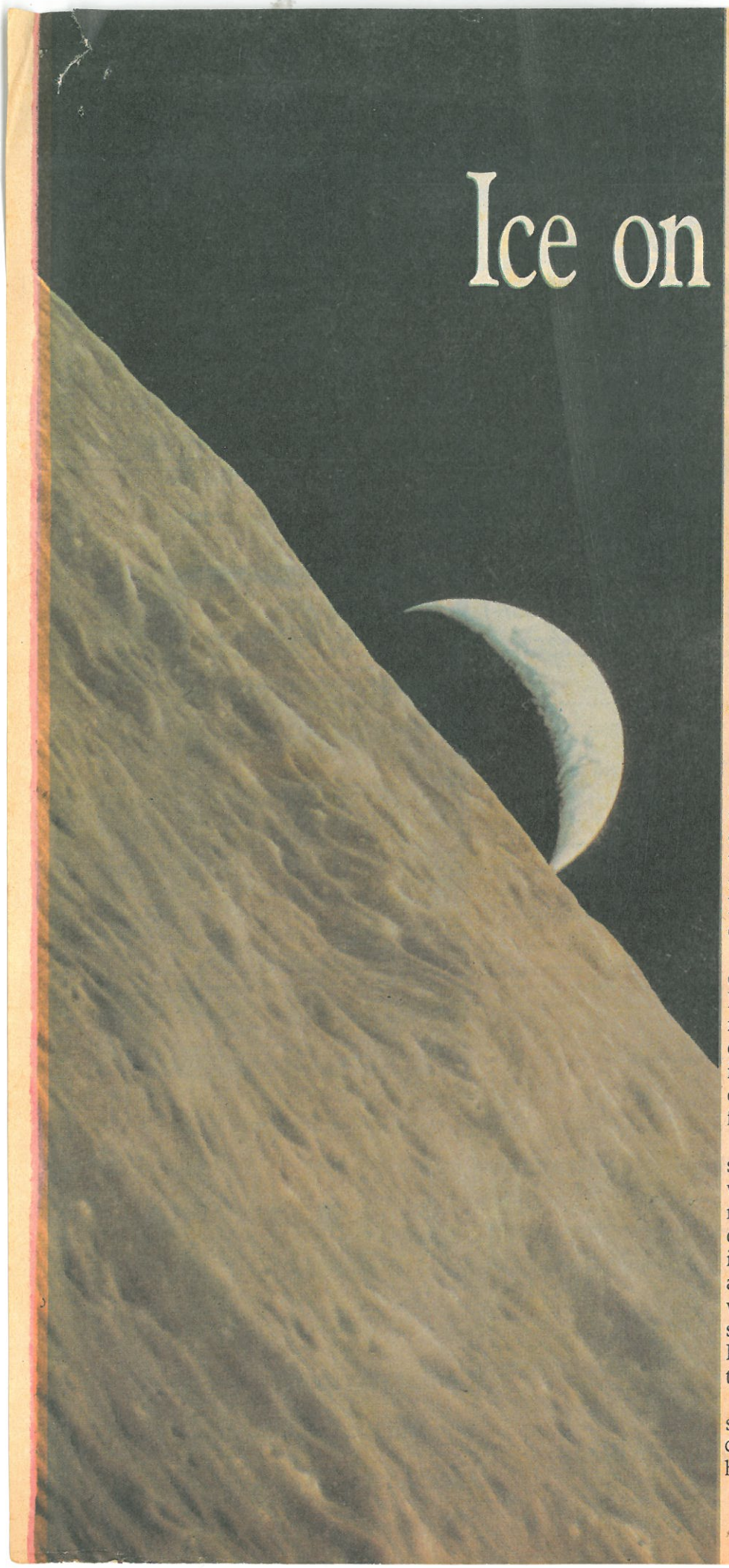

Ice on Moon

Yet another hidden treasure of the Moon has been explored. With conclusive evidence about the presence of Ice on the Moon, scientists are all set now to explore the possibility of setting up a lunar colony.

✍ G.P. Vinayababu

Moon is as old as the Earth and has been a source of constant curiosity for man right from the early stages of his creation. It is based on the Moon's movements that calendars are developed. It is the Moon which influences the sea water to rise up in the form of tides. It is based on the Moon that psychotic disorders are explained.

