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MARS: EXPLORING THE RED PLANET
Introduction

The emphasis in space exploration in recent decades has shifted from expensive mega-projects such as missions to the moon, to unmanned robotic probes. In fact, the working principle of the National Aeronautical and Space Agency (NASA) over the past 20 years has been "faster, better, cheaper." Emphasizing the pragmatic and the possible, several recent mission programs have focused on Mars, the most Earth-like of any of the planets in our solar system. While NASA had several setbacks when probes to Mars crashed or malfunctioned in the 1990s, the excitement has returned with back-to-back successful missions. The most recent success was the arrival of the 2001 *Mars Odyssey* spacecraft in orbit around Mars in February 2002. The *Odyssey*'s mission is to search the surface of the red planet for water, map the chemical elements on the surface, and analyze the radiation in the atmosphere. Early reports have already identified the presence of significant amounts of hydrogen, a sure indicator of water. This has created excitement and speculation among scientists—because water is a prerequisite for life. Missions involving landing probes in the near future will have the ability to perform more detailed analyses of the soil and perhaps determine if Mars ever sustained life forms, or if it currently does.

Confirming that life exists outside our planet would not only be scientifically exciting, but it would also lead to a re-examination of our concept of the universe. If life existed, or exists, on Mars, then it is certainly possible that life exists somewhere else in the billions of solar systems elsewhere in the universe. The question of life beyond planet Earth aside, a detailed analysis of Mars could provide clues as to how planets form, which will help us understand Earth's history.

Mars missions such as *Odyssey*'s have significantly added to the body of knowledge about that planet, but this has also fuelled debate. Critics believe that some scientists analyzing the data are guilty of wishful thinking. These critics believe that Mars is too cold or too inhospitable to have ever supported life. On the other hand, some space scientists worry that competing space programs, both commercial and military, are commanding the lion's share of funding for space exploration; all space programs around the world have faced budgetary constraints in recent years.

However early results from *Odyssey* and other Mars missions have rekindled the public's and the scientific community's interest in Mars, and we are reminded of the human love affair with space in general and with the alluring red planet. Mars has intrigued humans for thousands of years, and has figured prominently in fiction and the human imagination over the last century. Each discovery on Mars reinforces our desire to know if we are or are not alone in this universe, and underscores the fact that our aspirations and scientific querying reach beyond our terrestrial world.

MARS: EXPLORING THE RED PLANET
➢*A Scientific Mission*

Mars is a planet that has engaged the human imagination for millennia. In fiction, it has evoked many scenarios: at times it has been seen as the origin of beings that challenge earthlings for supremacy of the solar system; in other images it is a new frontier for human colonization. While the reality of the red planet may be less dramatic in a theatrical sense, what Mars could potentially reveal is certainly spectacular in a scientific sense. Mars does contain many secrets that may reveal important information about the formation of planets, including Earth, as well as clues to the possibility of life existing beyond Earth. The *Odyssey* space mission is a significant part of a series of missions to Mars that have continued since the 1960s. There is every indication that this exploratory program will continue for many more years.

Key Scientific Questions

As you watch this *News in Review* report, jot down notes that will help you answer the following questions:

1. What did the *Viking* and *Pathfinder* missions achieve?
2. Why is the presence of water so important to the study of Mars?
3. How will *Odyssey* be used to analyze the planet?
4. What challenges face engineers when designing spacecraft that can land on Mars?
5. How will the future Mars rover differ from the first one, *Sojourner*?
6. In what ways can Canada contribute to Mars exploration?
7. Why is human exploration of Mars unlikely, at least in the short term?

Follow-up Discussion

1. *Odyssey* certainly represents a major step in the development of space exploration technology. What spinoff effects might the success of this program have back here on Earth? How does the development of space programs like this benefit human society?
2. One of the current theories is that if life exists on Mars, it will likely be a hardy form of bacteria that could survive the extremes of the Martian environment. Should humans push ahead with surface exploration of that planet, possibly exposing Martian life forms to human contamination? Should we be concerned about the opposite effect, Martian microbes infecting Earth? Why is space exploration also an environmental issue?

