
Russian Academy of Sciences
Russian Federal Space Agency
ФОБОС - ГРУНТ
PHOBOS - GRUNT =
PHOBOS - SOIL
Phobos
Sample
Return
Mission
(C) IKI
PHOBOS - FREGAT
28:02:09
Oleg Korablev, IKI

Goals of the Mission

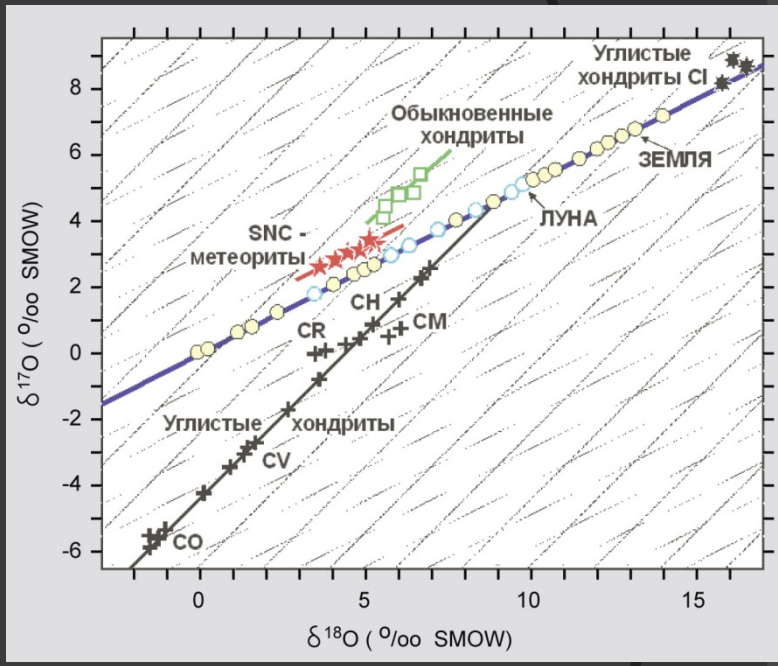
- Phobos regolith sample return,
- Phobos in situ study and remote sensing,
- Martian environment study
- Mars monitoring

Scientific Objectives of the Mission

- **study physical and chemical characteristics of Phobos regolith *in situ* and under laboratory conditions:** to answer questions related to primordial matter of the Solar system, and to origin of terrestrial planets:

  - Does Phobos contain traces of protosolar material?
    Isotopic ratios
  - Does Phobos material kindred to that of Mars and NSC meteorites?
    O^{16} –O^{17} – O^{18}, Kr/Ar/Ne ratio
  - Are there fragments ejected from Mars on Phobos?
    Search and analysis of such material
  - Is there organic matter on Phobos?
    Presence of amino acids, nucleotides, etc.
  - Age of Phobos
    1. Sm/Nd 2. Hf/W 3. U/Pb/Rb/Sr
  - Which type of meteorites Phobos material is close to?
    $\delta^{13}C$, δD, $\delta^{18}O$, $\delta^{17}O$, $\delta^{18}O$, H_2O

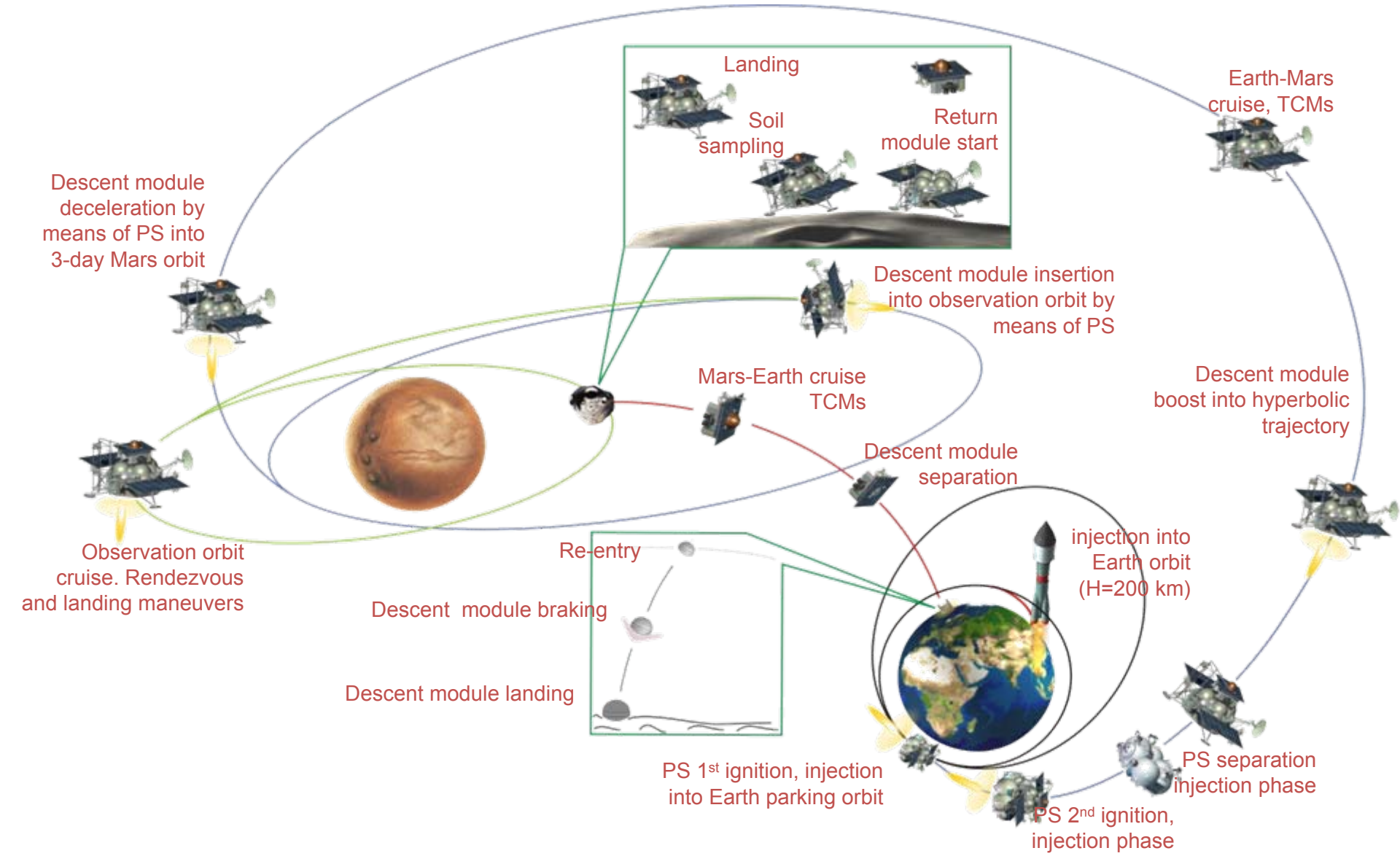
(E.Galimov courtesy)



