



**INITIATION OF THE PROJECT TO CREATE  
AN INTERNATIONAL AEROSPACE SYSTEM  
FOR MONITORING OF GLOBAL GEOPHYSICAL  
PHENOMENA AND FORECASTING OF NATURAL  
AND MAN-CAUSED DISASTERS**



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## 1. GENERAL INFORMATION

The forecasting of emergencies and development of natural and man-made phenomena on Earth is becoming a pressing issue. The most common and hazardous natural disasters today are earthquakes, tsunamis, volcano eruptions, landslides, floods, storms and droughts. Each year, catastrophic earthquakes take on average 30,000 human lives. The economic damage caused by seismic disasters reaches hundreds of billions of US dollars, in some cases, up to 40% of a country's national assets.

The direct annual damage from all types of natural and man-made disasters exceeds a trillion US dollars, which, according to our estimates, is a sum two orders of magnitude larger than that spent on the establishment of an aerospace system providing a short-term forecast of their occurrence.

The prediction of natural disasters and man-made catastrophes by monitoring their precursors, the reduction of their effects and the safeguarding of operational readiness are more economical than taking actions in the wake of events.

The complex of space- and air-based surveillance systems can monitor globally the Earth's surface, the atmosphere and the near-Earth space. It detects short-term precursors and reliably forecasts earthquakes, tsunamis and other global geophysical disturbances. Also, it can transmit monitoring data virtually to any point on the globe.

The USA seeks to create the integrated GEOSS (Global Earth Observation System of Systems), consisting of national space systems and individual Earth remote sensing (ERS) spacecraft of participant countries, under the GEO (Group on Earth Observation) program for global surveillance of economic and environmental activities on Earth. In addition, there is a similar European program, the Global Monitoring for Environment and Security (GMES). However, those systems cannot cope with such multi-purpose functions as monitoring of earthquake precursors, of origination, development and spread of tornadoes, typhoons and tsunamis, and the surveillance of the state of hazardous objects on Earth.

In this context, the creation of the international aerospace system for monitoring of global geophysical phenomena and forecasting of natural and man-caused disasters – International Global Monitoring Aerospace System (IGMASS), which is supposed to perform globally the above described functions, is critically important for solving the problems of an operational response to and a short-term forecast of natural and man-caused disasters.

## 2. TRENDS IN THE CREATION OF INTERNATIONAL SPACE-BASED SYSTEMS FOR MONITORING NATURAL DISASTERS

Ever more attention is given of late to the creation of international systems for monitoring natural disasters based on multiple-satellite complexes. Projects and initiatives for building global space-based systems for monitoring hazardous geophysical phenomena are in various stages of implementation in the USA, Europe and Asia.

### The Global Earth Observation System of Systems (GEOSS)

At present, on the initiative of the USA the Group on Earth Observation (GEO) coordinates transnational efforts in building the Global Earth Observation System of Systems (GEOSS) on the basis of the 10-year Implementation Plan (2005-2015). The end product must be a global public infrastructure that provides comprehensive data, in a close-to-real-time mode, for monitoring and forecasting the changes in the global environment, employing for this purpose, land-, sea-, air-, and space-based systems of monitoring the Earth for a wide range of users.

The objective of the GEOSS is to ensure a comprehensive, well-coordinated and steady observation of Earth. The GEOSS initiators sought to fill the need for modern high-quality durable global information as a basis for decision making and to create a system for mankind's progress in the following areas:

- reduction of loss of human life and material assets in natural and man-made disasters;
- study of ecological factors impacting people's health and wellbeing;

- improvement of energy resources management;
- study and forecast of climate change for adaptation to its volatility;
- improvement of water resources management based on better

understanding of the hydrological cycle;

- improvement of weather forecast and public notification;
- improvement of management and protection of land-, shore-, and sea-based ecology control systems;
- steady development of farming and struggle against desertification;
- monitoring and preservation of biological diversity.

The GEO includes 74 states and 51 participant organizations. Among participant states are Brazil, the UK, Germany, Italy, Canada, China, Norway, the USA, Ukraine, France, Uzbekistan and others.

Referred to the participant organizations are the African Association of Remote Sensing of the Environment (AARSE), the World Meteorological Organization (WMO), the World Federation of Public Health Associations (WFPHA), the Global Climate Monitoring System, the European Space Agency (ESA), the European Environment Protection Agency (EEA), and the United Nation Institute for Training and Research (UNITAR).

The GEOSS belongs to all of the participant states and organizations. The interlinked surveillance systems that will be incorporated by the GEOSS need uniform standards in architecture and data exchange. The Earth observation system is built so that its components function as a single unit. Each component of the GEOSS must be included in the GEOSS register and built in such a way that it will be able to interoperate with other systems. In addition, each participant of the GEOSS must obtain a subscription at the GEO to get data exchange principles, which must be used for a complete and open exchange of data, meteorology-related information and software products. These issues are critically important for the successful work of the GEOSS.

The GEOSS will distribute the information and analytical materials directly to users. The GEO is developing a GEO portal as a single Internet server for data

obtained via the GEOSS. The GEO portal's aim is to simplify it, integrating various data packages. For users without high-speed Internet the GEO has created a GEONETCast. This is a four-satellite system that transmits data to receiver stations with low power consumption.

The total cost of implementing the GEOSS will be high, but the GEO must supply only limited funding. The bulk of means will be made available under existing national and international schemes and by voluntary contributions to special projects. To ensure the GEO and Secretariat operation, the members and participant organizations will make voluntary financial and other donations through a dedicated foundation controlled by the Secretariat. Other users will make contributions for funding specific actions approved by the GEO.

Thus the GEOSS is "a system of systems" which will bring together the existing and in-development surveillance systems across the globe and will support the development of new systems.

#### The Global Monitoring for Environment and Security (GMES)

The system of the Global Monitoring for Environment and Security (GMES) is a joint initiative of the European Commission and the European Space Agency (ESA) aimed at building a European capability for obtaining and using operational information for global monitoring of the environment and assuring its security.

The objective of the GMES is to meet Europe's need for global control, to safeguard it, and to bolster the environment protection and security by timely provision of information about the ecological situation across the globe.

The GMES is Europe's contribution to the international Global Earth Observation System of Systems (GEOSS), the creation of which had been announced at the Third Earth Observation Summit held in Brussels in February 2005.

The object of the GMES is the provision of geo-strategic and information-related services in the field of environment protection, the insurance of secure

work of the European Union and the European Space Agency and the support of observation in space and non-space (in the air, at sea and on land).

The EU has elaborated a plan for implementation of the GMES. This envisions the establishment of the GMES full main capability in 2008.

The first three pilot services (operating areas) of the GMES earmarked for realization in 2008 include:

- receipt of information for controlling emergencies,
- receipt of information related to land-utilization,
- receipt of information for sea transport.

On 16 September 2008 the European GMES program was officially named Kopernikus. This was announced by the European Commission Vice-President Günter Verheugen in Lille, France, at the forum on the 2008 program.

The GMES program was launched for gathering information of observation of Earth surface from satellite- and land-based measuring systems. In conjunction with socio-economic, the processed data on changes in the environment and climate as well as on the utilization of natural resources can, if necessary, be made available to any inhabitant of Europe. Spacecraft, whenever necessary, can also supply security-related information.

The European Space Agency is responsible for development and acquisition of spacecraft for the program as well as for coordination of space-based assets belonging to European national satellite communications operators. France, Italy, Germany, Canada, Israel and some companies of non-European countries have joined the program.

Unlike the GEOSS, the GMES implies the creation of an own orbital group of observation spacecraft. For example, a short time ago the RS-20 carrier rocket put in orbit five German spacecraft Rapid Eye for the GMES. The launch took place on 29 August 2008 at the Baikonur Cosmodrome.

In order to promptly supply Earth observation data, the space-based complex will also include a series of five spacecraft, called Sentinels, which are now being developed specifically for the GMES by order of the ESA.

The Sentinel spacecraft will be supplying information for all areas of the GMES. The Sentinel-1 will provide radar images for farming and ocean research agencies. The Sentinel-2 will operate in an optic range with a high resolution. The Sentinel-3 will provide services in ocean study and global terrain monitoring. The Sentinel-4 and Sentinel-5 will supply data for monitoring the atmosphere content, respectively, from a geostationary and a polar orbit.

Also, it is planned to use in the GMES information from a number of dedicated spacecraft, such as Spot, Pleiades, Jason, SMOS, Calipso, Parasol, Megha, Tropiques, Vegetation, and Venus.

The land-based part of the GMES will receive information from spacecraft, process it and transmit to users.

The services provided by the GMES are divided into five main categories pertaining to land resources management, actions at sea and in the air, to aid in emergencies and to security-related missions.

These services can effectively address many ecological issues, such as the rational use of natural resources, food security, preservation of the biological diversity and the reliable forecast of air contamination. In addition, the information from the GMES will help to better understand the climate change problems.

#### Sentinel Asia, a system for warning about emergencies and natural disasters

The Sentinel Asia project was originally proposed by the Asia-Pacific Regional Space Agency Forum (APRSAF) in November 2004. The project envisions the creation of a system for control of and response to effects of natural disasters in the Asia-Pacific region by using remote sensing technologies combined with modern methods of spreading information via the Internet in a mode close to real time. Fifty-one organizations participate in the project, including 44 agencies from 18 countries and 7 international organizations.

The aims of the project are:

- to build a society, based on information and space technologies, in which human life is a top priority;



- to reduce the time needed for issue of the soonest and most accurate warning about impending dangers;
- to minimize victims and damage to economy.

Stages of system realization:

Stage 1. The creation of basic elements of the Sentinel Asia information system and its key junctions. This stage must show the role and capabilities of information technologies based on the standard Internet methods (February 2006 - December 2007).

Stage 2. The expansion of the basic information system by means of two new satellite communications systems (2008-2009).

Stage 3. Complete deployment of the Disasters Management Support System (Asia-Pacific system of warning and disaster control in the Asia-Pacific region).

The system architecture is being developed so it could receive and process variously formatted information coming from different ERS satellites, including geostationary platforms and new ERS spacecraft. Those are used and can be voluntarily supplied, via their national “information processing posts”, by individual countries of the region to the Sentinel Asia system. Also, the Sentinel Asia system is very well suited for regional transmission of satellite information of such promising systems as GEOSS, GMES and GEOS virtual satellite system.

The main functions performed by the system:

1. Operational surveillance of emergencies by means of ERS spacecraft in the event of major disasters.

At present it is planned to use for this purpose the Advanced Land Observing Satellite, ALOS (Japan Aerospace Exploration Agency, JAXA), Terra + Aqua (NASA) and other systems.

2. Acceptance of applications for monitoring.

Applications are accepted from organizations, members of the Asian Disaster Risk Service (ADRS), and from organizations representing the project participant countries, for monitoring major emergencies in the Asia-Pacific region by the Advanced Land Observing Satellite (ALOS).

### 3. Monitoring of forest fires and floods.

At present, for monitoring forest fires they use data supplied by MODIS (Moderate Resolution Imaging Spectroradiometer (NASA instrument)). For monitoring floods it is planned to use data supplied by TRMM spacecraft, GPM systems (NASA and JAXA), the Advanced Microwave Scanning Radiometer, ASMR-E (multi-channel radiometer of the satellite Aqua), and other devices.

### 4. Enhancement of the net's traffic throughput for using satellite-supplied images in responding to natural disaster.

The work on the enhancement of the nets' information traffic throughput will be supervised mainly by the Asian Institute of Technology (AIT) and the UN Economic and Social Commission for Asia and the Pacific (UN ESCAP).

At the exit of the Sentinel Asia system the following information products must be obtained:

- combined digital images of disaster areas with imposition of image information onto the cartographic base obtained by WEB-GIS under the Digital Asia project, etc.
- original from-space images of the Earth surface for transmission via the Internet, FTR protocol;
- images obtained locally from video cameras.

### The International Charter "Space and Major Disasters"

The project entitled the International Charter "Space and Major Disasters" is aimed at creating a single system of space-related data, the acquisition and delivery of the required information to those in distress resulting from natural or man-made disasters. The project was initiated by the European and French space agencies in 2000. The official notice of project was given 1 November 2000. Later on, the space agencies and organizations of Canada, India, the USA, Argentina, and Japan joined the Charter.

The prime goals of the International Charter "Space and Major Disasters" are:

- to coordinate the use of space systems in the event of natural and man-made disasters;
- to mitigate the impacts of natural disasters by supplying free ERS data.

The orbital complex of the project includes national ERS spacecraft of the Charter member states: ERS, ENVISAT (Europe), SPOT (France), RADARSAT (Canada), IRS (India), GOES (USA), SAC-C (Argentina), and ALOS (Japan).