MARS: EXPLORING THE RED PLANET

➢*Life on Mars*

We know that water is the essence of life on Earth. Eighty per cent of the Earth's surface is covered by water. The human body is mostly water, between 50 and 65 per cent. The brain itself is about 75 per cent water. Animals are conceived and carried until birth in a watery liquid, and evolutionary theory maintains that all life forms originated in the oceans.

SCIENTIFIC REFLECTION: How does water affect life and the quality of life around you? In small groups brainstorm answers to this question with regard to one of the following: recreation, health, food, sports, the environment. Choose a spokesperson to present the findings of the group. As a class, identify ways in which humans are dependent on an adequate water supply.

Water is a necessity in any venture undertaken by humans. Its possible presence on Mars in large volumes implies that life forms may have once existed there, and possibly still do.

POETIC REFLECTION: Why is water seen as the universal life medium? Consider and express in your own words the sentiments expressed in the following.

Almost 100 years ago, the English poet Rupert Brooke, described the importance of water this way:

> One may not doubt that, somehow, good
> Shall come of water and of mud;
> And, sure, the reverent eye must see
> A purpose in liquidity.
>
> But somewhere, beyond space and time,
> Is wetter water, slimier slime.

In a less poetic manner, scientists point out that water is the key element that suggests that Mars could have or does sustain life. The necessary ingredients for sustaining life include an energy source, carbon-based material, and water. The first two are relatively common in space. Water is less so. Scientists believe that Mars once had lakes, oceans, and rivers on its surface.

Evidence in Our Midst?

One of the more hotly debated scientific questions is whether or not meteorites that landed on Earth contain fossilized remains of Martian life. The 4.5-billion-year-old rocks, which have been found in various locations on our planet, match samples on Mars analyzed by space probes in 1976. One scientific speculation suggests that these Martian rocks were dislodged by a major impact on the red planet 15 million years ago, and that some reached Earth as meteorites. One rock in particular, found in the Antarctic, contains crystal impressions that supporters of this theory claim could only be formed by biological processes. Imre Friedmann, the NASA scientist who led the study said, "As far as I'm concerned, Martian bacteria were in this meteorite. When you put all the elements together, there can be no other

explanation." Critics of the theory believe that the crystal patterns may be inorganic in origin, or might even have resulted from bacteria from Earth that was acquired after the meteorites landed. This controversy will not be conclusively resolved until direct and extensive study can be made of the Martian surface.

Life on Mars Now?

While life on Mars sometime in the past is at least a possibility, the present existence of life is problematic. It would require a series of relationships to exist. Scientists know that much of the surface of Mars is incredibly arid, so that surface life would be next to impossible. However, William Boynton, chief scientist in charge the instrument aboard *Odyssey* that measures the presence of hydrogen notes the apparent abundance of water on the planet. He has said, "The signal we have been getting loud and clear is there is a lot of ice on Mars." His belief is that the water is likely ice mixed in with the dirt and dust on the top metre of the planet's surface, stretching from the southern polar cap north to about 60 degrees south latitude.

Life on or near the surface, however, would require some liquid water. The liquid could exist in this frozen environment if magma from the interior of Mars could heat it. On Earth, there have been cases of bacteria existing in the scalding environment of volcanic vents at the bottom of the ocean. If life can exist on Earth in such unlikely places, it may be possible on Mars as well.

Practical Considerations

Of the water on Earth, 97 per cent is salt water (primarily ocean water) and another two per cent of that is frozen at the poles. This means that humans survive on Earth using only one per cent of the Earth's water, the one per cent that is not saline. In terms of future exploration of Mars, this suggests two key considerations: (a) Mars would not necessarily require immense amounts of water to sustain life; and (b) humans travelling to Mars may be able to utilize this water, which would represent an immense weight savings in transportation.

