
# Phobos Sample Return Project

Space Research Institute

Vernadsky Institute of Geochemistry

Radioengineering and Electronics Institute

Apply Math Institute

Lavochkin Association

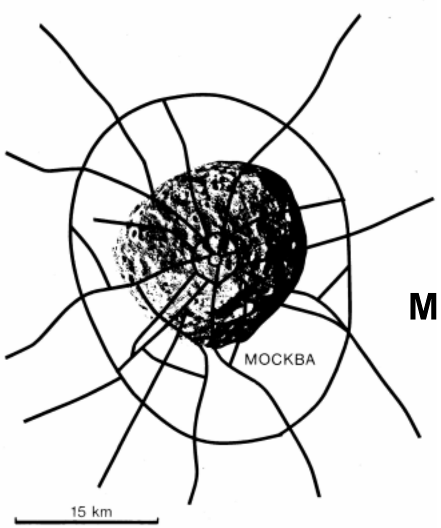
## Goals of the Mission

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

## Peculiarities of the mission:

1. **Samples return**
2. **Mars system science:**
   - **Martian moons** (regolith, internal structure, origin, evolution),
   - **Martian environment** (dust, plasma, fields),
   - **Mars** (surface and atmosphere global dynamics)

# Phobos and Deimos:  similarity and difference




| | | |
|---|---|---|
| **Dimentions** | 26,6x22,2x18,6 km | 15,0x12,4x10,8 km |
| **Dencity** | 1,9 ±0,1 g/cm$^3$ | 1,8 ±0,3 g/cm$^3$ |
| **Reflectance** | 0,071 ±0,012 | 0,068 ±0,007 |
| **Taxonomy** | T (or B, or D) | D (?) |
| **Morphology pecularities** | long fossas | no fossas |
| **Gravity** | 0,54 cm/c$^2$ | 0,31 cm/c$^2$ |
| **Circular orbit** | R=9378 km (2,76 $R_m$)<br>T=7h 39 min, i=24$^0$ | R=23459 km (6,9 $R_m$)<br>T=30h 21 min, i=24$^0$ |
| **Proper motion** | Synchronous rotation,<br>libration: T=10h, A=7$^0$ | Synchronous rotation |

**Problems driving to study the Martian satellites:**

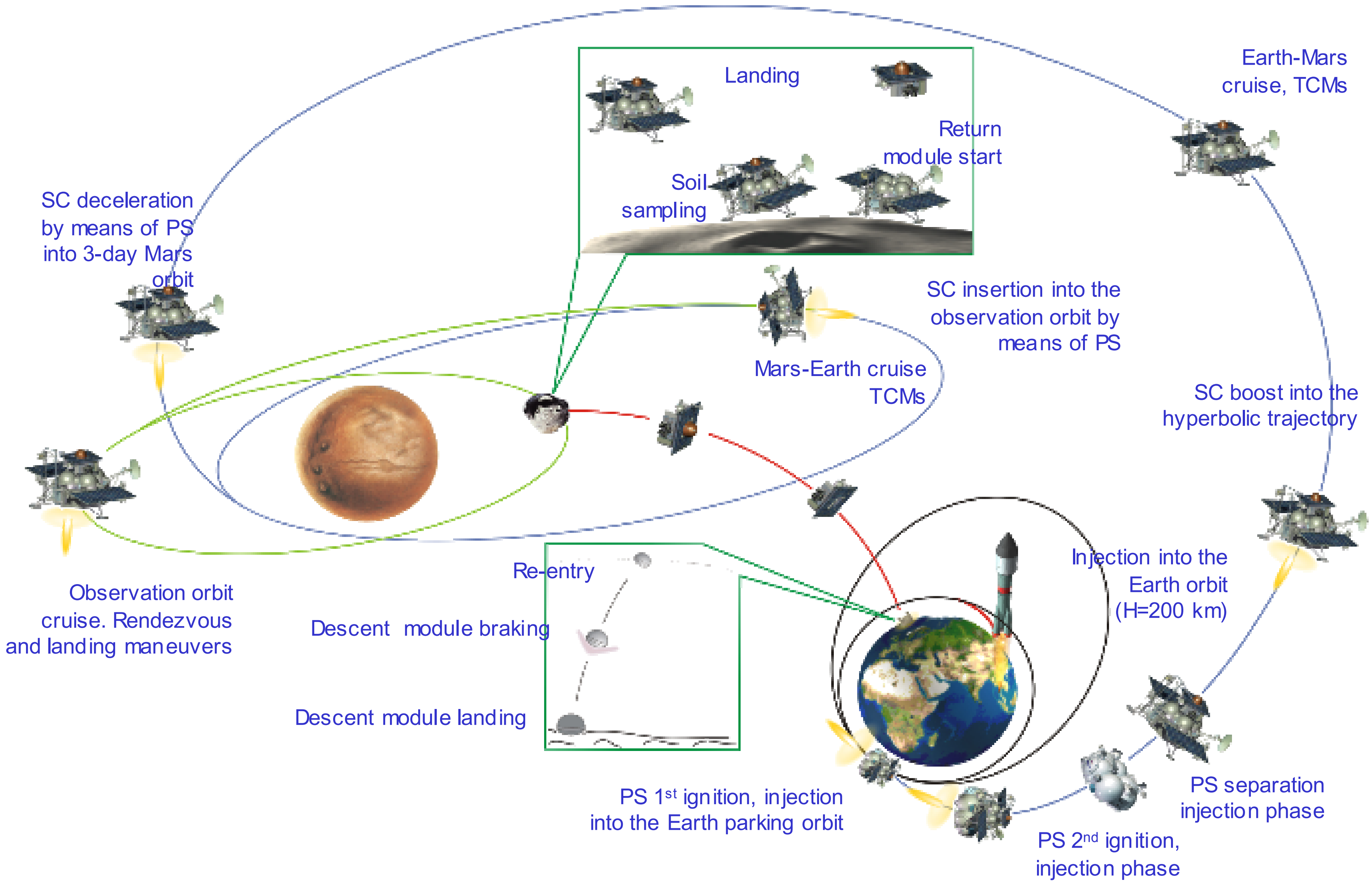
- origin of the Martian satellites,
- nature and characteristics of the regolith (relict matter?),
- difference in characteristics of the surfaces of Phobos and Deimos,
- low density,
- internal structure,
- peculiarity of the orbital and proper motion,
- dust tori ?

# Scientific objections

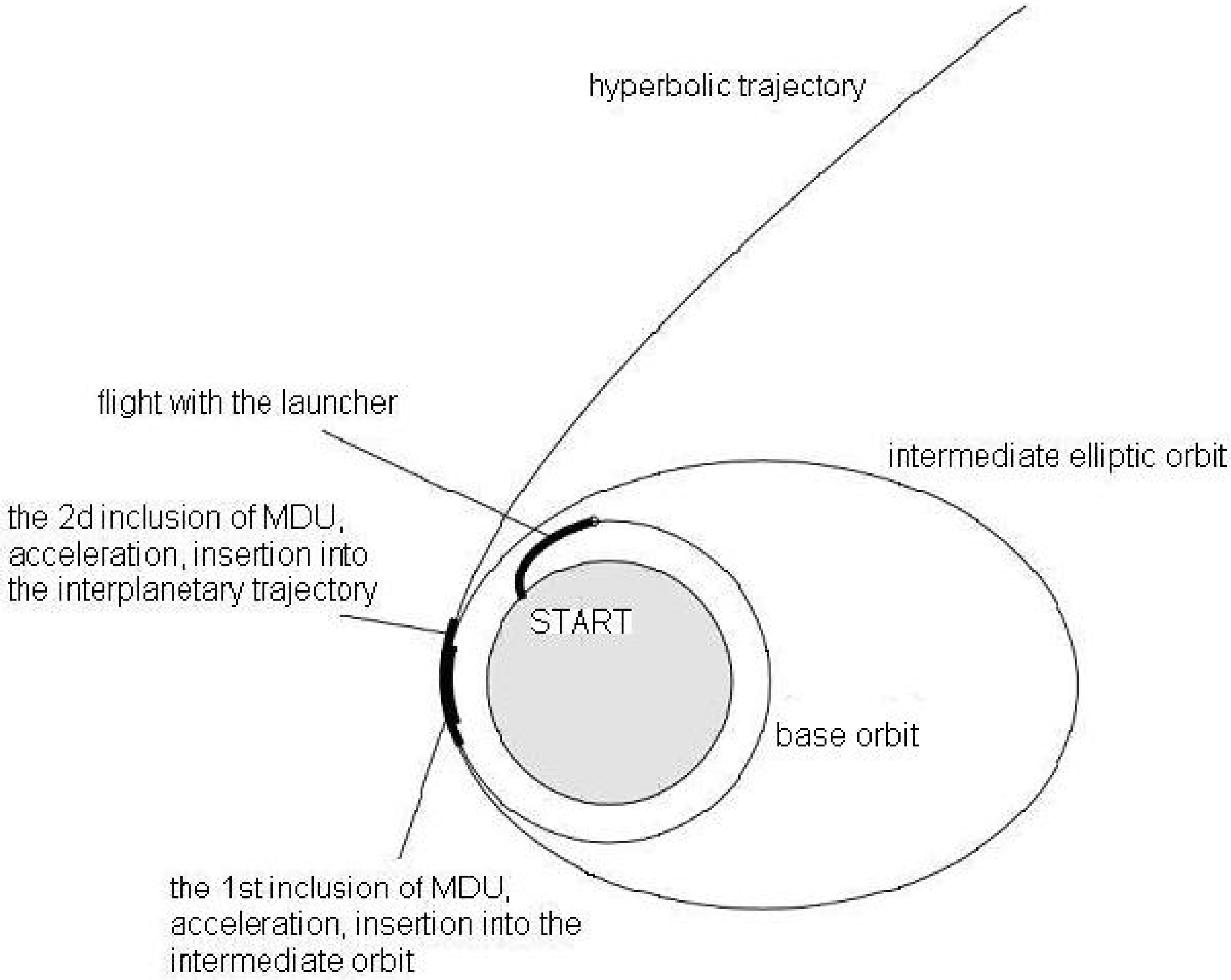
- **study physical and chemical characteristics of the Phobos regolith and subsurface layers *in situ* and under laboratory conditions** - these data can provide information on properties of primordial matter of the Solar system;
- **study of the role played by asteroidal impacts in the formation of terrestrial planets, in the evolution of their atmospheres, crusts, and inventories of volatiles**;
- **study of the origin of the Martian satellites and their relation to Mars** - these data can help in our understanding of their evolution and the origin of satellite systems near other planets;
- **search of possible trace of life or paleolife**;
- **study of peculiarities of orbital and proper motion of Phobos**, what is important for understanding their origin, internal structure, celestial mechanics applications;
- **study physical conditions of the Martian environment** (dust, gas, plasma components) what is important to study of treatment processes of small body regolith under influence of external conditions and creation of engineering model of the Martian environment for future Martian missions;
- **Monitoring of dynamic of the Martian atmosphere and seasons climate changing.**

PHOBOS SAMPLE RETURN

# MISSION PROFILE



# Launch of the spacecraft and transfer into the interplanetary trajectory




**Launch:**

Baikonur

**Base orbit:**

circular, 200 km, 2,8 revolutions (4 h.)

