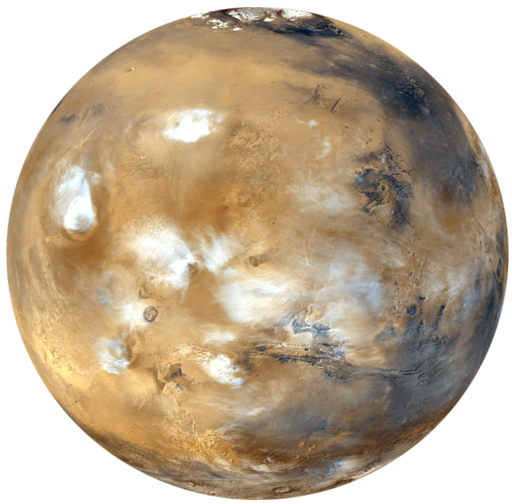
MARS ACTIVITIES



Teacher Resources
and
Classroom Activities

Mars Education Program
Jet Propulsion Laboratory
Arizona State University

Mars Missions
Information and Updates

Mission Information
Available at

Jet Propulsion Laboratory
Mars Exploration Home Page
http://mars.jpl.nasa.gov

More Educational Activities
Available at

Jet Propulsion Laboratory
Mars Education & Public Outreach Program
http://mars.jpl.nasa.gov/classroom

or

Arizona State University
Mars K-12 Education Program
http://tes.asu.edu/neweducation.html

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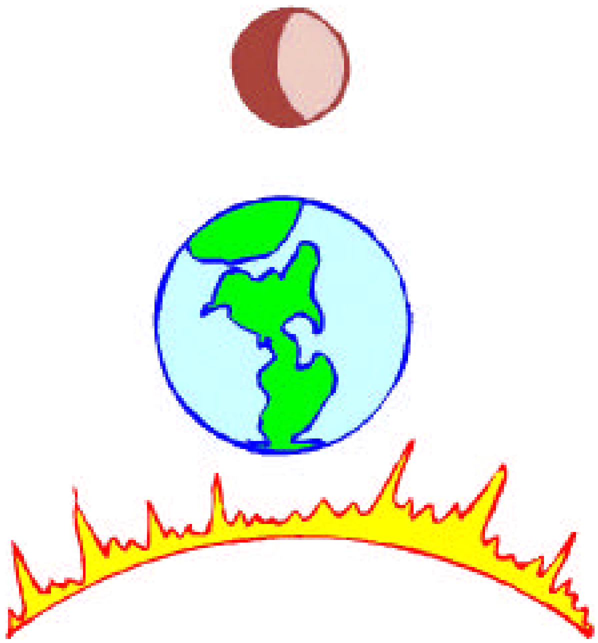
Earth, Moon, Mars Balloons

Introduction:

How big is the Moon; how far is it relative to Earth? Earth science and astronomy books depict a moon that is much closer and much larger than in reality. The example below is typical of what is found in textbooks:



The balloon activity will allow students the opportunity to construct a scale model of the Earth-Moon system, both in terms of planetary sizes and distances. In addition, students make a scale model of Mars, and discover how far one might have to travel to visit the most Earth-like planet in our Solar System. It is also a good icebreaker at the beginning of a semester, to get students to interact with each other.

National Science Education Standards:

Standard D: Earth in the Solar System

Materials (for a class of 27):

- 1 bag blue balloon (at least 9 per bag)
- 1 bag white balloons
- 1 bag red balloons
- 27 copies of Planetary Data Handout
- Rulers/measuring devices in both inches and centimeters

Step - By - Step Instructions:

1. Obtain balloons. The best are balloons with 2 1/2 inch diameter when deflated, but any balloons will work. An easy way to do this activity is to purchase balloons that are colored. The red, white, and blue balloons can be used for Mars, Moon, and Earth. (using green for Earth and yellow for the Moon are also fine).

2. Discuss the question of size of the Earth relative to the Moon. Determine what misconceptions the students may have.

3. Distribute balloons. It is best to provide one third of the class with "Earth" (i.e. blue), one third with "Moon" (i.e. white), and one third with "Mars" (i.e. red).

4. Distribute Planetary Data Handout, one per student.

5. Tell students that the Earth balloon will have a diameter of 20 cm. Have them figure out the scale (divide the Earth's actual diameter by 20 cm. Earth is about 63,800,000 times larger than 20 cm). Ask students with Earth balloons to inflate their model approximately 20 cm (obviously the balloon is not a perfect sphere, but neither is the Earth).

6. Ask students to look at the handout and calculate the size that the Moon and Mars should be, at the same scale as the Earth model. (Note the teacher's copy has the answers: the Moon should be about 5 cm, Mars about 11 cm).

7. Have students inflate the Mars and Moon balloons.

8. Ask students, at this scale, how far apart are the Earth and Moon? The diagrams seen in common textbooks might lead many of them to suggest that the Moon balloon should be held less than a meter from the Earth balloon.

9. Have students calculate the distance from Earth to the Moon at the same scale as the balloon models. The distance is about 6 meters. Have students holding the Earth models stand at one side of the room, and a partner holding a Moon model about 6 meters away.

10. Point out to students that they now have a scale model of the Earth-Moon system. Earth and its Moon are considered a double planet. The distance between the two is the distance traversed by the Apollo astronauts who went to the Moon in the 1960's and 70's. (Have students recall the film Apollo 13).

11. Compare the size of the Mars model with the Earth and Moon model. Look at the distance between Earth and the Moon.

12. Ask students how far away they think Mars will be at this scale. Have students attempt to demonstrate it in the classroom.

13. Have students calculate the distance to Mars at this scale. The answer is about 12,000 cm, which in more familiar terms is 3/4 of a mile! Have students identify a local landmark that is about 3/4 of a mile away.

14. Discuss the relative distance between Earth and Mars in the context of a human trip. How long did it take for Apollo astronauts to get to the Moon? (3 days) How long would it take for astronauts using similar technology to get to Mars? Mars Pathfinder, which launched in December 1996, arrived at Mars on July 4,1997 (7 months). Mars Global Surveyor, which launched in November 1996, arrived at Mars in September 1997 (11 months).

Extensions:

1. Ask students to make models of the Martian moons, Phobos and Deimos, at the same scale as the balloon models. They can calculate their scale diameters from the enclosed chart. It turns out that they are about the same size of a small grain of sand!

2. Have students convert all metric measurements into the English system.
1 inch = 2.54 cm, 1 mile = 1.6 km

Answers to balloon exercise:

Scale Distances		(km) / 638 =	(cm)
Earth	Moon	3.84×10^5	600 cm = 20 ft
Earth	Mars	7.80×10^7	1.2 x 105 cm = 3/4 mi

Planetary Data

	Mercury	Venus	Earth	Mars	Jupiter	Saturn	Uranus	Neptune	Pluto
Distance from the Sun (AU)	0.387	0.723	1	1.524	5.203	9.537	19.191	30.069	39.481
Approximate Distance from the Sun (10^3km)	57,910	108,200	149,600	227,940	778,400	1,429,725	2,870,980	4,498,250	5,906,370
Radius	2,439.7	6,051.8	6,378.14	3,397.2	71,492	60,268	25,559	24,764	1,195
Mass (Earth = 1)	0.054	0.88	1	0.149	1,136	755	52	44	0.005
Density (gm/cm^3)	5.43	5.24	5.515	3.94	1.33	0.70	1.30	1.76	1.1
Rotation Period (day length)	58.65	-243.02	0.99	1.03	0.41	0.44	-0.72	0.67	-6.39
Orbital Period (year in days)	88	225	365	687	4,333	10,760	30,685	60,190	90,800
Sideral Period (length of year in Earth years)	0.24	0.62	1	1.88	11.86	29.42	83.75	163.72	248.02
Orbital Tilt (degrees)	0	177.3	23.45	25.19	3.12	26.73	97.86	29.58	119.61
Satellites	0	0	1	2	16	18	15	8	1

Glossary

AU - astronomical unit, the distance between Earth and Sun (~1.495 * 10^8).

Rotation Period - the length of the day.

Orbital Period - the length of the year in Earth days.

Retrograde - when a celestial body rotates in the opposite direction of the Earth or clockwise.

Satellite - another name for a moon.

Sideral Period - the length of a planet's year in Earth years.

Tilt - how a far a planet is tilted sideways on its axis, measured in degrees.

Balloon Exercise

Body	Diameter (km) / 638 =	Approximate Scale (cm)
Earth	12,756	~20 cm
Moon	3,476	~5 cm
Mars	6, 794	~11 cm
Phobos	22	~0.03 cm

Scale Distances		(km)	/ 638 = (cm)
Earth	Moon	3.84×10^5	600 cm = 20 ft
Earth	Mars	7.80×10^7	1.2 x 105 cm = 3/4 mi

Rover Races

Goal: The students will learn the challenges of operating a planetary rover and problem solve solutions by using a hands-on simulation.

Objective: To have the rover driver design and execute a series of commands that will guide a human rover through a simulated Martian surface, allowing the rover team to experience some of the challenges of teleoperating a robotic vehicle on another planet.

Time Frame: 45 minutes

National Science Education Standards:

Standard G: Nature of science

National Math Education Standards:

NM.5-8.2 Communication
NM.5-8.13 Measurement

National Technology Education Standards:

NT.K-12.3 Technology Productivity Tools
NT.K-12.4 Technology Communication Tools

Items Needed:

- Large playing area (classroom, gym, or outside area)
- Three blindfolds per team
- A clipboard and pencil for each driver and official
- Obstacles - laminated construction paper works well (**note:** do not use any materials that the blindfolded students will trip or fall over).
- A stopwatch for the timer of each team
- Driver's sheet
- Job cards with team numbers

Background Information:

Many students think that robotic vehicles (like the Mars Pathfinder Sojourner Truth rover) can be driven much like they drive their toy radio-controlled cars. They imagine a rover driver watching a computer screen showing the rover on Mars and moving a joystick to make it go. The reality is not so! The time it takes for a command to reach the surface of another planet (such as Mars) varies with the distance between the planets involved. This prevents any "joy-stick" driving in real time. The commands travel via radio waves at the speed of light (186,000 miles / second) and can take many minutes to reach their destination. Much can happen to an interplanetary robotic vehicle during this time interval. If, for instance, a command were given from the Earth-base for it to go forward on Mars and the Earth-base got a reply (say 12 minutes later) saying that the rover was indeed traveling forward. It would then take another 12 minutes to send a command from the earth-base to stop the rover. If the rover runs into trouble, crashes, or flips over, there is no one there to fix the situation. The rover mission is over!

In real remote sensing operations using robotic vehicles, NASA uses "smart rovers." Rovers are programmed with artificial intelligence that helps to keep it out of trouble. During the Mars Pathfinder mission, the mission science team would decide, as a group, which areas of the landing site or which particular rocks located in the landing site they wished to investigate. This information was relayed to the rover driver. The driver, viewing the landing site on a computer screen and using *Virtual Reality* goggles, then designed and uploaded the commands to the rover on which target it needed to find. The rover would then "think" its way over to that target…very slowly (another big difference between the toy cars that often speed around and crash!)

The *Sojourner Truth* rover (JPL website: http://marsweb.jpl.nasa.gov) was equipped with a camera and lasers that sent a series of beams out in front of the rover. If the beams came back unbent, it meant that the way was clear of obstacles. The rover would then move 1/2 a wheel turn and stop. It repeated this cycle, slowly moving toward the designated target. If the beams come back bent, the rover decided how bent (how big of a rock or crater is in front of it) and chose to either go over the obstacle, if it was small enough, or avoid it all together by going around it. Eventually, the rover arrived at the predetermined target, ready to collect the science data. Once the rover reached the target, it used its camera to take a closer look or deploy a special instrument called the APXS (Alpha-Proton X-ray Spectrometer) to analyze the rock. The Sojourner rover was not designed to travel very far away from the lander (approximately 15 meters). The lander camera kept the rover in view at all times.

The *Athena* rover payload (Athena website at http://athena.cornell.edu), was designed for the Mars Explorer Rover Mission due to launch in 2003. These rovers are even smarter and bigger rovers! This "super-rover" will be much like a roving geologist on Mars. This rover will have a lot more instruments available onboard to test rock samples, soil samples, and conduct science experiments. This rover will travel much farther away from the lander (up to 1 kilometer) and have its own navigation capabilities. The Mars Explorer Rover will have a series of cameras (navcam, pancam, hazcam, and a bellycam) and will be able to send back different camera views for the scientists on Earth to see. As each rover travels across the surface of Mars, the scientists will periodically stop, have the panoramic camera take a picture, then pick an area in the camera's view to. Send the rover. Rocks will be selected for imaging up close by the camera and the microscopic imager. Since a reddish dust covers much of the rocks and surface of Mars, a special instrument called the Mini-Thermal Emission Spectrometer (mini-TES) will use an thermal infrared (TIR) detector to look through the dust and view what type of rock or mineral might be near the rover. Other types of instruments on the rover will be able to take other important scientific readings about the rocks they encounter.

Before any robotic vehicle (such as a rover) is sent into space to journey to another planet, it is tested here on Earth first. Scientists are already testing the prototype of the Athena rover. This prototype is called the FIDO (*Field Integrated Design and Operations*) rover and was tested the spring of 1999 and 2001 (FIDO website at http://fido.jpl.nasa.gov and http://wufs.wustl.edu/lapis2) in the western U.S. deserts by scientists and high school students.

Preparation:

1. Prepare a set of job cards for each rover team. Use 3” x 5” index cards, making a driver card, 3 rover cards, a timer card, and a judge card for each team.
2. This makes it easier to assign the next group of students by handing out the cards to reserve their role.
3. Use construction paper ties (red 12” x 12” work well) to create the obstacle course that the rovers will traverse. Laminated ties work the best and last for many uses. Do not use desks or chairs, as students may trip over them. Make any type of course by arranging the ties symmetrically. An easy example of this might be:

```
     0     0     0     0
     0     0     0     0              0 = rover teams
     0     0     0     0
      STARTING LINE
X     X     X     X     X
XX    XX    XX    XX   XX
X     X     X     X     X
X   X    X    X    X    X
X  XX   XX   XX   XX    X
X   X    X    X    X    X
XX  XX  XX XX   XX XX
X X   X   X   X   X  X
        FINISH LINE
```

Procedure:

1. Preface the activity with a lesson on planetary rovers (e.g. Sojourner, FIDO, or Athena). Good resources can be found at the APEX/Athena website at http://athena.cornell.edu or the Jet Propulsion Laboratory website at http://marsweb.jpl.nasa.gov or the FIDO website: http://fido.jpl.nasa.gov and http://wufs.wustl.edu/lapis2)

2. Choose or draw names of students to form teams of six. One student will be designated as "the rover driver", one will be the "team timer", and another will be the "team judge". The remaining three students will become the rover by hooking together in a line (both hands to the shoulders in front of them (O=O=O). The rover will be guided by the driver through an obstacle course (simulated Martian surface).

3. The drivers will proceed through the course first, writing down the instructions that will guide the rover through the course (i.e. 3 steps forward, stop, 1 step left, stop, etc.)

4. Once the drivers have recorded their upload sequences on their driver sheets, the rover races can begin. The rover teams line up at the starling line. The three rover members are blindfolded, as to not aid the driver in executing their commands. The rover members link up (to form the 3 sets of wheels like the real rover designs) with their hands on the shoulders of the person in front of them (it is fun to choose different-sized students to form a rover, as the different sizes of steps taken by each is more evident). The judges

will keep a tally of the number of foot faults that their rover team makes by counting each time the front rover person's foot steps on a red tile (Mars rock). The timer of each team will record the time it takes for their rover team to make it through the course. (NOTE: remind the teams that accuracy, not speed is more important when driving a robotic vehicle on another planetary surface.)

5. The teams will all start at the same time, with the timers starting the team stopwatches when the teacher indicates. The driver may stand near their team to give the command sequences, but may not physically touch their rover to help guide it (this is, after all, teleoperations!). They must guide their rover by voice only. The rover driver may not deviate from the commands that have been written in their previous trip through the course, even if the rover is going off course. Many times in robotic missions, a sequence of commands are sent all at once. Changes have to be added later.
6. Allow time for all teams to complete the course. Gather the class to debrief how the driving went - the challenges and what they might change to do a better job the next time.
7. The students might observe that their steps and those of the rover people might need some type of calibration (i.e. “take baby steps” or “take giant steps”). Turns might be more accurate by saying, “turn 45 or 90 degrees”. Running a rover with 3 axles is also different than walking a course singularly.
8. Repeat the activity as time permits, allowing the changes the students brainstormed to be tested

Race Variations:

1. Safety cones can be added to the course as return sample rocks to be collected. When the rover is in the proper position for the last person on in the rover team to bend down (blindfolded) and pick up the cone, the driver can command “retrieve rock sample”. Once the cone has been retrieved, the cone can be passed to the middle rover person to be carried.
2. A video camera and monitor could be set up, so that the driver is in another room, allowing for a closer simulation to teleoperation. The driver would have to interpret the images and driving pathway with only the camera images (camera being held by the lead rover person) to guide them. Commands could be sent via a “runner” student, simulating the wait time that occurs in real space communication. Real communication with Mars varies with the distance between Earth and Mars (4 minutes to 20+ minutes each way.)
3. The tiles can be arranged in any design to make the course easier or more difficult (according to grade level or student's ability.) If course is set up outside you might want to tape the underside of the tiles, to prevent the course being disturbed by any wind.
4. Talk about the time differences the teams took to complete the course. Are there advantages to taking it slower (more careful moves, less crashes) or perhaps the power supply is getting low and more territory needs to be covered (faster).

Extensions:

1) Have students design or build their own rovers, explaining what type of Instrumentation they would include and why it is necessary.

2) Have students research the types of rovers or other types of robotic spacecraft that are already traveling toward their destination or are being developed for solar system exploration. Another examples is:

   The MUSES C Mission (asteroids) website:

   http://sse.jpl.nasa.gov/missions/ast_missns/muses.html

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Rover Races

Information Sheet and Course Directions for Driver

Commands:

Right	(R)
Left	(L)
Backward	(B)
Forward	(F)
Stop	(S)
Rock Sample Retrieval	(RSR)

1) Write down the course directions for the rover to follow, counting your steps as you walk through the Mars course.

2) When the rover is in the correct position for the last person of the rover to collect a rock sample, use the Rock Sample Retrieval command.

3) The rover will only be able to follow your set of written commands. The commands to the rover cannot be any different than the ones you have written down.

Commands: (Example - 1. Forward 3 steps. Stop.
2. Turn left 1 step. Stop.)

1.	11.
2.	12.
3.	13.
4.	14.
5.	15.
6.	16.
7.	17.
8.	18.
9.	19.
10.	20.

Rover Races

Judges Sheet

Make a mark (example: IIII) every time the first person on the rover team steps on a tile (rock crashes!). Keep track through the whole course and make a total at the end.

NAME OF JUDGE:

NAME OF TIMER:

TOTAL ROCK CRASHES =

TOTAL TIME TO COMPLETE THE COURSE =

TOTAL ROCK SAMPLES COLLECTED

Areology - The Study of Mars

Objectives:
The student will have the opportunity to:

- Examine a simulated Martian surface core sample.
- Learn how an unknown core sample can be identified by matching it with a known sample.
- Discover how surface core samples can tell us about the history and make-up of Mars.
- Consume the core sample at the end of the exercise!

Mars Mission analogies:

1) A Mars robotic arm onboard a lander that could drill down approximately 1/2 meter into Martian surface.
2) A Mars long-range rover that can drill core samples in selected rocks for a sample return of Martian surface materials to Earth.

National Science Education Standards:
Standard A: Abilities necessary to do scientific inquiry
Standard G: Nature of science

National Technology Education Standards:
NT.K-12.5 Technology Research Tools

Materials needed (for each student):

- "Fun or bite size" candy bar (*Snickers, Milky Way, Mounds, Reeses Peanut Butter Cup,* etc)
- Two 3" long section of <u>clear</u> plastic soda straw
- Paper plate
- Plastic knife
- Graph paper or small ruler
- Wet wipes (optional for hand clean-up prior to activity, since edible material is involved.)

Procedure:

1) Distribute one candy bar to each student (use candy at room temperature, or a bit warmer.) Instruct students not to show their brand to anyone else. Ask each student to unwrap their bar and record observations about its surface: color, texture, composition, etc.
2) Have students take a "core sample" by carefully and steadily drilling a straw into their candy bar. Then ask them to record the number and thickness of layers, as well as color and texture of layers. What are the layers made of? Any repeated layers?
3) Have the students use knives to cut candy in two, so the layers can be viewed more easily in a cross-section. Discuss which layers were made first. How were the layers made?
4) Have the students make a second core sample using the other straw. Two students then exchange core samples. Can they identify a new sample by comparing it with one that is known?
5) Finally, allow the students to consume the samples.

Credit: This activity is adapted from *Mission to Mars* materials from the Pacific Science Center in Seattle, WA and Adler Planetarium. Submitted to *Live from Mars* by April Whitt and Amy Singel, Adler Planetarium. Teacher's Edition created by ASU Mars K-12 Education Outreach Program.

Areology: The Study of Mars

TEACHER EDITION

Directions: You have just received a Martian surface sample. It is your job to observe and determine all the scientific information you can from this sample. You will be taking a core sample from this Martian surface sample and answering the following questions. You will then receive a second core sample to compare to the first. List anything that is similar or different between the two samples.

1. Describe the color of your Mars sample: ***Have the Students observe the exact color of the surface. Is it milk chocolate color, dark chocolate, etc. Have them define in word variations to more distinctly describe what they are seeing.***

2. Describe the surface features of your Mars sample***: Is it smooth, wavy, lined, bumpy, speckled, etc.? Can they see different colors integrated into the surface?***

3. Draw a picture of any surface features you see on your Mars sample: ***Have them label some of their features (optional).***

4. What is your hypothesis (science guess) about the cause of any texture that you see on your Mars sample? ***If this was a Martian sample, what physical processes could have caused the textures or features you are seeing? (e.g. Water erosion (fluvial), wind erosion (aeolian), impacts, etc.)***

5. How many layers does your Martian core sample contain? ***This will vary, depending on the candy bar.***

6. Draw a picture showing the layers of your Martian core sample.

7. Which layers were made first, and why? ***The chocolate covering would be the surface the youngest area of deposit. The stratigraphy (the order of the layers) would grow older as they go down the straw, towards the bottom. This would generally be true, barring any unusual events, like earthquake faulting or magma (liquid rock) intrusion.***

8. Draw a picture of the second core sample showing any layers and surface features.

9. Compare the two core samples and list any similarities or differences from your first Martian core sample. ***Unless the student got an Identical core sample In the exchange, there should be some change. Compare the thickness of the top layers, colors, textures, smells, number of layers, sizes of layers, softness, hardness, etc.***

10. Would a core sample from Mars be important to the study of Mars? Why? ***A core sample would be very important to the study of Mars! Most of our science observations have been of surface features. To have a better understanding of the processes that formed the Martian features, probing the subsurface would be very important. There are also many unanswered questions the scientists are trying to find answers for: Is there water in the subsurface (perhaps that a human mission to Mars could access?) How many layers are there and how thick are the layers in the subsurface? Are there different rocks underground than there are on the surface of Mars? What can we tell about the climatic history of Mars from these layers (Mars '98 Mission)?***

11. Where would be the best place to study a Martian core sample…on Earth or on Mars? Why? ***Actually, a case could be made for both sites ... Earth would probably have better, more sensitive science equipment available, since spacecraft equipment is somewhat limited to space/cost/sensitivity factors Studying the sample on Mars would allow the scientist to observe the actual site and surroundings of the core sample. Was this sample typical of the rest of the terrain, or an unusual occurrence? A field study could be better conducted on Mars.***

12. What would account for the samples being different if they were both from Mars? ***The core samples may have been taken from different sites or different places on the planet. Remember that one sample does not necessarily translate to the whole planet being like the sample. (A good story is the "The Blind Men and the Elephant" where the blind men all feel a different part of the elephant and think they know what the whole elephant is like).***

Areology: The Study of Mars

<u>Directions</u>: You have just received a Martian surface sample. It is your job to observe and determine all the scientific information you can from this sample. You will be taking a core sample from this Martian surface sample and answering the following questions. You will then receive a second core sample to compare to the first. List anything that is similar or different between the two samples.

1) Describe the color of your Mars sample:

____

____

____

2) Describe the surface features of your Mars sample:

____

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____

____

3) Draw a picture of any surface features you see on your Mars sample:

4) What is your hypothesis (science guess) about the cause of any texture that you see on your Mars sample?

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5) How many layers does your Martian core sample contain?

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6) Draw a picture showing the layers of your Martian core sample.

7) Which layers were made first, and why?

8) Draw a picture of the second core sample showing any layers and surface features.

9) Compare the two core samples and list any similarities or differences from your first Martian core sample.

10) Would a core sample from Mars be important to the study of Mars? Why?

11) Where would be the best place to study a Martian core sample ... on Earth or on Mars? Why?

12) What would account for the samples being different, if both come from Mars?

Strange New Planet

ASU Mars K-12 Education Program 6/99

Adapted from NASA Education Brief “EB-112: How to Explore a Planet” 5/93

<u>Introduction</u>: *Strange New Planet* brings insight into the processes involved in learning about planetary exploration. This activity demonstrates how planetary features are discovered by the use of remote sensing techniques.

<u>Suggested Grade Level</u>: 5 - 8 (Can be used K - 12 with adaptations - simple observations vs. more data collection related to current remote sensing data and techniques)

<u>Objectives</u>: Students will be engaged in making multi-sensory observations, gathering data, and simulating spacecraft missions.

<u>National Science Standards Addressed</u>:

Standard A: Abilities necessary to do scientific inquiry

<u>Materials</u>: (Planets can be made from a combination of materials)

- Plastic bails, modeling clay, Playdoh©, styrofoam© balls, or rounded fruit (cantaloupe, pumpkin, oranges, etc.)
- Vinegar, perfume, or other scents
- Small stickers, sequins, candy, marbles, anything small and interesting!
- Cotton balls
- Toothpicks
- Objects that can be pierced with a toothpick to make a moon
- Glue (if needed)
- Towel (to drape over planets)
- Push-pins
- Viewer material (sheet of paper, paper towel roll, or toilet paper roll)
- 5” x 5” blue cellophane squares (one for each viewer) and other selected
- Colors to provide other filters for additional information
- Rubber bands (one for each viewer)
- Masking tape to mark the observation distances
- Student data sheet

Procedure:

1) Selecting a Planet

Choose an object such as a plastic ball or fruit (cantaloupe, etc) that allows for multi-sensory observations. Decorate the object with stickers, scents, etc. to make the object interesting to observe. Some of these materials should be placed discreetly so that they are not obvious upon brief or distant inspection. Some suggestions for features are:

- Create clouds by using cotton and glue
- Carve channels
- Attach a grape using a toothpick (to make moons or orbiting satellites)
- Affix small stickers or embed other objects into the planet
- Apply scent sparingly to a small area

For older students, teams can create their own planets for other teams to view. This allows the students to create their own set of planetary features and write up a key to these features for the team that explores that planet to compare to their own findings.

2) Set-up

Place the object (planet) on a desk in the back of the room. Cover the object with a towel before students arrive. Brief students on their task: To explore a strange new planet. Students can construct viewers out of loose-leaf paper by rolling the shorter side into a tube (can also use toilet paper roll or paper towel roll.) These viewers should be used whenever observing the planet. Form mission teams of 4-5 students. Make sure students have a place to record their data (student data sheets.) Encourage use of all senses (except taste unless specifically called for).

3) Pre-Launch Reconnaissance

This step simulates earth-bound observations. Arrange students against the sides of the room by teams. These areas will be referred to as Mission Control. To simulate Earth's atmosphere, a blue cellophane sheet could be placed on the end of the viewers, taped or held in place by a rubber band. This helps to simulate the variation that occurs when viewing objects through the Earth's atmosphere. Remove the towel. Teams observe the planet(s) using their viewers for 1 minute. Replace the towel. Teams can discuss and record their observations of the planet. At this point, most of the observations will be visual and will include color, shape, texture, and position. Teams should write questions to be explored in the future missions to the planet.

4) Mission 1: The Fly-by (Mariner 4,6,7 - 1965,1969,1969)

Each team will have a turn at walking quickly past one side of the planet (the other side remains draped under towel). A distance of five feet from the planet needs to be maintained. Teams then reconvene at the sides of the room (Mission Control) with their backs to the planet while the other teams conduct their fly-by. Replace towel over planet once all the fly-bys have taken place. Teams record their observations and discuss what they will be looking for on their orbit mission.

