September 2011

AEROSPACE AMERICA

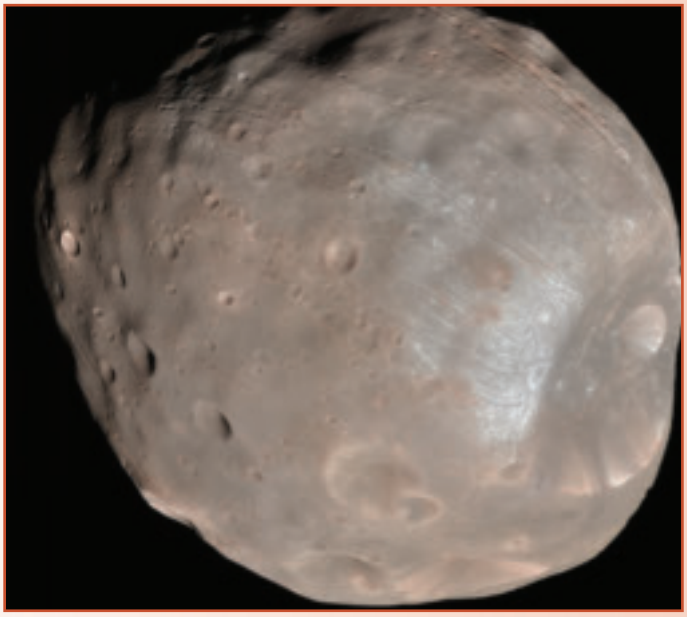
WINGS OF GOLD

One hundred years of U.S. Navy air power

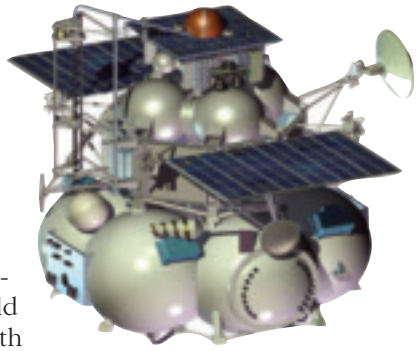
Launch vehicles: A worldwide roundup

A PUBLICATION OF THE AMERICAN INSTITUTE OF AERONAUTICS AND ASTRONAUTICS

Russian lander to head for Martian moon



Russia will soon launch an unmanned spacecraft to land on the Martian moon Phobos and return a sample of its soil and rock to Earth. Scientists will study the sample for signs of life on Mars, which bombards its moons with debris. The mission has breathed new life into the country's planetary science programs, which had fallen into decline in recent decades. If successful, the effort could add significantly to scientific understanding of the solar system as well as Mars and its moons.



Flight elements of the Phobos sample return include the orbiter/lander that will orbit Mars and match orbits with Phobos until landing is possible. The drilling rig is at left. Atop that is the return vehicle that will fire back toward Earth carrying the descent module with soil and rock samples that will land in 2014.

Russia, which has not flown a successful planetary mission in 30 years, is about to launch an unmanned spacecraft to the Martian moon Phobos to collect rock and soil samples and return them to Earth by 2014.

Also on board will be a small Chinese piggyback satellite to be released into Martian orbit as China's first mission to Mars. It will take images and atmospheric readings.

The Russian mission is set for launch toward Mars from the Baikonur Cosmodrome on board a Zenit rocket around November 8. Two weeks later, on November 25, NASA's Mars Science Laboratory (MSL) rover Curiosity will take off from Cape Canaveral on an Atlas V.

Diverse goals

Russian mission managers hope to score several firsts, the most important of which is the first round trip from Earth to Mars orbit, with a stop on the Martian moon Phobos to gather the samples.

Although the Russian and U.S. flights are designed to do totally different things, they both have important tasks to perform. One goal of the Phobos mission, the robotic return of rock and soil samples, could lead to the discovery of life on Mars. Martian meteoric impact debris has blasted the planet's moons and is sure to be part of any Phobos sample return. And the MSL, which will remain on the surface of Mars, has a powerful suite of instruments capable of characterizing organic carbon that could have been part of past life.

Phobos samples could also put into context the formation of Mars and its moons, helping to scale the formation of the solar system. The samples could make a major contribution to characterizing Mars.

If the mission is successful, the samples will be returned to Earth in 2014, landing at Russia's Sary Shagan missile test center, where advanced radars can track objects approaching from space.

The Russians have quietly sounded out American officials on using U.S. territory for a landing. But political hurdles involving planetary protection could arise—especially if a sphere with samples ruptures over U.S. territory—and will likely keep the target site in Russia.

