

Basic Principles of the Development Concept of the Russian Segment of the International Search and Rescue System COSPAS-SARSAT

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Abstract. The paper deals with basic principles of the suggested development concept of the Russian segment of the International Search and Rescue Satellite System COSPAS-SARSAT. The issues of the present status and principles of the future building of the system are discussed. An attempt to determine strategic development trends of the Russian segment in view of the documents of the strategic planning and the plans on the Programme development is made. The terms and main results of the realization of the suggested concept are given.

Keywords: COSPAS-SARSAT, search and rescue operations, Russian segment, development concept

Introduction

The paper presents the general provisions of the newly developed concept that defines the main directions of the organizational, technical and scientific policy for the fulfillment by the Russian Federation of the international obligations in accordance with the Agreement on the International COSPAS-SARSAT Program of 01.07.1988 (hereinafter the Agreement) [1].

The creation of the Russian segment of the COSPAS-SARSAT system is regulated by the Resolution of the Central Committee of the CPSU and the Council of Ministers of the USSR of 26.01.1977 No. 81-84 [2] and by the Resolution of the Council of Ministers of the USSR of 12.01.1978 No. 33-15 "On the creation of joint activities with the USA, Canada an experimental satellite system for determining the location of aircraft in distress"[3].

The conceptual development provisions were developed taking into account the efforts of the International Maritime Organization (IMO) to establish the Global Maritime Distress and Safety System based on the International Convention for the Safety of Life at Sea (SOLAS) signed in London November 1, 1974 [4], the International Convention on Search and Rescue, signed in Hamburg on April 27, 1979 [6], as well as the obligations of the International Civil Aviation Organization (ICAO) and the International Telecommunication Union (ITU) in the respective fields of activity.

Due to the systemic crisis that occurred in the Russian Federation at the end of the 20th century, many aspects of the creation and development of the COSPAS-SARSAT system were relegated to the background. The main system documents were not updated, while the system inevitably developed and moved forward. Therefore, there is a need to revise the basic system documents that regulate the creation of the elements of the system. The paper makes an attempt to examine the problem of creating and developing the system as widely as possible, taking into account the current state of the search and rescue system.

When considering the urgent issues of the development of the search and rescue system, it is necessary to take into account the provisions of the main system documents of strategic planning, the COSPAS-SARSAT Strategic Plan [7], and the 406 MHz Medium Earth Orbit Search and Rescue system (MEOSAR) [8].

Therefore, in this work, the concept of the Russian segment of the international search and rescue system COSPAS-SARSAT is defined, its current status is determined and the main problems and ways of development of the Russian segment and the COSPAS-SARSAT system as a whole are discussed.

The status of the COSPAS-SARSAT system

The COSPAS-SARSAT system is an international search and rescue system, the creation of which was defined by the Agreement [1] signed in Hamburg on April 27, 1979 between four countries: the USSR, the USA, France and Canada, taking into account the requirements of the International Convention on Search and Rescue.

The search and rescue system is designed to reduce, as much as possible, the delay in the delivery of emergency information to search and rescue services, as well as the time required to detect the emergency, since these parameters directly affect the probability of survival of the people in distress. Rapid detection and determination of the coordinates of the emergency also contributes to the reduction of the cost of search and rescue operations and risks for rescuers [7].

The international system is designed to ensure the transmission of emergency reports on a global, non-discriminatory and gratuitous basis. It operates in the frequency bands allocated by the International Telecommunication Union (ITU) solely for warning of emergencies, that is, situations that are a serious and imminent threat to the safety of human life.

The international COSPAS-SARSAT system in accordance with [1] consists of three segments: space, ground and radio beacons intended for the transmission of emergency radio signals at frequencies of 406 MHz, the characteristics of which comply with the requirements of the International Telecommunication Union and the COSPAS-SARSAT specifications.

The space segment, under normal operating conditions, should consist of at least four satellites. The ground segment includes local user terminals (LUTs) for receiving signals transmitted from the satellites and processing them for the purpose of locating the beacon, and mission control centers (MCCs) to obtain the output data from the reception stations and send the message about an emergency and its location to the appropriate rescue services (Figure 1).