5) Mission 2: The Orbiter (Mariner 9,1971-72; Viking 1 and 2 Orbiters, 1976-80; Mars Global Surveyor, 1996-present)

Each team takes two minutes to orbit (circle) the planet at a distance of two feet. They observe distinguishing features and record their data back at Mission Control. Teams develop a plan for their landing expedition onto the planet's surface. Plans should include the landing spot and features to be examined.

6) Mission 3: The Lander (Viking 1 and 2,1976-1982; Mars Pathfinder, 1997)

Each team approaches their landing site and marks it with a push pin (or masking tape if planet will pop using a pin.) Team members take turns observing the landing site with the viewers. Field of view is kept constant by team members aligning their viewers with the push pin located inside and at the top of their viewers. Within the field of view, students enact the mission plan. After five minutes, the team returns to "Mission Control" to discuss and record their findings.

Assessment:

Each individual student should complete a Student Data Sheet. Each team shares their data with the class in a team presentation. As a class, compile a list of all information gathered by the teams to answer the question “What is the planet like?” (or each planet if multiple planets are used). Have the class vote on a name of the newly discovered planet or the geologic features discovered using the rules for naming a planet (planetary nomenclature) which is located at the USGS website: (http://wwwflag.wr.usgs.gov/USGSFlag/Space/nomen). Teams critique their depth of observations and ability to work together.

Variations:

Create a solar system of planets, hang them from the ceiling and have students make observations of all the planets.

Name: ________________________________

Strange New Planet Student Data Sheet

A. Pre-Launch Reconnaissance - Earth-bound observations

1) Estimate your distance from the planet:_______________(feet or meters).

2) Using your viewer (with blue cellophane attached to simulate Earth's atmosphere) observe the planet. What types of things do you observe? Record any observations (shape of planet, color, size, etc.)

3) Discuss all of the observations with your team members while at Mission Control. Record any team observations that differ from yours.

4) As a team, write questions to be explored in the future missions to the planet. What else do you wish to know and how will you find that information out (special features of the planet, life of any kind, etc.)

   a.

   b.

   c.

   d.

B. Mission 1: The Fly-by (Mariner 4, 6, 7 - 1965,1969,1969)

Using their viewers (with the cellophane removed), each team will have a turn at walking quickly past one side of the planet. A distance of five feet needs be maintained from the planet. Teams will then meet back at Mission Control with their backs to the planet until all teams have completed their fly-by of the planet.

1) Record your observations of the planet. What did you see that was the same as your Earth observations? What did you see that was different? Can you hypothesize (make a science guess) as to why there were any differences?

2) Record any similarities or differences that your team observed.

3) List the team ideas as to what you want to observe on your next orbiting mission.

a.

b.

c.

d.

C. Mission 2: The Orbiter (Mariner 9, 1971-72; Viking I and 2 Orbiters, 1976-80; Mars Global Surveyor, 1996-present)

Using a viewer, each team takes a total of two minutes to orbit (circle) the planet at a distance of two feet. Divide the two minutes by the number of team members to get the time each person gets to orbit the planet. After your observation, return to Mission Control.

1) Record your observations of the planet. What did you see that was the same as your Earth or fly-by observations? What did you see that was different? Can you hypothesize (make a science guess) as to why there were any differences?

2) Record any similarities or differences that your team observed.

3) As a team, develop a plan for your landing expedition onto the planet's surface.

a. Where will you go and why? How did your team decide where to land?

b. What are the risks or benefits of landing there?

c. What specifically do you want to explore at this site?

d. What type of special equipment or instruments would you need to accomplish your exploration goals? (Remember, anything you bring has be small and light enough to bring on a spacecraft!)

D. Mission 3: The Lander (Viking 1 and 2, 1976-1982; Mars Pathfinder 1 1997)

Each team will approach their landing site and mark it with a push pin or masking tape. Each team member will take a turn observing the landing site through their viewer. Field of view (the area that you can see through your viewer) is kept constant by aligning the viewer with the push pin located inside and at the top of their viewers. Each team has a total of five minutes to view the landing site. After each member views the landing site, return to Mission Control.

1) Now that you have landed, what do you think you can accomplish at this landing site?

2) How long (in days) will it take you to get the job accomplished?

3) Was your mission successful? Why or why not?

4) What were the greatest challenges of this mission (Personally and as a team)? What would you change for the next mission?

5) List the members of your team.

a.

b.

c.

d.

e.

f.

Lesson Three — Lava Layering

Making and Mapping a Volcano

(Original activity is from *Exploring the Moon*, a Teacher's Guide with Activities for Earth and Space Sciences, NASA Education Product EP-306 1994.)

Part 1 —

Volcano Construction Experiments

About This Lesson

The focus of this activity is on the sequence of lava flows produced by multiple eruptions. Baking soda, vinegar, and play dough, are used to model fluid lava flows. Various colors of play dough identify different eruption events. Students will be asked to observe where the flows travel, make a model, and interpret the stratigraphy.

Objectives

Students will:

- construct a model volcano.
- follow a procedure to produce a sequence of lava flows.
- observe, draw, record, and interpret the history of the volcano.

National Science Education Standards

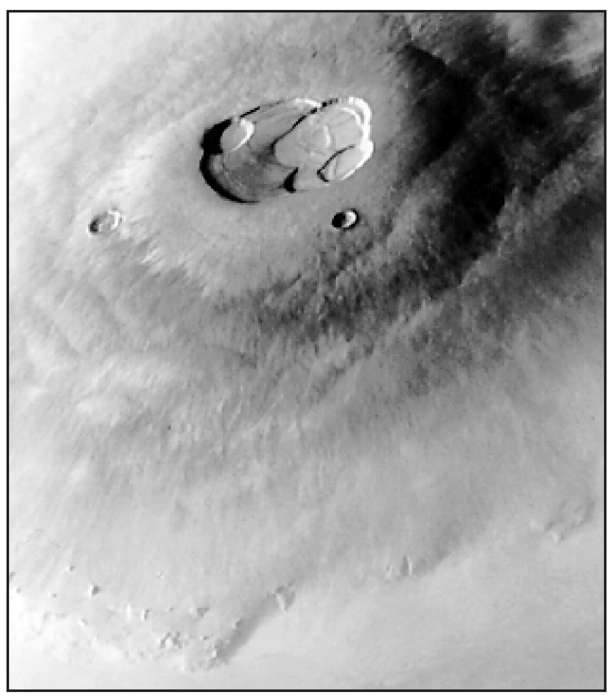
- Standard A: Understandings about scientific inquiry
- Standard F: Natural hazards

Background

Volcanoes and/or lava flows are prominent features on all large rocky planetary bodies. Even some asteroid fragments show evidence of lava flows. Volcanism is one of the major geologic processes in the solar system. Mars has a long history of volcanic activity from the ancient volcanic areas of the southern highlands to the more recent major volcanoes of the Tharsis bulge. Olympus Mons is a volcanic mound over 20 km above the surrounding plains. This one volcano would cover the entire state of Arizona!

Where volcanic heat and water interact here on Earth, scientists are finding life. In the hot springs of Yellowstone Park they have found abundant life forms including some very small bacteria. There is a possibility that life may have found a place in the ancient volcanic terrain of Mars.

Some of the volcanoes on Mars are basaltic shield volcanoes like Earth's Hawaiian Islands. Interpretations of photographs and soil analyses from the Viking and Pathfinder missions indicate that many of the lava flows on Mars are probably basalt. Scientists believe that basalt is a very common rock type on all the large bodies of the inner solar system, including Earth.



Olympus Mons, a martian shield volcano, as seen by the Viking Orbiter.

In addition to shield volcanoes, there are dark, flat layers of basaltic lava flows that cover most of the large basins of Mars and the Earth's moon. The eruption sources for most of the basin lava flows are difficult to identify because source areas have been buried by younger flows.

Generally, the overall slope of the surface, local topographic relief (small cliffs and depressions), and eruption direction influence the path of lava flows. Detailed maps of the geology of Mars and the Moon from photographs reveal areas of complicated lava layering. The study of rock layering is called stratigraphy.

Older flows become covered by younger flows and/or become more pocked with impact craters. Field geologists use differences in roughness, color, and chemistry to differentiate between lava flows. Good orbital images allow them to follow the flow margins, channels, and levees to try to trace lava flows back to the source area.

Vocabulary

eruption, source, stratigraphy, slope, layers

Materials Per Volcano Team

- ❑ 1 paper cup, 100 ml (4 oz.) size, cut down to a height of 2.5 cm
- ❑ 2 paper cups, 150-200 ml (6-8 oz.) size
- ❑ cardboard, approximately 45 cm square (other materials may be used: cookie sheet or box lid)
- ❑ playdough or soft clay — at least 4 fist-size balls, each a different color
- ❑ tape
- ❑ spoon
- ❑ baking soda (4-10 spoonfuls depending on number of flows)
- ❑ vinegar, 100-150 ml (4-6 oz.) depending on number and size of flows
- ❑ paper towels
- ❑ marker or grease pencil
- ❑ paper and pencil
- ❑ optional food coloring to color the vinegar if desired, 4 colors; for example, red, yellow, blue, green
- ❑ Student Sheet, *Lava Layering - Part 1* (pgs. 19-20)

Procedure

Advanced Preparation

1. Review background information and procedure.
2. Gather materials.
3. Prepare play dough using recipes provided or purchase play dough.
4. Cover flat work area with newspaper to protect from spills.

Classroom Procedure

1. This activity may be done individually or in cooperative teams. Groups of 2-4 usually work well.
2. Follow procedure on Student Sheet, *Lava Layering-Part 1*.
3. Discuss the progression of flows, noting that the youngest is on top and the oldest is on the bottom.
4. If Lava Layering Part 2 will be completed at a later time, be sure to cover the volcanoes securely with plastic.

Recipes

Play Dough (stove-top recipe)

Best texture and lasts for months when refrigerated in an air tight container.

2 cups flour — *1/3 cup oil, scant*
1 cup salt — *2 cups cold water*
4 teaspoons cream of tartar
food colorings (20 drops more or less)

Make this large batch one color or divide ingredients in half to make 2 colors. You will need 4 colors total. Combine ingredients and cook mixture in a large sauce pan, stirring constantly, until the dough forms a ball. Turn dough out onto a floured surface to cool. Then kneed until smooth and elastic. Cool completely; refrigerate in air tight containers.

Play Dough (no-cooking recipe)

2 cups flour — *2 tablespoons oil*
1 cup salt — *1 cup cold water*
6 teaspoons alum or cream of tartar
food colorings (as above)

Make this large batch one color or divide ingredients in half to make 2 colors. You will need at least 4 colors. Mix ingredients and kneed until smooth and elastic. Store in air tight containers.

STUDENT SHEET

Lava Layering — Part 1

Materials

- ❑ 1 paper cup, 100 ml (4 oz.) size, cut down to a height of 2.5 cm
- ❑ 2 paper cups, 150-200 ml (6-8 oz.) size
- ❑ cardboard or other surface, approx. 45 cm sq.
- ❑ playdough or soft clay, 4 fist size balls, each a different color.
- ❑ tape
- ❑ spoon
- ❑ baking soda, 50 ml (1/4 cup)
- ❑ vinegar, 100 ml (1/2 cup)
- ❑ paper towels
- ❑ marker or grease pencil
- ❑ paper and pencil
- ❑ optional: food coloring to color vinegar if desired.

Procedure

1. Take one paper cup that has been cut to a height of 2.5 cm and secure it onto the cardboard. (You may use a small loop of tape on the outside bottom of the cup.) This short cup is your eruption source and the cardboard is the original land surface.
2. Mark North, South, East, and West on the edges of the cardboard.
3. Fill a large paper cup about half full with baking soda.
4. Place one heaping spoonful of baking soda in the short cup.
5. Pour vinegar into a large paper cup leaving it half full.
   (optional: Fill 4 cups with 25 ml (1/8 cup) of vinegar. To each paper cup of vinegar add 3 drops of food coloring; make each cup a different color to match playdough. Set them aside.)
6. Set aside 4 balls of playdough, each in a different color.
7. You are now ready to create an eruption. Slowly pour a small amount of vinegar into your source cup and watch the eruption of simulated lava.
8. When the lava stops, quickly draw around the flow edge with a pencil or marker.
9. Wipe up the fluid with paper towels.
10. As best you can, use a thin layer of playdough to cover the entire area where lava flowed. Exact placement is not necessary. Match flow color and playdough if available.
11. On a separate sheet of paper record information about the flow. Indicate color, shape, direction of flow, and thickness. Indicate where this flow is in the sequence; first, second, etc.
12. Repeat steps 7 - 11 for each color of play dough available. Four to six flows show a good example of a shield volcano.

NOTES: You may add fresh baking soda to the source cup or spoon out excess vinegar from the source cup as needed. Be sure you mark where the lava flows go over previous flows as well as on the cardboard. Cover the entire area of each succeeding flow. This will resemble a strange layer cake with new flows overlapping old ones.

Student Sheet

Results

1. Look down on your volcano and describe what you see. Add your written description to the paper where you recorded the information about the flows. Include observations of flows covering or overlapping other flows. Make a quick sketch.

2. Where is the oldest flow?

3. Where is the youngest flow?

4. Did the flows always follow the same path? (be specific)

5. What do you think influences the path direction of lava flows?

6. If you had not watched the eruptions, how would you know that there are many different layers of lava? Give at least 2 reasons.

7. Which of the reasons listed in answer 6 could be used to identify real lava layers on Earth?

8. What are other ways to distinguish between older and younger layered lava flows on Earth?

9. Which of the reasons listed in answer 8 could be used to identify lava layers on Mars or the Moon?

10. What are other ways to distinguish between older and younger layered lava flows on Mars or the Moon? Look at orbital photographs if possible.

Part 2—

Volcano Mapping Extensions

About This Activity

Students will simulate a mapping and field exercise. It is very similar to the first steps that geologists employ when they map and interpret the geologic history of an area. Student teams will map and study the volcanoes produced by another team in Lava Layering, Part 1. Lava Layering, Part 2 is designed to promote the use of higher order thinking skills and encourages the questioning, predicting, testing, and interpreting sequence that is important to scientific inquiry.

Objectives

Students will:

- produce a map of an unknown volcano and show the sequence of lava flows.
- interpret the map data and infer the subsurface extent of the flows.
- predict where excavations will give the most information.
- simulate both natural and human excavations.
- write a short geologic history of the volcano.

Background

In the solar system, volcanism is a major process active now and in the past. All the large, solid inner solar system planetary bodies have surface features that have been interpreted as lava flows and volcanoes. Mars has spectacular volcanoes. Where volcanic heat and water are close together, hot springs likely formed. These thermal springs could have harbored microbial life.

The thought processes and sequence of observing, taking data, and interpreting that students use when completing this exercise are very similar to the real investigations done by field geologists.

Photo geologists use pictures taken by planes and spacecraft to interpret the history of a planet's surface. If they can get to the surface, they do field work by making maps and collecting samples. Geologists used pictures taken from Mars orbit to interpret the history of the planet's surface. Soon there will be some new data to add to the knowledge of Mars. The Mars Global Surveyor arrived at Mars in the fall of '97 and will return photos and other data about the surface of Mars. Pathfinder landed on July 4, 1997, and returned valuable data on weather, rocks and soil.

Materials

- ❑ volcano made of playdough from Lava Layering - Part 1, one volcano per team
- ❑ colored pencils or crayons
- ❑ metric rulers (two per group)
- ❑ straight edge for cutting (dental floss and wire to cut playdough if knives are not permissible)
- ❑ large width straws (one per group, or one 5 cm-long piece per student.)
- ❑ Student Sheet, *Lava Layering - Part 2* (pgs. 25-26)
- ❑ toothpicks, 5-10 per volcano

Procedure

Advanced Preparation

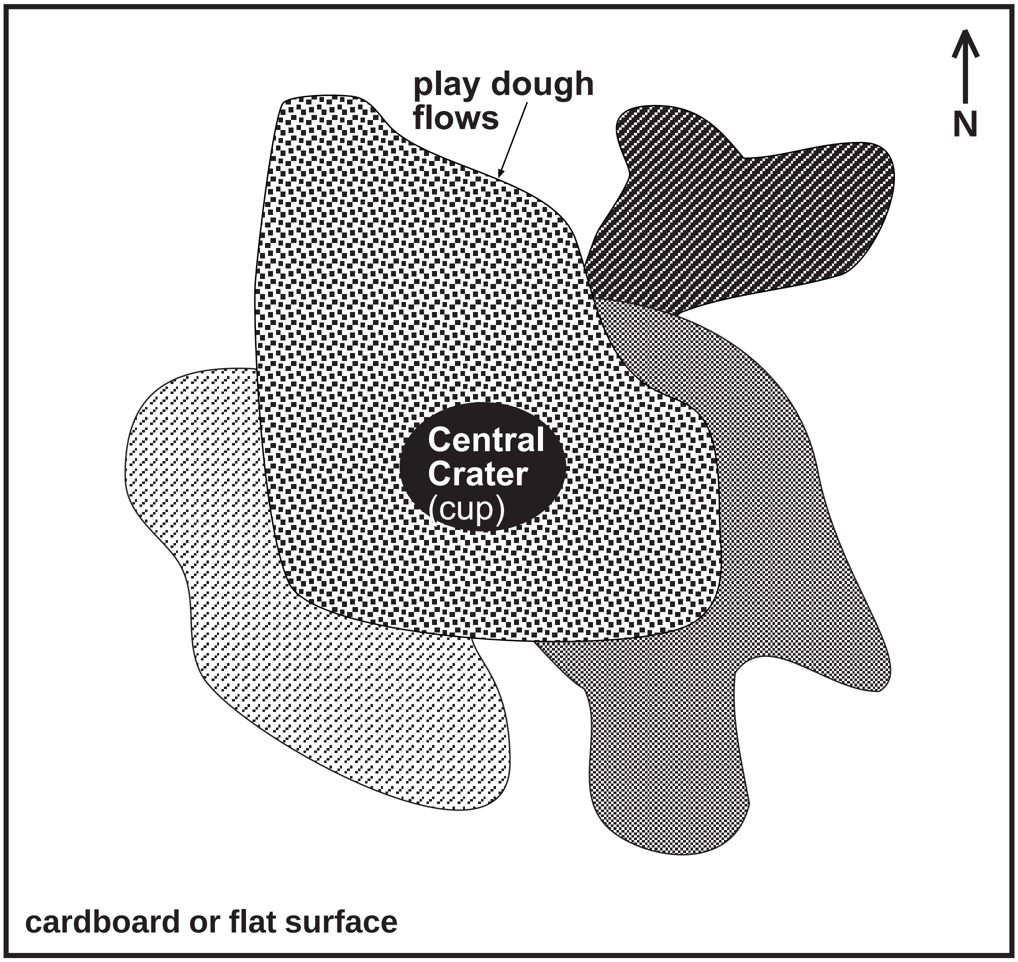
1. Gather materials.
2. Read procedure and background.
3. Small groups of students assemble volcanoes according to directions in Lava Layering- Part 1.
4. Mapping may be done immediately after volcano assembly or several days later. The playdough volcano must be covered with plastic if left more than a few hours.
5. Review map skills such as keys, scales, and measuring techniques.

Classroom Procedure

(This activity can easily be simplified as needed.)

1. Have teams trade volcanoes so that they will map a volcano with an "unknown" history. They may give the volcano a name if desired.
2. Ask groups to draw a map (birds-eye view) of the volcano. This may be made in actual size or they may make a scale drawing. The map should include a North direction arrow. An example drawn on the board or overhead may be helpful if students are not familiar with transferring measurements to a grid. Students will need to make careful observations and measurements to map the volcanoes accurately. Color and label the map.
3. Answer the questions on Student Sheet. **Note:** Some volcanoes may be more complex than others—each will be different!! There may be flows that are completely covered, some flows that have two separate lobes, and some flows for which the sequential relationship cannot be determined at the surface.
4. Lead the students to question what they cannot see below the surface. Where do the flows extend under the exposed surface? Lead them to name ways they can see what is below the surface without lifting the play dough. They may suggest drill holes or cores, river erosion and bank exposure, earthquakes, or road cuts and other excavations.
5. Have groups make a plan that shows on their map where they want to put the subsurface exposures. They should indicate how the proposed cores and cuts will maximize the information they might gain from excavations. Limit the number of exposures each group may use, i.e., five drill cores and one road cut and one river erosion.
6. Make the cuts or cores.
   - Remove drill core by pushing a straw vertically into the playdough, twisting if necessary, and withdrawing the straw. Blow through the open end of the straw to remove the core. Put the core on a toothpick and place it by the hole for reference.
   - River valleys may be made by cutting and removing a "v" shape in the side of the volcano (open part of "v" facing down slope).
   - To make road cuts, use knife or dental floss to cut and remove a strip about 1 cm wide and as deep as you want from any part of the volcano.
   - To make earthquake exposures, make a single cut and lift or drop one side of the fault line. Some support will be necessary.
7. Record cuts and cores on the map and in notes. Be sure to use location information, i.e., core # 2 is located on the blue flow in the Northeast quadrant of the volcano.
8. Observe hidden layers. Interpret data and draw dotted lines on the map indicating the approximate or inferred boundaries of the subsurface flows.
9. On a separate paper, write a short history of the volcano that relates sequence of flows and relative volumes of flows (or make a geologic column, a map key to the history that shows oldest geologic activity at the bottom and youngest at the top). Math classes may try to figure the volume of the various flows.
10. Compare the history developed by mapping in Part 2 with the original history from the group that made the volcano in Part 1. Write how they are similar or different.
11. Conduct debriefings at several stages of this activity.

Example of bird's eye view map of lava flows.



Student Sheet

Lava Layering — Part 2

Directions
Make a map of a volcano model. Do this from a birds eye view. Label flows and features.

1. How many flows can you see on your map?

2. Beside the map make a list of the lava flows, starting with the youngest flow at the top and finishing with the oldest flow at the bottom. Example: Top flow is a long, skinny, green flow.

3. Can you easily determine the sequence of flows (which came first, which came last) or are there some flows where you can't say which are younger or older? Put a question mark by the uncertain flows in the list on the map.

4. Are there parts of any flows that might be covered? Which ones?

5. What would you need to tell the sequence and shape of each flow? How could you get that information without lifting the playdough?

6. Think about what techniques will help you learn more about the interior of your volcano. Your teacher will lead a class discussion about these techniques before you experiment. Stop here and wait for the teacher to continue.

7. Document why each proposed experiment will be helpful in revealing information about your volcano. Conduct the experiments and record locations and the information gained.

8. Finish your map. On a piece of paper, write a description of the sequence that tells the history of the volcano. Compare your sequence to the history written by the group that originally made the volcano. Was your interpretation accurate? Explain.

9. Why would it be harder to map lava flows on Mars using spacecraft photos?

Lesson Five — Searching for Life on Mars

This lesson contains four exercises within three activities. The activities have been grouped to encourage students to think about the characteristics of life and about the possibility of looking for life on Mars.

Activity 1 — Imaginary Martians
Students will listen to one or more excerpts from science fiction that describe a fictional living organism from Mars. They will then draw their interpretations of the creatures and compare them to what they already know about life on Mars today.

Activity 2 — Looking for Life
Part A: An Operational Definition of Life Students will research characteristics of living organisms and develop a chart that will help them define important features of a living organism.
Part B: It's Alive! They will then use their definition to determine whether there is anything alive in three different soil samples, an experiment similar to the Mars Viking Lander in 1976 that looked for signs of life. Students will record their observations and draw pictures as they collect data from the samples.

Activity 3 — Mars Critters
Students will design a plant or animal life form that might survive on Mars.

Activity 1 — Imaginary Martians

About This Activity
Students will listen to one or more excerpts from science fiction that will describe fictional living organisms from Mars. They will then draw their interpretations and compare them to what they already know about life on Mars today.

Objectives
Students will:
- draw their interpretation of a Martian after listening to a science fiction reading.
- analyze the realism of this Martian based on today's knowledge of Mars environment.
- discuss the popularity of Mars in literature.

National Science Education Standards
- Standard C: Diversity and adaptations of organisms

Background

There are many science fiction stories related to Mars. Each one has its own explanation of how a Martian might look. The descriptions are based on the author's imagination and the known information about Mars from the time period. In this interdisciplinary activity, students will interpret an author's description of a Martian (language arts and art) and evaluate the possibility of such a creature living on Mars (science).

Vocabulary

interpretation, atmosphere, radiation

Materials

- ❑ drawing paper
- ❑ coloring utensils
- ❑ Student Sheet, *If You Went to Mars* (pg. 37)
- ❑ excerpts from science fiction novels Examples are Mars by Ben Bova (chapter 7), Out of the Silent Planet by C. S. Lewis (chapter 7), The Martian Chronicles by Ray Bradbury (February 1999-YUa), The Day The Martians Came by Frederick Pohl (chapter 17)

Procedure

Advanced Preparation

1. Check various novels and choose excerpt(s) to use.
2. Practice reading the excerpt(s).
3. Distribute student supplies.
4. Distribute the *If You Went to Mars* student sheet.

Classroom Procedure

1. Explain to the students that people in the past have had very different ideas of what life is like on Mars and that you would like to share some of these interpretations with them.
2. Ask the class to close their eyes and listen to the reading(s).
3. Read the excerpt(s) with animation and sound effects.
4. Tell the students to open their eyes, take the drawing materials of their choice, and draw what they think the author(s) described.
5. Ask the students why they think the author wrote the descriptions in this way. Discuss answers in terms of the literature and the time when the story was written.
6. Ask the students why they think there is so much literature about the planet Mars?
7. Ask each student to explain why the alien drawn could or could not really be found on Mars.
8. Discuss what it would be like to live on Mars. Use the *If You Went to Mars* student sheet.

Alternatives

1. Instead of a standard sheet of paper, have the students work in groups using a large sheet of butcher paper. Then you can also discuss how differently we each interpret what we hear. Display art.
2. Divide the class into teams and read several different excerpts, each team drawing an interpretation of a separate excerpt, then comparing the team drawings. Display art.

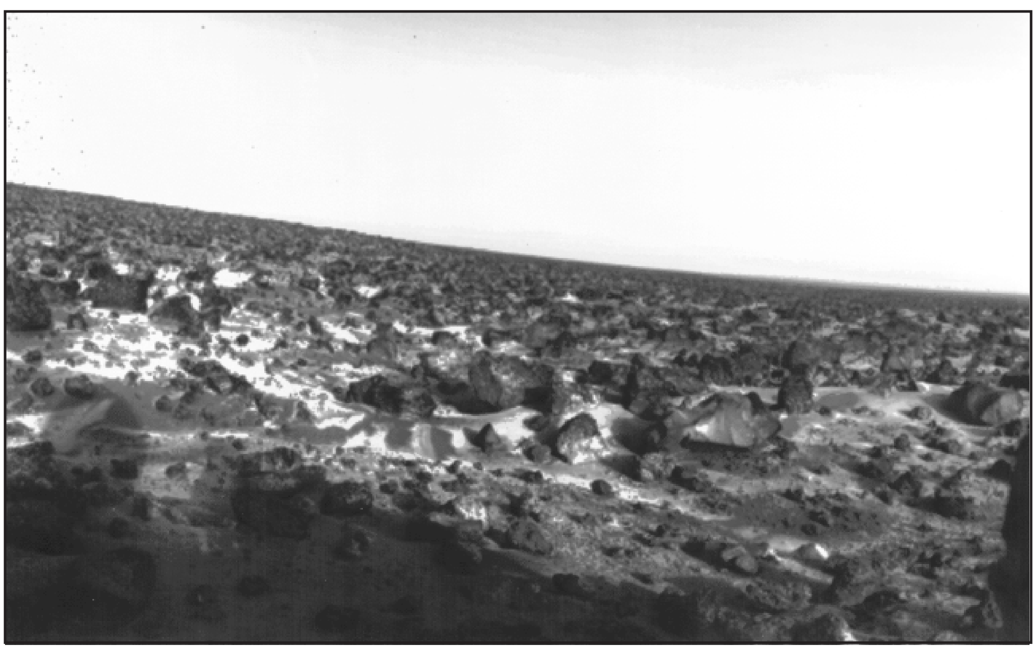
STUDENT SHEET

If You Went to Mars

from "Guide to the Solar System,"
by The University of Texas, McDonald Observatory

Mars is more like Earth than any other planet in our solar system but is still very different. You would have to wear a space suit to provide air and to protect you from the Sun's rays because the planet's thin atmosphere does not block harmful solar radiation. Your space suit would also protect you from the bitter cold; temperatures on Mars rarely climb above freezing, and they can plummet to -129°C (200 degrees below zero Fahrenheit). You would need to bring water with you; although if you brought the proper equipment, you could probably get some Martian water from the air or the ground.

The Martian surface is dusty and red, and huge duststorms occasionally sweep over the plains, darkening the entire planet for days. Instead of a blue sky, a dusty pink sky would hang over you.



STUDENT SHEET

FUNDAMENTAL CRITERIA FOR LIFE CHART

Fill in Criteria <u>after</u> the class has made observations and the teacher has grouped the observations.