The International Charter "Space and Major Disasters" is based on principles of voluntary transnational cooperation. The Charter's activities are coordinated by a committee formed from representatives of member states and the Secretariat. The prime goal of the project is to create a system that gathers and delivers, through authorized users, the space information to those in distress caused by natural and man-made disasters. In case of a major disaster (floods, oil spills, earthquakes, volcano eruptions, fires, etc.) the combined resources of participant states will be aimed primarily at establishing the causes of calamity, controlling the situation control in the disaster area, and rehabilitation efforts. The ERS data are supplied free as per established procedure on demand of an authorized user represented by a government body charged with monitoring of the natural disaster.

#### The Disaster Monitoring Constellation (DMC)

Since 2001 the Surrey University of the UK has been developing the Disaster Monitoring Constellation system. The governments of Algeria and the UK had funded the construction of the first two satellites.

Six spacecraft for the DMC will be manufactured by Surrey Satellite Technology Company (SSTL of the UK). The seventh craft using the same platform will be manufactured in Thailand (ThaiPaht-2).

The DMC satellites are designed for supplying operational information to various emergency response agencies.

In May 2002, an international consortium was formed, which included, in addition to Algeria and Britain, Turkey, China, Thailand and Nigeria.

The first to be launched was the Algerian satellite AlSat-1 (28 November 2002). A year later (September 2003), three satellites, NigeriaSat-1, BilSat-1 and UK-DMC were put in orbit. Those belong to the DMC system. In 2006 a Chinese satellite augmented the group.

The satellites are launched into the near polar orbit, which will enable monitoring of any point on the globe. The resolution of color images reaches 32 meters, and that of black-and-white ones four meters.

The information about natural disasters is transmitted from satellites to the relevant emergency response organization on whose territory the emergency occurred.

The information is transmitted via a non-commercial net of the Reuters Alernet agency. The net had been created specifically for coordination of the agencies' disaster response efforts. It should be noted that the information will be fed from satellites to pocket terminals of the workers of such agencies operating in the disaster area or close to it.

The constellation of satellites is international. But the craft as such "belong" to different states: NigeriaSat-1 to Nigeria, BilSat-1 to Turkey and UK-DMC to the UK. The participant countries of the DMC own and control their craft, but each participant can receive information from all of the satellites.

The DMC satellite group enables the users to receive daily the image of their region, i.e. to permanently monitor the development of emergencies and to promptly take actions.

Creators of the DMC planned that it would be replaced by the second generation systems, DMC-2, that feature a higher resolution, 2.5 m for black-and-white images and 5 m for multi-spectral ones. A type sample of the DMC-2 is the UK's micro-satellite TopSat. By weight it belongs to a micro-satellite, but features superior characteristics for operational performance and information processing. In addition, it is fitted with a new generation camera.

The TopSat is designed for optimizing the equipment and image reconnaissance methods for troop commands stationed in remote theaters of operations.

The customer for this is the UK's Defence Evaluation Research Agency (DERA). The British National Space Center (BNSC) participates in project funding. The prime developer of the spacecraft is the SSTL Company. The optronic systems are developed by Rutherford-Appleton Laboratory. The program cost totals US\$ 20.3 million.

A satellite, weighing roughly 120 kg, has been built on the basis of the Constella space platform with a three-axis orientation system.

The principal payload is an up to 30 kg optronic camera (the cost of development is US\$ 5 million). This provides "on-the-spot" linear resolution of 2.5 m in a panchromatic mode and 5 m in a multi-zonal photography mode. The altitude of the working solar synchronous orbit is 600-750 km; the inclination is 98°; the equator-crossing local time is 10.30. Based on results of in-orbit trials, a decision will be taken on whether it is reasonable to deploy a multiple mini-satellite system for performance of imaging reconnaissance for the troop command located in the theater of operations.

Constella-based mini-satellites are designed for optic survey of Earth surface. They are incorporated by a system monitoring a disaster area (DMC) and an Earth observation system (EAS) that performs the functions of ecological monitoring, natural resources exploration and applied research.

### 3. ANALYSIS OF PROJECTS OF INTERNATIONAL SPACE-BASED MULTI-SATELLITE SYSTEMS USED FOR MONITORING NATURAL DISASTERS

An analysis of projects of international space-based multi-satellite systems used for monitoring natural disasters showed that their special feature is dedication to recovery efforts following natural and man-made disasters and, to a lesser extent, the short-term forecasting of such events.

The short-term forecast of natural and man-made disasters and earthquakes needs dedicated operational information from across the globe concerning the changes in the Earth's lithosphere, atmosphere and ionosphere. Such information must be processed in a special way and transmitted to relevant decision-making organs. This can be achieved by building an optimum in-orbit complex with an adequate instrumentation package in conjunction with airborne systems, sensing equipment and efficient on-land infrastructure. None of the considered projects fully meets these requirements.

The DMC is focused on obtaining information only in the visible specter, which precludes forecasting of natural and man-made disasters.

The GEOSS does not imply the creation of its own in-orbit assets. Thus the spacecraft, built under the international aerospace monitoring system (IGMASS) provide information for forecasting natural and man-made disasters, will make a significant contribution to that system of systems. In its turn, the on-land infrastructure being created under the GEOSSS can be used by the IGMASS.

The GMES, Sentinel Asia, and the International Charter "Space and Major Disasters" programs are not supposed to comprehensively predict earthquakes because of the limited onboard instrumentation and the specific orbital structure of the systems.

The main characteristics of international space systems of monitoring of natural disasters and their comparison are shown in Table 1.

#### 4. APPLICATIONS AND ROLE OF IGMASS

An effective short-term (days and hours) forecast of an emergence and development of natural and man-made disasters on Earth minimizes the loss of human life and material damage at least by 20%. The growing need for it is obvious.

The problem is glaringly international. It can only be resolved by joint efforts of many countries.

**Table 1**

Comparative analysis of main characteristics of international space-based natural disaster monitoring system

Global Earth Observation System of Systems (GEOSS)	Global Monitoring for Environment and Security (GMES or Kopernikus)	Man-made and natural disaster warning system (Sentinel Asia)	International Charter "Space and Major Disasters"	Disaster management system (DMS)	International aerospace monitoring system for addressing global geophysical phenomena and prevention of natural and man-made disasters (IGMASS)
Goal of the Project					
Obtaining comprehensive ecological data for monitoring and forecasting changes in global environment by means of observation systems based in on land, at sea, in the air and space for wide range of users.	Supply of information on Earth for environment protection and security (cartography, management in emergency, long-term forecast) related to the activities of the European Union (EU) and the European Space Agency (ESA).	Prompt delivery of information for early warning about impending disasters, minimization of victims and social and economic damage in Asia-Pacific region by using information and space technologies.	Minimization of effects of natural and man-made disasters by supplying free ERS data from satellites.	Supply of operational information to organizations and agencies charged with disaster response and recovery.	1) Global monitoring of Earth's surface and atmosphere and of near-Earth space for forecasting natural and preventing man-made disasters; 2) Information support for users in need of navigation; 3) Specialists' remote training.
Participants of the Project					
GEO (Group on Earth Observation), charged with creation of GEOSS, includes 74 states and 51 participant organizations. Among them are: the UK, Germany, Italy, China, the USA, France and others.	Germany, Israel, Italy, Canada, France, some companies of non-European countries and others.	51 participant organizations from 18 countries and 7 international organizations. In particular: Australia, Bangladesh, India, Indonesia, Japan, Malaysia, Nepal, the	European Space Agency (ESA), France (CNES), Canada (CSA), India (ISRO), USA (NOAA), Argentina (CONAE), Japan (JAXA).	Algeria, the UK, China, Thailand, Nigeria, Turkey.	Russian Federation, Canada, EU countries, Asia-Pacific region countries, countries of Africa, South and Central America.

		Philippines, Thailand and others.			
Orbital group					
It is planned to use existing and future Earth observation systems based in space and elsewhere.	Orbital group consisting of Earth observation satellites for various applications, specifically, satellites of such series as: Sentinel, Spot, Pleiades, Jason, SMOS, Calipso, Parosol, Mega, Tropiques, IASI, Vegetation, Venus and others.	Orbital group consists of Earth observation satellites. In particular: ALOS (Japan), Terra+Aqua, TRMM, GPM (USA) and others. In future it is possible to use satellites in geostationary orbit.	Orbital group includes ERS satellites charter member-states: ERS, ENVISAT (Europe), SPOT (France), RADARSAT (Canada), IRS (India), GOES (USA), SAC-C (Argentina), ALOS (Japan).	7 Spacecraft in solar synchronous orbits (SSO) at altitude of 600-750 km.	6 Spacecraft in geostationary orbit; 3-4 spacecraft in SSO at altitude of 600-700 km; use of airborne monitoring systems; use of data from spacecraft of other systems.
Onboard dedicated equipment					
Optronic equipment, multi-channel radiometers, radars, altimeters.	Optronic equipment, multi-channel radiometers, radars, altimeters.	Optronic equipment, multi-channel radiometers, radars.	Optronic equipment.	Optronic equipment.	Visible and thermal imaging observation equipment, low- and high-frequency wave systems, plasma-aided equipment, energy particle monitoring systems, magnetometers, mass analyzers, spectrometers.
Information products					
Earth surface photographic images from space (monochromic and full-	Earth surface photographic images from space (monochromic and full-	Combined digital images with imposition of imaging information onto cartographic base,	From-space images of Earth surface (monochromic with 2.5 m resolution).	From-space images of Earth surface with resolution of 32 m for full-color images and 4	Dedicated operational global information about Earth's lithosphere,



color). Interpreted ERS data. Weather data. Observation frequency – 1-2 hours.	color). Radar-aided images. Information about Earth's gravitational and electromagnetic fields and Earth's surface movement parameters.	obtained via WEB-GIS technologies under Digital Asia project. Original from-space images of Earth surface for transmission by FTR Internet protocol. Images obtained on locality by digital video cameras.	Images obtained on locality from digital video cameras. Response time – 24-36 hours. Response time may be reduced in future.	m for monochromatic. In future 5 m for full-color, 2.5 for monochromatic. Information supply frequency – once in 24 hours.	atmosphere, and ionosphere's changes pattern; dedicated information processing and transmission to relevant control and management organs for decision making. Supply frequency – quasi-real time mode.
On-Earth infrastructure					
GEO portal. GEONETCast receiving stations (comprised of 4 satellites). In future – creation of a global infrastructure with involvement of marine and aerial observation sectors.	Receiving stations and centers for processing space information from Sentinel craft in Europe. In future – European segment of global on-Earth infrastructure (in framework of GEOSS).	Partially built in countries of the region. Satellite receiving stations with X-L range antennas, computing centers for preliminary processing of space information, Internet.	Charter member states' elements of on-Earth infrastructure supplied voluntarily (receiving stations, space information processing centers).	Project participant countries' elements of on-Earth infrastructure supplied on a voluntary basis. Transmission of data to pocket terminals.	A complex of interconnected topologically distributed on-Earth complexes for receiving, multi-level processing, storage and distribution of geo-space information from aerospace and on-Earth sources (see supplement, Fig.8).
Special features of the Project					
Large-scale international cooperation. Preparation of generalized information for statesmen. Transmission of data via Internet and by using communications satellites.	Large-scale international cooperation. Large multi-purpose orbital group of Earth observation satellites enables a wide range of exploration of natural phenomena.	Large-scale international cooperation. High speed of information reception and transmission to users. It is not planned to create in-orbit systems under the project.	Large-scale international cooperation. Free and prompt supply of ERS data. It is not planned to create in orbit systems and sophisticated on-	Large-scale international cooperation. Use of micro-satellites. Data transmission to pocket terminals.	Large-scale international cooperation. Use of micro-satellites. Creation, under the project, of in-orbit systems and sophisticated on-Earth infrastructure.

<p>It is not planned to create in-orbit systems under the project. Spacecraft created under IGMASS for short-term forecast of natural and man-made disasters will contribute to this system of systems.</p>			<p>Earth infrastructure under the project.</p>		<p>Very high response speed. All-embracing use of data from own spacecraft and those of other systems. Wide range of tasks addressed.</p>
<p>Comparative analysis results</p>					
<p>All-embracing forecast of natural and man-made disasters is impossible without IGMASS. Dependence on a large quantity of various Earth observation systems. Difficulties in coordination of processing of heterogeneous information.</p>	<p>The satellite onboard systems suite does not allow all-embracing analysis and prompt forecast of individual natural phenomena (e.g. earthquakes).</p>	<p>Limited capabilities of onboard systems do not allow to forecast natural and man-made disasters.</p>	<p>Limited capabilities of onboard systems do allow to forecast natural and man-made disasters.</p>	<p>Limited capabilities of onboard systems do not allow to forecast natural and man-made disasters. Relatively low response speed. No sophisticated on-Earth infrastructure.</p>	<p>Short-term forecast of natural and man-made disasters. Optimum in-orbit construction of space systems with relevant suite of onboard systems in conjunction with airborne assets and sensing control devices and effective organization of on-Earth infrastructure. Subsystems for navigational and informational support and remote learning.</p>
<p>Project implementation stage</p>					
<p>In creation</p>	<p>In deployment</p>	<p>In deployment</p>	<p>In operation</p>	<p>In deployment</p>	<p>In initiation</p>

Earthquakes are natural disasters that dramatically destabilize the economy and cause the highest death toll. In this context, the global prompt short-term forecast of these cataclysms is an acute, but still unresolved, problem.

