SETI INSTITUTE

Mission 1
Comparative Planetology

Searching Earth, Mars, and Venus for Signs of Life!

Overview

Mars is the planet in our solar system most like Earth. Both are tilted on their axis of rotation, both have seasons, ice caps, and winds, and both exhibit similar geologic features, some apparently carved out by water. However, Mars is much smaller than Earth, is very cold, and at present has little atmosphere. In the past, its atmosphere was dense, which helped make the surface of the planet much warmer. Venus is about the same size as Earth, but it is a hot, high-pressure planet with a dense cloud cover. Present conditions are quite harsh, but Venus shows evidence of once supporting an ocean and being more like Earth. Earth is the only planet that is known to have life, but our curiosity and the very possibility of life in our solar system require the search to continue! In mission 1.1, students see a video image show of present-day Earth, Mars, and Venus and search for features on these planets that might indicate life. In mission 1.2, students construct an orbital model of Earth, Mars, Venus, and the Sun. Students learn about conditions on the three planets and the relationship of these conditions to some of the requirements for the origin of life as we know it and its continued existence.

Mission 1.1
Materials

For a Class of 30

- *Voyages to Earth, Mars, and Venus* video
- Data Projection and Power point file**********************.
- "Voyages to Earth, Mars, and Venus" video script

For Each Student

- "Looking for Life" worksheet
- Pencil
- SET1 Logbook

Getting Ready

1. Set up the VCR and monitor and review the video images and the script.

2. The three video segments (one each for Earth, Mars, and Venus) can all be shown in one class period or one per day to allow more time for discussion. Gauge time accordingly.

3. Copy the worksheet “Looking for Life.”

Classroom Action

1. **Introduction.** Despite what we see in television shows and movies about space travel and extraterrestrials, Earth remains the only planet we know of that supports life. However, there is a great deal of scientific curiosity about life on other planets-some scientists are attempting to detect planets beyond our solar system, some are focusing on planets within our solar system. By participating in the Life: Here? There? Elsewhere? The Search for Life on Venus and Mars activities you will join scientists in searching for life in our planetary neighborhood.

   The most likely candidates with the potential for supporting extraterrestrial life are Venus and Mars. Why? Because they are the most Earth-like planets in our solar system. Both planets have been studied closely. Most of the surface of Venus has been mapped by radar and its atmosphere sampled by Magellan, a United States spacecraft. A Russian spacecraft, Venera, even landed on the surface of Venus and sent back photos of what it saw!

   Mars has been observed even more thoroughly. Like Venus, Mars has been carefully mapped by orbiting spacecraft. Unlike Venus, the surface of Mars was investigated over a long period of time by two NASA spacecrafts, Vikings I and 11, which landed on Mars in 1976. Scientific instruments on board measured the surface temperature, the speed of the winds, the composition of the atmosphere, and seismic activity, and also took pictures of the surrounding area. An on-board suite of instruments tried to detect the presence of life on Mars. While no conclusive evidence for life was found, the results have inspired future generations of scientists to join the search for extraterrestrial life.

   The missions to Venus and Mars raised many questions. Scientific evidence indicates that some of the conditions that led to the evolution of life on Earth also existed on both early Venus and early Mars. Could life have evolved on our neighboring planets? Could it still exist there? In the activities that follow, you will examine and compare Venus, Earth, and Mars. You will study the characteristics of living Earth organisms, learn a variety of methods of testing for life, study the results of the *Viking* life experiments, and finally, devise life-detection experiments that could be carried on some future spacecraft! In the process you will become comparative Planetologists and Exobiologists.

   Write “Comparative Planetologist” on the chalkboard. Ask students to look at the parts of the word *planetologist* to find its definition. Remind students that the suffix *ologist* means “one who studies.” Ask students what a *comparative* planetologist might do. *(Comparative planetologists explore and compare the planets to learn about their composition, formation, and major features. These aspects are important to our understanding of life in our solar system.)*

Write “Exobiologist” on the board. Ask students to look at parts of the word to find its definition. Remind students that the prefix *exo-* means “outside,” or “beyond.” *(An exobiologist is a scientist who studies life outside or beyond Earth.)*

2. **Worksheet.** Hand out the worksheet “Looking for Life.” Explain to students that there will be breaks during the video image show for them to answer the worksheet questions.

3. **Video Image Show.** Explain to students that they are going on three “space voyages” to look at Earth, Mars, and Venus. They will view each planet from a telescope, a spacecraft in orbit, and or images taken at the surface to see if they can tell if there is life on these planets.

   For Earth and Mars, the images will simulate a voyage to the planet, with the proximity of the “camera” getting closer and closer to the surface. For Venus, the images will present the radar mapping data received from the robotic *Magellan* spacecraft. *Magellan* images are created by computers from radar map data.

   Show the video segments for Earth, Mars, and Venus. During each segment, discuss what students are seeing on the planet in the images. Ask them if they can detect the presence of water or the presence of life in the soil or atmosphere. Would they know how to build a spacecraft and lander to survive the conditions on the planet? What do they think caused the major geologic features present on the planet? Suggest these causes: plate tectonics, volcanism, erosion by wind or water, and evaporation.