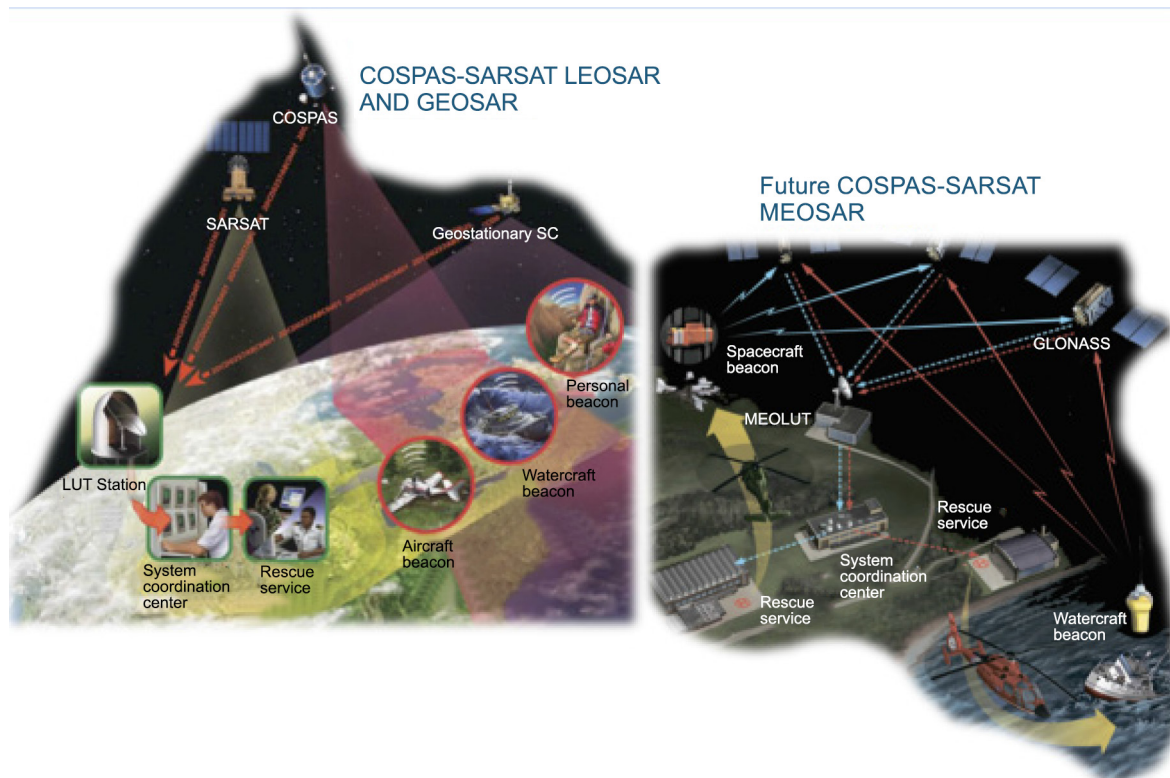


Fig. 1. Mode of operation of the international search and rescue system

In accordance with the Agreement, the USSR and later the Russian Federation are obliged to support two satellite platforms in the low Earth orbit, two receiver-processor units with memory units for working with beacon signals at a frequency of 406 MHz and two relays. In addition, the Russian Federation operates a MEOLUT for low-Earth orbit satellites, as well as the COSPAS mission center (CMC) of the system transmitting information to search and rescue services. In the future, we will apply the general term “Russian segment” of the international COSPAS-SARSAT system to the space and ground facilities of the international search and rescue system operated by the Russian Federation.

The overall operation of the COSPAS-SARSAT system is based on the fundamental requirement of the possibility of determining the coordinates of the ES independently from any other navigation system anywhere in the world [7, 9].

Due to ballistic restrictions, a significant disadvantage of the currently operational low-orbit segment of COSPAS-SARSAT (the constellation of the low-orbit spacecraft and their associated local user terminals are collectively called the LEOSAR) is the need to wait for a communication session with the satellite to

transmit information about the emergency situation and, therefore, the impossibility of alerting the emergency services in close to real-time mode.

In 1998, the Council of the International COSPAS-SARSAT Program decided to expand the capabilities of the COSPAS-SARSAT system by placing repeaters on geostationary satellites [8] in order to detect beacon signals at a frequency of 406 MHz (hereinafter, GEOSAR system). The service areas of geostationary satellites are fixed relative to the Earth's surface, thus each satellite provides a continuous coverage of the geographic area defined by its service area. This makes it possible to reduce the detection delays that are characteristic of the LEOSAR system. Given the altitude of each satellite, the GSODS ensures coverage of a very large area (about one-third of the Earth's surface, excluding regions above $\pm 70^\circ$ latitude).

