History of Cosmonautics in Russia

From Philosophy, ideas and first steps to the
last results and beyond

Fathers of the cosmonautics

On the next slide the one can see

the cover of the book

From the Earth to the Moon

written by the famous French author **Jules Verne** in 1862

Since then it is the most popular science fiction book in Russia and may be in the world

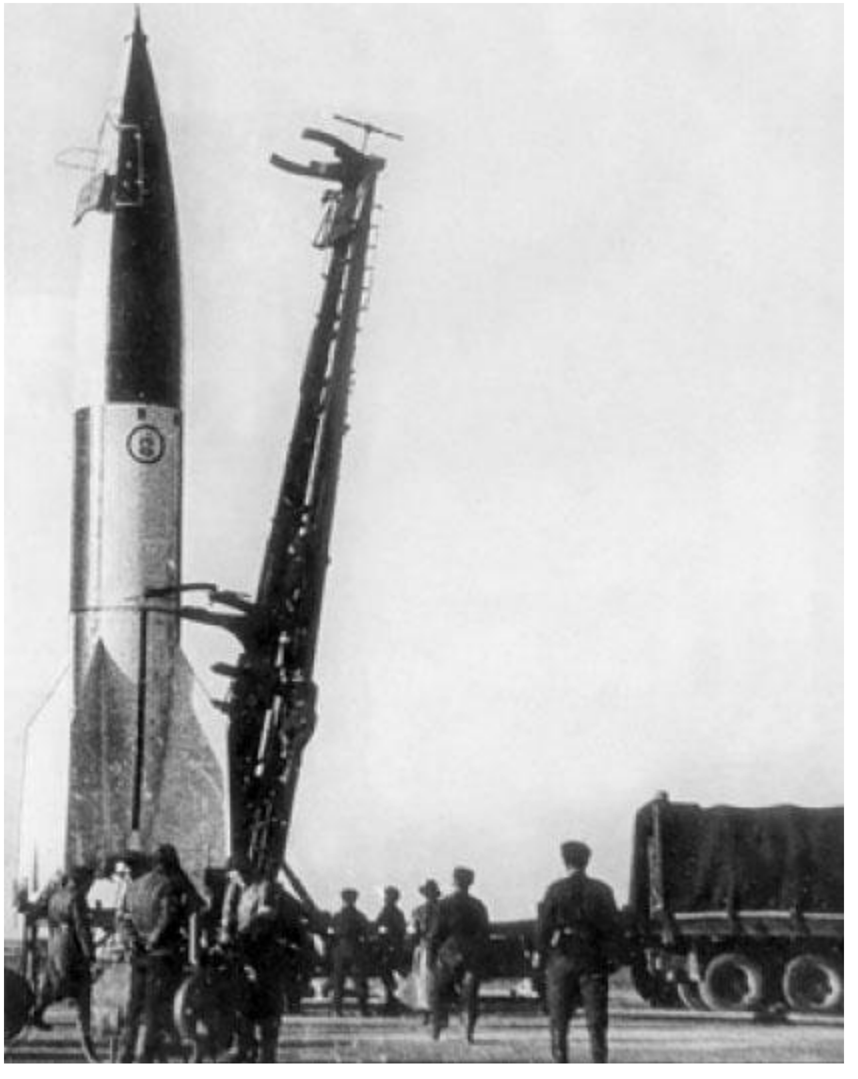
It has inspired a lot of people by ideas of space flight

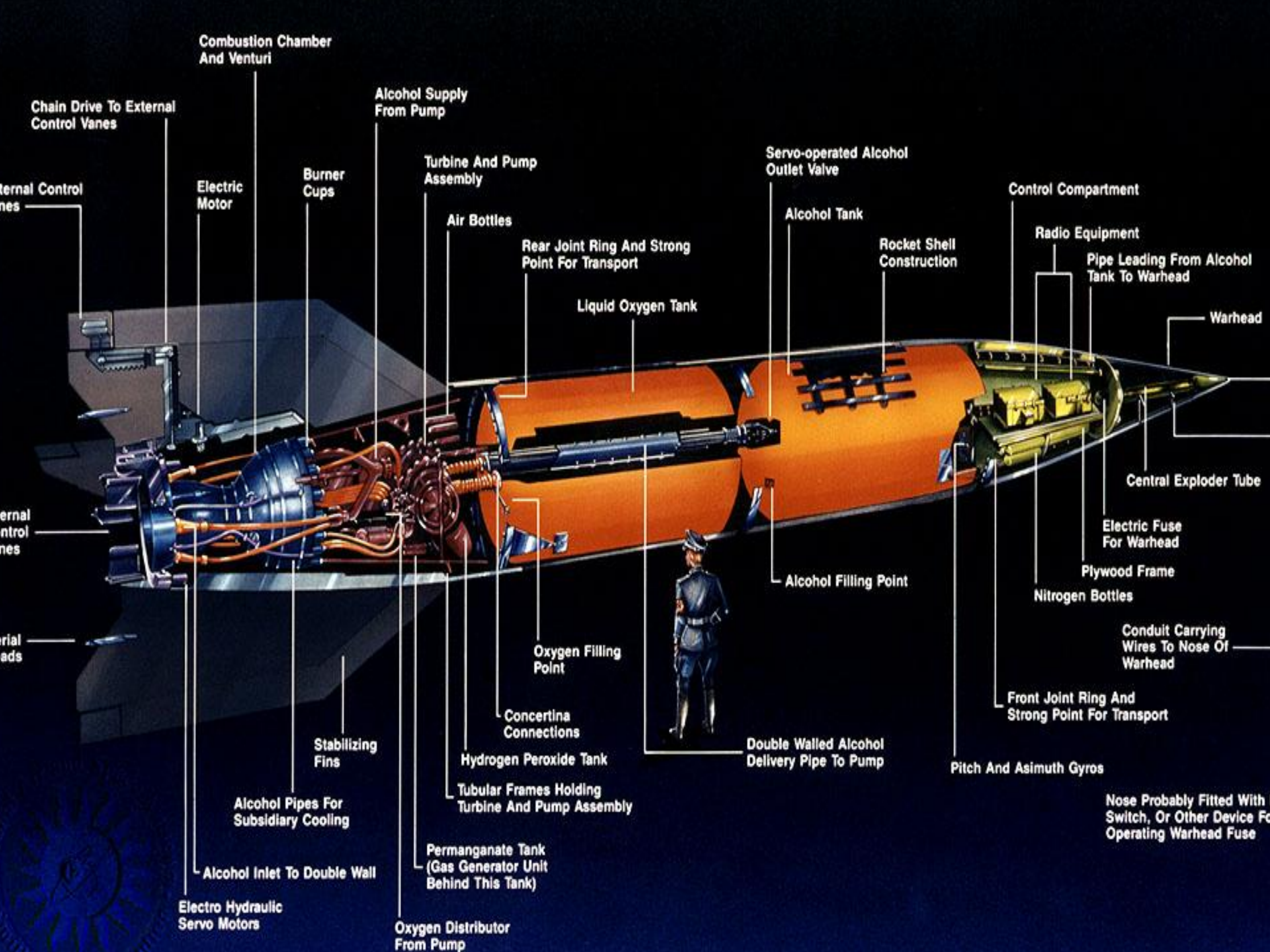
Following slides give his the portrait together with portraits of **KonstantinThiolkvskyi** - philosopher of cosmonautics and **Fridrikh Tsander** – pioneer of astrodynamics in Russia


FROM THE EARTH TO THE MOON
JULES VERNE


К. Э. ЦИОЛКОВСКИЙ

V-2 the first ballistic missile developed in nazi Germany More than thousand of them were used to attack London during WW2




Combustion Chamber And Venturi
Chain Drive To External Control Vanes
Alcohol Supply From Pump
Turbine And Pump Assembly
Servo-operated Alcohol Outlet Valve
Control Compartment
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Electric Motor
Burner Cups
Air Bottles
Alcohol Tank
Radio Equipment
Rear Joint Ring And Strong Point For Transport
Rocket Shell Construction
Pipe Leading From Alcohol Tank To Warhead
Liquid Oxygen Tank
Warhead
Central Exploder Tube
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ntrol
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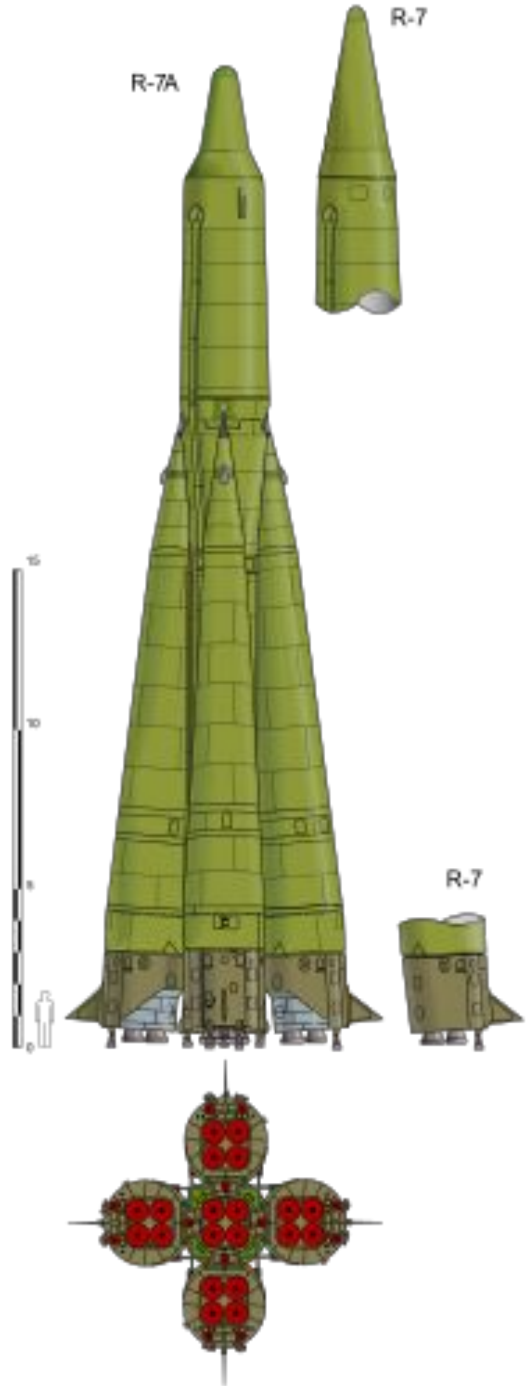
Electric Fuse For Warhead
Plywood Frame
Alcohol Filling Point
Nitrogen Bottles
rial
ads
Oxygen Filling Point
Conduit Carrying Wires To Nose Of Warhead
Front Joint Ring And Strong Point For Transport
Concertina Connections
Stabilizing Fins
Hydrogen Peroxide Tank
Double Walled Alcohol Delivery Pipe To Pump
Pitch And Asimuth Gyros
Tubular Frames Holding Turbine And Pump Assembly
Alcohol Pipes For Subsidiary Cooling
Nose Probably Fitted With
Switch, Or Other Device Fo
Operating Warhead Fuse
Permanganate Tank (Gas Generator Unit Behind This Tank)
Alcohol Inlet To Double Wall
Electro Hydraulic Servo Motors
Oxygen Distributor From Pump

Cold war and Russian response to American A-bomb

After American test of A-bombs in Hiroshima and Nagasaki at the end of WW2 in the USSR the symmetric response was presented in late forties and early fifties: atomic and thermonuclear (hydrogen) bombs

To deliver them to the target, as a tool the intercontinental ballistic missile capable to carry more than five tons "payload" has been developed, so called "semerka" (R-7) rocket

It could reach any point in US without any possibility to intercept it



R-7A
R-7
R-7

Critical problems solutions

- The rocket was two staged with kerosene-oxygen propellant
- It was to be developed in very short terms
- So the approach was instead overcoming the difficulties it was chosen to bypass them:

Both stages were started simultaneously on the ground, so it was not necessary to develop the methods to start engine in weightlessness and vacuum; instead of development of big cameras the combinations of groups from four with separate steering ones were chosen, etc.

The launch mass was 278 tons and it can deliver 5.4 t of ”payload” to 8000 km distance.

First successful flight was in 1957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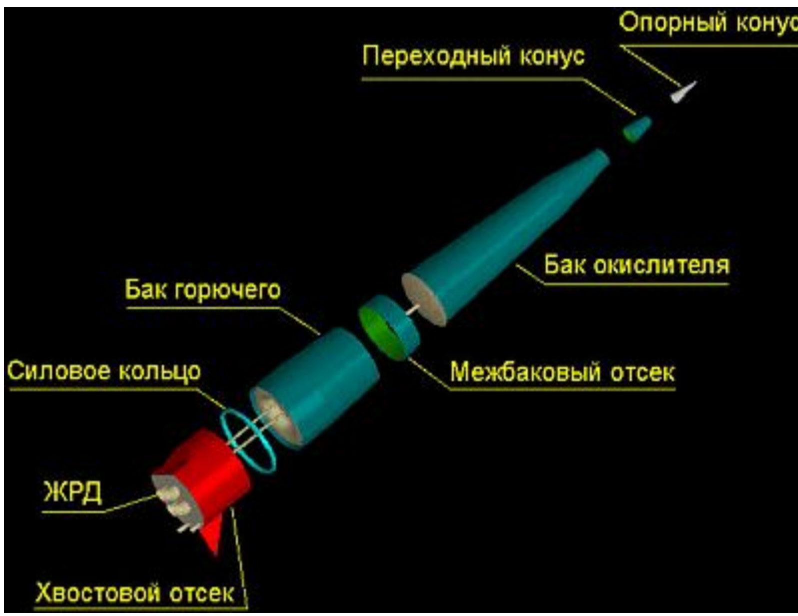
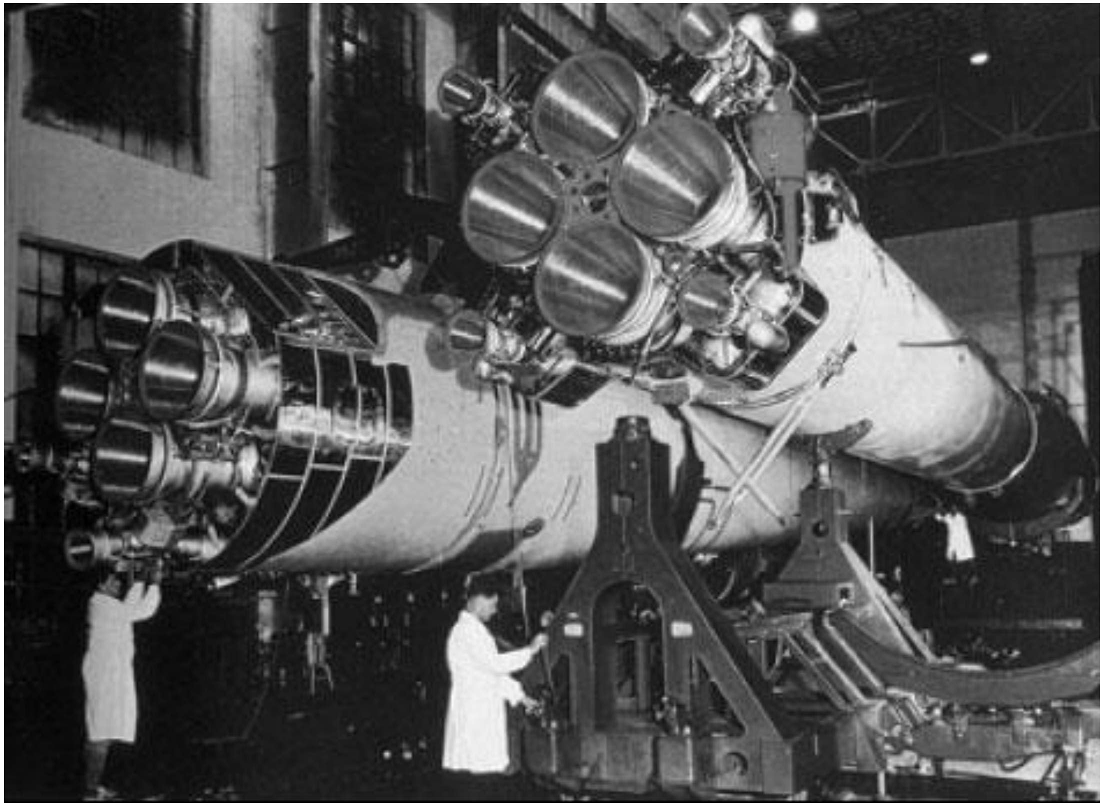
Separation of the first stage consisting from four blocks. Second stage (central block) operates uninterrupted from the liftoff

