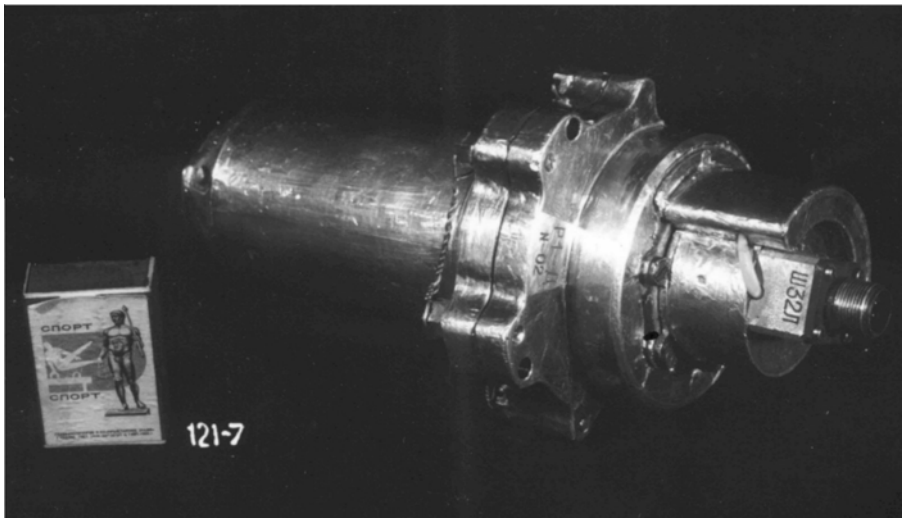
EXPERIMENTAL GEARBOX ASSEMBLY “R-1”



Customer: S.A.Lavochkin OKB, 1966-1968

Purpose:

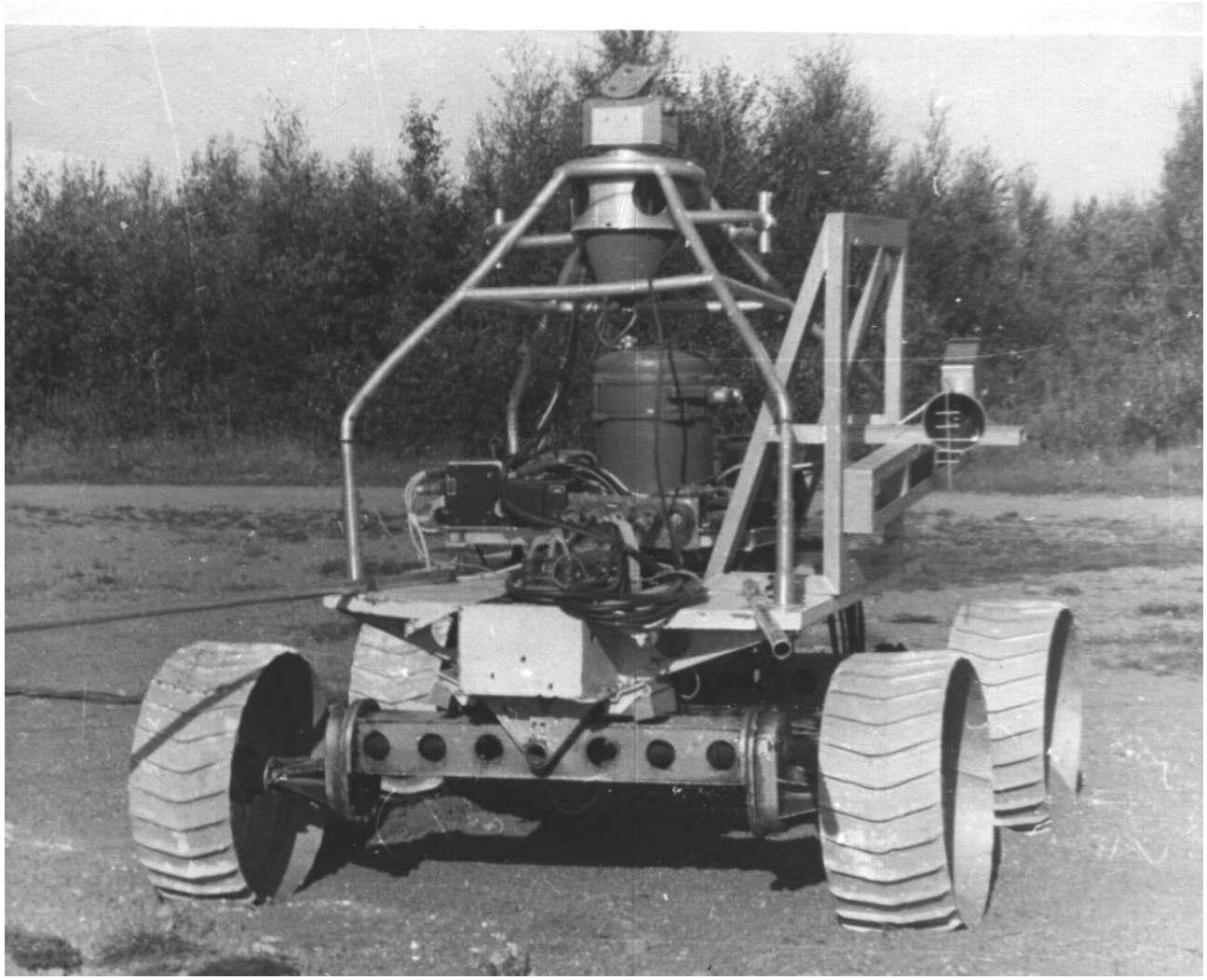
Comparative and selection tests of structural materials, coatings and lubricants for gear wheels and bearing as well as for investigating rear and energy loss in a pair of gears and estimation of its serviceability both when Earth-based testing in thermo-vacuum conditions and in space.

Tests were conducted on the board of the “Luna-11” and “Luna-12” orbital stations and in the thermo-vacuum chambers. Results obtained were used for developing the testing procedure for the Lunokhod-1 chassis tractive drive.

Technical data:

-Motor type	Direct-current motor with the magnetic clutch to pressurize
-Load condition for the pair of gears	In the scheme of a stand with circulating power
-Circulating power, W	10
-Gearbox ratio	1.44
-Pitch of a gear	0.3; 1.0
-Load condition in the closed loop	
contact stress in meshing, MPa	600
slip speed in meshing, m/s	0.28
-Mass, kg	1.5

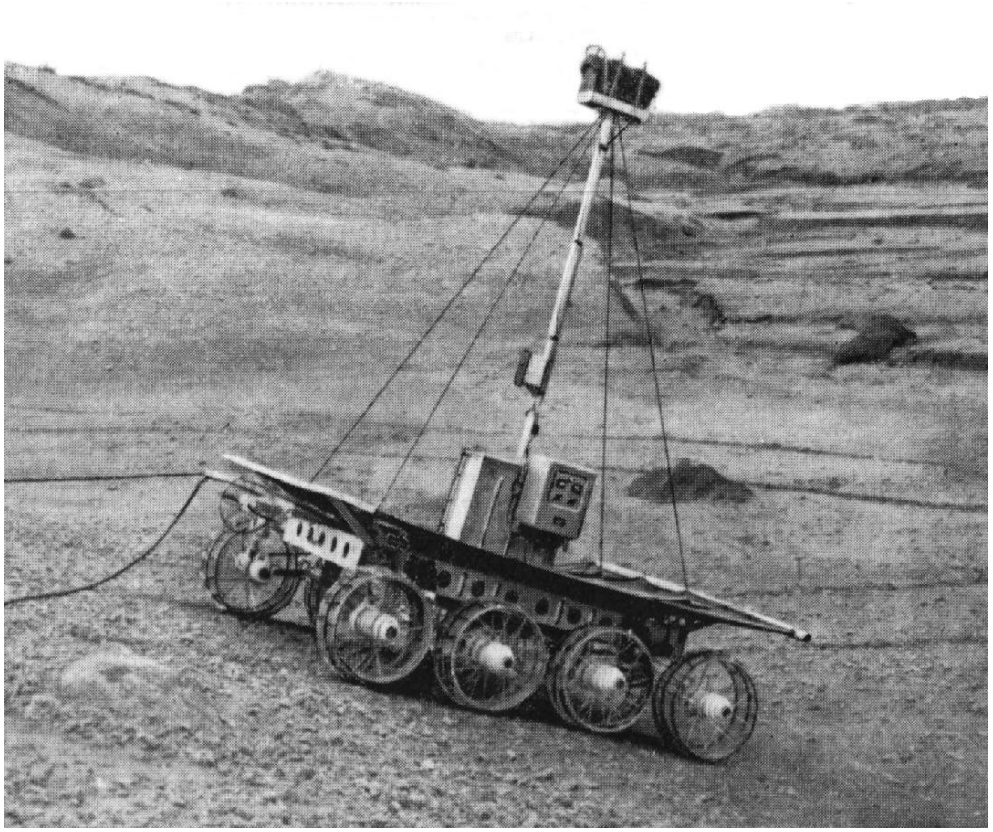
«Ш-1" First Moon Rover self-propelled mock-up (1965)



Purpose: check of technical decisions, debugging of the control system, investigation of interaction of the chassis with soil. Wheel arrangement is 4x4.

Front wheels are hard fixed at the frame. Rear wheels are installed on a beam connected with the frame by means of the hinge.

Running mock-up of the “Lunokhod’s” self-propelled chassis (1967)

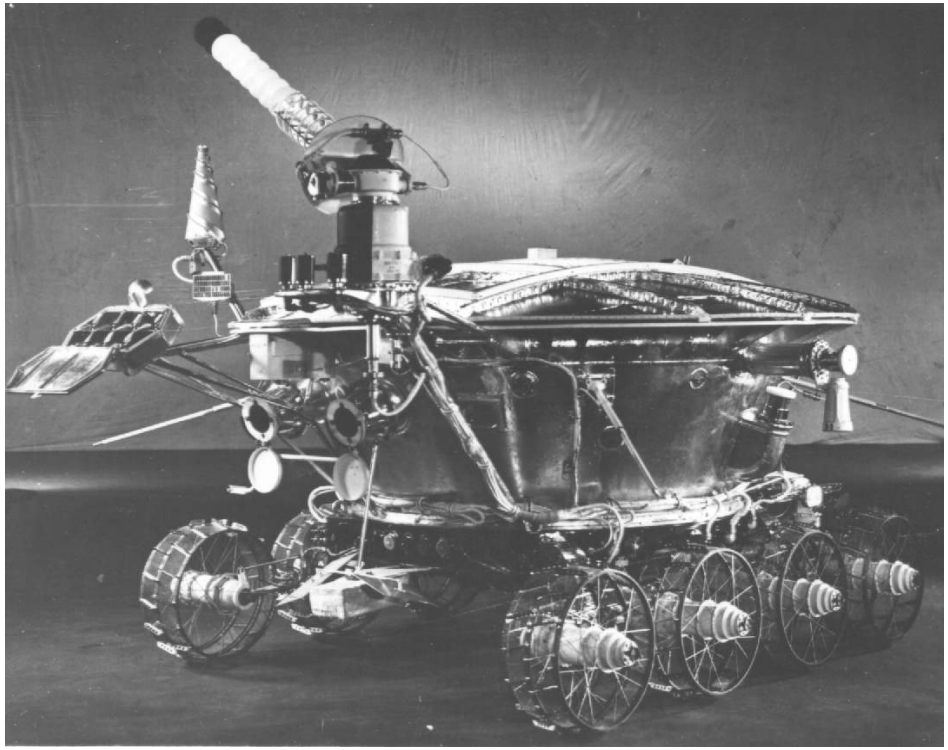


Purpose: determination of the traction and cohesion characteristics and cross-country capability of the chassis when moving over rugged terrain with simulation of Lunokhod’s moments of inertia, as well as debugging of control algorithms.

Running mock-up of the “Lunokhod’s-1” self-propelled chassis

Chassis mass……..……150 kg.
Wheelbase……1700 mm
Wheel track……..1600 mm
Wheel diameter…….…….510 mm
Travel speed……0.5 and 1 km/h
Chassis power consumption…….320 W

Self-propelled automatic chassis for "Lunokhod-1" and "Lunokhod-2" (1969)

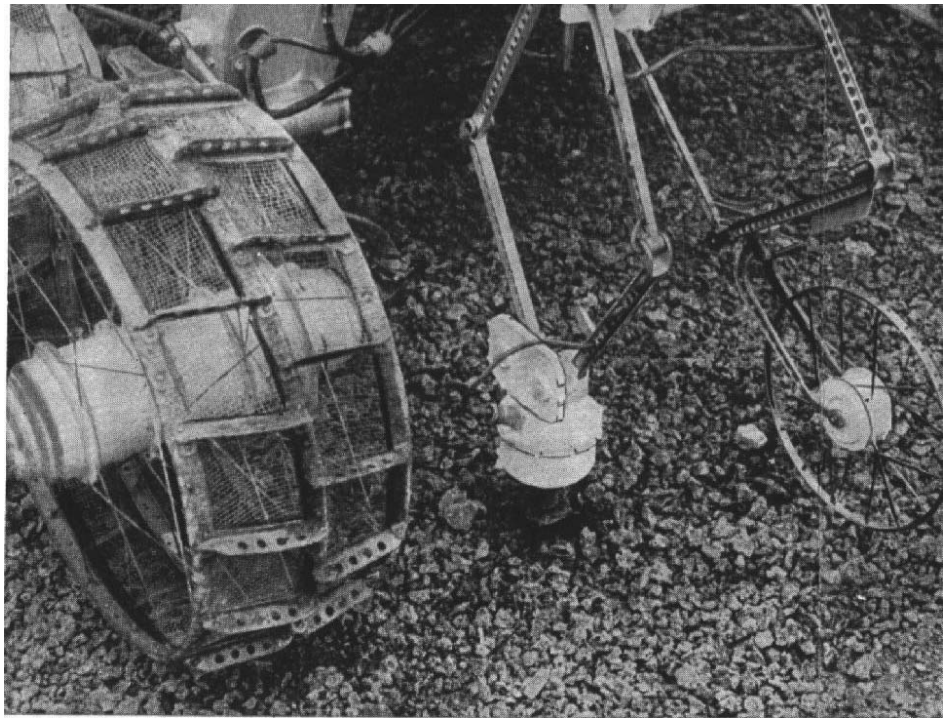


Chassis composition**:** eight rigid drive-wheels merged as four units having brackets for attaching to the Moon Rover container, individual suspensions for all the wheels, the automatic motion-control block, the "PROP" cross-country capability evolution instrument with the ninth wheel.