The Phobos sample return will take place some 20 years before NASA and ESA can return a much more significant sample of Mars rock and soil. A later rover, the NASA Max-C, is set for launch in 2016 and will select Martian samples for later pickup by ESA and NASA spacecraft.

New life for planetary programs

The former Soviet Union, which launched dozens of successful deep space probes in the 1960s through the 1980s, has not flown a fully successful planetary mission of any kind since the 1984 Vega-2 Halley's Comet/Venus mission. And it has launched no successful lunar or Mars missions in 30 years.

In 1988, Russia launched two missions to Phobos, hoping to drop small one-way landers onto its surface. But a software uplink problem led to the loss of Phobos 1, and Phobos 2 died because of an onboard computer error while maneuvering toward the roughly 16x14-mi. moon. The country's robotic Earth orbit and deep space science program has been largely suspended since the mid-1990s in the funding crisis that followed the collapse of the USSR.

Although tiny, Phobos holds great interest for those seeking to understand Martian history as well as the nature of planetary moons and asteroids. Some scientists believe Phobos was formed from material knocked off Mars, and that samples could be genuinely Mars-like. Others think it is a captured asteroid and could instead provide data on those ancient bodies—although it does not much resemble other asteroids seen so far.

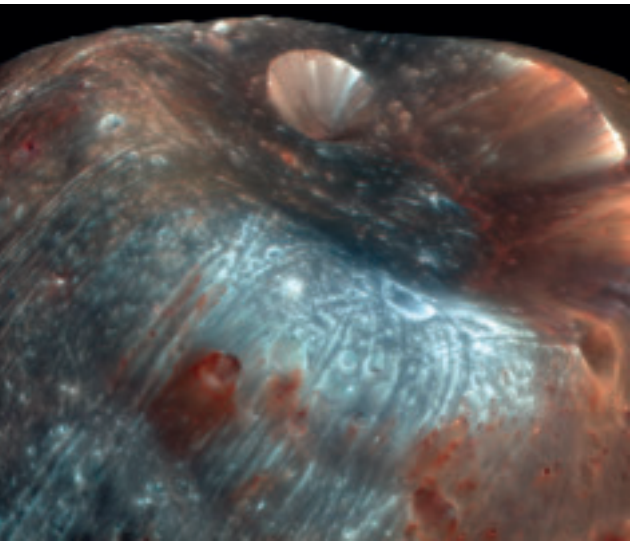
The spacecraft is being completed at NPO Lavochkin, near the Sheremetyevo airport in Northwest Moscow. The facility employs 5,000 people and is Russia's primary Earth-orbit and deep space science development company. It has 40 years of plane-

by Craig Covault
Contributing writer

tary mission experience including 15 successful flights to the Moon.

Lavochkin is beginning to reenergize its robotic capability for both lunar and Mars missions. The company has been tapped by the Russian government to lead all future robotic planetary development. The largest project in development is the Phobos mission, for which the Russian Space Research Center (IKI) is designing the sensor suite.

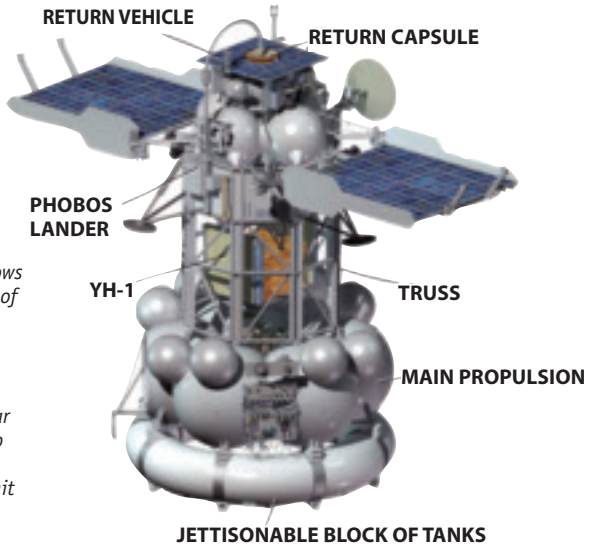
An ESA Mars Express image of 5.6-mi.-diam Stickney crater on Phobos shows the largest feature on the Martian moon. Scientists believe the brightest material is younger, with the many streaks on the crater rim indicative of landslides and even major fallout of Martian material blasted loose by meteorites.



In addition to the lunar and planetary missions, Russia is currently completing development of several new astrophysics and other Earth-orbit spacecraft, many of which involve IKI and Lavochkin.

