General Concepts & Components of Space Exploration

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First Edition, 2012

ISBN 978-81-323-4653-1

Published by:
The English Press
4735/22 Prakashdeep Bldg,
Ansari Road, Darya Ganj,
Delhi - 110002
Email: info@wtbooks.com

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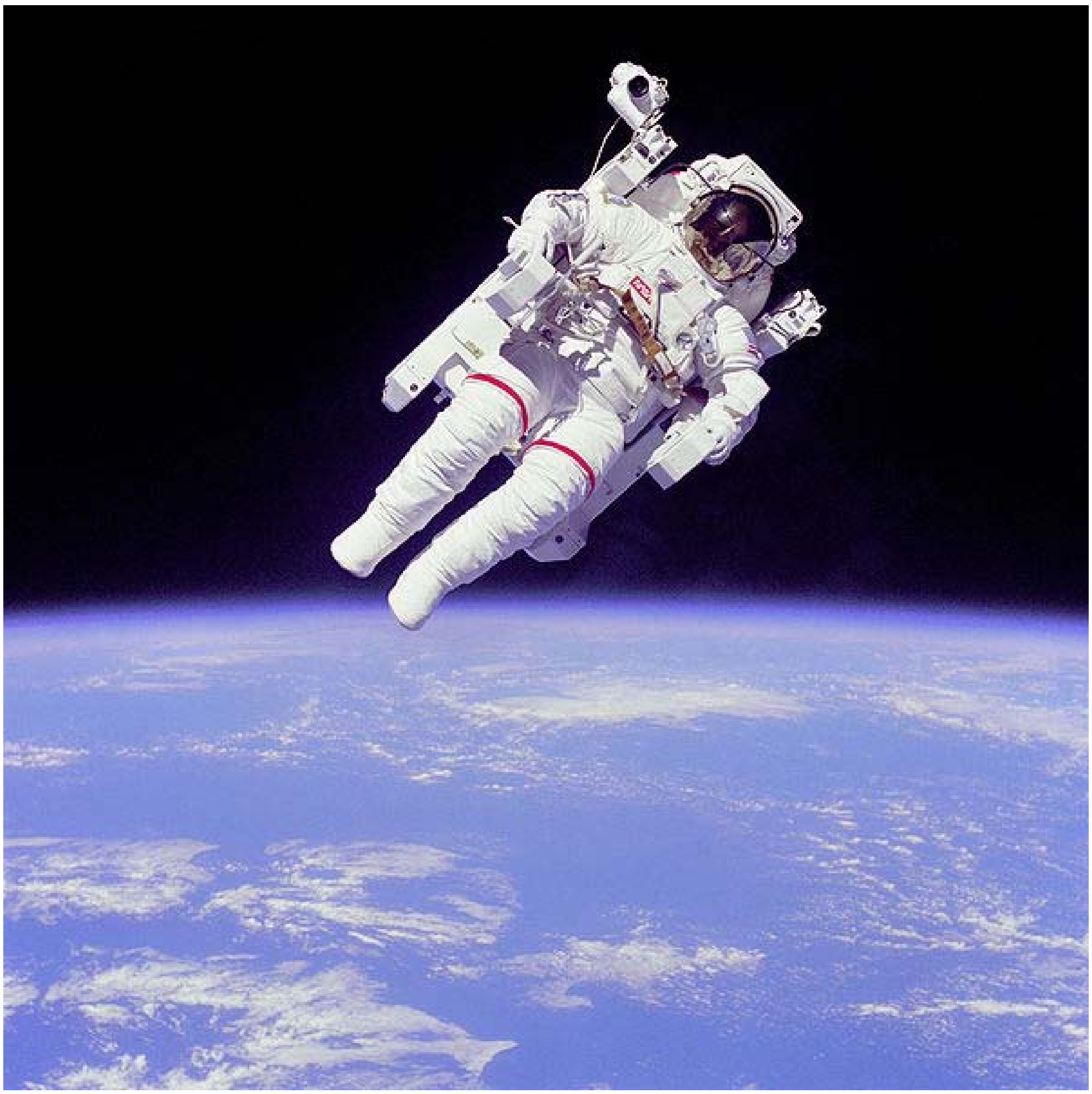
Astronaut

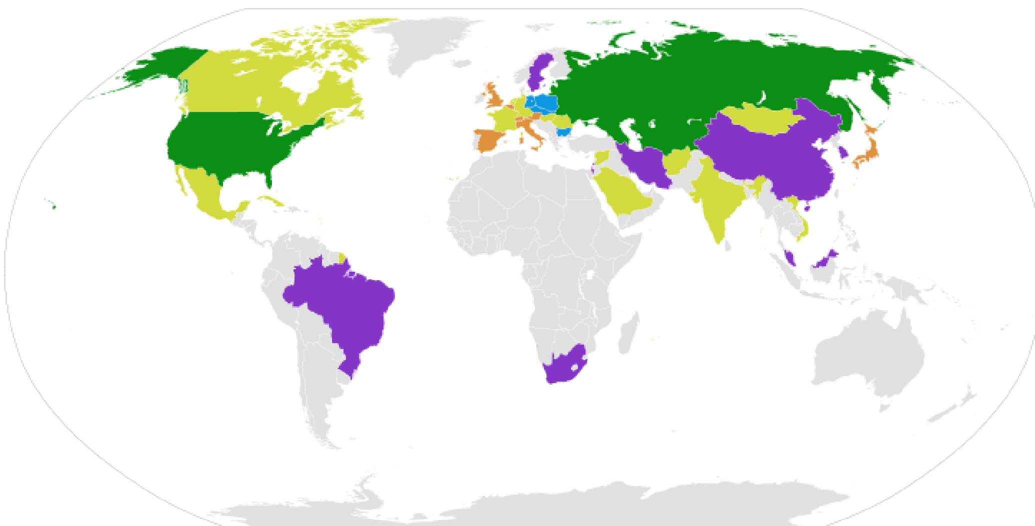


Astronaut Bruce McCandless II using a Manned Maneuvering Unit outside the United States Space Shuttle *Challenger* in 1984.

An **astronaut** or **cosmonaut** is a person trained by a human spaceflight program to command, pilot, or serve as a crew member of a spacecraft. While generally reserved for professional space travelers, the term is sometimes applied to anyone who travels into space, including scientists, politicians, journalists, and tourists.

Until 2003, astronauts were sponsored and trained exclusively by governments, either by the military, or by civilian space agencies. With the sub-orbital flight of the privately-funded SpaceShipOne in 2004, a new category of astronaut was created: the commercial astronaut.

Definition



Countries whose citizens have flown in space

The criteria for what constitutes human spaceflight vary. The Fédération Aéronautique Internationale (FAI) Sporting Code for astronautics recognizes only flights that exceed an altitude of 100 kilometers (62 mi). In the United States, professional, military, and commercial astronauts who travel above an altitude of 50 miles (80 km) are awarded astronaut wings.

As of September 19, 2009, a total of 505 people from 38 countries have reached 100 km (62 mi) or more in altitude, of which 502 reached Low Earth orbit or beyond. Of these, 24 people have traveled beyond Low Earth orbit, to either lunar or trans-lunar orbit or to the surface of the moon; three of the 24 did so twice: Jim Lovell, John Young and Eugene Cernan.

Under the U. S. definition, 496 people qualify as having reached space, above 50 miles (80 km) altitude. Of eight X-15 pilots who exceeded 50 miles in altitude, seven reached above 50 miles (80 km) but below 100 kilometers (about 62 miles). Space travelers have spent over 30,400 person-days (or a cumulative total of over 83 years) in space, including over 100 astronaut-days of spacewalks. As of 2008, the man with the longest time in space is Sergei K. Krikalev, who has spent 803 days, 9 hours and 39 minutes, or 2.2 years, in space. Peggy A. Whitson holds the record for the most time in space by a woman, 377 days.

Terminology

Sally Ride on *Challenger's* mid-deck during STS-7

Valentina Tereshkova, 1963 first woman in space

English

In the United States, Canada, United Kingdom, and many other English-speaking nations, a professional space traveler is called an **astronaut**. The term derives from the Greek words *ástron* (ἄστρον), meaning "star", and *nautes* (ναύτης), meaning "sailor". The first known use of the term "astronaut" in the modern sense was by Neil R. Jones in his short story "The Death's Head Meteor" in 1930. The word itself had been known earlier. For example, in Percy Greg's 1880 book *Across the Zodiac*, "astronaut" referred to a spacecraft. In *Les Navigateurs de l'Infini* (1925) of J.-H. Rosny aîné, the word *astronautique* (astronautic) was used. The word may have been inspired by "aeronaut", an older term for an air traveler first applied (in 1784) to balloonists.

The first known formal use of the term astronautics in the scientific community was the establishment of the annual International Astronautical Congress in 1950 and the subsequent founding of the International Astronautical Federation the following year.

NASA applies the term astronaut to any crew member aboard NASA spacecraft bound for Earth orbit or beyond. NASA also uses the term as a title for those selected to join its Astronaut Corps. The European Space Agency similarly uses the term astronaut for members of its Astronaut Corps.

Russian

Soviet Soyuz rockets like the one pictured above were the first reliable means to transport objects into Earth orbit.

Launch of a Proton-K

By convention, an astronaut employed by the Russian Federal Space Agency (or its Soviet predecessor) is called a **cosmonaut** in English texts. The word is an anglicisation of the Russian word *kosmonavt*, one who works in space outside the Earth′s atmosphere, a space traveller, which derives from the Russian word *kosmos* (космос), meaning "space", which in turn derives from the Greek words *kosmos* (κόσμος), meaning "universe", and *nautes* (ναύτης), meaning "sailor". For the most part, "cosmonaut" and "astronaut" are synonyms in all languages, and the usage of choice is often dictated by political reasons.

Russian Air Force pilot Yuri Gagarin was the first cosmonaut. Russian factory worker Valentina Tereshkova was the first woman cosmonaut, as well as arguably the first civilian cosmonaut. On March 14, 1995, Norman Thagard became the first American to ride to space onboard a Russian launch vehicle, arguably becoming the first "American cosmonaut".

The **Soviet space program** refers to the rocketry and space exploration programs conducted by the Soviet Union (USSR) from the 1930s until its dissolution in 1991. Over its sixty-year history, this primarily classified military program was responsible for a number of pioneering accomplishments in space flight, including the first intercontinental ballistic missile (1957), first satellite (Sputnik 1), first animal in space (the dog Laika on Sputnik 2), first human in space and Earth orbit (cosmonaut Yuri Gagarin on Vostok 1), first Moon impact (1959) and unmanned landing, first space rover, first space station, and first interplanetary probe.

The rocket and space program of the USSR, initially boosted by the assistance of captured scientists from the advanced German rocket program, was performed mainly by Soviet engineers and scientists after 1955, and was based on some unique Soviet and Imperial Russian theoretical developments, many derived by Konstantin Eduardovich Tsiolkovskii, sometimes known as the father of theoretical astronautics. Sergey Korolyov (also transliterated as Korolev) was the head of the principal design group; his official title was "chief designer" (a standard title for similar positions in the USSR). Unlike its American competitor in the "space race," which had NASA as a single coordinating agency, the USSR's program was split among several competing design groups led by Korolyov, Mikhail Yangel, Valentin Glushko, and Vladimir Chelomei.

Because of the program's classified status, and for propaganda value, announcements of the outcomes of missions were delayed until success was certain, and failures were sometimes kept secret. Ultimately, as a result of Mikhail Gorbachev's policy of *glasnost* in the 1980s, many facts about the space program were declassified. Notable setbacks included the deaths of Korolyov, Vladimir Komarov (in the Soyuz 1 crash), and Yuri Gagarin (on a routine fighter jet mission) between 1966 and 1968, and disastrous experiences with the huge N-1 rocket intended to power a manned lunar landing, and which exploded shortly after launch on each of four unmanned tests.

The Soviet Space Program was dissolved with the fall of the Soviet Union, with Russia and Ukraine becoming its immediate heirs. Russia created the Russian Aviation and Space Agency, now known as the Russian Federal Space Agency (RKA), while Ukraine created the National Space Agency of Ukraine (NSAU).

Funding and support

Despite the Soviet space program's achievements, it was "was neither a high priority nor a central tool of Soviet state policy." Khruschev had decided that the Soviet military's funding would focus on the Strategic Rocket Forces' ICBMs, and the space program "rode its coattails". While the West believed that Khruschev personally ordered each new space mission for propaganda purposes, and the Soviet leader did have an unusually close relationship with Korolyo and other chief designers, he "was more concerned about money and missiles than he was about cosmonauts and the cosmos...[H]e was never particularly interested in competing with Apollo."

While the government and the Communist Party used the program's successes as propaganda tools after they occurred, systematic plans for missions based on political reasons were rare, one exception being Valentina Tereshkova, the first woman in space, on Vostok 6 in 1963. Missions were planned based on rocket availability or ad hoc reasons, rather than scientific purposes. For example, the government in February 1962 abruptly ordered an ambitious mission involving two Vostoks simultaneously in orbit launched "in ten days time" to obscure John Glenn's Mercury-Atlas 6 that month; the program could not do so with Vostok 3 and Vostok 4 until August.

Untapped potential

Buran

The Buran shuttle

The Soviet space program produced the Space Shuttle Buran based on the Energia launcher. Energia would be used as the base for a manned Mars mission. Buran was intended to operate in support of large space based military platforms as a response first to the US Space Shuttle and then the Strategic Defense Initiative. By the time the system was operational, in 1988, strategic arms reduction treaties and the end of the Cold War made Buran redundant. On November 15, 1988, as snowy clouds and winds were swirling around Baikonur Cosmodrome in Kazakhstan, the Buran orbiter, attached to its giant Energia rocket, thundered into the gloomy early morning sky. Three hours and two orbits later, the 100-tonne craft glided back to a flawless landing just a few miles from its launch pad and just 3m off the runway centreline. Several vehicles were built, but only one flew an unmanned test flight; it was found too expensive to operate as a civilian launcher.

Canceled projects: Vesta

The Vesta mission would have consisted of two identical probes to be launched in 1991. It was intended to fly-by Mars and then study four small bodies, including asteroids belonging to different classes. At 4 Vesta a penetrator would be released.

Incidents and setbacks

The Soviet space program as well as its US equivalent has experienced a number of fatal incidents and failures.

The so-called Nedelin catastrophe in 1960 was a disastrous explosion of a fueled rocket being tested on launchpad, killing many personnel, engineers, and technicians working on the project.

The first cosmonaut fatality during training occurred on March 23, 1961 when Valentin Bondarenko died in a fire within a low pressure, high oxygen atmosphere.

The Voskhod program was cancelled after two manned flights owing to the change of Soviet leadership and nearly fatal 'close calls' during the second mission. Had the planned further flights gone ahead they could have given the Soviet space program further 'firsts' including a long duration flight of 20 days, a spacewalk by a woman and an untethered spacewalk.

The deaths of Korolyov, Komarov (in the Soyuz 1 crash) and Gagarin (on routine fighter jet mission) within two years of each other understandably had substantial negative impact on the Soviet program.

The Soviets continued striving for the first lunar mission with the huge N-1 rocket, which exploded on each of four unmanned tests shortly after launch. The Americans won the race to land men on the moon with Apollo 11 on July 20, 1969.

On April 5, 1975, the second stage of a Soyuz rocket carrying 2 cosmonauts to the Salyut 4 space station malfunctioned, resulting in the first manned launch abort. The cosmonauts were carried several thousand miles downrange and became worried that they would land in China, which the Soviet Union was then having difficult relations with. The capsule hit a mountain, sliding down a slope and almost slid off a cliff; fortunately the parachute lines snagged on trees and kept this from happening. As it was, the two suffered severe injuries and the commander, Lazerev, never flew again.

On March 18, 1980 a Vostok rocket exploded on its launch pad during a fueling operation, killing 48 people.

In August 1981, Kosmos 434, which had been launched in 1971, was about to re-enter. To allay fears that the spacecraft carried nuclear materials, a spokesperson from the Ministry of Foreign Affairs of the USSR assured the Australian government on August 26, 1981 that the satellite was "an experimental lunar cabin". This was one of the first admissions by the Soviet Union that it had ever engaged in a manned lunar spaceflight program.

In September 1983, a Soyuz rocket being launched to carry cosmonauts to the Salyut 7 space station exploded on the pad, causing the Soyuz capsule's abort system to engage, saving the two cosmonauts on board.

Chinese

Official English-language texts issued by the government of the People's Republic of China use *astronaut* while texts in Russian use космонавт (*kosmonavt*). In China, the terms "yǔhángyuán" (宇航员, "sailing personnel in universe") or "hángtiānyuán" (航天员, "sailing personnel in sky") have long been used for astronauts. The phrase "tàikōng rén" (太空人, "spaceman") is often used in Taiwan and Hong Kong.

The term **taikonaut** is used by some English-language news media organizations for professional space travelers from China. The word has featured in the Longman and Oxford English dictionaries, the latter of which describes it as "a hybrid of the Chinese term *taikong* (space) and the Greek *naut* (sailor)"; the term became more common in 2003 when China sent its first astronaut Yang Liwei into space aboard the *Shenzhou 5* spacecraft. This is the term used by Xinhua in the English version of the Chinese People's Daily since the advent of the Chinese space program. The origin of the term is unclear; as early as May 1998, Chiew Lee Yih (赵里昱) from Malaysia, used it in newsgroups.

Other terms

With the rise of space tourism, NASA and the Russian Federal Space Agency agreed to use the term "spaceflight participant" to distinguish those space travelers from professional astronauts on missions coordinated by those two agencies.

While no nation other than Russia (formerly the Soviet Union), the United States, and China has launched a manned spacecraft, several other nations have sent people into space in cooperation with one of these countries. Inspired partly by these missions, other synonyms for astronaut have entered occasional English usage. For example, the term **spationaut** (French spelling: *spationaute*) is sometimes used to describe French space travelers, from the Latin word *spatium* or space, and the Malay term *angkasawan* was used to describe participants in the Angkasawan program.

Space travel milestones

Yuri Gagarin, first human in space (1961)

The first human in space was Russian Yuri Gagarin, who was launched into space on April 12, 1961 aboard Vostok 1 and orbited around the Earth for 108 minutes. There are allegations that Gagarin ejected from landing module after re-entering the atmosphere and parachuted back, due to safety concerns about the craft's landing systems. The first woman in space was Russian Valentina Tereshkova, launched in June 1963 aboard Vostok 6.

Alan Shepard became the first American and second person in space on May 5, 1961 on a 15-minute sub-orbital flight. The first American woman in space was Sally Ride, during Space Shuttle Challenger's mission STS-7, on June 18, 1983. 1992, Dr. Mae Jemison, The first African American woman to travel in space, She was aboard STS-47 Spacelab-J

The first mission to orbit the moon, *Apollo 8*, included William Anders who was born in Hong Kong, making him the first Asian-born astronaut in 1968. In April 1985, Taylor Wang became the first ethnic Chinese person in space. On 15 October 2003, Yang Liwei became China's first astronaut on the Shenzhou 5 spacecraft.

The Soviet Union, through its Intercosmos program, allowed people from other "socialist" (i.e. Warsaw Pact and other Soviet-allied) countries to fly on its missions. An example is Vladimír Remek, a Czechoslovak, who became the first non-Soviet European in space in 1978 on a Russian Soyuz-U rocket. On July 23, 1980, Pham Tuan of Vietnam became the first Asian in space when he flew aboard Soyuz 37.

Neil Armstrong, first person to walk on the moon (1969).

Also in 1980, Cuban Arnaldo Tamayo Méndez became the first person of Hispanic and black African descent to fly in space, Guion Bluford became the first African American to fly into space. The first person born in Africa to fly in space was Patrick Baudry, in 1985. In 1988, Abdul Ahad Mohmand became the first Afghan to reach space, spending nine days aboard the Mir space station.

With the larger number of seats available on the Space Shuttle, the U.S. began taking international astronauts. In 1983, Ulf Merbold of West Germany became the first non-US citizen to fly in a US spacecraft. In 1984, Marc Garneau became the first of 8 Canadian astronauts to fly in space (through 2010). In 1985, Rodolfo Neri Vela became the first Mexican-born person in space. In 1991, Helen Sharman became the first Briton to fly in space. In 2002, Mark Shuttleworth became the first citizen of an African country to fly in space, as a paying spaceflight participant. In 2003, Ilan Ramon became the first Israeli to fly in space, although he died during a re-entry accident.

Age milestones

The youngest person to fly in space is Gherman Titov, who was 25 years old when he flew Vostok 2. (Titov was also the first person to suffer space sickness). The oldest person who has flown in space is John Glenn, who was 77 when he flew on STS-95.

Duration and distance milestones

The longest stay in space was 438 days, by Russian Valeri Polyakov. As of 2006, the most spaceflights by an individual astronaut is seven, a record held by both Jerry L. Ross and Franklin Chang-Diaz. The farthest distance from Earth an astronaut has traveled was 401,056 km (249,205 mi), when Jim Lovell, Jack Swigert, and Fred Haise went around the Moon during the Apollo 13 emergency.

Civilian and non-government milestones

Depending on the exact definition of 'civilian', the first civilian in space was either Valentina Tereshkova aboard Vostok 6 (she also became the first woman in space on that mission) or Joseph Albert Walker on X-15 Flight 90 a month later. Tereshkova was only honorarily inducted into the USSR's Air Force, which had no female pilots whatsoever at that time. Joe Walker had joined the US Army Air Force but was not a member during his flight. The first people in space who had never been a member of any country's armed forces were both Konstantin Feoktistov and Boris Yegorov aboard Voskhod 1.

The first non-governmental space traveler was Byron K. Lichtenberg, a researcher from the Massachusetts Institute of Technology who flew on STS-9 in 1983. In December 1990, Toyohiro Akiyama became the first paying space traveler as a reporter for Tokyo Broadcasting System, a visit to Mir as part of an estimated $12 million (USD) deal with a Japanese TV station, although at the time, the term used to refer to Akiyama was "Research Cosmonaut". Akiyama suffered severe space-sickness during his mission, which affected his productivity.

The first self-funded space tourist was Dennis Tito onboard the Russian spacecraft Soyuz TM-3 on 28 April 2001.

