Ground-based experiments – Via ISS – to remote space

International science project

Stage One: SIRIUS-17

Moscow, 2018

IBMP management of project SIRIUS

Orlov Oleg Igorevich

IBMP Director, member of the Russian Academy of Sciences, MD.

Co-director of the project, Chair of the Russian steering committee and the Russian program committee.

Research and applied efforts are concentrated on advanced projects and clinical and physiological investigations related to the medical monitoring and care of space exploration crews.

Belakovsky Mark Samuilovich

Head of an IBMP department.

Director assistant; chief manager; vice-chair of the Russian steering committee.

Experienced in organization and conduction of major international projects in space medicine and biology.

Honored worker of the public health care of Russian Federation, laureate of Russian Federation Government prize of science and technique, full member of International Academy of Astronautics, full member of Russian Academy of Cosmonautics named after K. E. Tsiolkovskiy.

Demin Evgueni Pavlovich

Head of an IBMP department.

Technical director.

Expert in atmospheric gas generation and supply systems, safety and EVA suits, integrated life support systems testing. Winner of the Russian Federation Governmental prize in science and technology.

Suvorov Aleksander Vladimirovich

Head of an IBMP department; MD.

Principle investigator; vice-chair of the steering committee; vice-chair of the Russian Bioethics committee.

Expert in space, underwater and sport medicine. Corresponding member of the Russian Academy of Cosmonautics named after K.E. Tsiolkovsky, honoured space technology tester; has awards of the Russian government and Federation of cosmonautics.

Gushin Vadim Igorevich

Deputy Head of the Department of IBMP RAS, MD.

Co-chairman of the project program committee, head of the psycho-physiological section of the project program.

Specialist in the psychology of labor, social psychology and psychophysiology. Winner of the Russian Federation Governmental prize in science and technology.

Ponomarev Sergey Alexeevich

Head of the Laboratory of IBMP RAS, Candidate of Medical Sciences.

Scientific coordinator of the project.

Specialist in the field of space immunology. Member of the Russian Academy of Cosmonautics. K.E. Tsiolkovsky.

HRP NASA management of project SIRIUS

William Paloski, Ph.D.

Director, NASA HRP.

Co-director of the project

Leads the efforts on behalf of NASA to develop and deliver research findings, health countermeasures, and human systems technologies to support human spaceflight.

Expertise in the study of sensorimotor perforamnce of astronauts.

Leticia Vega, Ph.D.

Associate Chief Scientist, International Collaborations NASA HRP.

Leads all international activities betweeen HRP and the international scientific community

Expertise in the study of bacterial biofilms.

Lisa Spence

HRP US Project Manager, SIRIUS.
Responsible for mission planning for HRP science

Brandon Vessey, Ph.D.

HRP US Science Implementation Manager, SIRIUS.
Responsible for complement development of HRP science.

Igor Savelev, Ph.D.

HRP International Project Manager, SIRIUS.
Responsible for planning and implementation of HRP science in NEK during SIRIUS mission.

Igor Kofman

HRP International Science Manager, SIRIUS.
Responsible for integration and implementation of HRP science in NEK during SIRIUS mission.

About project SIRIUS

Humanity is standing at the threshold of a new stage in space exploration – departure from Earth's orbit to explore the nearest objects in the solar system, such as the Moon and Mars, with the prospect of building communities on these planetary bodies. The International Space Station (ISS) is the primary venue to study the impact of spaceflight on human health and performance; however some human health risks are better studied in analog environments which can mimic one or more aspects of spaceflight. It allows investigators to study certain risks associated with spaceflight in a controlled manner, develop countermeasures to that risk, then validate and implement those countermeasures on ISS and beyond.

One type of analog is known as an Isolated, Confined, and Controlled (ICC) analog. The crewmembers are physically isolated from and have limited communication to the outside world. This allows the crewmembers to feel as if they are in an actual spaceflight environment.

Risks studied in an ICC analog include:

- Changes in cognitive and behavioral health;
- Adverse team performance;
- Adverse physical heath and performance;
- In mission medical monitoring, and diagnostics;
- Inadequate food, potable water, and supplies.

These and other issues will be studied during the international project known as SIRIUS (Scientific International Research In Unique terrestrial Station) conducted cooperatively by the Russian SSC Institute of Biomedical Problems (RAS) and the NASA Human Research Program. Together, with partner-organizations and a broad participation of investigators from Russia, Germany, Italy, Japan, and other countries, the project will be implemented in a series of isolation campaigns with increasing length at the ground-based experimental complex (NEK) located at the Institute of Biomedical Problems (IBMP) in Moscow, Russia. The NEK is an analog platform with multifunctional segments that can accommodate three to 10 test subjects.

It is intended that the SIRIUS program will take up to five years. SIRIUS embodies the direction of the national space policy of the Russian Federation through 2030 and development prospects (approved by President of the Russian Federation on April 19, 2013, decree No. Pr- 906), drafted Russian piloted cosmonautics strategy up to 2050 (State corporation ROSCOSMOS, 2015) and the NASA strategic plan of sustained remote space exploration (NASA Transition Authorization Act of March, 2017). The SIRIUS program will build upon the knowledge gathered during the MARS-500 mission, as well as other ICC analogs from throughout the world regarding the medical and psychological risks humans may encounter during long duration missions. SIRIUS will seek to find ways for crews to thrive while living and working away from Earth for months or years.

