Ground-based experiments – Via ISS – to deep space

International science project

SIRIUS

Stage three

SIRIUS-21

Moscow, 2022 г.

SIRIUS project management – IBMP RAS

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About «SIRIUS» project

Institute of Biomedical Problems of the Russian Academy of Sciences and the NASA Human Research Program (HRP) both conduct research to develop preventive measures and technologies to protect the health of astronauts and cosmonauts in a space flight. Based on this common goal, and taking into account the history of successful joint cooperation, IBMP RAS and NASA HRP have united the efforts of both organizations and interested international partners to conduct critical research for future human space exploration.

Going beyond the Earth's orbit and conducting manned studies of the nearest space objects in the Solar System (with the prospect of creating extraterrestrial orbital stations and planetary bases) is a new stage of human space exploration that requires solving a wide range of technical, physiological and psychological problems that the crew may face during the mission.

In order to solve the problems and to reduce the risks in interplanetary space missions, IBMP RAS and NASA HRP have decided to jointly use the controlled isolated environment of the IBMP's Medical and Technical Ground-Based Experimental Facility (NEK), and have organized the large-scale international isolation project called "SIRIUS" (Scientific International Research In Unique terrestrial Station) which includes a series of several joint scientific model experiments lasting 17, 120, 240 and 360 days.

Project Goals

The SIRIUS Project program is designed for a period of up to five years. It was developed on the basis of the main provisions of the draft Strategies of Russian Manned Cosmonautics for the period up to 2050 (ROSCOSMOS State Corporation, 2015) and NASA's Strategy for further deep space exploration and work program for the coming years (National Aeronautics and Space Administration Transition Authorization Act approved by the USA Congress, March 2017). The program is a continuation of the studies started within the Mars-500 Project, with the focus on medical and psychological risks during long-term autonomous manned space missions and the operation of orbital and planetary bases. The complex nature of the research conducted inside the isolated chambers of the Ground-Based Experimental Facility allows to address a number of psychological, physiological, medical-sanitary and ergonomic aspects of interplanetary missions that are crucial for planning.

General scenario

The concept of the proposed scenario is based on modeling the medical and psychological effects of the main significant events characteristic for long-duration missions performed by international crews. These include:

1. Long-term absence of resupply, limited resources and the resulting partial autonomy of the mission paired with a periodical search for the necessary logistics resources located outside of the established storages.
2. Regular and lengthy extravehicular activities accompanied by significant physical load and night work.
3. Performing professional activities that require mobilization of cognitive functions and complex motor skills after prolonged exposure to space flight factors (including isolation, monotony, inactivity, etc.). Docking with supply ships arriving at the station. Testing of robotic vehicles remote control skills, including operation with a time delay.
4. The problems of intra-group interaction and leadership in a cross-cultural crew in the conditions of a prolonged stay in a habitat with limited volume (crowding, sensory deprivation, monotony, imposition of contacts, etc.).
5. Changes in the volume and content of the crew's communication with the Mission Control Center and external communicants via audio and computer networks due to the group dynamics of the crew, the problems of intergroup interaction, as well as the changes in the psychophysiological status of cosmonauts.
6. Gender-mixed crews.
7. Performing joint international experiments with close interaction between the testers.

Stages of the project:

2017: 17 days (completed)

2019: 4 months (completed)

2020-2021: 8 months (completed)

2021-2022: 12 months

2023-2025: possible additional annual missions

Stage III

SIRIUS-21 (240-day isolation experiment)

SIRIUS-21 – was an 8-month experiment conducted inside the Ground-Based Experimental Facility (NEK) of IBMP RAS in Moscow. The international crew included three women and three men: crew commander, flight engineer, flight surgeon and three researchers.

SIRIUS-21 Scenario

The SIRIUS-21 mission scenario is based on the simulation of a long-term lunar mission and includes testing of the elements of a manned expedition to remote space objects.

The scenario seeks to simulate:

- classic negative factors typical for a space mission and/or a hermetic chamber experiment: sensory deprivation, monotony, restriction of social contacts, limited living space and controlled habitat;
- autonomous interplanetary mission factors, including limited resources and extravehicular activities on the surface of a planet;
- space crew's professional activities, such as docking of transport ships, landing of the lunar module and operating robots;
- communication delay of up to 5 minutes in one direction;
- crew composition mixed by gender and nationality;
- implementation of joint international experiments in close cooperation with the developers and directors of research;
- working out of emergency situations.

Mission stages

Mission Day 1. Crew ingress and launch to the low-Earth orbit.

Mission Day 2 - 4. "Docking" with the interplanetary station is carried out, the crew ingresses the station and tests it for operability.

Mission Day 5 - 8. Launch to lunar orbit and docking with the orbital station.

Mission Day 9 - 60. The crew performs regular operations to prepare the lunar lander, practice EVA elements and operates robotic vehicles on the Moon surface.

55 days after the start of the mission, a resupply vehicle pre-positioned in the lunar orbit docks to the station, and the crew transfers the cargo.

Mission Day 61 - 65. The first lunar EVA. The crew is divided into two groups: the landing crew of four people (two men and two women) and the orbital crew of two people. The four descend to the lunar surface, where for 4 days they perform 2 one-hour lunar EVA sessions in pairs (two EVAs for each pair). Each EVA involves walking on the lunar surface in a space suit using VR technologies. During the expedition, the crewmembers collect soil samples and operate a lunar rover model.

In the meantime, the orbital crew of two continues to carry out the flight program and provide technical assistance and support to their crewmates in the landing module. In addition, they operate robotic vehicles (RTS) on the surface.

Mission Day 66 - 121. The lander ascends from the lunar surface and docks with the orbital station. The 6-person crew performs the flight program (including RTS control) and analyzes the samples collected from the surface.

Mission Day 115. The second (final) pre-positioned resupply vehicle docks to the station and the crew performs cargo transfer operations.

Mission Day 122 - 126. Second lunar EVA. A different two-person orbital crew stays on the station this time.

Mission Day 127 - 189. Departure from the Moon and docking with the orbiter. The re-united crew continues to perform the orbital flight program, operate robotic equipment, and analyze data and samples.

Mission Day 190-194. Third (final) lunar EVA with another two-person orbital crew.

Mission Day 195-236. Departure from the Moon and docking with the orbiter. The re-united crew continues to perform the orbital flight program, operate robotic equipment, and analyze data and samples.

Mission Day 237 - 240. Return to Earth. The interplanetary spaceship reaches the Earth's orbit within three days, after which the lander undocks and lands within a day.

Medical-technical experimental facility scheme

The Ground-Based Experimental Facility of the IBMP RAS was designed for simulation of the life conditions and crew activities that are maximally close to real spaceships; as well as for support of experiments simulating space missions, including interplanetary ones, with the duration of 500 days or more and crews 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 m^3 is meant for simulation of the landing Martian module with a capacity of four crewmembers during 2-3 months, and it includes:

- living quarter, that includes four 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 m^3 is meant for conduction of medical and psychological experiments, and it includes:

- living quarter, including two 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 m^3 is meant for accommodation and living of six crew members, and it includes:

