Europe's Mars Express Will Search for Life on Red Planet

For the first time in a quarter of a century, a spacecraft is on its way to Mars to see if it can detect the existence or remnants of life. Marsha Freeman reports.

Of all the spacecraft that have been sent to Mars, only the two American *Viking* landers, which arrived at Mars more than 25 years ago, were specifically designed to search for life. The results were controversial, with almost all of the scientific community proposing that the mission *proved* that there was no life on Mars. But Dr. Gilbert Levin, who designed one of the three life-detection experiments on the *Viking* landers, insisted then, and continues to insist today, that the results of his experiment were inconclusive as far as there being life on Mars today, but did reveal that there has been life on Mars in the past.

The dramatic photographs returned from the instruments aboard the *Mars Odyssey* spacecraft over the past year, and also from the *Mars Surveyor*, launched in 1997 and still in orbit, have strengthened the evidence that liquid water, a prerequisite for life, did, at one time, flow on the surface of the planet. Even more intriguing, images from *Mars Odyssey* give evidence that there is a large amount of ice, and possibly caches of liquid water, beneath the surface of the planet.

But based on the consensus from the 1970s that there was no extant life on Mars, the United States has designed its present and future Mars missions to do more comprehensive inventories of the composition of the planet, focussing on trying to find the water, with no current plans to deploy instruments expressly to search either for life, or its remains.

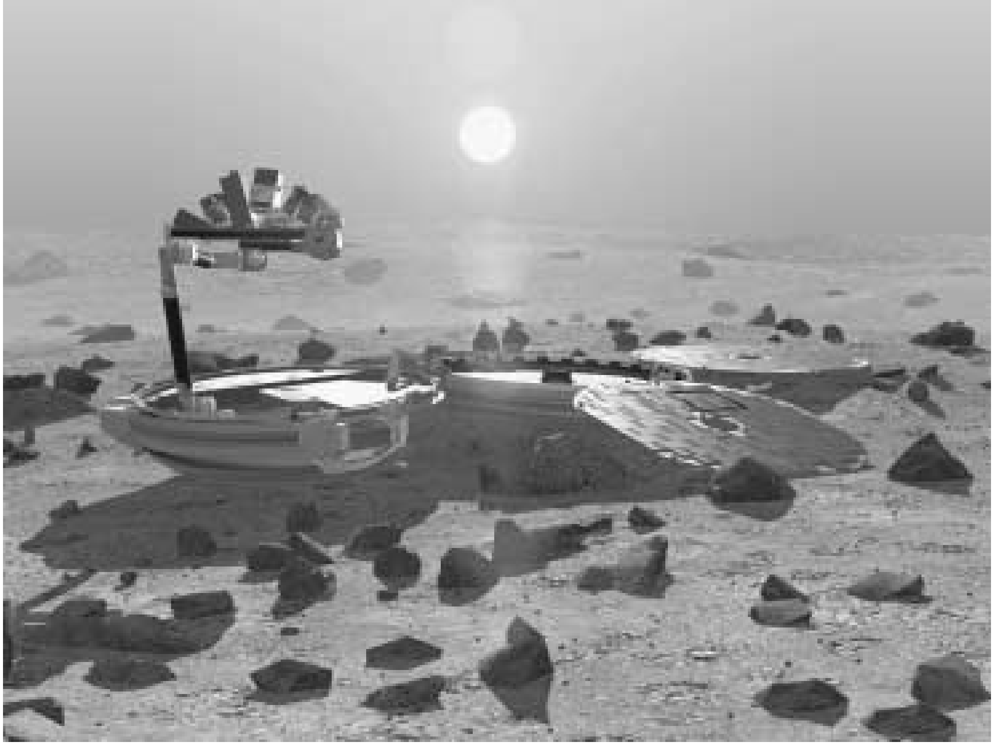
On the heels of the 1996 announcement by a team of researchers that a meteorite from Mars indicated fossil remains of past life, interest in the search for life was rekindled, and the European Space Agency decided to design, develop, and launch *Mars Express*, with a lander to search for direct and indirect evidence of life. The mission had to be quickly executed, to take advantage of the opportunity to launch to Mars this month.

Using a non-propulsive ballistic trajectory, where the spacecraft is fired into its pathway toward Mars from near the Earth, but coasts the rest of the distance, the opportunity to send spacecraft to Mars occurs only once every 26 months. This current year's opposition of Mars' and Earth's orbits will bring the two planets closer together than they will be again for decades.

