**Outer Space**

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*For other uses, see Outer space (disambiguation).*



The boundaries between the Earth's surface and outer space, at the Kármán line, 100 km (62 mi) and exosphere at 690 km (430 mi). Not to scale

**Outer space** is the void that exists between celestial bodies, including the Earth. It is not completely empty, but consists of a hard vacuum containing a low density of particles: predominantly a plasma of hydrogen and helium, as well as electromagnetic radiation, magnetic fields, and neutrinos. Theory suggests that it also contains dark matter and dark energy. In the space between galaxies, matter density can be as low as a few atoms of hydrogen per cubic meter. The baseline temperature, as set by background radiation left over from the Big Bang, is only 3 Kelvin; in contrast, temperatures in the coronae of stars can reach over a million Kelvin. Plasma with an extremely low density and high temperature, such as warm-hot intergalactic medium and intra-cluster medium, accounts for most of the baryonic (ordinary) matter in outer space; local concentrations have evolved into stars and galaxies. Intergalactic outer space takes up most of the volume of the universe, but even galaxies and star systems consist almost entirely of empty space. As of yet, space travel has been limited to the vicinity of the Solar System; the remainder of outer space remains inaccessible to humans other than by passive observation with telescopes.

There is no firm boundary where space begins. However the Kármán line, at an altitude of 100 kilometers above sea level, is conventionally used as the start of outer space for the purpose of space treaties and aerospace records keeping. The framework for international space law was established by the Outer Space Treaty, which was passed by the United Nations in 1963. This treaty precludes any claims of national sovereignty and permits all states to explore outer space freely. In 1979, the Moon Treaty made the surfaces of objects such as planets, as well as the orbital space around these bodies, the jurisdiction of the international community. Additional resolutions regarding outer space have been drafted by the United Nations, but these have not precluded the deployment of weapons into outer space.

**Discovery**

In 350 BC, Greek philosopher Aristotle suggested that *nature abhors a vacuum*, a principle that became known as the *horror vacui*. This concept built upon a 5th century BCE ontological argument by the Greek philosopher Parmenides, who denied the possible existence of a void in space. Based on this idea that a vacuum could not exist, in the West it was widely held for many centuries that space could not be empty. As late as the 17th century, the French philosopher René Descartes argued that the entirety of space must be filled.

In ancient China, there were various schools of thought concerning the nature of the heavens, some of which bear a resemblance to the modern understanding. In the 2nd century CE, astronomer Zhang Heng became convinced that space must be infinite, extending well beyond the mechanism that supported the Sun and the stars. The surviving books of the Hsüan Yeh school said that the heavens were boundless, "empty and void of substance". Likewise, the "sun, moon, and the company of stars float in the empty space, moving or standing still".

The Italian scientist Galileo Galilei knew that air had weight and so was subject to gravity. In 1640, he demonstrated that an established force resisted the formation of a vacuum. However, it would remain for his pupil Evangelista Torricelli to create an apparatus that would produce a vacuum in 1643. At the time this experiment created a scientific sensation in Europe. The French mathematician Blaise Pascal reasoned that if the column of mercury was supported by air then the column ought to be shorter at higher altitude where the air pressure is lower. In 1648, his brother in law, Florin Périer, repeated the experiment on the Puy-de-Dôme mountain in central France and found that the column was shorter by three inches. This decrease in pressure was further demonstrated by carrying a half-full balloon up a mountain and watching it gradually inflate, then deflate upon descent.

In 1650, German scientist Otto von Guericke constructed the first vacuum pump: a device that would further refute the principle of *horror vacui*. He correctly noted that the atmosphere of the Earth surrounds the planet like a shell, with the density gradually declining with altitude. He concluded that there must be a vacuum between the Earth and the Moon.

In the 15th century, German theologian Nicolaus Cusanus speculated that the universe lacked a center and a circumference. He believed that the universe, while not infinite, could not be held as finite as it lacked any bounds within which it could be contained. These ideas led to speculations as to the infinite dimension of space by the Italian philosopher Giordano Bruno in the 16th century. He extended the Copernican heliocentric cosmology to the concept of an infinite universe filled with a substance he called ether, which did not cause resistance to the motions of heavenly bodies. English philosopher William Gilbert arrived at a similar conclusion, arguing that the stars are visible to us only because they are surrounded by a thin ether or a void. This concept of an ether originated with ancient Greek philosophers, including Aristotle, who conceived of it as the medium through which the heavenly bodies moved.

