Robotic Missions of Russian Lunar Program

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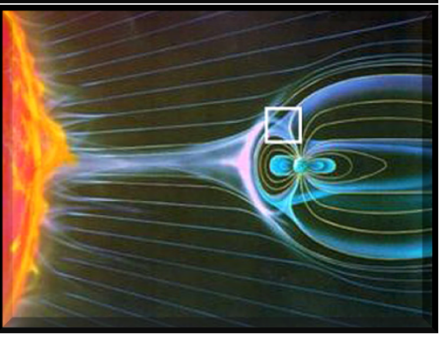
on behalf lunar science team of
Space Research Institute of the
Russian Academy of Sciences
Moscow

RUSSIAN FEDERAL SPACE PROGRAM 2016-2025

MOON, PLANETS, SMALL BODIES OF SOLAR SYSTEM

OUT OF-ATMOSPHERE ALL WAVE ASTRONOMY



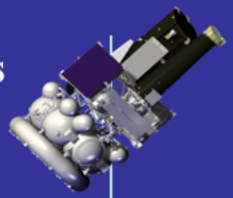
SPACE PLASMA AND SOLAR-TERRESTRIAL PHYSICS

BASIC PROBLEMS OF SPACE BIOLOGY AND MEDICINE

FSP-2025

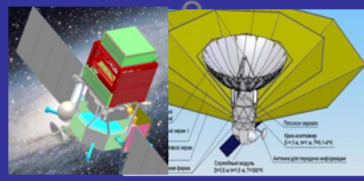
2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 позж

Astrophysics



Spectrum-RG

Spectrum-UV

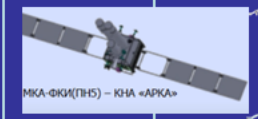


Spectrum-M

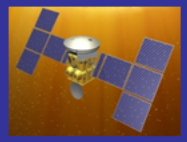
G-400, OLVE

Space weather

Resonance



Arch

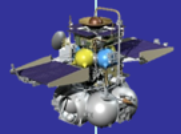


Interhelioprobe

Planetary research

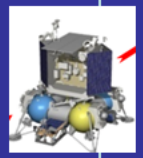
ExoMars-1

ExoMars-2

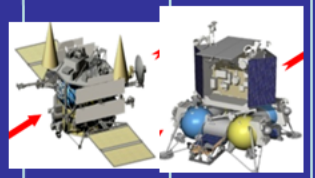


Boomerang = PhSR

Lunar research



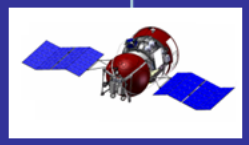
Luna-25



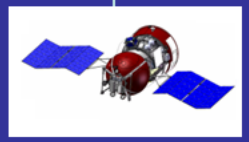
Luna-26, -27

Luna-28

Space biology and biotechnology



Bion-M



Bion-M2

ROSCOSMOS: MOON AND MARS ARE THE FIRST PRIORITY FOR 2016-2025

MAIN FEATURES:

- TWO MAIN DESTINATIONS MOON AND MARS
- NEW MISSION TO PHOBOS
- SAMPLE RETURN FROM THE MOON , PHOBOS AND MARS
- GRADUAL DEVELOPMENT – EACH MISSION IS A BASIS FOR THE NEXT ONE

MOON :

- POLAR REGIONS
- SEARCH WATER
- INTERNAL STRUCTURE
- EXOSPHERE
- SAMPLE RETURN

MARS:

- SEARCH WATER
- SEARCH LIFE
- INTERNAL STRUCTURE
- ATMOSPHERE
- SURFACE
- SAMPLE RETURN

PHOBOS:

- GEOCHEMISTRY
- INTERNAL STRUCTURE
- ORBITAL PARAMETERS
- SAMPLE RETURN

ROSCOSMOS: MOON AND MARS ARE THE FIRST PRIORITY FOR 2016-2025

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MOON :

- Luna-Glob (Luna-25) - 2019
- Luna-Resource Orbiter (Luna-26) - 2021
- Luna-Resource Lander (Luna-27) - 2021

MARS:

- ExoMars 2020

PHOBOS:

- PhSR 2024

Robotic precursors of Moon exploration

Goals of the 1st stage of Russian lunar robotic missions

Goal 1: Study of mineralogical, chemical, elemental and isotopic content of regolith and search for a volatiles in regolith of polar area of Moon.

Goal 2: Study of plasma, neutral and dust exosphere of Moon and interaction of space environment with Moon surface at poles.

Goal 3: Study dynamic of daily processes at lunar poles, including thermal property variations of subsurface layers of regolith and evolution of hydratation and volatiles.

Goal 4: Study of inner structure of Moon by seismic, radio and laser ranging methods.

Goal 5: Preparation for future exploration of Moon

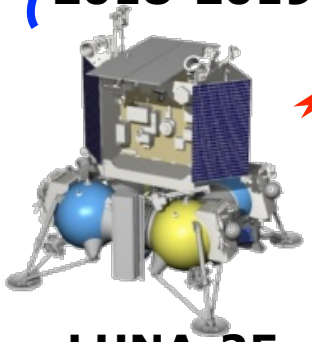
2015–2030: Projects with robotic spacecrafts

1976

LUNA-24

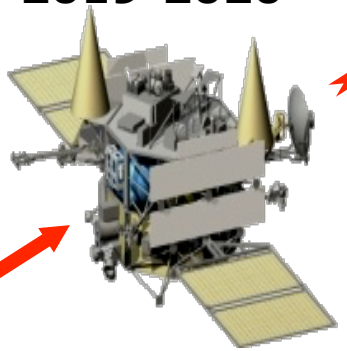
2016 - 2025

2018-2019



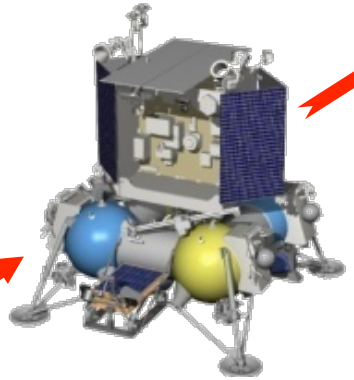
LUNA-25
(Luna-Glob)
Soft landing surviving and study of regolith and exosphere

2019-2020



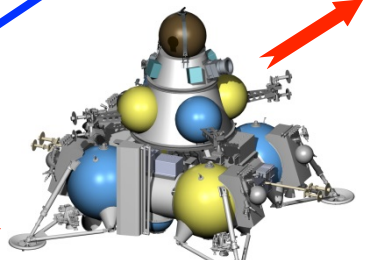
LUNA-26
(Luna-Resurs-1 Orbiter) Global resources reconnaissance and cartography

2020-2021

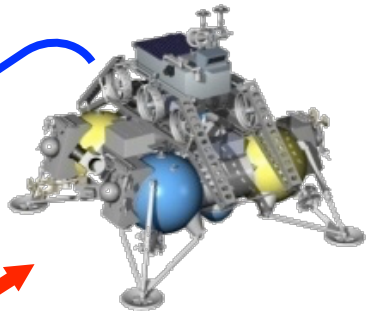


LUNA-27
(Luna-Resurs-1 Lander)
Safety and high precision landing, study of regolith in the depth, study of exosphere and inner structure, beacon for next mission

2025 - 2030

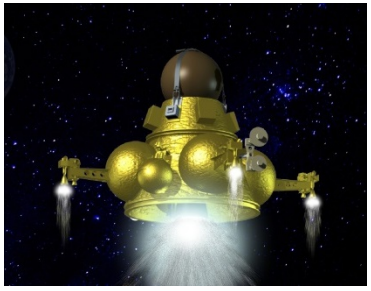


LUNA -28
(Luna-Resurs-2)
Lunar Polar Sample Return

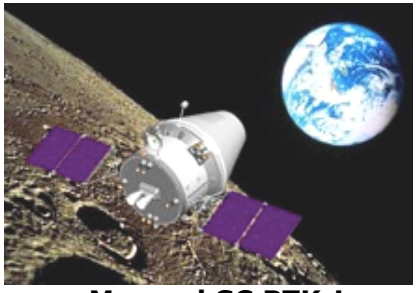


LUNA-29
Complex study of south polar area with rover

2025 – 2040: Projects with robotic and manned spacecrafts on lunar orbit



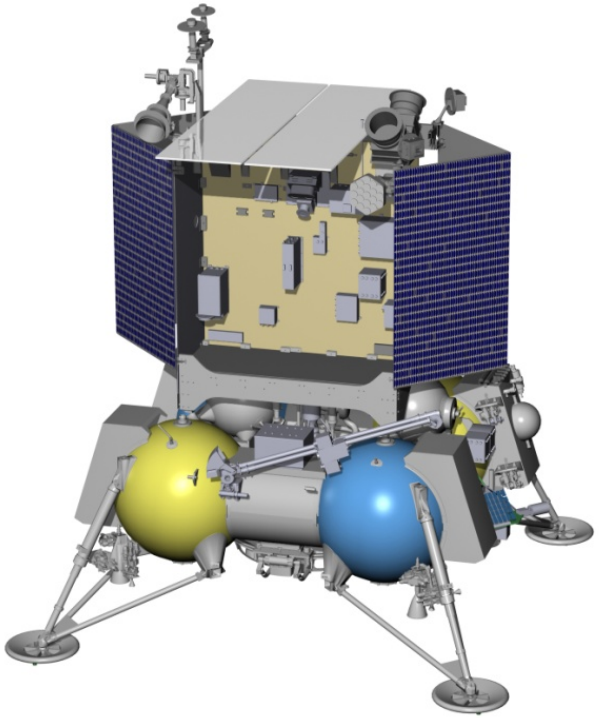
Reusable spacecraft «Corvet»



