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Space means of the Earth monitoring

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In the 20-th century the mankind was anxious about the threat of nuclear war which has hung above the Earth. In the 21-st century the threats to global safety were shifted toward the conglomerate of natural, technogenous, social factors. *(slide1).*

Safety's guarantees suggest identification of the state and dynamics of threat-bearing events and, hence, – the diagnostics and forecasting of crisis and extreme situations.

Now, under aegis of the United Nations and many international organizations, the programs of neutralizing natural disasters are implemented within the framework of the Integrated/International Global Observing Strategy (IGOS) and International Strategy Disaster Reduction (ISDR).

1. Space activity in the Earth remote sensing (ERS) area

Space means offer unique opportunities for diagnostics and monitoring of terrestrial objects and phenomena in the global scale, including natural and technogenous threats.

Space activity is directed at studying and utilizing the outer space, solving the tasks of acquisition and transportation of the information, energy, materials. In this case space means play a part of the shaper of information focused at maintaining the geosafety. *(slide2).*

In the geosafety respect, space means have played a historical role. The "space" rocket built in the Soviet Union, launching of the first Artificial Earth Satellite (AES) ("Sputnik") and delivery of a pendant to the Moon have stopped the nuclear aggression apologists. *(slide 3).*

At the present stage, the leading part in diagnostics of natural and technogenous threats from space belongs to the Earth remote sensing (ERS).

ERS represents an integrative process of satellite diagnostics, whose basis lies in the scientific knowledge of the Earth. The system approach, the space and new information technologies are basic ones for ERS. *(slide 4).*

ERS from space is applied to studying and monitoring of all terrestrial environments. The Earth monitoring includes observation, estimation and forecasting of: natural resources, the state of ground and water ecological systems, natural and anthropogenous emergency situations.

During space surveys the information on physical, chemical, biological, geometrical characteristics of observation objects in various Earth's environments is formed with using the functional dependences between them and measured parameters.

2. Technology of ERS from space

The measurement means, used for ERS from space, represent the satellites equipped with onboard instruments functioning in all accessible (for ERS) radio-frequency ranges: UV, VIS (B, Q, R), NIR, IR, TIR, MW with the spatial resolution from 10^{-1} to 10^{3} m *(slide 5)*.

Here, both passive and active sensing techniques are applied. In the first case the characteristics of reflected solar and Earth-generated electromagnetic radiation are measured. In the second case the source of target information is the flux of radio- and infrared emissions reflected from various observation objects.

The second technique possesses greater information capacity and, at the same time, it is rather complicated technologically.

ERS technology includes:

measurement of geometrical, energy, spectral characteristics of observation objects from satellite's board;

satellite video information transmission to ground reception and processing stations;

formation of an image, as a result of integration and transformation of radiation energy;

interdepartmental processing;

thematic processing. (*slide 6)*.

The algorithm of interdepartmental processing of ERS images includes:

spatial attribution from electronic maps and ground reference points;

archivation and generation of the electronic catalogue of ERS data;

obtaining multizonal maps for the given regions *(slide 7)*.

3. Geosafety threats diagnostics on the ERS basis

In the dangerous natural phenomena diagnostics, depending on the object, various geographical envelopes, as well as specific values of measured parameters (emission radio range, resolution on terrain, etc.) are used. The variety of dangerous natural phenomena includes:

geophysical dangerous phenomena (earthquakes, volcanic activity, tsunami);

geological dangerous phenomena (landslides, mud streams, avalanches);

hydrological dangerous phenomena (tropical cyclones, flooding, droughts, fires) (*slide 7)*.

Diagnostics of seismic danger forerunners is performed: in the lithosphere – from thermal anomalies; in the atmosphere – by tracing cloudy structures; in the ionosphere – from electromagnetic phenomena; in the heliosphere – from the Sun and solar corona. Here, the measuring instruments in the VIS, TIR, MW ranges are used with resolution on terrain of 10–500 м. (*slide 8)*.

