Chapter 5

Results of Scientific Research Obtained by Russian Scientists and Specialists during Implementation of Flight Scientific Programmes on Board of International Space Station

CONTENT

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This subsection provides information on the results of space experiments (SE) on the Earth exploration from space (EES) which were conducted on the RS ISS in 2016-2017: "Dubrava", "Napor-miniRSA", "Uragan", and "Scenariy".

5.1. SE «Dubrava»

Title: "Monitoring of forest ecosystems"

Leading organization: Mytishchi branch MSTU of N.E. Bauman (MGUL)

Purpose of the experiment: Development of methods for forest inventory, determination of natural and anthropogenic impacts on forest cover discovered from the ISS by usage of visual instrumentation and spectrometric monitoring and by usage hyperspectral and infrared equipment at subsequent stages of the experiment.

SE «Dubrava»was carried out during manned expedition in 2017 year. More than 1.95 GB of data volume were recorded. Preferable conditions for planning observations of land objects, except earlier stated, are defined. The possibilities of expansion of geography of observed objects of forest ecosystems, which takes into account existence of land information, were considered. In additions to observations of experienced Tellermanovsky forest area the sessions, based on use of the spectrometry equipment «Video Spectral System» (VSS) and photo cameras for observations of Emas (Brazil, woody savannas), Monteverde (The Canary Islands, the evergreen deciduous forests), Onkol (Chile, the Valdivsky woods) national parks, were held.

The evaluation of the obtained data quality for a possibility to decode pictures for tasks of SE was carried out. The majority of pictures have spatial resolutions and level of a cloudiness which do not allow to identify targeted objects. Images without such defects allow to preliminary describe forest canopy and to detect their borders (e.g. national park Onkol (Chile, the Valdivsky woods).

The object «Tellermanovsky forest area» in all sessions of observations was completely hidden by clouds. So, these data was not suitable neither for spectral analysis of stated objects, nor for lens adjustments.

SE «Dubrava» publications

1. Sanaev V.G., Stepanov I.M., Zaprudnov V.I. , Panferov V.I., Galkin Y.S., Burkov V.D. Accelerated innovation development of technologies aerospace monitoring of forest by means of the russian space systems sensing and displays them on the world leader : solution of the problem.// Forestry Bulletin. 2012. №4. pp.38-45.
2. Galkin U.S., Grankov A.G., Milshin A.A., Shmalenyuk A.S. Modeling radiowave weakening by the forest cover in the frame of the global model of land surface radioemission at L- and P- bands.// Леснойвестник. Forestry Bulletin. 2007. №2. pp.90-98.
3. Galkin Y.S., Shalaev V.S., Batyrev Y.P., Potapov V.N., Semenova V.P., EsenalievCh.D. Features of application forest inventory information at testing space pictures.// ForestryBulletin. 2010. №7. pp.37-39.
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5. Burkov V.D., Cheremisin M.V., Shalaev V.S. Application of remote sensing methods in the optical and microwave range on modeling stage of forest ecosystems.// Forestry Bulletin. 2011. №7. pp.41-50.
6. Burkov V.D., Leonov L.V., Cheremisin M.V., Shalaev V.S. Method of forestry monitoring based on remote sensing oriented selected.// ForestryBulletin. 2012. №4. pp.130-135.
7. Cheremisin M.V., V.D, Burkov. Aerospace forest monitoring using remote-oriented selected means optical and radar remote sensing.// Aerospace methods and gis–technologies in forestry and forest management: Proceedings of the V All-Russian Conference, dedicated to the memory of Vasily Iv. Sukhikh and Georgy N. Korovin. Moscow, Russia, April 22-24, 2013. –M. CEPF RAS, 2013. pp.221-223.
8. Cheremisin M.V., V.D, Burkov. Global monitoring of the woods by optical and microwave oven means of Remote sensing. // Collection of scientific articles of doctoral candidates and graduate students of MGUL. Publication № 357. 2012. pp.14-26.

5.2. SE «Napor-miniRSA» (SOT)

Title: «Experimental development of technology of a small-sized radar with a synthetic aperture based on microstrip active phased antenna arrays in the interests of solving environmental management problems, environmental control and emergency monitoring»

Leading organization: PAORSC «Energia»

Purpose of the experiment (for SOT): Development of a system of optical telescopes (SOT) for receiving and transferring the video images of the underlying Earth surface from service module to ground receiving stations via RSPI, including video images of test area recorded synchronously with radar observations, in interest of Russian and foreign organizations.

