NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Mars Exploration Rover Launches

Press Kit
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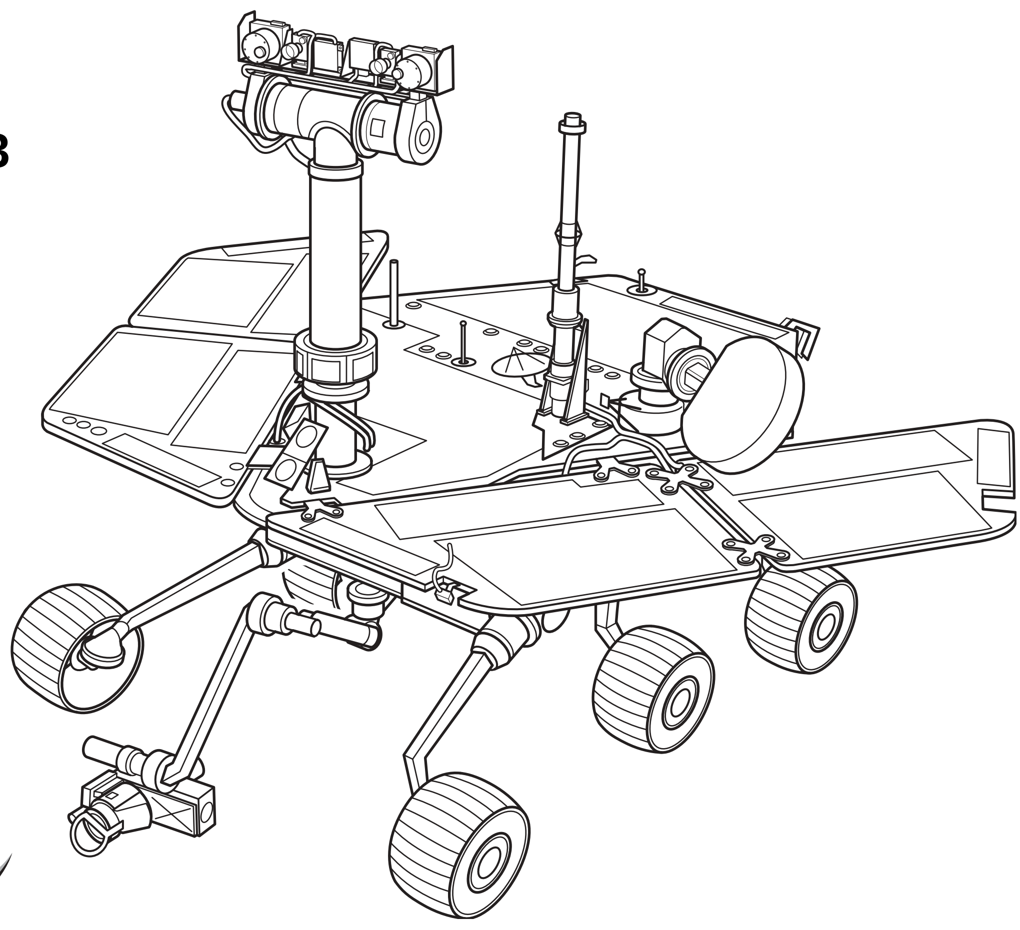

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GENERAL RELEASE:

NASA PREPARES TWO ROBOT ROVERS FOR MARS EXPLORATION

NASA's Mars Exploration Rover project kicks off by launching the first of two unique robotic geologists, as early as June 8. The identical rolling rovers see sharper images, can explore farther and examine rocks better than anything that's ever landed on Mars. The second rover mission, bound for a different site on Mars, will launch as soon as June 25.

"The instrumentation onboard these rovers, combined with their great mobility, will offer a totally new view of Mars, including a microscopic view inside rocks for the first time," said Dr. Ed Weiler, associate administrator for space science, NASA Headquarters, Washington.

"However, missions to Mars have proven to be far more hazardous than missions to other planets. Historically, two out of three missions, from all countries who have tried to land on Mars, ended in failure. We have done everything we can to ensure our rovers have the best chance of success, and today I gave the order to proceed to launch," Weiler said.

The first rover will arrive at Mars on Jan. 4, 2004, the second on Jan. 25. Plans call for each to operate for at least three months. These missions continue NASA's quest to understand the role of water on Mars. "We will be using the rovers to find rocks and soils that could hold clues about wet environments of Mars' past," said Dr. Cathy Weitz, Mars Exploration Rover program scientist at NASA Headquarters. "We'll analyze the clues to assess whether those environments may have been conducive to life."

First, the rovers have to safely reach Mars. "The rovers will use innovations to aid in safe landings, but risks remain," said Peter Theisinger, Mars Exploration rover project manager at NASA's Jet Propulsion Laboratory, Pasadena, Calif.

The rovers will bounce to airbag-cushioned landings at sites offering a balance of favorable conditions for safe landings and interesting science. The designated site for the first mission is Gusev Crater. The second rover will go to a site called Meridiani Planum. "Gusev and Meridiani give us two different types of evidence about liquid water in Mars' history," said Dr. Joy Crisp, Mars Exploration Rover project scientist at JPL. "Gusev appears to have been a crater lake. The channel of an ancient riverbed indicates water flowed right into it. Meridiani has a large deposit of gray hematite, a mineral that usually forms in a wet environment," Crisp said.

The rovers, working as robotic field geologists, will examine the sites for clues about what happened there. "The clues are in the rocks, but you can't go to every rock, so you split the job into two pieces," said Dr. Steve Squyres of Cornell University, Ithaca, N.Y., principal investigator for the package of science instruments on the rovers.

First, a panoramic camera at human-eye height, and a miniature thermal emission spectrometer, with infrared vision, help scientists identify the most interesting rocks. The rovers can watch for hazards in their way and maneuver around them. Each six-wheeled robot has a deck of solar panels, about the size of a kitchen table, for power. The rover drives to the selected rock and extends an arm with tools on the end. Then, a microscopic imager, like a geologist's hand lens, gives a close-up view of the rock's texture. Two spectrometers identify the composition of the rock. The fourth tool substitutes for a geologist's hammer. It exposes the fresh interior of a rock by scraping away the weathered surface layer.

Both rover missions will lift off from Cape Canaveral Air Force Station, Fla., on Delta II launch vehicles. Launch opportunities begin for the first mission at 2:06 p.m. EDT June 8 and for the second mission at 12:38 a.m. EDT June 25, and repeat twice daily for up to 21 days for each mission.

"We see the twin rovers as stepping stones for the rest of the decade and to a future decade of Mars exploration that will ultimately provide the knowledge necessary for human exploration," said Orlando Figueroa, director of the Mars Exploration Program at NASA Headquarters.

JPL, a division of the California Institute of Technology in Pasadena, manages the Mars Exploration Rover project for NASA's Office of Space Science, Washington.

For information about the Mars Exploration Rover project on the Internet, visit:

http://mars.jpl.nasa.gov/mer

NASA will feature live webcasts of the launches on the Internet at:

http://www.jpl.nasa.gov/webcast/mer

Cornell University’s web site on the science payload is at:

http://athena.cornell.edu

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Media Services Information

NASA Television Transmission

NASA Television is broadcast on the satellite AMC-2, transponder 9C, C band, 85 degrees west longitude, frequency 3880.0 MHz, vertical polarization, audio monaural at 6.8 MHz. The schedule for Mars arrival television transmissions will be available from the Jet Propulsion Laboratory, Pasadena, CA; and NASA Headquarters, Washington.

Launch Media Credentialing

News media representatives who would like to cover the launch in person must be accredited through the NASA Kennedy Space Center newsroom. Journalists may contact the newsroom at 321/867-2468 for more information.

Briefings

An extensive schedule of news and background briefings will beheld at JPL during the landing period, with later briefings originating jointly from JPL and NASA Headquarters. A schedule of briefings is available on the Internet at JPL's Mars News site (below).

Internet Information

Extensive information on the Mars Exploration Rover project including an electronic copy of this press kit, press releases, fact sheets, status reports, briefing schedule and images, is available from the Jet Propulsion Laboratory's Mars Exploration Rover newsroom website: **http://www.jpl.nasa.gov/mer** . The Mars Exploration Rover project also maintains a web site at: **http://mars.jpl.nasa.gov/mer** . Cornell University's web site on the science payload is at: **http://athena.cornell.edu** .

Quick Facts

Spacecraft

Cruise vehicle dimensions: 2.65 meters (8.7 feet) diameter, 1.6 meters (5.2 feet) tall
Rover dimensions: 1.5 meter (4.9 feet) high by 2.3 meters (7.5 feet) wide by 1.6 meter (5.2 feet) long
Weight: 1,062 kilograms (2,341 pounds) total at launch, consisting of 174-kilogram (384-pound) rover, 365-kilogram (805-pound) lander, 198-kilogram (436-pound) backshell and parachute, 90-kilogram (198-pound) heat shield and 183-kilogram (403-pound) cruise stage, plus 52 kilograms (115 pounds) of propellant
Power: Solar panel and lithium-ion battery system providing 140 watts on Mars surface
Science instruments: Panoramic cameras, miniature thermal emission spectrometer, Mössbauer spectrometer, alpha particle X-ray spectrometer, microscopic imager, rock abrasion tool, magnet arrays

Rover A Mission

Launch vehicle: Delta II 7925
Launch period: June 8-24, 2003
Earth-Mars distance at launch: 105 million kilometers (65 million miles)
Mars landing: Jan. 4, 2004, at about 2 p.m. local Mars time (8:11 p.m. Jan. 3 PST)
Landing site: Gusev Crater, possible former lake in giant impact crater
Earth-Mars distance on landing day: 170.2 million kilometers (105.7 million miles)
One-way speed-of-light time Mars-to-Earth on landing day: 9.46 minutes
Total distance traveled Earth to Mars (approximate): 500 million kilometers (311 million miles)
Near-surface atmospheric temperature at landing site: -100 C (-148 F) to 0 C (32 F)
Primary mission: 90 Mars days, or "sols" (equivalent to 92 Earth days)

Rover B Mission

Launch vehicle: Delta II 7925H (larger solid-fuel boosters than 7925)
Launch period: June 25-July 15, 2003
Earth-Mars distance at launch: 89 million kilometers (55 million miles)
Mars landing: Jan. 25, 2004, at about 1:15 p.m. local Mars time (8:56 p.m. Jan. 24 PST)
Landing site: Meridiani Planum, where mineral deposits suggest wet past
Landing time: Approximately 1:15 p.m. local Mars time (8:56 p.m. PST)
Earth-Mars distance on landing day: 198.7 million kilometers (123.5 million miles)
One-way speed-of-light time Mars-to-Earth on landing day: 11 minutes
Total distance traveled Earth to Mars (approximate): 491 million kilometers (305 million miles)
Near-surface atmospheric temperature at landing site: -100 C (-148 F) to 0 C (32 F)
Primary mission: 90 Mars days, or "sols" (equivalent to 92 Earth days)

Program

Cost: Approximately $800 million total, consisting approximately of $625 million spacecraft development and science instruments; $100 million launch; $75 million mission operations and science processing

Mars at a Glance

General

❑ One of five planets known to ancients; Mars was Roman god of war, agriculture and the state
❑ Yellowish brown to reddish color; occasionally the third brightest object in the night sky after the Moon and Venus

Physical Characteristics

❑ Average diameter 6,780 kilometers (4,212 miles); about half the size of Earth, but twice the size of Earth's Moon
❑ Same land area as Earth, reminiscent of a rocky desert
❑ Mass 1/10th of Earth's; gravity only 38 percent as strong as Earth's
❑ Density 3.9 times greater than water (compared to Earth's 5.5 times greater than water)
❑ No planet-wide magnetic field detected; only localized ancient remnant fields in various regions

Orbit

❑ Fourth planet from the Sun, the next beyond Earth
❑ About 1.5 times farther from the Sun than Earth is
❑ Orbit elliptical; distance from Sun varies from a minimum of 206.7 million kilometers (128.4 millions miles) to a maximum of 249.2 million kilometers (154.8 million miles); average distance from the Sun 227.7 million kilometers (141.5 million miles)
❑ Revolves around Sun once every 687 Earth days
❑ Rotation period (length of day) 24 hours, 39 min, 35 sec (1.027 Earth days)
❑ Poles tilted 25 degrees, creating seasons similar to Earth's

Environment

❑ Atmosphere composed chiefly of carbon dioxide (95.3%), nitrogen (2.7%) and argon (1.6%)
❑ Surface atmospheric pressure less than 1/100th that of Earth's average
❑ Surface winds up to 80 miles per hour (40 meters per second)
❑ Local, regional and global dust storms; also whirlwinds called dust devils
❑ Surface temperature averages -53 C (-64 F); varies from -128 C (-199 F) during polar night to 27 C (80 F) at equator during midday at closest point in orbit to Sun

Features

❑ Highest point is Olympus Mons, a huge shield volcano about 26 kilometers (16 miles) high and 600 kilometers (370 miles) across; has about the same area as Arizona
❑ Canyon system of Valles Marineris is largest and deepest known in solar system; extends more than 4,000 kilometers (2,500 miles) and has 5 to 10 kilometers (3 to 6 miles) relief from floors to tops of surrounding plateaus
❑ "Canals" observed by Giovanni Schiaparelli and Percival Lowell about 100 years ago were a visual illusion in which dark areas appeared connected by lines. The Mariner 9 and Viking missions of the 1970s, however, established that Mars has channels possibly cut by ancient rivers

Moons

❑ Two irregularly shaped moons, each only a few kilometers wide
❑ Larger moon named Phobos ("fear"); smaller is Deimos ("terror"), named for attributes personified in Greek mythology as sons of the god of war

Historical Mars Missions

Mission, Country, Launch Date, Purpose, Results

[Unnamed], USSR, 10/10/60, Mars flyby, did not reach Earth orbit

[Unnamed], USSR, 10/14/60, Mars flyby, did not reach Earth orbit

[Unnamed], USSR, 10/24/62, Mars flyby, achieved Earth orbit only

Mars 1, USSR, 11/1/62, Mars flyby, radio failed at 106 million km (65.9 million miles)

