MarsBots

A Mars and Robotics Learning Module for Grades 3-4 with activities in Science, Mathematics, Technology, and Language Arts

National Aeronautics and Space Administration (NASA)
Phoenix Mars Scout Mission, The University of Arizona and NASA
NASA’s Science, Engineering, Mathematics, and Aerospace Academy (SEMAA)

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All Images are courtesy of NASA unless otherwise noted.
Table of Contents
Acknowledgements......................................................................................................................... ii
Overview......................................................................................................................................... 2
Background..................................................................................................................................... 3
   Mars ............................................................................................................................................ 3
   Robots ......................................................................................................................................... 2
   History of Mars Exploration....................................................................................................... 3
   Robotic Missions to Mars ........................................................................................................... 4
National Education Standards Matrices........................................................................................ 11
Lesson 1: My Place in Space ........................................................................................................ 12
   Purpose: To deepen student understanding about their place in space, starting with their bedroom and extending out to the Milky Way. ................................................................. 12
Lesson 2: KWL-Mars ................................................................................................................... 17
   Purpose: To probe students’ prior knowledge about Mars, what students wish to learn about Mars, and chart new understandings during the course of the module.
Lesson 3: Play Dough Planets....................................................................................................... 19
   Purpose: To demonstrate the size (volume) differences between Earth, Earth’s Moon, and Mars through a hands-on activity.
Lesson 4: History of Mars Exploration......................................................................................... 22
   Purpose: To engage students in the wonder of the science and engineering of space exploration.
Lesson 5: Space Survey ................................................................................................................ 29
   Purpose: To demonstrate public opinion about space exploration and the use of robotics in space exploration.
Lesson 6: Mars Match Game ........................................................................................................ 32
   Purpose: To deepen student understanding of Mars, Mars exploration and the similarities and differences between the Earth and Mars.
Lesson 7: Touchdown Mars! ........................................................................................................ 51
   Purpose: To facilitate and engage students’ imagination about the processes and skills needed to explore our Solar System.
Lesson 8: Blind Mice .................................................................................................................... 52
   Purpose: To expand student understanding that combining information gathered by a variety of robots gives us a more comprehensive understanding of our Solar System.
Lesson 9: KWL-Robotics ............................................................................................................. 57
   Purpose: To probe students’ prior knowledge about robotics, what students wish to learn about robotics, and chart new understandings during the course of the module.
Lesson 10: Simple Machines ...................................................................................................... 59
   Purpose: To expand student understanding that simple machines affect our everyday lives and make tasks easier.
Lesson 11: Program It! ................................................................. 61
    Purpose: To introduce students to the fundamental communication skills necessary for successful robotic programming.

Lesson 12: The Phoenix Mission: Uncovering Martian Water .............................................. 63
    Purpose: To increase student knowledge about the Phoenix Mars Lander’s science mission to use robotic technology to uncover water on Mars.

Lesson 13: Phoenix’s Robotic Arm ...................................................................................... 68
    Purpose: To simulate remote operation of robotics in order to deepen student understanding of programming and communications in space exploration.

Lesson 14: Lander Design .................................................................................................... 70
    Purpose: To allow students to apply the understanding they have gained about landers and robotic components through a hands-on experience.

Lesson 15: Egg Drop Lander .................................................................................................. 75
    Purpose: To provide collaborative opportunity to design and test a lander and practice writing skills.

Lesson 16: Careers in Space .................................................................................................. 77
    Purpose: To help students understand the variety of careers in space exploration.
Overview

This is a Mars robotics learning module for grades 3 and 4, with extensions for younger students. The module expands the robotics strand of the Mars Public Engagement Program. The objective is for students to experience the hands-on, minds-on activities in the module allowing them to investigate the Martian environment and robotic technologies of space exploration, fostering inspiration to study science, mathematics, and language arts further. The Phoenix Mars Mission Education and Public Outreach (E/PO) program teamed up with NASA's Science, Engineering, Mathematics and Aerospace Academy (SEMAA) program to develop the MarsBots learning module.

