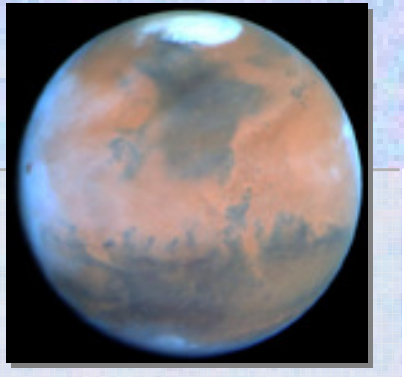


SPACE MEDICINE - FROM THE FLIGHT OF YURI GAGARIN TO EXPLORATION MISSIONS

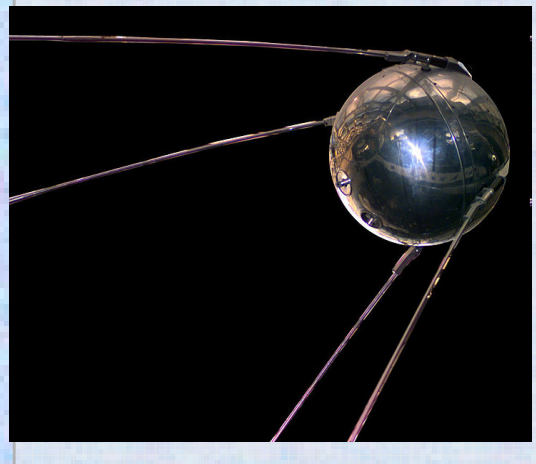
Grigoriev A.I., Orlov O.I. and Alferov A.V.

Russian Academy of Sciences

54 th Session of the Committee on the Peaceful Uses of Outer Space, June 1-10, 2011

DAWN OF THE SPACE ERA

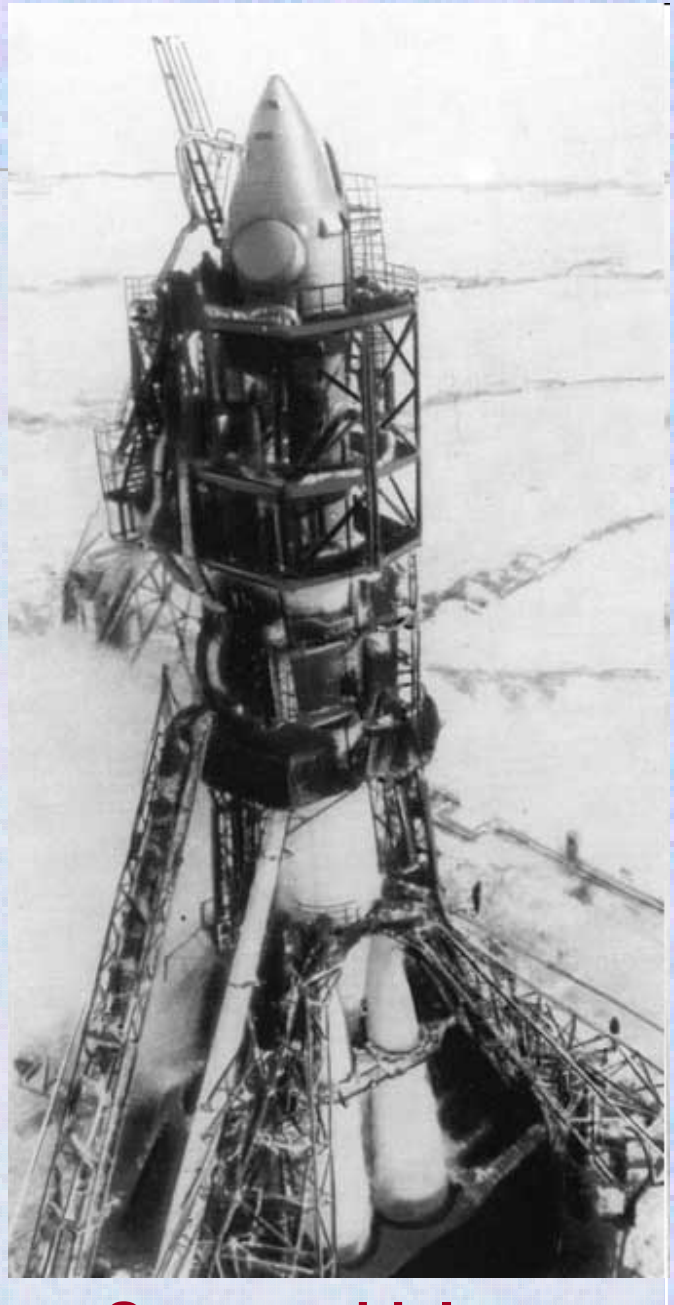
There were two epoch-making events in the history of cosmonautics :