[Unnamed], USSR, 11/4/62, Mars flyby, achieved Earth orbit only

Mariner 3, U.S., 11/5/64, Mars flyby, shroud failed to jettison

Mariner 4, U.S. 11/28/64, first successful Mars flyby 7/14/65, returned 21 photos

Zond 2, USSR, 11/30/64, Mars flyby, passed Mars but radio failed, returned no planetary data

Mariner 6, U.S., 2/24/69, Mars flyby 7/31/69, returned 75 photos

Mariner 7, U.S., 3/27/69, Mars flyby 8/5/69, returned 126 photos

Mariner 8, U.S., 5/8/71, Mars orbiter, failed during launch

Kosmos 419, USSR, 5/10/71, Mars lander, achieved Earth orbit only

Mars 2, USSR, 5/19/71, Mars orbiter/lander arrived 11/27/71, no useful data, lander burned up due to steep entry

Mars 3, USSR, 5/28/71, Mars orbiter/lander, arrived 12/3/71, lander operated on surface for 20 seconds before failing

Mariner 9, U.S., 5/30/71, Mars orbiter, in orbit 11/13/71 to 10/27/72, returned 7,329 photos

Mars 4, USSR, 7/21/73, failed Mars orbiter, flew past Mars 2/10/74

Mars 5, USSR, 7/25/73, Mars orbiter, arrived 2/12/74, lasted a few days

Mars 6, USSR, 8/5/73, Mars flyby module and lander, arrived 3/12/74, lander failed due to fast impact

Mars 7, USSR, 8/9/73, Mars flyby module and lander, arrived 3/9/74, lander missed the planet

Viking 1, U.S., 8/20/75, Mars orbiter/lander, orbit 6/19/76-1980, lander 7/20/76-1982

Viking 2, U.S., 9/9/75, Mars orbiter/lander, orbit 8/7/76-1987, lander 9/3/76-1980; combined, the Viking orbiters and landers returned 50,000+ photos

Phobos 1, USSR, 7/7/88, Mars/Phobos orbiter/lander, lost 8/88 en route to Mars

Phobos 2, USSR, 7/12/88, Mars/Phobos orbiter/lander, lost 3/89 near Phobos

Mars Observer, U.S., 9/25/92, lost just before Mars arrival 8/21/93

Mars Global Surveyor, U.S., 11/7/96, Mars orbiter, arrived 9/12/97, high-detail mapping through 1/00, now conducting second extended mission through fall 2004

Mars 96, Russia, 11/16/96, orbiter and landers, launch vehicle failed

Mars Pathfinder, U.S., 12/4/96, Mars lander and rover, landed 7/4/97, last transmission 9/27/97

Nozomi, Japan, 7/4/98, Mars orbiter, currently in orbit around the Sun; Mars arrival delayed to 12/03 due to propulsion problem

Mars Climate Orbiter, U.S., 12/11/98, lost upon arrival 9/23/99

Mars Polar Lander/Deep Space 2, U.S., 1/3/99, lander and soil probes, lost on arrival 12/3/99

Mars Odyssey, U.S., 3/7/01, Mars orbiter, arrived 10/24/01, currently conducting prime mission studying global composition, ground ice, thermal imaging

Mars Express/Beagle 2, European Space Agency, 6/2/03, Mars orbiter/lander, due to enter orbit 12/03, landing 12/25/03

Mars: The Water Trail

Thirty-eight years ago, on the eve of the first spacecraft flyby of Mars, everything we knew about the Red Planet was based on what sparse details could be gleaned by peering at it from telescopes on Earth. Since the early 1900s, popular culture had been enlivened by the notion of a habitable neighboring world crisscrossed by canals and, possibly, inhabited by advanced lifeforms that might have built them -- whether friendly or not. Astronomers were highly skeptical about the canals, which looked more dubious the closer they looked. About the only hard information they had on Mars was that they could see it had seasons with ice caps that waxed and waned, along with seasonally changing surface markings. By breaking down the light from Mars into colors, they learned that its atmosphere was thin and dominated by an unbreathable gas known as carbon dioxide.

The past four decades have completely revolutionized that view. First, hopes of a lush, Earth-like world were deflated when Mariner 4's flyby in 1965 revealed large impact craters, not unlike those on Earth's barren, lifeless Moon. Those holding out for martians were further discouraged when NASA's two Viking landers were sent to the surface in 1976 equipped with a suite of chemistry experiments that turned up no conclusive sign of biological activity. Mars as we came to know it was cold, nearly airless and bombarded by hostile radiation from both the Sun and from deep space.

But along the way since then, new possibilities of a more hospitable martian past have emerged. Mars is a much more complex body than Earth's Moon. Scientists scrutinizing pictures from the Viking orbiters have detected potential signs of an ancient coastline that may have marked the edges of a long-lost sea. Today's Mars Global Surveyor and Mars Odyssey orbiters have revealed many features that strongly appear to have been shaped by running water that has since disappeared, perhaps buried as layers of ice just under the planet's surface.

Although it appears unlikely that complex organisms similar to Earth's could have existed in any recent time on Mars' comparatively hostile surface, scientists are intrigued by the possibility that life in some form, perhaps very simple microbes, may have gained a foothold in ancient times when Mars may have been warmer and wetter. It is not unthinkable that life in some form could persist today in underground springs warmed by heat vents around smoldering volcanoes, or even beneath the thick ice caps. To investigate those possibilities, scientists must start by learning more about the history of water on Mars -- how much there was and when, in what form it existed, and how long it lasted.

One of the most promising ways to answer those questions is to look at the diverse clues that water has left on Mars. Besides the water-carved landforms visible for decades from orbiting spacecraft, many details of the story of water on the Red Planet are locked up in the rocks littered across its surface. Rocks are made up of building blocks known as minerals, each of which tells the story of how it came to be a part of a any given rock. Some types of minerals, for example, are known to form on Earth only submerged underwater, while others are profoundly altered when hot water runs through them, leaving behind residues. Up until now, it has been very difficult to get to know the minerals in martian rocks because we have not had the tools to unravel their mineralogies. By understanding Mars' rocks in a more complete manner, scientists can gain a better view into the history of liquid water on the planet. Like their predecessor mission, Mars Pathfinder, the Mars Exploration Rovers will pursue this goal by placing robotic geologists on the planet's surface -- ideally suited to "reading the rocks" to understand the still mysterious history of water, and even of life-friendly ancient environments.

Myths and Reality

Mars caught public fancy in the late 1870s, when Italian astronomer Giovanni Schiaparelli reported using a telescope to observe "canali," or channels, on Mars. A possible mistranslation of this word as "canals" may have fired the imagination of Percival Lowell, an American businessman with an interest in astronomy. Lowell founded an observatory in Arizona, where his observations of the Red Planet convinced him that the canals were dug by intelligent beings -- a view that he energetically promoted for many years.

By the turn of the last century, popular songs envisioned sending messages between worlds by way of huge signal mirrors. On the dark side, H.G. Wells' 1898 novel "The War of the Worlds" portrayed an invasion of Earth by technologically superior Martians desperate for water. In the early 1900s novelist Edgar Rice Burroughs, known for the "Tarzan" series, also entertained young readers with tales of adventures among the exotic inhabitants of Mars, which he called Barsoom.

Fact began to turn against such imaginings when the first robotic spacecraft were sent to Mars in the 1960s. Pictures from the 1965 flyby of Mariner 4 and the 1969 flybys of Mariner 6 and 7 showed a desolate world, pocked with impact craters similar to those seen on Earth's Moon. Mariner 9 arrived in 1971 to orbit Mars for the first time, but showed up just as an enormous dust storm was engulfing the entire planet. When the storm died down, Mariner 9 revealed a world that, while partly crater-pocked like Earth's Moon, was much more geologically complex, complete with gigantic canyons, volcanoes, dune fields and polar ice caps. This first wave of Mars exploration culminated in the Viking mission, which sent two orbiters and two landers to the planet in 1975. The landers included a suite of experiments that conducted chemical tests in direct search of life. Most scientists interpreted the results of these tests as negative, deflating hopes of identifying another world on where life might be or have been widespread. However, Viking left a huge legacy of information about Mars that fed a hungry science community for two decades.

The science community had many other reasons for being interested in Mars, apart from the direct search for life; the next mission on the drawing boards concentrated on a study of the planet's geology and climate using advanced orbital reconnaissance. Over the next 20 years, however, new findings in laboratories on Earth came to change the way that scientists thought about life and Mars.

One was the 1996 announcement by a team from Stanford University and NASA's Johnson Space Center that a meteorite believed to have originated on Mars contained what might be the fossils of ancient bacteria. This rock and other likely Mars meteorites discovered on several continents on Earth are believed to have been blasted off the Red Planet by asteroid or comet impacts. They are presently believed to have come from Mars because of gases trapped in them that unmistakably match the composition of Mars' atmosphere as measured by the Viking landers. Many scientists questioned the conclusions of the team announcing the discovery of possible life in one martian meteorite, but if nothing else the mere presence of organic compounds in the meteorites increases the odds of life forming at an earlier time on a far wetter Mars.

Another development that shaped scientists' thinking was spectacular new findings on how and where life thrives on Earth. The fundamental requirements for life as we know it today are liquid water, organic compounds and an energy source for synthesizing complex organic molecules. Beyond these basics, we do not yet understand the environmental and chemical evolution that leads to the origin of terrestrial life. But in recent years, it has become increasingly clear that life can thrive in settings much different -- and more harsh -- from a tropical soup rich in organic nutrients.

In the 1980s and 1990s, biologists found that microbial life has an amazing flexibility for surviving in extreme environments -- niches that by turn are extraordinarily hot, or cold, or dry, or under immense pressures -- that would be completely inhospitable to humans or complex animals. Some scientists even concluded that life may have begun on Earth in heat vents far under the ocean's surface.

This in turn had its effect on how scientists thought about Mars. Martian life might not be so widespread that it would be readily found at the foot of a lander spacecraft, but it may have thrived billions of years ago in an underground thermal spring or other hospitable environment. Or it might still exist in some form in niches below the currently frigid, dry, windswept surface, perhaps entombed in ice or in liquid water aquifers.

After years of studying pictures from the Viking orbiters, scientists gradually came to conclude that many features they saw suggested that Mars may have been warm and wet in an earlier era. And two currently operating orbiters -- Mars Global Surveyor and Mars Odyssey -- are giving scientists yet new insights into the planet. Global Surveyor's camera detected possible evidence for recent liquid water in a large number of settings, while Odyssey's camera system has found large amounts of ice mixed in with Mars surface materials at high latitudes, as well as potential evidence of ancient snowpacks.

The Three Ages of Mars

Based on what they have learned from spacecraft missions, scientists view Mars as the "in-between" planet of the inner solar system. Small rocky planets such as Mercury and Earth's Moon apparently did not have enough internal heat to power volcanoes or to drive the motion of tectonic plates, so their crusts grew cold and static relatively soon after they formed when the solar system condensed into planets about 4.6 billion years ago. Devoid of atmospheres, they are riddled with craters that are relics of impacts during a period of bombardment when the inner planets were sweeping up remnants of small rocky bodies that failed to "make it as planets" in the solar system's early times.

Earth and Venus, by contrast, are larger planets with substantial internal heat sources and significant atmospheres. Earth's surface is continually reshaped by tectonic plates sliding under and against each other and materials spouting forth from active volcanoes where plates are ripped apart. Both Earth and Venus have been paved over so recently that both lack any discernible record of cratering from the era of bombardment in the early solar system.

Mars appears to stand between those sets of worlds, on the basis of current yet evolving knowledge. Like Earth and Venus, it possesses a myriad of volcanoes, although they probably did not remain active as long as counterparts on Earth and Venus. On Earth, a single "hot spot" or plume might form a chain of middling-sized islands such as the Hawaiian Islands as a tectonic plate slowly slides over it. On Mars there are apparently no such tectonic plates, at least as far as we know today, so when volcanoes formed in place they had the time to become much more enormous than the rapidly moving volcanoes on Earth. Overall Mars appears to be neither as dead as Mercury and our Moon, nor as active as Earth and Venus. As one scientist quips, "Mars is a warm corpse if not a fire-breathing dragon." Thanks to the ongoing observations by the Global Surveyor and Odyssey orbiters, however, this view of Mars is still evolving.

Mars almost resembles two different worlds that have been glued together. From latitudes around the equator to the south are ancient highlands pockmarked with craters from the solar system's early era, yet riddled with channels that attest to the flow of water. The northern third of the planet, however, overall is sunken and much smoother at kilometer (mile) scales. There is as yet no general agreement on how the northern plains got to be that way. At one end of the spectrum is the theory that it is the floor of an ancient sea; at the other, the notion that it is merely the end product of innumerable lava flows. New theories are emerging thanks to the discoveries of Mars Odyssey, and some scientists believe a giant ice sheet may be buried under much of the relatively smooth northern plains. Many scientists suspect that some unusual internal process not yet fully understood may have caused the northern plains to sink to relatively low elevations in relation to the southern uplands.

Scientists today view Mars as having had three broad ages, each named for a geographic area that typifies it:

- The **Noachian Era** is the name given to the time spanning perhaps the first billion years of Mars' existence after the planet was formed 4.6 billion years ago. In this era, scientists suspect that Mars was quite active with periods of warm and wet environment, erupting volcanoes and some degree of tectonic activity. The planet may have had a thicker atmosphere to support running water, and it may have rained and snowed.

- In the **Hesperian Era**, which lasted for about the next 500 million to 1.5 billion years, geologic activity was slowing down and near-surface water perhaps was freezing to form surface and buried ice masses. Plunging temperatures probably caused water pooled underground to erupt when heated by impacts in catastrophic floods that surged across vast stretches of the surface -- floods so powerful that they unleashed the force of thousands of Mississippi Rivers. Eventually, water became locked up as permafrost or subsurface ice, or was partially lost into outer space.

