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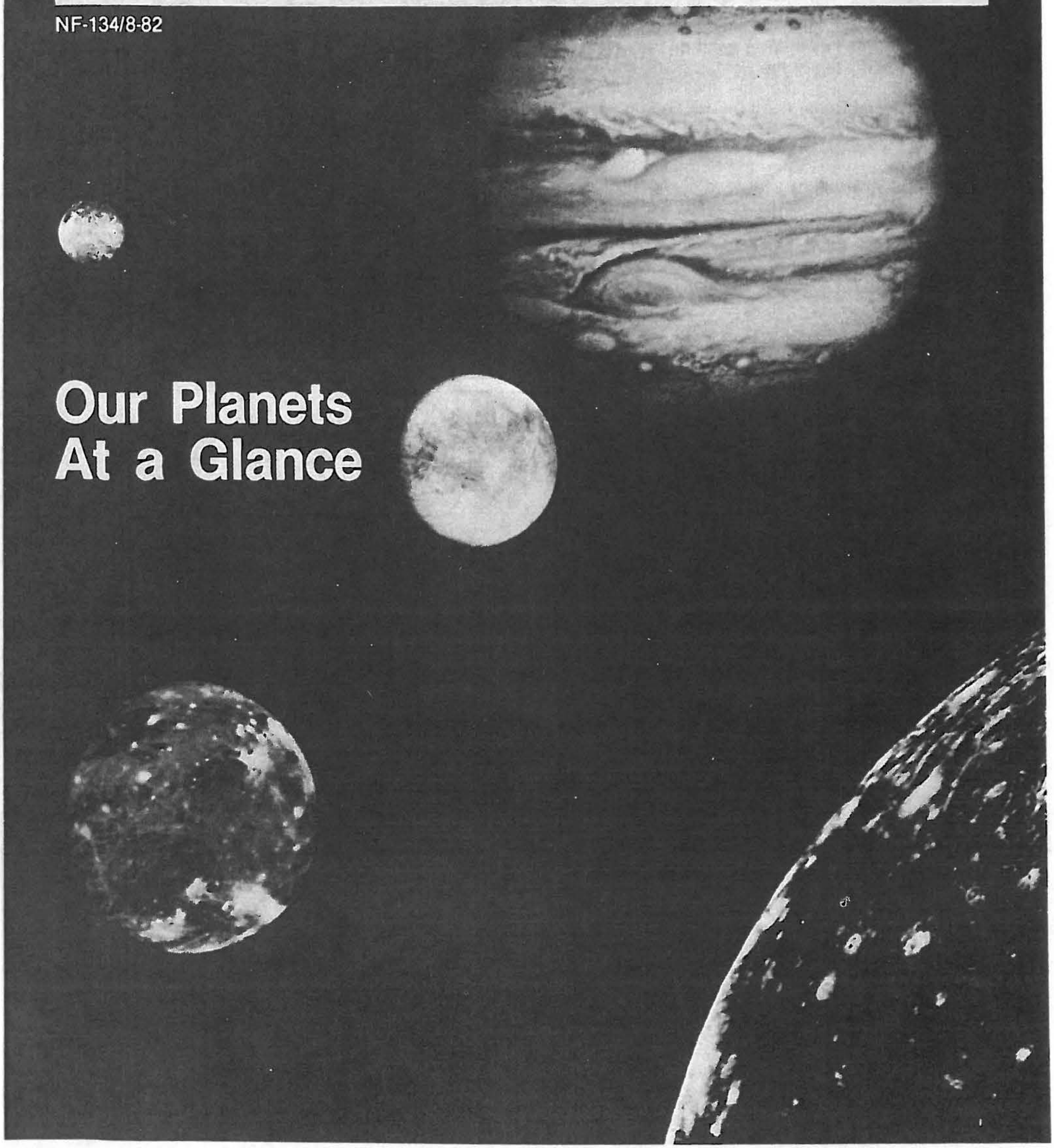
Our Planets At a Glance



Our Planets At a Glance

From our watery world we have gazed upon the cosmic ocean for untold thousands of years. The ancient astronomers observed points of light which appeared to wander among the stars. They called these objects planets, which means wanderers, and named them after great mythological deities—Jupiter, king of the Roman gods; Mars, the Roman god of war; Mercury, messenger of the gods; Venus, the Roman god of love and beauty; and Saturn, father of Jupiter and god of agriculture.

Science flourished during the European Renaissance. Fundamental physical laws governing planetary motion were discovered and the orbits of the planets around the Sun were calculated. In the 17th Century, astronomers pointed a new device called the telescope at the heavens and made startling new discoveries.

But the past 20 years have been the golden age of planetary exploration. Advancements in rocketry during the 1950s enabled mankind's machines to break the grip of Earth's gravity and travel to the Moon and to other planets.

American expeditions have explored the Moon, our robot craft have landed on and reported from the surfaces of Venus and Mars, our spacecraft have orbited and provided much information about Mars and Venus, and have made close range observations while flying past Mercury, Jupiter, and Saturn.

These voyagers brought a quantum leap in our knowledge and understanding of the solar system. Through the electronic sight and other "senses" of our automated probes, color and complexion have been given to worlds that existed for centuries as fuzzy disks or indistinct points of light.

Future historians will likely view these pioneering flights to the planets as one of the most remarkable human achievements of the 20th Century.

NASA Planetary Exploration

Spacecraft	Mission	Launch Date	Arrival Date	Status
Mariner 2	Venus flyby	8/14/62	12/14/62	Mission complete, craft in solar orbit.
Mariner 4	Mars flyby	11/28/64	7/14/65	Mission complete, craft in solar orbit.
Mariner 5	Venus flyby	6/14/67	10/19/67	Mission complete, craft in solar orbit
Mariner 6	Mars flyby	2/24/69	7/31/69	Mission complete, craft in solar orbit
Mariner 7	Mars flyby	3/27/69	8/5/69	Mission complete, craft in solar orbit.
Mariner 9	Study Mars from orbit	5/30/71	11/18/71	Mission complete, inoperable remains in Martian orbit.
Pioneer 10	Jupiter flyby	3/2/72	12/3/73	Primary mission complete, craft continues to return heliospheric information enroute toward interstellar space.
Pioneer 11	Jupiter/Saturn flybys	4/5/73	12/2/74 (Jupiter) 9/1/79 (Saturn)	Primary mission complete, continues to return information enroute toward interstellar space.
Mariner 10	Venus/Mercury flybys	11/3/73	2/5/74 (Venus) 3/29/74 (Mercury) 9/21/74 (Mercury) 3/16/75 (Mercury)	Mission complete, craft in solar orbit.
Viking 1	Unmanned landing on Mars	8/20/75	7/19/76 (in orbit) 7/20/76 (lander touchdown)	Mission complete, craft remains on surface and in orbit. Lander continues to send monthly weather reports, photos.
Viking 2	Unmanned landing on Mars	9/9/75	8/7/76 (in orbit) 9/3/76 (lander touchdown)	Mission complete, craft remains on surface and in orbit. Both lander and orbiter have ceased operation.
Voyager 1	Tour of Jupiter	9/5/77	3/5/79 (Jupiter) 11/12/80 (Saturn)	Primary mission complete. Craft continues to return heliospheric information enroute toward interstellar space.
Voyager 2	Tour of the outer planets	8/20/77	7/9/79 (Jupiter) 8/25/81 (Saturn) 1986 (Uranus) 1989 (Neptune)	Mission continues. Craft has surveyed two of four planetary targets. On way to Uranus
Pioneer Venus 1	Orbital studies of Venus	5/20/78	12/4/78	Orbiter continues to return images and data.
Pioneer Venus 2		8/8/78	12/9/78	Mission complete. Probes impacted on surface

Interplanetary Spacecraft

NASA's space probes to the planets have come in many shapes and sizes. While they are designed to fulfill separate and specific mission objectives, the craft share much in common.

Each space probe has consisted of various scientific instruments selected for the mission, supported by basic subsystems for electrical power, trajectory and orientation control, and for processing data and communicating with Earth.

Electrical power is required to operate the spacecraft instruments and systems. NASA has used both solar energy from arrays of photovoltaic cells and small nuclear generators as power plants on its interplanetary probes. Rechargeable batteries are employed for backup and supplemental power.

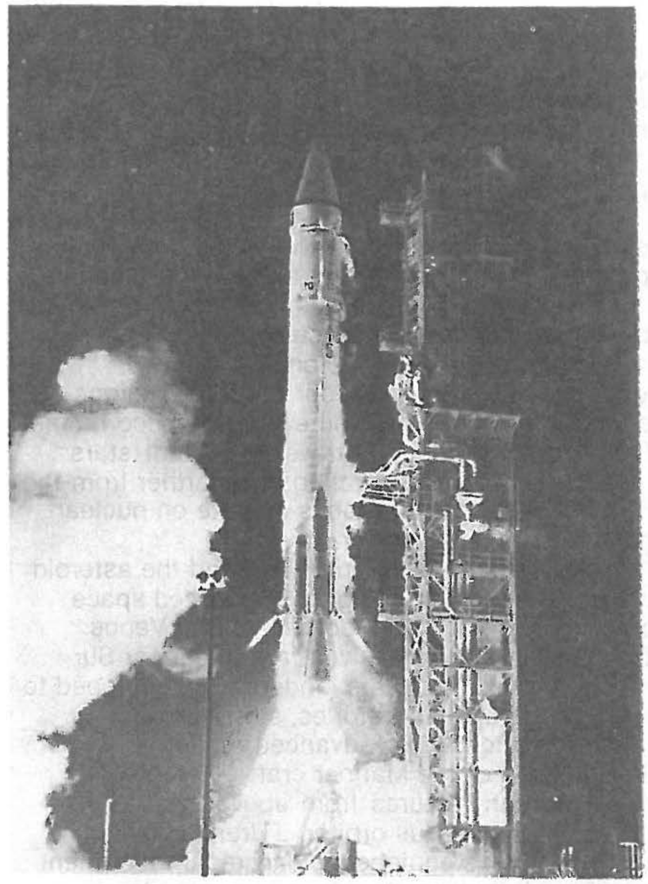
Imagine that a craft has successfully journeyed millions of miles through space to fly only once near a planet, and its cameras and other sensing instruments are pointed the wrong way as it zooms past the target! To help prevent this from happening, a subsystem of small thrusters is used to control interplanetary spacecraft. The thrusters are linked with devices which maintain a fix on selected stars. Just as the Earth's early seafarers used the stars to navigate the oceans, spacecraft use stars to keep their bearings in space. With the subsystem locked onto "fixed" points of reference, flight controllers can keep scientific instruments pointed at the target body and a spacecraft's communications antennas pointed toward Earth.