Joint scientific analog studies are essential for the preparation of exploration missions in the future. Roscosmos and NASA signed a joint statement in 2017 reflecting on the common vision for human exploration. NASA plans to expand human presence into the solar system starting in the vicinity of the Moon using its new deep space exploration transportation systems. Exploration beyond low Earth orbit challenges humanity's current capabilities in human spaceflight and will benefit from engagement by the international community.

Stages of the project:

November 2017: 17 days (complete)
2018: 14 days (dry run)
2018-2019: 4 months
2019-2020: 8 months
2021-2022: 1 year

2023-2025: Additional one-year missions (tentative)

Stage one.
SIRIUS-17 (17-day isolation)

SIRIUS-17 was the first mission in the project and served as a test run for the longer duration missions. The objectives for SIRIUS-17 included: 1) identifying types of investigations most suitable for subsequent missions, 2) lessons learned from the integration of international science process of international participant and science integration, and 3) elaboration of the scientific data sharing protocols

SIRIUS -17 began November 7, 2017 and concluded on November 24, 2017. Forty-four (44) studies were completed during the 17-day mission. These included studies on behavioral health, physiology, cellular biology and microbiological investigations; a list of investigations is located at the end of this booklet. After completion of the SIRIUS-17 mission, the Russian and US sides noted, with appraisal the overall success as evidence of its significance for joint Russian-US scientific projects. Lessons from the mission will be used by both sides in the course of preparations for the four-month mission of six crewmembers scheduled to begin in late 2018. Missions with planned durations of 8 and 12 months will follow.

Next Stages.

Planning for the four-month mission has begun. The long-standing, comprehensive isolation studies of human health and performance completed in the USSR and Russia in preparation for long- duration space flights beyond low Earth orbit were largely focused on testing human operations. However, virtually neglected has been the behavior aspects of humans while in confinement and sensory deprivation, the conditions of which they spend their mission. This lack of integrated behavior studies was associated with the fact that these investigations were directed strictly at evaluating the professional readiness of the crewmember. Moreover, past pursuits of these objectives was complicated by an acute shortage of methods and equipment. The subsequent SIRIUS missions will focus heavily in this area of study. Current hardware and software technologies make possible full-scale analysis of mixed team behavior, physical and mental effects of prolonged exposure to confinement, sensory deprivation, monotony, and limited communication with the outside world. This also allows the development of countermeasures which can be validated in flight. The significance of this research cannot be overestimated in light of mixed crew missions and deployment of planetary outposts planned by the international space community

Medical-technical experimental facility scheme

Medical-technical facility of SSC RF – IBMP RAS is meant for simulation of conditions of life and activity of the crew, that are maximally close to the conditions of real spaceships, for support of conduction of the experiment simulating a space flight, including interplanetary one, with the duration of not fewer than 500 days with the crew consisting of 4-6 people.

The facility consists of several experimental units (EU) including:

1. Module EU-50.
Module EU-50 with the total volume of 50 m3 is meant for simulation of the landing Martian module with staying in it of 3 crew members during 2-3 months, and it includes:

- living quarter, that includes 3 berths and working zone;
- kitchen;
- lavatory;
- two transfer tunnels with hatches for passing into the module EU-150 and into the lock chamber of the simulator of the Martian surface;
- life support systems.

2. Module EU-100.
Module EU-100 with the total volume of 100 m3 is meant for conduction of medical and psychological experiments, and it includes:

- living quarter, including 2 berths and working zone;
- kitchen – dining-room;
- lavatory;
- working places with the installed medical equipment;
- transfer tunnel with hatches connected with the module EU-150;
- hermetical door at the end of the module and emergency hatch at the opposite end of the module;
- life support systems.

3. Module EU-150
Module EU-150 with the total volume of 150 m3 is meant for accommodation and living of 6 crew members, and it includes:

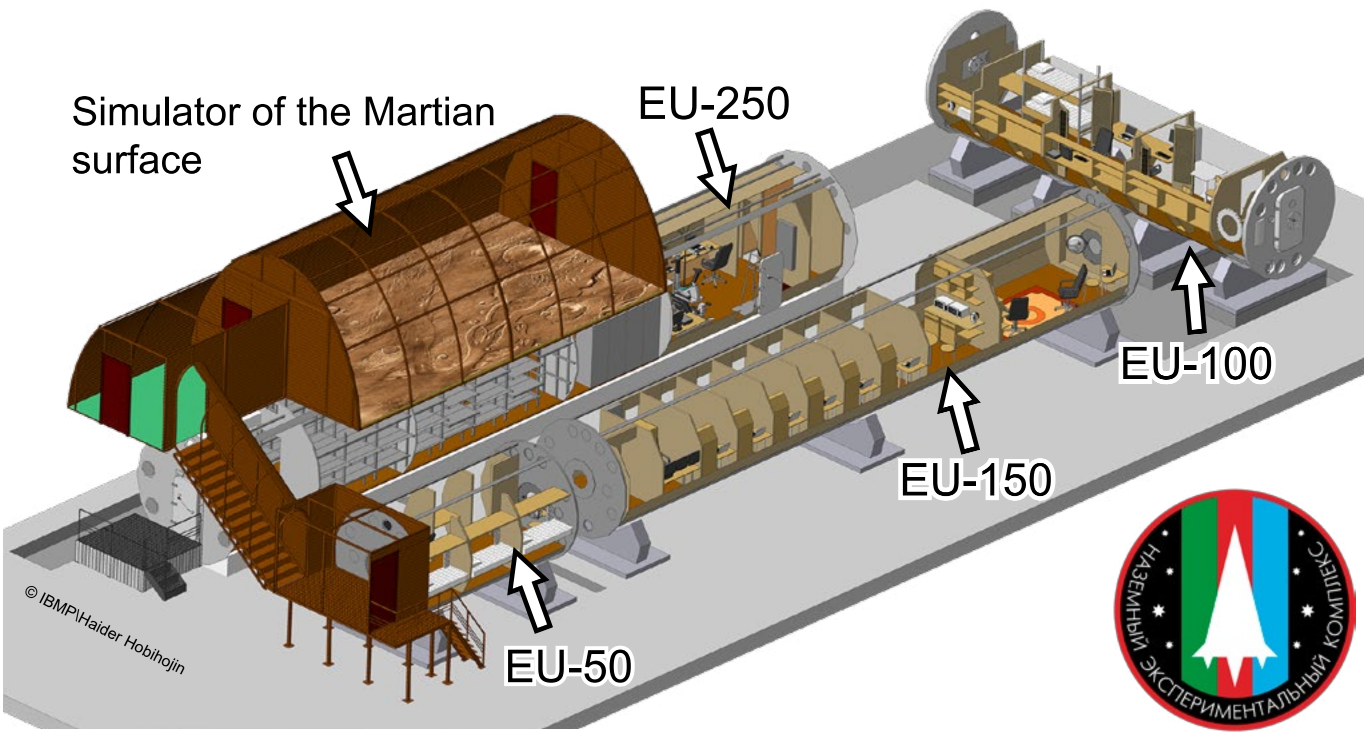
- 6 individual quarters;
- living-room for having rest and general gatherings;
- kitchen;
- lavatory;
- the main console;
- three transfer tunnels with hatches – end one for transfer into the module EU-50, end one for transfer into the module EU-100 and side one for transfer into the module EU-250;
- life support systems.

4. Module EU-250
Module EU-250 with the total volume of 250 m3 is meant for storing of food stores, installation of the experimental greenhouse, disposable plates and dishes, clothes, etc., it includes:

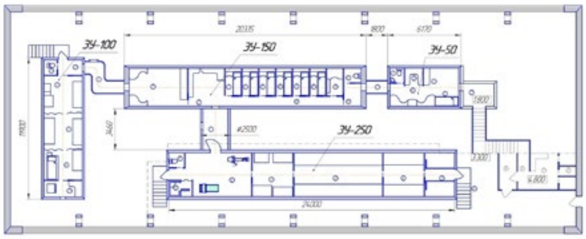
- freezer for storage of food products; ;
- store-place with shelves for storage of food stores that do not require special conditions of storage, and disposable plates and dishes, and clothes;
- room for experimental greenhouse;
- gym;
- lock chamber for giving away waste;
- three hermetical doors – one for connection of the module with the transfer tunnel into the module EU-150, two hermetical doors with metallic stairs at the ends of the module for pre-launch loading of food stores;
- life support systems.

