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STRUCTURAL RELIABILITY OF AIR TRAFFIC CONTROLLERS

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Abstract. *The types of air navigation systems operator's reliability based on the causes of errors are considered. The structural-analytical model of air navigation systems operator's reliability is developed. The mathematical dependence for calculation of the probability of error-free operation of air navigation systems operator is determined.*

Keywords: error; operator of air navigation systems; reliability; probability of error-free operation; reliability; structural reliability.

1. Introduction

The problem of the air navigation systems reliability is highly relevant today. The aviation safety and its efficiency depend on the required level.

B. Lomov considered the concept of reliability as a qualitative characteristic of the system (or a unit) to perform the necessary functions in specified time interval [4].

2. Analysis of research

Quantitative evaluation of the operator of air navigation system reliability can be used as a probability of the successful performance of work or task, at a given system operating step, at a given time interval [5].

Air traffic control system is ergatic control system, which includes both elements: technical equipment and operators that interact with the system.

Therefore, to obtain an objective assessment of reliability of air navigation system we should take into account not only the effect of air navigation systems technical equipment quality, but also results of operator of air navigation systems activity, that depends on many factors.

For example, ergonomic, organizational, psychophysiological, economic.

Psychophysiological factors include such components as shift-working arrangements, aging workforce, nervous tension, professional stress, information overload, intensity of work, duration of concentrated observation, number of objects simultaneously observed.

When we evaluate air navigation systems reliability, we can count only technical equipment failures, failures are not related to the operator activities. That means that the operator reliability defaults to the absolute when operator reliability $R = 1.00$.

However, a significant amount of technical equipment failures of air navigation systems, which occur due to the operator fault, indicates a significant impact of operator on the reliability of air navigation systems. Proportion of failures due to the activities of the operator varies from 20 to 95 percent in the reporting documentation was recorded that [3]. Therefore, the reliability of operator of air navigation systems is not absolute, and it should be taken into account in estimates of its characteristics. Otherwise, evaluation reliability of air navigation systems becomes too erroneous and exaggerated.

Moreover, if the decrease of the level of technical equipment reliability is connected with the appearance of failures, then the estimated reliability of operator of air navigation systems errors that occur in its activities. Error of operator of air navigation systems is an incorrect performing or failure to perform the prescribed action. [7]

Error of operator of air navigation systems can occur in the following cases:

1. Operator aims to achieve some incorrect goals ("substitution of the purpose").
2. Incorrect operators action that enable goal achievement.
3. Operator is idle when his participation is necessary. [5]

Operator errors are due to the following main reasons:

– unsatisfactory training or poor qualification of the operator;

– unsatisfactory performance of operating procedures by the operator;

– poor working conditions, such as poor equipment

availability, tightness of workroom or excessive temperature in it;

– lack of incentives for operators;

– high information overload, leading to information stress and information traps;

– poor physical condition that affects the functioning of operator of air navigation systems.

Indicated error causes can be considered independent and classified by the following four types:

1. Functional.
2. Operational.
3. Information.
4. Professional.

In accordance with the classification of the causes of operator of air navigation system errors was similar components of its reliability and their definitions were withdrawn.

Functional reliability of operator of air navigation system is the property of operator of air navigation system functional systems to ensure dynamic stability in the performance of professional tasks for a certain time and with a given quality. The concept of functional reliability deals with the nature of human adaptation to the energy control process of the object.

Operational reliability of operator of air navigation system is the ability to keep working capacity under the normal conditions in the working environment for a certain period.

Information reliability of operator of air navigation system is the correct flow of information processes in a given time period under the given external conditions. Factors, such as lack of time, information overload, high rate of information flow, cause mental stress and disrupt the process of information exchange with the control system, resulting in decreased information reliability of operator and reliability of whole ergatic system.

Professional reliability of operator of air navigation system is the inerrancy and timeliness of air navigation system operator at achieving a specific goal under the given conditions in the interaction with the hardware and other professionals under condition of correct perform regulations. The main reason for the decrease of professional reliability of operator of air navigation system is the ignorance of the basic tasks of instructions or professional activity and unwillingness to perform them.

Structural reliability of operator of air navigation system is the resulting reliability operator of operator of air navigation systems, which includes such components as informational, professional, functional and operational reliability for a given structure and known values of all its components (Fig. 2).