The concept of a universe filled with a luminiferous ether remained in vogue among some scientists until the early 20th century. This form of ether was viewed as the medium through which light could propagate. In 1887, the Michelson-Morley experiment tried to detect the Earth's motion through this medium by looking for changes in the speed of light depending on the direction of the planet's motion. However, the null result indicated something was wrong with the concept. The idea of the luminiferous ether was then abandoned. It was replaced by Albert Einstein's theory of special relativity, which holds that the speed of light in a vacuum is a fixed constant, independent of the observer's motion or frame of reference.

The first professional astronomer to support the concept of an infinite universe was the Englishman Thomas Digges in 1576. But the scale of the universe remained unknown until the first successful measurement of the distance to a nearby star in 1838 by the German astronomer Friedrich Bessel. He showed that the star 61 Cygni had a parallax of just 0.31 arcseconds (compared to the modern value of 0.287″). This corresponds to a distance of over 10 light years. The distance to the Andromeda galaxy was determined in 1923 by American astronomer Edwin Hubble by measuring the brightness of cepheid variables in that galaxy, a new technique discovered by Henrietta Leavitt. This established that the Andromeda galaxy, and by extension all galaxies, lay well outside the Milky Way.

The modern concept of outer space is based on the Big Bang cosmology, first proposed in 1931 by the Belgian physicist Georges Lemaître. This theory holds that the observable universe originated from a very compact form that has since undergone continuous expansion. Matter that remained following the initial expansion has since undergone gravitational collapse to create stars, galaxies and other astronomical objects, leaving behind a deep vacuum that forms what is now called outer space. As light has a finite velocity, this theory also constrains the size of the directly observable universe. This leaves open the question as to whether the universe is finite or infinite.

The term *outward space* was used as early as 1842 by the English poet Lady Emmeline Stuart-Wortley in her poem "The Maiden of Moscow", although she employed it in a terrestrial context. The expression *outer space* was used as an astronomical term by Alexander von Humboldt in 1845. It was later popularized in the writings of HG Wells in 1901. The shorter term *space* is actually older, first used to mean the region beyond Earth's sky in John Milton's *Paradise Lost* in 1667.

**Environment**



The Hubble Ultra-Deep Field image shows a typical section of space containing 10,000 galaxies interspersed by deep vacuum. Given the finite speed of light, this view covers the last 13 billion years of the history of outer space.

Outer space is the closest natural approximation to a perfect vacuum. It has effectively no friction, allowing stars, planets and moons to move freely along their ideal orbits. However, even the deep vacuum of intergalactic space is not devoid of matter, as it contains a few hydrogen atoms per cubic meter. By comparison, the air we breathe contains about 1025 molecules per cubic meter. The sparse density of matter in outer space means that electromagnetic radiation can travel great distances without being scattered: the mean free path of a photon in intergalactic space is about 1023 km, or 10 billion light years. In spite of this, extinction, which is the absorption and scattering of photons by dust and gas, is an important factor in galactic and intergalactic astronomy.

Stars, planets and moons retain their atmospheres by gravitational attraction. Atmospheres have no clearly delineated boundary: the density of atmospheric gas gradually decreases with distance from the object until it becomes indistinguishable from the surrounding environment. The Earth's atmospheric pressure drops to about 3.2 × 10−2 Pa at 100 kilometers (62 mi) of altitude, compared to 100 kPA for the IUPAC definition of standard pressure. Beyond this altitude, isotropic gas pressure rapidly becomes insignificant when compared to radiation pressure from the Sun and the dynamic pressure of the solar wind, so the definition of pressure becomes difficult to interpret. The thermosphere in this range has large gradients of pressure, temperature and composition, and varies greatly due to space weather. Astrophysicists prefer to use number density to describe these environments, employing units of particles per cubic centimeter.

On the Earth, temperature is defined in terms of the kinetic activity of the surrounding atmosphere. However the temperature of the vacuum cannot be measured in this way. Instead, the temperature is determined by measurement of the radiation. All of the observable Universe is filled with photons that were created during the Big Bang, which is known as the cosmic microwave background radiation (CMB). (There is quite likely a correspondingly large number of neutrinos called the cosmic neutrino background.) The current black body temperature of the background radiation is about 3 K (−270 °C; −454 °F). Some regions of outer space can contain highly energetic particles that have a much higher temperature than the CMB, such as the corona of the Sun.