Manned SC PTK-L

Luna-25 (Luna-Glob)

Expected results



Technology:

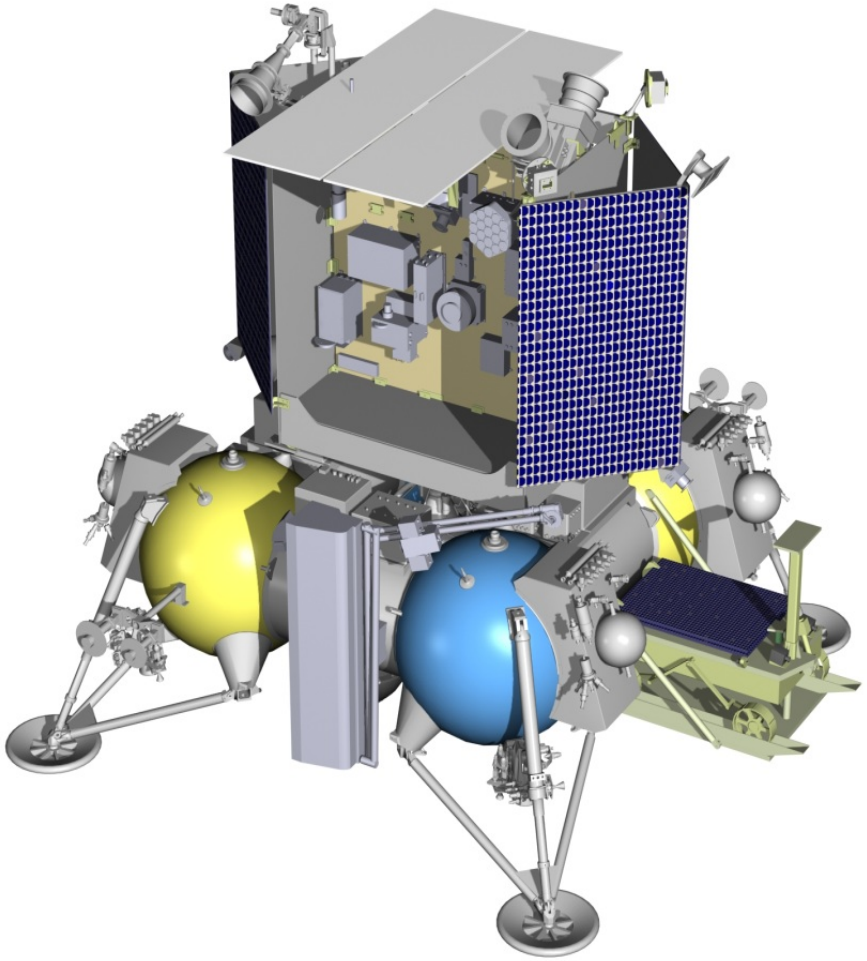
- Re-design of soft landing technology
- Pole-Earth radio link tests and experience
- Thermal design validation
- Robotic arm testing and validation

Science:

1. Mechanical/thermal properties of polar regolith
2. IR composition measurements of polar regolith
3. Water content and elements abundance in the shallow subsurface of the polar regolith
4. **Plasma and neutral exosphere at the pole**
5. **Plasma-Dust exosphere at the pole**
6. Thermal variations of the polar regolith

Luna-27 (Luna-Resource Lander)

Expected results



Technology:

- High precision landing and hazard avoidance
- Pole-orbiter UHF radio link tests and experience
- Cryogenic drill testing and validation

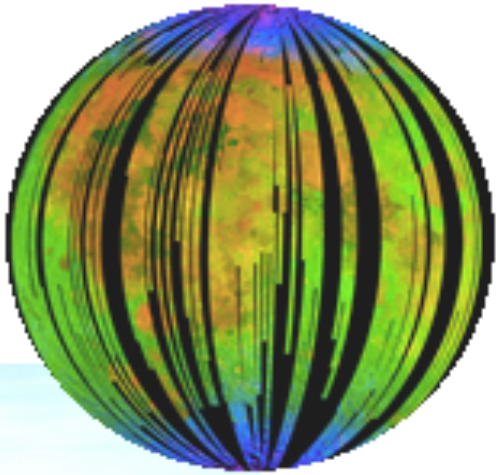
Science:

- Mechanical/thermal/compositional properties of polar regolith within 2 meters
- Water content and elements abundance in the shallow subsurface of the polar regolith
- **Plasma, neutral and dust exosphere at the pole**
- Seismometry and high accuracy ranging

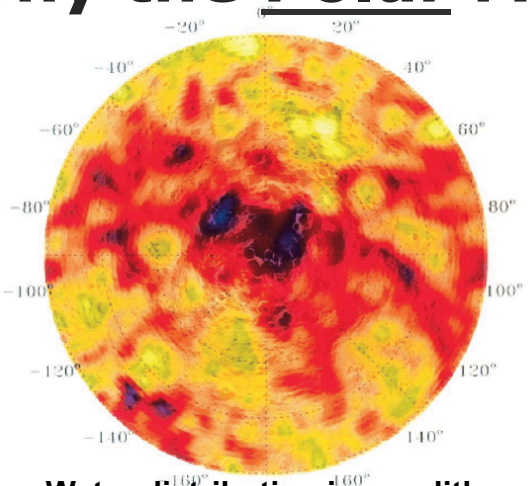
Luna-25 & -27 Instruments and Experiments

	Instrument	Description	L-25	L-27
Direct regolith study	Chromatographic complex	Analysis of volatiles content and isotopic ratios	Yes	Yes*
	LASMA	Laser Mass-spectrometry analyzer	Yes	Yes*
	PROSPECT	Drilling, sampling, sample handling, processing and analysis package	No	Yes
Remote regolith study	LIS-TV-RPM	TV imaging of nearest field and objects (including Robotic arm operations support); IR spectra of minerals	Yes	Yes*
	TV-Spectrometer	UV and optical imaging of minerals with UV excitation	No	Yes
	ADRON	Active neutrons & γ detector	Yes	Yes*
Mechanical, thermal, other properties of regolith	LMK	Robotic arm (including panorama and stereo imaging)	Yes	Yes
	RAT	Radio measurements of temperature of subsurface regolith	Yes	Yes
	TERMO	Direct measurements of thermal properties of regolith	Yes	Yes
Exosphere investigation	**PmL**	**Measurements of dust and plasma properties**	**Yes**	**Yes***
	ARIES	Measurements of plasma and neutrals	Yes	No
	LINA	Measurements of plasma and neutrals	Yes	Yes
Moon internal structure	Radio beacon	Radio signal with high stability	Yes	Yes
	SEISMO	Measurements of seismic activity	Yes	Yes
	Reflectors		Yes	Yes

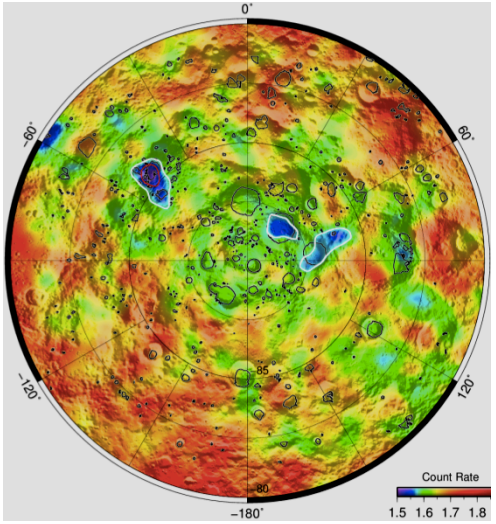
Why the Polar Moon?



Water distribution in regolith according to data from Chandrayan-1 (ISRO)



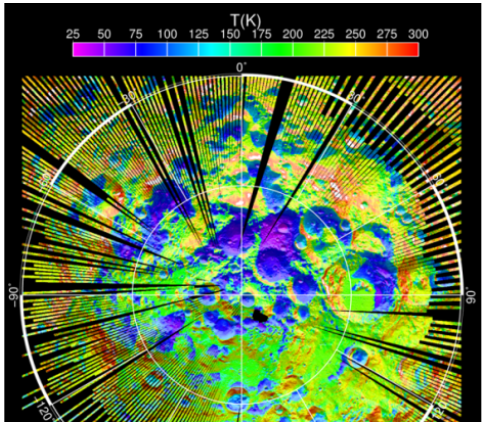
Water distribution in regolith according to data from Lunar Prospector (NASA)

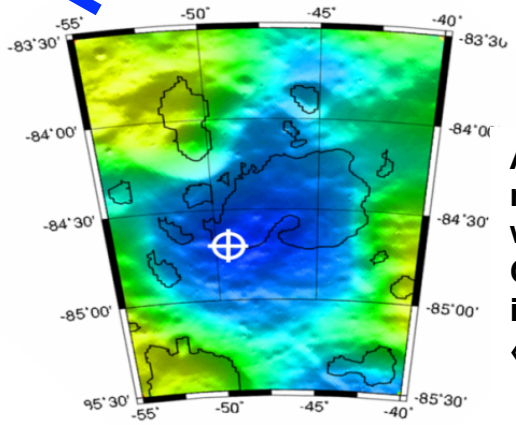


Water distribution in regolith according to data from LEND (Russia) onboard Lunar Reconnaissance Orbiter (NASA)