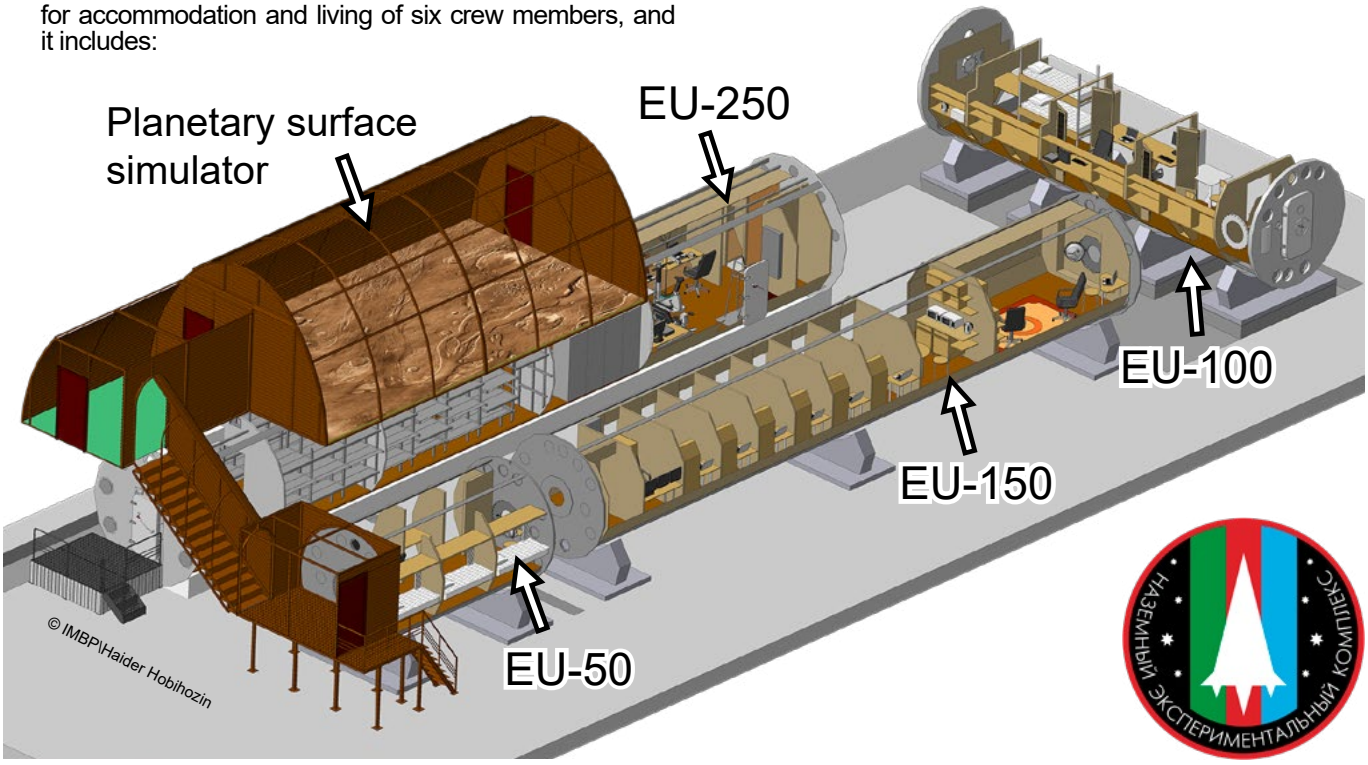
- six individual quarters;
- living-room for having rest and general gatherings;
- kitchen;
- lavatory;
- the main console;
- three transfer tunnels with hatches – end one for transfer into the module EU-50, end one for transfer into the module EU-100 and side one for transfer into the module EU-250;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

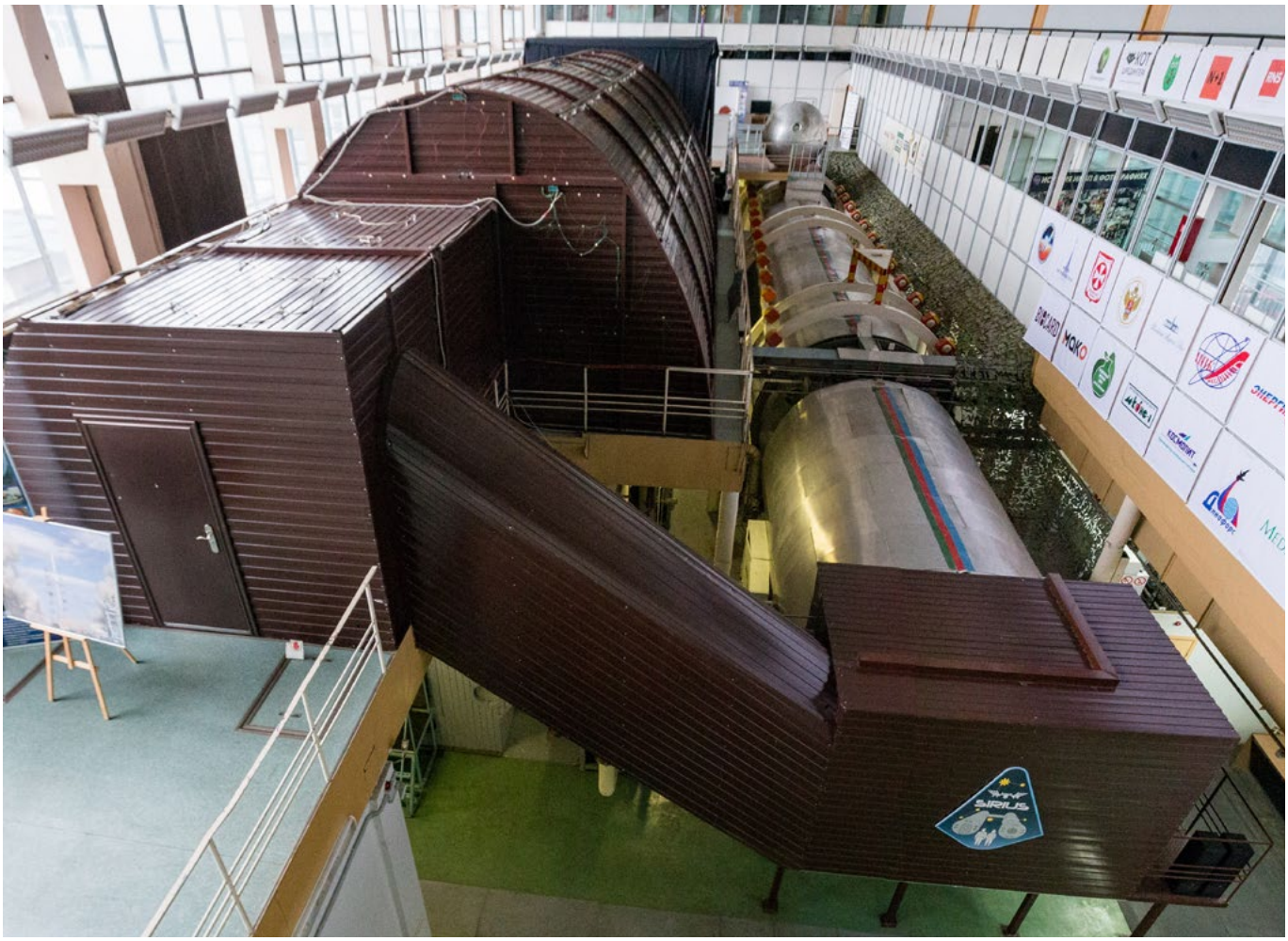
4. Module EU-250
Module EU-250 with the total volume of 250 m^3 is meant for storing of food stores, installation of the experimental greenhouse, disposable plates and dishes, clothes, etc., it includes:

- 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 "Planetary surface simulator" (PSS)
Module PSS with the total volume of 1200 m^3 is meant for simulation of planet surface, and it includes:
- simulator of planet surface that is a non-hermetical chamber meant for staying of the crew in space suits, isolating from the environment;
- non-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





The virtual reality system at the “Planet Surface Simulator” module

The extravehicular activity (EVA) simulation is one of the key elements of the mission scenario. It allows to reproduce some elements of a real space crew’s professional activities, and is also important to counteract monotony during prolonged isolation.

In SIRIUS-21, several tasks were performed during the EVA. The most significant ones include:

- the simulation of the Lunar landing and the execution of a modified “Field Test” program, that aims to evaluate the accuracy of motions in a virtual environment;
- the simulation of walking, running and jumping on the Lunar surface in low-gravity conditions;
- operator activities at the “Rover’ stand (operating a planetary vehicle simulator) in the conditions of reduced gravity.

Unlike wearable computers in SIRIUS-19, wireless video signal transmitters for VR helmets were used for the EVA in SIRIUS-21. This made it possible to create a virtual environment with maximum immersion, without the need for pre-start calibration or connecting wired interfaces between the helmet and the computer, and also enabled the participants to move freely around the site.

When simulating the test subjects’ motions around the Lunar surface, a special stand developed at the IBMP RAS is used to simulate the low-gravity effect. The stand is equipped with a system of dynamic suspension and a special suit for the legs and torso that distributes the load from the cable suspension system in the most comfortable way.

