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THE POSSIBILITY OF THE EVENT-BASED FLIGHT SAFETY CONTROL TAKING INTO ACCOUNT THE PARTICULAR QUALITIES OF THE PILOT

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The article analyzes the flight safety management process. The structure of the flight safety management system and the subject-object interaction which is in the base of this system functioning are shown. The necessity of aircraft intelligent on-board control systems development and implementation is proved. The tasks that such systems will allow to solve during the flight are outlined. Application prospects of the real and documented flight safety contours in the system of active flight safety management are considered. The possibility of active flight safety control based on the parametric control principle is shown. The necessity of flight safety management based on the event-based control principle with the use of documented flight safety contour is proved. The example which visually demonstrates the capabilities and prospects of event-based flight safety management has been considered. The necessity of a particular pilot psychical characteristics taking into account while forming the contour of documented flight safety is proved. For this purpose, the flight personnel mental state systematic monitoring with the aim of professional suitability indicator determination expediency is justified. The possibility of using the pilot's personal database for documented safety contour formation of each specific flight is considered in order to take into account the features of a particular pilot in managing flight safety. This should be a self-learning system that operates on the basis of the neural networks application and allows you to take into account all the characteristic and temperament features of each pilot in person. It is proved that the possibility of the pilot's mental state taking into account, expressed by the value of the professional suitability indicator, can be successfully implemented exactly in the event of flight safety management, which will lead to the security increase of the aviation system from exposure of hazardous factors during the flight mission.

Key words: flight safety, flight security, hazard, real flight safety contour, documented flight safety contour, mental state.

INTRODUCTION

Military aviation has become an indispensable means for the solution of geopolitical and strategic problems of the world leading powers, the symbol of power and prosperity. It is impossible to imagine in today's world any modern state force or deterrent action without the military aviation use [1].

The Armed Forces of the Russian Federation State Armament Program, which was launched in 2011, stipulates the mass supply of the new aircraft to the Air Force troops and educational institutions for the period up to 2020. In this regard, it is important to be ready to ensure high reliability, safe operation and effective combat use of military aviation systems.

The main goal of all aviation personnel of the Armed Forces of the Russian Federation, enterprises and institutions, organizing and conducting research, designing and creating new models of aviation technique and weapons, organizing and conducting repair and restoration work of aviation technique, training aviation personnel, i.e. everything related to military aviation, is maximization of aviation complexes combat potential characteristics. Three tasks must be successfully completed in order to achieve this goal:

1. Increase of aviation complexes combat potential. It consists in the development of new models and modern aviation equipment modernization in order to increase their striking power and maneuverability characteristics, as well as to improve the level of aviation specialists operating aviation equipment training.

2. Preservation of aviation complexes combat potential. It is aimed at the Russian Air Force flight safety improvement, flight search and rescue support perfection, and development of tactical techniques allowing us to minimize combat losses.

3. Combat potential of aviation complexes maintenance. It consists in the aviation complexes operation comprehensive support.

All stated above shows that the task of the Russian Air Force flight safety improvement - is the task of national importance. This is confirmed by the fact that the state aviation flight safety is defined as one of the Russian Federation National Security Component[1] [2, 3].

Many authors [4 – 13] devote their works to the increase of flight safety level provision. Due to the application of systematic measures aimed at the Russian Federation state aviation flight safety level increase, there has been a tendency to reduce the aviation accident rate in recent years. The main organizing and directing function in this task is performed by the flight safety bodies under the direct supervision of the Russian Federation Air Force Flight Safety Service Head.

However, aviation accidents happen to occur with state aircraft, and the aviation accident rate remains at an unacceptably high level of ≈ 2.5 – 2.3 aviation accidents per one hundred thousand hours of total flight time. In aviation of other world leading countries, the same indicator is 2 – 2.5 times lower.

Aviation accidents with the state aviation of the Russian Federation aircraft take away the lives of highly trained flight personnel, expensive aircraft are lost.

Under the conditions of supplying the forces with up-to-date aviation equipment and increasing the flight personnel standards, the flight accidents financial losses at the existing aviation accidents rate can make up 25 – 30 billion rubles annually.