Outside of a protective atmosphere and magnetic field, there are few obstacles to the passage through space of energetic subatomic particles known as cosmic rays. These particles have energies ranging from about 107 eV up to an extreme 1020 eV of ultra-high-energy cosmic rays. The peak flux of cosmic rays occurs at energies of about 109 eV, with approximately 87% protons, 12% helium nuclei and 1% heavier nuclei. The flux of electrons is only about 1% of that of protons in all energy ranges. Cosmic rays can damage electronic components and pose a health threat to space travelers.

**Effect on human bodies**

See also: Space exposure and Weightlessness



Because of the hazards of a vacuum, astronauts must wear a pressurized spacesuit while outside their spacecraft

Contrary to popular belief, a person suddenly exposed to a vacuum would not explode, freeze to death or die from boiling blood. However, sudden exposure to very low pressure, such as during a rapid decompression, could cause pulmonary barotrauma—a rupture of the lungs, due to the large pressure differential between inside and outside of the chest. Even if the victim's airway is fully open, the flow of air through the windpipe may be too slow to prevent the rupture. Rapid decompression can rupture eardrums and sinuses, bruising and blood seep can occur in soft tissues, and shock can cause an increase in oxygen consumption that leads to hypoxia. A pressure drop as small as 13 kPa, which produces no symptoms if it is gradual, may be fatal if it occurs suddenly.

As a consequence of rapid decompression, any oxygen dissolved in the blood would empty into the lungs to try to equalize the partial pressure gradient. Once the deoxygenated blood arrived at the brain, humans and animals will lose consciousness after a few seconds and die of hypoxia within minutes. Blood and other body fluids boil when the pressure drops below 6.3 kPa, a condition is called ebullism. The steam may bloat the body to twice its normal size and slow circulation, but tissues are elastic and porous enough to prevent rupture. Ebullism is slowed by the pressure containment of blood vessels, so some blood remains liquid. Swelling and ebullism can be reduced by containment in a flight suit. Shuttle astronauts wear a fitted elastic garment called the Crew Altitude Protection Suit (CAPS) which prevents ebullism at pressures as low as 2 kPa. Space suits are necessary to prevent ebullism above 19 kilometers (12 mi). Most space suits use around 30–39 kPa of pure oxygen, about the same as on the Earth's surface. This pressure is high enough to prevent ebullism, but evaporation of blood could still cause decompression sickness and gas embolisms if not managed.

Because humans are optimized for life in Earth gravity, exposure to weightlessness has been shown to have deleterious effects on the health. Initially, more than 50% of astronauts experience space motion sickness. This can cause nausea and vomiting, vertigo, headaches, lethargy, and overall malaise. The duration of space sickness varies, but it typically lasts for 1–3 days, after which the body adjusts to the new environment. Longer term exposure to weightlessness results in muscle atrophy and deterioration of the skeleton, or spaceflight osteopenia. These effects can be minimized through a regimen of exercise. Other effects include fluid redistribution, slowing of the cardiovascular system, decreased production of red blood cells, balance disorders, and a weakening of the immune system. Lesser symptoms include loss of body mass, nasal congestion, sleep disturbance, and puffiness of the face.

For long duration space travel, radiation can pose an acute health hazard. Exposure to radiation sources such as high-energy, ionizing cosmic rays can result in fatigue, nausea, vomiting, as well as damage to the immune system and changes to the white blood cell count. Over longer durations, symptoms include an increase in the risk of cancer, plus damage to the eyes, nervous system, lungs and the gastrointestinal tract. On a round-trip Mars mission lasting three years, nearly the entire body will be traversed by high energy nuclei, each of which can cause ionization damage to cells. Fortunately, most such particles are significantly attenuated by the shielding provided by the aluminum walls of a spacecraft, and can be further diminished by water containers and other barriers. However, the impact of the cosmic rays upon the shielding produces additional radiation that can affect the crew. Further research will be needed to assess the radiation hazards and determine suitable countermeasures.

**Boundary**

There is no clear boundary between Earth's atmosphere and space, as the density of the atmosphere gradually decreases as the altitude increases. There are several designated scientific boundaries, namely:

* The Fédération Aéronautique Internationale has established the Kármán line at an altitude of 100 kilometers (62 mi) as a working definition for the boundary between aeronautics and astronautics. This is used because at an altitude of roughly 100 km, as Theodore von Kármán calculated, a vehicle would have to travel faster than orbital velocity in order to derive sufficient aerodynamic lift from the atmosphere to support itself.
* The United States designates people who travel above an altitude of 50 miles (80 km) as astronauts.
* NASA's mission control uses 76 miles (122 km) as their re-entry altitude (termed the Entry Interface), which roughly marks the boundary where atmospheric drag becomes noticeable (depending on the ballistic coefficient of the vehicle), thus leading shuttles to switch from steering with thrusters to maneuvering with air surfaces.

