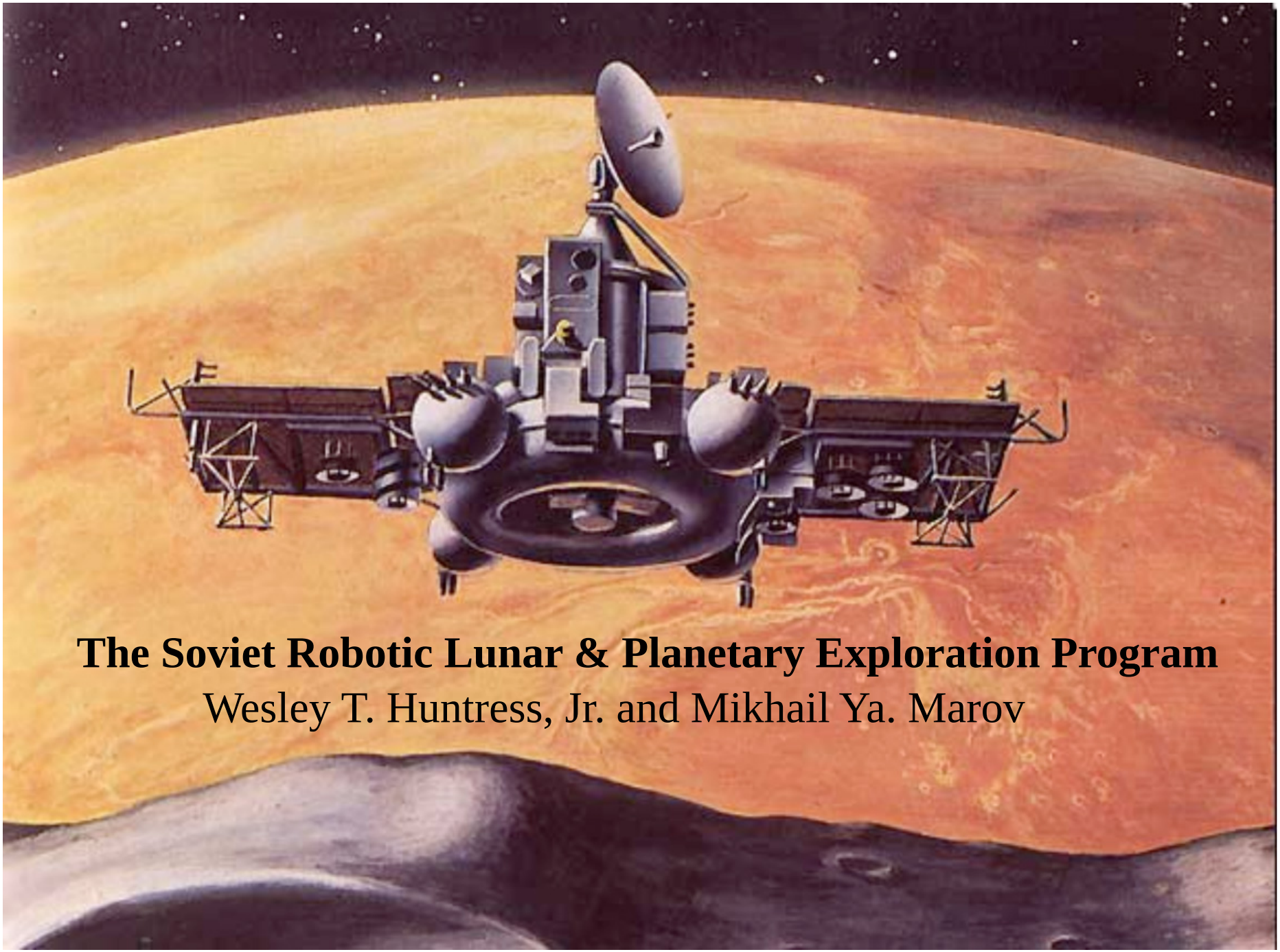
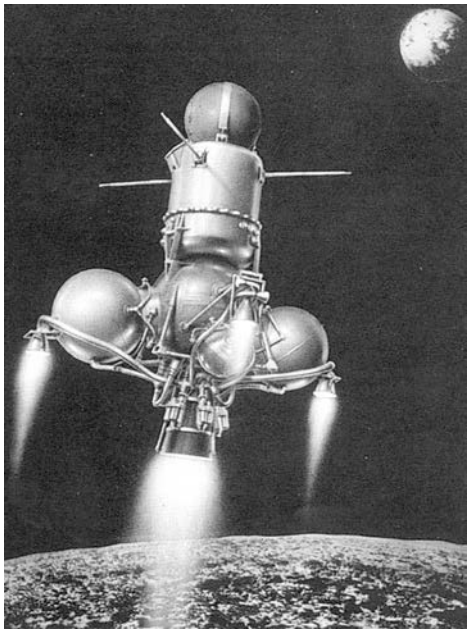


The Soviet Robotic Lunar & Planetary Exploration Program

Wesley T. Huntress, Jr. and Mikhail Ya. Marov

The Soviet Robotic Lunar & Planetary Exploration Program

Born as part of the Cold War and nearly died with it
Provided a sinister and mysterious stimulus to American efforts
Most events virtually unknown outside the closed circle of Soviet secrecy

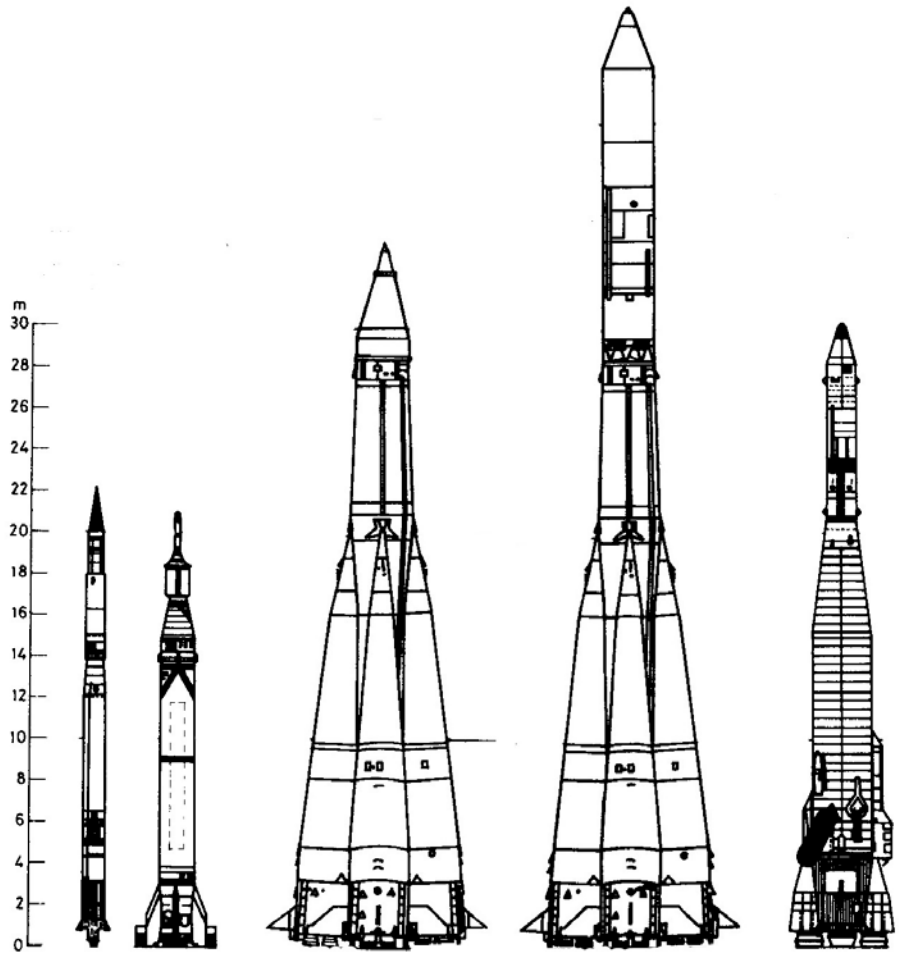


A tale of adventure, excitement, suspense and tragedy
A tale of courage and patience to overcome obstacles and failure
A tale of fantastic accomplishment, and debilitating loss

Sergei Korolev

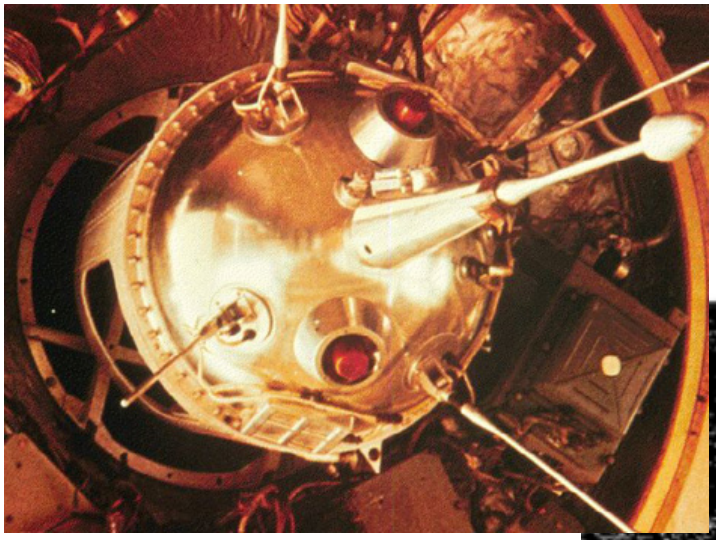
Mstislav Keldsh

1960 - Early Soviet and American Exploration Rockets

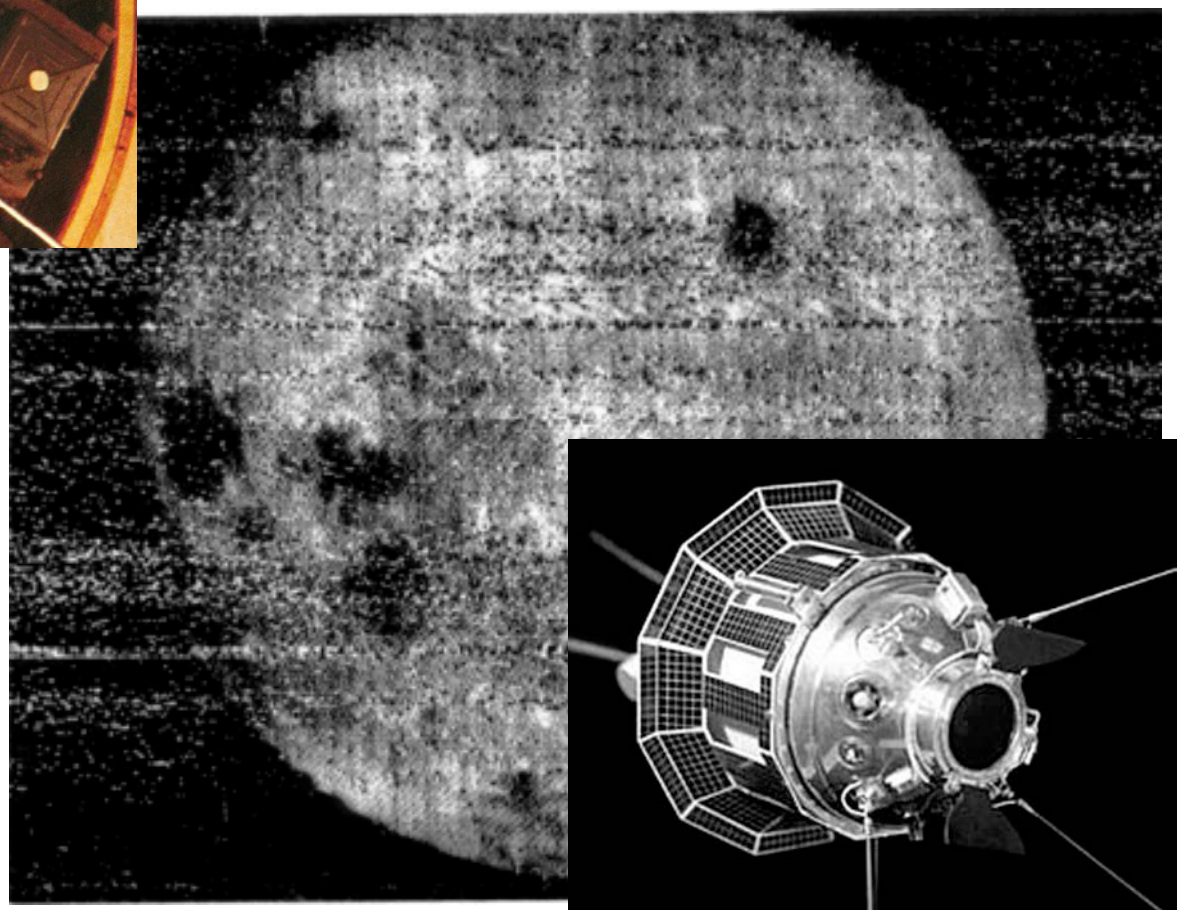


Vanguard Jupiter-C Luna Molniya Atlas-Agena

1958 - 1959 The Age of Robotic Lunar Exploration Opens



1958 - 3 failed impactor launches
1959 - 1 failed impactor launches
- 3 successful (Lunas 1, 2, 3)
1960 - 2 failed circumlunar launches



Luna 1 January 2, 1959
1st s/c to leave Earth
missed lunar impact
1st lunar flyby Jan 4, 1959

Luna 2 1st lunar impactor
Sept 14, 1959

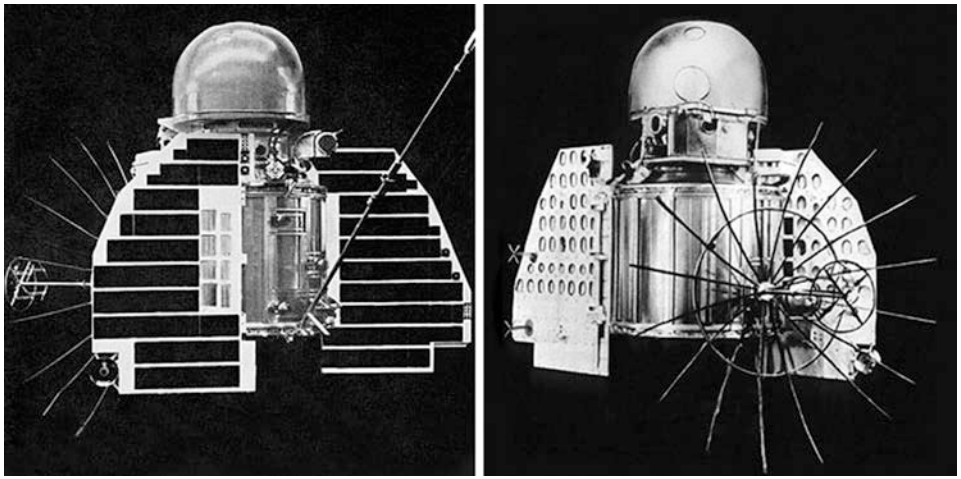
Luna 3 circumlunar flyby
1st farside picture
Oct 7, 1959