The learning module contains 16 standards-based lessons. These lessons are designed to progress logically from learning about Mars and why scientists and engineers want to explore Mars with robots (lessons 1 through 8) to the fundamental principles of robotics and how these principles are applied to design, construct, and test robotic explorers (lessons 9 through 16).

The MarsBots learning module is integrated to support fundamental concepts and skills in science, mathematics, and language arts. As a unit, the lessons in the module cover 3-4 weeks of classroom time. Lessons may also be used separately as stand-alone activities. The time it will take to complete each lesson is estimated.

MarsBots is designed to be adaptable for no-technology or low-technology school environments. Some of the activities have background resource materials that are freely available over the Internet. For those schools that do not have Internet access, these resources are available on CD-ROM, which may be requested by contacting:

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Tucson, Arizona 85705
520-626-8973 (voice)
520-626-1973 (fax)

For schools without computers, background resource materials not requiring computers (e.g., books) have been listed with the applicable MarsBots activities. For additional low-technology resources or for more information please contact Doug Lombardi at the above contact information.

A background section along with “italicized teacher notes” throughout the module will give the necessary background information to present the lessons. Typical student questions are anticipated and answered throughout MarsBots. The PowerPoint presentations used in individual lessons include a script with the information needed for the presentations.
Since ancient times, humans have been particularly fond of Mars. But why? All the planets in our Solar System are unique in their own way so why are we so fascinated with Mars? Most students are also very fascinated by the red planet. Ancient peoples were drawn to Mars by its red color, knowing the planet only as a bright point of light in the sky. The word “Mars” comes from the ancient Romans who named the planet after their god of war. The ancient Greeks called it Ares and other ancient cultures had different names for the red planet, as well as, their own unique stories about Mars. For more information on the history of early interest in Mars visit: http://mars.jpl.nasa.gov/mep/history/.

Today, humans are still drawn to Mars, but not just by its red color. We look at Mars, not as a god, but as a sister planet to Earth. Mars and Earth are similar in many ways, yet extremely different in others. But how do we know? How do we know what the similarities and differences are? The answer lies in robotic spacecraft. Since the 1960s, we have sent flyby, orbiter, and lander spacecraft to the red planet in order to study it in better detail. Each spacecraft has or had its own purpose and each contributes or contributed to our current understanding of Mars.
Mars is a cold, dry, dusty world with no liquid water on its surface — no rivers, lakes, or oceans. Global dust storms and whirlwinds, called dust devils, are frequent on the red planet. Surface winds have been recorded at up to 40 meters per second (80 miles per hour). While Mars is only 1/6th the volume of Earth, at present it has the same dry surface area as our ocean-covered planet. However, evidence from robotic spacecraft suggests Mars was very different in the past from the cold dry planet we see today.

Extensive spacecraft exploration of Mars has revealed geologic features that lead us to believe liquid water once flowed on the surface of the red planet. Channels connect high and low areas convincing most scientists that water eroded these channels long ago. Gullies, another geologic feature, provide evidence of past liquid water. Scientists are actively debating the formation of these gullies. One idea suggests that liquid water, flowing underneath a protective layer of snow, may form Martian gullies similar to those on Earth. Some gullies are so recent that they are likely to still be active periodically. However, no evidence exists of liquid water currently flowing on the surface, but evidence of past liquid water on the surface continues to build. Liquid water is important because all known life forms require it to survive.

Although scientists do not believe liquid water currently exists on the Martian surface, they know water exists in the form of ice. Both the north and south polar caps are made of frozen water. The polar caps expand and recede with the Martian seasons just like Earth’s polar caps. Mars has seasons like Earth because its rotational axis is tilted (approximately 25° compared to Earth’s 23.5°) with respect to the plane of its orbit. Since Mars’s year is roughly twice the length of Earth’s year, its seasons are also about twice as long. There are a lot of similarities between Earth and Mars and our understanding of Mars might give us insights into
our home, Earth. The exploration and discoveries on Mars continue with scientists on Earth, robots like the Phoenix Mars Lander, and maybe someday, humans on Mars.