To ensure that a space probe encounters a planet at the planned distance and on the proper trajectory, another major subsystem makes course corrections after the spacecraft is enroute.

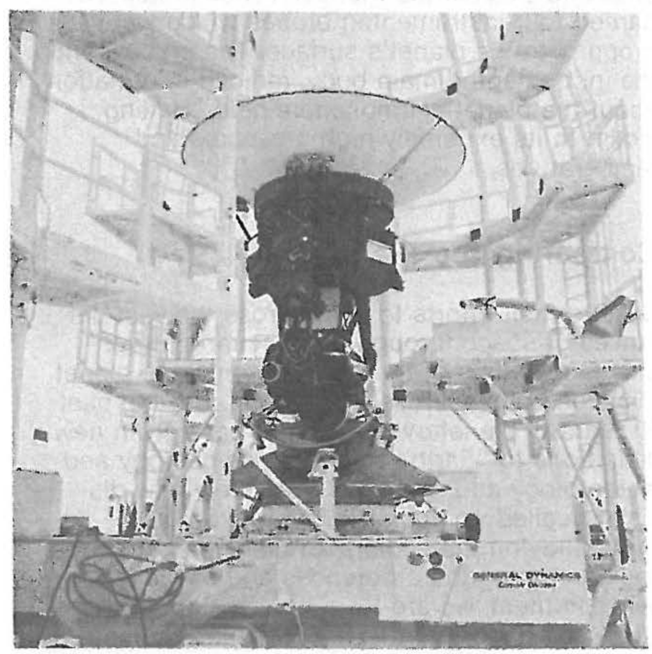
During the first decade of planetary flights, NASA spacecraft were dispatched to scan the other inner planets—Mercury, Venus, and Mars. These worlds, and our own, are known as the terrestrial planets because of their similarity to Earth's rocky composition.

For these early reconnaissance missions, NASA employed a highly successful series of spacecraft called Mariners. Their flights helped shape the planning of later missions. Between 1962 and 1973, seven Mariner missions were successful. Three Mariner attempts—the first, third and eighth—failed.

All of the Mariner spacecraft used solar panels as their primary power source. The first and the final versions of the spacecraft had two wings covered with photovoltaic cells. Other Mariner space probes were equipped with four solar panels extending from their octagonal bodies. Spacecraft in the series ranged from under 500 pounds (Mariner 2 Venus probe) to more than 2,000 pounds (Mariner 9 orbiter). Their basic



An Atlas Centaur rocket lifts away from its Cape Canaveral launch pad carrying the Mariner 6 space probe.



The Voyager 1 probe to the outer planets awaits final launch preparations at Kennedy Space Center.

design, however, remained quite similar throughout the program. The Mariner 5 Venus probe, for example, had originally been a backup spacecraft for the Mariner 4 Mars flyby. The Mariner 10 spacecraft sent to Venus and Mercury used components left over from the Mariner 9 Mars orbiter program

In 1972, NASA opened the second decade of planetary exploration with the launch of a Jupiter probe. Interest was shifting to the outer planets, giant balls of dense gas quite different from the terrestrial worlds we had surveyed.

Four spacecraft—two Pioneers and two Voyagers—were sent to tour the outer regions of our solar system. They will eventually become the first human artifacts to travel to distant stars.

Because they are traveling even farther from the Sun, the outer planet probes operate on nuclear-generated electric power.

While probing new territory beyond the asteroid belt, NASA developed highly specialized space craft to revisit our neighbors Mars and Venus. Twin Viking landers evolved from the lunar Surveyor program. The Mars landers were equipped to serve as biology laboratories, seismic and weather stations. Two advanced orbiters—descendents of the Mariner craft—were sent to study Martian features from above.

The Pioneer Venus orbiter, a drum-shaped spacecraft, was equipped with a radar instrument that "sees" through the planet's dense cloud cover to study surface features. A separate spacecraft called the Pioneer Venus multiprobe carried four instrumented probes which were dropped to the planet's surface. The probes, and the instrumented main body, radioed information about the planet's atmosphere before falling victim to its extremely high pressures and temperatures.

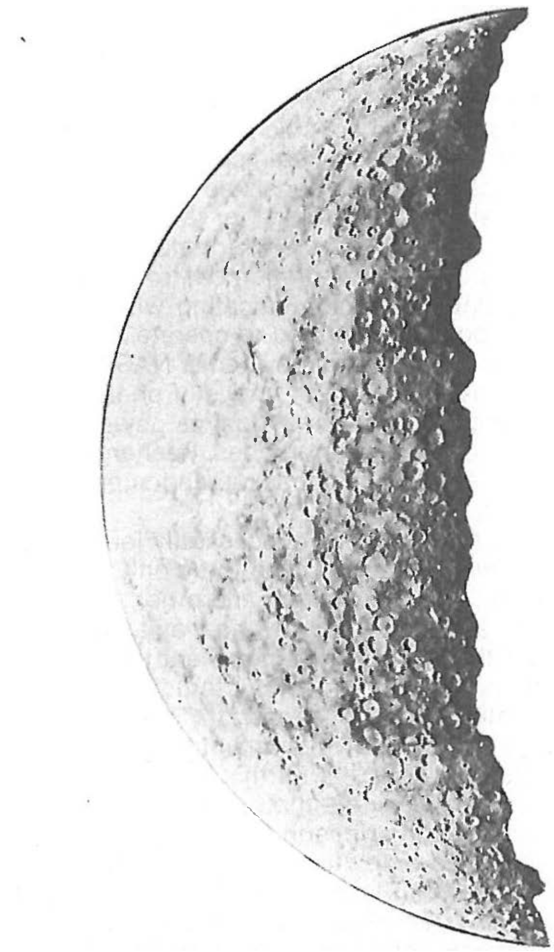
Comparing the Planets

Despite their efforts to peer across the vast distances of space through an obscuring atmosphere, scientists of the past had only one planet they could study closely, the Earth. But the past 20 years of planetary spaceflight have given new definitions to "Earth" sciences like geology and meteorology and spawned an entirely new discipline called comparative planetology.

By studying the geology of planets and moons, and comparing the differences and similarities between them, we are learning more about the origin and history of these worlds and the solar system as a whole.

Weather affects all of us on the Earth. In its extremes, weather can threaten life, and long term climatic changes on the Earth could be catastrophic. It is important to understand our complex weather machine. But other planets have weather too. By studying the weather on other worlds and comparing it to our own, we may better understand our Earth.

Geology and weather are just two major areas of science benefitting from our planetary space probes. Someday perhaps, terrestrial biologists will get their chance to compare the only lifeforms we've ever known, those on our Earth, to living creatures from another world.



The Moon-like surface of Mercury is revealed in this photograph taken by the approaching Mariner 10 spacecraft.

Mercury

Obtaining the first closeup views of Mercury was the primary objective of the Mariner 10 space probe, launched from Kennedy Space Center in November 1973. After a journey of nearly five months, which included a flyby of Venus, the spacecraft passed within 805 kilometers (500 miles) of the solar system's innermost planet on March 29, 1974.

The photographs Mariner 10 radioed back to Earth revealed an ancient, heavily cratered surface on Mercury, closely resembling our own Moon. The pictures also showed huge cliffs crisscrossing the planet. These apparently were created when Mercury's interior cooled and shrank, compressing the planet's crust. The cliffs are as high as two kilometers (1.2 miles) and as long as 1500 kilometers (932 miles).

Instruments onboard Mariner 10 discovered that the planet has a weak magnetic field and a trace of atmosphere—a trillionth the density of the Earth's and composed chiefly of argon, neon and helium. The spacecraft reported temperatures ranging from 510 degrees Celsius (950 degrees Fahrenheit) on Mercury's sunlit side to −210 degrees Celsius (−346 degrees Fahrenheit) on the dark side. Mercury literally bakes in daylight and freezes at night.

The days and nights are long on Mercury. It takes 59 Earth days for Mercury to make a single rotation. It spins at a rate of about 10 kilometers (about 6 miles) per hour, measured at the equator, as compared to Earth's spin rate of about 1600 kilometers (about 1,000 miles) per hour at the equator.

Mercury, like the Earth, appears to have a crust of light silicate rock. Scientists believe it has a heavy iron-rich core that makes up about half of its volume.