Mission and spacecraft design

The spacecraft consists of three stacked vehicles. The lowest vehicle will be the propulsion and systems bus for the trip to Mars, as well as the launch pad for the return spacecraft. It will then serve as a long-life science station on the surface of Phobos, equipped with about 20 science instruments and a drilling-rig/manipulator mounted on the side. The rig has a tube mechanism to transfer the sample up the side of the cruise/lander, past the Earth return spacecraft and into the Earth descent module.



Launch configuration shows the complex integration of multiple flight elements, including the propulsion modules. Extra fuel and component weight contributed to a two-year launch slip from 2009 to 2011 and a shift to the much more powerful Zenit booster instead of the Soyuz. The Chinese YH-1 Mars orbiter box is tucked midway in the truss.

After launch from Earth, the combined vehicles will spend 11 months in transit to Mars. The triple-deck spacecraft will be inserted into Martian orbit, where it will provide imagery and data on Mars and Phobos.

Several weeks later it will be maneuvered to fly in formation with Phobos. After extensive imaging to find a suitable landing site, the spacecraft will be maneuvered to make a gentle landing on the moon. Because Phobos has such minute gravity, the Russian lander could bounce off the moon at touchdown or drift away during surface sampling. To prevent either event, up-firing thrusters to hold the lander down onto the surface will be fired until harpoon-like anchors are spring ejected from the landing pads to physically secure the spacecraft to the surface.

The same side of Phobos always faces Mars. Science managers want to land on the Mars-facing side, because debris blasted at it from the Martian surface may have a greater chance of being sampled there. Such a landing site would also allow continuous observation of Mars from about 5,800 mi. away. But landing there also poses more risk for Earth communications and for spacecraft temperature control. Although the question is still open for review, it is likely the landing will take place on the side facing away from Mars, in the terminator area, where it can still see the planet but can also benefit from some shading.

Once the spacecraft is on the surface, its first major task will be to image the stars and Sun to update its navigation platform for an accurate Earth return maneuver.

The cruise/lander stage will also begin imaging the surface under the lander to pick a spot for sampling. The drilling rig will be able to swivel several degrees left or right to choose a spot suitable for both soil and rock specimens.

Sampling plans

The drilling and sampling process will require three to four days. The objective is to obtain 200 grams. The amount is not as important as getting below the surface and also finding at least one small stone. Preserving the integrity of the core sample is also desirable, to show layering.

The return spacecraft with the sample sphere will then be ejected off the top of the lander into its own orbit around Mars. Its small rocket engines will be used to

send the vehicle on an Earth return trajectory with the sample sphere riding on top.

A 2009 launch had originally been planned for the mission, but several instruments were not ready, especially the critical sampling mechanism. Managers decided to delay the launch until this year to fix this and address other problems.

According to Anatoly Shilov, deputy director of Roscosmos, the Russian Academy of Sciences realized that the planned sampling system was not powerful enough for the possibly hard surface or the team's desire to have rock samples. It was the same kind of system featured on the three unmanned sample devices used on Earth's Moon, with a tiny auger-type component that moved material into a flexible tube placed in the Earth return device. It also had the potential for overturning the lander during operations in the extremely weak gravity on Phobos, managers say.

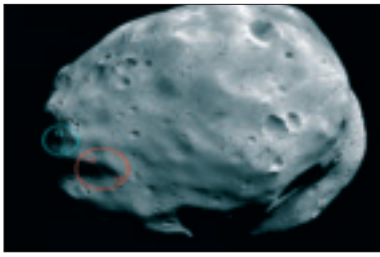
The new sample device will be more of a pounder/crusher that can break soil and small rocks without rocking the lander.

Poland is supplying Lavochkin with its Chomik (Hamster) soil sampling drill, designed originally for the European Philae lander now en route to land on a comet. Chomik will serve as a backup device in case the prime sample mechanism fails.

Approach and return

As the vehicle approaches Earth at the end of the 11-month transit, the descent module with the samples should separate from the Earth return spacecraft. The module should then dive safely through the atmosphere for recovery. About half the sample will be opened and distributed globally for analysis. The remaining 100 g will be held back for a time, for a second wave of analysis after results are in from the first studies.

Meanwhile, back on Phobos, the lander's instrument suite will be obtaining images and direct compositional measurements to complement and back up the sample return. Several spectrometers, heat probes, cameras, and other instruments will take detailed data on Phobos from its surface. The lander is designed to survive there for a year.



Mars Express image of Phobos has two locations annotated as primary spacecraft landing sites as determined by Russian project scientists and engineers. A key consideration will be the ability of the lander to image the stars for mission navigators before liftoff to plot the best route back into Mars orbit and ultimately to Earth.