1960 - 1961 The Age of Robotic Planetary Exploration Opens

The first launches to Mars and Venus

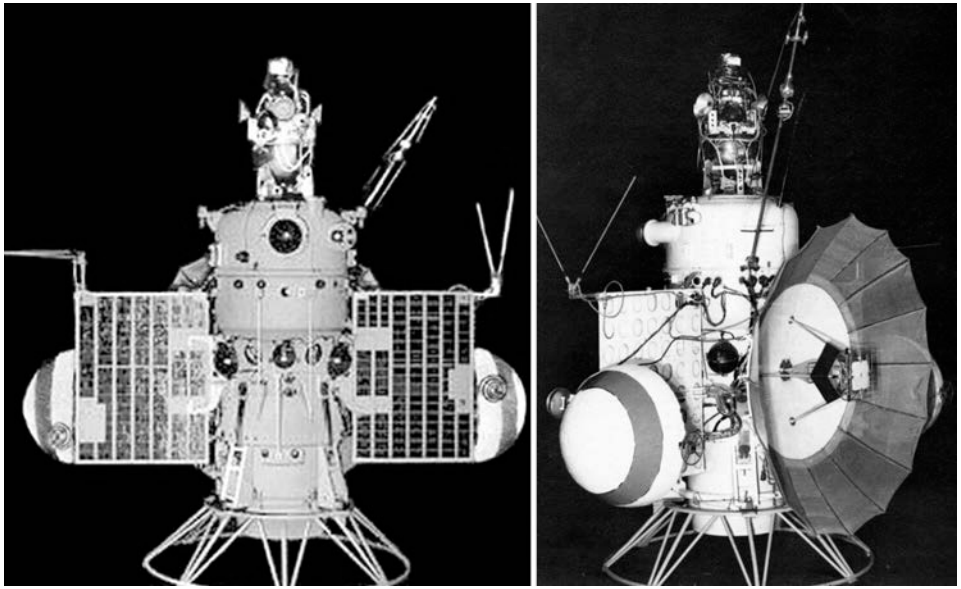
October 10 & 14 1960
2 Mars flyby launch failures
Maiden flight of the Molniya

February 1961
2 Venus impactor launches
1 success on Feb 12, 1961,
but **Venera 1** fails 5 days later



1962 The New 2MV Planetary Spacecraft

Modular design for both Venus & Mars and for both flyby and probe missions



Mars 1 Flyby Spacecraft

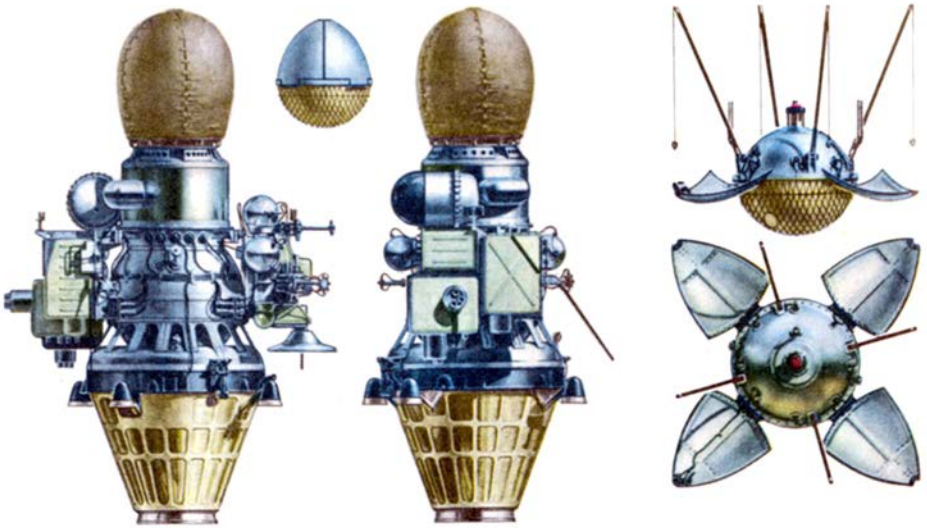
Five of six victimized by the launch vehicle
- 2 Venus probes, 1 Venus flyby
- 1 Mars probe (US attack scare), 1 Mars flyby

Mars 1 flyby vehicle successfully launched
- ACS problems, fails after 5 months
- while the US Mariner 2 succeeds at Venus

Mars 1 launched Nov 21, 1962
Lost inflight March 21, 1963

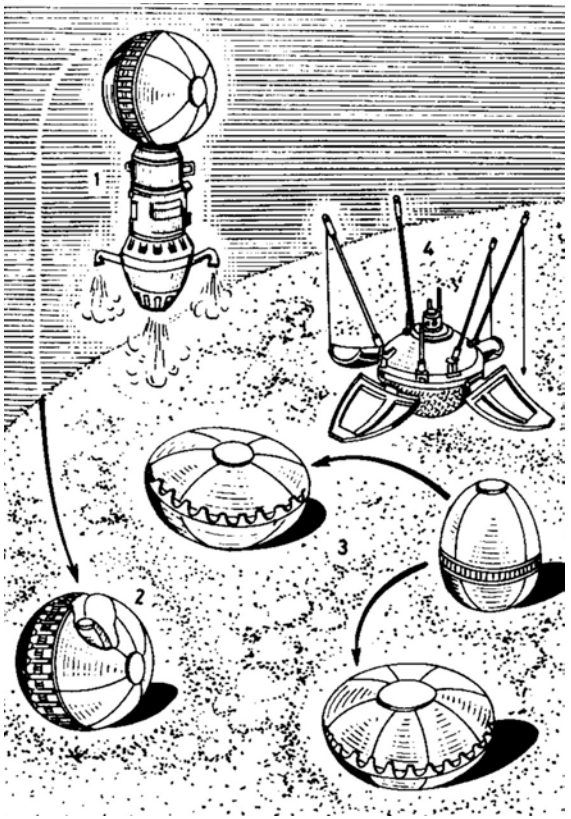
1963 - 1965 Three More Years of Frustration

A new 1500 kg spacecraft for lunar soft landing
transport module plus landing capsule



Eleven failed missions in 1963 – 1965!

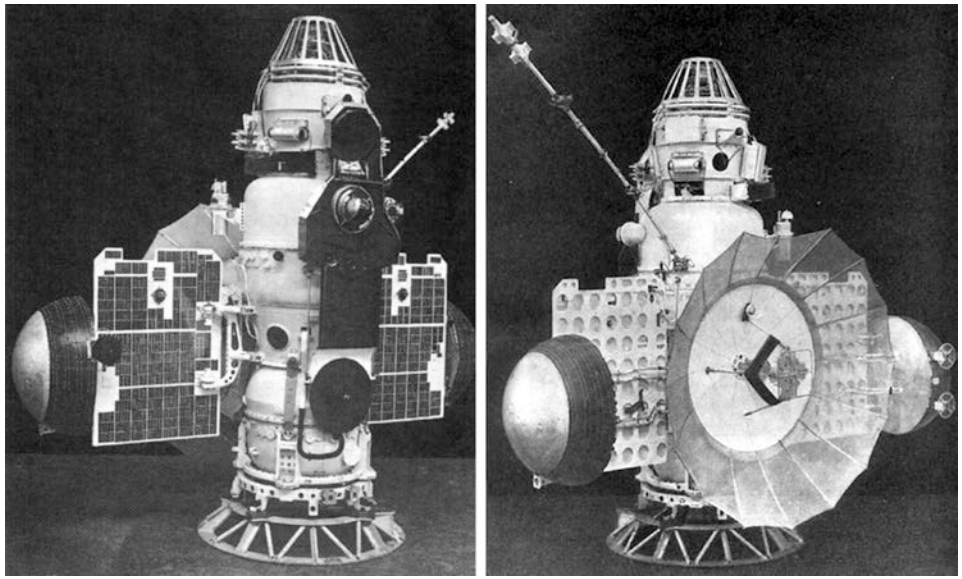
Six due to launch vehicle failures
Luna 4 - navigation failed, missed the Moon
Luna 5 – guidance failed, crashed
Luna 6 – mid-course failed, missed the Moon
Luna 7 – attitude control & retro failed, crashed
Luna 8 – air bag puncture & retro failed, crashed

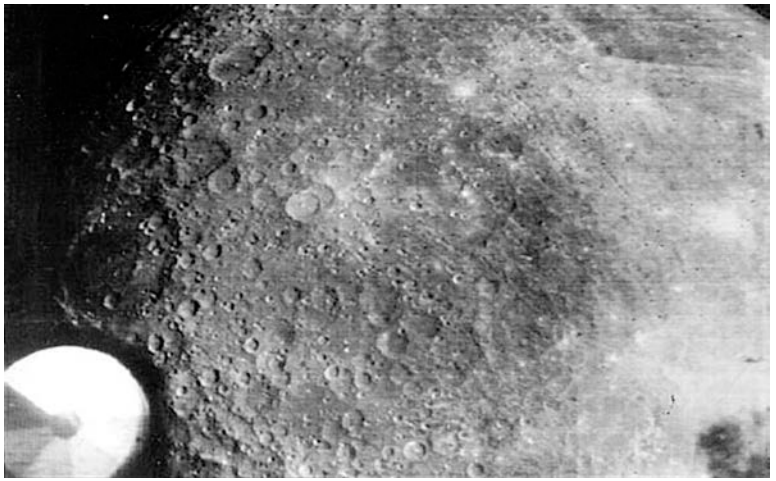


Air-bag landing scheme

1963 - 1965 Three More Years of Frustration

Back to Mars and Venus with a new planetary spacecraft - the 3MV



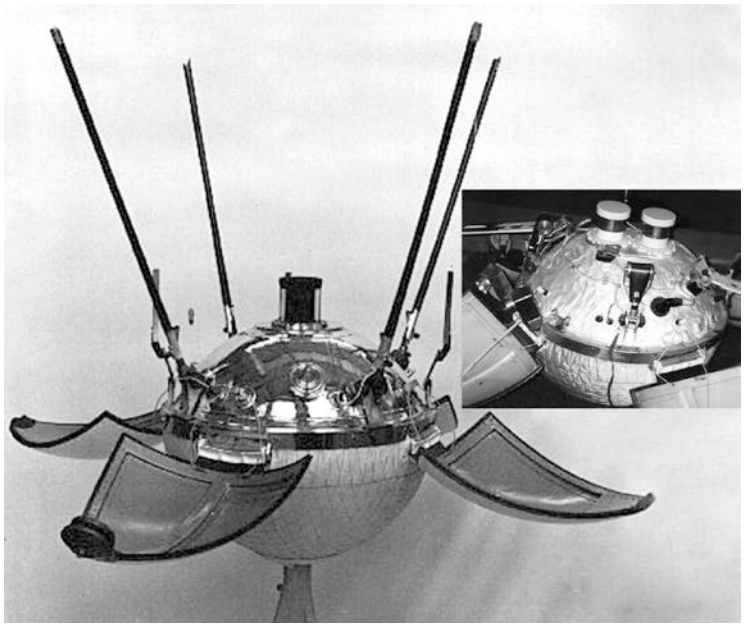


Zond 3 Mars s/c & lunar farside picture

Nov 11, 1963 – Test flight launch to Mars distance fails
Feb 19, 1964 – Test flight launch to Venus distance fails
Mar 27, 1964 – Venus probe launch fails
April 2, 1964 – **Zond 1** Venus probe, lost May 25, 1964 due to slow leak
Nov 30, 1964 – **Zond 2** Mars flyby, lost May 5, 1965 after multiple problems
July 18, 1965 – **Zond 3** Mars test succeeds at the Moon, survives for 8 mo., 150M km
Nov 12, 1965 – **Venera 2** Venus flyby, thermal problems, failed to return flyby data
Nov 16, 1965 – **Venera 3** Venus probe, thermal problems, lost 17 days before arrival
Nov 23, 1965 – Venera flyby launch fails

1966 - 1969 Success at the Moon and Venus, but Mars eludes

Luna 9 *- The first lunar soft lander, Feb 3, 1966*



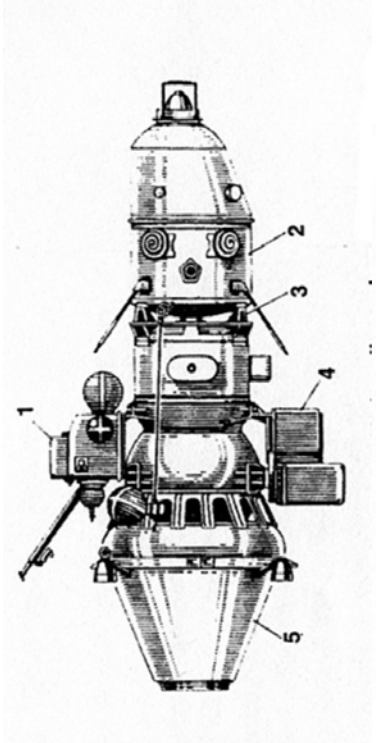
Luna 13 *– Dec 24, 1966*

1966 - 1969 Success at the Moon and Venus, but Mars eludes

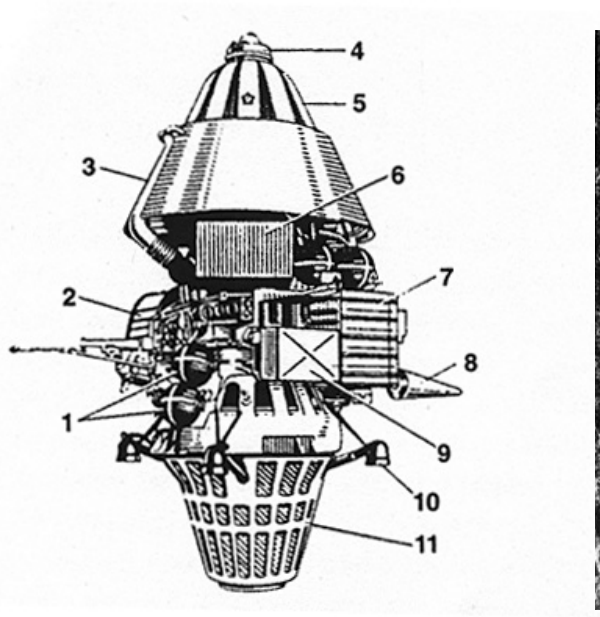
First Soviet Lunar Orbiters - 1966

Rushed together from Luna 9/13 vehicle
Replaced lander module with orbiter module
4 of 7 succeed March 1966 – April 1968
Luna 10 1st lunar orbiter – April 3, 1966