The Universe's Organizing Principle

There is certainly the *possibility* that life forms exist today on Mars. One can assume life exists elsewhere beside the Earth, since life, as an organizing principle, is embedded in the development of the Universe. On Mars, life forms most likely will be very small, such as bacteria, and probably live underground, so they will be difficult to find. *Mars Express* will deploy a remarkably small and compact lander, *Beagle 2*, to pick up where *Viking* left off, and continue the search for life.

Mars Express will carry out the search using various techniques. Indirectly, the orbiter will be mapping the below-surface water resources of the planet, to a much greater depth than ever before. It will also map the surface in great detail, to help determine how much water existed there in the past.



The Beagle 2 lander, carried on the European Mars Express spacecraft, will deploy a set of tiny instruments to investigate the possibility of life on Mars. At the end of its robot arm is the PAW, a collection of tools that can be rotated in to different positions, and applied to study Martian rocks and soil.

For the past few decades, scientists have described water as a prerequisite for life. Today, with the revelation that life exists in the most extreme environments on Earth, including undersea thermal vents and the inside of nuclear power plants, it is more likely that everywhere there is water, and some source of energy, there is life.

The clam-shaped *Beagle 2* lander, being delivered to the planet's orbit by *Mars Express,* will carry several instruments to search for indirect evidence that life existed, or exists, on Mars, by watching for the tell-tale signs and products of biological processes. For the first time, samples will be investigated from underneath Mars' surface, where they are sheltered from the life-threatening ultraviolet radiation that bathes the planet, and where liquid water may be yet located.

In December 2003, after an anxious six-month wait for *Mars Express* to arrive at its destination, scientists will no doubt, once again, rewrite the history of Mars, and possibly find evidence for life there.

Off to the Red Planet

Mars Express was launched on June 2, at 11:45 p.m. local time from the Russian Baikonur launch complex in Kazakstan.

The Russian *Fregat* upper stage attached to it fired twice, first to place the probe in a stable Earth orbit, and then to increase its velocity enough to escape Earth's gravity. At 92 minutes after launch, the *Fregat* separated from *Mars Express* and sent it on its way, at a speed of 65,000 miles per hour. Two days after launch, *Mars Express* maneuvered into a Mars-bound trajectory, and during its entire interplanetary cruise, the spacecraft will be pointed to the Sun to power its solar arrays.

Following the launch, Vasily Moroz, head of the Russian team taking part in the mission, proudly said that *Mars Express* "has left the Earth's orbit and is now on its way."

Rudi Schmidt, the European Space Agency's (ESA) *Mars Express* project manager, explained, "With *Mars Express*, Europe is building its own expertise in many fields. This ranges from the development of science experiments and new technologies—new for European industries—to the control of a mission that includes landing on another planet. We have never done this before."

Following launch, the spacecraft's solar arrays, needed to generate electricity, opened as planned, and to the relief of all, the spacecraft made contact with ESA's ground station in Western Australia, reporting that it is healthy and on its way.

On June 5, the launch clamps that held the *Beagle 2* lander to the main spacecraft were remotely commanded to release. This was a crucial milestone, since it will allow the lander to be separated from the orbiter when it arrives at Mars. The clamps were needed to keep the lander firmly attached to the mother spacecraft during the high-vibration rough ride to orbit.

In September, an adjustment will be made in the spacecraft's trajectory, and a total of three course corrections are possible. *Mars Express* will be making a journey of nearly

250 million miles.

The 2,500-pound *Mars Express* vehicle cost only $353 million. The cost was cut by using off-the-shelf technology, and about 80% of the hardware had already been designed for ESA's Rosetta spacecraft, set to encounter comet Churyumov-Gerasimenko in November 2014. It was built by a consortium of 24 companies from ESA's 15 member states, with the European aerospace company Astrium as the prime contractor. The spacecraft was developed, built, and tested in a record-setting four years, hence its name.

Mars Express will operate in a highly elliptical 7.5-hour polar orbit, which will take it within 150 miles of the planet's surface, for at least one Martian year, or 687 Earth days. The mission could be extended for additional investigations, and it is hoped that it will continue to operate beyond its nominal mission, to be able to support communications between Earth and spacecraft that will arrive at Mars during future years' launch opportunities.

