THE PLANETARY SOCIETY

The Planetary Society's ***Red Rover Goes to Mars Training Mission***

Mars Surveyor 2001 Notebook Pages

Mission Description

Although the Mars Surveyor 2001 lander mission was cancelled due to a reorganization of the Mars Exploration Program, the hardware and experiments will fly on upcoming lander missions. The Red Rover Goes to Mars Training Mission takes full advantage of the progress of the Mars Surveyor 2001 mission before its cancellation, as the educational foundation for student participation in an upcoming lander mission.

Mars Surveyor 2001 is one step in a long-term plan for exploring Mars. The effort began with *Mars Pathfinder* and *Mars Global Surveyor*, a pair of spacecraft that reached the Red Planet in 1997. The plan will culminate in missions that will ultimately return a sample of Mars to Earth.

Mars Surveyor 2001 is a mission with two parts: a lander and an orbiter. They will be launched separately but will often work in tandem.

2001 LAUNCH AND FLIGHT TO MARS

The *Mars Surveyor 2001* orbiter is scheduled to launch on March 30, 2001 and arrive at Mars on October 20, 2001. On arrival, the orbiter will begin aerobraking, dragging its solar panels through the Martian atmosphere. It will take the spacecraft several months to aerobrake gradually to a tight, two-hour orbit, which will give the instruments the best possible view of the planet.

The *Mars Surveyor 2001* lander will launch on April 10, 2001, several weeks after the orbiter, and land on Mars on January 22, 2002. Mission planners will choose the landing site in an equatorial range of 3˚N to 12˚S after looking at high-resolution images of the planet's surface. When considering a landing site, they will ask:

> Will the site be too rocky to land on?
> Will it be too steep?
> Will there be too much loose dust flying around as the rocket engine brings the lander to a soft landing?

An Engineer would select the safest possible site, and a scientist would select the most interesting possible site. Both perspectives need to be considered in making the final selection.

As soon as the lander hits the Martian atmosphere, it will deploy a parachute. The lander will then fire its engine for a powered descent and deploy landing gear. A camera (MARDI) will take pictures as the lander descends to the surface.

On the surface, the first thing the lander will do is open its solar arrays one at a time. This will take two hours. Then it will figure out how much of a slope it's resting on, and where North is. By the end of its first day on Mars, it will unstow the Robotic Arm, deploy the Pancam mast, take an image, turn on MIP, MARIE, the MECA electrometer and the rover, and check the rover's health.

The Lander will use the MSP '01 Orbiter and/or the Mars Climate Orbiter to relay data to and from Earth twice a day, at 4 a.m. and 4 p.m. Mars local time. This means that the Lander must be able to store instrument data and instruction sequences. To accomplish this, the batteries must be kept charged and warm, even while the lander is shut down at night. The mission will be successful when it has collected 75% of the planned science data over a period of 90 sols (Martian days).

SCIENCE GOALS OF THE MISSION

> Make a map of Mars, showing where various types of rocks and soils are found.
> Take pictures of the landing site in the last moments before touchdown (these close-up pictures from the descent camera will be compared to images of the same area from the orbiter. The comparison will help scientists better understand the details in orbiter images of other regions of Mars).
> Study the shapes and textures of rocks (morphology) around the landing site for signs of geologic processes, such as erosion by wind or water.
> Identify elements and compounds in the rocks and soils around the landing site.

continued…

Sponsored by the LEGO Company with Liberté Yogurt of Canada, Science Magazine, and the AAAS-Directorate for Education and Human Resources, in cooperation with NASA, Jet Propulsion Laboratory, Malin Space Science Systems, ASU Mars K-12 Education Program, and Visionary Products Inc.

> Find out how much hydrogen is in the soil just under the surface (hydrogen is an ingredient in water).
> Find out what kinds of minerals are on Mars by using spectroscopy (read about Spectroscopy in an encyclopedia or astronomy textbook).
> Analyze Martian soil and dust, and consider how they might affect a mission by human explorers (for example, fine dust could clog astronaut equipment).
> Measure radiation on Mars as a risk to human explorers and equipment.
> Try out a system for making rocket fuel on Mars, using the carbon dioxide in Mars' atmosphere. Fuel manufactured on Mars could be used by future robotic and human explorers for traveling around the planet or launching to orbit for a return trip to Earth.

MARS SURVEYOR 2001 SCIENCE INSTRUMENTS

Lander Instruments

> Mars Descent Imager (MARDI)
> Mars Radiation Environment Experiment (MARIE)
> Mars In-Situ Propellant Production Precursor (MIP)
> Mars Environmental Compatibility Assessment (MECA)
> Robotic Arm (RA) and Robotic Arm Camera (RAC)
> Stereoscopic Panoramic Imager (Pancam)
> Mini-Thermal Emission Spectrometer (Mini-TES)
> Mossbauer Spectrometer

Marie Curie Rover Instruments

> Alpha Proton X-Ray Spectrometer (APXS)
> Camera

Orbiter Instruments

> Gamma Ray Spectrometer (GRS) with a Neutron Spectrometer (NS) and a High Energy Neutron Detector (HEND)
> Thermal Emission Imaging System (THEMIS)
> Mars Radiation Environment Experiment (MARIE)

To learn more about these instruments and the experiments they will be used for, read all the Red Rover Goes To Mars Notebook Pages. As you find out about each instrument, ask yourself: "How will this experiment add to our knowledge of Mars and further efforts toward human exploration?" (Remember, even dust is important when exploring an alien world.) Expand your reading: look for other sources of useful information. It is a good idea to research *Mars Pathfinder* and *Mars Global Surveyor*, because some of the instruments and experiments aboard Mars Surveyor 2001 have connections to those missions.