H_2O

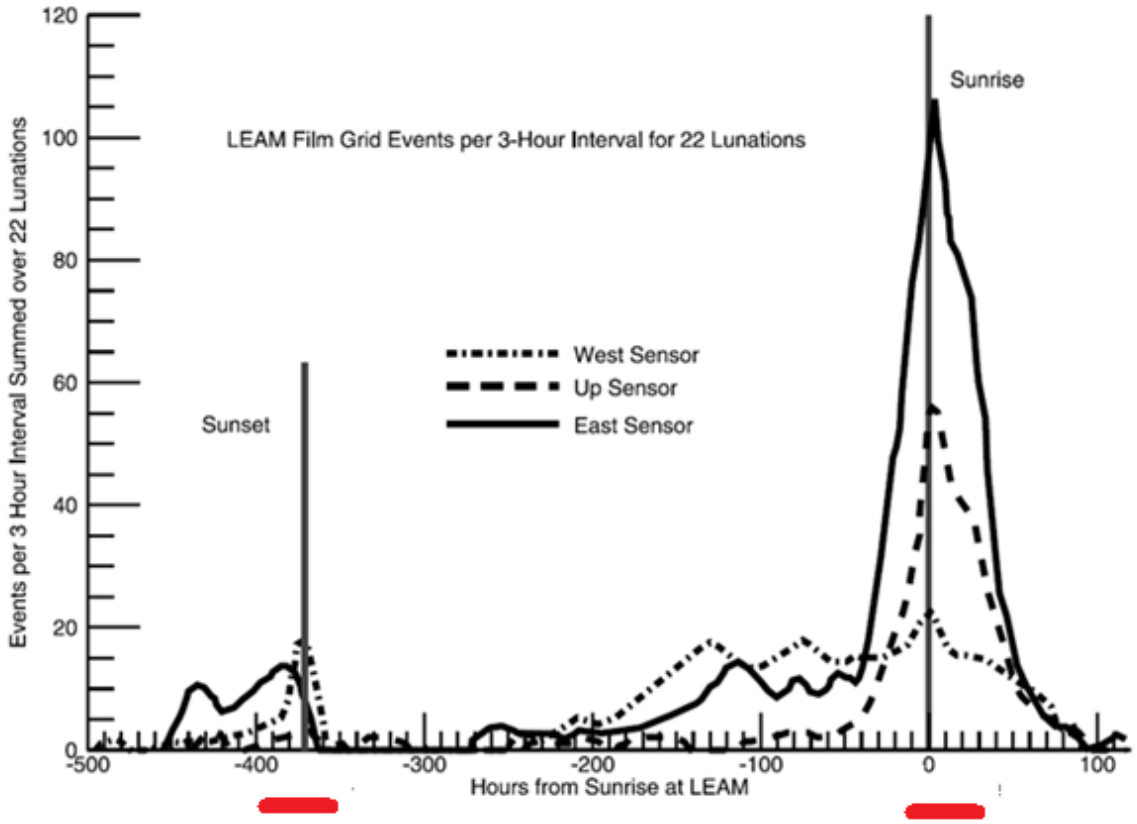
Temperature distribution in regolith according to data from Diviner onboard Lunar Reconnaissance Orbiter (NASA)





Area of direct registration of water in regolith in Cabeus according inpact experiment «LCROSS» (NASA)

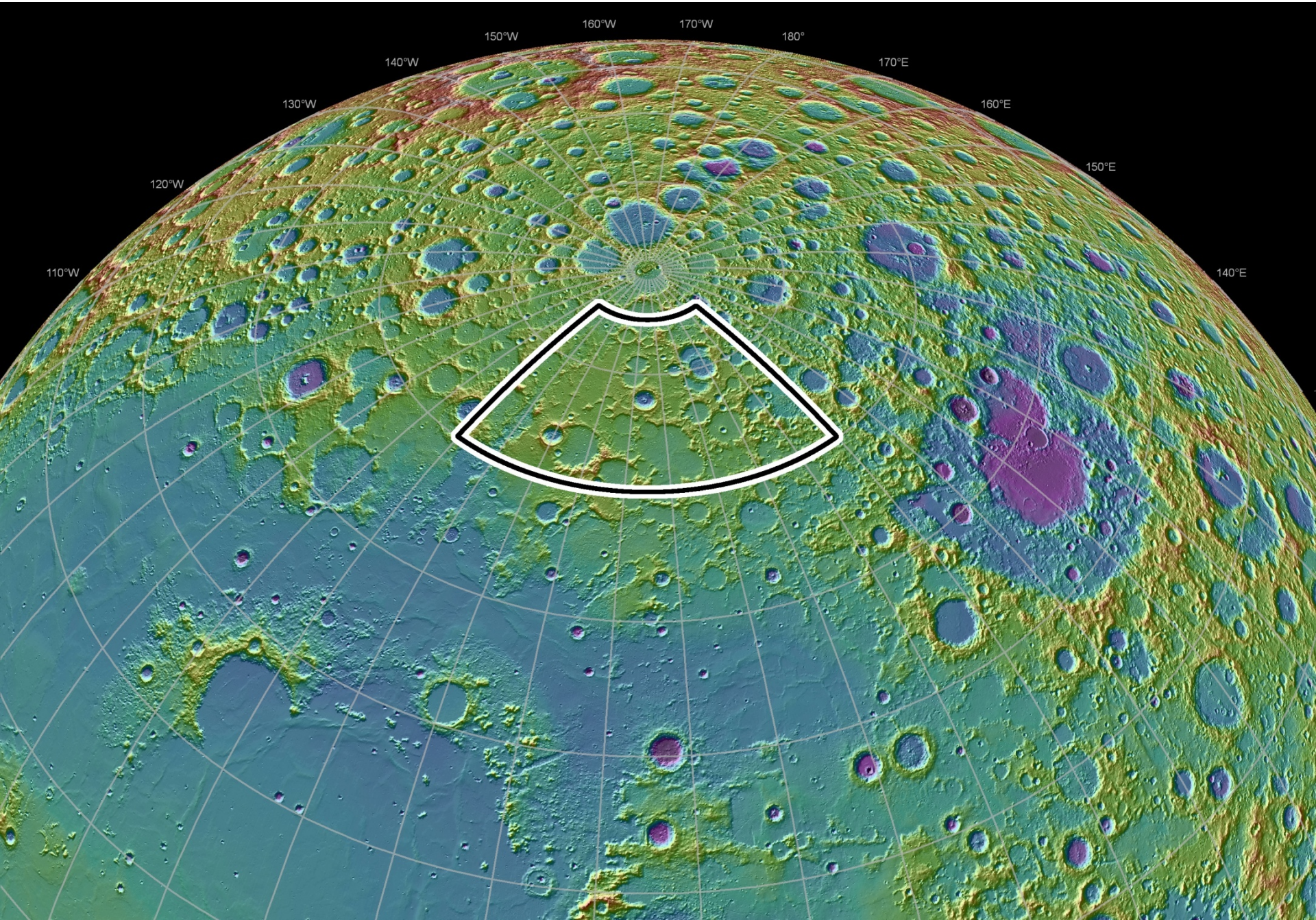
The Lunar Ejecta and Meteorites (LEAM) Experiment
deployed by the Apollo 17 astronauts as part of
the Apollo Lunar Surface Experimental Package on 11 December 1972



