Technical and economic feasibility of the on-board location system application for the aircraft and satellite communication system

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Abstract. The paper considers the joint application of the Iridium satellite communications system as well as the GLONASS and GPS satellite navigation systems that corresponds to the CNS/ATM concept. The originality of the proposed detection method is in constant communication between an object and a control center. The method can be applied to both manned and unmanned aircrafts. In any case, a control center can quickly respond to deviations of the trajectory of an object, or to an operation of accelerometers at critical overloads. The paper examines the advantages of introducing the Iridium satellite radio navigation system into the aviation sector to monitor aircrafts in both manned and unmanned aircrafts. Technical and economic advantages are given on the example of various search and rescue operations.

1. Introduction

The transition to more advanced air navigation systems is due to its limitations imposed by ground-based location means. The reason for the transition was the limited territorial use of ground-based means, their economically feasible use, as well as due to mistakes in determining the coordinates of the object due to multiple reflections of radio waves [1]. The development of GPS and GLONASS satellite navigation systems was the result of attempts to development a unified radio navigation field available over the entire area of the globe [2]. It is difficult to solve a similar problem with ground-based complexes, since the costs of accommodation and maintenance will be unacceptably high.

In [3], a task to increase the effectiveness of its monitoring from the ground with minimal changes in the air navigation equipment of the aircraft was set. The authors propose using the Iridium low-orbit satellite constellation [4] to transmit aircraft location data to a control center on the ground. Data transmission is possible both using GSM communication through ground centers, and using inter-satellite communication lines. Iridium communications satellites have full coverage of the earth's surface, which makes it possible to monitor aircraft in hard-to-reach areas.

The authors of [3-5] developed a monitoring scheme where a terminal-based programmable equipment of the USP type [6] is located on board. It receives signals from navigation satellites and
transmits data about the location of an object to a control center via communication satellites. At the control center, the coordinates obtained are analyzed and the flight path of the object is built.

According to the CNS/ ATM concept [7], the existing air navigation equipment should be gradually replaced by global systems. The reason for the air navigation support equipment improvement was mainly the increase in the number of aircrafts simultaneously flying. The existing ground-based beacons of the DME and VOR type have a limited range. In addition to this, VOR beacons in their frequency range 108-112 MHz have only 160 channels. At present, GPS and GLONASS satellite navigation systems are global.

It is necessary to develop a concept involving the receiving, processing and storage of the object’s navigation data to increase the monitoring efficiency of the object. The main condition is the uninterrupted access to data anywhere in space. Low-orbit satellite communications systems are suitable for the implementation of the described concept. The low-orbit Iridium system has full coverage of the earth's surface, while 180 km of airspace falls into the service area. This makes it possible to service aircraft flying mainly in the tropopause. The proposed concept involves the simultaneous use of GLONASS and GPS satellite navigation systems to determine aircraft coordinates and Iridium satellite communications system for transmitting location data to a control center.

The authors of [3-5] determined the feasibility of the joint use of the Iridium satellite system and GLONASS / GPS, as in [8]. However, it is important to show the technical and economic benefits of such implementation, as a rule, using different search and rescue operations for both manned and unmanned aircrafts [9-11].

2. Materials and methods

Take the information from the database “EMERCOM of Russia for the Krasnoyarsk Territory” and consider the real costs of finding a crashed aircraft and the theoretical benefit after the introduction of the Iridium satellite navigation system [2] in order to show the economic feasibility of using the on-board system for determining the location of aircraft.

The diagram in figure 1 shows examples of which aircraft and funds are spent on search and rescue operations.

![Figure 1. Costs for search and rescue operations.](image-url)
Analyzing the amount of costs for search and rescue operations in the presented examples, one can conclude that the allocated funds from the country's budget are used irrationally; and it is not permissible. One of the ways to optimize costs in the field of search and rescue is to introduce a tracking system that will reduce the cost of finding aircraft, thereby saving a significant part of the budget.

Often in searching for a crashed aircraft, search crews fly dozens, or even hundreds of hours because searching for a crash site in such vast areas is sometimes comparable to finding a needle in a haystack. However, the situation can be radically changed with the introduction of the Iridium satellite navigation system, which will have the coordinates and direction of the aircraft movement a few seconds before the crash. It will significantly reduce the cost of finding a distressed aircraft, as well as reduce the waiting time for assistance, the loss of which is often measured in human lives [2].