In 2009, scientists at the University of Calgary reported detailed measurements with an instrument called the Supra-Thermal Ion Imager (an instrument that measures the direction and speed of ions), which allowed them to determine that space begins 118 kilometers (73 mi) above Earth. The boundary represents the midpoint of a gradual transition over tens of kilometers from the relatively gentle winds of the Earth's atmosphere to the more violent flows of charged particles in space, which can reach speeds well over 600 miles per hour (1,000 km/h).

**Legal status**

Main article: Space Law

The Outer Space Treaty provides the basic framework for international space law. This treaty covers the legal use of outer space by nation states, and includes in its definition of *outer space* the Moon and other celestial bodies. The treaty states that outer space is free for all nation states to explore and is not subject to claims of national sovereignty. It also prohibits the deployment of nuclear weapons in outer space. The treaty was passed by the United Nations General Assembly in 1963 and signed in 1967 by the USSR, the United States of America and the United Kingdom. As of January 1, 2008 the treaty has been ratified by 98 states and signed by an additional 27 states.

Between 1958 and 2008, outer space has been the subject of multiple resolutions by the United Nations General Assembly. Of these, more than 50 have been concerning the international co-operation in the peaceful uses of outer space and preventing an arms race in space. Four additional space law treaties have been negotiated and drafted by the UN's Committee on the Peaceful Uses of Outer Space. Still, there remains no legal prohibition against deploying conventional weapons in space, and anti-satellite weapons have been successfully tested by the US, USSR and China. The 1979 Moon Treaty turned the jurisdiction of all heavenly bodies (including the orbits around such bodies) over to the international community. However, this treaty has not been ratified by any nation that currently practices manned spaceflight.

In 1976 eight equatorial states (Ecuador, Colombia, Brazil, Congo, Zaire, Uganda, Kenya, and Indonesia) met in Bogotá, Colombia. They made the "Declaration of the First Meeting of Equatorial Countries," also known as "the Bogotá Declaration", where they made a claim to control the segment of the geosynchronous orbital path corresponding to each country. These claims are not internationally accepted.

**Space versus orbit**

A spacecraft enters orbit when it has enough horizontal velocity for its centripetal acceleration due to gravity to be less than or equal to the centrifugal acceleration due to the horizontal component of its velocity. (See circular motion.) For a low-Earth orbit, this velocity is about 7,900 m/s (28,400 km/h; 17,700 mph); by contrast, the fastest airplane speed ever achieved (excluding speeds achieved by deorbiting spacecraft) was 2,200 m/s (7,900 km/h; 4,900 mph) in 1967 by the North American X-15.

To achieve an orbit, a spacecraft must travel faster than a sub-orbital spaceflight. The energy required to reach the velocity of low Earth orbit (32 MJ/kg) is about 20 times the energy required merely to climb to the corresponding altitude (10 kJ/(km·kg)). The minimum altitude for a stable orbit around Earth (that is, one without significant atmospheric drag) is around 350 kilometers (220 mi) above sea level. The escape velocity required to pull free of Earth's gravitational field altogether and move into interplanetary space is about 11,000 m/s (39,600 km/h; 24,600 mph)

People in orbit about the Earth float weightlessly because they are in free fall. However they are not outside the Earth's gravitational field. The orbiting spacecraft and its contents are accelerating toward Earth, but (in a perfectly circular orbit) this acceleration is a change in *direction* rather than a change in speed, bending the satellite's path from a straight line into a circle or ellipse around the earth. The weightlessness occurs because people inside a spacecraft are also orbiting the earth, at the same speed as the spacecraft that surrounds them.

Another way to describe the same situation is to consider a rotating frame of reference matching the satellite's orbit. In such a reference frame, there is a (fictitious) centrifugal force that exactly cancels the force of gravity, leaving no net force acting on the orbiting passengers. Earth's gravity reaches out far past the Van Allen belt and keeps the Moon in orbit at an average distance of 384,403 kilometers (238,857 mi).