Self-funded travelers

The first person to fly on an entirely privately-funded mission was Mike Melvill, piloting SpaceShipOne flight 15P on a sub-orbital journey, although he was a test pilot employed by Scaled Composites and not an actual paying space tourist. Seven others have paid to fly into space:

1. Dennis Tito (American): April 28 – May 6, 2001 (ISS)
2. Mark Shuttleworth (South African): April 25 – May 5, 2002 (ISS)
3. Gregory Olsen (American): October 1–11, 2005 (ISS)
4. Anousheh Ansari (Iranian / American): September 18–29, 2006 (ISS)
5. Charles Simonyi (Hungarian / American): April 7–21, 2007 (ISS), March 26 – April 8, 2009 (ISS)
6. Richard Garriott (American): October 12–24, 2008 (ISS)
7. Guy Laliberté (Canadian): September 30, 2009 – October 11, 2009 (ISS)

Training

The first NASA astronauts were selected for training in 1959. Early in the space program, military jet test piloting and engineering training were often cited as prerequisites for selection as an astronaut at NASA, although neither John Glenn nor Scott Carpenter (of the Mercury Seven) had any university degree, in engineering or any other discipline at the time of their selection. Selection was initially limited to military pilots. The earliest astronauts for both America and Russia tended to be jet fighter pilots, and were often test pilots.

Once selected, NASA astronauts go through 20 months of training in a variety of areas, including training for extra-vehicular activity in a facility such as NASA's Neutral Buoyancy Laboratory. Astronauts-in-training may also experience short periods of weightlessness in aircraft called the "vomit comet", the nickname given to a pair of modified KC-135s (retired in 2000 and 2004 respectively, and replaced in 2005 with a C-9) which perform parabolic flights. Astronauts are also required to accumulate a number of flight hours in high-performance jet aircraft. This is mostly done in T-38 jet aircraft out of Ellington Field, due to its proximity to the Johnson Space Center. Ellington Field is also where the Shuttle Training Aircraft is maintained and developed, although most flights of the aircraft are done out of Edwards Air Force Base.

NASA candidacy requirements

- Be citizens of the United States.
- Pass a strict physical examination, and have a near and distant visual acuity correctable to 20/20 (6/6). Blood pressure, while sitting, must be no greater than 140 over 90.

Commander and Pilot

- A bachelor's degree in engineering, biological science, physical science or mathematics is required, although service in the United States Air Force can exempt this.
- At least 1,000 hours flying time as pilot-in-command in jet aircraft. Experience as a test pilot is desirable.
- Height must be 5 ft 4 in to 6 ft 4 in (1.63 to 1.93 m).
- Distant visual acuity must be correctable to 20/20 in each eye

- The refractive surgical procedures of the eye, PRK (Photorefractive keratectomy) and LASIK, are now allowed, providing at least 1 year has passed since the date of the procedure with no permanent adverse after effects. For those applicants under final consideration, an operative report on the surgical procedure will be requested.

Mission Specialist

- A bachelor's degree in engineering, biological science, physical science or mathematics, as well as at least three years of related professional experience (graduate work or studies) and an advanced degree (master's degree = 1 year or a doctoral degree = 3 years)
- Applicant's height must be 5 ft 2 in to 6 ft 4 in (1.57 to 1.93 m).

Mission Specialist Educator

Mission Specialist Educators Lindenberger, Arnold, and Acaba during a parabolic flight

- Bachelor's degree with teaching experience, including work at the kindergarten through 12th grade level. Advanced degree not required, but is desired.

Mission Specialist Educators, or "Educator Astronauts", were first selected in 2004, and as of 2007, there are three NASA Educator astronauts: Joseph M. Acaba, Richard R. Arnold, and Dorothy Metcalf-Lindenburger. Barbara Morgan, selected as back-up teacher to Christa McAuliffe in 1985, is considered to be the first Educator astronaut by the media, but she trained as a mission specialist. The Educator Astronaut program is a successor to the Teacher in Space program from the 1980s.

Health risks of space travel

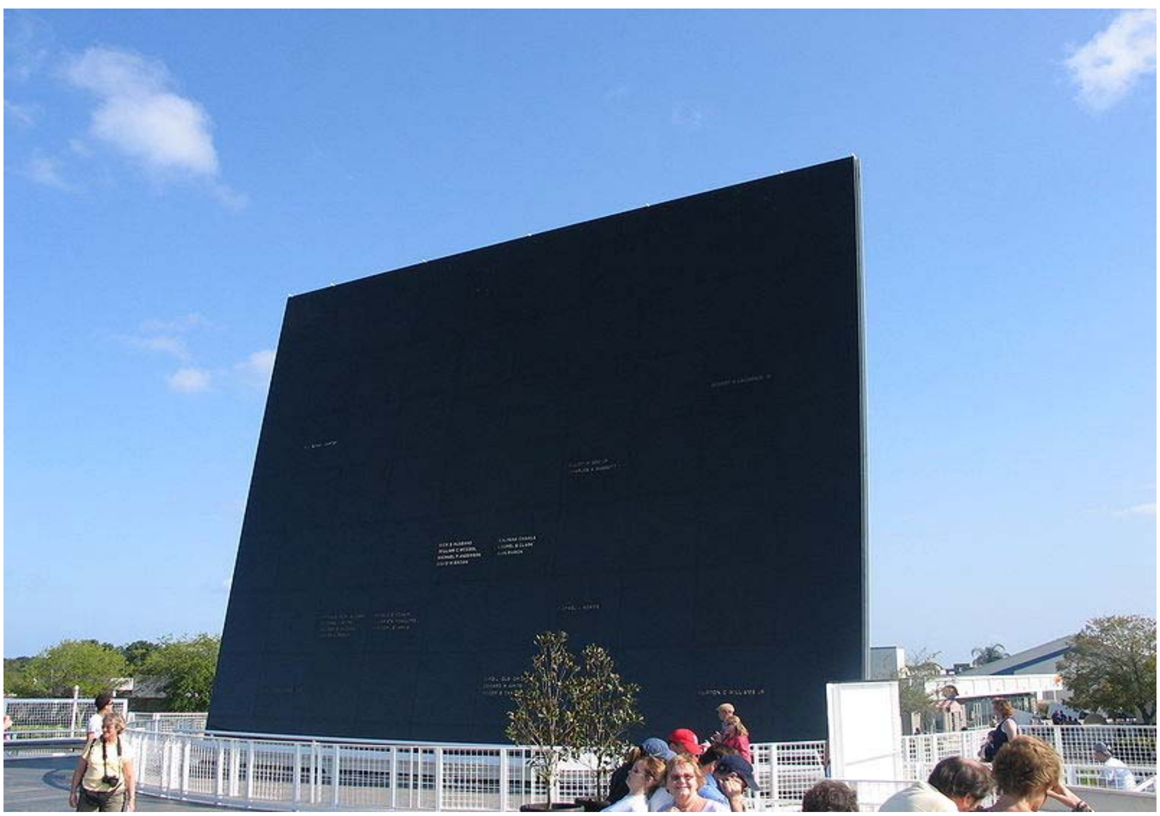
Astronauts are susceptible to a variety of health risks including decompression sickness, barotrauma, immunodeficiencies, loss of bone and muscle, orthostatic intolerance due to volume loss, sleep disturbances, and radiation injury. A variety of large scale medical studies are being conducted in space via the National Space and Biomedical Research

Institute (NSBRI) to address these issues. Prominent among these is the Advanced Diagnostic Ultrasound in Microgravity Study in which astronauts (including former ISS commanders Leroy Chiao and Gennady Padalka) perform ultrasound scans under the guidance of remote experts to diagnose and potentially treat hundreds of medical conditions in space. This study's techniques are now being applied to cover professional and Olympic sports injuries as well as ultrasound performed by non-expert operators in medical and high school students. It is anticipated that remote guided ultrasound will have application on Earth in emergency and rural care situations, where access to a trained physician is often rare.

Insignia

In Russia, cosmonauts are awarded Pilot-Cosmonaut of the Russian Federation upon completion of their missions, often accompanied with the award of Hero of the Russian Federation. This follows the practice established in the Soviet Union.

At NASA, people who complete astronaut candidate training receive a silver lapel pin. Once they have flown in space, they receive a gold pin. U.S. astronauts who also have active-duty military status receive a special qualification badge, known as the Astronaut Badge, after participation on a spaceflight. The United States Air Force also presents an Astronaut Badge to its pilots who exceed 50 miles (80 km) in altitude.



Space Mirror Memorial

Deaths

Nineteen astronauts have lost their lives during spaceflight, on four missions. By nationality, they are fourteen Americans, three Russians, one Ukrainian, and one Israeli. Several others have died while training for space missions.

The Space Mirror Memorial, which stands on the grounds of the John F. Kennedy Space Center Visitor Complex, commemorates the lives of the men and women who have died during spaceflight and during training in the space programs of the United States. In addition to twenty NASA career astronauts, the memorial includes the names of a U.S. Air Force X-15 test pilot, a U.S. Air Force officer who died while training for a then-classified military space program, a civilian spaceflight participant who died in the Challenger disaster, and an international astronaut who was killed in the Columbia disaster.

Chapter- 2

Spacecraft

Soyuz 19 spacecraft for the Apollo Soyuz Test Project

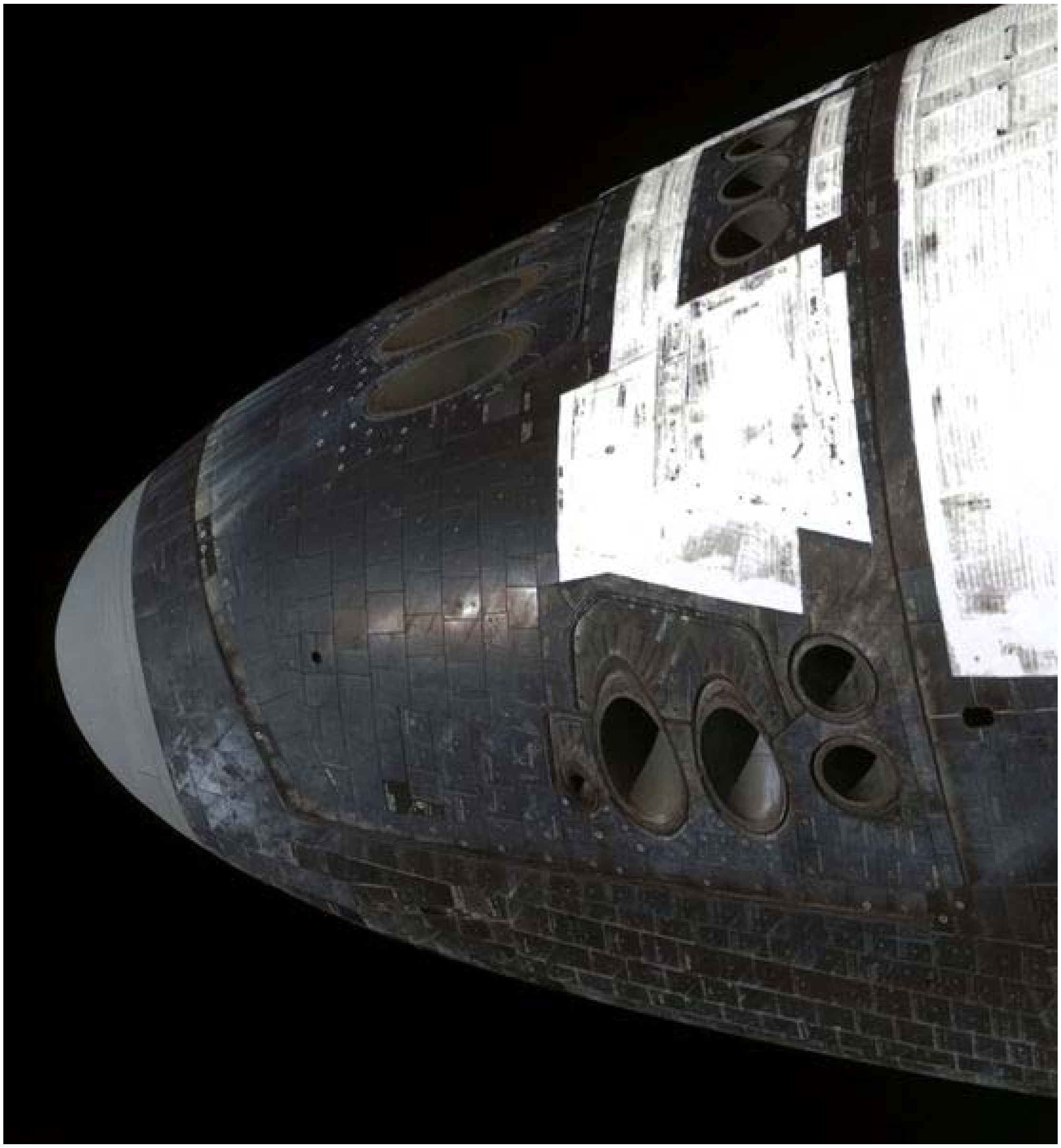
A **spacecraft** or **spaceship** is a craft or machine designed for spaceflight. Spacecraft is used for a variety of purposes, including communications, earth observation, meteorology, navigation, planetary exploration and space tourism. Spacecraft and space travel are common themes in works of science fiction.

On a sub-orbital spaceflight, a spacecraft enters space and then returns to the surface, without having gone into an orbit. For orbital spaceflights, spacecraft enter closed orbits around the Earth or around other celestial bodies. Spacecraft used for human spaceflight carry people on board as crew or passengers, while those used for robotic space missions operate either autonomously or telerobotically. Robotic spacecraft used to support scientific research are space probes. Robotic spacecraft that remain in orbit around a planetary body are artificial satellites. Only a handful of interstellar probes, such as Pioneer 10 and 11, Voyager 1 and 2, and New Horizons, are currently on trajectories that leave our Solar System.

Subsystems

A spacecraft system comprises various subsystems, dependent upon mission profile. Spacecraft subsystems comprise the spacecraft "*bus*" and may include: attitude determination and control (variously called ADAC, ADC or ACS), guidance, navigation and control (GNC or GN&C), communications (Comms), command and data handling (CDH or C&DH), power (EPS), thermal control (TCS), propulsion, and structures. Attached to the bus are typically *payloads*.

Life support
: Spacecraft intended for human spaceflight must also include a life support system for the crew.



Reaction control system thrusters on the nose of the U.S. Space Shuttle

Attitude control

A Spacecraft needs an attitude control subsystem to be correctly oriented in space and respond to external torques and forces properly. The attitude control subsystem consists of sensors and actuators, together with controlling algorithms. The attitude control subsystem permits proper pointing for the science objective, sun pointing for power to the solar arrays and earth-pointing for communications.

GNC

Guidance refers to the calculation of the commands (usually done by the CDH subsystem) needed to steer the spacecraft where it is desired to be. Navigation means determining a spacecraft's orbital elements or position. Control means adjusting the path of the spacecraft to meet mission requirements. On some missions, GNC and Attitude Control are combined into one subsystem of the spacecraft.

Command and data handling

The CDH subsystem receives commands from the communications subsystem, performs validation and decoding of the commands, and distributes the commands to the appropriate spacecraft subsystems and components. The CDH also receives housekeeping data and science data from the other spacecraft subsystems and components, and packages the data for storage on a data recorder or transmission to the ground via the communications subsystem. Other functions of the CDH include maintaining the spacecraft clock and state-of-health monitoring.

Power

Spacecraft need an electrical power generation and distribution subsystem for powering the various spacecraft subsystems. For spacecraft near the Sun, solar panels are frequently used to generate electrical power. Spacecraft designed to operate in more distant locations, for example Jupiter, might employ a Radioisotope Thermoelectric Generator (RTG) to generate electrical power. Electrical power is sent through power conditioning equipment before it passes through a power distribution unit over an electrical bus to other spacecraft components. Batteries are typically connected to the bus via a battery charge regulator, and the batteries are used to provide electrical power during periods when primary power is not available, for example when a Low Earth Orbit (LEO) spacecraft is eclipsed by the Earth.

Thermal control

Spacecraft must be engineered to withstand transit through the Earth's atmosphere and the space environment. They must operate in a vacuum with temperatures potentially ranging across hundreds of degrees Celsius as well as (if subject to reentry) in the presence of plasmas. Material requirements are such that either high melting temperature, low density materials such as beryllium and reinforced carbon-carbon or (possibly due to the lower thickness requirements despite its high density) tungsten or ablative carbon/carbon composites are used. Depending on mission profile, spacecraft may also need to operate on the surface of another planetary body. The thermal control subsystem can be passive, dependent on the selection of materials with specific radiative properties. Active thermal control makes use of electrical heaters and certain actuators such as louvers to control temperature ranges of equipments within specific ranges.

A launch vehicle, like this Proton rocket, is typically used to bring a spacecraft to orbit.

Propulsion

Spacecraft may or may not have a propulsion subsystem, depending upon whether or not the mission profile calls for propulsion. The *Swift* spacecraft is an example of a spacecraft that does not have a propulsion subsystem. Typically though, LEO spacecraft (for example *Terra (EOS AM-1)* include a propulsion subsystem for altitude adjustments (called drag make-up maneuvers) and inclination adjustment maneuvers. A propulsion system is also needed for spacecraft that perform momentum management maneuvers. Components of a conventional propulsion subsystem include fuel, tankage, valves, pipes, and thrusters. The TCS interfaces with the propulsion subsystem by monitoring the temperature of those components, and by preheating tanks and thrusters in preparation for a spacecraft maneuver.

Structures

Spacecraft must be engineered to withstand launch loads imparted by the launch vehicle, and must have a point of attachment for all the other subsystems. Depending upon mission profile, the structural subsystem might need to withstand loads imparted by entry into the atmosphere of another planetary body, and landing on the surface of another planetary body.

Payload

The payload is dependent upon the mission of the spacecraft, and is typically regarded as the part of the spacecraft "that pays the bills". Typical payloads could include scientific instruments (cameras, telescopes, or particle detectors, for example), cargo, or a human crew.

Ground segment

The ground segment, though not technically part of the spacecraft, is vital to the operation of the spacecraft. Typical components of a ground segment in use during normal operations include a mission operations facility where the flight operations team conducts the operations of the spacecraft, a data processing and storage facility, ground stations to radiate signals to and receive signals from the spacecraft, and a voice and data communications network to connect all mission elements.

Launch vehicle

The launch vehicle is used to propel the spacecraft from the Earth's surface, through the atmosphere, and into an orbit, the exact orbit being dependent upon mission configuration. The launch vehicle may be expendable or reusable.

Reusable vessels

Space Shuttle Columbia's first launch

Columbia orbiter landing

The first reusable spacecraft, the X-15, was air-launched on a suborbital trajectory on July 19, 1963. The first partially reusable orbital spacecraft, the Space Shuttle, was launched by the USA on the 20th anniversary of Yuri Gagarin's flight, on April 12, 1981. During the Shuttle era, six orbiters were built, all of which have flown in the atmosphere and five of which have flown in space. The *Enterprise* was used only for approach and landing tests, launching from the back of a Boeing 747 and gliding to deadstick landings at Edwards AFB, California. The first Space Shuttle to fly into space was the *Columbia*, followed by the *Challenger*, *Discovery*, *Atlantis*, and *Endeavour*. The *Endeavour* was built to replace the *Challenger* when it was lost in January 1986. The *Columbia* broke up during reentry in February 2003.

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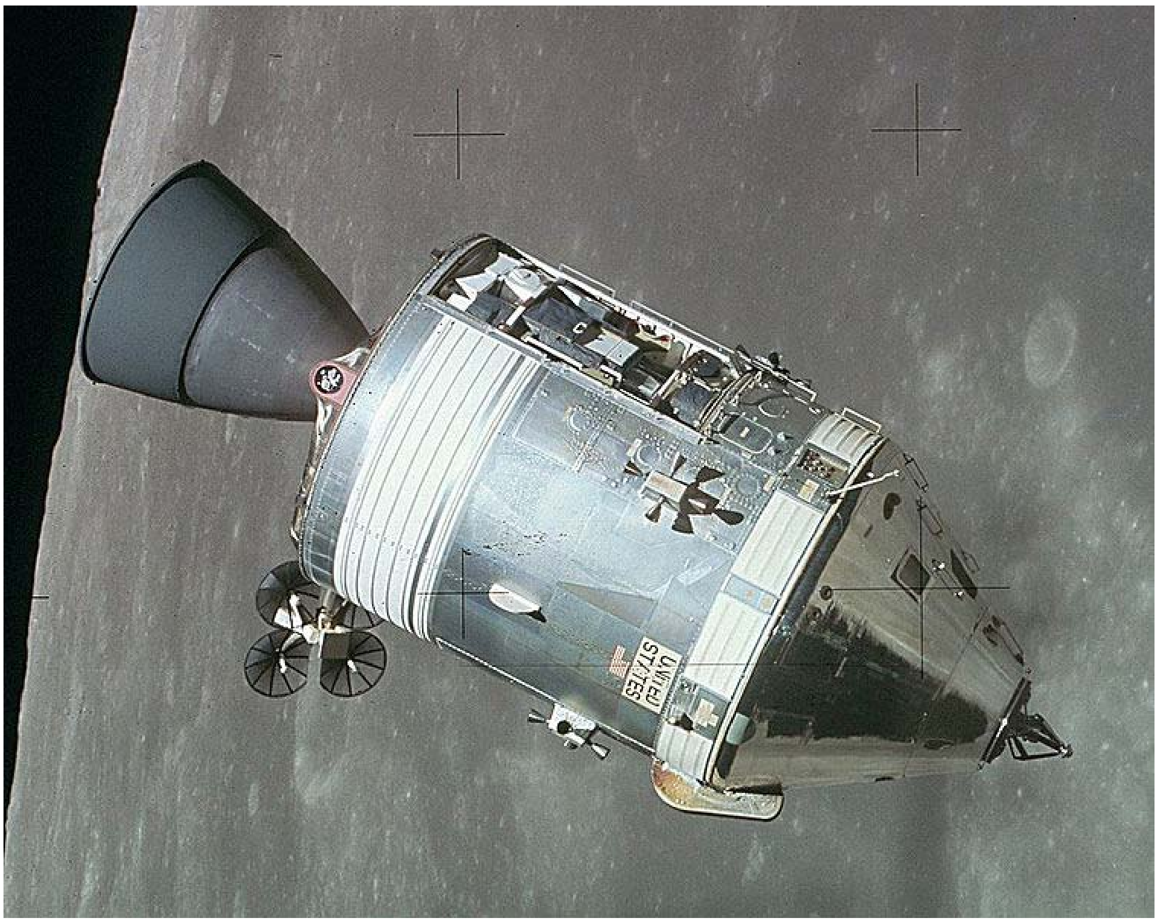
Manned spacecraft



The Apollo 15 Command/Service Module as viewed from the Lunar Module on August 2, 1971.