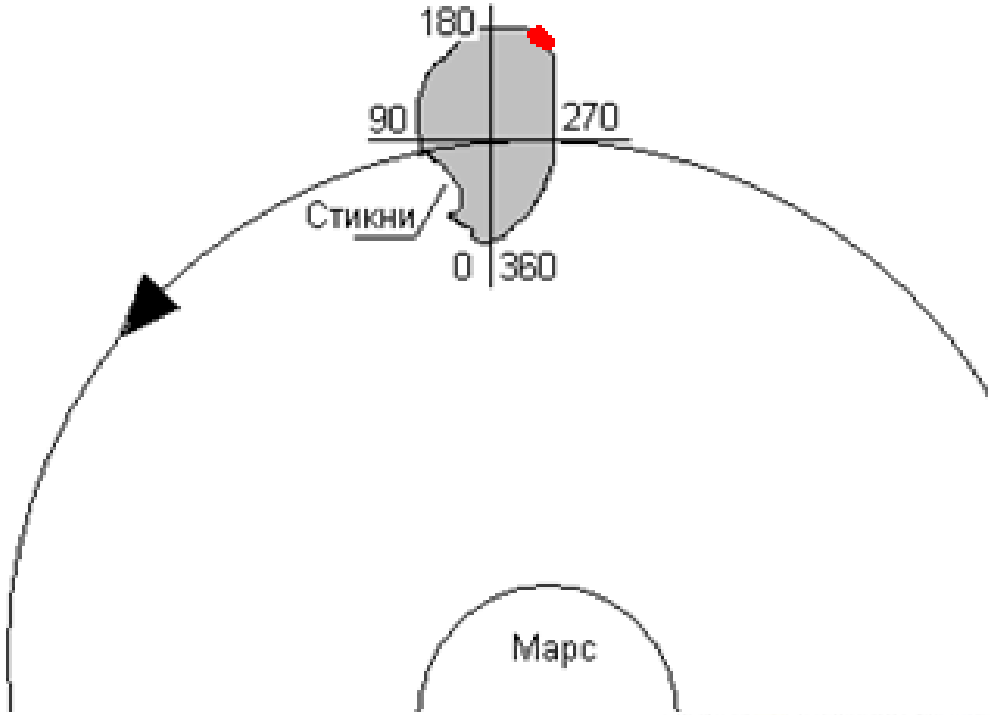
- **studies of orbital and proper motion of Phobos**, for understanding its internal structure, origin, and for celestial mechanics applications;
- **study the Martian environment** (dust, gas, plasma components), for assessing regolith weathering, of dissipation of Martian atmosphere, its interaction with solar wind;
- **monitor remotely the Martian atmosphere**, diurnal and seasonal cycles

PHOBOS SAMPLE RETURN

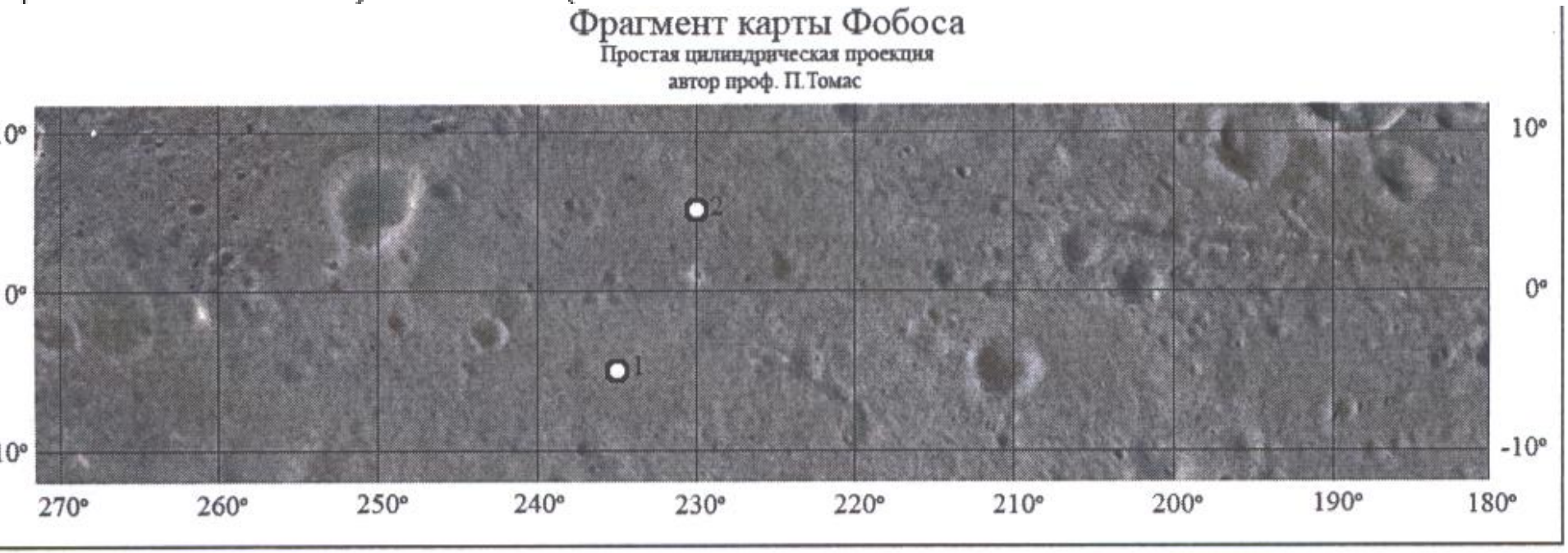
MISSION PROFILE



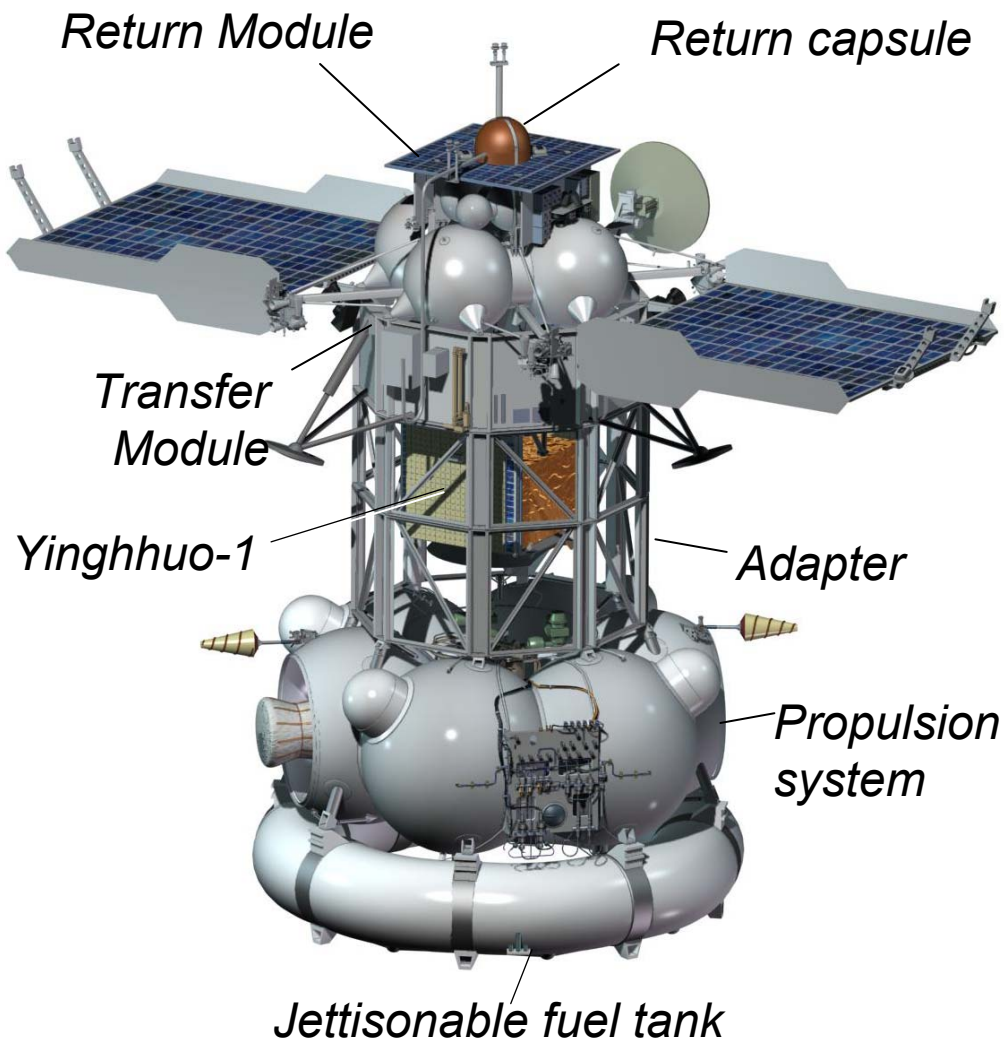
Landing site



Landing site :
5 grad N – 5 grad. S
230-235 grad.