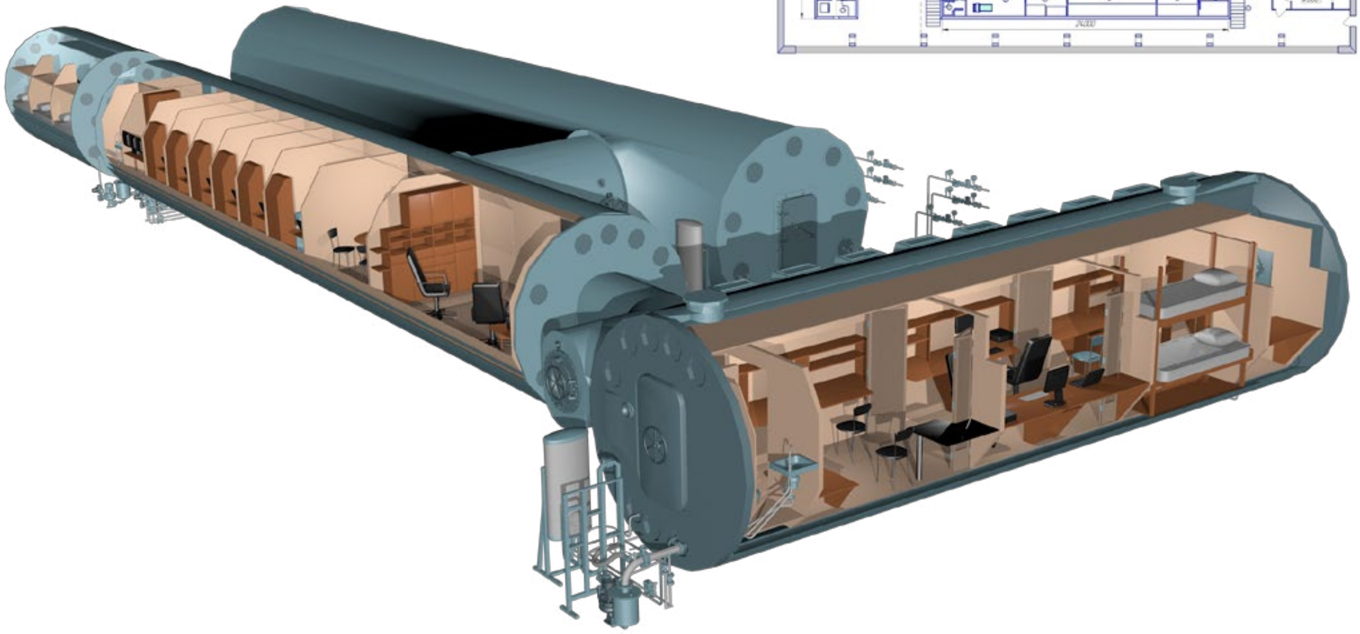
5. Module "Simulator of the Martian surface" (SMS)
Module SMS with the total volume of 1200 m3 is meant for simulation of the Martian surface, and it includes:
- simulator of the Martian surface that is a non-hermetical chamber meant for staying of the crew in space suits, isolating from the environment;
- hermetical stairs and caisson separating the SMS module from the module EU-50 and having storeroom for storage of the space suits, wardrobe and a transfer tunnel.

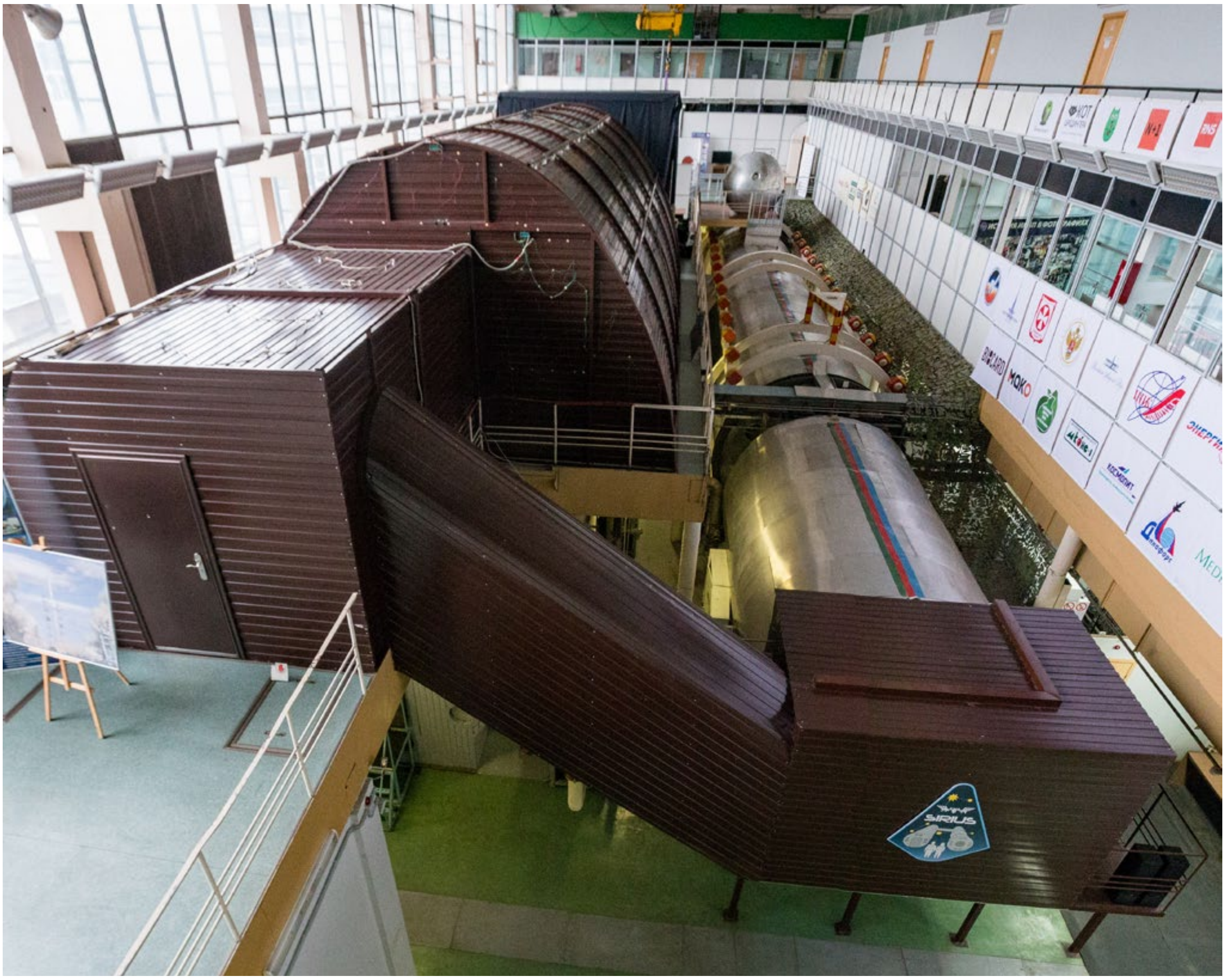
*EU - experimental units



In the 17-day experiment, two units were used – EU-100 and EU-150.