**Regions**

Space is a partial vacuum: its different regions are defined by the various atmospheres and "winds" that dominate within them, and extend to the point at which those winds give way to those beyond. Geospace extends from Earth's atmosphere to the outer reaches of Earth's magnetic field, whereupon it gives way to the solar wind of interplanetary space. Interplanetary space extends to the heliopause, whereupon the solar wind gives way to the winds of the interstellar medium. Interstellar space then continues to the edges of the galaxy, where it fades into the intergalactic void.

**Geospace**



Aurora Australis observed by *Discovery*, on STS-39, May 1991 (orbital altitude: 260 km)

**Geospace** is the region of outer space near the Earth. Geospace includes the upper region of the atmosphere, as well as the magnetosphere. The outer boundary of Geospace is the magnetopause, which forms an interface between the planet's magnetosphere and the solar wind. The inner boundary is the ionosphere. Alternatively, Geospace is the region of space between the Earth’s upper atmosphere and the outermost reaches of the Earth’s magnetic field. As the physical properties and behavior of near Earth space is affected by the behavior of the Sun and space weather, the field of Geospace is interlinked with heliophysics; the study of the Sun and its impact on the Solar System planets.

The volume of Geospace defined by the magnetopause is compacted in the direction of the Sun by the pressure of the solar wind, giving it a typical subsolar distance of 10 Earth radii from the center of the planet. However, the tail can extend outward to more than 100–200 Earth radii. The Van Allen radiation belts lie within the Geospace. The region between Earth's atmosphere and the Moon is sometimes referred to as **cis-lunar space**. The Moon passes through Geospace roughly four days each month, during which time the surface is shielded from the solar wind.

Geospace is populated by electrically charged particles at very low densities, the motions of which are controlled by the Earth's magnetic field. These plasmas form a medium from which storm-like disturbances powered by the solar wind can drive electrical currents into the Earth’s upper atmosphere. During geomagnetic storms two regions of Geospace, the radiation belts and the ionosphere, can become strongly disturbed. These storms increase fluxes of energetic electrons that can permanently damage satellite electronics, disrupting telecommunications and GPS technologies, and can also be a hazard to astronauts, even in low-Earth orbit. They also create aurorae seen near the magnetic poles.

Although it meets the definition of outer space, the atmospheric density within the first few hundred kilometers above the Kármán line is still sufficient to produce significant drag on satellites. Most artificial satellites operate in this region called low earth orbit and must fire their engines every few days to maintain orbit. This region contains material left over from previous manned and unmanned launches that are a potential hazard to spacecraft. Some of this debris re-enters Earth's atmosphere periodically. The drag here is low enough that it could theoretically be overcome by radiation pressure on solar sails, a proposed propulsion system for interplanetary travel.

**Interplanetary**

**Interplanetary space**, the space around the Sun and planets of the Solar System, is the region dominated by the interplanetary medium, which extends out to the heliopause where the influence of the galactic environment starts to dominate over the magnetic field and particle flux from the Sun. Interplanetary space is defined by the solar wind, a continuous stream of charged particles emanating from the Sun that creates a very tenuous atmosphere (the heliosphere) for billions of miles into space. This wind has a particle density of 5–10 protons/cm3 and is moving at a velocity of 350–400 km/s. The distance and strength of the heliopause varies depending on the activity level of the solar wind. The discovery since 1995 of extrasolar planets means that other stars must possess their own interplanetary media.

The volume of interplanetary space is a nearly total vacuum, with a mean free path of about one astronomical unit at the orbital distance of the Earth. However, this space is not completely empty, and is sparsely filled with cosmic rays, which include ionized atomic nuclei and various subatomic particles. There is also gas, plasma and dust, small meteors, and several dozen types of organic molecules discovered to date by microwave spectroscopy.

Interplanetary space contains the magnetic field generated by the Sun. There are also magnetospheres generated by planets such as Jupiter, Saturn, Mercury and the Earth that have their own magnetic fields. These are shaped by the influence of the solar wind into the approximation of a teardrop shape, with the long tail extending outward behind the planet. These magnetic fields can trap particles from the solar wind and other sources, creating belts of magnetic particles such as the Van Allen Belts. Planets without magnetic fields, such as Mars, have their atmospheres gradually eroded by the solar wind.