Living Organism	**Criteria**	**Criteria**	**Criteria**	**Criteria**	**Criteria**

Activity 2—

Looking for Life

About This Activity
In Activity A students will use research to develop their criteria for life. The class will combine their ideas in a teacher-guided discussion. In Activity B they will then use their definition of life to determine whether there is anything alive in three different soil samples. They will make observations and draw pictures as they collect data from the samples and experiment.

Objectives
Students will:

- form an operational definition of life.
- conduct a simulated experiment with soil samples similar to the experiments on the Mars Viking Lander.
- state relationships between the soil samples using their operational definition of life.
- make an inference about the possibility of life on Mars based on data obtained.

Background
We usually recognize something as being alive or not alive. But when scientists study very small samples or very old fossilized materials, the signs of life or previous life are not easy to determine. Scientists must establish criteria to work within their research. The tests for life used by the Viking Mars missions were based on the idea that life would cause changes in the air or soil in the same way that Earth life does. The Viking tests did not detect the presence of life on Mars. The Viking tests would not have detected fossil evidence of past Mars life or a life form that is very different from Earth life.

Vocabulary
criteria, characteristics, organism, replication, metabolic

Part A:

An Operational Definition of Life

About This Part
Students will conduct research to identify characteristics of living and non-living organisms. They will record their observations on a chart that will help the class to come to a consensus about how to identify living things.

Materials

- ❑ Student Sheet *Fundamental Criteria for Life Chart* (pg. 38)
- ❑ dictionaries and encyclopedias
- ❑ examples of living and non-living things (should include plants, animals, and microorganisms—pictures can be substituted for the real thing)

Procedure

Advanced Preparation

1. Gather materials.
2. Review Background and Procedure.

Classroom Procedure

1. Explain to students that their job is to come up with a definition of how living things can be detected.
2. Ask students to state (or write) what characteristics make an individual item alive or not alive. Encourage them to find pictures and definitions of living and non-living things. Allow the students use of dictionaries and encyclopedias. Use the examples on the following page to encourage the students but not to limit them.

Example: Consider a bear and a chair—they both have legs, but one can move on its own and the other would need a motor made by humans; therefore, independent movement might be one characteristic that indicates life.

Not every living organism needs legs or roots. But they do need a mode of locomotion or a way to get nutrients. Also, the bear breathes and the chair does not, another indication of life. Or consider a tree and a light pole. We know that a light pole can not reproduce— it is made by humans—and we know that the tree makes seeds that may produce more trees. The tree also takes in nutrients and gives off gasses and grows. The light uses electricity and gives off light, but it is strictly an energy exchange and there is no growth and there are no metabolic processes.

However, students might not list the fundamental criteria for life. They might go for the more obvious signs like methods of locomotion. The more subtle but fundamental signs of life are:

- metabolic processes that show chemical exchanges which may be detected in some sort of respiration or exchange of gases or solid materials.
- some type of reproduction, replication or cell division.
- growth.
- reaction to stimuli.

3. As a class, discuss the indications of life, asking for examples from a diverse sampling of living things. The teacher will paraphrase and group criteria on the blank chart, then guide the students to summarize the groupings to reflect the fundamental criteria for life.

4. Students will use these criteria for the following activities.

Part B: It's Alive!

About This Part

Students will take three different soil samples and look for signs of life based on the criteria from Part A.

Materials

- ❑ sand or sandy soil sample
- ❑ three glass vials, baby food jars, or beakers for soil per group
- ❑ sugar- 5 ml (sugar will be added to all soil samples)
- ❑ instant active dry yeast- 5 ml added to 50 ml of soil
- ❑ Alka-Seltzer tablets crushed- 1 tablet added to 50 ml of soil
- ❑ hot water - enough to cover the top of the soil in all jars (not hot enough to kill the yeast!)
- ❑ cups for distributing the water
- ❑ magnifying lens- 1 per group or individual
- ❑ Student Sheets *Data Chart I* and *Data Chart II* (pgs. 43-44)

Procedure

Advanced Preparation

1. Fill all jars 1/4th full of soil. (You will need 3 jars per team.)
2. Add just sugar to 1/3rd of the jars. Label these jars "A."
3. Add instant active dry yeast and sugar to 1/3rd of the jars. Label these jars "B."
4. Add the powdered Alka-seltzer and sugar to the remaining jars. Label these jars "C."
5. Give each group a set of three jars, a magnifying lens, and the chart from previous activity.

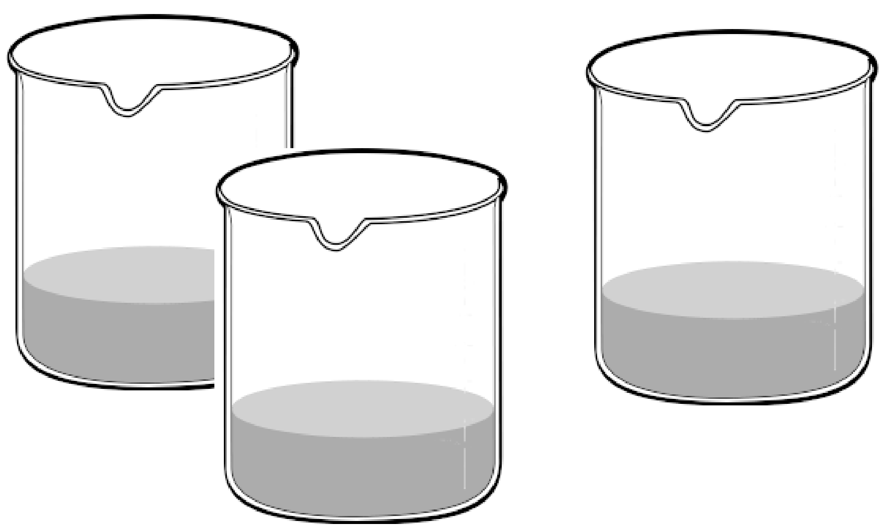
Classroom Procedure

(Information for teacher only— do not share all the information with students!)

1. Explain to the students that each team has been given a set of soil samples. No one knows if there is anything alive in them. The assignment is to make careful observations and check for indications of living material in them — based on their criteria.
2. Ask students to observe all three samples. They can smell and touch the samples but not taste them. Encourage students to put a few grains on a flat white surface and observe them with a hand lens. Students should then record their data.
3. Give each group a cup of water. (Use hot tap water (~50ºC) for the best results, do not kill the yeast.) Ask students to pour the water so that each sample is covered with the water.
4. Repeat step 2 and record data on a second sheet or in a separate area of the first sheet. Students should look for and record differences caused by adding water. After recording the first observations have students go back and observe again. (After about ten minutes Sample B will show even more activity.)
5. Discuss which samples showed indication of activity (B and C).
   Does that activity mean there is life in both B and C and no life in Sample A?
   Are there other explanations for the activity in either B or C?

   - Both B and C are chemical reactions
   - Sample C reaction stops
   - Sample B sustains long term activity
   - Sample A is a simple physical change where sugar dissolves

   Students should realize that there could be other tests that would detect life in Sample B. There might be microbes in the soil that would grow on a culture medium.
6. Determine which sample(s) contain life by applying the fundamental criteria for indicating life developed in Activity 2.
7. Tell students that Sample B contained yeast and Sample C contained Alka Seltzer. Discuss how scientists could tell the difference between a non-living chemical change (Alka Seltzer) and a life process (yeast) which is also a chemical change.
8. Discuss which of their criteria would identify yeast as living and Alka Seltzer as non-living.



STUDENT SHEET

IT'S ALIVE! DATA CHART I

Initial Descriptions (no water added):

Sample A:

Sample B:

Sample C:

Initial Drawings (no water added):

Sample A

Sample B

Sample C

STUDENT SHEET

IT'S ALIVE! DATA CHART II

Initial Descriptions (after water is added):

Sample A:

Sample B:

Sample C:

Initial Drawings (after water is added):

Sample A

Sample B

Sample C

Activity 3—

Mars Critters

About This Activity

In groups or as individuals, students will use their knowledge of Mars and living organisms to construct a model of a plant or animal that has the critical features for survival on Mars. This is a "what if" type of activity that encourages the students to apply knowledge. They will attempt to answer the question: What would an organism need to be like in order to live in the harsh Mars environment?

Objectives

Students will:

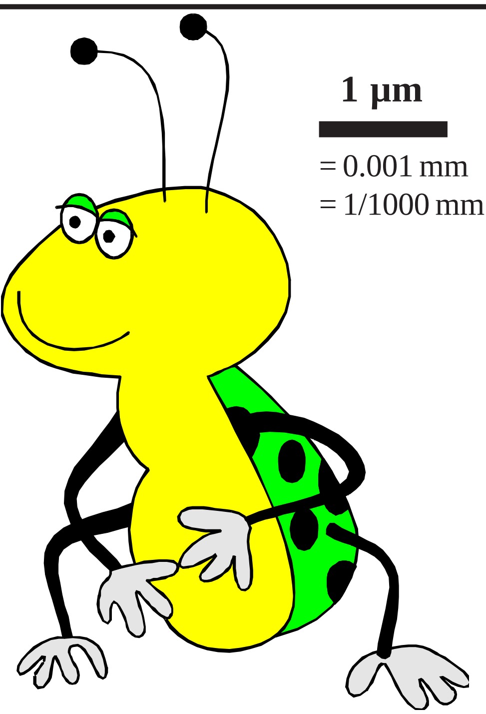
- draw logical conclusions about conditions on Mars.
- predict the type of organism that might survive on Mars.
- construct a model of a possible martian life form.
- write a description of the life form and its living conditions.

National Science Education Standards

- Standard C: Diversity and adaptations of organisms

Background

To construct a critter model, students must know about the environment of Mars. The creature must fit into the ecology of a barren dry wasteland with extremes in temperature. The atmosphere is much thinner than the Earth's; therefore, special adaptations would be necessary to handle the constant radiation on the surface of Mars. Also the dominant gas in the Mars atmosphere is carbon dioxide with very little oxygen. The gravitational pull is just over 1/3rd (0.38) of Earth's. In addition, Mars has very strong winds causing tremendous dust storms. Another requirement for life is food—there are no plants or animals on the surface of Mars to serve as food!



Scientists are finding organisms on Earth that live in extreme conditions previously thought not able to support life. Some of these extreme environments include: the harsh, dry, cold valleys of Antarctica, the ocean depths with high pressures and no sunlight, and deep rock formations where organisms have no contact with organic material or sunlight from the surface.

Vocabulary

ecology, adaptations, gravity, geology, atmosphere, radiation exposure, weather, environment

Materials

- ❑ paper (construction, tag board, bulletin board, etc.)
- ❑ colored pencils
- ❑ glue
- ❑ items to decorate critter (rice, macaroni, glitter, cereal, candy, yarn, string, beads, etc.)
- ❑ pictures of living organisms from Earth
- ❑ Student Sheet, *Mars Critters* (pg. 47)
- ❑ Student Sheet - Activity 1, *If You Went to Mars* (pg. 37)
- ❑ Mars Fact Sheet (pg. 56)

Procedure

Advanced Preparation

1. Gather materials.
2. Set up various art supplies at each table for either individual work or small group work. This activity may be used as a homework project.
3. Review the "If You Went to Mars" sheet, Mars Fact Sheet, and the background provided above. Other research and reading may be assigned as desired.

Classroom Procedure

1. Ask students to work in groups to construct a model of an animal or plant that has features that might allow it to live on or near the surface of Mars. Have them consider all the special adaptations they see in animals and plants here on Earth. They must use their knowledge of conditions on Mars, consulting the Mars Fact Sheet, *If You Went to Mars*, and other resources such as web pages if necessary. Some key words for a web search might be "life in space" or "extremophile" (organisms living in extreme environments). They must identify a specific set of conditions under which this organism might live. Encourage the students to use creativity and imagination in their descriptions and models.
2. If this is assigned as homework, provide each student with a set of rules and a grading sheet, or read the rules and grading criteria aloud and post a copy.
3. Review the information already learned about Mars in previous lessons.
4. Allow at least 2 class periods for this project: one for construction, one for presentation.
5. Remind the students that there are no wrong critters as long as the grading criteria are followed.
6. Include a scale with each living organism.

STUDENT SHEET

MARS CRITTERS

In order to better understand what types of life scientists will look for when they go to Mars, you will construct a model or draw a picture of an organism that has features that might allow it to live on or near the surface of Mars.

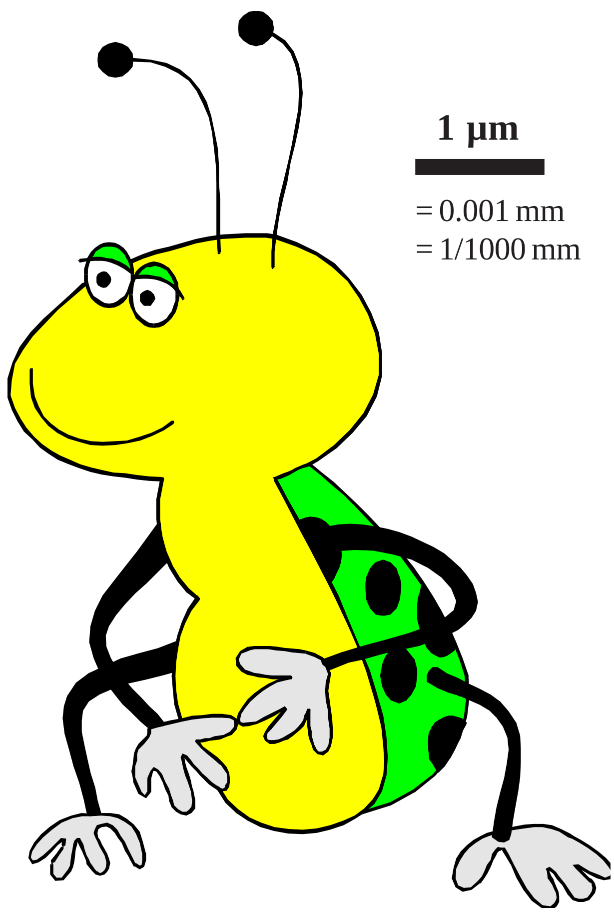
Conduct research about the environment on Mars. Consider the geology, gravity, atmosphere, radiation exposure, and weather. Choose a habitat somewhere in the Mars environment for the organism to live. Then construct a model of the plant or animal and include the special features it would need to live in that harsh environment. You may want to research the special adaptations animals and plants have to survive in difficult places here on Earth. Be creative and use your imagination.

Make a scale model or picture of your critter. Answer all the questions on the next page and attach them to the picture or model of your critter.

GRADING

1. Your entry will be graded on scientific accuracy (40%) and creativity (40%). Remember that everything on Mars must obey the laws of nature and your creature must have good martian survival traits. Provide a scale to indicate the true size of your critter.

2. Clear writing and correct grammar count for the remaining 20% of your total score.



Description and Questions

Use another page if more space is needed.

1. The critter's name:

2. Describe the habitat and climate in which your critter lives:

3. How does it move? Include both the form and method of locomotion. (For example: The miniature Mars Gopher leaps on powerful hind legs).

4. What does it eat or use as nutrients? Is it herbivorous, carnivorous, omnivorous, or other? What is its main food and how does it acquire this food?

5. What other creatures does it prey on, if any? How does it defend itself against predators?

6. How does your creature cope with Mars' extreme cold, unfiltered solar radiation, and other environmental factors?

7. Is it solitary or does it live in large groups? Describe its social behaviors.

8. What else would you like others to know about your critter?

Exploring Crustal Material from a Mystery Planet

Suggested Grade Level: K – 12

Correlated Topics:

Rocks and Minerals
Geology
Meteorology
Astronomy
Biology
Oceanography, Lakes' and Streams
Volcanism
Sedimentation
Weathering and Erosion
Botany

Objectives:

Students will:

- Observe the characteristics of crustal material samples.
- Classify crustal material into groups with similar properties.
- Infer causes for the characteristics of the various crustal samples.
- Infer the history of the “mystery" planet.

Process(es) Illustrated:

Questioning
Hypothesizing
Identifying variables
Inferring
Observing
Classifying
Inventing Concepts

Class of Activity: Exploratory: X Application: X Extension: X

Curriculum Connections: Language Arts

National Science Education Standards:

Standard A: Abilities necessary to do scientific inquiry

National Math Education Standards:

NM.5-8.8 Patterns and function

Materials Needed:

- Hand lens
- Toothpick and/or tweezers (optional)
- Sample "mystery" planet crustal material. Prepare a sample mixture of “typical” crustal material from a rocky planet. The exact composition is not critical, but include as many of the following as possible:
  - Coarse and fine sand, obtained from a playground, river, or beach

    - Small rounded "pea" gravel pebbles, obtained from a steam or gravel pit
    - Small flat "skipper" type round flat pebbles, obtained from a rocky lake or ocean beach (the flattening is caused by the wave motion at or near shore)
    - Angular crushed stone, obtained from a rural road, driveway, or concrete (cement) mixing plant
    - Table salt
    - Coarse rock salt (sidewalk melting salt or crushed water softener pellets)
    - Crushed clinkers from a coal furnace
    - Vermiculite or pearlite, obtained from a garden shop
    - Small fossil fragments or simulate by breaking shells into 1-cm pieces
- Any other rocky planet materials that you can obtain easily
- Metric graph paper to be used as a measuring device (mm or cm graph paper) as appropriate for the measuring skills of the student
- Large container, pail or pan, about 1-3 liter capacity (1-4 quart)

Procedures:

1. Give to each team two students a sheet of graph paper and a sample of crustal material. Be sure to include both large and small pieces.
2. Have the teams explore and observe as many properties and characteristics about each kind of substance they find. Remind students that they do NOT need to know what each substance is. Instead, lead them to describe the CHARACTERISTICS of the pieces, such as color, shape, size, shiny or dull, heavy or light, layers, mixed colors, flat or ball shaped, and any other properties they observe and can describe.
3. Have students share and discuss their observations.
4. Have students infer causes for the various characteristics of the materials. They might suggest volcanoes (cinders), water (sand and rounded pebbles), life (shell fragments), and many other cause-effect inferences.

Extensions:

1. Have students do library research to find out how various natural forces cause Earth features and then use inferences to apply these same forces to the "mystery planet".
2. Have students write or tell a story about the "mystery" planet.
3. Have the students write a paper about the environment on the "mystery" planet.

Credits:

Source of activity: "Exploring Crustal Material from a Mystery Planet" by D. Louis Finsand, ©1994 Project SPICA, President and Fellows of Harvard College, Cambridge, MA One of many activities in the available in the Project SPICA K-12 Teacher Resource Manual from Kendall/ Hunt Publishing Co., 4050 Westmark Dr., PO Box 1840, Dubuque, IA. 52004-1840. Additional information about obtaining prepared "mystery" planet crustal material and other Astronomy/ Earth Science materials can be obtained from the author by writing, to D. Louis Finsand, Spectrum House, 1501 W. 19th St. Cedar Falls, Iowa, 50613, Phone: (319) 273-2760.

EDIBLE MARS ROVER
Adapted from Jean Settle's "Edible Rockets"

Introduction:

In 1997, NASA used small robotic vehicles to explore Mars. The *Sojourner* rover was able to roll around the surface of Mars recording data about rocks at the landing site and taking close-up pictures of Martian surface features. The *Sojourner* rover never traveled more that a few tens of meters away from the *Pathfinder* lander. A new, larger rover is being developed for a possible Mars sample return mission. This long-range rover will help to kick-off a new era of exploration of the Red Planet. The long-range rovers will be collecting Mars rocks and soil to be returned to Earth. A prototype of this rover is called *FIDO* (*Field Integrated Design and Operations*). *FIDO* is being tested on Earth first. High school and middle school students were part of the *FIDO* team that helped to run the field tests in the Mojave Desert during the spring of 1999 and 2000. This activity will help to familiarize students with planetary rovers.

Grade level:

4th to 9th - Can be adjusted to other class levels

Objectives:

- Students will be able to identify the instrumentation aboard the *FIDO & Athena Long-Range Rover*
- Students will use creative thinking and problem solving skills to design the *FIDO* or *Athena Rover* using a supply of different foods.
- Students can create and explain the instrumentation on their own rover

National Sceince Education Standards:

Standard E: Abilities of technological design

National Technology Education Standards:

NT.K-12.5 Technology Research Tools

Suggested Materials (per student team):

3 graham crackers	1 roll of Smarties
6 creme wafer cookies	3 large marshmallows
1 snack-size Kit Kat	1 straw
1 Peppermint Patty	1 plastic knife
6 Rolos	7 toothpicks
8 gumdrops	1 sheet of 18” x 12” wax paper

Materials for a class of 25:

scissors
4 containers of frosting
paper towels
sturdy paper plates
25 copies of *Athena Rover* handouts

<u>Supplies Suggestion</u>:

The materials for this activity can be divided up for student (or parent volunteers) to supply. Another way to offset cost of this activity is to plan it after a major holiday when candy is on sale or closeout (Halloween, Easter, etc.)

<u>Procedure</u>:

To begin the lesson, introduce students to the different rovers. After finishing discussion, pass out above materials. The students need to decide which rover (Sojourner, FIDO, or their own design) they will construct with the materials provided. To minimize messiness students should use the wax paper surface. Frosting can be distributed by placing a spoonful on each students' sheet of wax paper. Frosting can be used to "glue" pieces together. Also, have an adult or student monitor the amount of candy each student takes. Encourage a small amount at first, with more available as the rover design is developed. The basic components can be pre-bagged in a plastic baggie ahead of time if desired. If multiple periods are doing this activity (middle school), only put out supplies for one period at a time to prevent shortages later in the day.

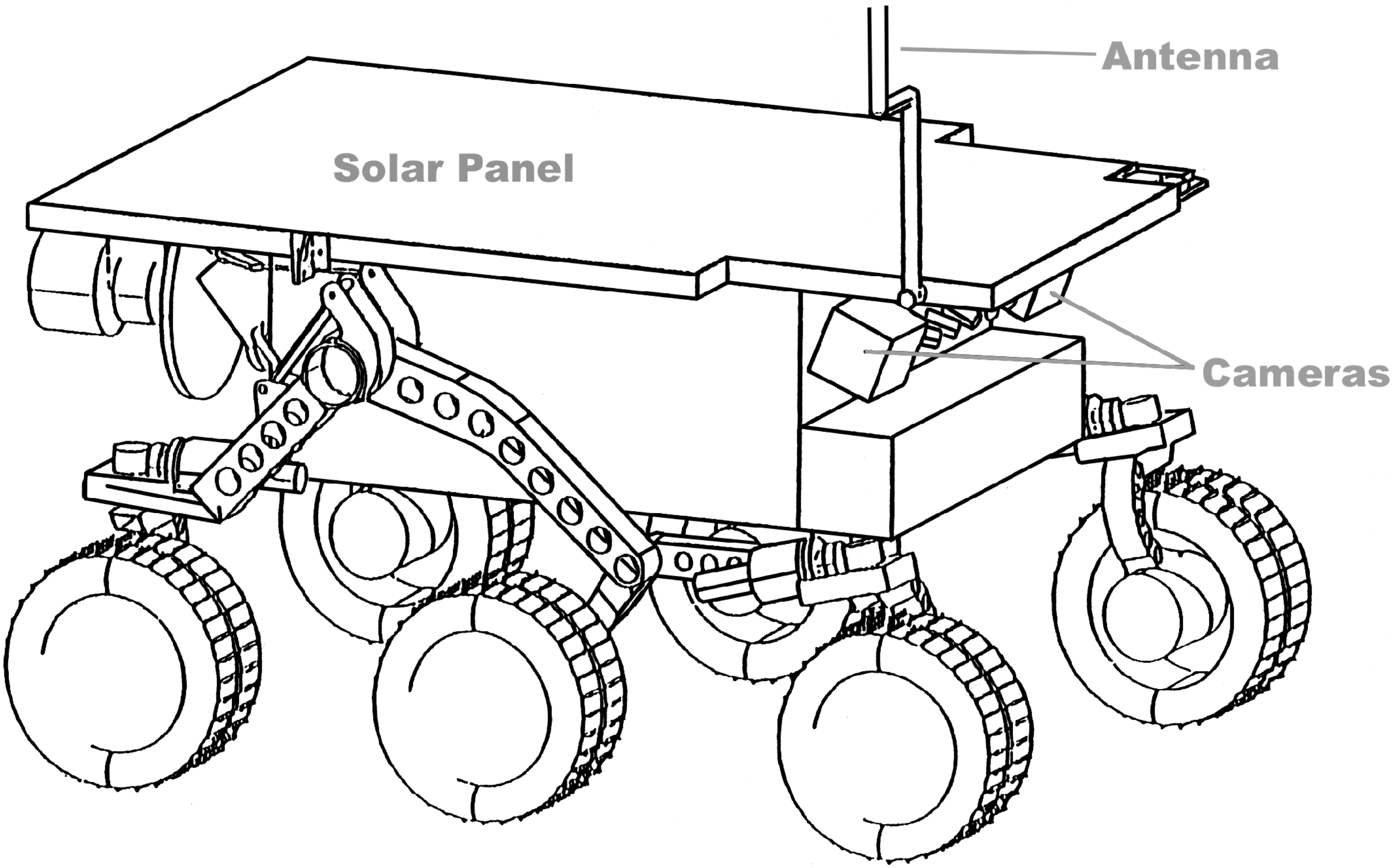
<u>Suggestions</u>:

- Encourage students to use given materials to design the rover.
- Allow students to design their spacecraft independently within their group. The final design to be constructed should be a group decision or a compilation of multiple designs. This activity is designed to facilitate creative thinking. There are no right or wrong answers.
- To reduce cost of supplies try the following:
- Assign each student to bring a different food item.
- Ask your PTO or Home School Association to provide funding for the activity.
- Have an adult or student monitor the amount of candy each student takes. Encourage a small amount at first, with more available as the rover design is developed.
- The basic components can be pre-bagged in a plastic baggie ahead of time if desired.
- If multiple periods are doing this activity (middle school), only put out supplies for one period at a time to prevent shortages later in the day.
- This activity can be done individually if enough materials can be supplied

<u>Assessment</u>:

Students display and discuss their models. After completion, have students discuss strategies they used to design their rover and its capabilities. This will allow them to share their problem solving and design strategies. Ask students how this activity helped them learn more about the technology and exploration strategies for NASA's missions to Mars.

Mars Pathfinder Rover



EDIBLE MARS SPACECRAFT
Adapted from Jean Settle's "Edible Rockets"

<u>Introduction</u>:

In 1996 two spacecraft, *Mars Global Surveyor* and *Mars Pathfinder*, were launched to Mars. These spacecraft kicked off a decade long, exploration of the *Red Planet*. The exploration continues with Mars spacecraft being launched every 26 months. Through this activity, students will become familiar with the missions and the type of equipment on board each spacecraft or create their own designs!

<u>Grade level</u>:

1-8, adjust to meet class needs

<u>Objectives</u>:

- Students will be able to identify two Mars spacecraft
  - a) *Mars Global Surveyor*
  - b) *Mars Pathfinder* and the rover, *Sojourner*
- Students will use creative thinking and problem solving skills to design either one or both of the above spacecraft using a supply of different foods.

<u>National Science Education Standards</u>:

Standard E: Abilities of technological design

<u>National Technology Education Standards</u>:

NT.K-12.5 Technology Research Tools

<u>Suggested Materials (per student team / other materials can be freely substituted)</u>:

- 3 graham crackers
- 1 roll of *Smarties*
- 6 creme wafer cookies (solar panels)
- 3 large marshmallows
- 1 snack-size *Kit Kat*
- 1 straw
- 1 Peppermint Patty
- 1 plastic knife
- 6 *Rolos* candies or *Reeses Peanut Butter Cups* (wheels)
- 7 toothpicks
- 8 gumdrops
- 1 sheet of 4" x 4" wax paper for icing
- 1 sturdy paper plate or cardboard sheet for building platform

Materials for a class of 25:

- scissors
- 4 containers of frosting
- paper towels
- 25 copies of Mars Global Surveyor, Mars Pathfinder, and/or Sojourner handouts

Procedure:

To begin the lesson, introduce students to the different Mars spacecrafts. After finishing discussion, pass out above materials. The students need to decide which spacecraft they will construct with the materials provided. To minimize messiness students should use the wax paper surface. Frosting can be distributed by placing a spoonful on each student's sheet of wax paper. Frosting can be used to "glue" pieces together.