   While showing the video images, ask students to speculate what they might see at the next, closer level of exploration (the next image). Show students the next image and have them compare what they see with what they expected. This exercise is especially good when observing the images of Mars or Venus because these worlds are unknown to the student audience. Have students discuss how each image reveals new insights and changes their understanding of the planet as a whole.

   After showing all the images, ask students if they think they could look at some other planet very, very closely and tell if there was evidence of life.

Mission 1.2 Materials

For a Class of 30

- “Planet Attribute Cards” (or optional “Blank Planet Attribute Cards”), cut apart (pages 38 and 39)
- Clock with a second hand
- Overhead projector
- “Comparing the Planets” transparency
- “Orbital Model” transparency
- (optional) Three colors of paint and brushes (if clay will dry hard)

For Each Team

- 50 meters of string
- 4 thumb tacks
- Meter stick
- Scissors
- 112 to 1 pound of clay
- Compass
- “Creating an Orbital Model” directions
- (optional) Pencils
- (optional) Piece of cardboard

For Each Student

- “Orbital Model” worksheet
- “Attributes of the Planets” optional worksheet
- Pencil

Getting Ready

1. Divide the clay into approximately equal chunks, one for each team of two students.

2. *(optional)* To save time in class, cut the string into the following lengths, 15 of each: .72 meters, 1 meter, and 1.52 meters. Or, if students will be cutting the lengths, cut the 50-meter length into 15 lengths of 3.24 meters each.

3. Copy the “Creating an Orbital Model” directions for each team and the “Orbital Model” worksheet for each student. Make one set of “Planet Attribute Cards.” Copy the “Attributes of the Planets” optional worksheet for each student if it will be used.

4. Prepare the transparencies “Comparing the Planets” and “Orbital Model.” Set up the overhead projector. (or Data projection and Power point file********.**

Classroom Action

1. **Preliminarily.** Divide the class into teams of two students each.

2. **Transparency**. Show the overhead transparency “Comparing the Planets.” Tell students that they will make models of these three planets with clay.

3. **Activity.** Ask the teams to construct their clay planets. First, the clay will be split into two equal balls. One of these balls becomes the first planet. The other ball should be divided into seven smaller balls of equal size. One of these balls becomes the second planet. The

remaining six small balls should be combined into one to become the third planet. The three clay “planets” are now sized in correct proportion to each other.

Ask students which clay planet they think represents Earth, Mars, and Venus. (Earth is represented by the largest clay ball ,Venus by the slightly smaller ball, and Mars by the smallest ball.) Ask students how many times bigger Earth is than Mars and how many times bigger Venus is than Mars. They should mark the surface of each planet-with the letter V, E, or M-so they can be quickly and positively identified. If the type of clay used will dry hard, have students paint each planet a different color.

4. **Transparency.** Show the overhead transparency “Orbital Model.” Tell students that they will make an orbital model with their three clay planets by following their “Creating an Orbital Model” directions.

   Hand out the “Creating an Orbital Model” directions and materials to each team. Give each team either three pieces of string (one each of lengths .72 meters, 1 meter, and 1.52 meters) or one piece of string (3.24 meters in length). Hand out the “Orbital Model” worksheet to each student.

   First, if the string has not already been so cut, students need to cut their string into the following lengths: .72 meters, to represent a scale average distance from Venus to the Sun; 1 meter, to represent a scale average distance from Earth to the Sun, and 1.52 meters, to represent a scale average distance from Mars to the Sun. These lengths represent the average distance between the Sun and the planet in the orbits of Venus, Earth, and Mars, respectively. (On this scale, 1 meter = 1 Astronomical Unit, or AU, which is 150 million kilometers.) Tell students that the distance scale is not the same as the size scale. Tell students that assuming the string size remains the same, the planets (if made at the same scale as the distances) would be infinitesimal, mere dust motes-thus there are two scales.

5. **Activity.** Have the teams construct their orbital models. Using thumb tacks, students should attach the appropriate string to each planet by pushing it into the clay or by using a tack, and then tie together the ends of the three strings. If possible, the knot where the three strings are tied together should be pinned to a firm surface like cardboard or a notebook. This knot represents the location of the Sun. The cardboard stabilizes the “Sun” in the center of the desk while students manipulate the “planets.”

   Have students use their clay models to discover the arrangements for the shortest and longest possible distances between Earth, Mars, and Venus. Have students use string and meter sticks to calculate how far away these planets are from one another. They should use compasses to draw the planetary orbits on their worksheets.

6. **Activity.** Have students form groups of two teams each for this activity. Each team should remove the central point of their orbital model (the Sun) from the cardboard and pin it to the eraser on a pencil. One student, representing the Sun, should hold this pencil high, so the strings don't get too tangled. Others students will take turns “becoming” Venus, Earth, and Mars, holding their respective planets high.

One student watches a clock with a Second hand to time the other students. First, Earth demonstrates one Earth year by walking counterclockwise around the Sun in 60 seconds. Next, Venus demonstrates one Venus year by walking counterclockwise around the Sun in 36 seconds. Then, Mars demonstrates one Mars year by walking counterclockwise around the Sun in 114 seconds.

