THE EARTH'S MOON

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PHYSICAL FEATURES

MARIA, or SEAS, are the most conspicuous features of the near side of the moon. These dark, level plains still bear the romantic Latin names bestowed on them by the Italian astronomer Riccioli in 1651. With Galileo, the first man to view the moon through a telescope (1609), Riccioli thought the maria to be water-filled areas. Now they are believed to be depressions filled with lava or volcanic ash. Curiously, the maria on the moon's far side are relatively small and few in number. Mare Orientale, on the western limb, is seen from an orbiting spacecraft as a gigantic bull's-eye with concentric rings of mountains. It is perhaps the moon's most spectacular feature.

CRATERS, in infinite number, pock the moon's surface. The largest of these—the primary craters—bear the names of astronomers, philosophers, scientists, and explorers. The biggest crater on the near side is Bailly—183 miles in diameter. Several unnamed craters on the far side exceed 200 miles in diameter. Theories of the craters' origins range from volcanism to impact by meteorites, asteroids, or the nuclei of comets.

RAYS, appearing to be fine surface material splattered out of the nearer craters, thinly overlie everything in their paths. Most obvious when the sun is high overhead, these 5- to 10-mile-wide bright streaks radiate for many hundreds of miles. The most extensive system is that emanating from Tycho.

MOUNTAIN RANGES, generally named after mountains on earth, lie in great arcs bordering the circular maria. Some of their peaks rank in height with the biggest terrestrial mountains.

RILLES—similar in cross section to shallow, flat-bottomed river beds on earth—sometimes extend hundreds of miles, through mountains, valleys, and craters.

ORBITAL PATHS

The paths of earth and moon are traced through one lunar month as if viewed from a point north of the solar system's plane. Moon's path is exaggerated for clarity. Actually it is always concave to the sun.

ARROW Ⓐ aligns earth and moon with the sun, 93,000,000 miles away. It also aligns earth and moon with a star at infinite distance.

The moon's rotation on its axis and its revolution around the earth are both counterclockwise from the north. Both motions take exactly the same time, because a tidal bulge on the moon's near side keeps that side always turned toward earth. During new moon the near side is dark while the far side is in sunlight.

Earth and revolving moon are shown in north polar view. Sun's rays coming from the top of this chart illuminate the halves shown in white; shadowed halves are in blue. Moon's hidden side is shown with green hatching. Inside this ring are the phases, in equatorial view, as we see them from earth.

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PHYSICAL PROPERTIES

THE CENTER OF GRAVITY of the earth-moon system lies 2,963 miles toward the moon from the center of earth—a point deep within earth's sphere. Based on this fact, we calculate the MASS of the moon as 0.012 that of earth, or 80 quintillion tons.

The moon's VOLUME is 5% billion cubic miles; its DENSITY (mass divided by volume) is about 0.6 times that of earth as a whole and 3.3 times that of water.

GRAVITY at the moon's surface exerts about a sixth the force of that on earth. A 150-pound person on earth would weigh but 25 pounds on the moon. A swing powerful enough to drive a golf ball 300 yards on earth would propel the same ball more than a mile on the moon, and a high jump of 21 feet would theoretically be possible from the lunar surface.

SURFACE COLOR is predominantly gray. However, the moon often appears golden when seen near earth's horizon. Higher in the sky, it appears white, tinted by earth's atmospheric haze, it usually appears pale or silvery.

ATMOSPHERE on the moon is almost nonexistent. Without it, there is no sound. Since there is no obscuring effect such as earth's atmosphere produces, a person on the moon will be able to see twice as many stars in the black sky as he could on earth.

TEMPERATURE varies widely on the moon's surface. In areas of direct sunlight it may reach 247° F., in the dark of the lunar night it plummets to −261° F. So great is the difference between lighted and shadowed spots that an unprotected person would burn in the searing sunlight or freeze quickly in the shadow of a rock.

ALBEDO is the percentage of light reflected from a surface. A perfectly reflecting object would have an albedo of 100 percent; a nonreflecting object, 0 percent. The moon, a very poor reflector, has an albedo of about 11 percent.