Water Research

Conduct research about some aspect of (a) water, (b) life forms existing in unlikely places, (c) heat and temperatures on Mars. Demonstrate the implications of your research for the planet Mars. Create a visual display of your findings.

MARS: EXPLORING THE RED PLANET
Martian Weather

Human explorers would require specialized adaptive systems to live and work in the hostile Martian environment. The atmosphere is extremely thin compared with Earth's and is composed mostly of carbon dioxide. The air pressure at the surface would be the equivalent of that in the atmosphere 35 kilometres above the surface of Earth, where normally only stratospheric balloons fly. The thin cirrus-like clouds in Mars' sky are most likely frozen carbon dioxide since the Martian atmosphere does not support water vapour well.

The temperatures vary wildly. As is the situation on Earth, it is much warmer at the equator than it is at the poles. The daytime temperature at the equator on Mars can reach 21 Celsius. The nighttime temperature at the same spot can plunge to -32 Celsius. The southern polar region receives very little sunlight; the temperature there is a constant -128 Celsius, which is below the freezing point of carbon dioxide. And these wide-ranging temperatures generate incredible wind storms.

Mars appears reddish in colour, even to the naked eye. This colour is derived from the red dust that coats the planet. The winds often generate large sandstorms that can reach eight kilometres in height, and last for weeks at a time. Occasionally, these storms grow large enough that they encompass the entire planet. The winds also shape the Martian landscape by creating massive sand dunes of various shapes and sizes.

Another weather phenomenon of note on Mars is the occurrence of dust devils. Dust devils occur where there is a temperature difference between the surface and the air above it. The Martian landscape is crisscrossed with tracks from the multitude of dust devils that occur. At present, the orbiting space probes can only see fuzzy shadows from the dust pulled up in the dust devil and the track it leaves behind in the sand.

A Martian Weather Watch

1. To see images of Martian storms, dust devils and sand dunes from Mars orbiters, go to NASA's Mars Web site at http://mars.jpl.nasa.gov/gallery/duststorms/. The site compares satellite pictures of Saharan sandstorms to those on Mars. The Martian sand dunes would not look out of place on our beaches or in our deserts. Choose an image, print it, and then write a descriptive passage in which you report what you see.

2. Create a televised or Web-based weather forecast for a human colony on Mars. Utilize graphics and weather maps to make it more authentic.

MARS: EXPLORING THE RED PLANET
The New Space Race

When the Soviet Union launched its space satellite *Sputnik* on October 4, 1957, it also launched an international space race. For the United States, the USSR's principal adversary, the goals for space exploration were simple and clear: regain the advantage and thus dominate this new field of endeavour, industry, and position of superiority. At the time, the U.S. was locked in a Cold War with the Soviet Union, which meant that although the two nations and their allies were not engaged in active military battle, they were competing relentlessly in every other aspect of modern society. The U.S. therefore wanted to prevail in every area, whether it was military power, economics, sports, or science and technology. Many Americans, and by extension, Canadians, accepted that the U.S. not only had to catch up to the Soviets with its space program, but had to surpass it in order to prove the superiority of the "free world."

The Soviet Union, however, leapt ahead of the U.S. again in April 1961, when it put the first astronaut, Yuri Gagarin, into orbit around Earth. In response, President John F. Kennedy declared that the U.S. would land a human on the moon by the end of the 1960s. Despite the risks and the uncertain technology, this mandate drove the U.S. space program for the next 10 years. *Apollo 11* landed on the moon on July 20, 1969. Five more landings took place before the Apollo program ended in 1972.