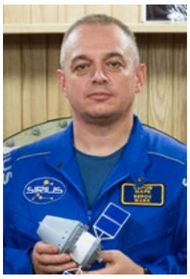






Crew members

Serov Mark Vyacheslavovich – Crew commander



Age: 45
Profession: engineer
Education and work history:
Graduated from the Aerospace Dept., Moscow Aviation Institute (MAI) in 1998. Also that year entered RSC-Energia first as an engineer of a planning division and then, since 2000, a planner of the MCC-M Chief Operational Control Group (GOGU).
On May 29, 2003 was approved by the Inter-departmental commission as a candidate to cosmonaut and on July 8, 2003 accepted to the RSC-Energia corps of cosmonauts. In 2005, finished the basic space training at GCTC with distinction; IDC gave him the qualification of a cosmonaut-investigator. Current position is the head of the Test-flight department, deputy director of the RSC-Energia Spaceflight Centre for advanced piloted complexes.

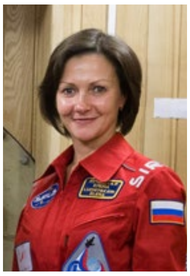
Kikina Anna Yurievna – Flight engineer-1

Age: 33
Profession: engineer
Education and work history:
Graduated with distinction from the Department of protection in emergencies of the Novosibirsk State Academy of water transport with the diploma of engineer-hydrotechnician (2006); graduated the Department of economics and management of enterprise (transport) of the Academy with the diploma of economist-manager (2008).
From 2008 till 2012, Program director of the Radio-Sibir-Altai, ltd. (Gorno-Altaisk, Republic of Altai). Applied to the first open cosmonauts' selection campaign in 2012 and was pronounced fit for training by the Chief medical commission (GMK).
In December of 2014 the Inter-departmental commission granted her the qualification of a test cosmonaut and moved to the position of GCTC test cosmonaut.

Viktor Fetter – Flight engineer-2

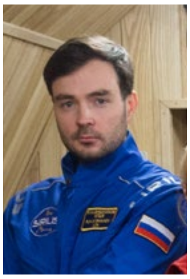
Age: 34
Profession: engineer
Nationality: Germany
Education and work history:
2000 - 2003 majored in mechatronics at Carl Zeiss-Oberkochen (Germany)
2007 - 2008 probation at EADS Astrium GmbH Space Transportation
2008 scientist at the Aalen University of applied sciences (Germany); functions: electronics development, manufacturing and testing.
2009 - 2013 system engineer in E-Nose project Phase C / D
2013 - 2014 system engineer in E-Nose project Phase E
Since 2013 Russia-contact manager of project Immunolab
Since 2015 manager for contacts with Russia (Glavkosmos, Energia-Sat, Progress, IBMP) on projects WISE and SAC (short-arm centrifuge). Since 2015, manager of project EDEN ISS (ground-based demonstration of plant growth technologies to be used in space flights for safe food production on the ISS and future space exploration vehicles and outposts).
Currently, manager of Airbus DS Life sciences and commercial projects.

Luchitskaya Elena Sergeevna – Investigator-1



Age: 37
Profession: physiologist
Education and work history:
In 2003 graduated with distinction the Vladimirsky State Pedagogical University and then took the graduate course to major in physiology. Defended a thesis and was awarded the degree of candidate of biological sciences in 2006.
Since 2005 a senior scientists at IBMP.
Investigator of ISS RS experiments Pneumocard and Sonocard (2007-2012) and, presently, Kardiovektor. Participated as an investigator in a parabolic flights campaign (France, 2014). Crew commander of the Moon-2015 project.
Participant in many Russian national and international congresses and conferences. Corresponding member of the International Academy of Astronautics since 2014.

Rukavishnikov Ilya Viacheslavovich – Crew physician



Age: 33
Profession: aerospace doctor
Education and work history:
In 2007 graduated with distinction the Department of general medicine at the Chuvash Ulianov State University.
In 2007 - 2008 was an intern surgeon at the Chuvash Republican clinical hospital in Cheboksary.
Since 2009, an IBMP scientist. In 2013 took the course of training in aerospace medicine.
Functions: development of means and methods of aid in emergency, medico-biological life support to space crews; medical member of the search-and-rescue team, medical surveillance of experiments with human subjects. Investigator of ISS RS experiments Motocard, Field Test, Algometry. Test-subject in an experiment with simulated effects of microgravity on human organism. Medical officer of Moon-2015.

