BIOLOGICAL INVESTIGATION ON BOARD «BION-M» №1 AND «FOTON-M» № 4

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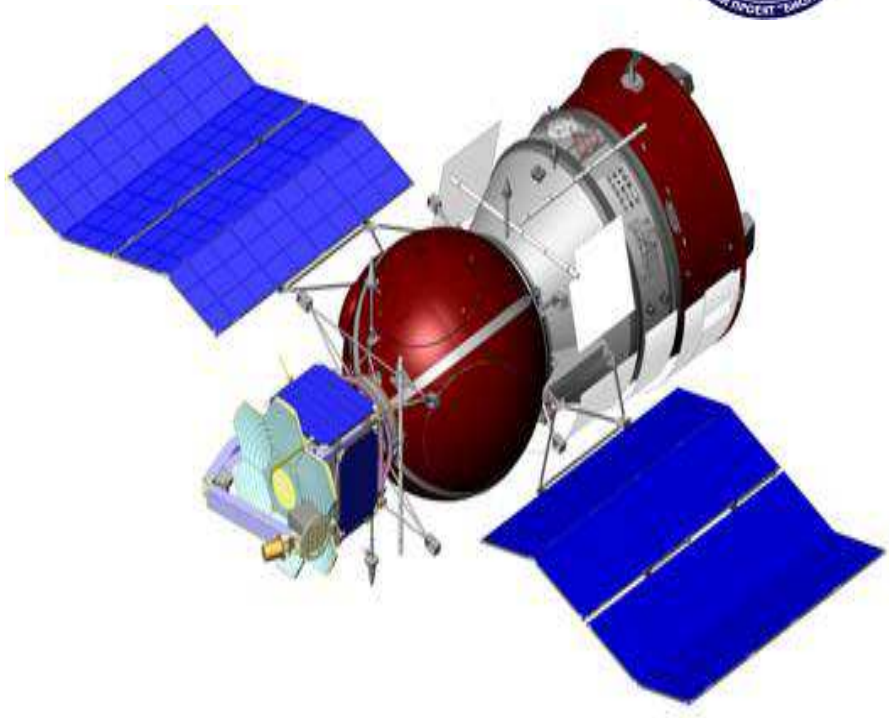
Scientific and Technical Subcommittee: Fifty-second session-2-13 February 2015

«BION-M» #1 spacecraft



Date of lunch – 19.04.2013

Launching side – «Byikonur»

Date of landing – 19.05.2013

Touchdown area – near Orenburg city, RF

Duration of flights – 30 days

Orbit parameters:

with the height up 575 km

Inclination – 64,9º

Total weigh of spacecraft – 6480 kg

Hardware weight - 650 kg inside and - 250 kg outside

Weight of recovery module – 2300 kg

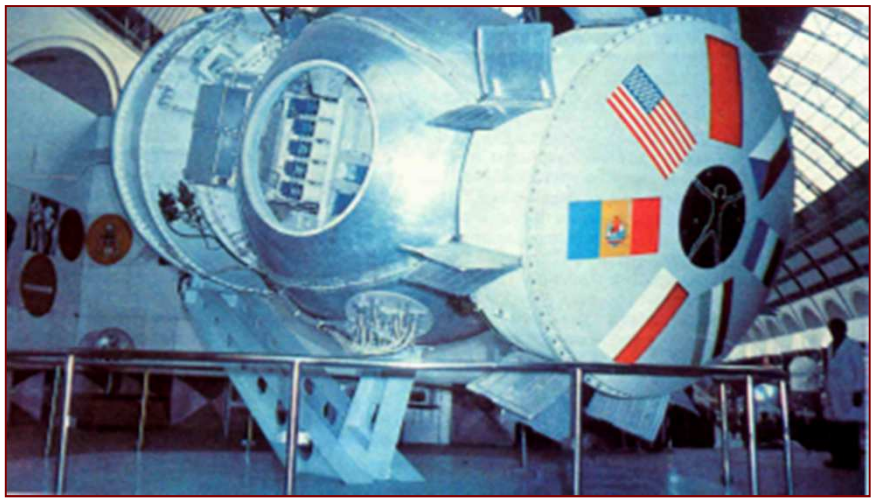
Temperature at outside space in orbital flight from -150 up to 125 ºC

Daily energy supply for hardware 550 w

BION PROGRAMM (1973 – 2013)

Conduction of multicenter physiological, morphological, biochemical, genetic studies in animals and plants in flights of special satellites (biosatellites), designed for conduction of biomedical researches.