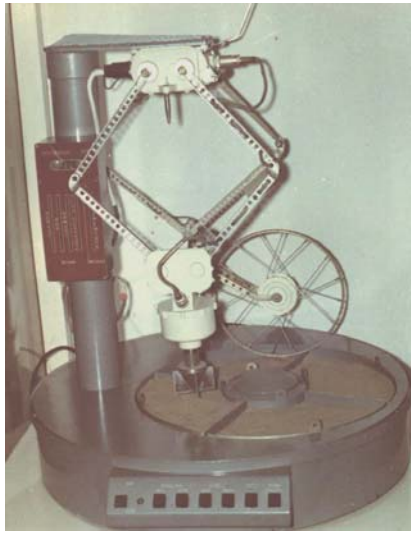
Self-propelled automatic chassis as a component of "Lunokhod 1"

Ratio of the chassis mass to the total "Lunokhod's mass……..1/9
Wheelbase……1700 mm
Wheel track……..1600 mm
Wheel diameter……510 mm
Travel speed……0.5 and 1 km/h
Chassis power consumption……320 W
Customer: Lavochkin Association

PROP” cross-country capability evaluation instrument (1969)

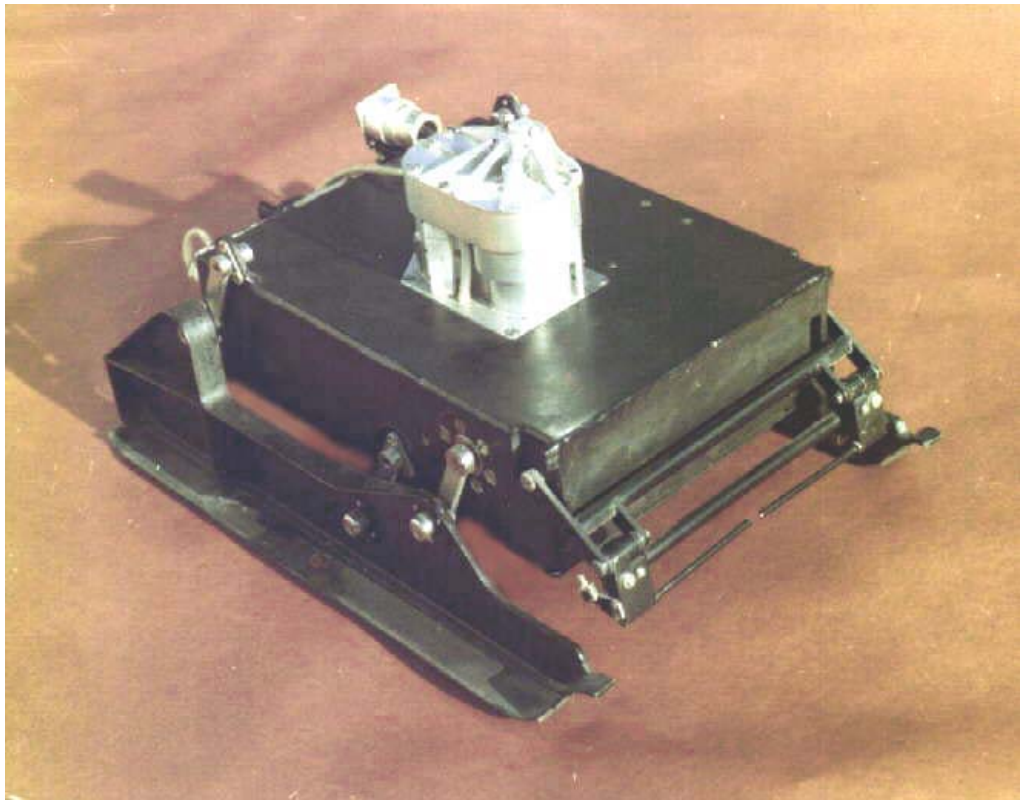


The instrument was a part of the “Lunokhod’s-1” and “Lunokhod’s-2” self-propelled chassis.
Purpose: investigation of mechanical properties of the Moon’s soil along the Lunokhod’s route.
Composition: the upper head with mechanisms for lifting and lowering lower head; lower head with the cone-vane penetrometer swinging mechanism and sensors; the ninth wheel with mechanisms for its lifting and lowering.

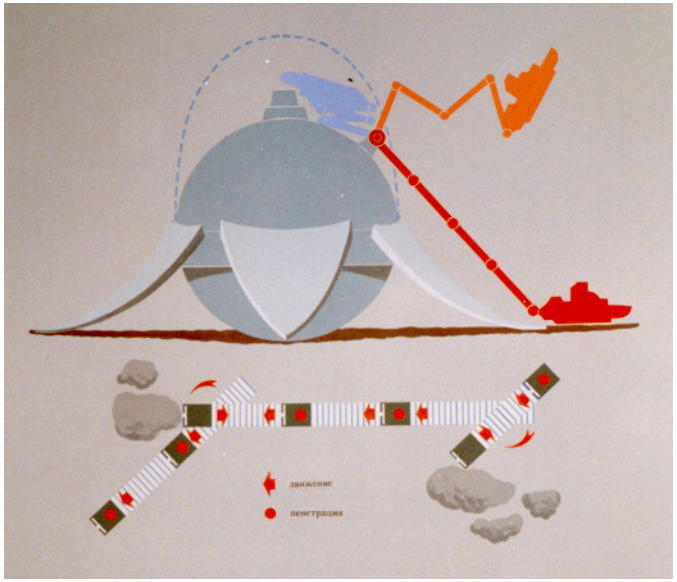


“PROP” instrument.
Penetration force of the penetrometer ……up to 23 kg
Penetration depth…….……..50-100 mm
Penetrometer’s angle of swing ……..…up to 90 degrees
Torque on the penetrometer……up to 0,5 kg

"PROP-M" Micro Mars Rover (1971, 1973)



It was installed on the "Mars-3" and "Mars-6" space stations.
Purpose: exploration of the Martian surface.
Micro Mars Rover composition: the body, ski-walking propulsive device, motion control system including the safety system and synchronisation system, dynamic penetrometer, radiation densimeter ("GEOHI" RAS).
Electrical power and telemetry are transmitted through a cable.



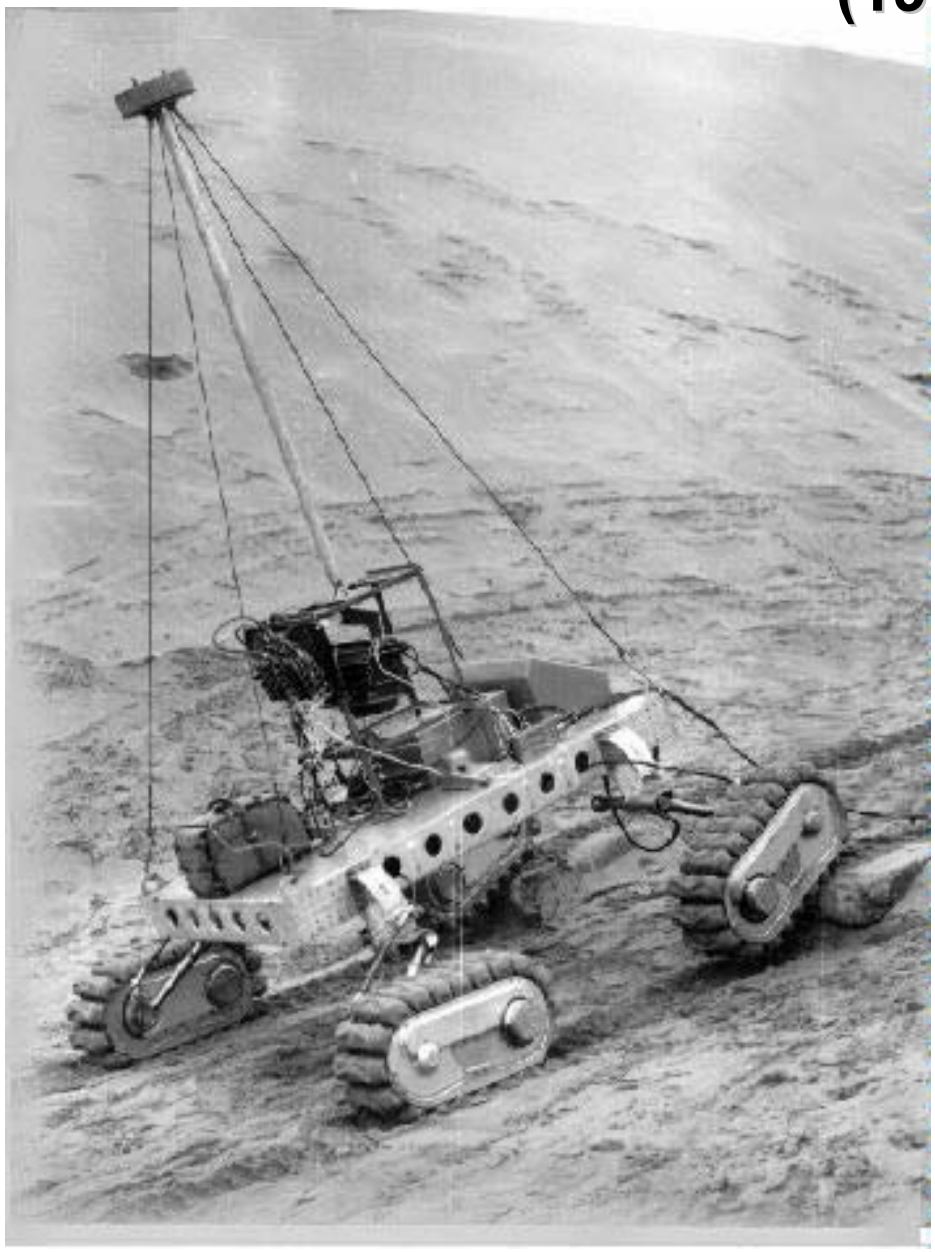
"PROP-M" Micro Mars Rover
Mass……4 kg
Overall dimensions……215x160x60 mm
Travel speed……1 m/h
Power consumption……5 W
Customer: Lavochkin Association.

"LIIIM" running mock-up with ski-walking propulsive device (1975)

Running mock-up was created in accordance with the "Mars-75" program.
Purpose: investigation of the ski-walking method of motion over powdered soil having low bearing strength.
Each ski has two electromechanical drives.

Mass……240 kg
Overall dimensions……..2x1.7 m
Travel speed…….……0.25 km/h

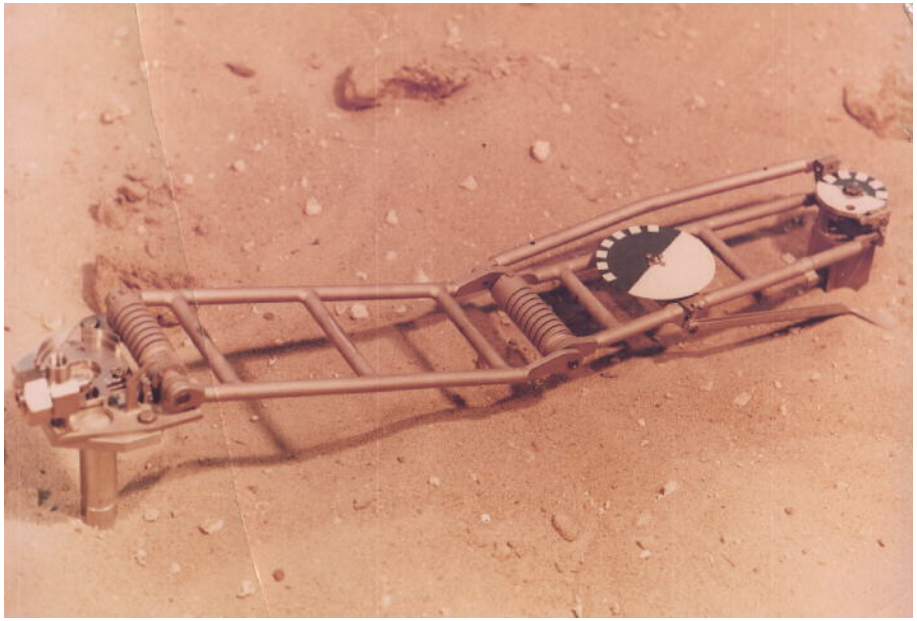
"4GM" running mock-up with a caterpillar propulsive device (1974)



The running mock-up was created when carrying out of a research and development works connected with creation of a "large Mars Rover".
The propulsive device has four autonomous caterpillar bogies, having the independent two-degree-of-freedom torsion suspension.
Purpose: investigation kinematics of the caterpillar propulsive device and its interaction with a relief and soil.