It assumes different meanings for different people in different contexts. For intimate lovers, it is an icon of romantic expression. For poets, it is an object of seamless imagination, while it is simply a source of eternal enchantment and unbounded curiosity for the common man.

Scientists, however, were not satisfied with merely appreciating the wonderful experience of a moonlit night. They wanted to probe into the origin and existence of this mysterious illuminous body. The great Italian astronomer Galileo Galilei (1564 - 1642) was the first person to study the lunar surface and publish a lunar map in 1610. He used his giant telescope to observe the surface of the Moon.

Further efforts to understand the surface of the Moon continued over the centuries after that, but it was only about half a century ago that serious efforts

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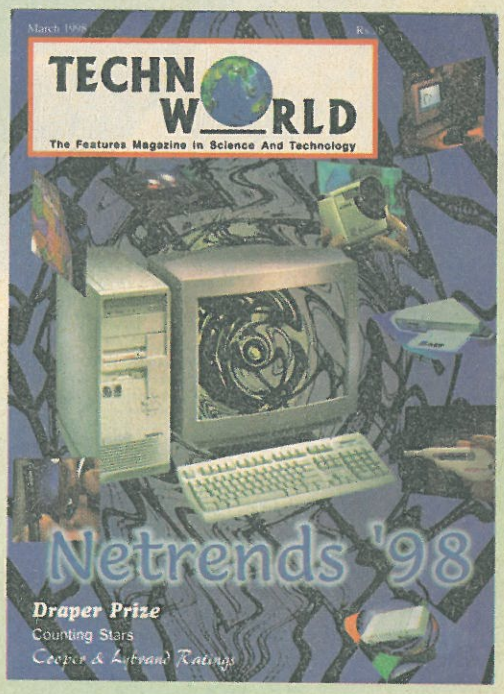

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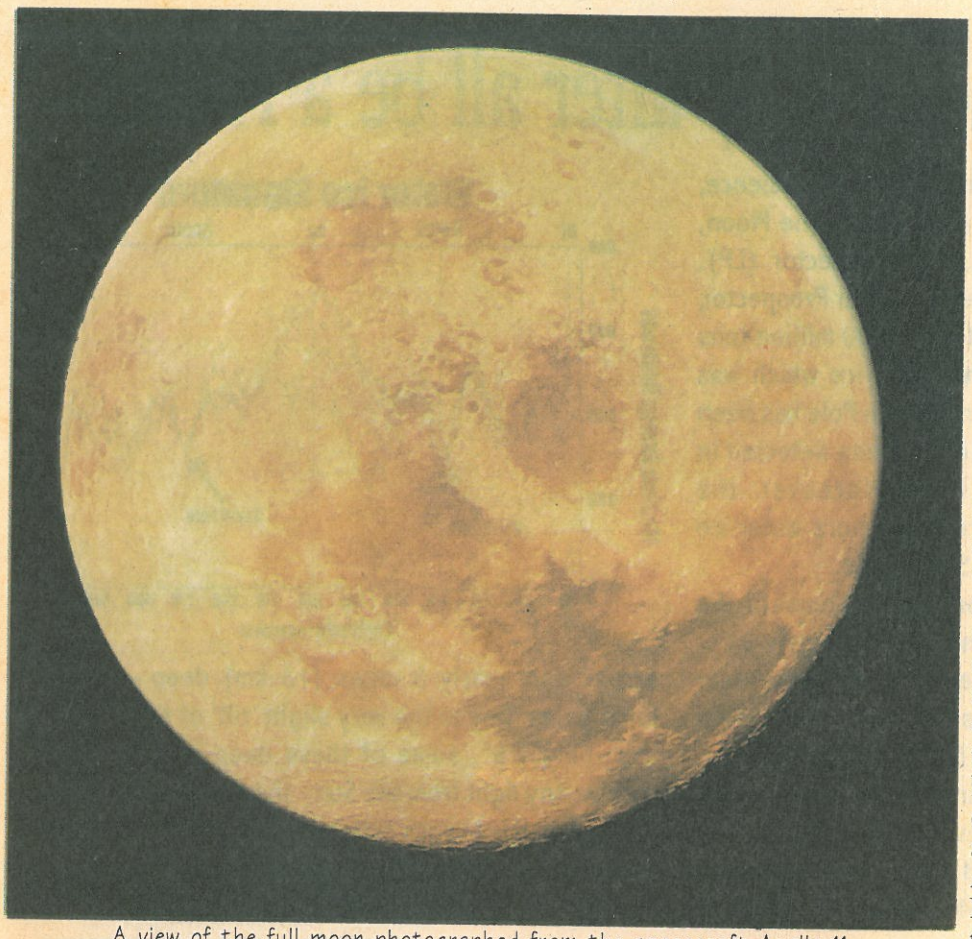