Phobos Sample Return S/C Mass Breakdown

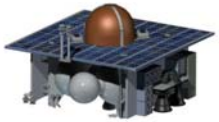


Subsystem	Mass, kg
Transfer-Orbital Module: – dry – charged	 690 1 240
Return Module: – dry – charged	 106.66 148.1
Return capsule	10.9
Frame with adapter and separation system	172
Chinese Spacecraft Yinghuo-1	115
Cruise propulsion system: – dry – charged	 592 5 842
Jettisonable fuel tank: – dry – charged	 335 3 390
Contingency margin	66
SC “Phobos-Soil” – dry – charged	 2 103.56 11 100

Phobos Sample Return S/C

the Earth-Mars Interplanetary flight

Approach Phobos and landing



The Mars-Earth interplanetary flight

At the Phobos surface after take off the Return Module

Payload

Instruments for S/C navigation and sampling

TV-system
Mechanical device for sampling

Instruments for study of Phobos regolith and internal structure

Panoramic and stereo camera
Gas Analytic Package (6 ovens + GCMS)
Messabuer spectrometer
Gamma and neutron spectrometer
Laser ablation TOF mass-spectrometer
Thermodetector
Long wave radar
Seismometer

Instruments for Martian environment study

Plasma, waves and magnetic field detectors
Dust particles detector

Returned experiment

LIFE

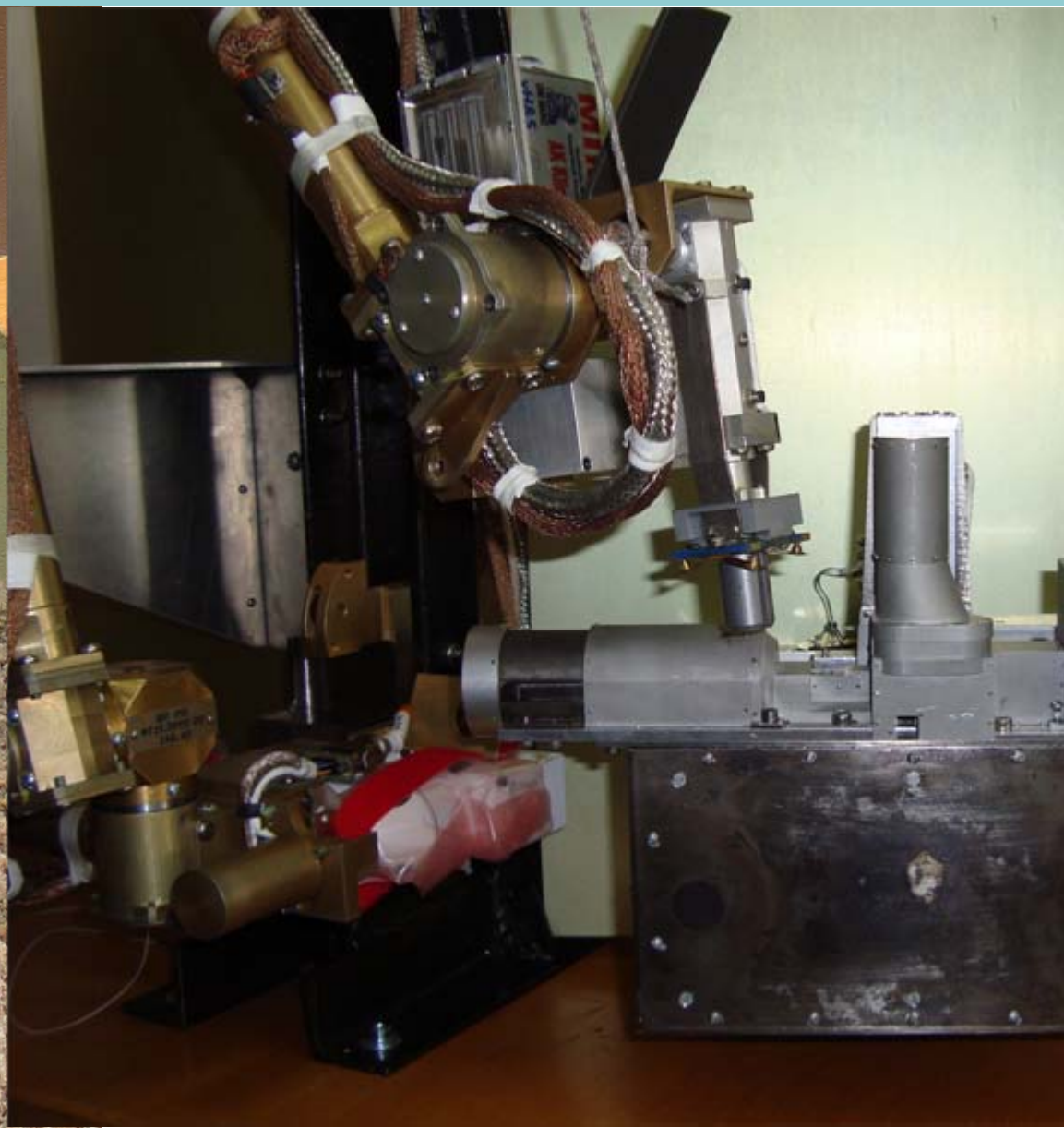
Robotic arm

- Position accuracy ± 5 mm
- Speed 10 ± 3 mm/s
- Full length 1000 mm
- Pressure force up to 1,5 H
- Sample volume 0,5–1,5 cm^3
- Number of samples min 15
- Mass 3,5 kg

Cooperation: IKI

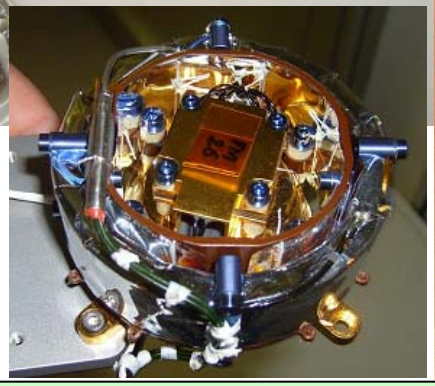
Robotic arm

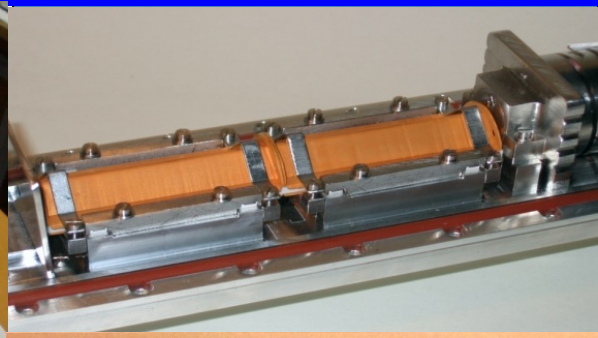
Sampling device with a collet holder (EM), and loading the TDA instrument (QM)