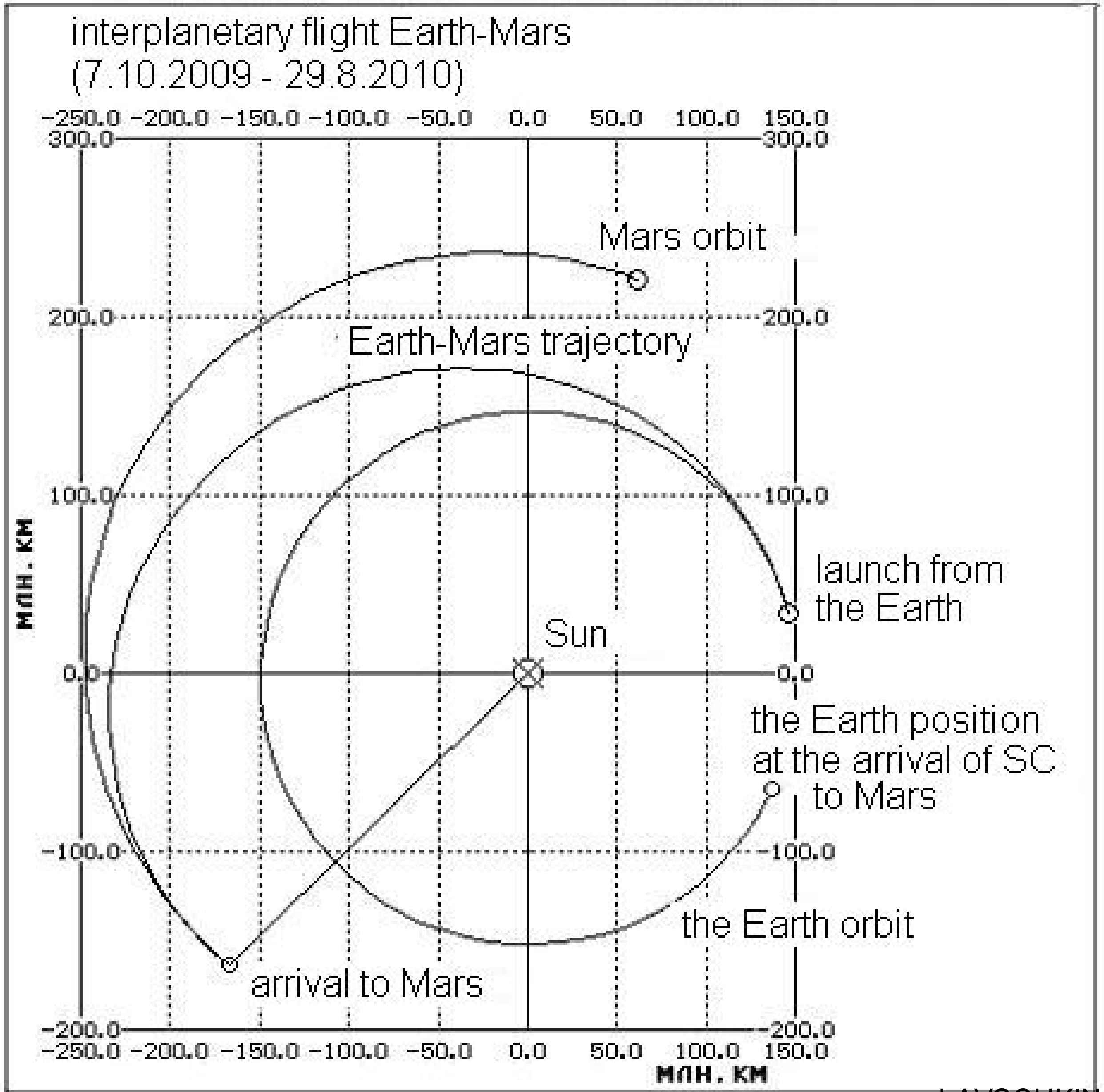
**Intermediate orbit:**

A=11100 km, p= 230 km, T=3,65 h. 7 revolutions (26 h.)

**Interplanetary trajectory:**

Asymptotic velocity 3,3 km/s

# The Earth-Mars Flight




**DSN**

Bear Lake (Moscow), Ussuriisk, Evpatoria

**3 corrections**

$\Sigma V$ = 45-60 m/s

# Insertion into the first Martian orbit

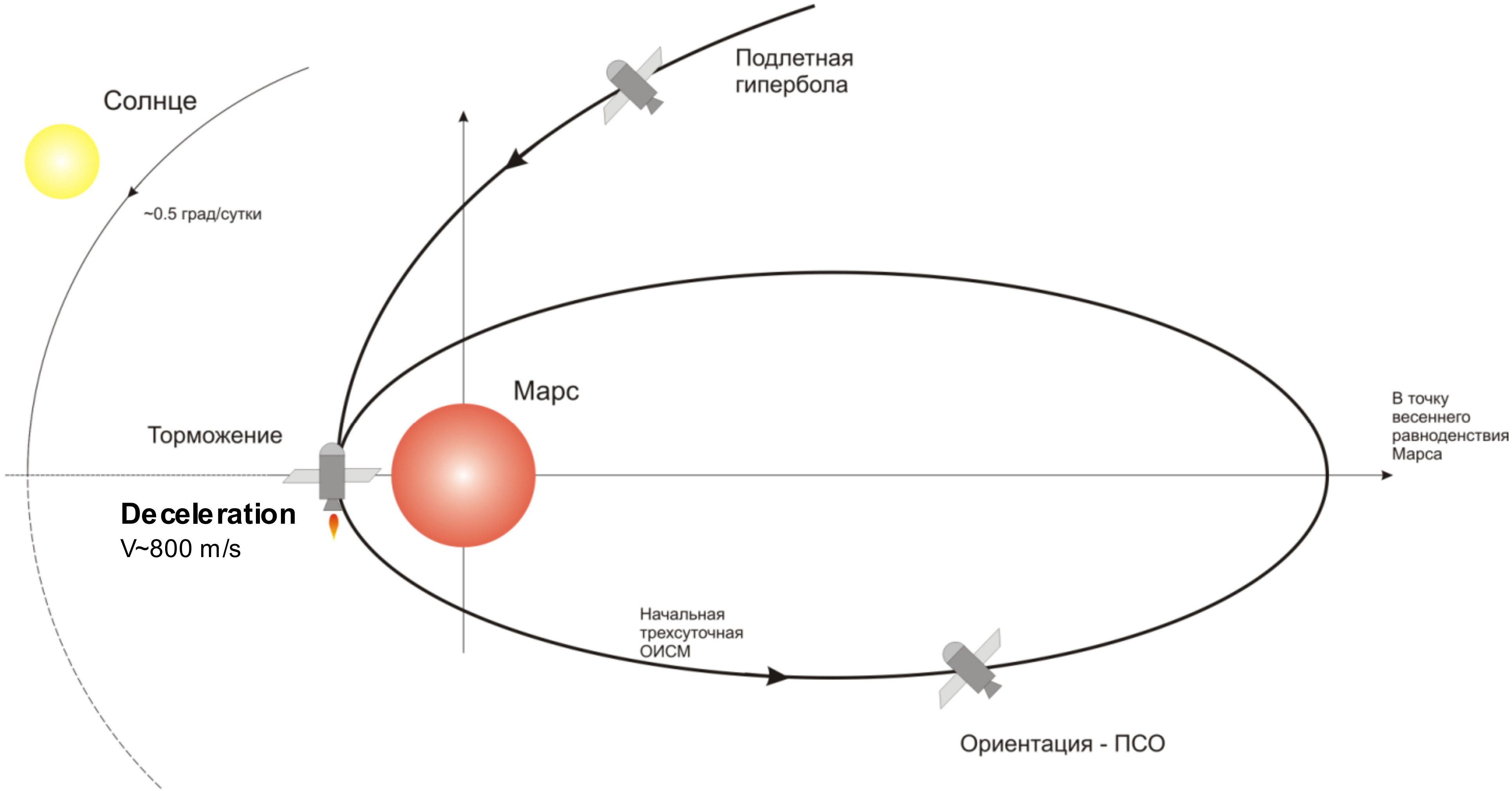
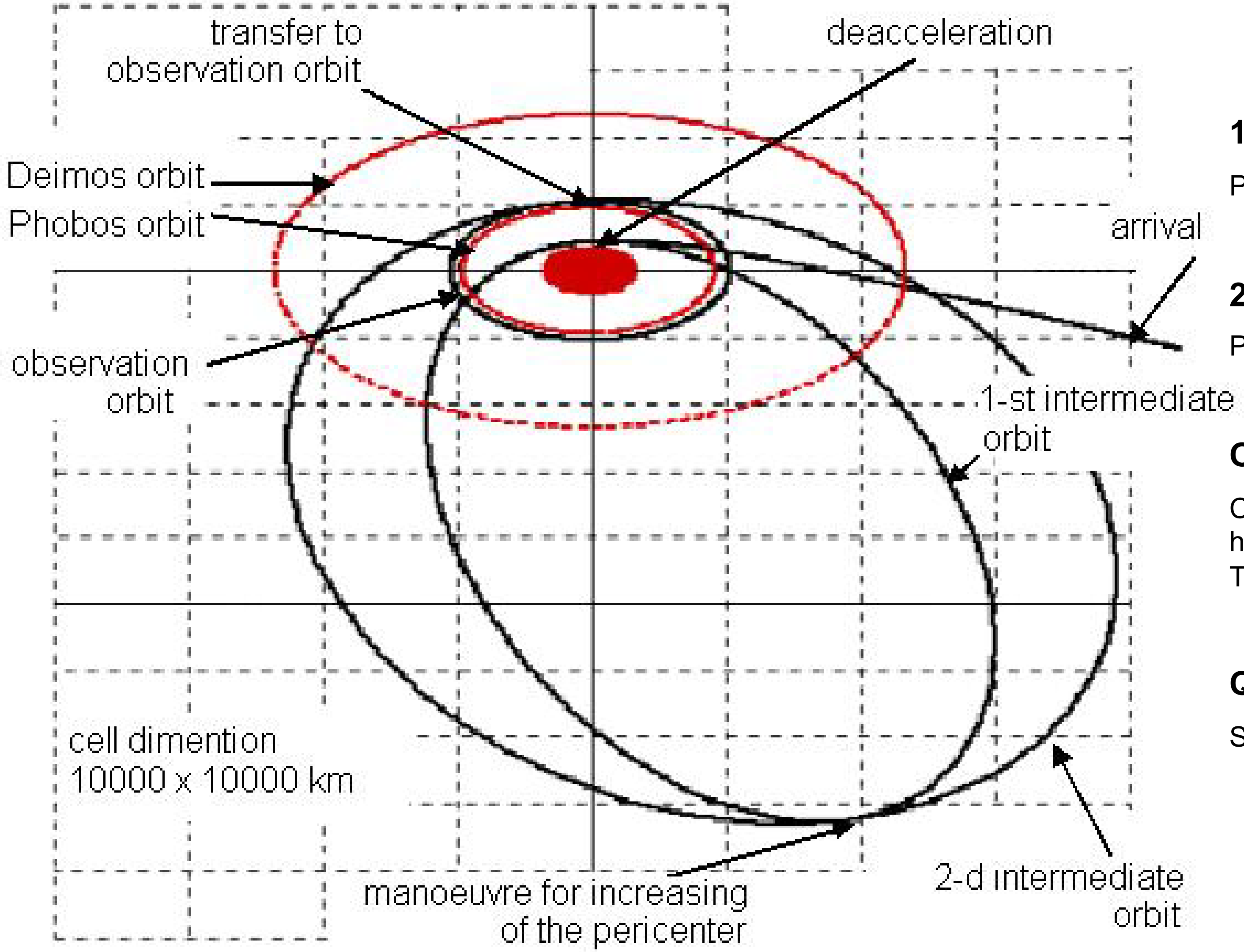