EROSION takes place at a very slow rate because there is no rain or wind as on earth.

A SIDEREAL MONTH, 27⅓ days, is the time it takes the moon to travel around the earth and realign with the sun (arrow Ⓑ) with the same star aligned at arrow Ⓐ.

A SYNODICAL MONTH, 29½ days, is the time it takes the moon to travel around the earth and realign with the sun (arrow Ⓑ). This period, also called a lunation, begins and ends with the new moon.

PATH OF EARTH AROUND THE SUN

MOON'S REVOLUTION AROUND EARTH

New Moon 29½ days
Crescent
First Quarter 7 days
Gibbous Moon
Full Moon 14 days
Last Quarter 22 days

SUNSET · MIDNIGHT · SUNRISE · NOON

MEAN SCALE

1:11,620,000

ONE DEGREE on the Equator and one degree of latitude equals 18.85 statute miles, or 30.34 kilometers.

LAMBERT AZIMUTHAL EQUAL-AREA PROJECTION

On this map every feature is in true direction from the center of its hemisphere. Area is constant throughout, so that a dime placed anywhere on the map will cover about 10,500 square miles (27,200 square kilometers); a quarter will cover about 19,400 square miles (50,250 square kilometers). In contrast, the phase diagrams below are drawn in orthographic projection—showing the moon as it is actually seen from earth. In that projection features near the edges of the sphere are more distorted by foreshortening.

CARDINAL DIRECTIONS

For centuries selenographers, or moon-mappers, charted the moon with its south pole at the top, following the inverted image they saw in their telescopes. Today, to conform to astronautic usage, north appears at the top of charts. As we view the hemisphere that faces the earth, west is to the left, and is referred to as the sunset limb; east is called the sunrise limb.

MOON LORE

Viewed with the naked eye, the full moon is a light disk with dark splotches. From these dark "seas," man's imagination has created mythical figures such as the Man in the Moon, whose right eye is Mare Imbrium. The beautiful Lady wears the brilliant amulet of Tycho and its rays. The Rabbit's head is Oceanus Procellarum; its tail is Mare Crisium.

MOONRISE · MOONSET

HARVEST MOON

The full moon nearest the autumnal equinox is called the harvest moon. For several nights it rises short-ly after sunset, its light allowing farmers to continue gathering their crops after the sun has gone down. The next full moon, a month later, is popularly called the hunter's moon.

APPARENT MOVEMENT OF AXIS

As seen from earth's mid-northern latitudes, the moon rises in the east and sets in the west. It rises with its north pole at the top but tilted to the left. As it crosses the southern sky, its axis becomes vertical; then the north pole tilts to the right as the moon sets. To an observer in earth's Southern Hemisphere, the moon rises in the east with its south pole, at the top, tilted to the right; crosses the northern sky; and sets in the west with the south pole tilted to the left. The degree of tilt varies with the season and the latitude of the observer.

THE CALENDAR

The moon has always served as one of man's timekeepers. Our week, roughly one quarter of the month, derives from the quarters of the moon—approximately seven days each. Monday is "moon-day." Religious events, too, are often determined by the moon. Christians set the date of Easter as the first Sunday after the first full moon following the spring equinox. The Jews celebrate Passover at first full moon after the spring equinox. The moon's waxing crescent marks the beginning and the end of the Moslem month of Ramadan.

METONIC CYCLE

About 400 B.C. the Greek astronomer Meton discovered that every 19 years the moon's phases recur on the same dates of the month. As an example, a full moon occurred on January 1, 1961. Not until 1980, after a cycle of 235 lunations (complete changes of the moon), will another full moon occur on January 1st. Occasionally the dates miss by one or two days, depending on the number of leap years in the cycle.

MOON GODS AND GODDESSES

Ancient man, in awe of the moon, often invested it with divine attributes. Sumerians worshipped it as Zu-en, or Sin, the "Lord of Wisdom." Thoth and Khons were Egyptian moon deities. Greeks knew the moon god-dess as Artemis, Selene, or Hecate. Romans called her Diana or Lucina. In the New World, the moon was Tecuciztecatl to the Aztecs, Ixchel, or "White Lady," to the Maya.