However, it should be noted that the GEOSAR system provides location information only if this information is provided from an external source (i.e., a receiver of the global navigation satellite system (GNSS) installed in a beacon) and transmitted in message from the beacon at a frequency of 406 MHz; the obstacles, if they block the radio beacon to SC communication line, cannot be

1978, January 12 – decree of the USSR Council of Ministers on the creation of a space search and rescue system “COSPAS”

1982, June 30 – first launch of the COSPAS-1 satellite

1987, September 10 – first rescue mission by a COSPASS signal

1987, December 8 – decree of the CPSU Central Committee on the system's operational commissioning

1988, July 1 – an international agreement on the International SAR system COSPAS-SARSAT

Article 3: General description of the system

“...space segment consisting of a minimum of four simultaneously operating satellite complexes...”

Article 5: Obligations of the parties:

Contributions of the parties into the space segment:

“...USSR: 2 satellite busses, 2 receiver-processor units, 2 relays...”

“...USA: 2 satellite busses...”

“...France: 2 receiver-processor units with memory units...”

“...Canada: 2 relays...”



First rescue



Launch of COSPAS-1

Fig. 2. History of the COSPAS-SARSAT system

eliminated, since the satellite is stationary with respect to the radio beacon; moreover, the energy potential of the radio beacon-SC-LUT communication link of the GEOSAR is significantly lower than that of the LEOSAR, taking into account the longer radio transmission distance.

To overcome these limitations, in 2000, Russia, the United States and the European Commission (EC) began consulting with the COSPAS-SARSAT executive bodies on the possibility of installing a relay for beacon signals on the medium-orbit satellite systems (hereinafter referred to as MEOSAR) and the inclusion of the MEOSAR equipment in the COSPAS-SARSAT system [8]. The program of the Russian Federation was named SAR/GLONASS, in the US the MEOSAR program is called the Distress Alerting Satellite System SAR/GPS (DASS) and the European system is called Galileo Search and Rescue System (SAR/GALILEO).

During the initial studies, various possible benefits of the MEOSAR compared to the existing systems (LEOSAR and GEOSAR) were identified, including: an almost instantaneous global coverage with the possibility of accurate independent location determination; stable radio beacon to SC communication lines, high levels of redundancy and satellite availability; resistance to the

presence of obstacles on the communication line to the radio beacon due to the movement of the spacecraft in orbit, as well as large number of spacecraft in the future; possibility of providing additional services.

Thus, the main shortcomings of the LEOSAR can be eliminated, and the operational characteristics of the COSPAS-SARSAT system can be substantially improved in the long term, provided that the additional capabilities offered by the geostationary and mid-orbit segments of the system are introduced.

Basic design concepts of the COSPAS-SARSAT system

The search and rescue system has a very rich history [10-15]. Since 1982, 41,750 lives have been saved in 11,750 rescue operations. COSPAS-SARSAT is a very unique phenomenon, since the solution of this problem (building one of the most humane systems in the history of mankind) today unites the efforts of several countries, often separated by political and ideological contradictions. That is why the development and change of the principles of the functioning of the system must be approached with due regard for the interests of all participants in the basic

Agreement. Here are some basic concepts for the future design of the system.

The COSPAS-SARSAT system should be a single set of spacecraft, land facilities and emergency beacons that are modified and improved in strict accordance with the COSPAS-SARSAT requirements under the mandatory and ongoing monitoring of the Search and Rescue Council [3, 11, 12].

The space segment of the COSPAS-SARSAT system, consisting of low-orbit, mid-orbit and geostationary elements, should be designed on a complementarity principles. In the medium term, taking into account the full deployment of COSPAS-SARSAT, the composition of the space segment of the system can be revised.

The ground segment should include ground stations capable of efficient operation and receiving information from spacecraft of a associated space segment. The system coordination center should ensure that emergency data received from the receiving station associated with any element of the COSPAS-SARSAT space segment reaches the search and rescue service or the point of contact for search and rescue [14].

Emergency radio beacons should be designed taking into account the growing needs of users of the search and rescue system, and in strict accordance with the future requirements of the COSPAS-SARSAT system.

The COSPAS-SARSAT system and the relevant national segments should develop and provide an adequate data capacity, taking into account the growth of the park of operating emergency beacons [7].

The creation of the COSPAS-SARSAT system, which effectively fulfills the assigned tasks, is possible only if all the countries-participants of the Agreement fulfill their obligations.