Схема подлета к Марсу и выход на начальную ОИСМ

# Orbits around Mars




**1-st intermediate orbit**

P=800 km, a=79000 km,T=3 d.

**2-d intermediate orbit**

P=9910 km, a=79000 km, T=3,3 d.

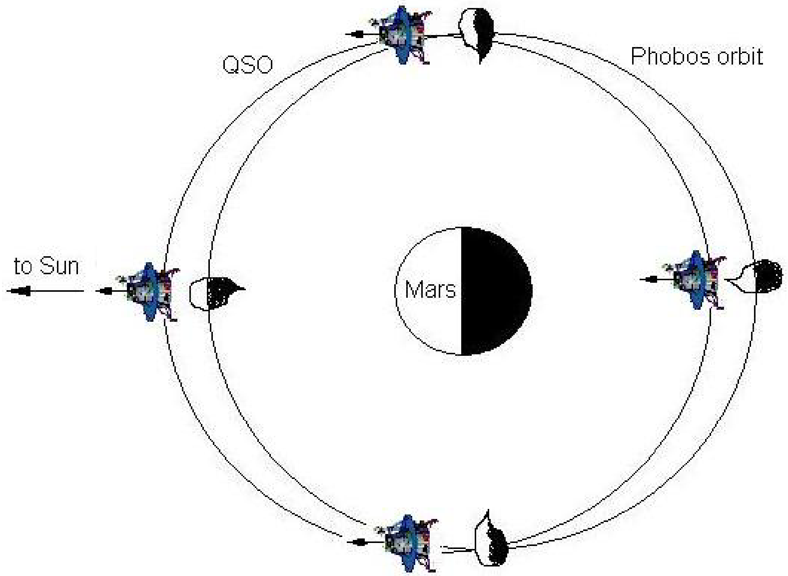
**Observation orbit**

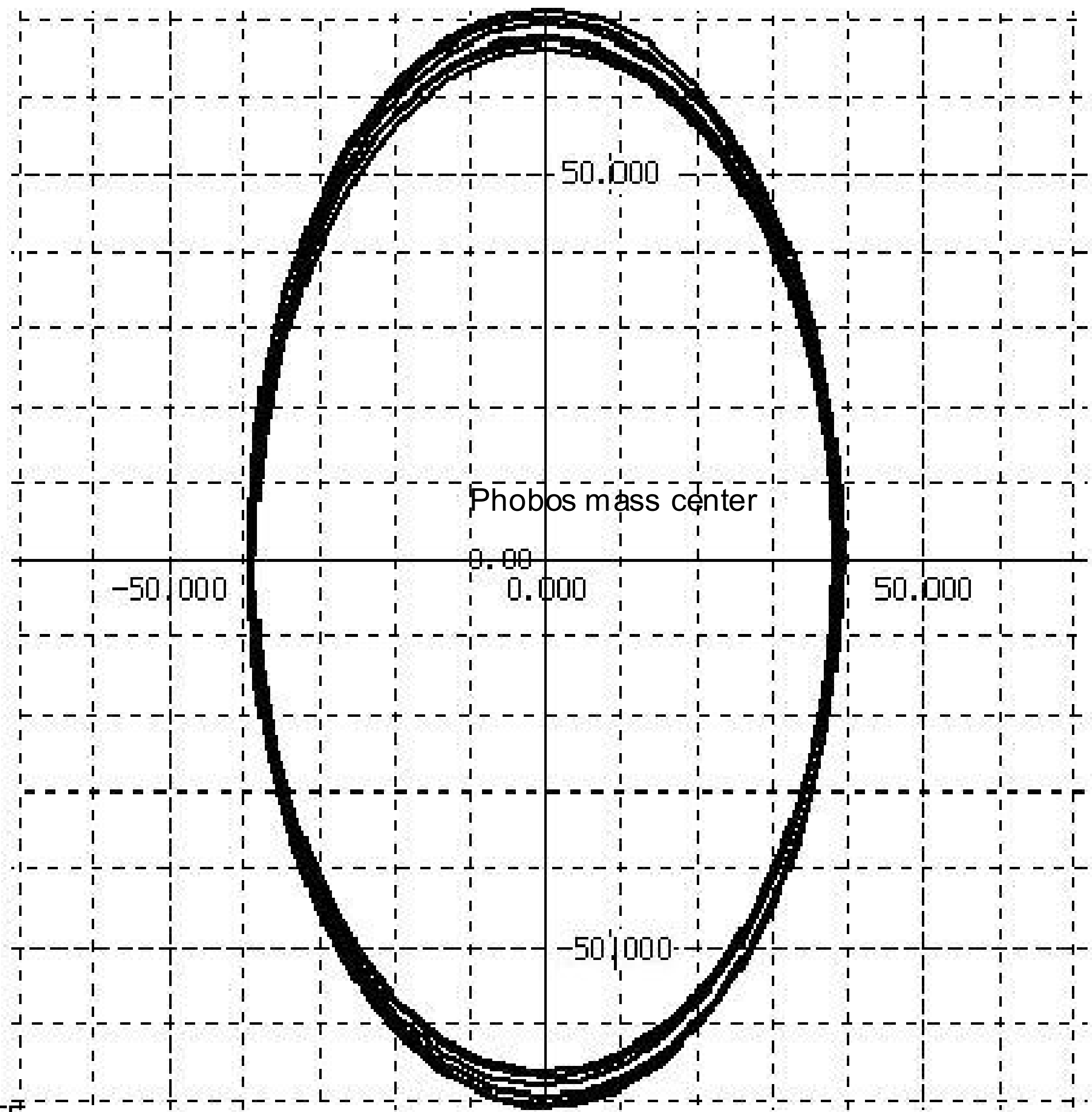
Circular, 9910 km (about 500 km higher then the Phobos orbit), T=8,3 h.