Biosatellite	Year of launch	Duration of flight (days)	Study subject
«Bion» #1	1973	21,5	Rats
«Bion» #2	1974	20,5	Rats
«Bion» #3	1975	19,5	Rats
«Bion» #4	1977	18,5	Rats
«Bion» #5	1979	18,5	Rats
«Bion» #6	1983	5	Monkeys - Rats
«Bion» #7	1985	7	Monkeys - Rats
«Bion» #8	1987	12	Monkeys - Rats
«Bion» #9	1989	14	Monkeys
«Bion» #10	1992	11,6	Monkeys
«Bion» #11	1996	13,7	Rats
«Bion-M» #1	2013	30	Mice, gecko, fishes, snails



Studies in rats and monkeys showed, that exposure to weightlessness leads to significant, but reversible functional, structural and metabolic changes in muscles, bones, myocard and neurosensory systems of mammals. Phenomenology of those processes was described and mechanism of development of the changes was studied.
Based on the researches data as well as on data, obtained from manned spaceflights, measures were designed, which can prevent human organism from negative influence of weightlessness. It provided a basis for long-term piloting orbital flights performance.

Bion-M1 Fundamental and Applied Experiments

Biomedical Experiments

Objective: To study the effects of microgravity on the animal body as a whole and on its individual systems

Specimens:

Mongolian gerbils (*Meriones unguiculatus*) – 8 males

Mice C57Bl/6 – 45 males, 5 of which were implanted with blood pressure sensors

15 geckos

Gravitational Biology, Biotechnology and Exobiology Experiments

Objective: To study the effects of microgravity and open space on intracellular processes

Specimens:

Lower invertebrates (snails)

Lower vertebrates (fish)

Microorganisms, seeds, higher plants, cultured cells and tissues

Biopreparations

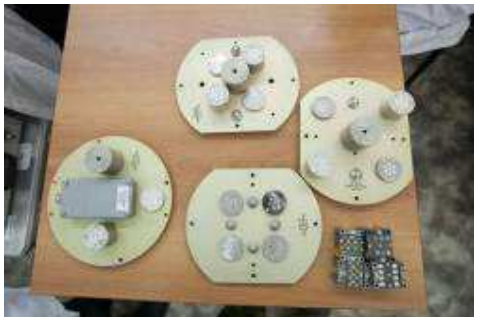
Radiation Biology and Radiation Physics Experiments

Objective: To study biologically important characteristics of cosmic ionizing radiation and its effects on living systems located inside or outside the spacecraft; to test new dosimetric methods and devices for their potential use in space exploration missions

Location: Dosimeters and biospecimen containing kits located inside or on the exterior walls of the spacecraft

Bion-M1 Hardware for Fundamental and Applied Experiments

- **Kontur-BM** – unit housing Mongolian gerbils
- **MLZh-01** – 3 modules, each containing a mouse habitat and a gecko habitat
- **BioCont-B** – 7 containers for gravitational biology experiments
- **OmegaHab** – aquarium containing unicellular algae (*Euglena gracilis*) and cichlid fish (*Oreochromis mossambicus*)
- **Ribes** – unit for studying growth of biospecimens
- **Graviton** – unit for measuring g-levels during flight
- **Bioimpedance** – unit for measuring impedance levels of cell cultures as a method of studying their structure and function
- **BioTrack-TD** – assembly for measuring ionizing radiation RBE for microorganisms
- **BB-1M - 4** boxes for studying the effects of microgravity on specimens at different stages of evolutionary development
- **RD3-B3** dosimeter - for radiation physics measurements
- **SPD dosimeter** - for radiation physics measurements
- **Phyto** – box for studying higher plant fruits and seeds
- **PPN payload** – 8 plates for radiation biology and physics experiments
- **Carbon** unit (within PPN 4K) for studying physical and chemical properties of silicon carbide (SiC) in the space environment
- **Meteorite** – assembly for exobiology experiment
- **Exobiofrost and Exomycology** - boxes containing permafrost samples (Exobiofrost container located on the exterior wall of the spacecraft)
- **Abiogenesis** – box containing peptides and nucleotides for studying their synthesis in open space
- **Bioutilizatio**n – box located in the Fragmenter unit for studying cellulose utilization



Set of Russian and foreign institutions – participants of the program of fundamental and applied experiments and researches (54).