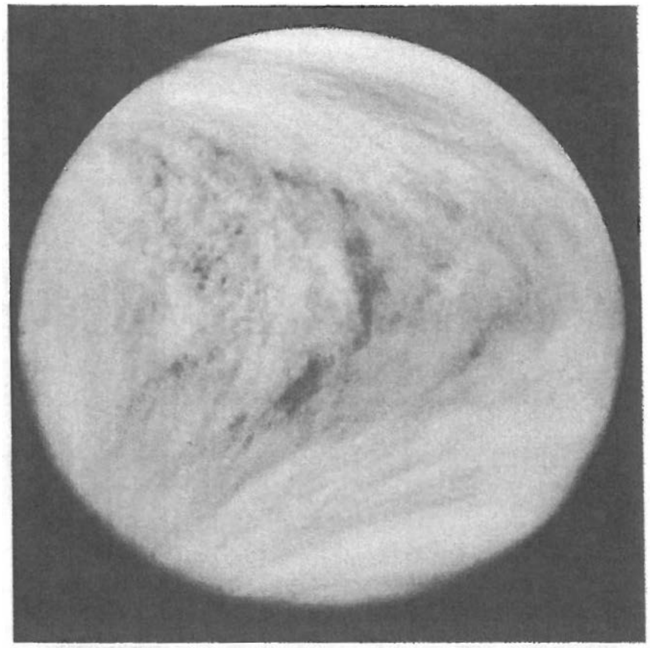
Mariner 10 made two additional flybys of Mercury—on September 21, 1974 and March 16, 1975—before control gas used to orient the spacecraft was exhausted and the mission was concluded.

Until the Mariner 10 probe, little was known about Mercury. Even the best telescopic views from Earth showed Mercury as an indistinct object lacking any surface detail. The planet is so close to the Sun that it is usually lost in the Sun's glare. When it is visible on Earth's horizon just after sunset or before dawn, it is obscured by the haze and dust in our atmosphere. Only radar telescopes gave any hint of Mercury's surface conditions prior to the voyage of Mariner 10.

Venus

Veiled by dense cloud cover, our nearest neighboring planet was the earliest subject of interplanetary explorations. The Mariner 2 space probe, launched August 27, 1962, was the first of more than a dozen successful American and Soviet missions to study the mysterious planet. As spacecraft zoomed by, plunged into the atmosphere, and gently landed on Venus, romantic myths and speculations about our twin planet were laid to rest.

Mariner 2 passed within 34,762 kilometers (21,600 miles) of Venus on December 14, 1962, and became the first spacecraft to scan another planet. Its instruments made measurements of Venus for 42 minutes. Mariner 5, launched in June 1967, flew much closer to the planet. Passing within 4,023 kilometers (2,500 miles) of Venus on the second U.S. flyby, its instruments measured the planet's magnetic field, ionosphere, radiation belts and temperatures. On its way to Mercury, Mariner 10 flew by Venus and returned ultraviolet pictures showing cloud circulation patterns in the Venusian atmosphere.



An enhanced photo taken by the Pioneer Venus Orbiter shows the circulation of the dense Venusian atmosphere.

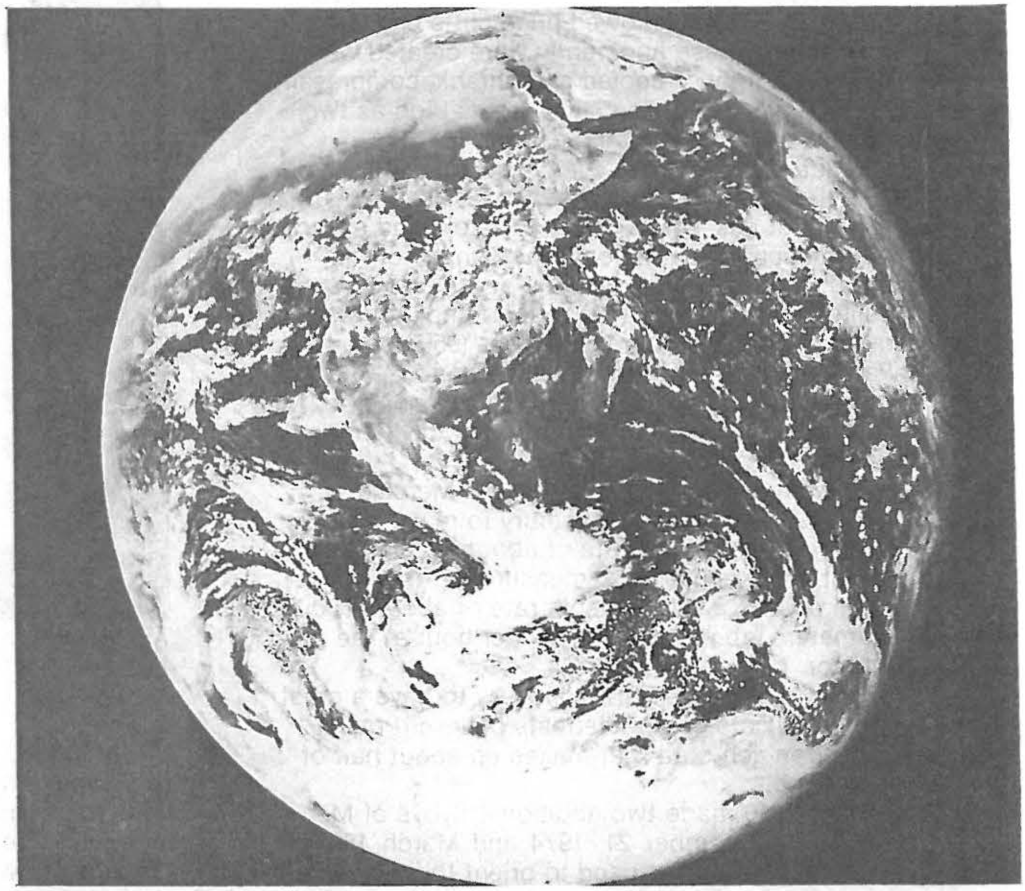
In the spring and summer of 1978, two spacecraft were launched to unravel the mystery of Venus. On December 4, the Pioneer Venus Orbiter became the first spacecraft placed in orbit around the planet.

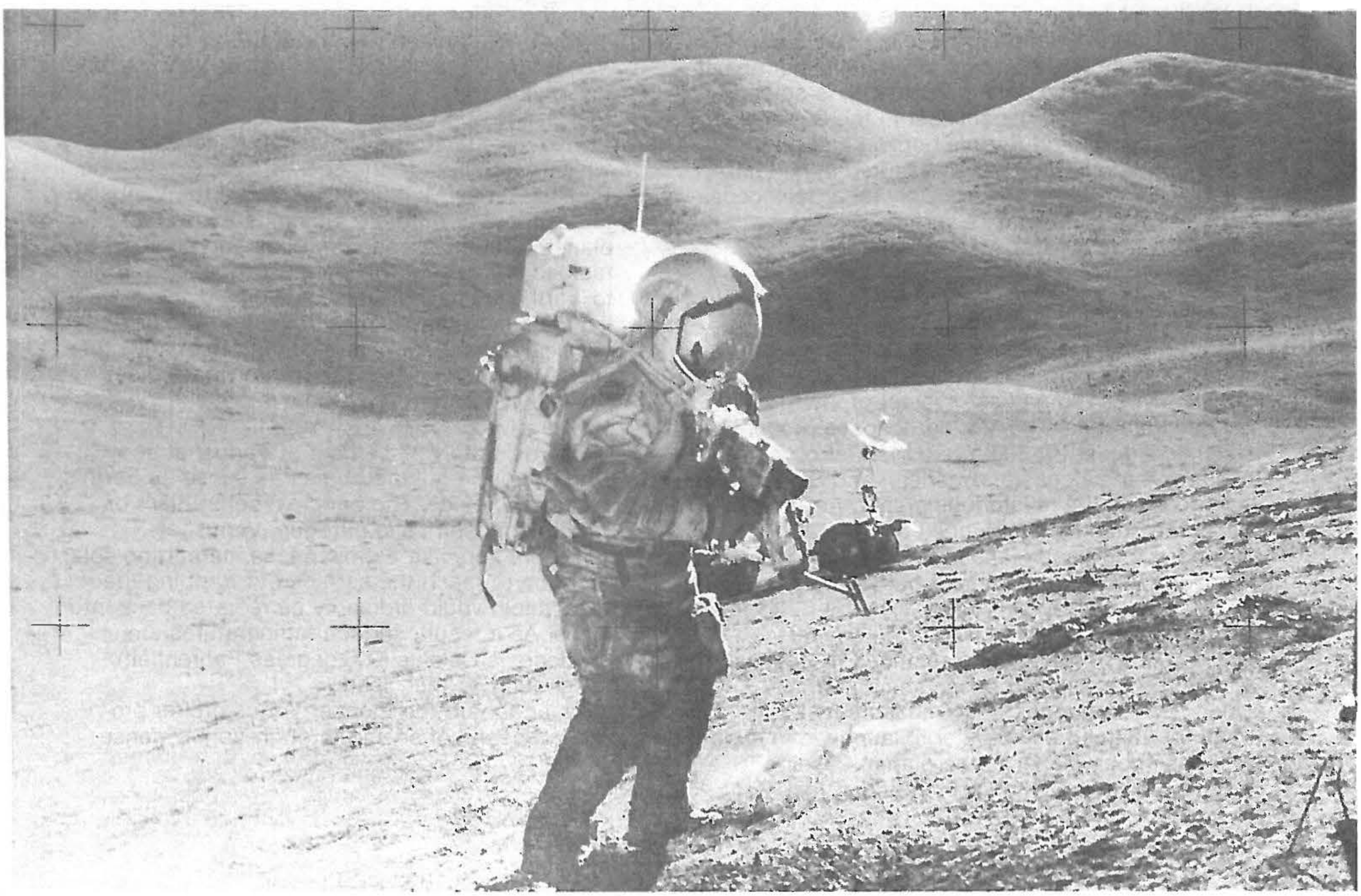
Five days later, the five separate components which had made up the second spacecraft—the Pioneer Venus Multiprobe—entered the Venusian atmosphere at different locations above the planet. Four independent probes and a main body radioed data about the planet's atmosphere back to Earth during their descent toward the surface.

Venus more nearly resembles Earth in size, physical composition, and density than any other known planet. However, spacecraft have discovered vast differences in how these planets have evolved.