Visit your nearest library or Regional Center for references such as *Science Magazine*, Mars Pathfinder issue, 5 December 1997, Vol. 278, Pages 1677-1848.

References:
R.S. Saunders, P.R. Ahlf, R.E. Arvidson, G. Badhwar, W. V. Boynton, P. R. Christensen, L.D. Friedman, K. Kaplan, M. Malin, T. Meloy, M. Meyer, I.G. Mitrofanov, P. Smith, and S. W. Squyres et al, "Mars 2001 Mission: Science Overview", Presented at the 30th Lunar and Planetary Conference, Houston, TX, March 15-19, 1999.

Spencer, "Lander Surface Operations," JPL D-16303

Sponsored by the LEGO Company with Liberté Yogurt of Canada, Science Magazine, and the AAAS-Directorate for Education and Human Resources, in cooperation with NASA, Jet Propulsion Laboratory, Malin Space Science Systems, ASU Mars K-12 Education Program, and Visionary Products Inc.

Mars Descent Imager (MARDI)

The Mars Descent Imager (MARDI) will give us a unique view of the landing site—looking down while the Mars Surveyor 2001 lander descends to the planet's surface. MARDI, positioned under the lander deck, will activate ten seconds after the lander's parachute deploys and take a total of ten images on the way down.

The first image, taken from high altitude, will show a large area, 8 kilometers across. As the lander comes closer to the surface, the picture area will become smaller—just 9 meters across in the final MARDI image. MARDI will acquire its final image from approximately 40 meters above the surface. An image taken below that altitude would likely show only dust being kicked up by the lander's rocket engine.

Resolution in the first image will be about 7 meters, which means the image will show details as small as 7 meters across (the size of a highway truck). The last MARDI image will resolve details as small as 9 millimeters (a child's fingernail).

The geographic and geologic overviews from the MARDI images will help mission planners decide where to begin the lander's investigations.

Sponsored by the LEGO Company with Liberté Yogurt of Canada, Science Magazine, and the AAAS-Directorate for Education and Human Resources, in cooperation with NASA, Jet Propulsion Laboratory, Malin Space Science Systems, ASU Mars K-12 Education Program, and Visionary Products Inc.

Athena Precursor Experiment (APEX)

The Athena Precursor Experiment (APEX) is a group of four instruments that will analyze rock and soil composition, shape, and texture. The goal of these studies is to determine environmental conditions on ancient Mars, which may have been warmer and wetter than today, more like the early Earth. By helping us understand the various rock types to be found on the Martian surface, APEX will prepare the way for Athena. Athena is the advanced, self-navigating rover being developed for the Mars Surveyor missions that will launch in 2003 and 2005. The 2005 mission will bring rock and soil samples from Mars to Earth.

PANCAM

A pair of panoramic digital cameras, together known as Pancam, will be mounted on the lander atop a mast. From this position, approximately 2 meters above the Martian surface, Pancam will provide high-resolution, multi-color, stereo images of the terrain and atmosphere up to several times a day. Pictures taken by Pancam will help with other experiments and instruments, including the *Marie Curie* rover, the rover's Alpha Proton X-Ray Spectrometer, the Mossbauer Spectrometer, and the Mars Environmental Compatibility Experiment (MECA).

MINI-TES

The Mini-Thermal Emission Spectrometer (Mini-TES) will sit on the deck of the lander beneath the Pancam. A periscope mirror mounted between the two Pancam cameras will reflect light down through the mast to the Mini-TES. Mini-TES will see the same features and rocks as the Pancam, but instead of viewing them in visible light, Mini-TES will see them in the thermal infrared.

Infrared is electromagnetic energy at longer wavelengths than visible light. Everything radiates electromagnetic energy. Very hot objects, such as light bulb filaments or the sun, radiate (glow) in the visible part of the spectrum. Cooler objects, such as rocks on the surface Mars, radiate in the thermal infrared. Although the thermal infrared is invisible to your eyes, Mini-TES can detect this light in minute detail. Just as different objects have different colors in visible light, different rock-forming minerals have distinctly different spectra (combinations of brightness at different wavelengths) in the thermal infrared.

To identify Martian rocks and minerals, mission scientists will compare the spectra seen by Mini-TES to the known spectra of pure mineral specimens on Earth. For further comparison, they may also use spectra from some of the 13 meteorites of Martian origin that have been found on Earth. Our understanding of how minerals form on Earth will give clues about how the same minerals formed on Mars. In this way, we can reconstruct what early Mars must have been like. Were environmental conditions once more favorable to life? Note: You may find it helpful to read about the Thermal Emission Spectrometer (TES) aboard another mission, the *Mars Global Surveyor*.