**Quasi synchronous orbit**

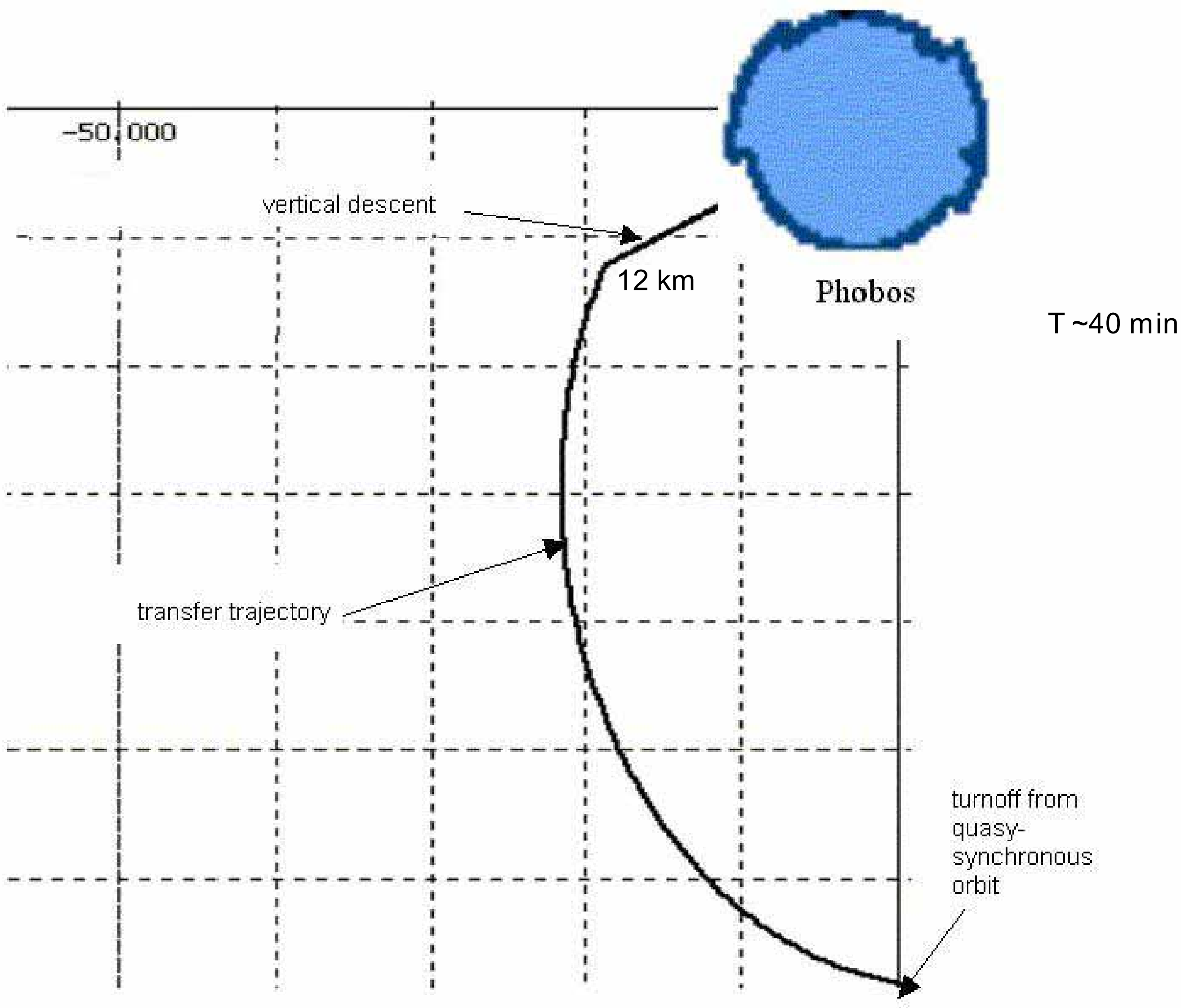
Similar to the Phobos orbit

# SC at the QSO

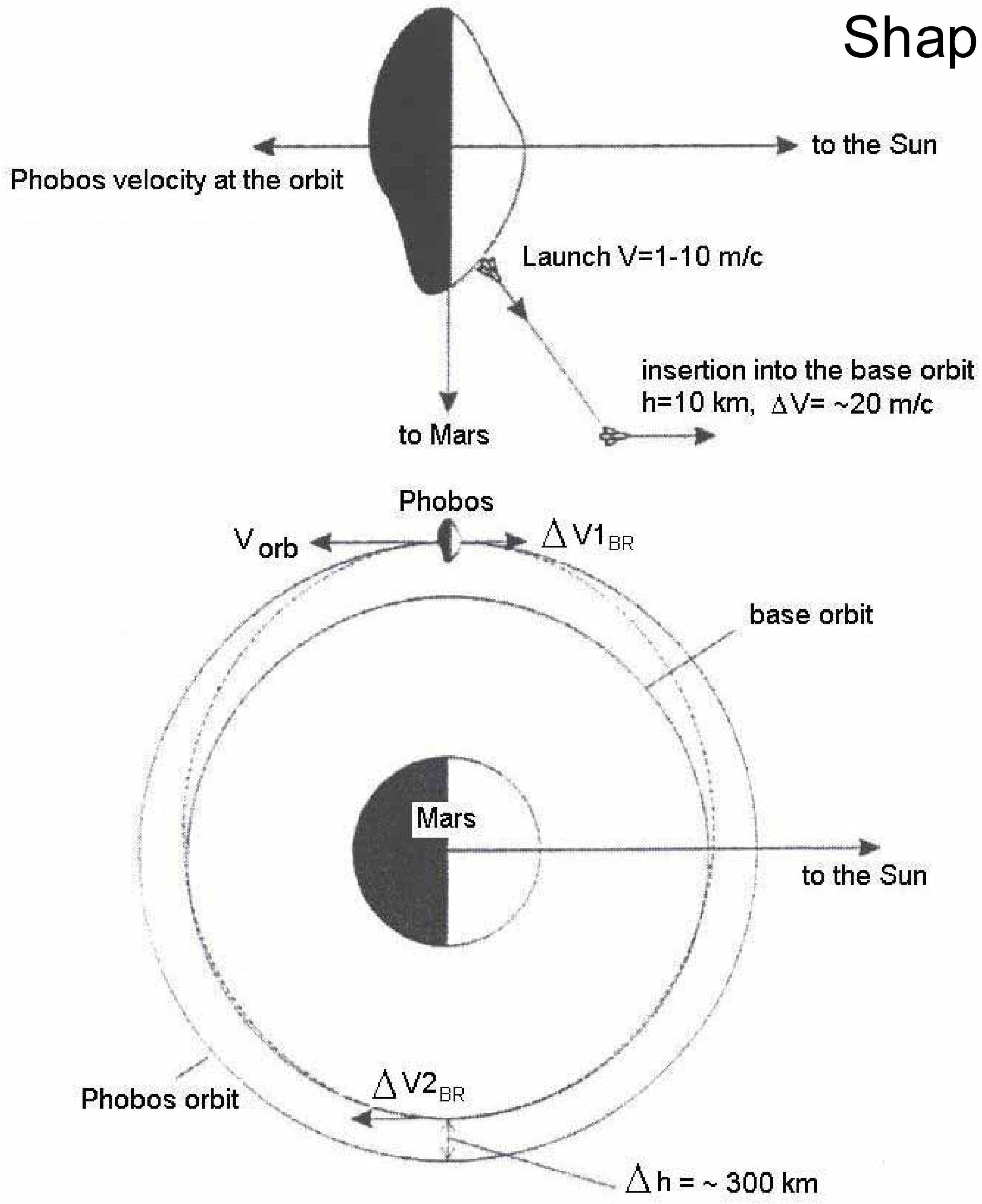

QSO
Phobos orbit
to Sun
Mars


50.000
Phobos mass center
0.00
-50.000
0.000
50.000
-50.000

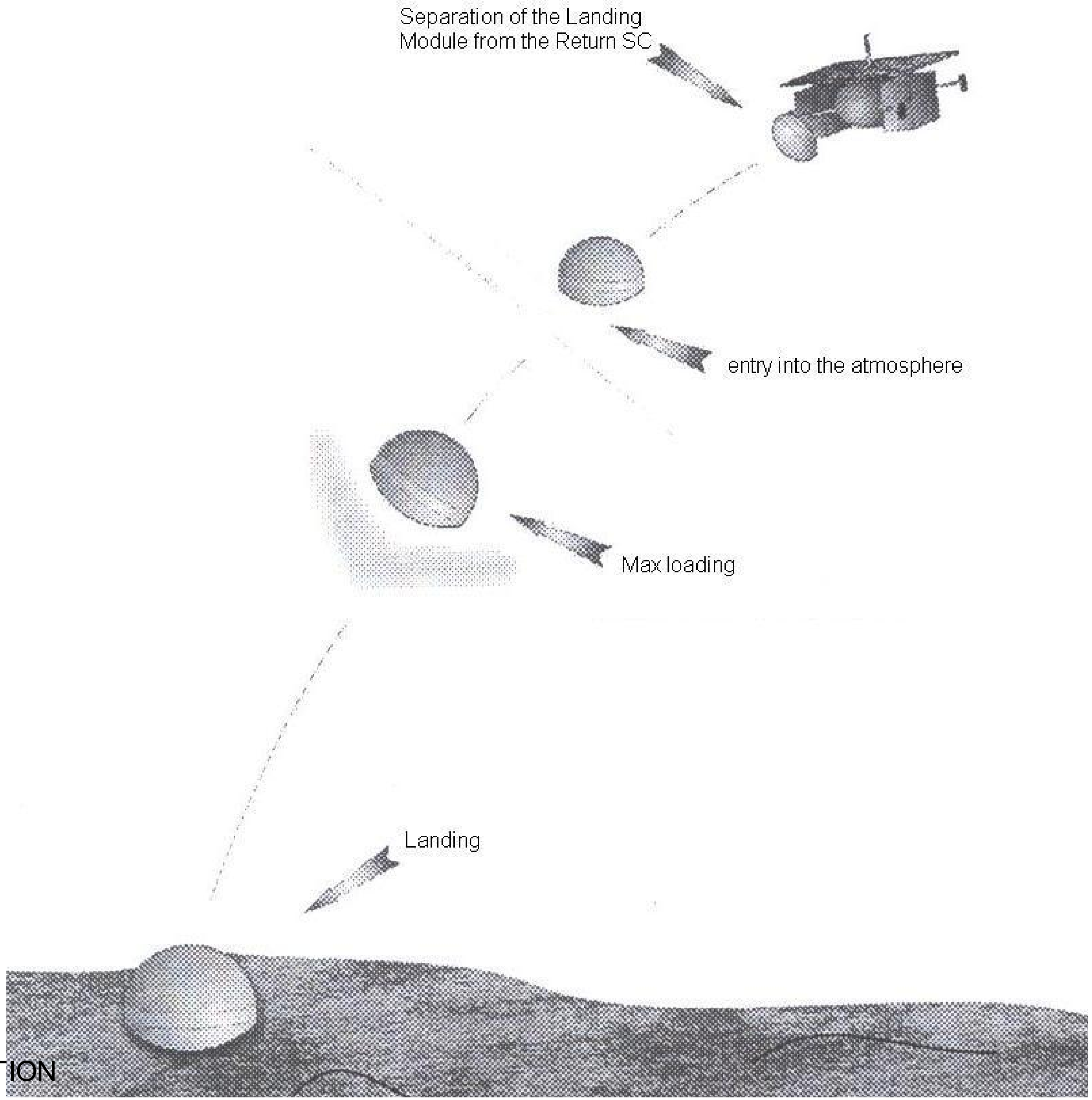
# Approaching Phobos and landing



# Shaping of the return sc orbits



# Entry into the atmosphere and landing at the surface of the Earth



## MAIN CHARACTERISTICS OF THE MISSION

Launch site…………………………………………............Baikonur Cosmodrome

Interplanetary Earth – Mars cruise time…………..…....10 – 11.5 months

Interplanetary Mars – Earth cruise time.....................10.5 – 11.5 months

Mission total time…………………………………...…~ 33-34 months

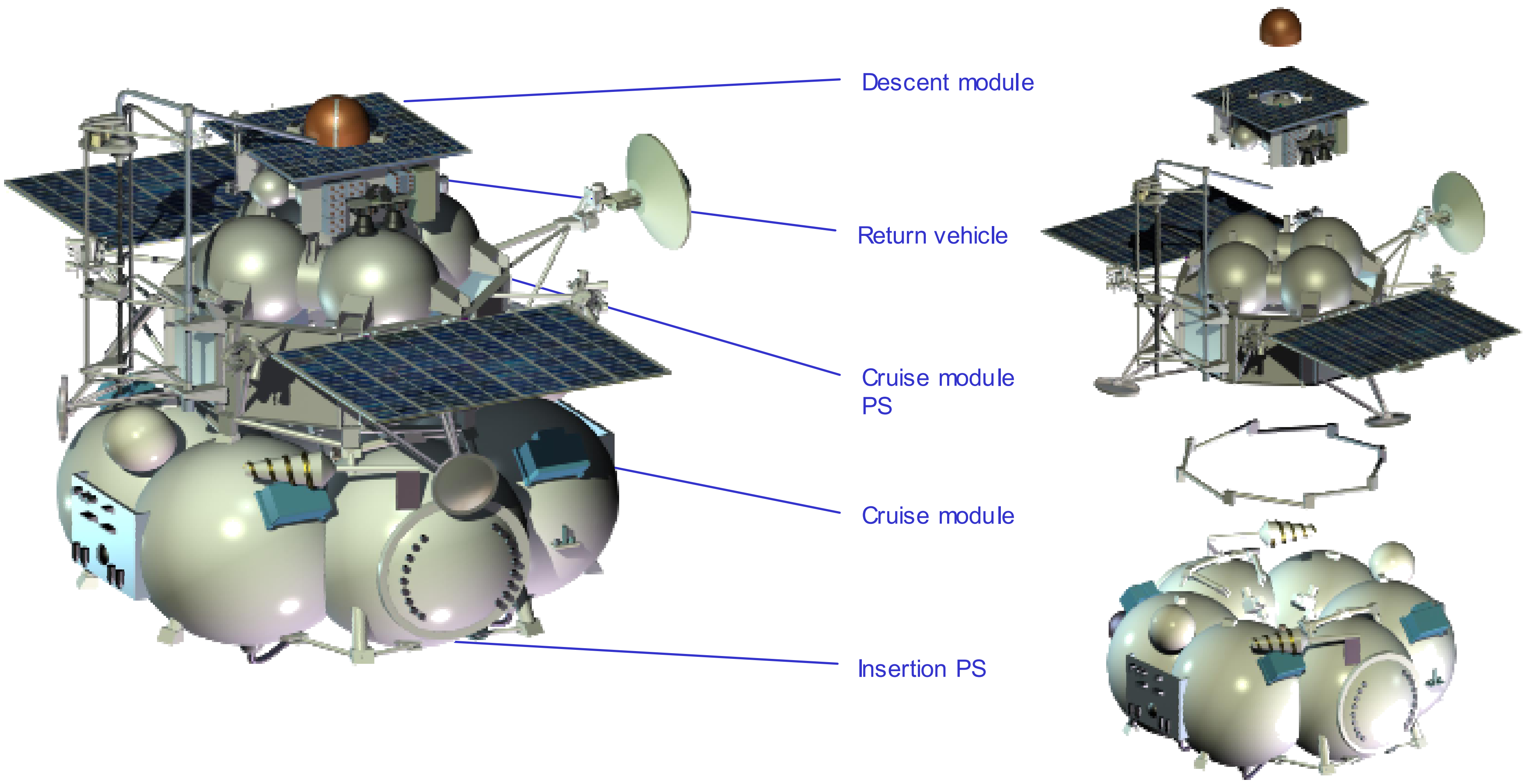
SC mass…………………………..……………………..8,120 kg

Scientific equipment mass……………………………..50 kg