The forecast of earthquakes must be especially reliable, which calls for all-embracing information obtained from various types of dedicated systems installed onboard satellites.

A large quantity of anomalies in atmosphere, ionosphere and on Earth surface can be regarded as forerunners of a pending earthquake. Such phenomena can be recorded by several systems onboard a satellite. Their total weight is 150 to 200 kg.

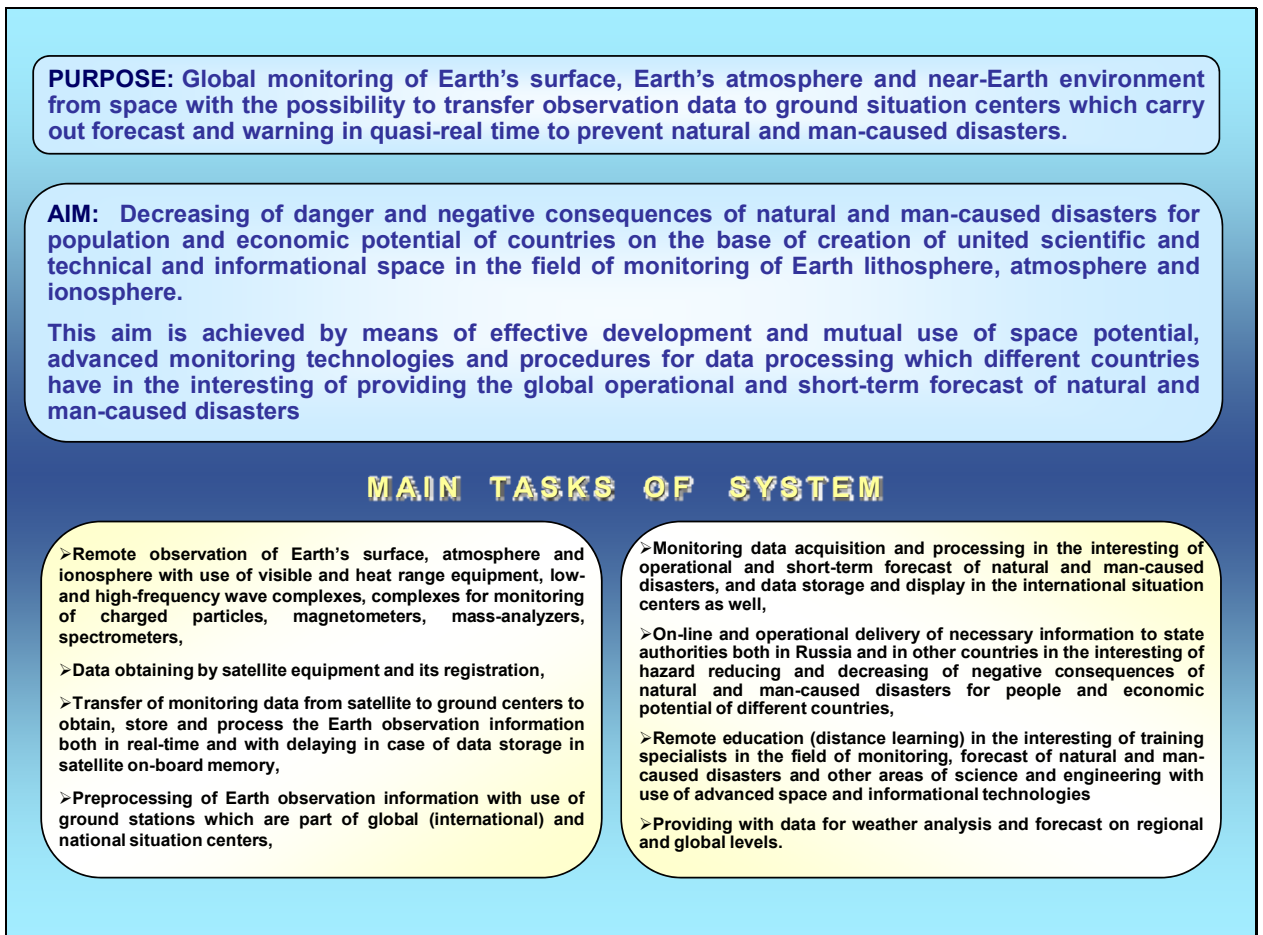
In order to reduce the number of satellites in an orbital group supplying prompt information across the globe, it is planned to put them in different orbits: geostationary and low (solar synchronous).

Only combined satellite- and aircraft-aided monitoring aimed mainly at detection of early forerunners ensures the required efficiency of records and the reliability of earthquake prediction.

The mix of space and aerial observation systems used for global monitoring of Earth, atmosphere and near-Earth space makes it possible to promptly transmit monitoring data to virtually any point on Earth.

In this context, the creation of IGMASS is one of the efficient means to promptly forecast such events across the globe.

**The role of IGMASS** is to globally monitor, from space, Earth's surface, atmosphere and near-Earth space, transmitting observation data to on-Earth crisis control centers operating in a quasi-real mode for forecasting natural and man-made disasters and mitigating their impacts. In addition, the system will make it possible to determine accurately objects' whereabouts, which is needed, among other things, for efficient cargo transportation, distance learning of specialists in monitoring and other fields of human activities (Fig.1).



**Fig. 1. Purpose and tasks of IGMASS**

**The goal of IGMASS** is to effectively enhance and promote the collective use of aerospace potential, advanced monitoring technologies, and global observation data processing for prompt warning about natural and man-made disasters in order to reduce the danger to and negative impacts on population and material assets across the globe. This could be achieved by creating a single network addressing scientific, technical and informational problems in monitoring Earth's lithosphere, atmosphere and ionosphere.

The primary task of IGMASS is observation of Earth's surface, atmosphere and ionosphere by using equipment operating in visible and thermal imaging ranges as well as low- and high-frequency wave systems, plasma-aided devices, energy particles monitoring complexes, magnetometers, mass analyzers and spectrometers. This is done for:

- global geological mapping of various rocks, folded and ruptured structures, dynamic monitoring of seismically dangerous areas;
- dynamic monitoring of hydrogenous ecological systems;
- detection of symptoms of impending earthquakes (measuring of tectonic plates' movement, monitoring of various signs of earthquakes and volcanic activities);
- monitoring of inception, development and spread of tornadoes, typhoons, tsunamis, cyclones and anti-cyclones;
- monitoring of potentially dangerous facilities (in terms of chemical, radiational, fire, explosion and flooding hazard) operating on Earth;
- collection and recording of information on board spacecraft;
- transmission of monitoring data to on-Earth receiving stations without or with delay (the latter mode practiced when data are accumulated in the spacecraft memory);
- primary processing of space data by on-Earth receiving stations and transmission of monitoring data to national and international crisis control centers;
- collection and processing of monitoring data for a prompt global forecast of natural disasters as well as their presentation to and storage at international crisis control centers;
- prompt supply of relevant information to state control organs of the project participant countries as well as to the UN for danger reduction and mitigation of negative impacts of natural and man-made disasters on population and material assets across the globe;
- supply of navigational information to users; such information is obtained by space-based navigation systems for addressing a wide range of social and economic tasks, including information support and telecommunications services;
- distance learning of specialists in monitoring and forecast of natural disasters and in other areas of science and technology, with the help of advanced space and information technologies.

Also, the data of space survey from IGMASS platforms are used for the following missions:

- analysis and forecast of weather on a regional and global scale;
- analysis and forecast of the state of seas, oceans and glaciers;
- monitoring of climate and global changes;
- emergencies control;
- ecological control of the environment and other functions.

Also, the results of space survey can be used to secure the safety of the world community and of participant countries of the IGMASS project. The specific applications are:

- the monitoring of compliance with requirements of international treaties of non-proliferation of weapons of mass destruction, of weapons reduction, etc.;
- the monitoring of settlement of conflicts in “trouble areas”;
- the monitoring of international terrorist organizations’ bases;
- the monitoring of main routes of drug trafficking;
- the monitoring of piracy at sea.

## 5. BASIC PRINCIPLES OF IGMASS

The world’s experience in building international multi-purpose space systems and the requirements of the current international law applied to space exploration define the basic principles of IGMASS as follows:

- unconditional compliance with standards and principles of the international law and of relevant unilateral and multi-lateral commitments, specifically, non-creation of obstacles to other countries’ exploration in space (in the area of electromagnetic compatibility of space systems), non-pollution of the environment or negative impact on it;
- wide use of results of work and research carried out under international programs for development of space equipment and monitoring systems as well as data collection and processing technologies;

- optimization of stages of building an international aerospace system of monitoring global geophysical phenomena with regard to the priority of tasks, technological developments and financial constraints;
- priority development of an in-orbit infrastructure of a system based on preliminary check-out and adaptation of the newest technologies in building onboard dedicated complexes;
- maximum use of capabilities of existing and future groups of spacecraft of international space-based ERS, navigation, communications and relay systems;
- integration of existing groups of spacecraft of Earth remote sensing, communications and relay into groups of space-based advanced systems being created as part of an international aerospace system for monitoring global geophysical phenomena;
- the use, by the international aerospace monitoring system, of information supplied by the world's existing elements of monitoring systems .

## 6. IGMASS COMPOSITION AND STRUCTURE

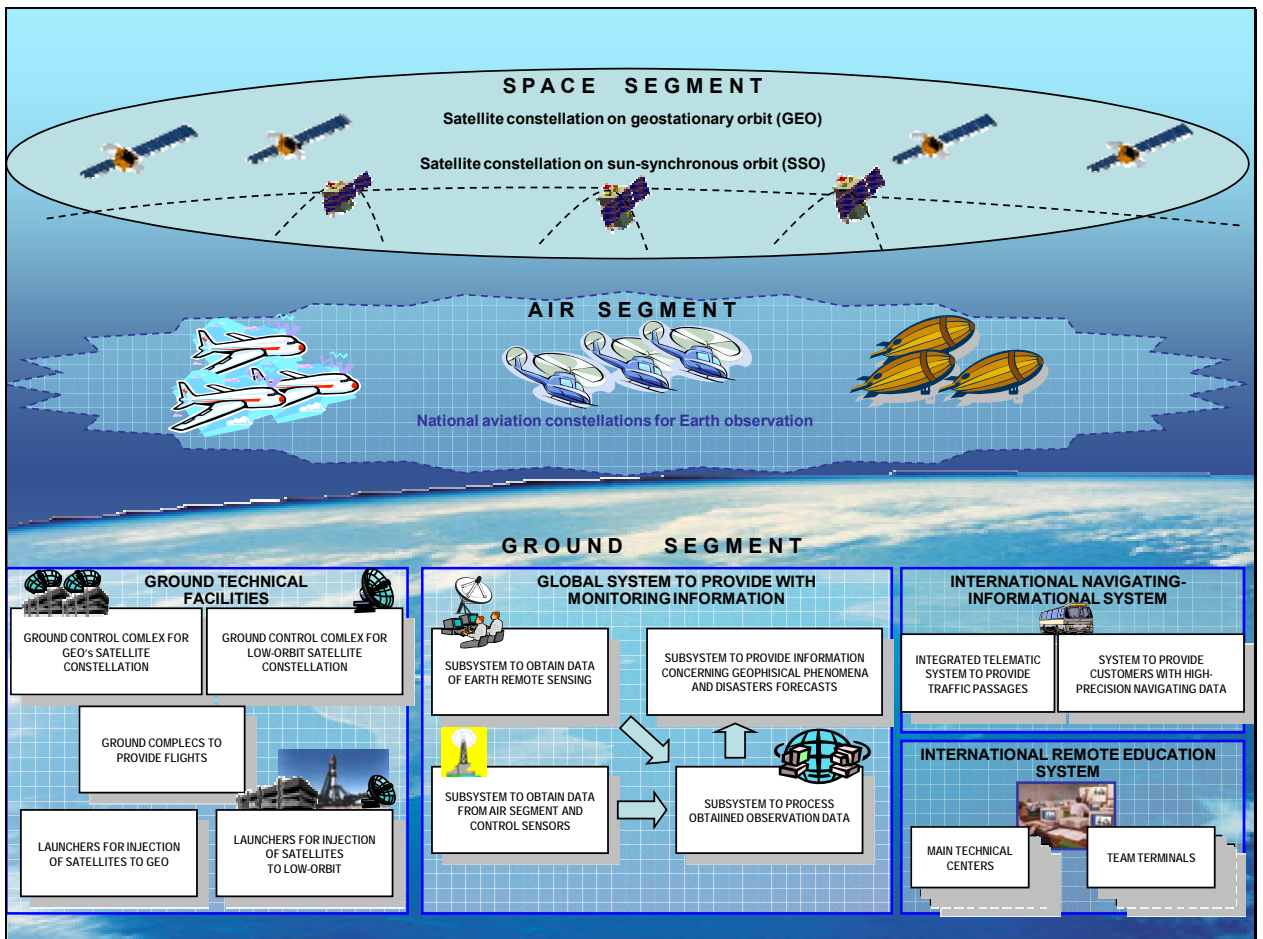
A fully operable IGMASS must consist of space-based, airborne and land-based segments (Fig.2).