1. Russian Federation(32), including:
institutes of RAS (20), universities and academies (12).




2. Ukraine (1)

3. Germany (4).

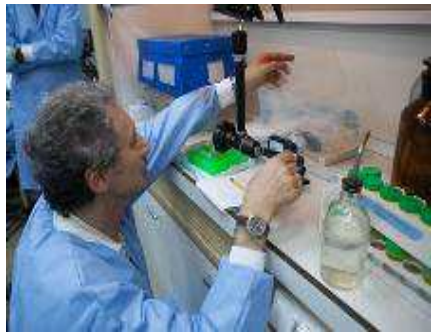
4. USA (12).

5. France (3).

6. Republic of Korea(1).

7. Japan (1).



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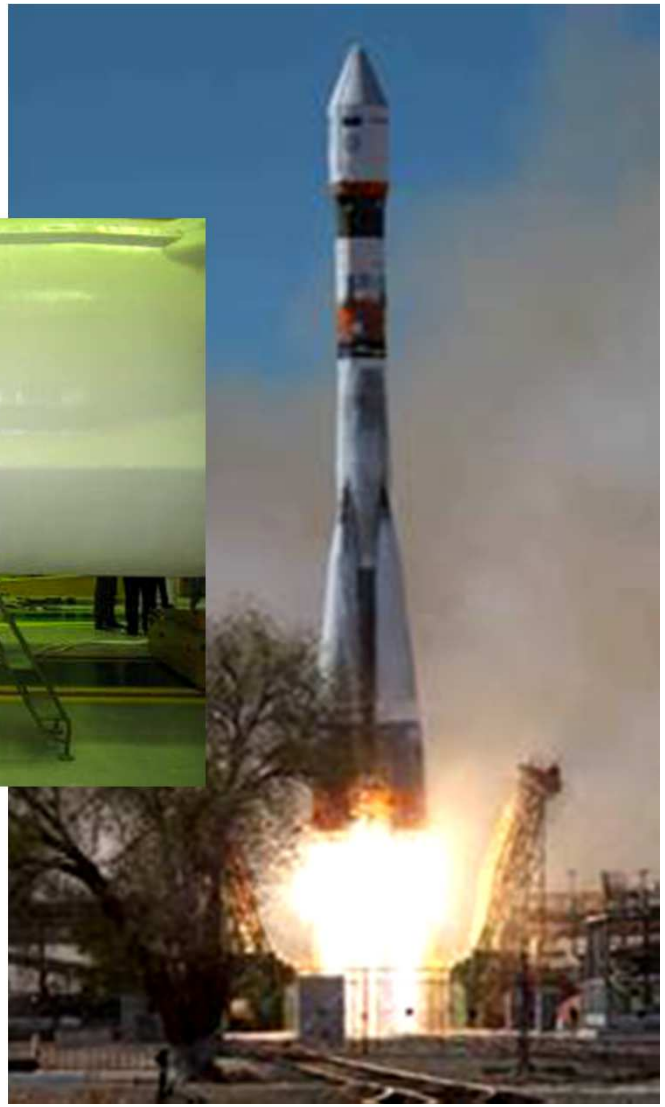
Bion-M1 Flight Experiments

1. GRAVITATIONAL PHYSIOLOGY EXPERIMENTS ON ANIMALS (5 experiments performed in-flight and 78 investigations conducted post-flight).
2. BIOLOGICAL EXPERIMENTS ON MICROORGANISMS AND PLANTS (8 experiments performed in-flight).
3. BIOTECHNOLOGICAL EXPERIMENTS (5 experiments performed in-flight).
4. EXOBIOLOGICAL AND ASTROBIOLOGICAL EXPERIMENTS (4 experiments performed in-flight).
5. INVESTIGATIONS OF RADIOBIOLOGICAL EFFECTS AND BIOLOGICALLY IMPORTANT PARAMETERS OF COSMIC IONIZING RADIATION (8 experiments performed in-flight).