- The **Amazonian Era** is the current age that began around 2 billion to 3 billion years ago. The planet is now a dry, desiccating environment with only a modest atmosphere in relation to Earth. In fact, the atmosphere is so thin that water can exist only as a solid or a gas, not as a liquid.

Apart from that broad outline, there is lively debate and disagreement on the details of Mars' history. How wet was the planet, and how long ago? What eventually happened to all of the water? That is all a story that is still being written.

In addition to studying the planet from above with orbiting spacecraft, NASA's Mars Exploration Program is putting robotic geologists on the surface in the form of instrumented rovers. Both of the landing sites selected for the Mars Exploration Rovers show evidence of water activity in their past. The rovers will look at rocks to understand the types of minerals that they are made of, and hence the environments in which they formed. This, in turn, will offer clues about the environment in which the rocks formed. Some types of rocks, for example, might be of types that form in running water, whereas others might be typical of the sediments that form on the beds of lakes.

Even if we ultimately learn that Mars never harbored life as we know it here on Earth, scientific exploration of the Red Planet can assist in understanding the history and evolution of life on our own home world. Much if not all of the evidence for the origin of life here on Earth has been obliterated by the incredible pace of weathering and global tectonics that have operated over billions of years. Mars, by comparison, is a composite world with some regions that may have histories similar to Earth's crust, while oth-

Where We've Been and Where We're Going

Building on scientific discoveries and lessons learned from past and ongoing missions, NASA's Mars Exploration Program will establish a sustained observational presence both around and on the surface of Mars in coming years. This will include orbiters that view the planet from above and act as telecommunications relays; surface-based mobile laboratories; robots that probe below the planet's surface; and, ultimately, missions that return soil and rock samples to Earth. With international cooperation, the long-term program will be guided by compelling questions that scientists are interested in answering about Mars, developing technologies to make missions possible within available resources. The program's strategy is to seek to uncover profound new insights into Mars' past environments, the history of its rocks and interior, the many roles and abundances of water and, quite possibly, evidence of past and present life.

The following are the most recently completed, ongoing and near-term future Mars missions of exploration in the NASA program:

❑ **Mars Pathfinder** (December 1996 - March 1998): The first completed mission in NASA's Discovery Program of low-cost, rapidly developed planetary missions with highly focused scientific goals, Mars Pathfinder far exceeded its expectations and outlived its primary design life. This lander, which released its Sojourner rover at the martian surface, returned 2.3 billion bits of information, including more than 17,000 images and more than 15 chemical analyses of rocks and soil and extensive data on winds and other types of weather. Investigations carried out by instruments on both the lander and the rover suggest that, in its past, Mars was warm and wet, with liquid water on its surface and a thicker atmosphere. The lander and rover functioned far beyond their planned lifetimes (30 days for the lander and 7 days for the rover), but eventually, after about three months on the martian surface, depletion of the lander's battery and a drop in the lander's operating temperature are thought to have ended the mission.

❑ **Mars Global Surveyor** (November 1996 - present): During its primary mapping mission from March 1999 through January 2001, NASA's Mars Global Surveyor collected more information than any other previous Mars mission. Today the orbiter continues to gather data in a second extended mission. As of May 1, 2003, it has completed more than 20,000 orbits of Mars and returned more than 137,000 images, 671 million laser-altimeter shots and 151 million spectrometer measurements. Some of the mission's most significant findings include: evidence of possibly recent liquid water at the martian surface; evidence for layering of rocks that points to widespread ponds or lakes in the planet's early history; topographic evidence that most of the southern hemisphere is higher in elevation than most of the northern hemisphere, so that any downhill flow of water and sediments would have tended to be northward; identification of gray hematite, a mineral suggesting a wet environment when it was formed; and extensive evidence for the role of dust in reshaping the recent martian environment. Global Surveyor provided valuable details for evaluating the risks and attractions of potential landing sites for the Mars Exploration Rover missions, and it will serve as a communications relay for the rovers as they descend to land on Mars and afterwards.

❑ **Mars Climate Orbiter** and **Mars Polar Lander** (1998-99): These spacecraft were both lost upon Mars arrival.

❑ **Mars Odyssey** (April 2001 - present): This orbiter's prime mapping mission began in March 2002. Its suite of gamma-ray spectrometer instruments has provided strong evidence for large quantities of frozen water mixed into the top layer of soil in the 20 percent of the planet near its north and south poles. By one estimate -- likely an underestimate -- the amount of water ice near the surface, if melted, would be enough water to fill Lake Michigan twice. Odyssey's infrared

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camera system has also provided detailed maps of minerals in rocks and soils. A layer of olivine-rich rock in one canyon near Mars' equator suggests that site has been dry for a long time, since olivine is easily weathered by liquid water. Nighttime infrared imaging by Odyssey's camera system provides information about how quickly or slowly surface features cool off after sunset, which gives an indication of where the surface is rocky and where it is dusty. Odyssey's observations have helped evaluate potential landing sites for the Mars Exploration Rovers. When the rovers reach Mars, radio relay via Odyssey will be one way they will return data to Earth.

❑ **Mars Reconnaissance Orbiter** (2005): This mission is being developed to provide detailed information about thousands of sites on Mars, connecting the big-picture perspective of an orbiter with a level of local detail that has previously come only from landing a spacecraft on the surface. The spacecraft's telescopic camera will reveal martian landscapes in resolution fine enough to show rocks the size of a desk. Maps of surface minerals will be produced in unprecedented detail for thousands of potential future landing sites. Scientists will search in particular for types of minerals that form in wet environments. A radar instrument on the orbiter will probe hundreds of meters (or yards) below Mars' surface for layers of frozen or melted water, and other types of geologic layers. Another instrument will document atmospheric processes changing with Mars' seasons, and study how water vapor enters, moves within and leaves the atmosphere.

❑ **Mars Scouts** (2007 and later): Mars Scouts are competitively proposed missions intended to supplement and complement, at relatively low cost, the core missions of NASA's Mars Exploration Program. From 25 original proposals, NASA selected four candidate Scout missions in late 2002 for further study. One will be chosen in August 2003 as the first Mars Scout, for launch in 2007. The four finalists include an orbiter, a lander, an airplane, and a quick dip into Mars' atmosphere to fetch dust and gas samples back to Earth. Mars Volcanic Emission and Life Scout consists of an orbiter for exploring Mars' atmosphere for emissions that could be related to active volcanism or microbial activity. Phoenix is a surface laboratory that proposes to land in Mars' northern plains to investigate water ice, organic molecules and climate. The Aerial Regional-scale Environmental Study proposes to fly a rocket-propelled aircraft through Mars' atmosphere to measure water vapor and other gases near the surface for improved understanding of the chemical evolution of the planet and potential biological activity. The Sample Collection for Investigation of Mars would swoop close enough to the martian surface to grab a sampling of atmospheric dust and gas and return them back to Earth. A second round of Scout solicitation in the future will select a handful of additional Mars Scout missions, one of which would fly in 2011.

❑ **Mars Science Laboratory** (2009): NASA proposes to develop and launch a roving science laboratory that would operate on Mars for more than a year and travel for at least several kilometers or miles. The mission would mark major advances in measurement capabilities and surface access. The rover will examine the potential of the Red Planet as a habitat for extant or extinct life. It would also demonstrate technologies for accurate landing and surface-hazard avoidance that will be necessary for sending future missions to sites that are scientifically compelling but difficult to reach. This mission is designed to make the transition from a program in which we "follow the water" to one in which we "follow the clues to search for the missing carbon" -- and hence to perform the first indirect life detection in a generation on the martian surface.

❑ **The Next Decade of Mars Exploration**: For the second decade of this century, NASA proposes additional reconnaissance orbiters, rovers and landers, and the first mission to return samples of martian rock and soil to Earth. The flexible program includes many options. Scientists and mission planners foresee technology development for advanced capabilities, such as Mars ascent vehicle, automatic rendezvous in Mars orbit and planetary protection.

ers serve as a frozen gallery of the solar system's early days.

Thus, even if life never developed on Mars -- something that we cannot answer today -- scientific exploration of the planet may yield critical information unobtainable by any other means about the pre-biotic chemistry that led to life on Earth. Mars as a fossil graveyard of the chemical conditions that fostered life on Earth is an intriguing possibility.

Science Investigations

The Mars Exploration Rover mission seeks to determine the history of climate and water at sites on Mars where conditions may once have been favorable to life. Each rover is equipped with a suite of science instruments that will be used to read the geologic record at each site, to investigate what role water played there, and to determine how suitable the conditions would have been for life.

Science Objectives

Based on priorities of the overall Mars Exploration Program, the following science objectives were developed for the 2003 rovers:

- ❑ Search for and characterize a diversity of rocks and soils that hold clues to past water activity (water-bearing minerals and minerals deposited by precipitation, evaporation, sedimentary cementation, or hydrothermal activity).

- ❑ Investigate landing sites, selected on the basis of orbital remote sensing, that have a high probability of containing physical and/or chemical evidence of the action of liquid water.

- ❑ Determine the spatial distribution and composition of minerals, rocks and soils surrounding the landing sites.

- ❑ Determine the nature of local surface geologic processes from surface morphology and chemistry.

- ❑ Calibrate and validate orbital remote-sensing data and assess the amount and scale of heterogeneity at each landing site.

- ❑ For iron-containing minerals, identify and quantify relative amounts of specific mineral types that contain water or hydroxyls, or are indicators of formation by an aqueous process, such as iron-bearing carbonates.

- ❑ Characterize the mineral assemblages and textures of different types of rocks and soils and put them in geologic context.

- ❑ Extract clues from the geologic investigation, related to the environmental conditions when liquid water was present and assess whether those environments were conducive for life.

Science Instruments

The package of science instruments on the rovers is collectively known as the Athena science payload. Led by Dr. Steven Squyres, professor of astronomy at Cornell University, Ithaca, N.Y., the Athena package was originally proposed to fly under different Mars lander and rover mission concepts before being finalized as the science payload for the Mars Exploration Rovers.

The package consists of two instruments designed to survey the landing site, as well as three other instruments on an arm designed for closeup study of rocks. Also on the arm is a tool that can scrape away the outer layers of rocks. Those instruments are supplemented by magnets and calibration targets that will enable other studies.

The two instruments that will survey the general site are:

- **Panoramic Camera** will view the surface using two high-resolution color stereo cameras to complement the rover's navigation cameras. Delivering panoramas of the martian surface with unprecedented detail, the instrument's narrow-angle optics provide angular resolution more than three times higher than that of the Mars Pathfinder cameras. The camera's images will help scientists decide what rocks and soils to analyze in detail, and will provide information on surface features, the distribution and shape of nearby rocks, and the presence of features carved by ancient waterways.

- The **Mini-Thermal Emission Spectrometer** is an instrument that sees infrared radiation emitted by objects. It will determine from afar the mineral composition of martian surface features and allow scientists to select specific rocks and soils to investigate in detail. Observing in the infrared allows scientists to see through dust that coats many rocks, allowing the instrument to recognize carbonates, silicates, organic molecules and minerals formed in water. Infrared data will also help scientists assess the capacity of rocks and soils to hold heat over the wide temperature range of a martian day. Besides studying rocks, the instrument will be pointed upward to make the first-ever high-resolution temperature profiles through the martian atmosphere's boundary layer. The data from the instrument will be complement that obtained by the thermal emission spectrometer on the Mars Global Surveyor orbiter.

The instruments on the rover arm are:

- The **Microscopic Imager** is a combination of a microscope and a camera. It will produce extreme closeup views (at a scale of hundreds of microns) of rocks and soils examined by other instruments on the rover arm, providing context for the interpretation of data about minerals and elements. The imager will help characterize sedimentary rocks that formed in water, and thus will help scientists understand past watery environments on Mars. This instrument will also yield information on the small-scale features of rocks formed by volcanic and impact activity as well as tiny veins of minerals like the carbonates that may contain microfossils in the famous Mars meteorite, ALH84001. The shape and size of particles in the martian soil can also be determined by the instrument, which provides valuable clues about how the soil formed.

❑ Because many of the most important minerals on Mars contain iron, the **Mössbauer Spectrometer** is designed to determine with high accuracy the composition and abundance of iron-bearing minerals that are difficult to detect by other means. Identification of iron-bearing minerals will yield information about early martian environmental conditions. The spectrometer is also capable of examining the magnetic properties of surface materials and identifying minerals formed in hot, watery environments that could preserve fossil evidence of martian life. The instrument uses two pieces of radioactive cobalt-57, each about the size of a pencil eraser, as radiation sources. The instrument is provided by Germany.

❑ The **Alpha Particle X-Ray Spectrometer** will accurately determine the elements that make up rocks and soils. This information will be used to complement and constrain the analysis of minerals provided by the other science instruments. Through the use of alpha particles and X-rays, the instrument will determine a sample's abundances of all major rock-forming elements except hydrogen. Analyzing the elemental make-up of martian surface materials will provide scientists with information about crustal formation, weathering processes and water activity on Mars. The instrument uses small amounts of curium-244 for generating radiation. It is provided by Germany.

❑ The arm-mounted instruments will be aided by a **Rock Abrasion Tool** that will act as the rover's equivalent of a geologist's rock hammer. Positioned against a rock by the rover's instrument arm, the tool uses a grinding wheel to remove dust and weathered rock, exposing fresh rock underneath. The tool will expose an area 4.5 centimeters (2 inches) in diameter, and grind down to a depth of as much as 5 millimeters (0.2 inch).