**The space-based segment of IGMASS** includes an in-orbit group comprised of spacecraft located in various orbits (lower and geostationary).

IGMASS uses extra information received from spacecraft: international systems of monitoring of natural disasters, such as GEOSS, GMES, DMC, Charter and Sentinel Asia.

The use of information supplied by spacecraft ensures, in the first place, its comprehensiveness and reliability, and, in the second place, enables optimization of IGMASS on-land dedicated system prior to the deployment of its in-orbit group.

IGMASS uses the in-orbit group of communications and relay spacecraft as well as information from global navigation systems like GLONASS, GPS and Galileo.



**Fig. 2. Structure of the International aerospace system for monitoring of global phenomena**

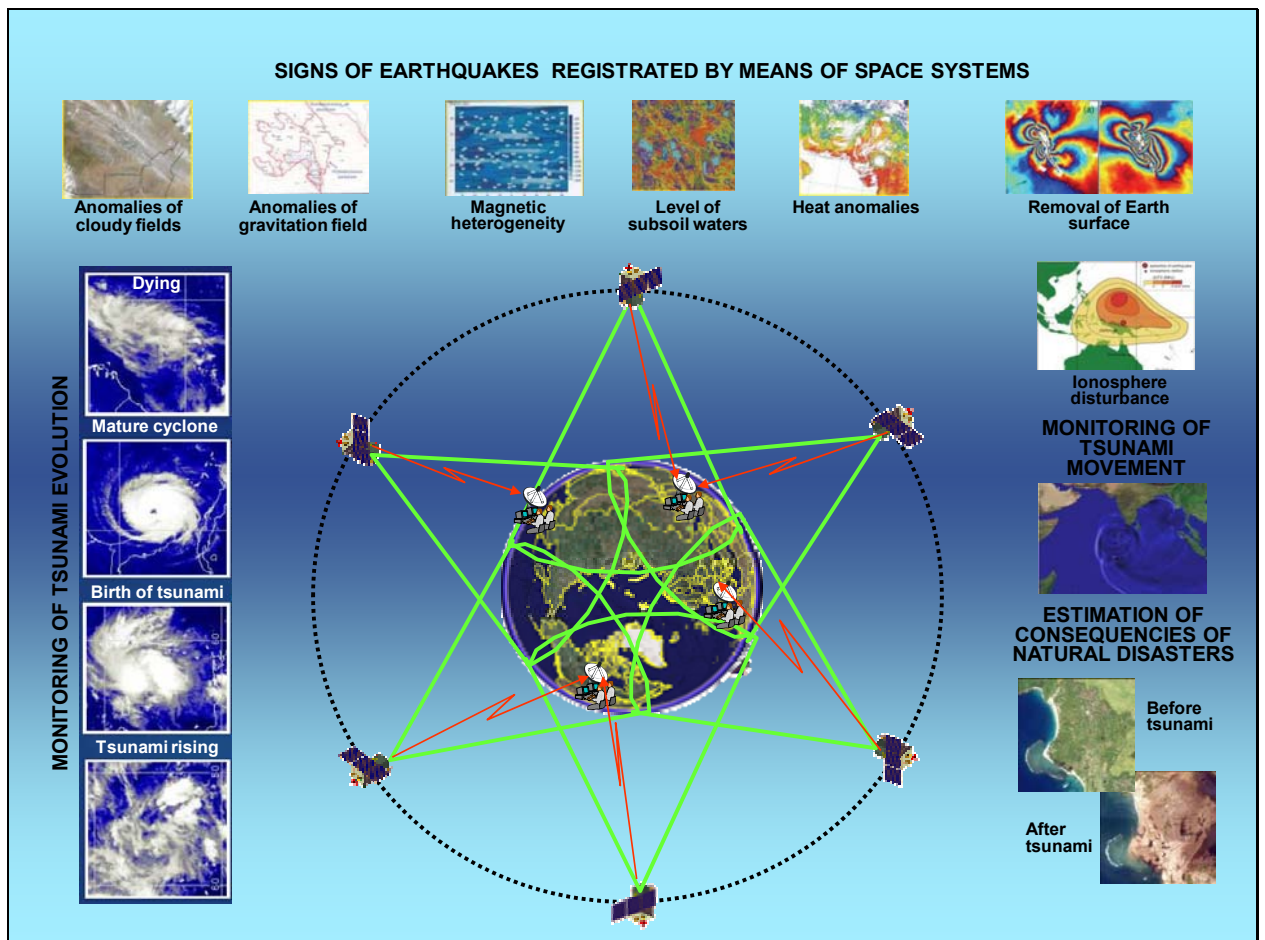
The space-based segment of IGMASS enables reception of background distributions and emission of disturbances of thermal, magnetic, and gravitational fields and plasma in ionosphere and detects changes in the ozone layer and atmosphere. It also detects geodynamic transformations in Earth's crust and hydrodynamic fluctuations in underground waters, which could be forerunners of natural and man-made disasters. The received data are transmitted to the situational awareness centers of the global system that supplies users with information on results of monitoring.

IGMASS in-orbit group includes spacecraft groups of upper and lower tiers.

A group of small-sized spacecraft of the upper tier includes six satellites in a geostationary orbit combined into two groups, three satellites in each. The apexes of two triangular planes, in the form of a constellation of six apexes (Fig.3) conventionally dissect Earth through the equator. One of the reasons why the upper



tier orbital group is deployed is to determine and record the satellites' points of sight in the geostationary orbit.

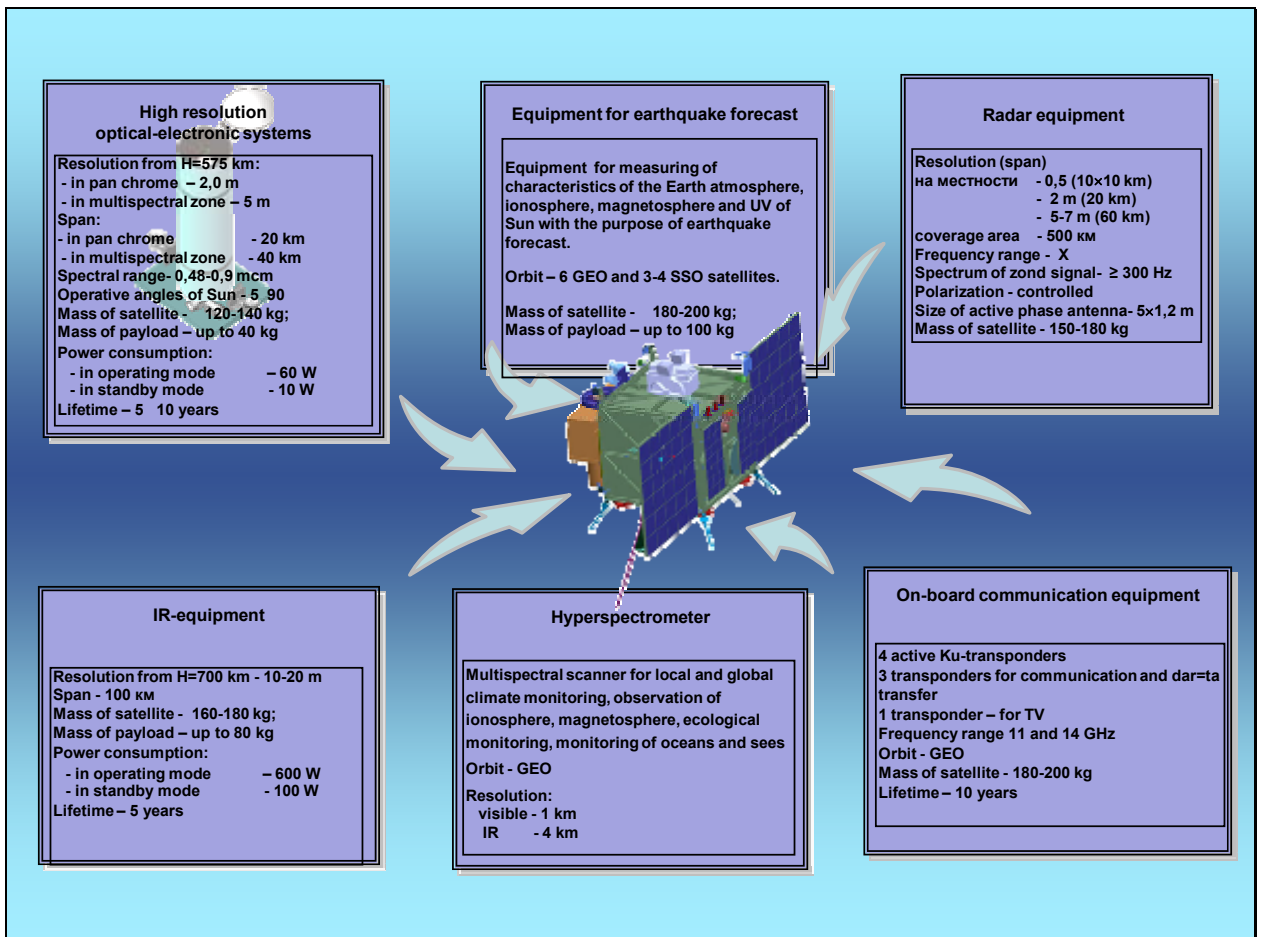


**Fig. 3. Orbital structure of geo satellite constellation**

The lower tier spacecraft group includes three to four satellites in solar-synchronous orbits at an altitude of 600-700 km with a uniform position of orbit planes in the longitude of the ascending knot.

For creating spacecraft included in the IGMASS it is possible to use a multi-role platform of a micro-satellite being developed in Russia by the A.A.Maksimov Research Institute of Space Systems. This is a branch of the Khrunichev State Research and Production Space Center. Such satellite can be used for observation, communication and relay missions (Fig.4).

IGMASS spacecraft are supposed to feature a modular design. The systems on board the basic module are not hermetically sealed (Fig.5).



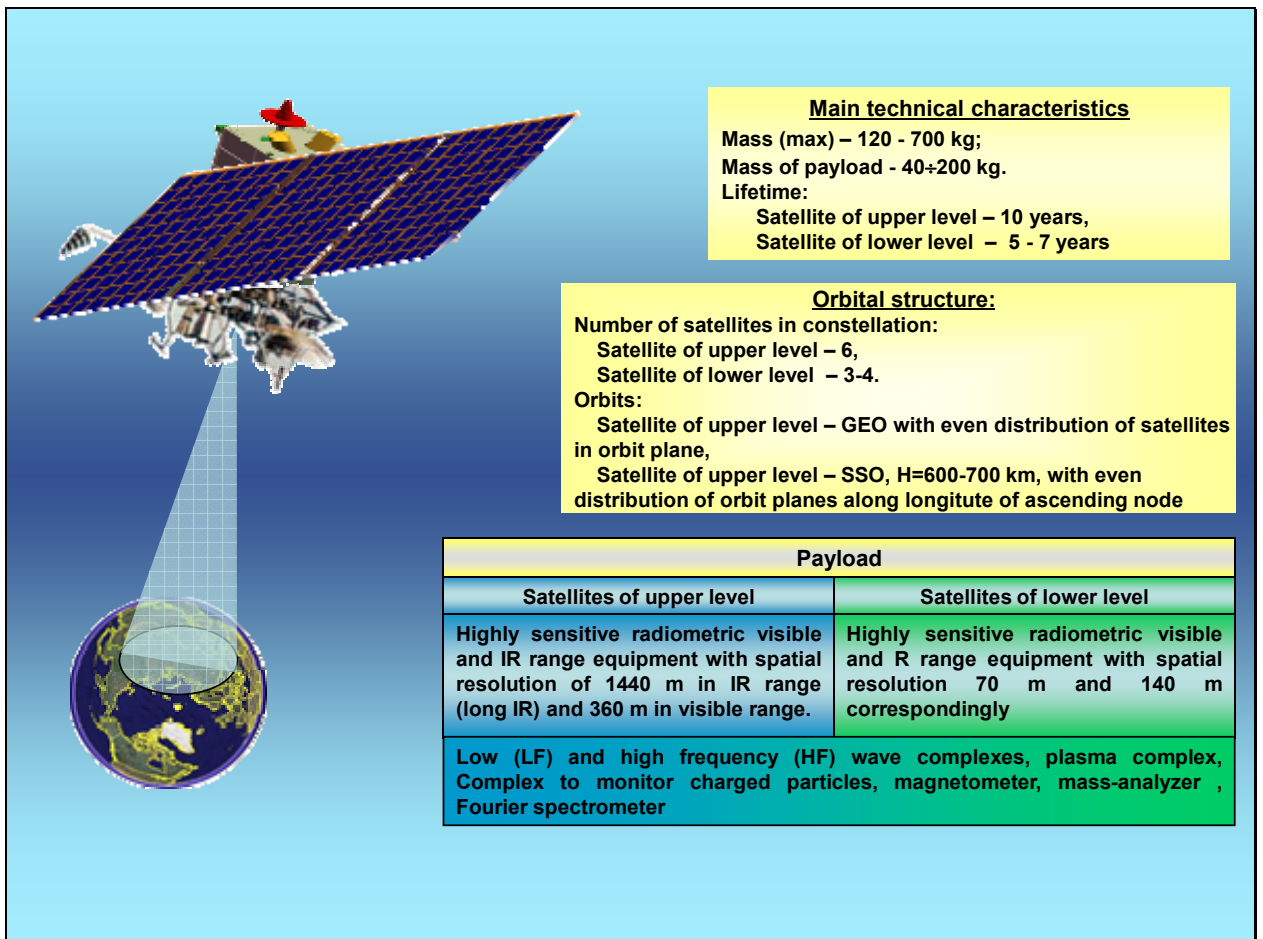
**Fig. 4. Use of unified microsatellite platform of Maksimov Space Systems Research Institute for Earth observation and communication purposes**

Spacecraft weigh not more than 600 to 700 kg. So according to the international classification they are small-sized spacecraft.