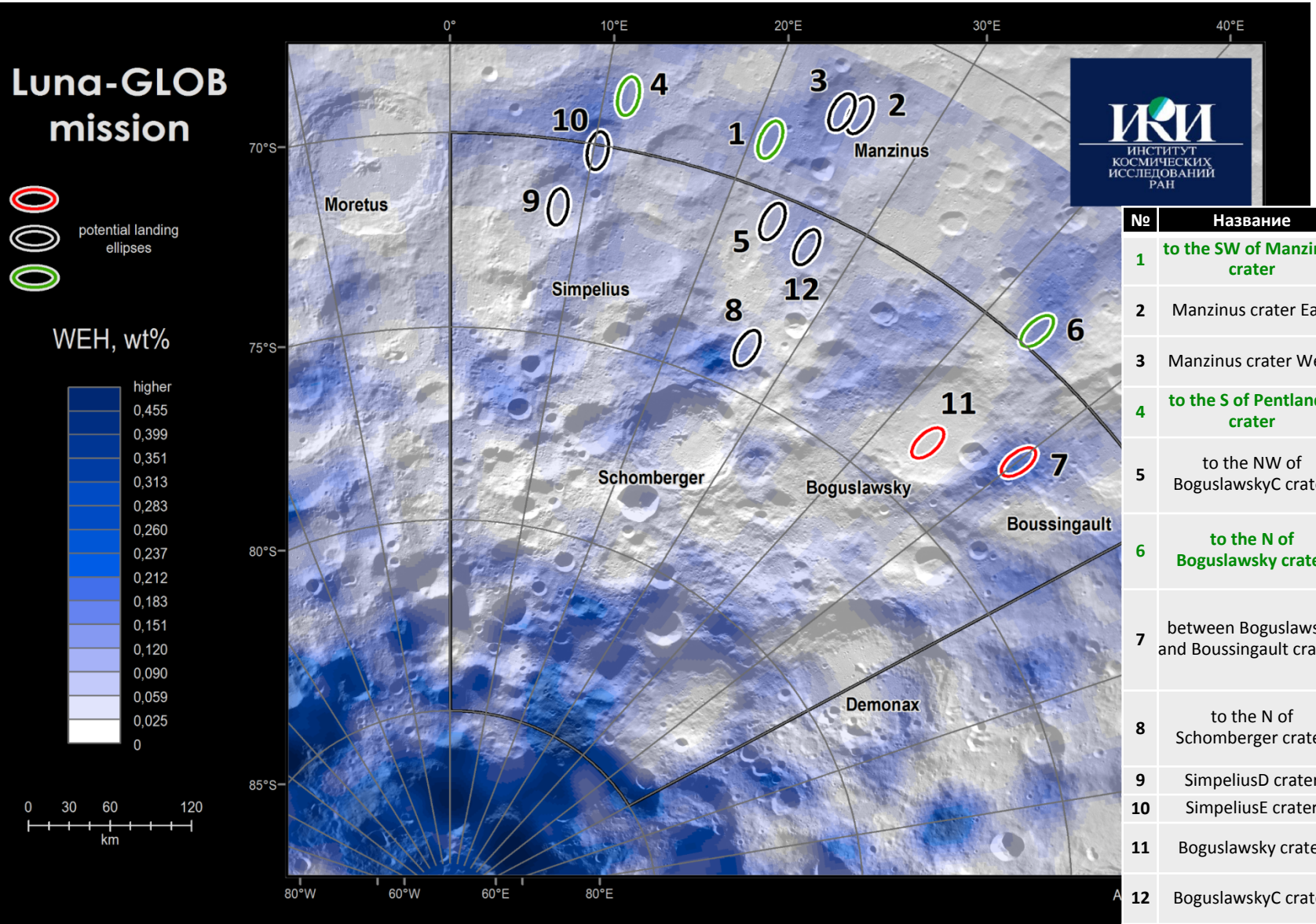
LEAM per 3-hour period, integrated over 22 lunar days

Number of impact events [after Berg et al., 1976]. The large increases at terminator crossings persist for several hours before and after sunrise and before the smaller increase at sunset, suggesting particles may be launched on long trajectories from the terminator.

Landing sites



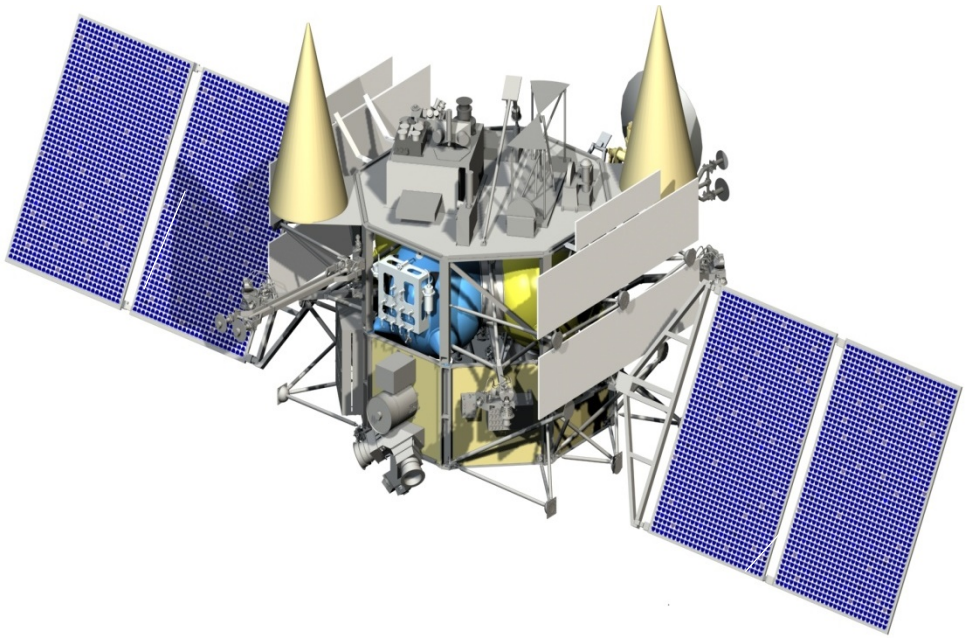
Luna-25 landing site selection



№	Название	Широта	Долгота
1	to the SW of Manzinus crater	-68,773	21,210
2	Manzinus crater East	-67,476	24,613
3	Manzinus crater West	-67,371	25,697
4	to the S of PentlandA crater	-68,648	11,553
5	to the NW of BoguslawskyC crater	-70,681	23,634
6	to the N of Boguslawsky crater	-69,545	43,544
7	between Boguslawsky and Boussingault craters	-72,161	50,085
8	to the N of Schomberger crater	-73,882	26,363
9	SimpeliusD crater	-71,718	8,186
10	SimpeliusE crater	-70,148	10,288
11	Boguslawsky crater	-73,400	44,000
12	BoguslawskyC crater	-70,930	26,715

Luna-26 (Luna-Resource Orbiter)

Expected results from Luna-26



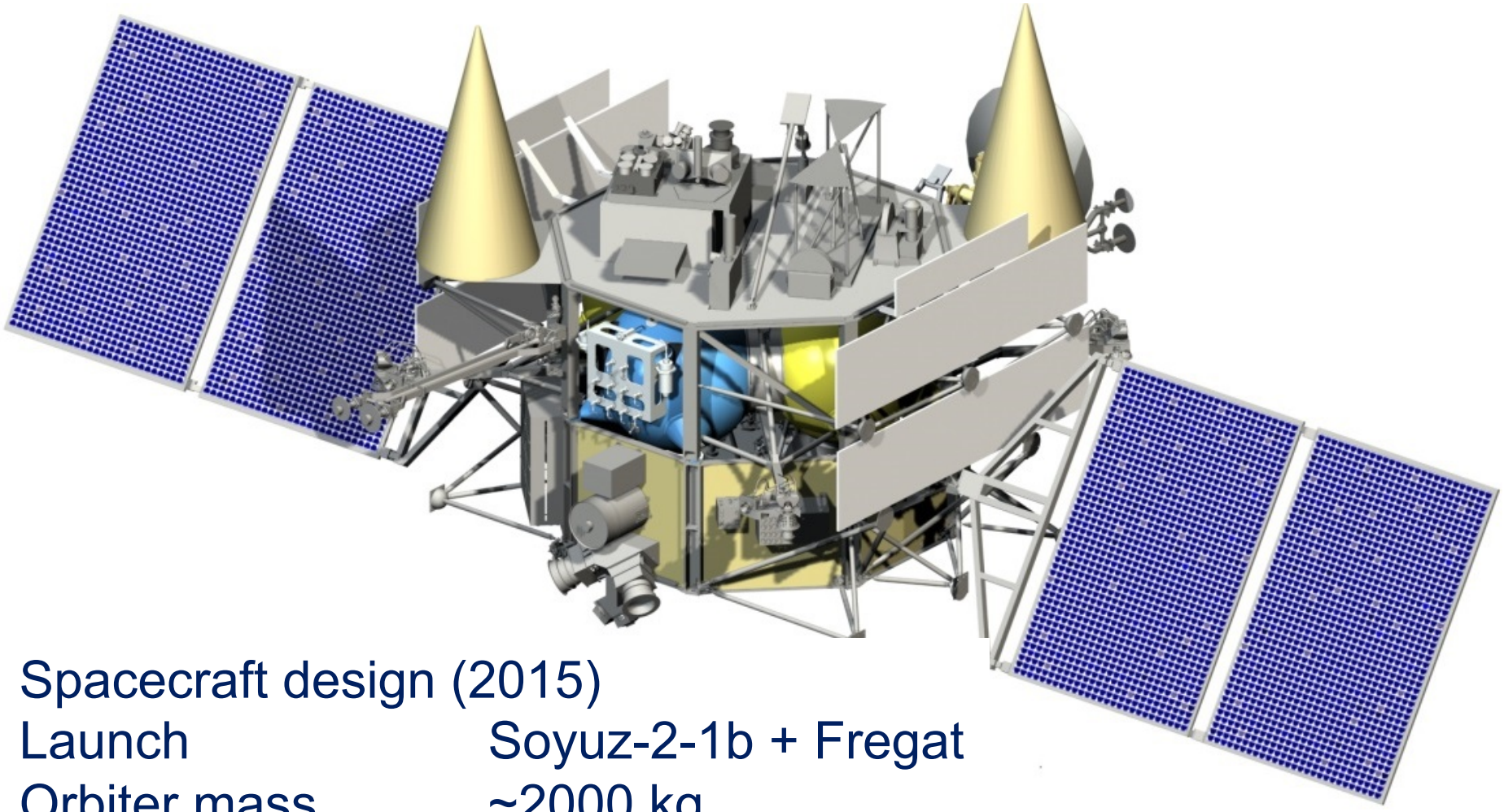
Technology:

- Polar-orbit UHF radio link tests and experience
- Orbital operations

Science:

- Space plasma in the lunar vicinity
- Luna-27 landing sites candidates

Luna Orbiter

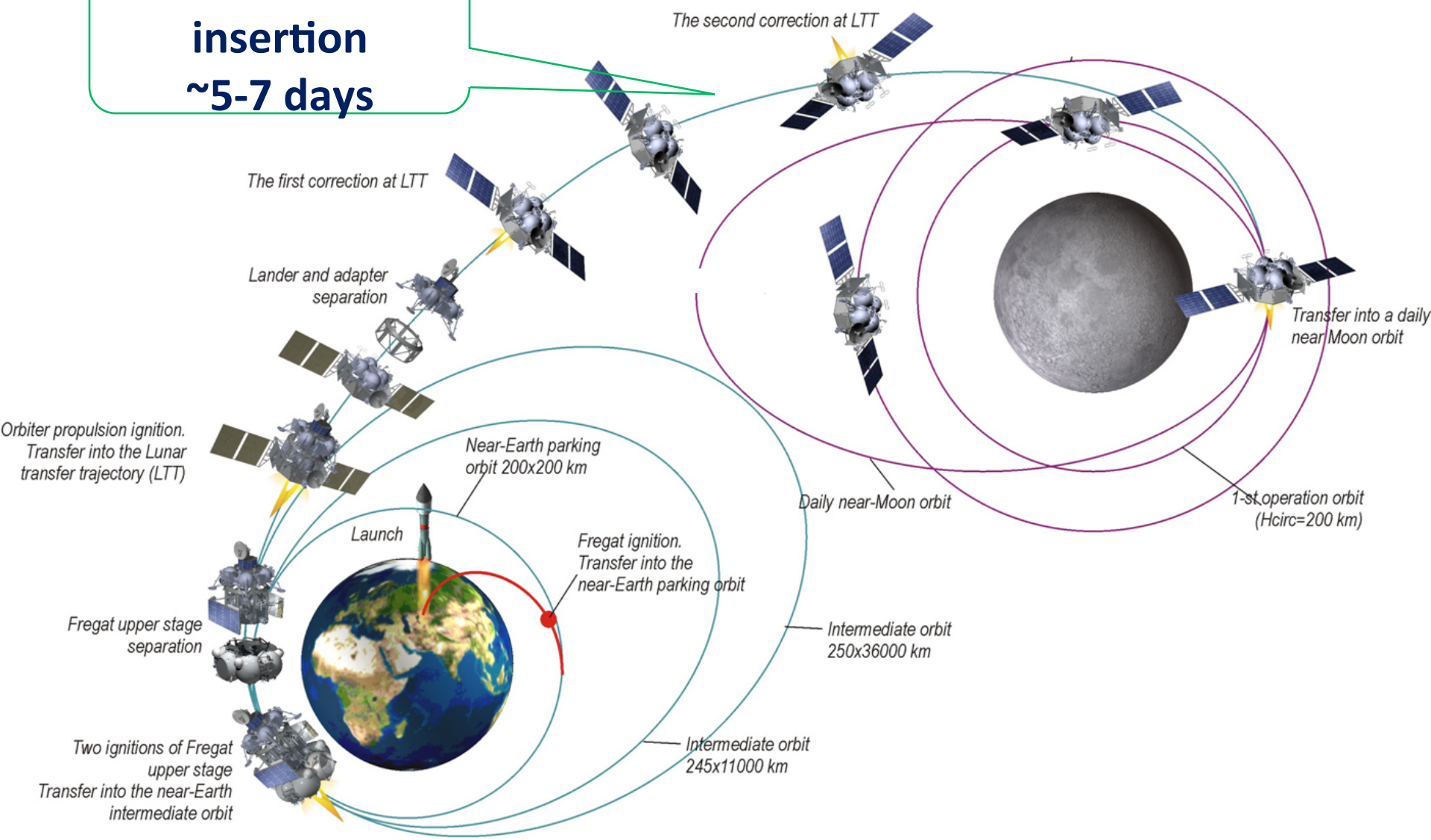


Spacecraft design (2015)

Launch	Soyuz-2-1b + Fregat
Orbiter mass	~2000 kg
Payload mass	~160 kg
TM downlink	16-18 or 100 Mbit/s (TBD)

Orbit

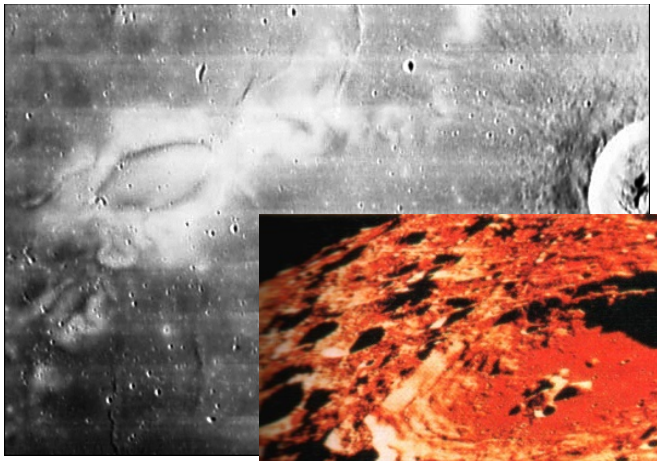
Moon orbit insertion ~5-7 days

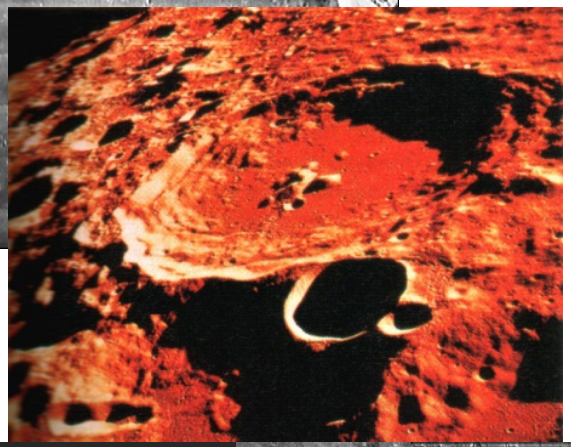


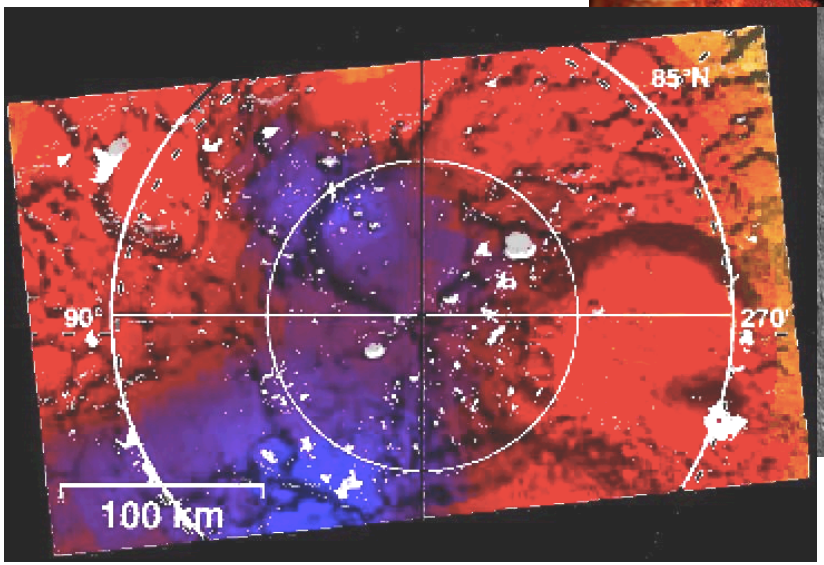
Luna Orbiter science

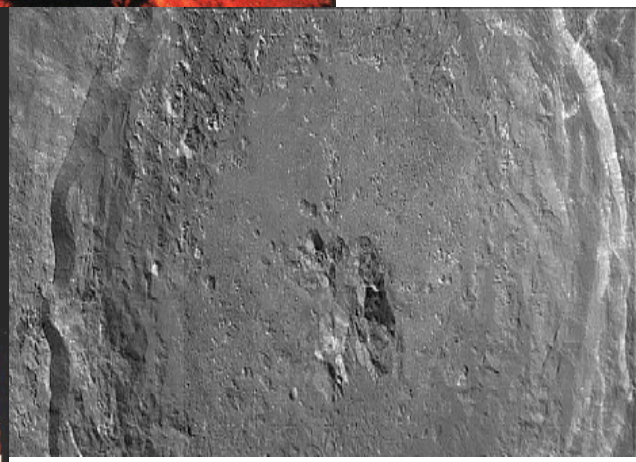
Moon surface science

- Topography
- Subsurface structure
- Hydrogen rich regions
- Chemical composition
- Moon gravity field