Mars Express was designed to relay data to Earth from NASA's two Mars exploration rovers, to be launched in June and arrive at Mars in early 2004. The American rovers will use *Mars Express* as a relay at least once, as a demonstration for broader international cooperation in future Mars exploration mission communications. Similarly, NASA's currently orbiting *Mars Odyssey* spacecraft will be used to relay communications to Earth when *Mars Express* is not in a good relative position to do so.

During operation, the orbiter will point its instruments at Mars for between half an hour and an hour per orbit, collecting data; and then, for the remainder of the time, transmit its data, and that of *Beagle 2,* to Earth.

Images coming since 1997 from the Mars Orbiter Camera, aboard NASA's Mars Global Surveyor, have revealed evidence of large-scale action of liquid water on the surface. In this image, taken in May 2003, gullies are seen at two different levels on the walls of a meteor impact crater. On Earth, similar gullies are formed from the flow of water.

Science From the Orbiter

The *Mars Express* orbiter will conduct global high-resolution imaging, planet-wide mineralogical mapping, and measure and characterize Martian atmospheric circulation. One focus will be to search for the "lost water" on Mars. Some of the water that was apparently once on the surface of Mars, it is theorized, could be stored in the forms of permafrost, rivers, pools, or aquifers, the rest having escaped into interplanetary space.

The orbiter houses seven scientific instruments:

• The High Resolution Stereo Camera (HRSC) will comprehensively map the planet, and produce full-color, three-dimensional images at 30-foot resolution. It will also photograph some selected areas at about 6-foot resolution. The higher resolution images will even allow *Mars Express* to see the tiny *Beagle 2* lander on the surface. By combining images at these two different resolutions, unprecedented pointing accuracy is expected, and the 3D images will reveal the topography of Mars in full color.

• The Mars Advanced Radar for Subsurface and Ionospheric Sounding (MARSIS) ground-penetrating radar will have the critical job of mapping the Martian subsurface searching for water. This method was used only once before in space, during an experiment on an Apollo lunar mission.

A 130-foot antenna will send low-frequency radio waves from the orbiting spacecraft toward the surface. Most of the radio waves will bounce off the surface of Mars, but some will penetrate to a depth of up to three miles, and be reflected back by the different materials underground. By contrast, the *Mars Odyssey* orbiter can only determine the concentration of elements, such as hydrogen, to a depth of about three feet.

Radio waves with two different frequencies will be aimed at the planet simultanously and, analyzing the echoes generated, MARSIS will be able to study the electrical properties of the reflecting surface, and thereby, its composition. It should also be able to pick out layers of rock interspersed with ice.

The instrument was built by Italy and NASA's Jet Propulsion Laboratory. "We have very little information about the crust of Mars more than about a meter below the surface, but with this instrument we hope to probe as deep as 5 kilometers," or three miles, said Dr. Jeffry Plaut, from JPL, who is co-principal investigator for the instrument. The other co-principal investigator is Prof. Giovanni Picardi, from the Universitá di Roma in Italy.

"Much of the water may lie too deep for us to detect it, but the radar will be capable of showing boundaries between many kinds of geologic materials, such as layers of lava, sheets of sand, sediments, debris from impacts, and ice-rich rock and soil. Seeing into the third dimension of the crust of Mars is what makes this a unique and exciting experiment," Plaut explained. "With the radar, we will try to detect boundaries between layers of different types of material. If there is a boundary between a rock-ice mixture at the surface and a rock-water mixture at depth, it will reflect the radio waves and we hope to detect it. We'll be looking for aquifers—subsurface reservoirs of liquid water—but nobody really knows whether Mars has them."

MARSIS might also detect other types of layer boundaries, such as between sediments and underlying volcanic rock, or between the polar ice caps and underlying liquid water. This type of instrument, carried by aircraft, has detected vast lakes under the polar ice caps on Earth.

It will also be used to study the characteristics of the Martian ionosphere, since this electrically charged upper region of the atmosphere will reflect some of the radio waves, sometimes hundreds of miles from their point of origin. Radar signals will be bounced off the ionosphere and the time delay of the reflected signals measured to determine the shape and height of the ionosphere.

• The Omega spectrometer, or Visible and Infrared Mineralogical Mapping Spectrometer, will determine the mineral composition of the soil, and its data will be used to draw up the first mineralogical map of the planet to 300-foot precision. The map will be built up from 900-foot squares. The instrument will measure the visible and infrared light reflected from the planet's surface. Of particular interest is the iron content of the surface, the water content of the rocks and clay minerals, and the abundance of non-silicate materials, such as carbonates and nitrates.