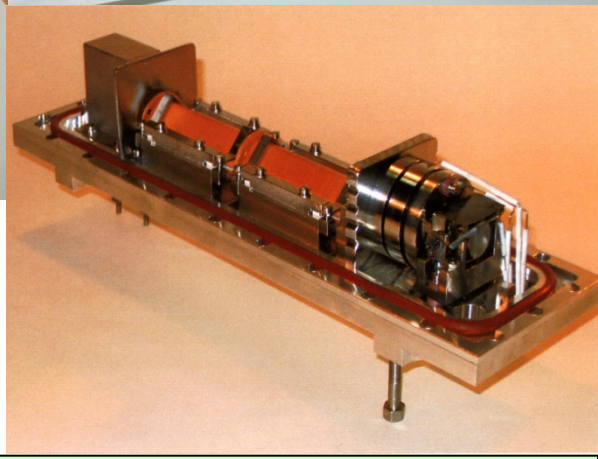


Gas-Chromatograph Complex

Therm.-Differenc.Analyzer TDA (pyrolytic cells) → **Chromatographer ChMS-1 + TDLAS** → **Mass-spectrometer MAL-1**







PI: Dr. M. Gerasimov

Cooperation:

IKI, Vernadsky, France, Germany, China

Chemical composition of volatile components in the soil of Phobos (bound water, organics, noble gases, isotopes of abundant molecules, etc.)

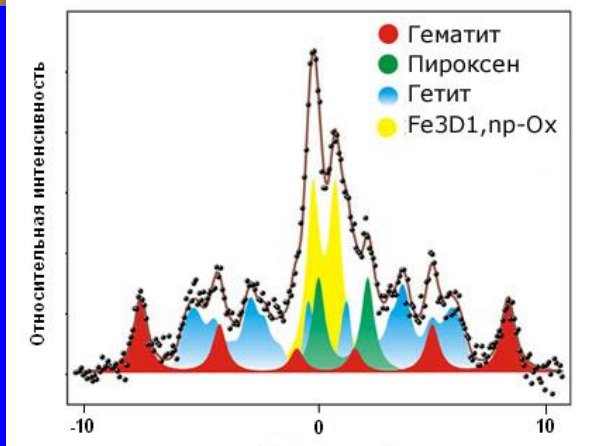
- TDA: to identify phase transitions during pyrolysis (6 ovens)
- GC: to measure the quantity of evolved gases, and chemical composition by the time of retention in a chromatographic columns. (2 columns)
- TDLAS: to measure quantity and isotopic composition of H_2O, CO_2, and C_2H_2 (four leasers)
- MS: to elemental composition of gases separated by GC.

MESSBAUER SPECTROMETER

MINERALOGICAL COMPOSITION STUDIES OF IRON COMPOUNDS IN THE PHOBOS SOIL

- The mineralogical identification of iron-bearing phases on the surface of Phobos
- The quantitative measurement of the distribution of iron among these iron-bearing phases
- The quantitative measurement of the distribution of iron among its oxidation states (e.g., Fe^{2+}, Fe^{3+}, and Fe^{6+})

Excitation source ^{57}Co
Similar experiment was carried out on NASA Mars rovers since 2005



Johannes-Gutenberg Universität Mainz,
Institut für Anorganische und Analytische Chemie
Dr. Goestar Klingelhoefer
Space Research Institute, Russia

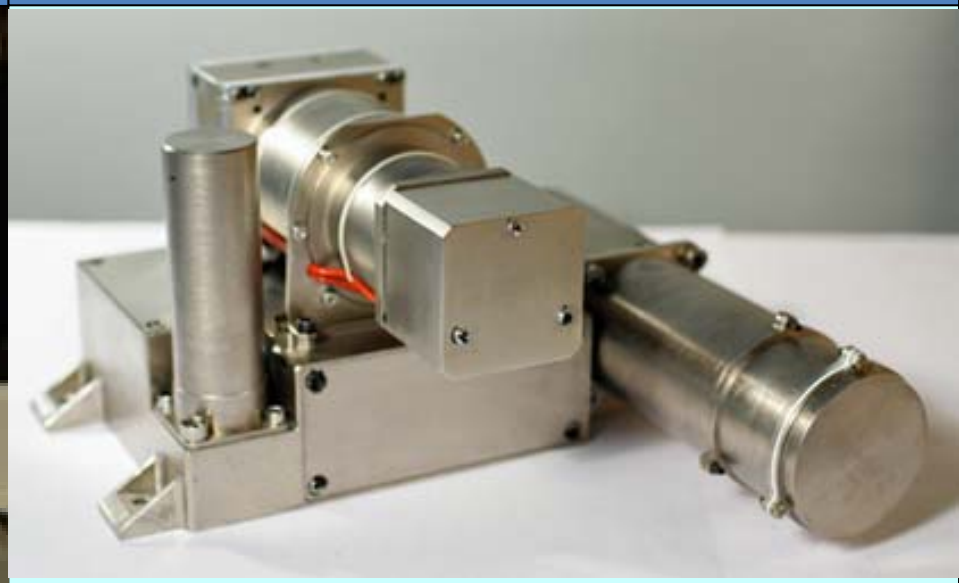
Nuclear – physical experiments

GAMMA-SPECTROMETER
PhGS

The study of the Phobos rocks chemical composition
The measurement of the chemical elements concentration on the Phobos surface: the rock-formed elements (from H to Fe) and the natural radioactive (K, Th, U) ones.

Energy of gamma-rays 0,3 - 9 MeV
Cooperation: Vernadsky Institute, SNIIP

NEURTON SPECTROMETER
HEND



Scientific tasks:
•studying composition of Phobos regolith;
•searching of hydrated materials or / and water ice on the subsurface of Phobos;
•development of physical model of radiation background on the surface of Phobos and on Martian orbits

Range of measurement::
- Neutrons – 0.4 eV – 15.0 MeV
- Gamma-rays – 100 keV – 10 MeV

PI - I. Mitrofanov
Cooperation: IKI, ESA

Mass-spectroscopy

Laser time-of-flight Mass- reflectron **LASMA**

Quantitative analysis of elemental and isotopic composition of Phobos' regolith at 30-50 μm

Mass range - 1-250 a.e.м.

Time-of-flight mass analyzer of secondary ions **MANAGA**

Measurement of elemental and isotopic composition oa secondary ions, generated from the surface of Phobos under the influence of Solar wind primary ions.