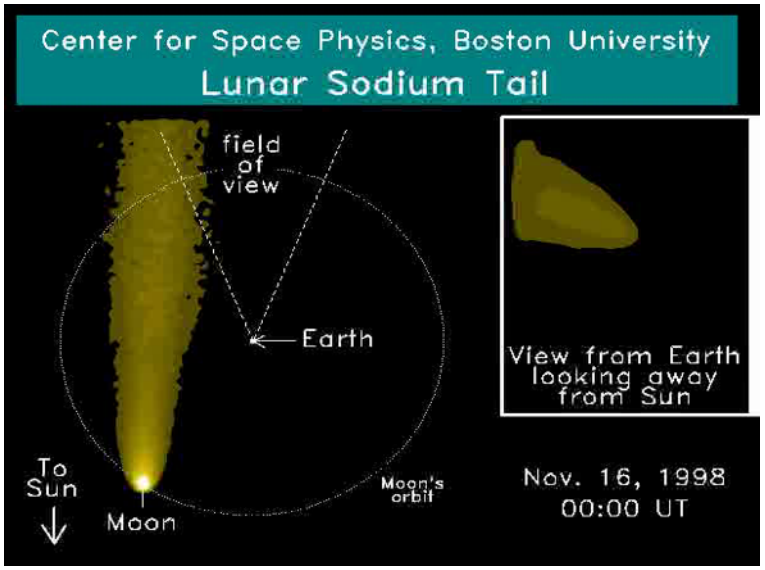


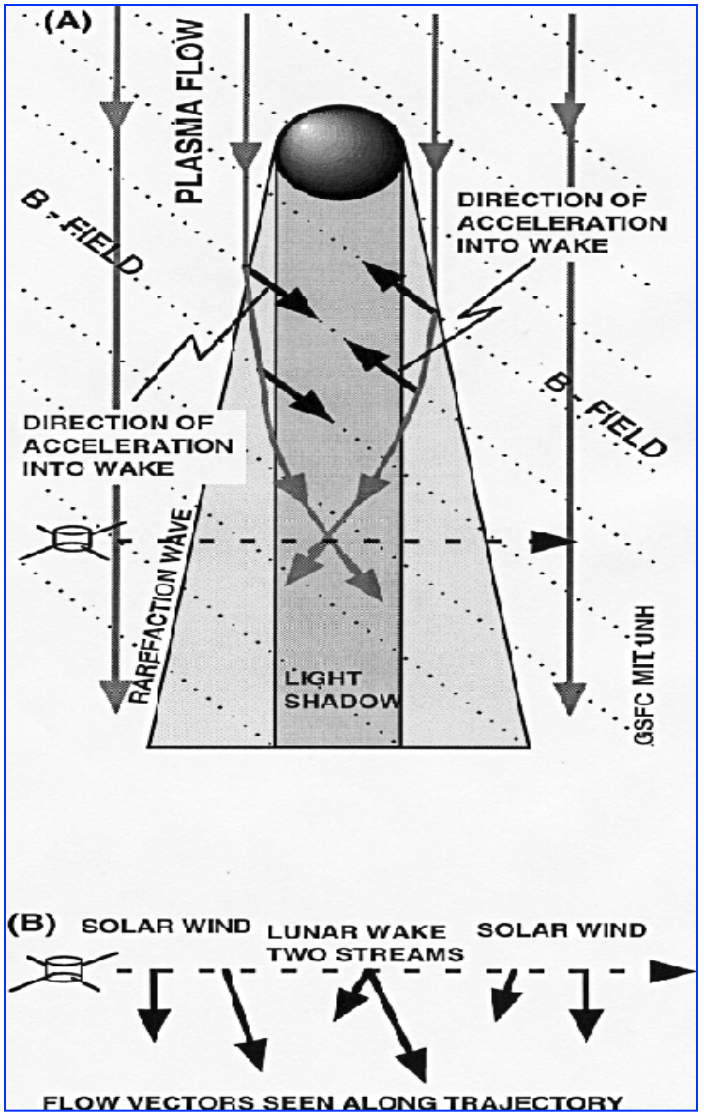


Luna Orbiter science

Circumlunar science

- Exosphere
- Solar wind – Moon interaction
- Lunar magnetic anomalies
- Micrometeors

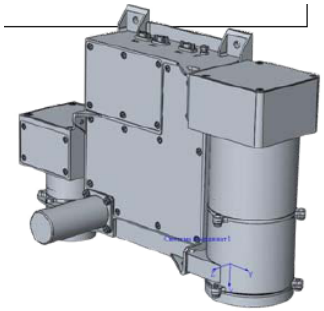


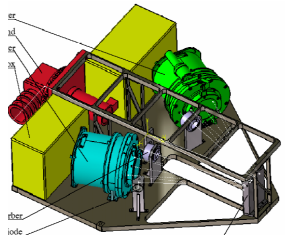


Luna Orbiter experiments

1. planetary experiments

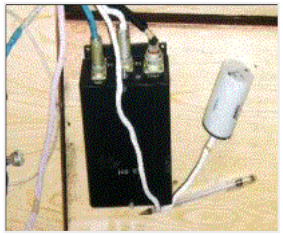
LGNS	neutron and gamma ray	**IKI**
LEVUS	UV exosphere 30-150 nm	**France/Japan/IKI** Bepi-Colombo PHEBUS
LUMIS	IR mapping 1-16 mkm	**IKI** Exomars ACS
LSTK	stereo camera	**IKI**
RLC-L	radar 20 and 200 MHz	**IRE**





Luna Orbiter experiments

2. plasma experiments



LPMS-LG magnetometer — **IKI**
DC field

LEMI electromagnetic waves — **Ukraine/Czech R/IKI**
magnetic fluctuations to 40 kHz

BMSW-LG solar wind — **Czech R/IKI**
plasma flow direction, velocity, density

ASPECT-L energetic particles — **Slovakia/IKI**
ions and electrons 20-1000 keV

LINA-R ions and neutral spectrometer — **IKI**
major ion species 10-30 000 keV

LNT neutral atoms spectrometer — **Sweden/IKI**

Luna Orbiter experiments

3. other

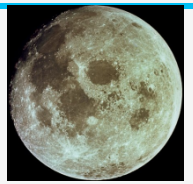
PKD	radio receiver high-precision orbit measurements	**IKI**
METEOR-L	circumlunar dust	**GeoKhi**
SSRNI2	data management system	**IKI**

CANDIDATE INSTRUMENTS

LYMUS/LAICA	all-sky survey of L-alpha	**LATMOS/Rykkio U/ IKI**

ROSCOSMOS: MOON AND MARS ARE THE FIRST PRIORITY FOR 2016-2025

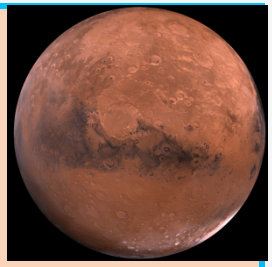
Dust instruments in the payload



Destination: The Moon

Mission: Luna-Glob Lander (2019)

Instrument: Lunar Dust Monitor (PmL-LG)



Destination: Mars surface

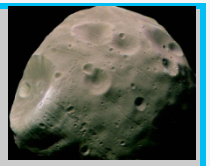
Mission: ExoMars (2020)

Instrument: Dust Suit (DS)

Destination: The Moon

Mission: Luna-Resource Lander (2021)

Instrument: Lunar Dust Monitor (PmL-LR)



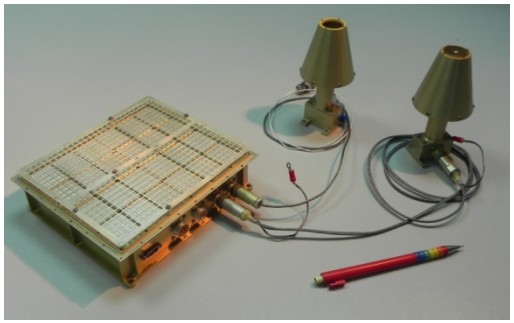
Destination: Martian orbits, Phobos

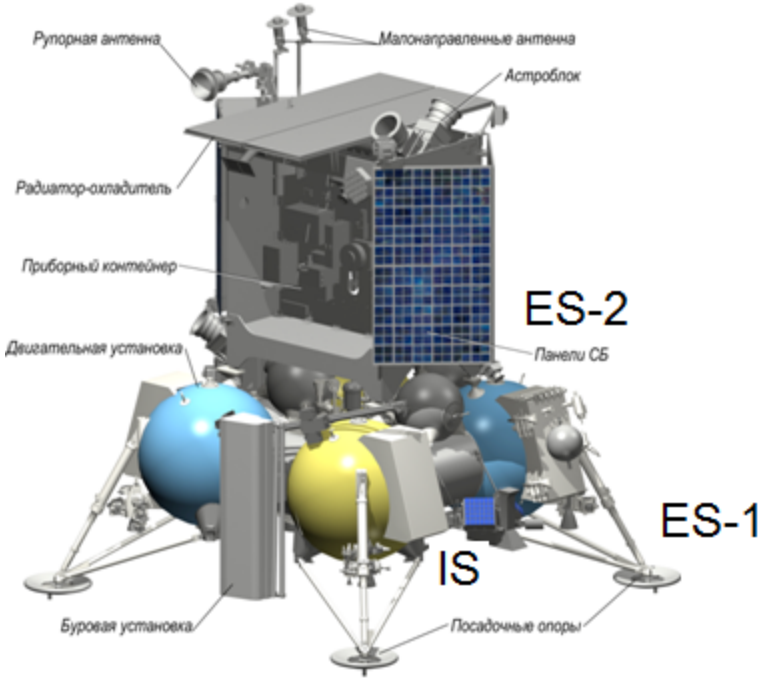
Mission: Boomerang (PhSR) (2024)

Instrument: Dust In the Martian EnviRonment (DIMER)

Lunar Dust Monitor (PmL)

PmL-LG





Min impulse is ~10^{-12} N·s (for SiO_2 sphere ~2 μm diameter with velocity ~1 m/c)

Max impulse is ~10^{-6} N·s (or even more).

Grid before PZT plates of Impact Sensor measure particle charges from ~10^{-14} C (~10000 electrons).