The first artificial satellite of Earth

– launch of the first artificial Earth's satellite on October 4, 1957

– space flight of Yuri Gagarin on April 12, 1961



Space vehicle VOSTOK

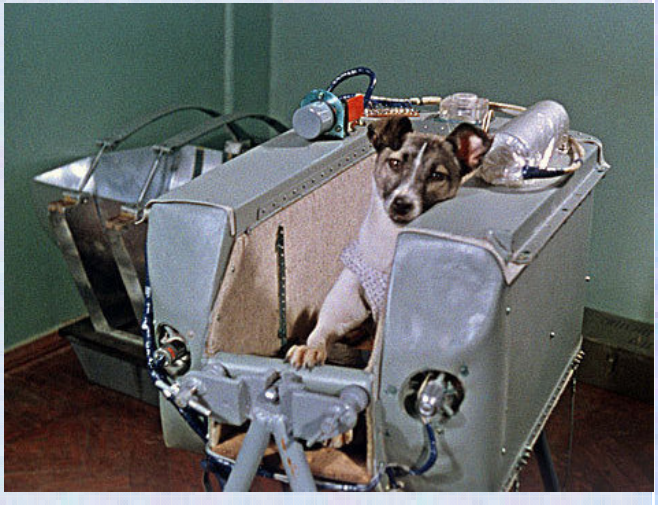
BIOMEDICAL RESEARCHES IN SUBORBITAL FLIGHTS

In 1940-1950, experiments with various bio-objects were made in suborbital flights. Their purpose was to study the effects of accelerations, short-term microgravity, ionizing and UV radiation, and other environmental stresses on the biological and physiological processes in living organism.
Experiments with dogs showed that animals could endure short periods of microgravity and accelerations without critical physiological disorders.

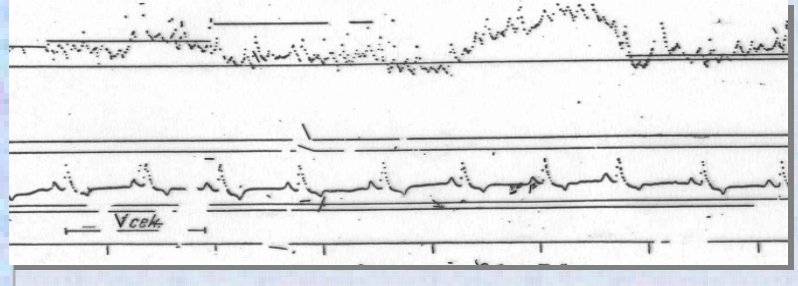
Almost 30 rockets carried dogs in the years between 1951 and 1960.

FIRST SPACE FLIGHT OF A LIVING BEING

Dog Laika



It was the first living being flown to space aboard the second Earth's artificial satellite (AES) on November 3, 1957).



A fragment of the physiological data record made in this flight.

ECG in leads I and II, blood pressure, cardiac tone (phonocardiogram), myocardial contractions (seismocardiogram), arterial pulse (sphygmogram), breathing rate, body temperature and movements were registered during the flight.

The experiment with Laika demonstrated the ability of living beings to endure accelerations and zero gravity.