Mass range - 1-300 a.e.м.
resolution > 100
sensitivity 1 ppm

PI: Prof. G. Managadze, IKI . Co-PI: Prof. Peter Wurz, Univ. Bern

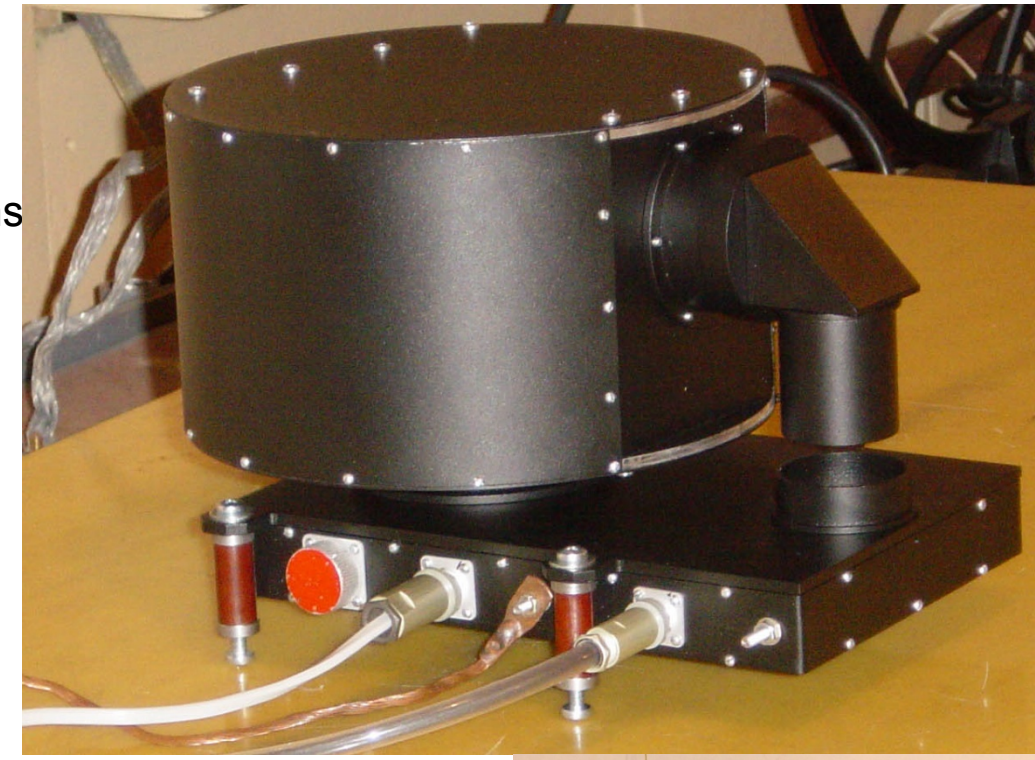
IR-spectroscopy

Fourier Spectrometer
AOST

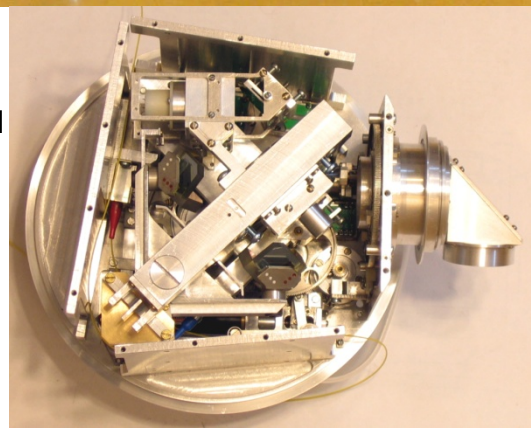
Martian atmosphere
- Methane, minor constituents (by Sun occultations)
- Profiles of temperature; diurnal variations
- Monitoring of aerosols

Martian soil
- Discriminating chemically-bound and adsorbed water bands
- Diurnal variations (temperature profiles, surface frosts)

Phobos
- Global mineralogical mapping (from quasi-synchronous orbit)
- Site spectrospy at *cm*-scale (after landing)



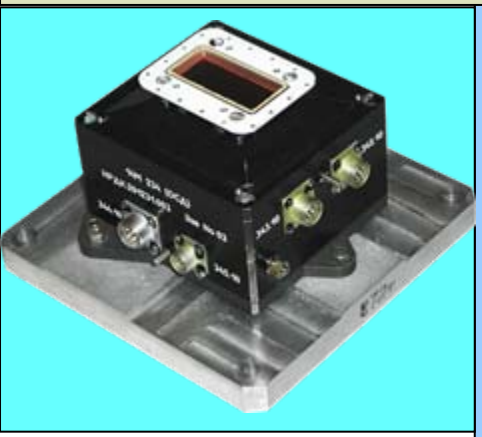
Spectral range 2,5 – 25 μ
Resolution: 0.9 cm^{-1}
Field of view - 2.3 deg
Mass 4 kg



PI: Prof. O. Korablev, IKI

TV cameras

TV system for observation and navigation **TSNN**



Goals :
- Navigation near Phobos;
- Landing sites selection;
- Support of control during landing;
- Phobos surface imaging

Wide-angle camera F= 18 mm, 23,2 x 23,2 grad,
Nerrow-angle camera F= 500 mm, 0,85 x 0,85 grad,

CCD matrix Kodak-1020
Number of active elements 1004 x 1004
Size of an element, μм 7,4 x 7,4
Spectral range, μм 0,4 – 1,0

Space Research Institute

TV cameras
PANCAM STEREO MICRO

PANCAM on the arm
F=12,4 mm

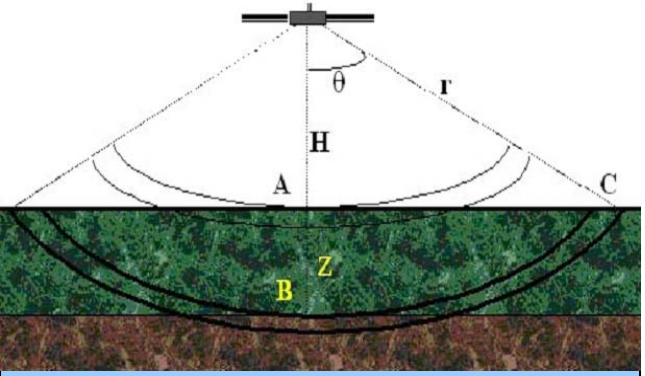
STEREO pair
Base 80 mm

Matrix:
Thomson-CSF TH 888A
Heritage:
Rosetta ESA mission

Cooperation:
J.-P. Bibring
IAS, Orsay, France
IKI

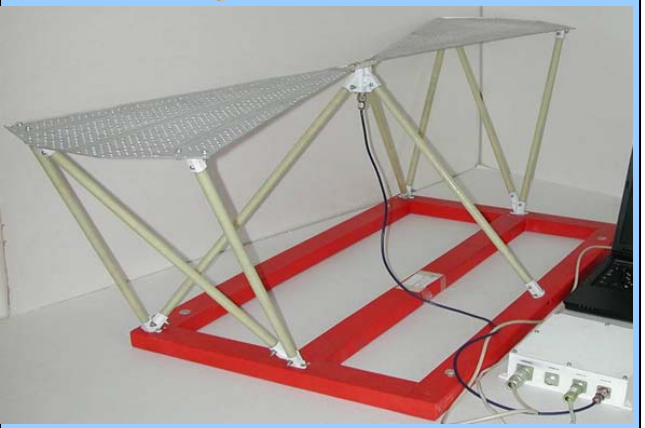
MicrOmega microscope
505, 600, 670, 750, 880 nm

Long Wave Radar
LWR



Phobos Surface and subsurface structure
Detection rock layers on depths 1–100 m

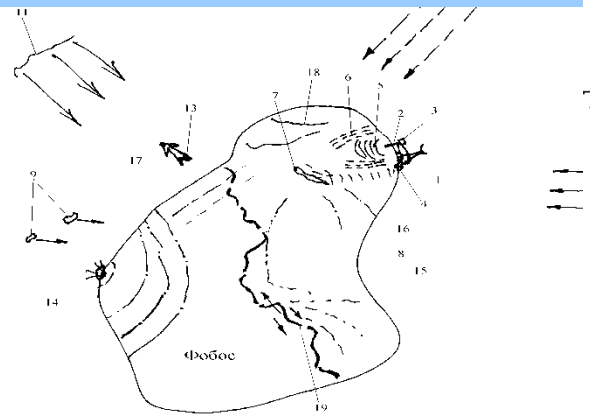
Frequency range 150±25 MHz
Resolution 2 m
Power of impulse 20 ÷25 Вт
Mass 3,5 kg



Cooperation: Radioengineering Inst.