Approximately 97 percent of Venus' atmosphere, about a hundred times as dense as Earth's, is carbon dioxide. The principal constituent of Earth's atmosphere is nitrogen. Venus' atmosphere acts like a greenhouse, permitting solar radiation to reach the surface but trapping the heat which would ordinarily be radiated back into space. As a result, surface temperatures are 482 degrees Celsius (900 degrees Fahrenheit), hot enough to melt lead.

Radar aboard the Pioneer Venus orbiter provided a means of seeing through Venus' dense





cloud cover and determining surface features over much of the planet. Among the features determined are two continent-like highland areas. One, about half the size of Africa, is located in the equatorial region. The other, about the size of Australia, is to the north.

There is evidence of two major active volcanic areas, one larger than Earth's Hawaii-Midway volcanic chain (Earth's largest)—with a mountain higher than Everest (Earth's highest mountain). The concentration of lightning over these two regions suggests frequent volcanic activity at both places. Discovery of active volcanism on Venus makes it the third solar system body known to be volcanically active. The others are Earth and the Jovian satellite Io.

Venus' predominant weather pattern is a high speed circulation of Venus' clouds which are made up of sulphuric acid. These speeds reach as high as 362 kilometers (225 miles) per hour. The circulation is in the same direction—east to west—as Venus' slow retrograde rotation. Earth's winds blow from west to east, the same direction as its rotation.

NASA's Pioneer-Venus orbiter continues to circle the planet. It is expected to send data about Venus to Earth for years to come.

Earth

From our journeys into space, we have learned much about our home planet—Earth. The first American satellite, Explorer 1, was launched from Cape Canaveral on January 31, 1958. It discovered an intense radiation zone, now called the Van Allen Radiation Region, surrounding Earth. Since then, other research satellites have revealed that our planet's magnetic field is distorted into a teardrop shape by the solar wind—the stream of charged particles continuously ejected from the Sun. We've learned that Earth's magnetic field does not fade off into space but has definite boundaries. And we now know that our wispy upper atmosphere, once believed calm and quiescent, seethes with activity, swelling by day and contracting by night. It is affected by the changes in solar activity and contributes to weather and climate on Earth.

Satellites positioned about 35,000 kilometers (22,000 miles) out in space play a major role every day in local weather forecasting. Their watchful electronic eyes warn us of dangerous storms. Continuous global monitoring provides a vast amount of useful data, as well as contributing to a better understanding of Earth's complex weather machine.

From their unique vantage point in space, spacecraft can survey the Earth's resources and monitor the planet's health.

As viewed from space, Earth's distinguishing characteristics are its blue waters and white clouds. Enveloped by an ocean of air consisting of 78 percent nitrogen and 21 percent oxygen, the planet is the only one in our solar system known to harbor life. Circling the Sun at an average distance of 149 million kilometers (93 million miles), Earth is the third planet from the Sun and the fifth largest in the solar system.

Its rapid spin and molten nickel-iron core give rise to an extensive magnetic field, which, coupled with the atmosphere, shields us from nearly all of the harmful radiation coming from the Sun and other stars. Most meteors burn up in Earth's atmosphere before they can strike the surface. The planet's active geological processes have left no evidence of the ancient pelting it almost certainly received soon after it formed.

The Earth has a single natural satellite—the Moon.

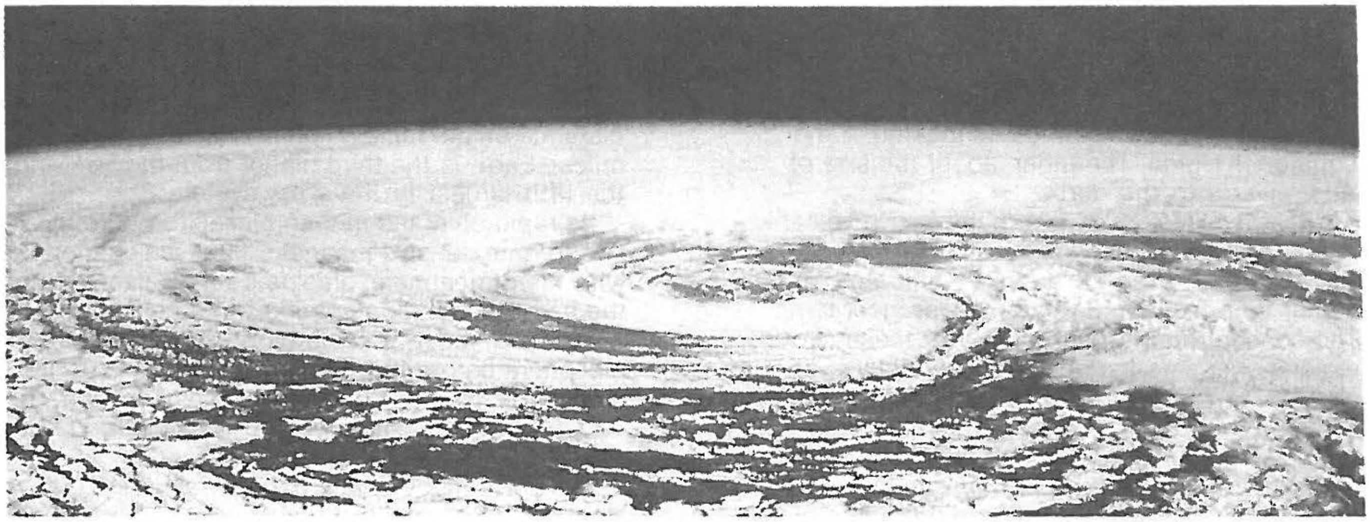
Moon

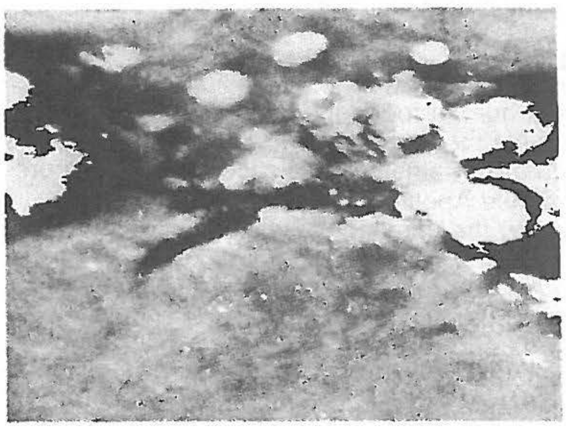
The first human footsteps upon an alien world were made by American astronauts on the dusty surface of our airless, lifeless companion. Before the manned Apollo expeditions, the Moon was studied by the unmanned Ranger, Surveyor, and Lunar Orbiter spacecraft.

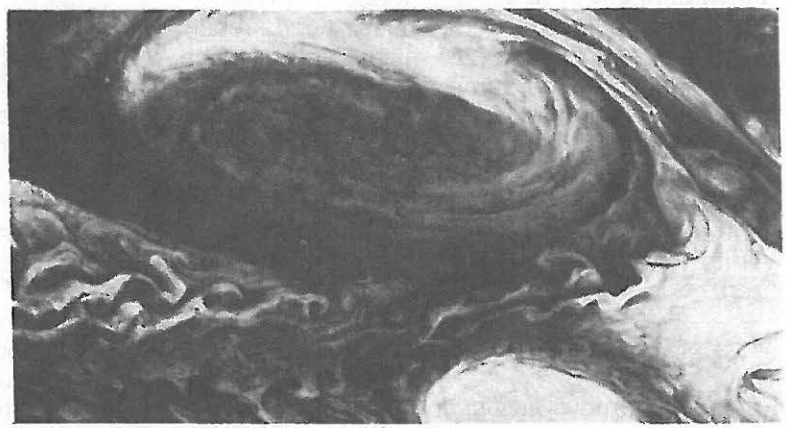
The Apollo program left us a large legacy of lunar materials and data. Six two-man crews landed on and explored the lunar surface between 1969 and 1972. They returned a collection of rocks and soil weighing 382 kilograms (842 pounds) and consisting of more than 2,000 separate samples.

From this material and other studies, scientists have constructed a history of the Moon dating back to its infancy. Rocks collected from the lunar highlands date about 4.0 to 4.3 billion years old. It's believed that the solar system formed about 4.6 billion years ago. The first few million years of the Moon's existence were so violent that few traces of this period remain. As a molten outer layer gradually cooled and a solidified into different kinds of rock, the Moon was bombarded by huge asteroids and smaller objects. Some of the asteroids were the size of small states, like Rhode Island or Delaware, and their collisions with the Moon created huge basins hundreds of kilometers across.