A view of the full moon photographed from the spacecraft Apollo 11 during its journey home.

began to be made to unravel the mystery of the Moon. With the data available about the lunar surface over the past five decades, Moon exploration has now reached a new peak with conclusive evidence about the presence of water on it. As the next step, Man's sights are on the setting up of a lunar colony.

The advancement in space technology and in the building of spacecraft made it possible for scientists to study the hitherto unexplored domains of our Solar System. And the exploration of the mysteries of our Solar System naturally began with the Moon, the only known natural satellite of the Earth. Direct lunar explorations started about five decades ago, though telescopic explorations were in place from several centuries before. In 1959, probes from the Soviet's Luna space craft first flew by and impacted the Moon's surface.

After this, a spate of space missions to the Moon were carried out by both the erstwhile Soviet Union and the United States of America in close competition. In response to the Soviet's Luna, NASA launched pioneer 4 which passed within 37,000 miles of the Moon. Further US missions like Ranger, Surveyor and Lunar Orbiter photographed the lunar surface extensively to pave the way for the human landing on the Moon. The greatest moment for mankind finally came on July 20, 1969, when Neil Armstrong set foot on the Moon, becoming the first man to land on the Moon - truly a small step for man and a giant leap for mankind. Apollo 11 and other Apollo missions were successful in returning scientific samples from the Moon - nearly 400 kg of Moon rock. To date there have been 22 missions to the Moon by NASA alone and several other missions by Europe, Japan and the erstwhile Soviet Union. After the successful landing of Neil Armstrong and his friends on the Moon in 1969, five other successful human landings have been achieved by NASA, apart

(contd. on page 33)

Moon formation theories

Theory	What does it say?
1. Impact theory	The Moon was formed when Earth collided with a very large object (the size of Mars or bigger), ejecting raw materials that eventually became the Moon.
2. Co-accretion theory	The Moon was formed in Earth's orbit along with all the other planets in the solar system.
3. Fission theory	The Earth was spinning at 10,000 miles/hr. in the early stages of formation of the Solar system. This resulted in the ejection of a large chunk of material in order to stabilise the earth. That chunk became the Moon.
4. Capture theory	The Moon was formed elsewhere in the solar system and was seized by the Earth.

Lunar colony may after all be a reality

The most hotly debated question in lunar science, as to whether water ice is available on the Moon, has been answered by the Lunar Prospector (LP). According to the data available from Lunar Prospector, there is somewhere between 10 and 300 million tons of water ice on the Moon. The water ice which was expected to be found on the lunar South Pole has been confirmed by LP. Surprisingly it has been detected in the craters of the North Pole. Moreover, the Prospector has detected nearly 50% more water ice in the North Pole than in the South Pole.

Comets and meteorites continually bombard the Moon. Water-rich meteorites and comets, largely water ice, may leave significant traces of water on the lunar surface. Energy from sunlight splits much of this water into its constituent elements hydrogen and oxygen, both of which usually fly off into space immediately. Some water molecules, however, may have literally hopped along the surface and gotten trapped inside enormous craters - some 1,400 miles (2,240 km) across and nearly 8 miles (13 km) deep - at the lunar poles. Due to the very slight 'tilt' of the Moon's axis, only 1.5°, some of these deep craters never receive any light from the Sun - they are permanently shadowed. It is in such craters that scientists expected to find frozen water. If found, water ice could be mined and then split into hydrogen and oxygen by solar panel-equipped electric power stations or a nuclear generator. Such components could make space operations as well as human colonisation on the Moon possible. Although the equatorial Moon rock collected by Apollo astronauts contained no traces of water, the recent Clementine mission suggested that small, frozen pockets of water ice (remnants of water-rich comet impacts) may be embedded unmelted in the permanently shadowed regions of the lunar crust.

