

## Earth's Moon

The regular daily and monthly rhythms of Earth's only natural satellite, the Moon, have guided timekeepers for thousands of years. Its influence on Earth's cycles, notably tides, has been charted by many cultures in many ages. The presence of the Moon moderates Earth's wobble on its axis, leading to a relatively stable climate over billions of years. From Earth, we always see the same face of the Moon because the Moon rotates once on its own axis in the same time that it travels once around Earth (called synchronous rotation).

The light areas of the Moon are known as the highlands. The dark features, called maria (Latin for seas), are impact basins that were filled with lava between 4 and 2.5 billion years ago. Though the Moon has no internally generated magnetic field, areas of magnetism are preserved in the lunar crust, but how this occurred is a mystery. The early Moon appears not to have had the right conditions to develop an internal dynamo, the mechanism for global magnetic fields for the terrestrial planets.

How did the Moon come to be? The leading theory is that a Mars-sized body collided with Earth approximately 4.5 billion years ago, and the resulting debris from both Earth and the impactor accumulated to form our natural satellite. The newly formed Moon was in a molten state. Within about 100 million years, most of the global "magma ocean" had crystallized, with less-dense rocks floating upward and eventually forming the lunar crust.

Since the ancient time of volcanism, the arid, lifeless Moon has remained nearly unchanged. With essentially no atmosphere to impede impacts, a steady rain of asteroids, meteoroids, and comets strikes the surface. Over billions of years, the surface has been ground up into fragments ranging from huge boulders to powder. Nearly the entire Moon is covered by a rubble pile of charcoal-gray, powdery dust and rocky debris called the lunar regolith. Beneath is a region of fractured bedrock referred to as the megaregolith.

Four impact structures are used to date objects on the Moon: the Nectaris and Imbrium basins and the craters Eratosthenes and Copernicus. Lunar history is based on time segments bounded by the age of each impact structure. A Copernican feature, for example, is as young or younger than the impact crater Copernicus, that is, about one billion years old or less.

The Moon was first visited by the U.S.S.R.'s Luna 1 and 2 in 1959, and a number of U.S. and U.S.S.R. robotic spacecraft followed. The U.S. sent three classes of robotic missions to pre-

pare the way for human exploration: the Rangers (1961–1965) were impact probes, the Lunar Orbiters (1966–1967) mapped the surface to find landing sites, and the Surveyors (1966–1968) were soft landers. The first human landing on the Moon was on July 20, 1969. During the Apollo missions of 1969–1972, 12 American astronauts walked on the Moon and used a Lunar Roving Vehicle to travel on the surface and extend their studies of soil mechanics, meteoroids, lunar ranging, magnetic fields, and solar wind. The Apollo astronauts brought back 382 kilograms (842 pounds) of rock and soil to Earth for study.

After a long hiatus, lunar exploration resumed in the 1990s with the U.S. robotic missions Clementine and Lunar Prospector. Results from both missions suggest that water ice may be present at the lunar poles, but a controlled impact of the Prospector spacecraft produced no observable water.

A new era of international lunar exploration began in earnest in the new millennium. The European Space Agency was first with SMART-1 in 2003, followed by three spacecraft from other nations in 2007–2008: Kaguya (Japan), Chang'e 1 (China), and Chandrayaan-1 (India). The U.S. began a new series of robotic lunar missions with the joint launch of the Lunar Reconnaissance Orbiter and Lunar Crater Observation and Sensing Satellite in 2009. This will be followed by the Gravity Recovery and Interior Laboratory in 2011 and the Lunar Atmosphere and Dust Environment Explorer in 2012. An international lunar network is under study for the next mission.

### FAST FACTS

Mean Distance from Earth	384,400 km (238,855 mi)
Orbit Period	27.32 Earth days
Orbit Eccentricity (Circular Orbit = 0)	0.05490
Orbit Inclination to Ecliptic	5.145 deg
Inclination of Equator to Orbit	6.68 deg
Rotation Period	27.32 Earth days
Equatorial Radius	1,737.4 km (1,079.6 mi)
Mass	0.0123 of Earth's
Density	3.341 g/cm <sup>3</sup> (0.61 of Earth's)
Gravity	0.166 of Earth's
Temperature Range	−233 to 123 deg C (−387 to 253 deg F)

### SIGNIFICANT DATES

1610 — Galileo Galilei is the first to use a telescope to make scientific observations of the Moon.

1959–1976 — The U.S.S.R.'s Luna program of 17 robotic missions achieves many "firsts" and three sample returns.

1961–1968 — The U.S. Ranger, Lunar Orbiter, and Surveyor robotic missions pave the way for Apollo human lunar landings. 1969 — Astronaut Neil Armstrong is the first human to walk on the Moon's surface.

1994–1999 — Clementine and Lunar Prospector data suggest that water ice may exist at the lunar poles.

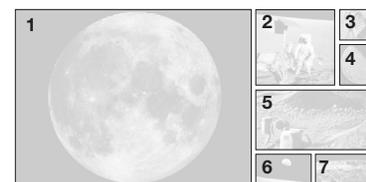
2003 — The European Space Agency's SMART-1 lunar orbiter inventories key chemical elements.

2007–2008 — Japan's second lunar spacecraft, Kaguya, and China's first lunar spacecraft, Chang'e 1, both begin one-year missions orbiting the Moon; India's Chandrayaan-1 soon follows in lunar orbit.

2008 — The NASA Lunar Science Institute is formed to help lead NASA's research activities related to lunar exploration goals.

2009 — NASA's Lunar Reconnaissance Orbiter and Lunar Crater Observation and Sensing Satellite (LCROSS) launch together in June, beginning the U.S. return to lunar exploration. In October, LCROSS was directed to impact a permanently shadowed region near the lunar south pole; the resulting impact debris will be analyzed to determine if it contains water ice.

### ABOUT THE IMAGES



**1** The dark areas in this lunar image are lava-filled impact basins. The bright ray feature (bottom) is associated with the crater Tycho.

**2** Apollo 12 astronaut Charles Conrad approaches Surveyor 3, a robotic spacecraft that soft-landed on the Moon 2-1/2 years earlier, in 1967.

**3** This footprint marks one of the first steps human beings took on the Moon in July 1969.

**4** False-color images such as this help scientists identify different types of soil on the Moon's surface.

**5** An illustration of future astronauts investigating a lava cave on the Moon.

**6** The Apollo 8 crew took this picture of Earth rising over the surface of the Moon in 1968.

**7** Copernicus Crater is part of the youngest assemblage of lunar rocks. The photo was taken by Lunar Orbiter 2 in 1966.

### FOR MORE INFORMATION

[solarsystem.nasa.gov/moon](http://solarsystem.nasa.gov/moon)