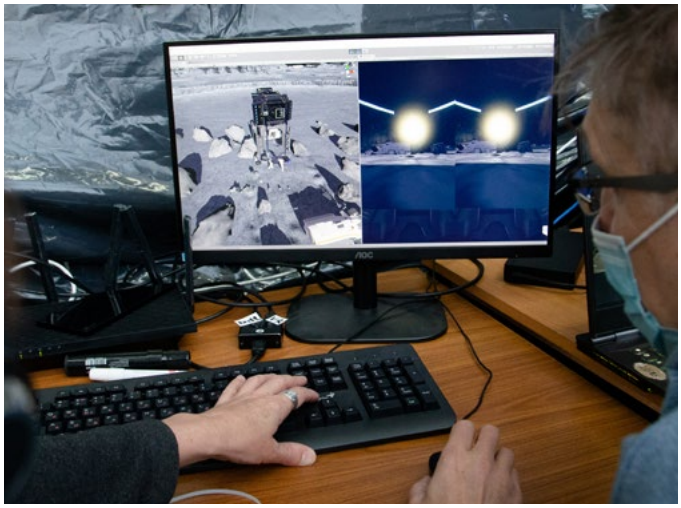
The “Rover” stand offers a range of tasks of various complexity with the choice of speed, trajectory and the number of obstacles to get over. Any actions taken by the test subjects will affect the task completion time and the number of occurring breakdowns and additional tests. The data analysis allows to evaluate both the effectiveness of performing the task and the personal psychological features of a participant.

To simulate the rover operation in the conditions of Lunar gravity, a system of dynamic hands suspension was installed on the stand, also developed by the IBMP RAS.

The used hardware and software system provides for maximum immersion into a complex technical environment, full-fledged interaction of astronauts with interactive objects during the EVAs (both individually and as part of crews), and training and research in the virtual reality.

Training on the virtual Moon prior to the start of the SIRIUS-21 experiment


ИМБП



SIRIUS-21 Crewmembers

Oleg Blinov – Crew Commander

Russia

Employment: Head of the department for design of complex simulators of promising transport spaceships at the Yu. A. Gagarin Cosmonaut Training Center.

Education: Kirov Military Aviation Technical School, Vyatka State Agricultural Academy, Master's degree at the Moscow Aviation Institute (National Research University).

From 2012 to 2016, he was a member of the ROSCOSMOS cosmonaut corps. At the Mission Control Center (Korolev, Russia), he supported the cosmonauts' extravehicular activities as an airlocking specialist.

Ashley Kowalski – Flight Engineer

USA

Employment: Project Manager of the Global Partnership Department of the Aerospace Corporation, a representative of the US Space Systems Command.

Education: Bachelor's and Master's degrees in Mechanical Engineering and Aerospace Engineering from George Washington University.

Ashley has experience as an analyst and a technical specialist in the development of the architecture of various space systems. She has participated in a number of joint space programs in Russia, Germany and China.

Victoria Kirichenko – Flight Physician

Russia

Employment: surgeon, Junior Researcher at the Department of Operational Management of Medical Support for Space Flights at the IBMP RAS.

Education: N. I. Pirogov Russian National Research Medical University, I. M. Sechenov First Moscow State Medical University, postgraduate course at the IBMP RAS.

William Brown – Researcher

USA

Employment: William has experience in various industries, including military, defense, consulting, medical, information and logistics.

Education: Master's degree from the Darla Moore School of Business at the University of South Carolina, Bachelor's degree in Russian language, Literature and Culture at the University of South Carolina. William has completed an additional bachelor's degree in computer science at the University of South Carolina.

Saleh Omar Al Ameri – Researcher

United Arab Emirates

Employment: Test-cosmonaut at the Mohammed Bin Rashid Space Center.

Education: Bachelor's degree in Mechanical Engineering from the Khalifa University, graduate of the UAE National Service.

He has a skydiver's license from the USPA (more than 200 jumps) and a Master Scuba Diver degree from PADI.

Ekaterina Karyakina – Researcher

Russia

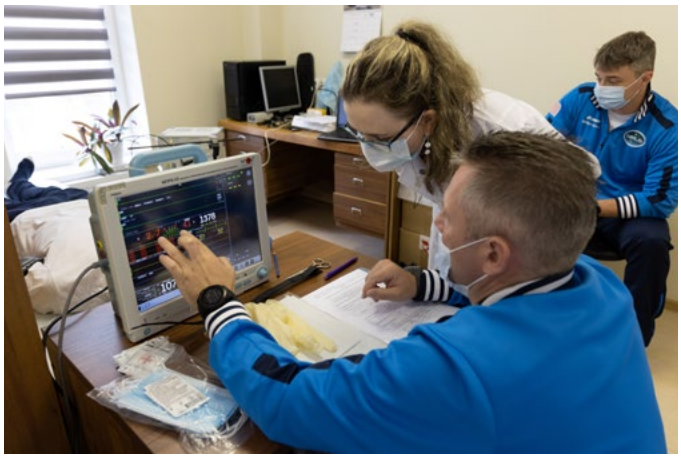
Employment: Flight attendant at the Nordwind Airlines.

Education: Department of Journalism of the Orenburg State Pedagogical University.

Worked as a Medical Coordinator at the GMS ECO Clinic of Assisted Reproductive Technologies.

On the Mission Day 33, left the experiment due to an injury.