SOTequipment:

- monoblock of high resolution camera (HRC),
- monoblock of medium resolution camera MRC.

During manned expeditions in 2016 and2017SE«Napor-miniRSA» (SOT) included the following activities:

- observations of test sites RSC «Energia»,
- regular observations, terminated since February 2017 («UrtheCast» company.

Practical applications of SOT data are available only after Russian operator will start to work with SOT data, that was not implemented in reported period.

5.3. SE «Uragan»

Title: “Experimental development of a ground-space system for monitoring and forecasting the development of natural and anthropogenic disasters”

Leading organization: PAO RSC«Energia»

Purposes of the experiment:

- monitoring and recording the development of catastrophic phenomena from the RS ISS and developing the criteria for the classification and interpretation catastrophic phenomena features,
- obtaining new experimental data with the help of FSS scientific equipment for performing high-resolution spectral measurements of the underlying surfaces with spatial interpolation for scientific and practical use in the conditions of permanent development of the Earth remote sensing system,

- the development of technical means and methods for observing the Earth's surface from the RS ISS in conditions of real limitations caused by the ballistic conditions of the ISS flight, the crew's work and rest regime, crew time resources, weather conditions and illumination conditions in the surveying area.

During the manned expeditions of 2016 and 2017 SE «Uragan» was conducted in accordance with the programs of implementation of scientific and applied research, planned manned expeditions

SE «Uragan» tasks:

- carrying out visual observations of the underlying Earth's surface based on the raw data transmitted via radiograms, recording the processes of development of catastrophic phenomena using photo camera equipment,
- data recording with scientific equipment «Photo spectral system» (FSS) and «Video Spectral System» (VSS) in the sessions of observing the Earth's surface from the ISS RS,
- operative collection and transfer of information on catastrophic natural phenomena from the ISS to the Earth.

During the manned expeditions, the crew performed visual observations and survey of predetermined areas of the Earth with potentially dangerous manifestations of natural and anthropogenic character with photo equipment with different spatial resolution on the terrain.

The interaction with the participants of the experiment on realizing the operative information retrieval via the radio channel from the ISS RS was continued to estimate the size and nature of the fault caused by natural and anthropogenic disaster events with possible forecasting of the situation development.

The crew performed visual observations and made photo pictures of the specified regions of the Earth with full-color SLR digital cameras Nikon D4, Nikon D3X and Nikon D800 with an effective number of matrix pixels of 16 million, 24.5 million and 36 million, respectively. The maximum number of details, when surveying the earth's surface with the ISS RS, can be achieved using a Nikon D800 camera, an AF-S Nikkor 600mm f / 4 lens and Nikon TC-20E and Nikon TC-17E teleconverters giving a focal length of 1200 mm and 1000 mm respectively. In 2017, the delivery of a new SLR digital camera Nikon D5 was scheduled.

When shooting with digital cameras, the long-focus AF-S Nikkor 400mm and SIGMA AF 300-800 F / 5.6 lenses from the CSPE photographic equipment were also used.

The most of the photo images was not done in the nadir (not at the sub-satellite point), but at an inclined distance of 450-600 km. The maximum design resolution for the delivered photo equipment is 1.6 m / pixel. The maximum spatial resolution on the terrain is about 2 m. Shooting of objects was carried out through the nadir portholes No. 7-No. 9 CM by cosmonauts with hands, without using special technical equipment for fixing the camera.

At the request of the curator, the state of photographic equipment, which was used to perform visual instrumental observations, was monitored and analyzed on the ISS RS followed by the release of an appropriate reference-report on the status of cameras on the ISS RS.

Processing the results of the survey of the Earth's surface, obtained in the sessions of the experiment, was carried out on an experimental support computer - laptop RSK1 (Think Pad Lenovo T 61p). Copying from digital memory cards of the results obtained in SE sessions was performed on removable hard drives delivered for recording, storing and uploading the results of the experiment.

Laptop RSK2 (Think Pad Lenovo T 61p) also provided the exchange of service data between the ISS RS and TsUP-M and information support of the crew, including the rapid transfer of the results of the experiment via the radio information transmission system (RSPI). So, the operational transmission of the requested observation results was carried out via RSPI, in some cases via OCA.

To provide the crew on the ISS RS with additional data and visual information, the ballistic-navigational display of the flight environment «Sigma» developed by the specialists of RSC «Energia» was used to simulate the conditions for surveying the observation areas. On board the ISS RS, the “Sigma” program is installed on laptops RSK1 and RSK2. The program allows you to perform an operational calculation (forecast) of the transit time and visibility conditions from the ISS RS of a given area of the Earth's surface.