In quantitative estimates of reliability informational, functional, professional and operational reliability components should be considered as series of connected parts of one physical system - operator of air navigation systems [1]. Presentation of a functional diagram of the reliability of system structural model as series of connection elements means that the failure of any parts of the system leads to a failure state. [2]

By analogy with the reliability of technical systems, in which one of the leading indicators of reliability is the probability of reliability function, for estimating the reliability of operator of air navigation system, let us introduce the index of probability of error-free operation. Probability of error-free operation is characterizes by the degree of sustainable efficiency of operator of air navigation systems within a given working cycle. [6]

Consequently, if we consider the relationship and influence constituents of error-free operation of operator of air navigation systems, it is necessary to note that the most important task of operator of air navigation system is to develop faithful errorless decisions.

Based on that, the probability of structural error-free operation of operator of air navigation systems can be represented as:

$$R_{str} = R_{prof} \cdot R_{op} \cdot R_{\inf} \cdot R_{func},$$

where – $R_{str} = R_{prof} \cdot R_{op} \cdot R_{\inf} \cdot R_{func}$ – probability of error-free operation of operator of air navigation systems: structural, professional, operational, informational, and functional, respectively. [6]

Fig. 4. shows the structure of informational and professional probability of air traffic controller. Let us consider the proposed simple structure depending on the type of connection links, serial and parallel.

In serial systems (Fig. 1) failure of any component of the structure leads to failure of the whole system. [2]