The active service life of IGMASS spacecraft in the upper tier must be at least 10 years, that of craft in the lower tier no less than 5 to 7 years.

The satellites operating in the geostationary orbit must be fitted with highly sensitive radiometric equipment working in a visible and thermal imaging range with a resolution of 1,440 m in the thermal (distant infrared) and 360 m in the visible range.

The satellites operating in the solar-synchronous orbit at an altitude of 600-700 km must be fitted with high sensitivity radiometric equipment working in the visible range with a resolution of 70 m and in the thermal imaging range with a resolution of 140 m.



**Fig. 5. Satellites for the International aerospace system for monitoring of global phenomena**

Also, the satellites must be fitted with suites of equipment based on:

- ultra-low / very low frequency wave system (30-100 Hz) for monitoring the tension of the quasi-stable electric field;
- high frequency wave system for monitoring the electric field oscillation specter in the range of 0.05-15.1 MHz or 0.05-6.35 MHz;
- plasma complex for monitoring the transversal and longitudinal speed of ion drift in the range of 0.02-5.0 km/s, ion density in the range of  $10^2 - 10^6 \text{ cm}^{-3}$ , ion temperature in the range of 300-10,000 K; ion density oscillation in the range of 0.5-1,000 Hz and ion component disturbance;
- video-photometric complex for monitoring the intensity and frequency of lightning discharge occurrence, TV image of areas of atmospheric glow in direction towards the Earth's limb, which image is obtained by a TV camera based

on the CCD (charge-coupled device) matrix and brilliance amplifiers; for monitoring the intensity of atmospheric emissions in chosen specters measured by photometers oriented towards the Earth's limb and nadir;

- system for monitoring energy particles for observation of electrons' energy specters in the range of 15-350 keV (kiloelectron-volt) and ions in the range of 15-3,200 keV registered in two directions, of time variations of particle flows in the chosen energy ranges;

- constant field magnetometer for monitoring three components of the geomagnetic field in the range of +/-60 microtesla with an error not exceeding 0.015 microtesla;

- mass-analyzer for monitoring ions' and neutral particles' distribution by weight in the range of 1-1,000 AMU (atomic mass unit) with time resolution of up to 30 millisecond;

- a spectrometer for monitoring the intensity of hydroxyl emissions in the specter in the range of  $\lambda = 727-1,103$  nm (nanometer) and in altitude from 85 to 110 km.

The small-sized spacecraft (SSS) platform is designed for installing onboard systems. The platform includes:

- onboard control system;
- support (auxiliary) systems.

During its service life in orbit the space platform and its support systems must ensure:

- workability of the SSS between communications sessions with on-Earth spacecraft control station within the assigned period;
- the support of orbit parameters;
- the support of SSS orientation with realization of a three-axis orientation;
- such an SSS orientation error in the orbital coordination system during survey that provides the required quality;
- the stability of angular speed, during operation of dedicated equipment, in each of the axes must be adequate for performance of assigned missions;

- transmission of information from dedicated equipment in direct transmission modes and with delay to on-Earth receiving stations.

Onboard control system (OCS) is designed for control, ballistic and navigation support and monitoring of the SSS operation in an autonomous mode or jointly with on-Earth control station. For the ballistic and navigation support it is envisioned to use the Global Navigation Satellite System (GLONASS), the Global Position System (GPS) and Galileo.

The OCS must ensure the performance of the following missions:

- the telemetric control and management of operation of onboard dedicated and support equipment;
- the formation of onboard time scale and synchronization of operation of onboard systems; issue of time reference to the dedicated equipment;
- relay of information about angular orientation of SSS axes and other auxiliary information to dedicated equipment;
- SSS ballistic and navigation support;
- communication sessions with on-Earth control stations for controlling SSS and introducing control software;
- orientation and stabilization of SSS with prescribed accuracy and rotation of SSS software to required angles with prescribed time and accuracy.

The support (auxiliary) systems include:

- radio line for dedicated information transmission (RLDIT);
- onboard service control channel equipment (OSCCE);
- power supply system (PSS);
- heat supply system (HSS);
- propulsion unit (PU).

RLDIT directly or with a delay transmits the digital information via digital radio lines – operating in an X range – to on-earth receiving stations that supply consumers with monitoring data covering global geophysical phenomena and forecasting natural and man-made disasters.

OSCCE provides a two-way communication between the onboard control system and the on-Earth control station for transmission of information from the SSS and for receipt and transmission of onboard control system's information.

PSS is designed for supplying electric power to SSS onboard equipment, including dedicated types, throughout its service life in orbit.

HSS supplies heat to onboard equipment within the required parameters.

The PU feeds corrective impulses for orbit correction and orientation of the SSS after separation from the carrier rocket as well as for maintenance of the working orbit parameters and relief of the orientation system gyroscopes during SSS active service life.

The navigation support of in-orbit IGMASS SSS must be global, continuous, and precise enough for controlling the whereabouts. Such requirements are best filled by GLONASS, GPS, and Galileo. The joint use of data supplied by those systems' spacecraft enhances the accuracy and reliability of SSS positioning which is necessary for performance of an array of tasks assigned to the craft.

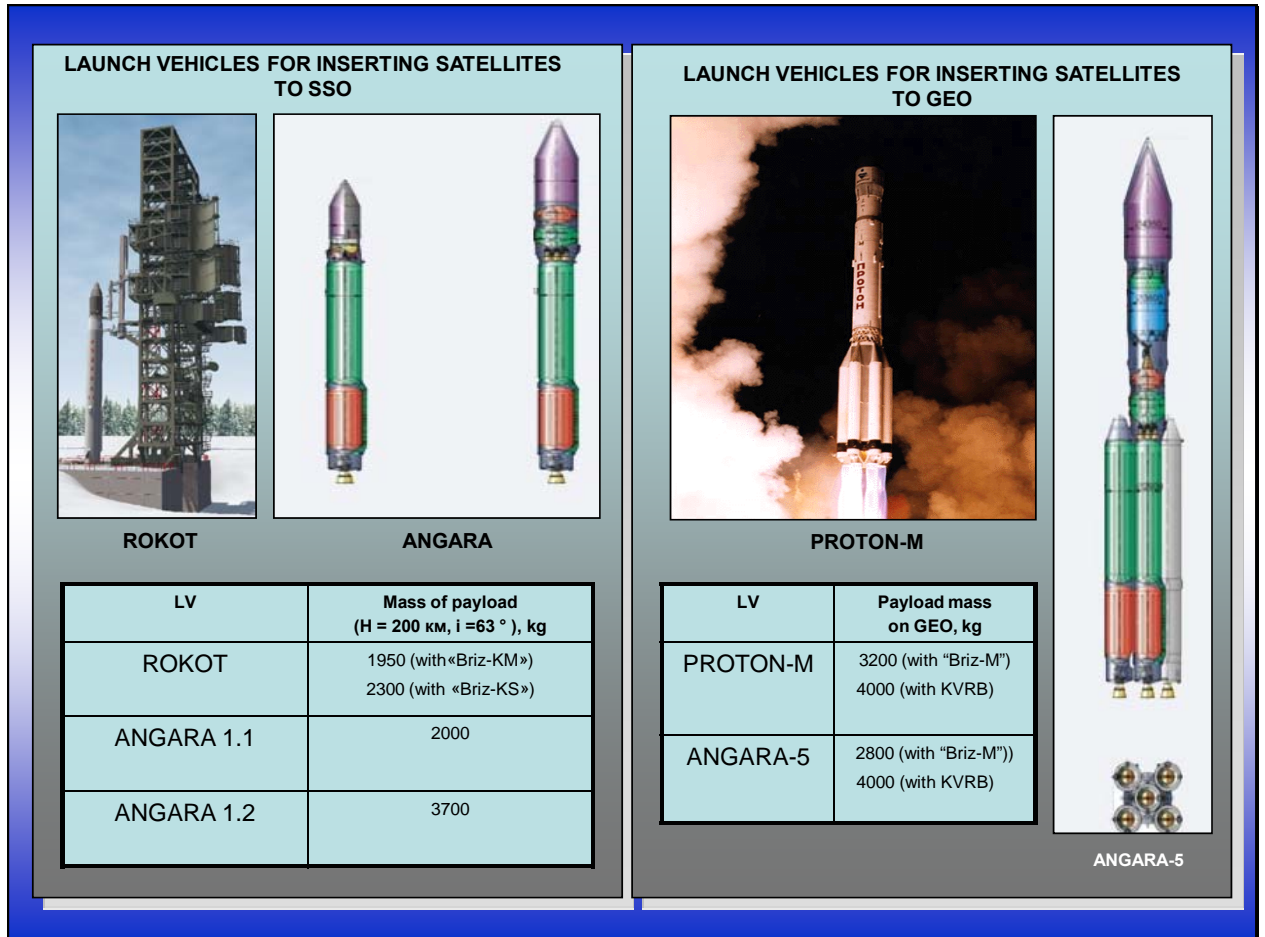
**The aerial segment of IGMASS** includes airborne assets (fixed- and rotary-wing aircraft and dirigibles).

The aerial segment of the system is created, if necessary, by each state at its own expense and is not international. Therefore its engineering appearance, development stages and the management of the creation process at these stages will be considered in follow-on studies.

**On-Earth segment of IGMASS** includes: on-land spacecraft launch and control complexes (space rocket complexes, on-land spacecraft control complex), and an on-land special purpose complex.

The launch complexes used for launching SSS of the international aerospace monitoring system must provide for individual, accompanying and collective launches of small-size spacecraft by using space rocket complexes at Russian and non-Russian cosmodromes.

For principal deployment of a group of the lower tier SSS it is reasonable to launch Russian carrier rockets like Rokot, Angara-1.1 and Angara-1.2 from the Plesetsk cosmodrome (Fig.6).



**Fig. 6. Rocket-and-space complexes**

For principal deployment of a group of the upper tier SSS it is reasonable to launch Russian carrier rockets like Proton-M from the Baikonur cosmodrome, and Angara-5 from the Plesetsk cosmodrome. Also, it is possible to launch them using similar non-Russian carrier rockets.