Preparation, training and baseline data collection of crew candidates

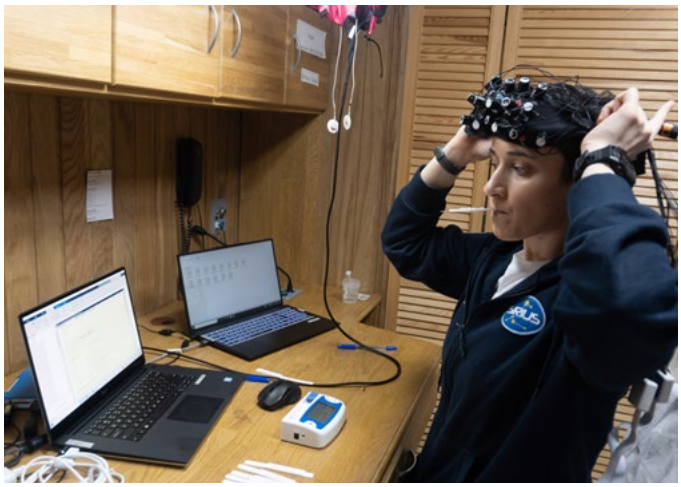




Start of the 240-day mission on November 04, 2021. Press-conference and launch

Research activities during the mission



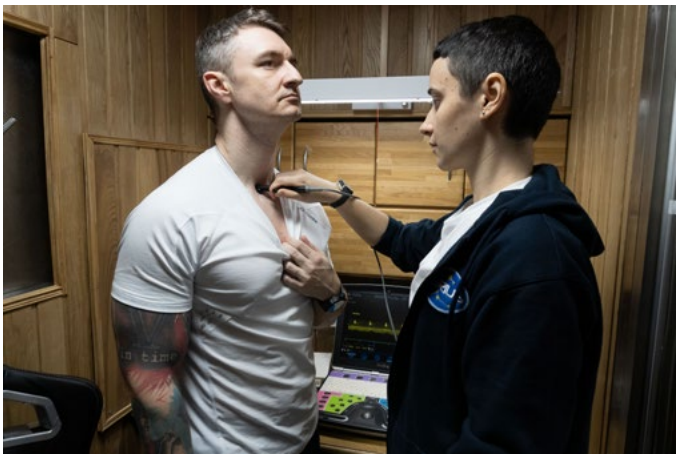



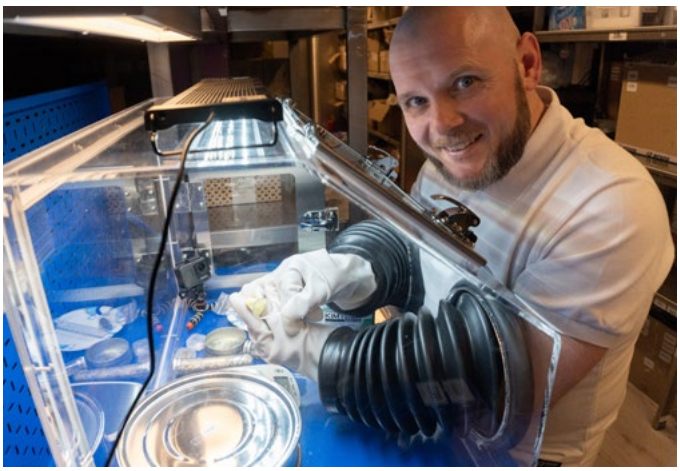


Research activities during the mission

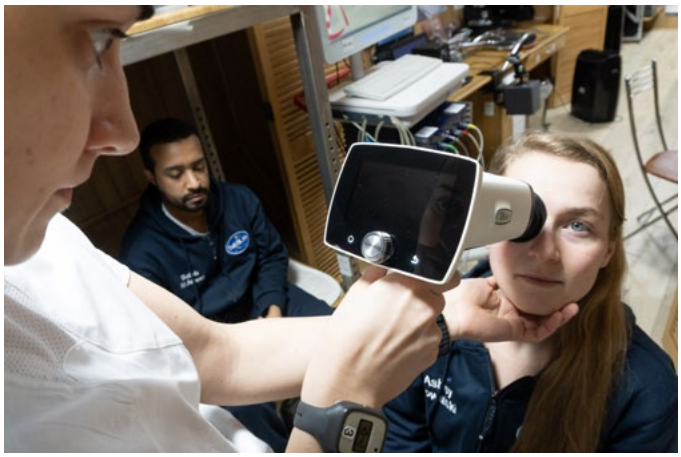


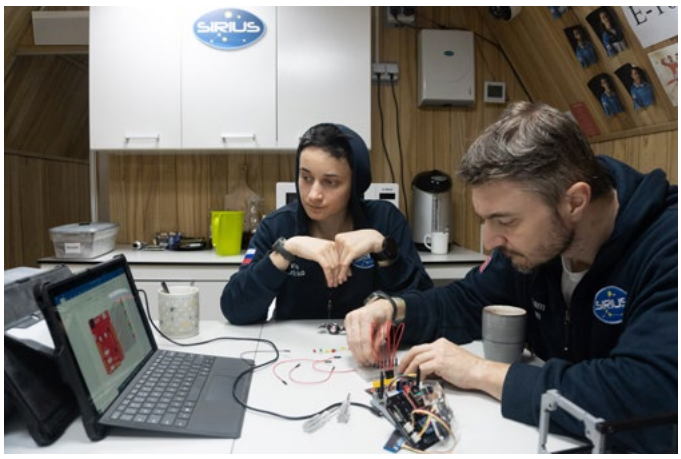




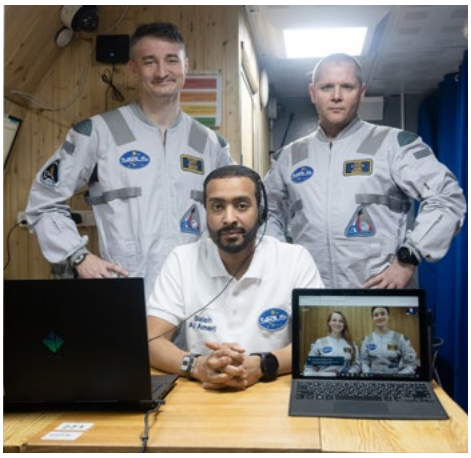



Research activities during the mission

««Descent on the Moon» during the SIRIUS-21 experiment

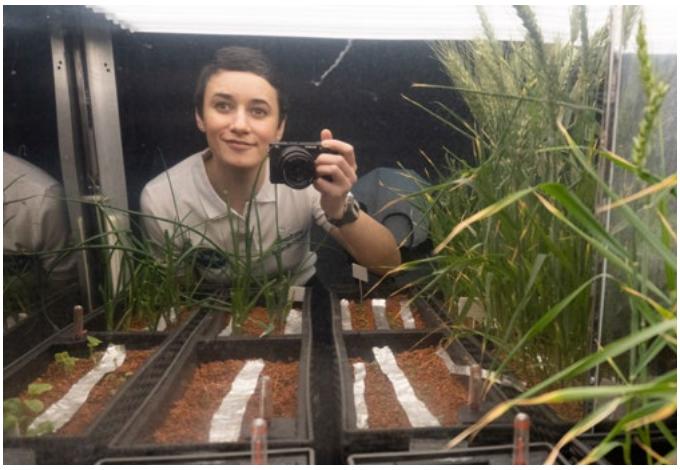





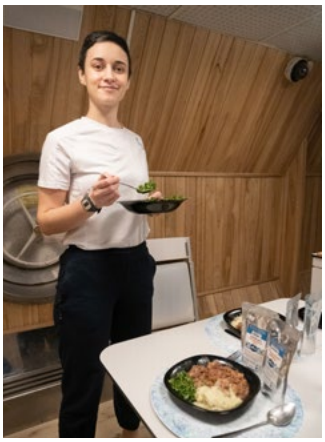



Greenhouse



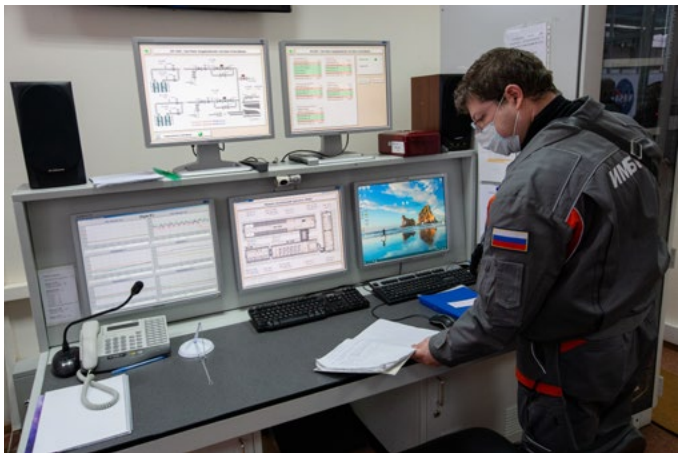



Taking a meal

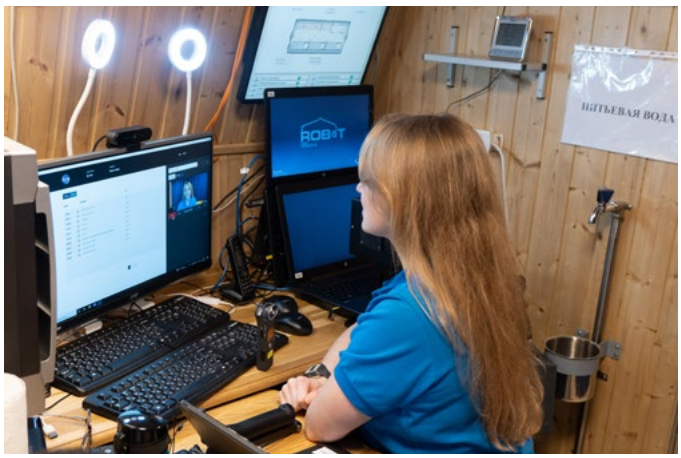



Recreation

External and internal mission control centers.
Observations and interactions with crew members





List of studies in the SIRIUS-21 experiment

1. Psychological and psychophysiological experiments

1Study of speech and non-verbal components of crew communication with the MCC in order to assess the psychophysiological state of crew members and the effectiveness of intergroup interaction.

Scientific Leader: Leading Researcher -Head of Lab Dr. Gushin V.I, MD, PhD (IBMP). Principle Investigator: Leading Researcher Dr. Shved D.M., PhD (IBMP). Co-PIs: Dr. Beata Gabriela Ehmann, PhD (Environmental Adaptation and Space Research Group, Institute of Cognitive Neuroscience and Psychology, Research Centre for Natural Sciences of the Hungarian Academy of Sciences); Researcher Khomenko Yu.G., PhD (N.P. Bekhtereva's Institute of the Human Brain)

1.2. The reliability dynamics indicators of the professional at performance of activity in the conditions of long isolation.

Scientific Leader: Head of Lab Prof. Barabanschikova V.V., MD, PhD (MSU). Principle Investigator: Associate Professor Kovalev A.I., PhD (MSU). Co-PI: «Yu.A. Gagarin Research & Test Cosmonaut Training Center». Supervisor from IBMP: Deputy Director on Science Prof. Bubeev Yuriy, MD, PhD

1.3. The study of psychological stability and adaptation in an isolated small group in the modeling of extreme factors of a long space flight.