Activities at the Baikonur cosmodrome

Preparation and launch of the Soyuz rocket carrying the «Bion-M» # 1 spacecraft (Baikonur Cosmodrome, April 19, 2013)



Landing of the Bion-M1 recoverable capsule (Orenburg area, May 19, 2013)

Activities at the «Bion-M» #1 landing site

Transportation of the flown mouse habitats from the Chkalovsky airport to IMBP 10 hours after «Bion-M» #1 landing

Activities in IMBP laboratories on May 19-20, 2013 that started 11 hours after «Bion-M» #1 landing

«BION-M» #1 – post-flight animal investigations (mice)

1. Behavioral tests demonstrated that *the animals maintained the operant conditioning for side preference elicited prior to flight although it took them longer to learn a new type of operant behavior, viz., side alternation. Extrapolating our observations on humans, it can be postulated that the capabilities of crewmembers to perform various tasks after a Martian mission may become limited.*

2. Study of the gene expression *controlling interrelated and critically important regulatory systems, i.e., serotonin and dopamine transmitters as well as the brain-derived neurotrophic factor (BDNF), indicated that exposure to the spaceflight effects caused brain changes.*

3.The cerebral changes identified in Bion-M1 mice *may be related to the lowered contractility of the basilar artery seen in the flown animals, which was also detected for the first time.*

«BION-M» #1 – post-flight animal investigations (mice)

4. It was for the first time that experimental data *showing changes in the cortical cytoskeleton of muscle cells of different types were obtained.*

5. Immunology investigations *revealed a significant decrease of the lymphocyte count in the spleen and thymus of the flown mice 12 hours after recovery.*

6. Bone investigations demonstrated *that, compared to the ground controls, the flown mice developed changes in the diaphyses of limb bones that included structural integrity impairment.*

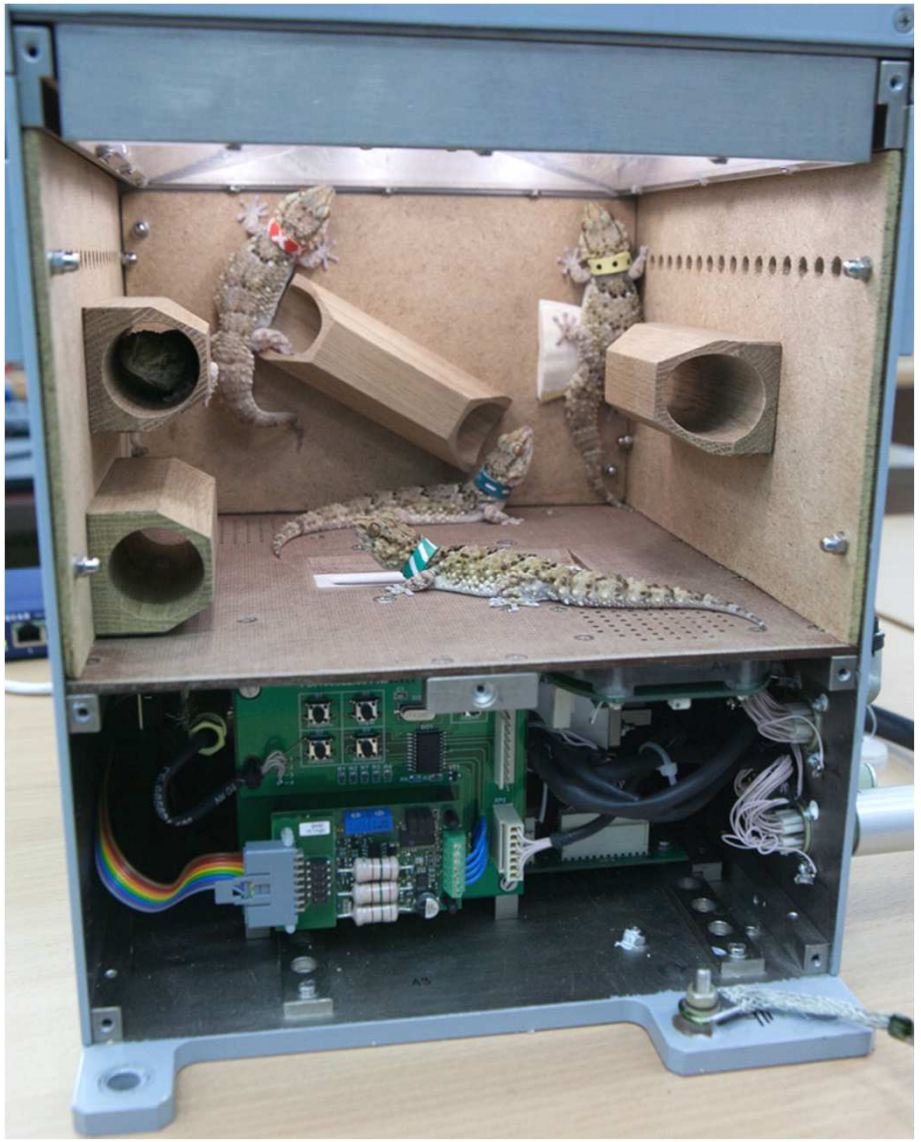
7. Increase of the marrow cell ability in flight mice to produce interleukine-1 (IL-1 - potential regulator of bone resorption and one of the factors involved into the osteoporosis pathogenesis) has been demonstrated.