MOSSBAUER SPECTROMETER

The Mossbauer Spectrometer is located near the middle of the forearm link of the Robotic Arm (past the elbow). Because it illuminates its targets with gamma rays, it is positioned to avoid irradiating soils that will later be observed by MECA. Mossbauer targets include rocks, soils, wind-deposited dust, and dust that adheres to two magnets mounted on the lander deck. It takes 12 hours to collect a Mossbauer spectrum.

Mossbauer spectra are used to study different minerals, particularly iron-bearing minerals. Like the other instruments, the Mossbauer Spectrometer will give us clues to the Martian environment at the time when the minerals formed. Were the minerals formed under high temperatures, or did they precipitate out of water? Are the iron-bearing minerals quick to oxidize, indicating a wetter and warmer environment on Mars in the past? Certain findings may point to environments which could have supported life.

ALPHA PROTON X-RAY SPECTROMETER (APXS)

The fourth APEX instrument, an Alpha Proton X-Ray Spectrometer (APXS), was used successfully on the *Mars Pathfinder* mission. As with *Pathfinder*, the Mars Surveyor 2001 APXS will be mounted on the rover, named *Marie Curie*. The APXS can determine which elements are found in rocks and soils beyond the reach of the lander's Robotic Arm. It will also be used to analyze the chemistry of soils that stick to a magnet mounted on one of the lander's legs. The APXS bombards its target rock or soil with alpha particles (helium nuclei) and examines reflected alpha particles, as well as the protons and X-rays scattered back into the instrument. Each chemical element scatters in a different way. After about 10 hours of "staring" at its target, the APXS has enough data to identify each element.

Using images from the Pancam, mission scientists will choose targets for the APXS and then program the rover to move to those locations. As with the other spectrometers, the APXS will help support the APEX's science goal of determining the environmental conditions on ancient Mars.

References
http://astrosun.tn.cornell.edu/athena/minites.html, July 6, 1999.
http://emma.la.asu.edu/MINITES/minilatest.html, July 6, 1999.
http://astrosun.tn.cornell.edu/athena/mossbauer., July 6, 1999.
http://mars.jpl.nasa.gov/2001/instruments/apex.html, July 6, 1999.
http://athena.cornell.edu/, August 24, 1999

Sponsored by the LEGO Company with Liberté Yogurt of Canada, Science Magazine, and the AAAS-Directorate for Education and Human Resources, in cooperation with NASA, Jet Propulsion Laboratory, Malin Space Science Systems, ASU Mars K-12 Education Program, and Visionary Products Inc.

Mars Environmental Compatibility Assessment (MECA)

As we progress in space exploration, we can look forward to a Mars mission with human explorers. Before we can launch that historic mission, we need to gather information about how to survive in the alien and extreme environment on Mars. To start with, we have to learn more about Martian soil and dust.

In everyday life on our planet, it is impossible not to pick up soil, dust, and small rocks. We wash dirt off everything from our posessions to ourselves. We change filters on engines and machinery because they accumulate choking dust. Working in the environment of another planet will require careful planning, and we will have to have a good understanding of the nature of Martian soil and dust.

Dust could be hazardous if it gets into sensitive equipment, causing malfunctions, or if it contaminates astronaut living space. Particles could cling to spacesuits or be inhaled or ingested. To help us plan for these hazards, the Mars Environmental Compatibility Assessment (MECA) has four instruments:

> Microscopy Station
> Electrometer
> Wet Chemistry Laboratory
> Adhesion/Abrasion Plates

MICROSCOPY STATION

The Microscopy Station will study soil particles brought to it by the Robotic Arm. Soil will be placed on different test surfaces, including magnets, metals, and sticky or textured material. Some of the surfaces will be set up for controlled rubbing tests, which will reveal properties such as the particles' hardness.

Samples collected by the Robotic Arm will be examined under the Optical Microscope. The Optical Microscope works the same way as microscopes at school and can show details as small as a few micrometers (a strand of fine hair might have a thickness of 140 micrometers or less). Also in the Microscopy Station is an Atomic Force Microscope (AFM), which can pick out details only nanometers in size. The AFM can produce topographic images of a particle, showing the peaks and valleys on its surface. Seeing how smooth or jagged a surface is will help us understand qualities such as slipperiness or tendency to snag.

The Mars Pathfinder mission found signs of quartz on the Red Planet, so MECA will be looking for this mineral in the dust and soil around the landing site. Extremely fine-sized quartz, which is very hard and sharp-edged, could cause problems for humans and equipment on Mars, as it has on Earth.

ELECTROMETER

Mounted to the heel of the Robotic Arm scoop, the Electrometer will measure static electricity that builds up when the Robotic Arm is digging. Digging causes friction, and friction can generate an electrical charge. For example, when you rub a balloon on a flannel shirt, the balloon can become electrically charged, causing it to stick to the shirt and other surfaces. On Mars, the Electrometer will monitor the atmosphere and soil for triboelectric charging: electrical charges caused by friction.

The Electrometer system includes five Triboelectric Sensors with different insulating materials. The sensors will measure the charge that builds up on each material when the Robotic Arm is digging.

In addition, the Electric Field Sensor will measure how powerful the electrostatic charge is on different surfaces. Finally, an Ion Current Sensor will measure the effects of ionizing radiation by sampling the local atmosphere for flows of ions.