PHASES OF THE MOON

In eleven drawings below, the moon appears as it does through a pair of binoculars. As the lunar month progresses, prominent moon features are revealed in turn by movement of the terminator—the line dividing sunlight and shadow. While the sunrise terminator moves across the face of the moon in the first five drawings, craters and mountains along its length become sharply defined. At full moon the ray systems reflect with brilliance. In the last five drawings, the sunset terminator again reveals the relief of the craters and mountains.

ELEVATIONS

On the main map, numbers beneath crater names indicate the vertical distance in feet from crater floor to rim. Numbers beneath mountain names show vertical distance from surrounding terrain to peak.

PROFILE OF A CRATER

Below, the cross section of Copernicus, a moon crater of average size, is compared with the cross section of Arizona's Grand Canyon. In this diagram vertical dimensions have been exaggerated four times. The State of Rhode Island would fit easily within the crater.

Cross section of Copernicus, 56 miles rim to rim
West Rim · East Rim
Copernicus floor is over 12,500 Feet below rim
South Rim · North Rim
Cross section Grand Canyon, 7 miles rim to rim

THE MOON'S DISK

The moon's diameter is 2,160 miles; its total surface, a spherical area, 14,650,000 square miles. Seen from earth, the moon appears as a full disk, measuring about ½ degree in the sky—the width of a pencil held at arm's length. Superimposed on the United States, the moon would cover an area from Las Vegas to Philadelphia.

MOON COMPARISONS

Of the 32 known satellites in the solar system, Jupiter's Ganymede is the largest. It is actually bigger than Mercury, the smallest planet. Earth's moon ranks fifth in size among satellites.

TITANIA (Uranus) · OBERON (Uranus) · RHEA (Saturn) · EUROPA (Jupiter) · IO (Jupiter) · MOON (Earth) · TRITON (Neptune) · CALLISTO (Jupiter) · TITAN (Saturn) · GANYMEDE (Jupiter)

SATELLITE-PLANET SIZE RATIO

Our moon's diameter measures about a fourth that of earth, its volume a fifteenth, and its mass about a hundredth. The moon is so much larger than any other satellite in relation to its parent planet that earth and moon are sometimes called "the double planet."

NOMENCLATURE

The names of lunar features are now governed by Commission 17 of the International Astronomical Union. In 1970 names will be assigned to far-side features yet unnamed.

THE APOLLO MISSION

The most daring excursion in the history of human endeavor is about to turn the moon into earth's stepping-stone to the universe. Lift-off at Cape Kennedy (1) begins the manned flight to the moon. The launch escape system is jettisoned as soon as the space vehicle is seen to be functioning properly. The booster rocket then thrusts the vehicle into an orbit (2) where it moves at 17,500 miles an hour. Eleven minutes have elapsed up to this point.

A final flight-path correction (13) prepares the vehicle for an accurate approach to earth. About two hours later the service module is jettisoned (14), leaving the command module with three astronauts to make its re-entry into the earth's atmosphere (15). The landing (16) in the Pacific Ocean near Hawaii takes place about 10 days after the Cape Kennedy lift-off.

While the space vehicle circles in its orbit 119 statute miles above the earth, precise calculations are made in preparation for the vehicle's acceleration to 25,000 miles an hour to escape from earth's gravitational clutch (3). From here, the vehicle coasts in a direct flight to the moon. Soon after the coasting phase begins the command-and-service module containing the astronauts separates from the lunar module, turns around, and docks with it nose to nose (4).

During the entire coasting period, tracking stations on earth determine the spacecraft's course. Drifting off pre-planned flight path may require small corrections to get back on course.

About five hours after leaving the orbit around earth, the first of several flight-path corrections (5) will be made.

The second flight-path correction (6) occurs about 24 hours after leaving orbit around earth.

If needed, a third flight-path correction (7) takes place about 24 hours before going into orbit around the moon.