**Robots**

A robot is a mechanical device which performs automated tasks either according to direct human supervision, a pre-defined program, or a set of general guidelines using artificial intelligence techniques. These tasks either replace or enhance human work, such as in manufacturing, construction or manipulation of heavy or hazardous materials or working in harsh environments like that of space.

Robots are made up of many components including simple machines. Simple machines affect our everyday life and make performing tasks easier. There are six types of simple machines: 1) lever, 2) pulley, 3) inclined plane, 4) screw, 5) wheel and axle, and 6) wedge. For more information on simple machines visit: http://www.grc.nasa.gov/WWW/K-12/Summer_Training/KaeAvenueES/Resource_Chart.html.

Machines made of two or more simple machines are called complex machines. Robots are complex machines made of several simple machines, sensors, power supplies, and electrical actuators. Sensors detect the conditions in the environment around the robot and inform the robot on what actions to take. The simple machines components within a robot allow the robot to perform specified actions. The power supply gives the robot the needed power to operate.

Robots are used on Earth everyday to help make tasks safer and easier. Engineers are designing robots to help commercial farmers harvest crops. Autonomous robots are being used by rescue workers to investigate hazardous areas such as collapsed buildings or harmful chemical environments. Law enforcement officers use robots to investigate and/or disarm bombs. Manufacturers use robots to perform repetitive assembly tasks. More information on robots can be found at: http://prime.jsc.nasa.gov/ROV/types.html. And information on agricultural robotics can be found at: www.peerlessequipment.com.

Throughout the history of space exploration robots have been used to gather information for scientists to study the unique and harsh space environment. In 1964, NASA sent the first robotic missions to Mars, Mariner 3 & 4. These spacecraft took the first up close pictures of Mars changing scientific understanding of the red planet forever. As technology improved so did the robotic Mars missions. The first images returned from Mars were grainy and lacked details. Forty years later, the cameras and scientific instruments sent to Mars are extremely sophisticated and precise giving scientists more
information to uncover the mysteries of Mars. Scientists believe that unlocking the secrets of Mars, using robotic exploration, will help us better understand our own planet, Earth.

**History of Mars Exploration**

Before humans began their robotic exploration of Mars, scientists on Earth used telescopes to observe Mars. Galileo is credited as being the first to observe Mars through a telescope in 1609. A year later in 1610 he wrote a friend saying, “I dare not affirm that I was able to observe the phases of Mars; nevertheless, if I am not mistaken, I believe that I have seen that it is not perfectly round.”

Christiaan Huygens observed Mars with improved telescopes and in 1659 produced a sketch of Mars showing what is believed to be Syrtis Major. Huygens also attempted to determine the length of one day by measuring the rotational period of Mars. He calculated a value of 24 hours, which is very close to the 24 hours and 39 minutes we now know to be Mars’ rotational period. Giovanni Cassini is credited as being the first to observe a polar cap on Mars. The southern polar cap appears on a sketch Cassini made of Mars in 1672.

Over 100 years later, the Earth based exploration of the red planet continued with William Herschel and his 1775 paper on Mars. The paper concluded that because of the planet’s obliquity, or tilt, Mars has season like Earth. In the same paper, he claimed the polar caps were thin layers of ice and snow that changed with the seasons.

In 1877, Giovanni Schiaparelli sketched what he called “canali” (channels) on Mars. Though Schiaparelli never claimed his “canali” to be artificial, he never denied it either. Percival Lowell, an American astronomer, believed that the “canali,” which he translated to “canals” were evidence of intelligent life on Mars. From his observatory in Flagstaff, AZ he made 917 sketches of Mars mapping 437 “canals,” (http://www.lowell.edu/). Lowell insisted until the day he died in 1916 that intelligent beings inhabited Mars. Lowell’s work had two effects; it generated enormous public interest in Mars and it gave planetary science a bad reputation among American astronomers during the first half of the 20th century.
Robotic Missions to Mars

Prior to the first spacecraft exploration of Mars, what was known about Mars was speculation based on drawings made late at night looking through telescopes. By the mid-1900’s most scientists believed that Mars possessed liquid water and vegetation. Observations with telescopes showed dark regions on Mars changing shape, color and size with the seasons which was interpreted as the growth and death of plant life. The first spacecraft to fly near Mars shattered that idea.