Ask groups to demonstrate various scenarios for the class. For example, how many revolutions does Venus make around the Sun in one Earth year? Have one team show only the movement of Venus while a second team shows only the movement of Earth. Both planets should begin at the same compass point and then orbit the Sun for 60 seconds at their appropriate orbital rate. (Earth will make 1complete revolution while Venus makes 1.66 revolutions.) Many other such comparisons can be made.

It is not practical to have three students representing the three planets orbiting one Sun at the same time because the strings tend to get very tangled. A solution is to mark out a chalk circle on the floor for each planet to follow; this way, students can carry the clay planets without the strings attached.

7. **Display.** Attach one of the planetary models to a bulletin board and hang the appropriate planet attribute card under each planet.

   Use the bulletin board to illustrate a discussion of how the distance from the Sun might be critical to whether or not there is a possibility for life to begin and survive on each planet. To get the discussion started, ask students to explain what they know about the evolution of the first life on Earth. What was Earth's early environment like? How might this compare to early Venus and Mars? How has Earth evolved in a way that allows life to thrive but Venus and Mars appear barren? Why are Mercury and Saturn unlikely candidates for life?

   As a wrap up to this discussion, describe the “Goldilocks Model”- the question of life seems to be connected with the question of whether or not liquid water can exist on the surface of a planet. Early in their evolution, Venus, Earth, and Mars all appear to have had liquid water. The changes in their planetary atmospheres have produced what some scientists call the “Goldilocks Model” of the inner solar system. Mars is too cold, Venus is too hot, and Earth is just right-for liquid water.

8. ***Optional Homework*.** Hand out the optional worksheet “Attributes of the Planets.” Give each student a copy of the “Planet Attribute Cards” to use in completing this homework assignment. Have students use the library to find additional information on the planets.

Going Further

Activity: The Rest of the Solar System

Ask students to calculate the scale size of each model planet, and how far away from the model Invite students to use more modeling clay to create an orbital model that contains all nine planets in a system and their major satellites. Provide students with the following algorithm for making scale diameter calculations of planets.

To calculate the size of a model planet:

1. Measure the diameter of your clay Earth in centimeters:

2. Divide 12,756 (actual diameter of Earth, in kilometers) by the diameter of your clay Earth: _____. This number is your scale of how many kilometers each centimeter represents.

3. For any planet, divide its actual diameter (in kilometers) by the scale number calculated in step 2. The answer is the diameter (in centimeters) for a clay model of that planet.

actual diameter / scale = model diameter

Sun to place its orbit. Caution: The gas giant planets (Jupiter, Saturn, Uranus, and Neptune) are so big (Jupiter, for example, has a volume 1,323 times that of Earth) that they will require some other material, such as fluffy cotton, to realistically construct them. Have students calculate the diameter of the ball of clay that would represent Jupiter.

Discussion/Research: Goldilocks in Space

Goldilocks found that Papa Bear's porridge was too hot, while Mama Bear's porridge was too cold. However, Baby Bear's porridge was just right. In a similar way, Venus today is too hot for life as we know it, while current Mars is too cold for life as we know it. It may be that only our own Earth is “just right.” Have students consider what would happen if Earth was nearer to the Sun, like Venus, or farther away, like Mars. What is the probability that Earth would be at just the right distance from the Sun? How much variation could there be in this distance, while still maintaining the right temperature range for life? Is this range related to the physical properties of water? Have students research why the planets formed at their particular distances from the Sun. Where do planets form within the disk of material that encircles a newborn star? How many planets that form in a system will have orbits that are the right distance (in the “life zone”) from a star so as to make them suitable for life?

Discussion: Greenhouses and Global Warming

Discuss the evolution of Earth, Mars, and Venus: Venus: each planet has evolved to become the way it is today. Early Mars was much like early Earth: it had a carbon dioxide (CO_2) atmosphere that trapped heat from the Sun like a greenhouse, and it had liquid water on its surface that carved rivers and channels. Mars was too small to retain its atmosphere, which gradually escaped into space, and the planet cooled down.

Venus once was covered with an ocean, but a dense greenhouse atmosphere gradually heated its surface and boiled away the water. Atmospheric sulfur dioxide (SO_2) oxidizes to form sulfur trioxide ($2S0_3$). Sulfur trioxide combines with the water in Venus' atmosphere to form sulfuric acid (H_2S0_4), an extremely corrosive chemical. Some of the water from the surface of Venus is now in its corrosive atmosphere.

Today, the life-supporting climate of Planet Earth is being threatened by the greenhouse effect. Most scientists fear that our global climate will increase in temperature as modern life-styles and technology produce increasing levels of greenhouse gases, such as carbon dioxide and methane. Some fear a spiraling effect that could leave Earth looking like Venus does today.

Research: Radar, Bats, and Dolphins

The *Magellan* spacecraft's images of Venus were constructed through radar imaging. Ask students to research radar. How does a radar camera work? How does the policeman's radar "gun" work? Does it send an image back to the police car? How is this radar similar to the way that bats, dolphins, and other animals use echo location to "see" where they are going in darkness or water? Can blind people learn to "see" by echo location?