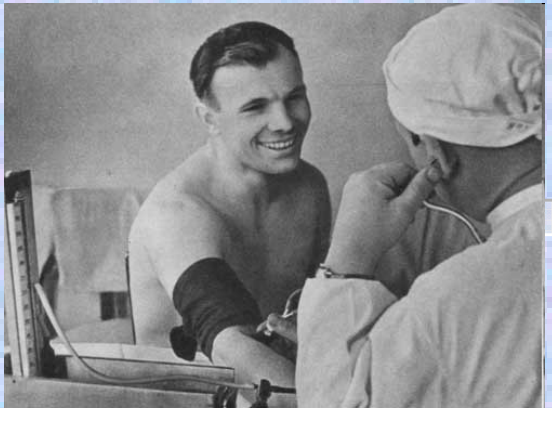
PROGNOSIS OF THE POSSIBILITY FOR HUMANS TO FLY IN SPACE

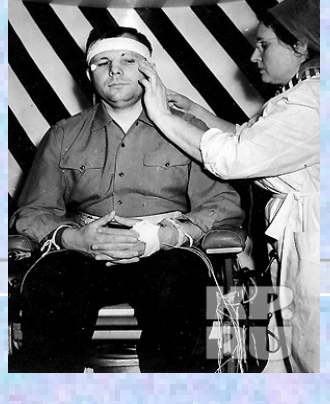
«A series of notable biological experiments on the second, third, fourth and fifth satellite-type vehicles answered many fundamental questions. They provided the benchmarks for the crucial conclusion: from the biological and medical standpoint circling orbital flights below the radiation belts will be safe for human health and life».
[N.M. Sisakian, V.V. Parin, V.N. Chernigovsky, V.I. Yazdovsky]

PREPARATION FOR THE FIRST HUMAN SPACEFLIGHT

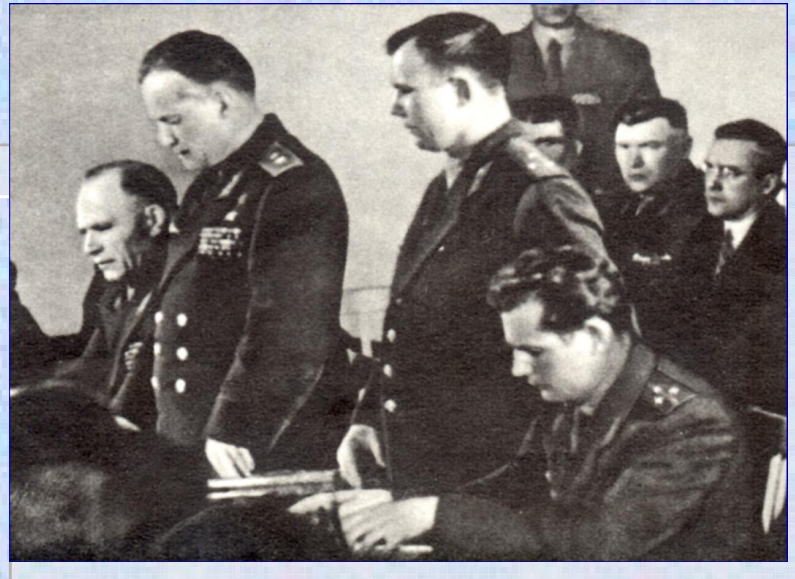
A system of cosmonauts' medical selection was developed. The basic requirements to candidates were excellent somatic and psychic health, tolerance of extreme factors (accelerations, hypoxia, isolation and others), high physical and mental ability, and psychological stability.

Candidates were subjected to testing in isolation and heat chambers, on centrifuge and in vibrochair; they got physical training and were taught rocketry and space technology, aerospace medicine, astronomy and geophysics.