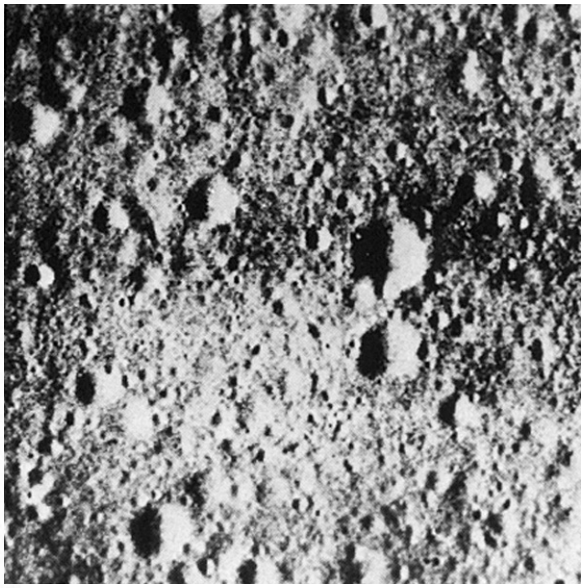
Lunar gravity mapping – mascons!
Radiation and magnetic field mapping
Cosmonaut landing site imagery
Technology tests for piloted program



Luna 10



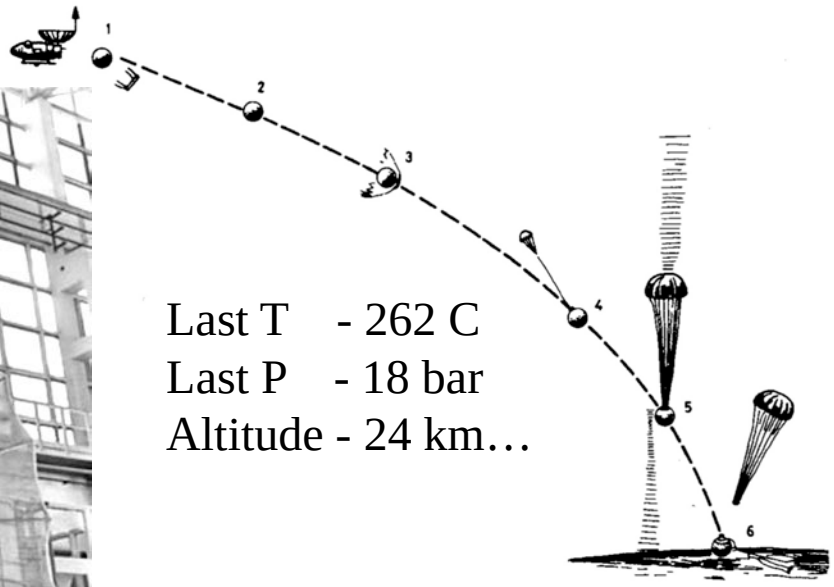
Luna 11, 12, 14



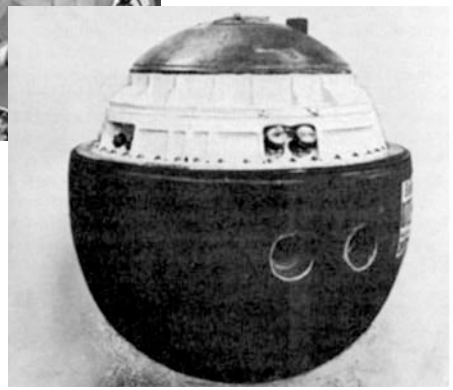
Luna 12 Image

1966 - 1969 Success at the Moon and Venus, but Mars eludes

Venera 4 *- Inside the Venusian Atmosphere Oct 18, 1967*



Last T - 262 C
Last P - 18 bar
Altitude - 24 km…

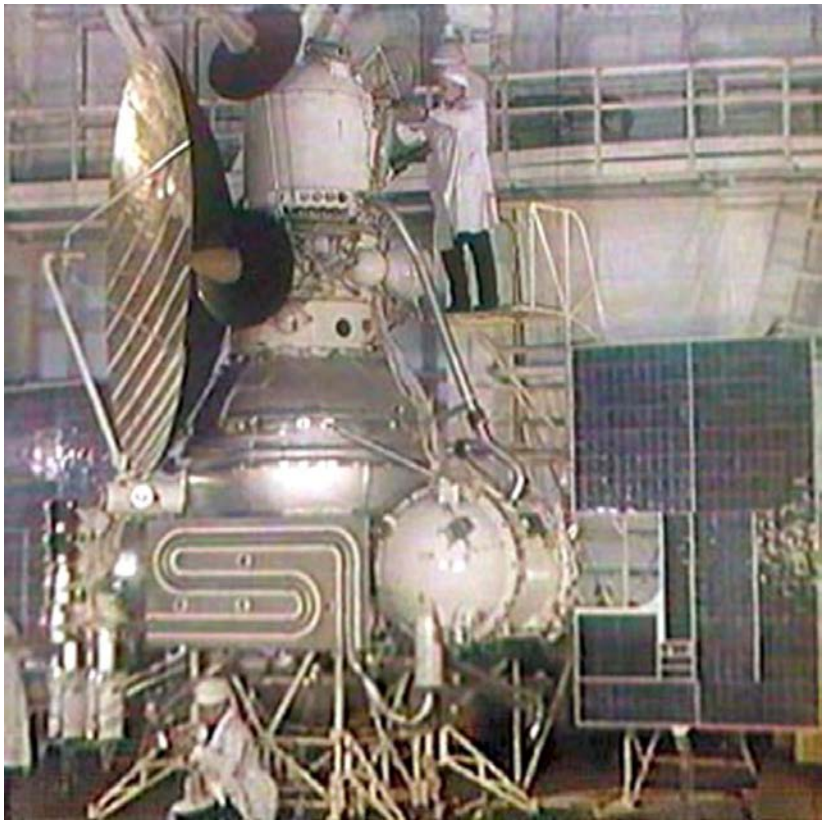


CO2	>90%	Derived @ surface:
N2	< 2.5%	442 C
O2	0.4-1.6%	90 bar
H2O	0.05-0.70 %	

Venera 5 and 6 *follow up in May 1969 – both cease at 27 bar, 18 km*

1966 - 1969 Success at the Moon and Venus, but Mars eludes

A bold new program for Mars goes bust



Mars 69 under test at Lavochkin
Final launch mass 4850 kg

New & demanding goal - soft landing
Comprehensive science objectives defined
1969 campaign to get atm & ephemeris data
Upstage Mariner 69 flybys and 71 orbiters

New heavy design for Proton launch
3yr new development challenge
Diverted by rush to succeed at Venus in ‘67
Lunar spacecraft based design fails
13 month for redesign…
3574 kg Orbiter with 280 kg Probe
Probe to be deployed from orbit
Probe deleted late: mass & test problems
Replaced with orbital module

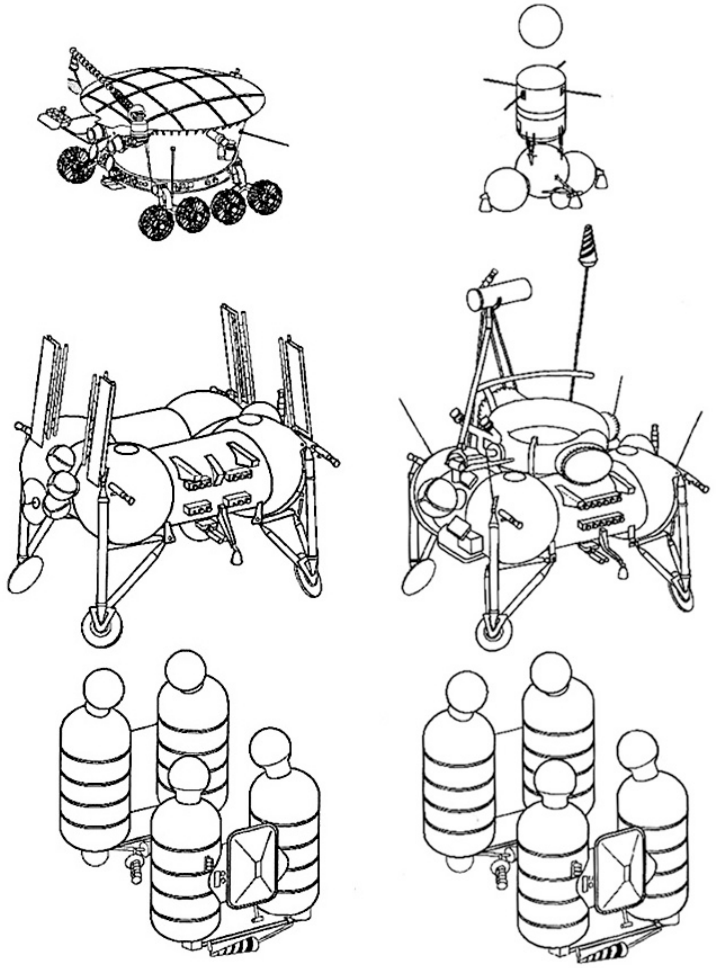
Both Protons exploded
Third stage on March 27, 1969
Booster on April 2, 1969
Missions virtually unknown in West…

1969 - 1976 Robotic Achievements in the Shadow of Apollo

New 5800kg Robotic Lunar Rovers and Sample Return Spacecraft

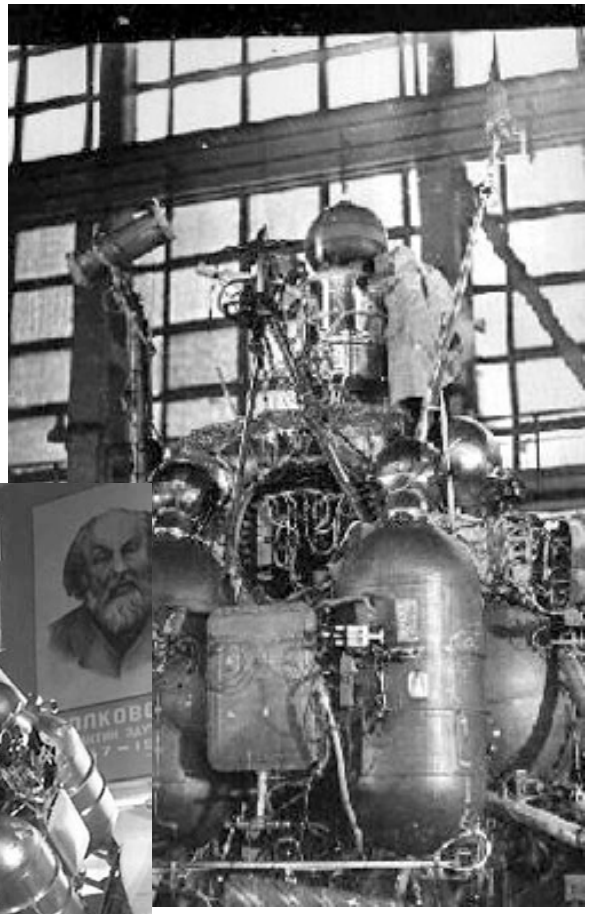
Rover

Sample Return



Used new Proton-K launcher

Luna 16



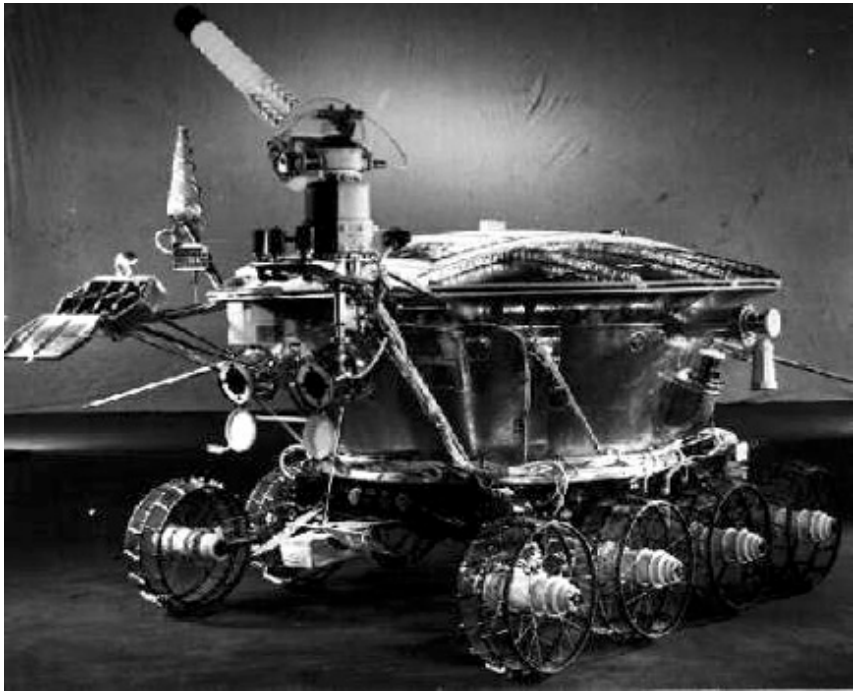
Luna 17

1969 - 1976 Robotic Achievements in the Shadow of Apollo

Robotic Lunar Rovers and Sample Return

Rover Launch History

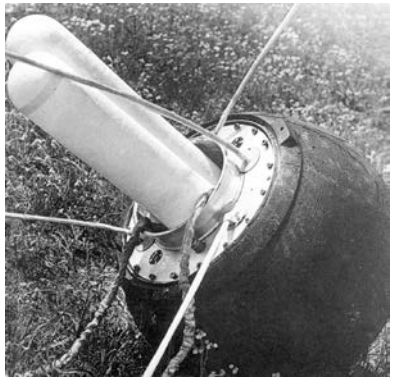
1969, Feb 19 Launch failure
1970, Nov 10 **Luna 17**/Lunokhod 1
1973, Jan 8 **Luna 21**/Lunokhod 2