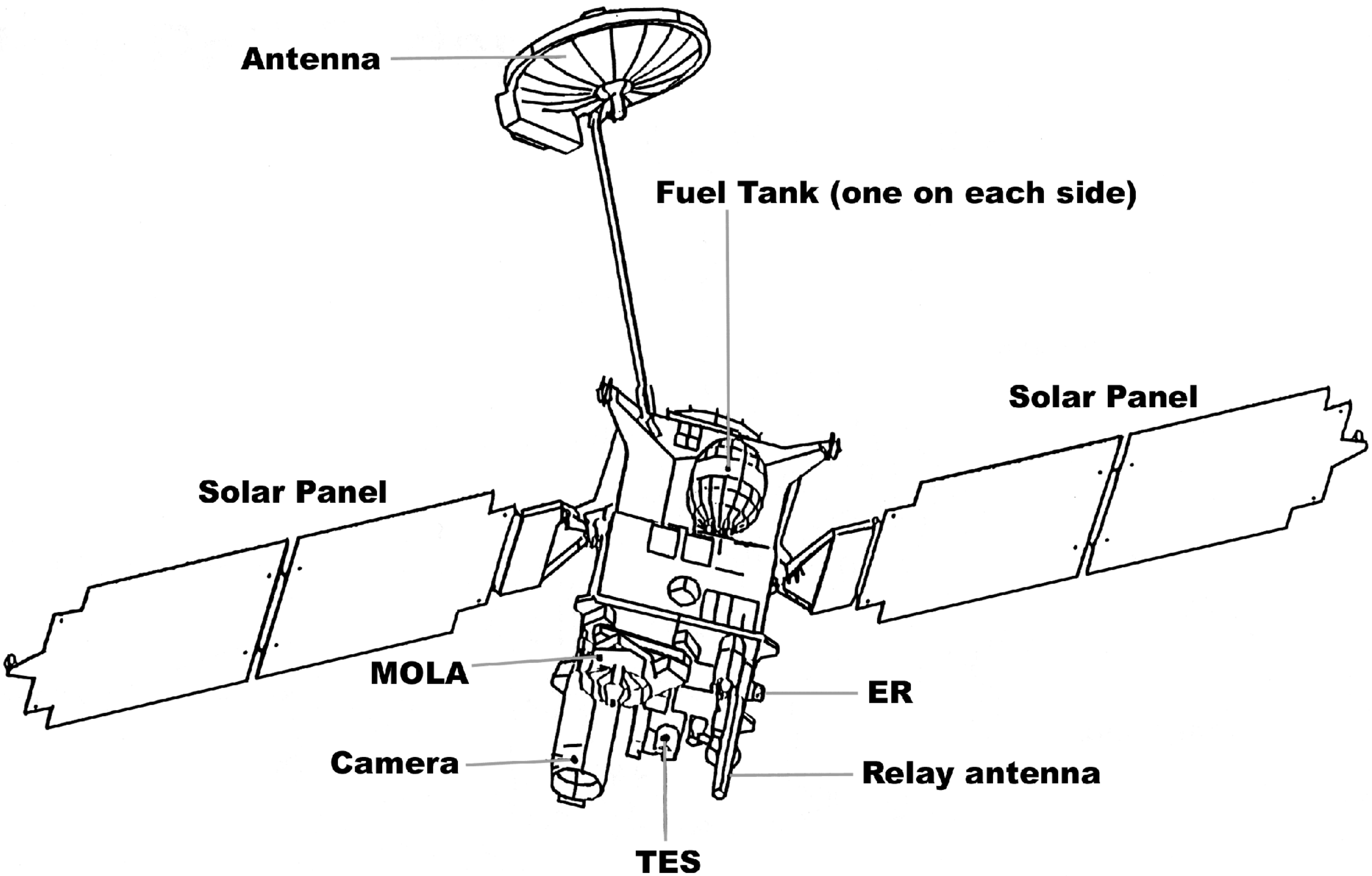
Assessment:

Students display and discuss their models. After completion, have students discuss strategies they used to design their spacecraft. This will allow them to share their problem-solving strategies. Ask students how this activity helped them learn more about the missions to Mars.

Suggestions:

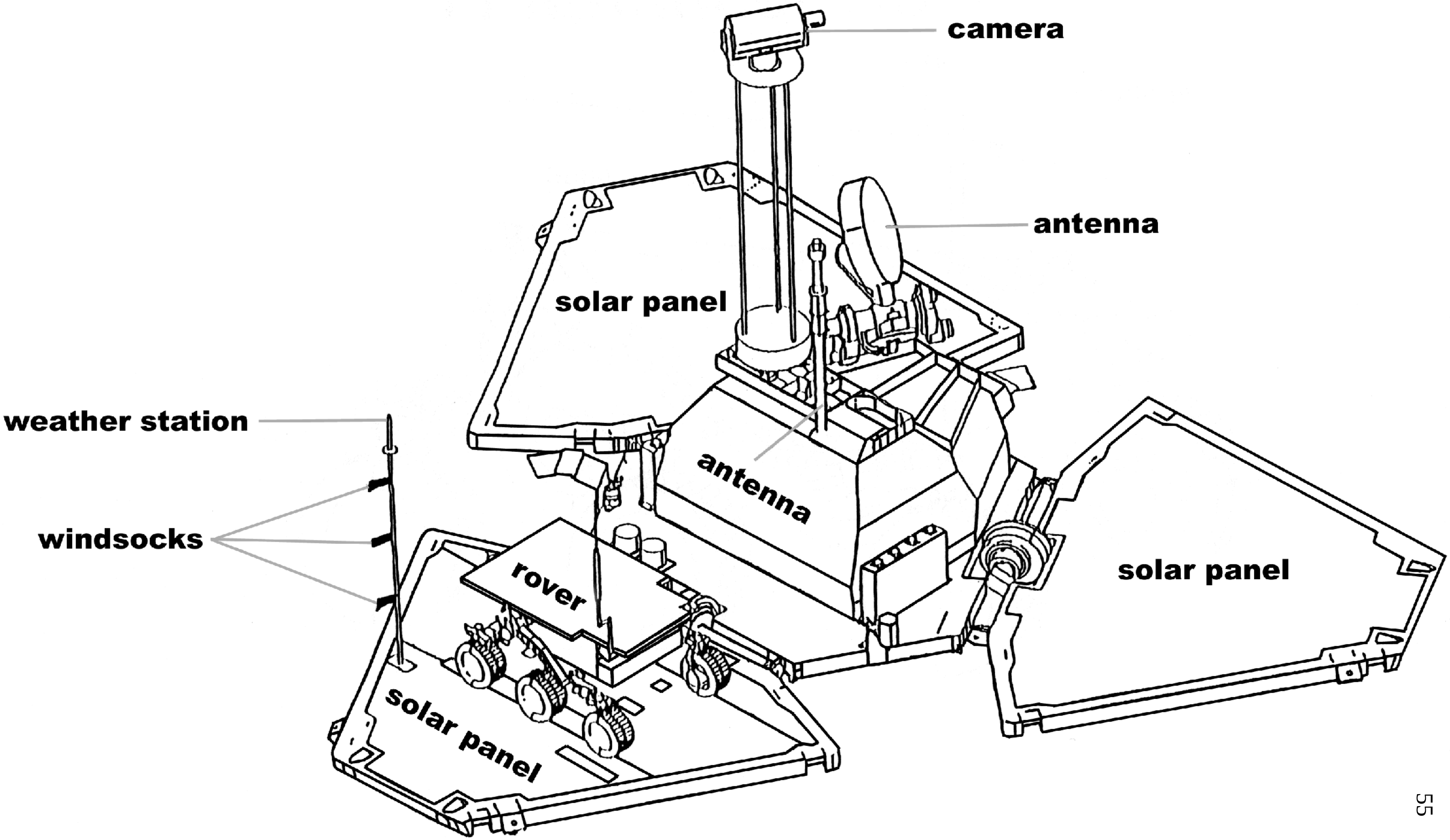
- Encourage students to use given materials to design all spacecraft and the rover,
- Have an adult or student assigned to the material table to oversee distribution of materials. Allow students to take a minimum of materials and return for additional materials to cut down on excessive materials being taken;
- Allow students to design their spacecraft independently if they wish. This activity is designed to facilitate creative thinking. There are no right or wrong answers; and
- To reduce cost of supplies try the following:
  - Purchase or get candy donated after major holiday.
  - Assign each student to bring a different food item.
  - Ask your PTO or Home School Association to provide funding for the activity.
  - Use cooperative learning and have one group of 3-4 students design all spacecraft with one set of materials.

MARS GLOBAL SURVEYOR

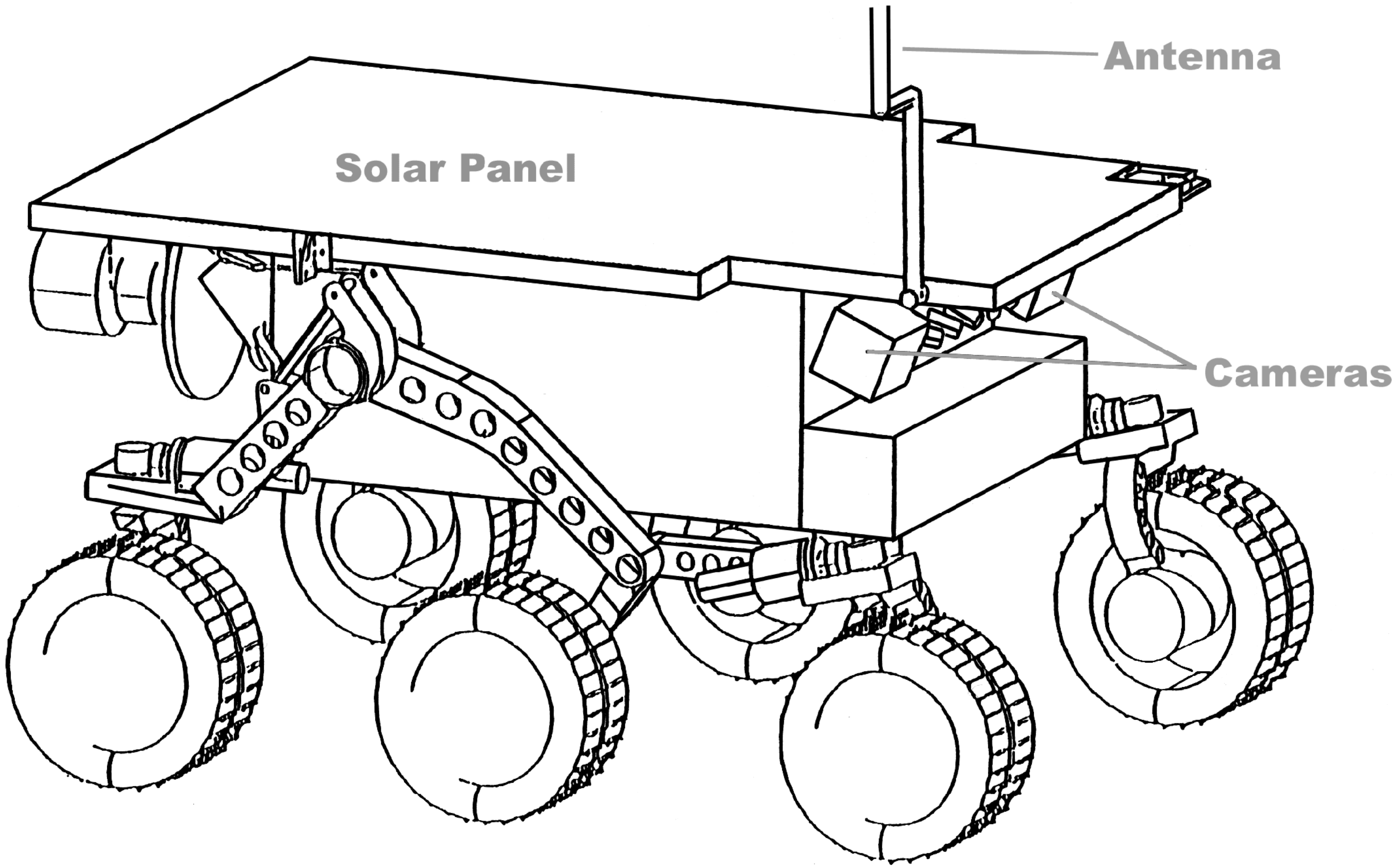


TES: Thermal Emission Spectrometer, used to analyze rocks
ER: Electron Reflectometer, used to measure magnetism
MOLA: Mars Orbiter Laser Altimeter, used to measure elevations

Mars Pathfinder



Mars Pathfinder Rover



"MARS METEORITES' FINGERPRINTS" or "Chips Off of the Old Block"

Goal: To familiarize students with comparing and contrasting scientific data.

Objective: To familiarize students with spectra as a means of identifying minerals.

Time Frame: 45 minutes

Grade Levels: 5th – 12th Grades

National Science Education Standards:

Standard A: Abilities necessary to do scientific inquiry
Standard E: Abilities of technological design
Standard E: Understanding of science and technology

National Technology Education Standards:

NT.K-12.6 Technology Problem-Solving and Decision Making Tools

Materials: Copies of Background information and copies of Figures 1 - 5 per group of students

Procedure: In each figure there will be spectra to analyze for similarities. Have the students compare and contrast the spectra to see if they can find similarities between the Earth minerals and those from Mars.

Assessment: After examining the different figures for spectral similarities and differences and discussing their patterns, students will investigate the different Earth minerals for composition and conditions for their formation. References such as the *Dictionary of Geological Terms* prepared by AGI, Internet sources, or a geology textbook may provide the necessary background information. Individual students reporting to their group or having groups report to the whole class about their findings will share the work and resources.

Credits:

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jdodds@micron.net

Resources:

- *Dictionary of Geological Terms*, by Robert L. Bates and Julia A. Jackson, Doubleday, NY, NY, 1984. (ISBN # 0-385-18101-9)
- "Mars Meteorites Give TES Geologists a Preview for the (Infra) Red Planet," by Vicky Hamilton, TES News, March 1997.
- "MGS/TES Will Investigate Martian Minerals," by P.R. Christensen and others, *Arizona Mars K - 12 Education Program 1995 - 1996 Education Supplement and Guide*, August, 1995.

"MARS METEORITES' FINGERPRINTS" or "Chips Off of the Old Block"

Background:

Mars Global Surveyor was launched in November 1996, on a Delta II rocket from Kennedy Space Center, Florida. It reached Mars and after a period of aerobraking has obtained a circular orbit in March, 1999. The mapping phase will last 2 Earth years and is in progress now. *(You may want to figure out how many Martian years equal one Earth year.) This mission carries five of the seven experiments that were lost with the Mars Observer including the Thermal Emission Spectrometer (TES). Phil Christensen and his science team at Arizona State University operate this project.

The TES will look at the infrared radiation emitted from the Martian surface. In a broad sense, TES will enhance the global understanding of the geology and climate of Mars. Specifically, the science team will be able to determine and map minerals on the surface, take the temperature of the surface, observe temperature and pressure of the atmosphere, see how the polar ice caps grow and shrink with the seasons, determine the composition and thickness of Martian clouds, and use temperature data to estimate the size of particles in the soil.

TES can detect the part of the electromagnetic spectrum known as the thermal infrared. You detect thermal infrared energy by feeling it as heat. TES can separate thermal infrared energy that makes a spectrum with wavelengths from 6 to 50 micrometers (1000 micrometers = 1 mm). *(You may want to review the electromagnetic spectrum with your students by brain storming ways that we make use of it.)

Rocks can absorb or emit infrared energy. The unique crystalline structure in a mineral allows it to have its own signature spectrum where there is a definite pattern of absorption or emissivity of infrared energy. Using Earth minerals and a spectrometer, a database has been created of six mineral spectra from Martian meteorites. These will be used to compare and analyze the data from TES as the *Mars Global Surveyor* is passing over the Martian surface.

In the 2001 mission, a thermal instrument will be launched on the orbiter – THEMIS. This instrument will collect data about the surface rocks and minerals on Mars. Other Mars mission thermal instruments might include a Mini-TES for future lander or long-range rover.

In the mean time, we have twelve Martian meteorites that have been collected here on Earth and can give us a preview of the Martian minerals. By studying the infrared spectra of these meteorites in the lab, the TES science team should be able to identify similar rocks on the surface of Mars, develop an understanding of how they were formed and even find where the meteorites originated.

<u>Figure 1</u>:

These are the middle infrared spectra of the four Martian meteorites named Nakhla, ALH77005, Zagami, and EET79001. These four meteorites represent three different types of rocks. Make observations of the spectra and group two together that look similar.

The grouping is the result of composition; Zagami and EET79001 are the two of the same type of rock. Both contain large amounts of two pyroxenes, augite and pigeonite, plus plagioclase feldspar and no olivine. Nakhla has abundant augite and olivine and there is also unshocked* plagioclase. ALH77005 is dominated by olivine with augite being abundant. This meteorite also has shocked* plagioclase. *The shock effect is probably induced by the impact on the Mars surface that ejected the meteorite.

<u>Figure 2</u>:

Fayalite, a variety of olivine, is isomorphous with forsterite and occurs chiefly in iron-rich igneous rocks. Forsterite occurs in basalts and rocks called peridotites (mostly made of magnesium-rich olivine). Look at the meteorite spectrum and compare it to the olivines.

Of the two olivines, fayalite is the dominant type in the ALH77005 meteorite.

<u>Figure 3</u>:

Nakhla is plotted with five pyroxenes. Even within the pyroxenes there is considerable variety. Which of the pyroxenes provides the best match with the spectrum of Nakhla?

Augite is the dominant pyroxene in the meteorite.

<u>Figure 4</u>:

In this figure, the meteorite Zagami is plotted with several different types of silicate minerals. Which of the silicates provides the best match with the Zagami spectrum?

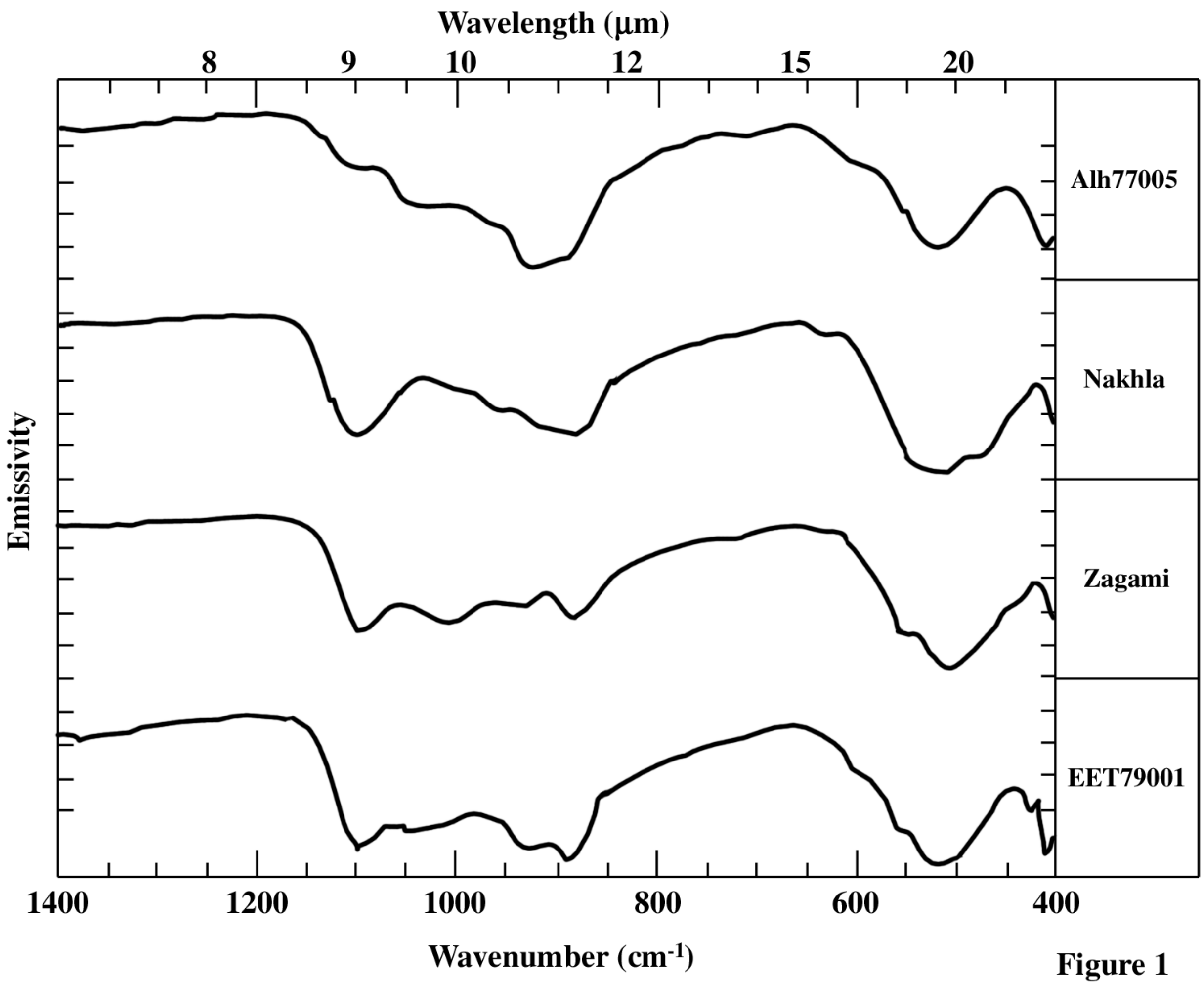
When analyzing the possible composition of the Zagami, the quartz and labradorite (a feldspar) have little in common with the Zagami spectrum. Structures of quartz and feldspar are similar to each other, but they are very different from the mafic minerals such as pyroxene and olivine. The augite, amphibole, and forsterite have much better matches to the meteorite spectrum.

<u>Figure 5</u>:

The meteorite Zagami is compared to the same pyroxene minerals as in Figure 3. These pyroxenes are either low in calcium (enstatite and bronzite) or high in calcium (diopside, augite, and hedenburgite). In this example, there are characteristics apparent of both types of pyroxenes in the meteorite.

<u>Conclusions</u>:

What do we know about Earth’s minerals that will help us to understand Mars’ minerals? That is the primary question to keep in mind. Students need to use the information researched to begin to answer that question.



Wavelength (μm)
8
9
10
12
15
20
Emissivity
Alh77005
Nakhla
Zagami
EET79001
1400
1200
1000
800
600
400
Wavenumber (cm-1)

Figure 1

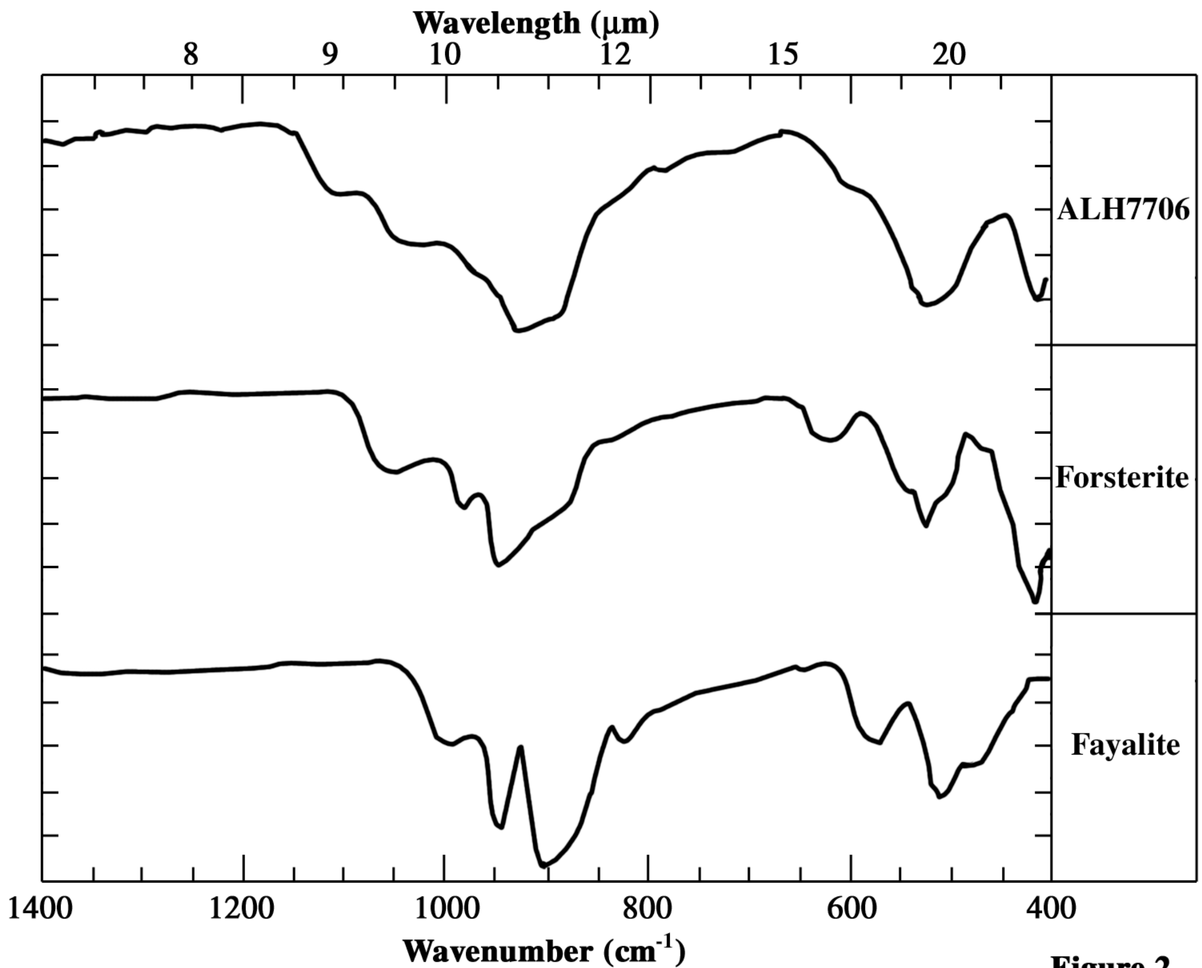

Wavelength (μm)
8
9
10
12
15
20
ALH7706
Forsterite
Fayalite
1400
1200
1000
800
600
400
Wavenumber (cm-1)