ON THE EVE OF THE LANDMARK EVENT



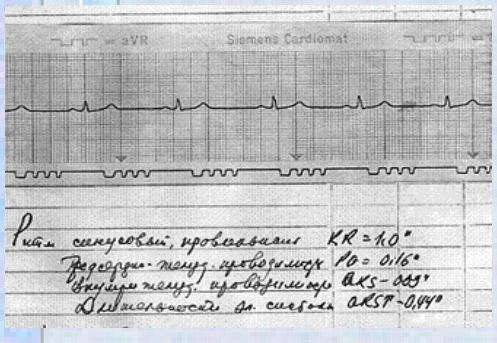
April 8, 1961
USSR State Commission entrusted Yuri A. Gagarin with the first flight to space

Pre-launch medical examination

Yuri Gagarin on the way to the pad

SPACE FLIGHT OF YURI GAGARIN

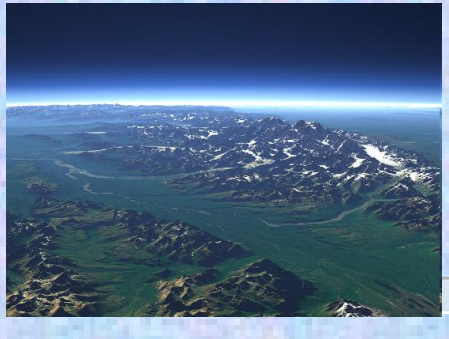
Medical monitoring of Gagarin‘s health was performed prior to launch, during and after the flight.



In flight, ECG in two thoracic leads, heart rate and pneumogram were registered.

ЭКГ Ю.А. Гагарина

Medical data were transmitted to Earth telemetrically.



Real-time medical monitoring was executed by physicians at the ground tracking stations.

The press conference in the USSR Academy of Sciences on April 15, 1961

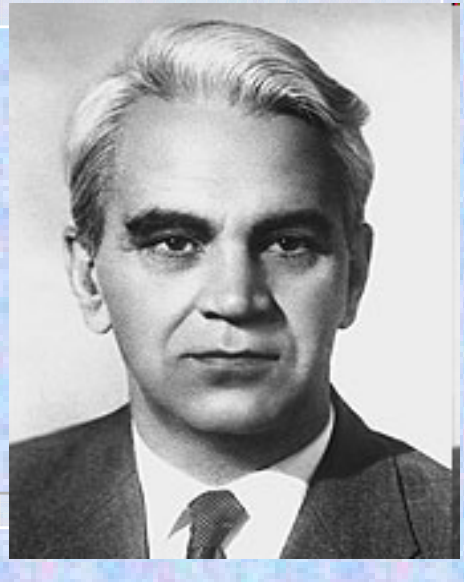
The main conclusion from the results of medical monitoring of Y. Gagarin during and after his flight was that short-term space flight does not cause pathological shifts in organism.

Gagarin's flight validated the possibility for humans to stay in space and made a foray into the new discipline, i.e. space medicine.

GAGARIN'S FLIGHT ORIGINATED SPACE MEDICINE

"Cosmonaut is a human whose activity takes place in extraordinary conditions… often nearing the limit of tolerance".
Yu.A. Gagarin

"… what is to be done requires, along with other researches, great efforts of *biologists and medical scientists* in order to study behavior of the human organism in a new setting and to provide conditions for its normal existence".



M.V. Keldysh

ADVANCEMENT OF SPACE MEDICINE OVER 50 YEARS SINCE THE FLIGHT OF YURY GAGARIN

- Determination and rating of spaceflight risk factors
- Description of the main syndromes developing in space flight
- System of medical support in extended missions enhanced by cutting-edge technologies
  - System of countermeasure for extended missions
  - Medical care system for crew on mission and during postflight rehabilitation
  - Stationary and portable (EVA) life support systems
  - Sanitary and hygienic monitoring and control technologies
  - Crew state and environmental control systems
  - Medical and psychological criteria of selection and preparation of cosmonauts, and evaluation of working efficiency during space flight
- Extensive programme of researches aimed to improve the biomedical support of space crews and to promote fundamental science

MAJOR RISK FACTORS AND SYMPTOMS ASSOCIATED WITH THE SPACEFLIGHT CONDITIONS

INITIAL PERIOD:

- Space motion sickness
- Redistribution of body fluids
- New locomotion stereotype

RISK FACTORS:

- microgravity
- accelerations
- space radiation
- deviations in environmental parameters
- neuroemotional tension
- hypokinesia

EFFECTS OF LONG-DURATION SPACE FLIGHT:

- changes in the neuromuscular system
- shifts in water-electrolyte metabolism and control
- cardiovascular functional alterations (orthostatic instability and physical deconditioning)
- changes in calcium turnover and bone density
- shifts in the adrenal system and endocrine organs
- functional anemia
- decline of immune reactivity
- neuropsychic asthenization

PRESENT-DAY SYSTEM OF SPACE CREW MEDICAL SUPPORT

Pre-launch:

- Medical selection and training
- Regular clinical and physiological investigations
- Health certification

During mission:

Monitoring and prediction of crew health state further in mission;
Control of the use of countermeasures
Planning and tracking crew timeline
Psychological support
Environmental monitoring
Radiation dosimetry, prediction and protection

Post-flight:

- Rehabilitation
- Professional longevity programme

CREW MEDICAL MONITORING SYSTEM

Parameters registered in Gagarin:

- pulse rate
- pneumogram
- ECG in two leads

Top priority parameters currently measured in an extended orbital mission:

- Blood pressure
- Pneumogram
- ECG in 12 leads
- Seismocardiogram
- Ballistocardiogram
- Kinetocardiogram
- Pulsigram
- Sphygmogram
- Rheoplethysmogram
- Blood and urine laboratory analyses
- Blood and urine biochemical analysis

MEDICAL MONITORING EQUIPMENT RECENTLY DELIVERED TO THE ISS RS

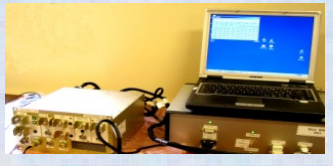
Integral medical system

- Rheplethysmography unit
- Electrophysiological data unit
- Blood pressure measuring unit
- Control and coupling unit

CARDIOMED

- hemodynamics in and functioinal state of leg veins
- diurnal ECG and BP (Holter monitoring)
- BP and HR vegetative regulation
- hemodynamic reactions to the LBNP functional test aimed to assess orthostatic stability in flight

Cardiomed

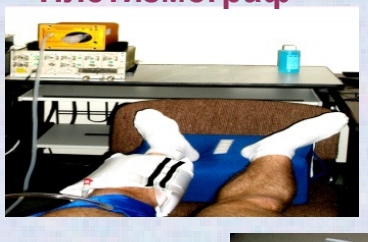


Cardiopress

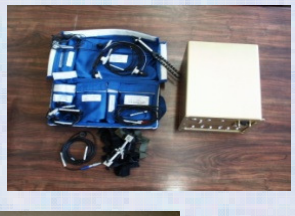
Holter BP

Holter ECG

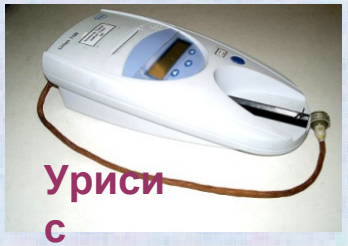
Плетизмограф



Doppler



- URYSIS – biochemical urine analyzer
- Chibis-M
- Beta-09
- Body mass measuring device



Уриси
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RUSSIAN SYSTEM OF COUNTERMEASURES FOR LONG-DURATION SPACE MISSIONS

Created by the Russian scientists, the system of countermeasures against the adverse effects of microgravity on human organism makes possible the implementation of long-duration space missions.

