Methodology for evaluating the effectiveness of integrated automation in aerospace industry

Sergey N. PADALKO*[,1], Aleksandr A. ERMAKOV[1], Fatima M. TEMMOEVA[1]

*Corresponding author
[1]Department of Applied Informatics,
Moscow Aviation Institute (National Research University),
4 Volokolamskoe Shosse, 125993, Moscow, Russian Federation,
snp7@inbox.ru*, aleral@mail.ru, fatima94temmoeva@gmail.com

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Abstract: *Aerospace (remote) methods today have become one of the most effective means to study the earth's surface. Taking into account the expansion of the range of tasks that the aerospace industry faces nowadays, as well as the fact that hyperspectral analysis of large volumes of data obtained during aerospace research is time-consuming and costly, the need for the introduction of automated control systems for aerospace enterprises is essential. The article is devoted to the study of approaches to evaluating the efficiency of the integrated automation in aerospace organizations. In the process of research, a technique based on the use of mathematical apparatus of fuzzy numbers and including an assessment of the productivity and stability of functioning of automation systems, as well as an analysis of the reliability of information exchange and security of information transmission. Therefore, the practical and theoretical significance of the chosen research topic is not in doubt.*

Key Words: *aerospace research, automated systems of control, integrated performance indicator, meteorological systems*

1. INTRODUCTION

Aerospace (remote) methods nowadays have become one of the most effective ways to study the Earth's surface.

The industries and applications of these methods are diverse and their quantity is increasing every year.

Presently, the results of the activities of aerospace industry organizations are used for: location of satellite communications; creation of global radio navigation systems; deployment of space meteorological systems; space geodesy; study of the Earth's natural resources from space; information support for land use, ecology and emergency situations; space intelligence for military security, etc. [1].

In addition, an analysis of armed conflicts of the last decades clearly demonstrates that geospatial information, which can be obtained by means of aerospace observation, is necessary to solve the problems of national security and defense.

Thus far, there is significant number of different methods of aerospace observation, a brief description of which is given in Table 1.

Table 1 - Characterization of aerospace research methods [2]

Aerospace research methods	Aviation	Space
Application boundaries	The lower layers of the Earth's atmosphere (troposphere and stratosphere) - up to a height of 100 km	Beyond the limits of the Earth's atmosphere (including the high atmosphere of the Earth) - above 100 km
Technical means of imaging	Aircraft - airplanes, helicopters, balloons, radio probes, etc.	Spacecraft, artificial Earth satellites, orbital stations, automated interplanetary stations, etc.
The resulting product	Aerial view	Space image
Scale of imaging	Large-scale	Large-, medium-, small-scale

At the same time, taking into account expansion of the range of tasks that the aerospace industry faces today, as well as the fact that hyperspectral analysis of large volumes of data obtained during aerospace research is time-consuming and costly, the need for introduction of automated systems for managing aerospace enterprises is essential.

This, in turn, necessitates the development and improvement of flexible and effective methods for assessing the effectiveness of integrated automation of organization of aerospace industry in order to determine ways to improve the characteristics of information received (spatial fragmentation, speed of information transfer from onboard to the Earth, radiometric quality, etc.).

Therefore, the practical and theoretical significance of the chosen research topic is not in doubt.

2. MATERIALS AND METHODS

Thus far, the main and most promising method for the automated control of complex dynamic systems and processes in vital and critical from the point of view of safety and reliability areas of functioning of aerospace enterprises is dispatch control and data collection.

The study of materials on the problems of constructing effective and reliable systems of dispatch control revealed the need for a new approach in development of such systems: human-centered design (or top-down, down-top), i.e. focus primarily on the human operator (dispatcher) and his tasks, instead of traditional and universally used hardware-centered (or bottom-up, up-bottom), in which, when building the system, the main attention was paid to the selection and development of technical means (equipment and software).

The application of the new approach in real space and aviation research and comparative testing of systems at the National Aeronautics and Space Administration (NASA), USA, confirmed its effectiveness, permitting operators to increase productivity, reduce procedural errors by an order of magnitude, and reduce to zero critical (not correctable) operator errors.

SCADA (Supervisory Control and Data Acquisition) - the process of gathering real-time information from remote points (objects) for processing, analysis and possible management of remote objects.