First Robotic Lunar Rover - Lunokhod 1

Sample Return Launch History

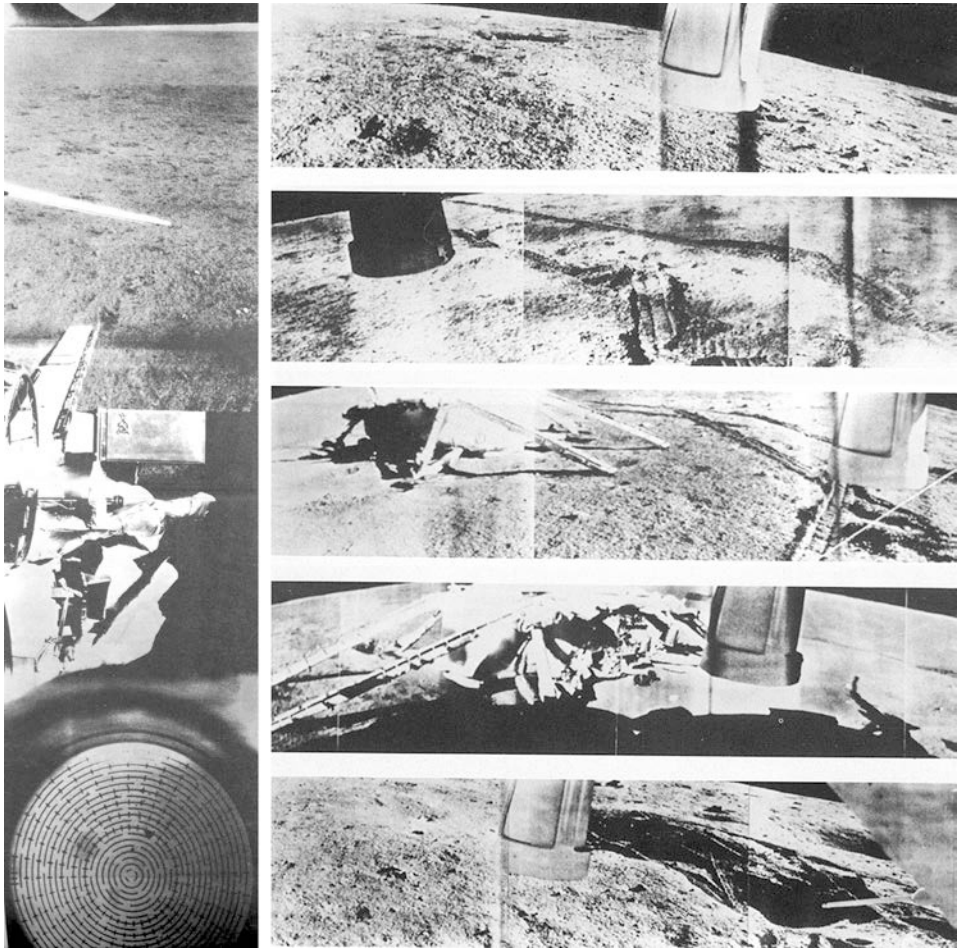
1969, Jun 14 Launch failure
1969, Jul 13 **Luna 15**, crashed
1969, Sep 23 Launch failure
1969, Oct 22 Launch failure
1969, Feb 6 Launch failure
1970, Sep 12 **Luna 16**, success
1971, Sep 2 **Luna 18**, failed at landing
1972, Feb 14 **Luna 20**, success
1974 Nov 2 **Luna 23**, damaged on landing
1975, Oct 16 Launch failure
1976, Aug 9 **Luna 24**, success



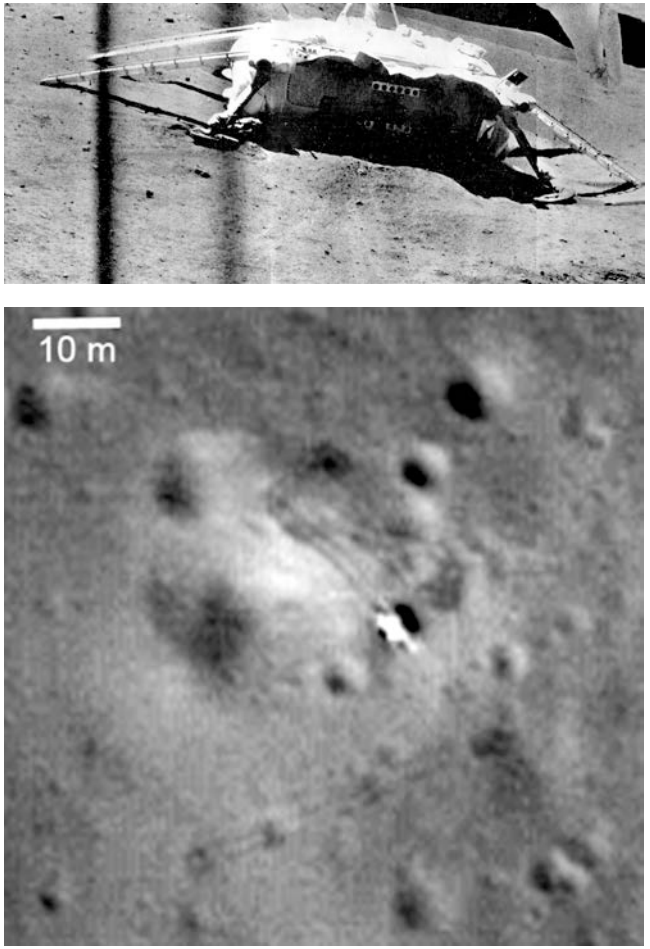
First Lunar Sample Return – Luna 16

1969 - 1976 Robotic Achievements in the Shadow of Apollo

Robotic Lunar Rovers and Sample Return



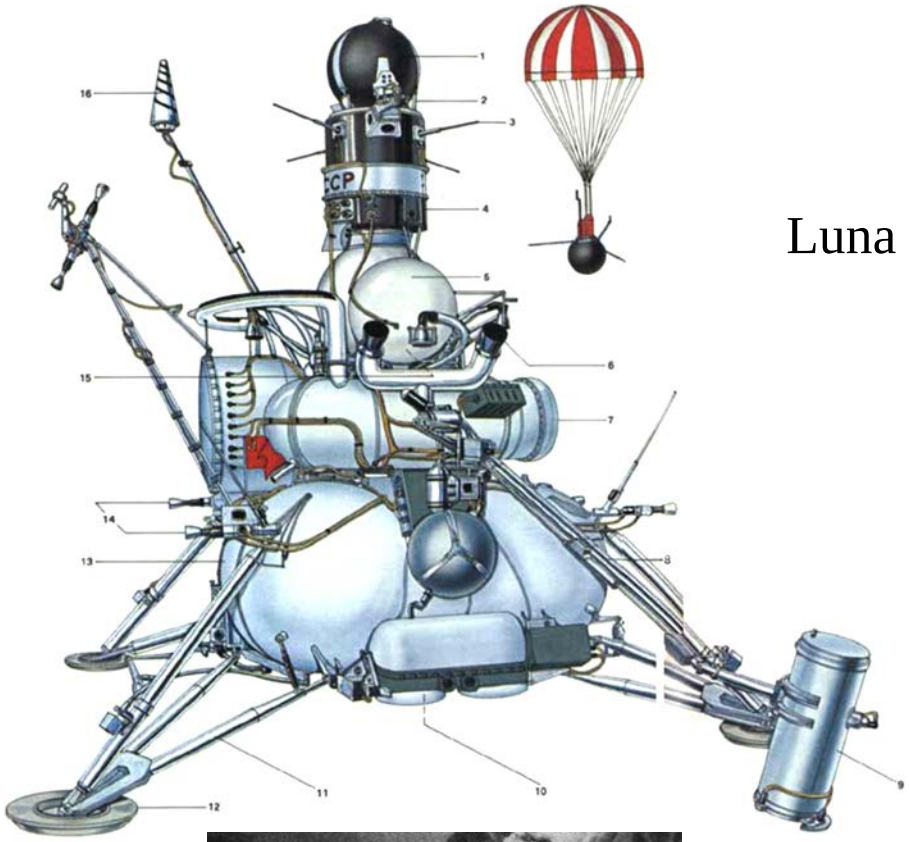
Lunokhod 1 Panoramas



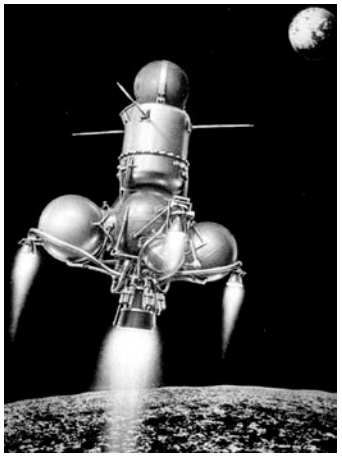
Lunokhod 2 lander

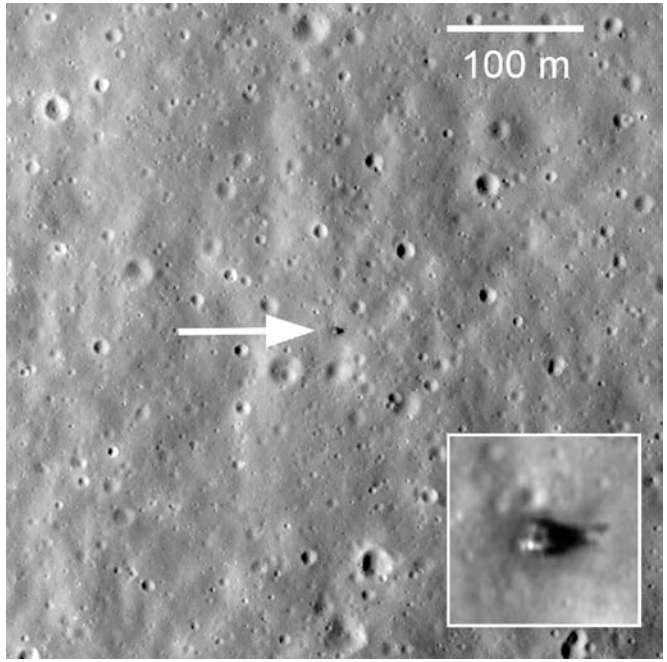
1969 - 1976 Robotic Achievements in the Shadow of Apollo

Robotic Lunar Rovers and Sample Return



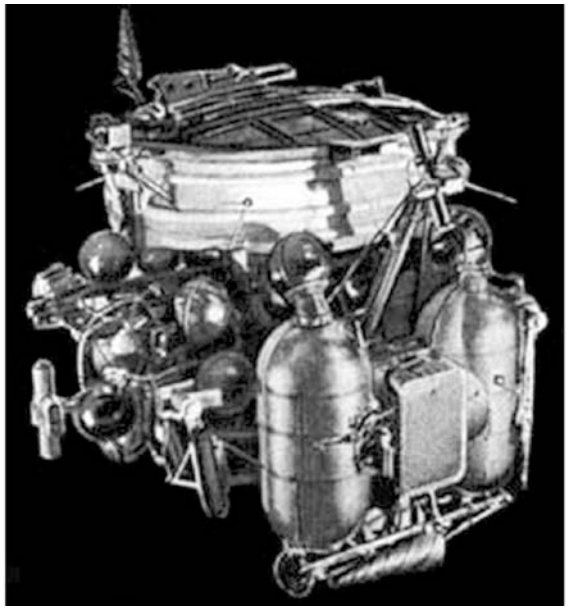
Luna 16





1969 - 1976 Robotic Achievements in the Shadow of Apollo

__Luna 19__ (1971) & __22__ (1974) Orbiters



Obtain data for human landing site selection

Surface imaging at high resolution – 100m x 400m
Altimetry measurements of lunar topography
Remote surface composition and dielectric properties
Accurate mapping of lunar gravity field
Radiation, plasma, micrometeorites in lunar orbit

1970 - 1972 Landing on Venus and Mars

First landing on Venus Dec 15, 1970, Venera 7

Venera 7 s/c

Venera 7 capsule

1970

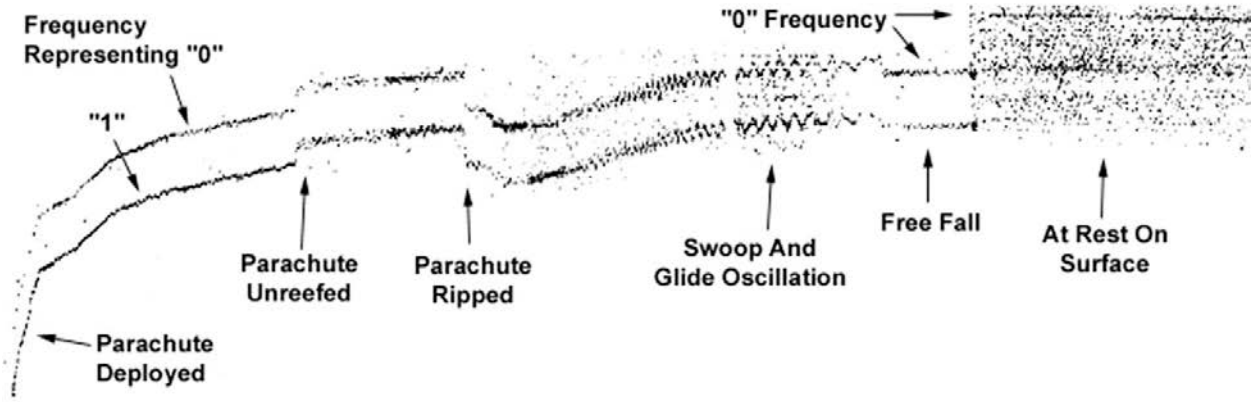
Venera 7 launch Aug 17, 1970
2nd launch fails Aug 22, 1970