A Russian Soyuz bringing a crew to the ISS

Orbital

Transport

Soviet/Russian

- Vostok Spacecraft
- Voskhod Spacecraft
- Shuttle Buran
- Soyuz Spacecraft

American

- Mercury Spacecraft
- Gemini Spacecraft
- Apollo Spacecraft
- Space Shuttle

Chinese

- Shenzhou Spacecraft

Spacestation

- Salyut
- Skylab
- Mir
- International Space Station

Other

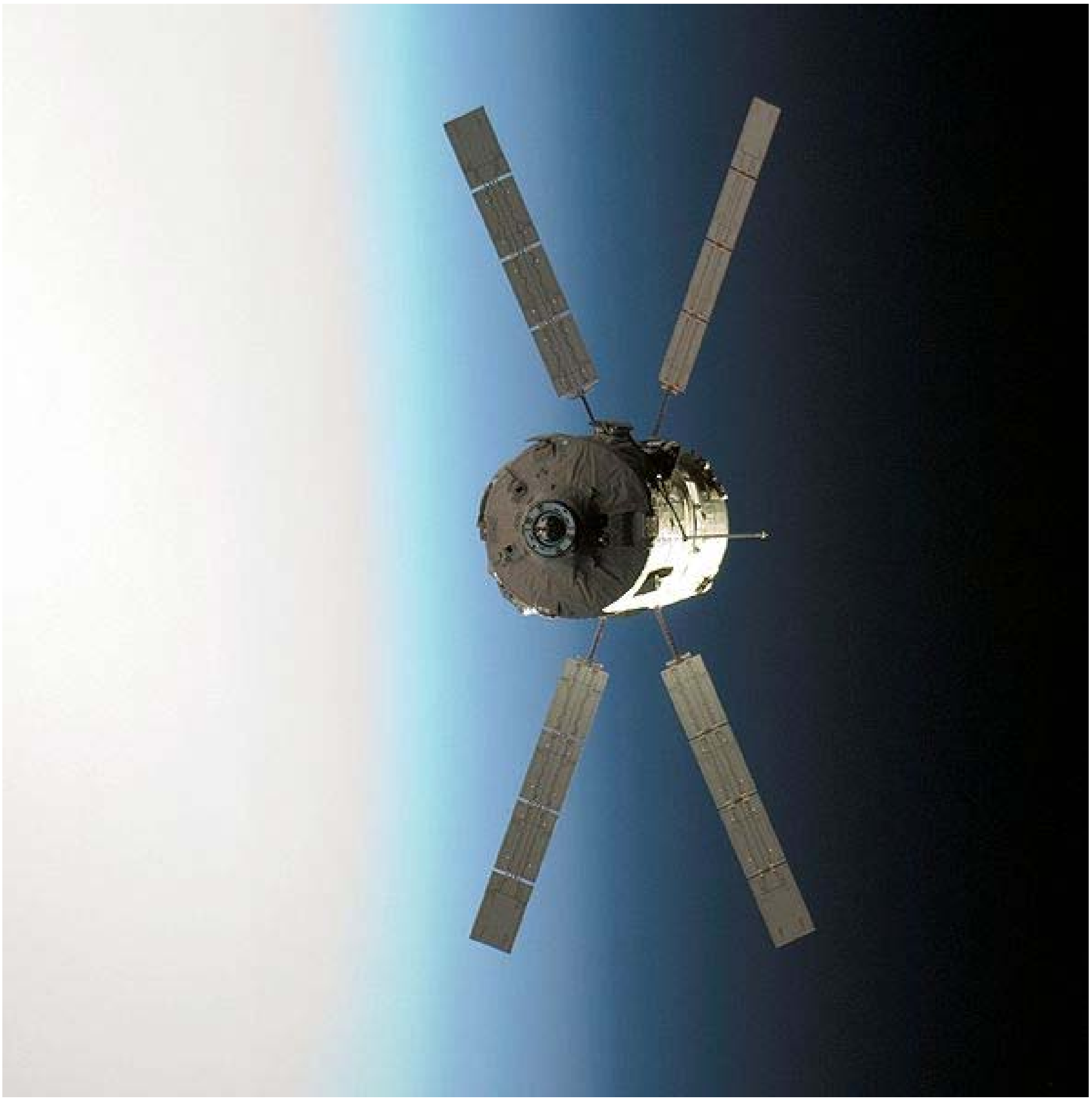
- Manned Maneuvering Unit – world's smallest manned spacecraft

Suborbital

- X-15 suborbital
- SpaceShipOne (commercial) suborbital
- SpaceShipTwo (commercial) suborbital

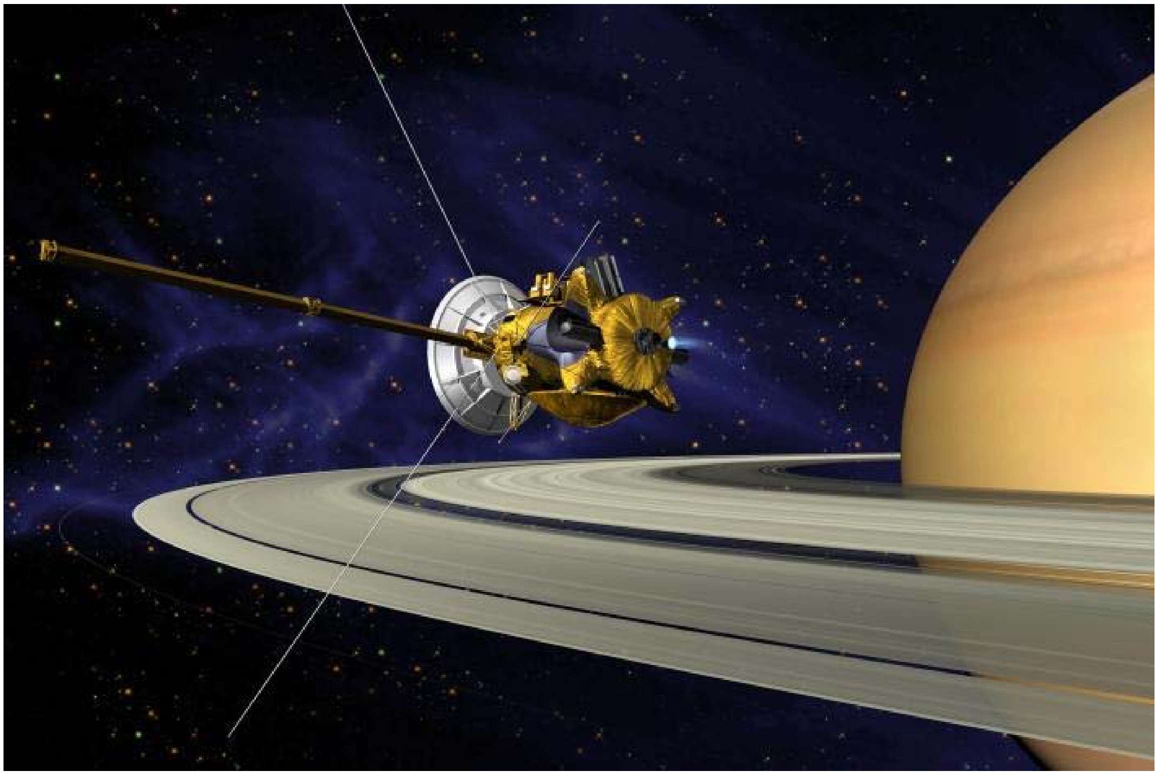
Unmanned spacecraft

The Hubble Space Telescope



The Jules Verne Automated Transfer Vehicle (ATV) approaches the International Space Station on Monday, March 31, 2008.

Soft landing capsule (NASA)



Artist's conception of Cassini-Huygens as it enters Saturn's orbit

Semi-manned or manned-spec unmanned spacecraft

- Automated Transfer Vehicle (ATV) – unmanned European cargo spacecraft
- Buran manned-spec Soviet shuttle (one mission only)
- H-II Transfer Vehicle (HTV) – unmanned Japanese cargo spacecraft
- Progress – unmanned USSR/Russia cargo spacecraft
- TKS – manned-spec unmanned USSR cargo spacecraft

Earth Orbit

- Explorer 1 – first US satellite
- Project SCORE – first communications satellite
- SOHO
- Sputnik 1 – world's first artificial satellite
- Sputnik 2 – first animal in orbit (Laika)
- Sputnik 5 – first capsule recovered from orbit (Vostok precursor) – animals survived
- STEREO – Earth environment observation
- Syncom – first geosynchronous communications satellite
- X-37 – spaceplane
- There are more than over 2,000 spacecrafts in orbit.

Lunar

- Clementine – US Navy mission, orbited Moon, detected hydrogen at the poles
- Kaguya JPN – Lunar orbiter
- Luna 1 – first lunar flyby
- Luna 2 – first lunar impact
- Luna 3 – first images of lunar far side
- Luna 9 – first soft landing on the Moon
- Luna 10 – first lunar orbiter
- Luna 16 – first unmanned lunar sample retrieval
- Lunar Orbiter – very successful series of lunar mapping spacecraft
- Lunar Prospector – confirmed detection of hydrogen at the lunar poles
- Lunar Reconnaissance Orbiter – Identifies safe landing sites & Locates moon resources
- SMART-1 ESA – Lunar Impact
- Surveyor – first USA soft lander
- Chandrayaan 1 – first Indian Lunar mission

Artist's conception of the Phoenix spacecraft as it lands on Mars

Planetary

- Akatsuki JPN – a Venus orbiter
- Cassini-Huygens – first Saturn orbiter + Titan lander
- Galileo – first Jupiter orbiter+descent probe
- IKAROS JPN – first solar-sail spacecraft
- Mariner 4 – first Mars flyby, first close and high resulution images of Mars
- Mariner 9 – first Mars orbiter
- Mariner 10 – first Mercury flyby, first close up images
- Mars Exploration Rover – a Mars rover
- Mars Express – a Mars orbiter
- Mars Global Surveyor – a Mars orbiter
- Mars Reconnaissance Orbiter – an advanced climate, imaging, sub-surface radar, and telecommunications Mars orbiter
- MESSENGER – first Mercury orbiter (arrival 2011)
- Mars Pathfinder – a Mars lander + rover
- New Horizons – first Pluto flyby (arrival 2015)
- Pioneer 10 – first Jupiter flyby, first close up images
- Pioneer 11 – second Jupiter flyby + first Saturn flyby (first close up images of Saturn)
- Pioneer Venus – first Venus orbiter+landers
- Venera 4 – first soft landing on another planet (Venus)
- Viking 1 – first soft landing on Mars
- Voyager 2 – Jupiter flyby + Saturn flyby + first flybys/images of Neptune and Uranus

Other – deep space

- Cluster
- Deep Space 1
- Deep Impact
- Genesis
- Hayabusa
- Near Earth Asteroid Rendezvous
- Stardust
- WMAP

Fastest spacecraft

- Helios I & II *Solar Probes* (252,792 km/h/157,078 mph)

Furthest spacecraft from the Sun

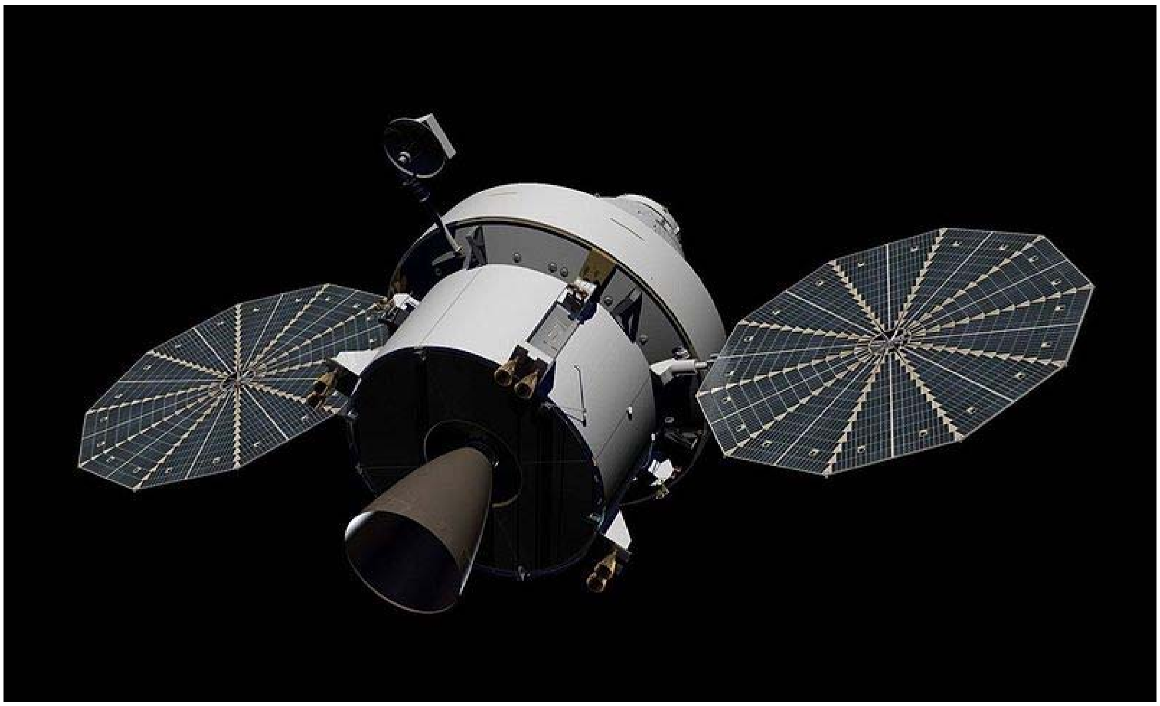
- Voyager 1 at 106.3 AU as of July 2008, traveling outward at about 3.6 AU/year
- Pioneer 10 at 89.7 AU as of 2005, traveling outward at about 2.6 AU/year

- Voyager 2 at 85.49 AU as of July 2008, traveling outward at about 3.3 AU/year

Heaviest spacecraft

- NASA *STS* Space Shuttle/Orbiter (109,000 kilograms / 107 long tons; 120 short tons)

Programs under development



The Orion spacecraft

Manned

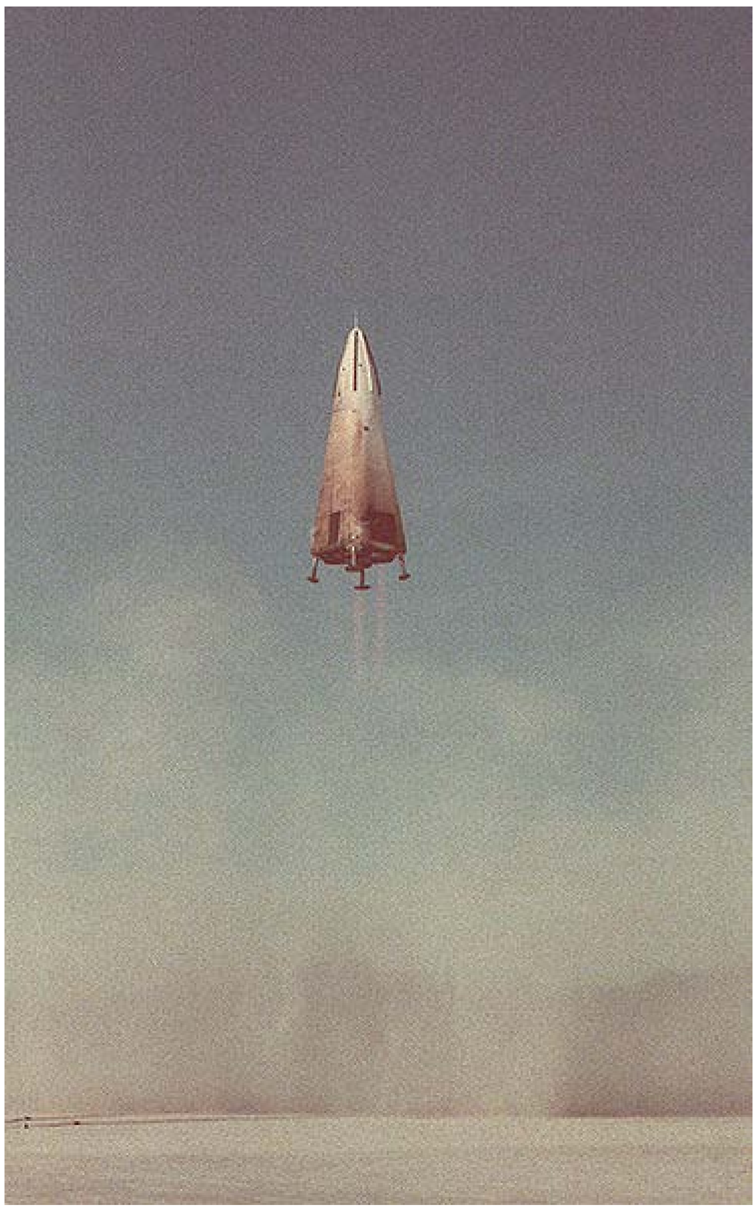
- Orion - capsule
- SpaceX Dragon - capsule
- Lynx rocketplane - suborbital
- ISRO Orbital Vehicle - capsule
- PTK NP spacecraft- capsule
- Dream Chaser - spaceplane
- Boeing CST-100 - capsule
- ESA Advanced Reentry Vehicle - capsule
- Skylon - single-stage-to-orbit spaceplane

Unmanned

- SpaceX Dragon - cargo delivery to the ISS

- Orbital Sciences Cygnus - cargo delivery to the ISS
- CNES Mars Netlander
- James Webb Space Telescope (delayed)
- ESA Darwin probe
- Mars Science Laboratory rover
- Shenzhou spacecraft Cargo
- Terrestrial Planet Finder probe
- System F6—a DARPA Fractionated Spacecraft demonstrator

Unfunded / canceled programs



The First Test Flight of the Delta Clipper-Experimental Advanced (DC-XA)

Multi-stage

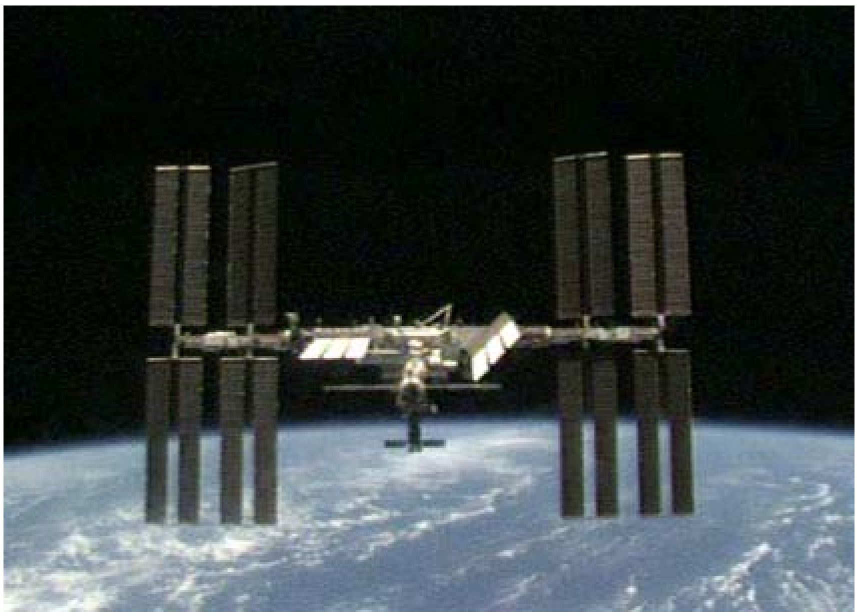
- Chinese Project 921-3 Shuttle
- Kliper—Russian "Clipper"
- ESA Hermes Shuttle
- Soviet Buran Shuttle
- Soyuz Kontakt
- Teledesic
- Manned Orbiting Laboratory
- X-20
- Altair - lunar lander

SSTO

- RR/British Aerospace HOTOL
- ESA Hopper Orbiter
- McDonnell Douglas DC-X (Delta Clipper)
- Roton Rotored-Hybrid
- Lockheed-Martin VentureStar

Chapter- 3

Spaceflight



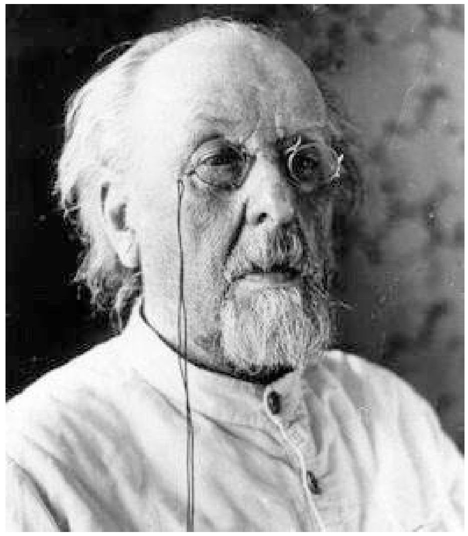
The International Space Station in earth orbit after a visit from the crew of STS-119

Spaceflight (also written **space flight**) is the act of travelling into or through outer space. Spaceflight can occur with spacecraft which may, or may not, have humans on board. Examples of human spaceflight include the Russian Soyuz program, the U.S. Space shuttle program, as well as the ongoing International Space Station. Examples of unmanned spaceflight include space probes which leave Earth's orbit, as well as satellites in orbit around Earth, such as communication satellites.

Spaceflight is used in space exploration, and also in commercial activities like space tourism and satellite telecommunications. Additional non-commercial uses of spaceflight include space observatories, reconnaissance satellites and other earth observation satellites.

A spaceflight typically begins with a rocket launch, which provides the initial thrust to overcome the force of gravity and propels the spacecraft from the surface of the Earth. Once in space, the motion of a spacecraft—both when unpropelled and when under propulsion—is covered by the area of study called astrodynamics. Some spacecraft remain in space indefinitely, some disintegrate during atmospheric reentry, and others reach a planetary or lunar surface for landing or impact.

History



Tsiolkovsky, "the father of human space flight"

The realistic proposal of space travel goes back to Konstantin Tsiolkovsky. His most famous work, "Исследование мировых пространств реактивными приборами" (*The Exploration of Cosmic Space by Means of Reaction Devices*), was published in 1903, but this theoretical work was not widely influential outside of Russia.