Scientific Leader: Leading Researcher Vinokhodova A.G., PhD (IBMP). Principle Investigator: Junior Researcher Kuznetsova P.G. (IBMP). Co-PIs: Leading Researcher – Head of Lab Larina I.M., MD, PhD (IBMP); Leading Researcher – Head of Group Vasilyeva G.Yu., MD, PhD (IBMP); Dr. Iva Solcova, PhD (Institute of Psychology, Prague Branch Academy of Sciences of the Czech Republic); Associate Professor Velichkovskaya S.B., PhD (State Linguistic University)

1.4. Study of daily motor activity and sleep quality of crew members for the prediction of the psychophysiological state and performance of human operators in isolation.

Scientific Leader: Head of Lab Dr. Vadim Gushin, MD, PhD (IBMP). Principle Investigator: Leading Researcher Dr. Dmitry Shved, PhD (IBMP); Researcher Stephania Fedyay (IBMP).

1.5. Investigation of the reliability of the professional activity of the human operator when performing operator tasks

Scientific Leaders: Leading Researcher Kotrovskaya T.I., MD, PhD, Head of Lab Gushin V.I., MD, PhD (IBMP). Principle Investigator: Researcher Schastlivtseva D.V. (IBMP). Co-PIS: Dr. Bernd Johannes (German Aerospace Center, Institute of Aerospace Medicine); Head of the Youth Team at the MOIDS Laboratory Chertopolokhov V. A.; Belousova M.D. (MSU)

1.6. Perception of Time.

Scientific Leader: Head of Department, Busina T.S., PhD (MSMSU named after A.I. Evdokimov). Principle Investigator: Assistant Professor Shalina O.S., PhD (MSMSU named after A.I. Evdokimov) Co-PIs: Specialist Kuvshinova O.L., PhD (Science and Methodology of Testing and Development Center "Human Technologies"). Supervisor from IBMP: Head of Lab Dr. Vadim Gushin, MD, PhD

1.7. Interpersonal interactions, communications and group effectiveness under simulated extreme conditions of flight to the Moon and being in lunar orbit.

Scientific Leader: Leading Researcher- Head of Lab Dr. Vadim Gushin, MD, PhD (IBMP). Principle Investigator: Leading Researcher Vinokhodova A.G., PhD (IBMP). Co-PIs: Leading Researcher – Head of Group Vasilyeva G.Yu., MD, PhD (IBMP); Researcher Lapkovskiy V.V. (Moscow Padagogic State University), Radvan Bahbouh, Assoc. Prof., Mgr. et Mgr., MUDr., PhD., IAAM, Charles University; Jan Evangelista Purkyne University in Ustinad Labem, Katerina Bernardova, PhD; Jaroslav Sýkora, PhDr. (QED Group)

1.8. The study of neurophysiological and psychophysiological dynamics of crew members.

Scientific Leader: Leading Researcher Kotrovskaya T.I., MD, PhD. Principle Investigator: Researcher Schastlivtseva D.V. (IBMP). Co-PI: IB Golubev V. G.

1.9. Emotion in space analog environments: detection and regulation of affective changes in response to a stressful condition in situation of confinement.

Scientific Leader: Prof. P.Mutzenhardt (University of Lorraine, Psychology and Neuroscience Lab). Principle Investigator: Prof. B. Bolmont (University of Lorraine, Psychology and Neuroscience Lab). Co-PIs: Dr. J.-P. Hainaut, Dr. C. Langlet (University of Lorraine, Psychology and Neuroscience Lab); Dr. Gauquelin-Koch Guillemette (CNES); Marnat Maurice (CNES/MEDES IMPS)

1.10. Mitigation of mental stress in isolation and confined environment.

Scientific Leader: Dr. Hasan Al-Nashash, PhD (American University of Sharjah). Principle Investigators: Dr. Fares Al-Shargie, PhD, Dr. Usman Tariq, PhD (American University of Sharjah). Supervisor: Dr. Fares Al-Shargie, PhD (American University of Sharjah).

1.11. The Psychological challenges of isolation during human spaceflight: the role of motivational dynamics.

Scientific Leader: Dr. Zahir Vally, PhD (United Arab Emirates University).

1.12. Objective evaluation of psychological distress in space exploration (simulation of environment of moon base).

Scientific Leader: Dr. Ichiyo Matsuzaki, MD, PhD (Tsukuba University). Co-PIs: Tadashi Murai, MD, PhD; Yuichi Oi, MD, PhD; Shotaro Doki, MD, PhD; Daisuke Hori, MD, PhD (Japan Atomic Energy Agency). Supervisor: Shin-ichiro Sasahara, MD, PhD (Tsukuba University).

1.13. Remote assessment of stress level using facial expression asymmetry and movement

Scientific Leader: Mariko Egawa, PhD (Shiseido Global Innovation Center). Co-PIs: Hirofumi Nakada, MD, PhD (USJ LLC); Takuya Tamura, MD, PhD (Sakurajyuji Group); Junichi Hosoi, PhD, and Kentaro Kajiya, PhD (Shiseido Global Innovation Center). Supervisor: Chika Katagiri, PhD (Shiseido Global Innovation Center).

1.14. A neuroergonomic approach to cis-lunar teleoperation

Scientific Leader: Dr. Raphaelle ROY, PhD (ISAE-SUPAERO). Supervisor: Dr. Vsevolod Peysakhovich, PhD (ISAE-SUPAERO).

1.15. Brain Changes and Spatial Navigation after Long Duration Isolation and Confinement and the Significance of Virtual Earth gazing to Augment Sensory Stimulation.

Scientific Leader: Alexander C. Stahn, PhD; Katharina Brauns, MSc. Co-PIs: Mathias Basner, MD; Katharina Brauns, MSc; Elena Fomina, PhD; Tom Hartley, PhD; Simone Kühn, PhD; Bernhard Riecke, PhD; Mathias Stangl, PhD; Anika Werner, MSc.

1.16. A biopsychosocial investigation of psychological stress, team function, performance and health during and after return from the isolation and confinement program.

Scientific Leader: Prof. Marc Jones, PhD. Co-PIs: Dr Nathan Smith; Prof. Emma Barrett; Dr Maria Cordero; Dr. Elizabeth Braithwaite (Manchester Metropolitan University); Professor Gro Mjeldheim Sandal (University of Bergen).

1.17. Physiological adaptation effects upon decision making and skills maintenance in ICE - 2.

Scientific Leader: Prof. Fabio Ferlazzo, PhD. Co-PIs: Prof. Rossella Ventura, PhD; Prof. Vittorio Pasquali, PhD; Prof. Diego Andolina, PhD; Prof. Stefano Sdoia, PhD; Dr. PierpaoloZivi, MSc (Sapienza University of Rome); Prof. Denise Giuliana Ferravante, MSc (Italian National Agency for New Technologies, Energy and Sustainable Economic Development). Supervisor: Prof. Rossella Ventura, PhD (Sapienza University of Rome).

1.18. SIMSKILL-VR.

Scientific Leader: Dr. Reinhold Ewald, Prof. Supervisor: Miquel Bosch Bruguera, Aer. Eng. (Institute of Space Systems, University of Stuttgart)

1.19. Integrated ethological study.

Scientific Leader: Carole Tafforin, PhD (ETHOSPACE). Co-PIs: Leading Researcher - Head of Lab Dr. Gushin V.I., MD, PhD (IBMP); Vinokhodova A.G., PhD (IBMP)

1.20. Human factors and behavioral performance – exploration measures (HFBP-EM) in NEK

PI: Suzanne Bell, PhD (NASA HRP) Co-PIs: Pete Roma, PhD (NASA BHP Laboratory); Lauren Landon, PhD; Gloria Leon, PhD. Supervisor: Lauren Landon, PhD (NASA HRP).

1.21. Understanding and preventing crew member task entrainment

PI: Jeff Le Pine, PhD. Co-PIs: Ned Wellman, PhD. Supervisor: Daniel Newton, PhD.

1.22. Facilitating the synergistic side of cultural diversity in LDSE: Identification of challenges and development of cultural training

PI: Shawn Burke, PhD. Co-PI: Eduardo Salas, PhD (William Marsh Rice University, Department of Psychological Sciences). Supervisor: Eduardo Salas.