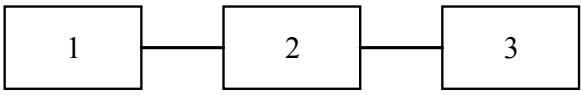

Fig. 1. Serial connected elements

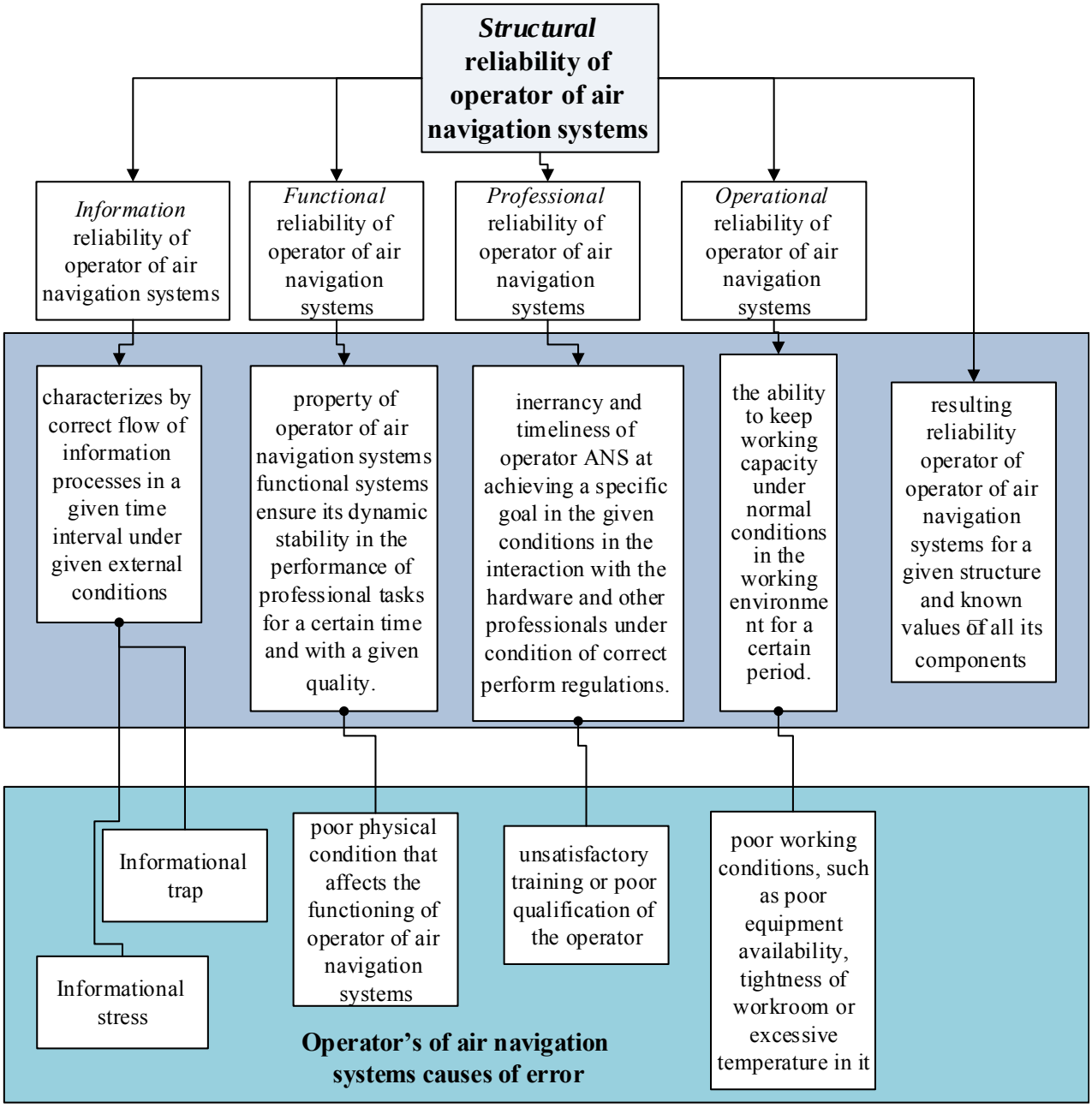

Fig. 2. Structure of operator of air navigation systems reliability and causes of operator's error

In general, the probability of error-free operation of the system with the serial elements is:

$$R = \prod_{i=1}^{m} R_i .$$

Where R – error-free operation, m – the number of serial elements in the system [1].

In a system with parallel structure (Fig. 3), system failure generally occurs only at failure of all elements.

In general, the probability of error-free operation of the system with the parallel elements is:

$$R = 1 - \prod_{i=1}^{m} (1 - R_i).$$

Where R – error-free operation, m – the number of parallel elements in the system.

Based on the proposed structural analytical model of operator of air navigation system at (Fig. 2) and

Structure of informational and professional probability of air traffic controller (Fig 4) developed formula of probability of error-free operation of operator of air navigation system:

$$R_{str} = \left[(1 - \prod_{e=1}^{l} (1 - R_o) \right] \cdot \left[(1 - \prod_{f=1}^{m} (1 - R_f) \right] \times$$

$$\times \left[\prod_{i=1}^{b} R_i \cdot (1 - \prod_{i=1}^{d} (1 - R_i) \right] \cdot \left[\prod_{n=1}^{k} R_p \right].$$