Spaceflight became an engineering possibility with the work of Robert H. Goddard's publication in 1919 of his paper 'A Method of Reaching Extreme Altitudes'; where his application of the de Laval nozzle to liquid fuel rockets gave sufficient power that interplanetary travel became possible. He also proved in the laboratory that rockets would work in the vacuum of space; not all scientists of that day believed they would. This paper was highly influential on Hermann Oberth and Wernher Von Braun, later key players in spaceflight.

The first rocket to reach 100 km was the German V-2 Rocket, on a test flight in June, 1944. On October 4, 1957, the Soviet Union launched Sputnik 1, which became the first artificial satellite to orbit the Earth. The first human spaceflight was Vostok 1 on April 12, 1961, aboard which Soviet cosmonaut Yuri Gagarin made one orbit around the Earth. The lead architects behind the Soviet space program's Vostok 1 mission were the rocket scientists Sergey Korolyov and Kerim Kerimov.

Rockets remain the only currently practical means of reaching space. Other non-rocket spacelaunch technologies such as scramjets still fall far short of orbital speed.

Phases of spaceflight

Spaceports

Saturn V on the launch pad before the launch of Apollo 4

A spaceflight usually starts from a spaceport (cosmodrome), which may be equipped with launch complexes and launch pads for vertical rocket launches, and runways for takeoff and landing of carrier airplanes and winged spacecraft. Spaceports are situated well away from human habitation for noise and safety reasons.

A launch is often restricted to certain launch windows. These windows depend upon the position of celestial bodies and orbits relative to the launch site. The biggest influence is often the rotation of the Earth itself. Once launched, orbits are normally located within relatively constant flat planes at a fixed angle to the axis of the Earth, and the Earth rotates within this orbit.

Reaching space

Proton Rocket heading for space

The most commonly used definition of outer space is everything beyond the Kármán line, which is 100 kilometers (62 mi) above the Earth's surface. (The United States sometimes defines outer space as everything beyond 50 miles (80 km) in altitude.)

In order for a projectile to reach outer space from the surface, it needs a minimum delta-v. This velocity is much lower than escape velocity.

For manned launch systems launch escape systems are frequently fitted to allow astronauts to escape in the case of catastrophic failures.

Launch pads, takeoff

A launch pad is a fixed structure designed to dispatch airborne vehicles. It generally consists of a launch tower and flame trench. It is surrounded by equipment used to erect, fuel, and maintain launch vehicles.

Other ways of reaching space

Many ways other than rockets to reach space have been proposed. Ideas such as the Space Elevator, while elegant, are currently infeasible, whereas electromagnetic launchers such as launch loops have no known show stoppers. Other ideas include rocket assisted jet planes such as Reaction Engines Skylon or the trickier scramjets. Gun launch has been proposed for cargo.

Leaving orbit

Achieving a closed orbit is not essential to lunar and interplanetary voyages, for which spacecraft need to exceed Earth escape velocity (or to closely approach it for lunar flights). Early Russian space vehicles successfully achieved very high altitudes without going into orbit. NASA considered launching Apollo missions directly into lunar trajectories but adopted the strategy of first entering a temporary parking orbit and then performing a separate burn several orbits later onto a lunar trajectory. This costs additional propellant because the parking orbit perigee must be high enough to prevent reentry while direct injection can have an arbitrarily low perigee because it will never be reached.

However, the parking orbit approach greatly simplified Apollo mission planning in several important ways. It substantially widened the allowable launch windows, increasing the chance of a successful launch despite minor technical problems during the countdown. The parking orbit was a stable "mission plateau" that gave the crew and controllers several hours to thoroughly check out the spacecraft after the stresses of launch before committing it to a long lunar flight; the crew could quickly return to earth, if necessary, or an alternate earth-orbital mission could be conducted. The parking orbit also enabled translunar trajectories that avoided the densest parts of the Van Allen radiation belts.

Apollo missions minimized the performance penalty of the parking orbit by keeping its altitude as low as possible. For example, Apollo 15 used an unusually low parking orbit (even for Apollo) of 92.5 by 91.5 nautical miles (171x169 km) where there was significant atmospheric drag. But it was partially overcome by continuous venting of hydrogen from the third stage of the Saturn V, and was in any event tolerable for the short stay.

Robotic missions do not require an abort capability or radiation minimization, and because modern launchers routinely meet "instantaneous" launch windows, space probes to the moon and other planets generally use direct injection to maximize performance. Although some might coast briefly during the launch sequence, they do not complete one or more full parking orbits before the burn that injects them onto an earth escape trajectory.

Note that the escape velocity from a celestial body decreases with altitude above that body. However, it is more fuel-efficient for a craft to burn its fuel as close to the ground as possible. This is another way to explain the performance penalty associated with establishing the safe perigee of a parking orbit.

Plans for future crewed interplantary spaceflight missions often include final vehicle assembly in Earth orbit, such as NASA's Project Orion and Russia's Kliper/Parom tandem.

Astrodynamics

Astrodynamics is the study of spacecraft trajectories, particularly as they relate to gravitational and propulsion effects. Astrodynamics allows for a spacecraft to arrive at its destination at the correct time without excessive propellant use.

Reentry

Vehicles in orbit have large amounts of kinetic energy. This energy must be discarded if the vehicle is to land safely without vaporizing in the atmosphere. Typically this process requires special methods to protect against aerodynamic heating. The theory behind reentry is due to Harry Julian Allen. Based on this theory, reentry vehicles present blunt shapes to the atmosphere for reentry. Blunt shapes mean that less than 1% of the kinetic energy ends up as heat that reaches the vehicle and the heat energy instead ends up in the atmosphere.

Landing

Recovery of Discoverer 14 return capsule

The Mercury, Gemini, and Apollo capsules all landed in the sea. These capsules were designed to land at relatively slow speeds. Russian capsules for Soyuz make use of braking rockets as were designed to touch down on land. The Space Shuttle glides into a touchdown at high speed.

Recovery

After a successful landing the spacecraft, its occupants and cargo can be recovered. In some cases, recovery has occurred before landing: while a spacecraft is still descending on its parachute, it can be snagged by a specially designed aircraft. This mid-air retrieval technique was used to recover the film canisters from the Corona spy satellites.

Types of spaceflight

Human spaceflight

The first human spaceflight was Vostok 1 on April 12, 1961, on which cosmonaut Yuri Gagarin of the USSR made one orbit around the Earth. In official Soviet documents, there is no mention of the fact that Gagarin parachuted the final seven miles. The international rules for aviation records stated that "The pilot remains in his craft from launch to landing". This rule, if applied, would have "disqualified" Gagarins space-flight. Currently the only spacecraft regularly used for human spaceflight are Russian Soyuz spacecraft and the U.S. Space Shuttle fleet. Each of those space programs have used other spacecraft in the past. Recently, the Chinese Shenzhou spacecraft has been used three times for human spaceflight, and SpaceshipOne twice.

Sub-orbital spaceflight

On a sub-orbital spaceflight the spacecraft reaches space and then returns to the atmosphere after following a (primarily) ballistic trajectory. This is usually because of insufficient specific orbital energy, in which case a suborbital flight will last only a few minutes, but it is also possible for an object with enough energy for an orbit to have a trajectory that intersects the Earth's atmosphere, sometimes after many hours. Pioneer 1 was NASA's first space probe intended to reach the Moon. A partial failure caused it to instead follow a suborbital trajectory to an altitude of 113,854 kilometers (70,746 mi) before reentering the Earth's atmosphere 43 hours after launch.

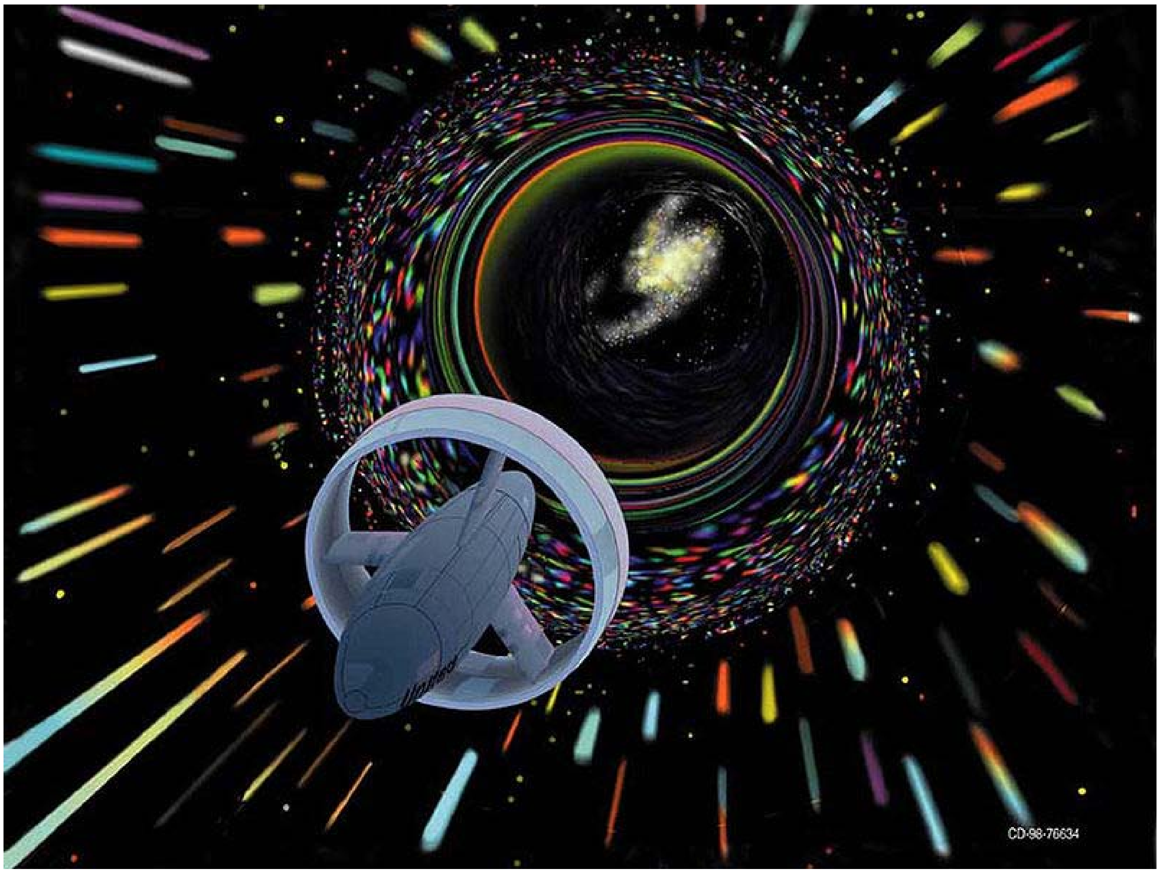
The most generally recognized boundary of space is the Kármán line (actually a sphere) 100 km above sea level. (NASA alternatively defines an astronaut as someone who has flown more than 50 miles or 80 km above sea level.) It is not generally recognized by the public that the increase in potential energy required to pass the Kármán line is only about 3% of the orbital energy (potential plus kinetic energy) required by the lowest possible earth orbit (a circular orbit just above the Kármán line.) In other words, it is far easier to reach space than to stay there.

On May 17, 2004, Civilian Space eXploration Team launched the GoFast Rocket on a suborbital flight, the first amateur spaceflight. On June 21, 2004, SpaceShipOne was used for the first privately-funded human spaceflight.

Orbital spaceflight

A minimal orbital spaceflight requires much higher velocities than a minimal sub-orbital flight, and so it is technologically much more challenging to achieve. To achieve orbital spaceflight, the tangential velocity around the Earth is as important as altitude. In order to perform a stable and lasting flight in space, the spacecraft must reach the minimal orbital speed required for a closed orbit.

Interplanetary spaceflight



An artist's imaginative impression of a vehicle entering a wormhole for interstellar travel

Interplanetary travel is travel between planets within a single planetary system. In practice, the use of the term is confined to travel between the planets of the Solar System.

Interstellar spaceflight

Five spacecraft are currently leaving the Solar System on escape trajectories. The one farthest from the Sun is Voyager 1, which is more than 100 AU distant and is moving at 3.6 AU per year. In comparison Proxima Centauri, the closest star other than the Sun, is 267,000 AU distant. It will take Voyager 1 over 74,000 years to reach this distance.

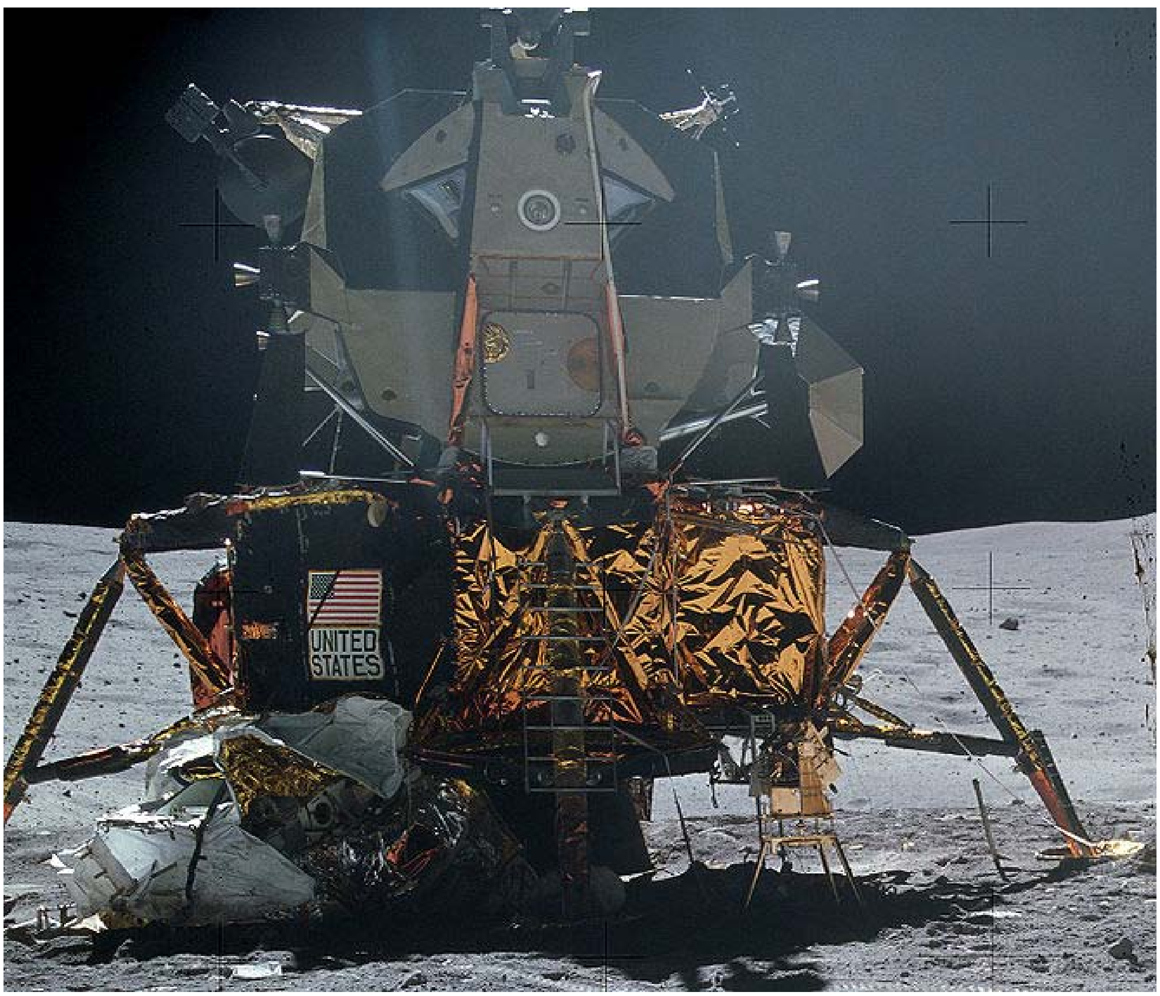
Vehicle designs using other techniques, such as nuclear pulse propulsion are likely to be able to reach the nearest star significantly faster.

Another possibility that could allow for human interstellar spaceflight is to make use of time dilation, as this would make it possible for passengers in a fast-moving vehicle to travel further into the future while aging very little, in that their great speed slows down the rate of passage of on-board time. However, attaining such high speeds would still require the use of some new, advanced method of propulsion.

Intergalactic spaceflight

Intergalactic travel involves spaceflight between galaxies, and is considered much more technologically demanding than even interstellar travel and, by current engineering terms, is considered science fiction.

Spacecraft and launch systems



The Apollo Lunar Module on the lunar surface

Spacecraft are vehicles capable of controlling their trajectory through space.

The first 'true spacecraft' is sometimes said to be Apollo Lunar Module, since this was the only manned vehicle to have been designed for, and operated only in space; and is notable for its non aerodynamic shape.

Spacecraft propulsion

Spacecraft today predominantly use rockets for propulsion, but other propulsion techniques such as ion drives are becoming more common, particularly for unmanned vehicles, and this can significantly reduce the vehicle's mass and increase its delta-v.

Expendable launch systems

All current spaceflight except NASA's Space Shuttle and the SpaceX Falcon 1 use multi-stage expendable launch systems to reach space.

Reusable launch systems

The *Space Shuttle Columbia* seconds after engine ignition on mission STS-1

The first reusable spacecraft, the X-15, was air-launched on a suborbital trajectory on July 19, 1963. The first partially reusable orbital spacecraft, the Space Shuttle, was launched by the USA on the 20th anniversary of Yuri Gagarin's flight, on April 12, 1981. During the Shuttle era, six orbiters were built, all of which have flown in the atmosphere and five of which have flown in space. The *Enterprise* was used only for approach and landing tests, launching from the back of a Boeing 747 and gliding to deadstick landings at Edwards AFB, California. The first Space Shuttle to fly into space was the *Columbia*, followed by the *Challenger*, *Discovery*, *Atlantis*, and *Endeavour*. The *Endeavour* was built to replace the *Challenger*, which was lost in January 1986. The *Columbia* broke up during reentry in February 2003.

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Challenges associated with spaceflight

Space disasters

All launch vehicles contain a huge amount of energy that is needed for some part of it to reach orbit. There is therefore some risk that this energy can be released prematurely and suddenly, with significant effects. When a Delta II rocket exploded 13 seconds after launch on January 17, 1997, there were reports of store windows 10 miles (16 km) away being broken by the blast.

Space is a fairly predictable environment, but there are still risks of accidental depressurisation and the potential failure of equipment, some of which may be very newly developed.

In 2004 the International Association for the Advancement of Space Safety was established in the Netherlands to further international cooperation and scientific advancement in space systems safety.

Weightlessness

Astronauts on the ISS in weightless conditions. Michael Foale can be seen exercising in the foreground.

In a microgravity environment such as that provided by a spacecraft in orbit around the Earth, humans experience a sense of "weightlessness." Short-term exposure to microgravity causes space adaptation syndrome, a self-limiting nausea caused by derangement of the vestibular system. Long-term exposure causes multiple health issues. The most significant is bone loss, some of which is permanent, but microgravity also leads to significant deconditioning of muscular and cardiovascular tissues.

Radiation

Once above the atmosphere, radiation due to the Van Allen belts, solar radiation and cosmic radiation issues occur and increase.

Further away from the Earth, solar flares can give a fatal radiation dose in minutes, and cosmic radiation would significantly increase the chances of cancer over a decade exposure or more.

Life support

In human spaceflight, the **life support system** is a group of devices that allow a human being to survive in outer space. NASA often uses the phrase **Environmental Control and Life Support System** or the acronym **ECLSS** when describing these systems for its human spaceflight missions. The life support system may supply: air, water and food. It must also maintain the correct body temperature, an acceptable pressure on the body and deal with the body's waste products. Shielding against harmful external influences such as radiation and micro-meteorites may also be necessary. Components of the life support system are life-critical, and are designed and constructed using safety engineering techniques.

Space weather

Space weather is the concept of changing environmental conditions in outer space. It is distinct from the concept of weather within a planetary atmosphere, and deals with phenomena involving ambient plasma, magnetic fields, radiation and other matter in space (generally close to Earth but also in interplanetary, and occasionally interstellar medium). "Space weather describes the conditions in space that affect Earth and its technological systems. Our space weather is a consequence of the behavior of the sun, the nature of Earth's magnetic field, and our location in the solar system."

Space weather exerts a profound influence in several areas related to space exploration and development. Changing geomagnetic conditions can induce changes in atmospheric density causing the rapid degradation of spacecraft altitude in Low Earth orbit. Geomagnetic storms due to increased solar activity can potentially blind sensors aboard spacecraft, or interfere with on-board electronics. An understanding of space environmental conditions is also important in designing shielding and life support systems for manned spacecraft.

Environmental considerations

Rockets as a class are not inherently grossly polluting. However, some rockets use toxic propellants, and most vehicles use propellants that are not carbon neutral. Many solid rockets have chlorine in the form of perchlorate or other chemicals, and this can cause temporary local holes in the ozone layer. Re-entering spacecraft generate nitrates which also can temporarily impact the ozone layer. Most rockets are made of metals that can have an environmental impact during their construction.

In addition to the atmospheric effects there are effects on the near-Earth space environment. There is the possibility that orbit could become inaccessible for generations due to exponentially increasing space debris caused by spalling of satellites and vehicles (Kessler syndrome). Many launched vehicles today are therefore designed to be re-entered after use.

Applications of spaceflight

Current spaceflights are frequently, but not invariably paid for by governments; but there are strong launch markets such as satellite television that is purely commercial, although the launchers themselves are often at least partly funded by governments.

Uses for spaceflight include:

- Earth observation satellites such as Spy satellites, weather satellites
- Space exploration
- Space tourism is a small market at present
- Communication satellites
- Satellite navigation

There is growing interest in spacecraft and flights paid for by commercial companies and even private individuals. It is thought that some of the high cost of access to space is due to governmental inefficiencies; and certainly the costs of the governmental paperwork surrounding NASA is legendary. If a commercial company were able to be more efficient, costs could come down significantly. Space launch vehicles such as Falcon I have been wholly developed with private finance, and the quoted costs for launch are lower.