Venera 7 lands Dec 15, 1970

1972

Venera 8 launch Mar 27, 1972
2nd launch fails Mar 31, 1972

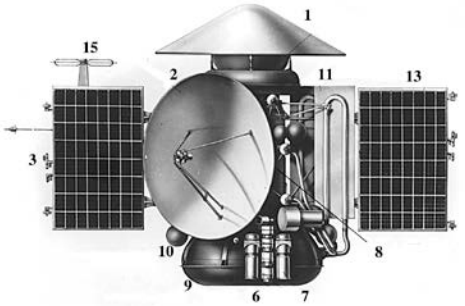
Venera 8 lands Jul 22, 1972

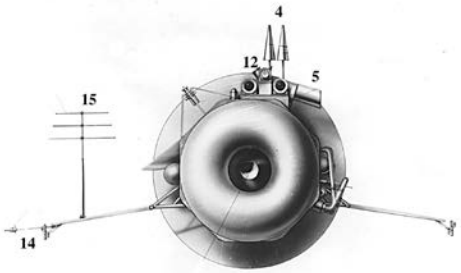


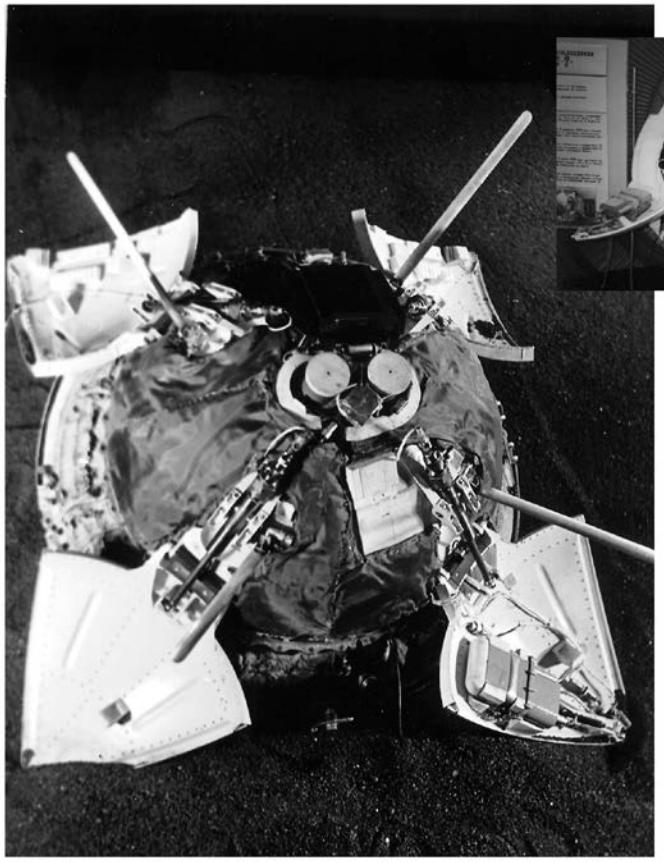
1970 - 1972 Landing on Venus and Mars

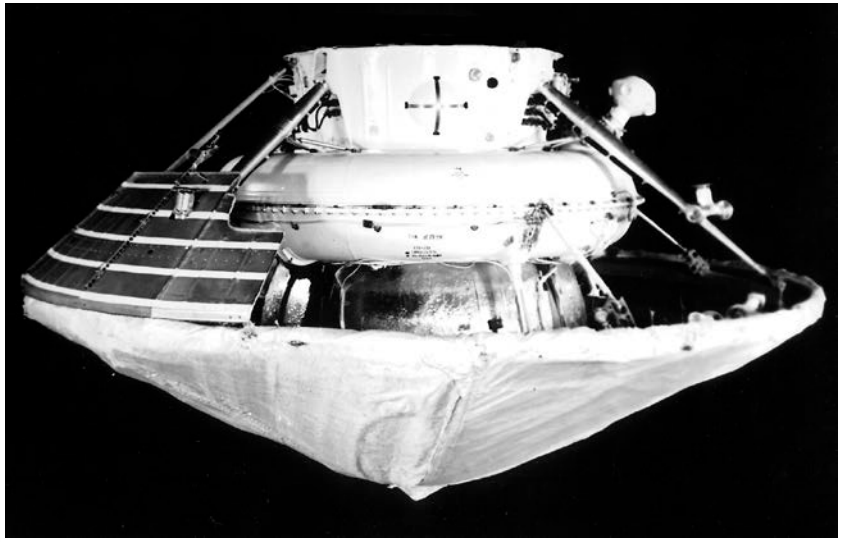
Three spacecraft for Mars landings in 1971

New 5-ton spacecraft design for Proton launch
US refuses to provide Mars ephemeris
Fast ‘pathfinder’ orbiter launch fails
Mars 2,3 orbiter/landers use auto optical nav





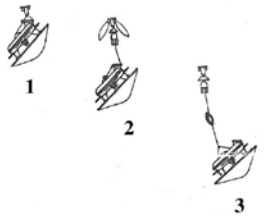


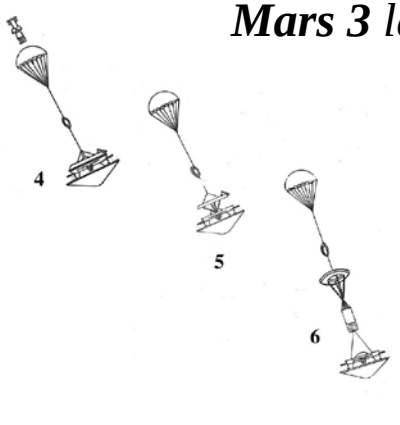


First landing on Mars Dec 2, 1971, Mars 3

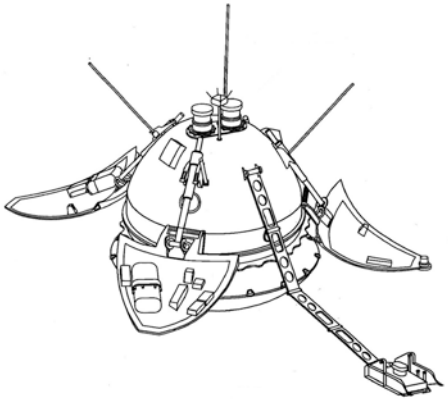
Mars 2 *crashed*

Mars 3 *lander fails 2 min after landing*

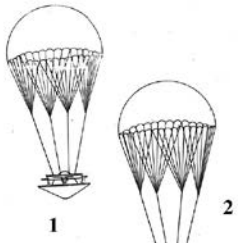


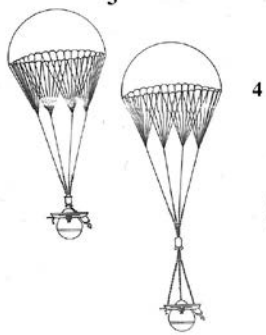


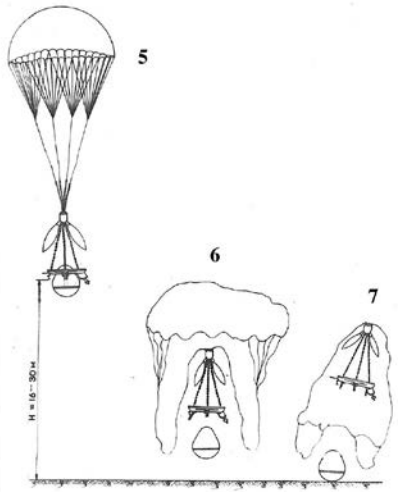
Descent Sequence



Lander Deployed





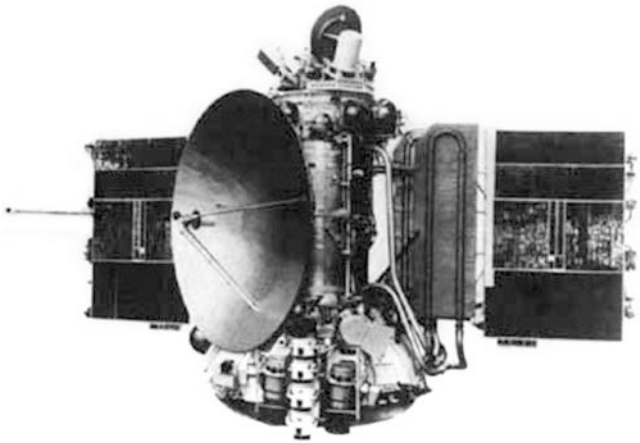


Entry System Deployment

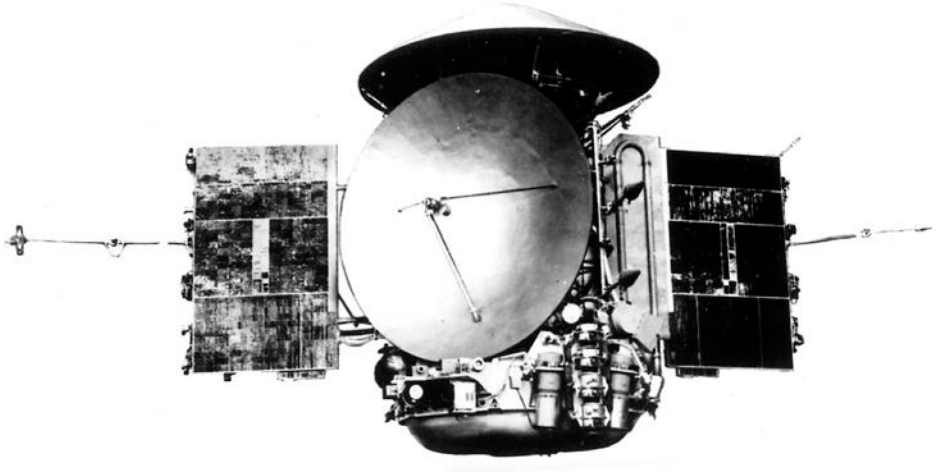
1973 - 1974 The Doomed Mars Fleet

Four spacecraft launched in 1973

Recover 1971 failures, beat Viking to the surface
Could not combine orbiters and landers in 1973
Launched two orbiters and two flyby/landers
Virtual copies of the Mars 71 spacecraft
Except for a crucial substitution of a transistor
All spacecraft plagued with onboard failures



Mars 4,5

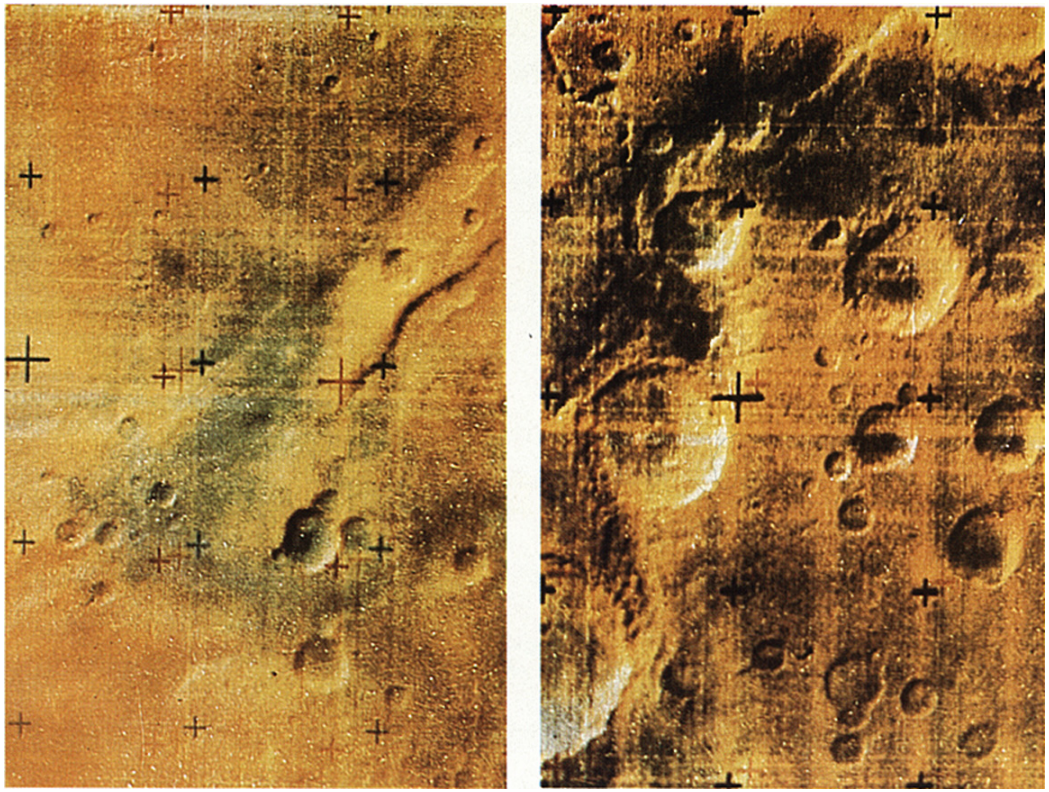


Mars 6,7

1973 - 1974 The Doomed Mars Fleet

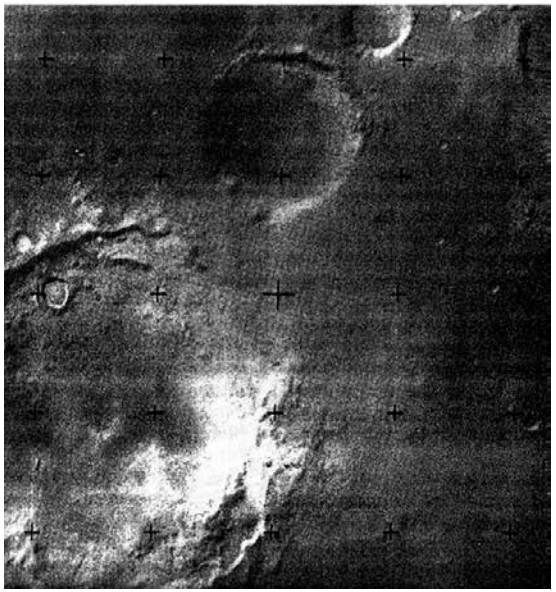
Little result for a massive investment

Mars 4 orbiter flew past planet
Mars 5 orbiter short lived
Mars 6 lander lost on landing
Mars 7 lander flew past planet