Since the light from the surface must pass through the planet's atmosphere to reach *Mars Express* in orbit, Omega will also measure aspects of atmospheric composition.

• The Planetary Fourier Spectrometer (PFS) will chart the composition of the Martian atmosphere, study its dynamics, and provide a very accurate measure of Martian water vapor, which is one of the reservoirs for the water that once flowed on the surface of Mars. It will study the infrared radiation emitted from molecules in the atmosphere, and their wavelengths, to measure the vertical pressure and temperature profile of carbon dioxide, and look for minor constituents, such as water, carbon monoxide, methane, and formaldehyde.

• The Analyzer of Space Plasma and Energetic Atoms (ASPERA) will investigate the interaction between the upper atmosphere and the interplanetary medium. The question to be answered is: How and at what rate did the solar wind scatter the bulk of the Martian atmosphere into space? Unlike the Earth, Mars does not appear to have a magnetic field that could have deflected the solar wind.

The electron spectrometer, along with ion composition and energetic neutral atom imaging components, will study Mars' immediate space environment, and reveal the numbers of oxygen and hydrogen atoms that are interacting with the solar wind, to help to reconstruct the history and evolution of the atmosphere over the past 3.5 billion years.

The instrument's measurements will complement those taken by the Japanese *Nozomi* spacecraft. *Nozomi* will be orbiting Mars in the most common, equatorial orbit, and *Mars Express* will be nearly perpendicular, in a near-polar orbit. So together, they will observe Mars' atmosphere and weather conditions from different perspectives.

• SPICAM, the Ultraviolet and Infrared Atmospheric Spectrometer, will investigate the composition of the atmosphere, from the wavelengths of light absorbed by the constituent gases. An ultraviolet sensor will measure ozone, and the infrared sensor will measure water vapor.

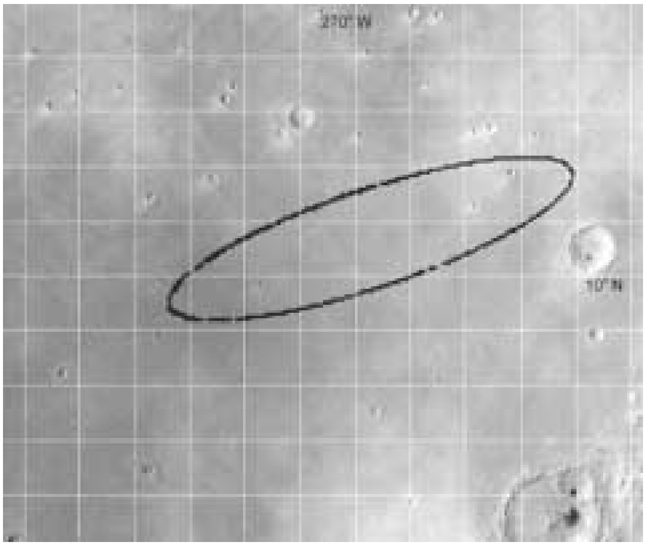
• MaRS, Mars Radio Science Experiment, will use the radio signals that are the medium through which to communicate data from the scientific observations, and instructions from mission control, between the spacecraft and Earth. With these signals, it will probe the planet's atmosphere, surface, and interior. Information from the interior will be gleaned from the planet's gravity field, which will be calculated from changes in the velocity of the spacecraft relative to Earth. The texture of the surface will be calculated from the way in which the radio waves are reflected from the surface.

When Beagle 2 Arrives at Mars

On Dec. 19, 2003, six days before arrival at the red planet, critical commands will be sent to *Mars Express* from Earth, to provide accurate guidance data for the separation of the lander from the orbiter. The orbiter has to release the *Beagle 2* lander into the correct trajectory at the specified speed, because the lander has no propulsion system and cannot correct any potential navigational errors, or receive any commands from Earth, during descent and landing.

Beagle 2 will hit the Martian atmosphere at 14,000 miles per hour, and the cruise through the atmosphere and air-bag landing will be the responsibility of the ground control team at the European Space Operations Center in Darmstadt, Germany.