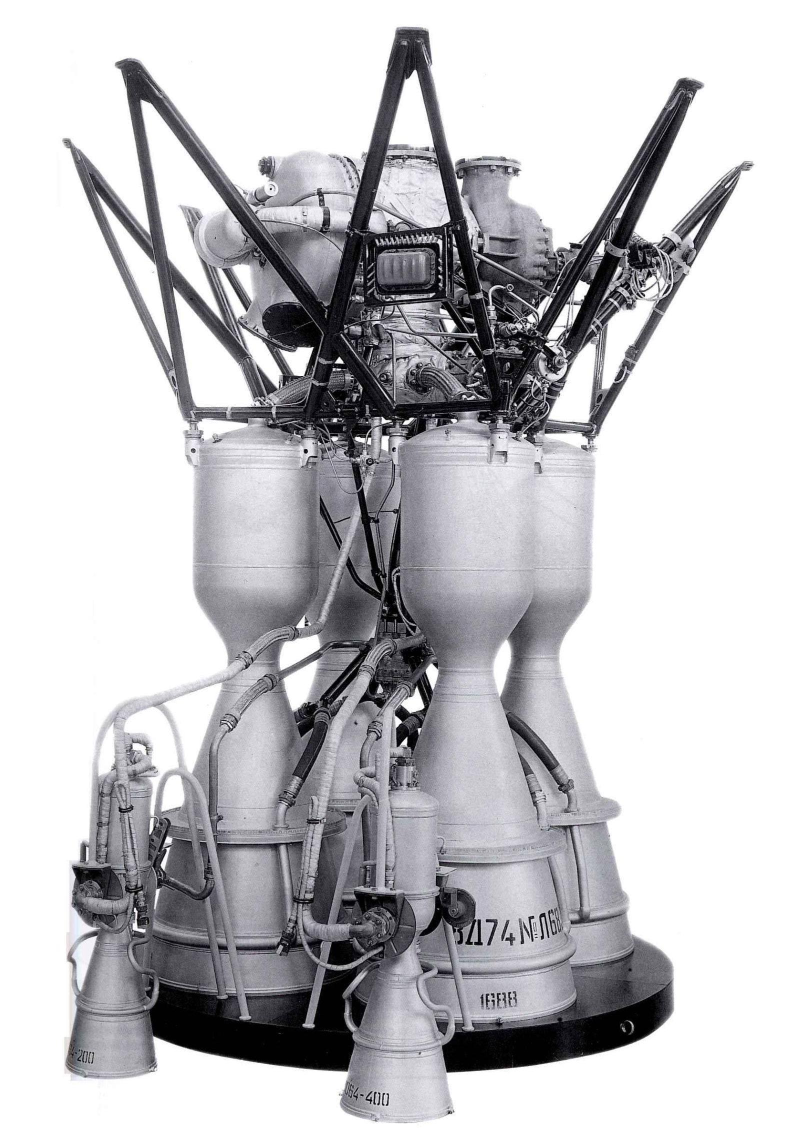
- Before separation procedure the engines of the first stage are cut off



Engines clusters mounted on the stages



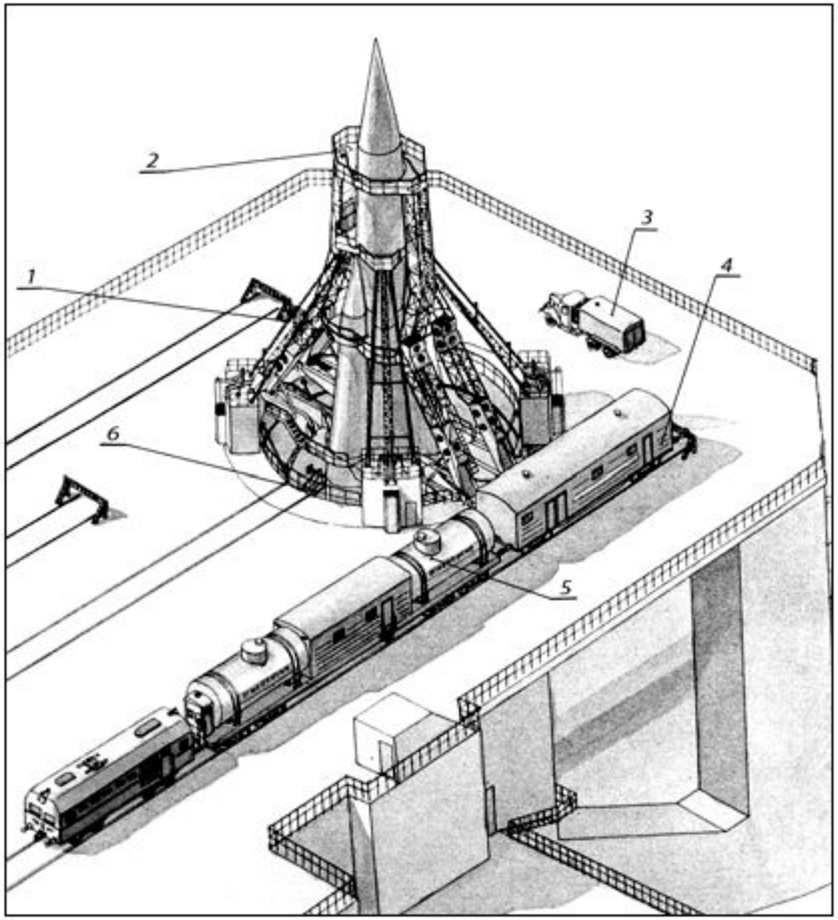
Rd-107 rocket engine for side block of “semerka”

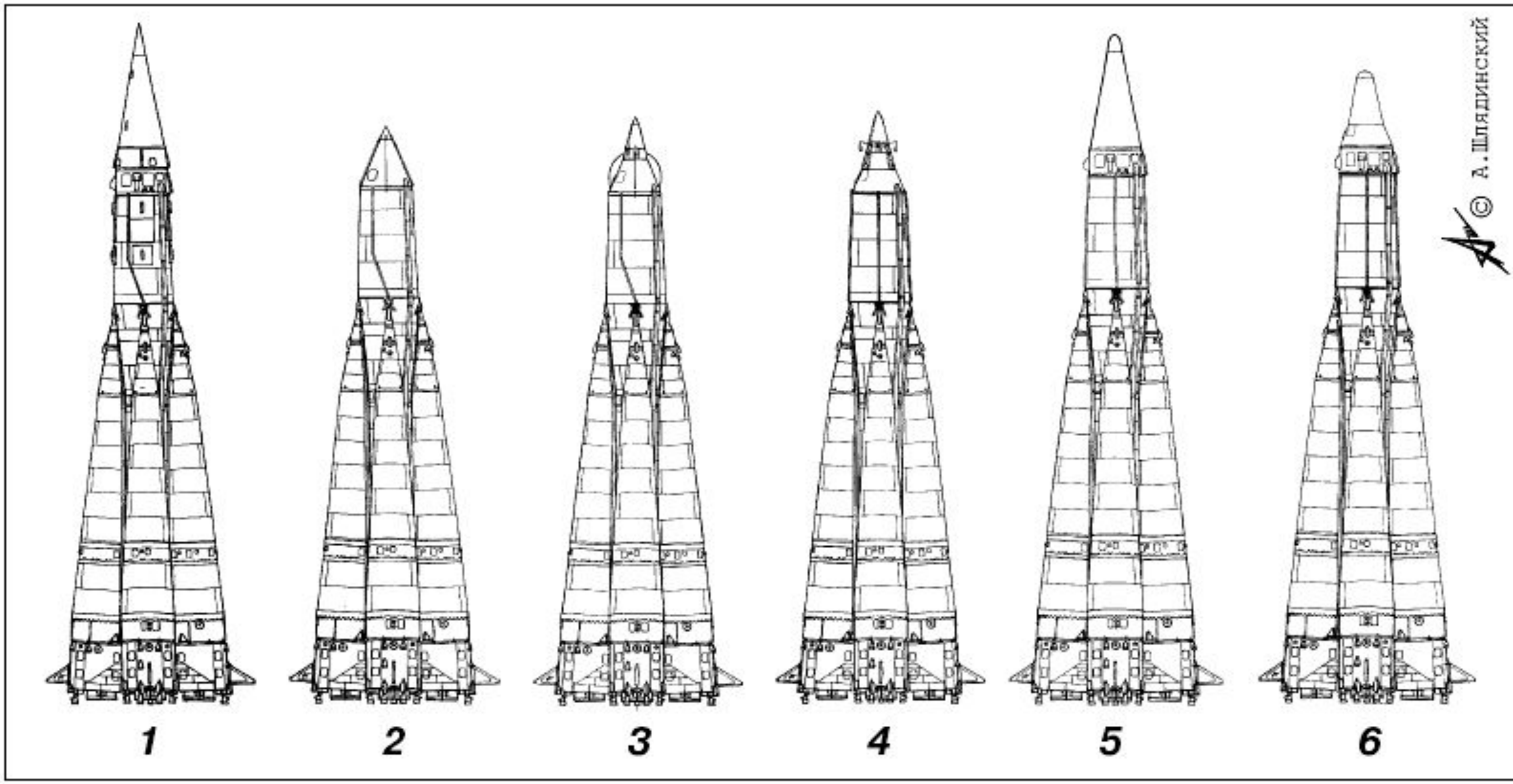


Engines cluster

32 rocket engine cameras lift launch vehicle into space

Launching pad for R-7




1
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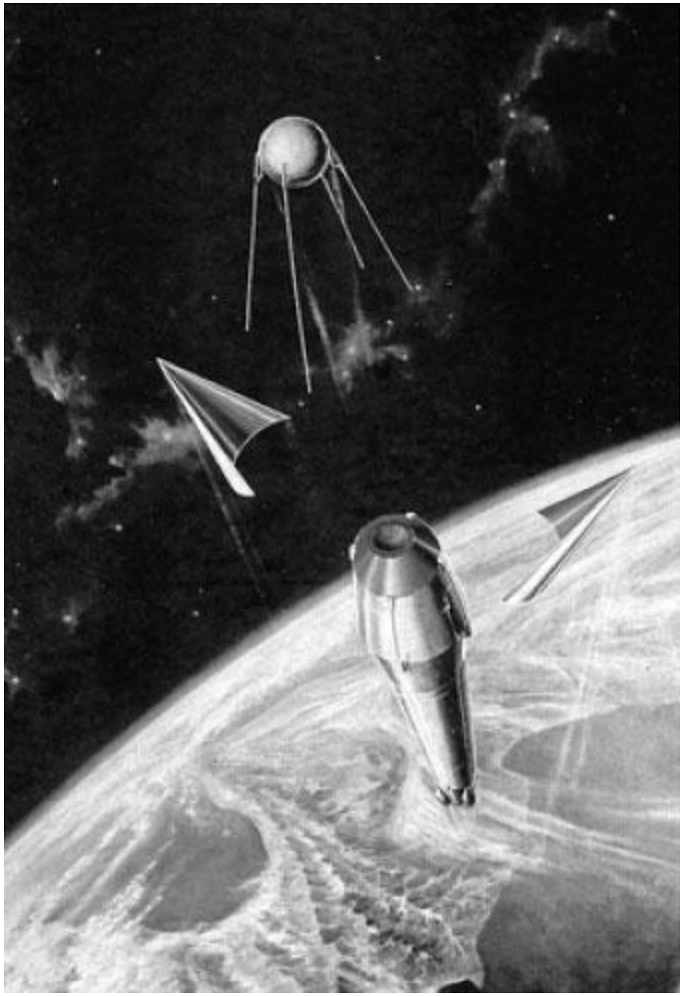
© А.Шлядинский

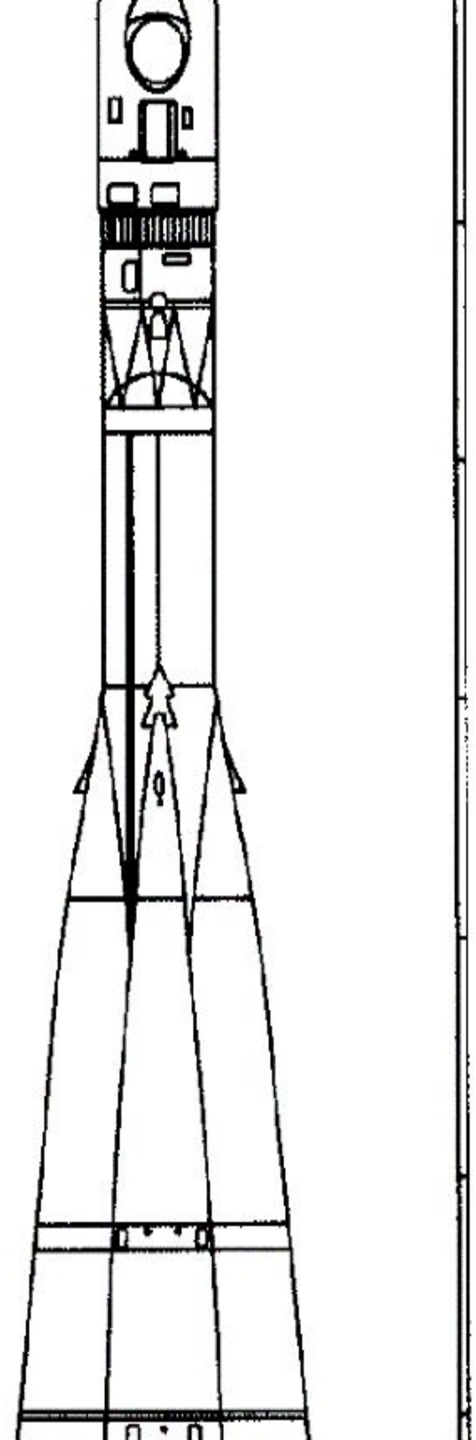


Launch vehicle "Vostok"

The third stage (Block E) was added.

"Hot" separation was used.

Hatch above is for cosmonaut emergency escape

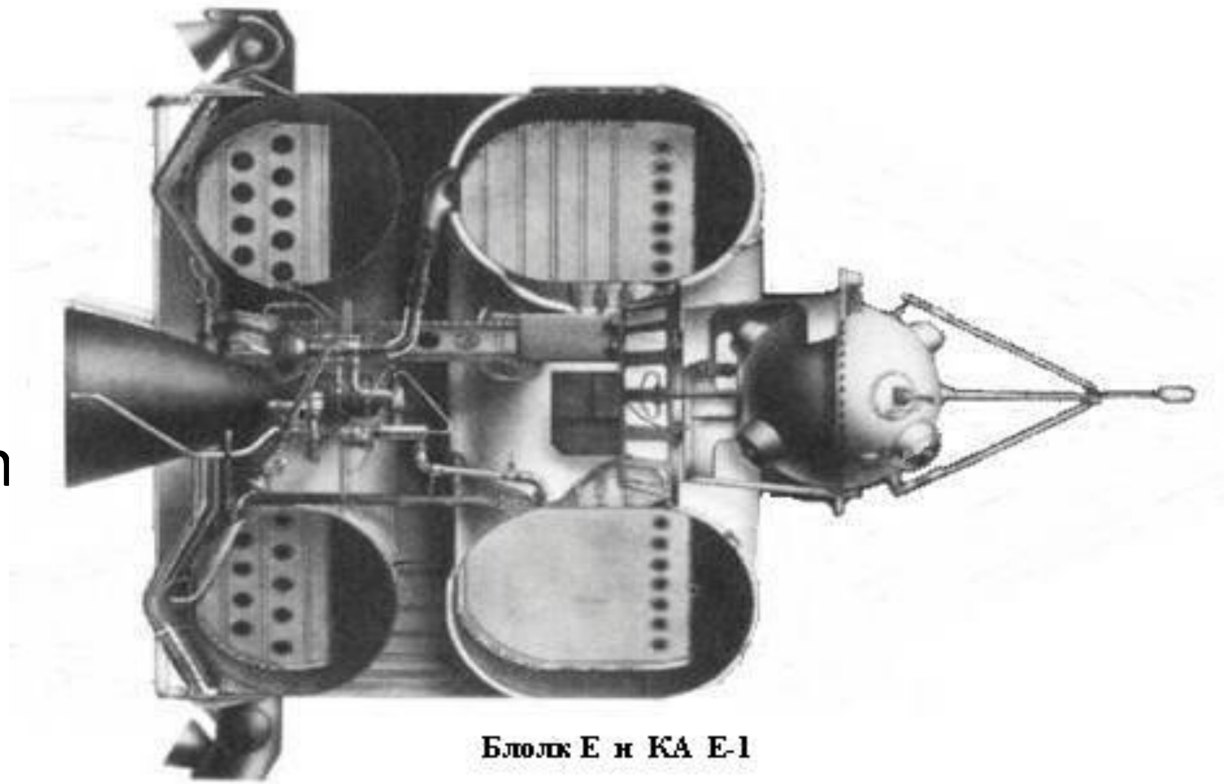


Luna-1 – first man made device reached extra-terrestrial space body: Moon (1959)