«BION-M» #1 animal investigations (geckos)

Bion-M1 carried 15 thick-toed geckos contained in 3 habitats, each housing 5 sexually mature females. The animals were for the first time provided with nutritious live feed, which they consumed normally in microgravity.

The geckos had well visible color markings, which helped discriminate their individual the behavior of each of them.

Analysis of video recordings showed that the animals did not experience any stress effects and well adapted to the 30-day spaceflight.



Microbiological investigations inside and outside «BION-M» #1

Microbiological investigations allowed the following conclusions to be made:

1. **Spaceflight factors impacted genetic material transfer across *Streptomycetes* strains.**

1. **Spaceflight factors provoked polarity after microbial crossing over seen as predominance of a chromosome fragment of one of the parental strains.**

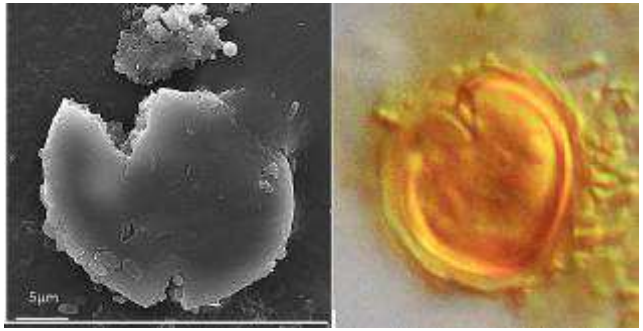
2. **Spaceflight factors impacted the synthetic rate of biologically active compounds: the flight microbial samples contained lower quantities of tylosin and desmycosin than the laboratory and synchronous controls.**

EXOBIOFROST and EXOMYCOLOGY experimental results

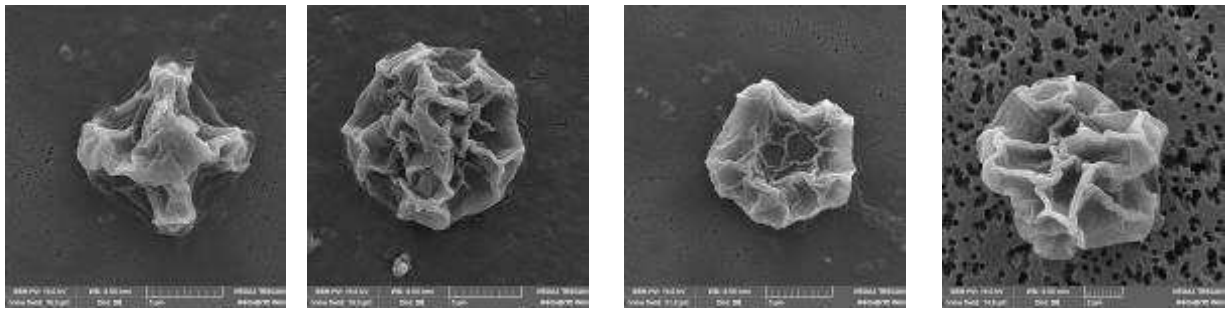
Existing tundra *Colpod*a strains were found to show greater resistance to the effects of the space environment than their fossilized representatives.