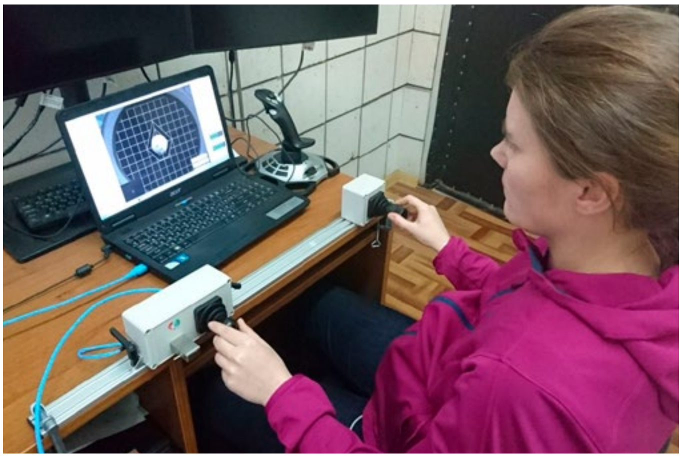
Lysova Nataliya Yurievna – Investigator-2

Age: 27
Profession: physiologist
Education and work history:
In 2012 graduated with distinction the Department of physical culture at the Moscow State Pedagogical University. Entered the graduate course at IBMP in 2012 and was awarded the degree of candidate of biological sciences in 2016.
Since 2011, works at the Laboratory of prophylaxis of the hypogravity-induced disorders as a scientist.
Functions: coaching the ISS cosmonauts, evaluation of cosmonauts' fitness level before and during space mission, surveillance of medical operations aimed at physical performance testing pre flight; consulting cosmonauts implementing in-flight experiment Prophilaktika-2 and post-flight experiment Locomotion, medico-biological evaluation of equipment developed for use in space research or ISS medical operations.
Candidate for participation in Moon-2015.
Application to the open selection to the Russian corpse of cosmonauts in 2017

Medical selection

Training in experimental procedures and baseline data collection



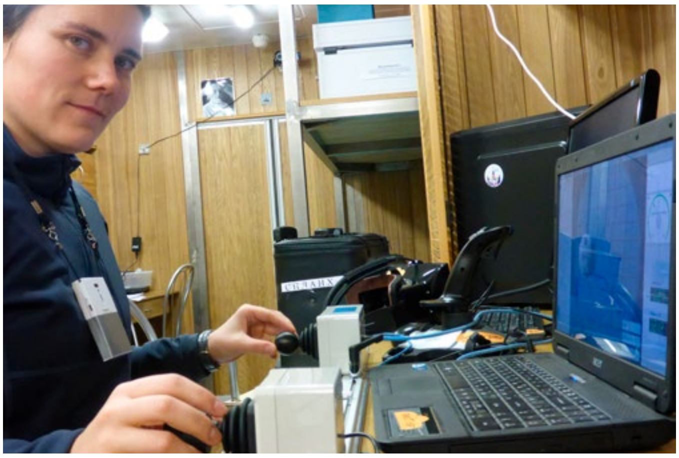





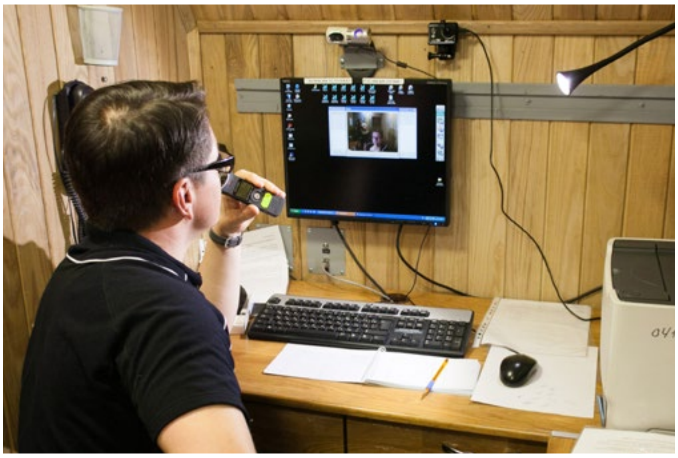
Start of the 17-day mission on November 7, 2017.
Press-conference and launch

Research activities during the mission

Research activities during the mission



Research activities during the mission

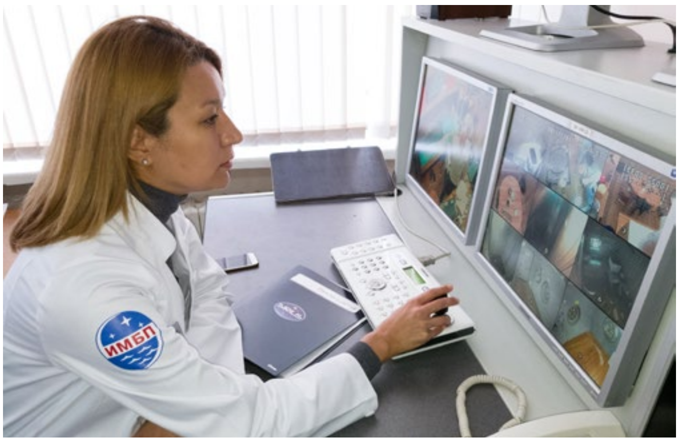


Telemedicine

Taking a meal

Recreation

Mission Control Center. Communication and interaction with the crew.