The level of forest-fire danger is determined by the state of humidity of forest territory in the NIR (1.0–25), IR (3–5), TIR (8–14), as well as in the MW (3.0 and 30–50 cm) ranges. Zones of smoke blanketing from forest fires are determined in the VIS and TIR ranges. Atmospheric clouds are observed in both ranges, and smoke loops disappear in the IR-zone. Fumes from woods are distinguished in the ranges: 0.454–0.965; 2.08–2.35; 3.6–4.08 microns. High-temperature phenomena's emissions in the large forest fires (CO, CO_2, NOx, CH_4, aerosols) are analyzed with using the IR-spectrometer having resolution of 0.4 nm. The wood fund territory of Russia is zoned according to the ways of forest fires monitoring (ground-, air-, space-based monitoring). (*slide 9)*.

Diagnostics of such hydrological dangerous phenomena as shallowing and flooding is performed in the VIS, NIR TIR, MW ranges with resolution of 0.5–10 km in the atmosphere and in the NIR range with resolution of 10–300 m on land (*slide 10)*.

Of interest is the early diagnostics of tropical hurricanes motion. In the Science-Technological Center (STC) "Cosmonit" a complex of pioneer works was performed, which demonstrated a possibility of identifying intra-oceanic processes, including typhoons, by measuring the brightness temperature of the ocean surface at some radio frequencies and algorithmic processing of these data. *(slide 11)*.

In the respect of emergency situations neutralization, of high importance seems to be fighting against the narcotics. The "Cosmonit" STC developed a unique technology for detecting plantations of narcotic-containing plants with using space means. This technology is based on calculations of spectral characteristics of narcotic-containing and masking vegetation, as well as on pixel-by-pixel classification of a "space" picture with distinguishing narcotic-containing vegetation pixels and deciphering of area objects. (*slide 12*).

4. System approach in the ERS from space

As the practice testifies, the ERS process is productively explicated by functioning of a technogenous space system solving the ERS tasks and, in particular, monitoring of emergency situations (ES) and dangerous natural phenomena (DNP). This type of systems relates to the category of "complex systems" (CS) possessing attributes of integrity, purposefulness, acceptability, continuity, compatibility, autonomy.

The ERS productivity is achieved due to system's properties determined by the vector of its information, dynamic and system parameters.

A quite essential factor in developing the particular ERS CS is determination of its purposes and a boundary with environment. The presence of a purpose is an immanent property of any complex system. At the same time, the hypertrophied purpose represents a threat of destroying the system in its "life cycle", even in the presence of hierarchical structure.

Two versions of a structurally functional scheme of ERS complex system for ES and DNP monitoring take place.

In both versions the complex system incorporates two segments: orbital and ground-based ones. The first segment accomplishes generation and recording of the information; the second one – its reception and processing.

The first version suggests functioning of DNP monitoring CS as a part of some higher-level system on the basis of the information-analytical center (IAC) of DNP monitoring.
This system includes also a set of Terrestrial-based measuring devices (ground-, air-, sea-based ones).

In the second version the information source for diagnostics is the ERS CS's measuring means.

The first version is perspective for ES and DNP monitoring in global scales. The second version is expedient to be used in solving local and regional tasks of ES and DNP diagnostics. (*slide 13)*.

ERS data are received from space means and processed by numerous stations scattered all over the world. In Russia, the ground-based complex of ERS data reception, processing and distribution (NKPOR) is functioning, which covers the whole territory of the country. It is formed by territorially distributed departmental networks, as well as by the stations belonging to regional bodies and juridical persons.

Now, under the management of the Federal Hydrometereology and Environmental Monitoring Service, 3 stations with antenna aperture of 12 m and 100 small stations are functioning. The Ministry for Protection of the Environment and Natural Resources maintains seven stations, the Ministry for Emergency Situations – 10 stations.