In addition, the rovers are equipped with the following that work in conjunction with science instruments:

❑ Each rover has three sets of **Magnet Arrays** that will collect airborne dust for analysis by the science instruments. Mars is a dusty place, and some of that dust is highly magnetic. Magnetic minerals carried in dust grains may be freeze-dried remnants of the planet´s watery past. A periodic examination of these particles and their patterns of accumulation on magnets of varying strength can reveal clues about their mineralogy and the planet´s geologic history. One set of magnets will be carried by the rock abrasion tool. As it grinds into martian rocks, scientists will have the opportunity to study the properties of dust from these outer rock surfaces. A second set of two magnets is mounted on the front of the rover for the purpose of gathering airborne dust. These magnets will be reachable for analysis by the Mössbauer and alpha particle X-ray spectrometers. A third magnet is mounted on the top of the rover deck in view of the panoramic camera. This magnet is strong enough to deflect the paths of wind-carried, magnetic dust. The magnet arrays are provided by Denmark.

❑ **Calibration Targets** are reference points that will help scientists fine-tune observations not only from imagers but also other science instruments. The Mössbauer spectrometer, for example, uses as a calibration target a thin slab of rock rich in magnetite. The alpha particle X-ray spectrometer uses a calibration target on the interior surfaces of doors designed to protect its sensor head from martian dust. The miniature thermal emission spectrometer has both an internal target located in the mast assembly as well as an external target on the rover's deck.

The panoramic camera's calibration target is, by far, the most unique the rover carries. It is in the shape of a **Sundial** and is mounted on the rover deck. The camera will take pictures of the sundial many times during the mission so that scientists can make adjustments to the images they receive from Mars. They will use the colored blocks in the corners of the sundial to calibrate the color in images of the Martian landscape. Pictures of the shadows that are cast by the sundial's center post will allow scientists to properly adjust the brightness of each camera image. Children provided artwork for the sides of the base of the sundial.

Landing Sites

Selection of the landing sites for the two Mars Exploration Rovers involved over two years of intensive study by more than 100 scientists and engineers. Their job was to find sites that offered both excellent chances for a safe landing and outstanding science after the landings are achieved.

To qualify for consideration, candidate sites had to be near Mars' equator, low enough in elevation (so the spacecraft would pass through enough atmosphere to slow them), not too rugged, not too rocky and not too dusty. In all, 155 potential sites met the initial safety constraints. The two that made the final cut satisifed all of the safety criteria; they also show powerful evidence of past liquid water, but in two very different ways:

- ❑ **Gusev Crater**, named after the 19th-century Russian astronomer Matvei Gusev, is an impact crater about 150 kilometers (95 miles) in diameter and about 15 degrees south of Mars' equator. It lies near the transition between the planet's ancient highlands to the south and smoother plains to the north.

  What makes Gusev an attractive landing site is a 900-kilometer-long (550-mile) meandering valley that enters the crater from the southeast. Called Ma'adim Vallis (from the Hebrew name for Mars), this valley is believed to have been eroded long ago by flowing water. The water likely cut through the crater's rim and filled much of the crater, creating a large lake not unlike current crater lakes here on Earth such as Lake Bosumtwi in Ghana). The lake is gone now, but the floor of Gusev Crater may contain water-laid sediments that still preserve a record of what conditions were like in the lake when the sediments were deposited.

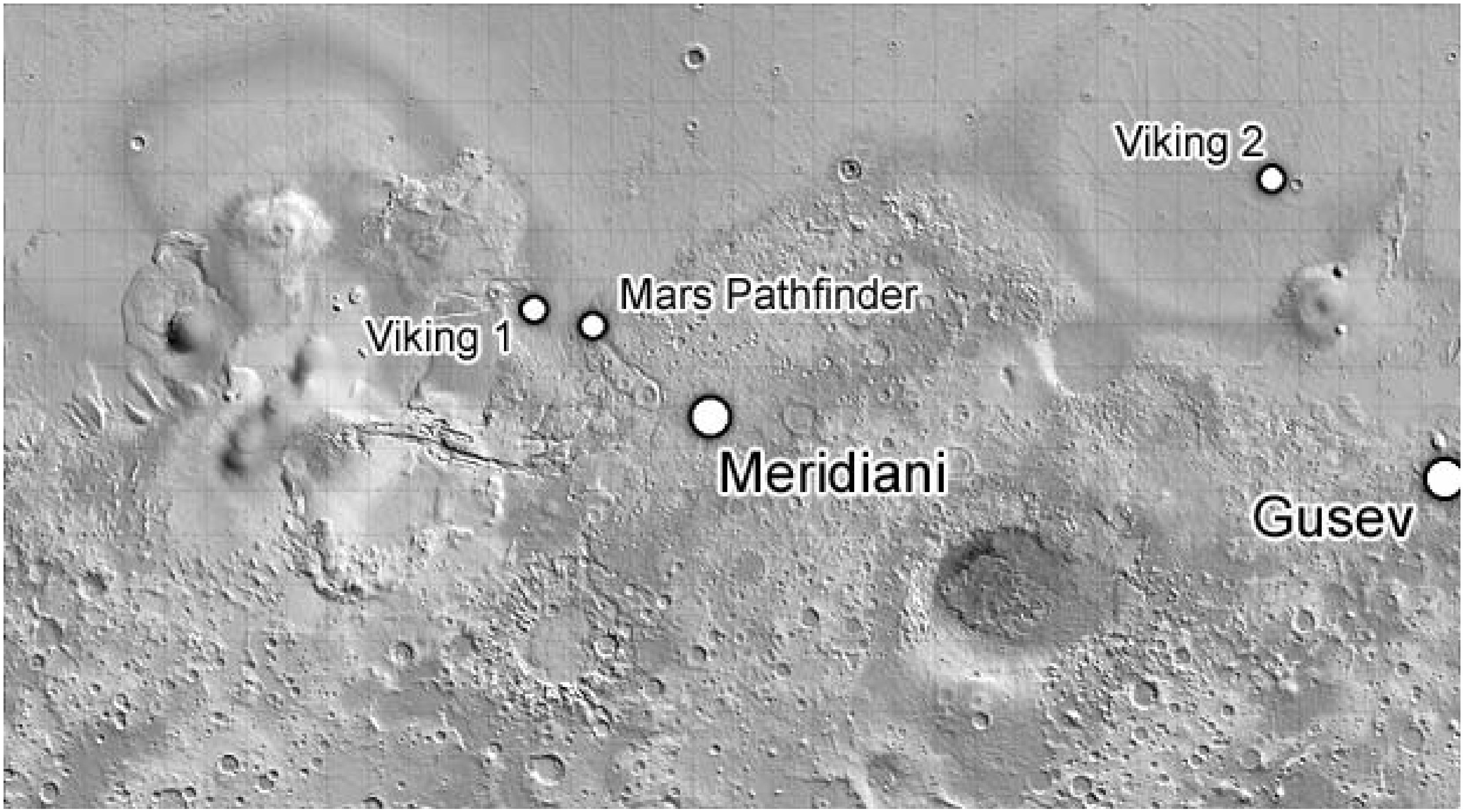
  Are lake sediments still preserved at Gusev Crater, or have they been buried by younger geologic materials? If sediments can be found, what do they reveal about the conditions that existed in the lake? Did the lake create an environment that would have been suitable for life? Are there other clues at Gusev that can reveal more about whether Mars had a warmer, wetter past?

- ❑ **Meridiani Planum** is near the martian equator, halfway around the planet from Gusev. The region of the planet in which it lies has been known as Meridiani since the earliest days of telescopic study of Mars, because it lies near the planet's meridian, or line of zero longitude. "Planum" means plains, and the name fits: Meridiani Planum is one of the smoothest, flattest places on Mars.

  The scientific appeal of Meridiani comes not from its smooth landscape, but from its strange mineral composition. Looking down from orbit, the thermal emission spectrometer instrument on the Mars Global Surveyor spacecraft has shown that Meridiani Planum is rich in an iron oxide mineral called gray hematite. Gray hematite is found on Earth, where it usually -- though not always -- forms in association with liquid water.

  Did the formation of the telltale mineral hematite at Meridiani involve liquid water? If it did, what was the process? Was the water in a lake? Was it percolating through rocks, perhaps at high tempera tures? Was it present only as a trace on the surfaces of rocks? If water was present, were the conditions at Meridiani favorable for life? Or did the hematite form by some other process that didn't involve water at all? And what other clues does Meridani Planum hold regarding past conditions on Mars?

Rover A -- the first to launch and land -- will go to Gusev, while Rover B will go to Meridiani.



Landing sites

Mission Overview

NASA's Mars Exploration Rover Project will deliver two mobile laboratories to the surface of Mars for robotic geological fieldwork, including the examination of rocks and soils that may reveal a history of past water activity.

Sequences of launch, cruise and arrival operations will dispatch each rover to a different area of the planet three weeks apart to explore those areas for about three months each.

The two identical rovers can recognize and maneuver around small obstacles on their way to target rocks selected by scientists from images sent by the rovers. They will conduct unprecedented studies of Mars geology, such as the first microscopic observations of rock samples. They will provide "ground truth" characterization of the landing vicinities that will help to calibrate observations from instruments that view the planet from above on Mars orbiters.

NASA selected the sites to be explored, Gusev Crater and Meridiani Planum, from 155 potential locations as the two offering the best combination of safe landing potential and scientific appeal in assessing whether liquid water on Mars has ever made environments conducive to life.

While the rovers and the instruments they carry are the centerpieces of the project, each rover mission also depends on the performance of other components: the launch vehicle; a cruise stage; a system for entering Mars' atmosphere, descending through it and landing; a versatile system for deep-space communications; Earth facilities for data processing; and an international team of engineers, scientists and others.

Launch Vehicle

The two rover spacecraft will be lofted on three-stage Delta II rockets from Florida's Cape Canaveral Air Station. Rover A will launch on a version of the Delta II known as model 7925, a vehicle with a history of more than 40 successful launches, including those of the Mars Global Surveyor, Mars Pathfinder and Mars Odyssey missions. Rover B will use a newer, slightly more powerful version called model 7925H; the H identifies the vehicle as a heavy lifter.

Both of the Deltas feature a liquid-fueled first stage with nine strap-on solid-fuel boosters; a second-stage liquid-fueled engine; and a third stage solid-fuel rocket. The difference between the two versions is in the size of the strap-on boosters. With their payloads on top, each launch vehicle stands 39.6 meters (130 feet) tall.

The first stage of the Delta II uses a Rocketdyne RS-27A main engine. The engine provides nearly 890,000 newtons (200,000 pounds) of thrust by reacting RP-1 fuel (thermally stable kerosene) with liquid oxygen. The nine boosters for the first rover mission are 1,016 millimeters (40 inches) in diameter and fueled with enough hydroxyl-terminated polybutadiene solid propellant to provide about 446,000 newtons (100,000 pounds) of thrust apiece. The nine for the second mission are each 1,168 millimeters (46 inches) in diameter, with about 25 percent more thrust.

The Delta's second stage is powered by a restartable Aerojet AJ10-118K engine, which produces about 44,000 newtons (9,900 pounds) of thrust. The engine uses a fuel called Aerozine 50, which is a mixture of hydrazine and dimethyl hydrazine, reacted with nitrogen tetroxide as an oxidizer.

A Star-48B solid-fuel rocket made by Thiokol powers the third stage. It adds a final kick of about 66,000 newtons (14,850 pounds), using a propellant made primarily of ammonium perchlorate and aluminum.

Launch Timing

Rover A will be launched between June 8 and June 24, 2003, followed by Rover B between June 25 and July 15, 2003. To allow changeover of ground equipment at the launch pads, the two missions must be launched at least 10 days apart, so if Rover A launches at the end of its launch period Rover B's launch will be slipped accordingly. Rover A will lift off from Cape Canaveral's Space Launch Complex 17A , while Rover B will use the station's Space Launch Complex 17B.

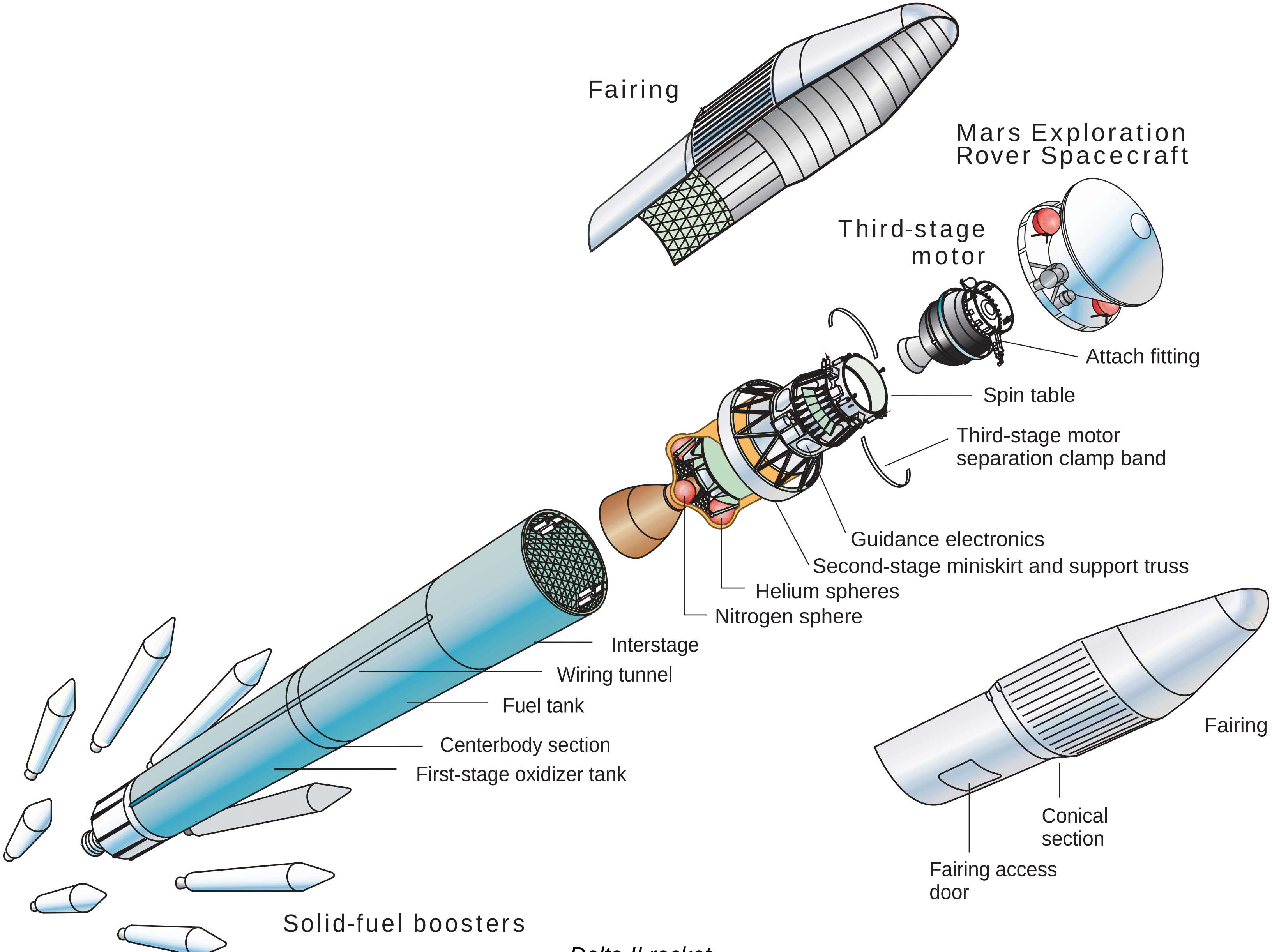
Each mission has a total of two nearly instantaneous launch opportunities each day. On the first day of Rover A's launch period, June 8, the first opportunity is at 2:05:55 p.m. Eastern Daylight Time. On the first day of Rover B's launch period, June 25, the first opportunity is at 12:38:16 a.m. EDT. Opportunities for both missions occur a few minutes earlier each day as the launch period progresses.