Seismometer
MUSS

Research of an internal structure of the Fobos;
Analysis of manifestation of external pulse influences (forcing) and fields.
Registration of seismic signals and wave fields of Phobos
Measurement seismo-gravitational fluctuations on a surface of Phobos in a range $3*10^{-5}$ -10 Hz

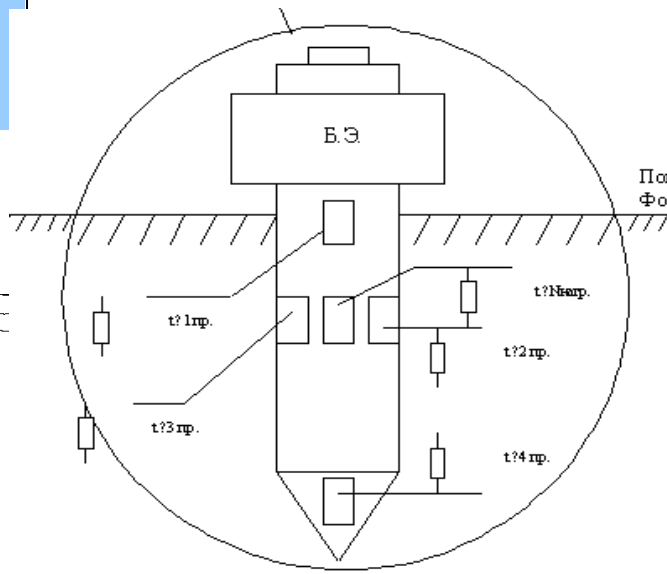


SAB Seismic Acoustic Block
60 db, 10-4 - 10-7 m/s2
BDSB Bandwidth-Duration Seismic Block
> 60 db, 10-7 - 10-10 m/s2
GRAC-F Seismic Gravimeter
> 100 db, f= 3*10-5 - 102 Hz.

Cooperation:
IFZ, VNIIFTRI, IKI, Vernadsky Inst.

Termodetector
TERMOPHOB

- Thermal measurements of Phobos surface
- Soil temperature, soil heat and electrical conductivity

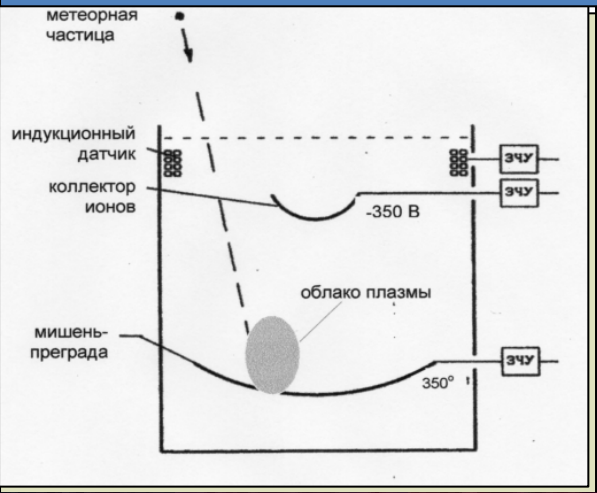


Characteristics:
Spectral chennels, mkm 0.45, 0.55, 0.65
Temperature range. 160-380 K
Resolution 0,1 grad
Mass 0,3 kg

Cooperation: Apply Math Institute

Investigation of the Martian environment

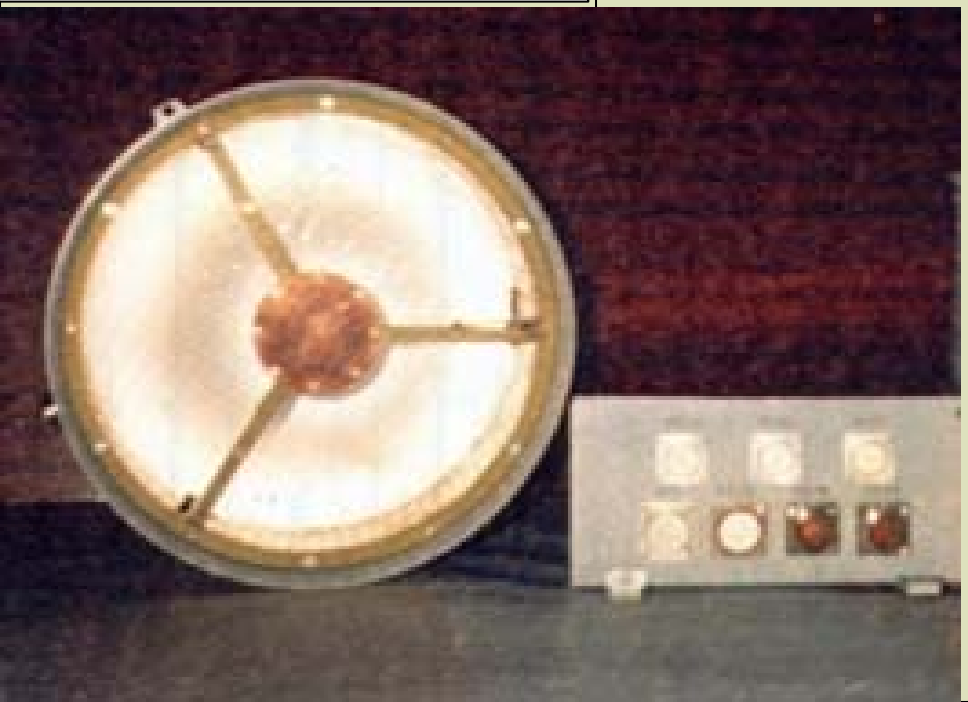
Micrometeorites detector
METEOR



Investigation of parameters of micrometeors (m, v)
Control micrometeor situation during the mission
Velocity range *3 до 35 km/sec*

Mass range 10^{-14} - 10^{-6} *g*

Cooperation:
Vernadsky Institute, ABEPC,
Lavochkin Association

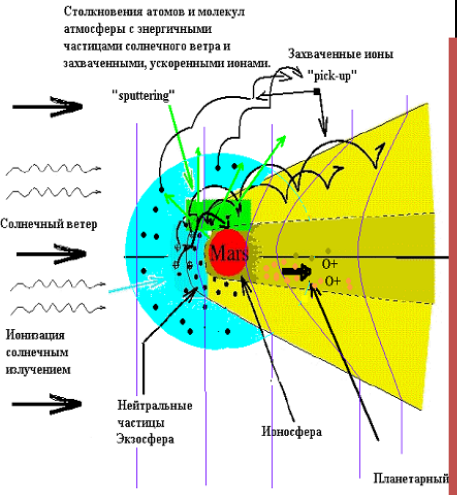


Martian environment

Plasma-Magnetic Suite
PhPMS

Main goal : STUDYOF PLASMA-WAVE PROCESSES OF SOLAR WIND INTERACTION WITH THE MARTIAN PLASMA

Measurements of quasistatic and variable magnetic fields, electron and ion fluxes, their angular and energetic distributions, ion composition of plasma in the near Mars environment.