The instrument which has been successful in determining the existence of water on the

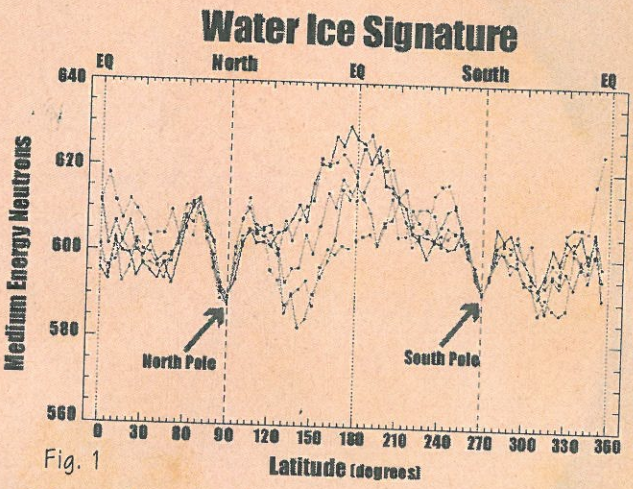
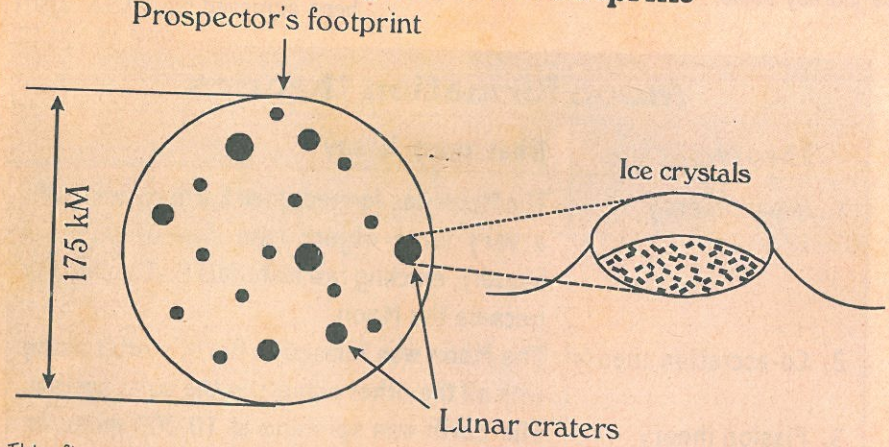


Fig. 1

Lunar Prospector's Footprint



This figure shows the Lunar Prospector's 'footprint', or mapping area, at both poles. This mapping area is roughly 150 km by 175 km. The footprint is round because Prospector is a spinning spacecraft and slightly elliptical because of the speed at which the rotating vehicle circles the Moon in its north-south polar orbit. In addition, the precise mapping area for each instrument varies slightly, due to size and distance factors peculiar to the positioning of each instrument.

Water Ice Crystals in Regolith

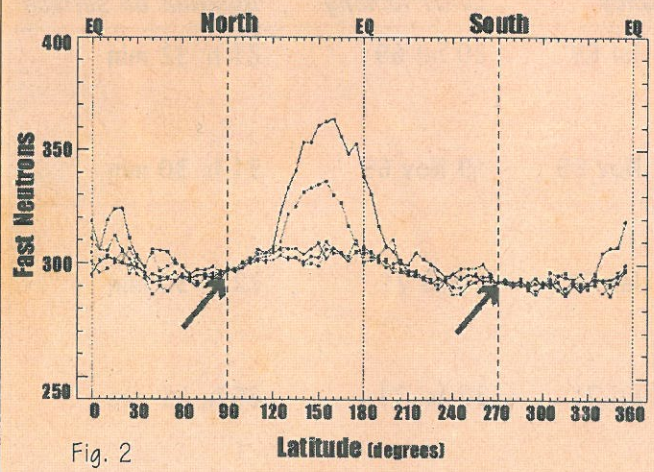


Fig. 2

Moon is the Prospector's Neutron Spectrometer, which can sense water ice (hydrogen) down to a depth of half-a-metre. Theoretical estimates has put the availability of water at two metres down the lunar surfaces. Further data from the gamma ray spectrometer will help mission scientists to sort out the precise distribution of lunar ice.