Phobos soil samples mass……..………………………..0.2 kg

PHOBOS SAMPLE RETURN

# SC MARS ORBIT INSERTION CONFIGURATION



# Payload

## *Instruments for sc navigation and sampling*

TV-system

Mechanical device for sampling

## *Instruments for study of Phobos regolith and internal structure*

Panoramic camera

Gas-chromatograph

Messbauer spectrometer

Gamma-spectrometer

Neutron spectrometer

Laser TOF spectrometer

Mass-spectrometer of secondary ions

IR spectrometers

Thermoprobe

Long wave radar

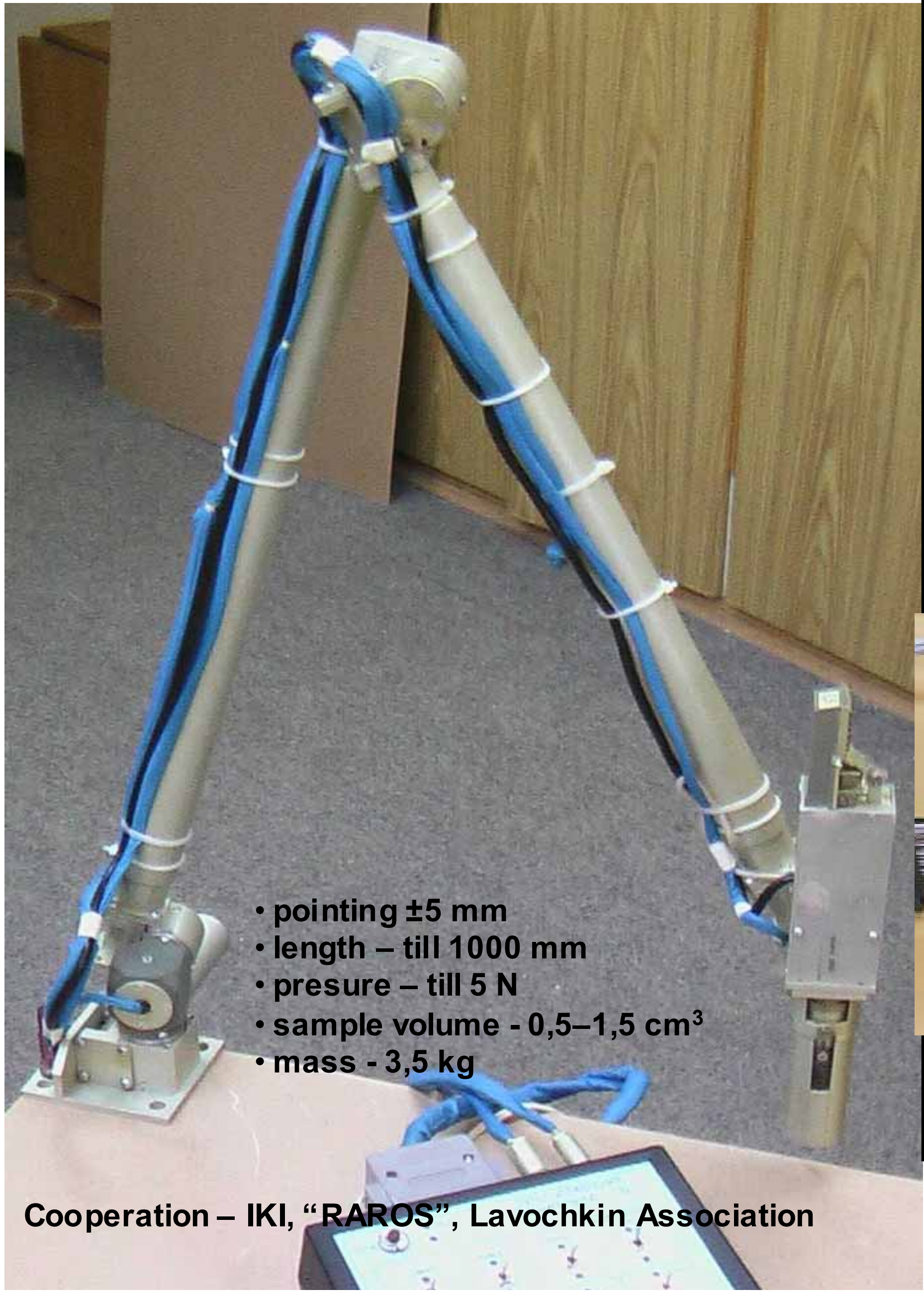
Seismometer

## *Instruments for Martian environment study*

Plasma, waves and magnetic field detectors

Dust particles detector

## Manipulator and sampling device

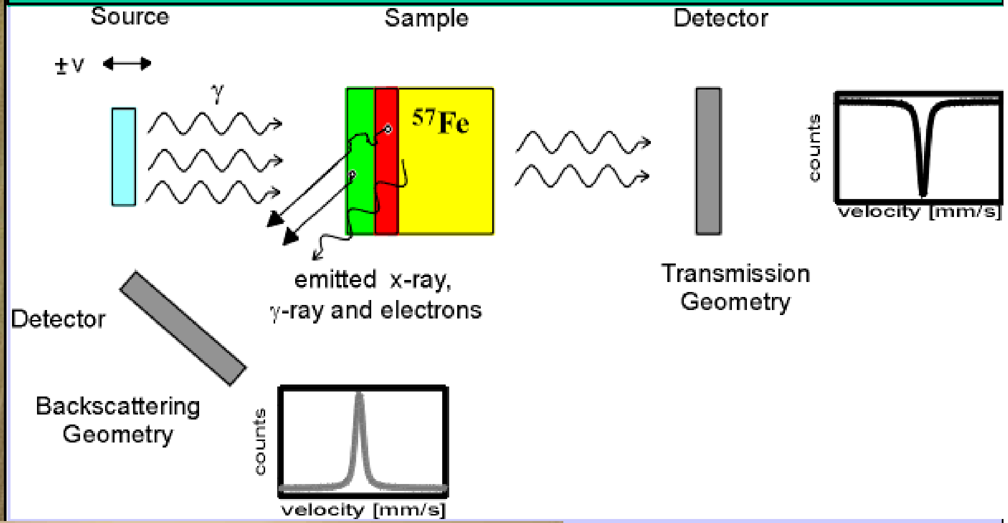


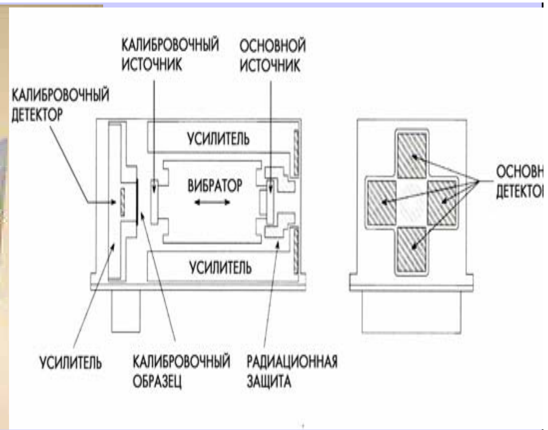
- pointing ±5 mm
- length – till 1000 mm
- presure – till 5 N
- sample volume - 0,5–1,5 $cm^3$
- mass - 3,5 kg