Mass……450 kg
Travel speed……1 and 2 km/h
Turning mode……..…side (tractor type)

Penetrometer for study of the Venus' soil (1976-1981)

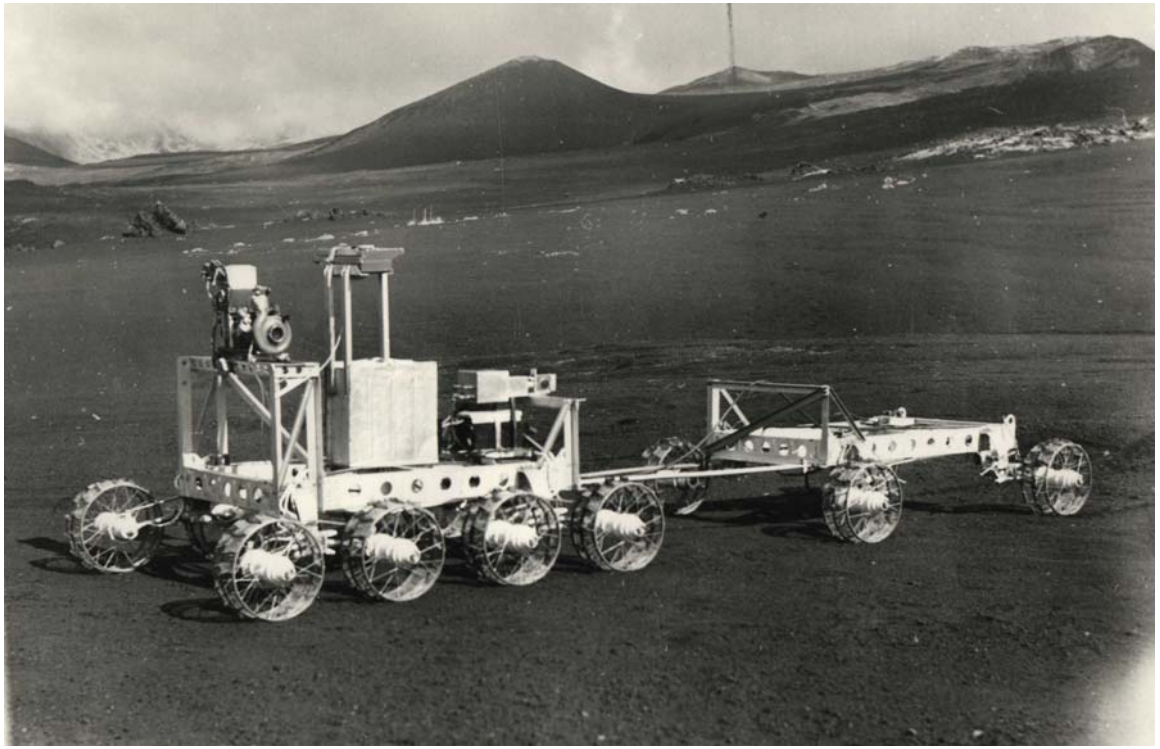


The penetrometer was installed on the "Venera-13" and "Venera-14" landers. Purpose: determination of physical and mechanical properties of soil and electric resistance of the soil surface layer of Venus. The penetrometer is the instrument of one-fold impact action.

"Venera-13" penetrometer
Overall dimensions……360x145x120 mm
Mass……..2.1 kg
Customer: Lavochkin Association

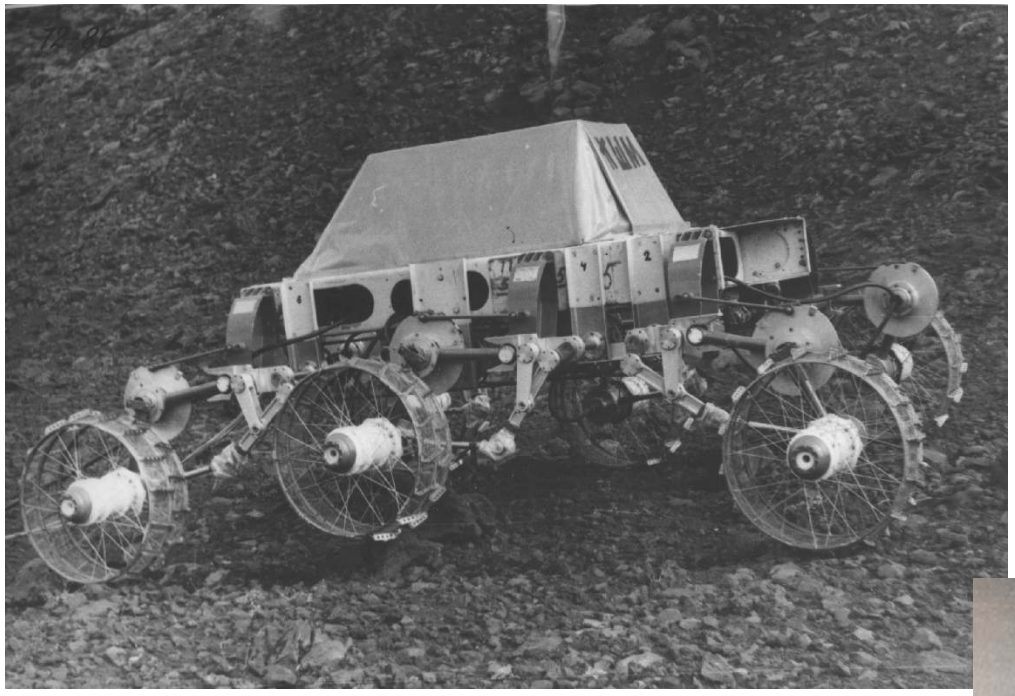
"XM-scepka" running mock-up of the coupling chassis (1971)

Purpose: investigation of cross-country capability and control methods of the coupling chassis. Operation of the diagonal and one-articulated couplers, efficiency of active and passive trailers, as well as electric differential drive of the trailer drive-wheels were investigated.
The mock-up was created on the base of the "Lunokhod's-1" chassis.



Wheel arrangement:
first section (tractor)……..8x8
second section (trailer)……..4x4
Mass:
first section (tractor)……..220 kg
second section (trailer)……290 kg
Travel speed……..0.24 km/h

«КШМ» RUNNING MOCK-UP WITH A WHEEL-WALKING PROPULSIVE DEVICE (1972)



Drive-wheels and suspension of the "Lunokhod's-1" chassis were used when creating the mock-up.
Purpose: substantiation of the wheel-walking method of motion, its theory and synthesis of the wheel-walking propulsive device, choice of a optimum regime of walking.

The running mock-up has systems of programmed control and automatic manoeuvring, as well as over-slipping protection of drive wheels.

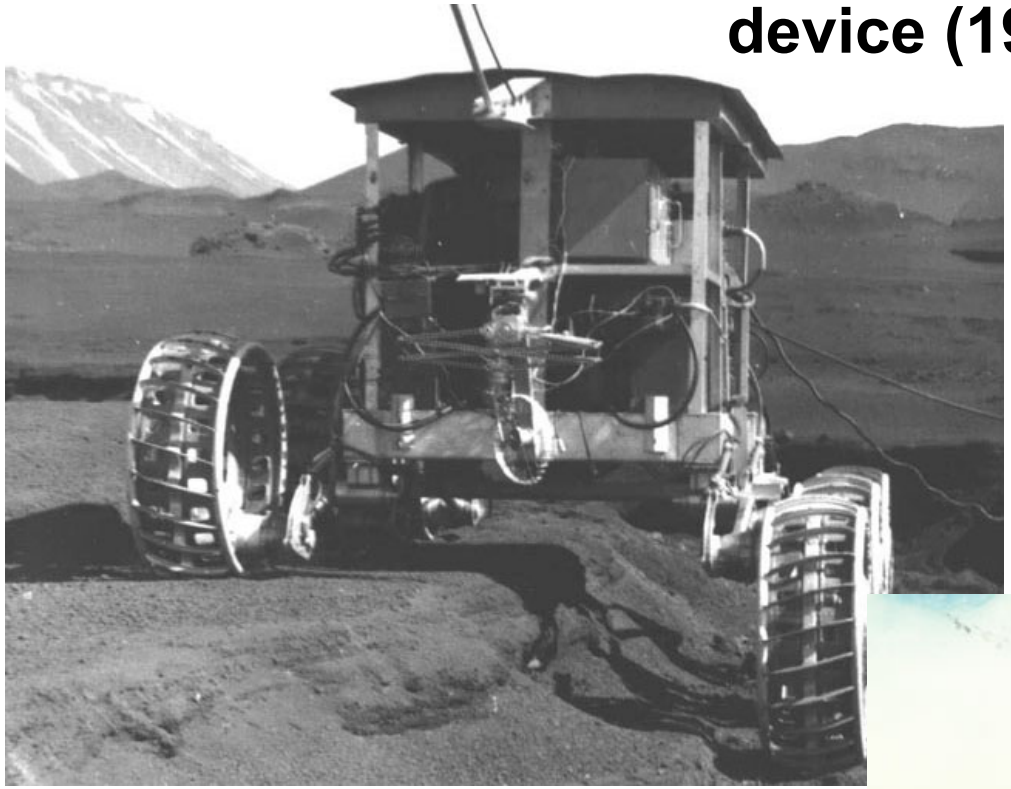
Mass…….320 kg
Wheelbase……1.7-2.2 m
Travel speed:
wheel mode…….……..0.9 km/h
walking mode……..……0.15 km/h
Surmounted slope with loose soil:
wheel mode……..……..18 degrees
walking mode…….……34 degrees

"XM-PK" running mock-up with turning wheels (1976)

Purpose: investigation of interaction of the turning wheels with soil when moving over slopes.

The mock-up was created on the base of the "Lunokhod's-1" drive-wheels. All the drive-wheels are provided with individual turning mechanisms.

"EOSAIII-1" running mock-up with six-wheel propulsive device (1978)

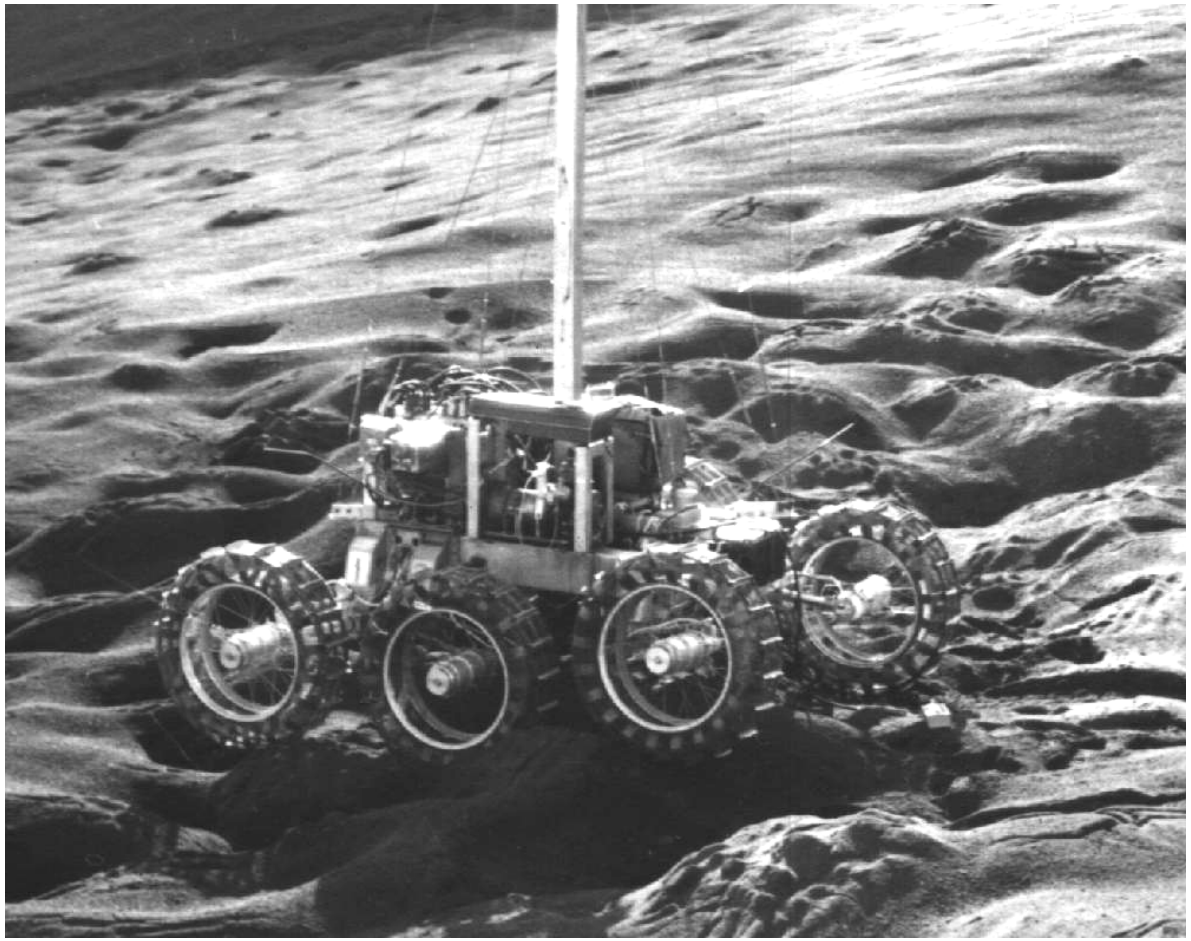


The running mock-up was created within the framework of the research and development works connected with the creation of perspective planetary rovers.
Purpose: design debugging of the wheel-walking propulsive device and automatic control systems.