PmL instrument characteristic for Luna-Glob (Luna 25)			
	Dimentions	Weight	Consumption
Impact Sensor IS	175 × 170 × 60	850 g	5 W
2 × Electric Field Sensors	Ø60 × 125	2 × 45 g = 90 g	< 0.01 W
Cables	20 cm & 3 m	50 g	< 0.01 W
	TOTAL	990 g	

PROXIMITY ELECTRONICS	**RS-485 Interface, ~ 10 Kb/s, (0.3 Mbit/day), preamplifiers, ADC, FPGA, DC-DC**
PROCESS OF MANUFACTURE	Engineering Model and Qualification Model passed tests. Flight prototype is under construction, Laboratory models is under analysis result.
TEMPERATURE	Work temperature + 65° ÷ - 40° C, storage temperature + 65° ÷ - 50° C
OPEN IN SPACE PART OF IS	Square of impact area S =0,025 m^2 of Impact Sensor
THERMAL CAPACITY	680 J/K
THERMAL FLUX TO POINT OF FASTENING	5 W

Roscosmos Martian Program

The first stage

2016

ExoMars TGO
Proton, Orbiter,
Two Russian instruments
ASC и FREND

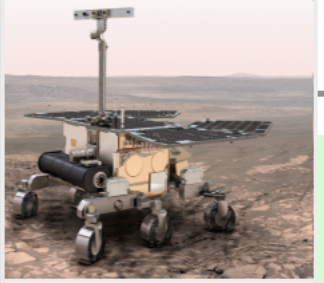
Orbiter

2020

ExoMars Lander

Proton,
Rover, Mars
Lander

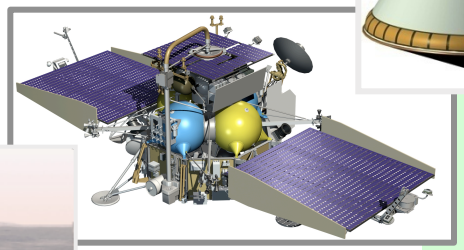
Mars-Rover



ExoMars Rover

Soil study along
the Rover way

2024

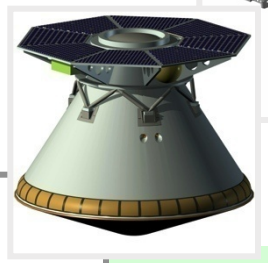


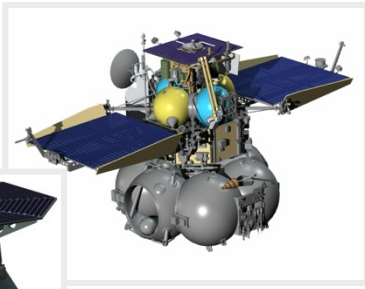
Boomerang
(Phobos-Soil-2)

Proton,
Phobos SR, Phobos
inverstigation

Under discussion

2026+



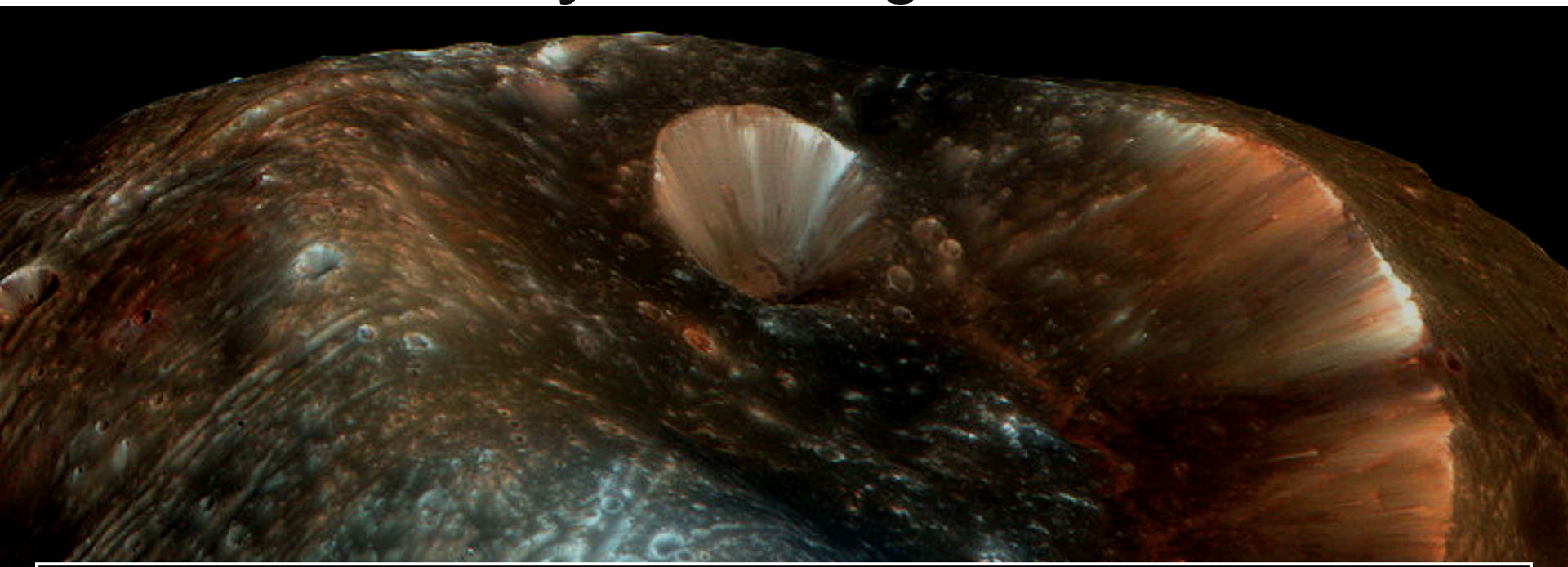


Mars-SR

2 Proton,
Mars SR,
Mars investigation

Under discussion

Why Phobos again?



Phobos and Deimos are unique objects among SS small bodies:

Are they:

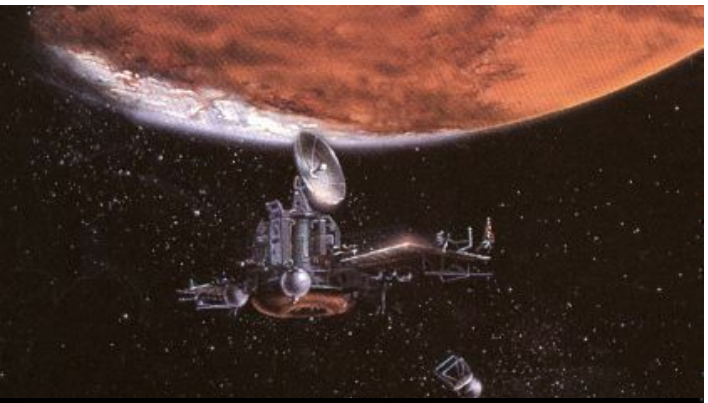
- **were formed together with Mars?**
- **captured asteroids like primitive bodies ?**
- **do they contain the Martian matter?**

- **And step to Mars Sample Return Mission**

Phobos studies

For many years studies of Phobos have been of high priority in the Russian program on planetary research.

- **the project was aimed to solve important scientific tasks**
- **delivery of soil samples to the Earth is an important step in preparation of a sample return mission to Mars.**