How does neutron spectroscopy determine the presence of water?

Small particles of energy called neutrons are continuously emanated from the surface of the Moon. This is an important input for the neutron spectrometer to determine the surface characteristics of the Moon. These neutrons are of three energy ranges - the low energy 'thermal' neutrons, medium energy 'epithermal' neutrons and high energy 'fast' neutrons. The interaction of these neutrons with the constituent ions on the surface of the Moon determines the composition of the surface. The wet lunar soil will contain hydrogen ions in abundance. The wet lunar soil (containing water) moderates (or slows down) the medium energy neutrons and the fast neutrons on interaction. This is an excellent indicator of the availability of water ice on the Moon. When the neutron collides with hydrogen ions, it will lose energy and will travel more slowly. In the graphic tabulated between the medium energy neutrons and the latitude of the moon (see Fig. 1), there is a perceptible dip near the poles, confirming the existence of hydrogen ions or the presence of water ice.

Based on the extent of the dips, mission scientists estimated that the total amount of water on the Moon could be anywhere between 10 and 300 million metric tons. Further data could make it much clearer for the scientists about the exact amount of water ice on the moon. One thing which is not known through medium energy neutrons is the nature of water, since the dips does not say whether the water is in the form of ice or not. This is confirmed to be in the form of ice with the data available from fast neutrons (see Fig. 2).

Source: www.nasa.gov

(contd. from page 31)

from one orbiter with humans aboard.

Moon formation: The first question which the scientists encountered in their quest to understand the Moon was its formation. During their exploratory missions to the Moon, the primary objective of the scientists was to find the necessary clues to formulate the Moon formation theory.

The present knowledge

Innumerable photographs have been taken of the lunar surface in successive missions carried out by both the United States and the Soviet Union. Moon rock samples are also available. The general conclusions based on all the data available from the Moon explorations so far include:

a) Moon consists of predominantly volcanic material and its composition is similar to that of the Earth.
b) Moon has a tiny metallic core, roughly 15 times smaller than that of the Earth.
c) The Moon has no significant magnetic field and it has no significant atmosphere.
d) The outermost layer of the Moon's surface is covered by regolith, a loose, dusty material.
e) The lunar crust is composed of a variety of primary elements, including thorium, potassium, oxygen, silicon, magnesium, iron, titanium, calcium, aluminium and hydrogen.
f) The unprotected regolith is constantly exposed to the solar wind, which carries both hydrogen and helium. If proved conclusively, the Moon will be the best source of helium anywhere in the Solar System.
g) The lunar crust ranges from 60 km on the near side to 100 km on the far side. The regolith varies from 3 to 5 m in the *maria* (or lowlands) to 10 - 20 m in the highlands.

The little knowledge we have gained about the lunar surface has provided clues not only to the formation of the Moon but also to the formation of the entire Solar System. Several theories have been put forth by scientists to

Manned Lunar Landing Missions

Spacecraft	*Crew*	*Launch*	*Lunar landing*	*Duration on surface*
Apollo 11	Edwin 'Buzz' Aldrin* Neil Armstrong* Michael Collins	16 Jul 69	20 Jul 69	21 h, 32 min
Apollo 12	Alan Bean* Charles Conrad* Richard Gordon	14 Nov 69	19 Nov 69	31 h, 30 min
Apollo 14	Edgar Mitchell* Stuart Roosa Alan Shepard*	31 Jan 71	5 Feb 71	22 h, 30 min
Apollo 15	James Irwin* David Scott* Alfred Worden	26 Jul 71	30 Jul 71	66 h, 55 min
Apollo 16	Charles Duke* Thomas (Ken) Mattingle John Young*	16 Apr 72	30 Jul 71	71 h, 2 min
Apollo 17	Eugene Cernan* Ronald Evans Dr. Harrison (Jack) Schmitt*	7 Dec 72	11 Dec 72	74 h, 59 min

** Two members of each crew actually walked on the lunar surface, the third remained in lunar orbit*

account for the formation of the Moon. The 'impact theory', which is one of the most widely accepted theories on the formation of the Moon, believes that the Moon was very much a part of the Earth some 4.5 billion years ago. Due to the impact of a large object, of the size of Mars, raw materials were ejected from its surface to form the Moon. Other theories like the 'co-accretion theory' holds that the Moon was formed as a part of the Solar System along with the Earth and the 'fission theory' states that the Earth shed some of the materials from its surface to stabilise itself, which became the Moon, while the 'capture theory' believes that the Earth captured the Moon into its orbit from the Solar System.