Mars 5 orbiter color images

Mars 4 flyby image

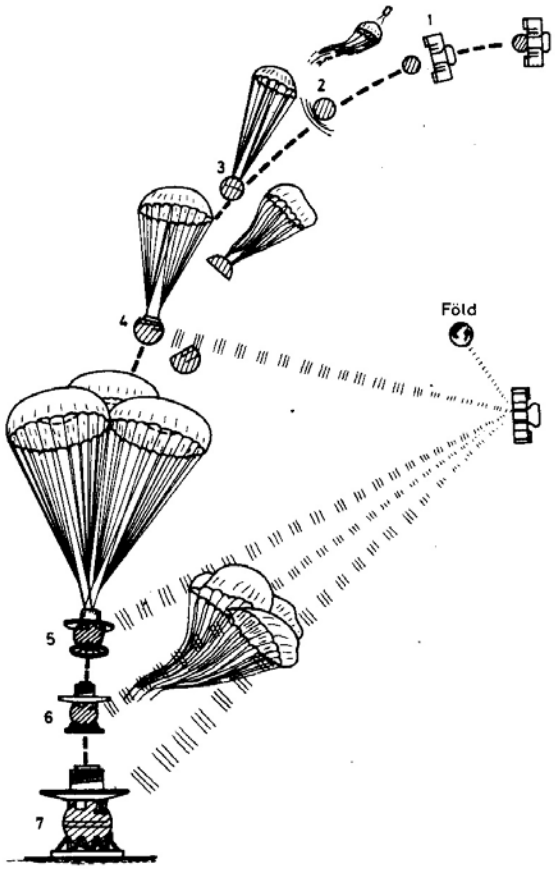


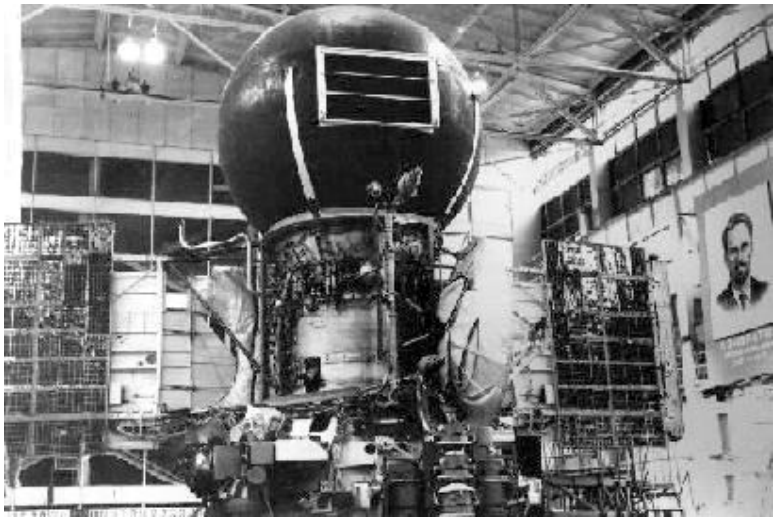
Mars 5 orbiter image

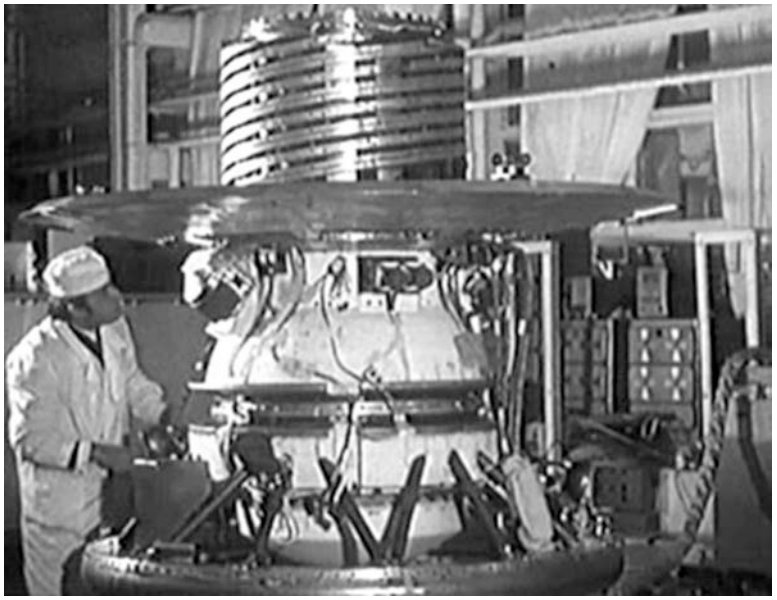
1975 - 1985 Venus becomes a “Red” Planet

1975 – A New Heavy Spacecraft for Venus based on the Mars 71 design

3380 kg orbiter (fueled)
1560 kg spherical entry system
660 kg lander w/sophisticated instruments
Free fall from 50 km



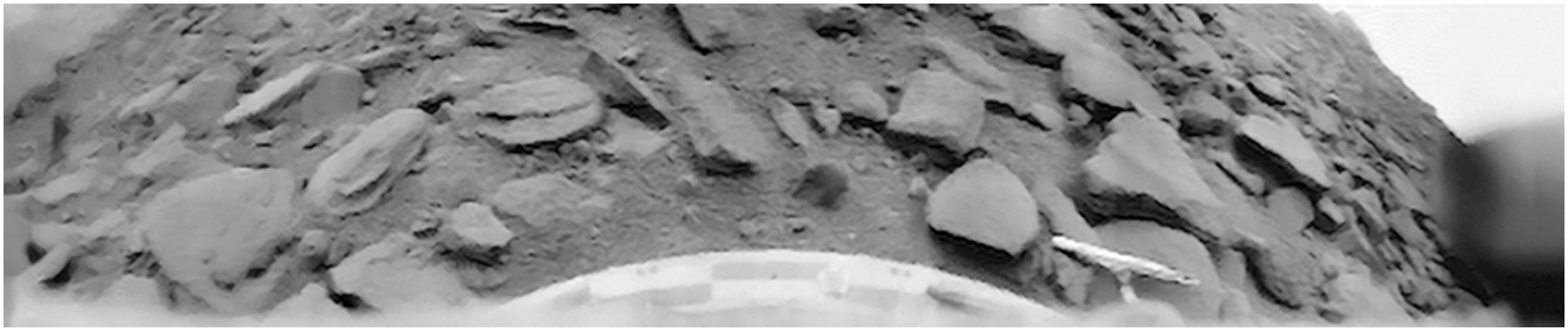




1975 - 1985 Venus becomes a “Red” Planet

*1975 - **Venera 9** becomes first Venus orbiter and first to return surface images*

Orbiters performed long term survey of ionosphere, atmosphere and clouds
Descent instruments made comprehensive in-situ measurements of atmosphere
Landers survived 53 & 65 minutes, took images and surface properties measurements



Venera 9 lander 180 deg panorama

Venera 10 lander 180 deg panorama

1975 - 1985 Venus becomes a “Red” Planet

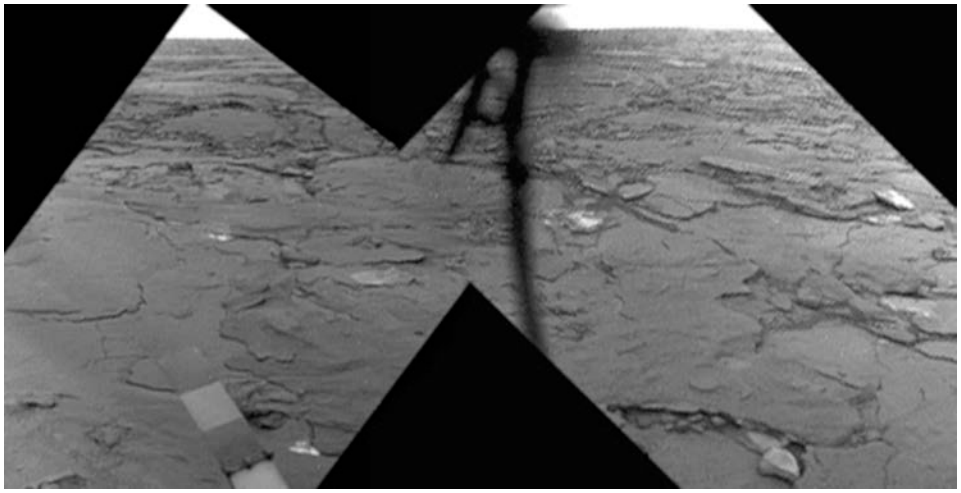
1978-1981 Exploiting the new Venera spacecraft

1978 - **Venera 11, 12** flyby & landers
- good measurement on descent but poor results on the surface

1981 - **Venera 12, 13** flyby & landers
- repeat Venera 11, 12 this time with success on the surface

Venera 13 color panorama

Venera 14 images reprocessed

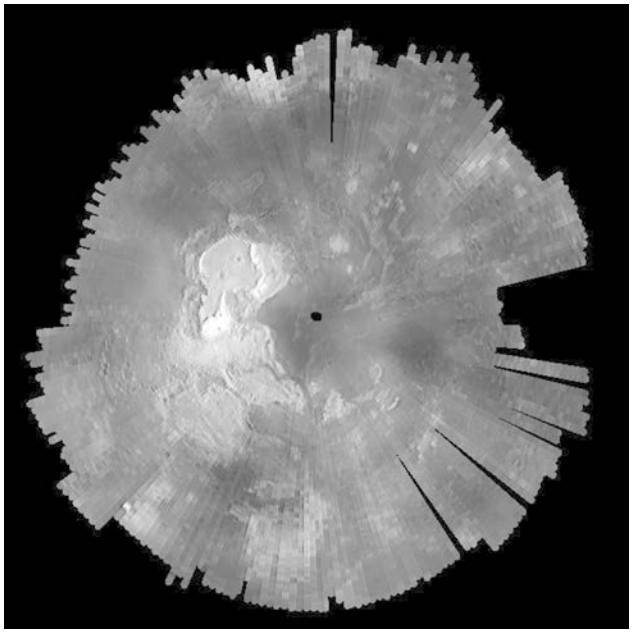


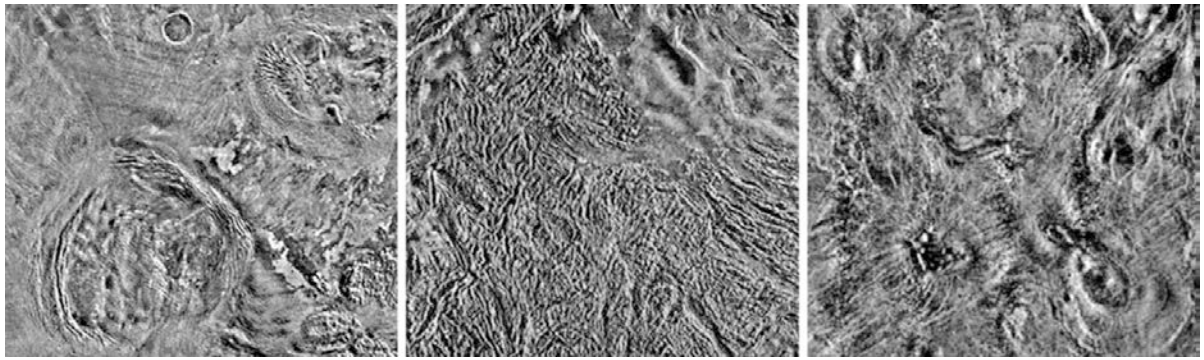
Achieved comprehensive physical & chemical properties of clouds, atmosphere and surface

1975 - 1985 Venus becomes a “Red” Planet

1983 Piercing the cloudy veil of Venus

Venera 15, 16 radar orbiters

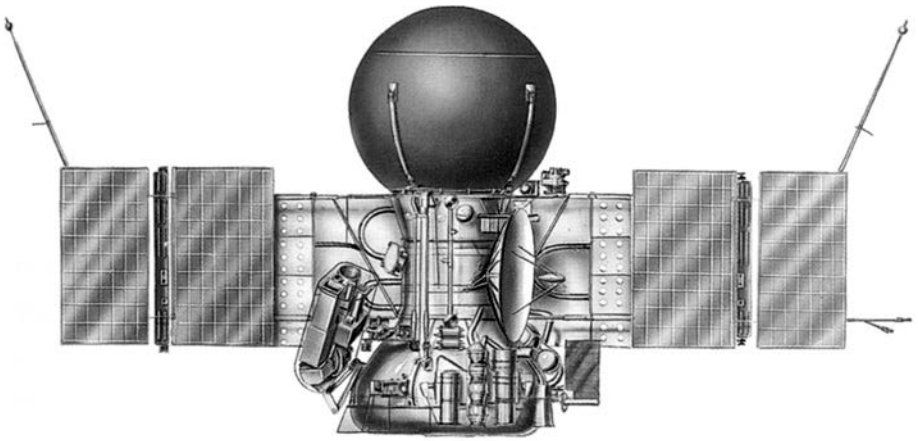




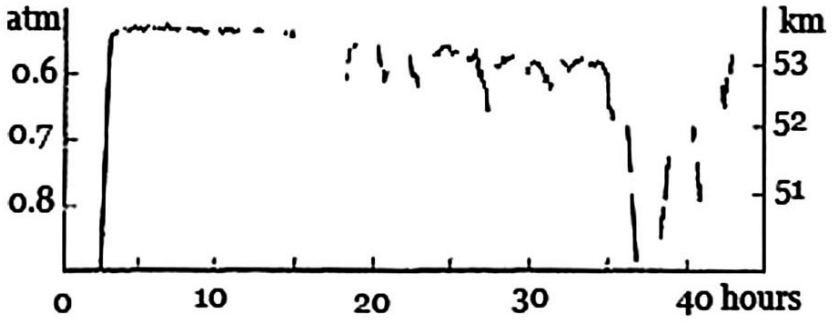
1984 - 1986 Venus Balloons and Comet Halley

*The Fabulous **Vega** Missions – first a drop at Venus*

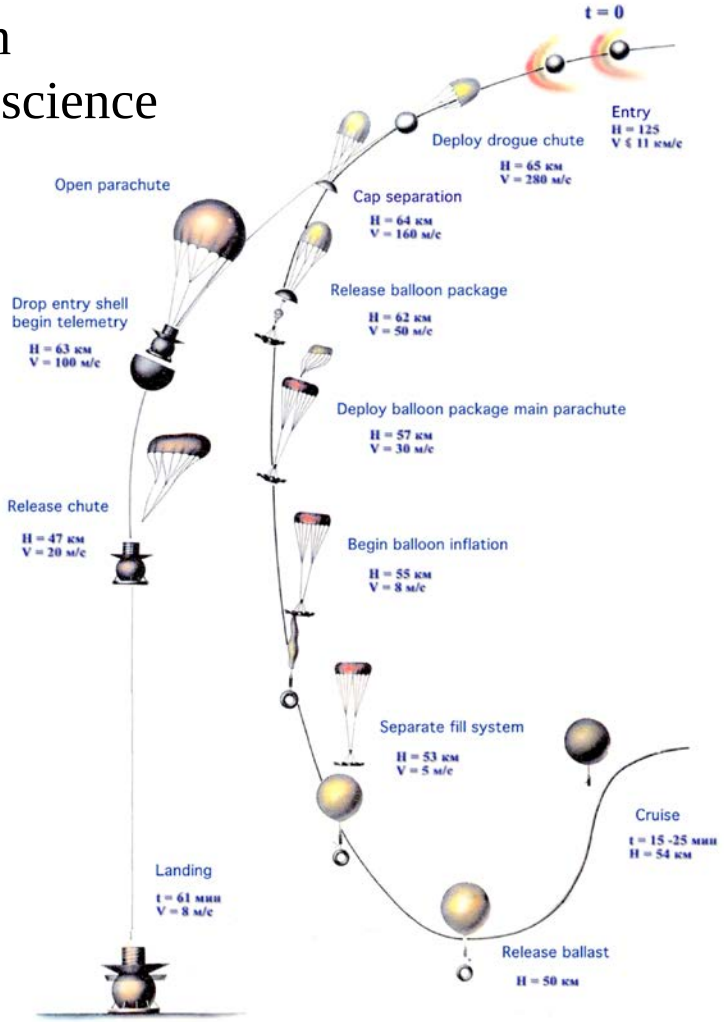
The Soviet's first open international mission
Massively instrumented for comprehensive science