The results of the experiment, obtained in manned expeditions of 2016 and 2017, when carrying out the «Uragan» FE, were delivered to Earth on hard disks as part of the return cargo on the ships «Soyuz MS» and «Soyuz MS-02». The amount of delivered information exceeded 90 GB.

At present, taking into account the equipment onboard the ISS, during the flight, the Russian cosmonauts of the ISS crews perform visual observations, photo and spectrometric registration of specified regions of the Earth in accordance with

the observation program developed for Each expedition, and also taking into account operational tasks.

Below the examples of results of analysis of information obtained from potentially dangerous and catastrophic objects, objects of systematic monitoring [1] are revealed.

1) Lake Baikal

In the study of space images, annular structures with a diameter of 5-7 km were found on the surface of the ice cover of Lake Baikal. This natural phenomenon that occurs in certain years, is recorded when shooting in late March - early April and there are only a few weeks. Figure 5.1 shows a fragment of an annular structure on the surface of the ice cover of Lake Baikal in the stage of destruction, obtained on 08/04/2017.

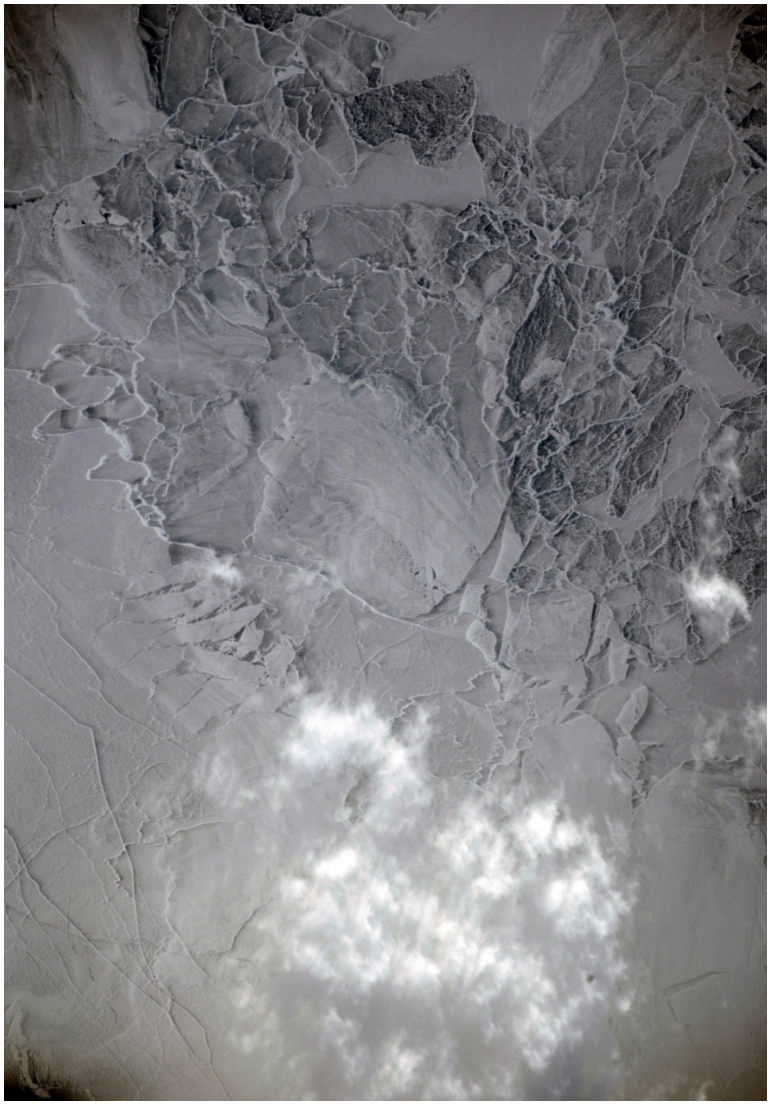

Figure 5.1 - A fragment of an annular structure on the surface of the ice cover of Lake Baikal in the stage of destruction 04/08/2017

2) Getting information about Russia's polluted cities

During the manned expeditions at 2016-2017 years the images of 23 ecologically polluted cities were obtained, the main contribution to the pollution of which is made by stationary sources. Figure 5.2 of March 1, 2017 shows an image of the Novolipetsk Iron and Steel Works and the city. On the opposite bank of the river is a metallurgical plant, which is the source of harmful compounds in the atmosphere of the regional center.

