ICT for training and evaluation of the solar impact on aviation safety

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Abstract. The paper discusses information and communication technology use for studying reasons of aviation accidents because of the aviation operator errors as result of internal and external influence. The model and technique are proposed and include integrated ICT united previously developed (initial professional selection and day-to-day pre-shift check), open access cloud-based (NASA and ICAO) and real-time operative (air traffic controllers and pilots control) ICTs, which data are stored in one database. Proposed ICT has been checked to study effect of the solar wind parameters (speed and density) on appearance of aviation incidents and accidents during one year observation. Results of that study were compared with corresponding results of another period of solar activity, as well as with data obtained in laboratory conditions to study cognitive tests performance under effect of the solar wind.

Keywords: ICT, aviation safety, astrophysics, database.

1 Introduction

The number of air traffic accidents and incidents (ATA) remains significant despite the efforts of the aircraft engineers and air carriers. Most of the causes leading to the erroneous actions in the flight are complex [1]. The causes of around 30 % of all air traffic accidents still cannot be identified applying current criteria, according to the International Civil Aviation Organization (ICAO). Those causes of the air traffic accidents, which were previously identified as unknown, can actually lie in the astrophysical factors affecting the activity of aviation operators (pilots, air traffic controllers) [2]. It is known that the parameters of solar activity such as solar wind (SW) can have a significant effect on human physical and mental health, first of all, in space and aviation flights [3]. Previous ground-based researches under NASA support of the

Earth´s surface have demonstrated that the negative impact of the solar wind parameters can occur at both high and even very low SW speed and density values [4].

Analyzing the reliability of the pilot in the aircraft control loop [5], the specialists stated that the most vulnerable link in emergent technologies is a lack of psychophysiological training, including soft skills (human factors) [6]. This is true in relation to flight crews as well as air traffic controllers [7]. To be prepared to the effective work, they need special training and re-training with the use of modern and appropriate technologies [8], accounted individual features of the trainees [9] and including adaptive tools [10].

Neurobehavioral performance in the structure of the «human factor» largely determines the success of professional flight operations and reliability of professionally important qualities in extreme situations [5]. Block psychophysiological qualities can be divided into specific, necessary for a pilot, quality (for example, cognitive abilities) and quality, providing resistance to the adverse effects of negative environmental factors (including greater influence of solar radiation, compared with Earth's surface) [11], compensated by the digital transformation of learning environment [12]. In general, it is useful to combine information regards a human psychological, psychophysiological and skills' features to assess and to predict the aviation personnel's reliability and safety, as well as information concerned work environment particularly solar wind components influencing a human performance.

Purpose. To develop the model and technique to study solar wind impact on aviation safety.

2 Methodology

The model developed to solve the task is based on the methodology for studying emergent industries operators' performance [13], and includes information about an aviation operator's psychophysiological abilities collected at stages of his/her professional selection and day-to-day pre-shift check, as well as extended by data from cloud sources the Aviation Safety Network (ASN) containing descriptions of the air traffic accidents that occurred due to human factors (i.e. category of air traffic accident, date, time, aircraft type, and location) [14], solar wind parameters at the time of each air traffic accident (speed V and density ρ), according to the National Oceanic and Atmospheric Administration (NOAA) [15].

The model of data collection and use for study a solar wind impact on aviation safety (air traffic controllers and pilots reliability) demonstrates the systemic nature of influencing factors (Fig.1).

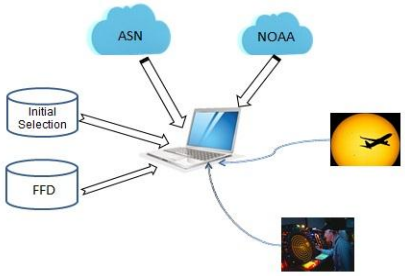

Fig. 1. The structure of innovation performance indicators in ICTs

Stages of the Study Process:

1. Data acquisition and database creation based upon related information sources
2. Creation of histograms and analysis of the findings
3. Discussion and interpretation of the results

The technique to study the solar wind impact on aviation accidents and incidents includes:

Data collection

- Data related to the particular aviation operator (air traffic controller and/or pilot) after initial professional selection stored in the database (DB).
- Data related to the same person after training/re-training stored in the DB.
- Data related to the same person stored by the system of the day-to-day pre-shift check in the DB.
- Safety data from the Aviation Safety Network (ICAO).
- Solar wind data from the National Oceanic and Atmospheric Administration (NASA).

Data analysis

- Histograms construction for the solar wind's density and speed.
- Histograms construction for the ATA events related the same SW frequency intervals.

Observation period: June 1, 2018 to September 2, 2019 (solar cycle 24, minimal solar activity period).

Results and Discussion

The exposure to solar radiation during space and air flights can have a profound effect on humans´ sensory nervous system. Moreover, other occupational groups of the aircraft industry (air traffic controllers) are also at risk of exposure to solar radiation. Thus, the solar wind has an ability to affect humans on the following three levels (Fig.2):

- On Earth´s surface (air traffic controllers)
- In the upper layers of atmosphere (pilots)
- In the space (astronauts).

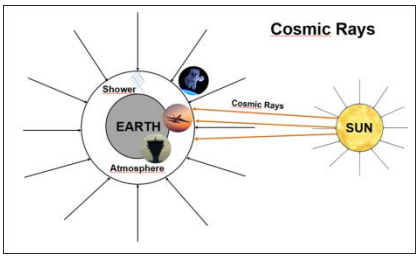

Fig. 2. Three levels of the SW impact on a human performance

However, the exact mechanism of such impact is not clearly understood yet. At the same time, it is known however that the Earth´s magnetic shield deflects the primary particles of the solar wind (protons and electrons). This collision generates secondary particles in the atmosphere forming their cascades and an extensive atmospheric shower. As a result, an aviation operator's performance can be influenced by them depending on a human psychophysiological resilience and train level, including soft skills.