The Vega 1,2 spacecraft



Vega 2 balloon flight profile

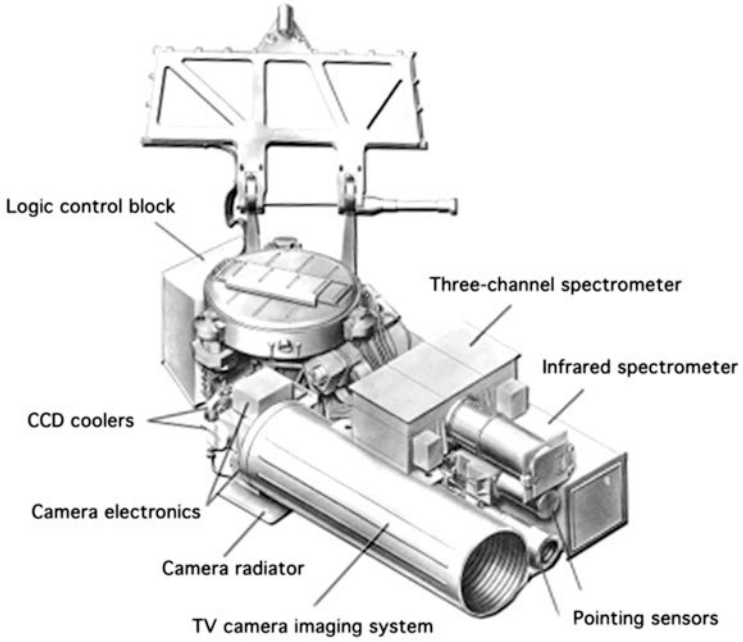


The first planetary balloon flight

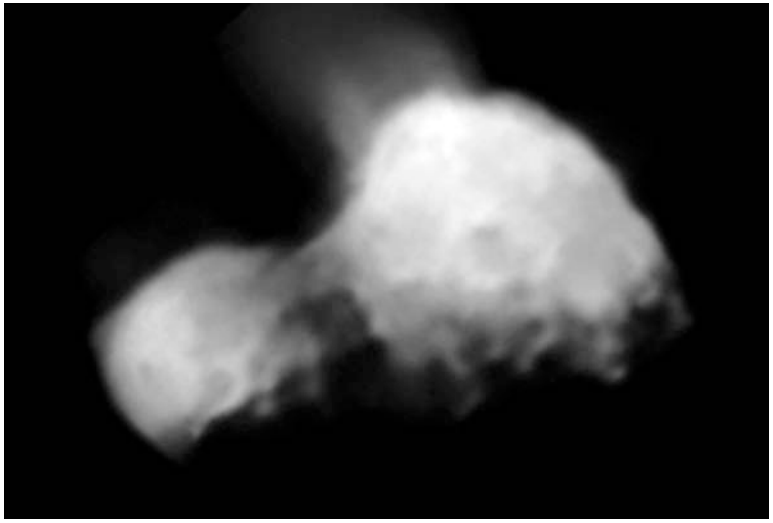
1984 - 1986 Venus Balloons and Comet Halley

*The Fabulous **Vega** Missions – then on to Halley*

A Soviet mission in the public spotlight from the outset
Highly international and an exceptional success on all counts
Provides key pathfinder data Europe's Giotto close flyby
A most daring, innovative, complex and successful mission
And a resounding scientific, political and public success



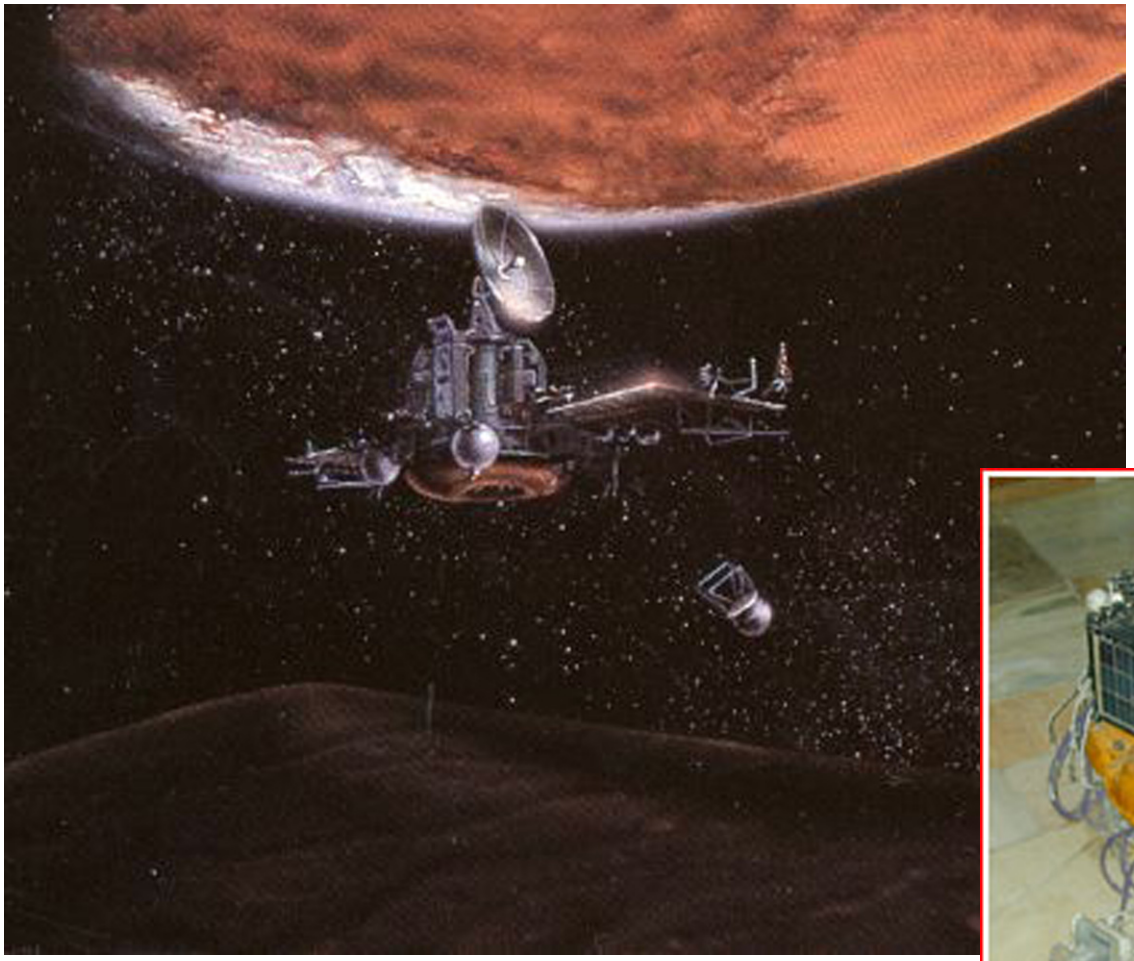
Vega scan platform



Vega 2 image of Halley

1988 - 1989 Another try at Mars goes badly

A new 6200 kg spacecraft with two Phobos landers and active remote sensors
Even more international than the Vega missions with a large, heavy payload



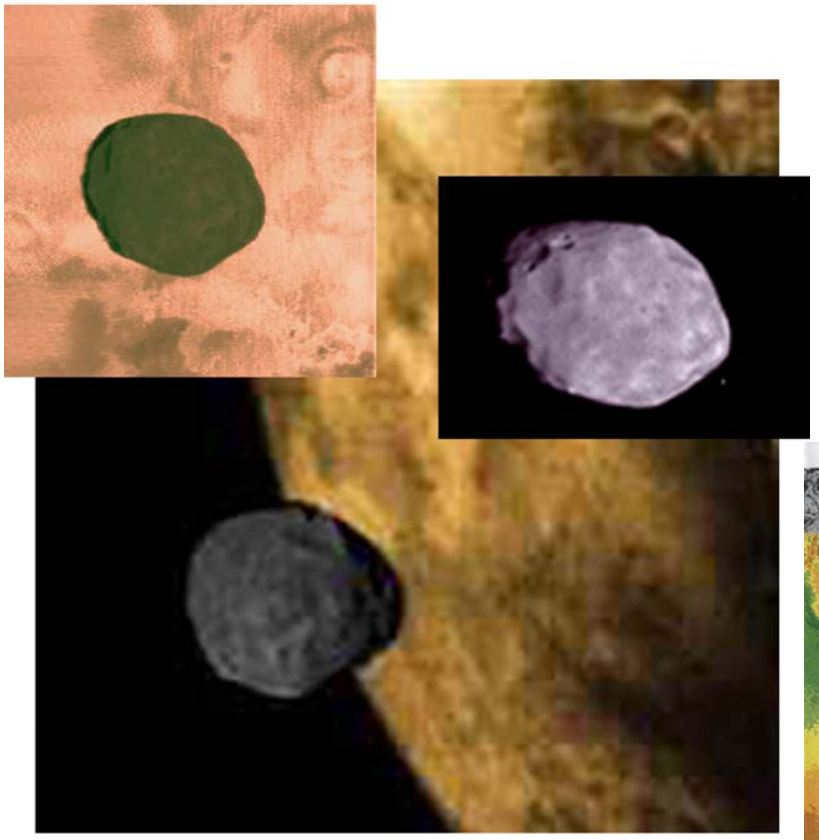
Phobos deploying mobile lander

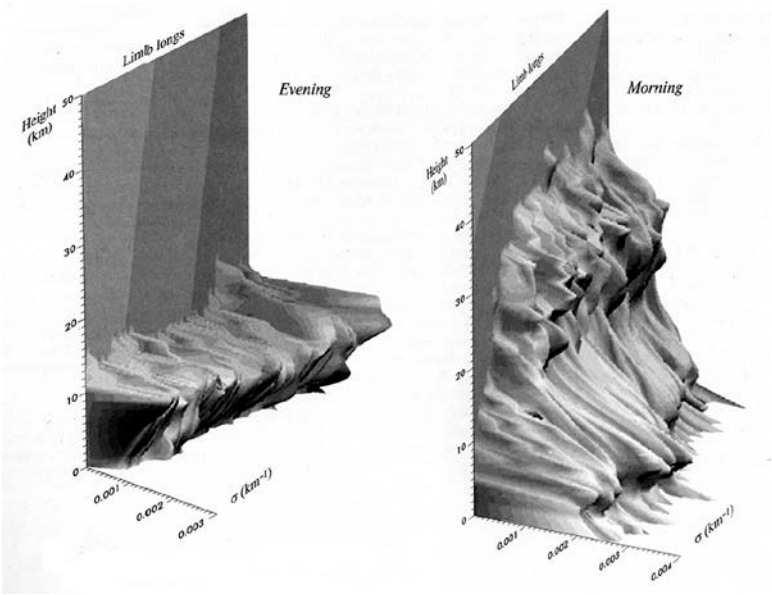
Phobos 1 fails enroute
Phobos 2 fails in Mars orbit

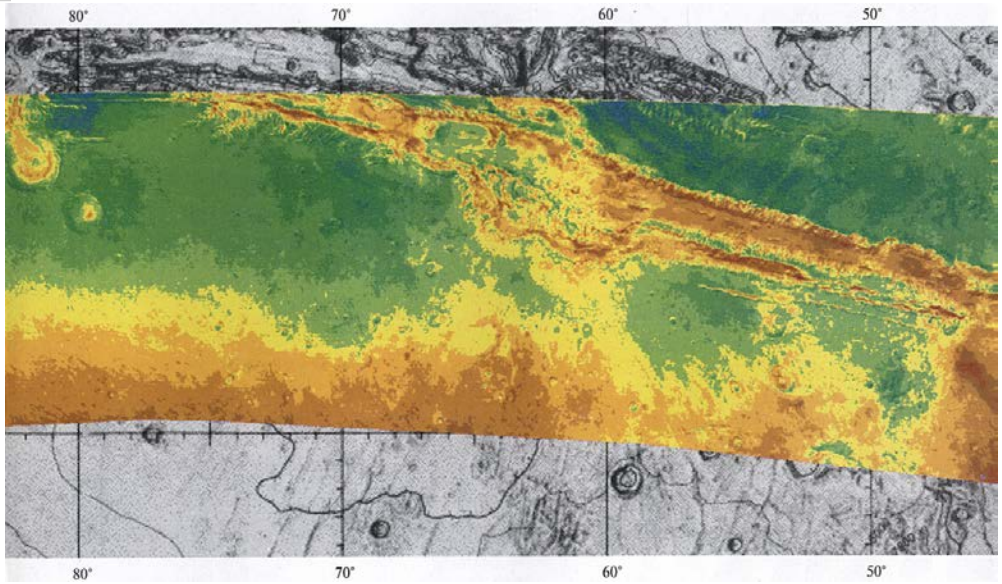
Phobos stationary lander

1988 - 1989 Another try at Mars goes badly

Phobos 2 obtained excellent data on Mars and on Phobos from Mars orbit before loss
More than all previous Soviet missions