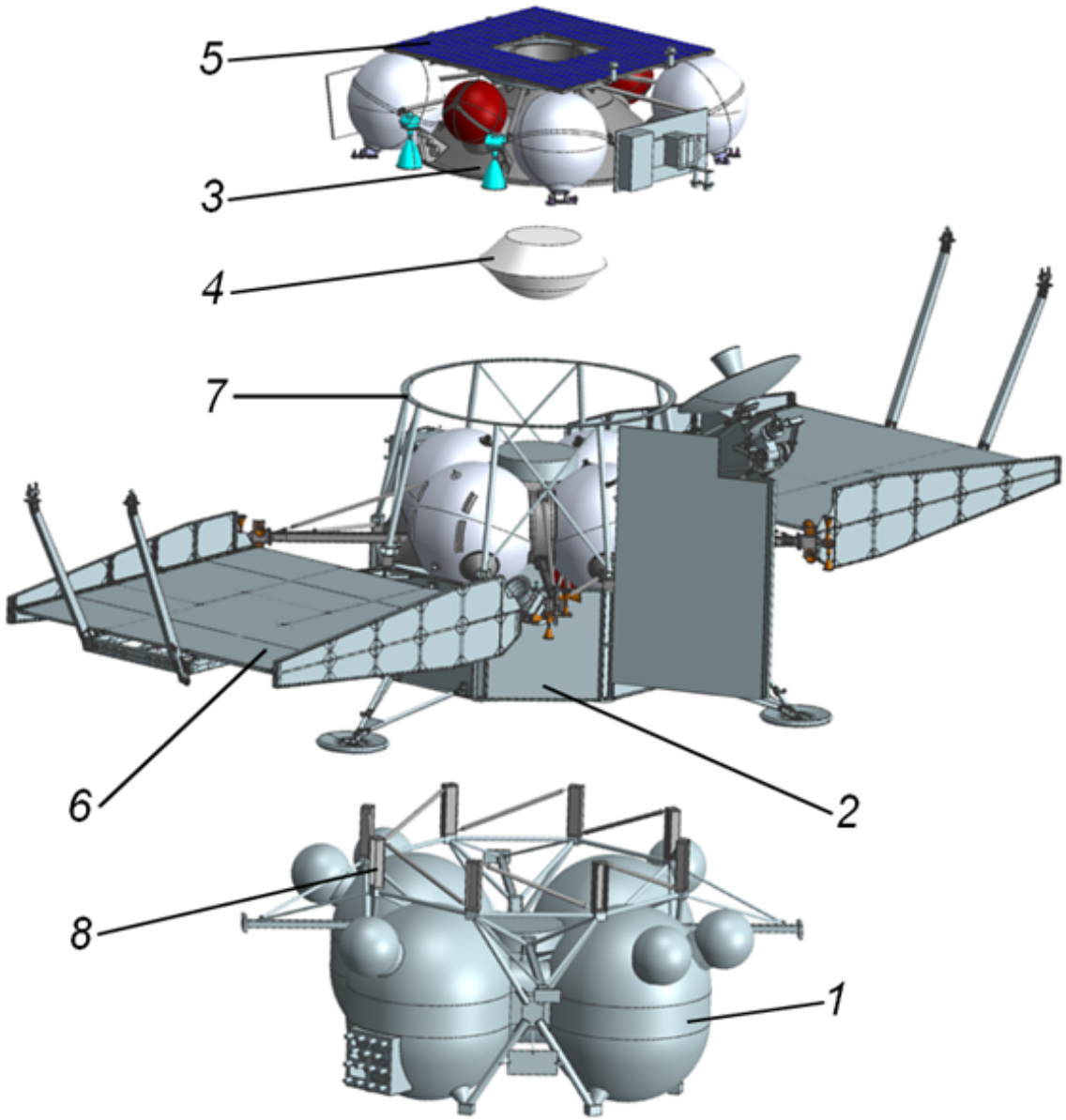


Phobos 2 SC
1988-1989

Phobos-Soil SC 2011

PHOBOS SR

ELEMENTS OF THE PHOBOS SR



1 - Main Propulsion System (MPS)

2 – Migratory SC - Lander

3 – Returned SC (RSC)

4 – Returned Capsule (RC)

5 – RSC Solar arrays

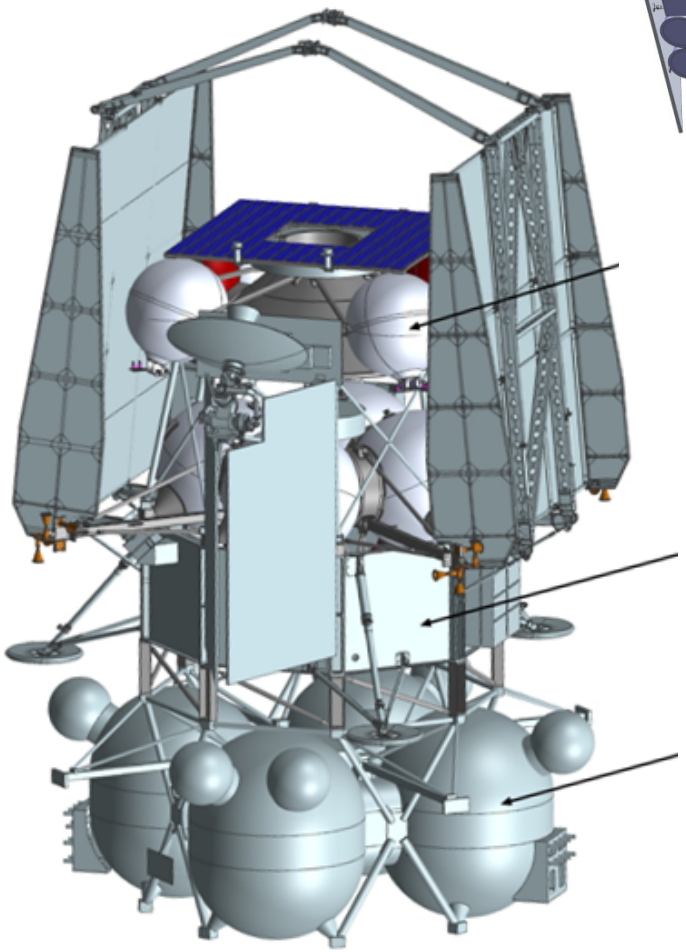
6 – Solar arrays

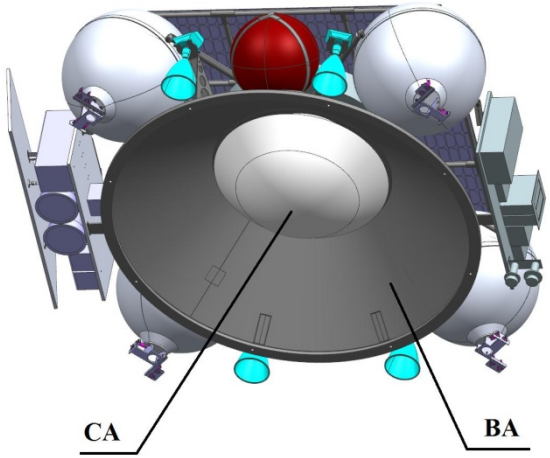
7 - SC Truss

8 - MPS Truss

Phobos Sample Return (Ph+D)

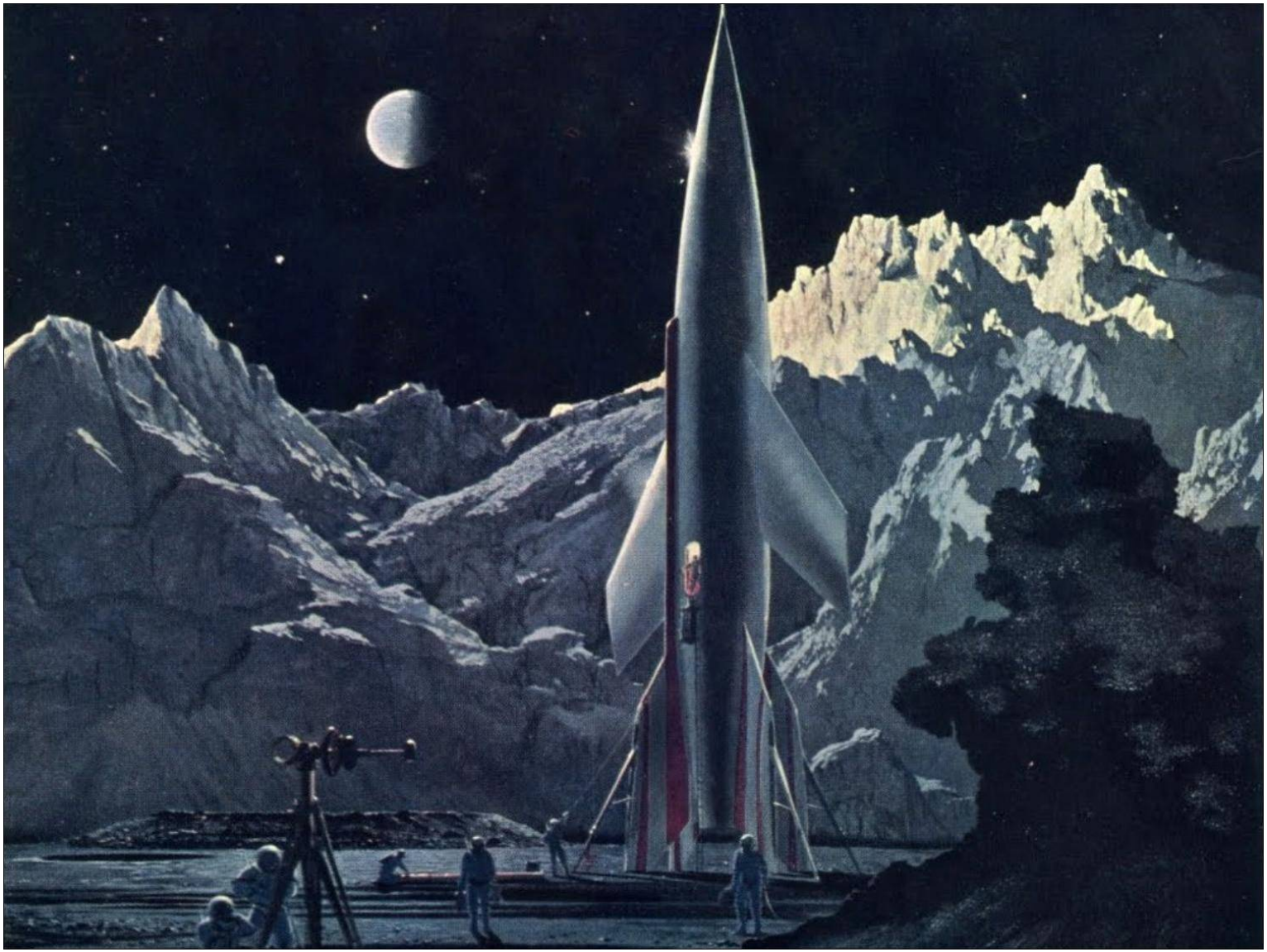
Main characteristics





Launch	2024 (TBD)
Rocket	Angara-5
Main propulsion system (wet)	5000 kg
SC (transfer + Lander)	~ 990 kg
Payload	~ 50 kg
Returned SC	380 kg
Returned Capsule	120 kg
Mass of samples	0,5 kg

Thank you!



Special Thanks

Luna-25 and Luna-27 — PS: I.G. Mitrofanov
PI: V.I. Tretiakov

Luna-27 — PS: A.A. Petrukovich

And for all who is involved in developing
the scientific instruments
for Russian Spacecrafts