Spaceflight induced lesions in the cysts of infusoria seen by:

1. Scanning electron microscopy
2. Phase contrast microscopy



Colpoda steinii strains proved to be more resistant to the spaceflight effects than *Exocolpoda augustini* strains. Scanning electron microscopy of Acanthamoeba cysts did not reveal any changes after their exposure to the space environment. They looked intact and mature.



It was shown that *Penicillium* fungi survived the exposure to the space environment better than *Mucor* and *Trichoderma* strains. Moreover, the number of *Penicillium* strains in the flown Alpine soil samples increased, suggesting their genetic and physiological adaptability, which requires further study.

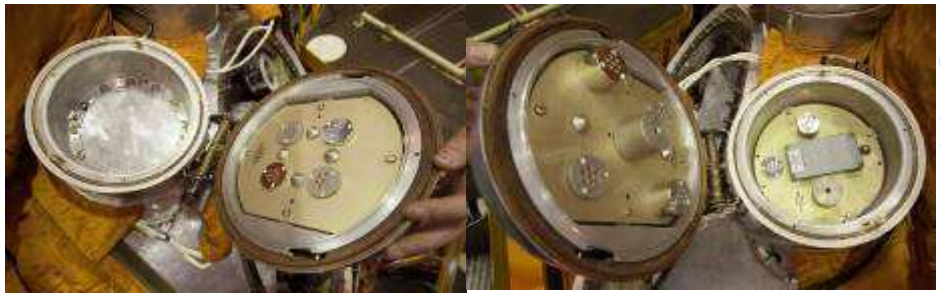
Meteorite experiment

The purpose of the Meteorite experiment was to verify whether microorganisms embedded in meteorite and asteroid type materials could survive their exposure to outer space and dense layers of Earth's atmosphere

It was demonstrated that out of different microorganisms only spore-forming bacteria *Carboxydocella ferrireduca* and *Bacillus pumilis* survived the exposure. These bacteria were embedded in a «meteorite» containing glauconite, i.e., iron potassium phyllosilicate mineral, characterized by low thermal conductivity whereas other microorganisms were placed in magnetite samples having higher thermal conductivity.

Measurement of radiation doses outside the BION-M1 spacecraft

Radiation measurements were performed using passive dosimeters PD-1, PD-2, PD-3, and PD-4 as well as and Bradoz stacks placed in the containers on the exterior walls of the spacecraft.



The Bion-M1 radiation experiment was the first to provide information about the dose rate variations and the contributions of Earth's radiation belts and galactic cosmic rays

The maximum level of the dose rate was **0.9 Gy/day**

Measurement of radiation doses inside the BION-M1 spacecraft

Radiation measurements were performed using bubble detectors, SPD stacks, and RD3-B3 dosimeters.
The maximum dose rate measured by bubble detectors (neutrons) was **0.1mSv/day** (as on the ISS!)
The maximum dose rate measured by SPD stacks (heavy charged particles) was **0.5 – 1.25 mGy/day** (**which was 6 times higher than on the ISS!**). **The dose gradient inside the spacecraft was 2.5**

Education program:

The purpose of the experiment was to observe the development of plants grown from the seeds flown for 30 days on «Bion – M» #1



