5% | 631.56 |

Table 5

Durations of air traffic controllers' tasks

| Type of task | Duration [s] |
|---|---|
| Routine tasks | 4 |
| Level change monitoring tasks | 13 |
| Conflict monitoring tasks | 25 |

To achieve WL=70, for example, the air traffic controller needs to solve eight routine tasks, one level change monitoring task, and one conflict monitoring task within five minutes. The variant of the frequency of individual tasks per five minutes, therefore, is 40. If an hour-long exercise is created, this means there will be 480 possible combinations of tasks. In order to create the exercise, it is also necessary to choose the right combinations so that ATCs are engaged in dialogue for more than 42 minutes during each exercise and the types of aircraft from Table 4 are also proportionally occupied in the exercises surrounding sites for a total of 10 min out of one hour. Therefore, in the simulation exercise, it is necessary to propose that the controller talks to the aircraft for another 32 to 35 minutes. Thus, a combination of broadcasting from Table 3 must be achieved so that every minute of the exercise controller has to speak to pilots for a long enough time. Thus, each minute of exercise has 39,813,120 possible combinations of broadcasts to achieve a sufficient load. Table 6 provides a possible exercise proposal. Each 5-min exercise section contains a set number of tasks to exert overload on the ATCs. At the same time, standard phrases that are likely to be used are assigned to each section. During the exercise, the ATCs will be involved in communication with the pilots for more than 32 minutes, to which the probable duration of coordination with other air traffic stations of 10 minutes or more is added. The right column lists the number and type of aircraft currently controlled by the ATCs.

Simulations developed in this manner enhance the technical skills of ATCs and provide valuable experience for their career development, thereby enhancing safety [23]. When creating case studies and simulation scenarios, ATC instructors can draw from real-world experiences or pre-existing simulation cases using simulation software. Utilizing an ATC simulator allows users to practice handling scenarios that may arise in real-world situations, improving their ability to manage aircraft traffic effectively and efficiently [6, 24].

## 6. CONCLUSIONS

The main basis for creating simulation exercises should be real situations and events that can occur in live traffic. The controller must be able to react to every situation that arises, and the better they have practiced different variants of activities and different scenarios, the more efficiently and safely they will be able to manage flight traffic. For that reason, it is necessary to create complete overloading scenarios for controllers to practice. In this way, ATCs can build confidence in their ability to handle a high volume of traffic and become more efficient when handling a lower volume of traffic. At the same time, they can recognize their boundaries and behaviors when completely exhausted. This feedback mechanism can help air traffic controllers during their shifts by making them more aware of the early signs of fatigue and exhaustion in themselves. By recognizing these signs, they can take proactive steps to manage their workload, such as communicating with their colleagues about the need to switch positions or take breaks.