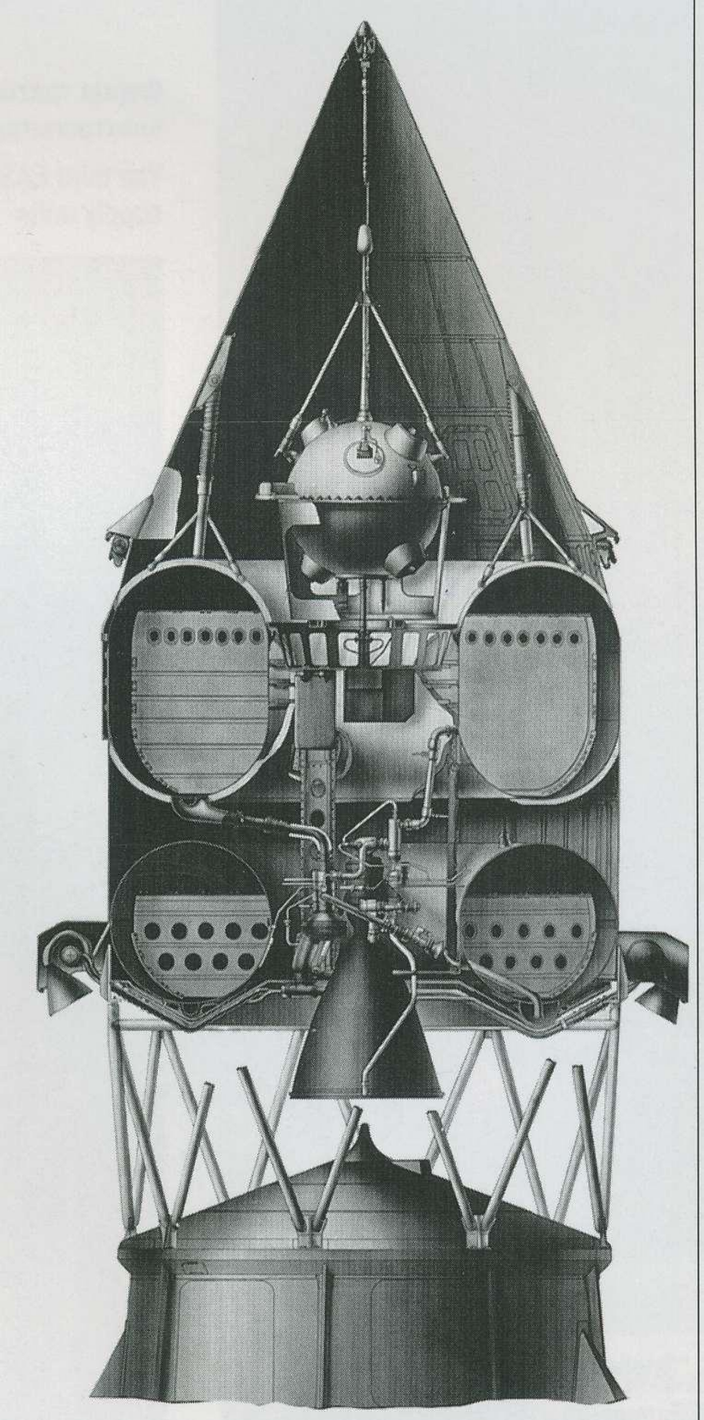
It was direct flight without parking orbit and without correction maneuvers

The Third stage for the first Lunar missions (Block E)

For engine
start the “hot”
separation
was used, i.e.
engine ignition
before separation



Блолк Е и КА Е-1

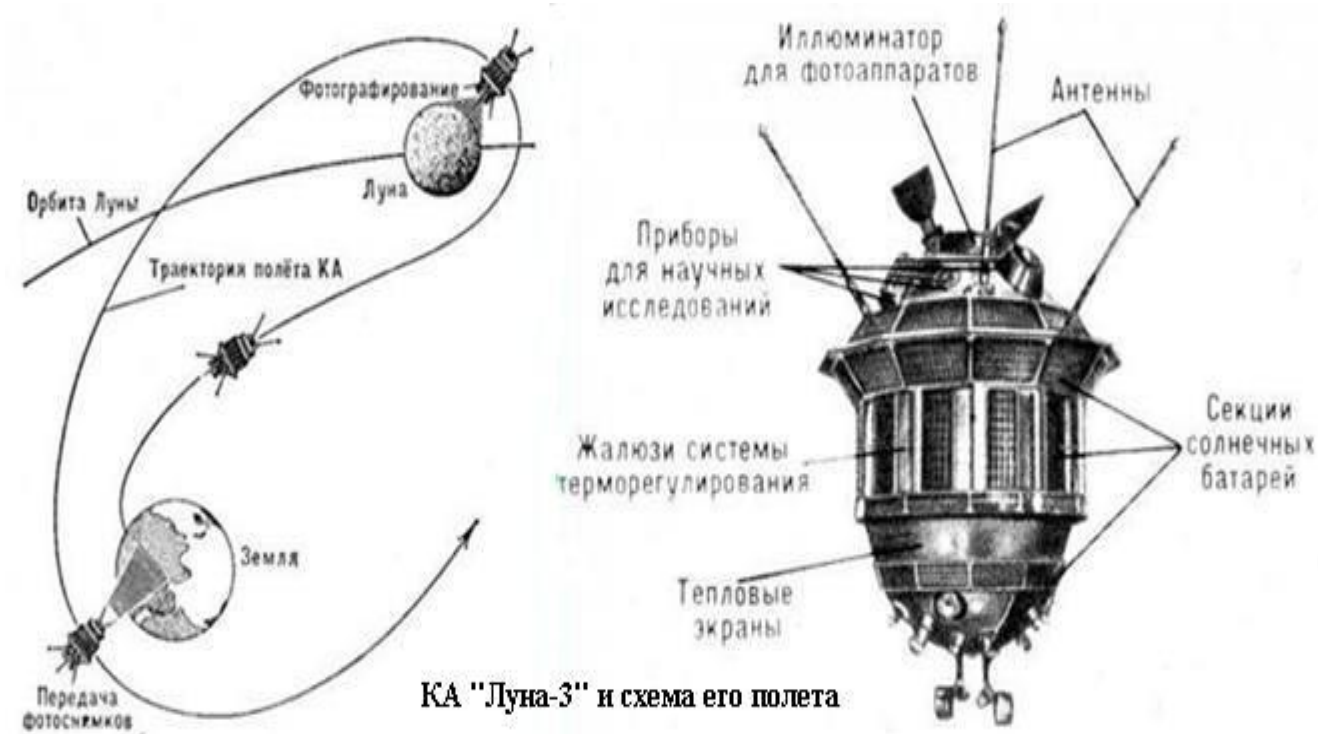


Block E the third stage
Truss between stages allows hot gas stream
Shield protects the second stage

Lunar fly by mission (Luna-3, 1959)

The first back side Moon photo was transmitted to the

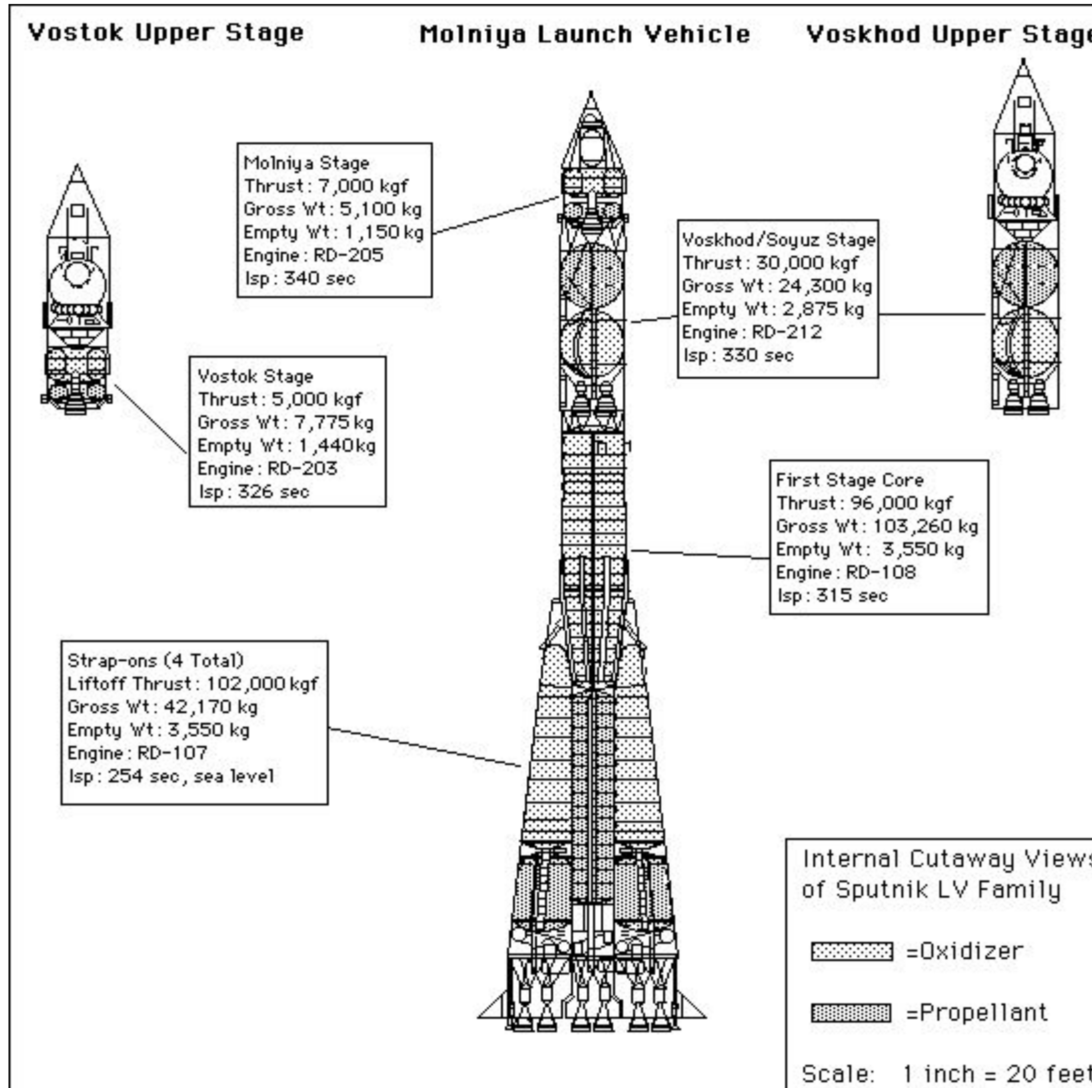
Earth



8K78 – the first Russian launcher with “cold” start of upper stage Molniya

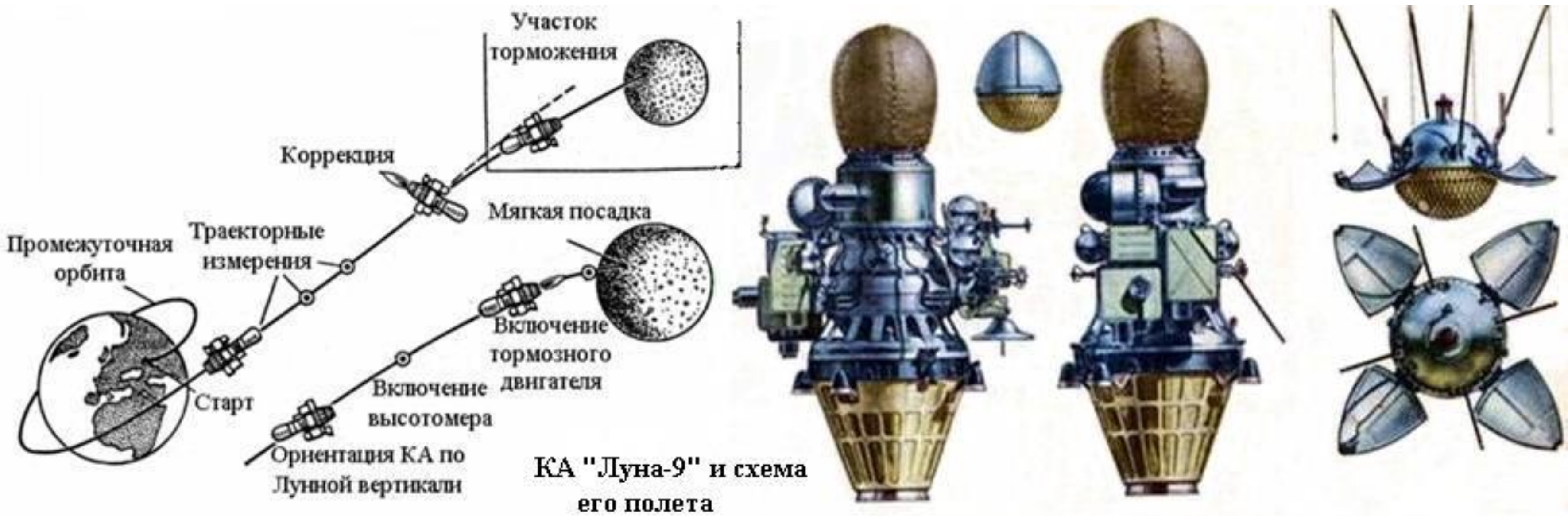
With development of this stage solar system and its planets became accessible and Moon approached so close that missions of Moon soil samples return missions could be realized

Liquid propellant engines cold start became doable by applying for this solid motors.



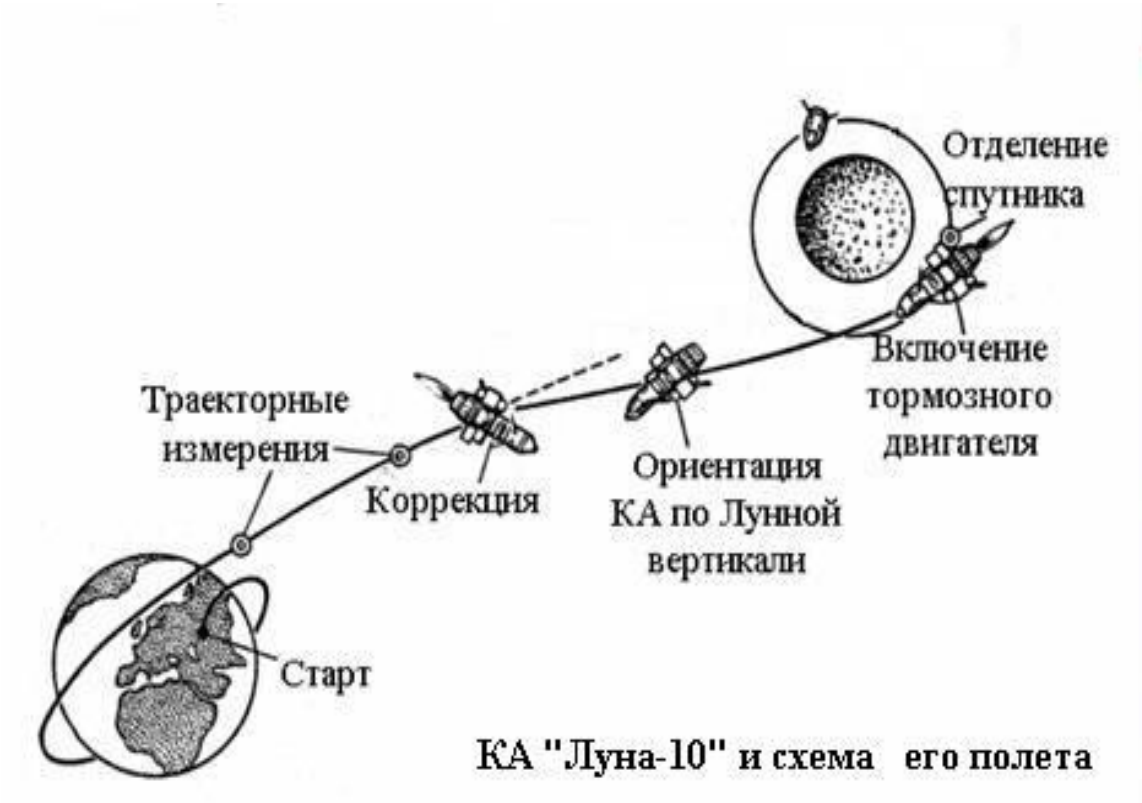
Luna-9 mission to the Moon surface (1966) On the right descending and landing module after soft landing and systems deployment

Key operations

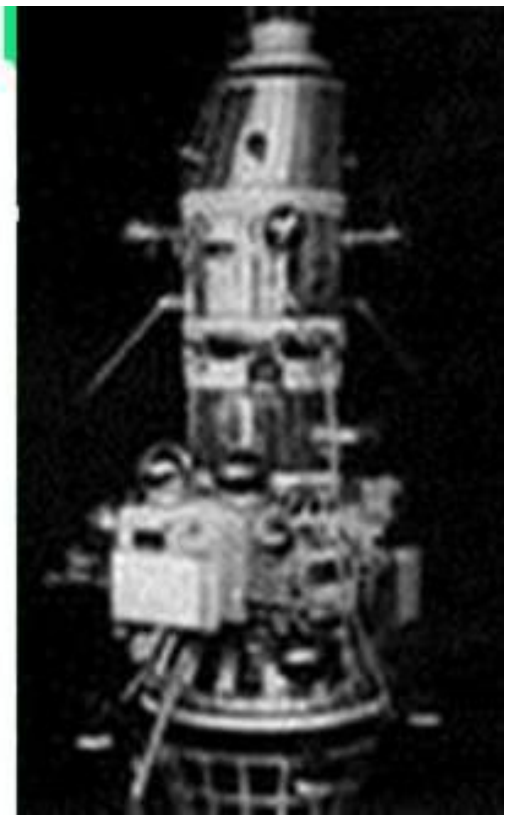


Luna-10 mission to the Moon satellite orbit (1966)

- Operations: tracking, correction maneuvers, orientation, braking maneuver, satellite separation