Mass……480 kg
Wheel diameter……..700 mm
Wheelbase……2.1-2.91 m
Travel speed:
wheel mode……0.3 km/h
walking mode……0.02 km/h

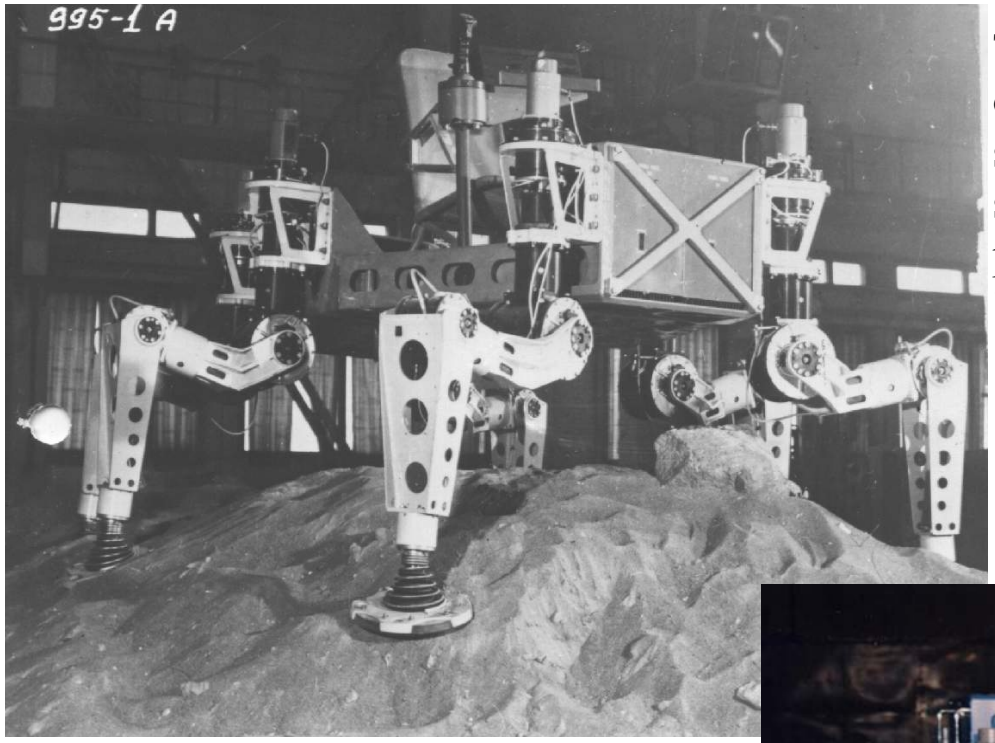
"XM-KPP" running mock-up (1978)

The running mock-up was created within the framework of the research and development works connected with the creation of perspective planetary rovers.
Purpose: investigation of dynamics when moving with heightened speeds.
Electromechanical drives consist of a two-speed motor and planetary transmission.
Wheels has metal-elastic tyres.

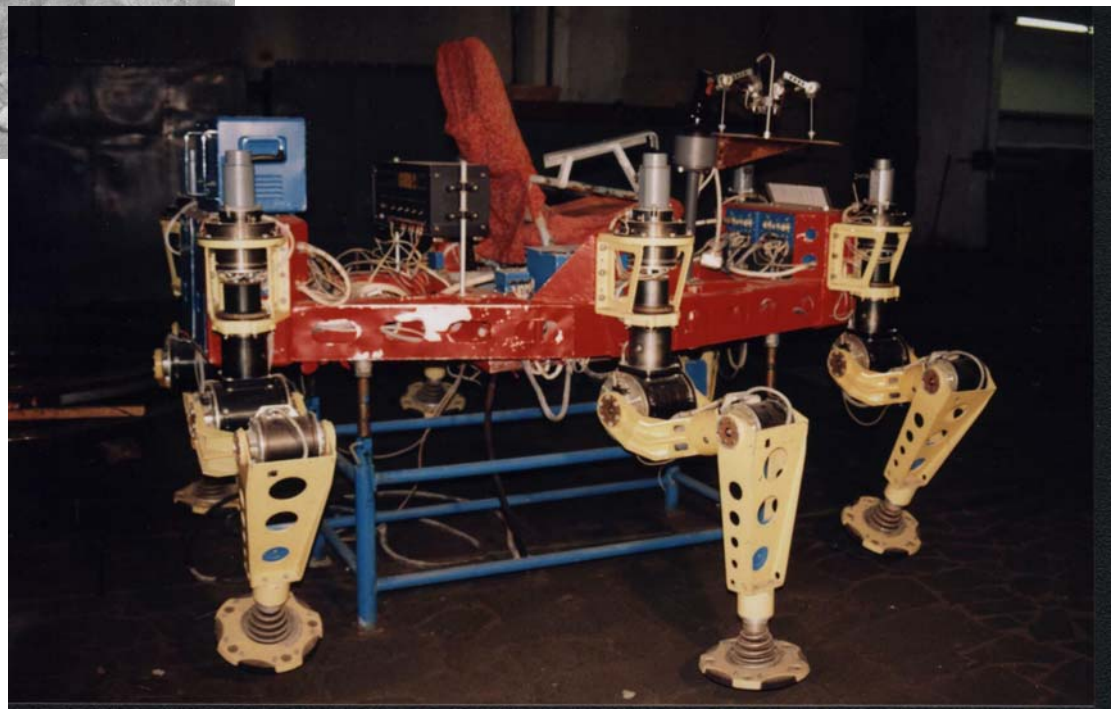


Wheel arrangement…….6x6
Mass……240 kg
Wheelbase……...2 m
Wheel diameter……0.75 m
Travel speed……0.51-5.1 km/h

"NMIIIA" six-leg walking running mock-up (1985)



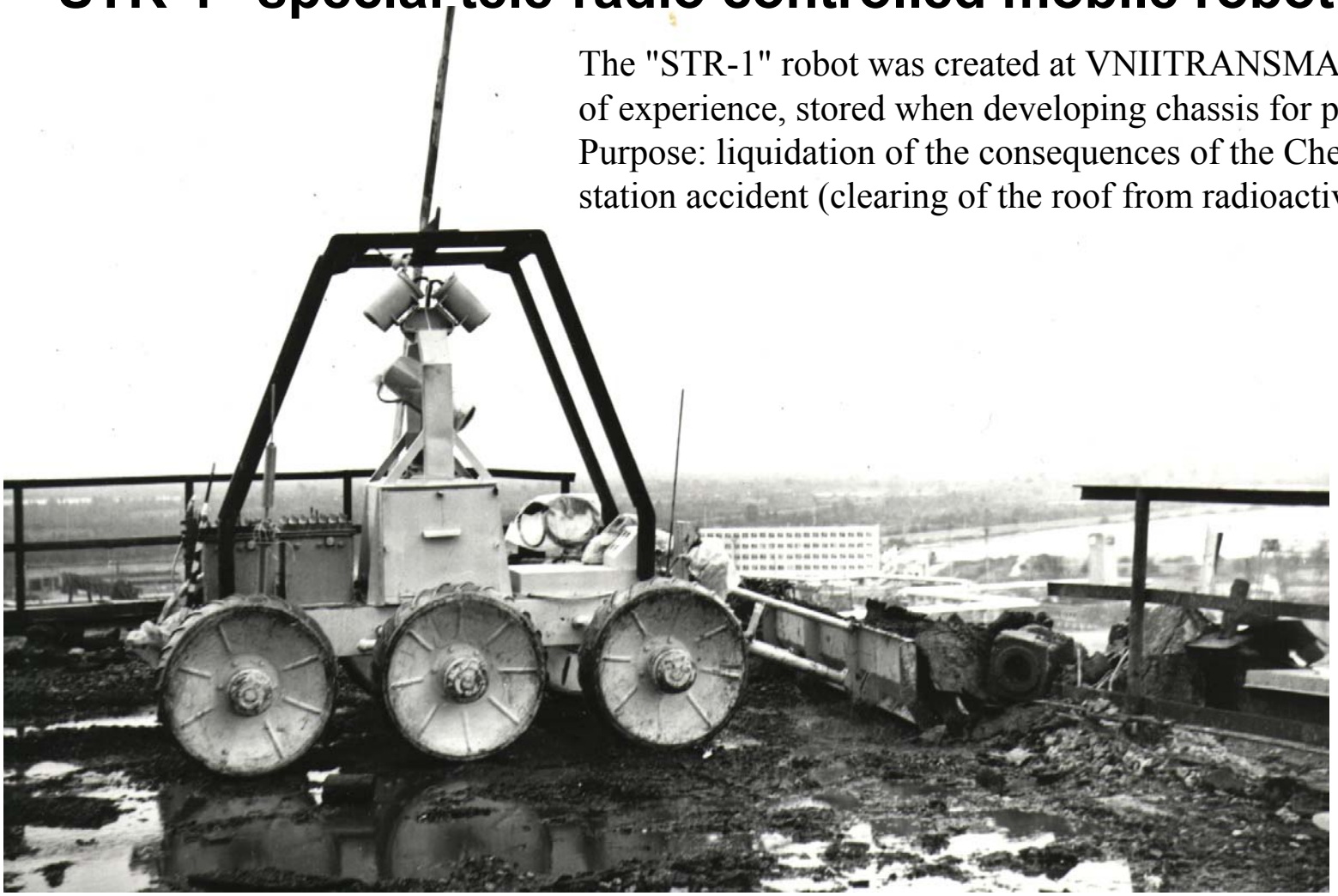
The running mock-up was created for debugging of the walking propulsive device and control system. The computer control system, "sensation" system, round-up- information system, driver place. Hinges of mechanisms for "leg" transfer, "thigh" bending have electromechanical drives.



Mass……750 kg
Load-carrying capacity……80 kg
Travel speed……0.7 km/h
Step length……..…….2 m

"STR-1" special tele-radio controlled mobile robot (1986)

The "STR-1" robot was created at VNIITRANSMASH on the basis of experience, stored when developing chassis for planetary rovers. Purpose: liquidation of the consequences of the Chernobil atomic station accident (clearing of the roof from radioactive waste).



STR-1

Mass……..……..900kg

Travel speed……..……0.46 and 1.0 km/h

Power consumption……..……..1.5 kW

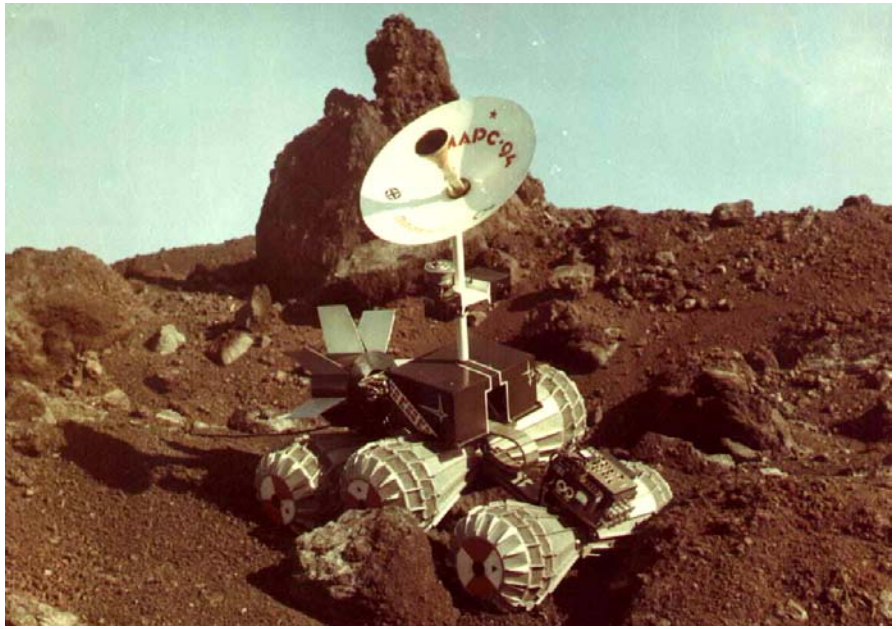
Duration of functioning to recharging of a storage battery……8 hours

Customer: "NIKIMT".