The loss of costly aviation equipment and particularly the loss of human lives as the result of aviation accidents, damages the state prestige of the Russian Federation in the world, undermines the morale of troops, reduces the combat potential of the Russian Federation military aviation, inflicts significant economic damage to the Russian Federation.

A high accident rate, or, in other words, a low level of military aviation flight safety, leads to our state military or economic security threats increase. All these facts indicate the urgent necessity to undertake all possible measures to reduce the accident rate and increase the level of flight safety in the Russian Federation Air Forces.

One of these measures may become the transition from the flight safety system that operates mainly utilizing retroactive methods of aviation system threats respond to the flight operations safety control system.

International and state standards dictate imperative flight safety management. In this regard, the Concept[2] defines the task of organizing the flight operations safety management system. In order to realize this task in aviation formations it is necessary to implement two information related contours of the flight safety control management system – the flight safety support control contour and the flight safety control contour, which function at three levels: strategic, operational and tactical.

[1] The Russian Federation National Security Strategy. The Russian Newspaper. December 31, 2015.
[2] The Russian Federation Armed Forces Aviation Safety Concept. Adopted by the Ministry of Defense of the Russian Federation 31.05.2017. M: Aviation Safety Service of the Armed Forces of the Russian Federation, 2017. 19 p.

Tactical level of flight operations safety control system is advised to be implemented in aviation military units, operational – in the formations, unions, commanderships, strategic – in the Russian Federation Armed Forces different types Head Commanderships and in the Air Forces Flight Safety Service.

The first contour should function at the strategic, operational, and tactical levels and is meant to be the flight safety supply control system. The flight safety supply control system should create the on-the-ground conditions for the performance of all flights and model the planned flights under forecasted conditions.

The second contour should function at the tactical level around each aircraft in flight and act as a safety control system for each flight. At the tactical level of the flight safety control system functioning, when organizing and performing flights, normalizing flight activities, investigating the occurred aviation events, organizing and conducting preventive measures, preparing crews, flight control group members and engineering personnel, aviation equipment to perform flights, ensuring the serviceability and reliability of technical elements of the aviation system, the flight safety control system should be operative. In other words, the flight safety control system operates constantly. The subjects of control, in this case, are the commander and supervisory personnel of the aviation military unit. The object of control is the aviation system of the tactical level (aviation military unit).

During the preparation for the flight of a specific "crew-aircraft" system, a flight safety subsystem is formed and operates. The number of such subsystems, which are the elements of the aviation unit flight control system, depends on the tasks of the flight shift. Each flight safety subsystem functions around a specific crew and a specific aircraft during the organization (preparation) of the flight. At the same time, the commandership and control personnel involved in the organization of the flight and aviation specialists of the corresponding type of support involved in ensuring the upcoming flight are the control entities. The control object is the primary aviation system.

As soon as the aircraft under the control of the crew has started to perform the flight task, all functions related to flight safety should be transferred to the safety control system of this flight. The purpose of this article is to analyze the functioning of the flight safety control system and, on the basis of this analysis, justify the possibility of event-based control of the primary aviation system security, taking into account the characteristics of each individual pilot in the process of flight safety control, in order to increase the efficiency of this process.

RESEARCH METHODOLOGY

The direct safety control takes place during the performance of each particular flight. At that, the active flight safety control presents the process of development and implementation of protective control actions which are adequate to the danger of the situation and are aimed at the increase counteraction and danger minimization, or, in other words, it is the development of responses to the danger of the flight situation in order to reduce this danger to the lowest possible level within the limits of the flight task.

The safety control of a particular flight takes place during the performance of the flight safety control system. This system is the complex of elements that are combined structurally and functionally to prevent the occurrence of an emergency situation during flight operation. The elements of the flight safety control system are the powers and means of the flight safety control.

Flight safety management facilities – are the pilot (crew) who flies the aircraft and the aviation personnel involved in flight control.

Flight safety control means – are all the aircraft on-board and the flight control center technical, information, telecommunication and software means used for flight safety control.

The analysis of the flight safety control process allowed us to determine that the subjects of the flight safety control system are the pilot and the controlling forces of the control center which coordinates the actual flight. At the same time, the pilot is the main subject, because it is he who affects the parameters of the "crew-aircraft" system through the use of controls, and the successful termination of the flight depends on his training, experience, and professionally important personal qualities.