Consider as an example the image of tracking search and rescue helicopters (figure 2) performing an intelligence operation to search for a missing helicopter without the Iridium navigation system in the territory of the Siberian Federal District.

As can be seen in Figure, eleven search and rescue helicopters were involved to search for one crashed aircraft. The vast geography of the search negatively affected the search time and the increase in the spent funds for fuel and aircraft maintenance.

Consider how the routes of search helicopters are compiled. During a visual inspection, the search area is divided into squares measuring 20x20 km according to a palette with a visual search grid. If necessary, a square of 20x20 km is divided into 4 squares of 10x10 km in accordance with the palette. For a more detailed survey of the rugged woodland terrestrial search and rescue team square 10x10 km is divided into 4 squares 5x5 km.

If, according to the results of a continuous survey of the search area with the help of radio equipment, the victims of the disaster were not detected and no contact was established, with the permission of the head of search and rescue operations, then a visual search is performed by such methods as "Comb", "Parallel tacking", "Expanding square".

The search by the Comb method (figure 3) is used to view a larger area in the shortest time and if there is a sufficient number of search helicopters. In most cases, the "Comb" method is used in organizing a search at great distances from the location of the search helicopters.
The search by the “Parallel tacking” method (figure 4) is used for a small number of search helicopters and for surveying a sufficiently large area. With this method, a search area is divided into several search sections (bands), which are viewed simultaneously by several single helicopters or sequentially by one helicopter.

The “Expanding Square” search (figure 5) is used in most cases in having data on the location of the aircraft disaster. The search is in a single helicopter inspection of the area around the known point where the crew of the injured is supposed to be.

3. Results and discussion
From the example considered above, it can be understood that the main search method was the multiple use of the “Parallel tacking” method. The reason for this was the fact that during the search and rescue operations, the leaders did not have more accurate coordinates about the place of the aircraft disaster. However, when equipping an aircraft in distress with a satellite tracking system, a search range would be significantly reduced, and the “Expanding Square” would become the main method. Thanks to this system, it is possible to reduce the search time for aircraft by reducing the number of sorties, since the search range will be determined as accurately as possible. On the basis of the analysis of the tracks of search and rescue helicopters and the assumption that a number of flights to search for a crashed aircraft can be reduced to the minimum values (from 1 to 5 flights), one can conclude that the flight hours are
significantly reduced. It means the economic benefit of using Iridium satellite navigation system on the sun [12].

Each flight examined approximately 2.7% of the final search territory; therefore, the total search territory could be reduced by 86-97%. It means that economic costs will be reduced in the same proportions.

In order to show more clearly the economic benefits of using a satellite tracking system for search and rescue operations, turn again to the data presented in the diagram (Figure 1). But recalculate it based on the fact that the Iridium satellite system was applied (figure 6).

![Figure 6. Cost ratio.](image)

The diagram in Figure 6 shows that if a satellite tracking system were used to monitor aircraft, the cost of finding aircraft would be reduced several times.

4. Conclusion

So, the aircraft monitoring system through the Iridium communications satellites is analyzed. The proposed communication scheme between an aircraft and a control center (ground) includes a GSM modem and at least one personal computer with the installed Navigator-S software [13] that has access to the Internet. На борту ВС требуется разместить терминал для приёма и отправки информации посредством сигналов GSM. It is necessary to install a terminal for receiving and sending information via GSM signals on board of the aircraft. The considered Data Terminal Equipment (UTP type equipment) [14] satisfies the goals set in the paper. It is necessary to have a server with the installed DBMS to organize a control center in order to process large volumes of information.

The proposed scheme for the joint use of the Iridium satellite communications system and the GLONASS as well as GPS satellite navigation systems corresponds to the CNS/ATM concept [7]. The originality of the detection system is in the uninterrupted communication between an object and a control center. Thus, a control center can respond quickly to deviations of the trajectory of the object, or the operation of accelerometers while critical overloads.

The paper considers the advantages of the Iridium satellite radio navigation system in the aviation sector to monitor aircrafts in both manned and unmanned versions. Technical and economic advantages are shown as an example of various search and rescue operations [15].
It can be concluded that the introduction of a satellite tracking system will reduce the cost of such operations by 86-97% taking into account the data on search and rescue operations.

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