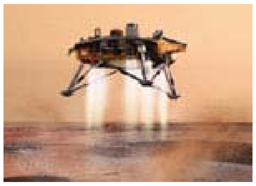
By Craig Covault



The NASA Phoenix Mars lander, carrying the most ambitious laboratory hardware ever sent to another planet, is ready for launch on a mission to taste Martian water and search for the organic carbon building-blocks of life near the planet's north pole.

The spacecraft's nearly 8-ft.-long robotic arm will dig trenches up to 3 ft. deep for imagery of subsurface layers and the retrieval of soil and ice samples for its complex mini-laboratories. This should enable Phoenix to determine what's happening now, relative to the suitability for life, at a specific landing site where scientists know there's water in the form of permafrost or ice. This is in contrast to the Mars rovers Spirit and Opportunity, which are equipped with geology sensors to determine what happened in the past, back to billions of years ago at their respective landing sites.

And Phoenix, with advanced technology from the U.S., Canada and Europe, will conduct much more complex sample processing and climate studies than was possible on the 1976 twin Viking landers that had a less capable arm and different analysis labs.

Liftoff of the $417-million flight from Cape Canaveral on a Delta II is set for Aug. 3 at 5:35 a.m. EDT at the start of a 20-day launch window. Mars will be 122 million mi. from Earth at launch.

The liftoff will be timed to the moment Earth rotates Delta Launch Pad 17A under the pathway in the sky to intersect a 423-million-mi. looping trajectory to intercept Mars 9.5 months later.

Phoenix is to make a powered descent May 25, 2008, near the Martian Arctic Circle. Mars will be 171 million mi. from Earth when the landing occurs. Moments after touchdown, the spacecraft's two 6.7-ft.-dia. solar arrays will unfurl like Chinese fans. With solar arrays deployed, the Lockheed Martin spacecraft will span more than 18 ft.

The north polar touchdown area equates in latitude to Barrow, Alaska, on Earth. At that latitude, potentially life-giving water-ice should lie just 3 ft. or less under the surface. This should put the ice in range of the Phoenix sampling arm, equipped with a scoop and tiny auger device that may prove critical to mission success (see p. 61).

The Canadian Space Agency is a formal Phoenix partner, and the European Space Agency also plays an important role. The spacecraft also carries key hardware from companies and labs in Canada, Denmark, Switzerland, Germany and Finland.

Unlike Spirit and Opportunity that continue to drive around on Mars, Phoenix is not a rover but a stationary lander like the two Viking missions. Instead of horizontal mobility, however, Phoenix has "vertical mobility" with a nearly 8-ft. robotic arm capable of digging as deeply as 3 ft. below the surface. The arm's shoulder and elbow joints use the same innovative brushless motor technology and gearing as the rover drive wheels.

Its landing weight of about 1,155 lb. is close to the Viking and rover landing weights. But Phoenix, folded into its aeroshell, spans more than 6 X 5 ft. across and several feet tall. This is too large to use air bags, as did the 1997 Pathfinder and Spirit and Opportunity rovers that landed in 2004.

Phoenix is similar to the 1999 south polar lander that crashed when its landing gear deployment accidentally tripped an engine shutoff switch high above the surface. The 2001 version of the south polar design was then canceled.

Phoenix, as its name implies, has risen from the ashes of those two missions with more robust engineering and a far greater risk management and testing regime, says Ed Sedivy, the Lockheed Martin spacecraft manager.

Under this first NASA Mars Scout type mission, the overall project is led by the principal investigator, Peter Smith, at the University of Arizona in Tucson. The Jet Propulsion Laboratory side of lander development is led by Barry Goldstein, JPL Phoenix project manager.

JPL will lead the cruise and entry, descent and landing phase; but once safely on the surface, the mission will shift to the lander science team at the University of Arizona Science Mission Operations facility in Tucson. Lockheed Martin will also help command the spacecraft from Littleton, Colo.

Phoenix cannot radio directly to Earth but must receive and transmit all data through the Mars Reconnaissance Orbiter (MRO) and the Mars Odyssey orbiter acting as relays. Odyssey originally found shallow ice critical to the latitude picked for Phoenix, while MRO images recently found a potentially fatal boulder density at the initial prime landing site.

MRO then also located a smoother area elsewhere in the Martian arctic where the landing has now been retargeted. In addition to being a safer location, unusual polygon-shaped soil freeze/thaw features found at the new site will add a scientific and imaging bonus, says Smith.

Phoenix is not designed to detect living organisms, but its atomic force microscope can see objects as small as 100 microns, the size of living or preserved bacteria. If extremely lucky, its organic chemistry laboratory could also possibly detect “biological processes that occurred in the past” (i.e., past life on Mars), says Smith in Tucson.

Any data that hints at such findings will start huge arguments on Earth about whether Phoenix has actually found life on Mars—or been tricked.

Its laboratory instruments have eight “bake and sniff” sample ovens and four cells where water from Earth will be stirred with Martian soil for analysis. To do such processing, the Phoenix instruments are robotic marvels with dozens of doors, valves and other moving mechanisms (see p. 60).

The main Phoenix objectives will be to search for organics, yet undetected on Mars. It will also sample ice/water that will be tested for its acidity and other properties, such as the potential to hold food sources for any life that might be there.

“We don’t really expect to answer whether life exists on Mars,” says Smith. “Our flight is really about habitability.” However, the Mars Science Laboratory rover—still in development for launch in 2009—will carry life-detection capability.