The system of in-flight countermeasures for the MIR and ISS crews was extended further by

- Upgrading of board equipment and procedures and
- Increasing the assortment of physical countermeasures by adding the resistive training devices, electrical stimulators, and axial loading suits

INNOVATIONS IN THE COUNTERMEASURES SYSTEM

Core components:

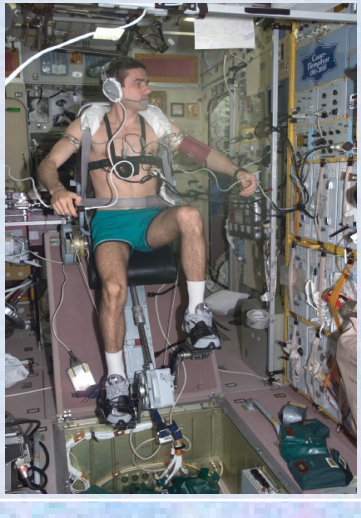
Multifunctioal training facility combining a bicycle, electromagnetic loading devices, and a treadmill

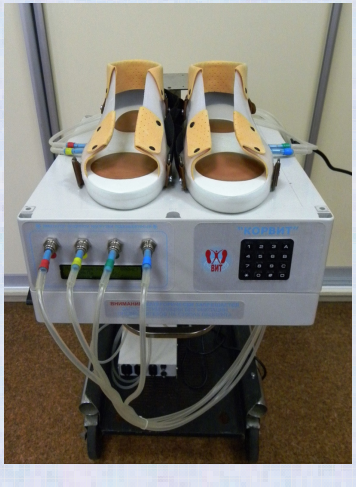
Upgraded electromyostimulator

Axial loading suit Pinguin

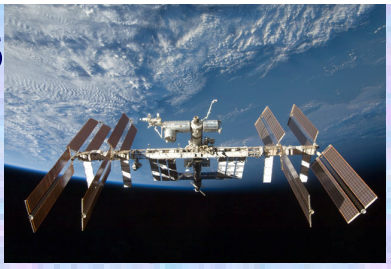
Mechanic planta stimulator

Bone density increasing pharmaceuticals





SPACE MEDICINE AND LIFE SCIENCES ON THE IS



The ISS research program has been particularly successful in the most important medical and life sciences areas:

Cardiovascular system

Psychophysiology

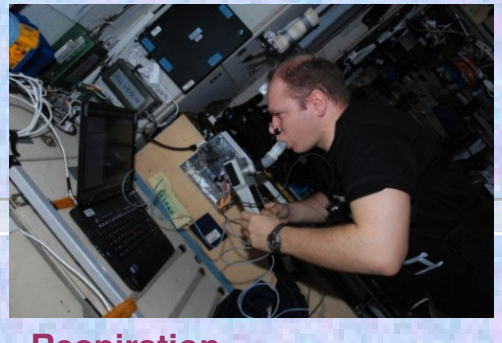
Radiobiology (investigations with humanoid phantom Matryoshka

Operator's efficiency

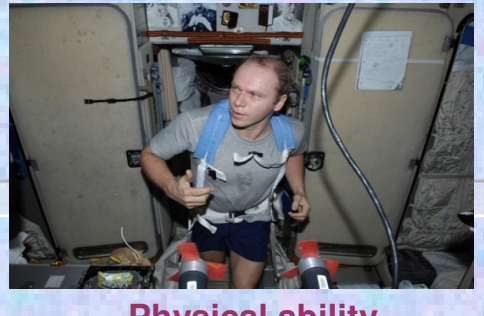
Plant development

Genetic investigations with Drosophila

LBNP



Respiration



Physical ability

Experiment Stimulus

MAJOR BIOMEDICAL PROBLEMS OF A PILOTED MISSION TO MARS

- Counteraction to the adverse effects of changing gravity
- Radiation dosimetry, prediction, protection, and treatment
- Psychological demands of the multinational mission; psychological support

- On-board medical care facilities and agents
- Reliability of life support systems
- Sanitation and hygiene provisions