Chapter- 4

Space Exploration

Saturn V rocket, used for the American manned lunar landing missions

Space exploration is the use of astronomy and space technology to explore outer space. Physical exploration of space is conducted both by human spaceflights and by robotic spacecraft. While the observation of objects in space, known as astronomy, predates reliable recorded history, it was the development of large and relatively efficient rockets during the early 20th century that allowed physical space exploration to become a reality. Common rationales for exploring space include advancing scientific research, uniting different nations, ensuring the future survival of humanity and developing military and strategic advantages against other countries. Various criticisms of space exploration are sometimes made.

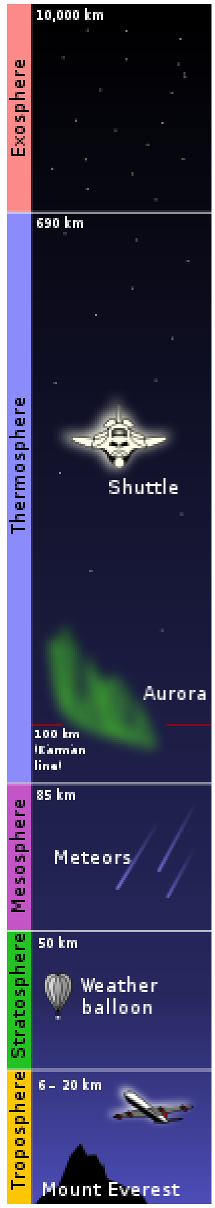
Space exploration has often been used as a proxy competition for geopolitical rivalries such as the Cold War. The early era of space exploration was driven by a "Space Race" between the Soviet Union and the United States; the launch of the first man-made object to orbit the Earth, the USSR's Sputnik 1, on October 4, 1957, and the first Moon landing by the American Apollo 11 craft on July 20, 1969 are often taken as the boundaries for this initial period. The Soviet space program achieved many of the first milestones, including the first living being in orbit in 1957, the first human spaceflight (Yuri Gagarin aboard Vostok 1) in 1961, the first spacewalk (by Aleksei Leonov) in 1965, the first automatic landing on another celestial body in 1966, and the launch of the first space station (Salyut 1) in 1971.

After the first 20 years of exploration, focus shifted from one-off flights to renewable hardware, such as the Space Shuttle program, and from competition to cooperation as with the International Space Station.

From the 1990s onwards, private interests began promoting space tourism and then private space exploration of the Moon.

In the 2000s, the People's Republic of China initiated a successful manned spaceflight program, while the European Union, Japan, and India have also planned future manned space missions. The United States has committed to return to the Moon by 2018 and later Mars. China, Russia, Japan, and India have advocated manned missions to the Moon during the 21st century, while the European Union has advocated manned missions to both the Moon and Mars during the 21st century.

History of exploration in the 20th Century

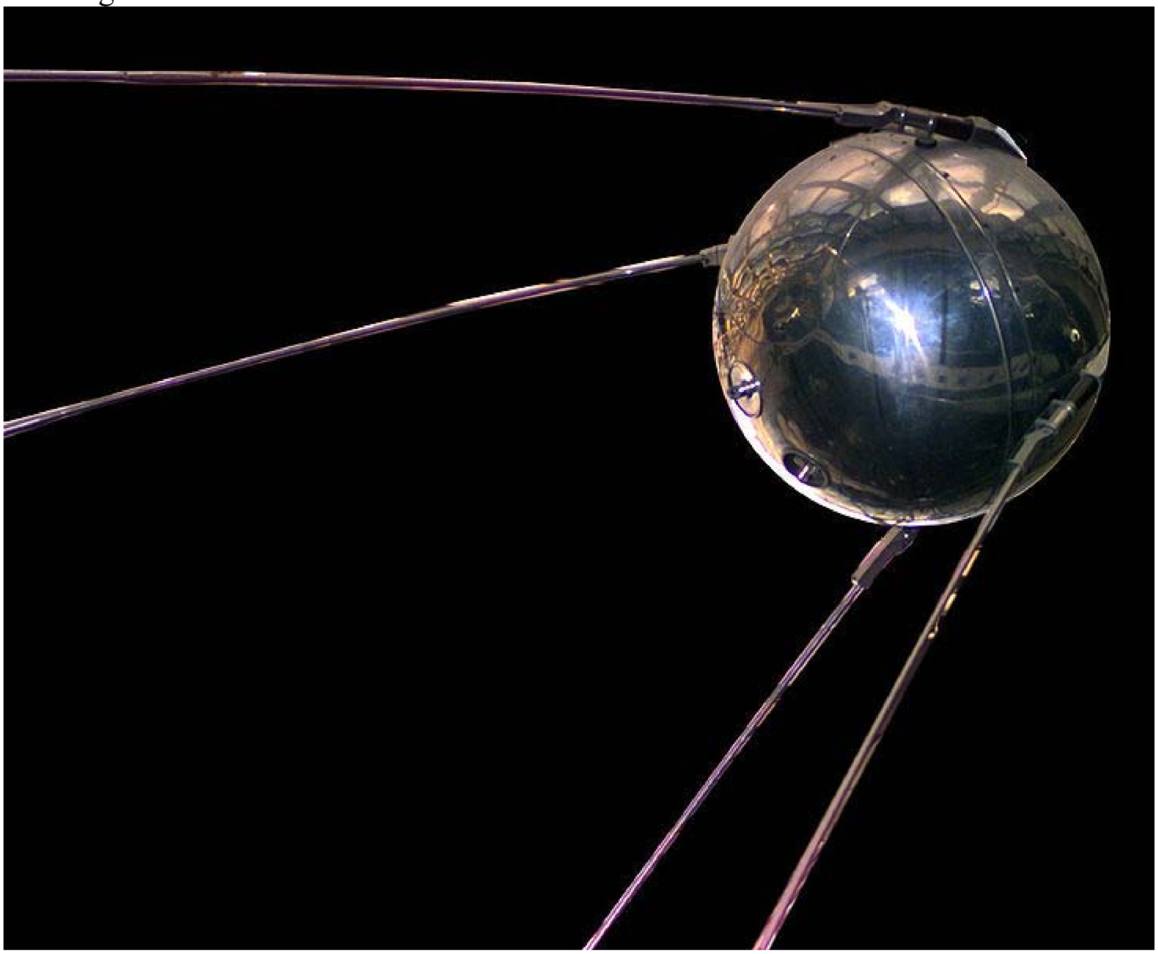


Most orbital flight actually takes place in upper layers of the atmosphere, especially in the thermosphere (not to scale)

In July 1950 the first bumper rocket is launched from Cape Canaveral, Florida. The Bumper was a two-stage rocket consisting of a Post-War V-2 topped by a WAC Corporal rocket. It could reach then-record altitudes of almost 400 km. Launched by General Electric Company, this Bumper was used primarily for testing rocket systems and for research on the upper atmosphere. They carried small payloads that allowed them to measure attributes including air temperature and cosmic ray impacts.

The first steps of putting a man-made object into space were taken by German scientists during World War II while testing the V2 rocket which became the first human-made object in space on October 3, 1942 with the launching of V-4. After the war, the Allies used German scientists and their captured rockets in programs for both military and civilian research. The first scientific exploration from space was the cosmic radiation experiment launched by the U.S. on a V2 rocket on May 10, 1946. The first images of Earth taken from space followed the same year while the first animal experiment saw fruit flies lifted into space in 1947, both also on modified V2s launched by Americans. Starting in 1947, the Soviets launched sub-orbital V2 rockets and their own variant, the R-1, including radiation and animal experiments on some flights. These suborbital experiments only allowed a very short time in space which limited their usefulness.

First flights



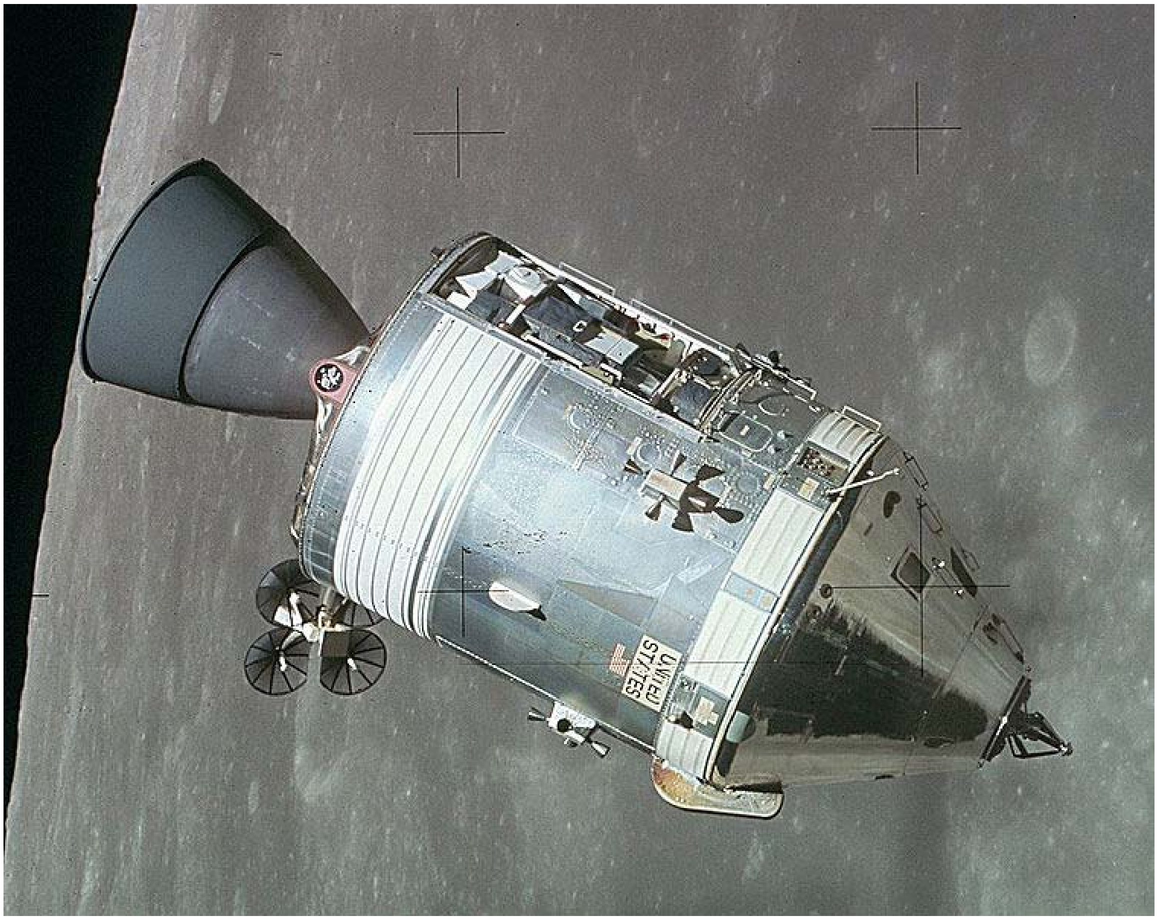
Sputnik 1, the first artificial satellite orbited earth at 939 km (583 mi) to 215 km (134 mi) in 1957, and was soon followed by Sputnik 2.

The first successful orbital launch was of the Soviet unmanned *Sputnik* ("Satellite I") mission on October 4, 1957. The satellite weighed about 83 kg (184 pounds), and is believed to have orbited Earth at a height of about 250 km (150 miles). It had two radio transmitters (20 and 40 MHz), which emitted "beeps" that could be heard by radios around the globe. Analysis of the radio signals was used to gather information about the electron density of the ionosphere, while temperature and pressure data was encoded in the duration of radio beeps. The results indicated that the satellite was not punctured by a meteoroid. Sputnik 1 was launched by an R-7 rocket. It burned up upon re-entry on January 3, 1958.

This success led to an escalation of the American space program, which unsuccessfully attempted to launch Vanguard 1 into orbit two months later. On January 31, 1958, the U.S. successfully orbited Explorer 1 on a Juno rocket. In the meantime, the Soviet dog Laika became the first animal in orbit on November 3, 1957.

First human flights

The first successful human spaceflight was *Vostok 1* ("East 1"), carrying 27 year old Russian cosmonaut Yuri Gagarin on April 12, 1961. The spacecraft completed one orbit around the globe, lasting about 1 hour and 48 minutes. Gagarin's flight resonated around the world; it was a demonstration of the advanced Soviet space program and it opened an entirely new era in space exploration: human spaceflight.



Apollo CSM in lunar orbit

The U.S. first launched a person into space within a month of Vostok 1 with Alan Shepard's suborbital flight in Mercury-Redstone 3. Orbital flight was achieved by the United States when John Glenn's Mercury-Atlas 6 orbited the Earth on February 20, 1962.

Valentina Tereshkova, the first woman in space, orbited the Earth 48 times aboard Vostok 6 on June 16, 1963.

China first launched a person into space 42 years after the launch of Vostok 1, on October 15, 2003, with the flight of Yang Liwei aboard the Shenzhou 5 (Spaceboat 5) spacecraft.

First planetary explorations

The first artificial object to reach another celestial body was Luna 2 in 1959. The first automatic landing on another celestial body was performed by Luna 9 in 1966. Luna 10 became the first artificial satellite of another celestial body.

The first manned landing on another celestial body was performed by Apollo 11 in its lunar landing on July 20, 1969.

The first successful interplanetary flyby was the 1962 Mariner 2 flyby of Venus (closest approach 34,773 kilometers). Flybys for the other planets were first achieved in 1965 for Mars by Mariner 4, 1973 for Jupiter by Pioneer 10, 1974 for Mercury by Mariner 10, 1979 for Saturn by Pioneer 11, 1986 for Uranus by Voyager 2, and 1989 for Neptune by Voyager 2.

The first interplanetary surface mission to return at least limited surface data from another planet was the 1970 landing of Venera 7 on Venus which returned data to earth for 23 minutes. In 1971 the Mars 3 mission achieved the first soft landing on Mars returning data for almost 20 seconds. Later much longer duration surface missions were achieved, including over 6 years of Mars surface operation by Viking 1 from 1975 to 1982 and over 2 hours of transmission from the surface of Venus by Venera 13 in 1982 (the longest ever Soviet planetary surface mission).

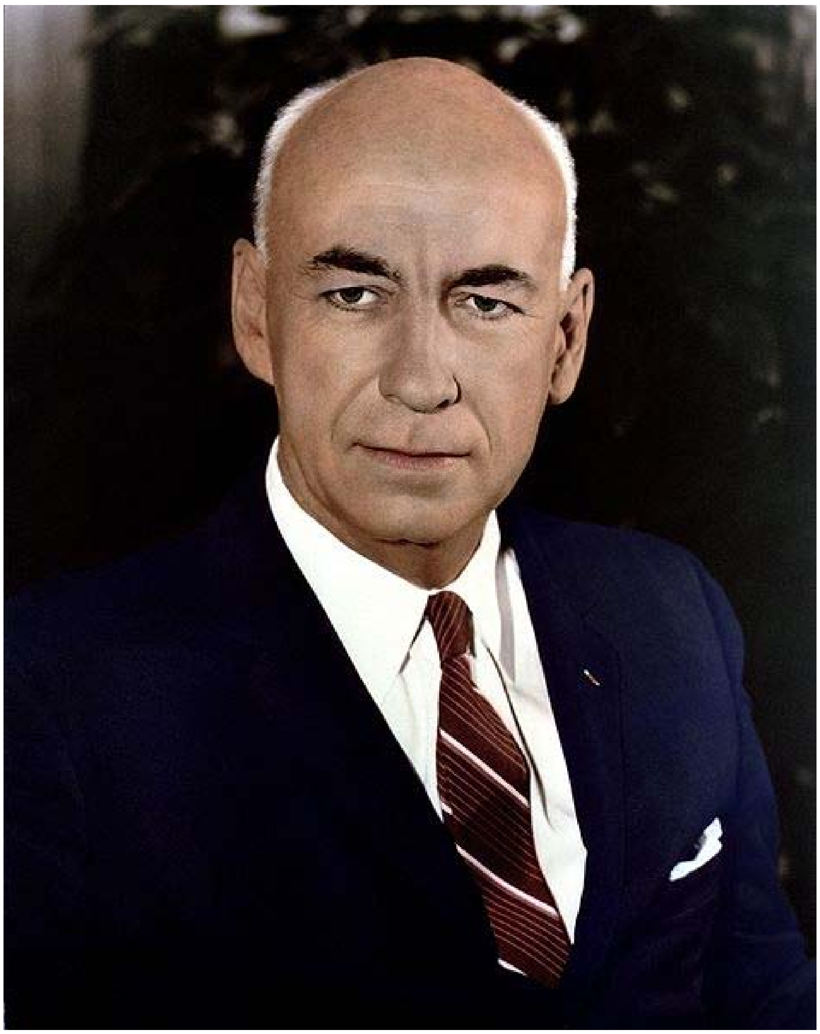
Key people in early space exploration

The dream of stepping into the outer reaches of the Earth's atmosphere was driven by rocket technology. The German V2 was the first rocket to travel into space, overcoming the problems of thrust and material failure. During the final days of World War II this technology was obtained by both the Americans and Soviets as were its designers. The initial driving force for further development of the technology was a weapons race for intercontinental ballistic missiles (ICBMs) to be used as long-range carriers for fast nuclear weapon delivery, but in 1961 when USSR launched the first man into space, the U.S. declared itself to be in a "Space Race" with Russia.

- **Konstantin Tsiolkovsky, Robert Goddard, Hermann Oberth**, and **Reinhold Tilling** laid the groundwork of rocketry in the early years of the 20th century.
- **Wernher von Braun** was the lead rocket engineer for Nazi Germany's World War II V-2 rocket project. In the last days of the war he led a caravan of workers in the German rocket program to the American lines, where they surrendered and were brought to the USA to work on U.S. rocket development. He acquired American citizenship and led the team that developed and launched Explorer 1, the first American satellite. Von Braun later led the team at NASA's Marshall Space Flight Center which developed the Saturn V moon rocket.
- Initially the race for space was often led by **Sergei Korolyov**, whose legacy includes both the R7 and Soyuz—which remain in service to this day. Korolev was the mastermind behind the first satellite, first man (and first woman) in orbit and first spacewalk. Until his death his identity was a closely guarded state secret;

not even his mother knew that he was responsible for creating the Russian space program.

- **Kerim Kerimov** was one of the founders of the Soviet space program and was one of the lead architects behind the first human spaceflight (Vostok 1) alongside Sergey Korolyov. After Korolyov's death in 1966, Kerimov became the lead scientist of the Soviet space program and was responsible for the launch of the first space stations from 1971 to 1991, including the Salyut and Mir series, and their precursors in 1967, the Cosmos 186 and Cosmos 188.



Robert Gilruth

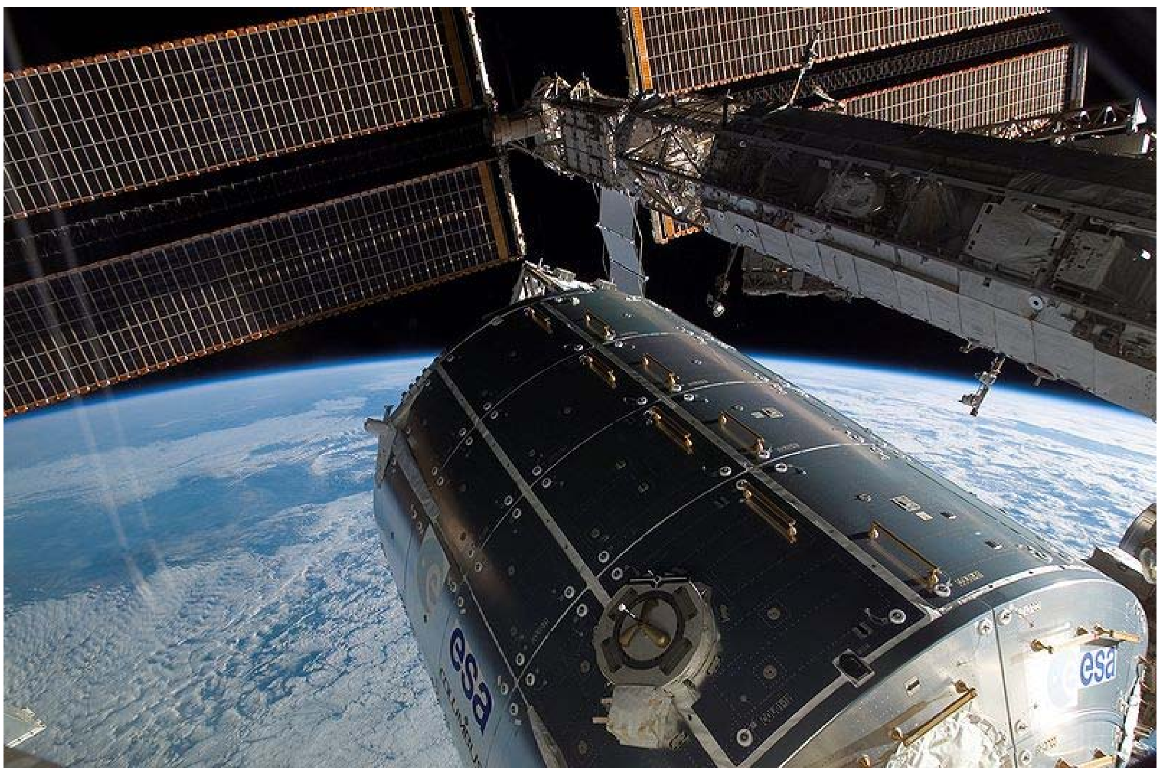
Other key people included:

- **Valentin Glushko** held the role of Chief Engine Designer for USSR. Glushko designed many of the engines used on the early Soviet rockets, but was constantly at odds with Korolyov.
- **Vasily Mishin** was Chief Designer working under Sergey Korolyov and one of first Soviets to inspect the captured German V2 design. Following the death of

Sergei Korolev, Mishin was held responsible for the Soviet failure to be first country to place a man on the moon.

- **Bob Gilruth** was the NASA head of the Space Task Force and director of 25 manned space flights. Gilruth was the person who suggested to John F. Kennedy that the Americans take the bold step of reaching the Moon in an attempt to reclaim space superiority from the Soviets.
- **Christopher C. Kraft, Jr.** was NASA's first flight director, who oversaw development of Mission Control and associated technologies and procedures.
- **Maxime Faget** was the designer of the Mercury capsule; he played a key role in designing the Gemini and Apollo spacecraft, and contributed to the design of the Space Shuttle.