The object of the flight safety control management system is the condition of the "crew-aircraft" system, determined by the indications of vitally important parameters, and, consequently, the pilot as well, who, acting as the main subject of the flight safety control system, appears to be the object for the control forces of the flight control center.

The [14] states that the tasks of flight safety control are solved directly during the flight performance and they are aimed at the elimination or localization of the unexpectedly occurred dangerous factors effect. The essence of this process consists in the timely determination of the primary aviation system going beyond the normal operating parameters which means the determination of the special in-flight situation occurrence during the flight and undertaking the control actions primarily to prevent the special situation grow into the emergency one, but in optimum alternative – to return the primary aviation system into the normal operating parameters of flight. At the same time, the special situation means any abnormal situation which happens to the primary aviation system as the result of dangerous factors exposure.

According to the degree of the crew (passengers) and aviation equipment risk consequences, special situations are subdivided into complicated, complex, emergency and catastrophic. Safety control of a particular flight reduces (compensates) the severity of dangerous factors manifestation when they occur and is aimed at reducing (eliminating) the option of the special situation development into an emergency or catastrophic one directly during the flight [15].

The preceding research in the field of active flight safety control [16 – 21] suggests that flight safety control should be based on an informational approach. The application of this approach to the solution of the active flight safety control problems will become possible in case the intelligent on-board flight control systems are developed and implemented on board the aircraft.

The flight safety control system should be created around each aircraft (the "aircraft crew-flight control center" system) and functionally it should consist of an on-board active flight safety control system and a ground-based flight safety control system.

The on-board aircraft safety control system should be formed up on the basis of the on-board information system with the functions of monitoring the necessary flight parameters, exchanging information with the ground system and other aircraft in real time operation mode, and the intelligent agent that solves the tasks of monitoring the safety of the current flight, issuing recommendations to the crew and actively intervening in the flight control in the event of an emergency situation in flight. The capabilities of the onboard intelligent agent directly depend on the characteristics and capabilities of the on-board information system [21].

The on-board flight safety control system will make it possible to solve the following on-board-the-aircraft tasks during the flight:

– flight situations machine-recognition and in-flight aviation events posting with the opportunity of sending this information to the ground flight control centers in real time operation mode;

– issuing recommendations to crew members for making decisions in a particular (complex, emergency) situation in flight;

– automatic control for the crew members' actions, aircraft technical condition and environment in routine and non-routine situations;

– transmitting information from the board of the aircraft to the flight control center of the flight control group and receiving the directions by the pilot on the aircraft control;

– aircraft control if an emergency situation resulting from the wrong actions of the crew or crew inaction occurs through the on-board automatic control system;

– crew members automatic rescuing in case the in-flight catastrophic situation occurs;

– collecting data related to the display of the familiar and new dangerous factors while operating the aircraft (aircraft on-board systems failure, crew's mistaken actions and violations, unpredictable worsening of flight conditions etc.) for further analysis on the ground.

Work [21] proves the necessity of documented and real contours flight safety formation in the system of flight safety information support in order to implement the active flight safety control. The essence of the idea is the following.

The aviation system is limited by the contour of real flight safety and it cannot function without an accident beyond these limits so it is inevitable that aviation accident may happen to it. In other words, the contour of real flight safety is the limit and the primary aviation system is unable to avoid aviation incidents beyond it.

The contour of real flight safety should be formed while creating a new model of aeronautical engineering, and be adjusted according to the results of aviation incidents investigation that occurred during the flight operational process of the aircraft.

The area defining the condition of aviation system is limited by the documented flight safety contour within which we can only find regular events which happened in the primary aviation system. The documented flight safety contour contains information about all protected conditions of the aviation system which can the dangerous factors effect. In other words, the documented flight safety contour is the limit within which the primary aviation system functions in a regular mode.

There is some space or an interval between the real and documented flight safety contours where abnormal events occurring in the aviation system can be found, and which at timely and adequate flight safety control system response do not result in aviation accident. This area, in [21], is called the "flight safety control interval". The width of the flight safety control interval makes it possible for the primary aviation system to respond successfully to the controlled events going beyond the contour of documented flight safety in order to prevent them from leaving the contour of real flight safety, and in the optimum alternative, "return" into the area of regular events taking place in the primary aviation system.