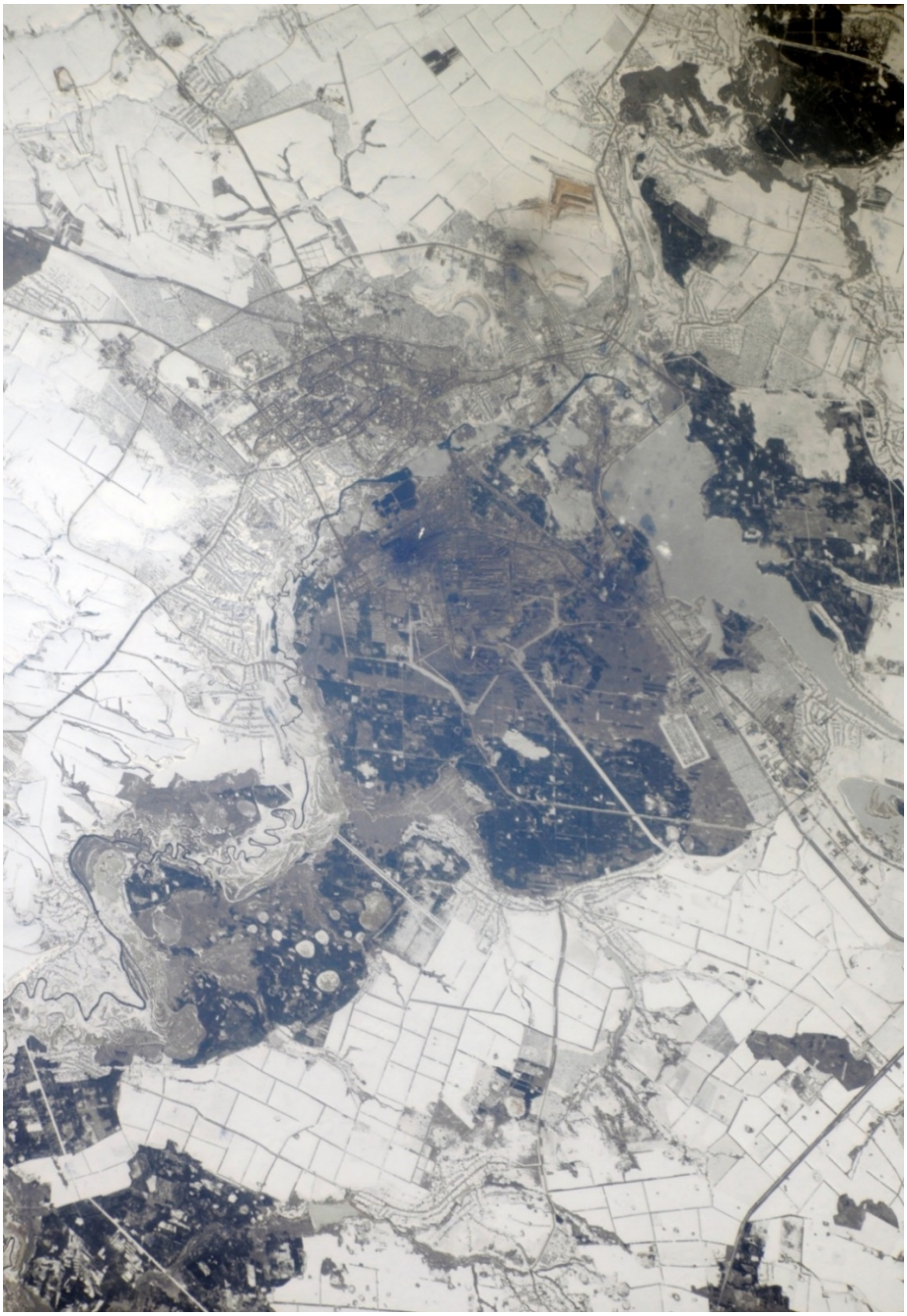

Figure 5.2 - Novolipetsk Metallurgical Combine and the city. (03/01/2017)

3) Aral sea

Monitoring the dried lake remains an important task of monitoring for each expedition of the ISS, because the future of the Aral sea remains a very acute problem.

In the spring of 2017, the most critical condition of the Aral Sea was recorded: in its western part, where the efforts of the international community, allocating funding in the form of grants to stabilize its drying, retained the last large volume of water. Due to the lowering of the water level, several islands appeared on its surface (see Figure 5.3). The flow through which small portions of water from the Syr Darya River flows into this part of the lake dried, and the dam practically blocked it.