Table 6

Simulation exercise

| 5-min section | Task | Number of Phrases | Number of Aircraft |
|---|---|---|---|
| 1 | 4 $O_{Fl}$, 2 $O_{Cnf}$, 1 $O_{Cl}$ | 2 $t_4$, 4 $t_6$, 3 $t_7$, 4 $t_{12}$, 3 $t_9$ | 3 X, 1Y |
| 2 | 3 $O_{Fl}$, 1 $O_{Cnf}$, 1 $O_{Cl}$ | 2 $t_5$, 2 $t_8$, 1 $t_1$ | 5 X, 1 Y |
| 3 | 7 $O_{Fl}$, 1 $O_{Cnf}$, 1 $O_{Cl}$ | 4 $t_6$, 3 $t_5$, 2 $t_8$, 1 $t_2$ | 9 X |
| 4 | 5 $O_{Fl}$, 1 $O_{Cnf}$, 1 $O_{Cl}$ | 6 $t_6$, 2 $t_3$, 2 $t_4$, 1 $t_2$ | 6X |
| 5 | 8 $O_{Fl}$, 0 $O_{Cnf}$, 1 $O_{Cl}$ | 3 $t_6$, 1 $t_5$, 2 $t_3$, 2 $t_4$ | 5 X, 3 Y |
| 6 | 3 $O_{Fl}$, 1 $O_{Cnf}$, 1 $O_{Cl}$ | 1 $t_6$, 1 $t_5$, 1 $t_2$ | 6 X, 3Y |
| 7 | 3 $O_{Fl}$, 0 $O_{Cnf}$, 2 $O_{Cl}$ | 3 $t_6$, 1 $t_5$, 3 $t_3$, 3 $t_4$ | 2 Y, 3 Z |
| 8 | 4 $O_{Fl}$, 0 $O_{Cnf}$, 2 $O_{Cl}$ | 2 $t_6$, 2 $t_5$, 4 $t_3$, 4 $t_4$ | 1 Y, 5 Z |
| 9 | 1 $O_{Fl}$, 3 $O_{Cnf}$, 1 $O_{Cl}$ | 4 $t_6$, 1 $t_8$, 3 $t_2$ | 5 Y, 3 Z |
| 10 | 12 $O_{Fl}$, 1 $O_{Cnf}$, 0 $O_{Cl}$ | 4 $t_6$, 8 $t_5$, 1 $t_1$ | 4 X, 6 Y |
| 11 | 9 $O_{Fl}$, 0 $O_{Cnf}$, 1 $O_{Cl}$ | 3 $t_6$, 3 $t_5$, 5 $t_{10}$ | 2 Y, 3 OT |
| 12 | 2 $O_{Fl}$, 2 $O_{Cnf}$, 1 $O_{Cl}$ | 5 $t_6$, 1 $t_8$, 2 $t_2$ | 5 X |

This article proposed a methodology based on an empirical investigation of traffic in the TMA and the creation of variants of possible scenarios for simulation exercises. With the acquisition of certain data on aircraft movements, the duration of the tasks that the controller performs during the course, and the evaluation of the duration of phrases that the controller uses, it is possible to compile an exercise with a precisely defined level of workload in predetermined sections. Workload, in this case, is understood as both the burden of the controller by practically constantly talking on the frequency with the aircraft and the determination of the workload level according to the EUROCONTROL methodology. The result is a timetable of exercises, or in other words, a methodology for the detailed design of simulation exercises. The methodology is applicable to air traffic units with any TMA arrangement and traffic combination. After the method is applied, specific aircraft routes can be determined by each air traffic control unit based on the data obtained from the methodology.

Future investigations could focus on ATCs themselves by examining their physical characteristics and overall responses to simulation exercises developed using the abovementioned methodology.

## References

1. Hopkins, V.D. *Human Factors in Air Traffic Control*. Taylor & Francis. 1995. ISBN: 9780748403578.
2. Majeed, M. Online estimation of terminal airspace sector capacity from ATC workload. *Air Traffic Management and Control*. DOI: 10.5772/intechopen.100274.
3. Chatterji, G. & Sridhars, B. Measures for air traffic controller workload prediction. *1st AIAA, Aircraft, Technology Integration, and Operations Forum*. 2001. DOI: https://doi.org/10.2514/6.2001-5242.
4. Majumdar, A. & Ochieng, W.Y. Factors affecting air traffic controller workload: multivariate analysis based on simulation modeling of controller workload. *Transportation Research Record: Journal of the Transportation Research Board*. 2002. Vol. 1788(1). P. 58-69. ISSN: 0361-1981. DOI: 10.3141/1788-08.
5. Di Mascio, P. & Carrara, R. & Frasacco, L. & Luciano, E. & Ponziani, A. & et al. How the tower air traffic controller workload influences the capacity in a complex three-runway airport. *International Journal of Environmental Research and Public Health*. 2021. Vol. 18(6). ISSN: 1660-4601. DOI: 10.3390/ijerph18062807.