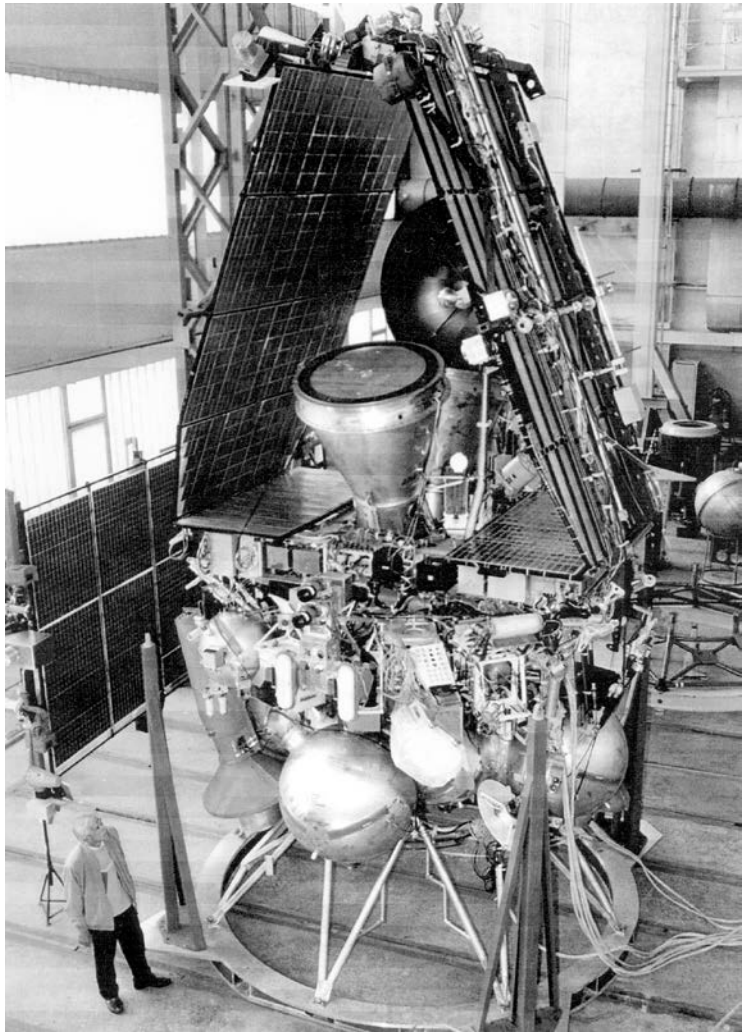




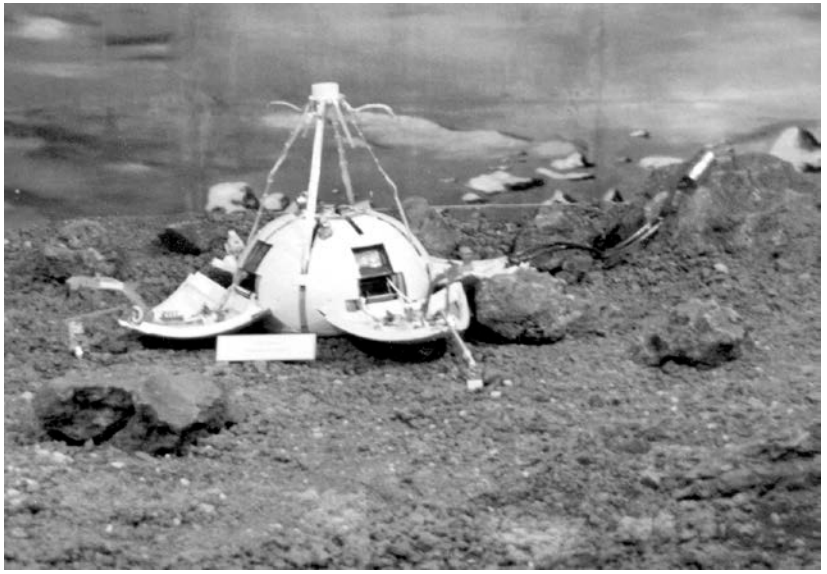
Although it failed its mission at Phobos
Phobos 2 was a success at Mars

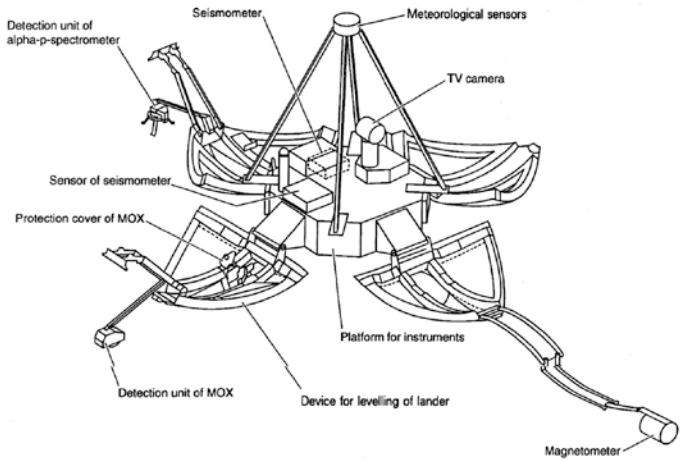
1996 – A final debacle at Mars

The second UMVL spacecraft, again with heavy international participation



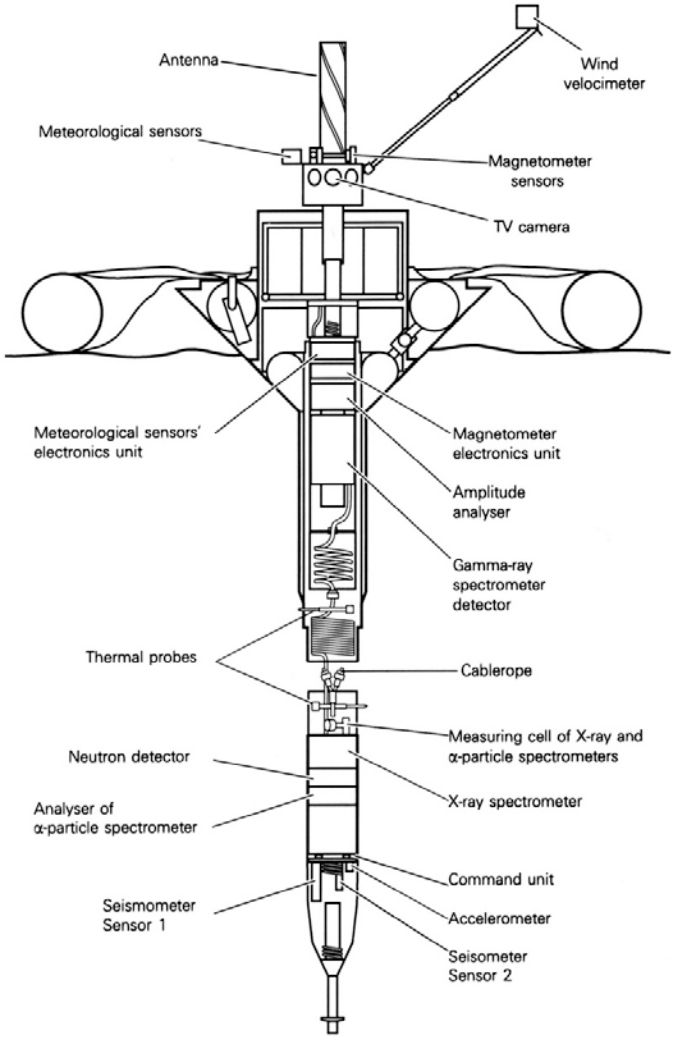
Mars 96 spacecraft



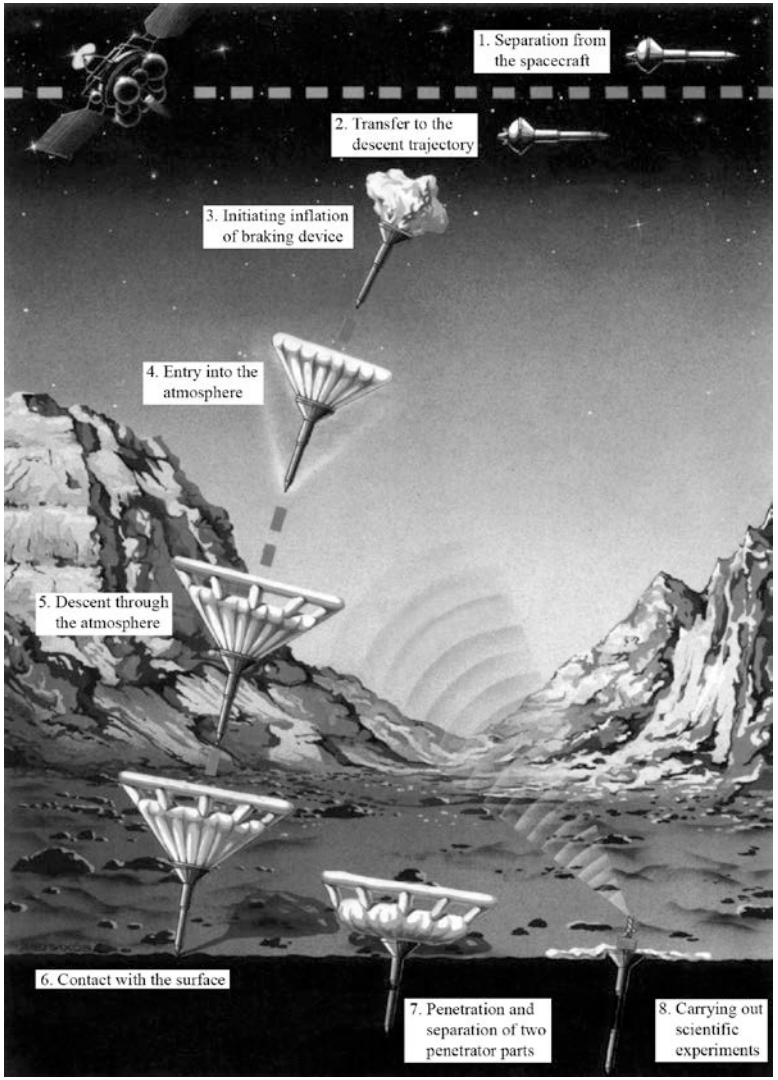


Mars 96 small lander

1996 – A final debacle at Mars



Mars 96 penetrator



Penetrator EDL sequence

Mars 96 - launch fails on Nov 16, 1996

Soviet exploration of the Solar System ends in 1996

A tragic loss of vision, enterprise and expertise

- courage and enthusiasm to try the previously impossible
- superb expertise in engineering design and development
- innovation in using technology available to accomplish the task
- masters of materials development and engineering
- masters of propulsion system engineering
- excellence in celestial mechanics, navigation and guidance
- excellence in automation and software, that later unraveled
- produced a stable of very powerful and readily available rockets
- a strong sense of competition with America, and
  an intense desire to stay ahead of and outperform US missions

- poor reliability of launch vehicles until mid-1970s
- handicapped by poor electronics technology
- lack of systems engineering discipline
- poor ground systems testing discipline
- complex, entangled, heavy-handed national system of control & supply

Extras

Achievements of the Soviet robotic exploration program

Lunar missions

First spacecraft to escape Earth's gravity	Luna 1	1959, January 2
First spacecraft to fly by the Moon	Luna 1	1959, January 4
First spacecraft to impact another celestial body	Luna 2	1959, September 14
First photographs of the far side of the Moon	Luna 3	1959, October 6
First lunar lander	Luna 9	1966, February 3
First lunar orbiter	Luna 10	1966, April 3
First circumlunar mission with Earth return	Zond 5	1968, September 20
First robotic sample return mission	Luna 16	1970, September 21
First robotic rover (Lunokhod 1)	Luna 17	1970, November 17

Venus missions

First launch attempt to Venus	1VA No.1	1961, February 4
First spacecraft to impact another planet	Venera 3	1966, March 1
First planetary entry probe	Venera 4	1967, October 18
First planetary lander	Venera 7	1970, December 15
First Venus orbiter	Venera 9	1975, October 22
First photographs from the surface of a planet	Venera 9	1975, October 22
First radar imagery of Venusian surface	Venera 15	1983, October 10
First planetary balloon	Vega 1	1985, June 11
First comet distant flyby	Vega 1	1986, March 6

Mars missions

First planetary launch attempt	1M No.1	1960, October 10
First spacecraft to impact Mars	Mars 2	1971, November 27
First lander on Mars (failed after landing)	Mars 3	1971, December 2
First atmospheric probe of Mars (lost at landing)	Mars 6	1973, March 12

1996 - 2011 Hiatus in Russian Exploration of the Solar System

- Russian space program turns almost exclusively to humans-in-orbit after 1991
- Russian Nat’l Science Academy space program cannot acquire necessary funds
- Mars 96 failure is an international disaster, foils Russian bid for int’l leadership, demoralizes the program, embarrasses a bankrupt Russian Gov’t, ends investment.

A tragic loss of vision, enterprise and expertise for 15 years

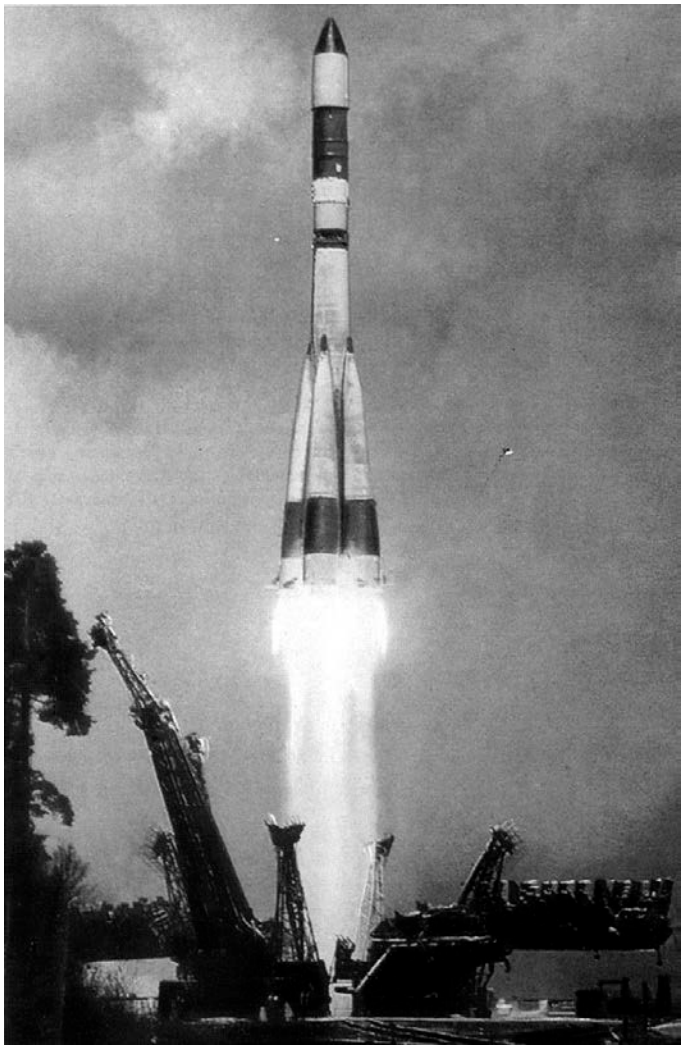
- USSR often got to the Moon, Venus and Mars first, only to be outdone later by US
- accomplished complex Lunar and Venus missions conceded by US
- never attempted to explore of the outer solar system
- badly outdone at Mars

2011 Phobos-Grunt mission developed to revive the program

- falls victim to the same problems inherent in Phobos 88 and Mars 96
- lack of discipline in design requirements, system engineering and ground test
- coupled with insufficient funding and government support

Unfortunate fate is bedfellow to Russian history

Soviet Launchers in the mid-1960s



Molniya Launch

Proton (1965)

Soyuz