Mariner Missions

In 1965, Mariner 4 revealed a Mars that looked similar to the Earth’s Moon. Though the pictures were blurred, the Martian surface was shown to be littered with craters. The Mariner 6 and 7 flybys in 1969 showed much the same thing, but with clearer images. Mariner 4, 6, and 7, however, concentrated on the southern hemisphere of Mars. Mariner 9, the first orbiter, imaged the entire planet and showed a much more geologically diverse Mars than its predecessors.

Global mapping of Mars by Mariner 9 led to the discovery of both Olympus Mons, the largest known volcano in the Solar System, and Valles Marineris, a canyon that dwarfs the Earth’s Grand Canyon by comparison. It is approximately the length of the continental United States. Mariner 9 revealed the global dichotomy of Mars – the older, heavily cratered southern highlands and the younger northern lowlands with volcanoes and volcanic plains. Mariner 9 also discovered many channels appearing to be ancient river beds. While the Mariner program was very successful, it was not without its failures. Mariner 3 never made it to Mars after its shroud failed to jettison and Mariner 8 failed during launch.

For more information and images from the Mariner missions visit: [http://nssdc.gsfc.nasa.gov/planetary/mars/mariner.html](http://nssdc.gsfc.nasa.gov/planetary/mars/mariner.html).

Viking Missions

The Viking missions, which followed the Mariner program, were composed of two orbiter-landers. Viking 1 reached Martian orbit on June 19, 1976 with the hope of landing on the surface on July 4. The original landing site was an area where a large channel empties onto a large plain. This was thought to be the best area where liquid water and near-surface ice could be found. However, this landing site was abandoned when Viking arrived because images of the site found that it was too dangerous. Rocks and small craters that could have been hazardous to the lander were observed scattered across the landscape. An alternative landing site was found and the Viking 1 Lander touched down on Mars on July 20, coincidentally on the seventh anniversary of the first Moon landing.
Viking 2 touched down on the opposite side of Mars on September 3, 1976. Besides taking photographs and collecting other science data on the Martian surface, the two landers conducted three biology experiments designed to look for possible signs of life. These experiments discovered unexpected and enigmatic chemical activity in the Martian soil, but provided no clear evidence for the presence of living microorganisms in the soil near the landing sites. To learn more about the Viking missions visit: http://mars.jpl.nasa.gov/missions/past/viking.html.

Russian Missions
While the United States was working on the successful Mariner and Viking programs Russia had a failure-plagued Mars program of its own. Of the fifteen Russian spacecraft bound for Mars between 1960 and 1988 only four spacecraft (Mars 3, Mars 5, Mars 6, and Mars 7) returned any data. And none of the missions met their mission objectives. For more information on Russia’s Mars efforts visit: http://www.russianspaceweb.com/spacecraft_planetary_mars.html.

Mars Observer
Seventeen years after the Viking missions, the United States attempted to return to Mars with the 1992 Mars Observer. Contact with the spacecraft was lost on August 21, 1993, three days before it was scheduled to reach Mars. An investigation concluded the most probable cause of the mishap was a fuel line rupture during fuel tank pressurization which would have caused the spacecraft to spin uncontrollably. To learn more about the Mars Observer visit: http://nssdc.gsfc.nasa.gov/nmc/tmp/1992-063A.html.