The first adjustment of the flight path (12) occurs 10 to 20 hours after leaving orbit around the moon. Additional corrections, spaced 8 to 10 hours apart, will be made if required.

As the space vehicle moves away from earth and the pull of gravity weakens, the voyage is like coasting uphill. Speed gradually diminishes, until at a point 220,000 miles from earth (8) the moon's gravity begins pulling the vehicle toward it.

After a 20-hour visit to the moon's surface, the lunar module ascends to rendezvous and dock with the still orbiting command and service module (9). The two men who had landed transfer into the command module. The lunar module is jettisoned and the three men accelerate to 5,000 miles an hour out of their lunar orbit, and then coast back to earth (11).

NEAR SIDE

HEMISPHERE ALWAYS FACING EARTH

FAR SIDE

HEMISPHERE ALWAYS TURNED AWAY FROM EARTH

North Pole · South Pole

THE LUNAR MONTH

New moon is the instant when the moon is aligned between sun and earth and the near side is totally dark. One day after new moon a thin crescent appears near earth's western horizon following sunset. By the seventh day the first quarter moon rises about noon and sets near midnight. Full moon, on the 14th day, rises at sunset and sets at sunrise. The waning moon is in its last quarter around the 22d day. After 29½ days the moon is aligned again for a new moon and the beginning of a new lunar month.

At the time of the new moon, an observer on the moon would see a full earth, a phenomenon about 80 times brighter than the full moon seen from earth.

3 days · 5 days · 7 days · 9 days · 12 days · 14 days · 17 days · 20 days · 22 days · 24 days · 26 days

When earth's atmospheric conditions are favorable, the full outline of the dark part of the moon, as well as the craters Aristarchus and Grimaldi, are visible because of reflected earthshine.

WAXING CRESCENT · FIRST QUARTER · WAXING GIBBOUS · FULL MOON · WANING GIBBOUS · LAST QUARTER · WANING CRESCENT

The terminator, progressing from east to west, moves along the equator at about 9½ miles per hour.

Earth, moon, and the mean distance between their centers appear here in true relative scale.

238,856 STATUTE MILES

The moon's elliptical orbit places it 221,463 miles from earth at perigee and 252,710 miles from earth at apogee.

DAILY, OR DIURNAL, LIBRATION

At moonrise the observer is actually on the western side of the earth as it rotates into sight of the moon. From this "elevated" position the observer sees slightly beyond the moon's eastern edge. The opposite is true at moonset, when the observer sees slightly beyond the moon's western edge.

Observer on earth at moonrise · Observer on earth at moonset

If required, a final flight-path correction (9) makes adjustments before entry into orbit around the moon. While orbiting the moon, the lunar module, with two men aboard, separates from the command-and-service module, manned by the third astronaut. The command-and-service module continues to orbit 69 statute miles above the moon while the 16-ton lunar module descends to the moon's surface (10).

CENTRIFUGAL FORCE

Earth rotates daily about an axis through its own center. However, the earth-moon system also rotates monthly about its center of gravity, which is not in the center of the earth. In effect, the earth wobbles about this eccentric point, causing a centrifugal force in the opposite direction from the moon.

PATH OF EARTH'S ORBIT · Spring Tide · Last Quarter · Neap Tide · New Moon · Spring Tide · Full Moon · Neap Tide · First Quarter

TIDES

The rhythmic rise and fall of earth's waters is caused mainly by the pull of the moon's gravity. The sun's gravity also influences tides, but because of its very great distance from the earth, it only modifies the moon's effect.

At times of new and full moon, the sun and moon align with the earth. Their combined forces produce the two high monthly tides called spring tides (not related to the season). At first and last quarter, the sun and moon are at right angles to the earth. This position creates the two low monthly tides, or neap tides.

While the moon pulls water to a bulge on its side of the earth, centrifugal force causes a bulge of water on the opposite side. The rotation of the earth beneath these bulges produces daily high and low tides.

Data for this map of the moon's far side was provided by U. S. Orbiter spacecraft photos.

