Polish penetrator to retrieve samples from the Martian moon Phobos

CHOMIK Heading for Mars

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The Fobos-Grunt probe (its Russian name meaning "Phobos-Soil") will begin its journey toward Mars in November 2011, carrying the unique geological penetrator CHOMIK developed at the Space Research Centre, PAS. Its task will be to collect sample from the larger of Mars' two moons – Phobos

For over a decade, the Space Research Centre, PAS has specialized in the construction of self-driving hammer penetrators intended for research and exploration of bodies in the Solar System. Hammer drive penetrators are among the most complex space instruments. Their design is made highly difficult by the need to pack precision mechanisms densely into a small space, by their impact-based mode of operation, which places great strain on the materials used, by the specific principles of operation in microgravity, and lastly by the extreme environmental physical conditions under which they have to work.

Penetrators – a Polish specialty

The first penetrator developed in Poland, called MUPUS (Multi-Purpose Sensors for Surface and Subsurface Science), was launched in February 2004

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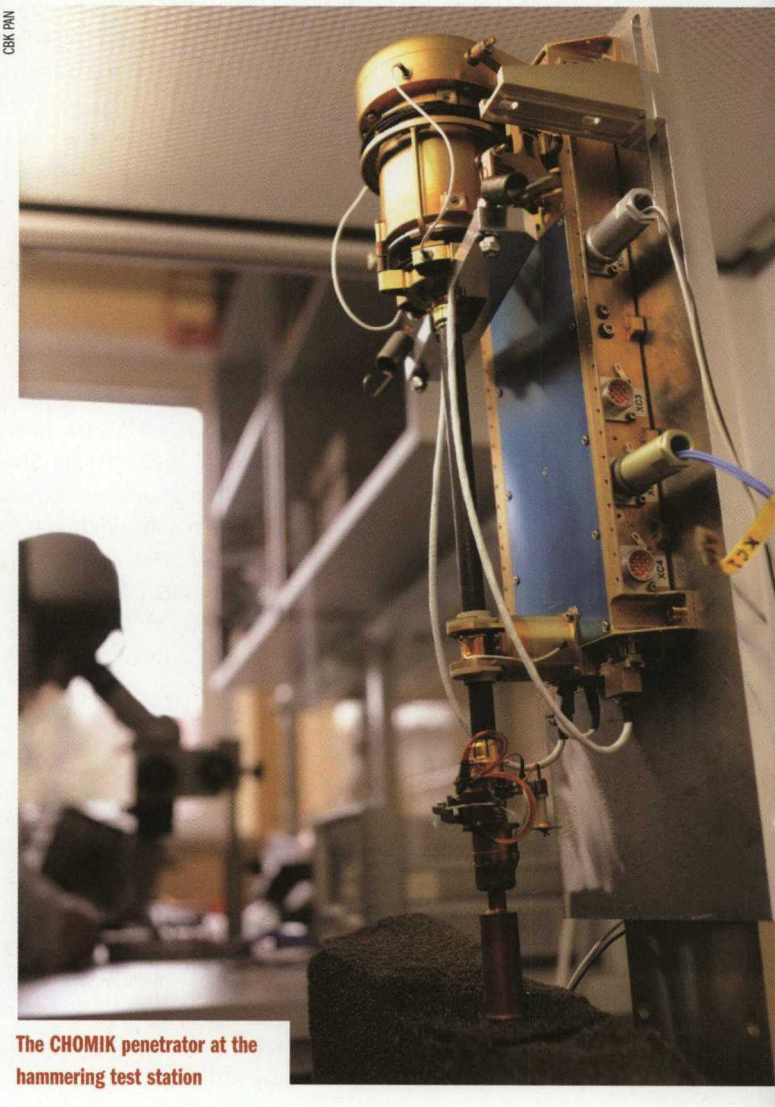
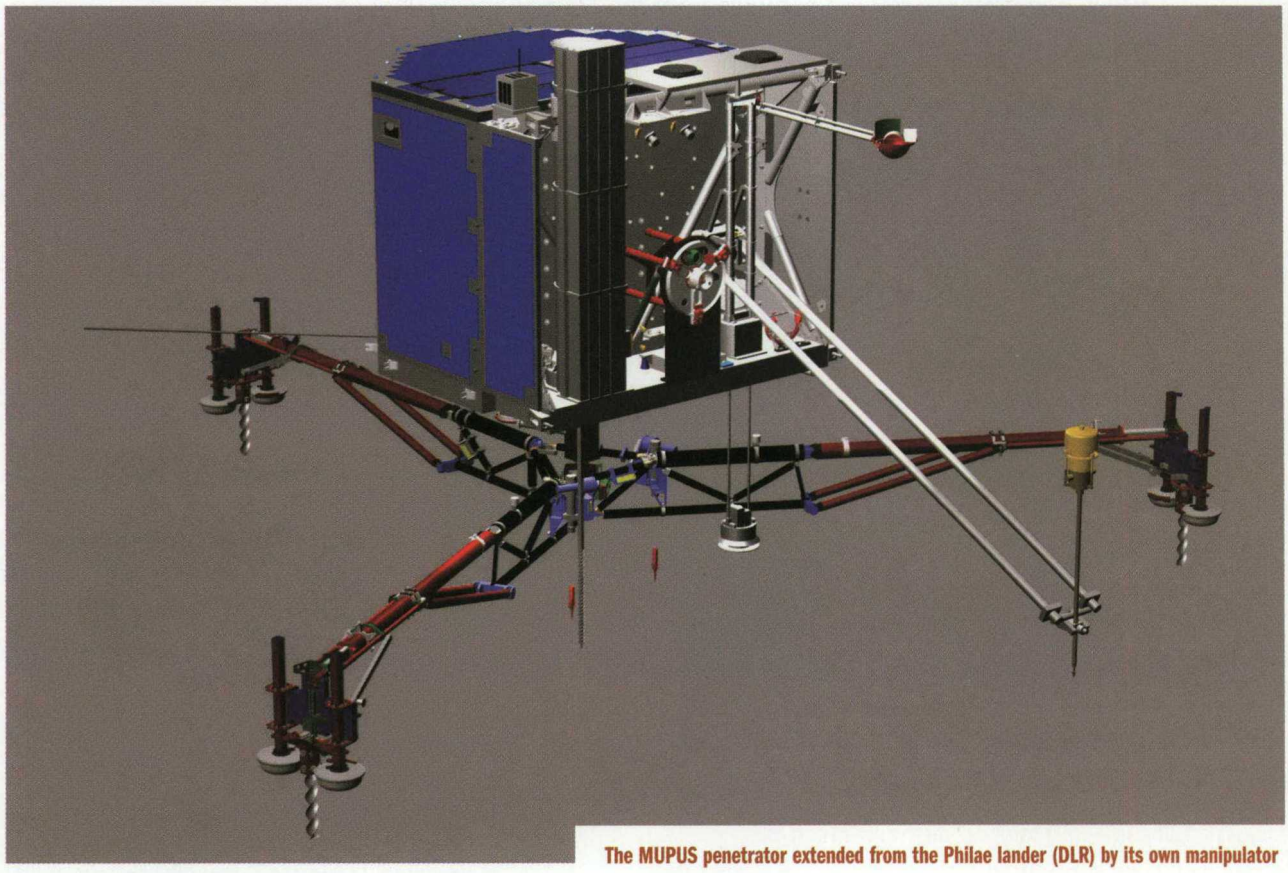