Mars Global Surveyor
The United States’ next attempt to reach Mars had a much different fate. Mars Global Surveyor became the first successful mission to the red planet in two decades when it launched November 7, 1996, and entered orbit on September 12, 1997. After an unplanned year and a half spent trimming its orbit from a looping ellipse to a circular track around the planet, the spacecraft began its prime mapping mission in March 1999. It observed the planet from a low-altitude, nearly polar orbit (circling the planet from the north to south poles) over the course of one complete Martian year, the equivalent of nearly two Earth years. Mars Global Surveyor completed its primary mission on January 31, 2001, and is now in an extended mission phase. The mission has studied the entire Martian surface, atmosphere, and interior, and has returned more data about the red planet than all the previous Mars missions combined.

Among key science findings, Global Surveyor has taken pictures of gullies and debris flow features that suggest there may possibly be current sources of liquid water, similar to an aquifer, at or near the surface.
of the planet. Magnetometer readings show that the planet’s magnetic field is not globally generated in
the planet’s core, like Earth, but is localized in particular areas of the crust. New temperature data and
close-up images of the Martian moon Phobos show its surface is composed of powdery material at least
1 meter (3 feet) thick, caused by millions of years of meteoroid impacts. Data from the spacecraft’s laser
altimeter have given scientists their first 3-D views of Mars’ north polar ice cap. More Mars Global
Surveyor information can be found at: http://mars.jpl.nasa.gov/missions/present/globalsurveyor.html.

Mars Pathfinder

In addition to the launch of the highly successful Mars Global Surveyor, 1996 marked the successful launch of the
Mars Pathfinder. On July 4, 1997, Mars Pathfinder, a spacecraft composed of a lander and a rover, landed on the
Martian surface. The lander portion of the Pathfinder mission was formally named the “Carl Sagan Memorial
Station” after the American astronomer and popular science interpreter. The rover portion of Pathfinder was
named Sojourner after American civil rights crusader Sojourner Truth. Both robots outlived their design lives —
the lander by nearly three times, and the rover by 12 times.

Mars Pathfinder used an innovative method of directly entering the Martian atmosphere, assisted by a
parachute to slow its descent through the thin Martian atmosphere and a giant system of airbags to
cushion the impact. The landing site, an ancient flood plain in Mars’ northern hemisphere at the
mouth of the huge canyon called Ares Vallis, chosen because scientists believed it to be a relatively safe
surface to land on and one which contained a scientifically interesting variety of rocks. The expectation
was that rocks had been transported by floods from the entire drainage basin of Ares Vallis.

Throughout its life, Mars Pathfinder returned more than 16,500 images from the lander and 550
images from the rover, as well as more than 15 chemical analyses of rocks and soil and extensive data on
winds and other weather factors. Findings from the investigations carried out by scientific instruments
on both the lander and the rover suggest that Mars was warm and wet at one time in its past, with water
existing in its liquid state and an atmosphere much thicker than at present. More information can be

Mars Climate Orbiter

On December 11, 1998, the Mars Climate Orbiter began its journey to
Mars. The Mars Climate Orbiter was designed to function as an
interplanetary weather satellite and a communications station for the Mars
Polar Lander. The orbiter carried two science instruments: a replica of an
atmospheric sounder the Mars Observer spacecraft lost in 1993, and a new,
lightweight color imager combining wide- and medium-angle cameras.
Sadly, the spacecraft was lost on arrival to Mars on September 23, 1999.
Engineers concluded that the spacecraft entered the planet’s atmosphere
too low and probably burned up. More information can be found at:
Mars Polar Lander
Less than a month after the Mars Climate Orbiter launched, the Mars Polar Lander lifted-off on its own journey to the red planet. Mars Polar Lander was an ambitious mission to set a spacecraft down on the frigid terrain near the edge of Mars’ south polar cap and dig for water-ice with a robotic arm. Piggybacking on the lander were two small probes called Deep Space 2 designed to impact the Martian surface to test new technologies. Mars Polar Lander and Deep Space 2 were lost at arrival December 3, 1999. An investigation concluded the most probable cause of the failure was a premature shutdown of the engines used to land the spacecraft. More information on the Mars Polar Lander can be found at: http://mars.jpl.nasa.gov/missions/past/polarlander.html.