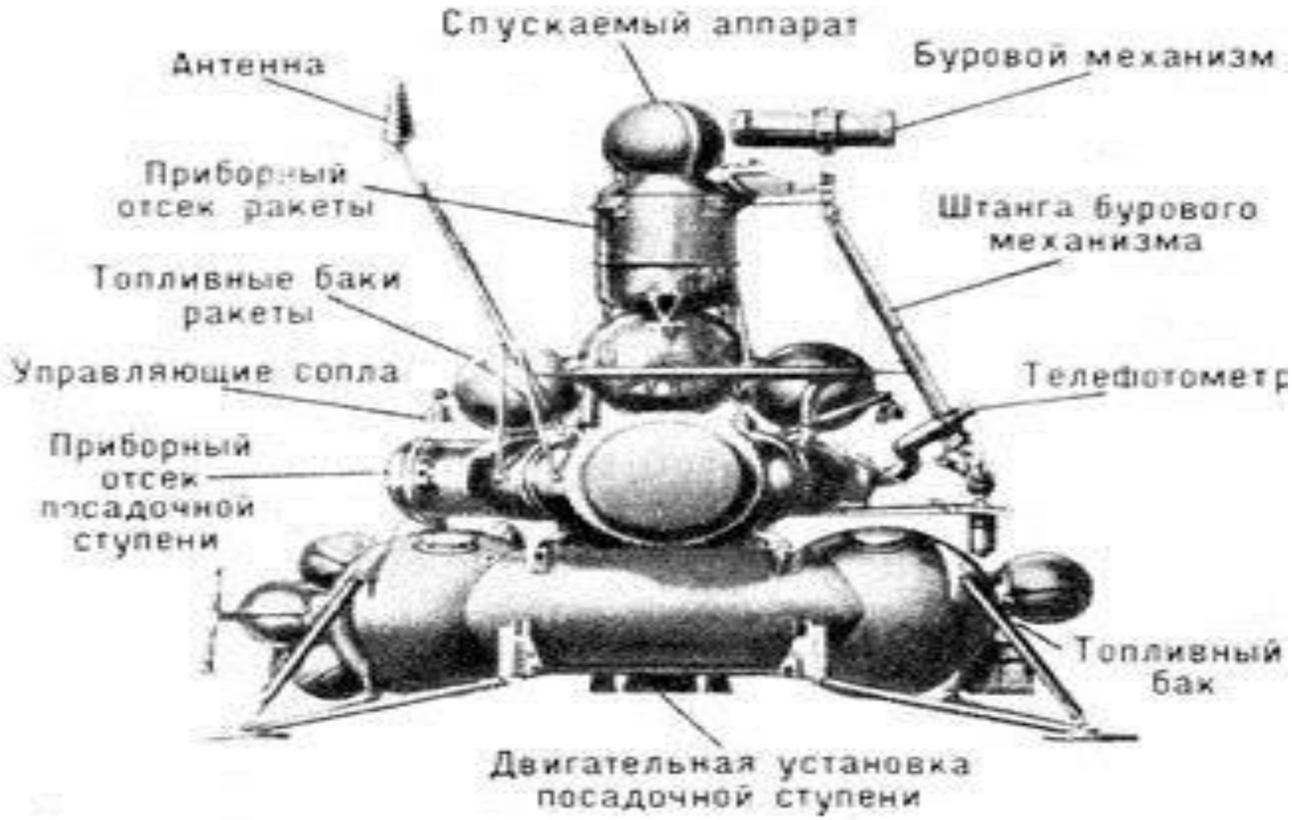


КА "Луна-10" и схема его полета



Lunar soil samples return spacecraft Luna-16 (1970) with landing module, ascending module and reentry capsule

Key instrument is drilling device

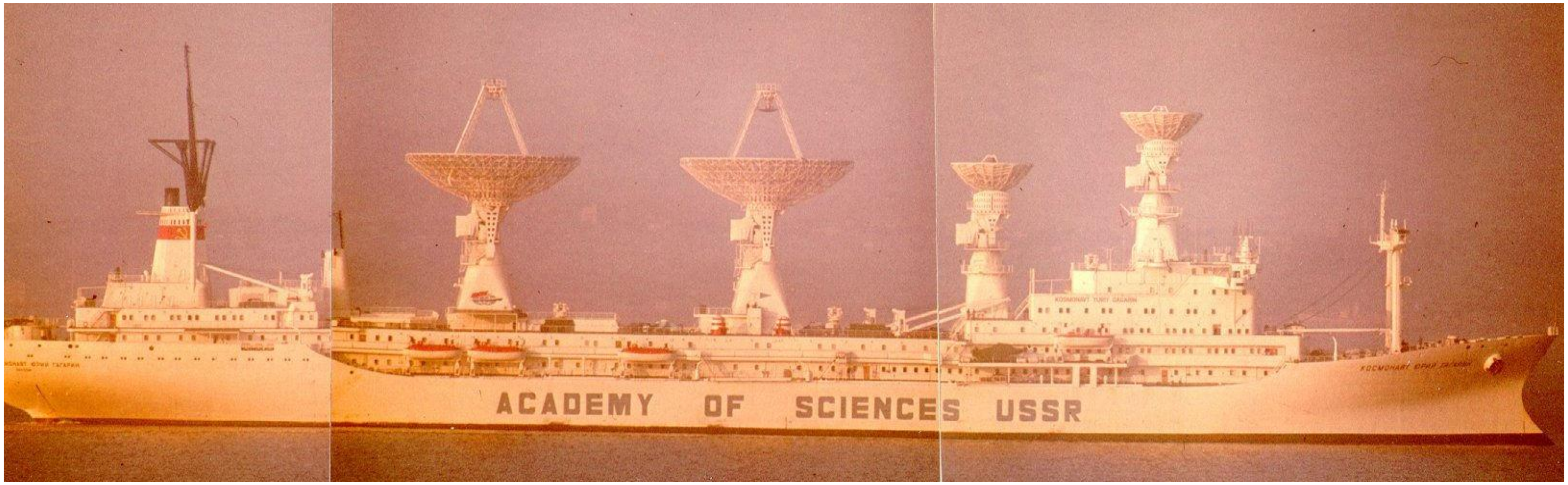


КА Е-8-5


ilroads
ch/test sites
mand
control site
arch
development
60°
asnoe Selo
St. Petersburg
Arkhangelsk
Plesetsk
Vorkuta 18
MOSCOW
Yaroslavl
Shelkovo
Nizhniy Novgorod
Vyatka
arkiv
Voronezh
Kazan
Perm
Yakutsk 17
Penza
Nizhniy-Tagil
Saratov
Ekaterinburg
Ufa
Samara
Volgograd
Kapustin Yar
Oral
Orenburg
Chelyabinsk
Angara R.
Kolpashev
Petropavlovsk
Kustanay
Omsk
Eniseisk 4
Komsomolsk
Aktobe (frm. Aktubinsk)
Tomsk
Svobodny
Krasnoyarsk
Kokchetav
Novosibirsk
Blagoveshchensk
KAZAKHSTAN
Pavlodar
Novokuznetsk
Chita
Arqalyq
Tselinograd
Barnaul
Irkutsk
Ulan-Ude
Aralsk
Zhangaqazaly
Baykonur
Karaganda
Semipalatinsk
Baikonur (Tyuratam)
Sary Shagan 3
Vladivostok
Qyzylorda
Balkhash
Lake Balkhash
Taldyqorgan
Zhambul
Shymkent
Alma-Ata
Tashkent
Bishkek
Maidanak 21
60°
70°
80°
90°
100°
110°
120°

"Cosmonaut Gagarin" ship as powerful sea based command and telemetry station

14 ships have been equipped by antennas and receiving/transmitting devises to compensate lack required points for global coverage on the territory of Russia



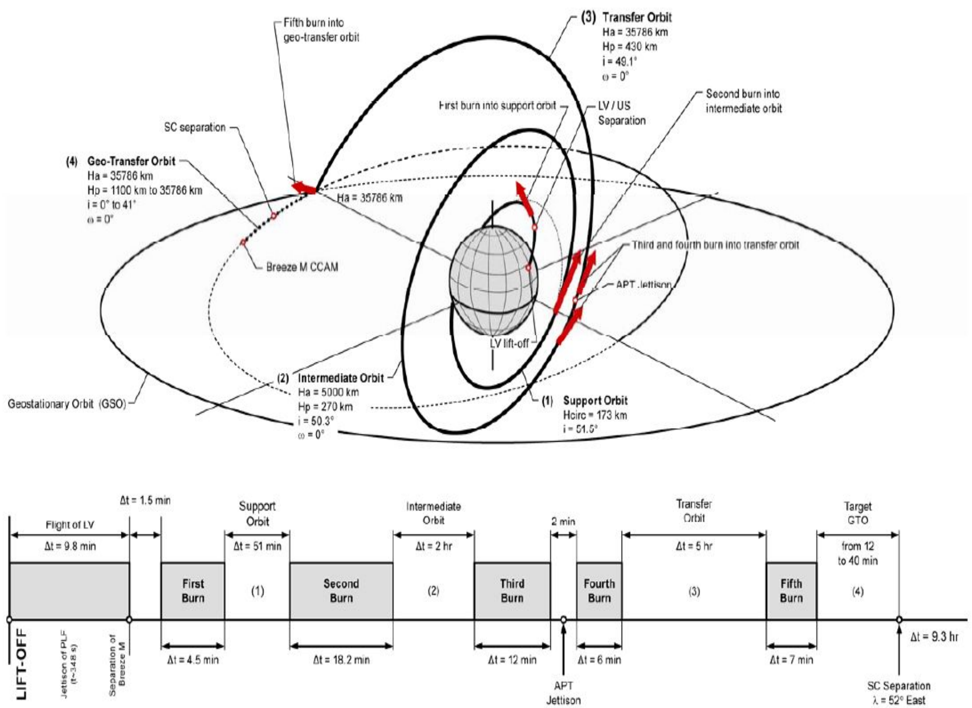
Geostationary Luch communication satellite for uninterrupted radiolink with near Earth spacecraft

Thus in for contemporary tasks the problem was resolved by introducing in regular service several space communication satellites

Difficult way to geostationary orbit from Russian territory

Proton Launch System Mission Planner's Guide, LKEB-9812-1990
Revision 7, July 2009

Figure 2.3.2-1: Typical 9-Hour Breeze M Mission Profile for SC Injection into GTO from the First Ascending Node of the Parking Orbit with an Inclination of 51.5°



Sea launch

- Launch from equator to geostationary orbit allows to increase payload mass by more than 50% with respect to the launch from Baikonur. For this Zenith launcher with Block-DM as upper stage was successfully used.

Proton start

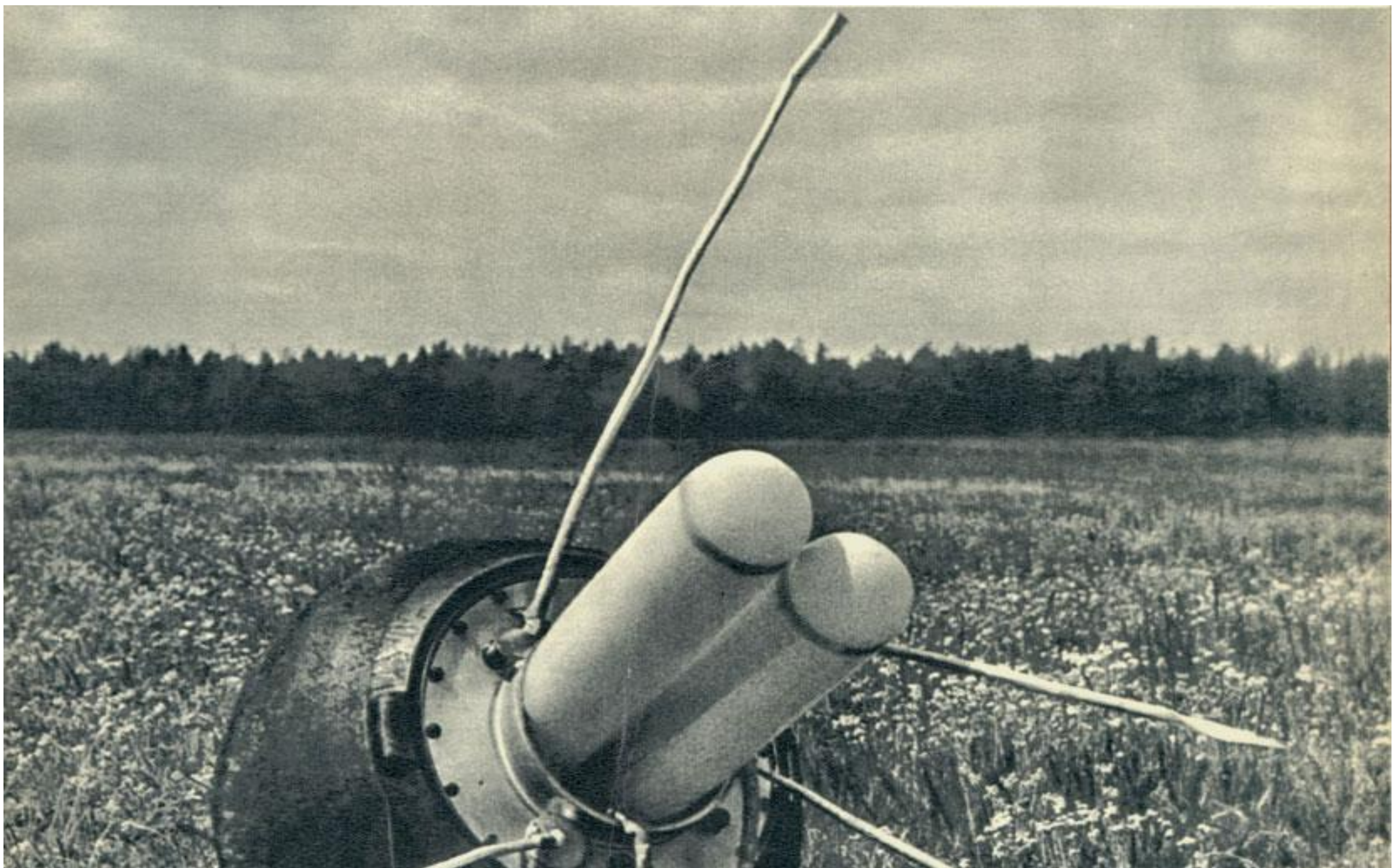
Initially was developed for military purposes, but very soon modified for Scientific and commercial Launches.
On International Market is operated by ILS International Launch Service

Luna landing module intended for Lunar sample return

Landing module with returning to the Earth spacecraft and atmosphere reentry module (at the up)

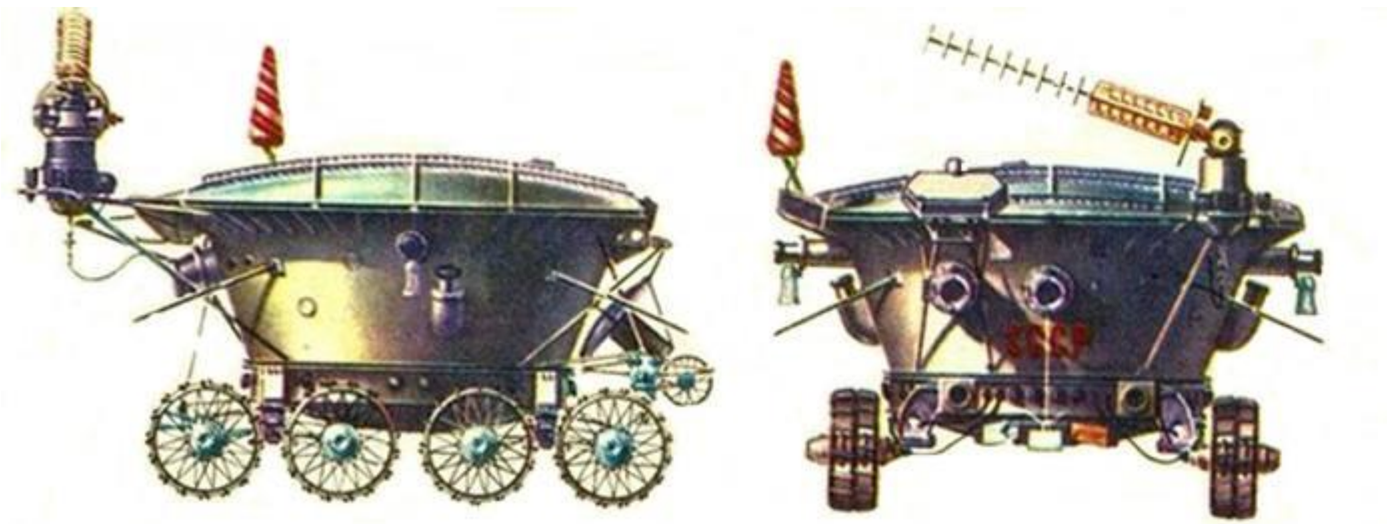
Lunar reentry module after returning to the Earth
Three missions with Moon soil samples delivery to the Earth were successful with total mass about 0.5 kg. The final mission in 1976.