With this information about electrostatic properties of the Martian environment, we can learn how to avoid problems in our use of electrical power. And we will know what kinds of coating or shielding will be needed to protect electronics on future missions.

continued…

Sponsored by the LEGO Company with Liberté Yogurt of Canada, Science Magazine, and the AAAS-Directorate for Education and Human Resources, in cooperation with NASA, Jet Propulsion Laboratory, Malin Space Science Systems, ASU Mars K-12 Education Program, and Visionary Products Inc.

Mars Surveyor 2001 Notebook Pages

WET CHEMISTRY LABORATORY

The Robotic Arm will deposit soil samples in four drawers in the Wet Chemistry Laboratory. A screen will keep out large particles. The drawer will then close, and the soil samples will be mixed with water and tested for:

- pH (how acidic or basic is the sample?)
- conductivity (can electricity flow through it?)
- heavy metals (is there any copper, lead, cadmium?)
- carbon dioxide
- oxygen
- redox potential (the tendency of a substance to combine with oxygen or release oxygen; look up "oxidation" and "reduction")
- corrosive potential
  Corrosive damage to life-support equipment or even human tissue on astronaut missions is a major concern. Identifying where and how such problems might arise is a major goal of MECA.

ADHESION PLATE

To help us learn how various materials stand up to conditions on Mars, the *Viking* and *Mars Pathfinder* missions included an adhesion plate for testing patches of material from Earth. The Adhesion Plate, consisting of 72 disks each a centimeter across, will be mounted on top of the MECA instrument package, exposed to wind-blown dust and sand. The patches on the Adhesion Plate will be materials used in astronaut equipment, such as nylon glove fabric, Plexiglas, silicon, and filter materials. We will observe this set with the Robotic Arm Camera to see how much sand and dust adhere to different materials.

References

http://mars.jpl.nasa.gov/2001/lander/meca/index.html. July 6, 1999.
http://mars.jpl.nasa.gov/2001/lander/meca/overview.html. July 6, 1999.
http://mars.jpl.nasa.gov/2001/lander/meca/science.html. July 6, 1999.
http://mars.jpl.nasa.gov/2001/instruments/meca.html. July 6, 1999.
http://mars.jpl.nasa.gov/2001/lander/meca/micro1.html. July 18, 1999.
http://mars.jpl.nasa.gov/2001/lander/meca.electro1.html. July 18, 1999.
http://electrochem.tufts.edu/mars.html. July 18, 1999.
http://mars.jpl.nasa.gov/2001/lander/meca/wetchem1.html. July 18, 1999.
http://mars.jpl.nasa.gov/2001/lander/meca/matches1.html. July 18, 1999.

Sponsored by the LEGO Company with Liberté Yogurt of Canada, Science Magazine, and the AAAS-Directorate for Education and Human Resources,
in cooperation with NASA, Jet Propulsion Laboratory, Malin Space Science Systems, ASU Mars K-12 Education Program, and Visionary Products Inc.

Mars In-Situ Propellant Production Precursor (MIP)

The package of instruments known as MIP is small, 40 x 24 x 25 centimeters, and low mass, 8.5 kilograms. Yet the information from this collection of five instruments will be vital to planning future missions with human explorers. MIP will test technologies that use Martian natural resources to make rocket fuel. Having rocket fuel available on Mars means that future missions won't have to bring fuel from Earth for their return trip, which means our spacecraft can be smaller, lighter . . . and much more fuel efficient.

The strategy for MIP is to acquire a batch of carbon dioxide (CO_2) from the Martian atmosphere and separate out its oxygen (the O_2 in CO_2). Oxygen can be burned as rocket fuel (propellant). Carbon dioxide is the most plentiful ingredient in the Martian atmosphere.

MIP will operate for a minimum of 90 Sols (Martian days), enough time to tell us about long-term effects of the Martian environment on the propellant-making equipment. The following five experiments are part of MIP:

- MAAC: acquiring CO_2 from the atmosphere
- OGS: separating out the oxygen
- MATE: supplying solar power for manufacturing equipment
- DART: dealing with dust build-up on solar panels
- MTERC: cooling the O_2 to liquefy it

MAAC: Mars Atmospheric Acquisition and Compression

MAAC will absorb CO_2 from the atmosphere during the cold Martian nights, when temperatures drop to around -73 degrees Celsius. After approximately 12.5 grams of CO_2 have been collected in a special sorbent bed, the bed will be heated and pressure within the system increased to roughly 100 times Mars' atmospheric pressure. Once the CO_2 is compressed, it can be passed on to the oxygen generator. There are no moving parts within the MAAC, giving the instrument the potential of a long and reliable life.

OGS: Oxygen Generator Subsystem

The job of the OGS is to receive compressed CO_2 and extract oxygen. CO_2 coming into the OGS from the MAAC will be electrolyzed (exposed to electrical current) at very high temperature (750 degrees Celsius), causing oxygen ions to be stripped away from the carbon dioxide. The liberated oxygen will be drawn to a filter made of zirconia, whose crystal framework will allow only the oxygen to pass through. The OGS can produce 0.5 cubic centimeters of O_2 per minute. The OGS will run ten times during the mission.