Magnetic sensors: search-coil and fluxgates

DC +/- 1000nT (0.1nT)
AC -10^{-6} nT / $Hz^{1/2}$ (10 Hz-100KHz)
current- 10^{-15} А/см^2/$Hz^{1/2}$10 Hz-100 KHz

Digital Processing unit

Spacecraft

Ion composition sensor 10 eV-15 KeV

Planetary ion sensor 3 eV – 3 KeV

Cooperation – IKI, Germany, France, Sweden, Ukraine

Celestial mechanical experiments

INVESTIGATION OF PROPER AND FORCED LIBRATION OF PHOBOS **LIBRATION**

Investigation of internal structure of Phobos:

- Inhomogenuity of the body
- Center of mass and momentum of inertia
- Density
- Peculiarities of orbital and proper motion

Solar sensor
Stellar sensor

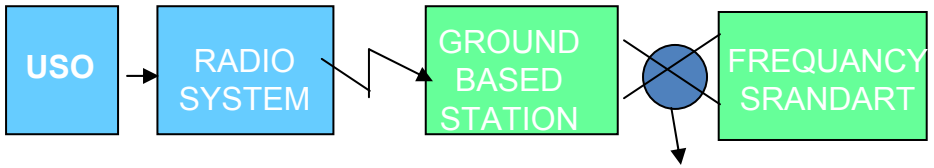
- matrix 1280x1024 pix

Resolution
- solar sensor 1 min.
- stellar sensor 10 sec.
- dynamic range 1000

Cooperation – IKI, LITMO, INFRATRON

ULTRASTABLE OSCILLATOR **USO**

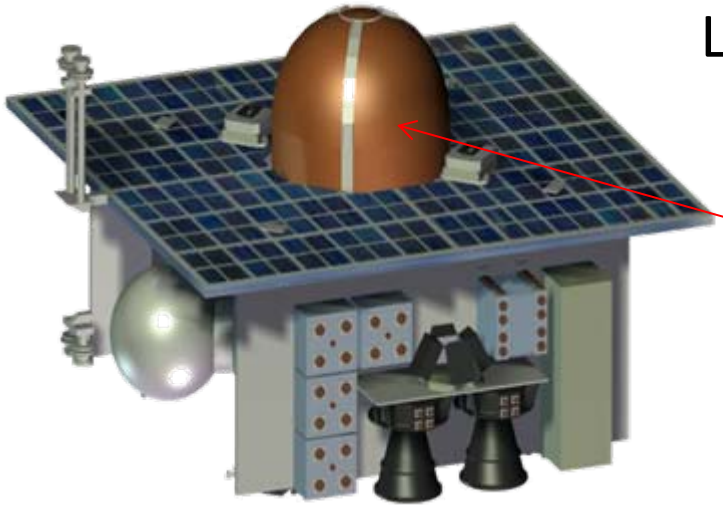
- improvement of solar system parameters (astronomical unit, orbital parameters of Mars and Phobos);
- experimental estimation of Phobos lifetime on its orbit;
- determination of the mass distribution inside Phobos;
- refinement of masses of large asteroids from main belt;
- refinement of experimental limit of the constancy (or detection of time variations) of universal gravitational constant;
- refinement of the geometrical connection of dynamical coordinate system with origin in solar system center of mass and quasar coordinate system based on the measurements of relative angular coordinates of quasars.

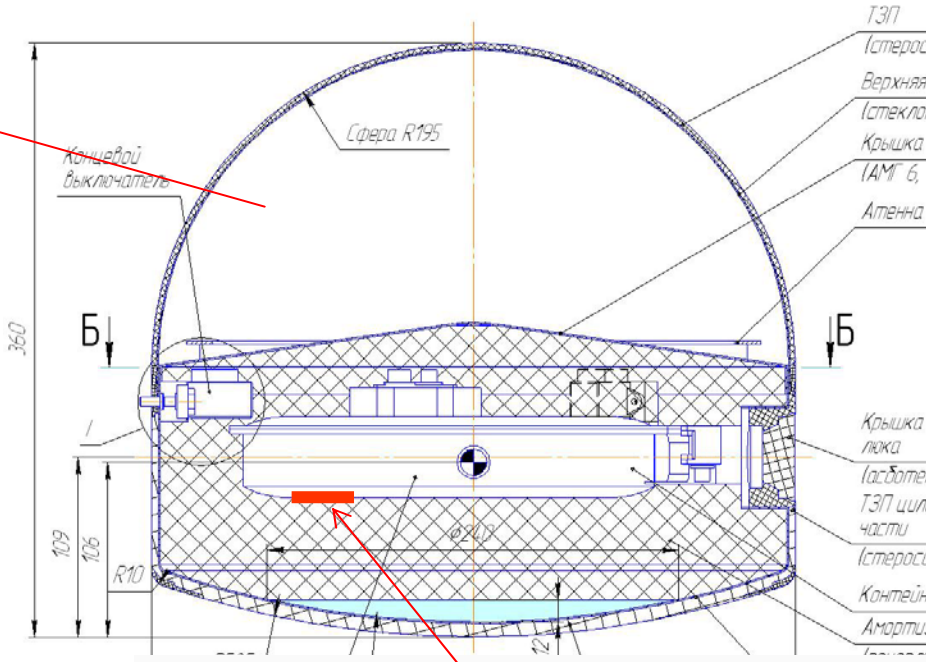


Stability better than 10^{-12}

Cooperation: IKI, JIVE

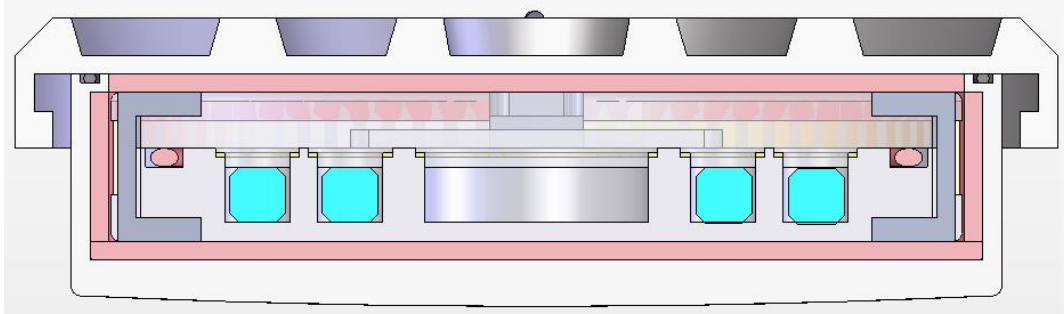
Living Interplanetary Flight Experiment **LIFE** (returned)