Future of space exploration



The European Space Agency's Columbus Module at the International Space Station, launched into space on the U.S. Space Shuttle mission STS-122 in 2008

In the 2000s, several plans for space exploration have been announced; both government entities and the private sector have space exploration objectives.

Targets of exploration

Astrobiology

Astrobiology is the interdisciplinary study of life in the universe, combining aspects of astronomy, biology and geology. It is focused primarily on the study of the origin, distribution and evolution of life. It is also known as **exobiology** (from Greek: έξω, *exo*, "outside"). The term "Xenobiology" has been used as well, but this is technically incorrect because its terminology means "biology of the foreigners". Astrobiologists must also consider the possibility of life that is chemically entirely distinct from any life found on earth.

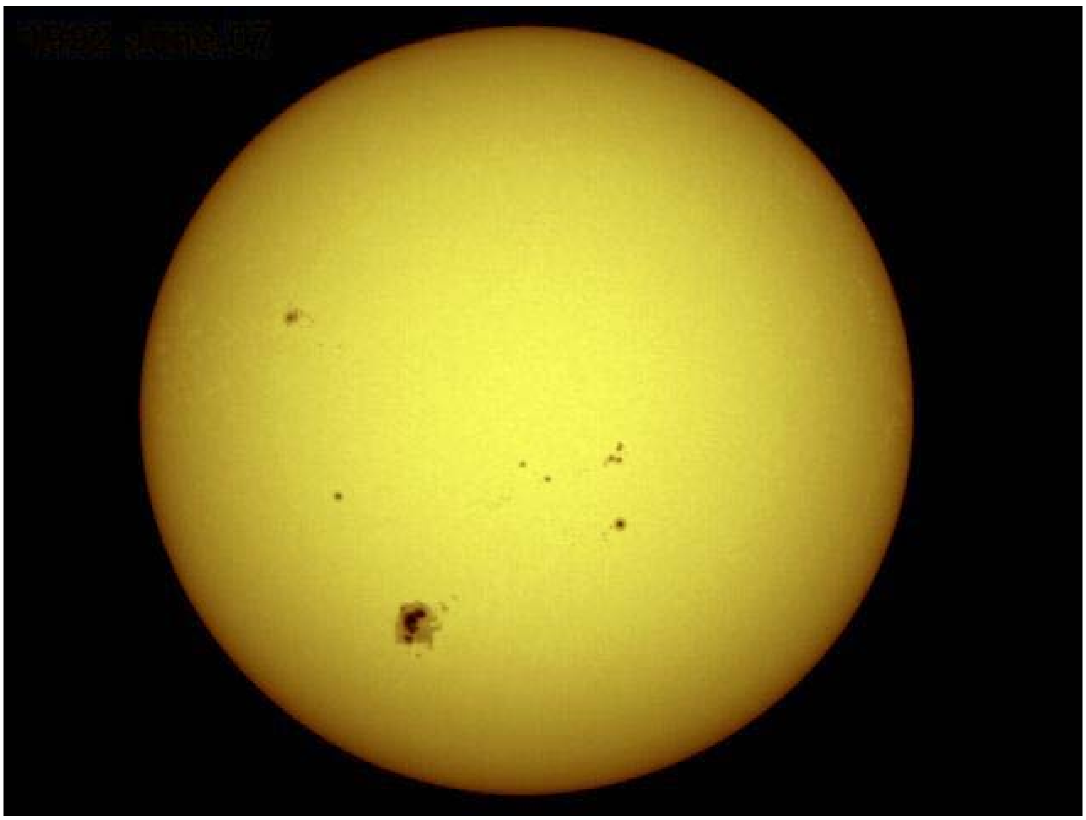
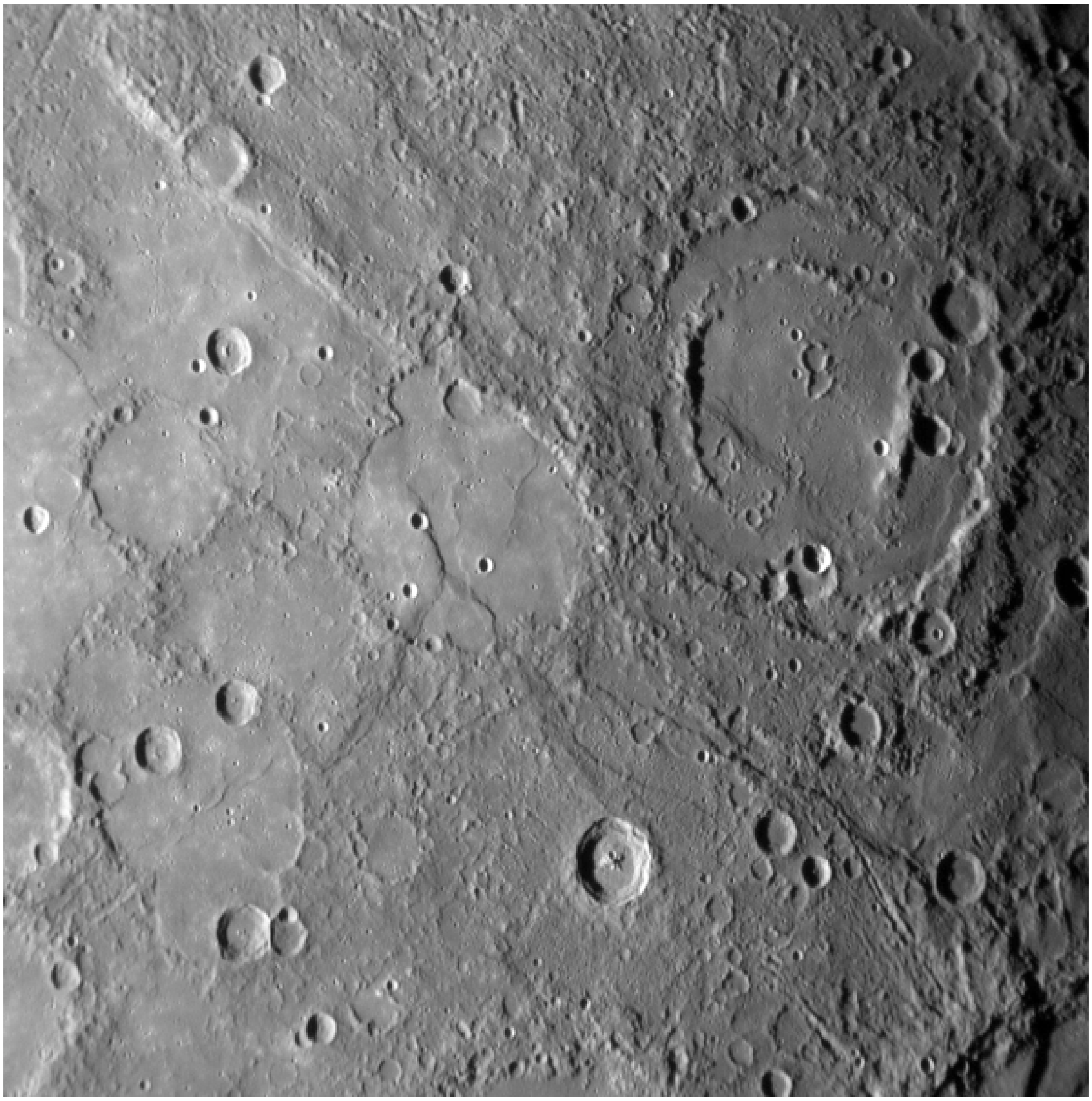


Image of the Sun from 7 June 1992 showing some sunspots

The Sun

While the Sun will probably not be physically explored in the close future, one of the reasons for going into space includes knowing more about the Sun. Once above the atmosphere in particular and the Earth's magnetic field, this gives access to the Solar wind and infrared and ultraviolet radiations that cannot reach the surface of the Earth. The Sun generates most space weather, which can affect power generation and transmission systems on Earth and interfere with, and even damage, satellites and space probes.

MESSENGER image of Mercury



A MESSENGER image from 18,000 km showing a region about 500 km across

Mercury

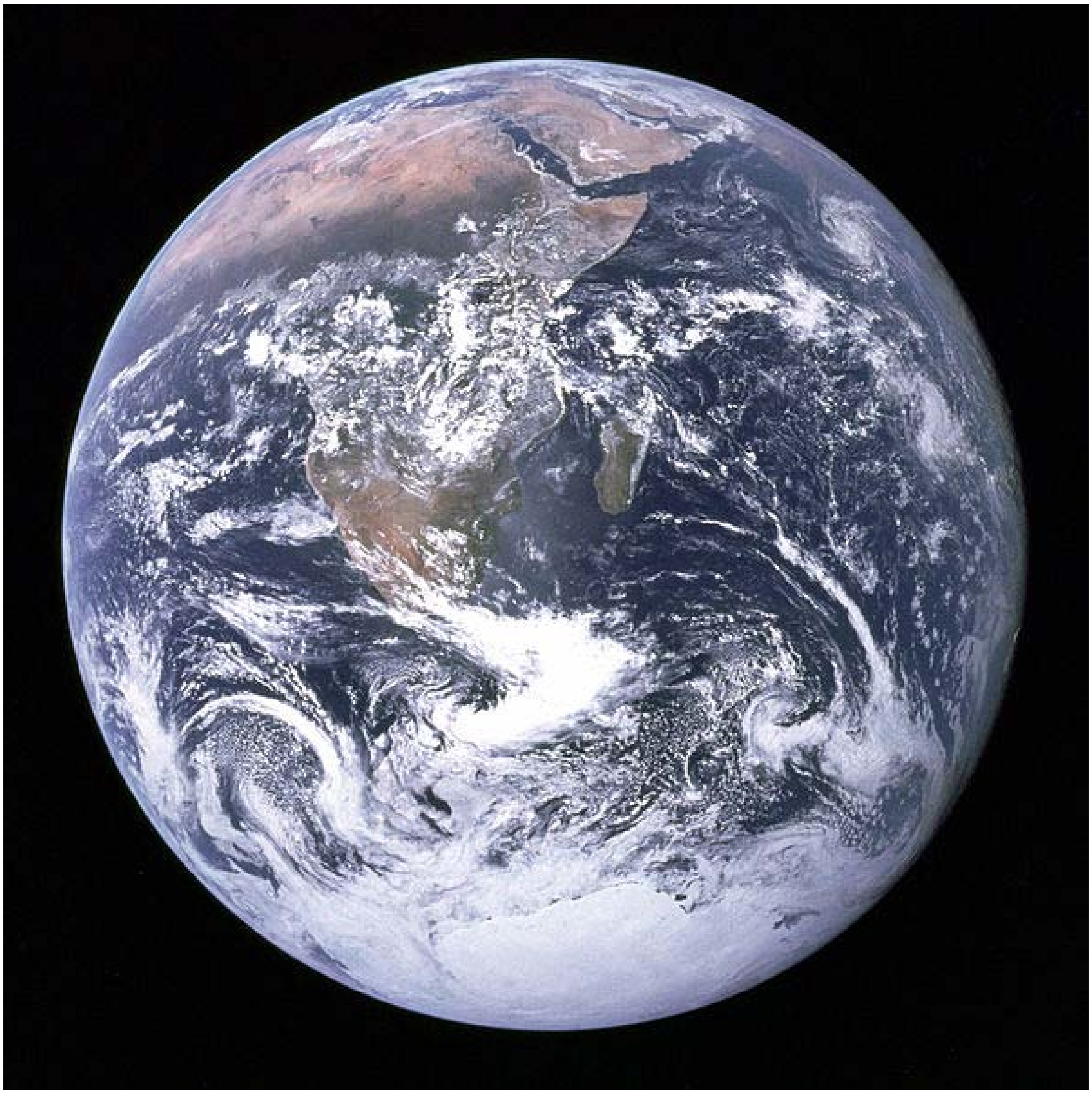
Mercury remains the least explored of the inner planets. As of January 2008, the Mariner 10 and MESSENGER missions have been the only missions that have made close observations of Mercury. MESSENGER made a fly-by of Mercury on 14 January 2008, to further investigate the observations made by Mariner 10 in 1975 (Munsell, 2006b). A third mission to Mercury, scheduled to arrive in 2020, BepiColombo is to include two probes. BepiColombo is a joint mission between Japan and the European Space Agency. MESSENGER and BepiColombo are intended to gather complementary data to help scientists understand many of the mysteries discovered by Mariner 10's flybys.

Flights to other planets within the Solar System are accomplished at a cost in energy, which is described by the net change in velocity of the spacecraft, or delta-v. Due to the relatively high delta-v to reach Mercury and its proximity to the Sun, it is difficult to explore and orbits around it are rather unstable.

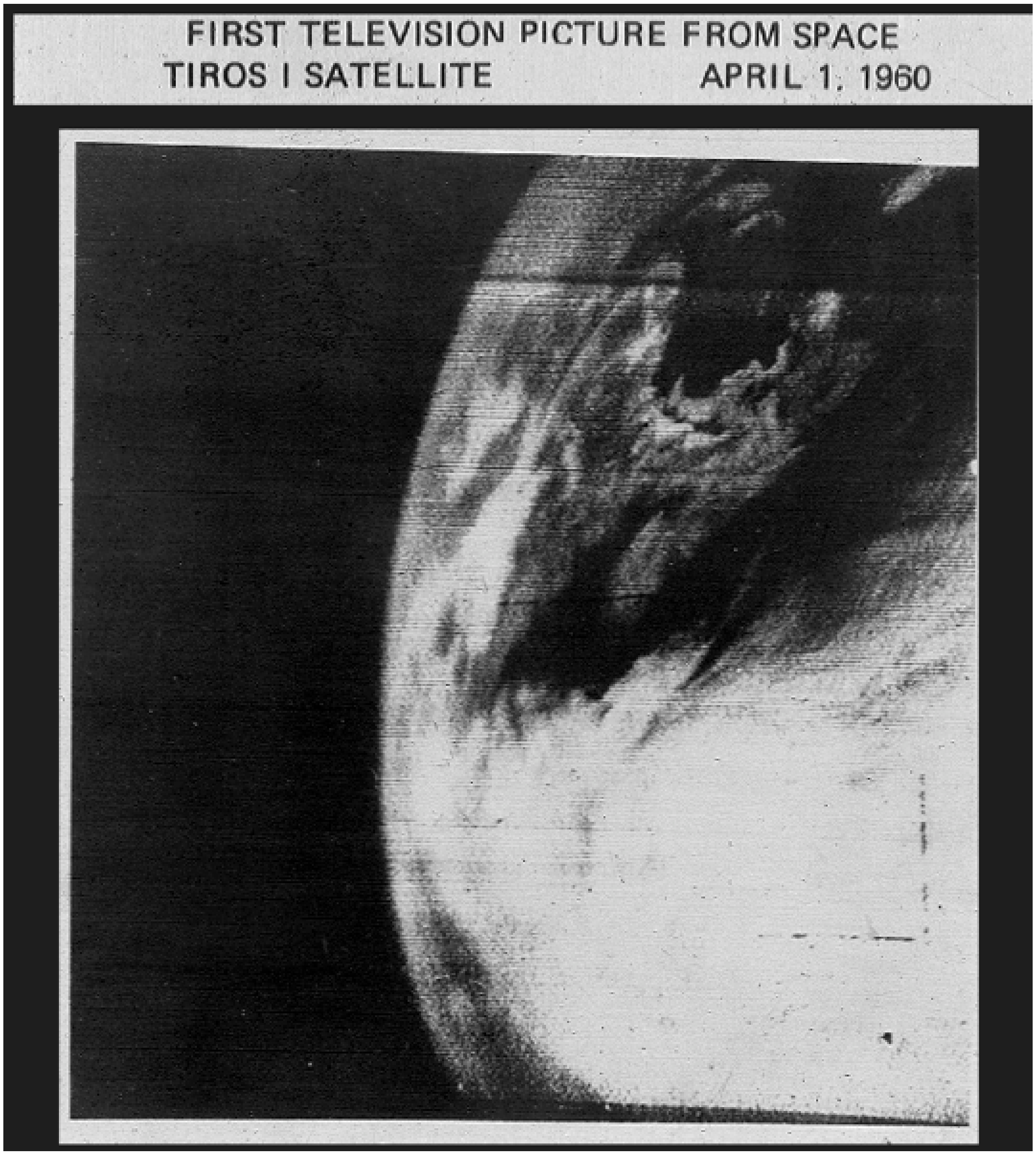
Mariner 10 image of Venus

Venus

Venus was the first target of interplanetary flyby and lander missions and, despite one of the most hostile surface environments in the solar system, has had more landers sent to it (nearly all from the Soviet Union) than any other planet in the solar system. The first successful Venus flyby was the American Mariner 2 spacecraft, which flew past Venus in 1962. Mariner 2 has been followed by several other flybys by multiple space agencies often as part of missions using a Venus flyby to provide a gravitational assist en route to other celestial bodies. In 1967 Venera 4 became the first probe to enter and directly examine the atmosphere of Venus. In 1970 Venera 7 became the first successful lander to reach the surface of Venus and by 1985 it had been followed by eight additional successful Soviet Venus landers which provided images and other direct surface data. Starting in 1975 with the Soviet orbiter Venera 9 some ten successful orbiter missions have been sent to Venus, including later missions which were able to map the surface of Venus using radar to pierce the obscuring atmosphere.



The "marble" Earth picture taken by Apollo 17



First television image of Earth from space

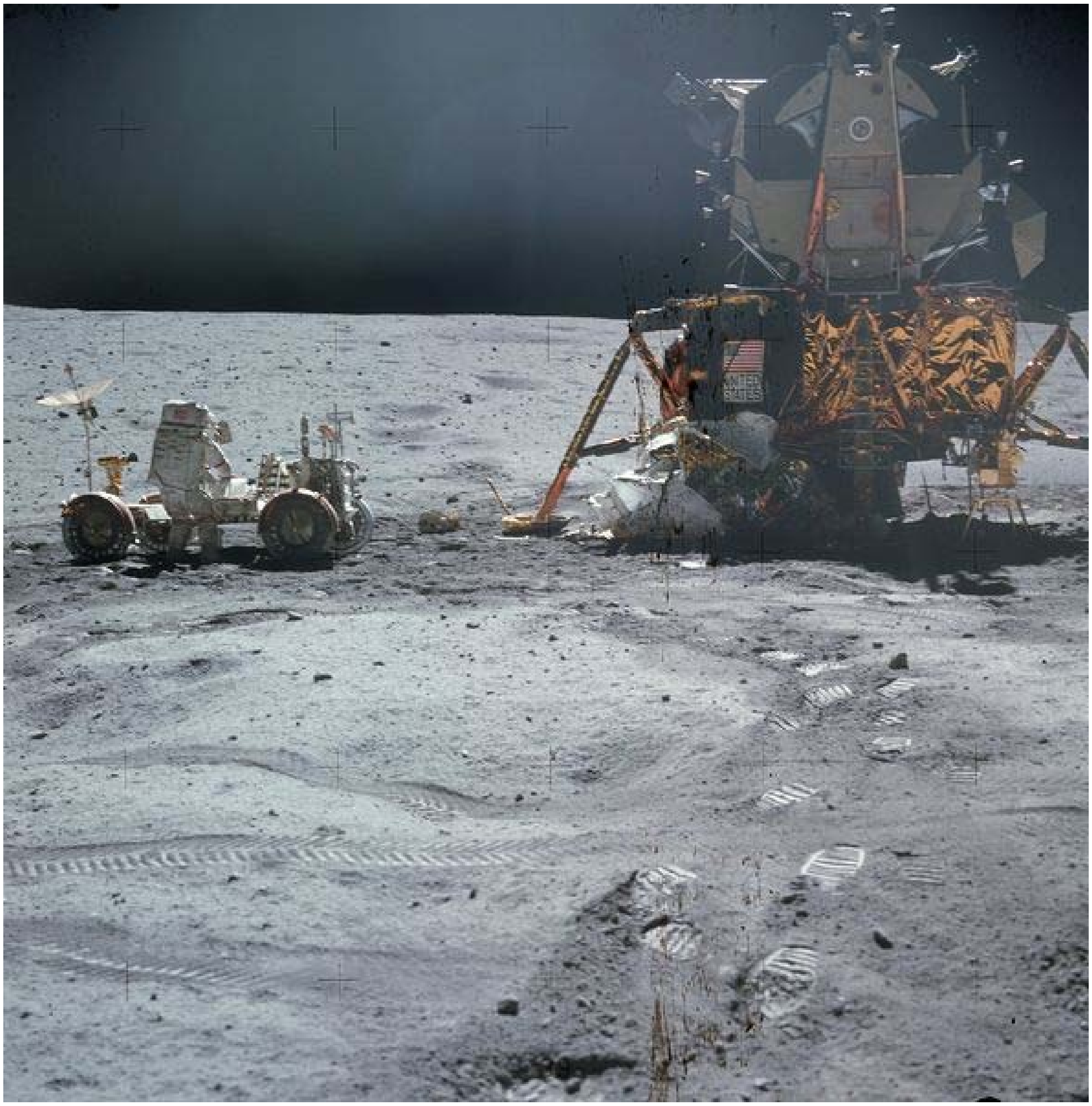
Earth

Space exploration has been used as a tool to understand the Earth as a celestial object in its own right. Orbital missions can provide data for the Earth that can be difficult or impossible to obtain from a purely ground-based point of reference.

For example, the existence of the Van Allen belts was unknown until their discovery by the United States' first artificial satellite, Explorer 1. These belts contain radiation trapped by the Earth's magnetic fields, which currently renders construction of habitable space stations above 1000 km impractical. Following this early unexpected discovery, a large number of Earth observation satellites have been deployed specifically to explore the

Earth from a space based perspective. These satellites have significantly contributed to the understanding of a variety of earth based phenomena. For instance, the hole in the ozone layer was found by an artificial satellite that was exploring Earth's atmosphere, and satellites have allowed for the discovery of archeological sites or geological formations that were difficult or impossible to otherwise identify.