- Antennas for search of the module after landing are seen



Russian Moon rover "Lunohod-1" delivered to the Moon by Luna-17 (1970)

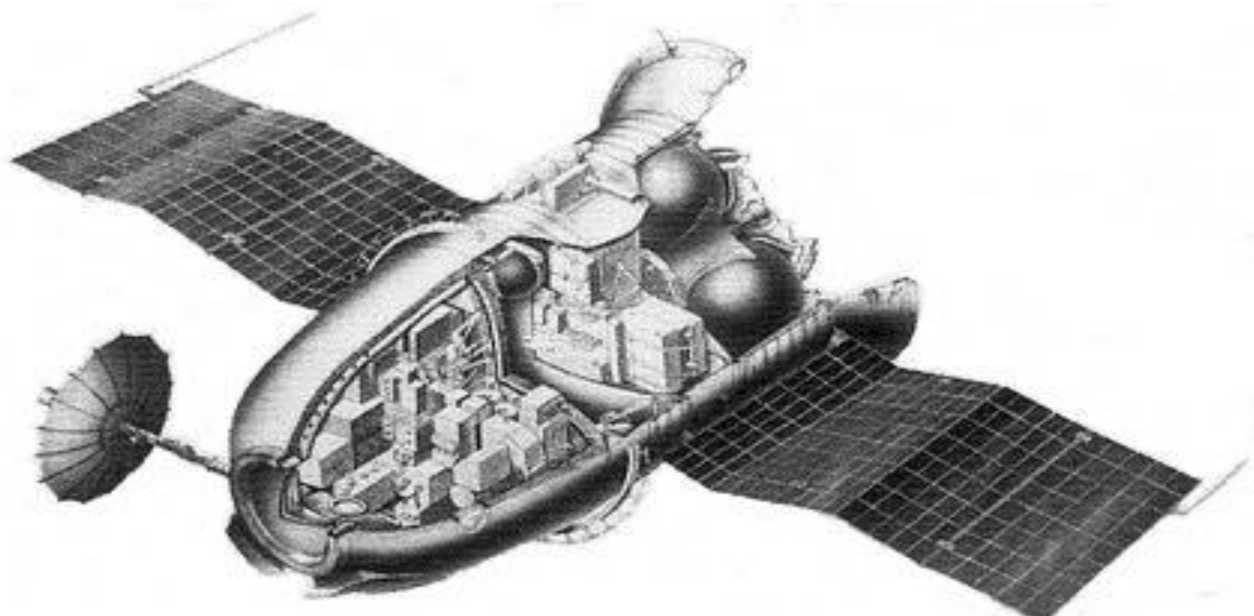
The rover explored vast area of the Moon controlled by ground base operator using radio link with it



"Луноход-1"

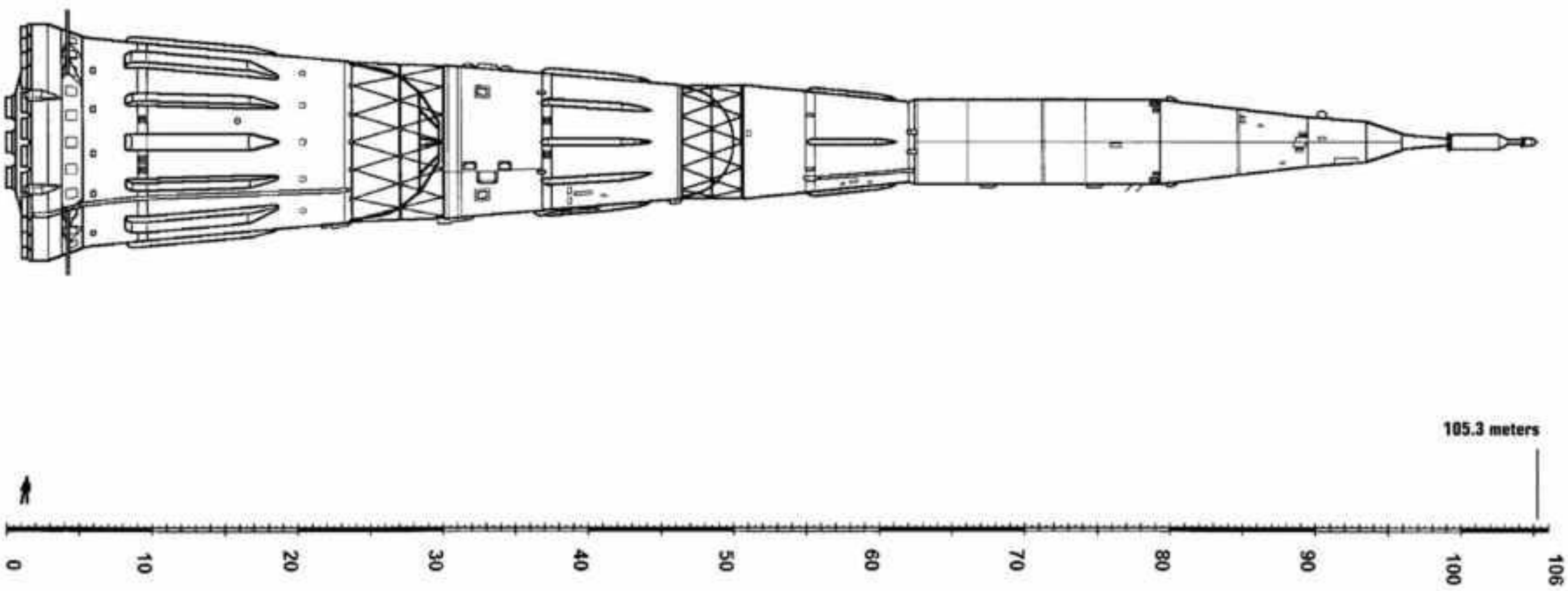
Moon zond to fly by the Moon with returning back to the Earth and consequent atmosphere reentry

Was developed as prototype for piloted Moon program (L-1)
The last flight (without crew) has been fulfilled in October 1970 under name Zond-8. Then program was stopped.



Космический корабль Л-1

N-1 launch vehicle scheme

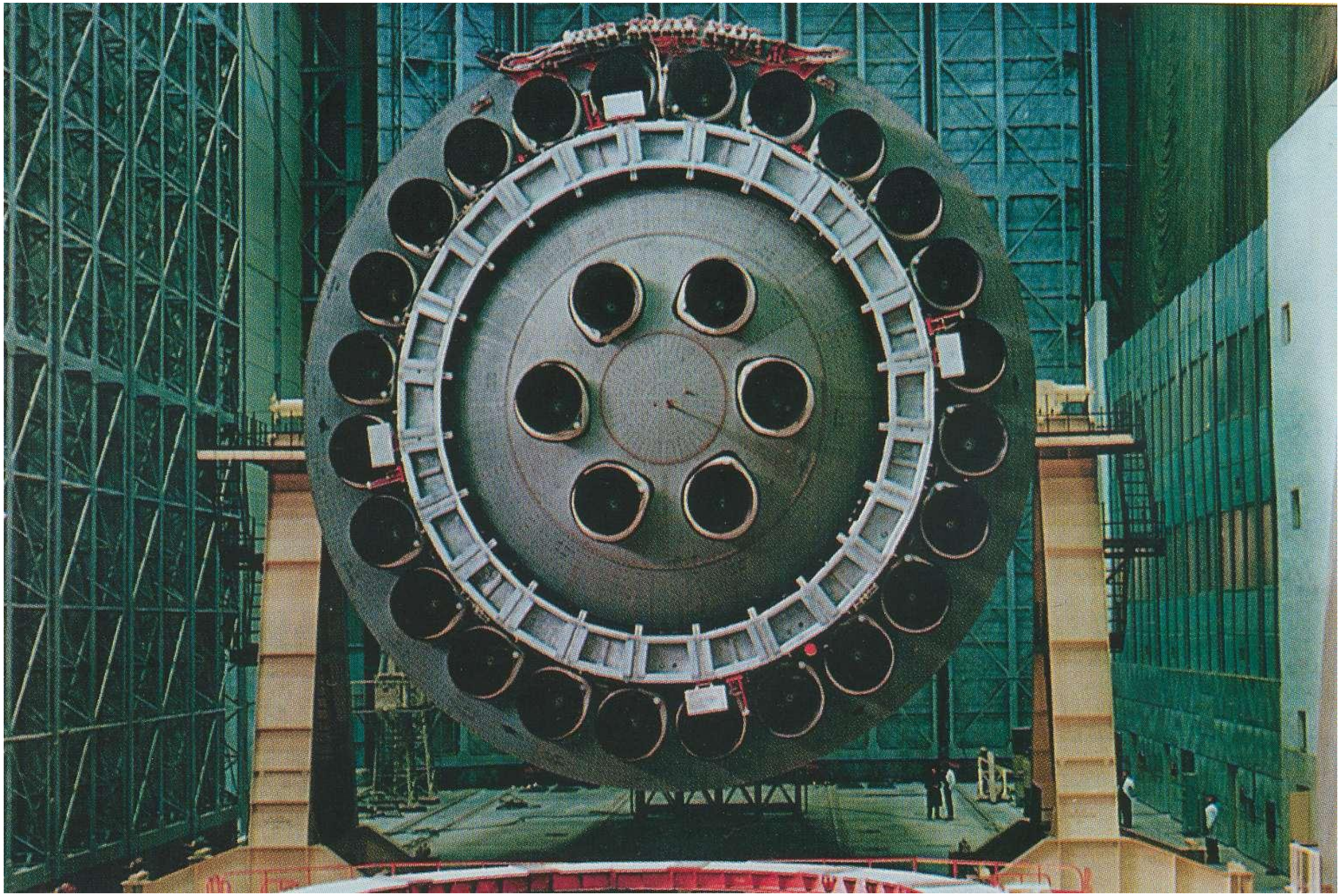


N-1 huge (3000 t, 30 rocket engines total thrust 4500t)
launch vehicle
for Moon piloted mission

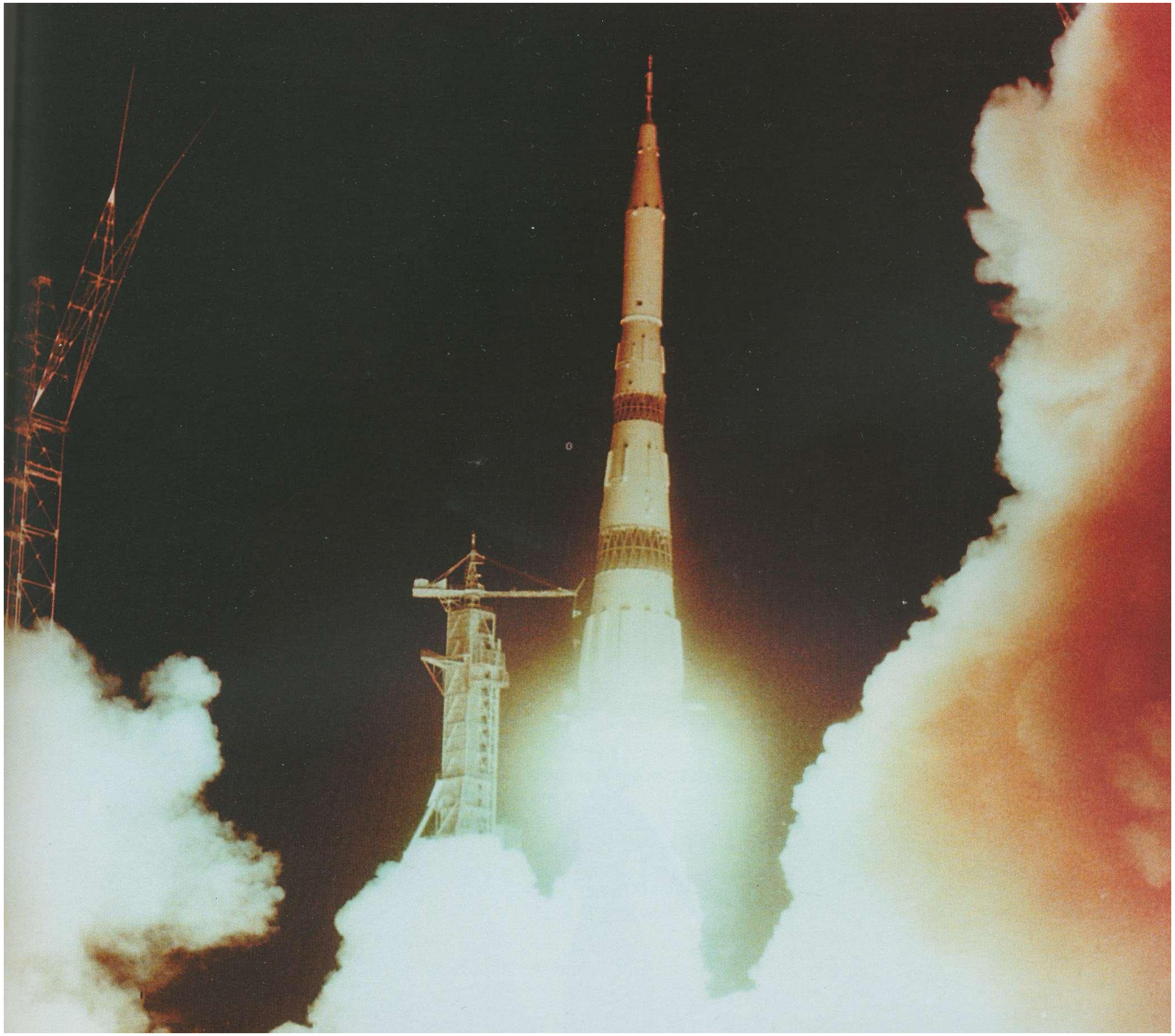
Four un successive launches have been attempted

The maximum diameter of the block is 16.8m (dimensions taken by stabilizers are 22.33m) with the height of 30.1m. The block houses 30 engines with ground thrust of 153 tf each

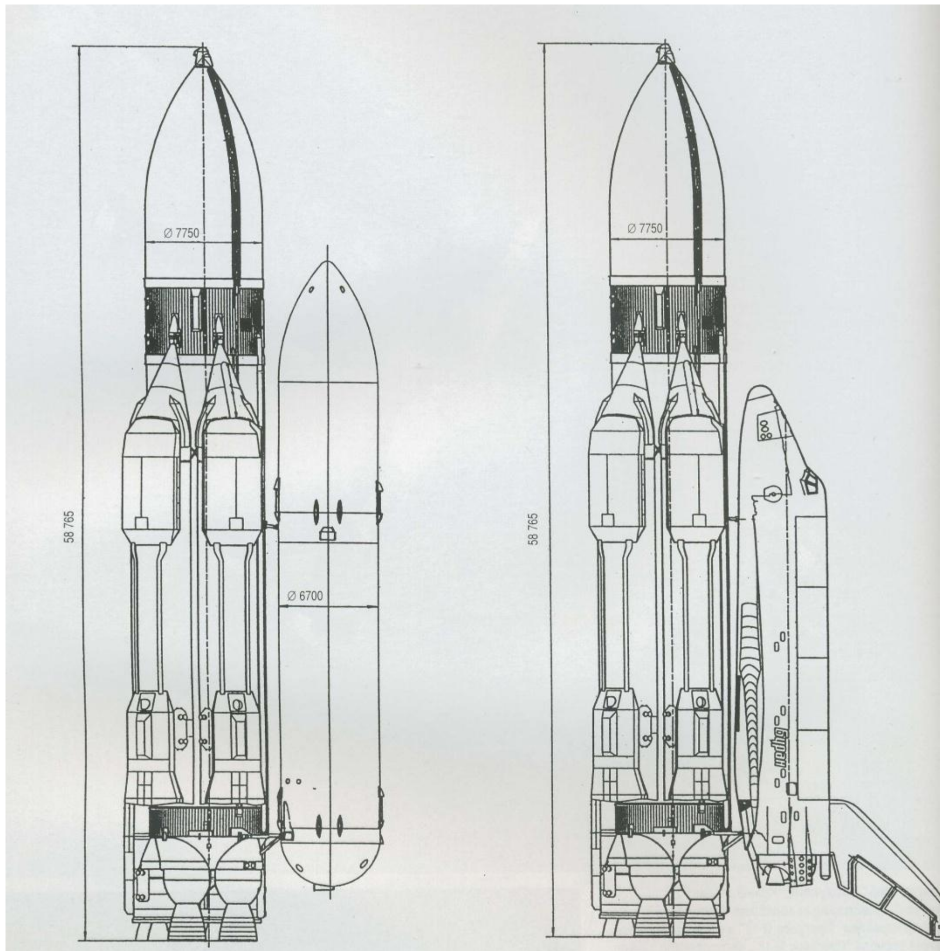
N1 Launcher



N1 start



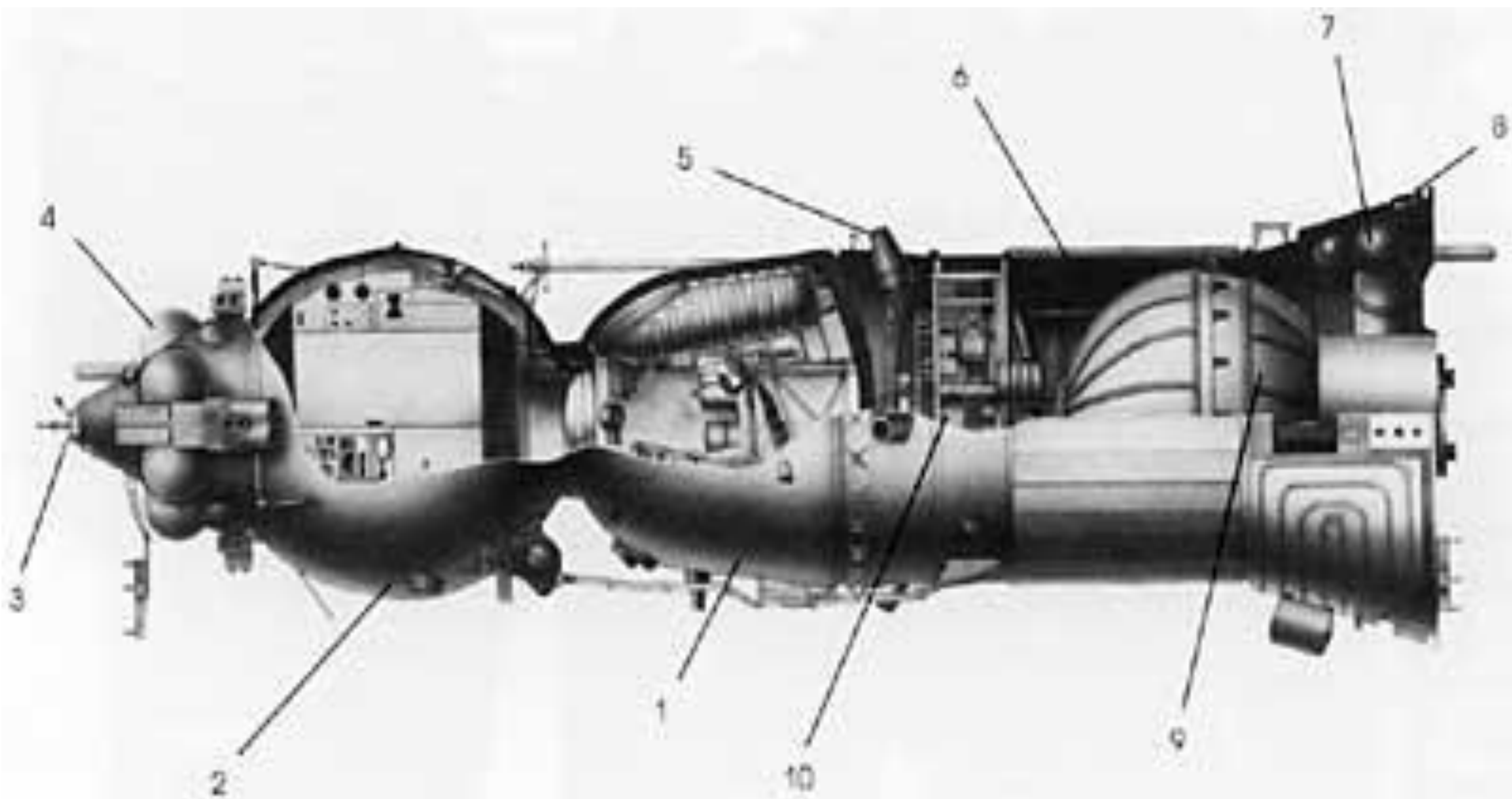
Energia launcher and Buran multiple space ship