The main results are as follows:

- Total number of the documented air traffic accidents: 63.
- SW speed rage by day: 294…612 km/s (57% of all ATAs: $V \leq 400$ km/s).
- SW density range: 0,3…17,1 proton/cm3 (60 % of all ATAs: $\rho \leq 3{,}1$ proton/cm3).

But the frequency distribution (using STATISTICS 6.0) of the ATA across the intervals of the revealed bounds of the SW density and speed is not uniform and has some "picks" in both parameters (Fig.3).

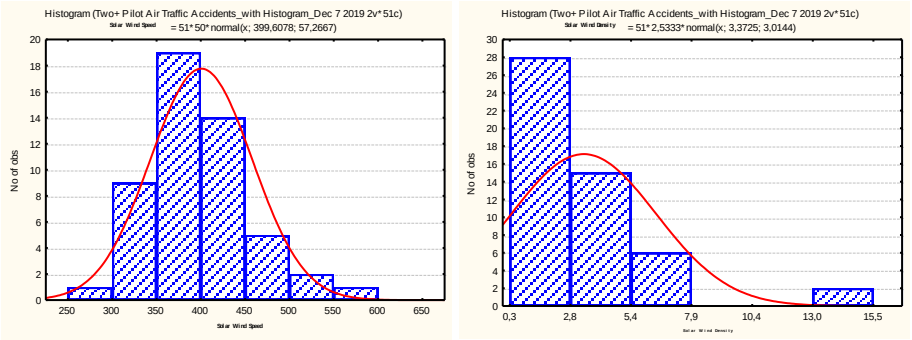

Fig. 3. SW density and speed across period of ATA studying

Distribution in accordance to intervals of the SW parameters in % of the whole numbers of events demonstrated very similar nature in relation to the SW speed (Fig. 4), but different distribution in relation to the SW density (Fig.5)

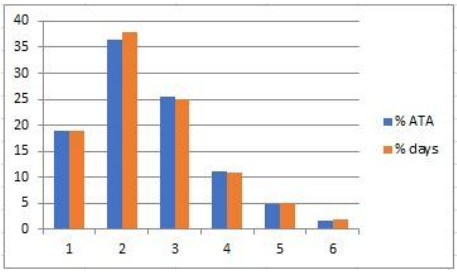

Fig. 4. % of the SW speed by intervals (see Fig.3) in comparison with ATA days

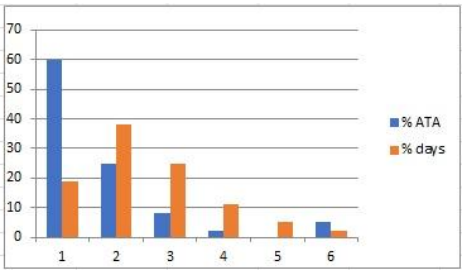

Fig. 5. % of the SW density by intervals in comparison with ATA days

These results correspond the results of the study a human-operator's cognitive changes under influence of the solar wind in laboratory conditions [4], but differ to some extent from the data of previous study [2] during observation period 1998-2009 (period of high solar activity of the 23rd solar cycle).

It has been confirmed the dependence of the probability of accidents on certain ranges of SW parameter values. However, in contrast to the known data about this dependence in the performance of cognitive activity in experimental conditions on Earth, it was revealed maximum impact on the speed of SW 500-600 km/s and density SW 7-11 proton/sm^3.

The study concluded that the astrophysical factors should be accounted in the analysis of air traffic accidents to ensure flight safety.

The study confirmed that the solar corpuscular radiation can pose risks to human mental health, i.e. central nervous system. The frequency distribution of the air traffic accidents by SW speed and density is uneven with the peaks between intervals ranging as follows: 350…400 km/s for SW speed and 0…3 proton/cm^3 for SW density.

The study has shown that further research is needed (i) to develop the aircraft accident classification by solar wind impact on certain types, phases, and geographical latitude of the flights, (ii) to assess the effects of SW proton energy on the activity of free neutrons and secondary protons in the atmosphere, and (iii) to examine the SW impact on the humans´ individual and group behavior in outer space.

Those results have confirmed that "Ergonomics as a scientific and practical discipline is aimed at ensuring high efficiency of human activity, its safety and comfort. One of the ways to achieve such a triple task is to create an effective psychophysiological support for the ability to work in the process of both work and learning. Macroergonomic approach involves the systematic solution of issues of analysis of a certain type of activity, designing its optimal conditions, selecting and adapting a person to this activity, solving technical and organizational issues of providing effective and safe education and labor" [16]. Besides, such an investigation could be used to monitor human abilities over a lifespan: in education, training and work, as well as all kind of life [17].

3 Concluding Remarks and Future Work

The air traffic dispatchers and air carriers can use the SW data to assess the risk of air traffic accidents. The main difference in laboratory study and in real settings (aviation) can be explained by the professional training/re-training level, as well as by team and inter-person work in real aviation activity in contrast with the laboratory participated subjects, who performed cognitive tests and concentrated on the prompt cognitive activity not having professional training, though both type of mental activity studied used ICT.

Further study of the modern astrophysical data (including various periods of solar cycle) and their application for the air traffic controlling (especially in the high latitudes) will lead to better understanding of the correlation between SW and air traffic accidents and later, developing an exact action plan based on the biophysical observations of equipment and pilot behavior.

Further modernization and improvement of the dispatch equipment in the aircrafts will enable for additional information for computer prognosis.

Apart from that, it can be considered to reduce the duration of occupational exposure to the SW and provide medical and psychological recovery measures for the affected occupational groups to compensate for any potentially negative impact.

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