The Moon as seen from the Earth



Apollo 16 astronaut John Young

Earth's Moon

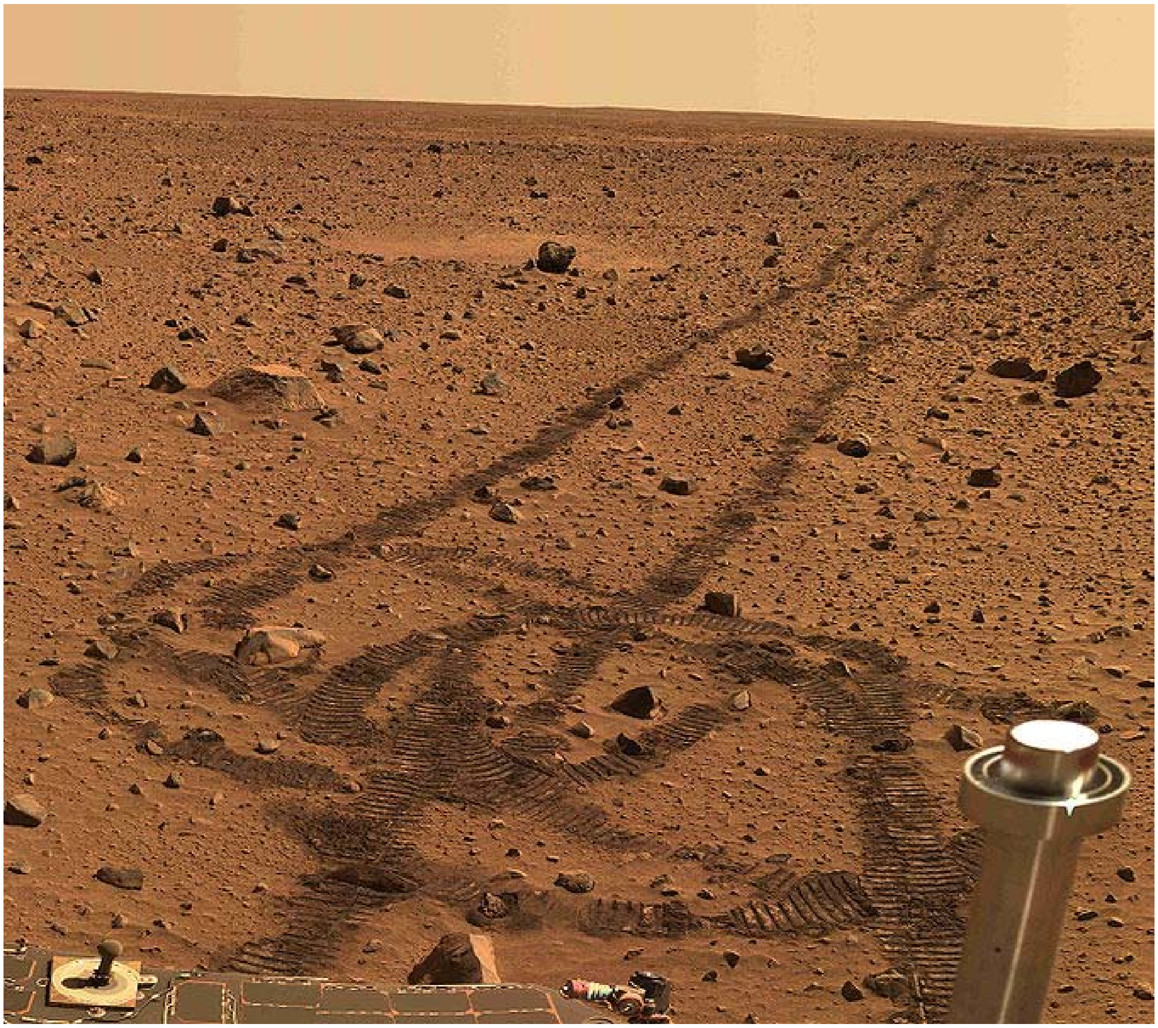
Earth's Moon was the first celestial body to be the object of space exploration. It holds the distinctions of being the first remote celestial object to be flown by, orbited, and landed upon by spacecraft, and the only remote celestial object ever to be visited by humans.

In 1959 the Soviets obtained the first images of the far side of the Moon, never previously visible to humans. The U.S. exploration of the Moon began with the Ranger 4 impactor in 1962. Starting in 1966 the Soviets successfully deployed a number of landers to the Moon which were able to obtain data directly from the Moon's surface; just four months later, Surveyor 1 marked the debut of a successful series of U.S. landers. The

Soviet unmanned missions culminated in the Lunokhod program in the early '70s which included the first unmanned rovers and also successfully returned lunar soil samples to the Earth for study. This marked the first (and to date the only) automated return of extraterrestrial soil samples to the Earth. Unmanned exploration of the Moon continues with various nations periodically deploying lunar orbiters, and in 2008 the Indian Moon Impact Probe.

Manned exploration of the Moon began in 1968 with the Apollo 8 mission that successfully orbited the Moon, the first time any extraterrestrial object was orbited by humans. In 1969 the Apollo 11 mission marked the first time humans set foot upon another world. Manned exploration of the Moon did not continue for long, however. The Apollo 17 mission in 1972 marked the last time humans would visit the Moon in any form and no human exploration mission is planned to reach the Moon any time in the near future.

Mars as seen by the HST



Part of a panorama taken by the Spirit rover in 2004

Mars

The exploration of Mars has been an important part of the space exploration programs of the Soviet Union (later Russia), the United States, Europe, and Japan. Dozens of robotic spacecraft, including orbiters, landers, and rovers, have been launched toward Mars since the 1960s. These missions were aimed at gathering data about current conditions and answering questions about the history of Mars. The questions raised by the scientific community are expected to not only give a better appreciation of the red planet but also yield further insight into the past, and possible future, of Earth.

The exploration of Mars has come at a considerable financial cost with roughly two-thirds of all spacecraft destined for Mars failing before completing their missions, with some failing before they even began. Such a high failure rate can be attributed to the complexity and large number of variables involved in an interplanetary journey, and has led researchers to jokingly speak of *The Great Galactic Ghoul* which subsists on a diet of Mars probes. This phenomenon is also informally known as the *Mars Curse*.

Phobos

The Russian space mission Phobos-Grunt, Scheduled to launch in 2011, will begin exploration of the Phobos and Martian circumterrestrial orbit, and study whether the moons of Mars, or at least Phobos, could be a "trans-shipment point" for spaceships travelling to Mars.

Voyager 1 image of Jupiter

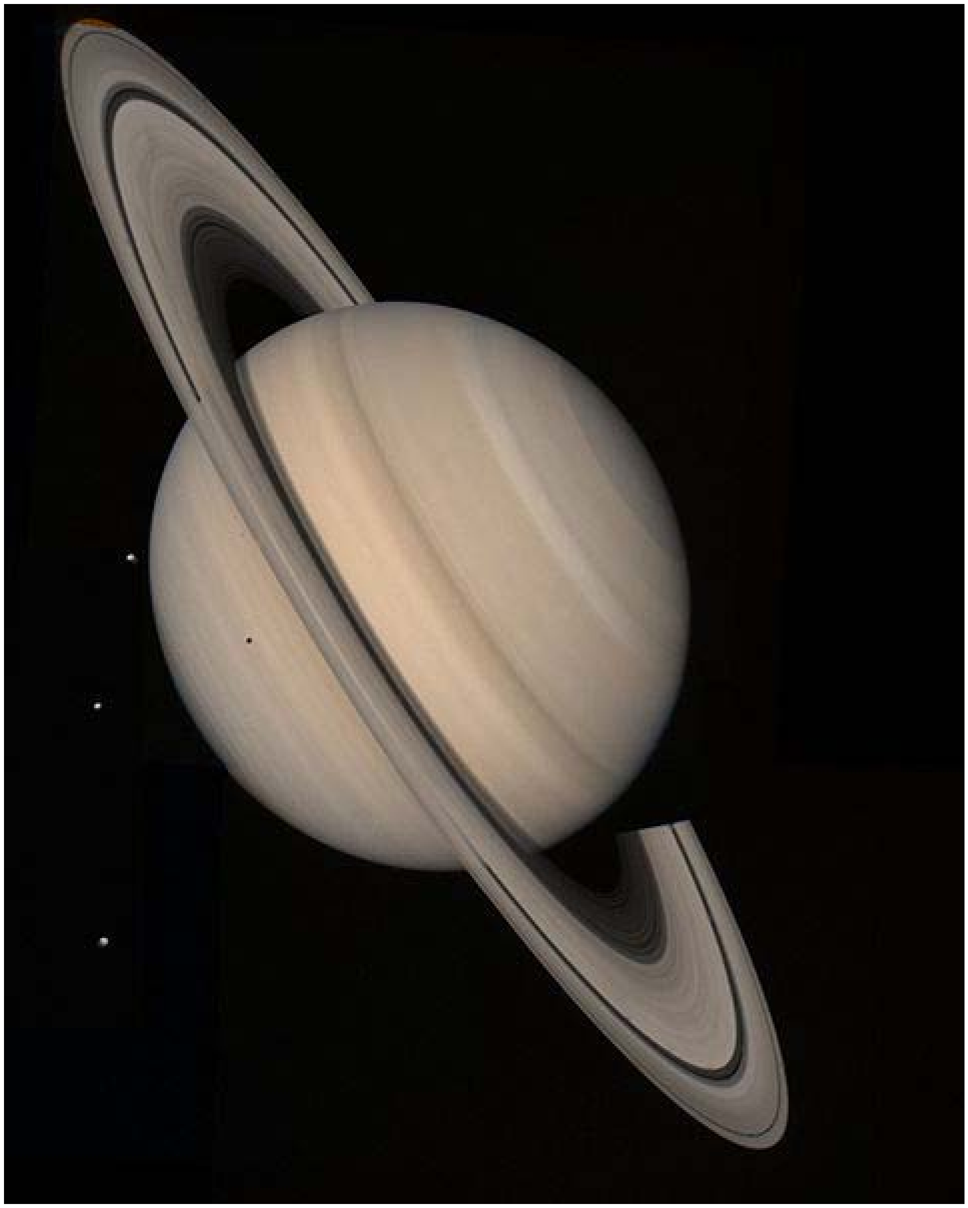
Image of Io taken by the Galileo spacecraft

Jupiter

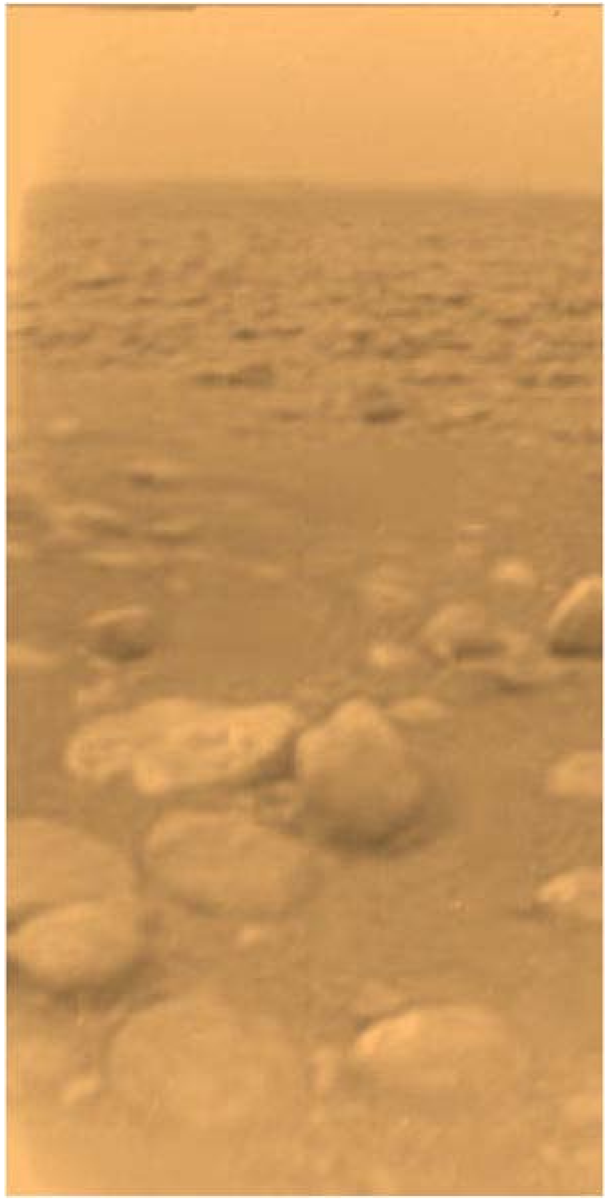
The exploration of Jupiter has consisted solely of a number of automated NASA spacecraft visiting the planet since 1973. A large majority of the missions have been "flybys", in which detailed observations are taken without the probe landing or entering orbit; the *Galileo* spacecraft is the only one to have orbited the planet. As Jupiter is believed to have only a relatively small rocky core and no real solid surface, a landing mission is nearly impossible.

Reaching Jupiter from Earth requires a delta-v of 9.2 km/s, which is comparable to the 9.7 km/s delta-v needed to reach low Earth orbit. Fortunately, gravity assists through planetary flybys can be used to reduce the energy required at launch to reach Jupiter, albeit at the cost of a significantly longer flight duration.

Jupiter has over 60 known moons, many of which have relatively little known about them.



A picture of Saturn taken by Voyager 2



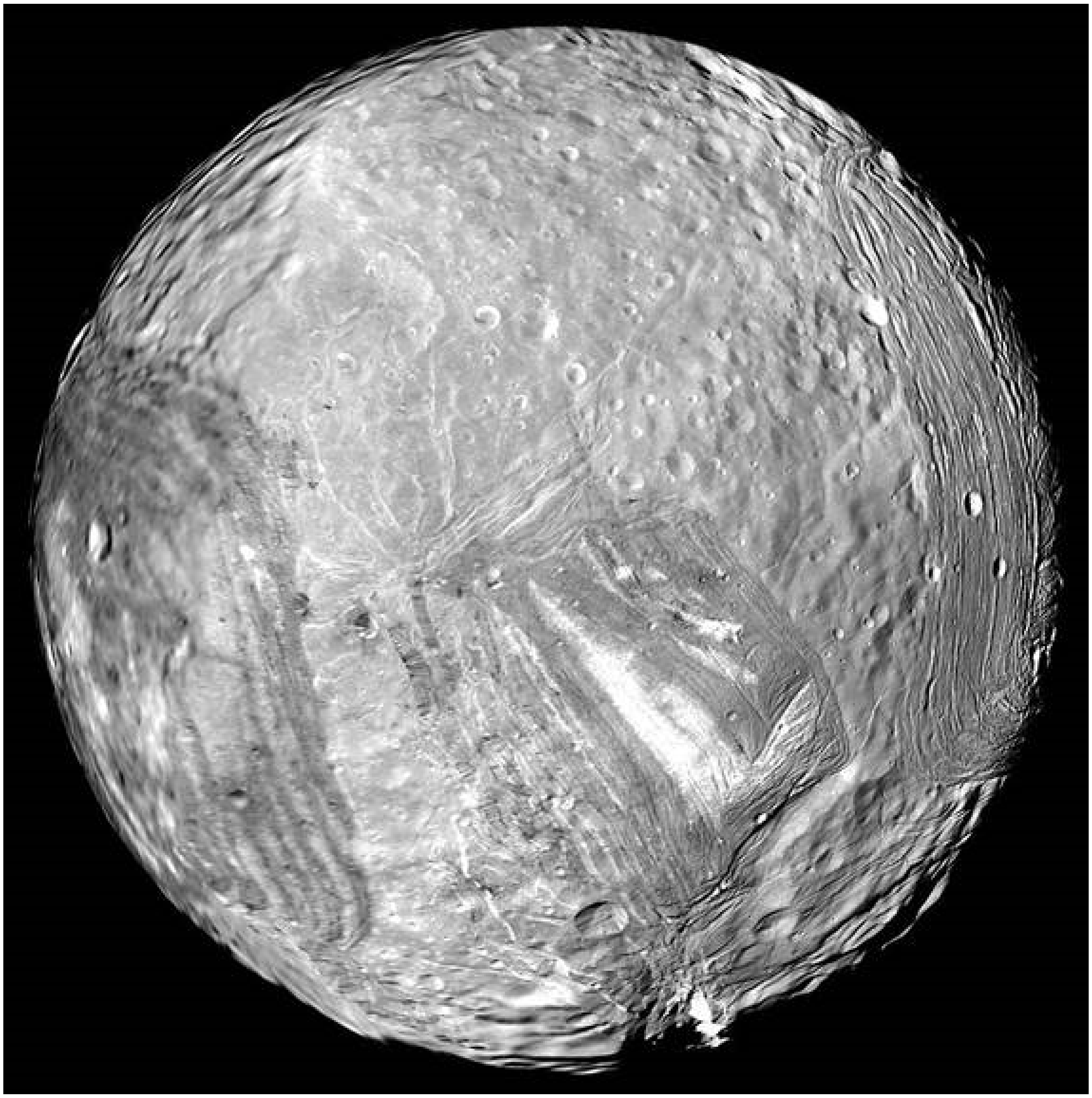
Huygens image from the surface of Titan

Saturn

Saturn has been explored only through unmanned spacecraft launched by NASA, including one mission (Cassini–Huygens) planned and executed in cooperation with other space agencies. These missions consist of flybys in 1979 by Pioneer 11, in 1980 by Voyager 1, in 1982 by Voyager 2 and an orbital mission by the Cassini spacecraft which entered orbit in 2004 and is expected to continue its mission well into 2010.

Saturn has at least 62 satellites, although the exact number is debatable since Saturn's rings are made up of vast numbers of independently orbiting objects of varying sizes. The largest of the moons is Titan. Titan holds the distinction of being the only moon in the solar system with an atmosphere denser and thicker than that of the Earth. As a result of the deployment from the Cassini spacecraft of the Huygens probe and its successful landing on Titan, Titan also holds the distinction of being the only moon (apart from Earth's own Moon) to be successfully explored with a lander.

Uranus from Voyager 2

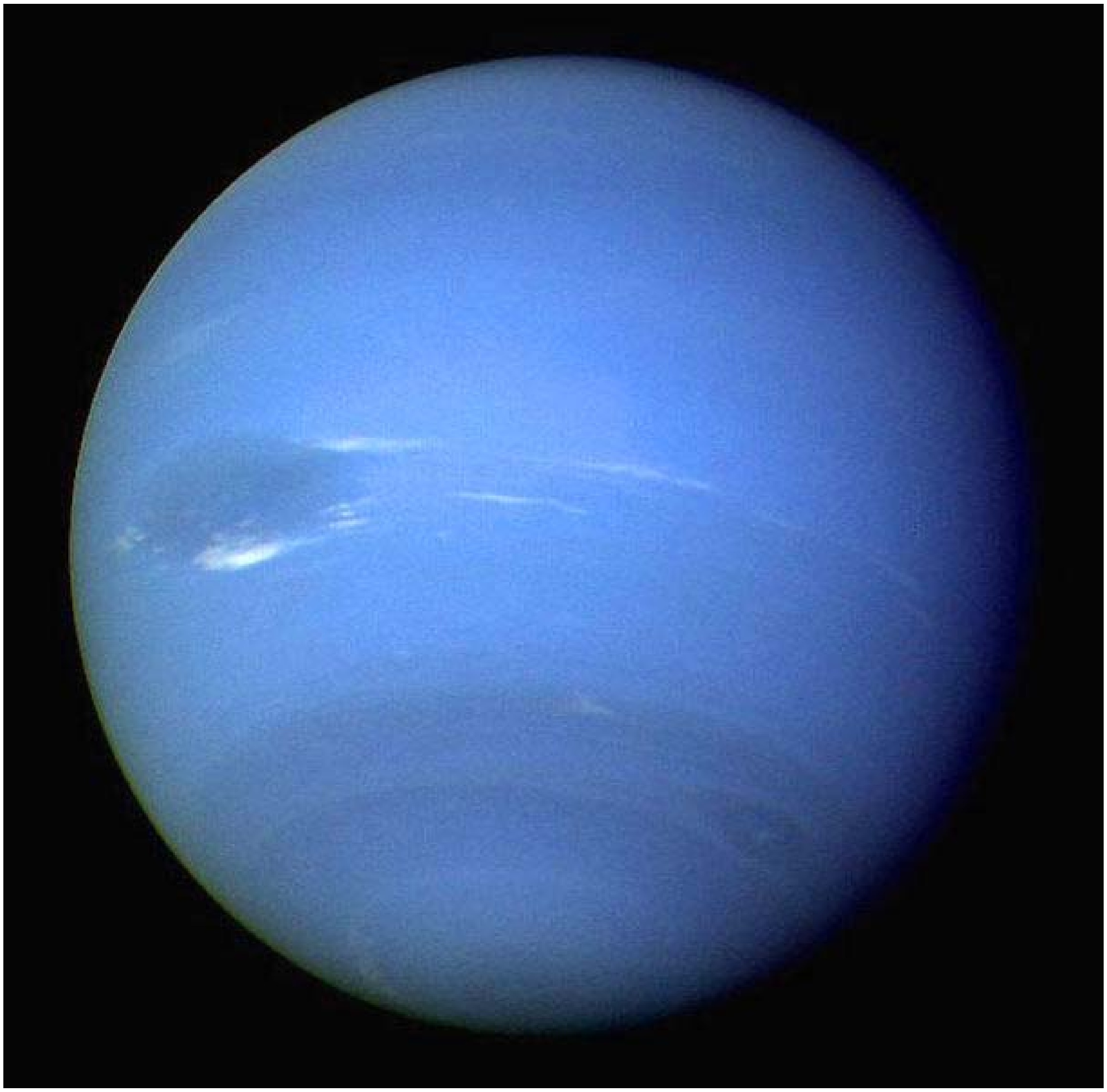


Voyager 2 image showing the tortured surface of Miranda

Uranus

The exploration of Uranus has been entirely through the Voyager 2 spacecraft, with no other visits currently planned. Given its axial tilt of 97.77°, with its polar regions exposed to sunlight or darkness for long periods, scientists were not sure what to expect at Uranus. The closest approach to Uranus occurred on January 24, 1986. *Voyager 2* studied the planet's unique atmosphere and magnetosphere. *Voyager 2* also examined its ring system and the moons of Uranus including all five of the previously known moons, while discovering an additional ten previously unknown moons.

Images of Uranus proved to have a very uniform appearance, with no evidence of the dramatic storms or atmospheric banding evident on Jupiter and Saturn. Great effort was required to even identify a few clouds in the images of the planet. The magnetosphere of Uranus, however, proved to be completely unique and proved to be profoundly affected by the planet's unusual axial tilt. In contrast to the bland appearance of Uranus itself, striking images were obtained of the moons of Uranus, including evidence that Miranda had been unusually geologically active.