MATE: Mars Array Technology Experiment

Having a reliable power source is crucial for any mission's success. Future Mars missions with human explorers will need more power to maintain life-support and other systems. Meeting this need is a technical challenge. To help us identify the technologies that work best on Mars, MATE will

- measure sunlight
- test different types of solar cells

MATE is scheduled to run each day at solar noon. In addition, one day per week it will run once per hour all day. It will run once per week at night. That adds up to 19 times per week unless other priorities limit MATE operations.

Solar cells. The solar cells to be tested by MATE will consist of five pairs of different cell types. We'll be looking to see which cells perform best on Mars, where the sunlight is less intense and temperatures are cooler than on Earth. Information from the *Viking* and *Mars Pathfinder* missions tells us that sunlight on Mars dims when there is a lot of dust blowing around in the atmosphere. Other MATE experiments will involve a string of solar cells, connected in series, to investigate ways to maximize power from solar cells.

continued…

Sponsored by the LEGO Company with Liberté Yogurt of Canada, Science Magazine, and the AAAS-Directorate for Education and Human Resources, in cooperation with NASA, Jet Propulsion Laboratory, Malin Space Science Systems, ASU Mars K-12 Education Program, and Visionary Products Inc.

Radiometers. To measure the intensity of sunlight on different days and at different times of day, MATE will use two radiometers, a global radiometer and a direct radiometer. A radiometer is a device that is sensitive to radiant energy, like sunlight. The MATE radiometers will generate a voltage in proportion to the level of solar intensity, so the voltage will go up and down according to the intensity of the sunlight.

The global radiometer has a wide field of view (forming an angle of 140 degrees) and will measure scattered light. The direct radiometer "sees" through a slit and so has a narrow field of view. It will look directly at the Sun once per day, when the Sun is overhead. The radiometers will take measurements every 20 seconds during a 15 minute interval centered around solar noon.

Temperature sensors. Eight temperature sensors, made of platinum, will be arranged around the MATE experiment. Two will be attached to the radiometers, two will be on the spectrometers, and the rest will be under solar cells. The accuracy of the temperature sensors is within 1 degree Celsius.

Spectrometers. Sunlight is a combination of energy at different wavelengths, and MATE has two spectrometers to detect these wavelengths. Sunlight on Mars will have a different mixture of wavelengths than we experience on Earth, because its atmosphere may block, transmit and scatter light differently. Together the two spectrometers, each covering its own range of wavelengths, will detect wavelengths from .3 microns to 1.7 microns.

Here is how the spectrometers work. Sunlight bounces off a diffraction grating, which separates it into its component colors – much like a prism. Then the different colors of light land on different parts of a photodiode array with 256 detectors. Each detector counts photons (particles of light) that land on it. This lets it measure the amount of light in the wavelength (color) range that reaches it. Data from the photodiode array will give us a better understanding of the solar energy available on Mars and help us build efficient power systems.

DART: Dust Accumulation and Removal Technology

Dust storms on Mars can sometimes envelop the entire planet, with dust clouds rising up to 20 kilometers. Smaller dust storms are an everyday part of Martian weather. When dust settles and accumulates on solar cells, it reduces their performance. Before humans begin exploring Mars, we need to learn how and how often to remove dust or, better yet, prevent it from settling on our solar arrays. DART is designed to measure how much dust accumulates and how much it affects the performance of a solar array. DART will also examine the dust itself and try out different techniques for keeping dust off the solar cells. The DART experiment is teamed with the MATE experiment, as both will add to our knowledge of solar power on Mars.

Sun position sensor. DART equipment includes a Sun position sensor, which locates the Sun relative to the solar panel. The sensor can also measure the optical depth of atmospheric dust, indicating the effect of airborne dust on how far you can see.

Microscope. A microscope, an important part of the diagnostic instrument package, will measure how much dust accumulates and how fast. It will also determine size distribution, so we will understand, as dust builds up, how many of the particles are large, medium, and small. The microscope will tell us about the particles' opacity, or their ability to block sunlight, and about the shapes of the larger particles, which will tell us about their history. The microscope will be mounted beneath a clear plate,

Sponsored by the LEGO Company with Liberté Yogurt of Canada, Science Magazine, and the AAAS-Directorate for Education and Human Resources,
in cooperation with NASA, Jet Propulsion Laboratory, Malin Space Science Systems, ASU Mars K-12 Education Program, and Visionary Products Inc.

where dust will be allowed to accumulate. The microscope will have a 40x objective lens, able to resolve particles as small as half a micron in diameter. Knowing about Martian dust in detail will help future mission planners decide on the best strategies for coping with it.

Materials Adherence Experiment. DART includes a Materials Adherence Experiment (MAE), identical to the *Mars Pathfinder* MAE. A solar cell will measure the intensity of sunlight through dust that has settled on a transparent plate. This plate can be rotated away so that the solar cell can compare solar intensity with and without the blocking layer of dust. This experiment will tell us how much effect dust build-up can have on solar array performance.