"Mir" Mars Rover running mock-up (1988)

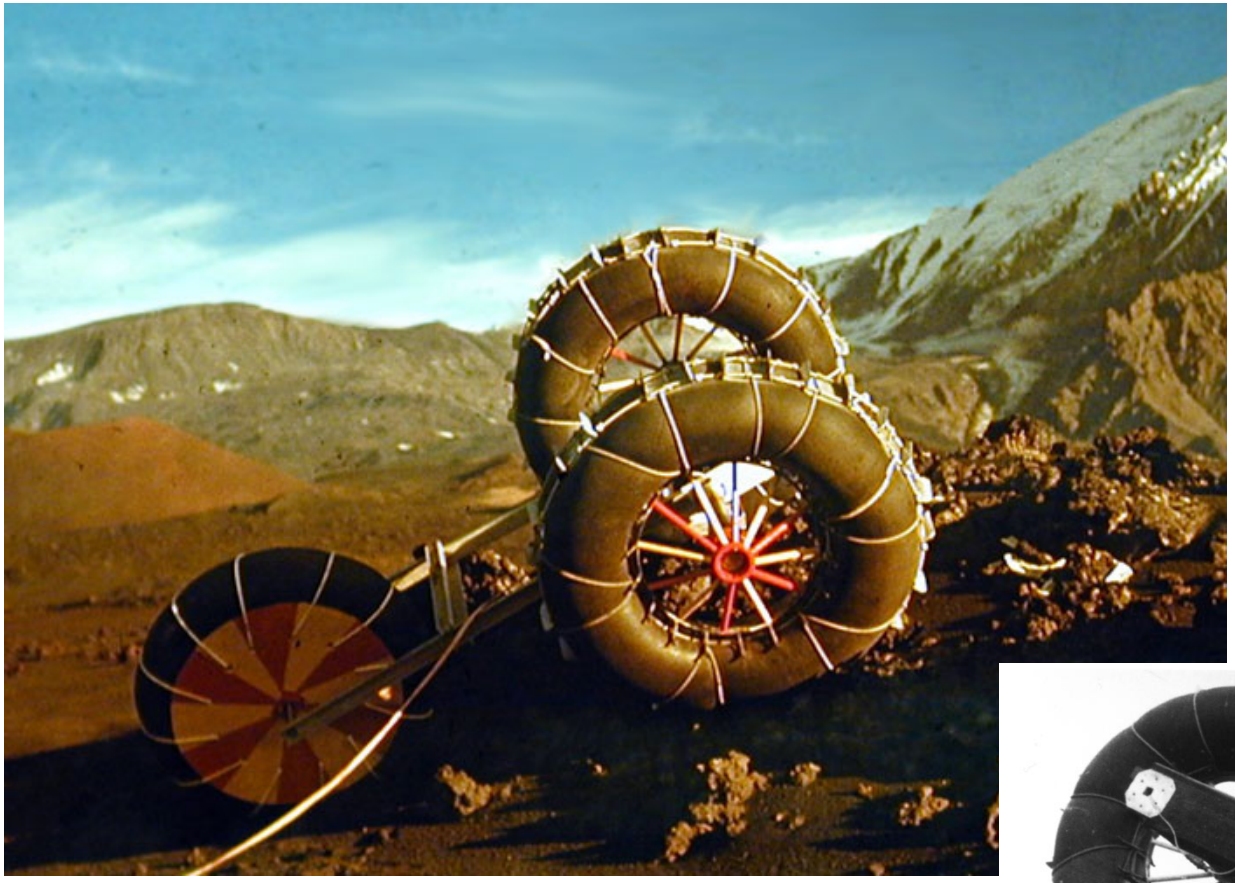
The running mock-up is three-section six-wheel apparatus with the articulated frame and non-clearance wheel-walking propulsive device.
The running mock-up has heightened longitudinal and transversal stability in consequence of low position of the centre of mass.

Mass……..……..200 kg
Diameter of the wheel cylindrical part……0.51 m
Wheelbase……1.4-2.5 m
Surmounted slope with loose soil
at the wheel-walking mode……34 degrees
Height of the surmounted bench……1 m



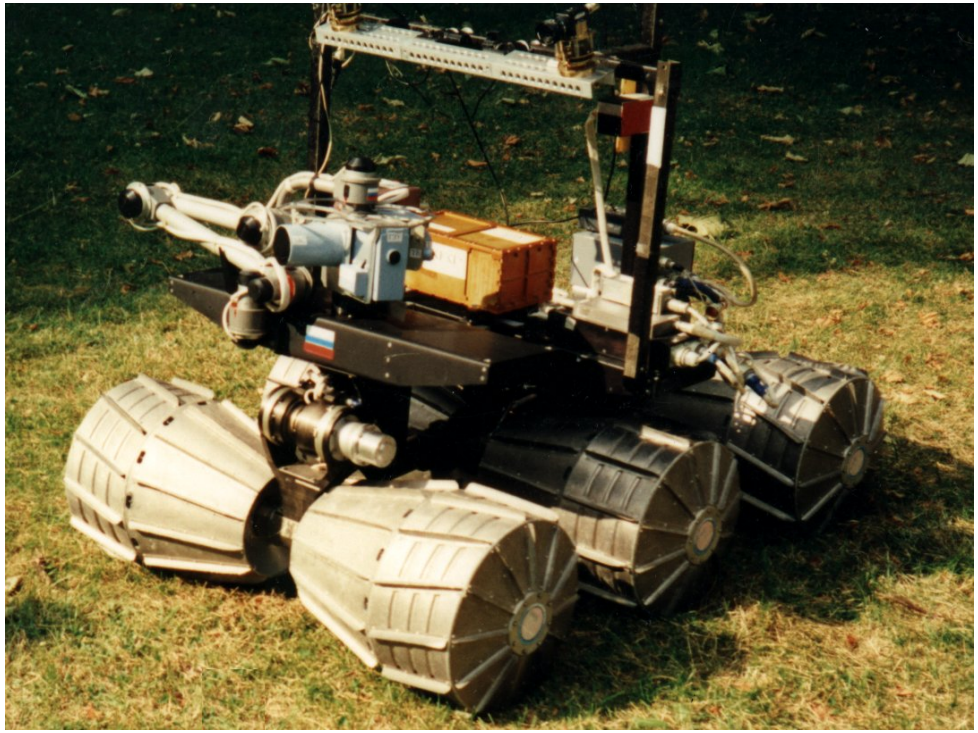
Running mock-up with inflatable wheels (1989)

Purpose: investigation of running characteristics of the propulsive device with large diameter inflatable wheels.



Chassis mass……..……95 kg.
Wheelbase……1600 mm
Wheel diameter……...1280 mm
Travel speed……0,15 - 0,9 km/h
Surmountable slope with loose soil ……33 degrees

Small Mars Rover running mock-up (1989)



The running mock-up was created within the framework of the "Mars-94" and "Mars-96" programs. The mock-up design contains technical decisions of the "Mir" mock-up.
The mock-up was demonstrated at 11 International Exibitions in the USA, Spain, Sweden, France, Germany, Korea, Taiwan.

The mock-up is awarded to silver medal at the 44th World Salon of Inventions (Brussels-Eureca-95).
Small Mars Rover mock-up
Mass……..……..70 kg
Wheelbase……..……....0.7-1.2 m
Wheel diameter……..0.35 m
Height of the surmounted obstacle……0.75 m

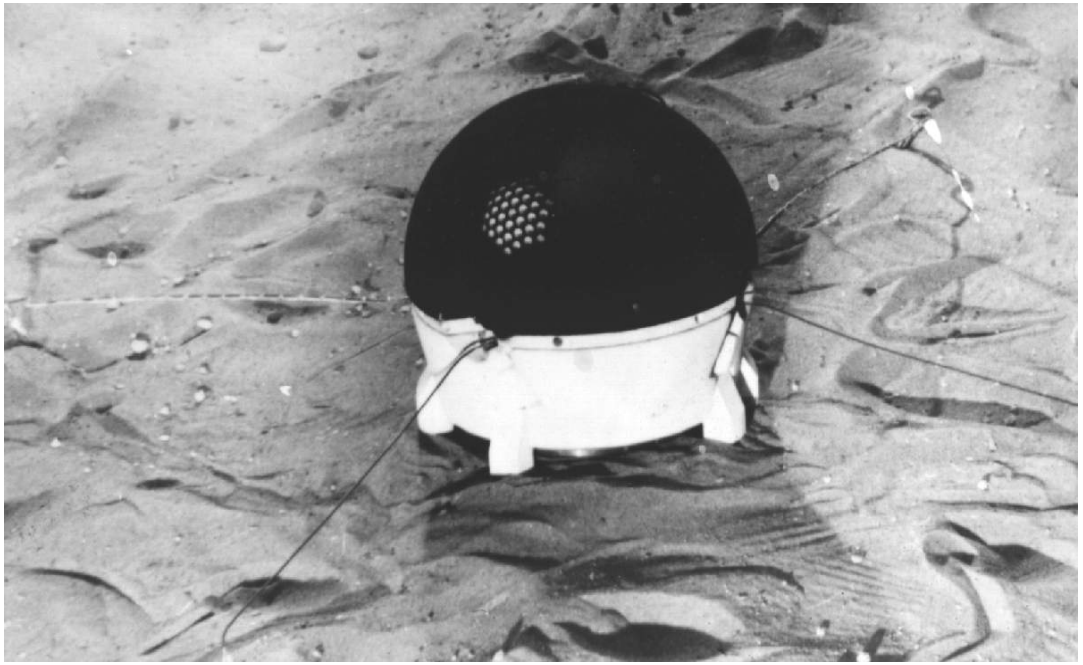
Mars Rover demonstrator (1990)

The Mars Rover demonstrator is the joint development and test of scientist and engineers of Russia, the USA, France and Hungary on the basis of the self-propelled chassis created of VNIITRANSMASH.

Tests on the Kamchatka volcanic terrain (Russia)

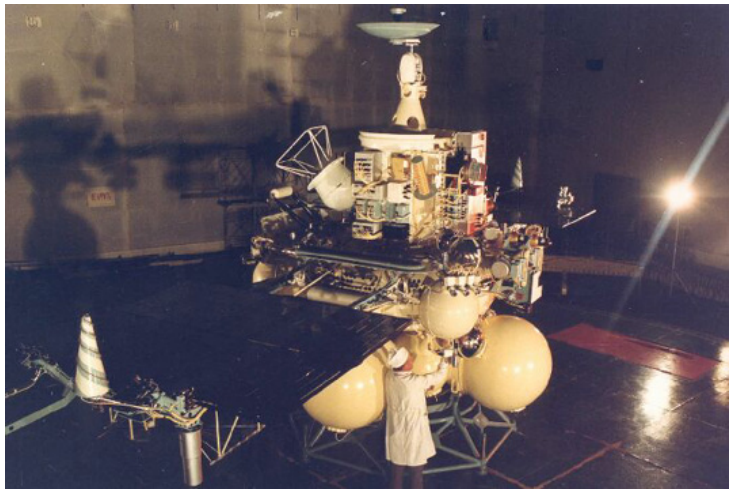
Tests in the Mojave Desert (USA)

"PROP-F" mobile (jumping) apparatus (1983-1987)



It was a part of the "Phobos-2"space station.
Purpose: delivery of scientific equipment set onto Phobos' surface including its transportation over a surface.
"PROP-F" apparatus is an automatic space station containing: the power source, radio-telemetric system, program unit, blocks of on-board automatic equipment, electromechanical jumping propulsive device, orientation system and scientific equipment set.

"PROP-F" mobile apparatus
Scientific equipment composition:
-automatic X-ray fluorescent spectrometer ("GEOHI" RAS);
- magnetometer ("IZMIR" RAS);
-gravimeter (SRI RAS);
-temperature-sensitive element (SRI RAS);
-unit for measurement of acceleration ("Biophispribor SKTB");
-soil electric resistance indicator (VNIITRANSMASH);
-dynamic penetrometer with a unit for soil sampling (VNIITRANSMASH)
Mass……45 kg
Amount of parameters transmitted……..18
Resource……3 hours
Customer: Lavochkin Association.

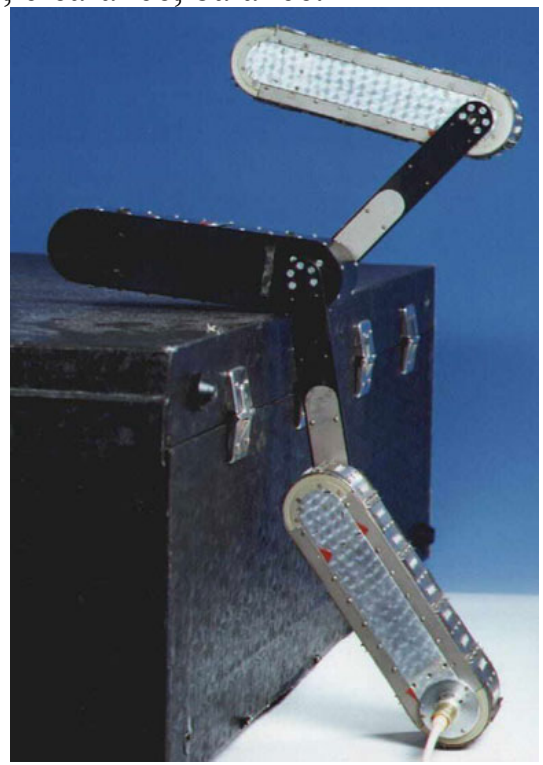


Earth-based demonstrator of three-sections Mini Rover (1992-1994)

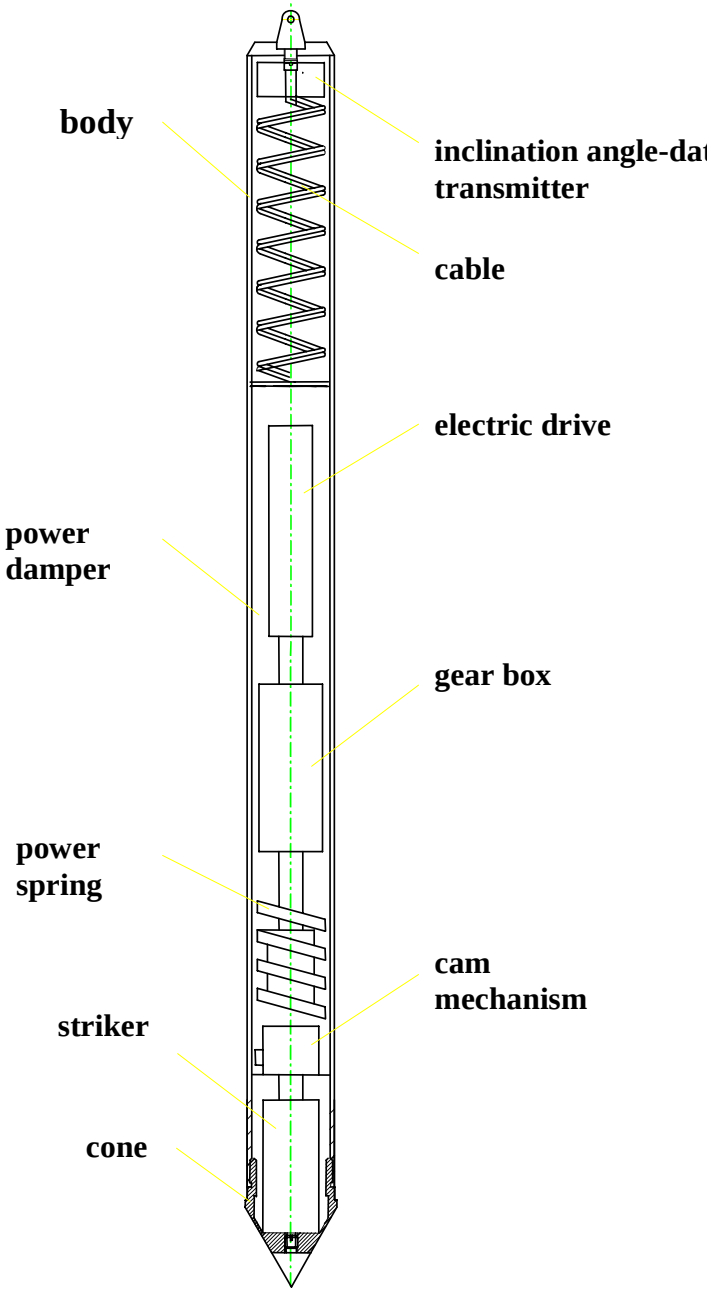
Mini Rover with the caterpillar propulsive device

Mass……..1.5 kg
Overall dimensions……..200x200x50 mm
Surmountable obstacles:
slope with loose soil……..29 degrees
slope with carpet path……..……up to 65 degrees
bench (height)……..…up to 300 mm
crack (width)……up to 300 mm
Customer: MPIC

It is the joint development with the Max Planck Institute fur Chemie (MPIC) (Germany).
The locomotion system consists of three sections connected with each other by means of levers having drives in the each section. It ensures rover motion with using caterpillar propulsive device, as well as walking mode of motion, and combined exact manoeuvring and positioning, change of the propulsive device configuration, clearance, balance.