The catastrophic bombardment died away about 4 billion years ago, leaving the lunar highlands covered with huge overlapping craters and a deep layer of shattered and broken rock. Heat produced by the decay of radioactive elements began to melt the inside of the Moon at depths of about 200 kilometers (124 miles) below its surface. Then, from about 3.8 to 3.1 billion years ago, great floods of lava rose from inside the Moon and

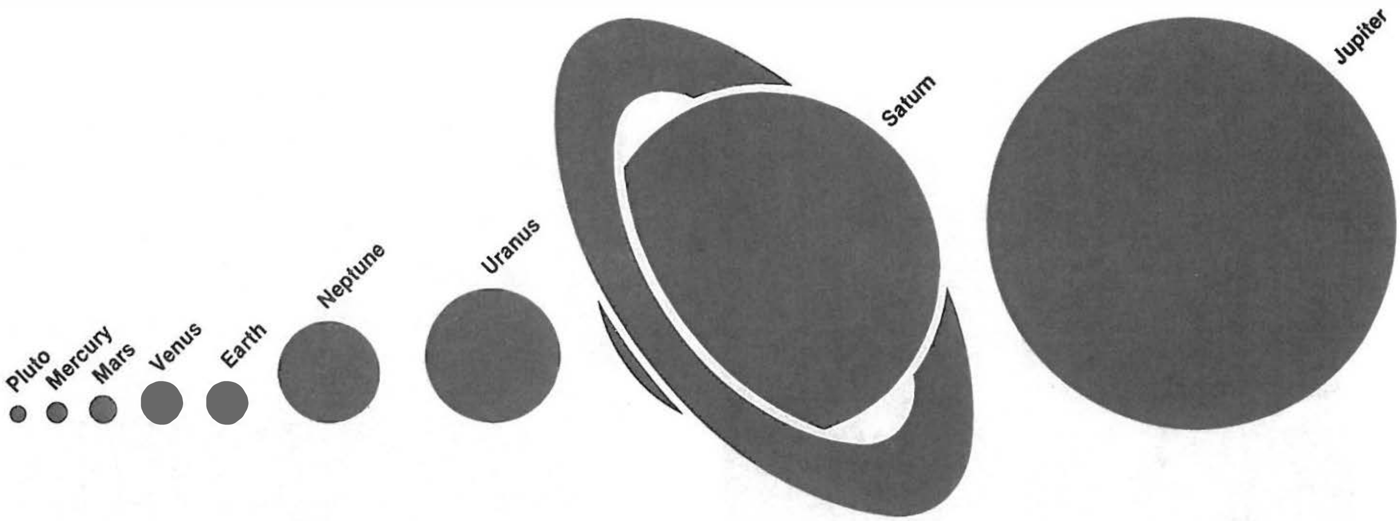






Hurricanes and typhoons on Earth are powered by differences in atmospheric temperatures and density. We know that similar weather conditions occur on Mars and Jupiter. Compare the sprawling Pacific storm (top) photographed by the Apollo 9 astronauts with a Martian cyclone (lower left) and Jupiter's Great Red Spot (lower right). The Martian cyclone is about 250 kilometers (155 miles) in diameter. The Great Red Spot on Jupiter is a hurricane-like feature which has raged for centuries. This single Jovian storm system is several times larger than the Earth.

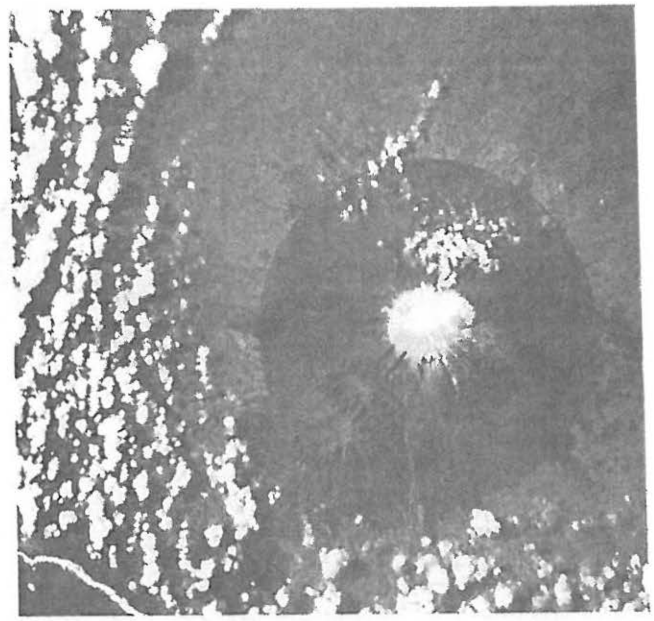
Jack Frost lives on Mars too. Light patches of frost on the Plains of Utopia (above) were observed during the Martian winter. The Viking landers became our first weather stations on another planet and scientists on Earth continue to get weekly updates from the Viking 1 site. Had Viking 1's first weather report been aired on the 6 p.m. news, it would have gone something like this: "Light winds from the east in the late afternoon, changing to light winds from the southeast after midnight. Maximum winds were 15 miles per hour. Temperatures ranged from minus 122 degrees Fahrenheit just after dawn to minus 22 degrees in midafternoon. Atmospheric pressure 7.70 milibars." (On Earth that same day, the lowest recorded temperature was minus 100 degrees Fahrenheit at the Soviet Vostock Research Station in the Antarctic.)

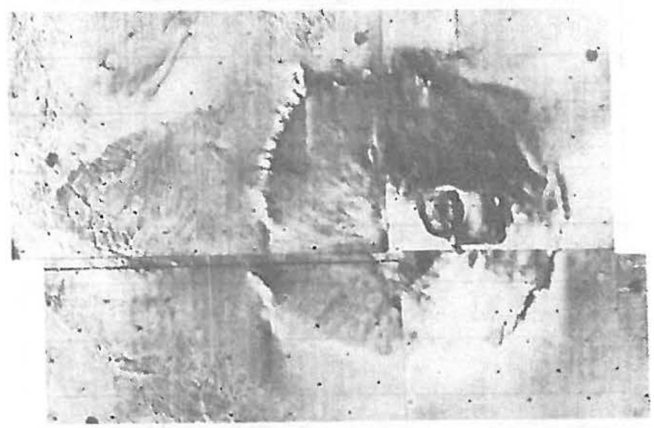


	Mercury	Venus	Earth	Mars	Jupiter	Saturn	Uranus	Neptune	Pluto
Mean Distance From Sun (Millions of Kilometers)	57.9	108.2	149.6	227.9	778.3	1,427	2,869	4,496	5,900
Period of Revolution	88 Days	224.7 Days	365.26 Days	687 Days	11.86 Years	29.46 Years	64.01 Years	164.1	247.7 Years
Rotation Period	59 Days	– 243 Days Retrograde	23 Hours 56 Minutes 4 Seconds	24 Hours 37 Minutes 23 Seconds	9 Hours 55 Minutes 30 Seconds	10 Hours 39 Minutes 20 Seconds	– 23.9 Hours Retrograde	22 Hours or Less	– 6 Days, 9 Hours 18 Minutes Retrograde
Inclination of Axis	2°	3°	23°27′	25°12′	3°5′	26°44′	97°55′	28°48′	60°?
Inclination of Orbit To Ecliptic	7°	3.4°	0°	1.9°	1.3°	2.5°	.8°	1.8°	17.2°
Eccentricity of Orbit	.206	.007	.017	.093	.048	.056	.047	.009	.25
Equatorial Diameter (Kilometers)	4,880	12,104	12,756	6,787	142,800	120,400	51,800	49,500	3,500
Atmosphere (Main Components)	Virtually None	Carbon Dioxide	Nitrogen Oxygen	Carbon Dioxide	Hydrogen, Helium	Hydrogen, Helium	Helium, Hydrogen, Methane	Hydrogen, Helium, Methane	None Detected
Known Satellites	0	0	1	2	16—1 Ring	21—23 Rings	5 Rings	2	1

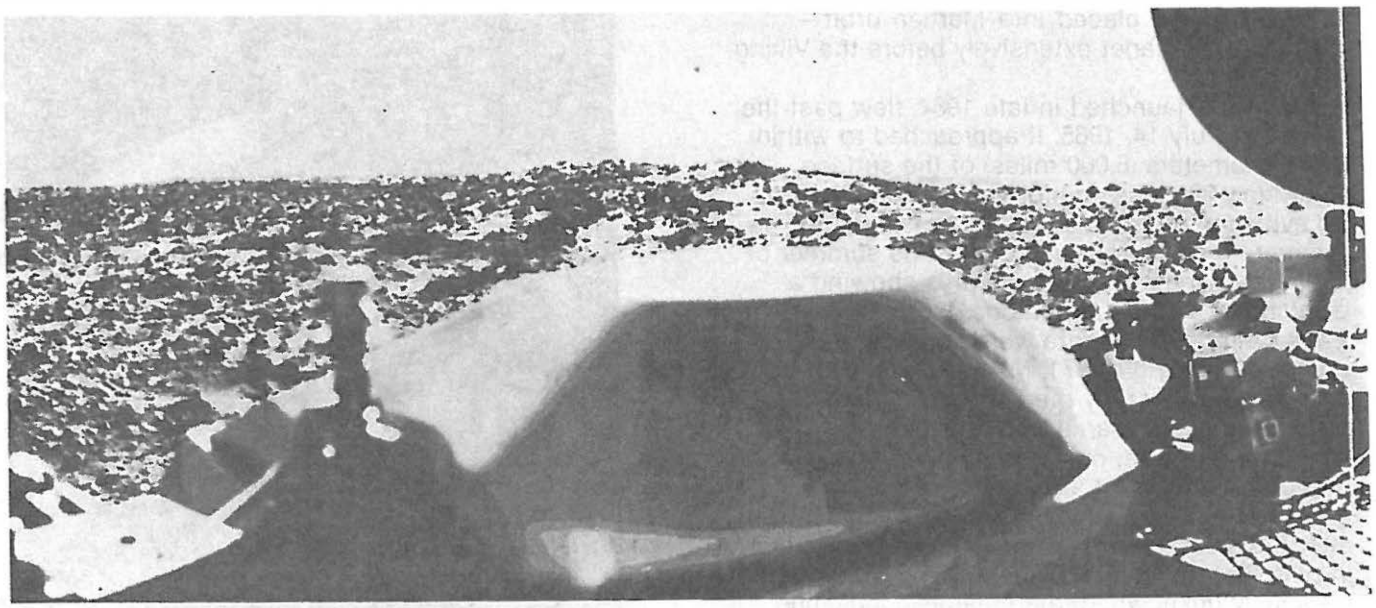
Large Martian channels (left) start near the volcano Elysium Mons and wind their way to the northwest for several hundred kilometers. Their origin is controversial: Did they form from lava flows or water released from the melting of ground ice during volcanic eruptions? Compare the Martian channels with the Skylab photograph of the Rio de la Plata river in Uruguay (right).