Energia on the launching pad

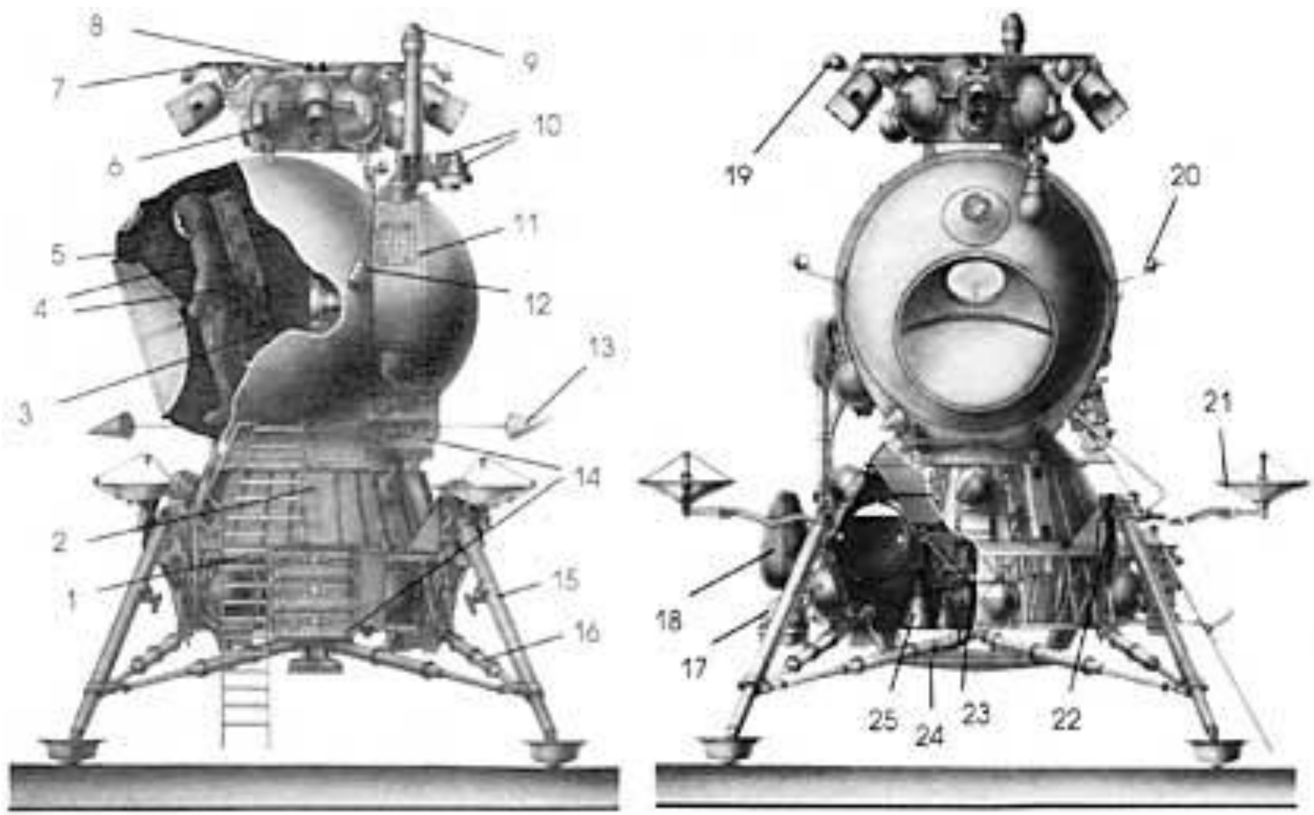
Lunar habitable module for flight on Moon satellite orbit and return to the Earth and reentry into atmosphere

It was part of Russian men flight to the Moon in framework of N1-L3 project



Lunar landing module

Module was intended for the land onto Lunar surface from Moon satellite orbit ,returning back to the orbital module and docking with it



Russian nuclear rocket engine RD-0410

It was developed in Voronez (1965 -1985) and
 tested separately from nuclear reactor.

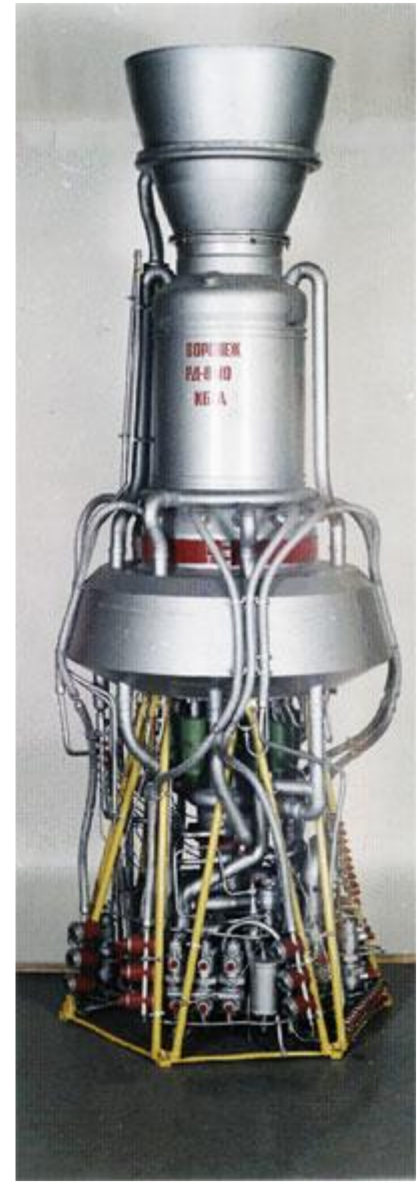
Propellent: Liquid hydrogen

Thrust 3.95t

Heat power 196 Mega Watt

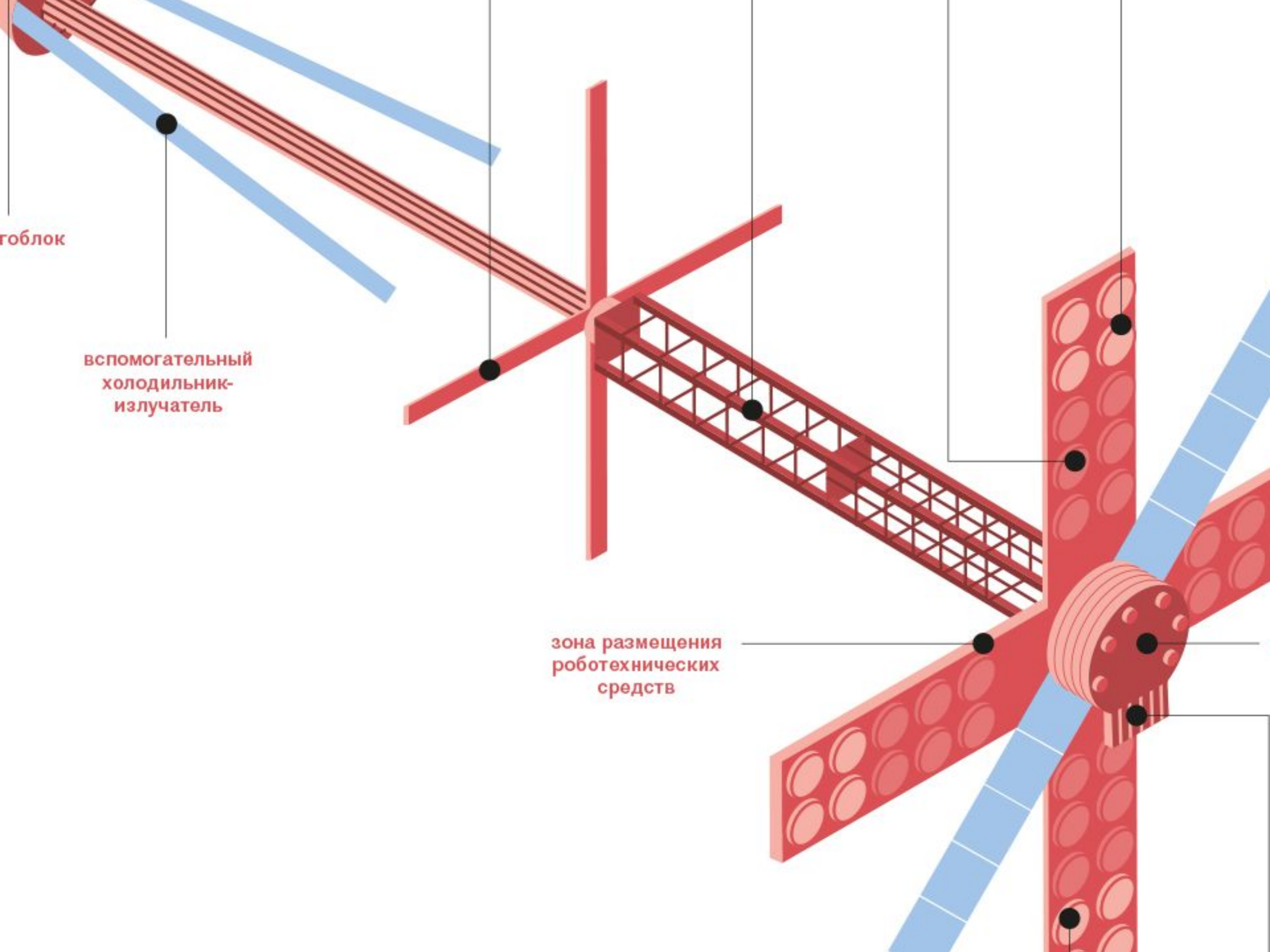
Fuel 80% concentration U235

Radiation protection shield mass 2t



Comparison characteristics of the Russian (Soviet) nuclear rocket engine (RD-0410)with American one (NERVA)

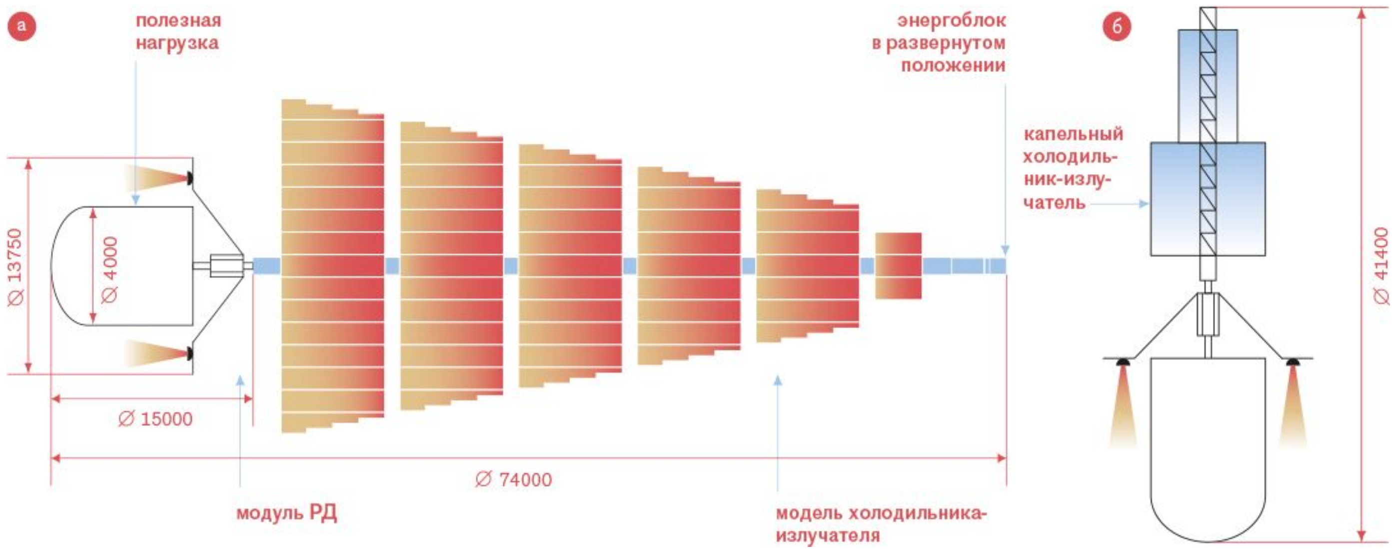
Показатель	*USSR*	*USA*
Период активных действий по тематике	*1961-1989*	*1959-1972*
Затраченные средства, млрд долларов *Money spent, $billions*	*~0,3*	*~2,0*
Количество изготовленных реакторных установок *Number of units manufactured*	*5*	*20*
Принципы отработки и создания	*поэлементный*	*интегральный*
Топливная композиция	*Твердыйраствор UC-ZrC, UC-ZrC-NbC*	*UC_2 в графитовой матрице*
Теплонапряженность активной зоны, средняя/максимальная, МВт/л *Power produced Mw/l*	*15/33*	*2,3/5,1*
Максимально достигнутая температура рабочего тела, К *Maximum temperature of propellant reached*	*3100*	*2550*
Удельный импульс тяги, с *Specific impulse s*	*940*	*850*
Ресурс работы на максимальной температуре рабочего тела, с	*4000*	*2400*



тоблок
вспомогательный холодильник-излучатель
зона размещения робототехнических средств

Scheme of contemporary nuclear energy and transportation unit

Two variants of heat dumping: by metal radiators (left) and by recuperated drops



Characteristics of energy and transportation unit

Mass kg	*20290*
Sizes in operational position m	*53.4-21x6-21x6*
Electric power Mega Watt	*1.0*
Specific impulse km/s	*Not less 70.0*
Power of electric rocket engines, Mega Watt	*not less 0,94*
Total thrust of cruise electric rocket engines, N	*not less 18.0*
Engine life, years	*10*
Launcher	*Angara-A5*

Spacecraft to resume Russian Lunar program

Luna-25 and Luna-27 are intended to explore polar regions of the Moon surface, Luna-26 is to explore Moon from the satellite orbit

Program of the Venus exploration 1961-1986

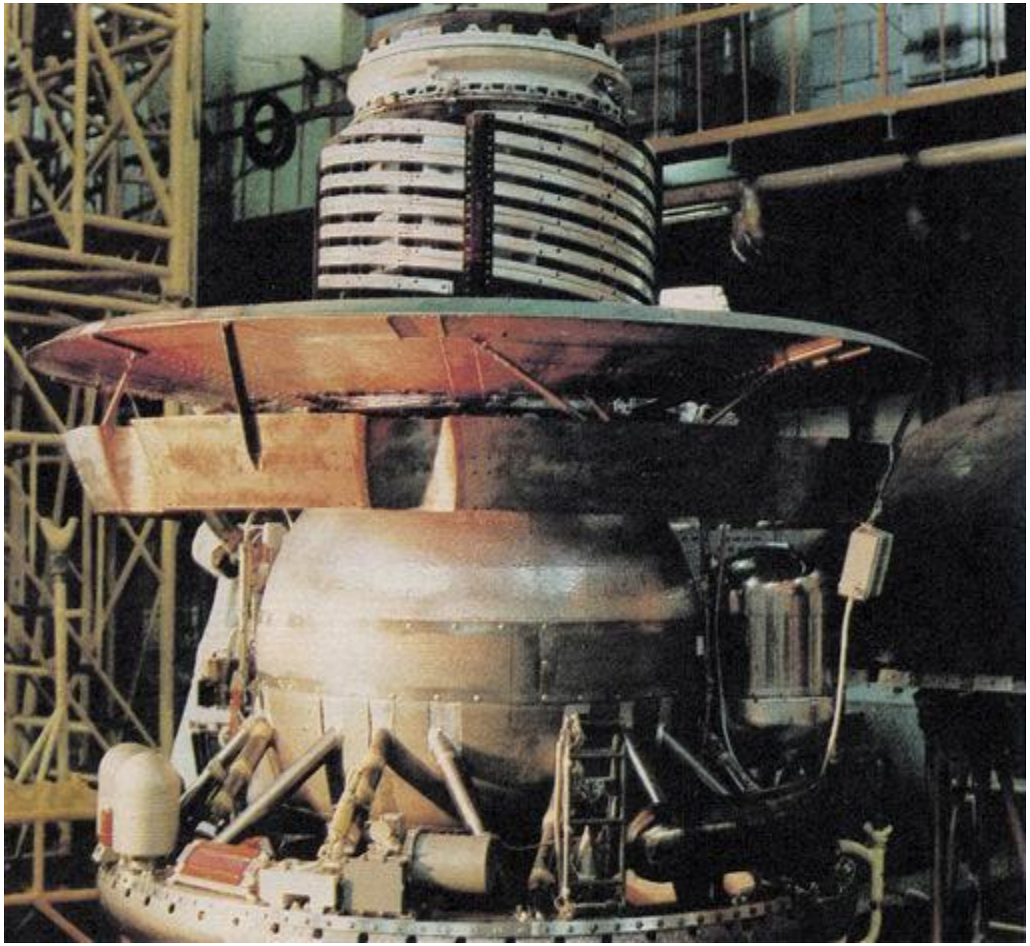
- The first spacecraft Venera-1 was launched to the closest vicinity of the Venus in 1961. It flied by Venus at the distance of 100000km.
- The first spacecraft reached surface of the Venus was Venera-3. It happened in 1966.
- First measurements in Venus atmosphere were done by Venera-4 in later in 1966. It was determined that the temperature and pressure of atmosphere of Venus near surface are several times higher than it was supposed before direct measurements. So the first spacecraft could not reach the surface because they have been destroyed in conditions of real environment. After deep modification of the landing module in order it can withstand the temperature up to 530 degrees Centigrade and 150 atmosphere pressure Venera-7 spacecraft has reached the surface of the Venus and executed the scientific measurements on the surface during 23 minutes,
- During further missions the photos of the surface were done and exploration of the Venus soil samples received by drilling. Radio mapping of Venus surface was done from the satellite orbit/
- 18 missions to Venus have been fulfilled, the last in 1986 with dropping landing modules on the way to Halley comet