The on-Earth control station performs the following functions:

the collection of telemetric and navigational information coming from SSS while the measuring, monitoring and checking station (MMCS) routinely controls the operation, or being part (in the frame structure) of target data fed to consumers on the land-based information reception post;

the processing and analysis of the telemetric information for controlling the current state of SSS and determining its capabilities to perform assigned functions;

the elaboration of short- and long-term plans for dedicated use of SSS as well as of a program for operation of on-Earth spacecraft control station's systems;

the development of work programs and corrective commands for managing onboard systems, the formation of databases of command programs and their delivery to the means of direct information exchange with SSS (land-based MMCS) together with target designation for their antennas;

the SSS control with management and introduction of command programs;

the measurement of current navigational parameters (MCNP), addressing the tasks of ballistic and navigational support: determination of orbit parameters, initial conditions of SSS movement, calculation of start-up data for orbit correction, etc.;

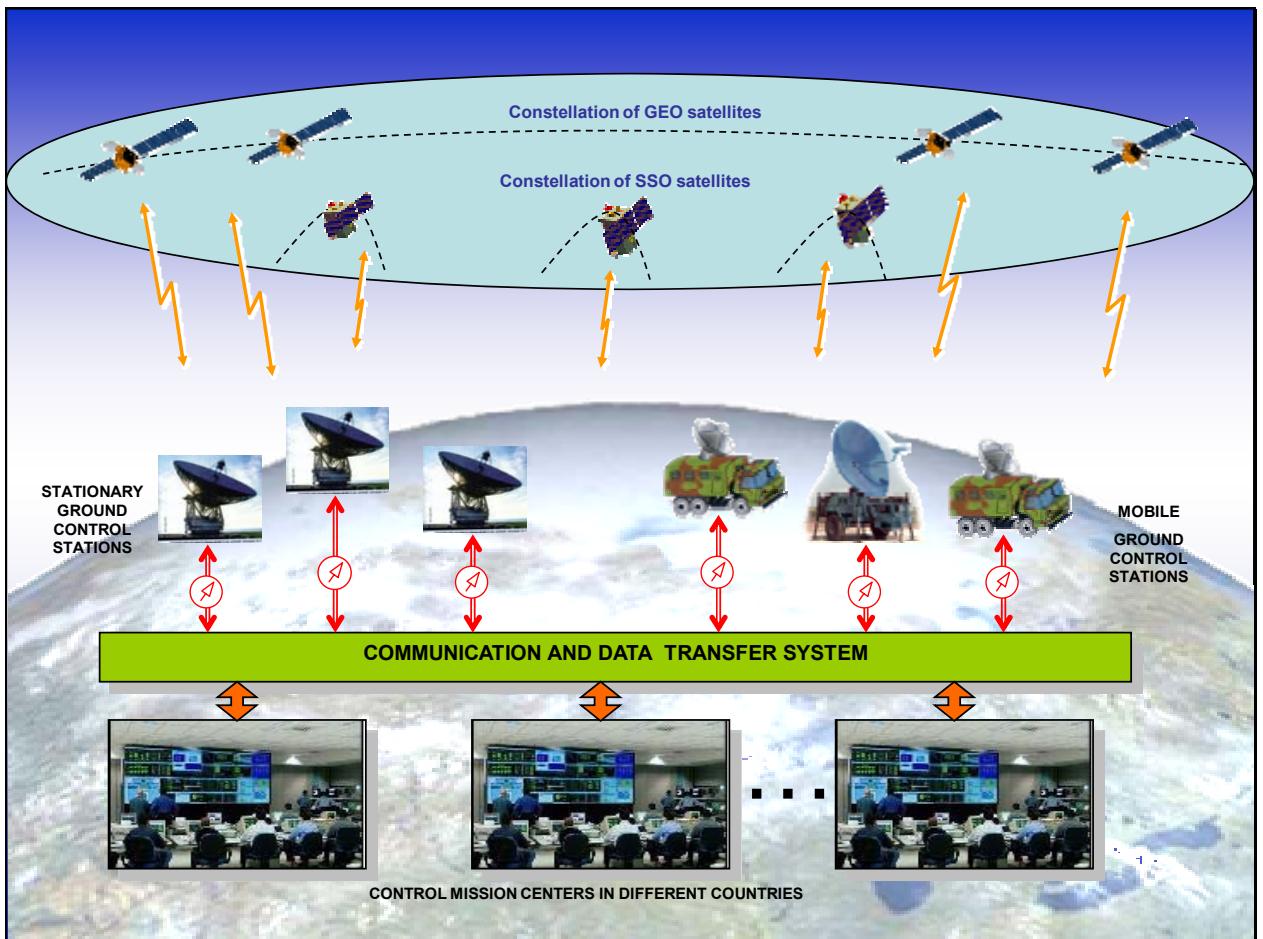
the establishment of information exchange between on-Earth spacecraft control stations (OESCS) and between OESCSs and external subscribers;

the information exchange via existing communications channels with the command and control post of the Belorussian space-based Earth remote sensing system (CCP BSBERS), which is necessary for survey planning and management as well as for transmission of information to consumers' receiving stations.

The IGMASS on-Earth control station includes (Fig.7):

- flight control centers (FCC) of project participant countries;
- land-based control and test stations with relevant means of SSS control and communication;
- transportable (mobile) MMCS and information exchange systems assigned to SSS flight control centers and deployed, if necessary, in relevant areas;
- on-Earth control station's (OECS) data transmission and communications system.





**Fig. 7. Ground control complex**

To ensure an adequate function and technical efficiency of the SSS IGMASS on-Earth control station it is necessary:

- to maximize the use of the world countries' existing on-Earth means of control with due regard to their condition and workload under current and future space programs;
- to use, in routine operation, a low- point method for controlling SSS in solar-synchronous orbits and a distributed organization/engineering structure of on-Earth MMCS and FCC for controlling SSS in the geostationary orbit;
- to use, in flight trials during insertion of SSS into an orbital work point, should emergency arise or repair become necessary, extra instrumentation and control stations and on-Earth control stations of other space system;

- to use navigation and ballistic support of SSS control in a routine mode based on measurements made by onboard navigation equipment of the users of GLONASS, GPS and Galileo;
- to introduce, in the future, coordinating command methods for controlling SSS employed for specific roles.

**On-Earth special purpose complex includes:**

- global system for supplying consumers with monitoring information on global geophysical phenomena and forecasting natural and man-made disasters;
- international navigation and information support system;
- international system of distant learning in monitoring and forecasting of natural and man-made disasters.

**Global system for supplying monitoring information to consumers (GSSMIC)**

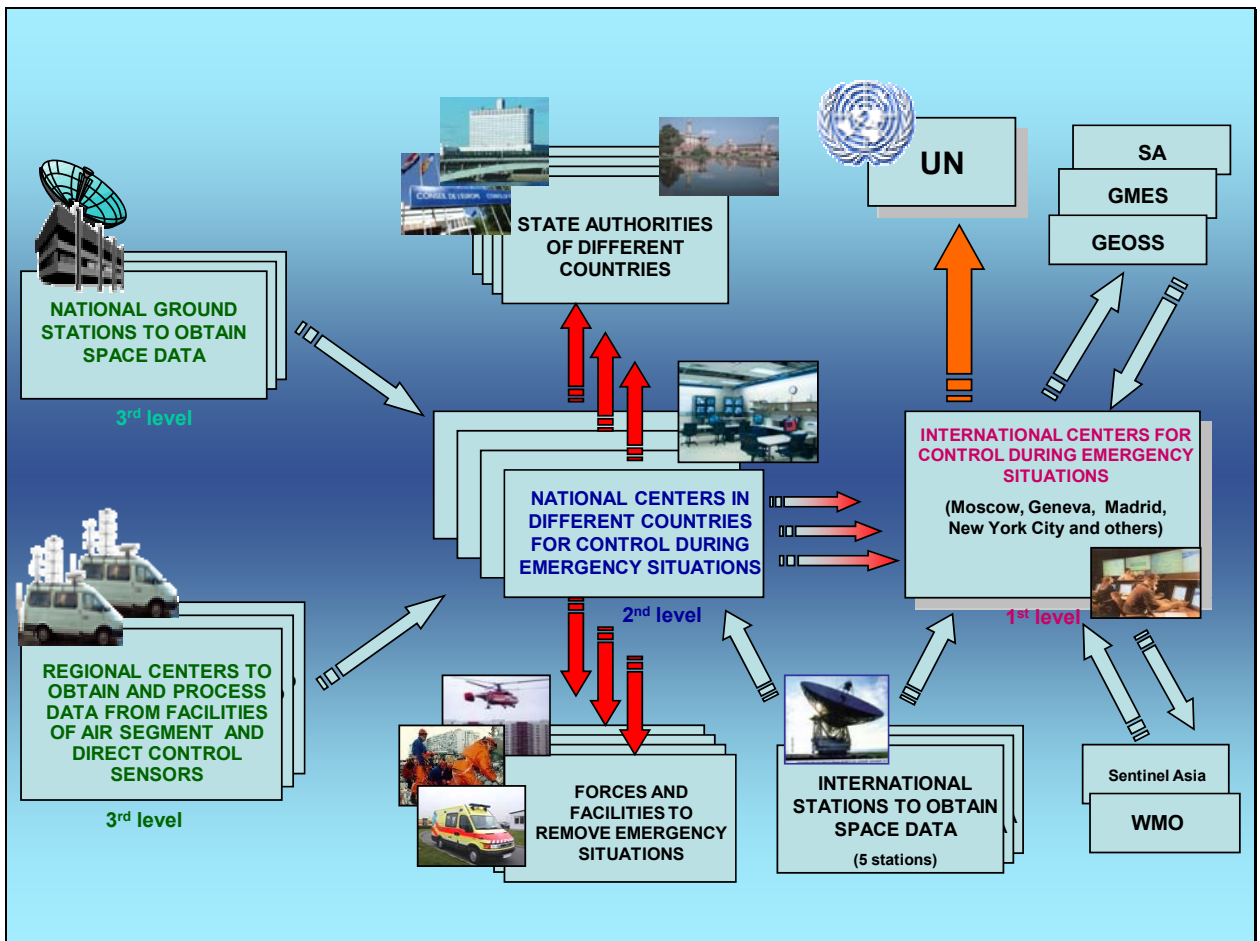
is designed for planning dedicated roles, reception, structure recovery, processing, storage and distribution of all types of information transmitted from IGMASS SSS.

In terms of organization and engineering this is a sophisticated system featuring a complex of interconnected topologically distributed on-land systems for receiving, multi-tier processing, storage and proliferation of space- and Earth-related information from land-based sources.

In terms of structure, the global system of supplying monitoring information on global geophysical phenomena and forecasting of natural and man-made disasters is a hierarchal complex with a radial topology including global monitoring and national situation awareness centers for controlling emergencies plus land-based stations for receiving space information integrated into a single telecommunications network.

Thus, the main structural elements of the GSSMIC are (Fig.8):

- the system's upper level consisting of two global crisis control centers situated in Russia and, say, in one of developed countries;
- GSSMIC medium level includes national situation awareness and crisis control centers conjugated with upper level centers;
- the GSSMIC lower level includes on-Earth space information receiving stations.



**Fig. 8. Global system to provide customers with monitoring data**

The national crises control centers are more important to individual states and so must be created at their expense.

Roughly five international space information reception stations are needed for prompt delivery of monitoring information from the upper tier SSS group. Distributed over the Earth surface (for instance, on the western coast of North

America, on the eastern coast of South America, in Central Africa, Indochina and Central Russia), they provide data to the world's monitoring centers.

To ensure the direct supply of data to national situation awareness centers, the states can establish, on their territories and at their own expense, the stations for reception of information from IGMASS SSS.

The five international stations deployed for reception of space information must also be used for reception of information from the lower tier SSS group.

**The international navigation and information support system** is designed for filling the states' need for navigational information received by space navigation systems for addressing a variety of social and economic problems, including information exchange and telecommunications. An on-Earth dedicated navigation and information support includes **an integrated telemathic system of transport corridors** and **a system for supplying consumers with high-precision navigational information.**

**The integrated telemathic system of transport corridors** is designed for: enhancing the network traffic throughput, ensuring traffic safety, protecting environment, and increasing cargo transportation efficiency via transport corridors. It must include a complex of information and software devices bringing together modern information and telecommunication technologies with organization of transport traffic based on a single territorially distributed and protected information resource of a state participating in this project.

**The system of supplying consumers with high-precision navigational information** is designed for forming navigational and informational space within which an unlimited number of mobile and fixed objects in any point on land, at sea or in the air fitted with navigational, sensing and data exchange systems are able to

automatically and accurately determine the whereabouts, based on signals from GLONASS, GPS, and Galileo.

The basic elements of the on-Earth dedicated complex of the international navigation and information support system can be co-developed under joint programs.