1.23. Team task switching in astronaut crews: integrating multi-team membership, multi-team systems, multitasking and multidimensional networks to monitor and enable functional work shifts in astronaut crews

PI: Leslie DeChurch, PhD. Co-PIs: Noshir Contractor, PhD (Northwestern University); Jessica Mesmer-Magnus, PhD; Alina Lungeanu, PhD. Supervisor: Savinkina A.O. (IBMP)

1.24. Key components of successful autonomous space missions

PI: Ute Fischer, Ph.D. Co-PI: Kathleen Mosier, PhD. Supervisor: Bryan Caldwell, PhD.

1.25. HRP Standard Measures in NEK

PI: Gilles R. Clement, PhD. Co-PI: Pete Roma, PhD (KBR).

2. Physiological studies

2.1. Study of the state of the food status and digestive system.

Scientific Leader: Leading Researcher Afonin B.V., MD, PhD (IBMP). Principle Investigator: Senior Researcher Valuyev V.A, MD, PhD (IBMP).

2.2. Study of the state of bone system in volunteers exposed to isolation conditions in hermetically closed environment (8 months)

Scientific Leader: Leading Researcher – Head of Group Vasilyeva G.Yu., MD, PhD (IBMP). Principle Investigator: Junior Researcher Gordienko K.V. (IBMP). Co-PIs: Leading Researcher – Head of Lab Larina I.M., MD, PhD; Leading Researcher Pastushkova L.Kh., MD, PhD; Leading Researcher Rykova M.P., MD, PhD (IBMP).

2.3. Effect of sleep deprivation, fragmentation and restriction on autonomous nervous system parameters and performance.

Scientific Leader: Ingo Fietze, Prof. Dr.med.; Thomas Penzel, Prof. Dr.rer.physiol (Interdisciplinary Center of Sleep Medicine, Charite Medical Clinic). Co-PIs: Leading Researcher – Head of Lab Suvorov A.V., MD, PhD; Researcher Demin A.V. (IBMP). Supervisor: Naima Laharnar, Dipl.-Psych.

2.4. Study of the effect of 8-month isolation with controlled environmental conditions on the change of the Kerdo vegetative index of in humans during the night sleep.

Scientific Leader: Leading Researcher – Head of Lab Suvorov A.V., MD, PhD. Principle Investigator: Researcher Demin A.V. (IBMP).

2.5. Parameters of external respiration and strength of respiratory muscles in conditions of long-term isolation.

Scientific Leader: Leading Researcher – Head of Lab Suvorov A.V., MD, PhD (IBMP). Principle Investigator: Junior Researcher Zaripov R.N. (IBMP)

2.6. Acoustical study of pulmonary ventilation during long-term isolation.

Scientific Leader: Leading Researcher Dyachenko A.I., PhD (IBMP). Principle Investigator: Researcher Mikhailovskaya A.N. (IBMP).

2.7. The study of the microcirculation via laser Doppler flowmetry under the influence of the tilt-test and isolation.

Scientific Leader: Leading Researcher – Head of Lab Suvorov A.V., MD, PhD (IBMP). Principle Investigator: Senior Researcher Fedorovich A.A., PhD (IBMP). Co-PI: Junior Researcher Pamova A.P. (IBMP). Supervisor: Leading Researcher Popova Yu., PhD (IBMP).

2.8. Study of the influence of isolation conditions and various types of training loads on the cardiopulmonary system at rest and in the performance of physical

work and the level of physical work capacity

Scientific Leader: Leading Researcher – Head of Lab Suvorov A.V., MD, PhD (IBMP). Principle Investigator: Junior Researcher Ruzhichko I.A. (IBMP)

2.9. Blood gases and acid-base balance in healthy humans under chronic exposure to moderately elevated CO2 in the rest and at the physical load under conditions of prolonged stay in a moderately hypercapnic environment

Scientific Leader: Leading Researcher – Head of Lab Suvorov A.V., MD, PhD (IBMP). Principle Investigator: Leading Researcher Popova Yu., PhD (IBMP).

2.10. Analysis of the dynamics of human performance in conditions of a reduced physical activity as a result of the impact of various training regimes with the purpose of constructing a mathematical model of the training process.

Scientific Leader and Principle Investigator: Leading Researcher – Head of Lab Fomina E.V., PhD (IBMP). Co-PIs: Dr. Uwe Hoffmann (German Sport University, Cologne Institute of Physiology and Anatomy). Supervisor from IBMP: Leader and Principle Investigator: Leading Researcher – Head of Lab Fomina E.V., PhD

2.11. Study of the expression of circadian rhythm regulation genes in subjects exposed to isolation in a hermetically closed environment (8 months).

Scientific Leader: Leading Researcher – Head of Group Vasilyeva G.Yu., MD, PhD (IBMP). Principle Investigator: Junior Researcher Afanasyeva D.P. (IBMP)

2.12. Study of the functional state of the human's operation visual system in conditions of 8 months of isolation with artificial LED lighting.

Scientific Leader: Academician, Director of the Helmholtz Research Institute of Eye Diseases of the Russian Ministry of Health Prof. Neroyev V.V., MD, PhD. Principle Investigators: Head of Department Prof. Zueva M.V. (Helmholtz Research Institute of Eye Diseases); Leading Researcher – Head of Group Manko O.M., MD, PhD (IBMP). Supervisor: Leading Researcher Smoleevskiy A.Ye., PhD (IBMP)

2.13. Assessment of LED ambient lighting on the human visual functions in isolation.

Scientific Leaders: Leading Researcher – Head of Group Manko O.M., MD, PhD (IBMP); Senior Researcher Prof. Rozhkova G.I., PhD (IITP RAS). Principle Investigators: Senior Researcher Gratcheva M.A., PhD (IITP RAS); Researcher Belokopytov A.V. (IITP RAS). Co-PIs: Kharkevih's IITP RAS. Supervisor: Senior Researcher Smoleevskiy A.Ye., PhD (IBMP)

2.14. The study of eye refraction in conditions of 8 months of natural light deprivation. .

Scientific Leader: Leading Researcher – Head of Group Manko O.M., MD, PhD (IBMP). Principle Investigator: Senior Researcher Smoleevskiy A.Ye., PhD (IBMP). Co-PI: Researcher, Physician Danilichev S.N. (GCTC).

2.15. Monitoring of the impact of the electromagnetic background of the environment on humans in isolation and shielding structures of premises.

Scientific Leader: Head of Lab Tsetlin V.V., PhD (IBMP). Principle Investigator: Leading Researcher Stepanova G.P. (IBMP). Co-PIs: Research Center for Biomedical Problems of Human Adaptation in the Arctic Federal State Budgetary Institution of Federal Research Center "Kola Scientific Center of the Russian Academy of Sciences",Natalya Belisheva, Chief Researcher, Doctor of Biological Sciences, corresponding member of MANEB. Supervisor: Head of Lab Ponomarev S.A., PhD (IBMP).

2.16. A personalized assessment of a human's adaptive capabilities in conditions of prolonged isolation based on the results of individual prenosological monitoring.

Scientific Leader: Senior Researcher Chernikova A.G., PhD (IBMP). Черникова А.Г. Principle Investigator: Lab Assistant Yakhya Yu.D(IBMP)

2.17. 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.

Scientific Leader: Leading Researcher – Head of Lab Moukhamedieva L.N., MD, PhD (IBMP). Principle Investigator: Senior Researcher Tsarkov D.S. (IBMP)

2.18. Impact of long-term isolation on the interaction between executive functions, prefrontal brain activity and cardiorespiratory regulation during physical exercise.

PIs: Dr. Uwe Hoffmann, PhD (German Sport University Cologne); Dr. Fabian Steinberg, PhD (Institute of Sport Science, Department of Sportpsychology, Johannes Gutenberg-University Mainz). Co-PIs: Dr. Jessica Koschate, PhD (Carl von Ossietzky University of Oldenburg); Dr. Elena Fomina, PhD (IBMP); Dr. Mathias Haeger, PhD (Charité - Universitätsmedizin Berlin, Institut für Arbeitsmedizin); Dr. Uwe Drescher, PhD (German Sport University Cologne, Department Exercise Physiology. Supervisor: Dr. Uwe Hoffmann, PhD.