Figure 2

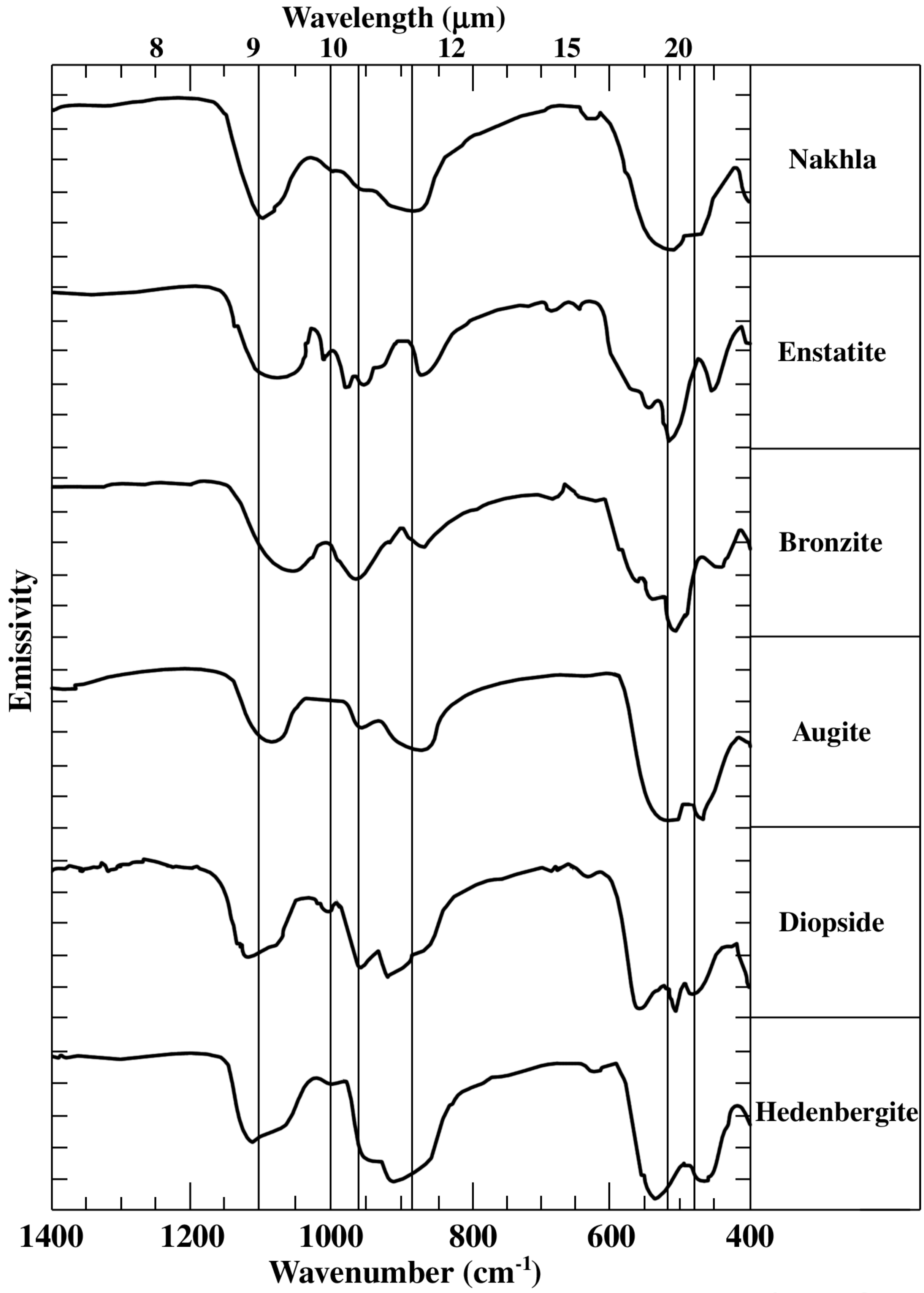
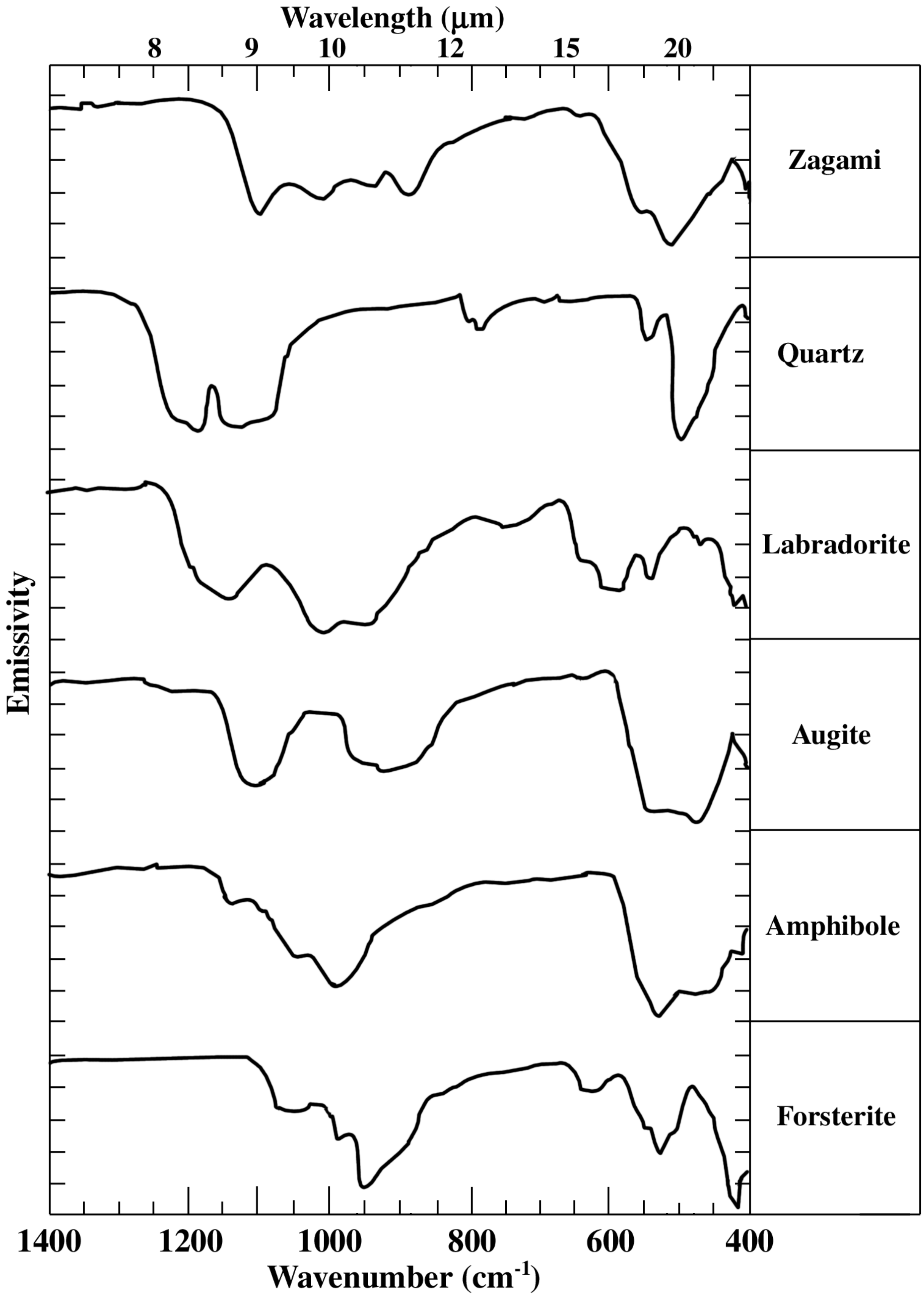

Wavelength (µm)
8
9
10
12
15
20
Emissivity
Nakhla
Enstatite
Bronzite
Augite
Diopside
Hedenbergite
1400
1200
1000
800
600
400
Wavenumber (cm-1)

Figure 3



Wavelength (μm)
8
9
10
12
15
20
Zagami
Quartz
Labradorite
Augite
Amphibole
Forsterite
Emissivity
1400
1200
1000
800
600
400
Wavenumber (cm-1)

Figure 4

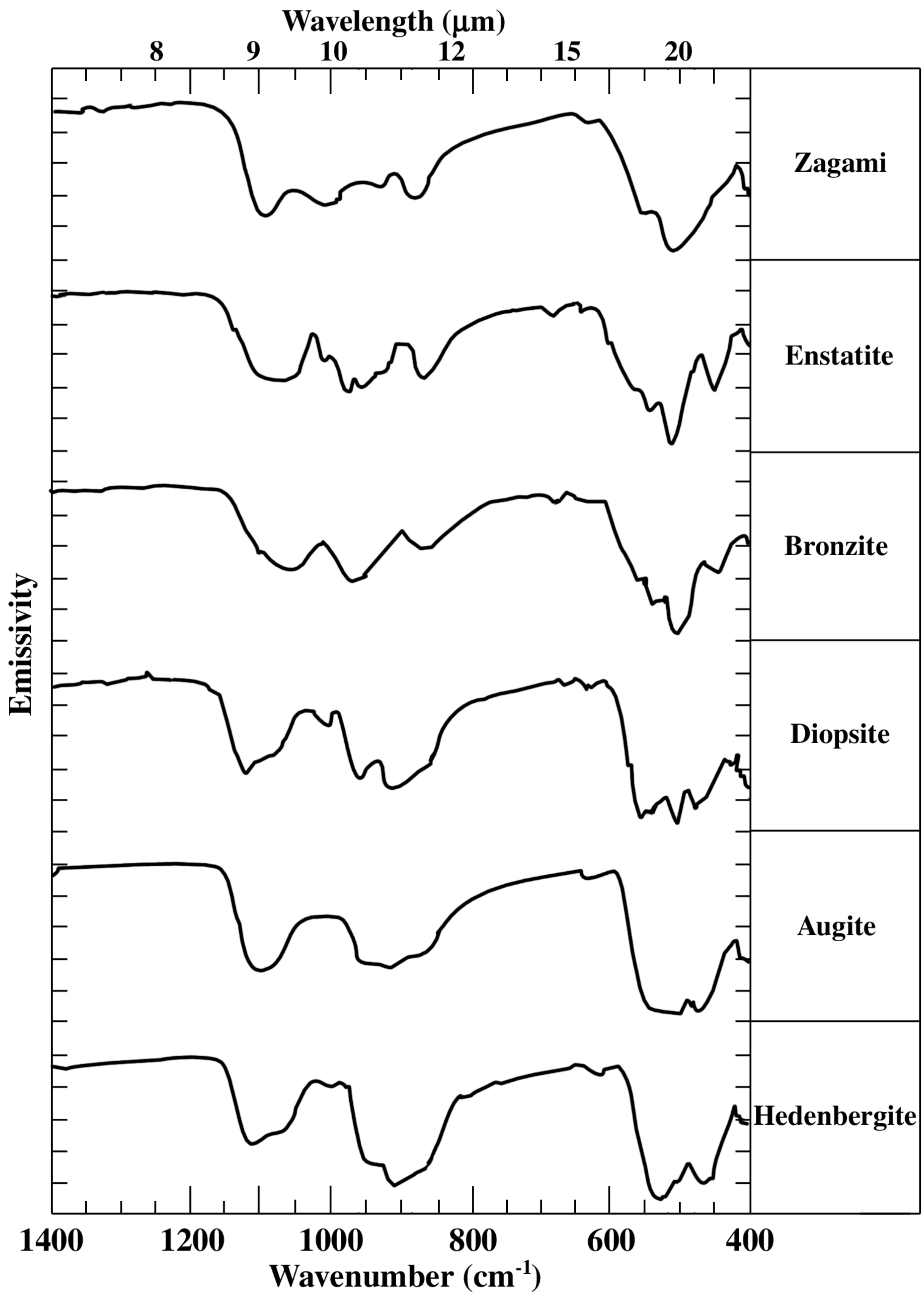

Wavelength (μm)
8
9
10
12
15
20
Zagami
Enstatite
Bronzite
Diopsite
Augite
Hedenbergite
Emissivity
1400
1200
1000
800
600
400
Wavenumber (cm-1)

Figure 5

INTRODUCTION TO CREATING A MISSION PLAN

Objective: Students will become familiar with the layout of a mission plan by learning the components of the scientific team's field trial mission plan.

National Science Education Standards:

Standards A: Understanding about scientific inquiry

National Technology Education Standards:

NT.K-12.5 Technology Research Tools

Materials:

- mission plan: use the URLs listed below for examples of mission plans
- highlighters
- board with chalk/dry erase markers

Check for prior learning:

- What is a mission plan? (a document that describes a mission and its components)
- What purpose does a mission plan serve? (gives an overview of the mission, introduces key players, discusses instrumentation to be used, describes the goals for the mission, etc.)
- Why is a mission plan important? (essential communication medium between scientists, mission planners, engineers)
- Who creates mission plans? (scientists, engineers, etc.)

New learning:

Students read through the mission plan highlighting information that they believe is key to the mission plan. When all students have finished, each shares with the group what he/she feels is important. Group comes to a consensus on important parts by discussing it and listing most important parts/information on the board. This becomes the template for the student mission plan that will be created in the next lesson.

Check for learning:

Final product, the template for a mission plan

Extension:

Look at other scientific mission plans for comparison to see if they all contain same components

URL'S:

http://mars.jpl.nasa.gov/mgs/overvu/overview.html

http://mars.jpl.nasa.gov/msp98/mission_overview.html

Credit: Anna Waldron, Lansing High School, Ithaca, NY; LAPIS Team Teacher.

“Out of sight”
Remote Vehicle Activity

Goal:

- The students will learn about the challenges faced while trying to operate a planetary rover.
- To work within a mission team setting, working together to problem solve and accomplish a common goal.

Objective:

- To operate a robotic vehicle while it is not directly in view of the driver or operations team.

Time Frame: Two 45 minutes periods

Grade Levels: 5th - 9th (can be adapted for other grade levels)

National Science Education Standards:

Standard E: Abilities of technological design

National Math Education Standards:

NM.5-8.1 Problem Solving

NM.5-8.13 Measurement

National Technology Education Standards:

NT.K-12.5 Technology research tools

NT.K-12.6 Technology Problem-Solving and Decision-Making Tools

Items Needed:

- Remote control car for each 4 to 6 member team (borrow from students)
- Measuring devices (meter stick or tape measure - Can change units to yards) - 2 per team
- Rocks or other marking devices to- set up 'way points' in which to drive car
- Background information on planetary rover teleoperation
- Student calibration and mission planning sheets
- Stopwatches
- Compasses
- Popsicle sticks
- Pencils
- Masking tape for marking starting lines
- Calculators (optional)
- Video camera and monitor (optional)

Procedure:

1) Divide the class into teams of 4 to 6 students (smaller groups better if you have enough robotic vehicles).

2) Choose two designated drivers (test driver and calibration driver) for each team. The drivers need to be sequestered away from seeing the vehicle course being set up. (Note: Be aware of making sure that some of the drivers are female. Most likely, the people volunteering vehicles will be male. Maybe selecting male and female as a team of drivers would be the answer).

3) During the time away from the course, the calibration driver (with the test driver helping) will calibrate the remote vehicle as to:

   - Distance traveled in 5 seconds (3 distance trials)
   - Time needed to turn in 45˚ increments, a full 360˚
   - Optional - Whatever other type of calibration test to get information you think might be important.
   - The rest of the team (course calibrators) will work on setting up a symmetrical course that the vehicle will drive through (the same course design for each team - multiple courses could be set up all at once to speed up the team testing) using the rocks or other items to serve as waypoints (or targets) that each vehicle will try to navigate to.

4) Have the course calibrating team members measure the distance to each object and record the distance on the course sheet (make sure all the teams are following the same path so that the times and accuracy can be compared).

5) Have the course calibrating team measure the angle of turn needed to point the remote vehicle toward the next waypoint. (Note: The turns should be made in 45˚ intervals for easier measurement.)

6) Once the drivers and course calibrating team members have finished their tasks and recorded all necessary data, all the team members can merge their data sets to create a mission plan scenario. Neither driver should still be allowed to actually see the course that the remote vehicle will be driving. This is to be a "blind" test. The measured distance to each waypoint can be calculated with the speed and time necessary to achieve each waypoint destination. This should give the driving time necessary for the remote vehicle to travel to each waypoint destination. Time and coordinates should be given for each waypoint direction (i.e. 12 seconds straight; stop; left 45˚; 17 seconds straight; stop; right 90˚, etc.)

7) Once the data is calculated, the test driver will have the course calibration team members place the remote vehicle at the designated course starting line. The test driver (who is not in direct eye-contact with the vehicle) will drive the team vehicle according to the mission plan calculations taken from the calibration speed tests

and course measurements. A team member can read out the commands and another member can time the remote vehicle's travel.

8) The calibration team members watching the test will measure the resulting movement of the remote vehicle and record the actual distance traveled by the remote vehicle next to the pre-measured data.

9) After the actual driving results are compared with the precalculated results, determine the adjustments needed to drive the remote vehicle more accurately and repeat the test to see if the changes helped.

Rover Background:

These team operations are much like the real FIDO field tests that took place out in the Mojave Desert in the spring of 1999. The FIDO Rover was calibrated and tested in much the same manner, with the “drivers” operating out of a small mobile trailer, away from actually watching the rover drive during the field testing. High school students from around the country (LAPIS Team Members) drove the rover via the Internet. While these tests were taking place, there were scientists, engineers, and students in the field to measure the actual results of the commands for the rover to move. In doing so, the rover software and responses to the commands could be tested while still here on Earth to see if they were indeed accurate. That way, when the commands are given to the Athena Rover (FIDO is the Earth test rover for the Athena Rover) on Mars, the scientists and engineers can have a better idea of what movement they might expect.

Evaluation:

The students can work in teams or individually. Assessment can be based on completion of student work sheets and team participation.

Team Name:

"Out of Sight" Student Worksheet

<u>Calibration Tests</u>:

Using a stopwatch and measuring tool, record the time or distance of the remote vehicle during the following tests. Make sure that all measurements are taken the same way each time and from the same starting place to insure they are accurate. Mark the starting place with a piece of masking tape.

Calibration Test	Distance or Time
How far did the remote vehicle travel in 5 seconds?	Distance trial # 1= meters
How far did the remote vehicle travel in 5 seconds?	Distance trial # 2= meters
How far did the remote vehicle travel in 5 seconds?	Distance trial # 3= meters
Add the three distances together and divide by 3 (the number of distance trials) to get the average distance the remote vehicle traveled in 5 seconds =	meters
Divide the average distance (answer in box above) by 5 seconds to get the distance per second =	meters/seconds
Time needed to turn 45˚ = Time needed to turn 90˚ =	seconds seconds
Time needed to turn 135˚ = Time needed to turn 180˚ =	seconds seconds
Time needed to turn 225˚ = Time needed to turn 270˚ =	seconds seconds
Time needed to turn 315˚ = Time needed to turn 360˚ =	seconds seconds
Time needed to come to a full stop =	seconds
Other remote vehicle test data: What else do you want to know? Invent your own test. My test is:	

Team name:

Student name:

"Out of Sight"
Mission Planning Sheet

<u>Directions</u>:

Using your data from the remote vehicle calibration tests and the measurements made by the calibration team, design a mission plan that will get your remote vehicle to each of the targets (waypoints) on the driving course. Use the average speed (meter/second) and the measured course distances (meters) to plan how long your rover will run in each direction to reach each waypoint. Also figure out how many degrees the rover must turn (how many seconds it takes to turn the right distance from the calibration tests) to go to the next waypoint. List your moves on this sheet.

<u>Remote Vehicle Mission Plan</u>

1) Distance to waypoint #1 = _______________meters
Remote vehicle time to waypoint #1 =__________________seconds

2) Turn_______________degrees for next waypoint
Remote vehicle time to turn______________degrees = ________________seconds

3) Distance to waypoint #2 =_______________meters
Remote vehicle time to waypoint #2 =__________________seconds

4) Turn_______________degrees for next waypoint
Remote vehicle time to tum______________degrees =_________________seconds

5) Distance to waypoint #3 = _______________meters
Remote vehicle time to waypoint #3 =__________________seconds

6) Turn_______________degrees for next waypoint
Remote vehicle time to turn______________degrees = ________________seconds

7) Distance to waypoint #4 = _______________meters
Remote vehicle time to waypoint #4 =__________________seconds

8) Turn_______________degrees for next waypoint
Remote vehicle time to turn______________degrees = ________________seconds

9) Distance to waypoint #5 = _______________meters
Remote vehicle time to waypoint #5 =__________________seconds

10) Turn_______________degrees for next waypoint
Remote vehicle time to turn______________degrees = ________________seconds

11) Distance to waypoint #6 = _______________meters
Remote vehicle time to waypoint #6 =__________________seconds

Team Name:

Student Name:

Student Course Calibration and Actual Results of Remote Vehicle Tests

Directions: Fill in the chart with the data your team collected:

1. Record the waypoint measurements taken along the course before the remote vehicle driving test;
2. Record the actual data collected as the remote vehicle runs the course. Were there any differences between the two measurements? If so, record the difference (in feet, inches, meters, or centimeters) in the "Difference in Results" box.

Actual Measurements to Waypoints	Actual Distance Traveled by Remote Vehicle	Difference in Results
Waypoint #1 measurement		
Waypoint #2 measurement		
Waypoint #3 measurement		
Waypoint #4 measurement		
Waypoint #5 measurement		
Waypoint #6 measurement		

Name:

"Out of Sight"
Student Questions

<u>Directions</u>: Answer the questions using the results from you remote vehicle test.

1) Did your actual test results differ from the calculated distance results?
If so, how and why?

2) What were the differences in operating the remote vehicle this way (not being able to see the course that the vehicle would have to drive on) versus just driving the remote vehicle the regular way?

3. What changes could you have made that would have given you better results?

4. What do you think would be the hardest challenge about driving a remote vehicle on another planet?

Mars Rover Websites

The Athena Rover Homepage

Mars Sample Return Mission:

http://athena.cornell.edu

LAPIS Student Rover Mission

FIDO Rover

http://wufs.wustl.edu/teamlapis

Mars Pathfinder Mission

Sojourner Truth Rover

http://mpfwww.jpl.nasa.gov/MPF/mpf/rover-ops.html

Probing Below the Surface of Mars

by Dr. Mary Urquhart, Jet Propulsion Laboratory

In this activity, students will record and graph temperature data to learn about the search for water on Mars. Students will use a model of an ice-rich and ice-free near-surface on Mars to examine how the ice content of the martian soil will affect the rate at which a warm probe will cool. This activity is matched to both NAS National Science Education Standards and NCTM Principles and Standards for School Mathematics.

Time Requirements:

One 45-minute class period for the activity, plus an additional 45-minute class period if the students will make graphs in class.

National Science Education Standards:

Standard A: Abilities necessary to do scientific inquiry
Standard B: Properties and changes of properties in matter
Standard C: Earth in the Solar System

National Math Education Standards:

NM.5-8.1 Problem Solving
NM.5-8.3 Reasoning
NM.5-8.13 Measurement

National Technology Education Standards:

NT.K-12.6 Technology Problem-Solving and Decision-Making Tools

You will need:

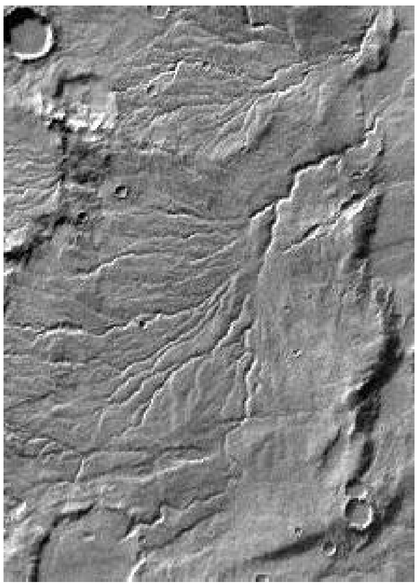
- 2 scientific classroom thermometers (The ideal thermometers are the large alcohol thermometers often found in school laboratories. Partial immersion thermometers are best. The thermometers should cover a range of at least 0 to 50 degrees C, or 32 to over 100 degrees F.)*
- 2 identical deep salad bar containers or disposable food storage containers (Inexpensive disposable food containers such as the deep Ziploc brand 32 ounce containers work well.)*
- 2 straws with a slightly larger diameter than the thermometers*
- 1 tray or plastic shoe box to hold the two food containers, cold water, and ice. (The walls of the tray should be at least a few inches high.)*
- cup to hold hot water*
- ice
- cold tap water
- hot tap water
- sand to fill each food container (Small bags of sand can be found in plant nurseries)
- access to a freezer the night before the activity
- wax paper
- transparent tape
- watch, clock, or stop watch
- data table for each student
- spoon (optional)
- masking tape (optional)
- permanent markers (optional)
- a cooler to transport the frozen materials (optional)
- graph paper (optional)
- two colors of colored pencils or pens (optional)
- petroleum jelly (optional)

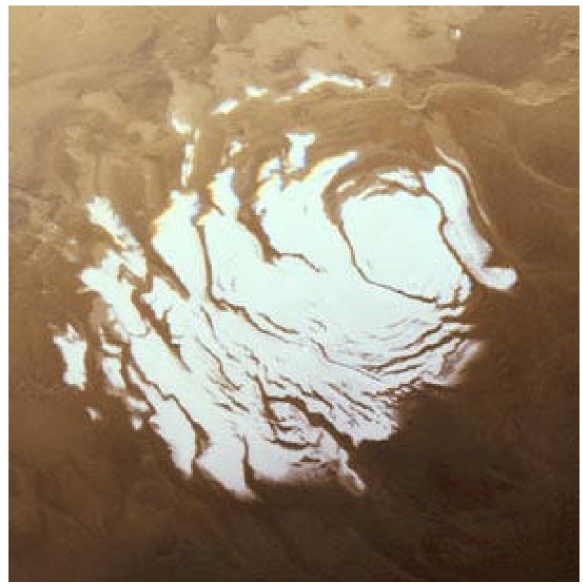
* you will need these supplies for each group of students doing the activity

Introduce the Activity:

Before the students begin the activity, spend a few minutes talking about how this activity is relevant to the ongoing search for water on Mars. The following paragraphs might help. I have also provided a student information sheet.

Mars is a cold desert. Long ago, liquid water flowed on the surface of Mars. Today, water still exists on Mars, but what we can see is ice. The polar caps of Mars are at least part water ice, like those of the Earth. Telescopes and spacecraft can see a type of clouds made of tiny crystals of ice, called cirrus clouds, drifting in the atmosphere of Mars. Frost can even cover the surface of rocks and soil in the morning, much like it does on cold mornings in many places here on Earth. Scientists who study Mars see evidence that Mars had much more water in its past, at least on the surface. What happened to that water?





Water carved valleys billions of years old and the south polar cap of Mars. credit:Viking Orbiter, NASA

Some of the water is believed to be frozen in the martian soil. Many regions on our own world have water frozen in the ground, either during the winter or, in very cold places, all year long. Water frozen in soil is simply called ground ice. If the ground ice remains throughout the year without melting, it is called **permafrost.** Permafrost is common in places like Siberia, northern Canada, and near the peaks of high mountains.

Mars is as cold, or colder, than the coldest places here on Earth. Any ground ice on Mars should stay frozen all year, and will be permafrost. However, finding the ground ice on Mars isn't easy. A dry layer of soil is believed to be on top of the icy soil, making it difficult to detect at the surface. One way to find the ice is to send a probe below the surface of Mars. Mars scientists have thought of several ways to search for permafrost on Mars. Some look at images of the surface of Mars taken by orbiting spacecraft like Mars Global Surveyor, which is currently in orbit around Mars. In these images, the scientists hope to find features similar to those made by permafrost here on the Earth, including wedge-shaped cracks in the ground that meet to form multisided shapes and look a lot like giant mud cracks. In 2001, NASA plans to send another orbiter to Mars. The Mars Surveyor 2001 orbiter has a special instrument called a Gamma Ray Spectrometer that will search for ground ice on Mars over the entire planet. This instrument is designed to "see" ice below the dry soil at the surface.

Another way to find the ice is to send a probe below the surface of Mars. Close to the poles, many Mars scientists think the dry layer of soil will be very thin, and the icy ground will be close to the surface. The Mars Microprobes, two grapefruit-sized spacecraft, were supposed to have impacted Mars at just such a place near the south pole, and penetrate up to about 1 meter (or 3 feet) into the soil. Unfortunately, the probes were never heard from. If they had survived and sent information back to us here on Earth, scientists might have been able to find ground ice on Mars. The dusty or sandy soil near the south pole may be dry, or it may be contain ice. If the soil in the top meter is ice-rich, the probes were designed to detect the ice in three ways:

- by measuring how fast the probe decelerates. Ice will make soil harder, causing the probes to slow down more quickly than they would in ice-free soil.
- by collecting a soil sample and testing it for the presence of water.
- by measuring how quickly the probes cool off after impact.

Today's activity will focus on how ice in the soil would affect the temperature of the probe after impact. Initially, each probe would have been much warmer than the cold martian soil. Gradually, however, the probe would have lost its heat to its surroundings, and would cool down. For this experiment, thermometers will take the place of the Mars Microprobes.

<u>A question to ask the students before the activity</u>:

Do you think the temperature will cool down faster with ice in soil, or without it? Ask the students why they answered a particular way. They might say the icy soil will cool faster for the wrong reason; they think of ice as cold. But, both icy soil and dry soil can be at the same temperature. If the soil is as cold as the ice, how will the ice change how fast the probes can cool?

<u>The day before (with or without the students)</u>:

1. Wet half of the sand, either in a tray or another container.
2. Hold a straw upright in the center of each of the two identical food containers. Trim the straw so that it is slightly shorter than the top of the container. This will allow the students to more easily read the thermometers and will allow you to stack the lidded containers later.
3. Wrap the end of each straw in wax paper, and cover the seams with transparent tape, this will help prevent an. excess water in the wet sand from filling the straw. Be careful not to wrap the entire straw in several layers or wax paper. This will make the contact between the straw and the sand very poor. *Note: coating the straw and wax paper with petroleum jelly may improve contact between the straw and the sand, It may also prevent the wax paper from absorbing moisture in repeated uses of the containers. Do not apply petroleum jelly before using the transparent tape.*
4. While holding the straw, fill one container with dry sand. Be careful to make sure the sand level is below the top of the straw. One person can do this, but it will be easier if one person holds the straw and another fills the container with sand.
5. Once again, while holding the straw, fill the second container with wet sand (using a spoon may help). The sand will compress under the added weight of the water, so you will need more sand to fill the same volume. Filling the container with dry sand and then adding water may increase the likelihood of the straw filling with water as well.
6. Let go of the straws. They should remain upright on their own after the containers have been filled.
7. If the students made their own sand-filled containers, label each container with the masking tape and markers. This is especially necessary if more than one group of students filled containers.
8. Place each container in a freezer for a few hours or overnight. Be careful not to tip the containers, which may cause the straws to shift.

<u>The day of the activity</u>:

1. Remove the containers from the freezer as soon to starting the activity as possible. The water in the sand should be frozen. If you need to remove them more than several minutes before the activity will begin, consider keeping them in a cooler. If you do use a cooler and ice, make sure that any water from melting ice doesn't enter the containers.
2. Just prior to beginning the activity, place the containers in the tray and put ice and cold water around them, being careful not to wet the sand, or displace the straw in the "dry" container.