The stations belonging to regional bodies and juridical persons (about 150 stations) are situated in Belgrade, Zelenograd, Irkutsk, Kaliningrad, Novokuznetsk, Reutov, Salda, Syktyvkar, St-Petersburg, Khanty-Mansiysk, Chita, Yuzhno-Sakhalinsk, etc. *(slide 14).*

The NKPOR stations are functioning within a wide radio-frequency range and, as a rule, are adapted to receiving and processing the data from various types of ERS satellites.

The NKPOR centers are equipped with sets of stations with aperture up to 12 m and carry out simultaneous data reception from several satellites located in the radio visibility zone. (*slide 15).*

5. Satellites applied for geosafety threats diagnostics

The orbital segment of the ERS space system is represented by the orbital systems of satellites. A quite essential requirement in the ES and DNP diagnostics is regular surveying of observation objects and operative data delivery for decision making. This is provided by the orbital system consisting of n satellites functioning for a long duration on solar-synchronous orbits, where $n > 1$.

ERS satellites are equipped with multi-spectral instruments of active and passive sensing of super high, high, mean and low spatial resolution.

According to their functional designation, ERS satellites are conventionally sub-divided into: hydrometeorological, Earth monitoring and detailed observation ones. The ES and DNP diagnostics tasks are solved, as a rule, jointly with the other ERS tasks.

The values of information and operational (dynamic and system) parameters of ERS satellites are determined by a circle of ERS target tasks including the diagnostics of certain types of ES and DNP.

The basic information, dynamic and system parameters include, respectively:

- resolution;	- efficiency;	- trustworthiness;
- observation band;	- regularity;	- reliability;
- spectral range;	- durability;	- accessibility;
	- global character;	- compatibility.

(*slide 16*).

Now (in 2010) the ERS orbital system incorporates about 130 satellites, 20 of which belonging to developing countries.

Hydrometeorological satellites are located on solar-synchronous and geostationary orbits and perform the atmosphere, ocean and land observations in the global scale. They are used also for diagnostics of emergency situations and for ecological purposes.

In the USA the operative space systems are continuously functioning: GOES on geostationary orbits, POES (since 1979) and DMSP (since 1999) on low orbits.

The meteorological “Metop-1” satellite is used in Europe since 2006.

In China the “Feng Yun” satellite meteorological system is functioning since 2005. The “Yaogan-6” ERS satellite was launched in April of 2009. The system of data transmission from the meteorological “Feng Yun-3A” satellite was actuated in October of 2009. In 2008 China launched, for the Earth monitoring, the optical-electronic ERS satellites HJ-1A and HJ-1B with resolution of 30 m and swath band of 720 km. The radar-tracking HJ-1C satellite joined them in 2009.

The second oceanologic Indian “Ocensat-2” satellite began functioning in 2009. In India the Resourcesat-series satellites are used for weather forecasting, searching for mineral resources, monitoring of crops, water resources, fishing trade areas, as well as for warning of emergency situations.

A considerable volume of the Earth monitoring data has been acquired since 2008 by the European orbital system consisting of six RapidEye mini-satellites carrying multi-spectral (6 ranges) optical-electronic instruments with resolution of 5 m and surveying band of 70 km.

With the purpose of ecological Earth monitoring, the MODIS spectrometer is used for global studies of aerosols. This instrument is installed on the American “Terra” and “Aqua” satellites. In 2009, with the task of measuring CO_2 and CH_4 concentration in the atmosphere, Japan launched into the solar-synchronous orbit the “Ibuki” satellite, which represents the first-in-the-world space researcher of greenhouse effect.

The data of high- and super-high spatial resolution from the American “Quick Bird”, “Ikonos”, “World View-1” (2007), “Geo Eye-1” (2008) satellites, as well as from the ERS satellites of France, India, Israel and Canada, are mostly demanded in the market now. Based on these data, the technology of complex representation of four-dimensional spatial information of various nature in a unified global medium is developed. (*slide 17*).

At the same time, the native Land of the first artificial satellite occurred to be at a humiliating state of full dependence on the foreign data in the ERS area. The share of Russia in the ERS data market equals less than 1%.