2.19. Assessing whole-body energy consumption and energy content before and during 8-month isolation.

PI: Prof. Dr. med. J. Rittweger. Co-PIs: Dr. Petra Frings-Meuthen, Dipl. Oec. Troph Ann Charlotte Ewald, Carolin Berwanger (Institute of Aerospace Medicine, DLR). Supervisor: Leading Researcher – Head of Group Vasilyeva G.Yu, MD, PhD (IBMP).

2.20. Exposure to a Space Analog Environment on Cardiovascular variability and Cardio- postural Interactions

Scientific Leader: Dr. Hanan Al Suwaidi MBBS, ABFM, MPH. Principle Investigator: Prof. Stefan du Plessis MSc, PhD, MBA. Co-PIs: Prof. Alavi Alsheikh-Ali BSc, MSc, MD, FACC (Mohammed Bin Rashid University of Medicine and Health Sciences College of Medicine); Gravitational Physiology and Medicine: Department of Space Flight and Aging Research, Medical University of Graz, Austria; Master of Science, Bachelor of Medicine Sciences, Ph.D., prof. Nandu Goswami; Master of Science, Bachelor of Biophysics Sciences, Ph.D., prof. Andrew Philip Blaber; Aerospace Physiology Laboratory, Simon Fraser University. Supervisor: Maria Makri, PhD, MBRU Research Office (Mohammed Bin Rashid University of Medicine and Health Sciences).

2.21. Bone loss and insulin resistance during a 8-months isolation period with a mixed exercise program: one step further towards Mars exploration

PI: Platat Carine, PhD. Supervisor: Jaleel Kizhakkayil, PhD.

2.22. The Impact of Isolation on Metabolic Biomarkers.

PI: Prof Dr Gerlinde Metz. Co-PIs: Tony Montina, MSc. Supervisor: Penny D'Agnone.

2.23. Delineating the effects of stress induced by confinement and isolation on circulatory and skeletal muscle function of crewmembers in 8-month analog mission (SIRIUS Project) measuring clinical, genomics, transcriptomic, and proteomics parameters.

PI: Adel B Elmoselhi, MD, PhD. Co-PIs: Rizwan Qaisar, MBBS, PhD; Rifat Hamoudi, PhD, CEng (College of Medicine, University of Sharjah); Nandu Goswami, MBBS, Post Grad Dipl Sci, PhD (Medical University of Graz, Austria). Supervisor: Rizwan Qaisar, MBBS, PhD (University of Sharjah).

2.24. Biomarkers as predictors of resiliency and susceptibility to stress in space flight.

PI: Namni Goel, PhD. Supervisor: Erika Yamazaki, BA, BS.

2.25. Food acceptability, menu fatigue, and aversion during long duration isolation mission in the NEK Analog.

PI: Grace Douglas, PhD (NASA). Co-PIs: Pete Roma, PhD (KBR); Millennia Young, PhD (NASA).

3. Immunity Studies

3.1. Conditions of the Toll-like receptors system of the human innate immunity cells during the long-term isolation.

PIs: Head of Lab Ponomarev S.A. PhD MD (IBMP); Brian E. Crucian PhD MD (NASA Johnson Space Center).

3.2. The effect of 8-month isolation in a hermetic object on the phenotypic and functional characteristics of the immunity of volunteer testers under the influence of regular physical exertion, in the context of individual typological characteristics.

Scientific Leader: Head of Lab Ponomarev S.A. PhD MD (IBMP). Principle Investigators: Specialist Kalinin S.A., PhD; Specialist Kutko O.V. (IBMP).

3.3. Predictive diagnosis of problems in the body on the basis of changes in the characteristics of extracellular DNA; identification of genetic markers that determine high or low level of resistance to stress.

Scientific Leader: Head of Lab Kostyuk S.V., PhD (Research Centre for Medical Genetics). Principle Investigator: Leading Researcher Yershova E.S., PhD (RCMG). Co-PIs: Umriukhin P.E., MD PhD (P. K. Anokhin Institute of Normal Physiology). Supervisor: Head of Lab Ponomarev S.A. PhD MD (IBMP).

3.4. Space simulation of lasting confinement effects on immune, microbiome and mood changes.

PI: Dr. Isabelle Mack, University Hospital Tübingen, Internal Medicine VI, Dept. of Psychosomatic Medicine and Psychotherapy. Co-PIs: Dr. Claude Lambert, Immunology Laboratory, Univ. Hospital, Plateau de biologie; Dr. Paul Enck,University Hospital Tübingen.

4. Metabolic studies

4.1. The study of human homeostatic reactions during 8-month isolation in a hermetic volume with simulation of planetary activity and under the influence of stress factors.

Scientific Leader: Leading Researcher – Head of Lab Markin A.A., MD PhD (IBMP). Principle Investigator: Leading Researcher Zhuravleva O.A., PhD (IBMP). Supervisor: Leading Researcher – Head of Lab Markin A.A., MD PhD (IBMP).

4.2. Human plasma hemostasis system in the experiment with 8-month isolation in a hermetically closed facility simulating a flight to the Moon and planetary activity

Scientific Leader: Leading Researcher – Head of Lab Markin A.A., MD PhD (IBMP). Principle Investigator: Senior Researcher Kuzichkin D.S., PhD (IBMP). Supervisor: Leading Researcher – Head of Lab Markin A.A., MD PhD (IBMP).

4.3 Studying the influence of typological features of the initial psychoneuroendocrine status, neurohormonal regulation of water-electrolyte homeostasis and metabolism, their dynamics and relationships on the choice of a strategy for adapting human body to conditions of long-term isolation in hermetic facilities and its implementation.

Scientific Leader: Leading Researcher Nichiporuk I.A., MD PhD (IBMP). Principle Investigator: Junior Researcher Chistokhodova S.A. (IBMP). Supervisor: Leading Researcher – Head of Lab Markin A.A., MD PhD (IBMP).

4.4. Neurohormonal, metabolic and psychological aspects of the adaptation of human body to the conditions of 8-month isolation in a hermetically closed facility.

Scientific Leader: Leading Researcher Nichiporuk I.A., MD PhD (IBMP). Principle Investigator: Leading Researcher Zhuravleva O.A., PhD (IBMP). Supervisor: Leading Researcher – Head of Lab Markin A.A., MD PhD (IBMP).

5. Telemedical studies

5.1. Continuation of work on the creation of algorithms for predicting the dynamics of the health status of crew members.

Scientific Leader: Leading Researcher – Head of Lab Perevedentsev O.V., PhD (IBMP). Principle Investigator: Researcher Chernogorov R.V. (IBMP).

6. Microbiological and sanitary-hygienic studies

6.1. Study of the characteristics of the operators' microflora in the experiment with long-term isolation and means of prevention.

Scientific Leader/PI: Head of Department Vyacheslav K. Ilyin, MD/Professor (IBMP). Co-PIs: Researcher Anna V. Gegenava, PhD; Senior Researcher Zoya O. Solovieva, PhD; Junior Researcher Kirill A. Chief (IBMP); Serge Ameye (The Planet Mars Baking Society); Head of Lab Alexander N. Agureev, Ph.D (IBMP). Supervisor: Senior Researcher Nonna A. Usanova (IBMP).

6.2. Research of biomedical, microbiological and technological aspects of using fermentation products in the conditions simulating expedition to the Moon

Scientific Leader/PI: Deputy Head of Division Kaspranskiy R.R., MD PhD (GCTC). Co-PIs: Prof. Gernet M.V. (V.M. Gorbatov's Federal Scientific Center for Food Systems). Supervisor: Head of Department Vyacheslav K. Ilyin, MD/Professor (IBMP).

6.3. Aerosol Accumulation in the Atmosphere of Hermetic Inhabited Objects During Prolonged Isolation.

Scientific Leader: P. Aleksandrov, D.Sc. (phisics), Director of Information Technologies Institute of NRC Kurchatov Institute. Principle Investigators: V. Kalechits, Ph D. (phisics), Chief of Aerosol Optical Instruments Laboratory of NRC Kurchatov Institute; A. Aleksandrova, D.Sc. (biology), Leading Researcher of the Department of Mycology and Algology at Biology Faculty at Moscow State University. Co-PIs: Biology Faculty at Moscow State University.