The requirement for real-time processing is due to the need to provide (issue) all the necessary events (messages) and data to the central interface of the operator (dispatcher). At the same time, the idea of real-time is different for various SCADA systems. The prototype of modern SCADA systems in the initial stages of the development of automated control systems was telemetry and signaling systems.

All modern SCADA systems include three basic structures:

- Remote Terminal Unit (RTU) is a remote terminal that accomplishes task processing (control) in real time. The range of its implementations is wide from primitive sensors that carry out information collection from an object to specialized multiprocessor fault-tolerant computer systems that process information and control in hard real-time mode. Its specific implementation is determined by the specific use. The use of low-level information processing devices can reduce the bandwidth requirements of communication channels with the central control center.
- Master Terminal Unit (MTU), Master Station (MS) control room (main terminal); provide data processing and high-level control, as a rule, in soft (quasi-) real-time mode; one of the main functions is to provide an interface between human operator and the system (HMI, MMI). Depending on the specific system, MTU can be implemented in a wide variety of forms, from a single computer with additional devices for connecting to communication channels to large computer systems (mainframes) and/or workstations and servers integrated into a local network. Normally, when constructing MTUs, various methods are used to increase the reliability and safety of the system.
- Communication System (CS) is a message system (communication channels) that is necessary for transmitting data from remote points (objects, terminals) to the central operator-dispatcher interface and transmitting control signals to RTU (or a remote object, depending on the specific system version).

Nonetheless, as practice shows, the enormous costs and the long duration of implementation of integrated automation at the enterprises of the aerospace industry do not guarantee results.

Thus, according to the annual Chaos Study, which has been published by the Standish Group since 1994, today's results indicate extremely low performance in this area of activity: only 16% of projects were completed on time, met budget and boasted the full range of functionality provided in terms of reference for the development of the project [3].

According to Price Water House Coopers, in 2015 in the West, the number of unsuccessful implementations of ERP class systems in the studied enterprises demonstrated a slight improvement of this indicator - up to 28% [4].

According to the US Department of Defense – one of the main users of aerospace industry information: 47% of paid orders for software development were completed, but the developed software was not used due to non-compliance with requirements; 29% of orders were never developed (not just on time, but never at all); 19% of paid software development contracts were broken due to deadlines; 3% of custom software was developed on time and these programs were used, but after serious improvements by our own specialists; only 2% of custom software was delivered on time, and did not require improvements [5].

3. RESULTS AND DISCUSSIONS

A study conducted by the authors indicates that traditionally in enterprises, a multiple criteria approach or simulation modeling is usually used to assess the automation efficiency of certain areas of operation, with the help of which a qualitative and quantitative analysis is performed.

At the same time, for the examination of the multipart automation of the organization of the aerospace industry, not all indicators are equally important, and traditional approaches do not allow evaluating the effectiveness in the conditions of ambiguity of specific initial data, which is inherent in aerospace research.

An important role here can be played by the works of the authors of [6], [7], [8], [9], [10], [11], [12], [13], [14].

Therefore, we believe that, given the requirements and features of the tasks performed by aerospace enterprises, it is advisable to use primarily such groups of indicators:

– performance indicators (average throughput C_{ATP}, system response time T_p, transmission delay time T_{zp});

– stability indicators (object noise immunity F_{op}, object technical reliability F_{tn}, functional stability F_{fs});

– reliability indicators (accuracy (absence of error) of information transfer K_{bi} the distortion coefficient of the transmitted information K_i);

– transmitting security parameters (decryption information coefficient K_{di}, security information channels coefficient K_{si}).

At the same time, taking into account the fact that the input data for calculating some of these indicators are made under conditions of uncertainty, it is advisable to represent them using the mathematical apparatus of fuzzy numbers [15], [16], [17], [18], [19], [20].

In order to build an integrated generalized indicator that will let us evaluate the effectiveness of the integrated automation of organization of the aerospace industry, we suggest:

– to normalize indicators for the range of possible values [0, 1];

– in the event that an increase in functioning efficiency of the automated system is achieved by reducing the values of the “reverse” indicator by subtracting it from 1.

As a result of these actions, we acquire a lot of “reduced” particular indicators, which in the general case can be represented as (Eq. 1):

$$F = \{f_i(x, y, z)\} \tag{1}$$

where $f_i(x, y, z)$ - i-th "reduced" partial indicator, which depends on a variety of arguments: x - real; y are fuzzy; z - quality.