Figure 5.3 –Aral sea. Several islands appeared on the surface due to the lowering of the water level. (03/12/2017)

SE «Uragan» publications

1. BeliayevM.Ju., Jurina O.A.The method for determining from a spacecraft the coordinates of a source of ring waves on a water surface// Application for invention № 2016114109 of 12.04.2016.

2. BeliayevM.Ju.,Rulev D.N.,Jurina O.A.Method for monitoring the movement of the glacier observed from the spacecraft // Application for invention № 2016125589 of 28.06.2016.
3. BeliayevM.Ju.,Rulev D.N.,Jurina O.A.Method for monitoring the position of the front of the glacier from a spacecraft in a near-circular orbit// Application for invention № 2016125591 of 28.06.2016.
4. BeliayevM.Ju.,Rulev D.N.,Jurina O.A.The method of observing terrestrial objects from a spacecraft moving along a circumterrestrial orbit// Application for invention № 2016125593 of 28.06.2016.

5.4. SE «Stsenariy»

Title: “Assessment of the development of catastrophic and potentially dangerous phenomena from the results of space observations”.

Leading organization: PAO RSC «Energia».

Purpose of the experiment: Elaboration of methods for assessing the development of catastrophic and potentially dangerous phenomena from the results of their observation from the ISS board by the remote sensing equipment.

SE «Stsenariy» tasks:

- Carrying out visual observations based on raw data transmitted from the Earth by radiograms, followed by registration of the development processes of catastrophic phenomenon using video-photo equipment,
- development of methods for monitoring potentially dangerous and catastrophic phenomena and environmental problems on the Earth's surface and evaluating their development from the RS ISS board in real conditions (including, if necessary, corrections of the orbit),
- obtaining experimental data of spectral measurements of the underlying surfaces of the study areas using scientific equipment «FSS» and «VSS».

The SE started implementation in the ISS50 expedition, which is revealed in the released express report on the SE «Stsenariy» [2]. During the expedition, visual observations were carried out on the initial data transmitted from the Earth in the form of radiograms. Monitoring and recording processes of development of catastrophic phenomena were carried out with the help of photographic equipment. The studies were carried out in accordance with the tasks of operational observations. The list of works carried out and the time spent by the crew during ISS50 are presented in Table 5.1.

Table5.1 - List of work performed and time spent by the crew during the ISS50

Date	Operations	Elapsed time
11.02.17	Observing forest fires in Chile	10
12.02.17	Observing forest fires in Chile	10
08.03.17	Observing forest fires in Russia and floods monitoring	10
10.03.17	Floods monitoring with use of photo equipment	10
11.03.17	Floods monitoring with use of photo equipment	10
29.03.17	Observations and photo registration. Talks with experts in the case of necessity	60

The total volume of information returned to Earth on HDD was 2.00 GB.

Raw data were received by PI and after preliminary processing they were transferred in accordance with the established procedure to the participant of the experiment at the Institute of Geography of the Russian Academy of Sciences for thematic scientific processing and geocoding of the received photo images.

SE «Stsenariy» publications

1. BeliayevM.Ju., Beliayev B.I., Sarmin E.E., Gusev V.F., Desinov L.V., Ivanov V.A., KrotJu.A., Martinov A.O.,Riazantsev V.V., Sosenko V.A.The device and flight tests of scientific equipment «Video Spectral System» onboard the RS ISS // Space Engineering and Technology, No. 2, 2016, pp.12-20.
2. BeliayevM.Ju., БоровихинП.А., KaravaevD.Ju., Rulev D.N., Riazantsev V.VOptimal planning of observations using mobile guidance platforms in the experiment «Hurricane» on the ISS // Materials of 51st Scientific readings in memory of K.E.Tsiolkovskiy, Kaluga, 2016, pp.91-92.
3. BeliayevM.Ju., Rulev D.N., Jurina O.A.Variant of the approach to the planning of observations of potentially dangerous glaciers on the Earth's surface from the side of the orbital station // Cosmonautics and Rocket Engineering,No.3, 2017, pp.107-115.

References

1. Express report on the space experiment « Experimental development of a ground-space system for monitoring and forecasting the development of natural and

anthropogenic disasters « for the period of expeditions ISS-49 and ISS-50. PAO RSC «Energia». 2017

2. Express report on the space experiment «Assessment of the development of catastrophic and potentially dangerous phenomena from the results of space observations» for the period of expedition ISS-50. PAO RSC «Energia». 2017