Cooperation – IKI, “RAROS”, Lavochkin Association

# Manipulator Instrument

## MESSBAUER SPECTROMETER



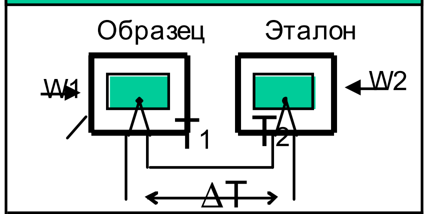

mass 0,3кг
Source $Fe^{57}$

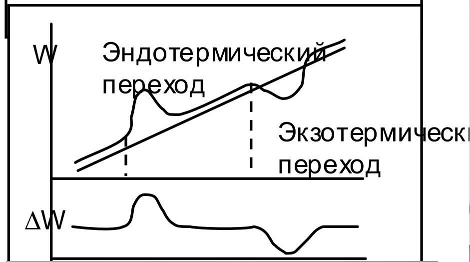
Cooperation –Mainz University, Germany, IKI,

# Gas-Chromatograph Complex

**Device for delivery and handling of samples**

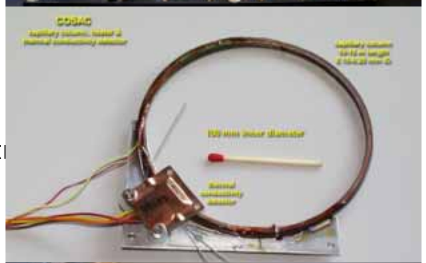
**Therm.-Differenc.Analyzer TDA (pyrolytic cells)**



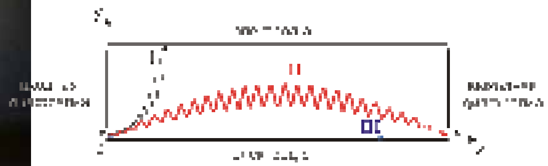

Mass 0,5 kg
T till 1000⁰

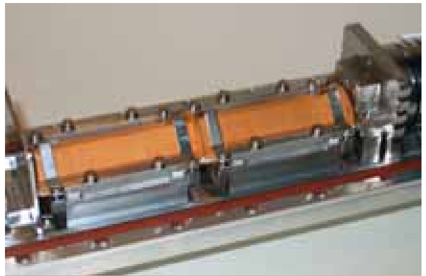
**Chromatograph ChMS-1**



Mass 4,5 kg
Sensitivity > $10^{-9}$

**Mass-spectrometer MAL-1**





Mass 3,5 kg
Mass range 1-150 а.е.м.

*Cooperation*
IKI, GEOHI, Chromatec, Germany, France

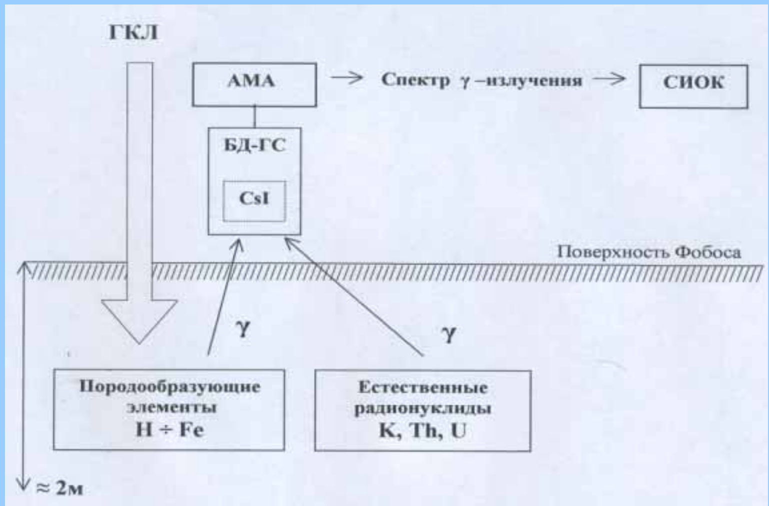
## Objectives

**Investigation of the ability and chemical composition of volatile components in the soil of Phobos (bound water, organics, noble gases, etc.)**

- to measure of the quantity of individual gas components in a complex gas mixture, which is evolved from the soil sample by pyrolysis, due to their separation by the time of retention in a chromatographic columns and detection by TCD sensor.
- to identifiy chemical composition of gas components by their calibrated time of retention and by spectroscopy of specific absorption lines for $H_2O$, $CO_2$, and $CH_4$ gases.
- to measure isotopic composition of C, H, and O elements by spectroscopy of specific absorption lines for $H_2O$ and CO2 gases.

# Nucler – 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.

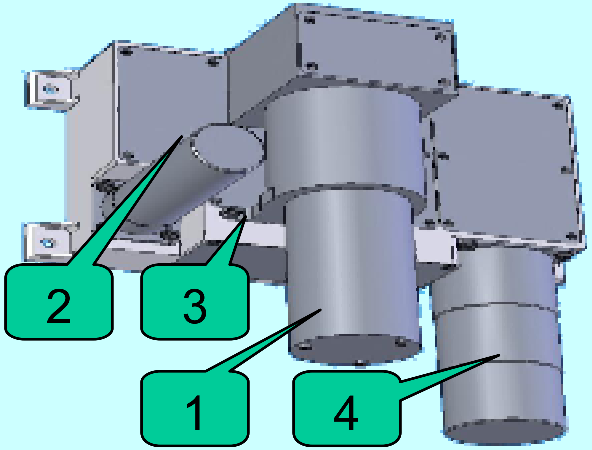
Range of measurements 0,3 - 9,0 MeV

resolution – 1-2 %

Mass 5,5 kg

Cooperation: GEOHI, SNIIP

## NEURTON SPECTROMETER
## **HEND**




*1 – module of scintillation detector*
*2 – module of neutron counter with moderator*
*3 – module of counters of thermal and epithermal neutron*
*4 –module of gamma-spectrometer*

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

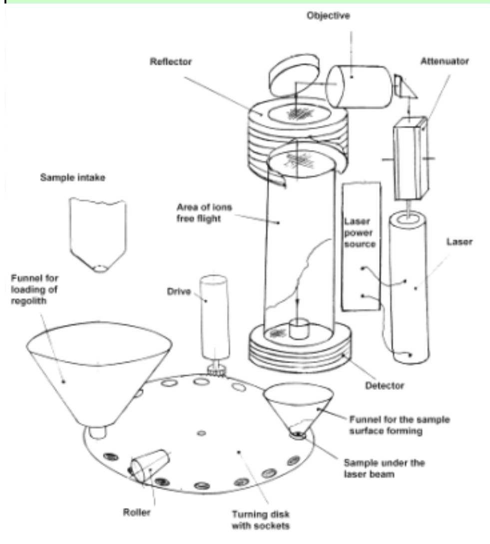
Range of measurement::
- Neutrons – 0.4 eV – 15.0 MeV
- Gamma-rays – 100 keV – 10 MeV

Energy resolution of LaBr3 crystal 3% for 662 keV (size h=5,08cm d=5,08cm).

Cooperation: IKI

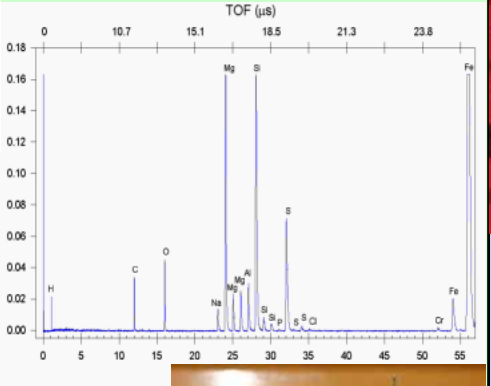
# Mass spectrometry

## Laser Time-of-flight Mass Spectrometer **LASMA**

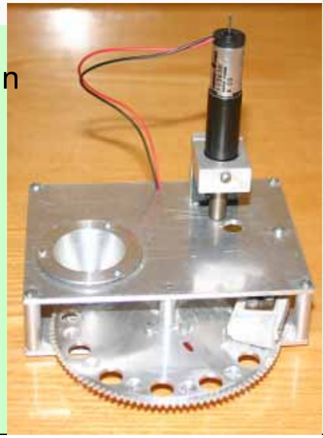



Quantitative analysis of elemental and isotopic composition of Phobos' regolith at 30-50 µm

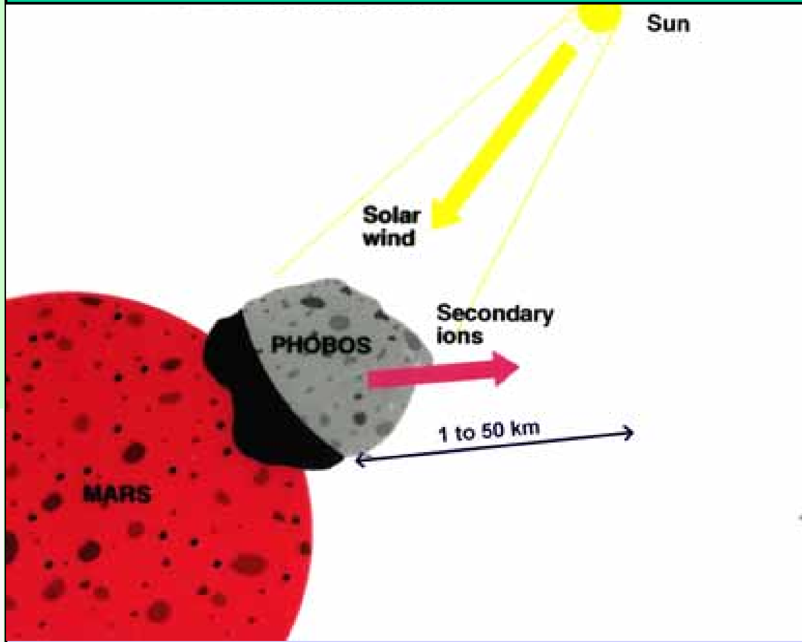
Mass range - 1-250 а.е.м.
resolution 300
Mass 1.4 kg




Cooperation IKI, «Polus»,

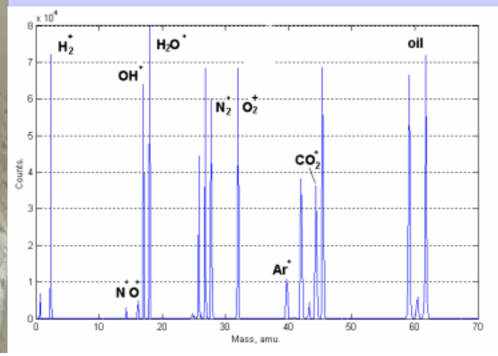


## Mass Spectrometer of secondary ions **MANAGA-F**




Cooperation –
IKI, Belorussia

Mass range - 1-300 а.е.м.
resolution > 100
sensitivity 1 ppm
mass 1.4 kg.