VEGA spacecraft for mission to Venus and Halley comet
Group from two ones have been launched. The third one was European Giotto spacecraft

- During Venus fly by the landing modules were delivered to the surface and two balloons traveled in Venus atmosphere. Then interplanetary spacecraft reached Halley coma (March 1986)

Landing module of Venera-Halley mission (1986)

In the sphere there are the instruments which are intended to explore hostile Venus atmosphere (470 C degrees of temperature and 90 atmosphere pressure)



Space radio telescope 10 meters diameter“Radioastron” now in flight

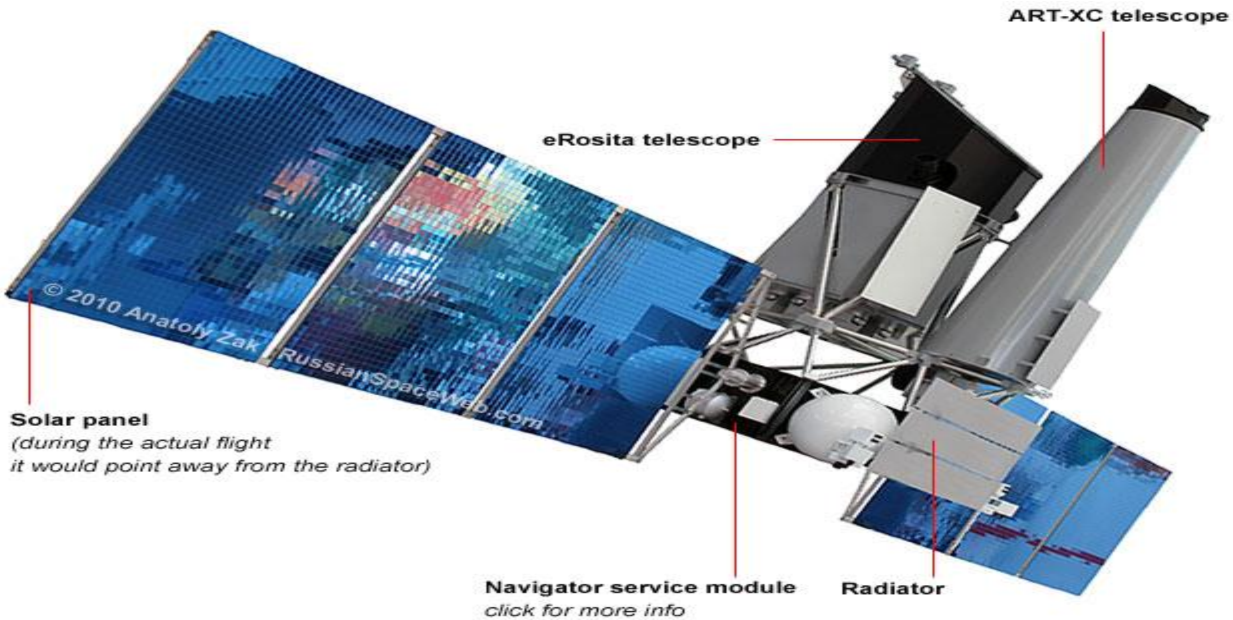
- Radioastron is intended for observations in the radio interferometer mode in pair with ground telescope

Radioastron s/c with folded antenna

Diameter of unfolded antenna is 10m
S/c is equipped by rocket engines for orbital parameters control and momentum wheels unloading.
Orbit is high elliptical with apogee reaching 350000 km height and perigee higher than 1000 km. So orbit parameters corrections are applied to avoid Close approaching to the Moon

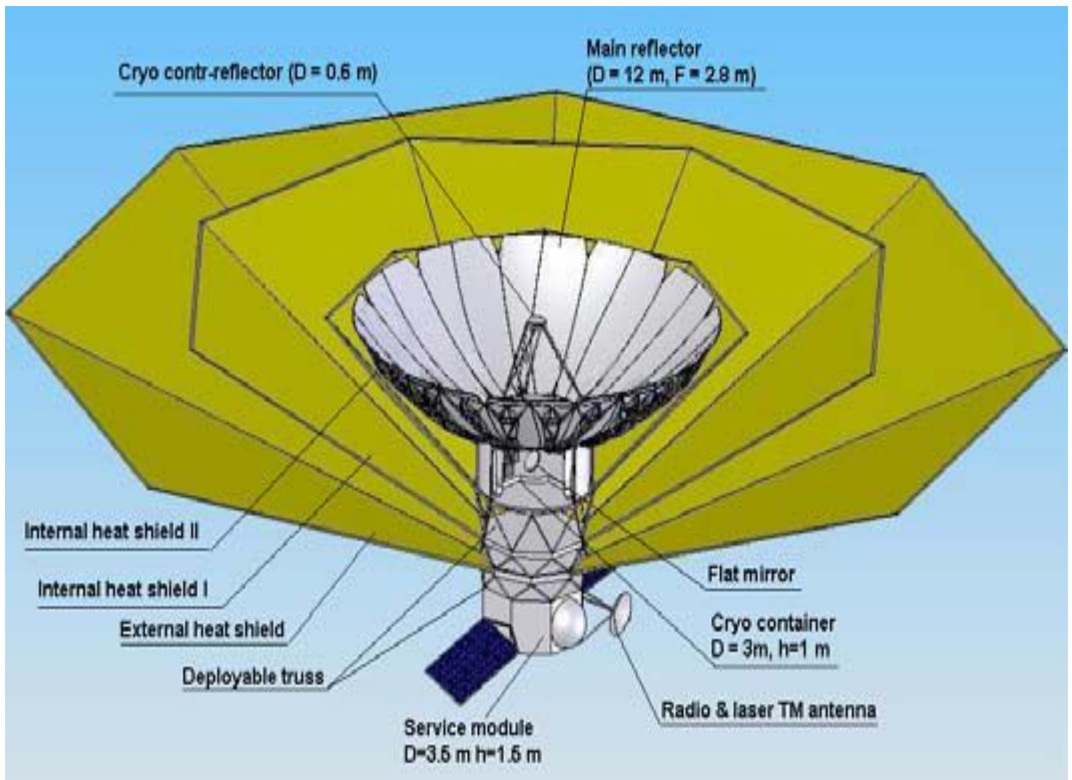
Spectrum-Roentgen-Gamma spacecraft

Two telescope are mounted onboard for systematic review of the sky in these wave bands

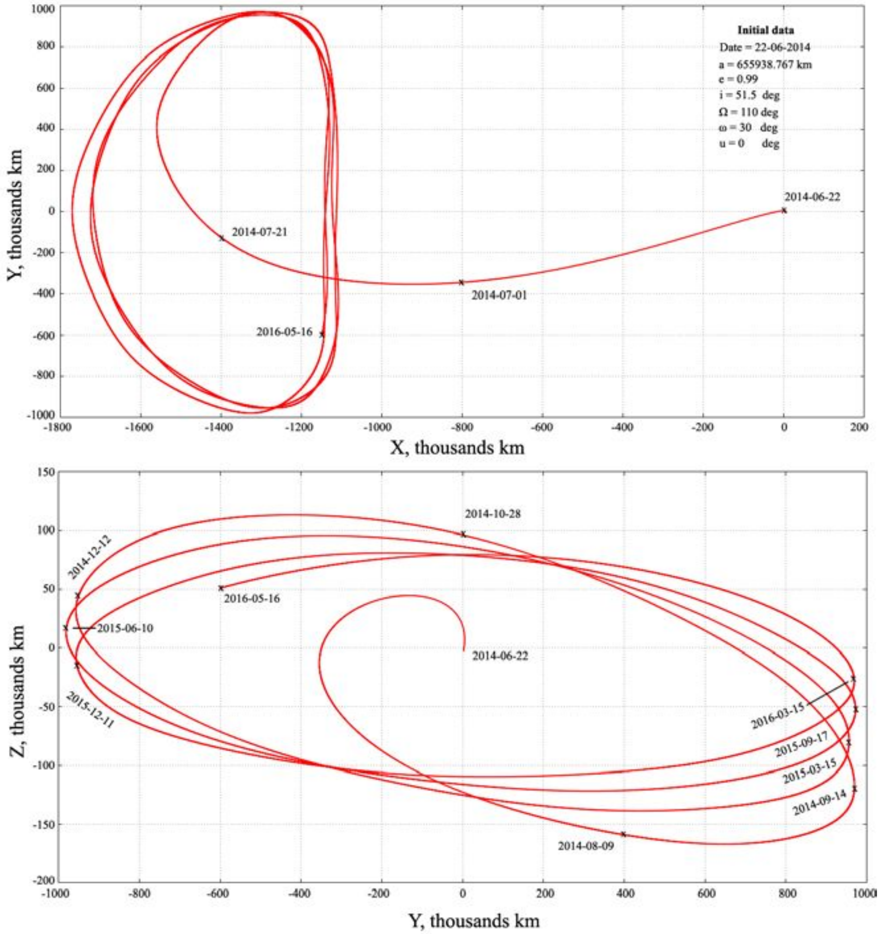


Millimitron space radio telescope

To be launched onto orbit into vicinity of Solar-terrestrial collinear libration point in mid 2020



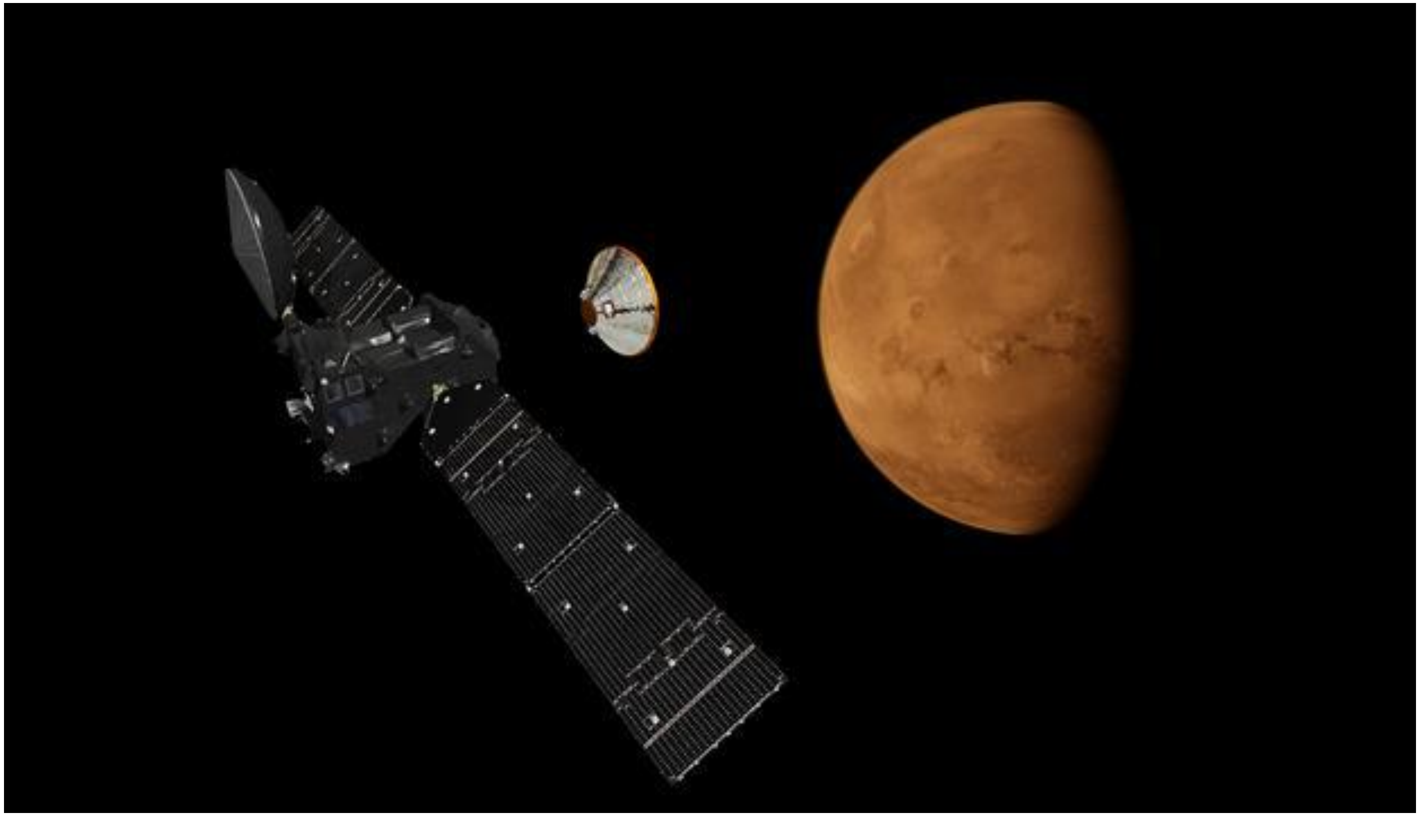
Orbit of SRG in solar-ecliptic coordinate system




АНГАРА-А5

ExoMars 2016 Trace Gas Orbiter and Descent and Entry Module

Descent Module is shown after separation two day before entry



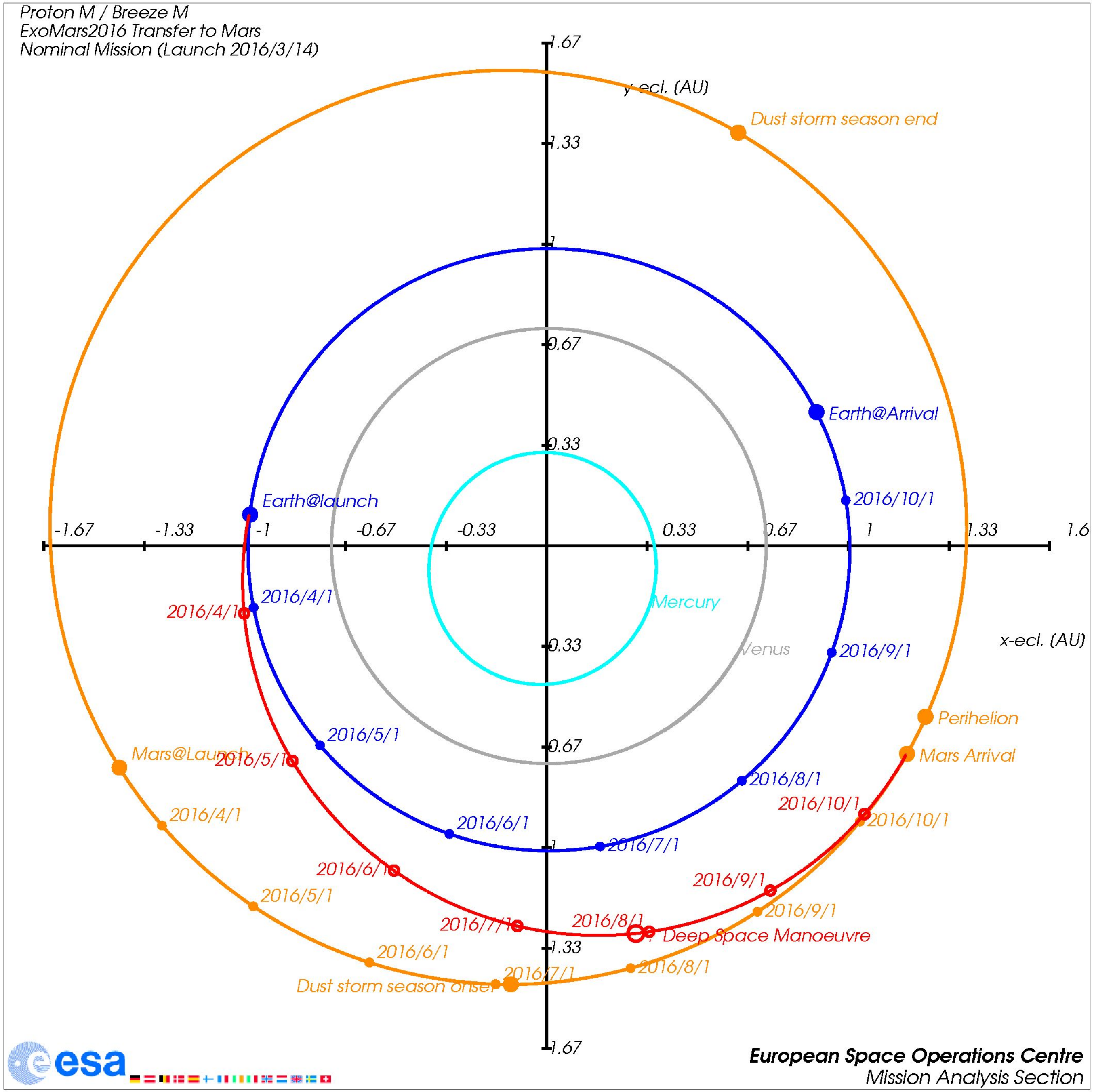
ExoMars Trace Gas Orbiter over the Mars

- New technology to transfer from high elliptical orbit to low circular one is planned to be used:
- successive aerodynamic braking in pericenter region