Launch Sequences

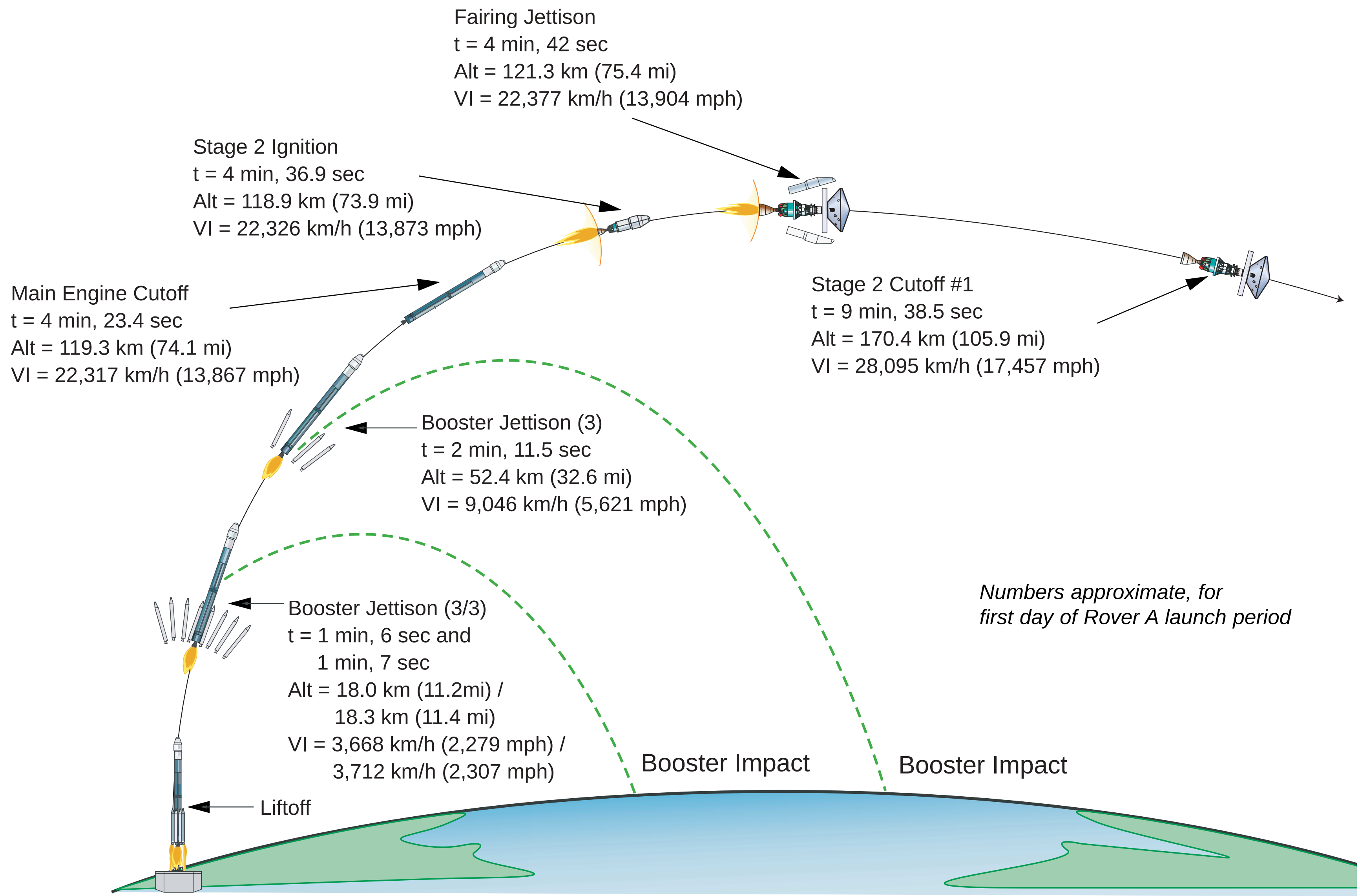
When each Delta II launches, its first-stage engine and six of its nine strap-on boosters ignite at the moment of liftoff. The remaining three boosters will ignite following burnout of the first six. The boosters' spent casings will be jettisoned in sets of three between 1 and 3 minutes after liftoff.

About 4 minutes and 23 seconds into the flight, the main engine will cut off. Within the following 20 seconds, the first stage will separate from the second, the second stage will ignite, and the nose cone, or "fairing," will fall away. At about 10 minutes after liftoff for Rover A and 9 minutes after liftoff for Rover B, the second-stage engine will temporarily stop firing.

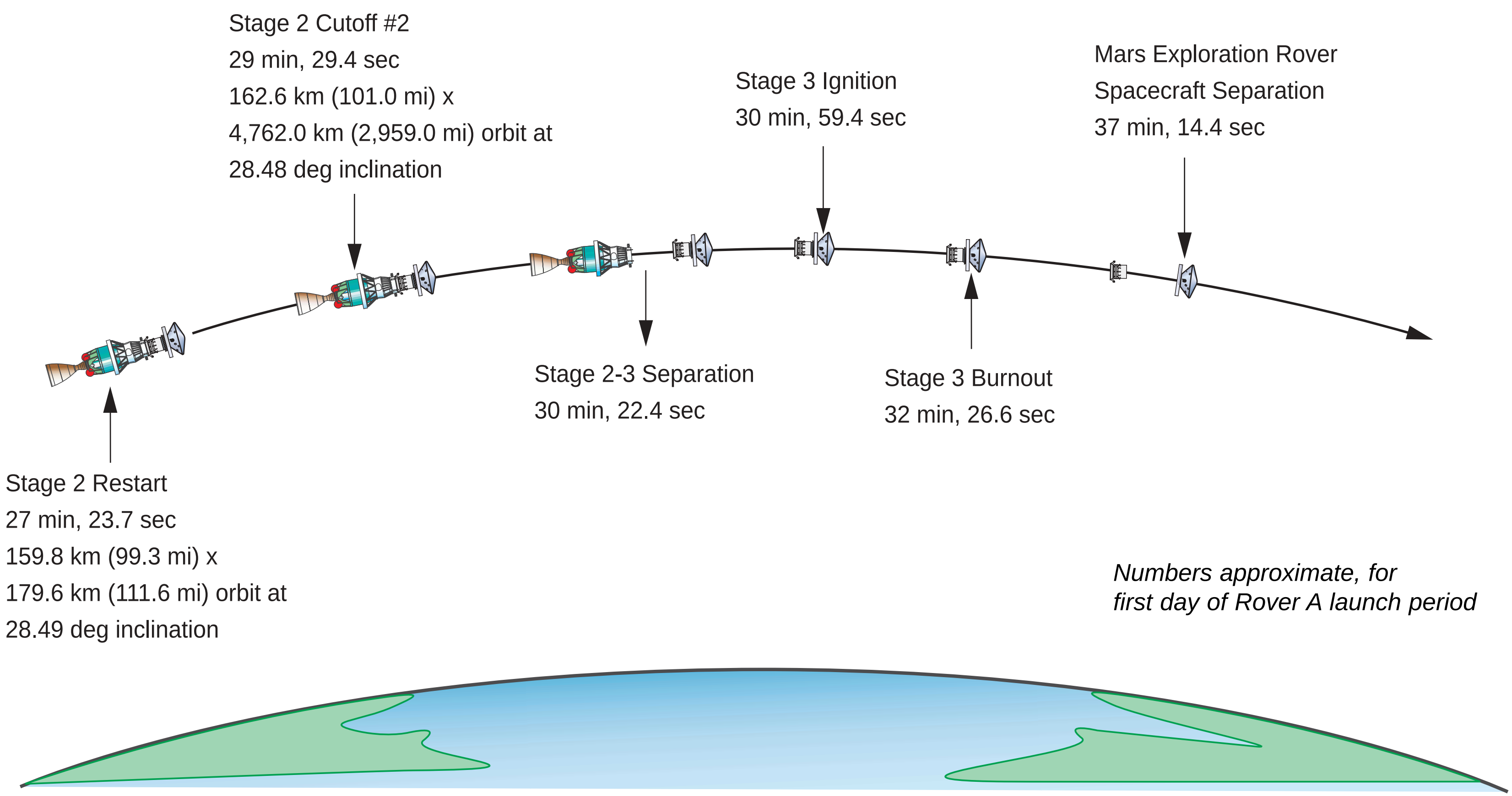
At this point, the spacecraft with the second and third stages of the Delta still attached will be in a circular parking orbit 167 kilometers (104 miles) above Earth. Before com-