The CHOMIK penetrator at the hammering test station



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The MUPUS penetrator extended from the Philae lander (DLR) by its own manipulator

aboard the Philae lander on the Rosetta mission to the comet 67P/Churyumov-Gerasimenko, classified by the European Space Agency (ESA) as a prestigious cornerstone mission. MUPUS' hollow rod contains a set of sixteen thermal sensors, which, after sinking to a depth of about 40 cm, will determine the thermal profile and thermal conductivity in the subsurface layers of the comet's nucleus. Analysis of the drilling itself, in turn, can provide valuable information about the mechanical properties of the soil. MUPUS will operate on the comet in 2014.

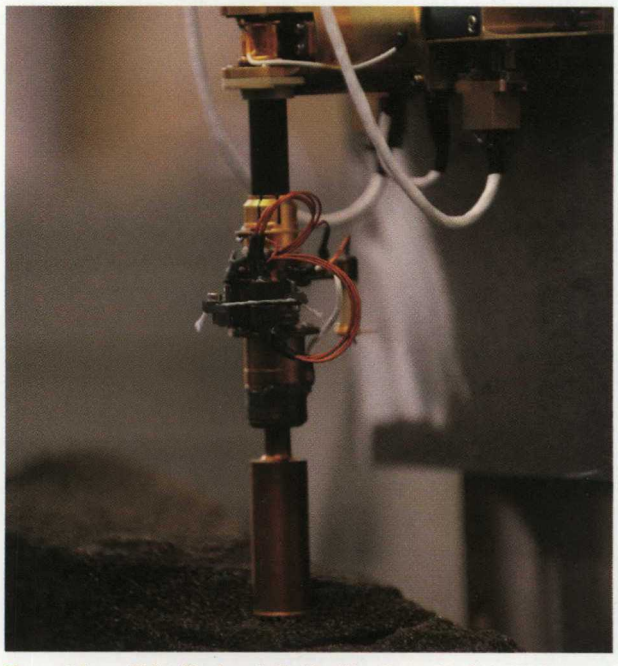
The challenge for engineers is to make the depth of drilling independent of the length of the rod, resulting in the design of two models for KRET-type penetrators ("kret" being the Polish for "mole"). These devices are characterized by high impact energy: 2.2 joules and 3.5 joules. During tests, the lower impact energy model demonstrated an ability to hammer to a depth of 5 meters in material with properties identical to the layer of weathered rock covering the Moon, i.e. lunar regolith.