Library Research: Missions to Outer Space

Have students research the Apollo, Venera, Magellan, Viking, and space shuttle missions that gathered data and took pictures on our neighboring planets. How were they taken? Have students research other interplanetary missions like Voyager I and Voyager 11, Pioneer, and Galileo. Were the pictures taken on these missions different? What conclusions have scientists come to by looking at these pictures? Most of these missions were not designed to detect life. Even so, could they do it? What measurement might they take, or what scene might they photograph, that would unequivocally show evidence of the presence of life?

Activity: Truth and the Tabloids

Ask students to bring in articles from various tabloids that "prove" that there is life on other worlds. Have them look for articles about the "Great Stone Face" on Mars, cities on the Moon, and so forth. How do we judge if these stories are truthful? Some students may believe anything they read, while others will automatically disbelieve anything that appears in a tabloid, even if it is true. Try to develop logical strategies for analyzing stories from tabloids or from the daily newspaper. Encourage students to be skeptics!

Arrange a lesson on how easy it is to "fake" photos, especially given the graphics computer technology available today. Many tabloid claims are simply hoaxes based on fake photos. Challenge students to make their own convincing "hoax" photos or videos of UFOs and extraterrestrials! What sort of proof would be enough to believe an extravagant claim, such as that of a flying saucer landing on Earth? Such a "grand" claim would require "grand" evidence. A physical artifact (not a photo of one) that could be tested and shown to be impossible to make on Earth would be "grand" evidence. Or a new fact, one that no one on Earth could possibly know or find out, but could still be substantiated by building a new telescope or other instrument would also be "grand" evidence.

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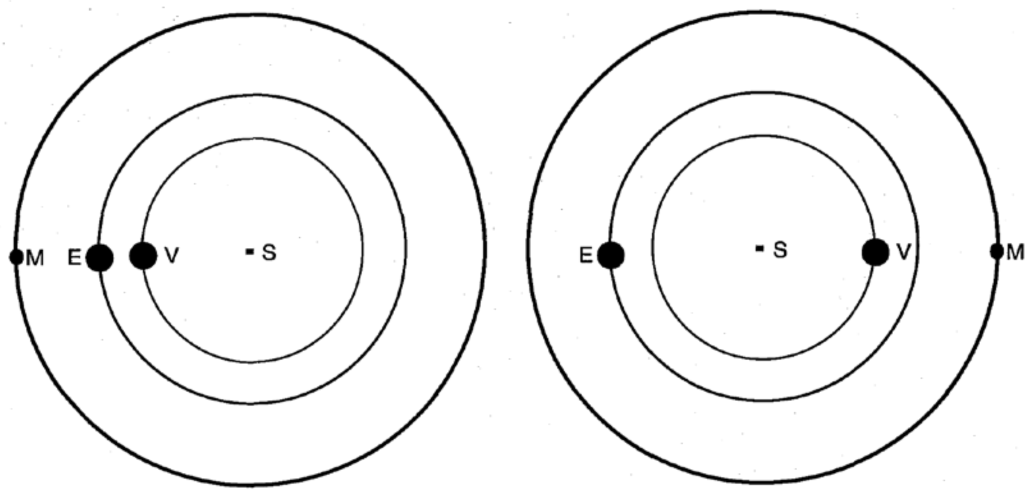
Orbital Model-Teacher's Key

1. On one of the blank orbital pictures below, add Venus and Mars to their orbital paths as close as possible to Earth. Label Venus with the letter V and Mars with the letter M. On the remaining blank orbital picture below, add Venus and Mars to their orbital paths as far as possible from Earth.

   Label the planets again.

Figure 1.1—Orbital Model.



2. If 1 meter on your orbital model represents 150 million actual kilometers, what is the shortest distance that can occur between Earth and Venus? .28 meters x 150,000,000 km = 42,000,000 kilometers Earth and Mars? .52 meters x 150,000,000 km = 78,000,000 kilometers

3. What is the greatest distance that can occur between Earth and Venus? 1.72 meters x 150,000,000 km = 258,000,000 kilometers

   Earth and Mars? 2.52 meters x 150,000,000 km = 378,000,000 kilometers

Script for Video Images

“Voyages to Earth, Mars, and Venus”

Ladies and gentlemen!

We are now going to take three imaginary voyages to three planets. The first is a voyage to Earth, the second is a voyage to Mars, and the third is a voyage to Venus.

We will imagine that we are seeing each planet through the cameras of a tiny spacecraft, which will approach and land to look for signs of life. In each case, the only information we will have about the planet is the information that we can see in the pictures the spacecraft sends back to us. In the case of Earth, it will be harder to imagine this because we live here and we know all about Earth. So, let's pretend that we are extraterrestrial scientists, perhaps exobiologists from a planet that orbits Alpha Centauri. This way, the only information we will have will be the information shown in the pictures.

As you watch the video, your challenge will be to study each picture carefully and see if you can find any evidence that there is life on the planet, or evidence that life was present in the past. If you can't find evidence of life in the pictures, see if you can find features of the planet that might make it a good environment for life. Raise your hands as you get ideas and I'll call on you to share them. Keep track of your ideas and your classmates' ideas on your “Looking for Life” worksheet. Okay, ready? Let's begin.