ExoMars 2016 spacecraft on transfer trajectory to Mars with descent and landing module

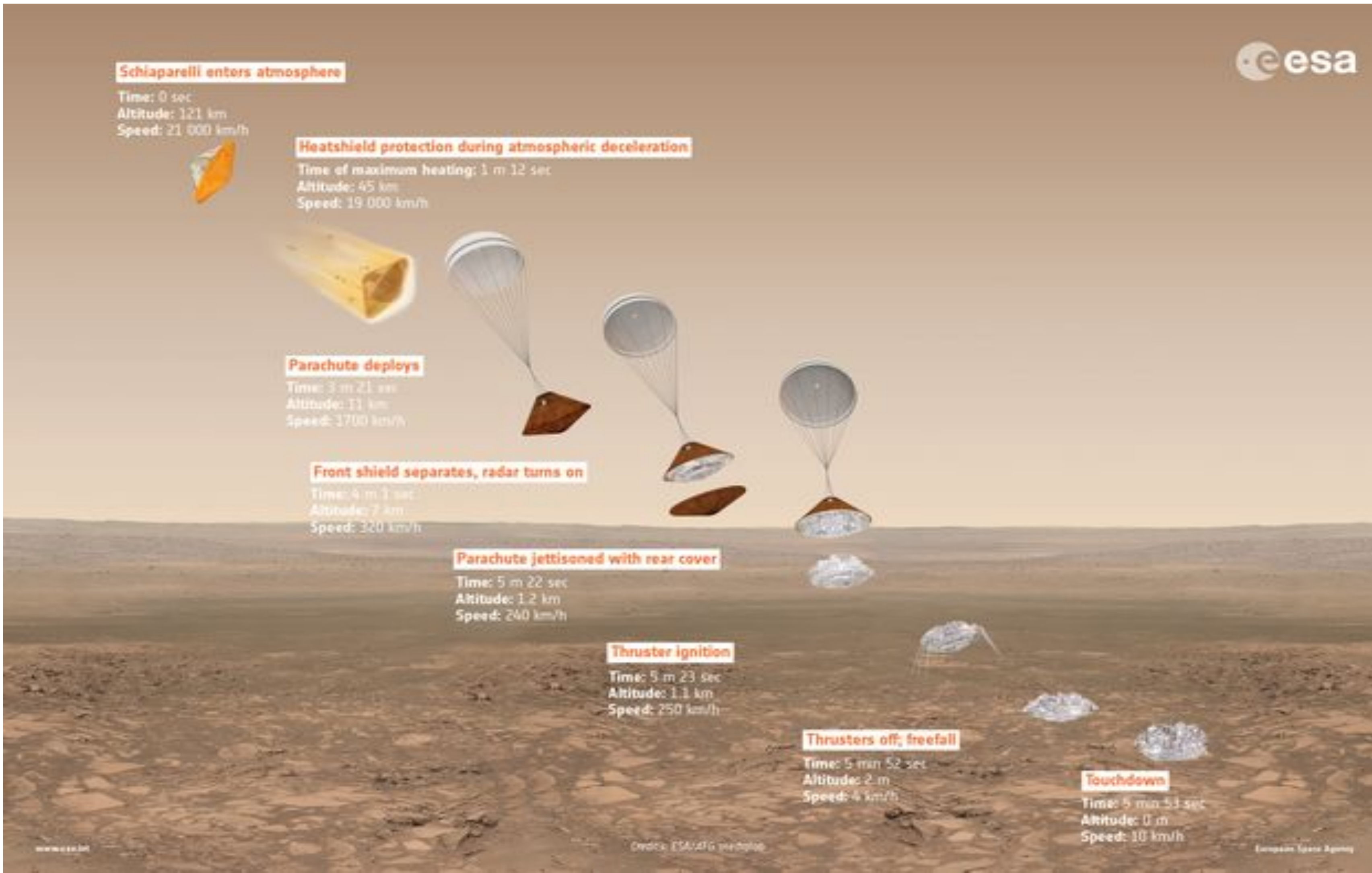
It was launched by Proton-M launcher with Breez-M upper stage on March 14 2016 and will arrive to Mars at October 19 2016.

Descent module is to be separated on October 16


Proton M / Breeze M
ExoMars2016 Transfer to Mars
Nominal Mission (Launch 2016/3/14)
y-ecl. (AU)
x-ecl. (AU)
Dust storm season end
Earth@Arrival
Earth@launch
2016/10/1
2016/4/1
Mercury
Venus
2016/9/1
Perihelion
Mars Arrival
Mars@Launch
2016/5/1
2016/8/1
2016/10/1
2016/6/1
2016/7/1
2016/9/1
2016/8/1
Deep Space Manoeuvre
Dust storm season onset
European Space Operations Centre
Mission Analysis Section

Entry and descent module of ExoMars

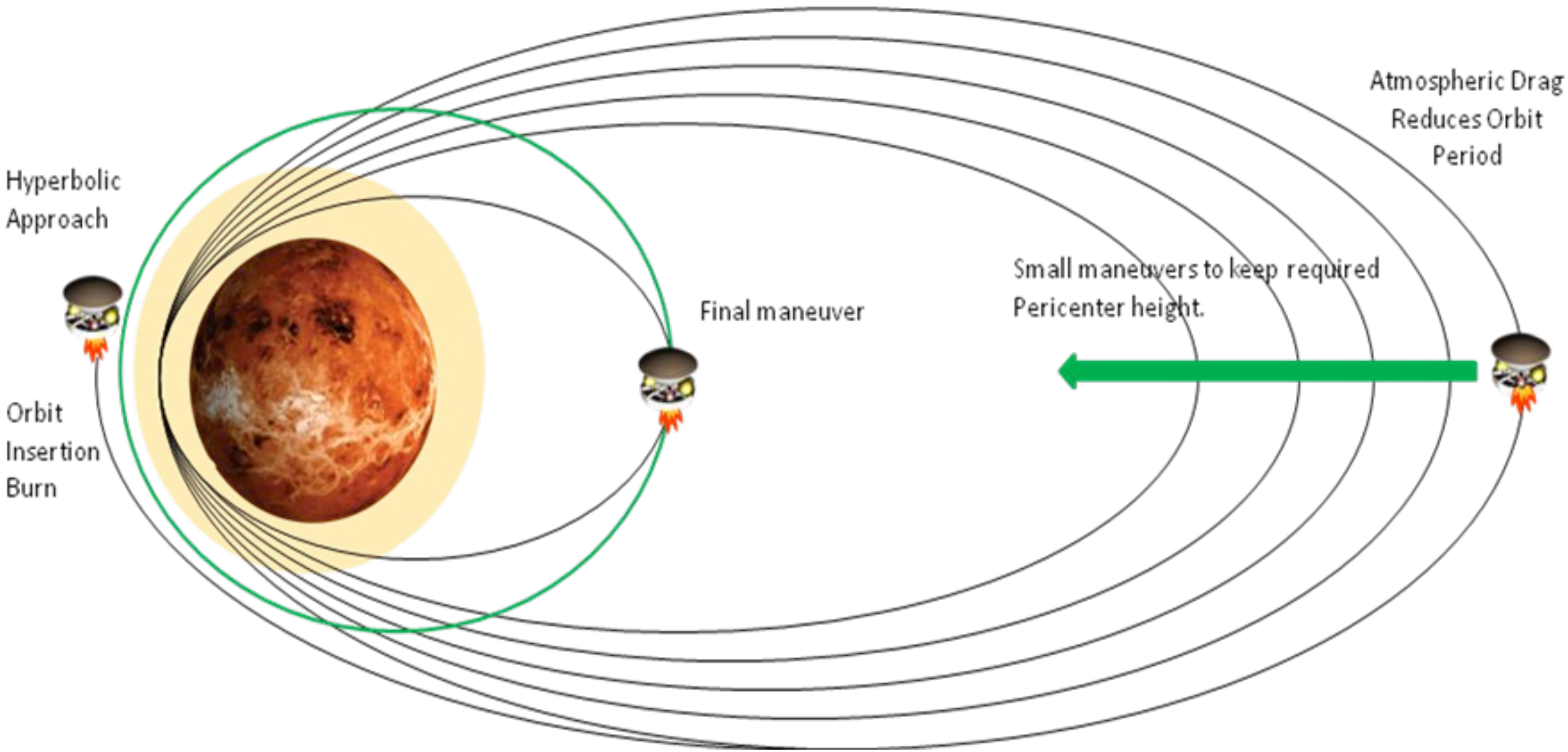
- Sequence of events during operations for reaching Mars surface



ExoMars 2016 for relay the signal from to be launched in 2020 Mars rover and surface station and for atmospehere studies

The spacecraft is to be delivered onto Mars high elliptical satellite orbit on October 2016 and then by aerodynamic drag is to be transferred onto low orbit simultaneously with this

entry and descent module will reach Mars surface by direct entry

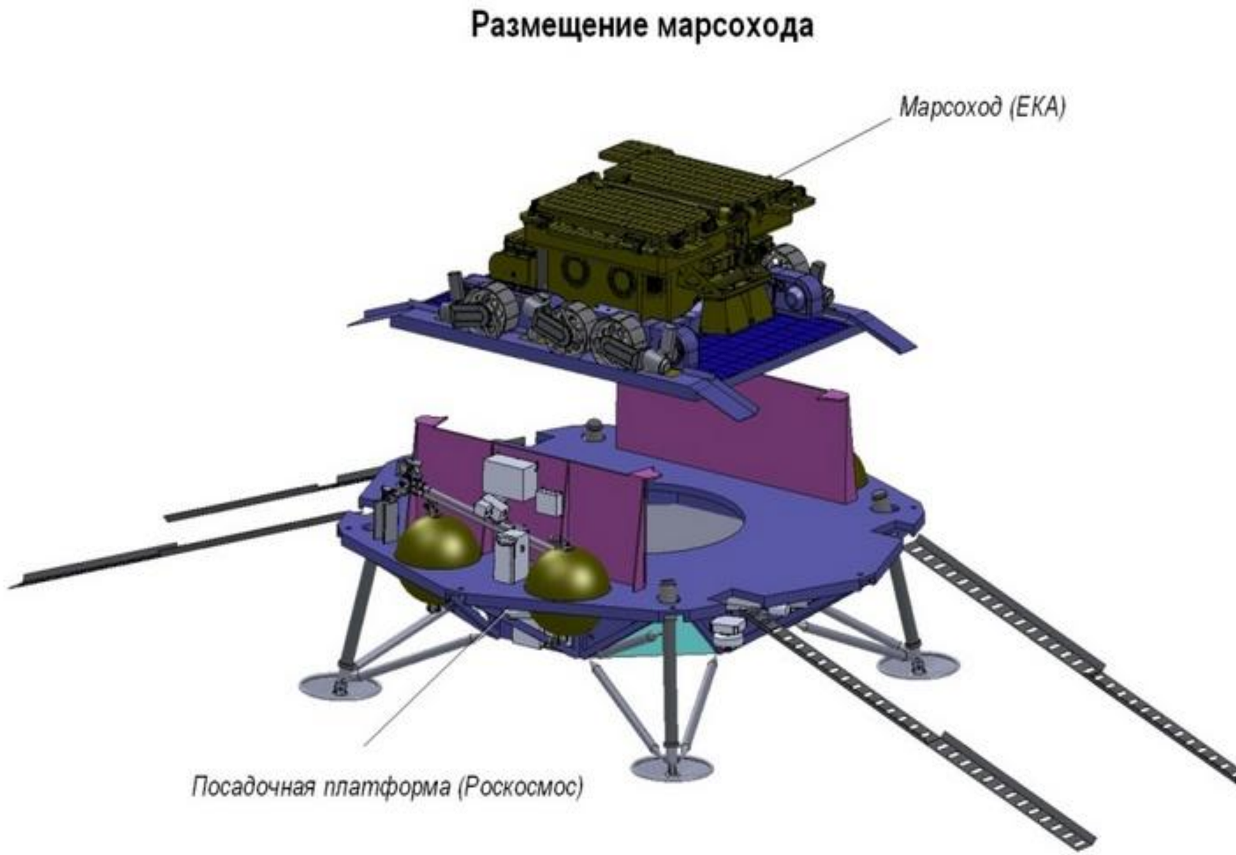


ExoMars 2020 Martian rover

Tests in lab

ExoMars 2020 Landing platform and Rover

After landing the Rover will leave platform for autonomous voyage on Mars surface with radio link supported ExoMars 2016 orbiter

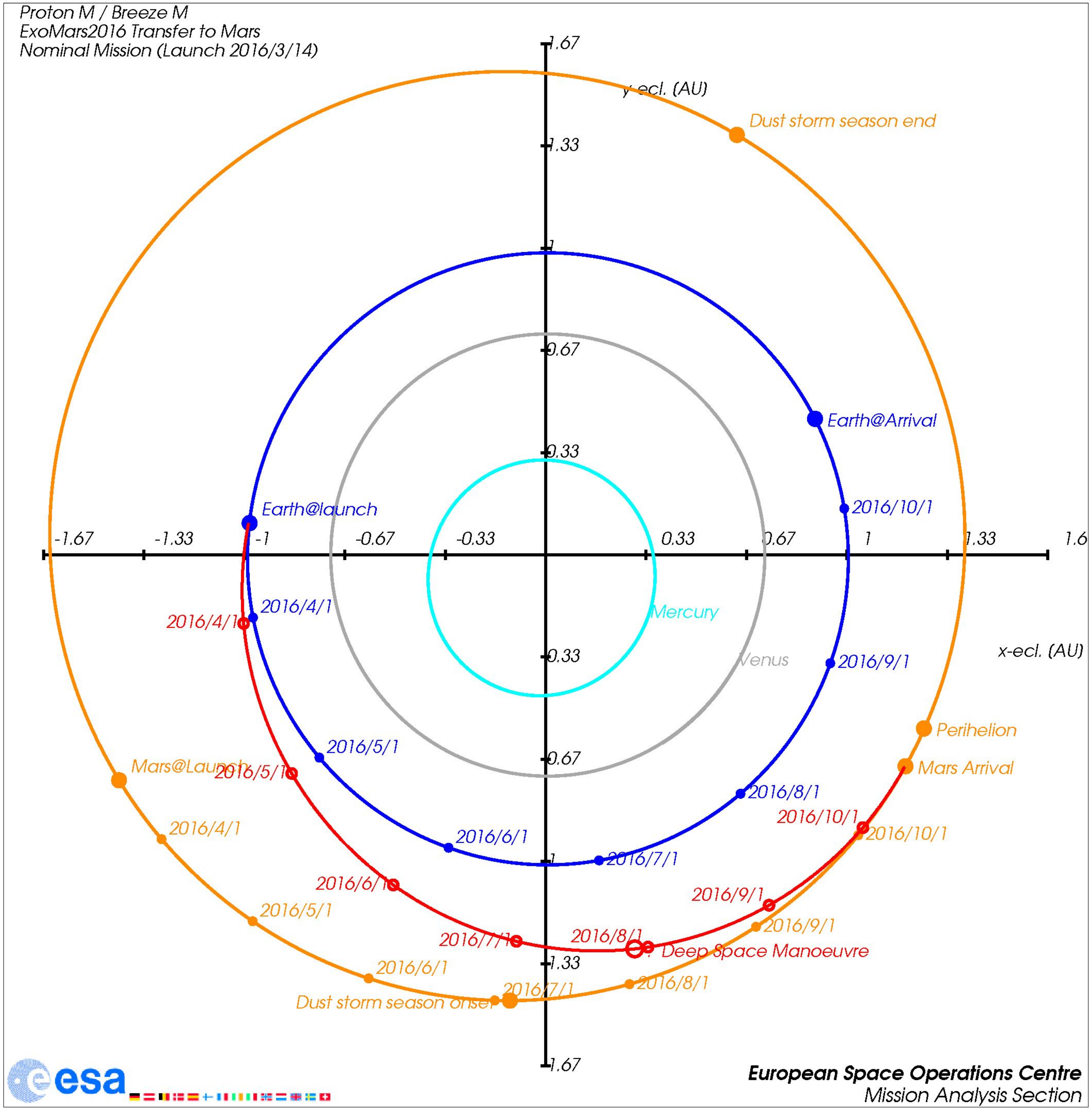


ExoMars transfer trajectory

Start March 14

Arrival to Mars

October 19



Mars region for piloted mission landing

23.1 East longitude, 39.1 North latitude