The author of [21] proves the possibility of flight safety control management applying the contours of real and documented flight safety, based on the so-called parametric control principle. The essence of such control is as follows.

The in-flight condition of the primary aviation system is reflected in the on-board information system in the form of formalized information about the current value of the vitally important controlled parameters. Let's conditionally call these parameters elementary events.

In order to control the primary aviation system threats which are manifested as dangerous factors in the common information space, it is necessary to describe them in the form of an event. The methods of such transformation are studied in [22]. In terms of the flight safety information support system, a hazard is an event that in aggregation with other specific events has led to the aviation accident or incident.

Thus, in the context of the flight safety information support, the in-flight primary aviation system current condition can be presented as a series of current elementary events.

When the primary aviation system functions in the regular mode all elementary events are located in the area limited by the documented safety contour (fig. 1). On-board information system is simultaneously functioning in the stand-by mode.

As soon as one event or a group of controlled elementary events is registered by the on-board information system beyond the contour of documented flight safety limits, the on-board information system passes into its active mode and implements one of the possible options for the aviation system protection.

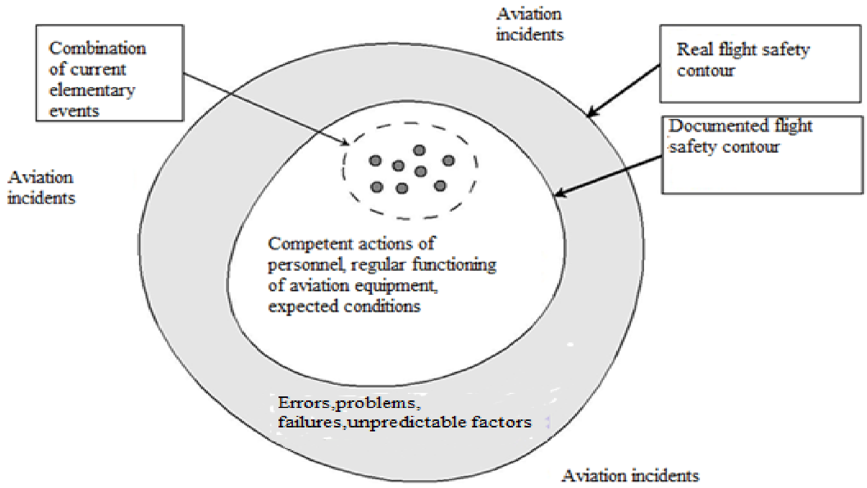

Fig. 1. Regular mode aviation system operation

The most obvious option is to return the aviation system into the contour of documented flight safety, for example, the removal of dangerous divergence of parameter, the failure consequences (switching to a backup system) removal and so on (fig.2).

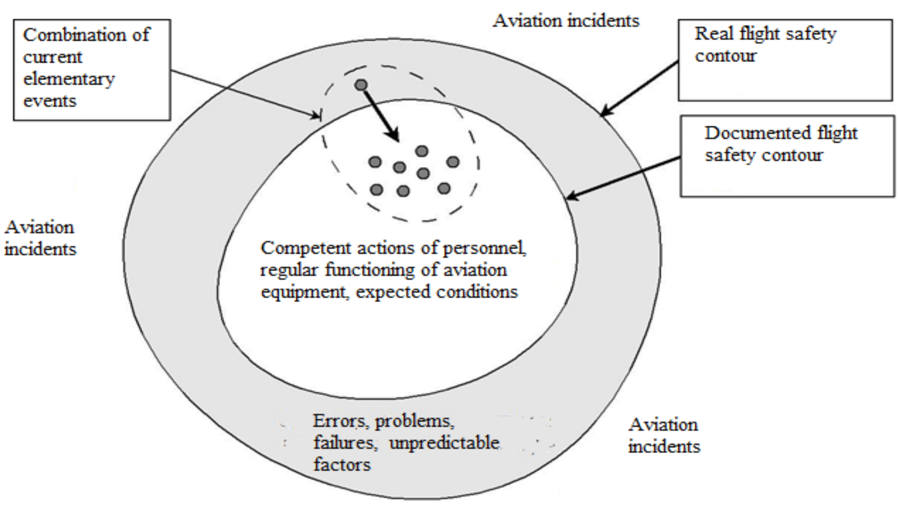

Fig. 2. Functioning of the aviation system under abnormal conditions (algorithm 1)

There is another method for protecting the aviation system, which is described in detail in [21]. In both cases, the on-board active flight safety control system starts functioning in an active mode as soon as the controlled elementary event goes beyond the limits of the documented flight safety contour. This is the essence of parametric flight safety control.