Impact craters are formed when a planetary surface is struck by a meteorite. Mercury, our Moon, and many of the icy, rocky satellites of the outer solar system are characterized by heavily cratered surfaces. On Earth, geological processes tend to destroy evidence of ancient crater impacts, although some more recent craters remain discernable. Compare the lunar craters (top) with craters on Mars (bottom).





Volcanoes are vents in a planet's crust that permit the escape of internal heat. The geologically active Earth has hundreds of volcanoes, like this one in New Zealand (top). Compare it to one of the large shield-type volcanoes on Mars (center). It was a surprise to scientists that Jupiter's moon Io is volcanically active (bottom). Voyager 1 photographed a volcanic plume (visible above the limb of Io) about 11 hours before its closest approach. Researchers believe tidal forces resulting from Jupiter's massive size are responsible for the internal heating of Io. The active volcanoes on Io are the only ones known in the solar system other than Earth's. In addition to Mars, evidence of volcanic activity in the past has been found on the Moon, Mercury and Venus.



A rock-littered, rolling landscape is seen by the Viking 1 lander after its touchdown on Mars. Parts of the spacecraft are visible in the foreground. This is a portion of the first panoramic view returned to Earth by the robot spacecraft.

poured out over its surface, filling in the large impact basins to form the dark parts of the Moon—called maria or seas. Explorations show that there has been no significant volcanic activity on the Moon for more than 3 billion years and, since then, the lunar surface has been altered only by the rare impacts of large meteorites and by the atomic particles from the Sun and stars.

If our astronauts had landed on the Moon a billion years ago, it would have looked very much as it does today, and thousands of years from now, the footsteps left by the Apollo crews will remain sharp and clear.

One question about the Moon that remains unsolved is where did it come from? Three theories attempt to explain its existence: that it formed near the Earth as a separate body, that it separated from the Earth, or that it formed somewhere else and was captured by the Earth. The notion that the Moon may have once been part of the Earth now appears less likely than the other suggestions because of the difference between the two bodies in chemical composition, such as the absence of water either free or chemically combined in rocks. The other two theories are about evenly matched in strengths and weaknesses. The origin of the Moon remains a mystery.

Mars

Of all the planets, Mars has long been considered the solar system's prime candidate for harboring extraterrestrial life. Astronomers observing the red planet through telescopes saw what appeared to be straight lines crisscrossing its surface. These observations—later determined to be optical illusions—led to the popular notion that intelligent beings had constructed a system of irrigation canals on the planet. In 1938, when Orson Welles broadcast a radio drama based on the science fiction classic "War of the Worlds," enough people believed in the tale of invading Martians to cause a near panic.

Another reason for scientists to expect life on Mars arose from apparent seasonal color changes on the planet's surface. That led to speculation that conditions might support a bloom of Martian vegetation during the warmer months and cause plant life to become dormant during colder periods.

In August and September 1975, two Viking spacecraft—each consisting of an orbiter and a lander—were launched from Kennedy Space Center, Florida on a mission designed to answer several questions, including: is there life on Mars? Nobody expected the spacecraft to spot Martian cities but it was hoped the biology experiments on board the landers would at least find evidence of primitive life, past or present.

The results sent back by the two unmanned laboratories, which soft-landed on the planet, were teasingly inconclusive. We still don't know whether life exists on Mars. Small samples of the red Martian soil were specially treated in three different experiments designed to detect biological processes. While some of the tests indicated biological activities were occurring, the same results could be explained by the planet's soil chemistry. There was a notable absence of evidence that organic molecules exist on Mars.

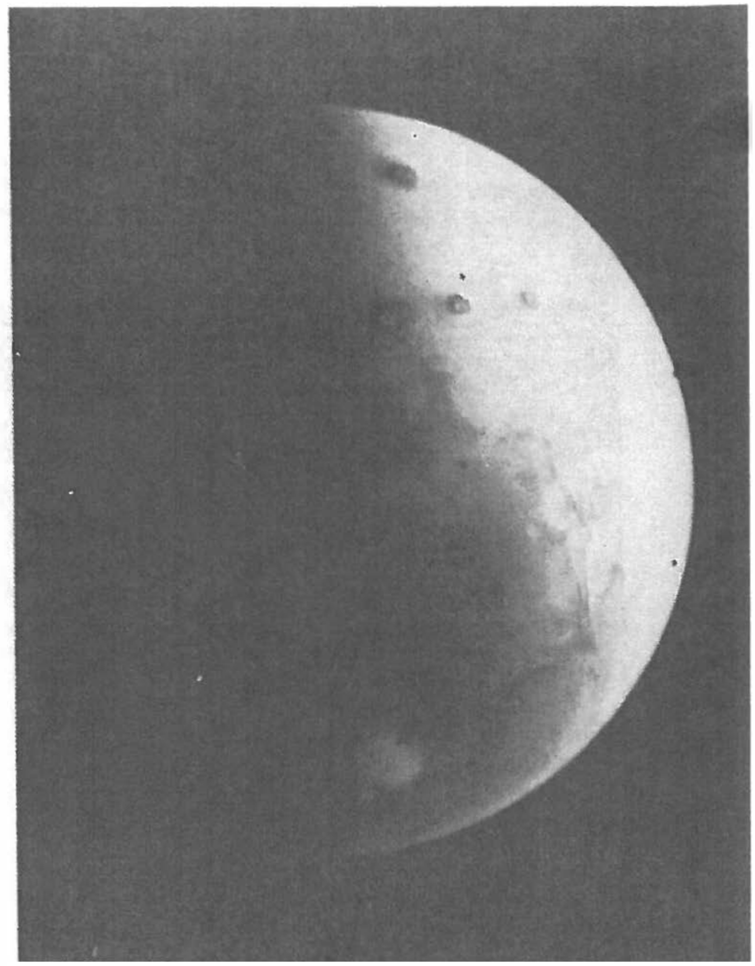
Despite the inconclusive results of the biology experiments, we know more about Mars than any other planet except Earth. Six U.S. missions to the red planet have been carried out. Four Mariner spacecraft—three which flew by the planet and one which was placed into Martian orbit—surveyed the planet extensively before the Viking missions.

Mariner 4, launched in late 1964, flew past the planet on July 14, 1965. It approached to within 9,656 kilometers (6,000 miles) of the surface. Returning 22 close-up pictures of Mars, it found no evidence of artificial canals or flowing water. Mariners 6 and 7 followed during the summer of 1969, returning about 200 pictures showing a diversity of surface conditions during their flybys. Earlier atmospheric data were confirmed and refined. On May 30, 1971, Mariner 9 was launched on a mission to study the Martian surface from orbit for nearly a year. It arrived five and a half months after liftoff, only to find Mars in the midst of a planet-wide dust storm which made surface photography impossible for several weeks. But after the storm cleared, Mariner 9 began returning the first of 7,000 pictures which revealed previously unknown Martian features, including evidence that rivers, and possibly seas, could have once existed on the planet. The Mariner missions to Mars were followed up with the Viking Project—the first American soft landing on the surface of another planet, excluding our own Moon.

All four spacecraft, two orbiters and two landers, exceeded by large margins their design lifetime of 90 days. The four spacecraft were launched in 1975 and began Mars operation in 1976. The first to fail was Orbiter 2 which stopped operating in July 24, 1978 when its attitude control gas was depleted because of a leak. Lander 2 operated until April 12, 1980 when it was shut down due to battery degeneration. Orbiter 1 operated until August 7, 1980, when it too used the last of its attitude control gas. Lander 1 is still operating.

Photos sent from the Plain of Chryse—where Viking 1 landed on July 20, 1976—show a bleak, rusty red landscape. A panorama returned by the robot explorer pictures a gently rolling plain, littered with rocks and graced by rippled sand dunes. Fine red dust from the Martian soil gives the sky a pinkish hue. Viking 2 landed on the Plain of Utopia, arriving several weeks after its twin. The landscape it viewed is more rolling than that seen by Viking 1, and there are no dunes visible.

Both Viking landers became weather stations, recording wind velocity and direction, temperatures and atmospheric pressure.



The four largest Martian volcanoes stand out as distinctive dark circular features in this photograph taken from a distance of 575,000 kilometers (350,000 miles) by the approaching Viking 1 spacecraft.

As days became weeks, the Martian weather changed little. The highest atmospheric temperature recorded by either lander was −21 degrees Centigrade (−17 degrees Fahrenheit) at the Viking 1 site in midsummer.

The lowest temperature, −124 degrees Celsius (−191 degrees Fahrenheit), was recorded at the more northerly Viking 2 site during winter. Wind speeds near hurricane force were measured at the two Martian weather stations during global dust storms. Viking 2 photographed light patches of frost—probably water ice—during its second winter on the planet.

The Martian atmosphere, like that of Venus, is primarily carbon dioxide. Present in small percentages are nitrogen, oxygen and argon, with trace amounts of krypton and xenon. Martian air contains only about 1/1000 as much water as Earth's but even this small amount can condense out and form clouds which ride high in the atmosphere, or swirl around the slopes of towering Martian volcanoes. Local patches of early morning fog can form in valleys.

There is evidence that in the past, a denser Martian atmosphere may have allowed water to flow on the planet. Physical features closely resembling shorelines, gorges, riverbeds and islands suggest that great rivers once existed on the planet.

Mars has two small, irregularly shaped moons, Phobos and Deimos, with ancient, cratered surfaces.

Jupiter

Outward from Mars and beyond the Asteroid Belt lie the giants of our solar system.