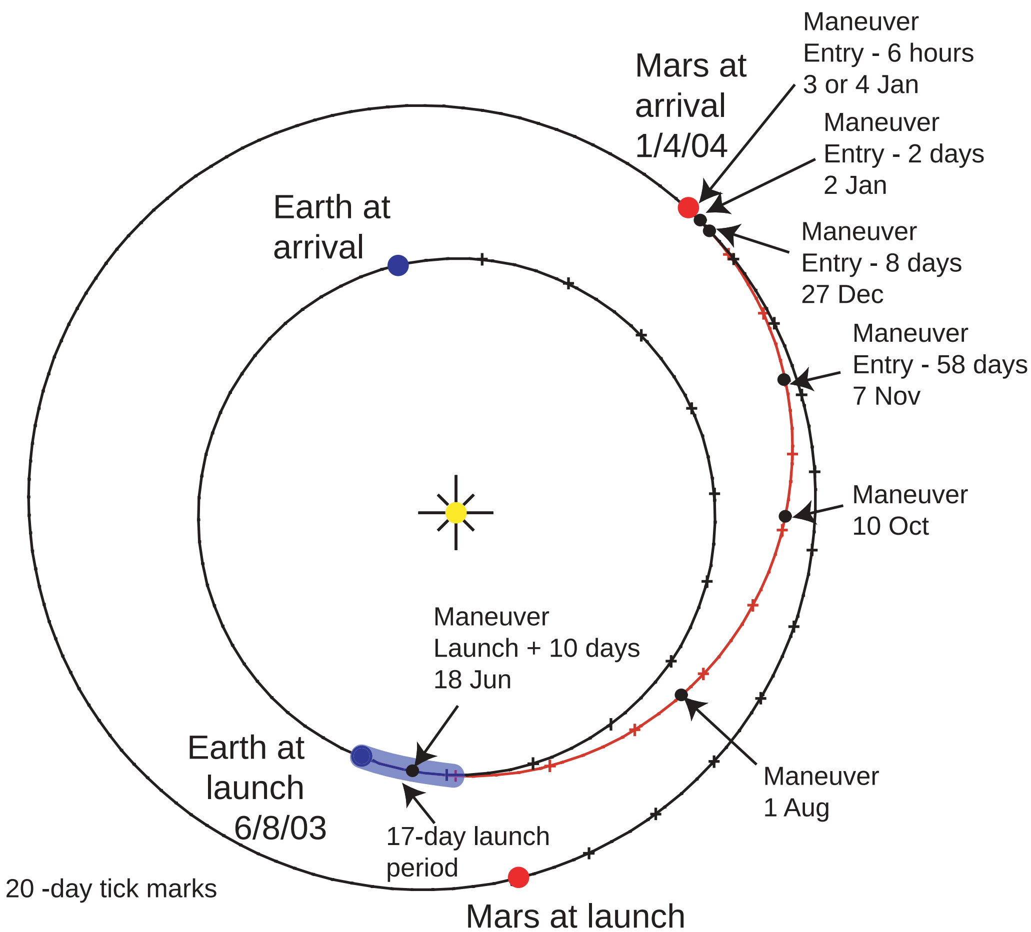
Delta II rocket



Launch phases



Launch phases

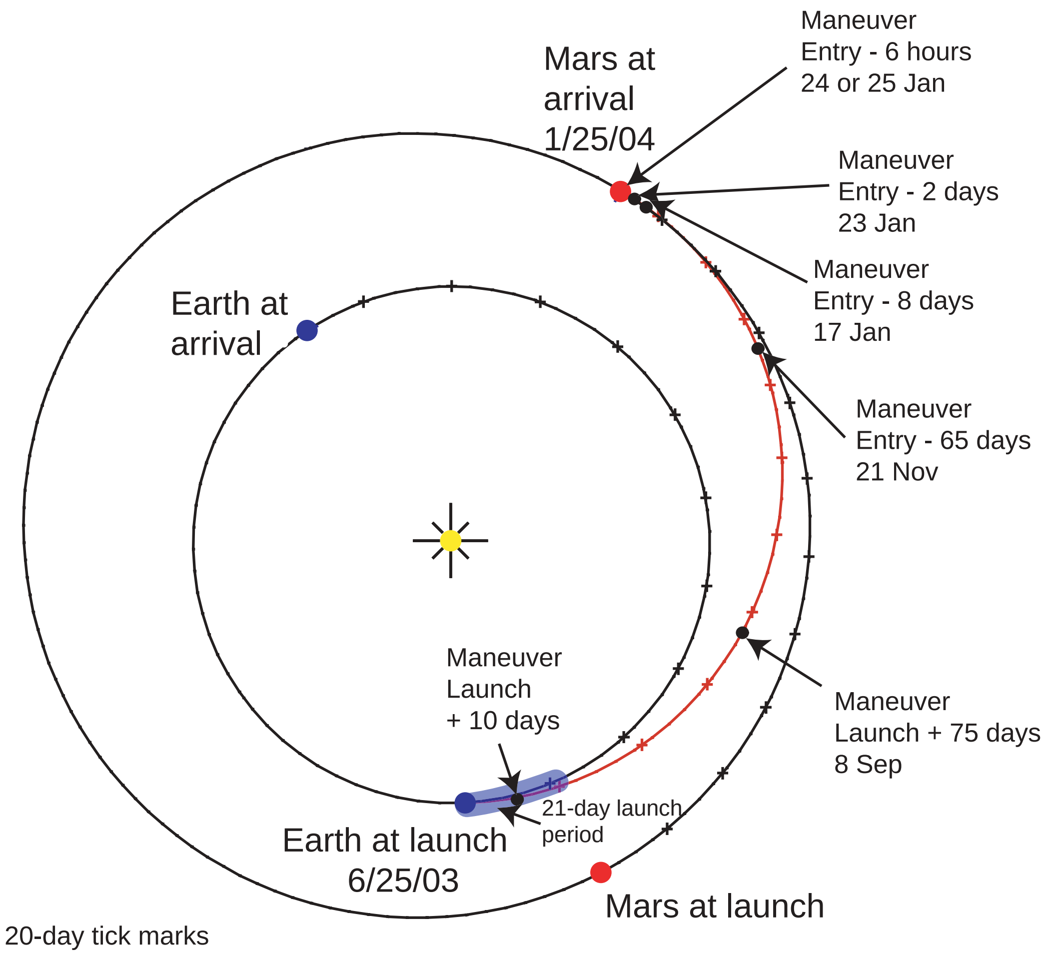


Rover A trajectory

pletion of even one orbit, however, the Delta's second stage will reignite to begin pushing the spacecraft out onto its interplanetary trajectory toward Mars. This begins about 14 to 19 minutes after liftoff for Rover A, depending on the date and time of launch, and about 59 to 67 minutes after liftoff for Rover B. The second burn of the Delta's second stage will last 2 to 3 minutes.

Small rockets will be fired to spin the Delta's third stage to about 63 rotations per minute on a turntable attached to the second stage. The third stage will then separate from the second, firing its engine for about 87 seconds to finish putting the spacecraft on course for Mars. To reduce the spacecraft's spin rate after the third-stage engine finishes firing, a set of yo-yo-like weights will reel out on flexible lines. These work like a twirling ice-skater's arms, slowing the spin as they are extended.

The spacecraft will shed the burned-out Delta third stage about 34 to 39 minutes after liftoff for Rover A and 78 to 87 minutes after liftoff for Rover B. Springs will push the third stage away, exposing an antenna on the rover spacecraft's cruise stage. Radio



Rover B trajectory

transmissions from the Delta II will enable controllers on the ground to monitor critical events throughout the launch sequence. However, communications with each Mars Exploration Rover spacecraft cannot begin until after it separates from the Delta's third stage. NASA's Deep Space Network will begin receiving radio signals from Rover A about 50 minutes after launch, using the network's Canberra, Australia, antenna complex. For Rover B, initial radio contact with the Deep Space Network is expected at the Goldstone, Calif., antenna complex one minute or more after third-stage separation.

Interplanetary Cruise and Approach to Mars

No matter which day in its launch period Rover A leaves Earth, it will reach Mars on January 4, 2004, so the journey may last anywhere from 194 to 210 days. Similarly, Rover B has a fixed appointment for arriving on January 25, 2004, so the duration of its journey to Mars will be from 194 days to 214 days, depending on its launch date.

Engineers refer to the first few months of each trip as the cruise phase, while the final

45 days before arrival are known as the approach phase. During both phases, each spacecraft is connected to a cruise stage that will be jettisoned in the final minutes of the flight. Solar panels on the cruise stage will provide electricity for the spacecraft in flight.

Thrusters on the cruise stage will be fired to adjust the spacecraft's flight path three times during the cruise phase and up to three more times during the final eight days of the approach phase. The first one or two of these maneuvers will commit the spacecraft to a specific target area on Mars. An additional thruster firing may be added during Rover A's cruise stage to allow ground controllers to retarget the landing site later if this is deemed necessary. Later maneuvers for both missions will refine the targeting based on calculations using frequently updated determinations of the spacecraft's position and course. The final trajectory correction maneuver, which is optional, is scheduled just six hours before landing.

Like NASA's Mars Odyssey orbital mission, the Mars Exploration Rover project will combine two traditional tracking schemes with a relatively new triangulation method to improve navigational precision. One of the traditional methods is ranging, which measures the distance to the spacecraft by timing precisely how long it takes for a radio signal to travel to the spacecraft and back. The other is Doppler, which measures the spacecraft's speed relative to Earth by the amount of shift in the pitch of a radio signal from the craft.

The newer method, called delta differential one-way range measurement, adds information about the location of the spacecraft in directions perpendicular to the line of sight. Pairs of antennas at Deep Space Network sites on two different continents simultaneously receive signals from the spacecraft, then use the same antennas to observe natural radio waves from a known celestial reference point, such as a quasar. Successful use of this triangulation method is expected to shave several kilometers or miles off the amount of uncertainty in delivering the rovers to their targeted landing sites.

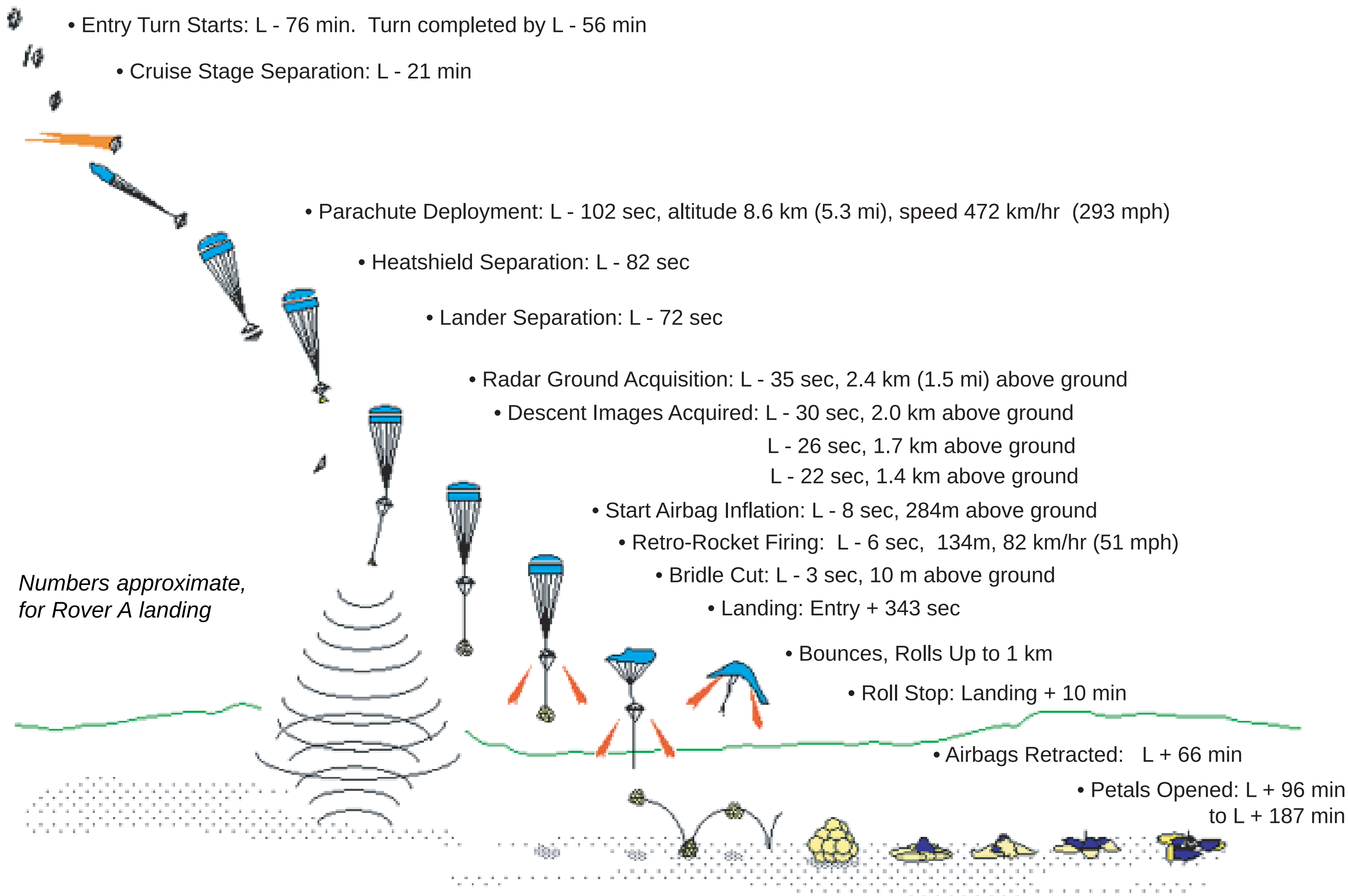
The months in which the rovers travel from Earth to Mars will also provide time for testing critical procedures, equipment and software in preparation for arrival.

Entry, Descent and Landing

The Mars Exploration Rovers will use the same airbag-cushioned landing scheme that successfully delivered Mars Pathfinder to the Red Planet in 1997.

About 70 minutes before entering Mars' atmosphere, each rover spacecraft will turn to orient its heat shield forward. From that point until the rover deploys its own solar panels after landing, five batteries mounted on the lander will power the spacecraft.

The planned sequence of events for entering the atmosphere, descending and landing



Entry, descent and landing

is essentially the same for each of the two rover missions. Fifteen minutes before atmospheric entry, the protective aeroshell encasing the lander and rover will separate from the cruise stage, whose role will at that point be finished. Each cruise stage will ultimately impact Mars.

Each spacecraft will hit the top of the atmosphere, about 128 kilometers (80 miles) above Mars' surface, at a flight path angle of about 11.5 degrees and a velocity of about 5.4 kilometers per second (12,000 miles per hour). Although Mars has a much thinner atmosphere than Earth does, the friction of traveling through it will heat and slow the spacecraft dramatically. The surface of the heat shield is expected to reach a temperature of 1,447 C (2,637 F). By 4 minutes after atmospheric entry, speed will have decreased to about 430 meters per second (960 miles per hour). At that point, about 8.5 kilometers (5.3 miles) above the ground, the spacecraft will deploy its parachute.

Within 2 minutes, the spacecraft will be bouncing on the surface, but those minutes will be packed with challenging events crucial to the mission's success.

Twenty seconds after parachute deployment, the spacecraft will jettison the bottom half of its protective shell, the heat shield, exposing the lander inside. Ten seconds later, the backshell, still attached to the parachute, will begin lowering the lander on a tether-like bridle about 20 meters (66 feet) long. Spooling out the bridle to full length will take 10 seconds. Almost immediately, a radar system on the lander will begin sending pulses toward the ground to measure its altitude. Radar will detect the ground when the craft is about 2.4 kilometers (1.5 miles) above the surface, approximately 35 seconds before landing.

The Mars Exploration Rover design has two new tools, absent on Mars Pathfinder, to avoid excessive horizontal speed during ground impact in case of strong winds near the surface. One is a downward-looking camera mounted on the lander. Once the radar has sensed the surface, this camera will take three pictures of the ground about 4 seconds apart and automatically analyze them to estimate the spacecraft's horizontal velocity. The other innovation is a set of three small transverse rockets mounted on the backshell that can be fired in any combination to reduce horizontal velocity or counteract effects of side-to-side swinging under the parachute and bridle.

Eight seconds before touchdown, gas generators will inflate the lander's airbags. Two seconds later, the three main deceleration rockets on the backshell -- and, if needed, one or two of the transverse rockets -- will ignite. After 3 more seconds, when the lander should be about 15 meters (50 feet) above ground and have zero vertical velocity, its bridle will be cut, releasing it from the backshell and parachute. The airbag-protected lander will then be in free fall for a few seconds as it drops toward the ground.

The first bounce may take the airbag-protected lander back up to 15 meters (49 feet) or more above the ground. Bouncing and rolling could last several minutes. By comparison, the airbag-cushioned Mars Pathfinder bounced about 15 times, as high as 15 meters (49 feet), before coming to a rest 2-1/2 minutes later about a kilometer (0.6 mile) from its point of initial impact.

Twelve minutes after landing, motors will begin retracting the airbags, a process likely to take about an hour. Then the lander petals will open. No matter which of the four petals is on the bottom when the folded-up lander stops rolling, the petal-opening action will set all four face up, with the rover's base petal in the center.