Voyages to Earth

Image # 1

We're approaching Earth, the third planet out from a G-type yellow star. We're passing the planet's single moon en route to our destination. The Moon is now about 160 kilometers below us; the planet is still about 400,000 kilometers away. We see Earth against the black backdrop of pace. The Sun is straight above us, out of the picture, 150 million kilometers away. Look at the razor-sharp horizon of the Moon; it turns abruptly from brown to black at the edge. This is because earth's Moon has no atmosphere. On a planet with an atmosphere, the horizon is fuzzy and discolored. Let's proceed to the next image and then start looking for signs of life.

Image # 2

We're getting closer. Seen from this distance, Earth is always about half-covered with slowly moving white vapors. The vapors swirl in streams and in huge circular patterns. If we watch long enough, we could eventually map the surface of the planet under the vapor cover. We see that the surface consists of irregular brownish shapes -continents- against a blue background. Toward the southern pole of the planet the surface is white. The brown surface features do not change their shapes during the year. The white surface feature toward the southern pole gets a little bigger in winter, then shrinks again in summer. What are these features? Do you see any signs of life? Do you see any signs of an environment that might support life?

Image # 3

We're getting closer. If our spacecraft stayed here for a year, it would be easy to see that some of the continents are green in spring, then turn brown during summer and fall, then (near the poles) turn white in winter. Near the equator, the continents stay green all year or (in some areas) only turn brown (but not white) for part of the year. What causes these color changes? Do you see any signs of life? Do you see any signs of an environment that might support life?

Image # 4

Closer still! From about 160 kilometers up, we see more surface detail. The vertical blue strip through the center of the photo has an interesting feature. Its opposite shores fit together! It looks like the blue strip is a widening crack that was once much narrower. Not much white vapor here. Also, the surface colors are patchy. The dark patches get slightly darker and bigger when there is more vapor here. What are these features? Do you see any signs of life? Do you see any signs of an environment that might support life?

[Notes: The horizon is slightly fuzzy, indicating an atmosphere. As more convincing proof of an atmosphere, there is a dust storm blowing out over the water. No proof yet that the blue stuff is a liquid.]

Image # 5

Our spacecraft is now flying about 160 kilometers over the surface, preparing for its final descent. Below us we see that the surface isn't smooth. There are meandering channels that join and go downhill toward the blue area. The higher elevations have white on them. The white patches get bigger in winter and smaller in summer.

What are these features? Do you see any signs of life? Do you see any signs of an environment that might support life?

Image # 6

Cowabunga! There is a cloud of something billowing up from the surface of the planet! What can it be?

[Notes: Possibilities are a volcano, something burning on the surface, a dust storm, or a chemical reaction that is creating vapors. In any case, it is clear that there is an atmosphere. If there is a fire, then the atmosphere must contain oxygen.

Image # 7

Suddenly we have a view that suggests that the blue areas consist of some liquid with waves on the surface!

What could it be? Do you see any signs of life? Do you see any signs of an environment that might support life?

[Notes: This image shows clear, faint, geometric patterns on land that would be very difficult to attribute to a nonliving process. Certain fault lines on Earth are very long and absolutely straight, but this view definitely raises the possibility that intelligent life may be at work.]

Image # 8

We're nearing touchdown! We fly by an immense crater! What can it be?

[Notes: The straight lines in this view could be due to faults, but, as in the preceding image, they are probably the work of intelligent beings. From the image, it cannot be determined whether the crater is volcanic or meteoritic.]

Image # 9

This planet has active volcanoes! Our space probe goes flying by one that is actually erupting!

Image # 10

We've landed! There is a huge wave of some liquid surging toward us! We have time for only one reading-air temperature is 12” C -and a quick look through the microscope camera.

Image # 11

There it is! It's round….. it's about four centimeters in diameter.... it's-Our probe has stopped sending pictures!

Stop and Assess What You've Seen on Earth

Rewind the video and take a second look at various images if students want to study them longer. Give students time to answer the following two questions on their “Looking for Life” worksheet.

1. In the images of Earth, did you see any environmental features that could support life as we know it?

(The liquid's temperature of 12” C indicates that it is probably water. An atmosphere is present. Oxygen is present, but only if the class agrees that the cloud in image # 6 was actually smoke.)

2. In the images of Earth, did you see any features that could only have been created by life?

(No. Color changes could be caused by seasonal moistening of the surface by rains. Straight lines could have been caused by geologic faults. Geometric figures could have been caused by huge regional faulting patterns. However, the geometric patterns could also have been caused by intelligent life.)

Voyages to Mars

Image # 12

Our next space voyage in search of life will be to the planet Mars, the fourth planet out from a G-type yellow star. But first, let's re-create a real voyage to Mars. In the 1970s, NASA launched two spacecraft toward this planet. These were called the *Viking* missions. This image shows one of those missions.

Mars is the fourth planet from the Sun. When the first *Viking* spacecraft was launched, Earth was at the seven o'clock position in its orbit and Mars was at the five o'clock position in its orbit. In this view, both planets are going counterclockwise. The *Viking* spacecraft followed this dotted line and intercepted Mars midway between its eleven and twelve o'clock positions. By that time, Earth had passed Mars and was now at Earth's eight o'clock position. When the spacecraft arrived at Mars, it went into orbit around the red planet and detached a landing device. At that time, Earth and Mars were about **225** million miles apart.