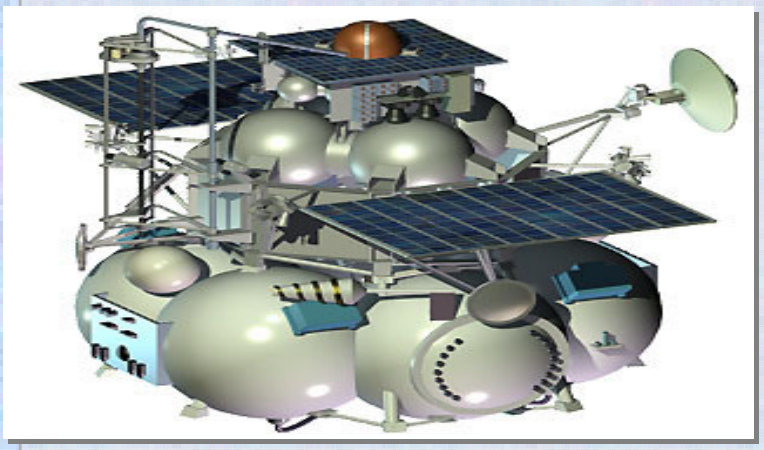
FOBOS-GRUNT PROJECT (2011-2013)

Scientific program:

- **Bio-indication of future space exploration routes**
- **Testing the viability of terrestrial life forms beyond the geomagnetosphere and bio-material transportability across outer space**

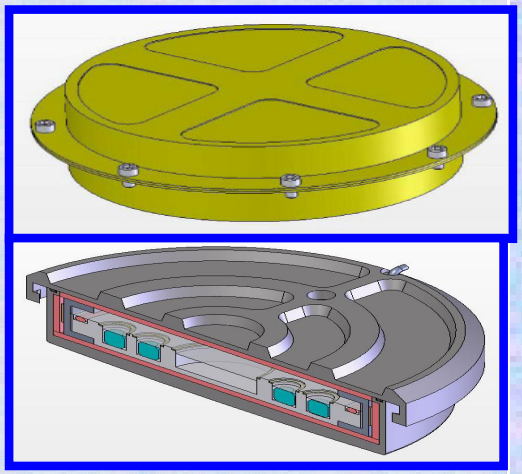
Planetary quarantine:

Implementation of the COSPAR call for prevention of Earth contamination by extraterrestrial living organisms.



Assembled Fobos-Grunt spacecraft

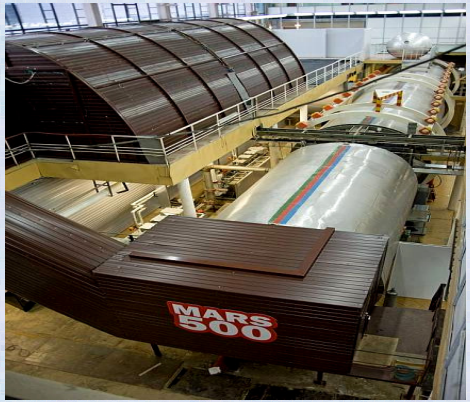
Container for bio-objects



Project participants: ISR/RAS, IBMP/RAS, Institute of microbiology/RAS, Soil Science Dept./MSU, Lavochkin SPA, US Planetary Society

LONG-DURATION SIMULATION EXPERIMENT TOWARD THE DEVELOPMENT OF BIOMEDICAL SYSTEM FOR A MANNED MISSION TO MARS (2009 - 2011)

1. **Biomedical objectives:**
   - Development testing and evaluation of original means and methods of medical health monitoring, prevention and correcting of unfavorable shifts in the human physiological systems;



Experiment facility

2. **Psychophysiological objectives:**
   - Optimization of the crew selection and training system
   - Development testing of proposed methods of operator's efficiency and psychophysiology evaluation
   - Observation of attitudes within the multicultural crew

3. **Habitability objectives:**
   - microclimate monitoring and LSS functioning evaluati
   - Hybrid LSS development testing
   - Resources management


Mars surface simulator

SIGNIFICANCE OF GAGARIN'S FLIGHT

"The heroic deed of Gagarin is an immense contribution to science; he ushered in a new epoch in the history of mankind – the starting of human flights to space, taking the path of interplanetary communications".

M.V. Keldysh

Thank you for your attention!