The impact theory seems to be the most plausible theory to explain the formation of the Moon which has been proved by the several lunar explorations.

With all these exploratory missions to the Moon, only a quarter of the lunar surface has been explored. This has left them with more questions than answers. But the Lunar Prospector (LP) mission will change all that. The Lunar Prospector spacecraft is the third in a series of missions under NASA's discovery program. The discovery program intends to develop frequent, low-cost missions to explore the Solar System.

The Lunar Prospector will address many unanswered questions about the Moon's resources, origin and structure. The first and foremost question which it is expected to answer is evidence about the possible availability of water on the Moon. Evidence of this has already been provided by the LP within the first two months of its operation. The early

Neil A. Armstrong, Michael Collins, Edwin E. Aldrin of Apollo 11.

explorations ruled out the possibility of any water of its own on the Moon. But the Moon has been bombarded by comets (mixtures of dust and ice) for billions of years. Any ice deposited on the lunar surface would evaporate due to warm sunlight. However, near the Moon's poles, where the Sun never shines, the ice is unlikely to melt. This led scientists to believe that ice might be present near the poles. The ice presence theory was put forth in the 1970s and was later strengthened by the Clementine mission to the Moon in 1994. Apart from that, the LP will study the elemental composition of the lunar crust, gas releases of the lunar interior and the relationship of out-gassing to the lunar atmosphere. It will also map lunar magnetic fields, provide information about the Moon's inner core, map the Moon's gravity field and investigate the effects of volcanic activity. Resources like hydrogen, helium and iron are expected to be found on the Moon that would be very important to build and maintain a Solar System launching pad and perhaps to eventually establish a lunar colony. Other resources on LP's agenda include nitrogen and carbon dioxide.

More about the Lunar Prospector mission

The Lunar Prospector spacecraft is one of the smallest spacecrafts sent by NASA to explore our Solar System. The spacecraft is shaped like a drum with dimensions of 4.25 ft (1.3 m) height, and 4.5 ft (1.4 m) diameter. When full of fuel, the Prospector weighs 650 pounds (295 kg). The Lunar Prospector has a list of mission objectives which will provide vital clues to our understanding of the Moon and our Solar System.

The Lunar Prospector which entered the Moon orbit on January 11, 1998, after 5 days of its launch on January 6, 1998, has started sending scientific data about the nature of the surface of the Moon. The data made available by NASA on March 5, 1998, suggests that the Lunar Prospector has found conclusive evidence about the presence of water ice on the Moon. It has also been able to pinpoint, through tabulations, the approximate amount of

The Moon

Age	:	3 - 4.6 billion years
Mean distance from the Earth	:	384,400 km
Perigee	:	363,300 km (nearest distance from the Earth)
Apogee	:	405,500 km (farthest distance from the Earth)
Mean orbital velocity of its revolution around the Earth	:	3,680 km/h
Escape velocity	:	2.38 m/s
Volume	:	2217.273 km^3
Lunar crust	:	60 km covered with a layer of powdery dust called Regolith.
Diameter	:	3476 km
Mass	:	7.34×10^{22} kg

Lunar Prospector

Launch date	:	Jan 6, 1998
Spacecraft entered the Moon orbit	:	Jan 11, 1998
Launch vehicle	:	Lockheed Martin Athena II rocket
SPACECRAFT		
Kind	:	Spin stabilised
Pay load	:	Five instruments
Shape	:	Drum shaped 4.25 ft high, 4.5 ft dia.
Weight with full of fuel	:	295 kg
Power source	:	Rechargeable solar power Ni-H_2 batteries
orbit		
a) Primary mission	:	100 Kms. from the surface of the Moon.
b) Extended mission	:	10 Kms. from the surface of the Moon.
Speed	:	5,868 Km/hr
Time taken for 1 revolution	:	118 mins.
Mission objectives	:	(i) To prospect the lunar crust and atmosphere for potential resources, including minerals, water ice and certain gases. (ii) To map the Moon's gravitational and magnetic fields. (iii) To learn more about the size and content of the Moon's core.
Mission cost	:	$63 million (including launch and operational cost)

water on the surface of the Moon. With this, the Lunar Prospector has achieved what it was expected to in its first phase of operation i.e. to provide inputs on the availability of ice on the satellite.