To send the spacecraft on a straight-line path to Mars would require a huge amount of fuel. The curved dotted-line path was followed because it required the least amount of fuel. Most of the fuel the *Viking* required was burned at launch. Once the spacecraft had left Earth's atmosphere, it simply coasted along its natural path to arrive at Mars. The remaining fuel was used to slow the lander as it dropped to the planet.

Image # 13

After it detached from the orbiting spacecraft, the *Viking* lander dropped to the surface of Mars using a parachute and retro rockets. The parachute by itself wasn't enough, due to the very thin atmosphere of Mars. From the surface, the lander conducted scientific tests and radioed its findings back to the orbiter. The orbiter then radioed the findings to Earth. In our voyage to Mars to search for signs of life, we will see images that simulate what might have been seen from the *Viking* spacecraft as it approached Mars, and also images that were actually taken by the *Viking* lander.

Image # 14

Seen from Earth by telescope, this is about the best view one can get of Mars. The planet is about 50 million miles away. The view is fuzzy because we are looking at it through Earth's atmosphere. Even at this distance and even with the fuzzy view, we see that Mars has permanent white patches at its northern and southern poles, and irregular dark shapes against a reddish-orange background. Each polar white patch gets bigger during the winter in its hemisphere and' much smaller during summer. The dark patches get bigger during summer and smaller during winter, just the opposite of the white patches.

What could these patches be? Do you see any signs of life? Do you see any signs of an environment that might support life? [Notes: The white patches could be frozen water.]

Image # 15

Our spacecraft is closing in! The view is now clear because we are looking through the vacuum of space and not through Earth's atmosphere. We see a lot of details on the surface that can't be seen from Earth. There are three big craters in a line. Running across the middle of the planet is a huge canyon so gigantic that if it were on Earth it would go from California to New York. We don't see much of the moving white vapor that we saw on Earth from the same distance.

What could these features be? Do you see any signs of life? Do you see any signs of an environment that might support life?

[Notes: The canyon is called the Mariner Valley, or Valles Marineris, after the spacecraft that discovered it. It is also called the Grand Canyon of Mars.]

Image # 16

We're now flying over the surface of Mars about 100 miles up. We see that the surface is quite pocked with circular craters. We also see meandering channels that go downhill and end abruptly along a line of cliffs. From this height we sometimes see the entire surface of Mars become fuzzy and indistinct; some or all of its features disappear for a while, reappearing after weeks or months.

What could this phenomenon be? Do you see any signs of life? Do you see any signs of an environment that might support life?

[Notes: Sandstorms, which are evidence of an atmosphere and winds, are obscuring the view.]

Image # 17

We're over the southern pole of Mars! The white patch below us seems to be piled up in layers. It's summer down there. This is as small as the white patch ever gets. As it shrinks, it leaves islands of white behind it that are separated from the main polar cap.

What could the white patch and white islands be? Do you see any signs of life? Do you see any signs of an environment that might support life?

Image # 18

Lower! We are flying past a giant volcano! It is bigger than Mount Everest. It is the biggest volcano in the entire solar system! If we were to watch it, we would see that it sometimes has white vapor near its summit. However, the vapor seems to form *outside* of the crater. As another peculiar feature, the volcano is "cut off" around its base. Instead of sloping smoothly to the Martian plain below, its base is formed of huge, nearly vertical cliffs, some of the highest cliffs in the entire solar system.

How did the volcano get that way? Is it active? Do you see any signs of life? Do you see any signs of an environment that might support life?

[Notes: The volcano is named Mount Olympus.]

Image # 19

Lower! It looks like **. . .** like **. . .** a sculptured stone "face"! (Ahhh……. is it Elvis? Is it Nixon?) Nearby we see what appears to be featureless country with craters, big rock formations, and numerous small black dots.

What could this stone "face" be? Do you see any signs of life? Do you see any signs of an environment that might support life?

[Notes: This is the famous "Great Stone Face" from tabloid newspapers. If this were the work of intelligent life, comparable to the pyramids of Egypt, for example, one might expect to see a ruined city surrounding it or some other traces of its builders. Of course, one might claim that all the other traces of the builders have been buried under drifting sand. Virtually all geologists consider this a natural formation, sure to show up by chance among millions of other rocks that do *not* have a familiar-looking appearance.]

Image # 20

Our lander is down! And what do we see? First, a self-portrait. Next…..

Image # 21

This is the surface of Mars as actually seen by one of the *Viking* landers. Unlike our imaginary vehicle to Earth, the *Viking* landers continued to operate for many years after they settled on Mars, sending back pictures and data the entire time. They observed many passages of the seasons. Among other interesting observations, the pictures often showed that the ground was white in early morning. As the sun rose, the white disappeared, lingering longest in the shadows of rocks. At no time did the ground appear to be wet. Pictures of the landers also showed that the sand moved; it blew around and piled up in different ways. Aside from these changes, the views from the landers were exactly the same when they finally stopped working, years after touchdown.

What are the features in this view? Do you see any signs of life? Do you see any signs of an environment that might support life? What would you watch for if you had several years to watch this landscape for the appearance of life?

[Notes: Examples of things to watch for could include tracks in the sand, growth or movement of the rock-like objects-maybe life-forms look like rocks on Mars, growths of lichen-like objects on the rocks, something passing by in the distance, an increase in the number of rock-like objects.]