The Lunar Landing

Public interest declined in space programs after the U.S. was seen to have won the space race to the moon, a logical and also highly symbolic goal. More importantly, federal funding was curtailed. Through the 1970s and 1980s, many space program jobs, in the U.S. primarily but in North America and elsewhere as well, were lost as projects were scaled back. The one exception was the development of the space shuttle program, which allowed astronauts to enter space, but also return and land in the same vehicle. This program is still in operation. For exploration beyond Earth's orbit—where the shuttles cannot go—the U.S. space agencies developed relatively low-cost unmanned probes. Other space agencies from Europe and Asia have also implemented programs that either complement or compete with the U.S. initiatives. As the technology has grown so quickly, the public is often unaware of these ongoing projects, except when key discoveries or impressive photographic images are revealed. The construction of the International Space Station, however, has received a great deal of public attention. This permanent laboratory complex created by 16 nations will be bigger than a Boeing 747 and will be the third most brilliant object in the night sky next to the moon and Venus. The station will be able to house seven astronauts who maintain the laboratories and conduct low-gravity experiments. The structure is scheduled to be completed in 2006.

Discussion

The interval between the launching of *Sputnik* and the U.S. lunar landing was only 12 years. In terms of space exploration, a great deal can be accomplished in a relatively short period. Is competition, international or otherwise, what should drive space exploration? Are there other motives and motivations we should consider?

MARS: EXPLORING THE RED PLANET
A Diversified Space Program

During the first two decades of the space race only two countries were exploring space, the U.S. and the USSR. Today there are competing programs even within the U.S. itself. In addition, regions and countries such as Europe and Japan have rival programs. As with the U.S. and Russian programs, however, budgetary cutbacks may eliminate or reduce the scale of some of the missions in all of these agencies. Consider the scientific and international business implications of the following examples of the current space industry. How are they related?

The United States

The *Odyssey* spacecraft was designed by the Jet Propulsion Laboratory (JPL) from California, as were the *Mariner* and *Viking* programs. It has recently had competition from the Applied Physics Laboratory (APL), based out of Maryland. The APL secured a contract from NASA for asteroid explorers. It sent the *Near Earth Asteroid Rendezvous* (NEAR) spacecraft to the asteroid Eros, which it orbited and on which it then landed in 2001. APL also has contracts to explore Mercury and Pluto, and nearby comets. APL has been able to do this on a comparatively minuscule budget. Even though JPL continues to be the primary space exploration laboratory, APL has now begun to steal some of the attention.

Europe

The European Space Agency (ESA) has a full slate of unmanned probes that will explore Mercury, Venus, Mars, and map stars in the Milky Way. The Mercury missions would include two probes, one to map the planet, and the other to analyze the magnetosphere. The *Gaia* astrometry mission involves a probe that would map the positions of roughly one billion stars.

Japan

Japan has three agencies: the Institute of Space and Astronautical Science (ISAS), the National Space Development Agency (NSDA), and the National Aerospace Laboratory (NAL). Japan is constructing one of the laboratory modules for the International Space Station. While Japan's program has focused primarily on communications and weather satellites, it has plans for a lunar orbiter in 2003. The ISAS for its part has also sent the only non-Russian and non-American probe to Mars.

Discussion

Each country with a space program is also implementing funding cutbacks. In some cases, recessionary pressures have resulted in space programs being labelled as luxuries. In the U.S., money has been diverted either into space defence programs or big budget programs like the space shuttle or the space station. In your opinion, what priority—financial or otherwise—should be placed on space exploration?

MARS: EXPLORING THE RED PLANET

➢*Humans on Mars?*

According to the various space agencies, the human exploration of Mars is at the very least decades away. They claim that the technology necessary to safely transport astronauts to and from the red planet is beyond current capabilities. Critics of programs planning human exploration of Mars also note that robot probes are cheaper, increasingly sophisticated, and ultimately expendable, if there were any accidents. Nevertheless, the idea of human exploration of Mars remains a driving force. It is difficult to imagine that we would have been as enthralled as we were if a machine had taken the first "giant leap for mankind" on the moon's surface rather than astronaut Neil Armstrong.