Mars Odyssey
2001 Mars Odyssey is an orbiting spacecraft designed to determine the composition of the planet’s surface, to detect water and shallow buried ice, and to study the radiation environment. Mars Odyssey carries three main science instruments to reach these goals: The Gamma Ray Spectrometer, the Thermal Emission Imaging System, and the Mars Radiation Environment Experiment. The spacecraft was launched on April 7, 2001, arrived at Mars on October 24, 2001 and began its science mapping on February 18, 2002 after months of slowly getting into the correct orbit around Mars.

The surface of Mars has long been thought to consist of a mixture of rock, soil and icy material. However, the exact composition of these materials is largely unknown. At the time of this publication, Odyssey is collecting data that are used to identify the minerals present in the soils and rocks on the surface and to study small-scale geologic processes and landing site characteristics. By measuring the amount of hydrogen in the upper meter of soil across the whole planet, the spacecraft is helping researchers understand how much water may be available for future human exploration, as well as give us clues about the planet’s climate history. The orbiter is also collecting data on the radiation environment to help assess potential risks to any future human explorers, and can act as a communications relay for future Mars landers. More information can be found at: http://mars.jpl.nasa.gov/missions/present/odyssey.html.
Mars Express
Mars Express, launched in June 2003, is an international effort, which will explore the atmosphere and surface of Mars from polar orbit. NASA is participating in the mission planned by the European Space Agency and the Italian Space Agency. The spacecraft carries a science payload with several European instruments rebuilt after they were lost on the ill-fated Russian Mars '96 mission, as well as a communications relay to support the communication needs of future Mars lander missions. The mission's main objective is to search for sub-surface water from orbit and deliver a lander to the Martian surface. The lander was named Beagle 2 after the ship in which Charles Darwin set sail to explore uncharted areas of the Earth in 1831. After coming to rest on the surface, Beagle 2 was to perform exobiology and geochemistry research; however, no contact was made with the lander after it was to have reached the Martian surface.

Seven scientific instruments onboard the orbiting spacecraft are studying the Martian atmosphere, the planet’s structure and its geology. In early 2004, the Mars Express science team confirmed that the spacecraft had detected evidence of water-ice all throughout the southern polar cap. Mars Express has also returned many interesting images of Vallis Marineris, and other Martian geologic features. More information and images can be found at: http://mars.jpl.nasa.gov/missions/present/express.html.

Mars Exploration Rovers
In the summer of 2003, two powerful Mars rovers began their voyage to the red planet. They arrived on opposite sides of Mars in January 2004 to roam across the surface and search for clues to the history of water on Mars. The robotic explorers, Spirit and Opportunity, can travel more than 100 meters (about 109 yards) in a Martian day, more than the Mars Pathfinder traveled throughout its entire mission. The rovers arrived on Mars within weeks of each other for a three to five month mission. Due to the vast success of the rovers, the mission has been greatly extended and at the time of this publication the rovers are still roaming the Martian surface after celebrating their one-year Martian anniversary (687 days).

Each rover carries a sophisticated set of instruments that allow it to search for evidence of liquid water that may have been present in the planet’s past. The identical geologist rovers are searching for and characterizing a wide range of rocks and soils. This information will unlock clues to help scientists understand past water (in liquid or ice form) activity on Mars. The landing sites were selected because they appeared to have been affected by liquid water in the past. Gusev Crater, where Spirit landed, is a possible former lakebed in a giant impact crater. Meridiani Planum, the landing site of Opportunity, has mineral deposits (hematite) that suggests Mars had a wet past. The rovers have found several minerals believed to have formed in
the presence of liquid water. More information about the Mars Exploration Rovers can be found at: [http://marsrovers.jpl.nasa.gov/overview/](http://marsrovers.jpl.nasa.gov/overview/).