During its descent through the Martian atmosphere, the lander's heat shield will protect it, and a drogue parachute will open to slow it down. At the appropriate moment, the heat shield will be jettisoned, and the main parachute deployed. Three air bags, similar in design to those first used on



The Beagle 2 lander has been targetted to land within the ellipse shown here, at Isidis Planitia, which is a flat basin with pitted ridges, small craters, and a variety of ripples and sand dunes. Scientists hope to find evidence that ground water and ice lurks beneath the surface.

the Mars *Pathfinder* mission in 1997, will cushion its landing, which is scheduled for Christmas Day. The bags are designed to withstand punishment similar to pushing a personal computer off a chair onto a concrete floor, and expecting it to work. After landing, the air bags will deflate, and *Beagle*'s four solar arrays, which are shaped like petals, will unfurl.

The landing capsule mass, including the heat shield, parachute, and air bags, is about 130 pounds, and the clam-shaped, tiny lander itself is about 66 pounds—about the size of a dog basket. The miniature *Beagle 2* is less than 10% of the mass of the Mars *Pathfinder*. It has been stripped of all unessential gear, and even of some back-up systems.

Once *Beagle 2* lands, it will emit a "beep" to signal operators at the United Kingdom's Jodrell Bank radio telescope station, that it has touched down safely. The lander will operate on the surface for about six (Earth) months, and relay its data to Earth via the orbiter.

The lander cost about $57 million to develop and build, much of it raised from industry and fundraising by the scientists and engineers, who were determined that it fly. To be able to be carried by the already-designed spacecraft, the lander could not be any larger, or heavier, than it is. It is powered by five solar batteries, which resemble flower petals when the lander is fully deployed. And one of the weight-saving innovations was to carry out experiments that generate heat within the lander during the night, rather than during the day. As that energy dissipates it keeps the lander warm, eliminating the need for night-time heaters.

Scientists hope to be able to determine the lander's precise position on the surface, when there is an eclipse of Mars' tiny moon Phobos in February 2004. The shadow that Phobos casts on the surface, as it passes over the lander, will be observed by the orbiter, pinpointing its position.

The *Beagle 2* lander concept was conceived in 1997 by Prof. Colin Pillinger, at the Open University in Milton Keynes, Great Britain. The original *Mars Express* mission that ESA was planning was for just an orbiter. But Pillinger reasoned—after the 1996 discovery that the ALH84001 Mars meteorite might harbor the fossils of life—that there should also be a small lander, to pick up the search for life where *Viking* had left off. Dr. Everett Gibson, a geochemist who was on the Mars meteorite team, is an adjunct scientist for the life-detection experiment on the *Beagle 2*.

ESA approved the lander in November 1999, and to be ready to launch in June 2003, time was of the essence. Many of the instruments on *Beagle 2* are derived and updated from the European instruments that were aboard the ill-fated Russian *Mars '96* spacecraft, which failed to escape Earth orbit.

The lander will touch down at Isidis Planitia, which is a flat, near-equatorial basin, where it is thought that groundwater ice could possibly be present a few feet below the surface. The plain covers the floor of an extremely ancient, large basin formed by an asteroid or comet impact, perhaps more than 4 billion years ago. It is Mars' third-largest impact basin and the floor has chains of pitted ridges, smaller meteor impacts, and a variety of light-colored ripples and small dunes. The region could be a sedimentary basin where traces of life could have been preserved.

This particular basin was chosen as a landing place because, being near the equator, it is in the warmest region of the cold planet, which reduced the amount of thermal protection needed for the lander. Because the basin lies below the Martian "sea level," the atmosphere is deeper, giving *Beagle*'s parachutes more time to slow the spacecraft's descent.

The Search for Life

The heart of *Beagle 2*'s life detection search is the PAW—the Position-Adjustable Workbench—which is attached to the end of the robot arm. Mounted at the end of the arm on the PAW are two cameras, a microscope, two types of spectrometers, and a torch to illuminate the surface. It also houses the corer/grinder and the mole, which will be deployed to collect rock and soil samples for analysis. These samples will be the subjects of the critical tests to see if life can be detected on Mars.

"The design of the PAW has been a challenge in miniaturization and mass optimization," said Derek Pullan, scientific payload manager. "It weighs only 5.5 pounds, yet will play a crucial role in imaging objects of interest close up, conducting *in-situ* measurements of rocks and soils, and supplying the Gas Analysis Package with samples." The data that are collected by the PAW's instruments will also allow Mars rocks to be dated with absolute accuracy for the first time.