LIBRATION

Three major motions of the moon and earth allow us to see more than 50 percent of the moon's surface even though the same side is always turned toward the earth. The combined effects of all three librations make 59 percent of the moon's surface visible from earth. The extra 9 percent is indicated by a dashed line on the map of the moon's far side.

LIBRATION IN LONGITUDE

The moon rotates once on its axis and revolves once around the earth in the same length of time. It turns on its axis at a constant speed, but its velocity around the earth varies due to its elliptical orbit. Thus, as the moon makes a quarter turn on its axis, it moves less than one-quarter of the trip around earth (A to B). At B we can see 6° 17' beyond the left, or western, edge. From B to C the moon catches up with its rotation on its axis and libration is 0° at C. The situation is reversed from C to A. The total effect is that of watching the moon slowly shake its head, as if saying "no."

MOON'S ELLIPTICAL ORBIT

LIBRATION IN LATITUDE

As if nodding its head "yes," the moon allows observers on earth to see 6°41' beyond its "top" at one time and 6°41' beyond its "bottom" about two weeks later. This libration results from the 6°41' inclination of the moon's equator to the plane of its orbit.

Moon's axis is nearly perpendicular to the ecliptic.
MOON'S ORBIT · 5°09' · ECLIPTIC

UNMANNED SPACECRAFT

On the map are 22 landed spacecraft. Russia's Luna 2 (located at F10 on the map) made the first crash-landing on September 13, 1959. On February 3, 1966, Luna 9 (3) made the first hard-landing. Luna 3 flew around the moon taking the first pictures of the far side. October 7, 1959, Zond 3 safely returned to earth from a trip around the moon. September 21, 1965, America's Ranger 7 (L7), Ranger 8 (I12), and Ranger 9 (J9), transmitted high-quality photographs of proposed landing sites just before each crash-landed. Surveyor 1 (O3) made the first soft-landing on June 2, 1966, then sent back thousands of close-up pictures of the lunar surface. Five Orbiters photographed 99½ percent of the moon and were then deliberately crashed into it.

COMMAND MODULE · SEXTANT · TELESCOPE · LIBRATION · ZODIAC · CHARTS · OCEAN OF STORMS · SPACE SUIT · SPACE PROBE · ECLIPSE · NUMBER · ANDERS · MOON ARMY · CHRONOLOGY · UNIVERSE · SEA OF FERTILITY · ARMSTRONG · ASTRONAUT · ARCHITECTURE · ASTRONOMY · ARMA · ALPINE · SERGE · ROCKET · CRATERING · APOLLO · ORBITER · ROVER · LANDER · ATLAS · ROCKET · CRATERING · APOLLO · ORBITER · ROVER · LANDER · ATLAS

★ BECK MOON • SEA OF NECTAR • SPUTNIK • ZERO G • CAVORITE • RETROROCKETS • HIJKI AND EEL • LEIBNITZ MOUNTAINS • MEDCOURSE CORRECTION • LICK OBSERVATORY • GREEN CHEESE • JAMES MCDIVITT • COBRA HEAD • PALE MOON • ROBERT GILRUTH • VOLCANIC CRATERS • DROGUE PARACHUTE • HERM-ANN ORBETH • ALAN SHEPARD • ASTROLOGY • SOMNIUM • CABBAGE MOON • DIANA • HANS FFAAL • MARSHALL SPACE FLIGHT CENTER • ORBITER 3 • A OK • PARIS OBSERVATORY • METEORITIC CRATERS • GORDON COOPER • CYRANO DE BERGERAC • YAW CONTROL • LINE OF APSIDES • MANY MOONS • FRIENDSHIP 7 • ANOMALISTIC PERIOD • BRENNICULUS • MCDONALD OBSERVATORY • MARE IMPERIUM • 5,890,000,000 CUBIC MILES • CIS-LUNAR SPACE • LUNA 15 • SELENODETIC CONTROL • PERILUNE • PILL OF IMMORTALITY • DOBERYL MOUNTAINS • SILVERY MOON • TERRA CALORIS ★

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