**Mars Reconnaissance Orbiter**

NASA’s Mars Reconnaissance Orbiter (MRO) was launched on August 12, 2005 and will arrive at Mars in March 2006. After several months of aerobraking, a process used to slow the spacecraft down and get it into the desired orbit, the orbiter will begin science operations in November 2006. The robotic orbiter will send extreme close-up images of the Martian terrain, carry a sounder (a type of instrument that measures changes in atmospheric temperature or composition with height) and a radar experiment to find subsurface water. MRO’s goals include looking for safe and scientifically worthy landing sites for future exploration.

Equipped with the most powerful camera ever flown on a planetary exploration mission, the spacecraft will image details of the Martian terrain with extraordinary clarity. While past cameras on Martian orbiters could identify objects no smaller than a large room, the camera on MRO will be able to spot something as small as a breakfast table. This will provide astoundingly detailed views of the geology and structure of Mars and help future landers and rovers find safe landing sites. More information can be found at: [http://mars.jpl.nasa.gov/missions/present/2005.html](http://mars.jpl.nasa.gov/missions/present/2005.html).

**Phoenix Mars Lander**

The Phoenix Mars Mission is the first chosen for NASA’s Scout program, a competition to provide smaller, lower-cost spacecraft. Named for the mythological bird, Phoenix uses a spacecraft that was intended for use by 2001’s Mars Surveyor lander prior to its cancellation. It also carries improved variations of instruments that flew on the lost Mars Polar Lander. Phoenix will land in the arctic plains of Mars between 65° and 72°-north latitude, approximately where northern Canada is on Earth. Phoenix will study the history of water on Mars and determine whether the Martian arctic soil can support life.

As a stationary lander, the robotic spacecraft will use a 2 meter (6.5 feet) long arm to be the first to dig into the Martian soil and touch water-ice. Soil and water-ice samples will be delivered to a sophisticated suite of science instruments for analysis. During the course of the three-month mission, Phoenix will take images of the landing site’s geology, seek to update our understanding of Martian atmospheric processes, and analyze soil and ice samples to determine the composition and characteristics of the arctic terrain. For more information on the Phoenix mission, visit: [http://phoenix.lpl.arizona.edu](http://phoenix.lpl.arizona.edu).
Scheduled for launch in December of 2009, the Mars Science Laboratory will collect Martian soil samples and rock cores and analyze them on the Martian surface for organic compounds and environmental conditions that could have supported microbial life now or in the past. Mars Science Laboratory is intended to be the first planetary mission to use precision landing techniques, making the landing zone three to five times smaller than previous Mars surface missions. The rover will be twice as long (at approximately 3 meters or 10 feet) and three times as heavy (at approximately 520 kilograms or 1150 pounds) as the Mars Exploration Rovers.

Like the twin rovers, Mars Science Laboratory will have six wheels and cameras mounted on a mast. Unlike the twin rovers, it will carry a laser for vaporizing a thin layer from the surface of a rock and analyzing the elemental composition of the underlying materials. It will then be able to collect and crush rock and soil samples and distribute them to on-board test chambers for chemical analysis. Its design includes a suite of scientific instruments for identifying organic compounds such as proteins, amino acids, and other acids and bases that attach themselves to carbon backbones and are essential to life as we know it. It could also identify features such as atmospheric gases that may be associated with biological activity. More information can be found at: http://mars.jpl.nasa.gov/missions/future/msl.html

For more information about all robotic Mars missions visit: http://mars.jpl.nasa.gov/missions/.
# National Education Standards Matrices

## National Science Education Content Standards: K-4

<table>
<thead>
<tr>
<th>Standard</th>
<th>Lesson 1</th>
<th>Lesson 2</th>
<th>Lesson 3</th>
<th>Lesson 4</th>
<th>Lesson 5</th>
<th>Lesson 6</th>
<th>Lesson 7</th>
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<th>Lesson 11</th>
<th>Lesson 12</th>
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<th>Lesson 14</th>
<th>Lesson 15</th>
<th>Lesson 16</th>
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<tbody>
<tr>
<td>A: Inquiry</td>
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## Principles and Standards for School Mathematics: K-4

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## NCTE/IRA Standards for English Language Arts

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