In Russia in September of 2009, after a long break, the meteorological “Meteor-M” satellite was put into orbit. A unitary launching of the “Meteor-M” satellite into orbit is an insufficient condition to make contribution into the global system of meteorological observations from space. The orbital system of identical satellites should be formed on the “Meteor-M” basis, or this satellite should have a common format of files with other system’s satellites. In addition, the instrument composition of “Meteor-M” concedes to foreign analogues in its characteristics. And only the microwave radiometer meets modern requirements.

In Russia the ERS satellites of high- and super-high resolution have been launched only sporadically. The "Monitor-E", "Resource-DK" satellites with optical-electronic instruments and the photo satellite of "Cobalt" series were launched in 2005, 2006 and 2008, respectively. At present, the "Resource-DK" satellite is functioning for the Earth monitoring purposes (*slide 18)*.

6. The global complex of ERS systems GEOSS

Space activity in the ERS area, including the geosafety threats diagnostics, is accomplished within the framework of national and regional programs, which are designed to coordinate the works on large-scale problems and include generation of one or several complex systems. In the given case the program can be considered as a certain meta-system.

Leading positions in this area are now hold by USA, France, Germany, India, China, Japan, Canada, Israel.

The National satellite systems for environment monitoring from the polar orbit are functioning in the USA – namely, the DMSP and NOAA systems. On their basis, the NPOESS system is produced, which includes: the DMSP satellites exploited now by USA's Ministry of Defense, domestic satellites NPOESS and the "Metop" satellites produced jointly with EUTMETSAT. In addition, the "WindSat/Coriolis", "Terra/EOS" and "AQUA/EOS" satellites are attracted to this system operation.

The most significant space programs of Earth observation are: the European program of monitoring and providing the Earth safety GMES, the Canadian space program on the RADARSAT satellites basis, the Japanese Earth observation program on the ADEOS satellites basis, the Indian Earth remote sensing system IRS.

At present, the project of the Global complex of GEOSS ERS systems is developed on the basis of regional programs with participation of 43 countries. This complex will incorporate developments of all countries in the basic thematic directions, such as: determination of chemical composition of the atmosphere and precipitation of deposits, sounding of the ocean, imaging of the Earth surface.

Supplying with the global multi-system information is supposed to be performed in the following key areas:

– Earth observation in the weather area (within the World Meteorological Organization framework);

– land, water, climate, ice cover and ocean observation in the direction of:

a) understanding of natural disasters by means of using the systems coordinated by the International Strategy for Disasters Reduction (ISDR);

b) climate investigation within the framework of the World Climate Research Program (WSRP) by means of the global system of climatic observations in support to VOOP and UNFCCC;

c) monitoring and modeling of the state of ocean by means of the Global Ocean Observation System (GOOS);

d) monitoring within the framework of the Integrated Global Observation Strategy Partnership (IGOS-P), including oceans, carbonic gas, water cycle, Earth's solid body processes (with an accent on geological dangers), coastal zone, chemistry of the atmosphere and the Earth/biosphere system. *(slide 19*).

In Russia the works on environment monitoring (ecological monitoring), including the diagnostics of emergency situations and dangerous natural phenomena, are legally registered by a series of directive documents:

The RF Government Decree of March 31, no. 177 authorized the Statute on organization and realization of the federal monitoring of environment (state ecological monitoring).

Within the framework of a Unified State Program, the system of prevention and liquidation of emergency situations in Russia accomplishes space monitoring of DNP and ES, whose designation is determined by the GOST R. 22.1.04-96.

The ecological monitoring tasks, including ES and DNP diagnostics with using space means, are solved fragmentarily by:

- the All-Russia center of monitoring and forecasting the emergency situations of natural and technogenous character of the Ministry for Emergency Situations of Russia;
- the Hydrometeorological Center of Russia;
- the means of the Central Base of Aviation Protection of Forests;
- the departmental and regional centers of ERS data reception and processing. *(slide 20).*

7. Conclusion

The science-technological stock, acquired by the world community in the space activity area, provides wide using of space means in the diagnostics of geosafety threats.