After the activation of the rover, the two stereo cameras

After separation from the Mars Express spacecraft, the Beagle 2 lander will descend to the surface of Mars slowly, over a period of five days. Air bags, similar to those used in the 1997 Pathfinder mission, will protect it upon landing.

will be rotated into position and stretched out on the arm, to provide a panoramic view of the landing site. Because the PAW cannot be operated in real time from the Earth, due to the communications time and to physical hardware limitations on telemetry, the 3D model the cameras create will be used by the lander to guide the instruments into position alongside target rocks and soil. "Provided the features in the landscape don't move around, it will be valid for the whole mission!" joked Andrew Coates, who worked on the camera at the Mullard Space Science Laboratories, at University College in London. The cameras will then take close-up images of nearby soil and rocks to find potential candidates for further analysis, and will be used to navigate the arm throughout the mission.

The *Viking* experiments indicated that the chemical and radiation conditions on the surface of Mars, in addition to the extreme cold and dryness, may well have driven life under rocks, and underground. *Beagle 2* has two instruments to peer into and under rocks, under surface soil, and down into the upper crust. The purpose is to expose the scientific instruments to material that has not been oxidized, and most likely sterilized, on the surface.

On the PAW is a corer/grinder. When a rock is found that is suitable for study, the PAW will be rotated until the grinder is in position to grind away the weathered, dust-covered surface. The PAW can then be repositioned, and the instruments rotated, for the microscope or spectrometers to analyze the exposed material.

The corer/grinder consists of a drill bit which can be moved over to scrape a surface, or be positioned in one spot to drill down to remove a sample of rock powder for analysis. "The drill head is a clever design, consisting of two parts," says Lutz Richter from the DLR, the German Aerospace Center, in Cologne. "When drilling, it generates a powder. Once you've reached the drilling depth you can close the drill head to collect the sample." It is expected that the corer/grinder will collect three or four samples for analysis. The rock corer/grinder was provided for *Beagle 2* by the Hong Kong Polytechnic Institute in China.

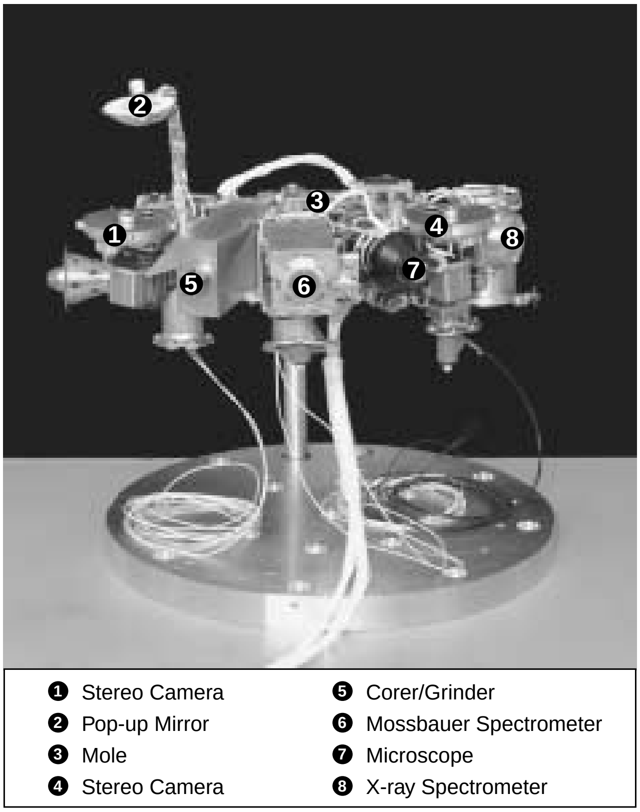
The diminutive size of the 130-pound landing capsule, with Beagle 2 tucked inside it, is evident, as seen here, before shipment to be integrated with Mars Express.

The PAW also contains the "mole," as it is nicknamed, or PLUTO, for Planetary Underground Tool, to unearth samples for analysis. The mole is a wire-guided mini-robot, tethered to the lander. Using a compressed spring mechanism, the mole will crawl horizontally up to several feet across the surface. Once it has reached a target, it can burrow its way under rocks to collect unexposed soil. Samples will be grabbed and held in a cavity in the tip of the mole and then can be dropped into the Gas Analysis Package (GAP), the mini-laboratory on the lander. In addition to burrowing under rocks and soil, the PAW can be positioned so the mole will burrow vertically to collect samples as much as four feet under the surface.