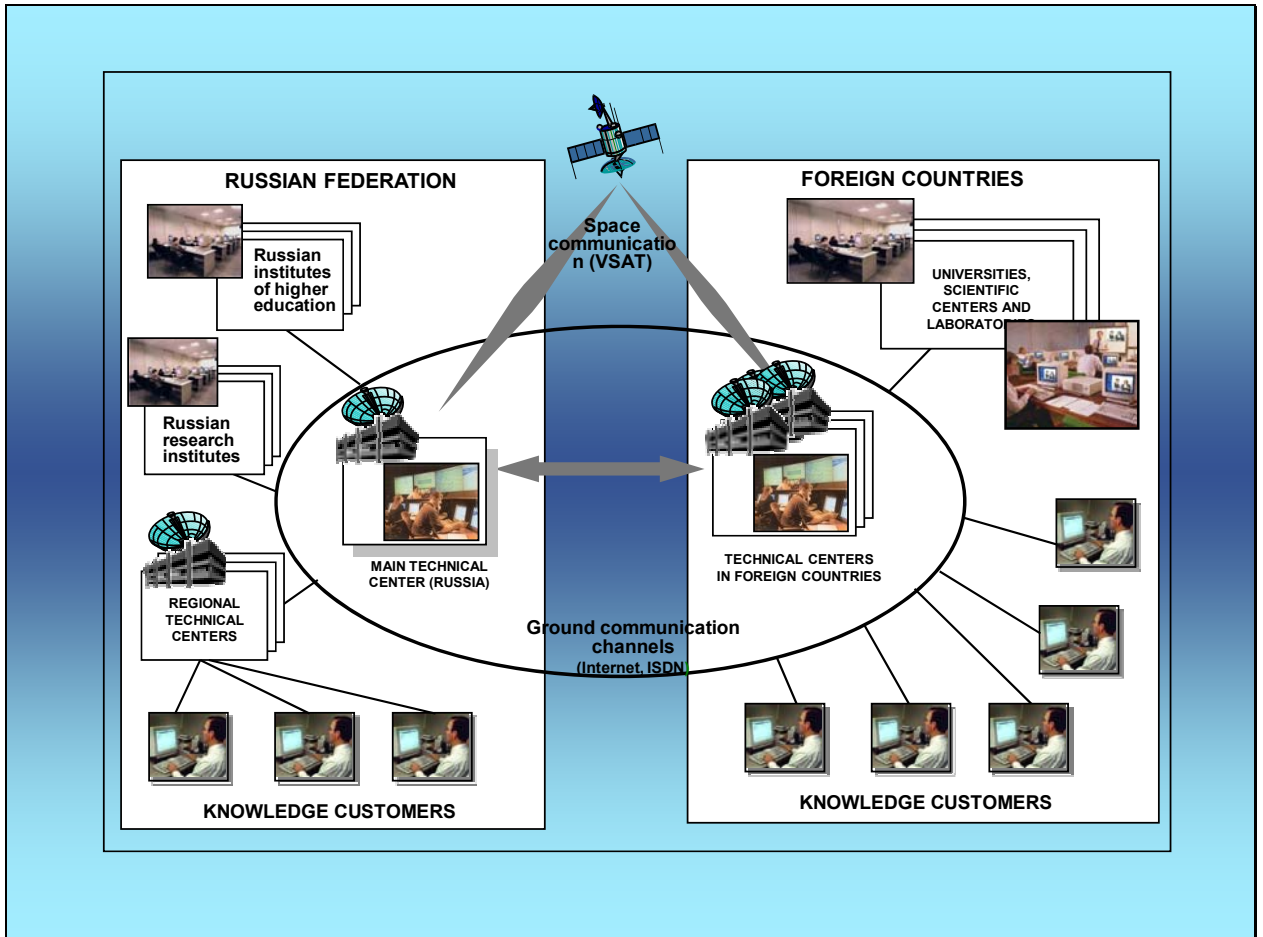
**The international system of distant learning in monitoring and forecasting of natural and man-made disasters** performs the following function:

- enhancing a capability of learning in monitoring and forecasting of natural and man-made disasters for Russian and non-Russian citizens residing far from major educational institutions;
- enabling learners to get knowledge in monitoring and forecasting of natural and man-made disasters at their place of residence or work;
- improvement of professional skills of personnel of organizations and companies in countries involved in monitoring and forecasting natural and man-made disasters;
- improvement of training for experts in operation of IGMASS elements and in organization of its employment;
- improvement of students' knowledge at educational institutions (schoolchildren, college and university students).

The composition of the distant learning system (Fig.9):

- main technical centers of distant learning in the Russian Federation and other countries participating in the project, which centers are fitted with modern equipment for storage, presentation, processing and transmission of learning information and which equipment conducts, via a telecommunication system, interactive training of specialists of the project's participant states;

- local technical centers of distant learning and the world's research and training institutions;
- technical aids of learners' themselves.



**Fig. 9. Remote education (distance learning system)**

Both land- and space-based satellite communication systems will be used to transmit learning information and to conduct distant learning sessions.

## 7. POTENTIAL MAKE-UP OF PARTICIPANTS OF THE IGMASS BUILD PROJECT

The aerospace system for efficient short-term (days and hours) forecast of occurrence and development of natural and man-made disasters on Earth can only be built by joint efforts of many countries having a significant capability in space rocketry and newest technologies.

In addition, countries prone to natural disasters like earthquakes, tsunamis, floods and other calamities, and hence anxious to receive forecasts of their occurrence, must take part in the project.

The potential member states of the project to build the IGMASS are the Russian Federation, the USA, Canada, the EU countries, Japan, India, China, Indonesia and other countries of the Asia-Pacific region, Australia, African countries, and countries of South and Central America.

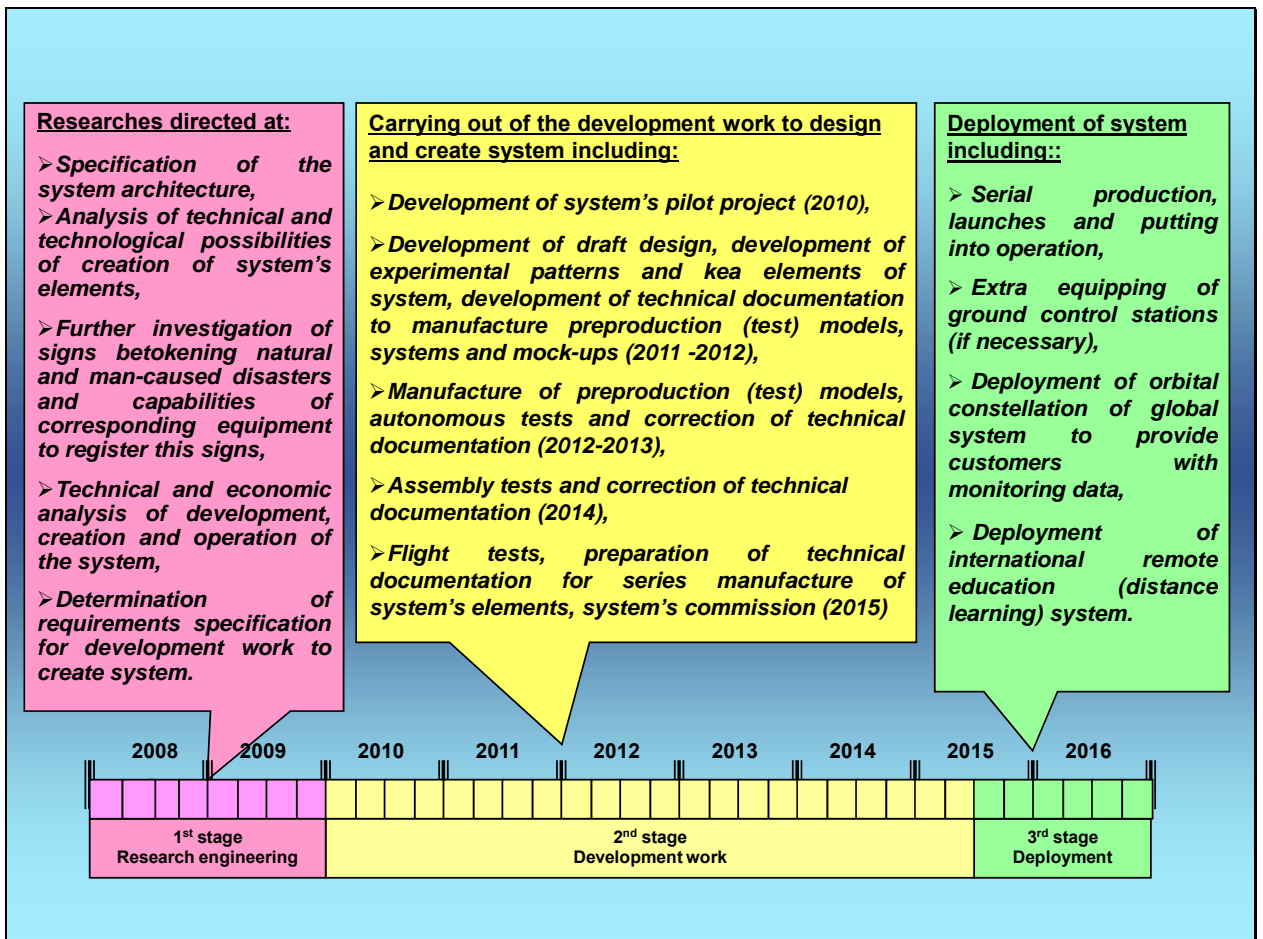
The participants of the IGMASS project must be countries on whose territories it is planned to place international space information receiving stations distributed over Earth (western coast of North Africa, eastern coast of South America, Central Africa, Indochina and central part of Russia).

The distribution of functions among the project participant states and the terms of their cooperation in realizing the project must be defined during the development of the IGMASS systemic project (conceptual design).

## 8. MAIN TRENDS IN CREATION, APPLICATION AND DEVELOPMENT OF IGMASS. A THROUGHPUT PLAN FOR BUILDING IGMASS

The building of the IGMASS can be divided into three stages (Fig.10):

- research work;
- research and development work for building the IGMASS;
- deployment of the IGMASS.



**Fig. 10. Stages of creation of international aerospace system for monitoring of global phenomena**

The research work is scheduled for 2009-2010, including the elaboration of a technical proposal for IGMASS (2010). The work to be done during this period includes:

- optimization of general capabilities of the system;
- analysis of technological and manufacturing capabilities in the creation of IGMASS;
- follow-on research into forerunners of natural disasters and into capabilities of modern equipment to register them;
- feasibility study of development, production and operation of IGMASS;
- preparation of technical specifications for research and development of IGMASS.

The IGMASS research and development is due for 2011-2016. This must include:



- the development of a conceptual design, of experimental prototypes, and of key elements of IGMASS plus work documentation for pilot products (2011-2013);
- fabrication of pilot samples, autonomous trials, and amendment of work documentation (2012-2013);
- comprehensive interdepartmental trials and amendment of work documentation (2015);
- flight trials, preparation of documentation for serial production items, system deployment (2016).

Deployment of the international aerospace system for monitoring global geophysical phenomena and forecasting natural and man-made disasters is due for completion in 2016-2017.

Given below is a preliminary throughput plan for building IGMASS (table 2).

## 9. ASSESSMENT OF IGMASS CONSTRUCTION EXPENSE AND OF ITS OPERATING EFFICIENCY

The feasibility study of building and deployment of an international aerospace system for monitoring global geophysical phenomena and forecasting natural and man-made disasters showed that the approximate cost of work will amount to:

- research work – US\$ 20 million;
- IGMASS research and development work – US\$ 180 million;
- IGMASS deployment – US\$ 1 billion;

The total cost of creation and deployment of the system may reach US\$ 1.2 billion.

Table 2

IGMASS BUILD PROJECT THROUGHPUT PLAN

Effort name	Work in scheduled period, by years									
Research work	Research work									
	Requirement specification for R&D									
R&D			Conduct of R&D							
R&D stagesP		System project development	Development of the conceptual design, IGMASS experimental key elements and work documentation				Comprehensive inter-service trials			
			Manufacture of IGMASS pilot examples, independent trials, amendment of work documentation				Conduct of flight trials, preparation of series production			
Serial deliveries								10 SSS		
Operation								Completion of IGMASS deployment		
								Introduction into routine operation		
years	2009	2010	2011	2012	2013	2014	2015	2016	2017	

The IGMASS funding sources must be determined at the stage of system engineering.

The IGMASS will help to address humanitarian, ecological and economical problems (Fig.11).