6.4. The impact of prolonged confinement and social isolation on the composition and the functional potential of the human gut microbiota.

Scientific Leader: Danilenko V.N., Head, Department of Genetic Foundations of Biotechnology, Prof. Doctor of Biological Sciences (IOGEN RAS). Principle Investigator: Senior Researcher Averina O.V., Ph.D (IOGEN RAS). Co-PIs: Head of Department Vyacheslav K. Ilyin, MD/Professor (IBMP); Chief Scientific Advisor, Head Boris Tsigankov, Ph.D. (Institute of Mental Health and Addiction). Supervisor: Vatlin A.A.

6.5. Microbial diversity in SIRIUS-21: Survivors on novel antimicrobial two-component surfaces.

Scientific Leader and PI: Grohmann, Elisabeth, Prof. Dr. Co-PI: Dr. Ralf Moeller (German Aerospace Center, Institute of Aerospace Medicine). Supervisor: Daniela Wischer, Dr.

7. Operational and technological experiments

The Operational and Technological Program includes the studies aimed at maintaining the health and performance of the crew, working out the methods and means of distance learning, monitoring sanitary and hygienic measures and activities and reproducing the necessary products in a space mission using the elements of biological life support systems and additive technologies.

Main objectives:

- to check the quality indicators and to work out the methods of using scientific and standard medical equipment to be operated on the ISS in the conditions of isolation in a hermetic object;
- to work out the technologies of remote training for the crew members using limited means of communication with the imitation of a long-duration interplanetary flight and assessment of the quality of the work performed;
- to create new methods for organizing work and evaluating its effectiveness, as well as helping the crew during long-term isolation and performing tasks in an altered gravitational environment during long-distance space flights;
- to work out technologies and find technological solutions for the tasks that will be required in the conditions of long-term social deprivation while performing long-duration space missions and surface activities.

7.1. Modeling of planetary extravehicular activity using virtual reality systems and lunar gravity simulation

Scientific Leader: Leading Researcher – Head of the Laboratory Dr. Vadim Gushin, MD, PhD; Leading Researcher – Head of Laboratory, Head of Department Dr. Elena Tomilovskaya, PhD (IBMP). Principle Investigator: Senior Researcher Dr. Dmitry Shved, PhD (IBMP). Co-PI: Victor Chertopolokhov (Faculty of Cosmic Research, Lomonosov Moscow State University)

7.2. Studying the influence of a limited amount of resources (sanitary hygiene, food, clothing, water supply and medicines) of the crew on its behaviour and interaction with the MCC

Scientific Leader/PI: Leading Researcher - Deputy Head of Department Dr. Poddubko S.V., PhD; Leading Researcher – Head of the Laboratory Dr. Vadim Gushin, MD, PhD (IBMP). Principle Investigator: Savinkina A.M. Co-PI: OOO (LLC) «Skantech».

7.3. Psychological support for crews in conditions of high autonomy

Scientific Leader: Senior Researcher Karpova O.I. Principle Investigators: Junior researcher Potapova K.V., Karapetyan A.S. Co-PI: Volosyuk Yu.A. (IBMP).

7.4. Assesment of the crewmembers' nutritional status in long-duration model experiments simulating an 8-month interplanetary mission

Scientific Leader/PI: Head of Clinical Diagnostic Center "Healthy and sports nutrition" Burlyaeva E. A., PhD (Federal Research Center of Nutrition and Biotechnology). Co-PI: Zainudinov Z.M., MD PhD Head Physician of the "Clinic of Therapeutic Nutrition" (Federal Research Center of Nutrition and Biotechnology)

7.5. Studies on formative 3D biofabrication of tissue constructs carried out by programmable self-assembly of living tissues and organ constructs in microgravity conditions using magnetic field.

Scientific Leader: Head of Research Vladimir A. Mironov, M.D., Ph.D. (Laboratory for Biotechnological Research of 3D Bioprinting Solutions). Principle Investigator: Yusef D. Khesuani, Cofounder, Managing partner of 3D Bioprinting Solutions». Co-PI: IBMP. Supervisor: Yusef D. Khesuani, Cofounder, Managing partner of 3D Bioprinting Solutions».

7.6. Remineralizing and cleansing effect on the hard tissues of teeth of two-component complexes of the Remarsgel line

Scientific Leader: Sergey A. Kholodov, MD, General Director, «Dental Space Clinics». Principle Investigator: Vsevolod Y. Kapitonov, MD, PhD, «Dental Space Clinics». Supervisor: Senior Researcher Aleksandr E. Smoleevskiy, PhD (IBMP)

7.7. Testing of voice assistant technology for operational and methodological support of crew activities in a chamber facility

Scientific Leader: Ashmanov S., CEO of LLC «Virtual Assistants». Principle Investigator: Zubarev E., Project Manager LLC "Virtual Assistants". Co-PI: Lead Researcher Dr. Rulev D., Ph.D (Department of Support for Space Experiments and Mathematical Modeling, Center «Targeted Use of Manned Space Systems», S.P. Korolev Rocket and Space Corporation Energia). Supervisor: Researcher Dr. Dmitry Shved, PhD (IBMP).

7.8. Monitoring of underwear and garment application and their change and sanitary-hygienic activities on processing for conditions of the manned space flight

Scientific Leader/PI: Head of Department Irina V. Shumilina, PhD (IBMP).

7.9. Acoustic monitoring.

Responsible institution: NASA HRP.

7.10. Lighting environment monitoring in different NEK modules

Responsible institution: NASA HRP.

7.11. Air and surface microbial monitoring

Responsible institution: NASA HRP.

7.12. The analysis of lunar rocks samples – the Glovebox

Responsible institution: NASA HRP.

7.13. Practicing the skills of collecting and processing data, including parameters of habitat systems, ship flight paths, lunar or stellar data («Data analysis»).

Responsible institution: NASA HRP.

7.14. Study of the influence of changes in the controlled parameters of the light environment on the threshold characteristics of the operator's perception of visual information during the 8-month study with isolation according to the SIRIUS project.

Scientific Leader: Senior Researcher – Head of Lab Agureev a.N., PhD. Principle Investigator: Researcher Kutina I.V (IBMP). Co-PI: Senior Researcher Gvozdev S. M., PhD, General Director of Bilayt-Trade a scientific expert of the UN Project on the development of energy-efficient lighting in the Russian Federation, an expert of the technical committee on lighting under Rosstandart. Supervisor: Researcher Kutina I.V (IBMP).

7.15. The study of the functional characteristics of greenhouses for life support systems and psychological support of space crews of the lunar station and the lunar base in long-term ground-based analog

experiments.

Scientific Leader – Head of Department V.N. Sychev, PhD (IBMP). Principle Investigator: Leading Researcher M.A. Levinskikh, PhD. Co-PI: Head of Laboratory V.I. Guschin, PhD. Supervisor: Leading Researcher I.G. Podolskiy, PhD. IBMP

7.16. Assembling, testing and configuring a small robotic device («Rover»).

Responsible institution: NASA HRP.

7.17. Development and testing of a simulated satellite CubeSat.

Responsible institution: NASA HRP.

7.18. Lunar crater identification

Responsible institution: NASA HRP.

7.19. Dynamic control models in a manned spacecraft

PI: A.I. Shurov, GCTC

7.20. Space robotics

PI: V.A. Dikarev, GCTC

7.21. Space biology and biotechnology.

PIs: Popova E.V., Kutnik I.V., GCTC.

7.22. Maintenance and repair of computer equipment.

PI: Belyaev N.A., GCTC

7.23. Development of the crew interaction with the Earth during the repair of mechanical parts based on additive technologies and 3D prototyping.

PI: Kovrigin S.N., GCTC

7.24. Study of the crew members' ability to perform operations to eliminate emergency situations (NShSs) associated with the restoration of the station's equipment operability (repair) in the conditions of information isolation

PI – Spirin E.A., GCTC.

7.25. Evaluation of the use of interactive electronic technical manuals (IETRs) during space experiments.

Scientific Leader: Director General Shukshunov V., Professor (OOO «Tsentr trenazherostroeniya» (Center for Training Equipment Construction)). PI: Pototsky S., Deputy General Director, Professor. Co-PIs: Leading Researcher – Head of Group Galina Vasilyeva, PhD Leading Researcher Yulia Popova, PhD. IBMP.

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