Mars Surface Operations

Opening of the four-sided lander will uncover the rover tucked snugly inside. Each rover's first action will be to unfold its solar-array panels. Then, still in a crouch, it will take images of the immediate surroundings with four hazard-identification cameras mounted below the plane of the solar panels.

Since the rovers rely on sunlight to generate electrical power, their operations on the surface will run on a schedule timed to the length of the martian day. A martian day, or "sol," lasts 24 hours, 39 minutes and 35 seconds.

Each rover will need to spend several sols completing housekeeping tasks before moving off its lander. Before the first martian night, each rover may deploy its main antenna and the mast on which its panoramic camera and navigation camera are mounted. The navigation camera will take the first panorama of the landing site. Once transmitted to Earth during the following sol, the panorama and initial imaging by the rover's hazard-identification cameras will help mission engineers identify the safest route for the rover's later departure from the lander.

The rover will rise up from its crouching position and stand up at its full height while still on the lander base petal. From this height, it will take a 360-degree high-resolution, stereo, color panorama with its panoramic camera and a matching 360-degree panorama with its miniature thermal infrared spectrometer. Scientists will rely heavily on those images to decide which rocks the rover should go examine.

Unlike Mars Pathfinder, when each Mars Exploration Rover rolls off its lander, the lander's role in the mission will have ended. A new chapter in Mars exploration will begin.

In the next few sols after roll-off, the rover will finish checking and calibrating its science instruments and move to whichever nearby rock or patch of soil the science team has selected as the first target by analyzing the panoramic and infrared images taken earlier. The rover will examine each target up close, then begin moving on the following sol toward its next target. It may travel as much as about 40 meters (44 yards) in a sol, but is likely to cover less than that on most travel days as it maneuvers itself to avoid hazards on the way.

To coordinate their work with the rovers, flight team engineers and scientists operating the rovers from NASA's Jet Propulsion Laboratory in Pasadena, Calif., will be living on a martian schedule, too. The 40-minute difference from Earth's day length means that, by about two weeks after the rovers land on Mars, team members' wake-up times and meal times will have shifted by about 9 hours. After the second rover reaches Mars, its team will be working on a different martian schedule that the first rover's team because the two chosen landing sites are about halfway around Mars from each other. When it's noon at Meridiani, it's midnight at Gusev. Each rover will typically transmit each sol's accumulation of data in the martian afternoon. The flight team will analyze that data, refine plans for the next sol's rover activity, and send updated commands to the rover the next martian morning.

Each rover has a prime-mission goal of operating for at least 90 martian sols (92 Earth days) after landing, though environmental conditions such as dust storms could cut the mission shorter.

Mars' distance from the Sun varies much more than Earth's does, and Mars will have passed the closest point to the Sun in its 23-month elliptical orbit about 5 months before the rovers arrive. The distance between Mars and the Sun will therefore increase by about 7 percent between mid-January and mid-April 2004, resulting in two principal consequences for how long the rovers can keep working. The rovers land at the end of summer in Mars' southern hemisphere, and with the onset of autumn the decreasing intensity of solar radiation reaching their solar panels will lessen the amount of electrical power produced. Also, colder nights will increase the need for electrically powered heating to keep the batteries warm enough to work. On top of those factors, a less predictable but possibly most important element limiting the rovers' lifetime will be the accumulation of dust on their solar panels.

Communications

Like all of NASA's interplanetary missions, the Mars Exploration Rover project will rely on the agency's Deep Space Network to track and communicate with both spacecraft. During the critical minutes of arrival at Mars, the two rovers will communicate essential spacecraft-status information throughout their atmospheric entry, descent and landing. On the surface of Mars, the rovers will be capable of communicating either directly with Earth or through Mars orbiters acting as relays. The distance between Earth and Mars will increase by about 65 percent between mid-January and mid-April 2004, reducing the rate at which data can be transmitted across space.

The Deep Space Network, which will be 40 years old on December 24, 2003, transmits and receives radio signals through large dish antennas at three sites spaced approximately one-third of the way around the world from each other. This configuration ensures that spacecraft remain in view of one antenna complex or another as Earth rotates. The antenna complexes are at Goldstone in California's Mojave Desert; near Madrid, Spain; and near Canberra, Australia. Each complex is equipped with one antenna 70 meters (230 feet) in diameter, at least two antennas 34 meters (112 feet) in diameter, and smaller antennas. All three complexes communicate directly with the control hub at NASA's Jet Propulsion Laboratory, Pasadena, Calif. The network served more than 25 spacecraft in 2002.

The network has been preparing to deal with an extraordinary level of demand for interplanetary communications in late 2003 and early 2004. Several missions besides the Mars Exploration Rovers will be conducting critical events. Among others, the European Space Agency's Mars Express will enter Mars orbit after dropping the Beagle 2 lander to the surface; Japan's Nozomi orbiter will be arriving at Mars; NASA's Stardust spacecraft will fly by a comet; and NASA's Cassini spacecraft will be nearing its mid-2004 arrival at Saturn. The Deep Space Network is upgrading antenna capabilities at all three complexes and is completing the construction of a new 34-meter antenna at the Madrid complex. That new antenna alone will add about 70 hours of spacecraft-tracking time per week during the periods when Mars is in view of Madrid.

During each Mars Exploration Rover mission's early cruise phase, a low-gain antenna mounted on the cruise stage will provide the communications link with Earth. A low-gain antenna does not need to be pointed as precisely as a higher-gain antenna. During early cruise it would be difficult to keep an antenna pointed at Earth and the solar panels oriented toward the Sun, due to the Sun-Earth angle at that stage of the mission. Later in the cruise toward Mars, the angle between the Sun and Earth will shrink, making it possible for the spacecraft to switch to a more directional medium-gain antenna, also mounted on the cruise stage.

Data transmission is most difficult during the critical sequence of atmospheric entry, descent and landing activities, but communication from the spacecraft is required during this period in order to diagnose any potential problems that may occur.

Minutes before the spacecraft turns to point its heat shield forward in preparation for entering Mars' atmosphere, the cruise stage's low-gain antenna will take over again, which will reduce the data transmission rate to 10 bits per second, less than 2 percent of the mid-gain antenna's rate. Through this antenna and later through other low-gain antennas on the backshell, lander and rover, transmissions during the next hour or more will consist of simple signal tones coded to indicate the accomplishment of critical activities. For example, a change in tone will tell controllers when the spacecraft has successfully jettisoned its cruise stage about 15 minutes before hitting the atmosphere. During the descent through the atmosphere, about 36 ten-second signal tones will be transmitted.

Before its first night on the surface of Mars, each rover may deploy its high-gain antenna for use the following morning. The rovers will be able to communicate directly with Earth at transmission rates greater than 11,000 bits per second using this antenna.

About a minute before each lander drops to the martian surface, another important communication method -- relay through Mars orbiter spacecraft -- will begin to be used.

An antenna mounted on each lander will transmit status information to the orbiting Mars Global Surveyor from the time the descending lander emerges from the backshell until ground impact. If that antenna survives the first bounce, it will continue to relay information for a few minutes as the lander bounces and rolls to a stop. The orbit of Mars Global Surveyor will be adjusted in preceding weeks to place it over the landing vicinity during those crucial minutes to receive the transmissions. The orbiter will later transmit the data to Earth.

Throughout each rover's surface mission, a rover-mounted antenna will be able to communicate with Mars Global Surveyor and Mars Odyssey for several minutes once or twice per sol while each of the two orbiters pass overhead via a UHF link at 128,000 bits per second. Plans call for using direct-to-Earth communications for transmissions critical to mission success, but about half the total data returned from the rovers could be relayed via the orbiters. One engineering goal for the project is to demonstrate relay capability at least once with the European Space Agency's Mars Express orbiter, which is due to begin circling Mars in December 2003.

Planetary Protection Requirements

In the study of whether Mars has had environments conducive to life, precautions are taken against introducing microbes from Earth. The United States is a signatory to an international treaty that stipulates that exploration must be conducted in a manner that avoids harmful contamination of celestial bodies.

The primary strategy for preventing contamination of Mars with Earth organisms is to be sure that the hardware intended to reach the planet is clean. Each Mars Exploration Rover spacecraft must comply with requirements to carry a total of no more than 300,000 bacterial spores on any surface from which the spores could get into the martian environment. Technicians assembling the spacecraft and preparing them for launch frequently cleaned surfaces by wiping them with an alcohol solution. The planetary protection team carefully sampled the surfaces and performed microbiology tests to demonstrate that each spacecraft meets requirements for biological cleanliness. Components tolerant of high temperature, such as the parachute and thermal blanketing, were heated to 110 C (230 F) or hotter to kill microbes. The core box of each rover, containing the main computer and other key electronics, is sealed and vented through high-efficiency filters that keep any microbes inside. Some smaller electronics compartments are also isolated in this manner.

Another type of precaution is to be sure that other hardware doesn't go to Mars accidentally. When the Delta’s third stage separates from the spacecraft, the two objects are traveling on nearly identical trajectories. To prevent the possibility of the Delta's third stage hitting Mars, that shared course is deliberately set so that the spacecraft would miss Mars if not for its first trajectory correction maneuver, about 10 days later.

The NASA planetary protection officer is responsible for the establishment and enforcement of the agency’s planetary protection regulations.

Launch Safety

The rovers use small amounts of radioactive materials in two science instruments and to prevent electronics from getting too cold during martian nights. NASA has safely used radioactive materials for four decades in a variety of scientific instruments and for spacecraft heating or electrical power when necessary.

There is little radiological danger to the public from a Mars Exploration Rover 2003 launch accident. Analysis performed for the mission's environmental impact statement indicates that the chance of an accident occurring during launch is about 1 in 30. Most accidents would not present a threat to the radioisotope heater units onboard the spacecraft because of the rugged design of the units. There are also small-quantity radioactive sources on board the spacecraft (curium-244 and cobalt-57) that are used for instrument calibration or science experiments. Since these small sources of curium-244 and cobalt-57 have relatively low melting temperatures compared to the plutonium dioxide in the radioisotope heater units, these radioactive materials would likely be released in an early launch accident (i.e., the first 23 seconds of launch). The chance of an early launch accident that releases any radioactive material is about 1 in 1,030.

If a launch-area accident resulting in the release of radioactive sources were to occur, spectators and people off-site in the downwind direction could be exposed to small quantities of radionuclides. The person with the highest exposure would typically receive less than a few tens of millirem. (The average annual dose from naturally occurring sources of radiation in the United States is about 300 millirem per year.) No health consequences would be expected with this level of radiation exposure.

Precautionary measures include deployment of radiological monitoring teams and remote air monitoring stations at strategic locations at the launch site. A radiological control center at Kennedy Space Center would coordinate any local emergency actions required during the pre-launch or early launch phases of the mission in the event of a launch mishap.

In the event of a radiological release, federal, state and county agencies would determine an appropriate course of action for any areas outside the Cape Canaveral Air Station-Kennedy Space Center site based on actual monitoring information.

Spacecraft

Each of the two Mars Exploration Rover spacecraft resembles a nested set of Russian dolls. The rover will travel to Mars tucked inside a folded-up lander wrapped in airbags. The lander in turn will be encased in a protective aeroshell. Finally, a disc-shaped cruise stage is attached to the aeroshell on one side and to the Delta II launch vehicle on the other.

Cruise stage

The cruise stage provides capabilities needed during the seven-month passage to Mars but not later in the mission, such as a propulsion system for trajectory correction maneuvers. Approximately 2.6 meters (8.5 feet) in diameter and 1.6 meters (5.2 feet) tall, the disc-shaped cruise stage is outfitted with solar panels and antennas on one face, and with fuel tanks and the aeroshell on the other. Around the rim sit thrusters, a star scanner and a Sun sensor.

The propulsion system uses hydrazine propellant stored in two titanium tanks. Since the the entire spacecraft spins at about 2 rotations per minute, fuel in the tanks is pushed outward toward outlets and through fuel lines to two clusters of thrusters. Each cluster has four thrusters pointing in different directions.

The star scanner and Sun sensor help the spacecraft determine its orientation. Since the rover's solar arrays are tucked away inside the aeroshell for the trip, the cruise stage needs its own for electrical energy. The arrays can generate more than 600 watts when the spacecraft is about as far from the Sun as Earth is, and about half that much when it nears Mars.