In order to control the flight safety in the real-time mode effectively it is necessary to have the opportunity of control based on the event-trigger principle of control. The essence of such flight safety control is the following.

The on-board information system is constantly in active operation during the flight. In the standard setting of aviation system, the function of the on-board information system should include the comparison of current elementary events combinations and a great number of elementary events combinations which are beyond the documented flight safety contour.

In case the totality of the primary aviation system controlled parameters approaches the condition, which threatens the aviation system transition into the flight safety control interval (let's call it the maximum acceptable one) it is necessary to determine immediately the elementary events "lacking" for the perfect totality at which the primary aviation system will turn out to be beyond the documented flight safety contour. Having detected such events, the on-board information system immediately informs the pilot about the necessity to prevent such an event or a group of events.

Let's study the example that will help you understand how the active event-based flight safety control should be implemented on the base of the on-board information system. For example, according to the flight task, the pilot must perform an aerobatics maneuver associated with the flight at extremely low speed. During the task performance the aviation system operates in a regular mode situation, but skidding can lead to a stall or break into a spin. When the totality of parameters approaches the maximum acceptable condition, the on-board information system immediately determines what is "lacking" for the aviation system transition from a regular mode situation to a special one and issues information for the pilot in the form of, for example, a voice command: "Do not allow skidding".

In case the aviation system went beyond the limits of documented flight safety contour, the flight safety control should be carried out in accordance with the principles of parametric control, the detailed examples of which are presented in [21].

The most important advantage of the event control is the technical possibility of an instant response implementation to the occurrence of a flight situation, in which the primary aviation system is separated from falling into the flight safety control interval due to the absence of one or more elementary events. This response consists of the immediate imposition of additional restrictions on certain events that are included in the documented flight safety contour. At the same time, documented flight safety contour takes a new form that allows to perform the safe flight with minimum transition risk for the condition of primary aviation system into the flight safety control interval. Thus, the form of the documented flight safety contour can constantly be changing during the flight by the on-board active flight safety control system, according to the complexity of the flight situation in which the primary aviation system operates in a regular mode.

In order to control the safety of a specific flight effectively it is necessary to form the contour of documented safety of a specific flight, which represents the documented flight safety contour realization applicable to a particular aircraft, particular pilot (crew) and to the particular conditions of the flight task. The documented flight safety contour represents the formalized information about limitations at all stages and modes of the planned flight.

As an example of the possibility to control the safety of flight, taking into account the specific characteristics of the particular pilot, it seems appropriate to present the option of technical solution for the problem of taking into account the peculiarities of an exact pilot while creating the documented flight safety contour.

To increase the efficiency of the flight safety control function due to the use of an on-board flight safety system, it is reasonable to use a personal database of a specific pilot. This should be a self-learning system that operates on the basis of the neural networks application and allows you to take into account all the nuances related to the "personal" piloting technique, the peculiarities of a character and temperament of each individual pilot while creating the documented flight safety contour.

A special attention should be paid to the pilot's mental health which is a very important indicator characterizing his professional suitability. Today, this indicator is not taken into systematic account, with the exception of the stage when applicants enter the flight school, where they undergo psychological selection at the selection stage, which confirms high level of mental abilities and brain functioning. And this is further perceived as an eternal state, but the mind, like the body, changes over time and requires control. Therefore, it is reasonable to carry out a periodical monitoring of the flight personnel mental health utilizing the system of the tests which is similar, for example, to those used for psychological selection before initial training stage in a flight school. The indicator of professional suitability obtained as the result of such test should be taken into imperative account while creating the documented flight safety contour.