6. Soeadyfa Fridyatama, D.A. & Suparji, S. & Sumbawati, M.S. Developing air traffic control simulator for laboratory. *TEM Journal*. Vol. 12(3). P. 1462-1474. ISSN: 2217-8333. DOI: 10.18421/TEM123-26.
7. *Fatigue Management Guide for Air Traffic Service Providers*. International Civil Aviation Organization, 2016.
8. Yazgan, E. & Sert, E. & Şimsek, D. Overview of studies on the cognitive workload of the air traffic controller. *International Journal of Aviation Science and Technology*. 2021. Vol. 2(1). P. 28-36. ISSN: 2687-525X. 10.23890/IJAST.vm02is01.0104.
9. Galy, E. & Paxion, J. & Berthelon, C. Measuring mental workload with the NASA-TLX needs to examine each dimension rather than relying on the global score: an example with driving. *Ergonomics*. 2018. Vol. 61(4). P. 517-527. ISSN: 0014-0139. DOI: 10.1080/00140139.2017.1369583.
10. Suárez, N. & López, P. & Puntero, E. & Rodriguez, S. *Quantifying Air Traffic Controller Mental Workload*. 2014. Available at: https://www.researchgate.net/publication/289653261.
11. Wickens, C.D. & Mccarly, J.S. *Applied Attention Theory*. Boca Raton. CRC Press. 2019. DOI: 10.1201/9780429059261.
12. Hilburn, B. *Cognitive complexity in air traffic control – A literature review.* EEC Note 04/04, Eurocontrol. 2004.
13. Mehta, R.K. & Parasuraman, R. Effects of mental fatigue on the development of physical fatigue. *Human Factors: The Journal of the Human Factors and Ergonomics Society*. 2014. Vol. 56(4). P. 645-656. ISSN: 0018-7208. DOI: 10.1177/0018720813507279.
14. Van Cutsem, J. & Marcora, S. & De Pauw, K. & Bailey, S. & Meeusen, R. & et al. The effects of mental fatigue on physical performance: a systematic review. *Sports Medicine*. 2017. Vol. 47(8). P. 1569-1588. ISSN: 0112-1642. DOI: 10.1007/s40279-016-0672-0.
15. Lorist, M.M. & Boksem, Maarten, A.S. & Ridderinkhof, K.R. Impaired cognitive control and reduced cingulate activity during mental fatigue. *Cognitive Brain Research*. 2005. Vol. 24(2). P. 199-205. ISSN: 09266410. DOI: 10.1016/j.cogbrainres.2005.01.018.
16. Athenes, S. & Averty, P. & Puechmorel, S. & Delahaye, D. & Collet, C. ATC complexity and controller workload: trying to bridge the gap. *HCI-02 Proceedings*. 2002.
17. *Pessimistic sector capacity estimation*. European Organization for the Safety of Air Navigation. 2003.
18. Skybrary Aviation Safety. *Situational Awareness*. SKYbrary. 2024. Available at: https://skybrary.aero/articles/situational-awareness.
19. Harcar, I. & Antoso, M. & Fabry, N. & Nemethova, H. & Sutak, N. & et al. Training models for military air traffic controllers. *2020 New Trends in Aviation Development (NTAD)*. 2020. P. 89-92. ISBN: 978-1-7281-7325-2. DOI: 10.1109/NTAD51447.2020.9379105.
20. *Operational Concept Validation*. FAA/EUROCONTROL, COOPERATIVE R&D, European Air Traffic Management Program, Edition 1.3. 2003. Available at: http://www.eurocontrol.int/faa-euro/APgroup-meetings/AP5/OCVSD%20-V1-3.pdf.
21. *Development of Transport by Telematics*. Communications in Computer and Information Science. 2019. Cham: Springer International Publishing. 2019. ISBN: 978-3-030-27546-4. Available at: http://link.springer.com/10.1007/978-3-030-27547-1_26.
22. ICAO, 2001. *Aeronautical Telecommunications (Annex 10).* International Civil Aviation Organization, Chicago.
23. Hanakova, L. & et al. 2017. Determining importance of physiological parameters and methods of their evaluation for classification of pilots psychophysiological condition. *2017 International Conference on Military Technologies (ICMT).* Brno, Czech Republic. P. 500-506. DOI: 10.1109/MILTECHS.2017.7988810.
24. Ulvr, J. & Mach, O. & Rackova, P. & Rusnakova, K. & Smrz, V. New personality evaluation of pilot candidates in Czech Air Force. *2023 New Trends in Aviation Development (NTAD)*. 2023. P. 256-261. ISBN: 979-8-3503-7041-6. DOI: 10.1109/NTAD61230.2023.10380134.

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