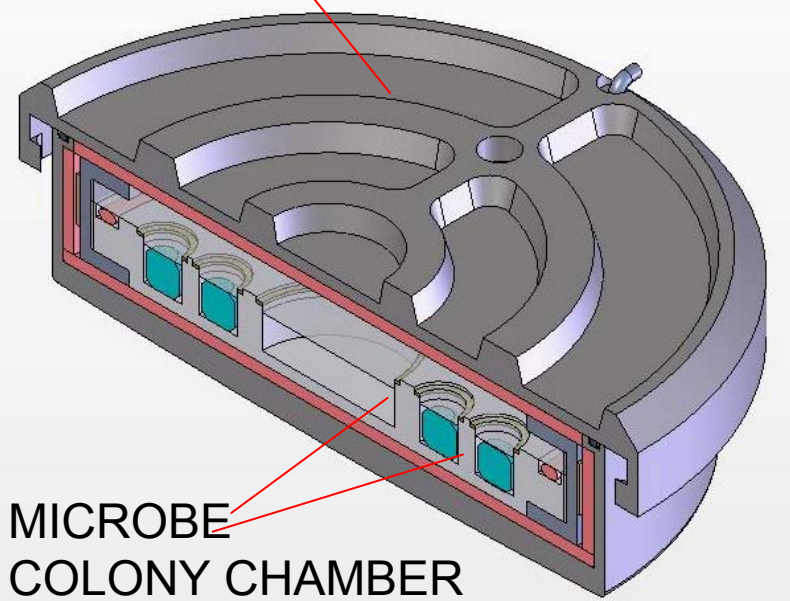




Goals: Study of the survivability of microorganisms during interplanetary transfer

- BIO-CARRIER IS SHOCK MOUNTED
- TRIPLE VACUUM SEALED
- DOUBLE LOCKED
- PLANETARY STERILE





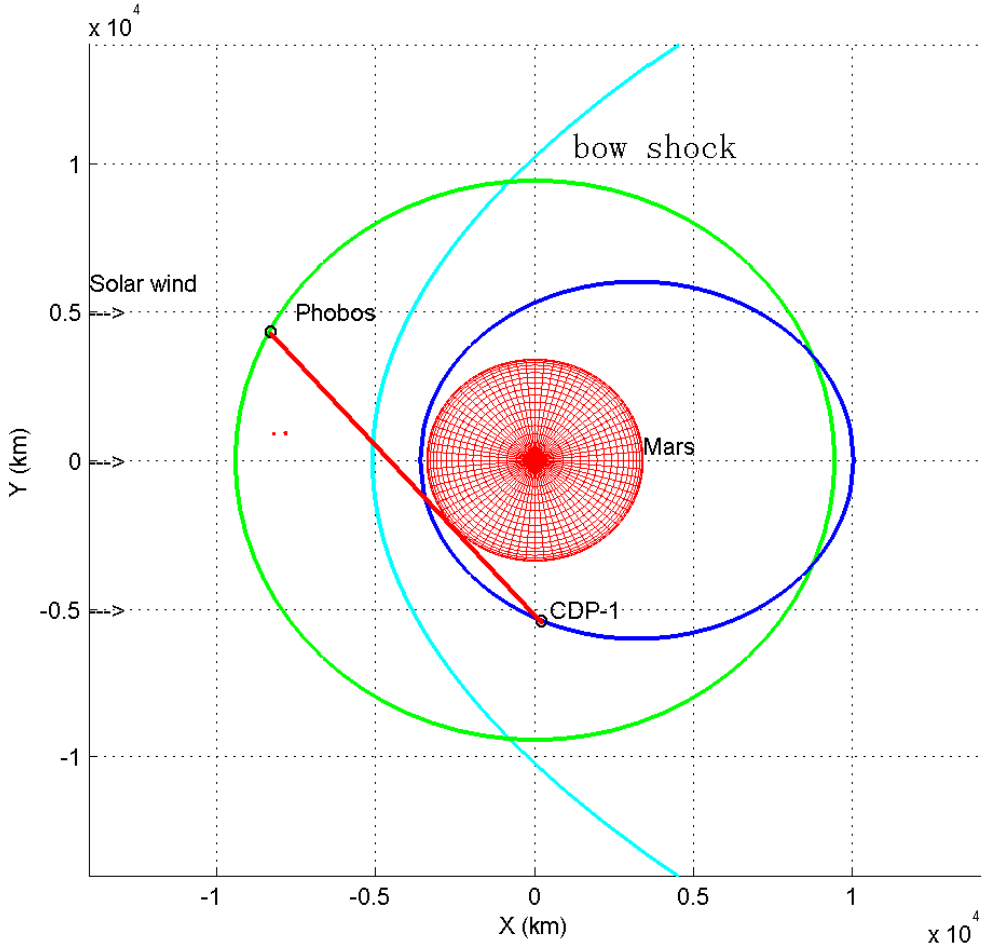
MICROBE COLONY CHAMBER

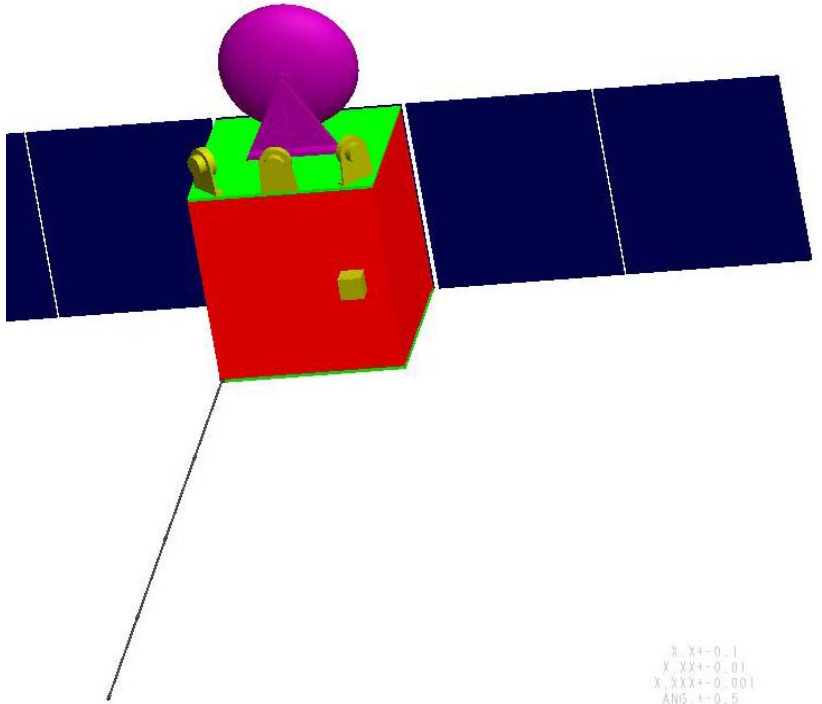
Participants: Planetary Society, IKI, IMBP, MSU

Chinese Mars Micro-satellite, Yinghuo-1

Investigation of the interaction of the solar wind with Mars

- bow shock
- ions escaping,
- ionosphere





- Microsatellite,
- Total mass 112Kg,
- Power budget: 75W
- 3-axis stabilized platform
- Rigid boom for FGM

Integrated spacecraft

NEWS OF THE PROJECT

- Launch in 2011 (widow opens ~25 Dec)
- TM (and possibly TC) using ESA antennae
- New head of NPOL (from Feb 2010)
- Flight instruments returned to IKI for calibrations/upgrades

International contributions

- ESA
  - ground segment;
  - detector of NGRS (ESTEC)
- France
  - A set of cameras for technical vision, MicrOmega (IAS)
  - GC columns/detectors (LATMOS)
  - TDLAS (LATMOS/Uni Reims)
  - Contribution to FTIR
  - Particip. to Plasma package
- Germany
  - Moessbauer spectrometer (MPCh Mainz)
  - Contribution to GCMS (MPS Lindau)
- Sweden
  - A channel of Plasma package
- China
  - Subsatellite Yinghou (contractual)
  - TDA sample preparation crusher (Uni Hong-Kong)

Planetary society : participation to LIFE return experiment