"We will start operations by deploying the mole straight down beneath the surface," says Lutz Richter. "The first soil sample will be taken a few inches below the surface and then delivered to the gas analyzer. The next sample will be taken three feet down and the third, 4.5 feet down. Then, depending on what the terrain looks like, we'll do lateral deployment."

Whether or not the samples that the mole and the corer/grinder dig up contain evidence of life, will be determined by analysis provided in the Gas Analysis Package. The purpose of the GAP facility is to detect possible signs of life, and to precisely date the rock samples. The experiment is a miniaturized version of the laboratory equipment that Colin Pillinger, who designed it, uses to analyze Martian meteorites that land on Earth. His laboratory is one of the world's best for studying extraterrestrial samples for signs of carbon.

Unlike the *Viking* life-detection experiments, GAP will be able to analyze individual atoms. Samples will be placed



The smallest set of scientific instruments ever developed to investigate the possibility of life on Mars will be deployed on the Beagle 2 lander.

into a bank of 12 different furnaces, to analyze 12 different samples. Following a programmed set of heating and cooling steps, in which each sample is heated gradually in the presence of a fresh supply of oxygen, the by-products of burning will "bake out," and reveal the composition, age, and ash components of the Martian soil. The carbon dioxide generated at each temperature will be delivered to a mass spectrometer, which will measure its abundance, and the ratio of the isotopes of carbon-12 to carbon-13, the difference between them being only the number of neutrons.

Biological processes prefer the use of the lighter carbon-12 in the construction of organic molecules. The mass spectrometer will separate out the two different forms of the carbon dioxide, the biotic and abiotic, and measure their relative abundance. German scientist Manfred Schidlowsky has compiled data for some 10,000 different laboratory samples, and the difference between the ratios of the two isotopes, in organic and mineral phases, shows how biological systems leave a ubiquitous signature of life, even in specimens where there are no visible fossil remains.

Biologically produced compounds burn at a lower temperature than those that are produced geologically, so the gas analysis ratios might change as the burning temperature steadily increases. At 300-400° Centigrade, organic material burns. At 600-700° carbonate rocks break down, and at higher temperatures, gas trapped in the rocks diffuses out. The temperature at which the carbon is generated, therefore, reveals something about its origins.

An excess of carbon-12 at a lower temperature would be a strong indicator of past or present life. Scientists propose that such an isotopic signature is preserved over billions of years. On Earth, a high carbon-12 to carbon-13 ratio has been found in rocks up to 4 billion years old, and is taken as evidence that there was life on Earth that long ago. It is hoped that the same occurred on Mars.

Scientists will also be looking for the presence of methane during the burning of the samples, and in the atmosphere, because on Earth, some life forms produce methane. But methane is quickly destroyed, through oxidation, so if methane is found on Mars today, it could indicate that there is some form of replenishment from active biological processes still taking place.

Other instruments on the *Beagle* lander will aid in the search for life. The microscope on the PAW will be able to examine details, and pick out features, such as small as bacteria. It has filters to illuminate samples in red, green, blue, and ultraviolet. Some inorganic rocks fluoresce naturally in ultraviolet light, but so does chlorophyl. "We'll turn the visible Light-Emitting Diodes on, one-by-one, to see what the rock looks like in different colors, and then combine them to see it in white light," explains Nick Thomas, the principal investigator from the Max Planck Institut für Aeronomie in Germany. The microscope will reveal the textures of rock surfaces, to help determine if they are of sedimentary or volcanic origin. It will also reveal the shape and size of dust particles, and the microscopic structure of rocks.

The Mossbauer Spectrometer on the PAW will investigate the mineral composition of rocks by irradiating exposed rock surfaces and soil with gamma rays emitted by a radioactive isotope, cobalt-57, and then measure the spectrum of the gamma rays that are reflected back. The way gamma rays are reflected depends upon the electronic environment of the atoms, so this technique can reveal how atoms are bound chemically. Data will be used to compare the nature of iron minerals in the pristine interior as compared to those on the weathered surface, to help characterize the oxidizing nature of the present atmosphere.

The age of the rocks that *Beagle 2* explores will be a key piece of data, especially if any indications of life are found. X-ray spectrometers will measure the elemental composition of rocks by bombarding exposed rock surfaces with X-rays from four radioactive sources, two iron-55 and two cadmium-109 isotopes. "We will measure the percentages by weight of three types of constituents," explains George Fraser, who built the X-ray spectrometer at Leicester University. "First, the bulk constituents, such as silicon and iron; second the trace elements, such as strontium, which tells about the rocks'

Flotilla of Spacecraft

Mars Global Surveyor was launched by NASA in 1996 and has been in orbit around the planet since 1997. It continues to reveal fascinating details of the surface topography of Mars, including regions of seasonal change and the effect of water on Mars in the past.