# IR - spectroscopy

## Thermal Infrared Multispectral Mapper
## **TIMM**

Measurements of the Phobos thermal radiance in 35 spectral channels. The instrument produces spectral images up to 40x40 pixels. Each pixel represents the interferogram of the corresponding surface on Phobos. By means of Fourier analysis, each interferogram is transformed to a spectrum.

Study surface mineralogy and physical properties of Phobos using multi-spectral thermal-infrared images (7 - 15 $\mu$m).

Mapping Phobos in both day and night multi-spectral infrared images at 0.4-1.0 km per pixel resolution.

The specific objectives

(1) determine the mineralogy and petrology of localized deposits

(1) study the surface temperature and thermal inertia.

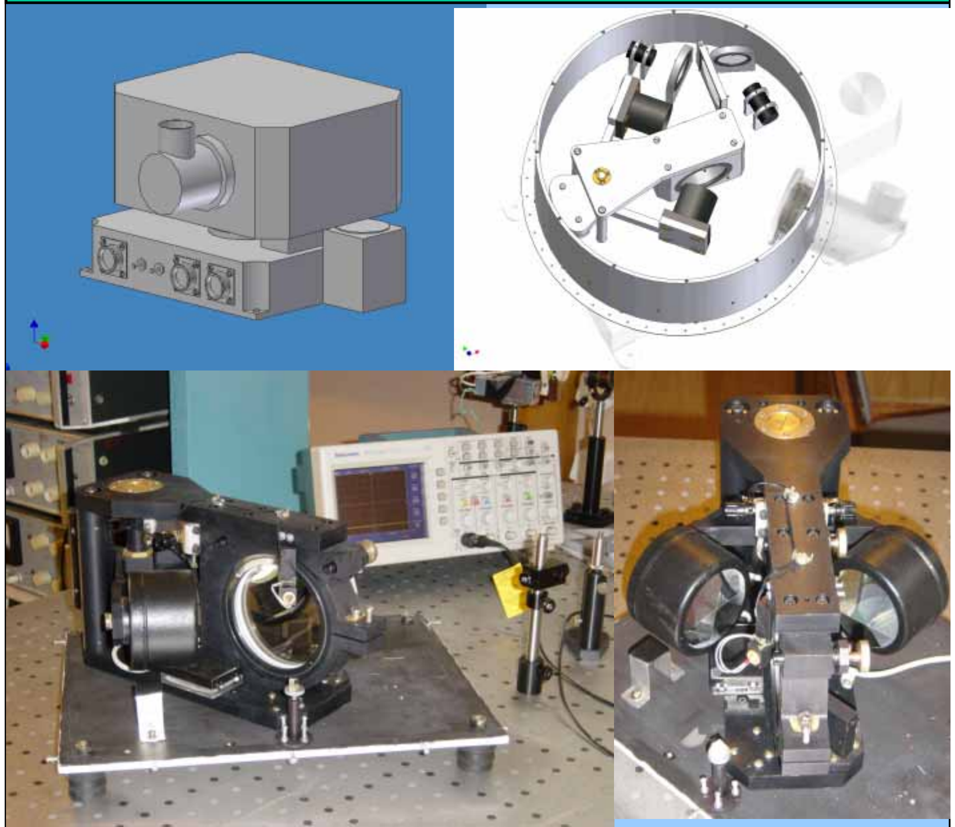
TIMM is imaging Fourier interferomete

Spectral range: 625 – 1333 cm$^{-1}$

Resolution 20 cm$^{-1}$
Mass 2,5 kg

Cooperation IKI, Italy

## Fourier Spectrometer
## **AOST**



Spectral range 2,5 – 25 μ
resolution: 0.45 cm$^{-1}$
Field of view - 2.3 deg
Mass 4 kg

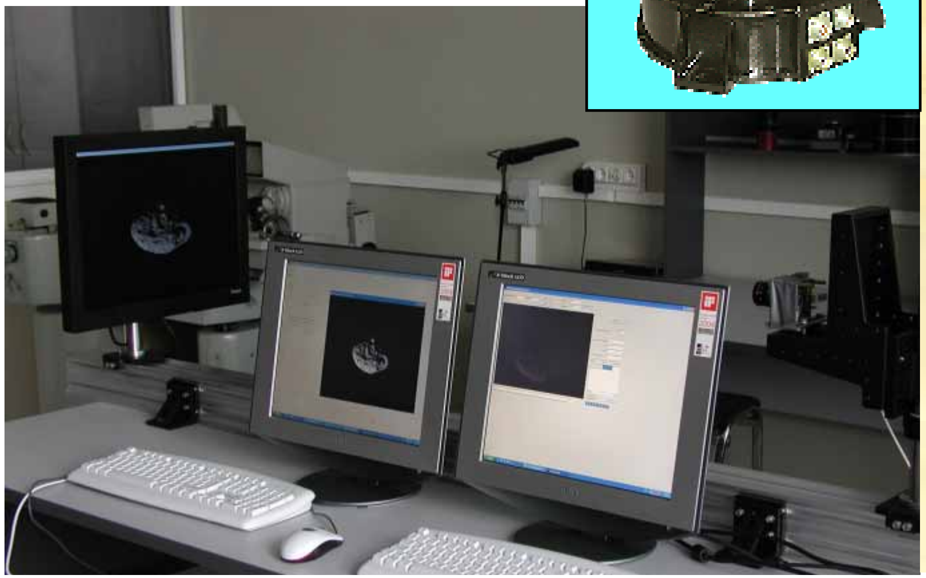
Кооперация: IKI, Italy, Germany, France

# TV cameras

| TV system for observation and navigation **TSNN** | Panoramic TV camera **PANCAM** |
|---|---|

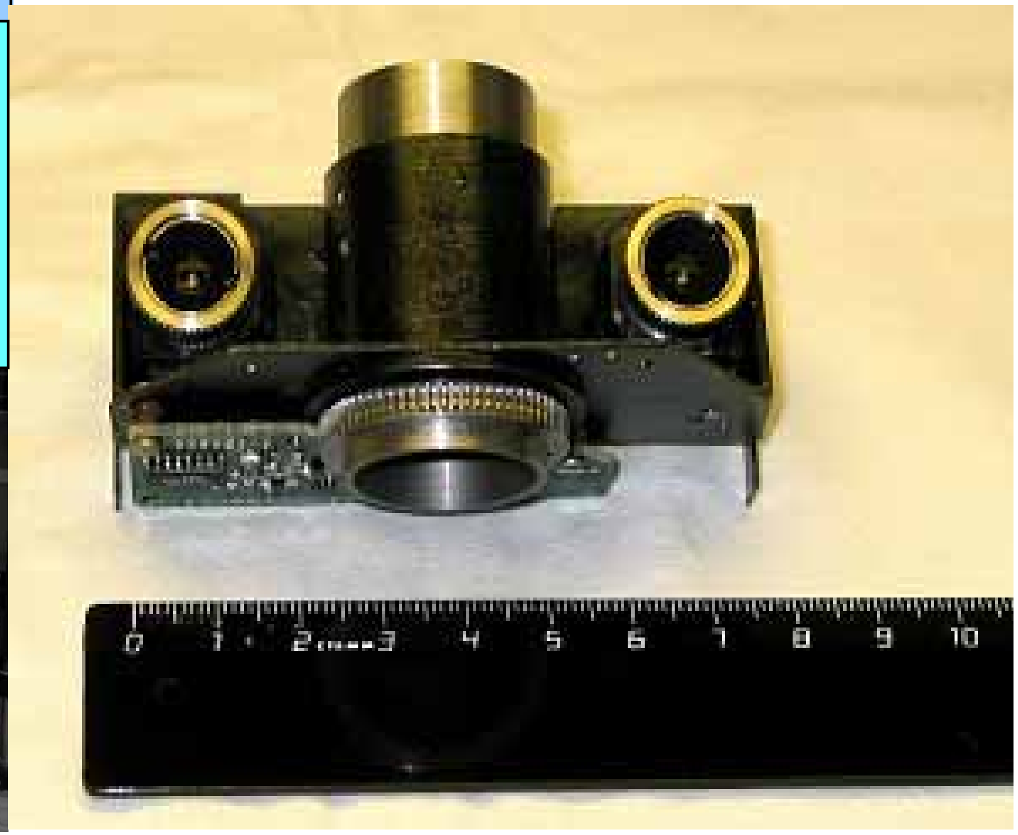
F = 500 и 18 мм
Field of view 0,85x0,85 и 23,2 x 23,2
mass 1,8 и 1,2 kg

**Characteristics of the matrix**
Kodak-1020
1004 x 1004
Size of the elements, μм 7,4 x 7,4
Spectral range, μм 0,4 – 1,0



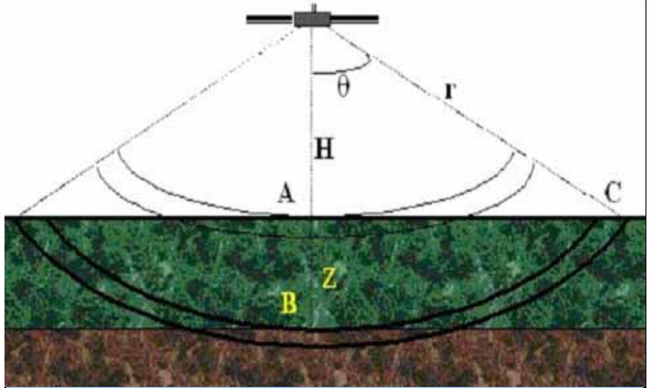
resolution 3 arc min.
Dynamic range 1000
Field of view 60x360 grad
Spectral chanals
0.45± 0.05
0.65±0.05
0.95±0.05
Matrix 1280x1024 pix
mass 0,45 kg

Cooperation –
IKI, INFRATRON, LITMO

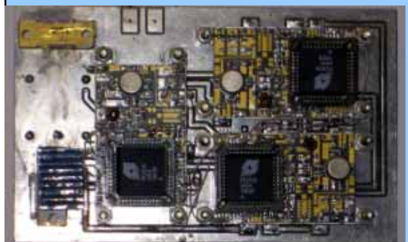


# Sounding instruments

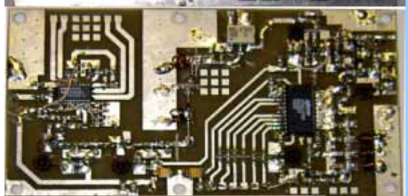
## Long waves planetary radar
## **DPR**