Dust prevention. What methods can we use to deal with dust particles that may be only a micron in size? We'll test two methods during this mission. The first is to tilt the solar cells at various angles—30, 45,and 60 degrees—to see if any works better to keep dust from sticking. One of the tilted solar cells will have a low-friction coating. This hard coating will resist abrasion, or scratching, due to wind-blown particles. Even very small scratches can give dust particles a place to lodge and accumulate.

The second method for dust prevention involves applying a continuous electrostatic charge to prevent dust from adhering. Just as static electricity can make things cling (for example, on a dry day, hair is attracted to a comb), it can also be used to repel. This strategy might work especially well on Mars, which is dry.

MTERC: Mars Thermal Environment and Radiator Characterization

This experiment will test technology for cooling, which is needed in two stages of propellant production. Recall that MAAC heats up carbon dioxide in a sorbent bed; after the CO_2 is passed to the OGS, the sorbent bed must be cooled down to collect the next batch of Martian atmosphere. Also, the oxygen coming out of the OGS, to be used as propellant, must be cooled until it liquefies. One way to lower the temperature is to use a radiator, a device that dissipates heat energy into the surrounding environment in the form of infrared radiation. The emissivity, or efficiency with which a radiator dissipates heat, depends on the materials it is made of.

MTERC will test four radiator plates, to examine the effect of dust accumulation and abrasion on radiator performance. Two of the plates have high-emissivity designs, and two are low-emissivity. As experimental controls, one plate of each type will be covered.

References

D.I. Kaplan, J.E. Ratliff, R.S. Baird, G.B. Sanders, K.R. Johnson, P.B. Karlmann, K.J. Juanero, C.R. Baraona,G.A. Landis, P.P. Jenkins, and D.A. Scheiman, "In-Situ Propellant Production on Mars: The First Flight Demonstration," Presented at the 30th Lunar and Planetary Science Conference, Houston, TX, March 15-19, 1999.

G.A. Landis, P.P. Jenkins, C. Baraona, D. Wilt, M. Krasowski, and L. Greer, "Dust Accumulation and Removal Technology Experiment on the Mars 2001 Surveyor Lander," Proc. 2nd World Conference on Photovoltaic Energy Conversion, Vienna, Austria, July 1998, pp. 3699-3702.

G.A. Landis, "Mars Dust Removal Technology," Journal of Propulsion and Power, Vol. 14, No. 1, pp. 126-128. Jan. 1998; paper IECEC-97345.

D.A. Scheiman, M. Krasowski, L. Greer, D. Spina, C. Baraona, D. Wilt, P. Jenkins, and G.A. Landis, "Mars Array Technology Experiment for the 2001 Lander," Proc. 2nd World Conference on Photovoltaic Energy Conversion, Vienna, Austria, July 1998, pp. 3675-3678.

HYPERLINK
http://mars.jpl.nasa.gov/2001/lander/lander_marie_text.html
http://mars.jpl.nasa.gov/2001/lander/lander_marie_text.html, July 6, 1999.

Sponsored by the LEGO Company with Liberté Yogurt of Canada, Science Magazine, and the AAAS-Directorate for Education and Human Resources,
in cooperation with NASA, Jet Propulsion Laboratory, Malin Space Science Systems, ASU Mars K-12 Education Program, and Visionary Products Inc.

Sundial

"Two Worlds, One Sun" will be inscribed on the sundial going to Mars aboard the Mars Surveyor 2001 mission. In history, people used sundials to track the apparent motion of the Sun across the sky and to tell the time of day. Now we have a chance to continue the use of this tool on another planet. The lander's panoramic camera (Pancam) will image the sundial and the shadow cast on it by the Sun.

Students sent in suggestions that shaped the final sundial design. One idea was to inscribe the word *Mars* in as many languages as possible to represent the diversity of cultures on Earth. Because of that suggestion, the sundial includes 24 languages, representing three-quarters of Earth's people. A message engraved on the side panels reads:

> People launched this spacecraft from Earth in our year 2001. It arrived on Mars in 2002. We built its instruments to study the Martian environment and to look for signs of life. We used this post and these patterns to adjust our cameras and as a sundial to reckon the passage of time. The drawings and words represent the people of Earth. We sent this craft in peace to learn about Mars' past and about our future. To those who visit here, we wish a safe journey and the joy of discovery.

On the top surface of the sundial there are rings in black, gray, and white that we will use for calibrating the Pancam. The rings represent the orbits of Earth and Mars, and there are blue and red dots to show where Earth and Mars will be in their orbits at the time of the Mars Surveyor 2001 landing. A post in the middle of the sundial will cast a shadow that will be imaged by the Pancam. Mirrored sections along the outer ring of the sundial's surface will reflect the color of the Martian sky above the lander. Throughout the mission, the post's shadow and the mirrored reflection of the sky will be updated frequently on the World Wide Web.

Sponsored by the LEGO Company with Liberté Yogurt of Canada, Science Magazine, and the AAAS-Directorate for Education and Human Resources,
in cooperation with NASA, Jet Propulsion Laboratory, Malin Space Science Systems, ASU Mars K-12 Education Program, and Visionary Products Inc.