The essence of the proposed idea is as follows. The documented flight safety contour with reference to the "ideal" pilot, taking into account psychological peculiarities and limitations of the person in № 1 format of professional selection which is determined while entering the university, and taking into consideration the conditions of the upcoming flight performance is generated by the on-board information system before each flight. Just before the flight task performance starts the personal database of the particular pilot is linked up to the on-board flight safety system. For convenience, let's call it the "personal neural network adapter of the pilot". Personal neural network adapter of the pilot is a self-learning system that allows you to take into account the above mentioned peculiarities of a particular pilot which were demonstrated in the totality of previous flights. Taking into account the data issued by output layer of the personal neural network adapter of the pilot into the on-board flight safety system and its further integration with the data used for the documented flight safety contour creation, the on-board information system makes the documented flight safety contour applicable to the specific features of the peculiar pilot and conditions of the peculiar flight.

The opportunity of taking into account the pilot's mental state which is expressed by the indicator of professional suitability can successfully be implemented at the event-based flight safety control. The value of this indicator must affect the on-board information system sensitivity while forming the documented flight safety contour during the flight task performance. The lower the pilot's mental state objective evaluation the earlier the on-board information system should determine the maximum possible totality of controlled events, which has potential risk of the aviation system transition into the flight safety control interval. In order to do that, at the lowered indicator of the pilot professional suitability, the on-board information system should reduce the maximum possible value of controlled states and at earlier stages warn about the risk of danger, immediately forming the new form of documented flight safety contour. This will give the pilot with a reduced indicator of professional suitability an additional resource for compliance with all safety measures when piloting the aircraft, in order to prevent the occurrence of special situation and to increase the "crew-aircraft" system protection from the impact of dangerous factors while performing the flight task.

CONCLUSION

Thus the flight safety control process analysis which was conducted as well as the procedure of real flight safety and documented flight safety contours application in the flight safety control system leads to the conclusion that flight safety control based on the event-based control principle will allow us to control the protection of primary aviation system in the real-time mode.

So, the information about professional suitability value of a particular pilot while creating the documented flight safety contour will allow you to take into account the state of the pilot's mind during flight safety control. All this will contribute to the more successful implementation of the flight safety control functioning.

In conclusion, it should be noted that real safety can only be controlled in a particular flight due to keeping the crew functioning parameters and aircraft systems in the given range of acceptable values. Since the flight safety threat only occurs during the flight, it is necessary to create a flight safety control system on board the aircraft. Theoretical, technical and informational facilities for creating such a system are currently available.

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ВОЗМОЖНОСТЬ СОБЫТИЙНОГО УПРАВЛЕНИЯ БЕЗОПАСНОСТЬЮ ПОЛЕТА С УЧЕТОМ ОСОБЕННОСТЕЙ ЛЕТЧИКА

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В статье проводится анализ процесса управления безопасностью полета. Показана структура системы управления безопасностью полета и субъектно-объектное взаимодействие, на котором построено функционирование этой системы. Мотивирована незаменимость разработки и внедрения интеллектуальных бортовых систем управления на борту воздушного судна. Обозначены задачи, которые позволят решать такие системы во время выполнения полета. Рассмотрены перспективы применения в системе активного управления безопасностью полета контуров реальной и документированной безопасности полетов. Показана возможность активного управления безопасностью полета, построенная на параметрическом принципе управления. Обоснована необходимость управления безопасностью полета, основанная на событийном принципе управления с использованием контура документированной безопасности полета. Рассмотрен пример, наглядно демонстрирующий возможности и перспективы событийного управления безопасностью полета. Доказана целесообразность учета психических особенностей конкретного летчика при формировании контура документированной безопасности полета. С этой целью подтверждена целесообразность систематического контроля психического состояния летного состава с определением показателя профессиональной пригодности. Рассмотрена возможность использования персональной базы данных летчика при формировании контура документированной безопасности каждого конкретного полета с целью учета особенностей конкретного летчика при управлении безопасностью полета. Это должна быть самообучающаяся система, функционирующая на основе применения нейронных сетей и позволяющая учитывать все особенности характера и темперамента каждого конкретного летчика. Доказано, что возможность учета психического состояния летчика, выраженного значением показателя профессиональной пригодности, может быть успешно реализована именно при событийном управлении безопасностью полета, что приведет к повышению защищенности авиационной системы от воздействия опасных факторов в ходе выполнения полетного задания.

Ключевые слова: безопасность полетов, безопасность полета, опасный фактор, контур реальной безопасности полетов, контур документированной безопасности полета, психическое состояние.

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