The Russian contribution to the international system should include both the space and ground segments, as well as the radio beacons of different purposes. The Russian segment of the COSPAS-SARSAT system, like the system as a whole, should be designed guided by the principles of integration of spacecraft, ground facilities, and emergency beacons, taking into account the most efficient use of the resources and capabilities of the system.

The Russian segment of the COSPAS-SARSAT system should be a single set of ground and space based facilities that are developed and created by the Russian Federation to ensure compliance with the international obligations of the COSPAS-SARSAT program in accordance with the Agreement and other normative documents of the international system.

The future development of the COSPAS-SARSAT system should provide all users and consumers with guaranteed, global, timely and free access to information about emergencies. The COSPAS-SARSAT system should dynamically improve its operational characteristics, enabling it to improve the effectiveness of search-and-rescue operations.

Although the COSPAS-SARSAT system does not intend to compete with commercial systems providing telecommunications services and positioning services, the system must continuously improve the quality of alerting and positioning services to ensure the long-term search and rescue requirements for ICAO, IMO, and other users and consumers.

In addition, the system should take into account the long-term development trends of the newly created telecommunications systems.

Strategic directions for the development of COSPAS-SARSAT

Taking into account the strategic plan for the development of the COSPAS-SARSAT system [7] and the projected needs of the main users of the system, it is necessary to determine the strategic directions of the prospective activity. Efforts must be made to address the issues in various areas of the system's development.

Technological modernization of space and ground elements of the Russian segment of the COSPAS-SARSAT system

Fulfillment of international obligations by the Russian Federation to maintain and replenish if necessary the LEOSAR (two spacecraft with search and rescue equipment on board) of the COSPAS-SARSAT system in the short and medium term is a critical task that should be solved in the nearest term. In 2017, two spacecraft "Meteor-M" No. 2-1 and No. 2-2 with search and rescue equipment on board are expected to be launched.

In view of the development of space elements, it is necessary to ensure the modernization, creation and deployment of the corresponding ground facilities.

For the successful operation of the Russian segment of the LEOSAR, it is necessary to modernize the LEOLUT stations to work with the on-board equipment of the new generation.

In addition, it is necessary to deploy the last generation of the GEOLUT stations, developed in the Russian Federation within the framework of the Federal Space Program for 2006-2015.

Currently, COSPAS-SARSAT is making great efforts to implement the LEOSAR system as soon as possible, the deployment of which involves significant expansion of capabilities compared to the existing segments due to the use of a large number of GLONASS/GPS/GALILEO navigation devices as relays of emergency beacon signals.

One of the priorities of the current development of the Russian segment and the search and rescue system as a whole is the development and deployment of payloads and ground stations of the medium-orbit segment COSPAS-SARSAT of a new generation that meets all the requirements of the COSPAS-SARSAT system, including the accuracy of determining the coordinates for any type of emergency beacons.

It should be noted that in the current programs (FTP "GLONASS") until 2025, it is planned to create a minimum of eight search and rescue payloads for placement on board of medium-orbit spacecraft.

In accordance with the plans for the development of the Russian space segment of COSPAS-SARSAT, in general, it is necessary to ensure the development and creation of the maximally unified onboard equipment for retransmission of emergency signals to be installed on board of a new generation of COSPAS-SARSAT low-orbit, mid-orbit and geostationary spacecraft.

One of the fundamentally new features of the medium-orbit system is the acknowledgment function, that is, providing a return channel with a radio beacon, which allows to confirm the receipt of a distress signal and the beginning of a rescue operation. To ensure the operation of this function, it is necessary to develop and deploy an appropriate ground infrastructure in the Russian Federation which allows sending "receipts" on board spacecraft and then transfer them to consumers.

The emergence of additional functions and subsystems within the Russian segment leads to the necessity of modernization of the Russian mission control center of the COSPAS-SARSAT system, which manages the acknowledgment subsystem and integrates the information from the receiving stations of the new generation of low-orbit, mid-range and geostationary segments.

Improvement of the regulatory and legal framework of COSPAS-SARSAT

The regulatory framework of COSPAS-SARSAT

At present, there is a serious need to revise the regulatory and legal framework of the COSPAS-SARSAT system, not only at the level of the Council of the system, but also at the state level in the Russian Federation.

In the Russian Federation, the relays of the COSPAS-SARSAT system are being prepared for launch in the medium term on the spacecraft of the Arktika-M system in the highly elliptical Earth orbit.