**Interstellar**

Main article: Interstellar medium

**Interstellar space** is the physical space within a galaxy not occupied by stars or their planetary systems. The interstellar medium resides—by definition—in interstellar space. The average density of matter in this region is about 106 particles per cm3, but this varies from a low of about 104–105 in regions of sparse matter up to about 108–1010 in dark nebula. Regions of star formation may reach 1012–1014 particles per cm3. Nearly 70% of this mass consists of lone hydrogen atoms. This is enriched with helium atoms as well as trace amounts of heavier atoms formed through stellar nucleosynthesis. These atoms can be ejected into the interstellar medium by stellar winds, or when evolved stars begin to shed their outer envelopes such as during the formation of a planetary nebula. The cataclysmic explosion of a supernova will generate an expanding shock wave consisting of ejected materials, as well as galactic cosmic rays. A number of molecules can form in interstellar space, as can tiny, 0.1 μm dust particles.

**Intergalactic**

**Intergalactic space** is the physical space between galaxies. The huge spaces between galaxy clusters are called the voids. Present estimates put the average mass density of the Universe at 5.9 protons per cubic meter, of which normal, baryonic matter has a density of one proton per four cubic meters. The density of the universe, however, is clearly not uniform; it ranges from relatively high density in galaxies (including very high density in structures within galaxies, such as planets, stars, and black holes) to conditions in vast voids that have much lower density than the universe's average.

Surrounding and stretching between galaxies, there is a rarefied plasma that is thought to possess a cosmic filamentary structure and that is slightly denser than the average density in the universe. This material is called the intergalactic medium and is mostly ionized hydrogen; i.e. a plasma consisting of equal numbers of electrons and protons. The IGM is thought to exist at a density of 10 to 100 times the average density of the universe (10 to 100 hydrogen atoms per cubic meter). In rich galaxy clusters, it reaches densities as high as 1000 times the average density of the universe (the intra-cluster medium).

The reason the IGM is thought to be mostly ionized gas is that its temperature is estimated to be quite high by terrestrial standards (though some parts of it are only "warm" by astrophysical standards). As gas falls into the intergalactic medium from the voids, it heats up to temperatures of 105 K to 107 K, which is high enough for the bound electrons to escape from the hydrogen nuclei upon collisions. At these temperatures, it is called the warm-hot intergalactic medium. Computer simulations indicate that on the order of half the atomic matter in the universe might exist in this warm-hot, rarefied state. When gas falls from the filamentary structures of the WHIM into the galaxy clusters at the intersections of the cosmic filaments, it can heat up even more, reaching temperatures of 108 K and above.

**Exploration and applications**

Main articles: Space exploration, Space colonization, and Space manufacturing

For the majority of human history, space was explored by remote observation; initially with the unaided eye and then with the telescope. Prior to the advent of reliable rocket technology, the closest that humans had come to reaching outer space was through the use of balloon flights. In 1935, the U.S. *Explorer II* manned balloon flight had reached an altitude of 22 km (14 mi). This was greatly exceeded in 1942 when the third launch of the German A-4 rocket climbed to an altitude of about 80 km (50 mi). In 1957, the unmanned satellite *Sputnik 1* was launch by a Russian R-7 rocket, achieving Earth orbit at an altitude of 215–939 km (134–583 mi). This was followed by the first human spaceflight in 1961, when Yuri Gagarin was sent into orbit on Vostok 1. The first humans to escape Earth orbit were Frank Borman, Jim Lovell and William Anders in 1968 on board Apollo 8, which achieved lunar orbit and reached a maximum distance of 377,349 km (234,474 mi) from the Earth.

In order to explore the other planets, a spacecraft must first reach escape velocity, which will allow it to travel beyond Earth orbit. The first spacecraft to accomplish this feat was the Soviet Luna 1, which performed a fly-by of the Moon in 1959. In 1961, Venera 1 became the first planetary probe. It revealed the presence of the solar wind and performed the first fly-by of the planet Venus, although contact was lost before reaching Venus. The first successful planetary mission was the Mariner 2 fly-by of Venus in 1962. The first spacecraft to perform a fly-by of Mars was Mariner 4, which reached the planet in 1964. Since that time, unmanned spacecraft have successfully examined each of the Solar System's planets, as well their moons and many minor planets and comets. They remain a fundamental tool for the exploration of outer space.

The absence of air makes outer space (and the surface of the Moon) ideal locations for astronomy at all wavelengths of the electromagnetic spectrum, as evidenced by the spectacular pictures sent back by the Hubble Space Telescope, allowing light from about 13.7 billion years ago—almost to the time of the Big Bang—to be observed.

The deep vacuum of space could make it an attractive environment for certain industrial processes, such as those that require ultraclean surfaces.