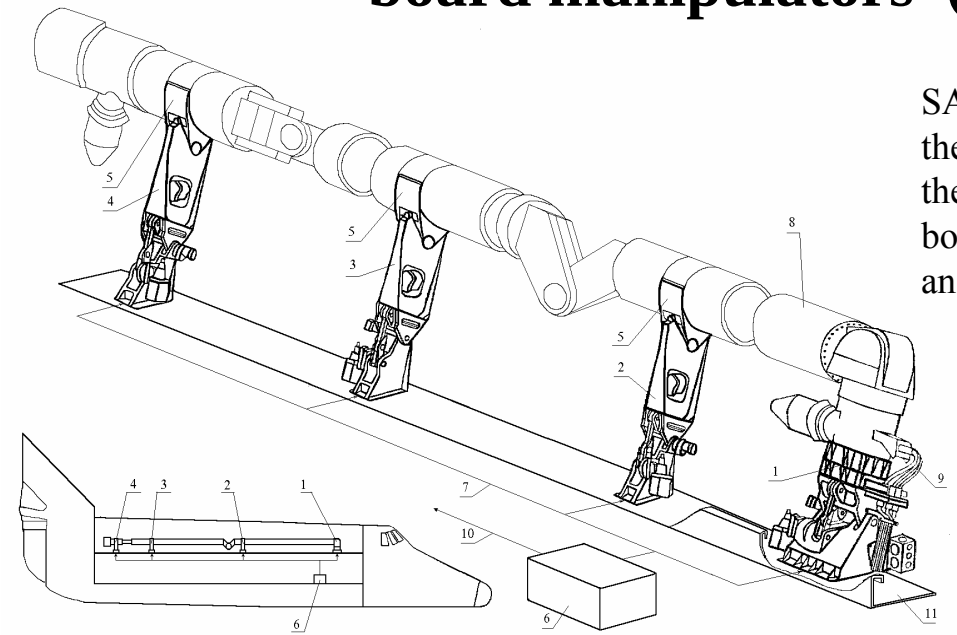
Small mobile penetrometer (1994-1996)



The penetrometer was created on the basis of the contract with DLR (Germany). The small penetrometer was supposed to be used for study of comets surface ("Rozetta" ESA project). Diminutive electric drives of the "Faulhaber Motoren" firm was used (they were de-buged at VNIITRANSMASH).

Mass…….0.4 kg
Length……..……325 mm
Diameter……...……19 mm
Penetration speed into sand……..2 mm per impact
Temperature interval……...……-190…+100^{0}C
Customer: DLR (Germany).

"Buran" orbital spacecraft system for attaching and deploying on-board manipulators (SADBM) (1983-1992)



SADBM was intended for mechanical and electric integration of the board manipulators with a glider load-carrying structure of the "Buran" orbital spacecraft and fixing-defixing of the on-board manipulator, as well as turn their into operating position and transport position.

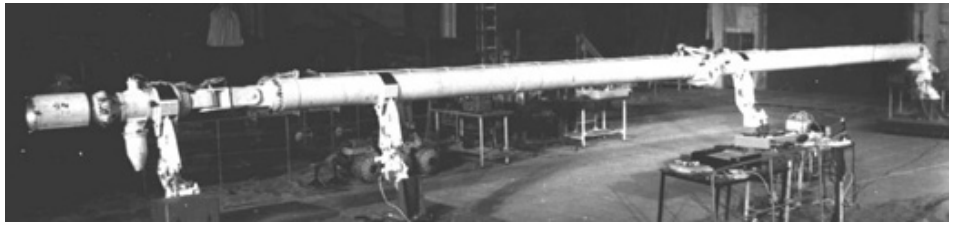
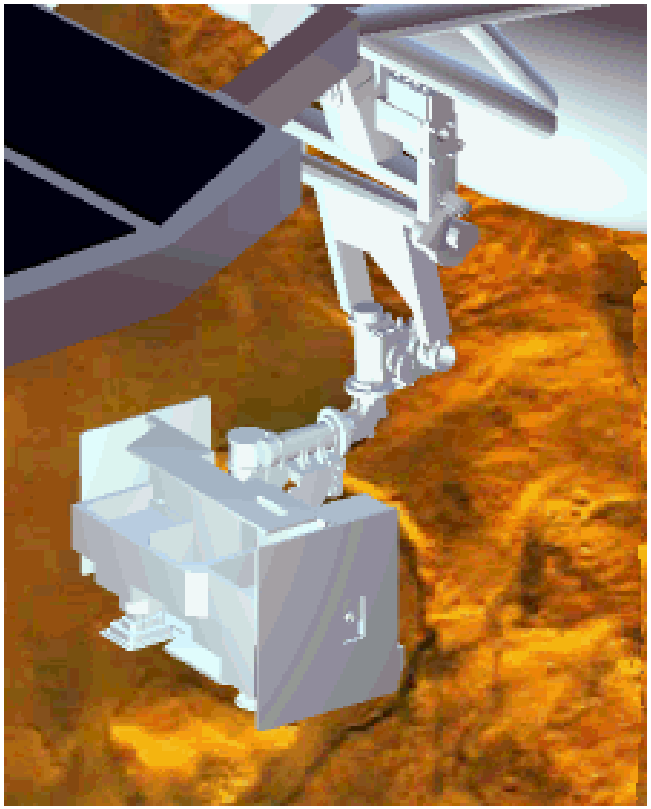
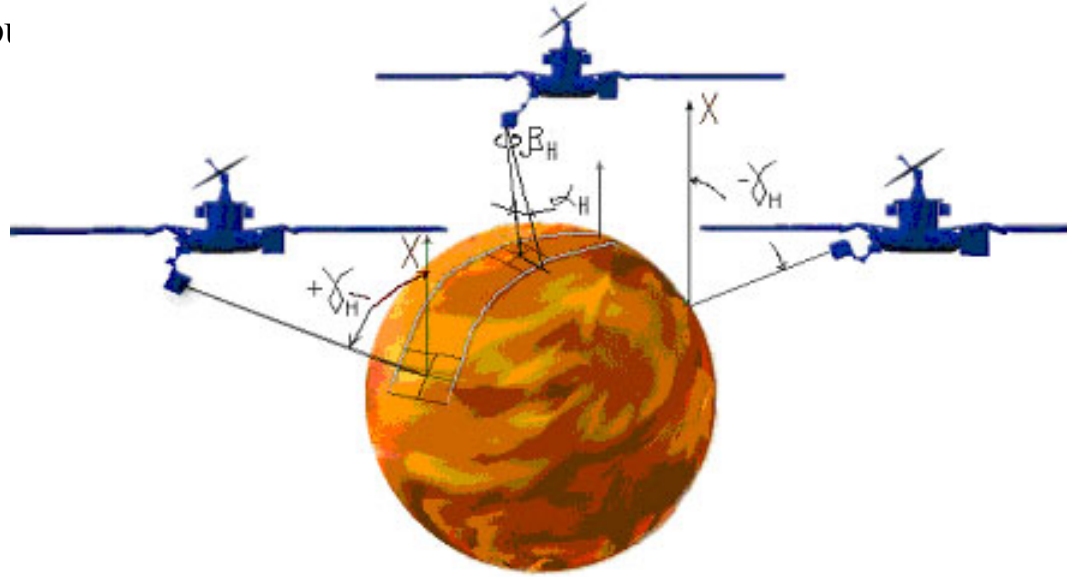


Fig. 1. Installation of ADS OBM support units and manipulator in payload compartment of orbital vehicle (a) and mechanical coupling of ADS OBM support units with the airframe boom and on-board manipulator (b):
1 – root unit, 2 – sholder support unit, 3 – elbow support unit, 4 – hand support unit, 5 – strap holders, 6 – ADS OBM control unit, 7 – on-board network, 8 – on-board manipulator (mechanical arm-TSNII RTK), 9 –transit cable of manipulator, 10 – communication with control complex of orbital vehicle, 11 – airframe longeron,
Composition: four supports (root assembly to which the on-board manipulator is attached and three beds which fix the manipulator at the transport position), control block and cable system.
SADBM mass ……..……..……..……..125 kg
Power consumption..……..……...……20 W
Temperature interval……..……-110…+160^{0}C
Resource……105 flights (100 hours)
SADBM passed all the complex of the Earth-based debugging and was presented to flight test as a component of the "Buran" orbital spacecraft.
Customer: RSC Energia

Three-axis stabilized platform (TAP) for the "Argus" complex (1990-1996)



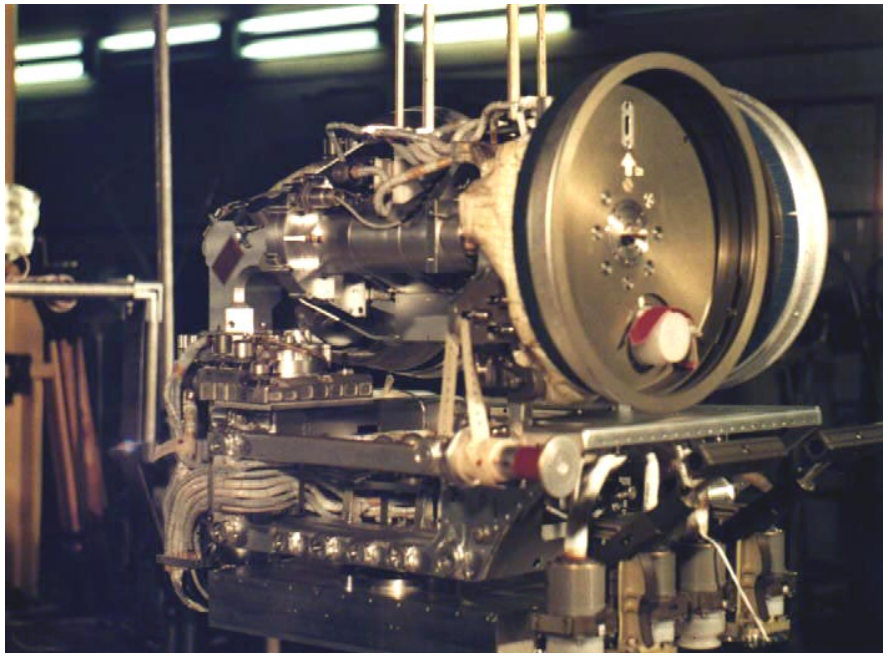
The TAP "Argus" was a part of the "Mars-96" space station.
Purpose: deployment of the scientific equipment block (SEB), its guidance at the surface of Earth and stabilization of position independently of a space station vibrations. Functions of stabilization and guidance are separated between two control contou



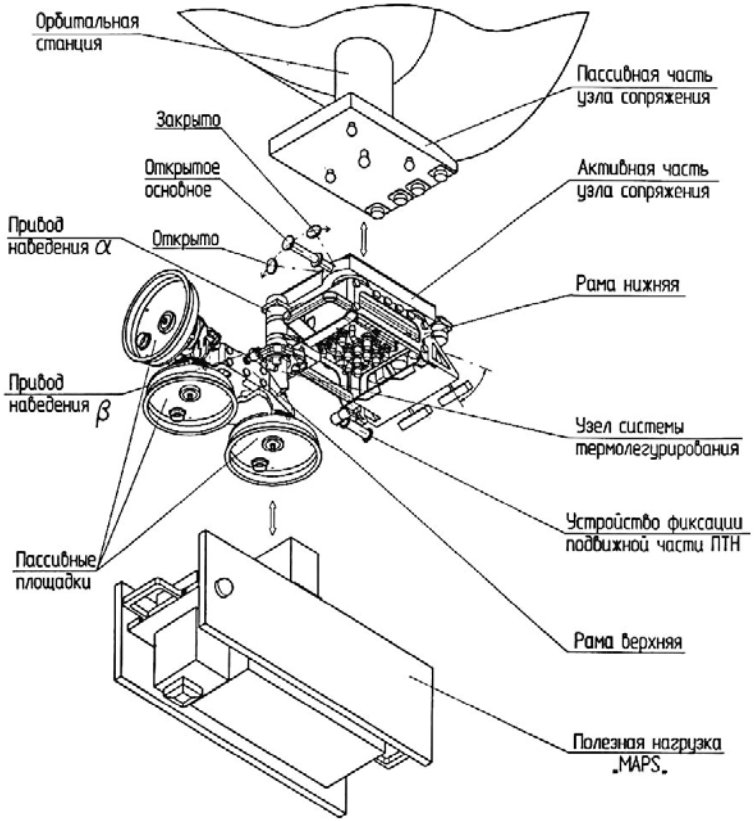
TAP "Argus" (without SEB)
Composition: the scientific equipment block (SRI RAS, Germany, France), mechanism of fixing and defixing with the space station, mechanism of carrying out SEB, three drives of SEB guidance, multiprocessor computing system (SRI RAS), gyroscopic block ("NIIPM").