The international COSPAS-SARSAT system does not regulate the use of spacecraft in highly elliptical orbits, there are no corresponding regulations and standards for the use of information, there is no ground infrastructure.

To fully use the developed equipment, it is necessary to prepare and issue the relevant documentation of the COSPAS-SARSAT system at the level of the Search and Rescue Council.

To accelerate the introduction of this equipment into the COSPAS-SARSAT system, it is proposed to consider the possibility of commission of the spacecraft on highly elliptical orbits as an expansion of spacecraft capabilities on geostationary (and geosynchronous) orbits, complementing the geostationary segment of the system. This step will significantly shorten the timing of the implementation of the relevant procedures for commissioning relays and increase their quantity.

Normative documentation of the state level of the Russian Federation

The resolution of the Central Committee of the CPSU and the Council of Ministers of the USSR on the establishment of the Russian segment of COSPAS-SARSAT was adopted in 1978 (Decree of the Central Committee of the CPSU and the Council of Ministers of the USSR of 26.01.1977 No. 81-84 and USSR Council of Ministers Decree of 12.01.1978 No. 33-15, "On the creation of an experimental satellite-based system to determine the location of aircraft that have suffered an accident in cooperation with the United States and Canada"). It does not take into account the current realities of the development of the organizational structure of the space industry in the country and the COSPAS-SARSAT system.

It is necessary to draft and issue a resolution of the Government of the Russian Federation regulating the modernization and maintenance of existing (low-orbit and geostationary) and the creation of new elements (mid-orbit) of the Russian segment of COSPAS-SARSAT.

According to the requirements of the COSPAS-SARSAT system documents [8], it is necessary to determine the provider organization (supplier) of the elements of the space segment in the Russian Federation at the state level. The main tasks of the organization-provider (supplier) of the space segment is the organization of the uninterrupted operation of all elements of the COSPAS-SARSAT space segment under the responsibility of the Russian Federation; and ensuring the continuous provision of ephemeris information from spacecraft to the COSPAS-SARSAT ground segment.

Taking into account the changes in the organizational structure of the industry management, in order to increase the efficiency and ensure the unconditional fulfillment of the international obligations of the Russian Federation in the field of search and rescue, it is necessary to regulate and establish the institute of the General Designer of the Russian segment of the COSPAS-SARSAT system.

In 2000, the COSPAS-SARSAT Council decided to use personal radio beacons as part of the system. Currently, 12 countries have already adopted relevant laws allowing citizens to use the equipment in case of emergency.

In the Russian Federation in 2016, the first steps were taken to introduce COSPAS-SARSAT personal beacons. It was decided by the State Committee of Radio Frequencies that their application is possible taking into account the current frequency distributions.

Nevertheless, in the short term it is necessary to issue a complete package of regulations defining the use of personal radio beacons in the Russian Federation, as well as establishing contact points for the transfer of information and the procedure for carrying out search and rescue activities using signals from such devices.

The emergence of this regulatory framework will make it possible to ensure a significant development of the search and rescue system for personal use, including for possible use in road transport as a part of the emergency response system ERA-GLONASS.

Development of the critical technologies

In the interests of sustainable development of the Russian segment of the search and rescue system, as well as in the interests of ensuring the technological independence of the Russian Federation in the development of such systems, it is necessary to ensure the development of the following technologies in different segments.

In the interests of the space segment, it is necessary to ensure the development of a technology for creating COSPAS-SARSAT unified on-board equipment for all the segments, including a new generation of on-board receiver-processor units that provide reception and processing of the beacon signal with a higher accuracy. In addition, technologies for creating on-board relays of COSPAS-SARSAT beacon signals with a return channel are required.

For the ground segment, it is necessary to ensure the creation of technology for processing information and calculating the location of emergencies with an increased accuracy, the technology of the handshake system, the technology for creating antenna arrays for LUT stations, the technology of creating virtual antenna systems for receiving information (the technology of using distributed antenna systems within a single terrestrial information processing infrastructure), as well as radio-photonics technologies as elements of antenna systems of LUT stations.

For creating emergency beacons required are the technology of creating high-capacity batteries, technology for efficient encoding and transmission of information, short-range drive elements of prospective sea-based beacons.