The activity begins:

1. For a hands-on activity, divide the class into groups of 4 to 5 students. If this activity will be done as a demonstration, select 5 students to do this activity for the class.
2. Distribute the pre-made table (*see pg. 5.*), or make a 3-column table with time in the first column and two blank columns for the temperatures of the two probes. Make a place to record the starting temperature for each thermometer, the temperature every 15 seconds for the first minute, every 30 seconds for the next two minutes, and once every minute up to 6 minutes or so. If this activity will be done as a demonstration, have two of the student volunteers make separate tables on the board for the dry sand and the icy sand.
3. If you prepared the trays prior to the students arrival, give the students the tray with the containers and the ice water.
4. Fill the cup with hot tap water. Place the two thermometers into the hot water. Wait a few minutes until the thermometers have adjusted to the temperature of the water. Tell the students that heating the thermometers in hot water simulates the heating the probes will experience as they pass through the atmosphere and impact Mars's surface.
5. Record the temperatures of the thermometers as the starting temperatures.
6. Place one thermometer into each straw.
7. Record the temperature of each thermometer at the recommended intervals over a period of 6 minutes. In groups of 5 students, have one student keep track of time for the group, two students read the temperatures off of the thermometers (with one thermometer each), and two students record the temperatures in the table(s). For groups of 4, announce the time intervals to the class. A clock the entire class can see may help in both cases. If a group has an extra student, he or she can be responsible for making sure the data is recorded on schedule. Groups of 2 to 3 students will also work if the temperatures of the dry sand or the icy sand are measured one at a time. If you choose this option, obtain new hot water to heat the thermometer, preferably close to the previous starting temperature.
8. Have all of the students in each group complete their individual tables from the recorded data for the entire group.
9. Before putting away the trays, have each student test the hardness of the two samples with his or her fingers. This will simulate another way in which the probes will look for water ice. The icy sand will be much harder than the dry sand, making it more difficult for a finger to penetrate below the surface. On Mars, if ground ice is present, the probes will slow down more quickly, and will not go as deep as they will in ice-free soil.

For younger students who have not been introduced to graphing, or if time is very limited, you can end here with a qualitative discussion of the data. Which "probe" cooled faster? Was the result a surprise to the students, or was it expected?

Graphing the data:

1. Have the students plot the data for each of the probes on the same piece of paper, preferably using a different color for each probe. Time should be plotted on the horizontal axis, and temperature on the vertical axis. For students new to making graphs, this can be done in groups. For students who have been previously introduced to graphing, this should be done individually.
2. Compare the results from the class. Did one sample consistently cool the thermometer faster than the other?

Follow up:

Discuss the results of the experiment with the class.

<u>Why did the sample with the ice make the thermometer cool down faster</u>?

The icy-sand conducts (moves) heat away from the thermometer better than the dry soil. The dry sand has pockets of air around each of the tiny grains. These pockets of air, called pore space, act as insulation, and make it harder for the heat to be passed from one part of the container to another. Air spaces are often used as insulation in buildings. Double paned windows have a sheet of glass on either side of a pocket of air. Air space is also used in walls, and insulation usually has a high fraction of pore space.

When water is added and is frozen into the soil, ice fills the pore spaces. The combined material is less insulating and can conduct heat away from the thermometer and into the sand more efficiently. On Mars, dry soil will be more insulating than dry soil here on Earth. The air in the pores still transports heat in the soil, even if not very efficiently. The denser the air is, the better it is at moving heat. On Mars, the air is much thinner than here on Earth, and therefore will be even more inefficient in conducting heat.

Note: *Poor contact between the straw/thermometer and the icy sand can cause the thermometer to cool off more slowly in the icy sand sample. You should be able to identify this problem by a visual inspection of the sample. The thermometer is then better insulated by the air pocket around the straw than it is in the dry sand sample. Also, if the samples are not kept frozen, the experiment will not work properly. If either problem happens, all is not lost. Discuss with the students that result was not as expected (by you), and use this as an opportunity to discuss experimental design. How might the students improve the design of the experiment?*

If the Mars Microprobe Mission had succeeded, but *didn't* find ice in the soil of Mars, would that mean that permafrost doesn't exist on Mars? No. The probes from the Mars Microprobe Mission would have only sampled one area on Mars, and would have told us about the ground very near the surface. **What other methods could be used to search for ground ice on Mars?**

Suggestions for materials:

Containers:

Inexpensive disposable food containers such as the deep Ziploc brand 32 ounce containers work well. They come in four packs for about $3.

Sand:

Several sources of sand are available. Fine to medium grained playground sand or clean construction can be purchased in 50 lb bags from many hardware stores. Small bags of sand, intended for the purpose of mixing with soil, can be found in plant nurseries. Masonry sand and aquarium sand may also work, however, the grains maybe courser than would be ideal. Of course, natural sources of sand such as a beach will also work just fine. Make sure the dry sand really is dry before beginning the experiment. Some types of sand, such as those for use with plants, may be packaged moist. You can dry sand quickly by spreading it in a thin layer in a tray, and then leaving it in the sun on a warm day or by baking it in your oven at about 225 degrees Fahrenheit for about an hour.

Straws:

Not all straws labeled "jumbo" really are. If you cannot find straws that are slightly larger than the diameter of your thermometers (probably about 6 to 7 mm, so an 8 mm straw would work well), try wrapping a small piece of wax paper around a pen that is just a bit larger in diameter than the thermometers. Make sure that the bottom of the pen is also covered in wax paper, and seal the seams in the wax paper with transparent tape. You may need to leave the pen in the wet sand until the water has frozen, and in the dry sand until you are ready to begin the experiment.

Thermometers:

The ideal thermometers are the large alcohol thermometers often found in school laboratories, and these are also relatively inexpensive. Partial immersion thermometers (which require insertion only to a specified depth to accurately measure the temperature of a material) are best. The thermometers should cover a range of at least 0 to 50 degrees C, or 32 to over 100 degrees F. One source for various types of inexpensive alcohol thermometers is Carolina Biological Supply Company at http://www.carolina.com. Other suppliers of scientific equipment for schools are also likely to have partial immersion alcohol thermometers.

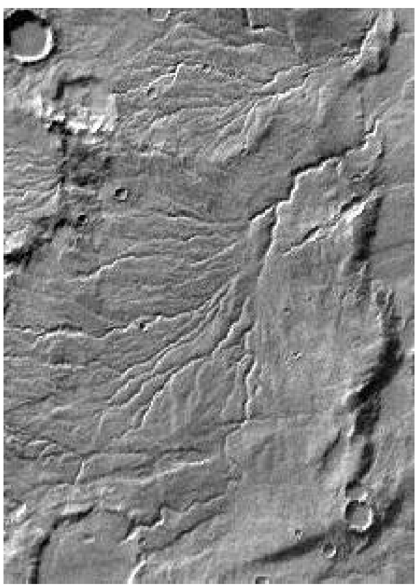
Acknowledgements:

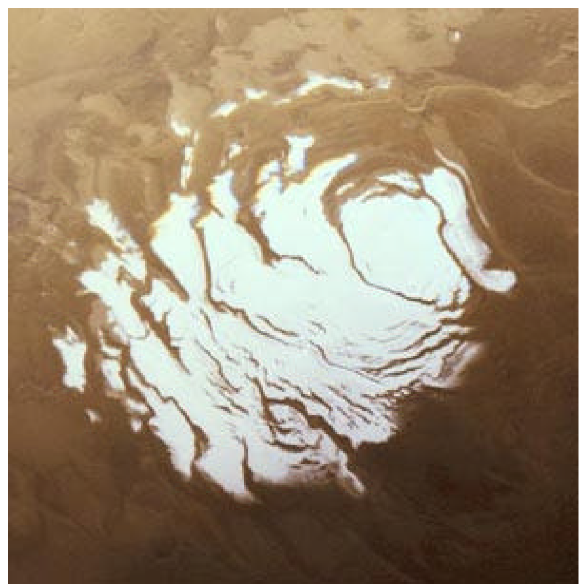
Thank you to Sheri Klug at ASU, Steve Klug, a middle school teacher in Arizona, Sally Urquhart, a high school teacher in Texas, and Carol Hjorth, a high school math teacher in Texas, for providing helpful reviews and suggestions. A special thanks to Mike Lichtman and the GATES students at Verdugo Woodlands Elementary in Glendale, CA., who field-tested this activity.

Probing Below the Surface of Mars
Student Information Sheet
Mars and the Search for Water

Mars is a cold desert. Long ago, liquid water flowed on the surface of Mars. Ancient water carved valleys were imaged by the Viking spacecraft, and more recently, by Mars Global Surveyor. The valleys are billions of years old, and look much like river valleys here on the Earth. Mars Pathfinder landed at a place on Mars that is the site giant flood, but no liquid water from that ancient flood remains on the surface.

Today, water still exists on the Red Planet, but what we can see is ice. Like the Earth, Mars has polar caps in both the north and the south. These ice caps are at least partly made of water ice. Telescopes and spacecraft can see a type of clouds made of tiny crystals of ice, called cirrus clouds, drifting in the atmosphere of Mars. Frost can even cover the surface of rocks and soil in the morning, much like it does on cold mornings in many places here on Earth. Scientists who study Mars see evidence that Mars had much more water in its past, at least on the surface. What happened to that water?





Water carved valleys billions of years old and the south polar cap of Mars. credit: Viking Orbiter, NASA

Some of the water is believed to be frozen in the martian soil. Many regions on our own world have water frozen in the ground, either during the winter or, in very cold places, all year long. Water frozen in soil is simply called ground ice. If the ground ice remains throughout the year without melting, it is called **permafrost.** Permafrost is common in places like Siberia, northern Canada, and near the peaks of high mountains.

Mars is as cold, or colder, than the coldest places here on Earth. Ground ice on Mars should stay frozen all year, and will be permafrost. However, finding the ground ice on Mars isn't easy. A dry layer of soil is believed to be on top of the icy soil, making it difficult to detect at the surface. Mars scientists have thought of several ways to search for permafrost on Mars. Some look at images of the surface of Mars taken by orbiting spacecraft like Mars Global Surveyor, which is currently in orbit around Mars. In these images, the scientists hope to find features similar to those made by permafrost here on the Earth, including wedge-shaped cracks in the ground that meet to form multisided shapes and look a lot like giant mud cracks. In 2001, NASA plans to send another orbiter to Mars. The Mars Surveyor 2001 orbiter has a special instrument called a Gamma Ray Spectrometer that will search for ground ice on Mars over the entire planet. This instrument is designed to "see" ice below the dry soil at the surface.

Another way to find the ice is to send a probe below the surface of Mars. Close to the poles, many Mars scientists think the dry layer of soil will be very thin, and the icy ground will be close to the surface. The Mars Microprobes, two grapefruit-sized spacecraft, were supposed to impact the surface of Mars near the south pole in December 1999. Part of each tiny probe was designed to penetrate up to about 1 meter (or 3 feet) into the soil. Unfortunately, the probes were never heard from. If they had survived, scientists might have been able to find ground ice on Mars. The dusty or sandy soil near the south pole may be dry, or it may be contain ice. If the soil in the top meter is ice-rich, the probes were designed to detect the ice in three ways:

- by measuring how fast the probes slow down after impacting the surface. Ice will make soil harder, causing the probes to slow down more quickly than they would in ice-free soil.
- by collecting a soil sample and testing it for the presence of water using a heater and a tiny laser.
- by measuring how quickly the probes cool off after impact.

The Mars Polar Lander, also lost in December 1999, was also designed to search for ice. Instead of sending tiny probes into the soil, it would have used a robotic arm to dig a trench down into the surface to look for water ice and collect samples. In what other ways do you think scientists could search for ground ice on Mars?

Answering the question of what happened to the water on Mars is important to Mars scientists for many reasons. Water is related to the climate of Mars and finding ground ice could help scientists understand how the climate of Mars has changed over time. Did bacteria ever live on Mars? Does anything live underground on Mars today? Knowing how much water Mars had in the past and what has happened to that water will help us answer these questions. Someday, people may even go to Mars, and those people will need water.

Even though the Mars Microprobes and Mars Polar Lander were lost in December 1999, the search for ground ice on Mars goes on. Maybe someday new missions to Mars will probe the subsurface for water, just like the tiny Mars Microprobes were designed to. How might you design a mission to look for water on Mars?

Time	Dry Sand	Icy sand
Starting Temperature		
15 seconds		
30 seconds		
45 seconds		
1 minute		
1 minute 30 seconds		
2 minutes		
2 minutes 30 seconds		
3 minutes		
4 minutes		
5 minutes		
6 minutes		

Good Vibrations

Remote Sensing Data Collection:
Thermal Emission Spectrometer (TES)

Objective:

Students will learn about the use of thermal emission spectroscopy and will gain knowledge about a planet's surface and atmosphere. This activity will relate current remote sensing planetary exploration techniques to students through the eyes of a robotic mission.

National Science Education Standards:

Standard A: Abilities necessary to do scientific inquiry
Standard D: Earth in the Solar System

Participants:

- Sun
- Timer
- Communication Center
- Mars Mineral Shakers (up to 12)
- TES
- Data Stream
- Scientist

Materials:

Any materials can be used as props. Here are some suggestions:

- Cool sunglasses
- Stopwatch
- Headset or telephone
- Mars mineral shakers (small pom-pom)
- Clip board, pencil, and data sheet
- Mirrored CD
- Portable radio (for radio waves)
- Rock or mineral book
- Hula-hoop or rope circle
- Colored chalk or dry-eraser markers

NOTE: We are trying to change the stereotypes of scientists, please, no white lab coats, glasses, or pocket protectors

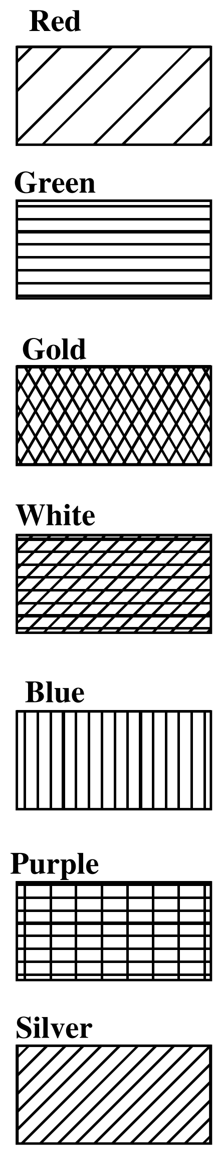
Background:

Thermal emission spectroscopy is a technique currently being used by a Mars Global Surveyor spacecraft instrument called TES (Thermal Emission Spectrometer). The purpose of TES is to measure the thermal infrared energy (heat) being emitted from Mars. From this data, scientists can learn much about the geology (rocks and minerals) and atmosphere of Mars.

The Mars Global Surveyor spacecraft had a two year intensive mapping mission. During this time, the TES instrument systematically built a mineral map of Mars. This information is used to understand the rocks on Mars, the composition of the Martin atmosphere, and the temperature variations that occur on its surface. With this information, future Mars missions can plan interesting landing sites, know what kind of mineral resources are available on the surface, and understand more of the history of Mars.

A comprehensive background on the TES instrument and infrared spectroscopy is available at our website: http://tes.asu.edu/newwhatstes.html.

Orbit 1	Orbit 2
1.	
2.	
3.	
4.	
5.	
6.	
7.	
8.	
9.	
10.	
11.	
12.	



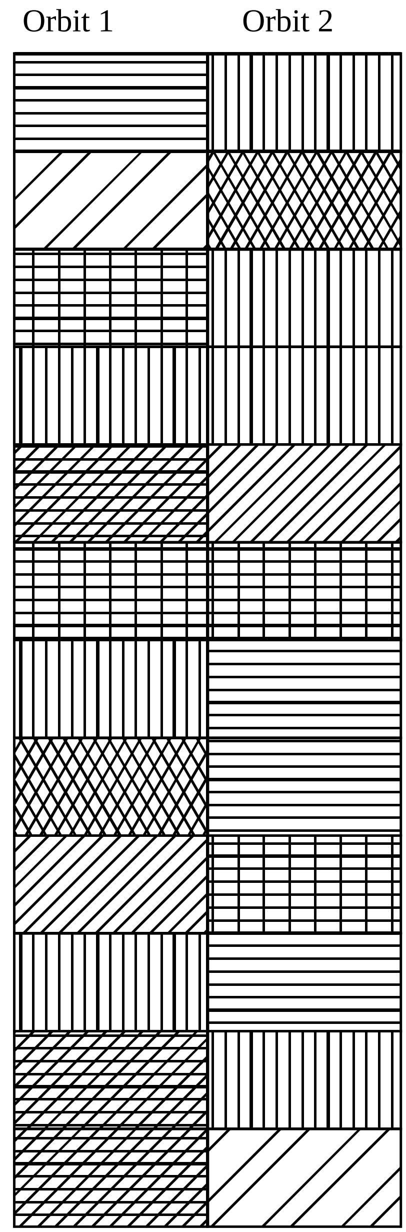


Figure #1 – This diagram can be drawn on a chalk board or white board. Each column represents a different orbit and each row represents a different rock reading from TES.

Figure #2 – A sample of a completed data set. This could be done on a chalk or dry-erase board and recorded by the Scientist.

Procedure:

An open classroom area is needed to demonstrate the TES data collection.

1. Select students to fill the positions listed in the participant list. You can draw names or have the students apply for positions.
2. Make a color key for the mineral shaker colors on the white board or chalk board, (see Figure #2).
3. Draw a table on the board to simulate the data return (Figure #1). The scientist will color in the portion of the orbit according to the mineral color. This simulates the way that data is collected and image maps are produced in TES data. The table on the board should be numbered 1-12 to match the data sheet being returned to the communication center. The communication center person will then read back the data collected by TES to the scientist, and the scientist will color the appropriate mineral color in the squares 1-12.

4. The Sun is positioned in the center of the open area (with glasses!). The Mars minerals each get one shaker to start. They should all hold onto the hula-hoop with their left hand and have their shaker in their right hand. Tell the students to hold their shakers on the floor until the game is explained. The TES instrument is located in the locale of the Sun, because the instrument reads the heat emission best when the surface is warmed during the day (approximately 2:00pm).
5. The TES instrument (with CD mirror around neck) is positioned next to the Sun.
6. The Data Stream is located next to the TES instrument (with the portable radio). These radio waves will transmit the TES data back to Earth.
7. Timer (optional): A timer with the stopwatch can be used to time the actual data readings from TES (1 every 2 seconds).
8. The Communication Center person will read the data delivered by the Data Stream to the Scientist.
9. The Scientist will record the data for interpretation by the class. Are there any similarities or differences in the way racks were sequenced?
10. The second orbit can be repeated as in the first orbit with students in a different order or with multiple shakers given to the students to simulate real rocks. In this case each numbered box may have more than one color. Students can then compare the two orbits.

Conclusion:

This activity will help students to understand the thermal infrared science that has been conducted during the Mars Global Surveyor mission, the 2001 orbiter mission, and the 2003 rover mission. We hope that this information is helpful and appropriate for your students and welcome any feedback.

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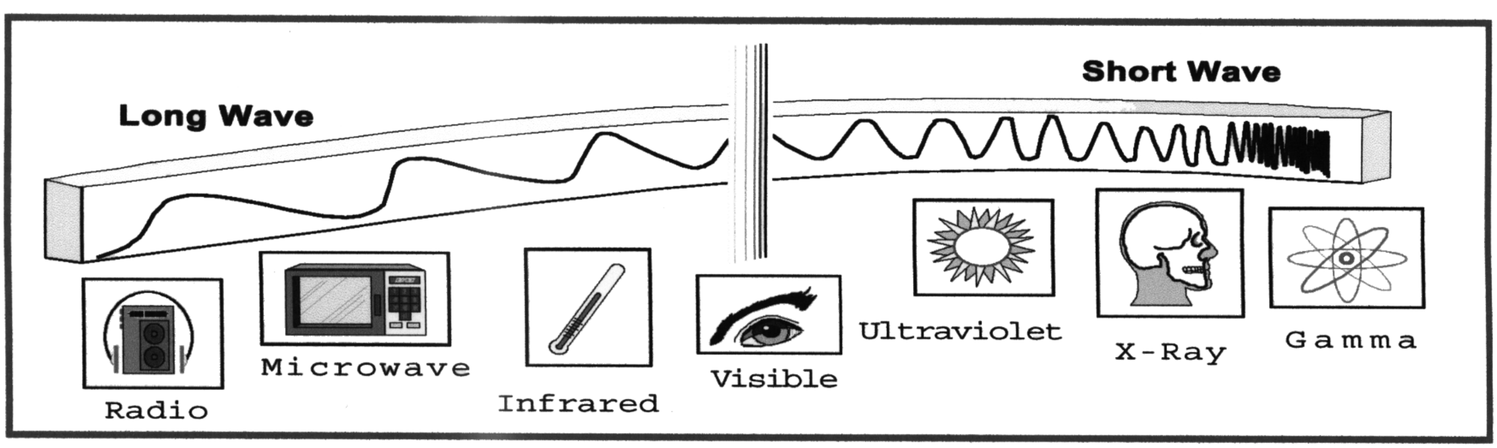
The Electromagnetic Spectrum



Thermal Emission Spectrometer Data Sheet

Orbit #1 - Take data every 2 seconds. Record each color vibration in boxes 1 – 12 by marking a mark. Make only one mark under one color for each line.

Color of Minerals

Red	Gold	Green	White	Blue	Purple	Silver
1.						
2.						
3.						
4.						
5.						
6.						
7.						
8.						
9.						
10.						
11.						
12.						

Thermal Emission Spectrometer
Data Sheet

<u>Orbit #2</u> - Take data every 2 seconds. Record each color vibration in boxes 1 – 12 by marking a mark. Make only one mark under one color for each line.

Color of Minerals

Red	Gold	Green	White	Blue	Purple	Silver
1.						
2.						
3.						
4.						
5.						
6.						
7.						
8.						
9.						
10.						
11.						
12.						

Name: ______________________

Good Vibrations

1. How do scientists learn about rocks on Mars?

____

____

____

2. What do the rocks help us learn about Mars?

____

____

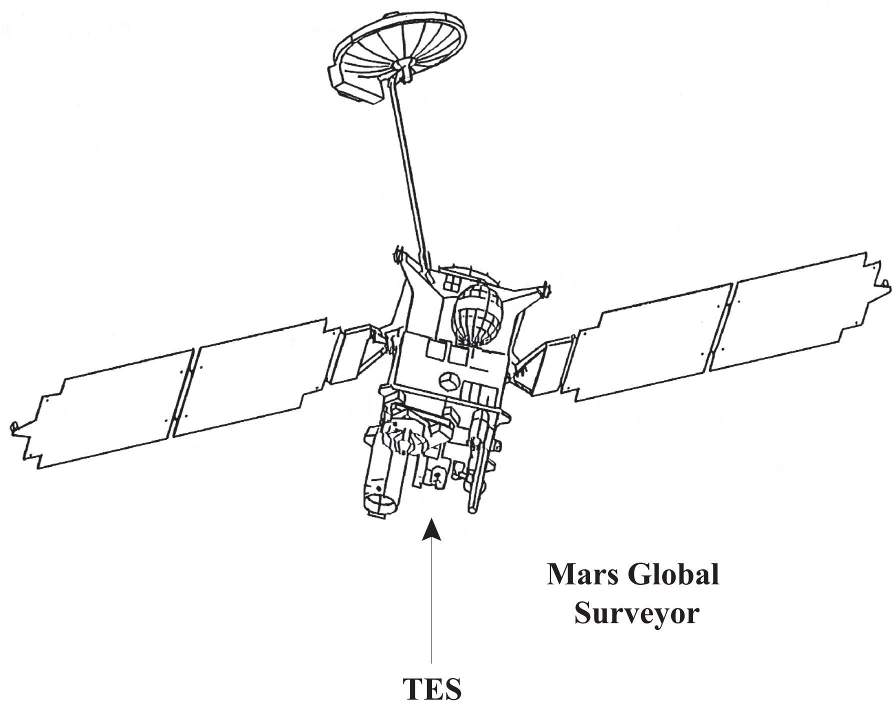
____

3. Why do you think that scientists are interested in the kinds of rocks that Mars has?

____

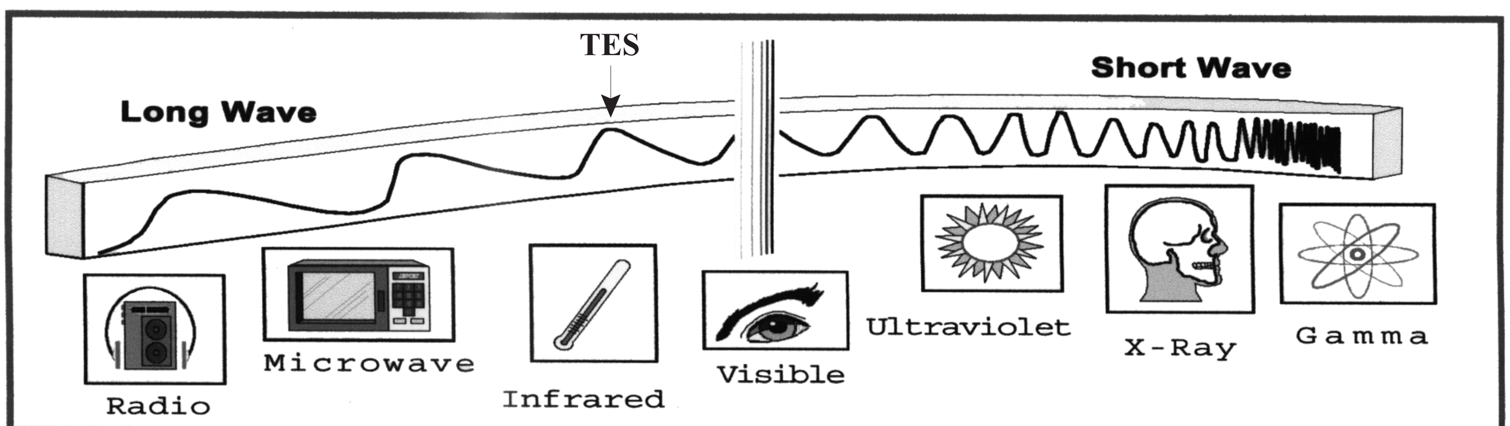
____

____



Mars Global Surveyor

The Electromagnetic Spectrum



The Mathematics of Mars
I Have…Who Has?

By Marshalyn Baker

Mathematics Teacher, William Jr. High, Oakland, Maine

Goal: Students will work in learning groups to discover the mathematics of Mars.

Objective: Students will gain knowledge of Mars mathematical facts and vocabulary by engaging in an activity, "I Have...Who Has, the Mathematics of Mars."

Time Frame: 10 Minutes

Grade levels: 5 to 8 (can be adjusted to other grades)

National Science Education Standards:

Standard D: Earth in the Solar System

National Math Education Standards:

NM.5-8.1 Problem Solving

NM.5-8.4 Connections

NM.5-8.5 Number Relationships

NM.5-8.7 Computation and Estimation

NM.5-8.9 Algebra

NM.5-8.10 Statistics

NM.5-8.12 Geometry

NM.5-8.13 Measurement

Materials:

Index cards (26 per set)

Glue

Scissors

Color copies of the text "I HaveWho Has, the Mathematics of Mars" (Use a different color for each group that you have.)

Procedure:

Choose someone to begin. The student should read “I Have…Who Has?” text for “The Mathematics of Mars”. The person who has the matching number answers. The students continue to answer until the last card is matched with the card that started the activity. You can do this several times and try to beat the time of the previous round. If this is done in groups of three or four students, each group will need their own set of cards.

It can be done as a whole class. You could make additional cards if you have more than 26 students. You also could get students to write their own cards for other planets.

The Cards:

I have a 21 km diameter. This is Phobos, a moon of Mars. Who has 120 hectometers?

I have 12 kilometers. This is the diameter of Deimos, one of the moons of Mars. Who has 2.06 * 10 to the eighth power?

I have 206,000,000 km. This is the minimum distance that Mars is from the Sun. Who has the second square number?

I have 4. Mars is the fourth planet from the Sun. Who has ninety-three thousandths?

I have 0.093. This is the eccentricity of the orbit of Mars. (0.00 is a perfectly circular, orbit.) Who has 1.88 Earth years?

I have 687 Mars sols (days). This is the period of revolution of Mars. Who has an acute angle?

I have 25 degrees 12'. This is the inclination of the axis of Mars. Who -has 111.5 + 116.4?

I have 227.9. This is the number of millions of km that represents the mean distance of Mars from the Sun. Who has the identity element for addition?

I have 0, the number of rings that Mars has. Who has 8.2 * 3?

I have 24.6 Earth hours. This is a day on Mars. Who has .95?

I have 95%. This represents the percentage of carbon dioxide in the Mars atmosphere. Who has 150?

I have a range of -125 degrees C to 25 degrees C. This represents the global extremes on Mars. Who has 6.4 * 1026 g?