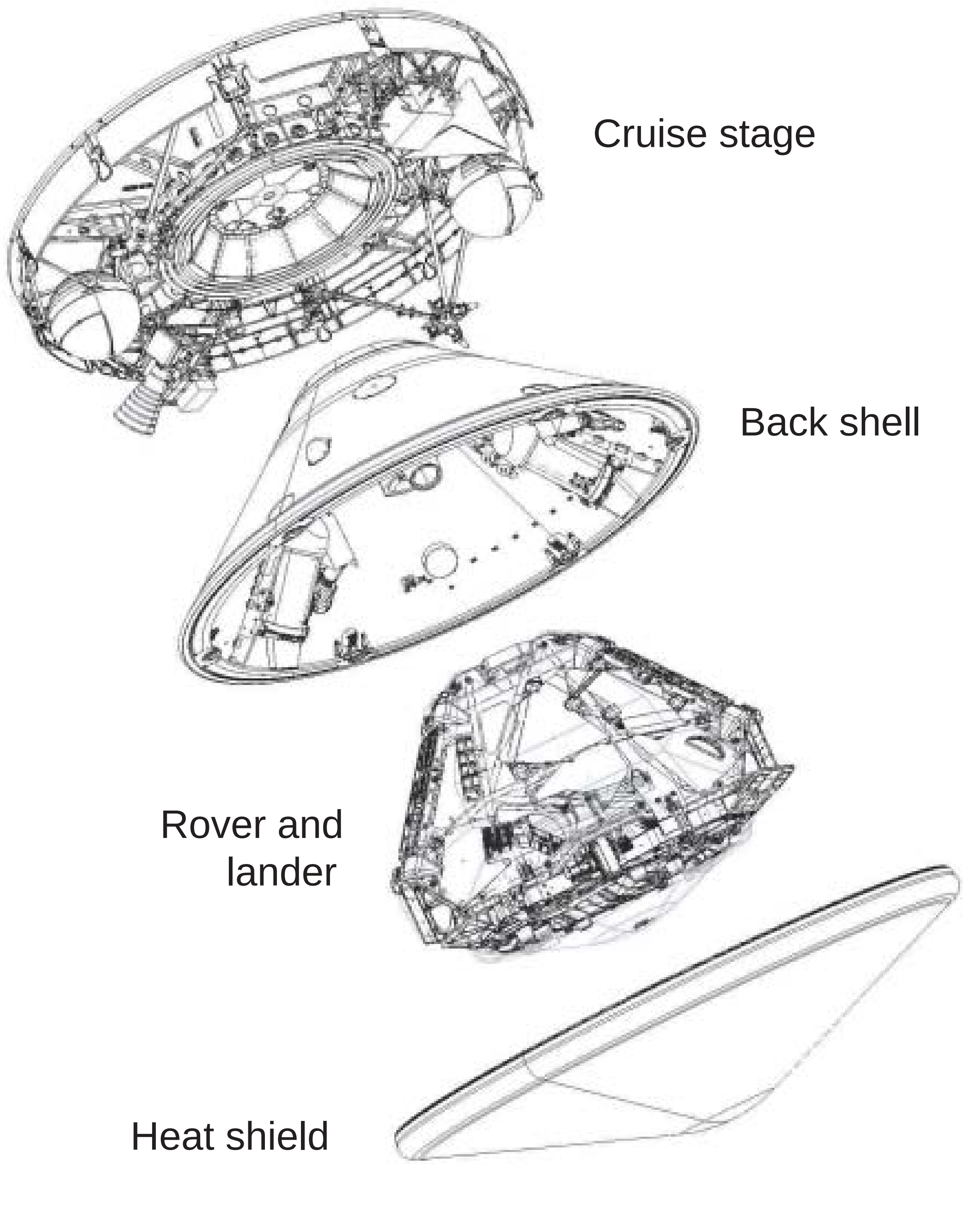
The cruise stage also carries a system for carrying excess heat away from the rover's computer with a pumped freon loop and rim-mounted radiators.

Entry, Descent and Landing System

The system for getting each rover safely through Mars' atmosphere and onto the surface relies on an aeroshell, a parachute and airbags. The aeroshell has two parts: a heat shield that faces forward and a backshell. Both are based on designs used successfully by NASA's Viking Mars landers in 1976 and Mars Pathfinder in 1997.

The parachute is attached to the backshell and opens to about 15 meters (49 feet) in diameter. The parachute design was tested under simulated martian conditions in a large wind tunnel at NASA's Ames Research Center near Sunnyvale, Calif.

The backshell carries a deceleration meter used to determine the right moment for deploying the parachute. Solid-fuel rockets mounted on the underside of the shell



Flight system

reduce vertical velocity and any excessive horizontal velocity just before landing.

The airbags, based on Pathfinder's design, cushion the impact of the lander on the surface. Each of the four faces of the folded-up lander is equipped with an envelope of six airbags stitched together. Explosive gas generators rapidly inflate the airbags to a pressure of about 6900 Pascal (one pound per square inch). Each airbag has double bladders to support impact pressure and, to protect the bladders from sharp rocks, six layers of a special cloth woven from polymer fiber that is five times stronger than steel. The fiber material, Vectran, is used in the strings of archery bows and tennis racquets.

Lander

The lander, besides deploying the airbags, can set the rover right-side-up, if necessary, and provides an adjustable platform from which the rover can roll onto Mars' surface. It also carries a radar altimeter used for timing some descent events, as well as two antennas.

The lander's basic structure is four triangular petals made of graphite-epoxy composite material. Three petals are each attached with a hinge to an edge of the central base petal. The rover stays fastened to the base petal during the flight and landing. When folded up, the lander's petals form a tetrahedral box around the stowed rover. Any of the petals could end up on the bottom when the airbag-cushioned bundle rolls to a stop after landing. Electric motors at the hinges have enough torque to push the lander open, righting the rover, if it lands on one of the side petals.

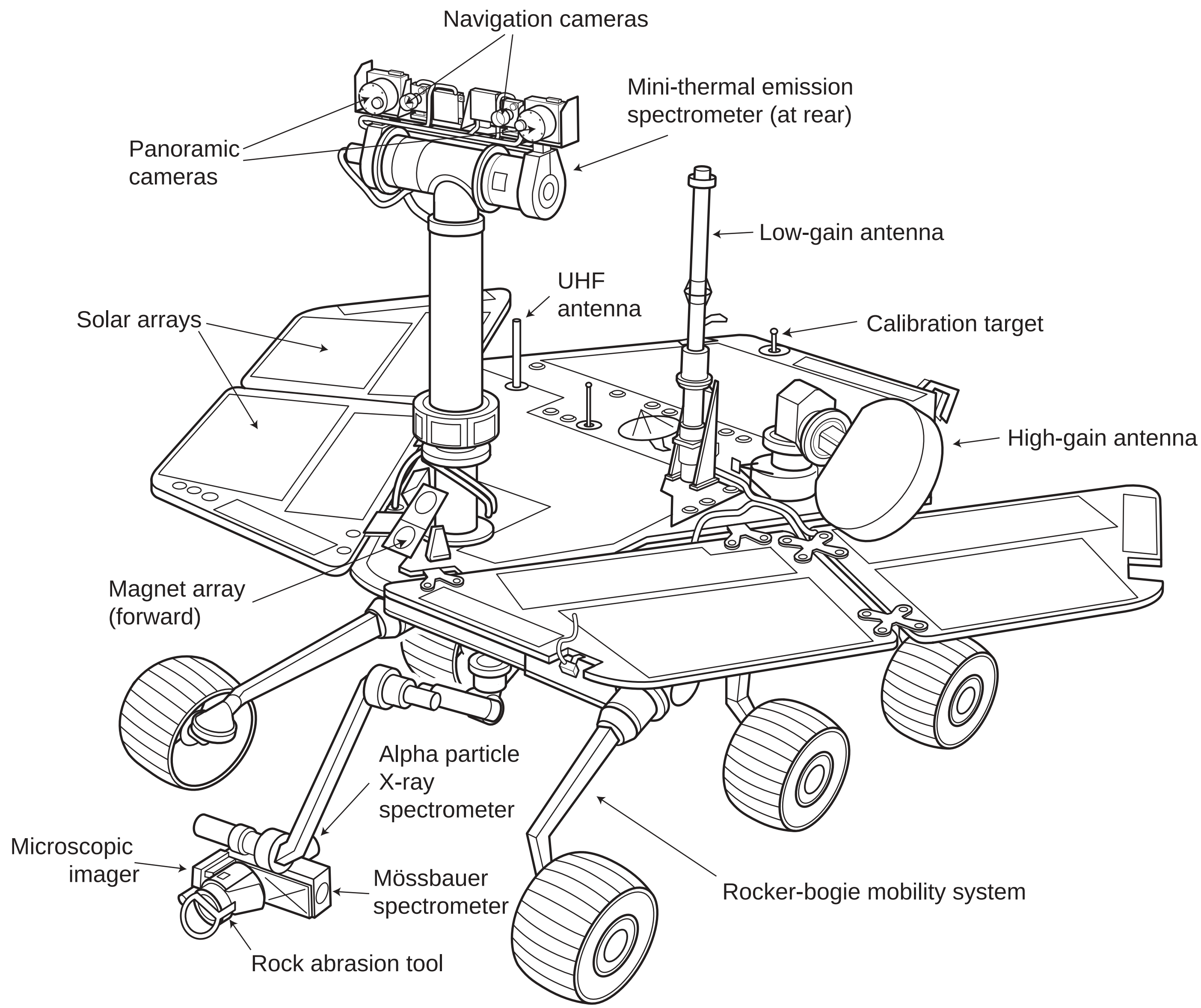
Other motors retract the deflated airbags. An apron made out of the same type of tough fabric as the airbags stretches over ribs and cables connected to the petals, providing a surface that the rover can drive over to get off the lander. The side petals can also be adjusted up or down from the plane of the base petal to accommodate uneven terrain and improve the rover's path for driving off of the lander.

Nearly 4 million people have a special connection to the Mars Exploration Rover project by having their names recorded on each mission's lander. Each of the two landers carries a digital versatile disc, or DVD, containing millions of names of people around the world collected during a "Send Your Name to Mars" campaign, which ended in November 2002.

Rover

At the heart of each Mars Exploration Rover spacecraft is its rover. This is the mobile geological laboratory that will study the landing site and travel to examine selected rocks up close.

The Mars Exploration Rovers differ in many ways from their only predecessor, Mars Pathfinder's Sojourner rover. Sojourner was about 65 centimeters (2 feet) long and



Mars Exploration Rover

weighed 10 kilograms (22 pounds). Each Mars Exploration Rover is 1.6 meter (5.2 feet) long and weighs 174 kilograms (384 pounds). Sojourner traveled a total distance equal to the length of about one football field during its 12 weeks of activity on Mars. Each Mars Exploration Rover is expected to travel six to 10 times that distance during its three-month prime mission. Pathfinder's lander, not Sojourner, housed that mission's main telecommunications, camera and computer functions. The Mars Exploration Rovers carry equipment for those functions onboard and do not interact with their landers any further once they roll off.

On each Mars Exploration Rover, the core structure is made of composite honeycomb material insulated with a high-tech material called aerogel. This core body, called the warm electronics box, is topped with a triangular surface called the rover equipment deck. The deck is populated with three antennas, a camera mast and a panel of solar cells. Additional solar panels are connected by hinges to the edges of the triangle. The solar panels fold up to fit inside the lander for the trip to Mars, and deploy to form a total area of 1.3 square meters (14 square feet) of three-layer photovoltaic cells. Each layer is of different materials: gallium indium phosphorus, gallium arsenide and germanium. The array can produce nearly 900 watt-hours of energy per martian day, or sol. However, by the end of the 90-sol mission, the energy generating capability is reduced to about 600 watt-hours per sol because of accumulating dust and the change in season. The solar array repeatedly recharges two lithium-ion batteries inside the warm electronics box.

Doing sport utility vehicles one better, each rover is equipped with six-wheel drive. A rocker-bogie suspension system, which bends at its joints rather than using any springs, allows rolling over rocks bigger than the wheel diameter of 26 centimeters (10 inches). The distribution of mass on the vehicle is arranged so that the center of mass is near the pivot point of the rocker-bogie system. That enables the rover to tolerate a tilt of up to 45 degrees in any direction without overturning, although onboard computers are programmed to prevent tilts of more than 30 degrees. Independent steering of the front and rear wheels allows the rover to turn in place or drive in gradual arcs.

The rover has navigation software and hazard-avoiding capabilities it can use to make its own way toward a destination identified to it in a daily set of commands. It can move at up to 5 centimeters (2 inches) per second on flat hard ground, but under automated control with hazard avoidance, it travels at an average speed about one-fifth of that.

Two stereo pairs of hazard-identification cameras are mounted below the deck, one pair at the front of the rover and the other at the rear. Besides supporting automated navigation, the one on the front also provides imaging of what the rover's arm is doing. Two other stereo camera pairs sit high on a mast rising from the deck: the panoramic camera included as one of the science instruments, and a wider-angle, lower-resolution navigation camera pair. The mast also doubles as a periscope for another one of the science instruments, the miniature thermal emission spectrometer.

The rest of the science instruments are at the end of an arm, called the "instrument deployment device," which tucks under the front of the rover while the vehicle is traveling. The arm extends forward when the rover is in position to examine a particular rock or patch of soil.

Batteries and other components that are not designed to survive cold martian nights reside in the warm electronics box. Nighttime temperatures may fall as low as minus 105 C (minus 157 F). The batteries need to be kept above minus 20 C (minus 4 F) for when they are supplying power, and above 0 C (32 F) when being recharged. Heat inside the warm electronics box comes from a combination of electrical heaters, eight radioisotope heater units and heat given off by electronics components.

Each radioisotope heater unit produces about one watt of heat and contains about 2.7 grams (0.1 ounce) of plutonium dioxide as a pellet about the size and shape of the eraser on the end of a standard pencil. Each pellet is encapsulated in a metal cladding of platinum-rhodium alloy and surrounded by multiple layers of carbon-graphite composite material, making the complete unit about the size and shape of a C-cell battery. This design of multiple protective layers has been tested extensively, and the heater units are expected to contain their plutonium dioxide under a wide range of launch and orbital-reentry accident conditions. Other spacecraft, including Mars Pathfinder's Sojourner rover, have used radioisotope heater units to keep electronic systems warm and working.

The computer in each Mars Exploration Rover runs with a 32-bit Rad 6000 microprocessor, a radiation-hardened version of the PowerPC chip used in some models of Macintosh computers, operating at a speed of 20 million instructions per second. Onboard memory includes 128 megabytes of random access memory, augmented by 256 megabytes of flash memory and smaller amounts of other non-volatile memory, which allows the system to retain data even without power.

Program/Project Management

The Mars Exploration Rover Project is managed by the Jet Propulsion Laboratory, Pasadena, Calif., for NASA's Office of Space Science, Washington, D.C. At NASA Headquarters, Dr. Edward Weiler is associate administrator for space science, Orlando Figueroa is Mars program director, Dr. Jim Garvin is the lead scientist for the Mars Exploration Program, David Lavery is Mars Exploration Rover program executive and Dr. Catherine Weitz is Mars Exploration Rover program scientist.

At the Jet Propulsion Laboratory, Dr. Firouz Naderi is the Mars program manager, Dr. Dan McCleese is Mars chief scientist, Peter Theisinger is Mars Exploration Rover project manager and Dr. Joy Crisp is Mars Exploration Rover project scientist.

At Cornell University, Ithaca, N.Y., Dr. Steve Squyres is principal investigator for Mars Exploration Rover's Athena suite of science instruments.

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