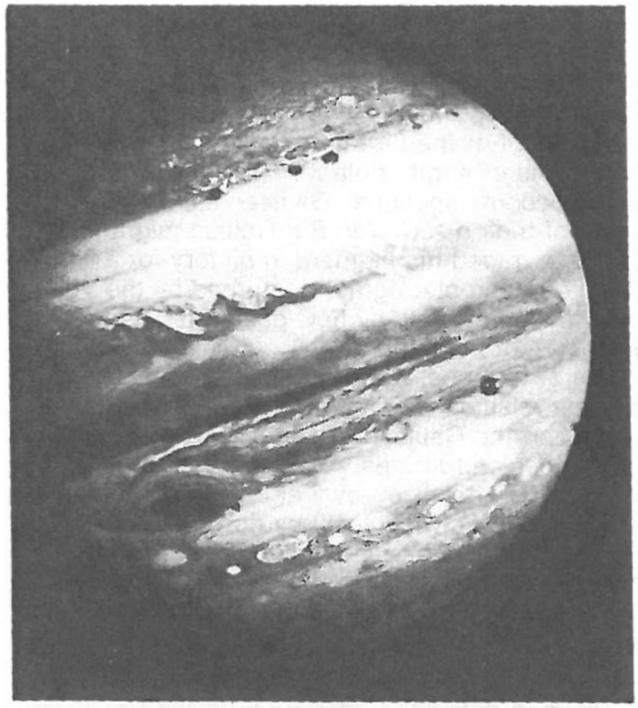
In March 1972, NASA dispatched the first of four space probes to survey the colossal worlds of gas and their moons of rock and ice. For each probe, Jupiter was the first port of call.

Pioneer 10, which lifted off from Kennedy Space Center March 2, 1972, was the first spacecraft to penetrate the Asteroid Belt and travel to the outer regions of the solar system. In December 1973, it returned the first closeup pictures of Jupiter as it flew within 130,354 kilometers (81,000 miles) of the planet's banded cloudtops. Pioneer 11 followed a year later. Voyagers 1 and 2 were launched in the summer of 1977 and returned spectacular photographs of Jupiter and its 16 satellites during flybys in 1979.

During their visits these exploring spacecraft found Jupiter to be a whirling ball of liquid hydrogen, topped with a uniquely colorful atmosphere which is mostly hydrogen and helium. It contains small amounts of methane, ammonia, ethane, acetylene, phosphene, germanium tetrahydride and possibly hydrogen cyanide. Jupiter's clouds also contain ammonia and water crystals. Scientists believe it likely that between the planet's frigid cloud tops and the warmer hydrogen ocean that lies below, there are regions where methane, ammonia, water and other gases could react to form organic molecules. Because of Jupiter's atmospheric dynamics, however, these organic compounds, if they exist, are probably short lived.

The Great Red Spot has been observed for centuries through Earth-based telescopes. It is a tremendous atmospheric storm, similar to Earth's hurricanes, which rotates counterclockwise.

Our space probes detected lightning in Jupiter's upper atmosphere and observed auroral emissions similar to Earth's northern lights in the Jovian polar regions.



Jupiter looms ahead of the Voyager 1 spacecraft. The Great Red Spot is visible at the lower left. Slightly above the feature, and to the right, is the volcanically active moon Io.

Voyager 1 returned the first evidence of a ring encircling Jupiter. Photographs returned by the spacecraft and its companion Voyager 2 showed a narrow ring too faint to be seen by Earth's telescopes.

Largest of the solar system's planets, Jupiter rotates at a dizzying pace—once every 9 hours, 50 minutes and 30 seconds. It takes the massive planet almost 12 Earth years to complete a journey around the Sun. The planet is something of a mini solar system, with 16 known moons orbiting above its clouds.

A new mission to Jupiter—the Galileo Project—is being readied for the late 1980s. An atmospheric probe will descend into Jupiter's cloud layers while another spacecraft orbits the planet.

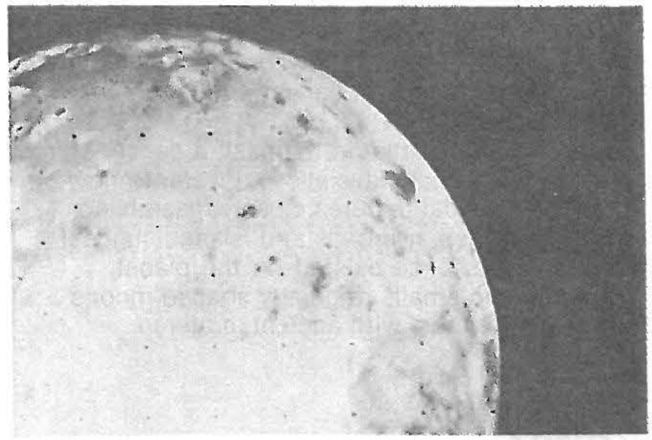
Galilean Satellites

In 1610, Galileo Galilei aimed his telescope at Jupiter and spotted four points of light orbiting the planet. For the first time, humans had seen the moons of another planet. The four worlds would become known as Galilean satellites, in honor of their discoverer. But Galileo might happily have traded his moment in history for a look at the dazzling photographs returned by the Voyager spacecraft as they flew past Jupiter's four planet-sized satellites.

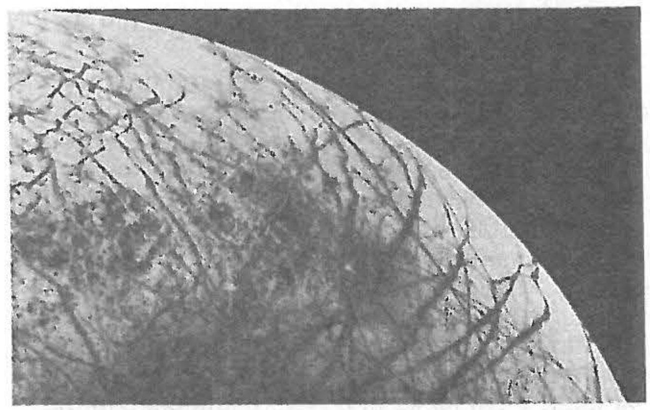
One of the most remarkable findings of the Voyager mission was the discovery of active volcanoes on the Galilean moon Io. It was the first time volcanic eruptions were observed on a world other than Earth. The Voyager cameras identified at least eight active volcanoes on the moon. Plumes extended as far as 250 kilometers (155 miles) above the moon's surface. The satellite's pizza-colored surface, rich in hues of oranges and yellow, is probably the result of sulphur-rich materials which have been brought to the surface by volcanic activity.

Europa, approximately the same size as our Moon, is the brightest Galilean satellite. Its surface displays a complex array of streaks that indicate the crust has been fractured.

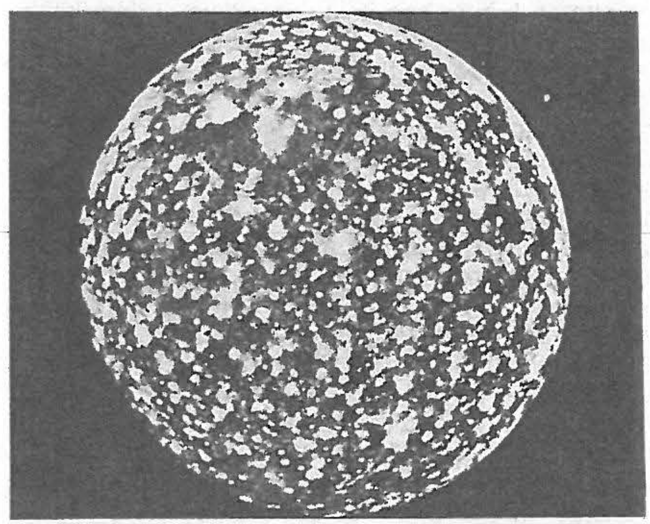
Like Europa, the other two Galilean moons—Ganymede and Callisto—are frozen worlds of ice and rock. Ganymede is the largest satellite in the solar system—larger than the planet Mercury. It is composed of about 50 percent water or ice and the rest rock. Callisto, only slightly smaller than Ganymede, has the lowest density of any Galilean satellite, implying that it has large amounts of water in its composition. More detailed studies of the Galilean satellites will be performed by the next orbiting spacecraft scheduled to be sent to Jupiter.



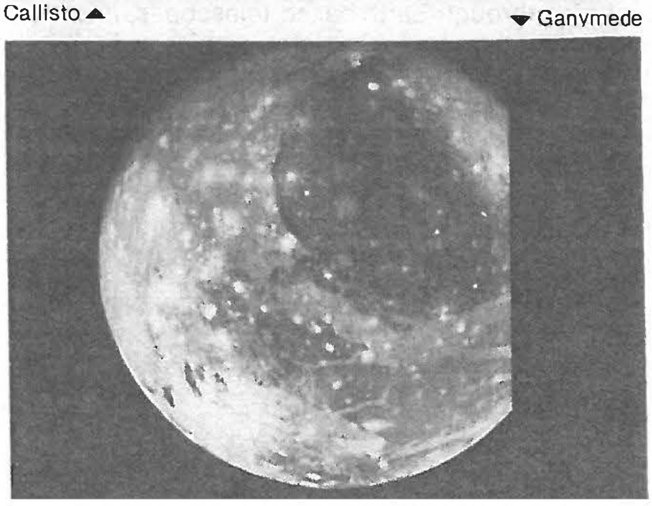
Io



Europa



Callisto ▲ ▼ Ganymede



Saturn

No planet in the solar system is adorned like Saturn. Its exquisite ring system is unrivalled. Like Jupiter, Saturn is composed mostly of hydrogen. But in contrast to the vivid colors and wild turbulence found in Jupiter's clouds, Saturn has a more subtle, butterscotch hue and its markings are often muted by high altitude haze.

Three American spacecraft have visited Saturn. Pioneer 11 zipped by the planet and its moon Titan in 1979, returning the first closeup pictures. Voyager 1 followed in November 1980, sending back breathtaking photographs that revealed for the first time the complexities of Saturn's ring system and moons. Voyager 2 flew by the planet and its moons in August 1981.

The spacecraft discovered that there are actually thousands of ringlets encircling Saturn.