Mars Odyssey has been sending back thousands of groundbreaking photographs and thermal images of Mars since it reached orbit in 2001. It has been able to locate treasure troves of water ice beneath the surface, and sites where water may have flowed to the surface recently.

Japan's **Nozomi** orbiter spacecraft was launched in 1998, but due to technical problems during its trip, has been delayed, and will finally go into orbit around Mars in January 2004. It will study Mars' atmosphere for an equatorial orbit.

Mars Express, built by the European Space Agency and launched on June 2, will arrive at Mars in December. In a near-polar orbit, it will examine the atmosphere and search for water using radar. On Christmas Day, its **Beagle 2** lander will touch down on Mars, with the primary task of searching for life.

The first of NASA's twin rovers, **Spirit,** was launched on June 10, and **Opportunity** is scheduled for launch June 25. Their mission is to investigate signs of the past existence of water on the surface of Mars.

origins and history; and third, we'll measure potassium, which will give us the first radioisotope date for Martian rock taken from the surface." Measurements of potassium will be combined with measurements of argon by the GAP, to date rocks, using the fact that the isotope potassium-40 decays to argon-40.

In addition to the PAW and its life detection capabilities, the lander's robotic arm has a wind sensor allowing it to look for variations in wind speed with height. An X-ray spectrometer will measure the chemical composition of the rocks. If the chemistry looks promising, the sample can be investigated under the microscope, to investigate its mineralogy and reveal the structure. The gamma-ray Mossbauer spectrometer can then tell us how oxidized the rocks are.

There are also seven tiny sensors stowed in the base of the lander to monitor radiation, dust, and atmospheric oxides in the near-lander environment on the surface. There is an ultraviolet sensor, which will help determine the characteristics of the bath of life-destroying UV rays on the surface of the planet. The UV flux has never before been measured directly on the surface of Mars, but it is very important to the question of life.

American scientist and *Mars Express* participant Edward Gibson hopes that in the future, there will be many "sons of *Beagle*" scattered throughout the whole surface of Mars. "If we can send a multitude of these vehicles onto the surface in some . . . high-risk areas, we have a good chance of getting some really interesting data on the natural of potential living systems that might have been on the planet in the past," Gibson says.

More Missions To Come

Mars Express was the second of the current fleet of Mars-bound spacecraft to head out on its journey. Japan's *Nozomi* (Hope) spacecraft was launched in 1998. It had been due to reach Mars in October 1999, but soon after launch, an engine problem forced engineers to reroute the spacecraft, delaying arrival at Mars to January 2004. Then, on April 21, 2002, the spacecraft was damaged due to a large solar flare, which caused its power system to malfunction. Engineers are attempting to work around the communications problems, before *Nozomi* arrives at Mars early next year, which will be at the same time that the two Mars Excursion Rovers launched by NASA will arrive there.

In 2001, the European Space Agency and the National Space Development Agency of Japan held the first *Nozomi-Mars Express* workshop, to cooperate on the observation plans for the two spacecraft. The two agencies later established a program of joint investigations between the ESA/*Mars Express* and Japanese programs, and there has been an exchange of co-investigators between the instrument teams. European teams will process some of the data that is downlinked from the Japanese craft, and Japanese scientists will take part in data analysis, once *Mars Express* arrives at its destination.

At a March 2001 joint meeting, *Mars Express* project scientist Agustin Chicarro observed: "For too long, Europe and Japan have been looking for partners across different oceans [that is, in the United States]. Now, we realize that we're sitting at different ends of the same landmass."

During the month of June, NASA will launch two Mars Exploration Rovers, named *Spirit* and *Opportunity,* which will look not for life, but for its major prerequisite—water. The five-foot tall rovers will be able to travel hundreds of yards, doing extensive examinations of rocks and soil, and roaming over the surface of Mars to find the most fruitful targets for analysis.

The technological heritage, and experience gained from the development and construction of *Mars Express,* are also being applied by ESA for its upcoming *Venus Express* mission, which is slated to be launched in late 2005.

But for now, all eyes will be focused on Mars, where there will be two landers, two rovers, and four orbiters examining the red planet, starting at the end of this year.