It should be noted that in order to ensure the effective functioning of automation systems of enterprises in aerospace industry, each of these indicators should be within the permissible limits $f_{min} \leq f_i(x, y, z) \leq f_{max\,i}$.

For individual "reduced" indicators $f_{min\,i}$ and $f_{max\,i}$ can be determined based on the requirements for values of the initial corresponding indicators.

If such an approach cannot be used, it is suggested to use the method of expert estimates to calculate $f_{min\,i}$ and $f_{max\,i}$.

The set of requirements for “reduced” indicators $f_{min\,i} \leq f_i(x, y, z) \leq f_{max\,i}$ defines a system of restrictions.

In order to maximize the efficiency of the functioning of automated systems in the aerospace industry, we will make a comprehensive indicator F_{tks}.

Since individual indicators are independent, the complex indicator will be determined additively (Fig. 1).

According to Figure 1, to construct a comprehensive indicator F_{tks} it is necessary to calculate the weighted sum of the individual elements of the set of “reduced” particular indicators $F = \{f_i(x, y, z)\}$ (Eq. 2):

$$F = \Sigma \alpha_i f_i xyz \tag{2}$$

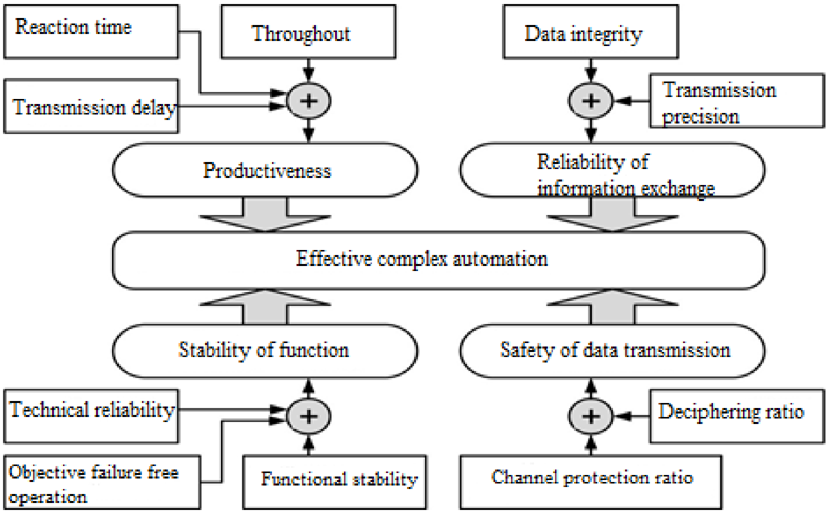

Fig. 1 - Structural and analytical scheme for formation of an integrated indicator of effectiveness of automated systems in the aerospace industry

4. CONCLUSIONS

During the past 10-15 years, interest for the problems of building highly efficient and highly reliable systems of supervisory control and data collection has sharply increased. Investigation and analysis of most accidents and incidents in aviation, land and water transport, industry and energy, some of which led to catastrophic consequences, demonstrated that if in 1960s human error was the initial cause of only 20% of incidents (80%, respectively, due to technological failures and breakdowns), then in 1990s the share of the human factor increased to 80%, and, due to the continuous improvement of technologies and increased reliability of electronic equipment and machines, this share may still increase.

The main reason for such trends is the old traditional approach to construction complex automated control systems, which is often used now: focusing primarily on using the latest technical (technological) achievements, the desire to increase the degree of automation and functionality of the system and, at the same time, underestimation of the need to create an effective human-machine interface Human-Machine Interface, i.e. user-oriented interface (operator). It is no coincidence that for the last 15 years, i.e. The epoch when powerful, compact, and inexpensive computing tools appeared, the peak of research in the USA came up on the human factor in control systems, including the optimization of the architecture and Human-Machine Interface of supervisory control systems and data collection.

Therefore, summing up the results of the study, the following conclusions can be made. The enterprises of the aerospace industry and the results of their work play a crucial role in providing information for solving scientific, environmental, and national economic problems and problems of national security and defense. The significant benefits of aerospace observation over other types of technical control: global approach, extraterritoriality, long-term operation, responsiveness, continuity and comprehensiveness determine the critical task of integrated automation of aerospace industry organizations and assess the effectiveness of such automation. To resolve this scientific problem, a technique was formalized based on the use of the mathematical apparatus of fuzzy numbers and includes an assessment of productivity and stability of functioning of automation systems, as well as an analysis of reliability of information exchange and security of information transfer.

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