Image # 22

This object was not seen by the *Viking* landers. It is something from Earth. But what would you think if a microscope on our lander was seeing this object in the Martian soil? Would that be evidence that there is now life on Mars? That life had existed on Mars in the past?

Stop and Assess What You've Seen on Mars

Rewind the video and take a second look at various images if students want to study them longer. Give students time to answer the following two questions on their “Looking for Life” worksheet.

1. In the images of Mars, did you see any environmental features that could support life as we know it?

   (The sinuous channels on Mars suggest that water was once present. The numerous asteroid craters suggest that there has been no water action or erosion for a long time. The fact that the surface never appears wet suggests that the white substance must be evaporating rather than melting, which suggests that at least some of it may be frozen carbon dioxidedry ice-rather than frozen water. The vapors seen forming around Mount Olympus and other high elevations are clouds; this indicates a very thin atmosphere is present.)

2. In the images of Mars, did you see any features that could have been created by life?

   (No. Reasons for the color changes are unknown, but they could be caused by a nonliving process-perhaps vapor-laden air from the melting polar caps spreads and freezes each night, roughening the Martian surface; or perhaps lighter-colored sand blows over darker material and then blows away again, seasonally. The long watch of landscapes at the two Viking *lander sites revealed absolutely nothing that would indicate the presence of life.)*

Voyages of Venus

Image # 23

Venus is the second planet out from a G-type yellow star-our Sun. Venus is our closest neighbor in space. From Earth, Venus appears mysterious, mantled in creamy yellow “clouds.”

What could the clouds be made of? What might be hiding underneath these clouds? A swamp full of tree-size ferns and fighting dinosaurs? A dry, barren desert of swirling sand? A thriving alien civilization? What are these clouds? Do you see any signs of life? Do you see any signs of an environment that might support life?

Image # 24

In this composite photographic view, we can see that Venus and Earth are almost twins in size, and both planets orbit close to the same star. Could Venus and Earth be identical twins? From Earth, it is difficult to tell. Although the clouds on Venus change and swirl, they never break apart to reveal the surface of Venus. Probes from Earth have shown that the cloud layer on Venus is very thick, and that the clouds are not made of water vapor, but of sulfuric acid, which is water combined with sulfur dioxide. Sometimes, drops of acid begin to fall toward the surface, but they never arrive there. They evaporate because of the intense surface heat.

Do you see any signs of life on either planet? Do you see any signs of an environment that might support life?

Image # 25

We're invited to view the pictures sent back from the *Magellan* mission to Venus! (In 1989, NASA's space shuttle *Atlantis* launched the *Magellan* spacecraft toward Venus.) This spacecraft did not land on Venus, nor did it drop off a lander. Landers don't last long on the surface of Venus. The Russian lander *Venera* was crushed after about 20 minutes on the surface by an atmospheric pressure of 1,260 pounds per square inch, which is 90 times the atmospheric pressure on Earth! Instead the *Magellan* spacecraft orbited Venus for years, sending back information to Earth. The *Magellan* sent back radar mapping data and atmospheric data until October 12, 1994, when it was sent into the planet's atmosphere to do a few last atmospheric tests before crashing on the surface of Venus. It was a kamikaze spacecraft!

Image # 26

This was the *Magellan* spacecraft. Because of the thick cloud cover on Venus, *Magellan* didn't just take photographs using visible light. Instead, *Magellan* used a synthetic aperture radar to map the surface features. Radar waves penetrate the clouds, bounce off of the surface, and return to the spacecraft.

Based on the time it took a radar signal to bounce back to *Magellan* we can tell how far the surface of Venus is below the spacecraft (whether it reflects off a tall mountain or the bottom of a deep valley, for example). On-board computers translate the radar data into striking “pictures” of the surface of Venus.

Image # 27

Suddenly the once-hidden surface of Venus fills the entire screen! We are seeing the surface of Venus, as it appears beneath the mantle of creamy yellow clouds. This is a composite view of one hemisphere of Venus, made by combining the data from many, many radar images. Over 98 percent of the planet's surface was mapped by *Magellan.*

What do you see in this composite view? What is the surface of Venus really like? What could the light and dark areas be? Do you see any signs of life? Do you see any signs of an environment that might support life?

Image # 28

The next image from Magellan's orbit shows the Northern Hemisphere drifting into view. There are more light and dark areas visible, in different patterns. But there are no polar ice caps; Venus is much too hot for that! Sensors reveal that the surface of Venus is above 460º C, which is hot enough to melt lead! No wonder the rain (sulfuric acid) evaporates before it reaches the surface!

Do you see any signs of life? Do you see any signs of an environment that might support life?

Image # 29

Are we getting closer? In a way, we are. We are magnifying our image and looking at a much smaller portion of the planet. This is like using a zoom lens on a camera. All the radar images from Magellan appear in black-and-white as in this picture, though it is possible to have the computer color the image.

What makes the black-and-white pattern? What is the huge circular feature near the center of the picture? Do you see any signs of life? Do you see any signs of an environment that might support life?