TAP mass……..……115 kg
SEB mass……..……..84 kg
Accuracy of stabilization……..1.5 angular min (for the each axis)
Power consumption (average value)……..……..….80 W
TAP resource…….……..……..2000 hours
Customer: SRI RAS.

"PTN Orientator" platform of precise guidance (1996-1997)



Purpose: mechanical connection and electric mating of scientific equipment, developed by "Boing" firm (USA), with the board of the "Mir" orbital station("Spektr module) and at the same time to orient axis of sight to nadir.
"PTN Orientator"
The "Orientator" platform composition: two drives of guidance, unit of electric mating with the orbital station, units of connection with orbital station, units of connection with scientific equipment.



PPG mass……85 kg
Scientific equipment mass……112 kg
Maximum dynamic error of deviation
from the program trajectory, no more…..……..6 angular min
Power consumption (average value)……80 W
Resource……2000 hours
Customer: RSC "Energia".

"IARES-L" planetary rover chassis demonstrator (1993-1996)

Chassis demonstrator was created within the framework of the Eureka program.
Composition: six drive-wheels (DW), six drives for turning DW, wheel-walking mechanisms, mechanisms of longitudinal and transversal stabilization, as well as multiprocessor motion control system (joint development of VNIITRANSMASH and KFKI/RMKI, Hungary).

Mass of the demonstrator……150 kg
Mass of the chassis……80 kg
Overall dimensions…….1235x1200x730 mm
Amount of degrees of freedom……19 degrees of freedom including 17 controlled degrees
Surmountable obstacles:
bench (height)……..up to 500 mm
crack (width)……up to 500 mm
Travel speed at wheel mode……0.35 m/s
Power consumption……400 W
Customer: CNES (France).

"LAMA" chassis demonstrator (1994-1995)

Demonstrator was created by VNIITRANSMASH on the basis of the contract of Lavochkin Association with the Alkatel French firm. The contract objective was to develop Martian mission and Earth-based Mars Rover demonstrator.

Chassis composition: the hinge-articulated frame, six drive-wheels, walking mechanisms for the extreme axles.

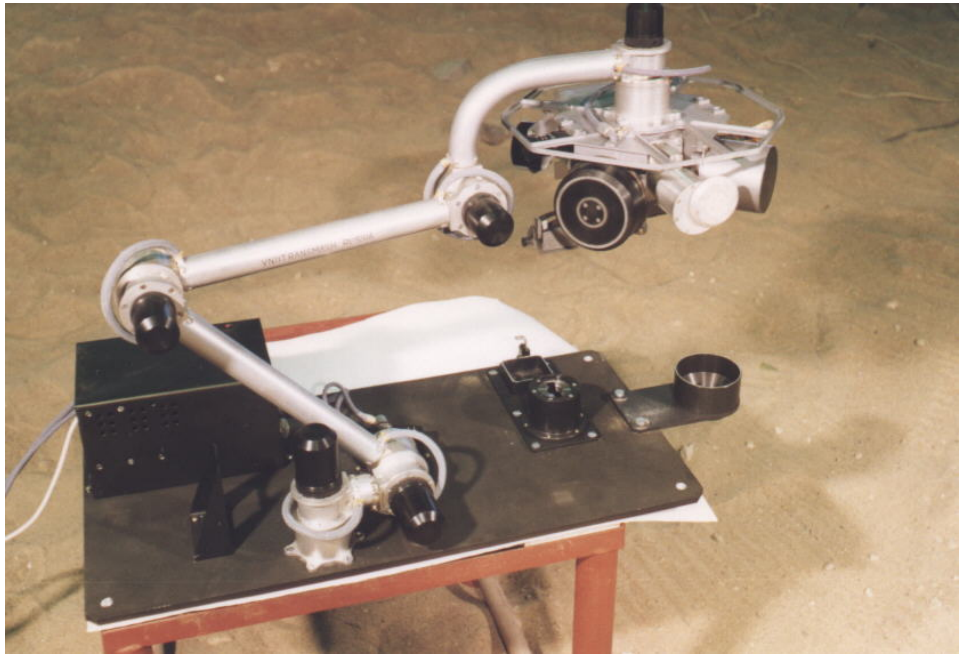
Mass……165 kg
Overall dimensions……..……..…….1650-2170x1220x524 mm
Payload…….……90 kg
Travel speed…….…….0.06…0.18 m/s
Mode of turning…….……side (tractor type)
Surmountable obstacles:
slope with loose soil……..25 degrees
bench (height)……..…up to 500 mm
Duration of motion with using storage batteries……..3.5 hours
Customer: Alkatel (France).

"LRMC" demonstrator (1997)

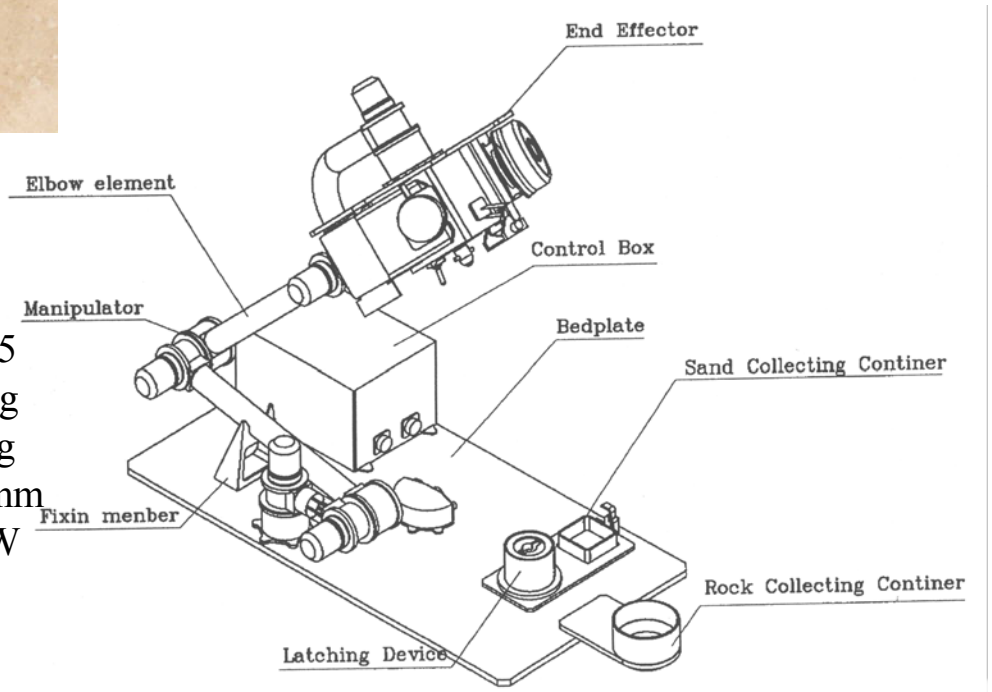
Wheel arrangement is 4x4. Wheels are turning with individual drives. The motors and gear boxes of the "Mackon" firm (Swiss) was used (they were de-buged at VNIITRANSMASH).

Mass (including two automobile storage batteries)……..120 kg
Payload mass……..……..……..60 kg
Overall dimensions……1200x900x525 mm
Maximum travel speed…….……0.38 km/h
Customer: European Space Agency (ESA).

"RRP" Moon Rover manipulator mock-up ("LEDA" project) (1997)



Purpose: the debugging of interaction of scientific devices and tools with surface investigated as well as control algorithms.
Composition: manipulator, plate with mock-ups of scientific devices and tools, control block.



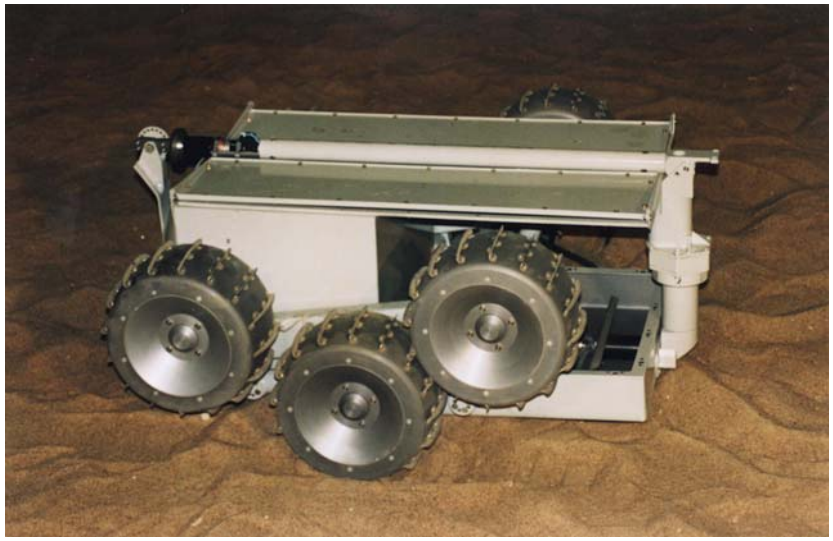
Amount of degrees of freedom……..5
Mass……..5 kg
Load-carrying capacity……1.5 kg
Accuracy of positioning……± 5 mm
Power consumption……2.3 W
Customer" ESA/ESTEC

Conception for an autonomous Mars rover (project COMARO)

The project was fulfilled in 1998-2000 by common efforts of the international team of scientists and specialists representing CNES and LAAS (France), MPIC (Germany), J.-St.Co. VNIITRANSMASH, Mechanics Institute of Moscow State University and Lavochkin Scientific and Production Association (NPOL) (Russia) with supporting of INTAS (International association on assistance to co-operation with scientists of the new independent states of former Soviet Union) and CNES.

Main peculiarity of the project is that the Mars rover is autonomous apparatus and is intended to operate at a large distance from a landing site that essentially increases effectiveness of scientific investigations.

- Mars rover total mass	50 kg
- Mass, kg, no more	19
-Power supply in the continuos mode, W, no more	10
-Power supply in the peaking mode, W, no more	25
-Maximum motion speed, km/h	0.2
-Angle of static stability, dg	40
-Slope climbed, dg	20
-Bench surmounted, m	0.35
-Ditch surmounted, m	0.4



System of robotics complexes SRTK

SRTK was developed in 2000 to order of the ITUTsR GP NIKIMT on the base of STR. In 2002 SRTK was equipped, in addition, with the active trailer.

Purpose: Radiation, dosimetric and visual reconnaissance, restoration works after accidents in the zone subjected to radioactive contamination, clearing the terrain and rooms from radioactive waste and soil, transportation of technological equipment, tools and reservoirs with materials having radioactive contamination.

SRTK composition:

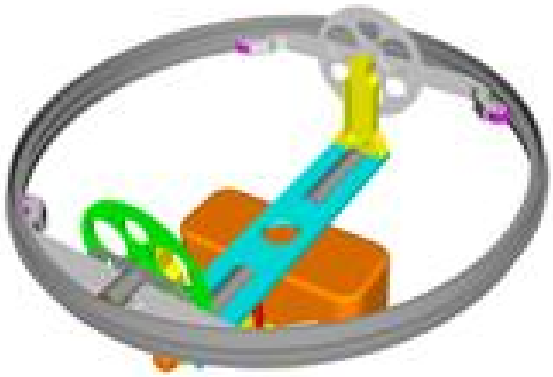
-mobile apparatus KRT-100M, equipped with the bulldozer blade, dosimeter, coupler for evacuation;

- mobile apparatus KRT-200M, equipped with the bulldozer blade, dosimeter, coupler for evacuation, manipulator, support assembly with changeable tools;

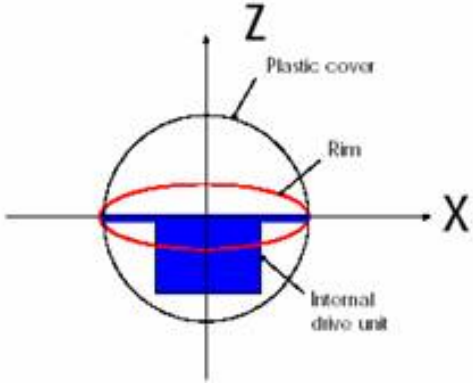
-two mobile control stations PPU-1 and PPU-2 on the base of cross-country automobiles with the bodies KUNG;

-active trailer for the KRT-100M.