CD for Mars Surveyor 2001 Lander

The first Martian library will be in the form of a small CD aboard the Mars Surveyor 2001 lander. Information on the CD will give future explorers some ideas about why we came to Mars. The CD includes:

> a history of Mars missions from Earth
> an international collection of science fiction stories about Mars
> messages from science fiction writer Arthur C. Clarke and planetary scientist Carl Sagan
> children's art

There is still room on the CD for materials that you create as part of the Red Rover Goes to Mars program. The CD is another way for students and teachers to participate in the Mars Surveyor 2001 mission.

The CD will have a binary code printed around the outside edge. In the Red Rover Goes to Mars educational project, you will have an opportunity to decipher the code. You can build a sensor on a turntable to read the code, or you can take part in an activity using a cardboard replica of the CD. A cartoon character made of LEGO(blocks will be featured on the face of the CD and will also appear when the CD is played, acting as a guide.

The CD will be only 8 instead of the usual 12 centimeters in diameter, so that it adds as little mass as possible to the lander. If the CD is mounted within the view of the Robotic Arm Camera, as planned, it will be possible to involve the CD in an experiment. For example, the MECA team suggested that the Robotic Arm could dump a first scoop full of soil on the CD before putting any in the MECA sample chambers. This would serve as a practice maneuver, allowing controllers to see just how much real Martian soil the Robotic Arm can scoop at a time. Since we know the size of the CD, the size of that first scoop full of soil would be easy to figure out.

Sponsored by the LEGO Company with Liberté Yogurt of Canada, Science Magazine, and the AAAS-Directorate for Education and Human Resources,
in cooperation with NASA, Jet Propulsion Laboratory, Malin Space Science Systems, ASU Mars K-12 Education Program, and Visionary Products Inc.

Mars Radiation Environment Experiment (MARIE)

Before sending human explorers to Mars, we need to have a thorough knowledge of the radiation hazard on that world. Earth has a thick, nitrogen/oxygen atmosphere that protects us from cosmic and solar radiation, but Mars has a thin, carbon dioxide atmosphere. We don't know yet how the Martian atmosphere affects the radiation that pours in from space.

MARIE consists of two instruments. One aboard the orbiter will take measurements above the atmosphere while the other, on the lander, will take measurements at the planet surface. Together, the two sets of measurements will tell us what happens to incoming radiation as it travels through the Martian atmosphere. This will help us determine how much shielding future missions will need for spacecraft, spacesuits, and other equipment.

RADIATION

The word *radiation* encompasses different kinds of energy, including all the types of energy in the electromagnetic spectrum, from radio waves, microwaves, and infrared (heat) to visible light to ultraviolet rays, X-rays, and gamma rays. But the kind of radiation that MARIE will measure comes in the form of high-energy particles – fast-moving bits and pieces of atoms. These include protons, electrons, neutrons and atomic nuclei.

Ionizing radiation includes X-rays, gamma rays, and high-energy particles. Ionizing radiation has enough energy to break off parts of atoms that it runs into, knocking electrons loose from their atoms. Atoms that have missing or extra electrons, and hence a positive or negative charge, are called ions.

On Earth we are all exposed to low levels of radiation every day from natural sources and often from human-made sources, such as dental X-rays. Too much exposure to ionizing radiation causes radiation sickness, which can be fatal. It also leads to long-term health problems, especially an increased risk of cancer. Ionizing particles also disrupt electronics, which astronauts rely on for life support, communications, navigation, and more.

MARIE ORBITER SPECTROMETER

Astronaut missions face threats from two sources of radiation:

> Galactic cosmic rays (GCR), originating from supernovas and pulsars. GCR is a low-dose but constant source of radiation that can be harmful with exposure over a long period of time. It affects the human central nervous system and increases the risk of cancer.

> Solar energetic particle (SEP) events are bursts of radiation from the Sun, released during huge eruptions called solar flares.

MARIE will measure both of these kinds of radiation. The spectrometer aboard the orbiter has a telescope tube to gather cosmic ray particles. The gathered particles then run into a stack of detectors – slices of treated silicon one millimeter thick. Some of the detectors (position-sensitive detectors) can be used to determine the particle's direction of travel, which indicates whether it is a SEP (coming from the Sun) or a GCR.

The more energy a particle has, the more detectors it will penetrate. If a particle penetrates all of MARIE's silicon

continued…

Sponsored by the LEGO Company with Liberté Yogurt of Canada, Science Magazine, and the AAAS-Directorate for Education and Human Resources, in cooperation with NASA, Jet Propulsion Laboratory, Malin Space Science Systems, ASU Mars K-12 Education Program, and Visionary Products Inc.

detectors, it finally reaches a detector made of Schot glass, a material that reveals the Cherenkov effect. The Cherenkov effect occurs when a particle is so energetic (traveling so fast) that it travels faster than light can through the same medium. The blue glow from the water in a nuclear reactor is an example of the Cherenkov effect.

Using data from the detectors, we can calculate the charge and mass of captured particles, and from this information we can determine whether the particle was originally from hydrogen, helium, or other heavier elements.