Rationalizing

The Mars Society was founded in 1998. Its mandate is to promote and encourage the exploration and settlement of Mars, both through government and privately funded space missions. In its Founding Declaration, it lists the reasons why humans should go to Mars. Working in small groups, read the list of reasons paraphrased below and assess the validity of each. Which ones do you find the most or least reasonable or compelling? Are there other reasons you might add to the list?

1. Humans are ready. We are better able to prepare a mission to Mars today than we were to send humans to the moon during the 1960s.

2. Curiosity. There are strong indicators that Mars once possessed life, and may still. The need to discover answers is a strong motivation.

3. Knowledge about Earth. Mars is the planet in the solar system most like our own. Practical information can be obtained to help us survive the environmental changes that are occurring.

4. Opportunity. If our planet's ecosystem degrades because of climatic changes or pollution, humans may need another habitat to utilize. Practicality aside, it is part of the human experience to move about and start anew.

5. Adventure. Human civilization is dynamic. It will stagnate without fresh challenges. If only one per cent of young people were inspired by Mars exploration, it would translate into millions more people involved in science, medicine, engineering and research. The returns to society would be tremendous.

6. Robotic limitations. While robots are increasingly sophisticated, they still fall far short of human capabilities. Human explorers can do far more complicated analyses on Mars than the robot probes.

MARS: EXPLORING THE RED PLANET

➢*A Brief History of Mars*

The planet Mars has figured prominently in descriptions of space throughout human history. Because of its reddish hue the planet is one of the most recognizable objects in the night sky, alongside Venus and the moon. We know today that its colour is derived from the red soil on the planet that is often swept about in immense sandstorms.

Mars appeared in historical accounts almost as soon as humans began to write them. Here is a brief history of humans observing Mars.

3000 BCE Egyptians refer to Mars as *Har décher* meaning the "red planet." They also recognize the retrograde movement of the planet, describing it as one "who travels backwards."

1200-300 BCE Ancient Greeks call the planet Ares, who was the god of war. Ares was the son of Zeus, the primary god (also the planet Jupiter). Ares was murderous and bloodstained, and was disliked by the other gods. The most militaristic city, Sparta, often made sacrifices of prisoners of war to Ares.

422 BCE The earliest Babylonian records of the planet appear.

384-322 BCE The Greek philosopher Aristotle concludes correctly that Ares (Mars) is higher up in the heavens than the moon, after he witnesses an occultation of Mars. (An occultation occurs when a celestial body, in this case the moon, passes in front of another, concealing it.)

400-300 CE Mars is given its current name by the Romans. Mars, like Ares, was also the god of war, but was much more prominent in Roman culture. Mars was second only to Jupiter, and considered the protector of Rome. Sacrifices were made before and after military expeditions.

1609 Galileo Galilei observes Mars with a primitive telescope. However, astronomical study and speculation are limited by the prohibitions of the Roman Catholic Church in Europe. Many scientists are threatened or even executed for contradicting the idea that Earth is the centre of the universe.

1666 Giovanni Cassini determines the approximate length of the Martian day as 24 hours, 40 minutes. (Today it is measured at 24 hours, 37 minutes and 22.663 seconds.) He also observes the polar ice caps.

1877 Giovanni Schiaparelli makes note of *canali* (channels) from his observations of Mars. English translations refer to "canals." The Suez Canal has only recently been built, so the implication is commonly expressed that superior intelligence is or was present on Mars. Considerable science fiction writing with respect to Mars ensues.

August 11, 1877 Asaph Hall discovers the moons of Mars. He names them Phobos (fear) and Deimos (flight) after the Roman mythological characters.

1901 At the Lowell Observatory in Flagstaff, Arizona, photographs are taken of Mars. By 1960, 126 000 photos of the planet have been taken.

1911 A dog is struck and killed by a meteorite in Egypt. In the 1980s the meteorite is determined to have originated from Mars, one of 16 in total that have been located from various sites on Earth.