Completion of the 17-day mission of November 24, 2017

Most important lines of research during mission SIRIUS-17

1. Consolidated studies

1.1. **Human Factors and Behavioral Health Performance (HFBP). Behavioral Health and Performance (BHP) Standard Measures in NEK.** PI: Peter Roma (HRP NASA).

1.2. **Biomarkers as Predictors of Resiliency and Susceptibility to Stress in Space Flight.** PI: N. Goel (University of Pennsylvania).

1.3. **Research of the influence of dynamics of neurohormonal regulation of metabolism and typological features of the initial psychophysiological status on features of adaptive reactions of the human organism in short-term confinement in hermetic chambers in the conditions adequate to the inhabitancy of the International Space Station.**
PI: I.Nichiporuk, T.Juravleva (IBMP)

1.4.**Study of lipid peroxidation biomarkers in breath gas of healthy human during physiological adaptation to conditions of isolation, with biological-technical testing of analytical instruments for monitoring of biomarkers and environmental air at the conditions of space flight.**
PI: L.Muhamedieva, D.Tsarkov (IBMP)

1.5. **Complex assessment of the operator's neurophysiological and psychophysiological characteristics dynamics in the process of skills improving of simulated professional activity in isolation conditions.**
PI: T.Kotrovskaya, D.Schastlivtseva (IBMP), Co-executors: B. Johannes (DLR Institute of Aerospace Medicine Space Physiology, Germany), F. Fischer (Space Bit GmbH, Germany).

1.6. **Study of daily motor activity and sleep quality of the crew members in order to predict the operator's psychophysiological state and performance.**
PI: V.Gushin, D. Shved (IBMP), Co-executors: I. Waitly, (University College London, United Kingdom); X-W. Baltser (Chronomar GmbH, Germany), B. Johannes (DLR, Germany).

2. Psychological and psychophysiological studies

2.1. **Habitability Assessment of NEK. Photo, Videos, Task.**
PI: M. Greene (HRP NASA)

2.2. **Psychological support of crews in conditions of high autonomy.**
PI: O. Karpova, K. Potapova (IBMP)

2.3. **Psychological stability and adaptation in an isolated small group under simulated extreme conditions of extended spaceflight.**
PI: A.Vinohodova, P.Kuznetsova, G.Vasileva (IBMP), I.Sholcova (Institute of psychology of the Academy of Sciences of the Czech Republic), K.Tafforen, (Ethospace, France)

2.4. **Chronotype, interhemispheric asymmetry and adaptation to stress.**
PI: O.Karpova, M.Zakrujnaya (IBMP)

2.5. **Study of oral and written communication of the crew with Mission Control Center in order to assess the psychophysiological state of the crew members and the effectiveness of intergroup interaction**
PI: V.Gushin, D. Shved, (IBMP), Co-executors: I. Waitly, (University College London, United Kingdom) B. Jehmann (Natural Sciences Research Center of the Hungarian Academy of Sciences), A.Kolodzhejchik (Association of Nova Astronomy, Poland)

2.6. **Interpersonal interactions, communications and group effectiveness under simulated extreme conditions of extended spaceflight.**
PI: V.Gushin, A. Vinokhodova, (IBMP), Co-executors: K. Bernardova (QEDGroup, Czech Republic)

3. Physiological studies

3.1. **Human Health Countermeasures (HHC). ISS FIT (Food Intake Tracker).**
PI: Sara R. Zwart, CoPI: I.Savelev, I.Kofman (HRP NASA).

3.2. **Psychophysiology and physiology of the visual sensory system in the international**

isolation experiment.
PI: V.Neroev, M. Zueva (Moscow Institute of Eye Illnesses, Russia), O.Manko (IBMP).

3.3. **Dynamic complex assessment of the effect of the isolation factors of the hermetic object on the psychophysiological functions of vision.**
PI: G.Rojkova, S. Rychkova, O. Manko.

3.4. **Study of pain sensitivity in humans in conditions of prolonged isolation.**
PI: A. Polyakov, I.Rukovoshnikov (IBMP).

3.5. **Investigation of the isolation factors' effect on the myocardium electrophysiological properties and their relationship with the autonomic regulation of blood circulation.**
PI: R.Baevskiy, V.Rusanov (IBMP).

3.6. **Investigation of the cardiovascular system adaptation processes and its regulatory mechanisms at night to isolation conditions.**
PI: I.Funtova, E.Luchitskaya (IBMP).

3.7. **Studying the dynamics of adaptive reserves of the body and the functional conditions of the cardiovascular system in isolation.**
PI: F.Chernikova, O.Isaeva (IBMP).

3.8. **The study of microcirculation via laser Doppler flowmetry and computer capillaroscopy.** PI: A.Phedorovich, A.Pamova (IBMP).

3.9. **Features of the pattern of breathing and the dynamics of the vegetative Kerdo index in a healthy person during day and night hours in isolation.**
PI: A.Suvorov, F.Demin (IBMP), I.Fietze (Charité, Germany).