Russian high school students loading seeds into the BB-1 kit


Japanese high school students are planting flown seeds

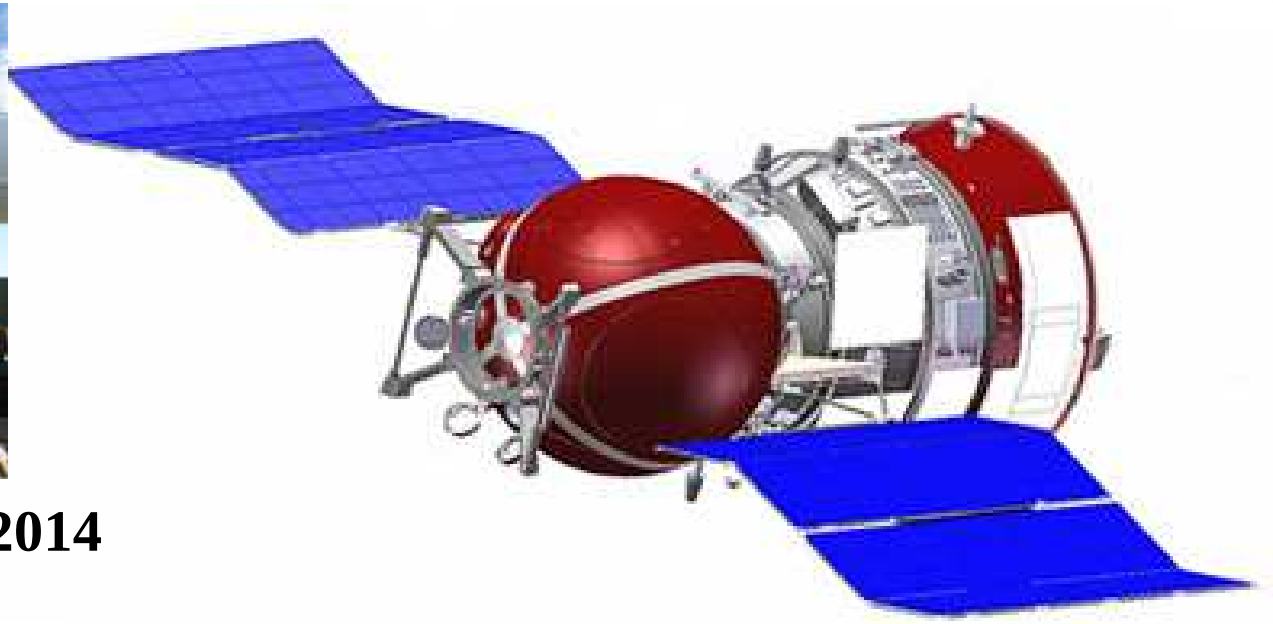
Organizational results

1. After a 16-year hiatus in Russian biosatellite flights, Bion-M1 efforts helped create an infrastructure and a team of young scientists and engineers from various research centers and industry capable of realizing large-scale projects of challenging complexity.

2. Bion-M1 efforts also contributed to the establishment of a wide collaboration of scientists from over research institutes of the **Russian Academy of Sciences, Russian Academy of Medical Sciences, many Russian universities and medical academies** as well as from lead universities and research centers of the **Ukraine, Kazakhstan, Germany, France, Bulgaria and the United States.**

3.Today IMBP has laboratories and facilities for implementing many research projects; its scientists have developed and tested methods and procedures needed to perform, using advanced technologies, cellular, molecular and genetic investigations of mechanisms underlying responses of living systems to spaceflight effects and to evaluate biological costs of the exposure for animals and humans.

«Photon-M» #4



Date of lunch – July 18, 2014

Duration – 45 days

Launching side – Byikonur
Touchdown area –
near Orenburg city, RF

Date of landing – September 01, 2014

Experiments, Specimens, Hardware Onboard “FOTON-M” №4

1. **Study the effects of microgravity on the reproductive behavior, embryonic development and adult organisms of geckos (hardware “GK-04”).**
2. **Study changes in the intracellular systems and perform *in vitro* fluorescence analysis of immunocompetent cells exposed to microgravity (“Fluor-P”).**
3. **Study the structure and function of pure fungal culture and fungal spores as well as the thallus of fungal symbiotic organisms with lichens in space (“Biocontainers”)..**
4. **Study spaceflight effects on the microbial complexes isolated from permafrost soil samples (“Biocontainers”).**
5. **Study microbial decomposition of organic substrates (polyethylene film) in space flight (“Biocontainers”).**
6. **Artificial meteorite and survival of simple forms of life (Microbes and Biopreparations) during reentry (Artificial meteorite on the Foton outer wall).**
7. **Radiation dosimetry experiment (Dosimeters).**
8. **Study the epigenetic role of the gravity force in the development of multicellular organisms (Fruit fly).**
9. **Study methods for generating electricity in microgravity using microorganisms - Electricity generating microbes (microbial fuel cells).**

THANK YOU FOR YOUR ATTENTION