[Notes: The circular feature is the volcano Sapas Mons.1

Image # 30

This is the same area as the last picture, at the same magnification, although the circular feature seems to be revealed in more detail. This picture is a “false-color” image. Scientists had the computer print the picture in color. The orange colors were chosen because the Russian lander Venera was able to send back a few color photographs of the surface of Venus before it was crushed by the tremendous atmospheric pressure. The Venera lander saw a red-orange world, dimly lit, as Earth is on an overcast day.

What could the circular feature be? Do you see any signs of life? Do you see any signs of an environment that might support life?

Image # 31

It's amazing what a computer can do with a little data! This is another false-color image of the same circular area interpreted according to the height of the features. This is called a perspective view, because it lets us see what the terrain looks like from another perspective. This is just as the surface would look from an airplane flying over the surface of Venus but beneath the cloud cover. The sky is not really black; scientists left the image black because there is no radar data for the sky. (Radar can only image surface features.) The sky would also be orange in a photograph taken from the surface of Venus. Also, the little bump on the horizon and all the vertical features have been exaggerated 10 times so they are easy to see. (Venus is a very flat world. Mountains are only about half as high as those on Earth.)

What could the terrain be? Do you see any signs of life? Do you see any signs of an environment that might support life?

Image # 32

This is a false-color perspective view of another area. Even with 10-times exaggeration, most of the terrain appears flat, but there are some bumpy formations near the horizon. Most of the surface of Venus appears to be covered by volcanic rocks. Ancient lava flows appear to form vast, flat plains. What could the bumpy formations be? Hills? Mountains? Volcanoes? Venusian monsters? Could the flat area be an ancient ocean bed? A dry desert? Do you see any signs of life? Do you see any signs of an environment that might support life?

[Notes: The bumpy formations are volcanoes: the larger is Sif Mons and the smaller is Gula Mons.]

Image # 33

This is another false-color perspective view of the two bumpy formations near the horizon. They are mountains! They are also volcanoes! One is 2 kilometers high; the other is 3 kilometers high. Only 15 percent of the surface of Venus is mountainous today.

What might the surface of Venus have been like in the past? What do you think the brightly colored lines are? Why do you think so? Do you see any signs of life? Do you see any signs of an environment that might support life?

Stop and Assess What You've Seen on Venus

Rewind the video and take a second look at various images if students want to study them longer. Give students time to answer the following two questions on their “Looking for Life” worksheet.

1. In the images of Venus, did you see any environmental features that could support life as we know it?

   (No. The clouds may look promising, but they do not hold any liquid water; life as we know it requires liquid water. The water in the clouds is combined with sulfur dioxide to make sulfuric acid, which is corrosive to living things on Earth. The high temperature and extreme pressure do not look promising either. The most likely place for life on Venus might be in the upper atmosphere, which is cooler and under less pressure. But the upper atmosphere is mostly carbon dioxide.)

2. In the images of Venus, did you see any features that could have been created by life?

   (No. There is nothing that even appears promising.

Comparative Planetology

Searching Earth, Mars, and Venus for Signs of Life!

Looking for Life-Teacher's Key

Answers to student questions:

Earth

1. Yes. A temperature of 12° C indicates that the liquid is probably water, which is vital to life. The slightly fuzzy horizon is evidence that an atmosphere is present that contains oxygen if it was smoke that was seen in image # 6. As more convincing proof of an atmosphere, there was a dust storm blowing off out over the water in image # 4.

2. No. The color changes could be caused by seasonal moistening of the surface by rains. The smoke could be a volcano, something burning on the surface, a dust storm, or a chemical reaction that is creating vapors. Straight lines might have been caused by geologic faults, and geometric figures might have been caused by regional faulting patterns. Still, geometric patterns on land would be very difficult to attribute to a nonliving process. Certain fault lines on Earth are very long and absolutely straight fault lines are present on Earth, but image # 7 definitely raises the possibility that intelligent life may be at work.

Mars

3. Yes. The channels on Mars suggest that water was once present. The numerous asteroid craters suggest that there has been no recent water action or erosion. Because the surface never appears wet, the white substance must be evaporating rather than melting, which suggests that at least some of it may be frozen carbon dioxide-dry ice-rather than frozen water. The vapors seen forming around Mount Olympus and other high elevations are clouds; this indicates a very thin atmosphere is present. Sandstorms can also be seen occurring in the atmosphere.

4. No. The color changes could be due to a nonliving process-perhaps vapor-laden air from the melting polar caps spreads and freezes each night. The long watch of landscapes at the two *Viking* lander sites revealed nothing that would indicate the presence of life. Also, *Viking* scientific tests for life were negative. Geologists consider the famous "Great Stone Face" on Mars to be a natural formation, sure to show up by chance among millions of other rocks that do *not* have a familiar-looking appearance. If this were the work of intelligent life, one might expect to see a ruined city surrounding it or some other traces of its builders.

Venus

5. No. The clouds may look promising, but all the water they contain is combined with sulfur dioxide to form sulfuric acid; life as we know it requires liquid water. The clouds are made of sulfuric acid, which is corrosive to living things on Earth. The high temperature and extreme pressure do not look promising either. The most likely place for life on Venus might be in the upper atmosphere, which is cooler and under less pressure. But the upper atmosphere is mostly carbon dioxide.

6. No. There is nothing that even appears promising.