3.10. **Lung volumes and forced respiratory parameters in isolation.**
PI: A.Suvorov, R.Zaripov (IBMP).

3.11. **Study of ventilation and respiratory exchange while resting and during physical exercise.**
PI: A.Suvorov, I.Rujychko (IBMP) .

3.12. **Assessment of the ventilation sensitivity of the respiratory center before and after isolation.** PI: Yu.Shulagin, E.Ermolaev (IBMP).

3.13. **Evaluation of the countermeasure efficacy of physical training in conditions of reduced level of physical activity.**
PI: E.Fomina, K.Uskov (IBMP).

3.14. **Countermeasure of reduction in mental health by means of physical training in conditions of isolation taking into account the volunteers' individual-typological features.**
PI: E.Fomina, A.Savinkina (IBMP)

3.15. **Testing of methods of space experiment SPLANCH and study of the state of digestive system and circadian rhythms of electrical activity of the gastrointestinal tract.**
PI: B.Afonin, E.Sedova (IBMP).

3.16. **Evaluation of human cardiovascular system reactions, in particular cardiac contractility, using seismocardiogram (SCG) analysis based on high-frequency 3-dimensional precordial accelerometry in response to simulated prolonged isolation.**
PI: R.Baevskiy, E.Bersenev (IBMP).

4. Immunity, metabolic, biochemical and genetic studies

4.1. **The influence of the short-term isolation on the signaling pathways of pattern-recognition receptors of the human innate immune cells.**
PI: S.Ponomarev, A.Sedova (IBMP).

4.2. **Effect of the exercise on the immune status of the volunteers before and after short-term isolation in a chamber, taking into account individual-typological characteristics of the volunteers.**
PI: S.Ponomarev, S.Kalinin (IBMP).

4.3. **Influence of the sleep deprivation and increased emotional burden on the state of innate and adaptive immune system of humans in the conditions of short-term isolation in the chamber.** PI: S.Ponomarev, M.Rykova (IBMP).

4.4. **The influence of the short-term isolation in a chamber on the phenotypic**

characteristics of dendritic cells generated from the monocytes of peripheral human blood.
PI: S.Ponomarev, O.Kutko (IBMP).

4.5. **Investigation of metabolic reactions in volunteers during short-term isolation in the hermetic chamber.**
PI: A. Markin, O.Juravleva (IBMP).

4.6. **Predictive diagnostic of distress in organism based on changes in the extracellular DNA characteristics.**
PI: S. Kostiuk, E.Ershova (Medical genetics research center, Russia), P.Umrihin (Research Institute of Normal Physiology by P.K. Anokhin).

4.7 **Study of the hemostasis system reactions in volunteers during short-term isolation in the hermetic chamber.**
PI: D. Kuzichkin, A.Markin (IBMP).

4.8. **Investigation of morpho-biochemical parameters of erythrocytes and the hemoglobin hemoporphyrin state in short-term isolation in a hermetically sealed environment.**
PI: S. Ivanova, N.Anisimov (IBMP).

4.9. **Investigation of the dynamics of some biochemical markers and nucleic acids as predictors of pathological processes in conditions of isolation in chamber.**
PI: P.Ogurcov, A.Polyakov, A.Niyazov (IBMP).

4.10. **Blood gases and acid-base balance in humans under isolation exposure.**
PI: A.Suvorov, Yu. Popova (IBMP).

4.11. **Study of the state of bone tissue, kidney function and water-electrolyte homeostasis in the subjects staying in short-term isolation in a pressurized compartment (17 days).**
PI: G.Vassilieva, V.Novikov (IBMP).

5. Sanitary-hygienic and micro-biological research

5.1. **Study of the physiology of the dentoalveolar system of operators and means of infections prevention.**
PI: V. Ilyin, N.Usanova (IBMP).

5.2. **Application of an artificial analogue of the nasal secretion for the prevention of dysbacteriosis of the upper respiratory tract of a person in conditions of prolonged isolation.**
PI: V. Ilyin, N.Usanova (IBMP)

5.3. **Remineralizing effect on hard tooth tissues of the two-component complex Remarsgel.**
PI: S. Kholodov, V.Kapitonov (Dental Space Clinic, Russia).

6. Telemedicine

6.1. **Video analysis and recordings of the talks team members in the NEK.**
PI: A.Polyakov, S.Pozdnyakov, S.Kantemiriva (IBMP).

6.2. **Evaluation of efficiency of automated orientation in means and methods of medical assistance on board of the hermetically closed object.**
PI: O.Perevedencev, R.Chernogorov (IBMP).

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The authors:
Belakovsky M.S. (IBMP RAS), Voloshin O.V. (IBMP RAS),
Suvorov A.V. (IBMP RAS)

Contacts

State Scientific Center of the Russian Federation Institute of Biomedical Problems of the Russian Academy of Sciences (SSC RF – IBMP RAS)

Russia, 123007, Moscow,
Khoroshevskoye shosse, 76a

Tel.: +7 (499) 195-1500
Fax: +7 (499) 195-2253
E-mail: info@imbp.ru, pressimbp@gmail.com

«SIRIUS» project

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