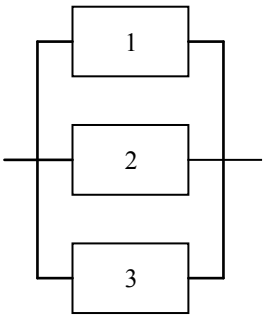

Fig. 3. Parallel connected elements

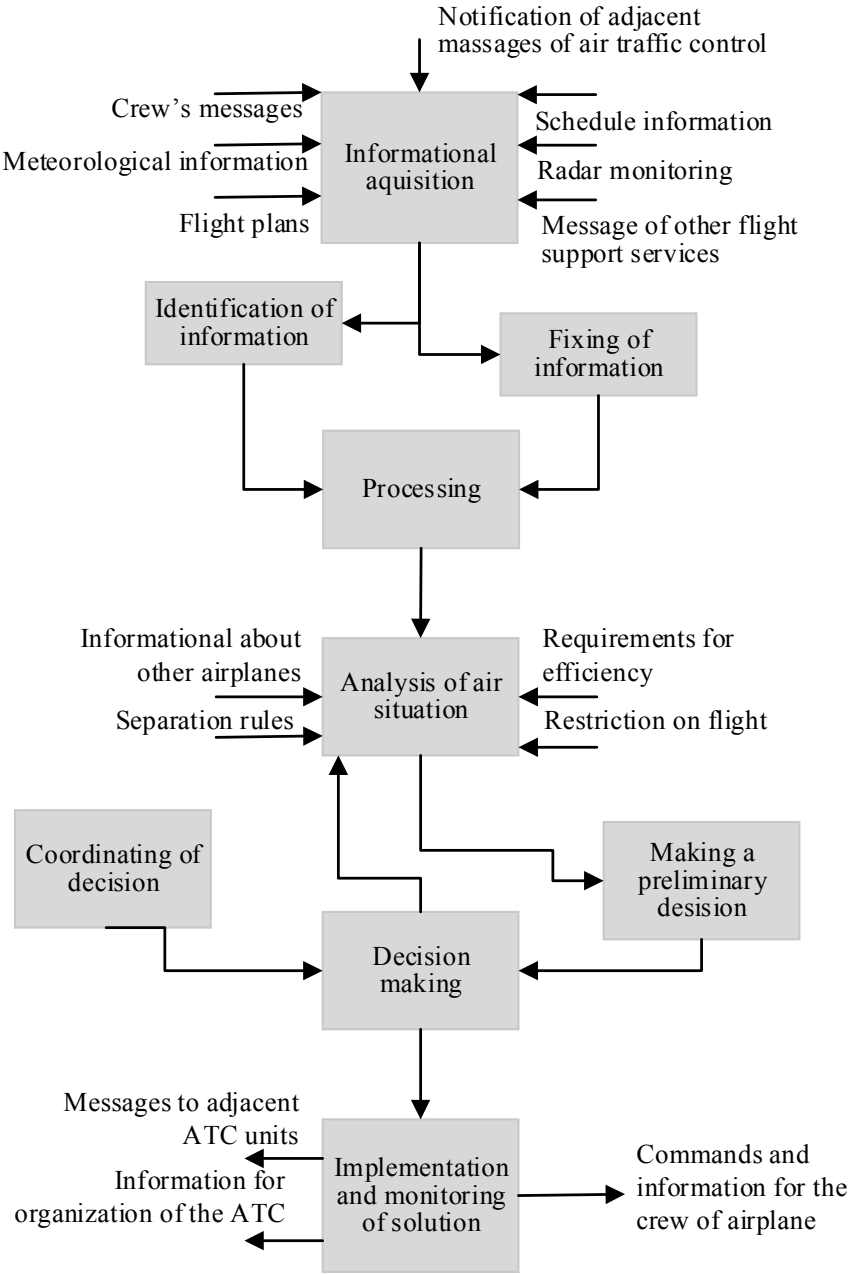

Fig. 4. Structure of informational and professional probability of air traffic controller

Where:

$R_{op} = 1 - \prod_{e=1}^{l}(1 - R_o)$ – complex operational probability of error-free operation of operator of air navigation systems

R_o – operational probability of error-free operation of operator of air navigation systems

$R_{func} = 1 - \prod_{f=1}^{m}(1 - R_f)$ – complex functional probability of error-free operation of operator of air navigation systems

R_f – functional probability of error-free operation of operator of air navigation systems

$R_{prof} = \prod_{n=1}^{k} R_p$ – complex professional probability of error-free operation of operator of air navigation systems

R_p – professional probability of error-free operation of operator of air navigation systems

$R_{\text{inf}} = \prod_{i=1}^{b} R_i \cdot (1 - \prod_{i=1}^{d}(1 - R_i)$ – complex informational probability of error-free operation of operator of air navigation systems

R_i – informational probability of error-free operation of operator of air navigation systems

3. Conclusions

1. When it is necessary to avoid the overstatement of the reliability of such ergatic system, as air navigation system a calculation of operator of air navigation systems reliability, as one of the functional part of system should be taken into account.

2. If needed, more objective of operator of air navigation systems reliability assessment indicators should depends on the underlying causes of errors to consider such objective components of operator of air navigation systems reliability as informational, functional, professional and operational reliabilities.

3. Failure of any parts of the structural reliability of operator of air navigation systems leads to failure state of all air navigation systems.

4. When we evaluate the air navigation systems reliability, only technical equipment failures are counted. Failures are not related to the operator activities, this means that the operator reliability defaults to the absolute when operator reliability R = 1.00.

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О. В. Кожохіна[1], В.М. Грібов[2], С.І. Рудас[3]. Структурна надійність оператора аеронавігаційної систем

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Розглянуто види надійності оператора аеронавігаційної системи залежності від причин скоєних помилок. Розроблено структурно-аналітична модель надійності оператора аеронавігаційної системи. Виведена математична залежність для розрахунку безпомилковості роботи оператора аеронавігаційної системи

Ключові слова: ймовірність безпомилкової роботи; надійність; оператор аеронавігаційних систем; помилка; структурна надійність.

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Рассмотрены виды надежности оператора аэронавигационной системы зависимости от причин совершаемых ошибок. Разработана структурно-аналитическая модель надежности оператора аэронавигационной системы. Выведена математическая зависимость для расчета безошибочности работы оператора аэронавигационной системы

Ключевые слова: вероятность безошибочной работы; надежность; оператор аэронавигационных систем; ошибка; структурная надежность.

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