Expected results of the implementation of the Concept

The implementation of the proposed concept for the development of the Russian segment of the COSPAS-SARSAT system will allow:

to fulfill the international obligations of the Russian Federation to maintain the space segment of the COSPAS-SARSAT system, eliminating the threat of significant deterioration of the system's capabilities due to a critical reduction in the number of the spacecraft in operation;

to modernize the COSPAS-SARSAT hardware and equipment, providing the possibility of creating new ground, sea and space based technologies;

to develop the procedure for the use of personal radio beacons in the territory of the Russian Federation, and, consequently, to increase the efficiency of the COSPAS-SARSAT system on the territory in the Russian Federation;

to increase the effectiveness of search and rescue operations, including by reducing the time required to determine the coordinates and improve the accuracy of locating the emergency;

to increase the degree of safety of sea navigation and air traffic in the territory of the Russian Federation, as well as the efficiency of public administration in emergency situations.

To assess the effectiveness of the implementation of the Concept, it is planned to create a system of indicators and benchmarks, which should include the requirements established by the state on the basis of requests from users (the corresponding rescue services) of the COSPAS-SARSAT system.

The main state indicators of the Russian space segment of the COSPAS-SARSAT system should be:

ensuring the national interests in the field of information support for conducting search and rescue operations;

the effectiveness of the COSPAS-SARSAT system;

the availability of the COSPAS-SARSAT system;

information support of measures to improve the safety of road, air and sea traffic;

general integration compatibility of equipment, elements and segments of the COSPAS-SARSAT system.

Indicators at the COSPAS-SARSAT system level should be developed taking into account the requirements of the internal standards and regulatory documents of the system, the standards and requirements of IMO, ICAO; they should reflect the quality of its segments, elements and / or subsystems, the degree of their consolidation, interoperability, technical infrastructure and compliance to the accepted standards.

Terms and stages of implementation of the concept

The main activities for the creation and development of the Russian segment of the COSPAS-SARSAT system are:

- In the short term (until 2018):

development, fabrication and launching of two spacecraft into low Earth orbit in order to ensure the unconditional fulfillment of the international obligations of the Russian Federation; in accordance with the Agreement; maintaining the operation of the geostationary segment; modernization of the Russian part of the COSPAS-SARSAT ground segment; testing and putting into operation a prospective MEOLUT station;

- in the medium term (until 2022):

the development of a new generation of maximally uniform payloads for the formation of the low-orbit, mid-orbit and geostationary elements of the COSPAS-SARSAT space segment; maintenance of the functioning of low-orbit and geostationary elements of the space segment; partial deployment of the mid-orbit space segment; development and deployment of a coordination center for a system supporting new elements of the COSPAS-SARSAT space segment, including the acknowledgment system;

- in the long term (until 2030):

the end of the life cycle of the low-orbit segment of the COSPAS-SARSAT system, the full deployment and commissioning of COSPAS-SARSAT MEOSAR. Creation and introduction into the system of LUT stations on the basis of a single or "virtual" antenna system. Full-scale introduction of the second-generation beacons, with a support for a return channel.

Conclusion

In conclusion, it should be noted that significant efforts are being made in the Russian Federation to develop the Russian segment of the international search and rescue system COSPAS-SARSAT.

Although the pace of deployment of elements of the Russian segment of the international COSPAS-SARSAT system has been somewhat reduced recently, new models of on-board and ground equipment were created within the framework of the Federal Space Program for 2006-2015, as well as in the framework of specialized programs of the Ministry of Transport of the Russian Federation . In addition, the formation of a promising scientific and technical base is stipulated by the current Federal target programs.

The development of information and production technologies in the Russian Federation provides an opportunity to substantially modernize and create the equipment of a new generation for terrestrial and space based COSPAS-SARSAT systems.

To ensure the sustainable development of the Russian segment of the COSPAS-SARSAT system and the search and rescue system as a whole, it is necessary to ensure the unconditional deployment and commissioning of the MEOSAR, since this direction is declared strategic in the

In turn, the deployment and maintenance of the MEOSAR will require the development and implementation of a number of critical technologies that will allow the production of ground-based and space-segment equipment, as well as components of emergency beacons meeting the international performance requirements.

In the long term, it is necessary to consider the possibility of joint development of COSPAS-SARSAT with the space segments of automatic identification systems (AIS) and dependent surveillance (ADS) of ships and aircraft, taking into account the rapid development of space systems extending the traditional capabilities of mobile object monitoring systems.

Systemic development of the Russian segment of COSPAS-SARSAT is possible only on condition that it provides continuous financing for the development and creation of its advanced elements and is currently envisaged in the framework of the Federal Space Program for 2016-2025, the GLONASS FTP, as well as in the specialized programs of the Ministry of Transport of the Russian Federation.

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