1963 Hyron Spinrad records water measurements on Mars using a spectrometer. The figures indicate that the Martian atmosphere is extremely dry, with less than one thousandth of the water in the air above the Sahara Desert.

July 15, 1965 The U.S. *Mariner 4* space probe flies by Mars, transmitting pictures.

July 20, 1965 The USSR *Zond 3* space probe flies by Mars.

1971 The USSR crafts *Mars 2* and *Mars 3* enter into orbit around Mars. *Mars 3* successfully lands on the planet, but ceases transmission after only 20 seconds. *Mars 2* is able to transmit pictures during 363 orbits.

1975 The U.S. crafts *Viking 1* and *Viking 2* enter into orbits around Mars. The pictures from the surface are the most comprehensive views to date.

November 1996 The U.S. *Mars Observer* orbits the planet, providing high-resolution images for mapping purposes. It is also used for atmospheric studies.

December 1996 The U.S. *Mars Pathfinder* provides the most dramatic images of the planet's surface. The module includes a six-wheeled "rover" vehicle called *Sojourner* that is able to move about the surface as directed by scientists back on Earth.

February 2002 The *Odyssey* orbiter arrives and enters into orbit around Mars.

2003 Mars will be at its closest point to Earth, and its greatest brightness, in 284 years.

Research

Research one topic suggested in the chronology above. Create a short presentation, including pictures or graphics, to illustrate your findings.

MARS: EXPLORING THE RED PLANET
Science and Science Fiction

In his 1970 play *A Yard of Sun* playwright Christopher Fry wrote: "There may always be another reality/To make fiction of the truth we think we've arrived at."

In a sense this is what humans have often done with information they have concluded about Mars. The information was often the best available for the time, but often incomplete or inaccurate due to the limitations of technology. As early as the 17th century, astronomers had established that Mars had a similar length of day to that of Earth, and that it had polar ice caps. Channels on the surface were described as canals, implying that they had been created by intelligent beings at least as capable as the inhabitants of Earth. Darker sections of Mars observed through telescopes were wishfully depicted as vegetation.

These speculations by early scientists were quickly assimilated by authors into works of fiction. The existence of Martians, a race that by turns could be earthlings' superiors, competitors, allies, or conquerors, became a common theme. In terms of fiction and our imagination, no other planet has had the same hold on us. In much of science fiction Earth is inevitably threatened by Martians, not Venusians or Jovians. Even when science improved to the point where earlier findings about Mars' surface and atmosphere were disproved, authors and human society at large never quite gave up on the notion of sentient beings coming from Mars.

On October 30, 1938, Orson Welles broadcast a dramatic adaptation on radio of H.G. Wells' *War of the Worlds*. The broadcast was performed as an unfolding news story about Martians landing and defeating Earth's armies. Many people, however, tuned into the program late and did not hear the opening of the broadcast during which a disclaimer announced that the events were fictional. Considerable panic ensued. Many people fled the cities in their cars, armed themselves with loaded guns, or even wrapped their heads in wet towels to protect themselves from Martian poison gas.

Radio Time

Obtain and listen to a copy of the radio broadcast of *War of the Worlds*. What techniques did Orson Welles use that made some of the details seem real? What parts of the broadcast should people clearly have recognized as a dramatic simulation?

What media-created parallels exist today in which truth and fiction are blended for entertainment purposes? For example, how do reality-based shows depict actual events? How can the viewer of such shows know what is real and what is enhanced or staged for the cameras? Why are they not, in this sense, depictions of reality? While most people would not believe a Martian invasion storyline today, what kind of subject matter could be dramatized in a fictional way, or presented in such a way, that could actually cause panic?