Frequency range 150±25 МГц
Vertical resolution 2 m
mass 3,5 kg



oscillator



receiver

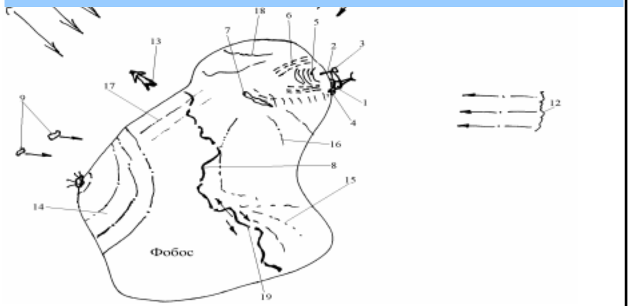
Antenna

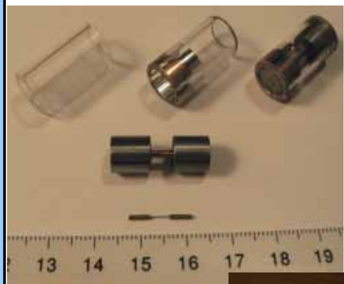
Cooperation , IRE

## Seismometer
## **MUSS**

Registration of seismic signals and wave fields of Phobos, measurement seismo-gravitational fluctuations on a surface of Phobos

Internal structure and energy state of Phobos;



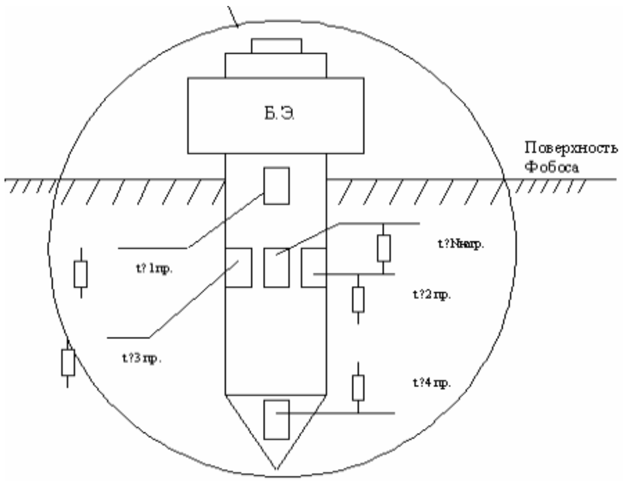




range 3 $10^{-5}$ -10Hz
20G – $10^{-6}$G
10м/с$^2$ – 10-4 м/с$^2$
$10^{-3}$ м/с$^2$ – $10^{-8}$ м/с$^2$

Cooperation
IPhE,
VNIIFTRI
NPO, IKI,
GEOHI

## Termoprobe
## **TERMOFOB**

Active thermal measurements of Phobos surface based on the heat conductivity inverse problem solutions

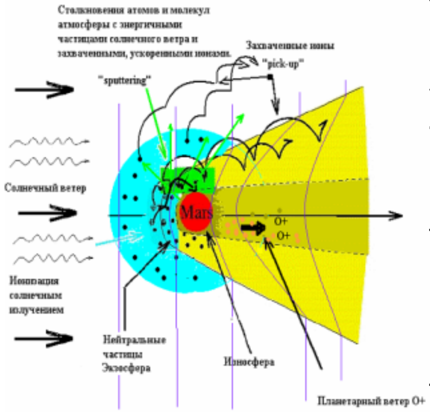



Spectral range, μm 0.45, 0.55, 0.65
Temperature range 160-380 К
Resolution 0,1 grad.
Масса 0,3 кг

Cooperation AMI

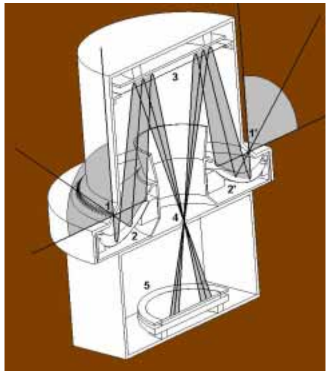
# Investigation of the Martian environment

## Plasma-waves system FPMS



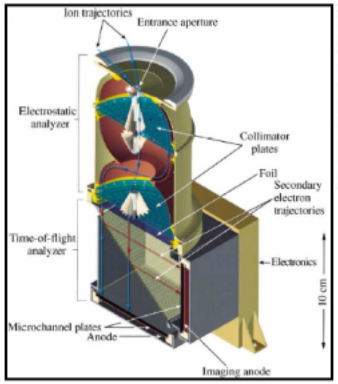

STUDYOF PLASMA-WAVE PROCESSES OF SOLAR WIND INTERACTION WITH THE MARTIAN PLASMA

Measurements: 3d distribution functions of protons, electrons and ion components; quasistatic and variable magnetic fields, electric field and plasma current fluctuations

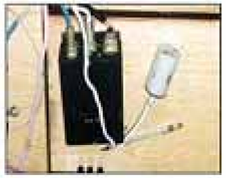


planetary ions spectrometer

10 eV – 15 keV




High energy ions spectrometer
10 eV – 50 keV



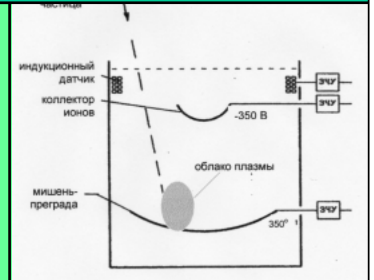
Magnetic field sensors

Mass 3,0 kg

**Cooperation** – IKI, Hungary, Austria, Germany, France, Holland

## Micrometeorites detector METEOR

Investigation of parameters of micrometeors (m, v).
Control micrometeor situation during the flight.
Velocity range *3 до 35 km/sec*
*Mass range $10^{-14}$ до $10^{-6}$ g*



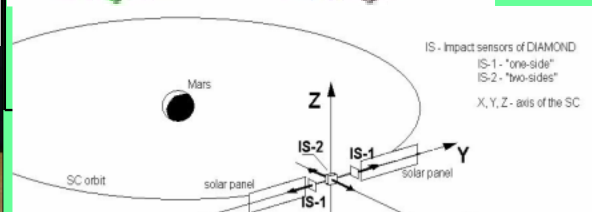

Mass 3,5 kg

**Cooperation:**
GEOHI, ABEPC, NPO Lavochkin

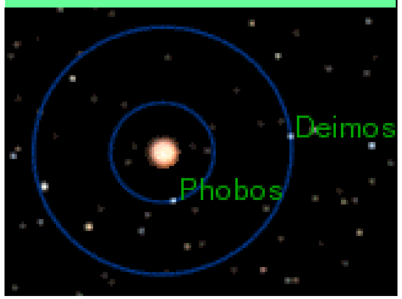
## Dust particle detector DIAMOND

**Registration of dust particles in the Martian dust belts.**

**Area of the sensor $10^{-2}$ m$^2$**
**Sensitivity $6{,}5\cdot10^{-10}$ kg·m/c**
**Max moment $4{,}0\cdot10^{-4}$ kg·m/c**




**Cooperation:**
Italy and IKI

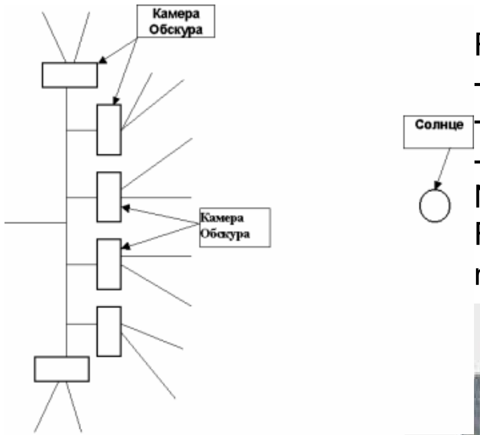


# Celestial mechanic experiments

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

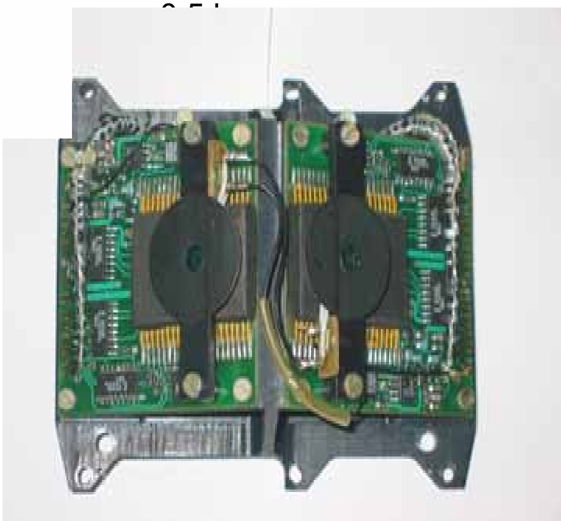
Investigation of internal structure of Phobos:

- Inhomogeneity of the body
- Center of mass and momentum of inertia
- Average density
- Proper and forced motion




Resolution:
- obscure camera 1 arc min.
- star sensor 10 min.
- dynamic range 1000

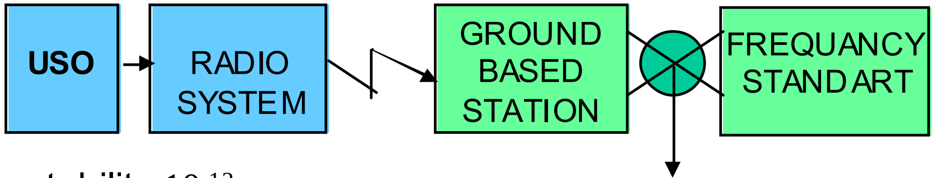
Number of obscure cameras 7
Field of view – half of sphere
matrix 1280 x 1024 pix



Cooperation: – IKI, INFRATRON, LITMO

## ULTRASTABLE OSCILLATOR
## **USO**

- refinement 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 $10^{-12}$
mass 0,35 kg

Cooperation: IKI, MARION

# Relevance of the instruments to the mission scientific objectives

| Instruments / Science fields | Panoramic camera | Manipulator | Chromatograph | Gamma spectrom. | Neutron spectrom/ | Seismometer | Long Wave Radar | Dust Detector | Plasma, waves, field |
|---|---|---|---|---|---|---|---|---|---|
| **Morphology** | + | + | | | | | | | |
| **Geochemistry** | | + | + | + | + | | | | |
| **Internal structure** | | | | | | + | + | | |
| **Martian environment** | | | | | | | | + | + |