I have 6566.4 g or 6.5664 kg. This is the mass of Mars. Who has 2.49 *10 to the eighth power?

I have 249,000,000 km. This is the maximum distance Mars is from the Sun. Who has .38?

I have 19/50. This is approximately 1/3 which is the relationship of gravity on Mars to Earth's gravity. Who has 9.4 million?

I have $9,400,000. This is the cost of the Thermal Emission Spectrometer that was aboard the Mars Global Surveyor, which began orbiting Mars in September, 1997. Who has 9/10?

I have 90%. This is an estimate of water that is probably gone from Martian reservoir into the Mars atmosphere. Who has 2 to the third power * 3?

I have 24. This composite number represents the number of languages that Mars was etched in a sundial, which will reach Mars in 2004. Who has 62 * 124?

I have 7688 square miles. This is the area of the landing site of the Mars Pathfinder. Who has 11/50 tons?

I have 440 pounds. This represents the weight of a Mars Micromission, which is an independent spacecraft and payload launched aboard Ariane 5 rockets in the future. Who has 6.0 * 10 to the fifth power?

I have 600,000 meters. This is the base distance of Olympus Mons, A Mars volcano, which is the biggest in the solar system. Who has 2 to the fourth power * 3 to the second power * 5 to the second power?

I have 3600. Years ago, Babylonians wrote about the looping motion of Mars, a "star that wandered." Who has a palindrome?

I have 22. This was the number of black and white images Mariner 4 took of the Southern Hemisphere of Mars in 1965. Who has a perfect number?

I have 6 millibars, the surface pressure of Mars, which is about 1/200th that of Earth's. Who has 1.5 * 10 to the third power?

I have 30 cm by 50 cm. This is the approximate area of Moe, a rock on the surface of Mars, visited Sept 8, 1997 by the Mars Pathfinder. Who has a range of 44?

I have 6 to 50 micrometers, the wavelengths TES (Thermal Emission Spectrometer) can measure. Who has 3 * 7 km in diameter?

Assessment:

Put these letters on the back of the cards (in order). If students are correct, they spell a Mars connection.

[MATHEMATICS*FACTS*0F*MARS*]

You can also look at the improvement in the time it takes each group to go through the cards.

Another suggestion is to have students design their own "I have…who has."

I have:

21 km diameter.
This is Phobos, a moon of Mars.

Who has:

120 hectometers?

[m]

I have:

12 kilometers.
This is the diameter of Deimos, one of the moons of Mars.

Who has:

2.06 * 10 to the eighth power?

[a]

I have:

206,000,000 km.
This is the minimum distance that Mars is from the Sun.

Who has:

the second square number?

[t]

I have:

4.
Mars is the fourth planet from the Sun.

Who has:

ninety-three thousandths?

[h]

I have:

0.093.
This is the eccentricity of the orbit of Mars
(0.00 is a perfectly circular, orbit.)

Who has:

1.88 Earth years?

[e]

I have:

687 Mars sols (days).
This is the period of revolution of Mars.

Who has:

an acute angle?

[m]

I have:

25 degrees 12'.
This is the inclination of the axis of Mars.

Who has:

111.5 + 116.4?

[a]

I have:

227.9.
This is the number of millions of km that represents
the mean distance of Mars from the Sun.

Who has:

the identity element for addition?

[t]

I have:

0.
The number of rings that Mars has.

Who has:

8.2 * 3?

[i]

I have:

24.6 Earth hours.
This is a day on Mars.

Who has:

.95?

[c]

I have:

95%.
This represents the percentage of carbon dioxide
in the Mars atmosphere.

Who has:

150?

[s]

I have:

a range of -125 degrees C to 25 degrees C.
This represents the global extremes on Mars.

Who has:

$6.4 * 10^{26}$ g?

[*]

I have:

0.64 * 10^{24} kg.
This is the mass of Mars.

Who has:

2.49 * 10 to the eighth power?

[f]

I have:

249,000,000 km.
This is the maximum distance Mars is from the Sun.

Who has:

.38?

[a]

I have:

19/50.
This is approximately 1/3 which is the relationship of gravity on Mars to Earth's gravity.

Who has:

9.4 million?

[c]

I have:

$ 9,400,000.
This is the cost of the Thermal Emission Spectrometer that was aboard the Mars Global Surveyor,which began orbiting Mars in September, 1997.

Who has:

9/10?

[t]

I have:

90%.
This is an estimate of water that is probably gone from Martian reservoir into the Mars atmosphere.

Who has:

2 to the third power * 3?

[s]

I have:

24.
This composite number represents the number of languages that Mars was etched in a sundial which will reach Mars in 2004.

Who has:

62 * 124?

[*]

I have:

7688 square miles.
This is the area of the landing site of the Mars Pathfinder.

Who has:

11/50 tons?

[o]

I have:

440 pounds.
This represents the weight of a Mars Micromission which is an independent spacecraft and payload launched aboard Ariane 5 rockets in the future.

Who has:

6.0 * 10 to the fifth power?

[f]

I have:

600,000 meters.
This is the base distance of Olympus Mons, a Mars volcano, which is the biggest in the solar system.

Who has:

2 to the fourth power * 3 to the second power * 5 to the second power?

[*]

I have:

3600.
Years ago, Babylonians wrote about the looping motion of Mars, a "star that wandered."

Who has:

a palindrome?

[m]

I have:

22.
This was the number of black and white images Mariner 4 took of the Southern Hemisphere of Mars in 1965.

Who has:

a perfect number?

[a]

I have:

6 millibars.
This is the surface pressure of Mars, which is about $1/200^{th}$ that of Earth's.

Who has:

1.5 * 10 to the third power?

[r]

I have:

30 cm by 50 cm.
This is the approximate area of Moe, a rock on the surface of Mars, visited Sept 8, 1997 by Mars Pathfinder.

Who has:

a range of 44?

[s]

I have:

6 to 50 micrometers.
This is the wavelengths TES (Thermal Emission Spectrometer) can measure.

Who has:

3 * 7 km in diameter?

[*]

Mars Bingo

<u>Goal</u>: To allow students to be introduced, learn, and rehearse vocabulary and concepts related to Mars and Mars missions.

<u>Objective</u>: To recognize the vocabulary definition being given and complete either a horizontal, vertical, or diagonal row on the game board.

<u>Time Frame</u>: 45 minutes

<u>Grade Levels</u>: 5th - 9th grades

<u>National Science Education standards</u>:

Standard D: Earth in the Solar System

<u>Materials</u>:

- Blank Mars Bingo game board sheet
- List of vocabulary words and definitions (must use more vocabulary words than the number of squares on the game board)
- Teacher Vocabulary Clue Sheet to cut into strips
- Scissors to cut up some student squaw to cover the correct clues
- Simple prizes (penny candy or small items of interest)

<u>Procedure</u>:

1) Have the students review the vocabulary words on the Mars Bingo Student Vocabulary Hand-out sheet.
2) Have the students choose which vocabulary words they wish to use on their Mars Bingo game board sheet (24 in all).
3) Have the students write the words in the Bingo squares (any order they wish) on the Mars Bingo game board sheet. (Note: Pen would be better than pencil to avoid erasures on the game board sheet).
4) The clues to the vocabulary words (with the correct answer included) should be cut into strips and mixed up. The clues are then drawn one at a time (by the teacher or other designated helper) and read.
5) The clue reader needs to keep track of the words the have been given, so they may be reviewed to verify the winner.
6) The class then responds with the correct answer and the students that have that vocabulary word on their Mars Bingo sheet will cover the correct vocabulary word as the clue given with a paper square or simply cross out the word (if game is only to be played once).

7) The first student that has a vertical, horizontal row or diagonal row of vocabulary words covered indicates so by saying “bingo” or other designated appropriate word.
8) The words are then reviewed to make sure they were correct.

<u>Alternate Procedures</u>:

1) A permanent classroom set of Mars Bingo cards with vocabulary randomly chosen and permanently written in the squares can be made and laminated. Students can cut out squares of paper to cover the vocabulary that has been called out, and used in the game.
2) This activity can be used as a stand-alone type of activity for familiarizing students with Mars terms and vocabulary they might recognized in media articles covering the missions.
3) The students can be allowed to use the vocabulary sheets to look up the proper answers to the clues, working either in groups or alone.

<u>Assessment</u>:

Student participation and familiarization with vocabulary words within a class environment. Students can also be quized independently by writing the correct matching, vocabulary word to the definition in a quiz format.

<u>Credits</u>:

ASU Mars K-12 Education Program, P.O. Box 871404, Tempe, AZ 85287;
(480) 727-6495

Mars Bingo Vocabulary
Student Handout

1) **<u>Olympus Mons</u>:** The largest volcano on Mars (and in the Solar System!). Olympus Mons is 16 miles high (approximately 3 times as high as Mt. Everest - Earth's tallest mountain) and would cover the same area as the state of Arizona!

2) **<u>Valles Marineris</u>:** The longest canyon system on Mars (and in the Solar System!) This canyon is approximately 2500 miles long and reaches depth of nearly 3 to 6 miles deep in some places.

3) **<u>687</u>:** The number of Earth days that make a Martian year. Remember that a year is the amount of time it takes a planet to travel all the way around the Sun. The Earth has a year that is 365 1/4 days long. If you lived on Mars, you would be a little older than 1/2 the age you are now.

4) **<u>Viking Missions</u>:** The name of the Mars missions (2 orbiters and 2 landers) that were sent to look for life on Mars in 1975-1976.

5) **<u>Carbon Dioxide</u>:** The main component (over 95%) of the Martian atmosphere (air).

6) **<u>Mars Pathfinder</u>:** The name of the Mars mission that landed on Mars on July 4,1997. There had not been a landing on Mars in 21 years, before this mission successfully landed. The main objective of this mission was to test new ideas in spacecraft engineering and to study the rocks.

7) **<u>25.5 degrees</u>:** The amount of tilt of the axis of Mars.

8) **<u>Sojourner Truth</u>:** The name of the first rover on Mars, named after a Civil War slave who helped other slaves become free. This rover was also the first rover sent to another planet and rolled around on Mars for nearly three months. The rover weighs 23 pounds, is 2 feet long, 11/2 feet wide, and 1 foot tall.

9) **<u>Mars Global Surveyor</u>:** The name of the spacecraft that began orbiting Mars in 1997. This mission collects data that will help us understand how high and low the mountains and valleys are, tell us about the minerals and rocks an the surface of the planet, take better pictures of the planet than we have ever had before, and reveal the magnetic history of the planet. The mission will last until at least 2001.

10) **<u>1/2 Diameter</u>:** The size comparison of diameters (ratio) of Mars to Earth.

11) **<u>MOLA</u>:** The Mars Orbiter Law Altimeter: An instrument that uses a laser bounced off the Martian surface to figure out how tall (or deep) the Martian surface features are.

12) **<u>MOC</u>:** The Mars Orbiter Camera that is taking the pictures of Mars and is part of the Mars Global Surveyor Mission.

13) **<u>Red Planet</u>:** The nickname of Mars. This nickname was given because of the red dust that covers the planet and helps to give it its color.

14) **<u>37</u>:** The number of minutes that the Martian day is longer than an Earth day.

15) **<u>Phobos</u>:** The larger moon of Mars. The translation of the name means “fear”.

16) **<u>Deimos</u>:** The smaller moon of Mars. The translation of the name means “terror”.

17) **<u>MAG/ER</u>:** The instrument on board the Mars Global Surveyor that will search for a magnetic field around Mars.

18) **<u>Teleoperation</u>:** The remote operation of a robotic device, such as a rover or science instrument aboard a spacecraft.

19) **<u>Payload</u>:** Anything that a flight vehicle (like a spacecraft) carries beyond what is required for its operation during flight. This includes the scientific instruments and planetary rovers on the Mars missions.

20) **<u>Escape Velocity</u>:** The speed that any object must travel in order to escape the gravitational pull of a planet.

21) **Aerobraking:** The way a spacecraft can slow down by using the atmospheric drag of a planet. The Mars Global Surveyor and Mars Polar Orbiter used this method.

22) **Astronomical Unit:** The measuring unit for distances in the Solar System. One A.U. is equal to the mean distance from the Sun to the Earth (approximately 93,000,000 miles).

23) **TES:** The Thermal Emission Spectrometer instrument on board the Mars Global Surveyor that is studying the minerals, rocks, and atmosphere of Mars.

24) **FIDO:** The prototype rover being tested to get ready for the Mars Return Sample Missions. The initials stand for Field Integrated Design and Operations.

25) **Athena:** The name of the long-range rovers that will be the rolling "field geologists" of the Mars Sample Return Missions. This is a bigger rover design than the Sojourner rover. It will be able to drill rocks and collect rock and soil samples. It comes with a microscopic imager and several spectrometers to give information about the rock right there on Mars. It also has a camera that will be able to rise above the rover and take pictures for the science team back on Earth. Through these pictures, the scientists will be able to direct the rover to the areas they wish to study.

26) **Pancam:** The name of the camera that will be on the Athena rover. The name stands for panoramic camera.

27) **Air Bags:** The Mars Pathfinder used these to bounce into the Martian surface on July 4,1997. This was called a passive style landing.

28) **APXS:** The Alpha Proton X-Ray Spectrometer instrument that was on the Sojourner rover. This instrument was able to indicate what kind of minerals were in the rocks that it tested.

29) **Polar Caps:** These are located at the North and South Poles of Mars and are composed of water ice and Carbon Dioxide ice.

30) **<u>Mojave Desert</u>:** This is where the FIDO rover was tested to see if the instruments and software could operate correctly before the Athena rover (the rover that FIDO is being tested for) was sent to Mars. Other places this rover is tested are: Hawaii and the Mars Yard at Jet Propulsion Laboratory.

31) **<u>Navcam</u>:** The camera that is used to navigate the FIDO and Athena rovers.

32) **<u>Mini-Corer</u>:** The instrument on FIDO and Athena that will drill into rocks. These drill cores are about the diameter of a pencil. The drill cores collected on Mars will be returned for study here on Earth.

33) **<u>Mars Sample Return Mission</u>:** The Mars missions that will be returning Mars rocks samples (drill cores) and Mars soils to Earth.

34) **<u>Spectrometer</u>:** The instrument on the FIDO and Athena rovers that can detect iron minerals in soil and rocks. It has been tested on Earth and will be sent to Mars.

35) **<u>Color Microscopic Imager</u>:** The instrument on the FIDO and Athena rovers that is able to give scientists a very close and detailed picture of rocks and soils and will aid scientists in the interpretation of the minerals within the rocks.

36) **<u>Mom Surveyor 2001 Mission</u>:** The orbiter mission, which will launch from Earth in April of 2001. This mission will carry the THEMIS, Marie and GRS instruments.

37) **<u>Sol</u>:** One day on Mars.

38) **<u>Ares Vallis</u>:** The Mars Pathfinder landing site. Scientists think this is an area on Mars that experienced a very large flood in its ancient history. Mars Pathfinder landed here on July 4,1997.

39) **<u>NASA</u>:** National Aeronautics and Space Administration.

40) **<u>Mars</u>:** The fourth planet from the Sun that is named after the god of War.

Mars Bingo Vocabulary

Teacher Clue Sheet

Instructions: Cut the vocabulary words into strips. Mix the strips up and draw a vocabulary word. Read the definition to the class and wait for students to give the correct answer to the clue given.

---

1) **Olympus Mons:** The largest volcano on Mars (and in the Solar System!) Olympus Mons is a shield volcano that is 16 miles high (approximately 3 times as high as Mt. Everest- Earth's tallest mountain), is 370 miles across and would cover the same area as the state of Arizona!

---

2) **Valles Marineris:** The longest canyon system on Mars (and in the Solar System!) This canyon is approximately 2500 miles long and reaches depth of nearly 3 to 6 miles deep in some places.

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3) **687:** The number of Earth days that make a Martian year. Remember that a year is the amount of time it takes a planet to travel all the way around the Sun. The Earth has a year that is 365 1/4 days long. If you lived on Mars, you would be a little older than 1/2 the age you are now.

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4) **Viking Missions:** The name of the Mars missions (2 orbiters and 2 landers) that were sent to look for life on Mars in 1975-1976.

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5) **Carbon Dioxide:** The main component (over 95%) of the Martian atmosphere (air).

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6) **Mars Pathfinder:** The name of the Mars mission that landed on Mars on July 4, 1997. There had not been a landing on Mars in 21 years, before this mission successfully landed. The main objective of this mission was to test new ideas in spacecraft engineering and to study the rocks.

7) **<u>25.5 degrees</u>:** The amount of tilt of the axis of Mars.

---

8) **<u>Sojourner Truth</u>:** The name of the first rover on Mars, named after a Civil War slave who helped other slaves become free. This rover was also the first rover sent to another planet and rolled around on Mars for nearly three months. The rover weighs 23 pounds, is 2 feet long, 11/2 feet wide, and 1 foot tall.

---

9) **<u>Mars Global Surveyor</u>:** The name of the spacecraft that began orbiting Mars in 1997. This mission collects data that will help us understand how high and low the mountains and valleys are, tell us about the minerals and rocks on the surface of the planet, take better pictures of the planet than we have ever had before, and reveal the magnetic history of the planet. The mission will last until at least 2001.

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10) **<u>1/2 Diameter</u>:** The size comparison of diameters (ratio) of Mars to Earth.

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11) **<u>MOLA</u>:** The Mars Orbiter Laser Altimeter: An instrument that uses a laser bounced off the Martian surface to figure out how tall (or deep) the Martian surface features are.

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12) **<u>MOC</u>:** The Mars Orbiter Camera that is taking the pictures of Mars and is part of the Mars Global Surveyor Mission.

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13) **<u>Red Planet</u>:** The nickname of Mars. This nickname was given because of the red "rusty" dust that covers the planet and helps to give it its color.

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14) **<u>37</u>:** The number of minutes that the Martian day is longer than an Earth day.

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15) **<u>Phobos</u>:** The larger moon of Mars. The translation of the name means “fear”.

16) **<u>Deimos</u>:** The smaller moon Of Mars. The translation of the name means “terror”.

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17) **<u>MAG / ER</u>:** The instrument on board the Mars Global Survey that will search for a magnetic field around Mars.

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18) **<u>Teleoperation</u>:** The remote operation of a robotic device, such as a rover or science instrument aboard a spacecraft.

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19) **<u>Payload</u>:** Anything that a flight vehicle (like a spacecraft) carries beyond what is required for its operation during flight. This includes the scientific instruments and planetary rovers on the Mars missions.

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20) **<u>Escape Velocity</u>:** The speed that any object must travel in order to escape the gravitational pull of a planet.

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21) **<u>Aerobraking</u>:** The way a spacecraft can slow down by using atmospheric drag of a planet. The Mars Global Surveyor and Mars Polar Orbiter used this method.

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22) **<u>Astronomicial Unit</u>:** The measuring unit for distances in the Solar System. One A.U. is equal to the mean distance from the Sun to the Earth (approximately 93,000,000 miles).

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23) **<u>TES</u>:** The Thermal Emission Spectrometer instrument on board the, Mars Global Surveyor spacecraft that is studying the minerals, rocks and atmosphere of Mars.

24) **<u>FIDO</u>:** The prototype rover being tested to get ready for Mars Return Sample Missions. The initials stand for Field Integrated Design and Operations.

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25) **<u>Athena</u>:** The name of the long-range rovers that will be the rolling "field geologists" of the Mars Sample Return Missions. This is a bigger rover design than the Sojourner rover. It will be able to drill rocks and collect rock and soil samples. It comes with a microscopic imager and several spectrometers to give information about the rock right there on Mars. It also has a camera that will be able to rise above the rover and take pictures for the science team back on Earth. Through these pictures, the scientists will be able to direct the rover to the areas they wish to study.

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26) **<u>Pancam</u>:** The name of the camera that will be on the Athena rover. The name stands for panoramic camera.

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27) **<u>Air Bags</u>:** The Mars Pathfinder used these to bounce into the Martian surface on July 4, 1997. This was called led a passive style landing.

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33) **<u>Mars Sample Return Missions</u>:** The Mars missions that will be returning Mars rocks samples (drill cores) and Mars soils to Earth. Scientists will study these samples to learn more about Mars.

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34) **<u>Mossbauer Spectrometer</u>:** The instrument on the FIDO and Athena rovers that can detect iron minerals in soil and rocks. It has been tested on Earth and will be sent to Mars.

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35) **<u>Color Microscopic Imager</u>:** The instrument on the FIDO and Athena rovers that is able to give scientists a very close and detailed picture of rocks mid soils and will aid scientists in the interpretation of the minerals within the rocks.

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38) **<u>Sol</u>:** One day and night on Mars.

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38) **<u>Ares Vallis</u>:** The Mars Pathfinder landing site. Scientists think this is an area on Mars that experienced a very large flood in its ancient history. Mars Pathfinder landed here on July 4, 1997.

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39) **<u>NASA</u>:** National Aeronautics and Space Administration.

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40) **<u>Mars</u>:** The fourth planet from the Sun that is named after the god of war.

Mars Bingo Card

Pick 24 vocabulary words and write them in your squares. You can put them in any order you wish. If you get a vocabulary word right, cover the word with a piece of paper. When you get a complete row filled (horizontally, vertically or diagonally) call out a “bingo”.

		Mars Bingo		

Mud Splat Craters

Objective: To observe crater formation and to identify the distinctive features of impact sites.

National Science Education Standards:

Standard A: Abilities necessary to do scientific inquiry

Standard F: Natural hazards

Background: What does a crater look like? What happens to a planet's surface during an impact? What are the features created during an impact? (*Note:* This activity should be done outside or in an area where the floor can be covered with plastic sheeting.) Many features can affect the size and shape of an impact crater (i.e. size of impactor, angle of impactor, type of soil or rock at impact…). Students can explore some of these factors by changing the amount of mud, the amount of water in the mud, the "planet surface", or even trying different impact velocities.

Materials:

- Large tub or pan. Plastic dishpans or a double layer foil-roasting pan will work best.
- Fairly clean dirt
- Large spoons to mix the mud
- Broom and dustpan
- Aprons or men's old front button shirts (to protect clothes)
- Water pitcher
- Sturdy plastic spoons for students
- Handout
- Babywipes or paper towels to clean mud off skin

Procedure: Mix the mud ahead of time, not making it too soupy. Make a poster showing the different crater features or use the student handout. The objective is to take a spoonful of mud and fling it into the dishpan. The impact should create crater features. Have the students identify as many features as possible and list them on their handout.

Extension: Show students actual fluidized craters from the surface of Mars and introduce such topics as ground ice or possible underground water on Mars. The following is a link to actual fluidized craters:

http://www.msss.com/mars_images/moc

Name:

MUD SPLAT CRATERS!

<u>Procedure</u>:

1. Scoop a spoonful of mud out of the box.
2. Carefully fling the mud back into the box.
3. Repeat this five times and draw your favorite crater below.

<u>Observations/Conclusions</u>:

1. Draw your best crater, labeling the different features.

2. What are the features of the "perfect" crater?

    1)

    2)

    3)

    4)

    5)

    6)

3. What are two reasons impact craters could look different?

    1)

    2)

Illustration 1: This diagram shows the stages of an impact of a crater. Used by permission of CRATERS! by William K. Hartman with Joe Cain.

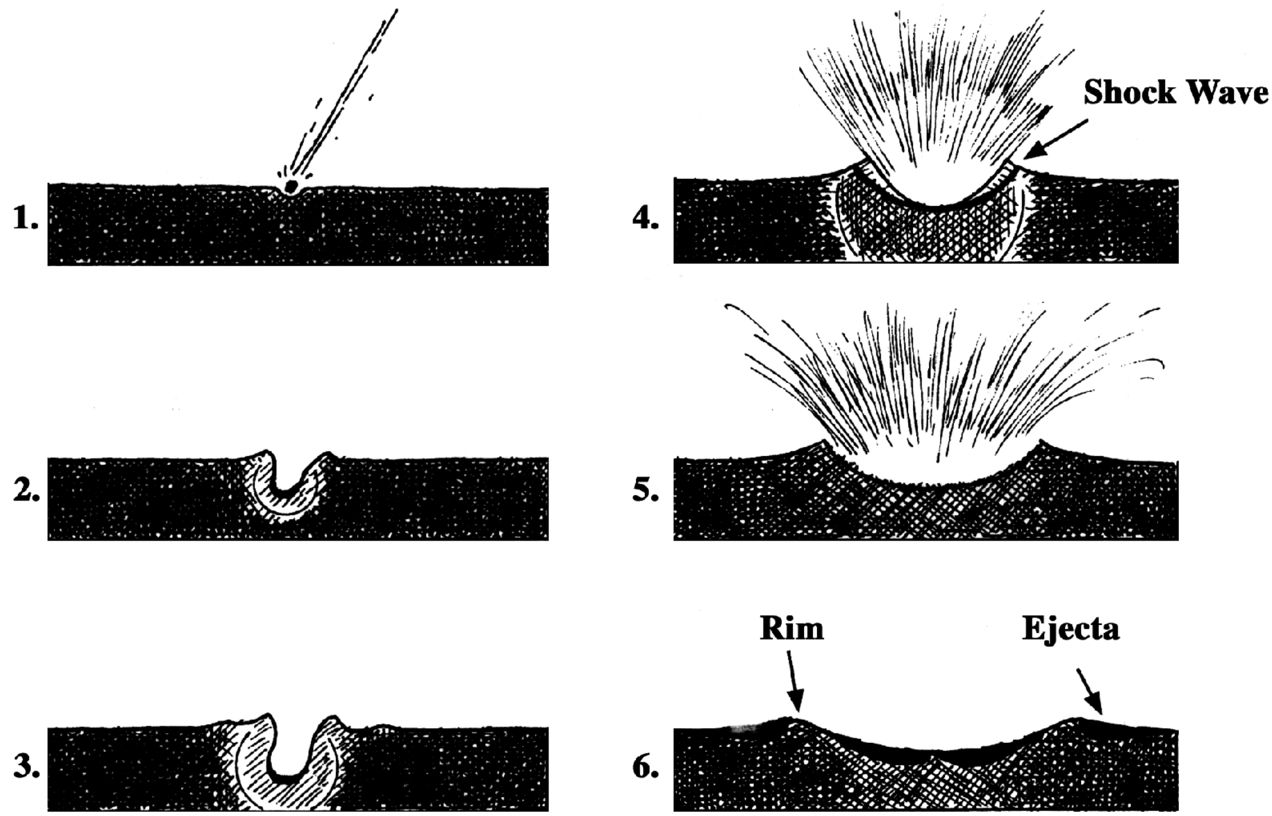
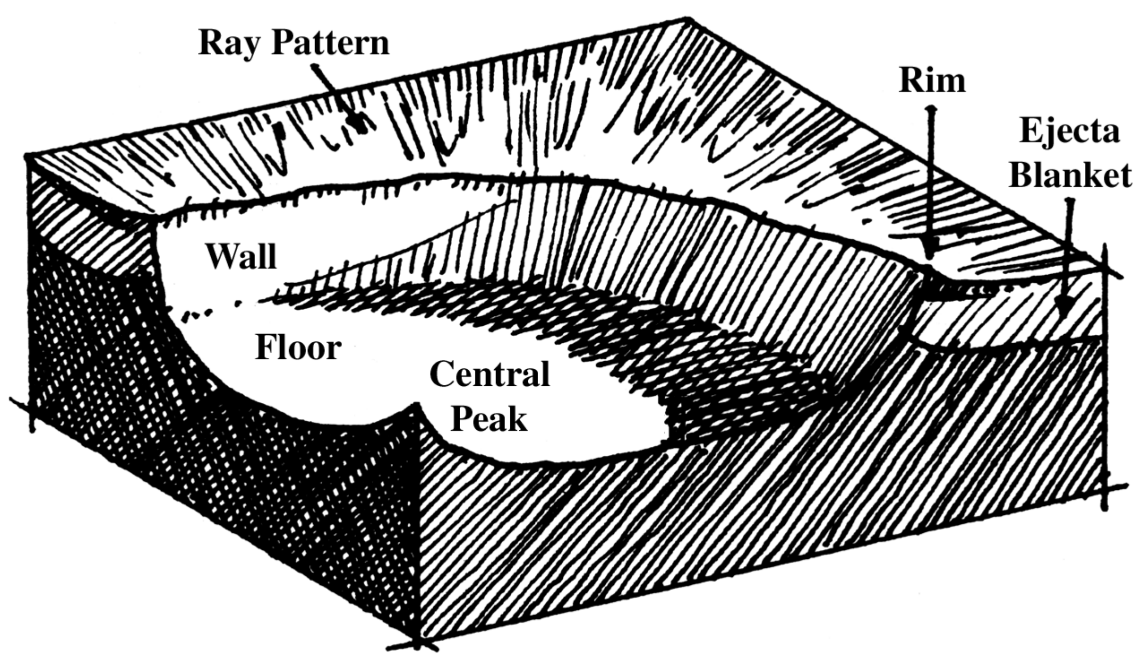


Illustration 2: This diagram shows the features created by an impact crater. Used by permission of CRATERS! by William K. Hartman with Joe Cain.