The Martian Library

The number of works of fiction that feature the planet Mars is extensive. Some of the classic fictional accounts include:

War Of The Worlds, 1898, by H.G. Wells
A Princess of Mars, 1912, by Edgar Rice Burroughs. (Rice Burroughs is the author of *Tarzan*; this is the first of an 11-book series on Mars.)
The Martian Chronicles, 1951, by Ray Bradbury. (This collection of short stories about the conquest of Mars questions human actions and motives.)
The Sands of Mars, 1952, by Arthur C. Clarke. (A writer travels to Mars and discovers life. In the book, Mars is just starting to make itself independent of Earth by the success of a secret project that involves the complete reformation of the planet.)
Stranger in a Strange Land, 1961, by Robert Heinlein. (The child of a stranded astronaut brings superior Martian knowledge and abilities back to a corrupt Earth.)
A World of Difference, 1990, by Harry Turtledove. (The inhabitants of the fourth planet destroy the 1976 *Viking* probe.)
Red Mars (1993), *Green Mars* (1995), *Blue Mars* (1997), by Kim Stanley Robinson. (This is a trilogy about the colonization of Mars.)

Movies based on space have always been enormous box office successes. The *Star Wars* and *Star Trek* films, *E.T.*, *Alien*, and *2001: A Space Odyssey* are some of the biggest. Of the many science fiction films, quite a few that have centred on the planet Mars. These include: *Red Planet* (2000); *Mission to Mars* (2000); *Mars Attacks* (1996); *Total Recall* (1990); *Invaders from Mars* (1986); *Planet of Blood* (1966); *Santa Claus Conquers the Martians* (1964); *Robinson Crusoe on Mars* (1964); *Abbot and Costello Go to Mars* (1953)

Activities

1. Read one of the books listed above and write a book report in which you suggest what elements of real science have been integrated into the story.

2. With reference to a film about space or Mars that you have seen, suggest what aspects of the story appeal to important human emotional needs.

MARS: EXPLORING THE RED PLANET
Discussion, Research, and Essay Questions

1. In this *News in Review* report Canadian astronaut Marc Garneau comments on Canada's possible involvement in a Mars space program saying, "The time frame is a very short one. . . . [I]f we decide that we would like to go to Mars . . . the earliest we can get involved is 2007. We're already late at the table. The Italians and the French have already signified a strong interest and have asked to participate in missions going to Mars. . . . So we're already late in the day." Discuss reasons why Canada should or should not get involved in an international Mars space program.

2. Research an aspect of the *Odyssey* mission that interests you and design an information package whose purpose is to educate the public to the significance of this mission. Start your research at NASA's Jet Propulsion Web site (http://mars.jpl.nasa.gov/odyssey/).

3. A controversial link between Canada and the NASA Mars project is a dispute between scientists and the Inuit over a 20-kilometre long crater in Nunavut. The crater was created by a meteorite strike 23 million years ago. NASA has used the crater for study because it resembles the terrain that probes would encounter on the Martian surface. They also studied how bacteria existed around thermal vents in an otherwise extreme environment. In 1999, the local Inuit denied researchers access to 70 per cent of the crater, citing a 1993 land agreement. They believe that the research project disrupts their hunting grounds and pollutes their environment. Scientists are attempting to reach a compromise. Research this issue and write an editorial in which you present a clear point of view on the issue.

4. A significant proportion of the world's space programs are dedicated to commercial ventures. The U.S. is facing increasing competition from France, Japan, China, Russia, and even Ukraine. The non-U.S. agencies are becoming increasingly economic and reliable and thus attractive to their clients. Research the commercial aspects of space programs and explain how the space industry has become big business.

5. Panspermia is the theory that life does not start independently on any planet on which it is found; rather it travels from planet to planet via meteorites. Bacteria have been found to survive in the very harsh conditions of space, and some scientists believe that such bacteria can survive in rocks torn from planets through collisions with asteroids or comets. In his article "Are We All Aliens?: The New Case For Panspermia" on the Web site Space.com, Senior Science Writer Robert Roy Britt discusses this theory. Locate and read this article. Summarize Britt's views on the theory and suggest why this theory or the theory that life exists elsewhere in the universe other than on Earth has enormous implications for human society and human culture.