Effects in the humanitarian aspect include:

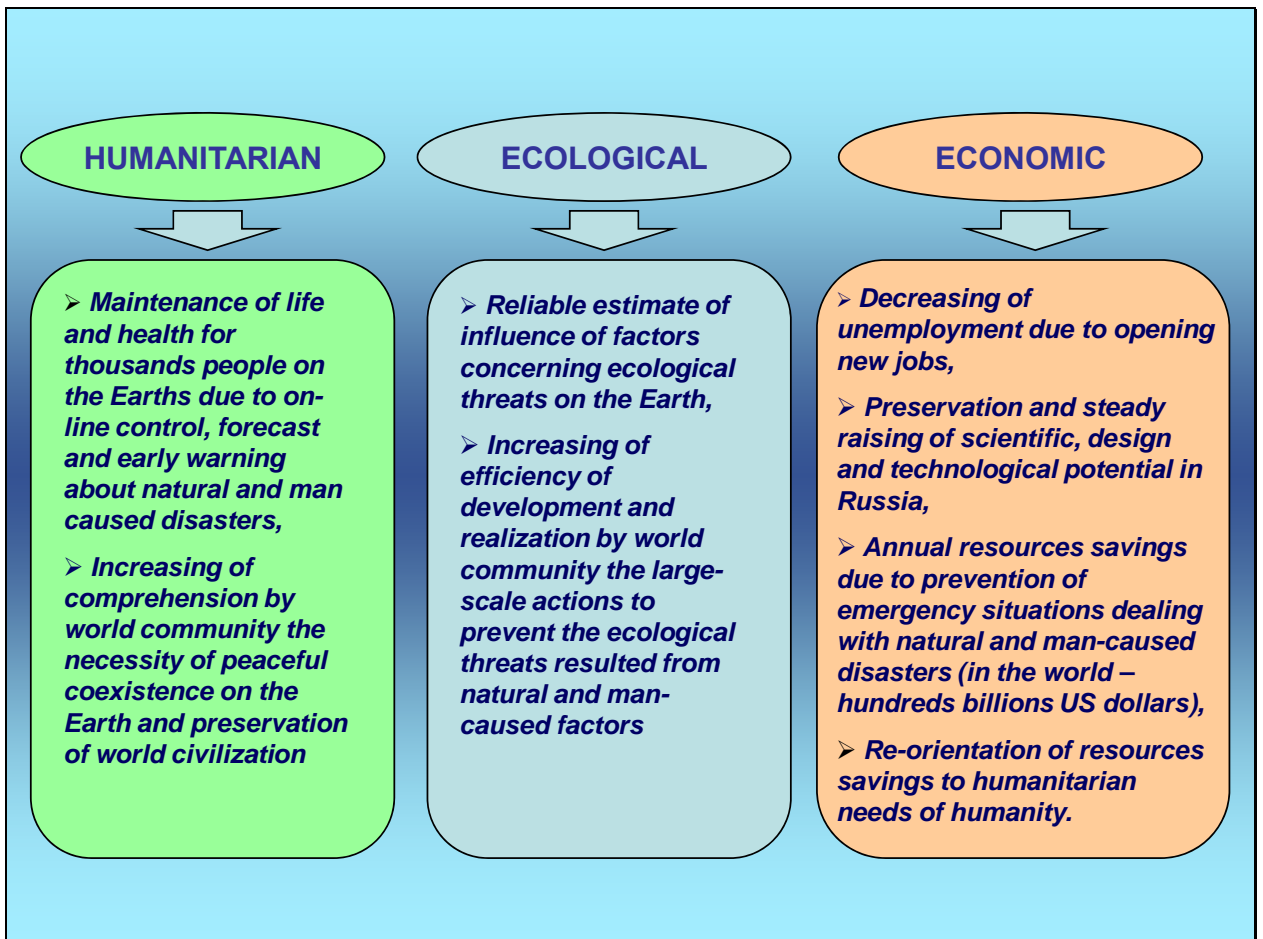
- the preservation of health and life of hundreds of thousands of people on Earth thanks to permanent control and forecast of natural and man-made disasters and early warning of population about natural disasters and global calamities;
- better realization, by the world community, of the necessity of peaceful co-existence on Earth and preservation of the world civilization.

Effects in the economic aspect include:

- the creation of 700,000 to 800,000 new jobs in space rocketry industry of the participant states;
- retention and buildup of research, engineering and technological capability of participant states;
- annual saving of financial and other means thanks to prevention of emergencies (mitigation of negative impacts) caused by man-made disasters, and warning about natural disasters that could bring billions of dollars worth of damage;
- re-orientation of saved funds towards humanitarian needs.

Effects in the ecological aspect include:

- the obtaining of reliable information about the impact of human activity on the environment and the Earth;
- more effective development and implementation, by the world community, of large-scale efforts aimed at addressing ecological threats generated by natural and man-made disasters.



**Fig. 11. Effect resulted from creation and operation of the International aerospace system for monitoring of global phenomena**

Economic effects of the IGMASS are to be expected following its deployment in 2013-2015. The chief ones will include:

- prevention of damage by well-timed supply of state agencies of the project's participant countries and other interested organizations with the fullest possible information about predicted and past natural disasters, the effects of ecological catastrophes, major man-caused accidents and other calamities;
- making profit from sale of information and services to consumers of monitoring information;
- economic effect of distant learning system used by consumers of monitoring information.

The effective control at all levels (international, federal, regional, interdepartmental) is based on full and reliable data concerning the state and development of facilities and resources (components of environment and natural objects, as well as man-made assets and assets of on-land infrastructure). Therefore the evaluation of IGMASS efficiency took into account the possibility of resolving, in favor of the project participant states, one of today's most important problems, i.e. the prevention of damage from recent and predicted natural and man-made disasters and ecological catastrophes.

The currently observed changes in the state control methods relate to refocusing activities from response to prevention of dangerous phenomena. They ensure high economic and "managerial" efficiency of efforts made in the framework of IGMASS. According to experts' estimates, the warning about adverse situations and dangerous objects along with registration of their forerunners and the forecast of likely development and spread of emergencies that might affect the project participant states will shorten disaster response time and reduce the cost of recovery operations by roughly 20%.

The use of the distant learning system will:

- reduce the cost of training of specialists and users of the system (by 30 to 35% of the cost of traditional learning system);
- improve the possibility of getting knowledge by various categories of citizens via distance learning in monitoring and forecasting of natural and man-made disasters;
- ensure the continuity of workers' in-plant training, re-training and testing;
- reduce new specialists' training time by using dedicated syllabuses;

- reduce the time of disseminating knowledge, skills and expertise accumulated in the use of distance learning system in the sphere of monitoring and forecasting of natural and man-made disasters;
- reduce specialists' time of training in new work methods.

An indirect economic effect of building and using the IGMASS can be estimated as follows:

- the prevention of damage thanks to well-timed supply, to participant states' official agencies, of the fullest possible information about past and predicted natural disasters, accidents and catastrophes (it is planned to reduce by 20% the cost of prevention of and response to accidents and catastrophes);
- the improvement of participant states' general education system with a focus on personnel supply in the sphere of monitoring and forecasting of natural and man-made disasters by using a distance learning system (30 to 35% cost reduction as compared to the traditional training methods);
- creation of engineering prerequisites for consolidating positions of project participant states on the world space technology market;
- creation of permanent high skill jobs in plants and organizations of project participant countries;
- accumulation of research and engineering expertise in space technologies.

It should be noted that during creation and operation of the IGMASS, the economic effect in some areas – initially defined as secondary – may prove direct and powerful. Telling examples of this are the sale of distance learning programs, buildup of investments thanks to the states' increased funding and the attraction of private investors and other schemes.

The economic benefits of the IGMASS will be considered at a greater length and specified during research and development.

In order to protect copyright to engineering decisions, operating principles and general concept of the IGMASS used for monitoring global geophysical phenomena and forecasting natural and man-made disaster, an application was made for issue of a patent with a priority of invention from 13 April 2007. The patent issuance was approved.

## 10. IGMASS BUILD PROJECT INITIATION

The building of the IGMASS is an international effort. Therefore it must be controlled by a true partnership and long-term transnational cooperation in design, manufacture, and operation with mandatory involvement of a management company.

Hence, in building and using the IGMASS regard must be taken of legislature and technical regulations of all participant states. In addition, consideration must be given to the current international treaties, conventions and agreements between states for space exploration. Those accords include:

- an agreement on principles of space exploration and the use of space, including the Moon and other celestial bodies, which came into force October 10, 1967;
- an agreement on rescue and handover of astronauts and objects launched into space, which agreement came into force December 3, 1968;
- a convention on international responsibility for damage caused by space objects, which convention came into force September 15, 1976.

The IGMASS build project initiator is the International Academy of Astronautics (IAA) in association with Russia's Tsiolkovsky Academy of Cosmonautics (RTsAC) and other national astronautics academies supported by the UN.

The main tasks of the IGMASS initiation stage are:

- the recognition of the need for this project;
- the definition of the general purpose of the project;
- delineation of project bounds (end results);
- determination of the customer, managing board and project participants;
- determination of an approximate amount of work under project and of resources required;
- formation of the project directorate;
- election of a lead organization and appointment of a project manager for the initiation stage.

The project directorate shall be formed in compliance with requirements of the international law for effective performance of tasks in the sphere of organization, legal support, financial funding of the IGMASS project as well as for coordination and supervision of efforts towards building the IGMASS.

The directorate founders can be:

- governments of project participant states (represented by relevant ministries and agencies);
- international and national academies of astronautics (cosmonautics);
- various international and national endowments;
- space ministries and agencies of project participant states;
- Russian and non-Russian companies;
- other legal entities and natural persons.

The planned authorized capital must be US\$ 300,500 billion used at the initial stage of building the IGMASS.



The directorate's funds are formed on the basis of own (stock) capital attracted finances and undistributed profits from operations performed. The project directorate will be international. The directorate's stocks can be distributed among UN member states that expressed willingness to participate in the IGMASS project. On behalf of the project participant states part of investments will be provided by the states in the form of infrastructure of on-land equipment of the IGMASS (combination of facilities for supporting and controlling aerospace and other systems). The rest are private investments in this project. The interested countries' subscription to directorate's stocks will be made in compliance with their economic capability, as practiced by the World Bank. The proposed quota for Russia is 19 to 25%. In the course of normal operation of IGMASS the project directorate will provide information services across the globe.

The lead organization and manager of the IGMASS build project at the initiation stage will be the Research Institute of Space Systems, a branch of the Khrunichev State Research and Production Space Center (further on referred to as the RISS). The RISS has a rich expertise in research, design and manufacture, based on modern space, telecommunications and information technologies.

The experience and expertise were obtained in successful theoretical and practical activities towards creating on-Earth space infrastructure and space systems components under international and federal programs supervised by the Khrunichev Center. Some space and on-land systems components are patented by the Russian Federation.

To do work at the next stages of the IGMASS project, the lead organization – the system's developer – is determined in compliance with international law and with regard to results obtained at the initiation stage.

The lead organization and project manager at the initiation stage must ensure:

- the performance of research and development for creation of the IGMASS;
- understanding by all of the involved parties of the general aims, constraints and results of the project;
- determination of main participants and performers of the project, definition of their interests, competence and commitments;
- determination of conditions of project realization, as well as external and internal limitations and risks;
- agreement of authority and responsibility of the project manager;
- determination of principles of project structure and interaction procedures;

Among mandatory essential activities during the IGMASS project initiation is a comprehensive research into the system construction and related areas. Such work includes:

- research and development of models of forerunners of situations leading to emergencies;
- development of principles and methods of parametric control of forerunners of geophysical phenomena;
- creation of tools (target instruments) for aerospace systems used in local and global Earth remote sensing;
- development of mathematical, logical, and software models for processing monitoring information and forecasting emergencies.

It is reasonable to involve the project participant states' leading research organizations, enterprises and exploration centers in performance of this research and development.

The customer for such comprehensive research and development could be the International Academy of Astronautics.

The main results of the project initiation must be:

- formation of the IGMASS project directorate;
- elaboration of the IGMASS build concept, IGMASS feasibility study (business plan), project certificate;
- results of a comprehensive research and development for building the IGMASS;
- patents for the IGMASS and its components;
- legal and regulatory basis for cooperation in building the IGMASS;
- determination of cooperation between national and international organizations and enterprises involved in building the IGMASS and distribution of liabilities.

Work done under the IGMASS build program at the initiation stage is funded by budgetary and non-budgetary sources organized by the project directorate and the International Academy of Astronautics. Overall, the IGMASS project build program shall be funded 40 to 50 percent by extra-budgetary sources.

Referred to such funding sources are the project directorate's authorized capital and credits of national and international commercial banks (during creation of the system), funds provided by the project directorate during normal operation of the system as results of services in the provision of monitoring and forecasting information made available to the federal and commercial organizations.

## BIBLIOGRAFY

1. Kiselev A.I., Medvedev A.A., Menshikov V.A. *Astronautics. Summary and prospects.* – Springer-Verlag Wien New York, 2003.
2. Menshikov V.A. Proposition concerning creation of international aerospace system for monitoring of global phenomena. *Acta Astronautica.* 2009. № 1.
3. Menshikov V.A., et al. Multiple Use of Earth Observation, Meteorological and Navigation Space Means for the Purposes of On-Line Monitoring of Natural Resources and Stationary and Mobile Objects. 57 International space congress. – Valencia, Spain, 2006.
4. Information about Global Earth Observation System of Systems (GEOSS). [www.epa.gov/GEOSS](http://www.epa.gov/GEOSS).
5. Information about Global Monitoring for Environment and Security (GMES). [www.gmes.info/](http://www.gmes.info/).
6. Information about «Sentinel Asia». [www.asiasentinel.com/index.php](http://www.asiasentinel.com/index.php).
7. Information about Disaster Monitoring Constellation (DMS). [www.pryroda.gov.ua/index.php.newsid](http://www.pryroda.gov.ua/index.php.newsid).
8. Information about International Charter “Space and Major Disasters”. [www.oosa.unvienna.org/pdf/reports/ac105\\_841R.pdf](http://www.oosa.unvienna.org/pdf/reports/ac105_841R.pdf).

INITIATION OF THE PROJECT TO CREATE AN INTERNATIONAL AEROSPACE  
SYSTEM FOR MONITORING OF GLOBAL GEOPHYSICAL PHENOMENA AND  
FORECASTING OF NATURAL AND MAN-CAUSED DISASTERS

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