Solar System Bead Distance Activity

Goal: The students will understand the distances between the Sun, planets, and small objects in the Solar System.

Objective: To create a model demonstrating the scale distances of the Solar System using astronomical units that have been converted into a 10 centimeter scale.

National Science Education Standards:

Standard D: Earth in the Solar System

National Math Education Standards:

NM.5-8.5 Number Relationships

NM.5-8.13 Measurement

Materials:

- Planet beads (large craft pony beads in 11 colors):

Sun	yellow
Mercury	solid red
Venus	cream
Earth	clear blue
Mars	clear red
Asteroid belt	black
Jupiter	orange
Saturn	clear gold
Uranus	dark blue
Neptune	light blue
Pluto	brown

- 4.5 meters of string for each student
- Small piece of cardboard to wrap Solar System string around (10 cm x 10 cm)
- Meter sticks or measuring device
- Student handout

Background:

- To speed up the activity for younger students, the string may be pre-cut and a set of Solar System beads may be put into a plastic ziplock bag for each student. Also, for younger students, a measured marking grid can be put on a table top so the students can mark their measured distances and then tie off the beads. If the pre-marking method is used, extra distance must be added to each planet distance to accommodate the string within each knot (approximately 4 cm for a double knot around the bead). Tape newspapers to the surface where the students will be marking their strings, so they do not mark up the counter or floor.
- For older students, measurements are made each time from the Sun to the planet and tied on after each measurement.

Student Procedure:

1. Convert the various AU distances to centimeters and complete the chart on the student hand-out sheet.
2. Measure and cut a piece of string 4.5 m long.
3. Using the calculated cm distances, tie the bead onto the string using a double knot.
4. When finished with the activity wrap the Solar System string (with beads) around the cardboard holder.

Credits: Tom Gates - NASA Educator, NASA Ames Research Center. Adapted by Steve Klug, Fees Middle School, Tempe, AZ and Sheri Klug, ASU Mars K-12 Education Program, Tempe, AZ.

Solar System Bead Distance Activity

Introduction: Our Solar System is immense in size by normal standards. We think of the planets as revolving around the Sun, but rarely consider how far each planet is from the Sun. Furthermore, we fail to appreciate the even greater distances to the other stars. Astronomers use the distance from the Sun to the Earth as one "astronomical unit". This unit provides an easy way to calculate the distances of the other planets from the Sun.

Vocabulary: Astronomical Unit - 1 AU = approximately 150 million kilometers (93 million miles)

Activity: We will construct a distance model of the Solar System to scale, using colored beads as planets. The chart below shows the planets and asteroid belt in order along with their distance from the Sun in astronomical units. First, complete the chart by multiplying each AU distance by our scale factor of 10 cm per astronomical unit. Next, use the new distance to construct a scale model of our Solar System. Start your model by cutting a 4.5 m piece of string. Use the distances in cm that you have calculated in the chart below to measure the distance from the Sun on the string to the appropriate planet and tie the colored bead in place. When you are finished, wrap your string Solar System around the cardboard holder.

Planet	AU	Scale value (cm)	Color
Sun	0.0 AU	__________cm	yellow
Mercury	0.4 AU	__________cm	solid red
Venus	0.7 AU	__________cm	cream
Earth	1.0 AU	__________cm	clear blue
Mars	1.5 AU	__________cm	clear red
Asteroid belt	2.8 AU	__________cm	black
Jupiter	5.0 AU	__________cm	orange
Saturn	10.0 AU	__________cm	clear gold
Uranus	19.0 AU	__________cm	dark blue
Neptune	30.0 AU	__________cm	light blue
Pluto	39.0 AU	__________cm	brown

Consider that if you were traveling at the speed of light, it would take 8 minutes to travel from the Sun to the Earth (1 AU). It would take 4.3 years (traveling at the speed of light - 300,000 kilometers per second) to reach the next nearest star, Alpha Centauri!

Show the model to your teacher for a grade. You may keep the model!

Planet	AU	Color
Sun	0.0 AU	Yellow
Mercury	0.4 AU	Solid Red
Venus	0.7 AU	Cream
Earth	1.0 AU	Clear Blue
Mars	1.5 AU	Clear Red
Asteroid belt	2.8 AU	Black
Jupiter	5.0 AU	Orange
Saturn	10.0 AU	Clear Gold
Uranus	19.0 AU	Dark Blue
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Alka-Seltzer Rockets
How to Build Your Own Rocket

<u>Before you start</u>:

Building this rocket will help you to understand how real rockets propel themselves into space. **ASK AN ADULT TO HELP YOU!**

<u>What you will learn</u>:

You can use baking soda and vinegar to propel an object across the floor. The object, in this case your rocket, will slide across the floor by the chemical reaction created from the combination of baking soda and vinegar.

A scientist from the early 1700's, named Isaac Newton, came up with an idea about how things move through space. He said a force pushing on an object will create a second force, with the same strength as the first, going in the opposite direction. This idea is now called Newton's Third Law of Motion.

<u>National Science Education Standards</u>:

Standard A: Understandings about scientific inquiry
Standard B: Motions and forces
Standard B: Transfer and energy
Standard E: Abilities of technological design

<u>National Technology Education Standard</u>:

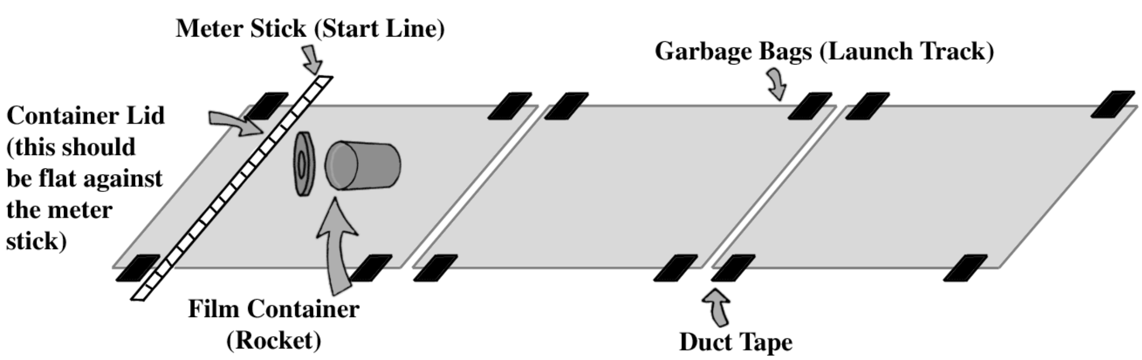
NT.K-12.3 Technology Productivity Tools

<u>What you need</u>:

- Yard stick
- Measuring tape (several feet long)
- Stopwatch (watch with a second hand)
- Baking soda
- Vinegar
- Clear plastic film container (lid snaps closed from inside lip of canister, the black and gray canisters do not work as well)
- Large garbage bags
- Duct tape
- Paper towels

<u>Directions</u>:

1. Tape several large garbage bags to the floor, creating a runway, see diagram.
2. Tape a yardstick to the floor on the narrow side. This can be used as the start line for your launch track.



3. Put a small amount of baking soda into the canister.
4. Add enough vinegar to just cover the baking soda and quickly replace the lid. You can also use Alka-Seltzer tablets and water.
5. Set the rocket on the start line, one end of the plastic bag, with the cap facing you. **BE CAREFUL, IMPROPER USE OF YOUR ROCKET CAN CAUSE EYE INJURIES.**
6. Time the rocket to see how long it takes from launch to when it comes to a complete stop.
7. Place a marker along side the runway where the rocket ends and measure the distance to the final resting point of the rocket.
8. Does the amount of baking soda and vinegar used change the distance that the rocket goes? Try different amounts (**WITH ADULT PERMISSION**) and record you results.

Evaluation:

1. Was the student able to get the canister to travel using the baking soda and vinegar propulsion system?
2. Was the student able to record the results and answer the questions?
3. Was the student able to make any conclusions about the amount of baking soda used and the distance the canister rocket traveled?

Extensions:

1. Does the amount of baking soda used affect the length of time the rocket is propelled? How about the amount of water used?
2. If weight were added to the canister (such as clay to the outside of the canister), would that affect the distance and time the rocket was propelled? Why?
3. What role does gravity play in rocket launches? How does a real rocket get beyond the pull of Earth's gravity?

CAUTION: There is danger of eye or facial injury if rockets are launched upward instead of horizontally. The canisters sometimes discharge prematurely. If canisters are launched upward (vertically), safety glasses should be worn and the activity should be under strict adult supervision.

Name________________________

Team #______________________

Alka-Seltzer Rocket Data Sheet

Instructions:

- Your team will use some baking soda and vinegar to propel your rocket canister.
- Measure the time each rocket takes to come to a complete stop.
- After each test, measure the distance your rocket traveled.
- Use the same amount of baking soda and vinegar for the first 4 trial and average the distance traveled and the time of each launch.
- Finally, test the rockets with different amounts of baking soda and vinegar and time the last 4 trials.
- How do they compare to the first trials?
- Were there any other factors that you needed to keep constant?

Rocket Number	Amount of Baking Soda	Amount Vinegar	Distance Traveled (inches or cm)	Time (seconds)
1				
2				
3				
4				
Average of Rows 1-4				
5				
6				
7				
8				

Alka-Seltzer Rockets
Student Sheet

<u>Newton's Third Law</u>:

If one object exerts a force on a second object, the second object exerts an equal but opposite force on the first.

<u>Directions</u>:

Answer the following questions based on what you learned from you rocket experiments.

1. What do you think was taking place inside the canister with the baking soda and vinegar?

2. Why do you think the canister cap blew off?

3. How is this similar and/or different from a real rocket?

4. How did using different amounts of baking soda effect the time and distance traveled by the canister?

5. How does Newton's Third Law of Motion relate to the rocket launching?

Soda Straw Rocket Activity

Goal: Students will study how basic rocket processes are applied to space flight.

Objective: Students will demonstrate the ability to conduct an experiment and analyze and interpret the results.

National Science Education Standards:
Standard A: Abilities necessary to do Scientific Inquiry
Standard B: Motions and forces
Standard E: Abilities of technological design

National Mathematics Education Standards:
Measurement
Patterns and Functions

National Technology Education Standards:
NT.K-12.3 Technology Productivity Tools

Materials:

- Soda Straw Rocket Templates
- Soda Straw Rocket Data Log Handout
- Soda Straw Rocket Data Analysis Handout
- Sharpened pencil
- Tape
- Straw
- Meter stick and/or tape measure

Procedures:
Soda Straw Rockets is an extremely versatile activity that can be easily adapted to accommodate a broad range of students in varying age groups. The procedure presented here is but one of many possible ways the activity can be utilized – feel free to experiment and modify!

Students should follow the instructions provided on the soda straw rocket template in order to construct their rocket. Students can be organized into groups of 4-6 so that each of the students within the group can build a rocket with a different length nose cone. Students should select a control for this experiment. This control should be something similar to what you are testing, but something that will be unaffected by the things you are changing. For this experiment, construct one control rocket that has almost no nose cone at all. Just tape the end of the paper tube closed. Students will launch each rocket one at a time and record the distance it traveled (in centimeters) on the Data Log Handout. Students may wish to write in any observations they want to remember as they perform their experiments. Students should do five trials of the experiment and record the results on their Data Log. Students will then graph their data on the Data Analysis handout in order to draw a conclusion as to which nose cone length produced the best rocket.

Extensions:

1. Students can determine the mean, median and mode each rocket distance.
2. Students can experiment and design a new template for a rocket that they feel will fly better than the rocket design provided.
3. Students can complete this experiment focusing on launch angles rather than nose cone lengths.

NOTE: Rocket launching should take place in an open enough area where students are able to stand out of the way of rockets being launched.

Soda-Straw Rocket Template

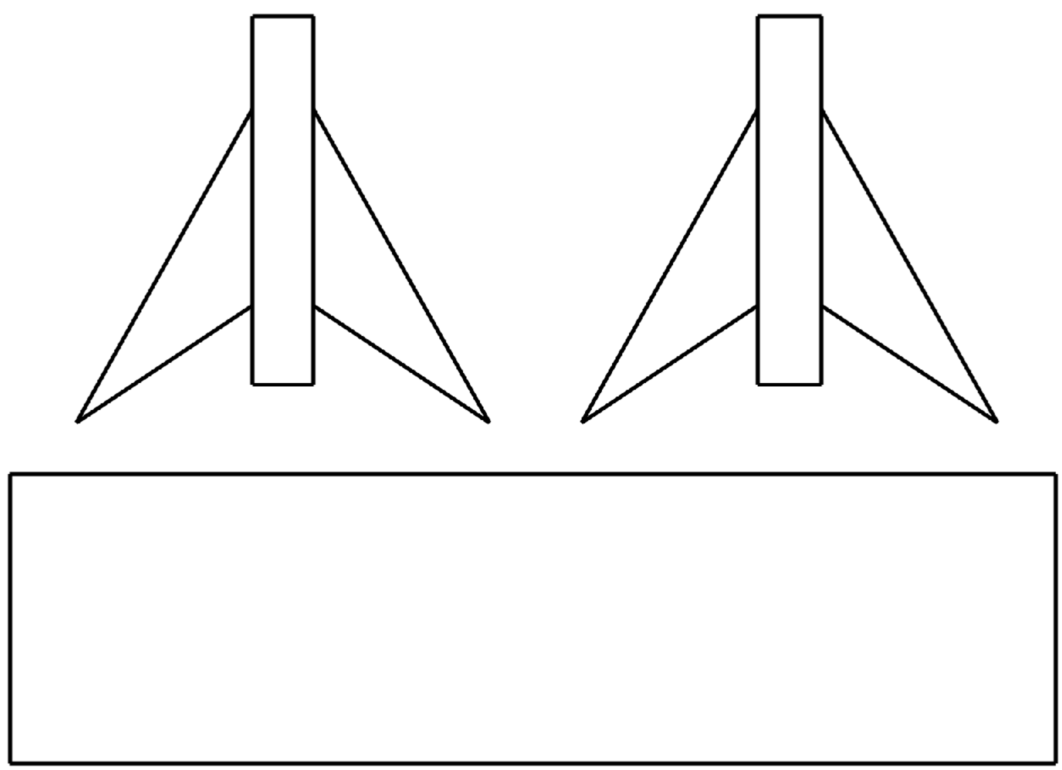
1. Carefully cut out the rectangle. This will be the body tube of the rocket. Wrap the rectangle around a pencil length-wise and tape the rectangle so that it forms a tube.

2. Carefully cut out the two fin units. Align the rectangle that extends between the two fins with the end of your body tube and tape it to the body tube. Nothing should stick out past the body tube! Do the same thing for the other fin unit, but tape it on the other side of the pencil, so you have a "fin sandwich".

3. Bend the one fin on each fin unit 90 degrees so that each fin is at a right angle to its neighbor. When you look along the back of the rocket, the fins should form a "+" mark.

4. Using the sharpened end of your pencil, twist the top of the body tube into a nose cone. Measure your nose cone from its base to its tip and record the length on your Data Log and on the rocket itself.

5. Remove the pencil and replace it with a soda straw. Blow into the straw to launch your rocket! Record the distance it travels on your Data Log.



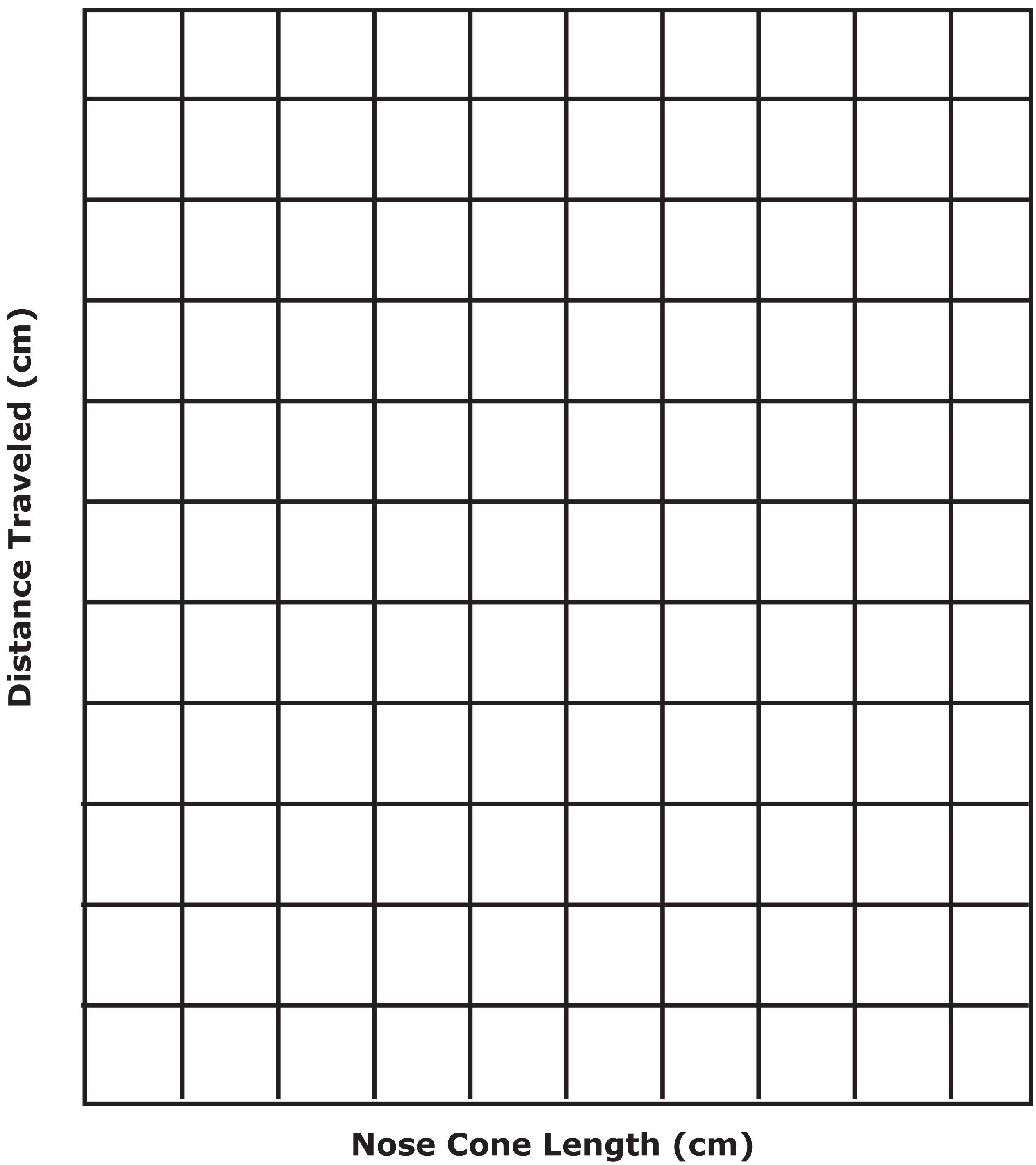
Courtesy…John Callas (JPL)

Soda-Straw Rocket Data Log

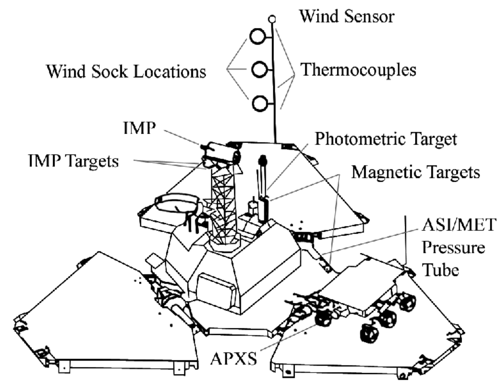
Distance Traveled (in cm)

Length of Nose Cone	Trial #1	Trial #2	Trial #3	Trial #4	Trial #5	Notes
Control						

Soda-Straw Rocket Data Analysis



MARS PATHFINDER
TWO DIMENSIONAL MODEL



Compiled by Amalia Kingsbury
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These instructions are to help you create your own *Mars Pathfinder two dimensional model. It's amazing to see first hand how small Mars* Pathfinder was.
The dimensions given are approximate. They are very close to the real dimensions. Also, drawings are not to scale.

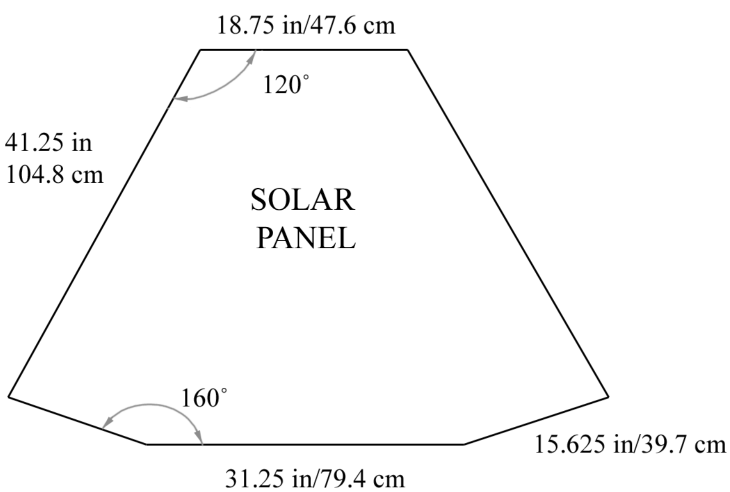
NATIONAL SCIENCE EDUCATION STANDARDS:
- Standard E: Abilities of technological design

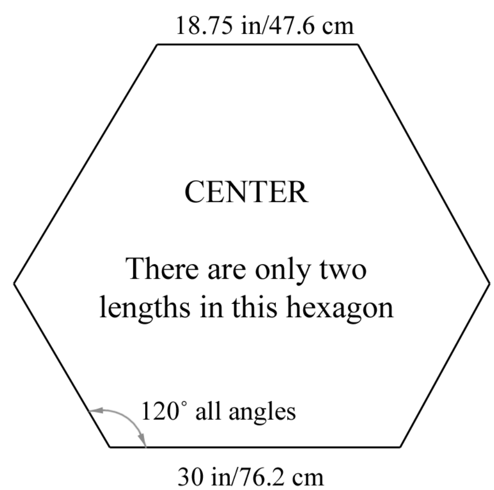
NATIONAL MATH EDUCATION STANDARDS:
- NM.5-8.13 Measurement

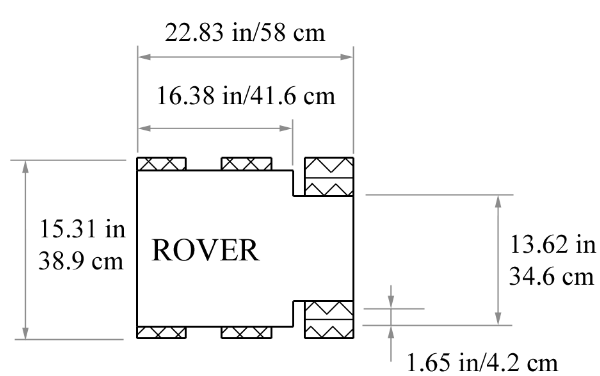
NATIONAL TECHNOLOGY EDUCATION STANDARDS:
- NT.K-12.3 Technology Productivity Tools

MATERIALS
- 13 dark blue pieces of cardboard 22" x 28" for 3 solar panels
- 4 white pieces of cardboard 22" x 28" for I center panel
- 1 blue piece of 22" x 28" cardboard for Sojourner microrover
- 2 rolls of clear packing tape

INSTRUCTIONS
1. Since cardboard is not manufactured large enough to fit the model's dimensions, it is necessary to tape several pieces of cardboard together to make a 76" x 44" sheet for each panel.
2. After making the 76" x 44" cardboard sheets, simply draw and cut all panels. Sojourner microrover will fit nicely onto a 22" x 28" piece of cardboard.
3. Enjoy your model!







Mars Pathfinder Egg Drop and Landing (EDL)

National Science Education Standards:
Standard A: Abilities of inquiry science
Standard E: Abilities of technological design

National Technology Education Standards:
NT.K-12.3 Technology Productivity Tools
NT.K-12.6 Technology Problem-Solving and Decision-Making Tools

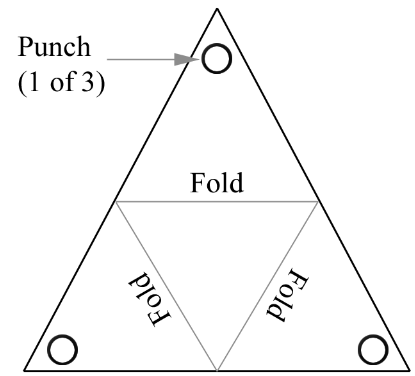
Materials:
1 cereal box, 4 balloons, 5 m of string, newspaper,
1 egg, tape, scissors, ruler, pencil, hole punch

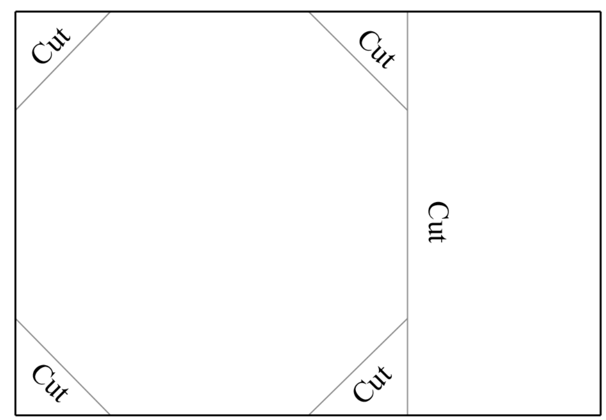
Lander
1. Starting with a cereal box, unfold the box
2. On one side of the box, trace an equilateral triangle, 22 cm (8.5 in) on a side.
3. Cut out the triangle and punch a single hole near each vertex.
4. Fold the triangle into a tetrahedron to form a "lander".
5. Place the egg inside the tetrahedron and tape closed along each seam.
6. Tie a 1-m (40 in) piece of string through the holes at the vertices.

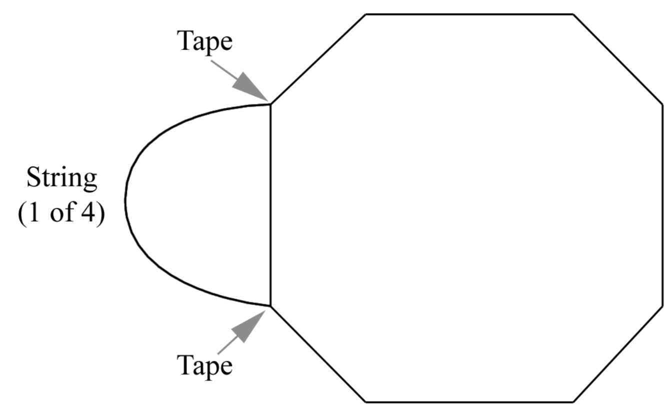
Parachute
1. Unfold a large piece of newspaper.
2. Cut off the edge of the newspaper sheet to form a square.
3. Cut off each corner of the square to form an octagon.
4. Using four 1-m (40 in) pieces of string, tape each end of each string to adjacent corners of the octagon parachute.

Air Bags
1. Inflate four 25-cm (10 in) balloons.
2. Using tape rolled back on itself, tape each balloon to each face of the lander.
3. Gather the four strings on the parachute and tie them to the string on the lander.

Entry, Descent and Landing (EDL)
Drop your "Pathfinder" from a high place and see if your payload (egg) survives!







Cool Internet Sites

JPL Mars Mission Homepage: http://marsweb.jpl.nasa.gov

NASA Astrobiology Homepage:
http://nai.arc.nasa.gov/index.cfm

ASU Mars Education / Thermal Emission' Spectrometer Homepage:
http://tes.asu.edu

Athena Rover Homepage: http://athena.cornell.edu

Windows to the Universe Homepage:
http://www.windows.ucar.edu/windows2.html

Stardust Homepage: http://stardust.jpl.nasa.gov

Hubble Space Telescope:
http://quest.arc.nasa.gov/hst/index.html

Cassini Mission to Saturn:
http://www.jpl.nasa.gov/cassini

Galileo Mission to Jupiter: http://galileo.jpl.nasa.gov

Deep Space Network Homepage:
http://deepspace.jpl.nasa.gov/dsn/dsn_educ.html

Solar System Simulator: http://space.jpl.nasa.gov

SETI Homepage: http://www.seti-inst.edu/Welcome.html

Astronomy Picture of the Day
http://antwrp.gsfc.nasa.gov/apod/astropix.html

Planets: http://pds.jpl.nasa.gov/planets

Space Place: http://spaceplace.jpl.nasa.gov