Ball-shaped robot



Functional principle

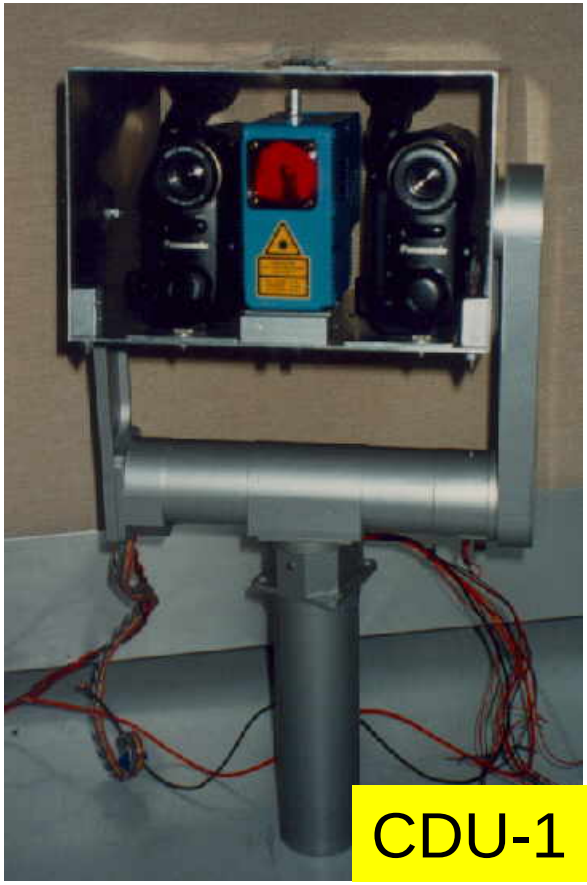


3D model of IDU-5

The ball-shaped robot principal technical data are the following:

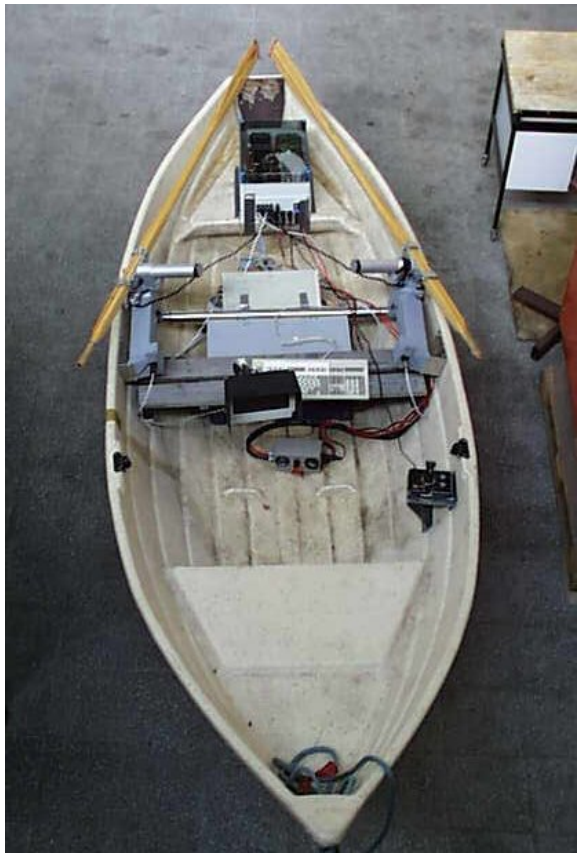
-cover internal diameter, mm	240/300
-maximum mass/ IDU mass, kg	3/1.5
-speed of motion on an even horizontal surface, m/s, no less	0.5
-supply direct voltage, V	12
-capacity of a storage battery, A h,	1.5

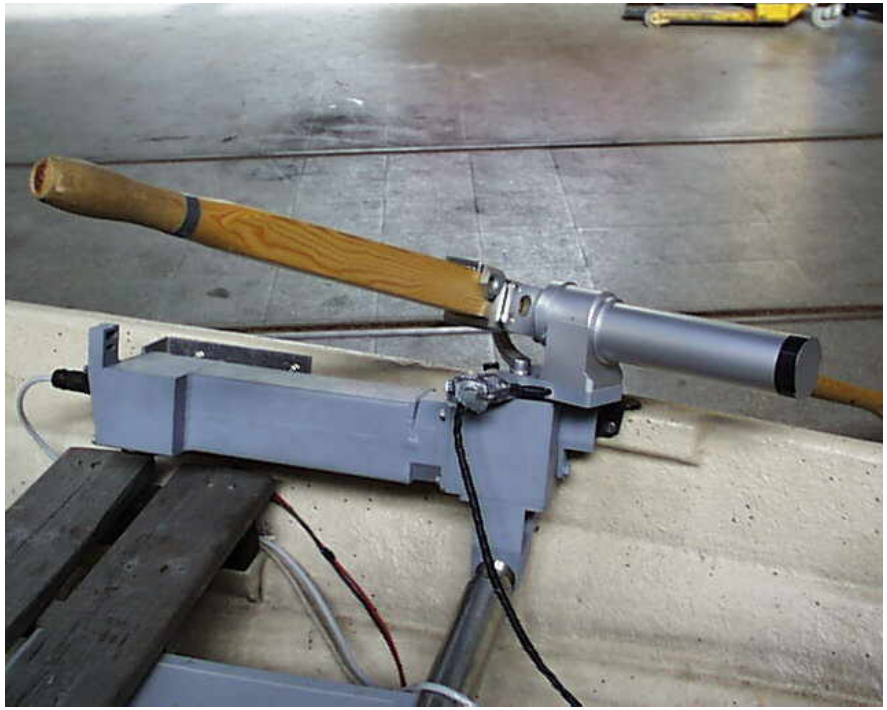
Steering/turning platforms for the on-Earth mobile robots



Parameter	CDU-1	CDU-2
Mass, kg, no more	4	2.1
Overall dimensions, mm	241 x 243 x 155	150 x 200 x 150
Angle of rotation, degree		
horizontal plane vertical plane	180 (+-90) 120 (+-60)	360 (+-180) 180 (+-90)

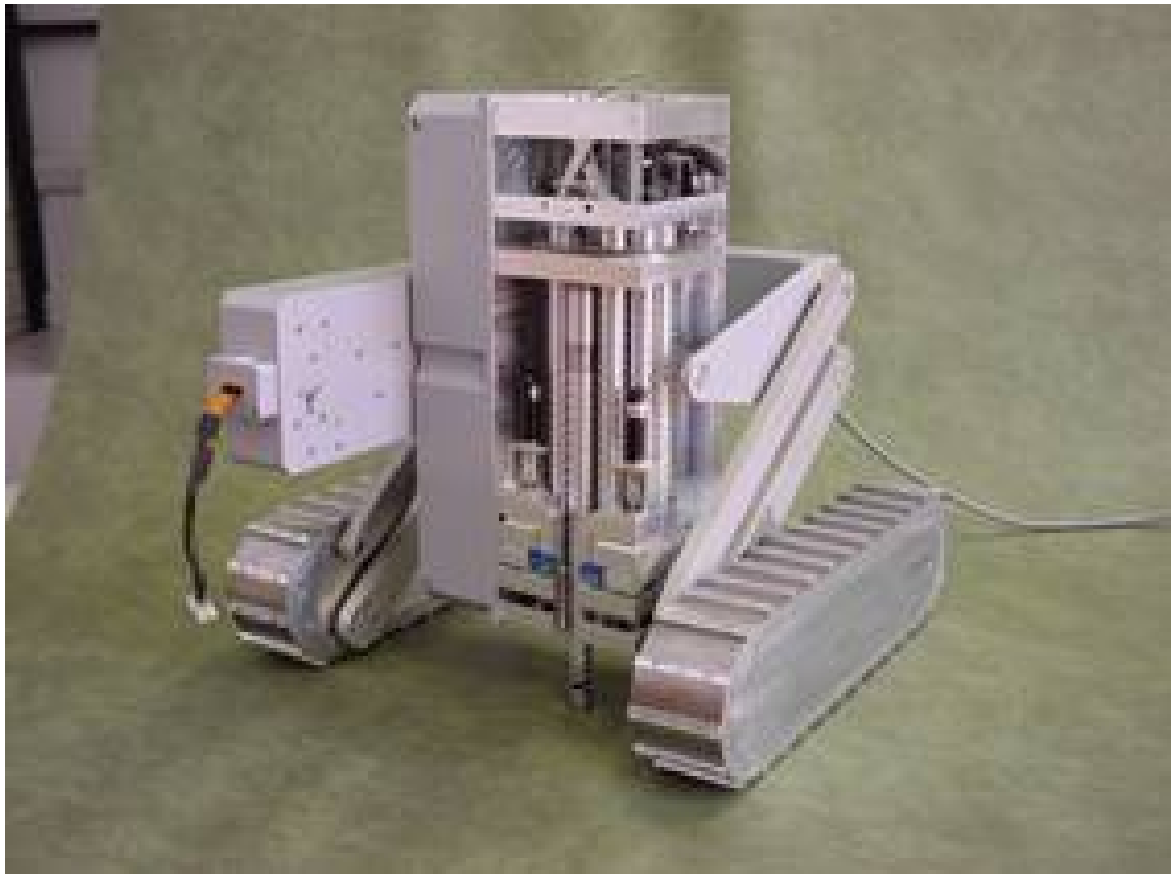
Oar-rowing robot (Robotics boat)

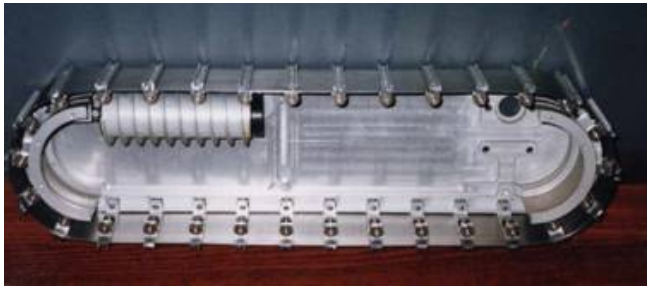




-Boat type	**Small standard 4 m rowing boat**
-Mass without equipment	**70**
-Total mass with equipment	**210**
-Velocity (calm water, mass-285 kg), km/h	**1.8-2.0**
-Length of oar, m	**2.2**
-Main motor:	
nominal power, W	**250**
gear ratio	**92.7:1**
-Lifting motor	
nominal power, W	**70**
gear ratio	**216:1**

Track locomotion system for the micro robot RoSA-2

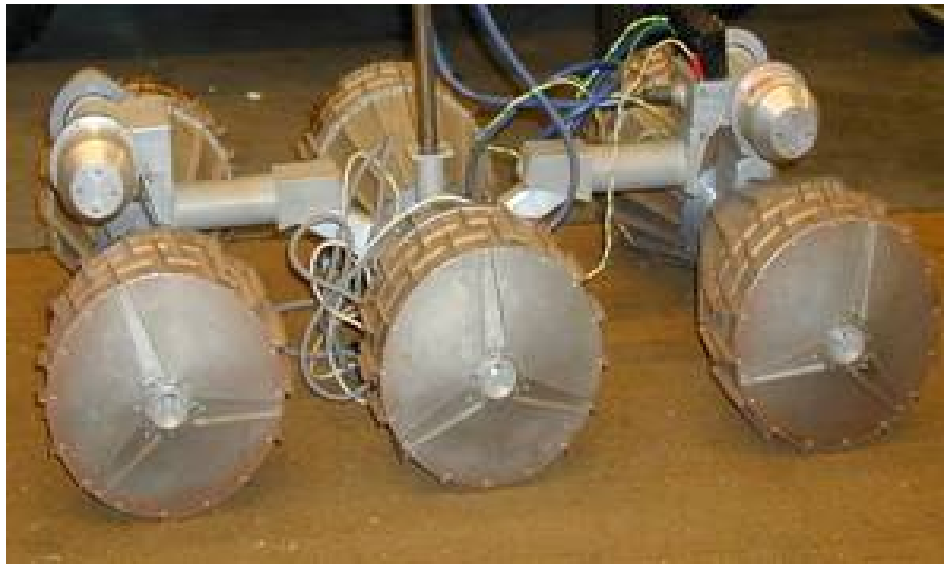




The locomotion system has the following main characteristics:

-maximum motion speed on the horizontal surface, m/h	60
-mass of chassis/ payload mass, kg	5/7
-overall dimensions (LxWxH) in stowed position, mm	400x400x110
-slope climbed (with minimum clearance), degr.	up to 30
-obstacle surmounted (with minimum clearance), mm	60 (height)
-cable length, m	40

Wheeled chassis JRover for the planetary rovers.



-Mass of chassis/, Payload mass, kg	**30/30**
-Dimensions (length x width x height), m	**Variable: 0.8-1x0.65x0.4**
-Step length, m	**0.1**
-Drive:	
motor	**Maxon DC motor RE 118798, d=36mm**
gearhead	**Planetary gearhead 110407, d=42mm**
-Drive number	**8**
-Position sensor in hinges and mechanisms for walking:	
type	**potentiometer**
resistance, Ohm	**4.7**
Motor velocity-type transducer	**Digital encoder HP HEDS 5540**
Motion speed on a horizontal rigid surface, km/h	**1.2**
Storage batteries capacity, Ah	**0.7**
Obstacles surmounted:	
loose soil slope, dg:	
wheeled mode/ wheel-walking mode	**20/30-32 (angle response)**
separated rock (height),m/vertical obstacle, m	**0.35-0.55/0.35-0.55**

Walking locomotion system Hybtor for the mobile service robot WorkPartner

Main parameters of the platform are the following:

-Dimensions (length x width x height), m	1.4x0.4x0.5-1.2
-Motion speed on a horizontal rigid surface, km/h	7.0
-Mass, kg	200
-Payload mass, kg	60