MARIE Lander Spectrometer

The lander spectrometer is very similar to the orbiter spectrometer. It will measure

- accumlated radiation dose
- dose rate
- linear energy transfer (which gives an idea of how severely ionizing a particle is)

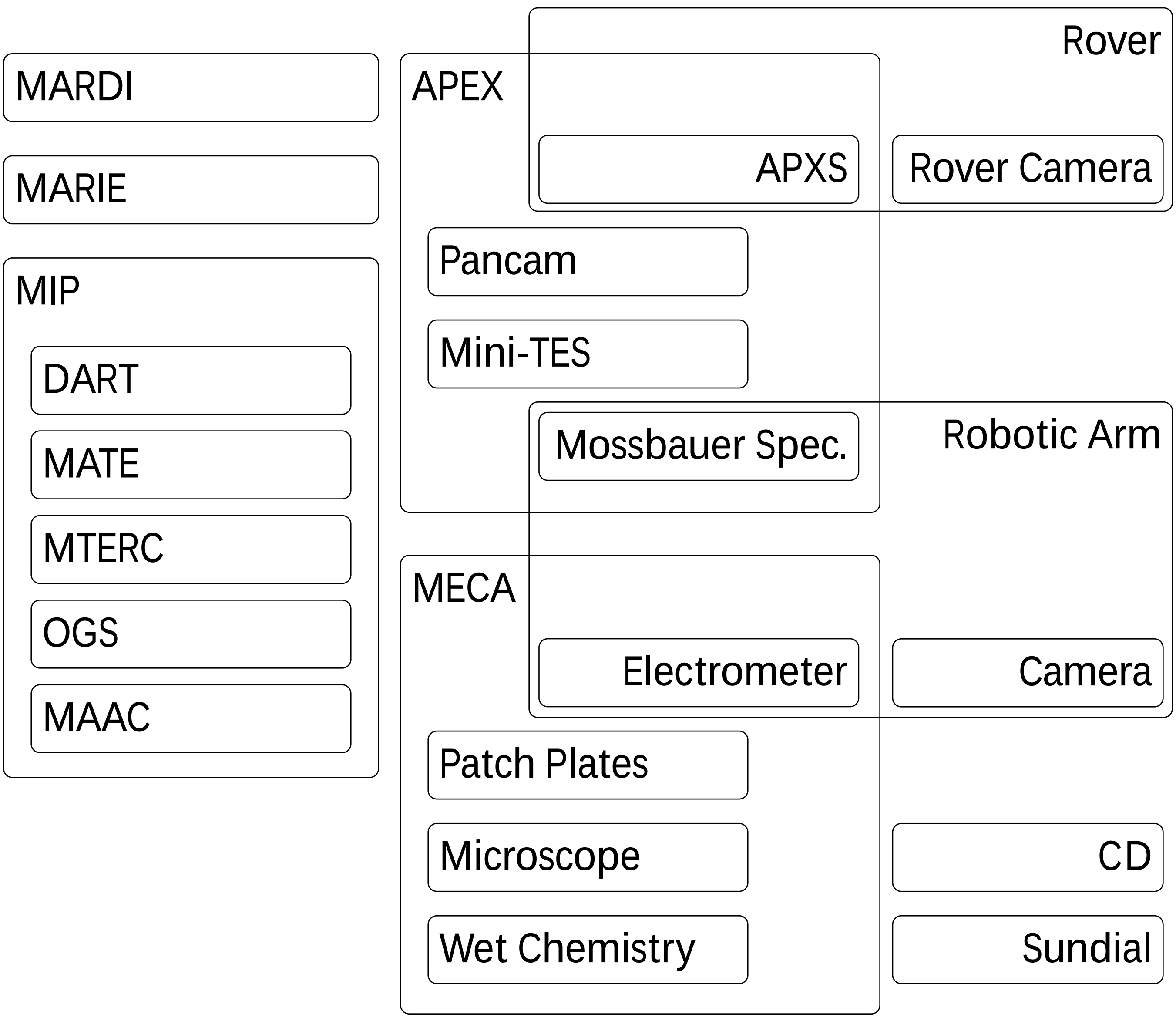
The lander spectrometer has two detectors made of silicon, two position-sensitive detectors, and a pair of proportional counters (each a gas-filled cylinder) instead of a Cherenkov detector. The proportional counters are covered with materials that have about the same penetrability as living cells. One counter is sensitive to all energetic particles, while the other is only sensitive to particles with electrical charges. By comparing results from both counters, we will be able to see how much of the penetrating radiation is made of neutrons.

Data from the lander spectrometer will also allow us to sort out how much penetration occurs by protons and nuclei of heavy elements. The more massive particles, such as protons, neutrons, and nuclei, cause greater damage to cells.

References:
Gautam D. Badhwar, "Martian Radiation Environment Experiment (MARIE)", Mail Code SN, Earth and Solar System Exploration Division, NASA Johnson Space Center, Houston, TX 77058-3696.

Sponsored by the LEGO Company with Liberté Yogurt of Canada, Science Magazine, and the AAAS-Directorate for Education and Human Resources,
in cooperation with NASA, Jet Propulsion Laboratory, Malin Space Science Systems, ASU Mars K-12 Education Program, and Visionary Products Inc.

Instrument/Experiment Overview



Sponsored by the LEGO Company with Liberté Yogurt of Canada, Science Magazine, and the AAAS-Directorate for Education and Human Resources,
in cooperation with NASA, Jet Propulsion Laboratory, Malin Space Science Systems, ASU Mars K-12 Education Program, and Visionary Products Inc.