The Lunar Prospector is a mission which has a short mission life and specific objectives. Unlike earlier lunar missions, the LP will be in a polar orbit and not in an equatorial orbit.

By this, the Prospector will be able to map the entire surface of the Moon including the poles. A rechargeable battery will power the Lunar Prospector while it is on the dark side of the Moon. Each time it appears in the Sun, it will recharge.

The Prospector has a mission life of one year. During its normal mission period of one year, the space craft will map the Moon from a 100km altitude orbit. After this it will begin an extended mission of 6 months. The extended mission will be very crucial for the better understanding of lunar surface. During the extended period, the spacecraft will drop down to an elliptical orbit with a minimum altitude of 6 miles (10 km). All five instruments will continue to function enabling them to obtain data with much higher resolution.

The Lunar Prospector is seen as a very important mission as it is expected to map the entire lunar surface for the first time. All the earlier missions by all the countries put together have been able to explore only 25% of the lunar surface.

The Prospector will not have any cameras on board unlike other spacecraft. It will conduct data measurements over the entire lunar surface with the help of the five instruments on board. The entire spacecraft pay load contains only the instruments. An S band transmitter and an S band receiver will communicate information between the prospector and the Earth via NASA's deep space network with the help of two antennae on board: the omni antenna and the medium gain antenna.

The spacecraft will neither land on the Moon nor will it bring samples down to the Earth.

Due to its unusual non-uniform gravitation field, the spacecraft will have to spend more fuel to remain in orbit during the extended period. This will provide vital information about the gravitational field of the Moon apart from clearly determining the amount of fuel required for future lunar missions. After 6 months of extended missions, the LP is expected to die down on the surface of the Moon.

During its mission the spacecraft will circle the Moon once every 118 minutes. Another important feature of the LP is that it is 'spin stabilised', meaning it rotates around its own up and down axis, spinning like a top. Such spin stabilisation keeps the spacecraft's orientation in space under control.

The first couple of months of operation of the Lunar Prospector has already yielded some results which could have far-reaching implications on our understanding of the Moon. Data regarding the presence of water, the estimation of the amount of water and the determination of the distribution of magnetic fields have already been sent by the Lunar Prospector. Its usefulness in determining the exact nature and composition of the lunar surface would be available once the LP completes the normal mission and enters into the extended mission.

Keep watching these pages. We would be bringing you exciting stuff from the Lunar land. ❑

Lunar Gravity

The Doppler Gravity Experiment (DGE) will improve our understanding of the Moon's gravitational field, enabling future lunar missions to use fuel more efficiently. The gravitational field of the Moon is not uniform and is considered to be bumpy. This is due to mass concentration (or mascon's) on the surface and large asymmetry due to the fact that the crust is thicker on the far side of the Moon. These bumps are easily detected by the LP spacecraft, as they cause speeding up or slowing down of the orbiting spacecraft. The speed of the spacecraft is determined by 'Doppler effect', the same effect which causes a train siren to sound higher than normal when it is nearing us and lower than normal when it is moving away from us.

The siren in this case is the spacecraft's radio signal whose frequency shifts slightly as it moves towards or away from the Earth. With the mapping of the entire lunar surface, it is possible to determine the distribution of the gravitational field over the entire lunar surface. If the LP enters into the extended mission, it would enhance our understanding of the Moon even more.

LUNAR LAUNCHPAD

Conclusive evidence about the presence of water on the Moon has come as great news for lunar scientists. This has quenched their thirst for more information on lunar water. Why is the presence of water on the Moon such an important discovery?

The Moon is the nearest object to the Earth in our solar system. It is also the most widely probed heavenly body. The evidence of water on the Moon would mean that a lunar base can be established which can be a stop-off point for missions to the rest of the solar system. This would also mean that humans can ultimately set up a colony on the Moon. The water ice could be mined and split into hydrogen and oxygen by solar panel-equipped electric power station or a nuclear generator.