As a result of the successes of Polish penetrators, scientists of the Russian Federal Space Agency approached the Space Research Centre, PAS with the proposal that they build a penetrator which would carry out the primary objective of the Fobos-Grunt mission: to sample soil from the surface of the Martian moon, if necessary in hard, rocky ground. These burrowing properties have earned this new, unique geological penetrator the name CHOMIK (the Polish word for "hamster").

The Fobos-Grunt mission

One of the most important tasks for the Fobos-Grunt mission is to collect samples from Phobos' surface to be delivered back to Earth. According to the latest plans, the probe will be launched in November 2011 onboard a Zenit-2 launcher. It is due to enter Mars' orbit six months later, with the landing scheduled for early 2013. A month later a return module with a capsule containing soil samples enclosed in a Polish-made container will be launched back towards Earth. The return capsule and container will weigh around 11 kg, and should land in Kazakhstan in mid-2014. Under an agreement between the Russian Space Research Institute, the Lavochkin Research and Production Association in Moscow, and the Space Research Centre, PAS in Warsaw, Polish researchers will form part of the international team who will analyze the material from Phobos. More than a dozen Polish researchers and specialists from the Space Research Centre, PAS, from the Institute of Geological Sciences, PAS in Warsaw and Wrocław, and from the company Astri Polska are working on the mission. The lander will remain on Phobos, where it will continue studying the Red Planet's surface.

Phobos is an irregular object of relatively low density, measuring around 27x22x18 km. Its escape velocity is relatively close to the speed of a sprinter, which makes the landing and takeoff maneuvers relatively simple to conduct. Phobos is similar to objects from the fringes of the Solar System, forming the Kuiper Belt beyond the Neptune orbit. The satellite orbits Mars at a distance



The container which will return to Earth with soil samples from Phobos

of just 9400 km - in contrast, our own Moon is 40 times further away from the Earth. This proximity and absence of an atmosphere make Phobos an ideal base for observations of Mars itself, with the planet filling up to a quarter of its horizon. Phobos' low average density (1.87 g/cm3) so far remains a mystery. It has been interpreted as a result of high porosity, although it may also indicate a high ice content. The most recent photos of Phobos' surface show it to be covered in regolith - a layer of weathered rocks. The moon's origins remain unexplained; early spectrometric data indicate that it has properties typical of a C/D type asteroid, suggesting that Phobos may be an asteroid captured by Mars into its planetary orbit. However, a competing hypothesis suggests that the moon was formed already in the Red Planet's orbit. Measurements taken by the CHOMIK penetrator and analysis of the soil samples it collects should help unravel the mystery.

How does it work?

CHOMIK is a complex space instrument with a low mass (1.4 kg), fully designed and constructed at the Space Research Centre, PAS. It features three main subsystems: the penetrator itself, control electronics, and a lock-and-release mechanism. The penetrator comprises a driving mechanism and rod with a container at the end, capable of holding a few cubic centimeters of soil. The driving head is based on an electromagnetic drive tried and tested on the MUPUS penetrator.

The penetrator is to be hammered into the surface under low gravitational conditions, and this demands that the lander should be subject to reaction forces no greater than 3 Newtons. However, CHOMIK's hammering power can reach as much as 500-1000 Newtons. As such, in order to ensure low reaction force values, a linear overload coupling has been used between the rod and the manipulator, as well as a flexible suspension of the device's counterweight in relation to the rod, providing a dynamic support. This allows CHOMIK to work safely alongside the lander; at the same time its high impact energy will allow it to collect samples even if the surface turns out to be rocky and too hard for other sample-collecting tools. Another important feature of CHOMIK's drive is a separate mode of operation with a reduced impact force, which will be deployed automatically if the surface is too loose. Once the container is filled with soil, it will be removed and delivered to the central soil container by the manipulator. The sample container will be discarded, revealing a sharp mandrel, which will crush hard rock in order for it to be collected by other instruments on the lander. Next to the mandrel there are two specially designed thermal sensors for registering the thermal properties of Phobos' soil. Mechanical properties of the soil will be assessed with a potentiometric depth sensor, transmitting information on displacement at each strike of the hammer.

As has been the case for all instruments used in space missions, CHOMIK underwent a series of thorough tests carried out on four models of the instrument: a structural and thermal model, two engineering and qualification models, and a flight model. Following good results of the vibration and shock tests, the CHOMIK was subjected to its most difficult trial: thermal and vacuum tests, which showed the instrument functioning correctly at temperatures below -100°C.

The CHOMIK penetrator has been recently integrated with the manipulator and awaits the launch of the Fobos-Grunt mission in November 2011. ■

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The MUPUS device

Further reading:

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