Saturn's rings are composed of countless low-density particles orbiting individually around the equator at progressive distances from the planet's cloud tops. Analysis of radio waves passing through the rings showed that the particles vary widely in size, ranging from dust to boulders. Most of the material is ice and frosted rock.

Scientists believe the rings resulted, either from a moon or a passing body which ventured too close to Saturn and was torn apart by great tidal forces, or the incomplete coalescence of primordial planetary material, or from collisions with larger objects orbiting the planet.

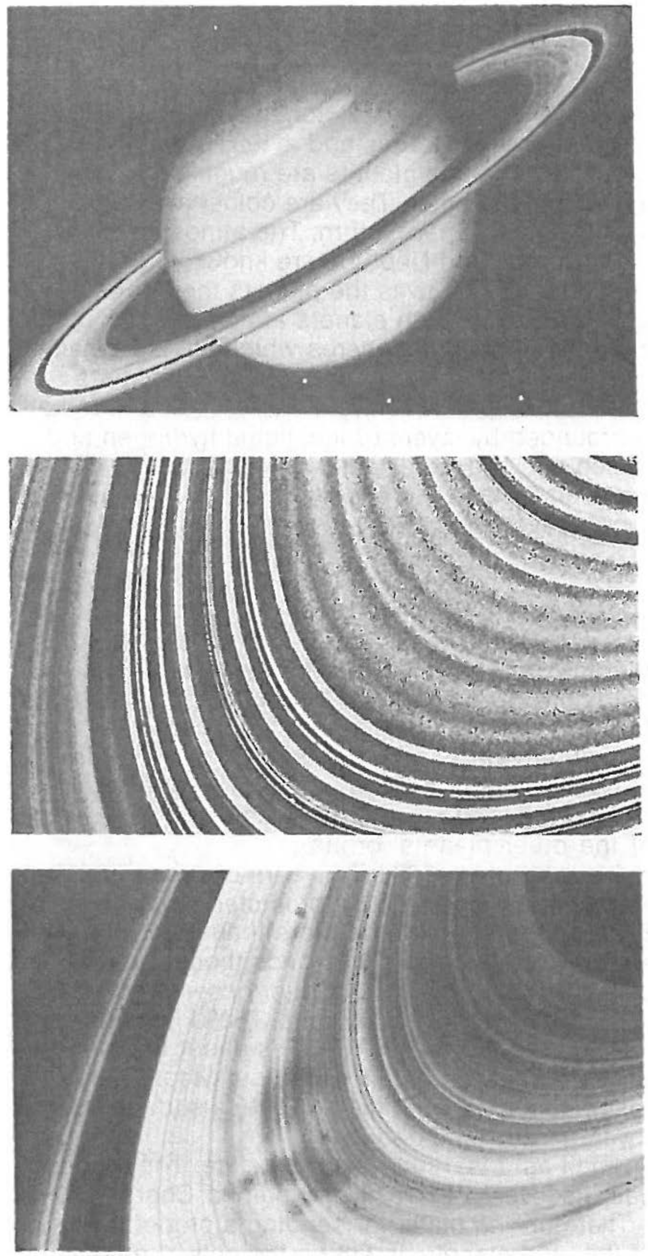
Unable either to form into a moon or to drift away from each other, individual ring particles appear to be held in place by the gravitational pulls of Saturn and its satellites.

Radio emissions quite similar to the static heard on an AM car radio during an electrical storm were detected by the Voyager spacecraft. These emissions are typical of lightning but are believed to be coming from the planet's ring system rather than its atmosphere. No lightning was observed in Saturn's atmosphere. But as they had at Jupiter, the Voyager spacecraft saw a version of Earth's northern and southern lights near Saturn's poles.

The probes also studied Saturn's moons, detected undiscovered moons, found some that share the same orbit, and determined that Titan has a nitrogen-based atmosphere.

A large constituent of Titan's atmosphere is methane. The surface temperature of Titan appears to be around the "triple" point of methane, meaning methane may be present on Titan in all three states: liquid, gaseous, and solid (ice). Methane, therefore, may play the same role on Titan that water plays on Earth.

Although the spacecraft's cameras could not peer through the dense haze that obscures the surface of Titan, measurements indicate Titan may be a place where rain or snow falls from methane clouds and rivers of methane cut through methane glaciers.



Voyager 2 photographs of the Saturn ring system during its August 1981 approach. The shadow of the planet's exquisite ring system can be clearly seen in the equatorial region.

Continuing photochemistry due to solar radiation may be converting Titan's methane to ethane, acetylene, ethylene, and, in combination with nitrogen, hydrogen cyanide. The latter is a building block to amino acids. Titan's temperature is believed to be too low to permit progress beyond this stage of organic chemistry. However, this condition may be similar to that which occurred in the atmosphere of the primeval Earth between three and four billion years ago.

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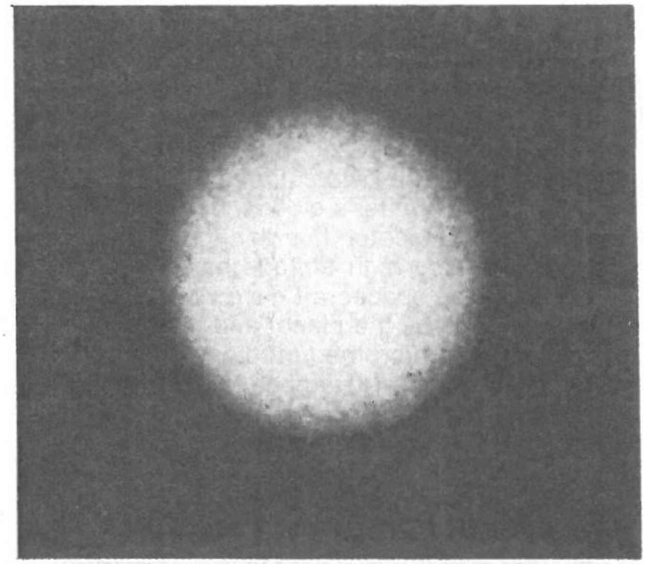
Uranus and Neptune

The first spacecraft to reach these bluish green giants will be Voyager 2, scheduled for a 1986 encounter with Uranus and a 1989 survey of Neptune. The two planets are roughly the same in mass and diameter. They are colder and significantly denser than Saturn. The atmospheres of both Uranus and Neptune are known to contain methane, which gives the planets their unusual greenish color. Both planets are believed to possess deep atmospheres which are principally composed of hydrogen and helium. Scientists theorize the planets have cores of rock and metal surrounded by layers of ice, liquid hydrogen and gaseous hydrogen. Uranus has a system of faint rings discovered in 1977. Uranus has five known moons, Neptune, two.



This fuzzy image is the planet Uranus, photographed through a 36-inch telescope carried aloft in a high altitude balloon.

Pluto

Pluto is an oddity of the solar system. It has nothing in common with the gas giants. It travels farther from the Sun than any of the rest, yet the eccentricity of its orbit periodically carries it inside of Neptune's orbit. Pluto's orbit is also highly inclined; that is, it is well above and below the plane of the other planets' orbits.

Discovered in 1930 after years of searching by astronomers looking for a predicted ninth planet, Pluto appears to be little more than a celestial snowball. Its diameter was once thought to be greater than Mercury's but later observations calculate it between 3,000 and 3,500 kilometers (1,864 and 2,175 miles), which is about the same size or somewhat smaller than our Moon. Earth-based observations indicate Pluto's surface is covered with methane ice.

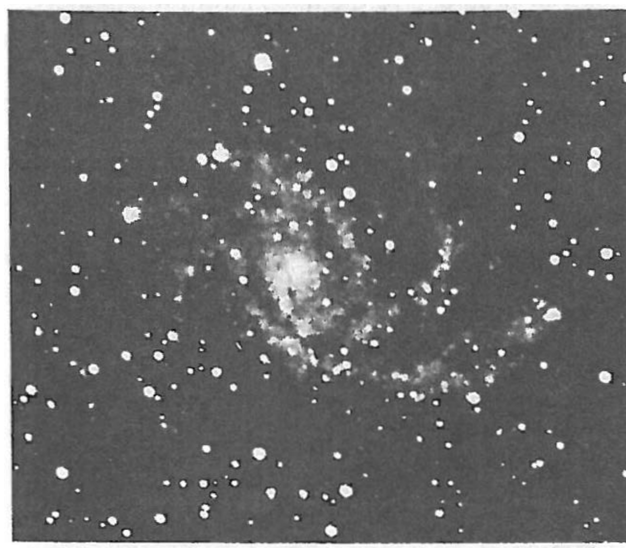
Small as it is, Pluto has a satellite. The moon was discovered in 1978 and named Charon.

There are no plans for sending a probe to Pluto. Of the nine planets, it will be the only one not visited this century by automated spacecraft, providing the Voyager 2 flies near Uranus and Neptune as planned.

Beyond

There may still be undiscovered planets that orbit the Sun. Some scientists believe there is evidence for a tenth planet beyond the orbit of Pluto. The search for new worlds in our solar system continues with Earth-based telescopes.

Soon the search for unknown planets will be extended to our neighboring stars with a new orbiting observatory—the Space Telescope. This unmanned telescope will be carried into orbit by the Space Shuttle in the mid 1980s.



U.S. Naval Observatory photo of the spiral galaxy NGC 6946.

Unimpaired by Earth's image-distorting atmosphere, the Space Telescope will enable astronomers to peer much farther into space and view objects much dimmer than they can with Earth-based telescopes.

Scientists may be able to spot planets orbiting nearby stars, proving what most researchers already believe—that the formation of star-orbiting planets occurs commonly in the universe.

As we study new worlds and expand the infant science known as comparative planetology, we are gradually piecing together age-old puzzles.

Automated probes to the planets are helping unravel the mystery of how the solar system formed and how it evolved into its present state. The missions are also telling us about our home planet, by studying the weather, geology and other conditions of our neighbors in space.

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