Organics are any material that contains carbon and hydrogen and usually other elements such as nitrogen, sulfur and oxygen. If Phoenix finds organics of any type, it will be a major discovery in its own right—meaning that life on Mars, past or present, is at least possible. This would also boost the stock in earlier Viking lander data, which found no organics but did find potential metabolic activity in the soil.

A Phoenix finding of organics also could breathe new life into a 1996 theory by Johnson Space Center and Stanford University scientists, who believe they found evidence for Martian life in a meteorite discovered in Antarctica.

Phoenix uses the airframe from the 2001 canceled lander, but the vehicle has been rebuilt and upgraded significantly under an aggressive risk-reduction and testing program.

Sedivy, the Lockheed Martin spacecraft manager, told Aviation Week & Space Technology that given what the testing and risk assessments turned up, he’s “not surprised” the tightly budgeted 1999 south polar lander crashed and its 2001 version canceled. So much for faster-cheaper-better concepts.

“I think one of the hardest things has been understanding the tentacles leading from higher risk parts of the earlier programs into Phoenix to make sure we have rooted them all out,” says Tim Gasparrini, deputy program manager for entry, descent and landing at Lockheed Martin.

Also, the 2001 spacecraft was built for an equatorial landing, not a north polar site as the Phoenix version of the hardware. Going polar changed a lot of things, especially temperatures inside the aeroshell that encases the lander during cruise and Mars atmospheric entry (see photo, p. 59).

There have been many thermal management changes, says Guy Beutelschies, chief Phoenix systems engineer. Other key areas receiving much more test or redesign are:

•Connectors. Virtually all of the lander’s multitude of connectors have gone through greater analysis and test for reliability and susceptibility to temperature and physical shock.

•Landing radar. Developed by Honeywell from an F-16 radar, initial testing found double the antennas were needed on the bottom of the spacecraft to provide a full duplex feedback. This avoids the need for slower and less accurate time division multiplexing with each antenna sharing transmit and receive duty.

To obtain much better radar testing, Lockheed Martin asked Vertigo Inc. of Lake Elsinore, Calif., to develop a complex winch for one of its helicopters. The test radar was hung on the winch and then reeled in or out, depending on the altitude desired, as the pilot varied horizontal velocity according to the horizontal speeds needed for the tests.

•Final descent rocket engines. The Phoenix descent propulsion system consists of 12 68-lb.-thrust Aerojet hydrazine engines. The system has gone through far more testing than 1999 or 2001 versions of the spacecraft.

Although all 12 are on during the final 26-sec. descent from 1,870 ft. after separation from the parachute, they fire at up to 10 pulses per sec., but at varied throttle settings and sequencing.

Analysis indicated this shakes the propellant lines. To assess these stresses, the Lockheed Martin team at Littleton rigged an engineering version to fire water pulses through the engines to mimic the hydrazine flow (see top photo, p. 58). Those data were then used for propellant line modifications, then actual hydrazine live-fire tests of the entire engineering lander on complete descent profiles.

Myriad factors are at play in the final descent sequence, including attitude control for the balanced use of propellant out of both large hydrazine tanks. The spacecraft also needs to land for maximum shading during the day, so ices exposed by the arm don’t melt before they reach the analysis equipment.

Another unique feature is the Backshell Avoidance Maneuver (BAM) software. During the parachute descent, it measures wind direction; then after lander separation, it fires the descent rockets to fly the spacecraft several tens of feet laterally away from where the backshell and parachute are calculated to land.

“When you come off the chute, you’re not quite sure where you’re going to fly, or how maybe you’re going to twist around at separation,” says Gasparrini.

“So the first thing that happens is you get the engines warmed up with about five pulses. This is called the tip-up maneuver, where the spacecraft aligns its center of gravity with the velocity vector so software can take control of the vehicle. Until then, it literally has fallen without any engine firings for 3 sec., “a frightening period,” says Smith.

“The next part of the powered descent is called the gravity turn, where the vehicle adjusts its final landing azimuth,” Gasparrini says. That also allows the propellant tanks to drain equally.

The engines then fire to establish a constant-velocity descent so the maximum horizontal velocity at touchdown is no more than 1.4 meters/sec. and the vertical touchdown velocity is ±1 meter/sec.

The complex MECA and TEGA instruments will do sample analysis (see p. 60).

The other science systems include:

•Mars Descent Imager. Built by Malin Space Sciences Systems in San Diego, the Mardi imager will acquire a series of wide-angle, color images of the landing site from about 5-mi. altitude all the way down to the surface. The imagery will characterize the landing site to aid surface science and help MRO later find Phoenix.

•Robotic Arm Camera. The camera on the arm will obtain extremely detailed closeups of layering in the trenches, illuminating them with blue, green and red lights for color differentiation. The imager was built by the University of Arizona and the Max Planck Institute for Solar System Research in Germany.

•Surface Stereoscopic Imager. Mounted on a several-foot-high mast, the University of Arizona camera has 12 wavelengths and the same resolution capability as those on the Mars rovers.

•Meteorological hardware. Canadian Space Agency meteorology instruments will record temperature and pressure, as well as wind speed and direction. Its light-detection and laser ranging instrument will fire straight up to obtain data on dust and clouds over the Martian arctic. MD Robotics and Optech in Canada built much of the system. ESA components will aid wind detection.

(This is the first in a series of articles on the Phoenix Mars lander mission.)

http://www.aviationweek.com/aw/generic/story.jsp?id=news/aw061107p1.xml&headline=Phoenix%20Mars%20Lander%20Readied%20for%20Launch&channel=space