Picture of Neptune taken by Voyager 2

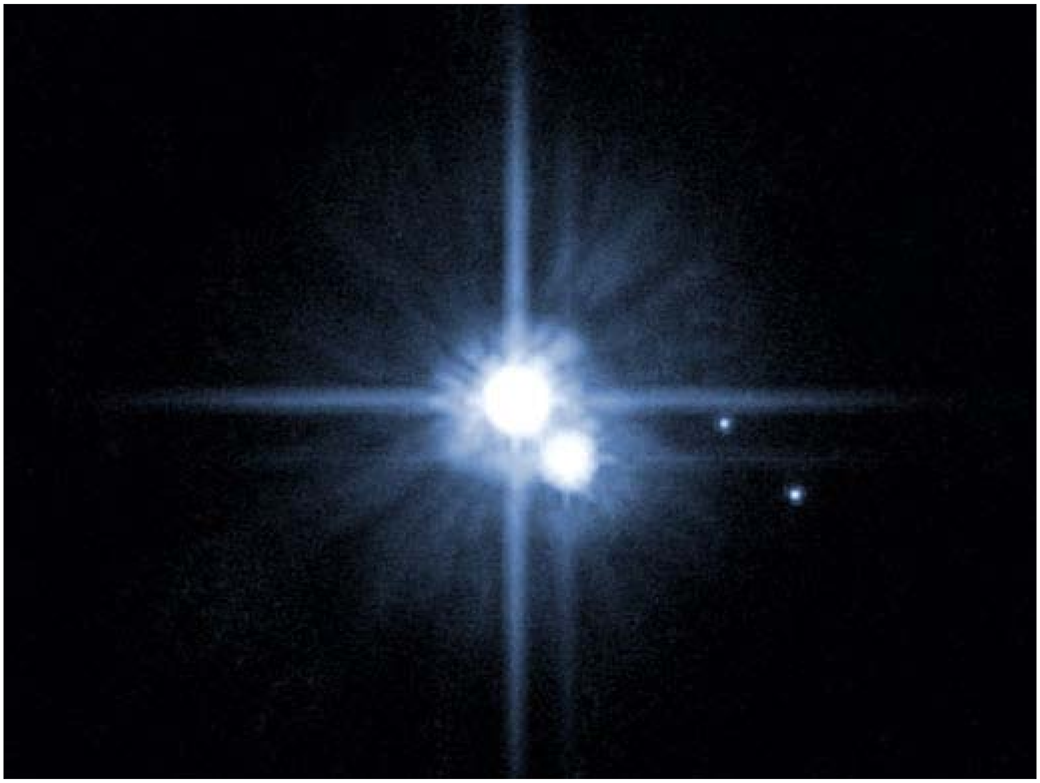
Triton as imaged by Voyager 2

Neptune

The exploration of Neptune began with the August 25, 1989 Voyager 2 flyby, the sole visit to the system as of 2009. The possibility of a Neptune Orbiter has been discussed, but no other missions have been given serious thought.

Although the extremely uniform appearance of Uranus during Voyager 2's visit in 1986 had led to expectations that Neptune would also have few visible atmospheric phenomena, Voyager 2 found that Neptune had obvious banding, visible clouds, auroras, and even a conspicuous anticyclone storm system rivaled in size only by Jupiter's small Spot. Neptune also proved to have the fastest winds of any planet in the solar system, measured as high as 2,100 km/h. Voyager 2 also examined Neptune's ring and moon system. It discovered 900 complete rings and additional partial ring "arcs" around Neptune. In addition to examining Neptune's three previously known moons, Voyager 2 also discovered five previously known moons, one of which, Proteus, proved to be the last largest moon in the system. Data from Voyager further reinforced the view that Neptune's largest moon, Triton, is a captured Kuiper belt object.

Dwarf planets



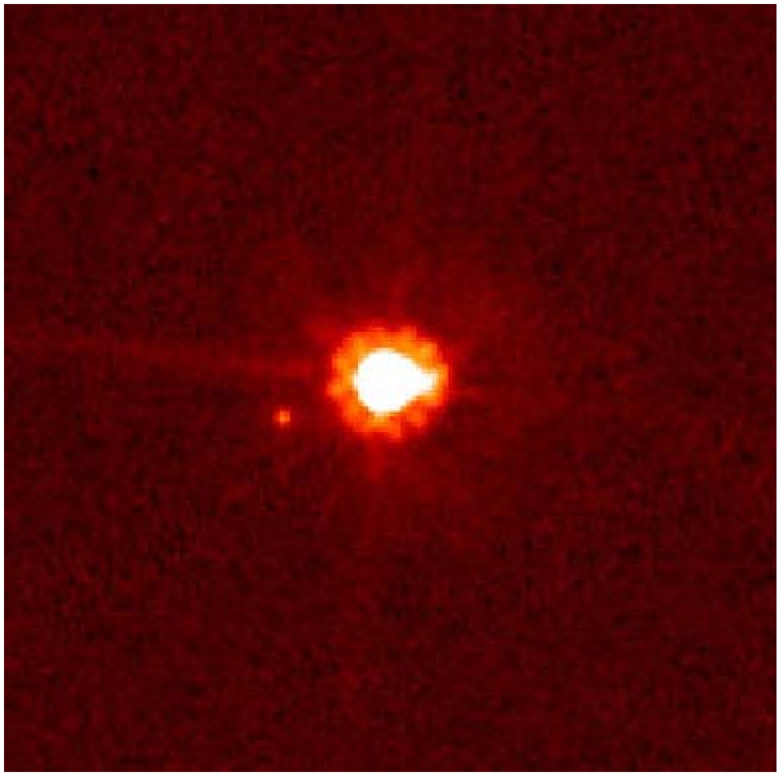
Pluto with its moons

Pluto

Pluto and Charon (1994)

The dwarf planet Pluto (considered a planet until the IAU redefinition of "planet" in October 2006) presents significant challenges for spacecraft because of its great distance from Earth (requiring high velocity for reasonable trip times) and small mass (making capture into orbit very difficult at present). *Voyager 1* could have visited Pluto, but controllers opted instead for a close flyby of Saturn's moon Titan, resulting in a trajectory incompatible with a Pluto flyby. *Voyager 2* never had a plausible trajectory for reaching Pluto.

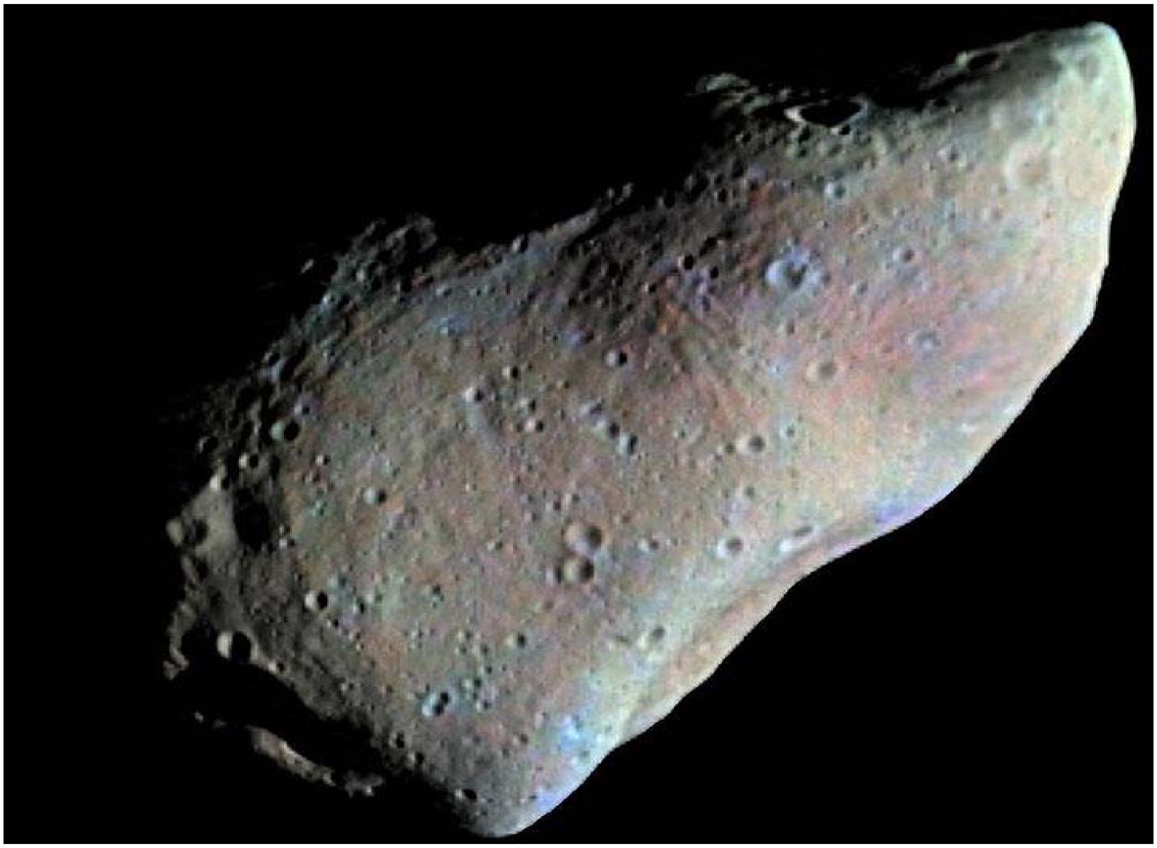
Pluto continues to be of great interest, despite its reclassification as the lead and nearest member of a new and growing class of distant icy bodies of intermediate size, in mass between the remaining eight planets and the small rocky objects historically termed asteroids (and also the first member of the important subclass, defined by orbit and known as "Plutinos"). After an intense political battle, a mission to Pluto dubbed *New Horizons* was granted funding from the US government in 2003. *New Horizons* was launched successfully on January 19, 2006. In early 2007 the craft made use of a gravity assist from Jupiter. Its closest approach to Pluto will be on July 14, 2015; scientific observations of Pluto will begin five months prior to closest approach and will continue for at least a month after the encounter.



Eris and Dysnomia by Hubble

Ceres

Ceres is relatively ill explored at present, but in 2015 Nasa's Dawn space probe is expected to arrive at and enter into orbit around the dwarf planet.



951 Gaspra

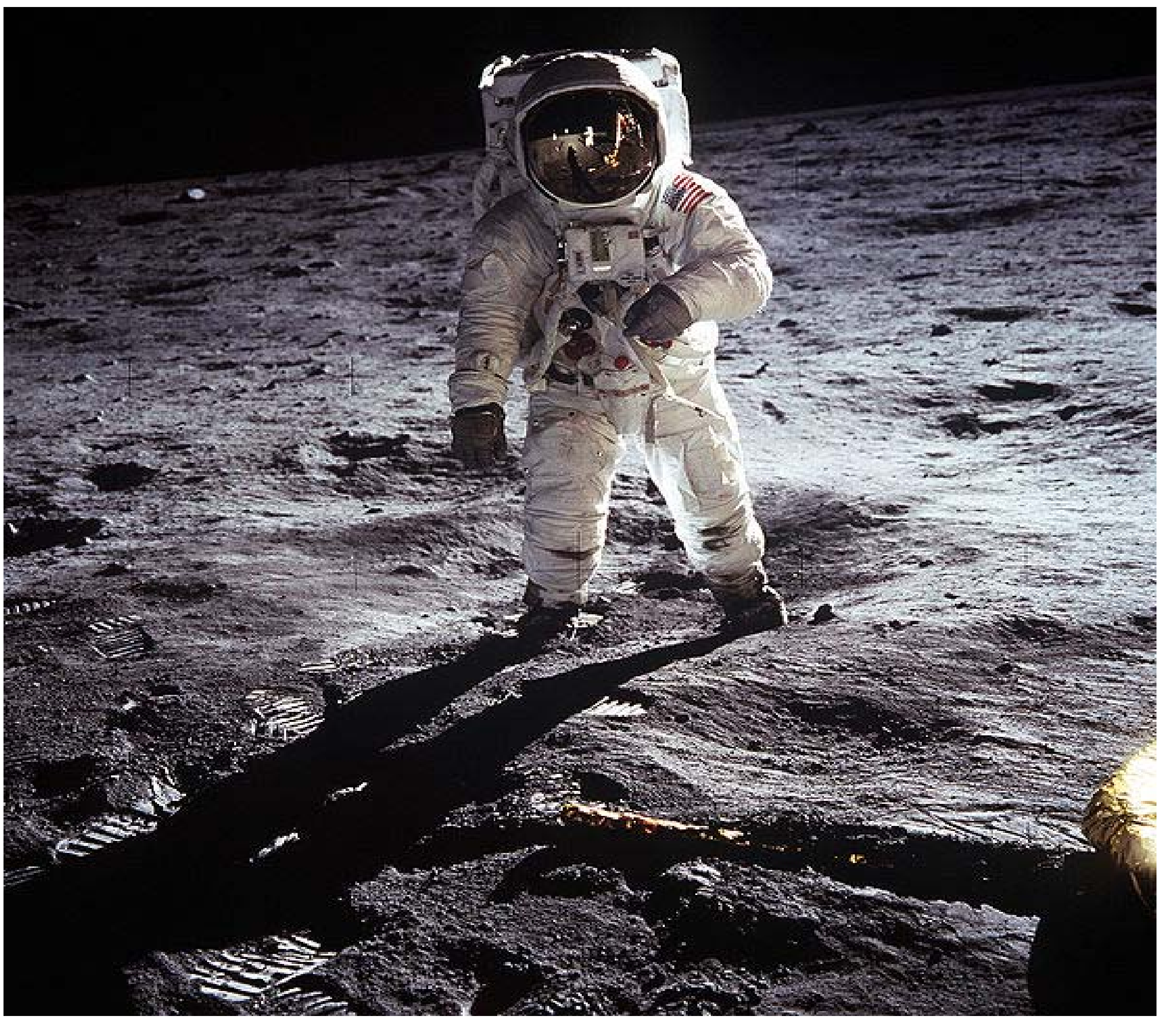
Asteroids and comets

Until the advent of space travel, objects in the asteroid belt were merely pinpricks of light in even the largest telescopes, their shapes and terrain remaining a mystery. Several asteroids have now been visited by probes, the first of which was *Galileo*, which flew past two: 951 Gaspra in 1991, followed by 243 Ida in 1993. Both of these lay near enough to Galileo's planned trajectory to Jupiter that they could be visited at acceptable cost. The first landing on an asteroid was performed by the NEAR Shoemaker probe in 2000, following an orbital survey of the object. The dwarf planet Ceres and the asteroid 4 Vesta, two of the three largest asteroids, are targets of NASA's Dawn mission, launched in 2007 September.

While many comets have been closely studied from Earth sometimes with centuries-worth of observations, only a few comets have been closely visited. A few long-period comets are currently the furthest known objects in the solar system. In 1985, the International Cometary Explorer conducted the first comet fly-by (21P/Giacobini-Zinner) before joining the Halley Armada studying the famous comet. The Deep Impact probe smashed into 9P/Tempel to learn more about its structure and composition while the Stardust mission returned samples of another comet's tail. The Philae lander will attempt to land on a comet in 2014.

Hayabusa was an unmanned spacecraft developed by the Japan Aerospace Exploration Agency to return a sample of material from a small near-Earth asteroid named 25143 Itokawa to Earth for further analysis. Hayabusa, formerly known as **MUSES-C** for Mu Space Engineering Spacecraft C, was launched on 9 May 2003 and rendezvoused with Itokawa in mid-September 2005. After arriving at Itokawa, Hayabusa studied the asteroid's shape, spin, topography, colour, composition, density, and history. In November 2005, it landed on the asteroid and attempted to collect samples but it is not clear whether the sampling mechanism worked as intended. Nevertheless, there is a high probability that some dust was trapped in the sampling chamber during contact with the asteroid, so the chamber was sealed, and the spacecraft returned to Earth on 13 June 2010.The spacecraft also carried a detachable minilander, MINERVA, but this failed to reach the surface.

Rationales



Astronaut Buzz Aldrin, had a personal Communion service when he first arrived on the surface of the Moon.

The research that is conducted by national space exploration agencies, such as NASA and Roscosmos, is one of the reasons supporters cite to justify government expenses. Economic analyses of the NASA programs often showed ongoing economic benefits (from things such as spin-offs), generating many times the revenue of the cost of the program.

Another claim is that space exploration is a necessity to mankind and that staying on our home planet will lead us to extinction. Some of the reasons are lack of natural resources, comets, nuclear war, and worldwide epidemic. Stephen Hawking, renowned British theoretical physicist, said that "I don't think the human race will survive the next thousand years, unless we spread into space. There are too many accidents that can befall life on a single planet. But I'm an optimist. We will reach out to the stars."

NASA has produced a series of Public Service Announcement videos supporting the concept of space exploration.

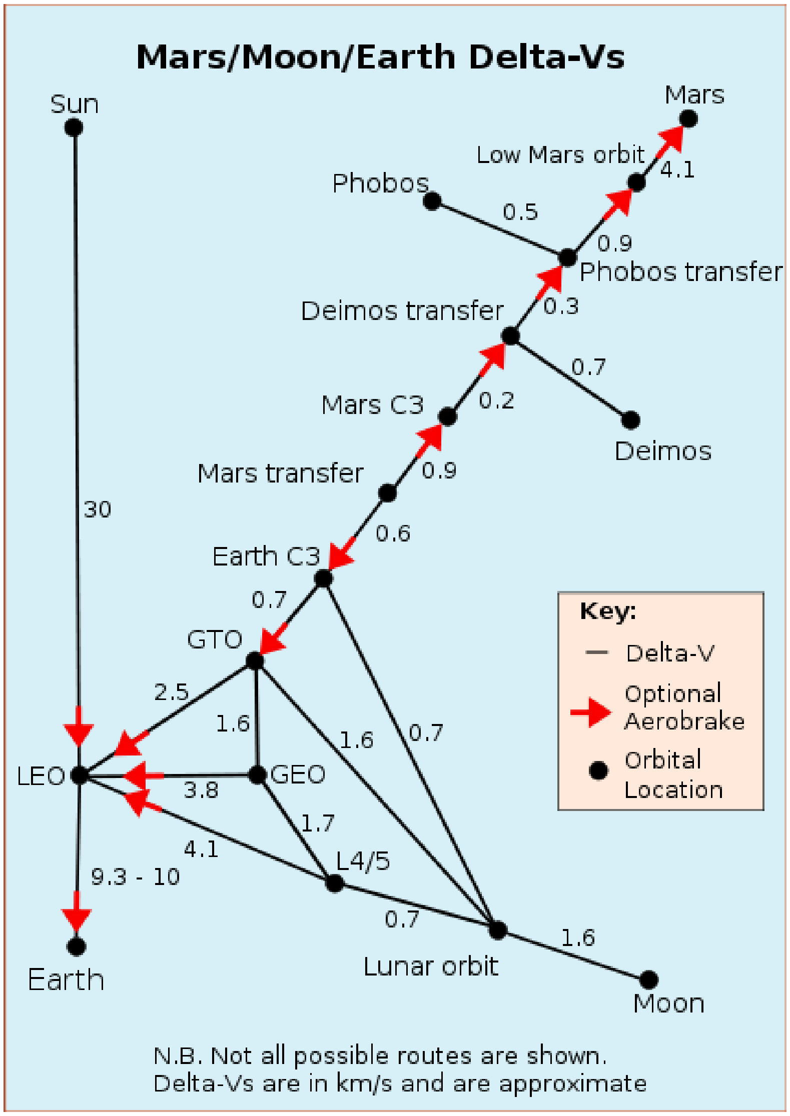
Overall, the public remains largely supportive of both manned and unmanned space exploration. According to an Associated Press Poll conducted in July 2003, 71% of U.S. citizens agreed with the statement that the space program is "a good investment", compared to 21% who did not.

Arthur C. Clarke (1950) presented a summary of motivations for the human exploration of space in his non-fiction semi-technical monograph *Interplanetary Flight*. He argued that humanity's choice is essentially between expansion off the Earth into space, versus cultural (and eventually biological) stagnation and death.

Opposition

Critics such as the late physicist and Nobel prize winner Richard Feynman have contended that human space travel (as distinguished from space exploration in general, such as robotic missions) has never achieved any major scientific breakthroughs.

Related topics



Delta-v's in km/s for various orbital maneuvers

Spaceflight

Spaceflight is the use of space technology to achieve the flight of spacecraft into and through outer space.

Spaceflight is used in space exploration, and also in commercial activities like space tourism and satellite telecommunications. Additional non-commercial uses of spaceflight include space observatories, reconnaissance satellites and other earth observation satellites.

A spaceflight typically begins with a rocket launch, which provides the initial thrust to overcome the force of gravity and propels the spacecraft from the surface of the Earth. Once in space, the motion of a spacecraft—both when unpropelled and when under propulsion—is covered by the area of study called astrodynamics. Some spacecraft remain in space indefinitely, some disintegrate during atmospheric reentry, and others reach a planetary or lunar surface for landing or impact.

Satellites

Satellites are used for a large number of purposes. Common types include military (spy) and civilian Earth observation satellites, communication satellites, navigation satellites, weather satellites, and research satellites. Space stations and human spacecraft in orbit are also satellites.

Militarization of space

Militarisation of space took place since the 1960s, and is now evolving into weaponisation of space with actual placement of weapons by space-faring nations for decisive military advantage.

While military activities have certainly taken place in space and space is an operating location for many military spacecraft (such as imaging & communications satellites) or a temporary transit medium for weapons (such as ballistic missiles), permanent placement of large-scale operational weapons in space has never been conducted.

Space colonization

Space colonization, also called space settlement and space humanization, would be the permanent autonomous (self-sufficient) human habitation of locations outside Earth, especially of natural satellites or planets such as the Moon or Mars, using significant amounts of in-situ resource utilization.

To date, the longest human occupation of space was the space station Mir, which was continuously inhabited for almost ten years, including Valeri Polyakov's record single spaceflight of almost 438 days. Long-term stays in space reveal issues with bone and muscle loss in low gravity, immune system suppression, and radiation exposure.

Many past and current concepts for the continued exploration and colonization of space focus on a return to the Moon as a "stepping stone" to the other planets, especially Mars. At the end of 2006 NASA announced they were planning to build a permanent Moon base with continual presence by 2024.

Chapter- 5

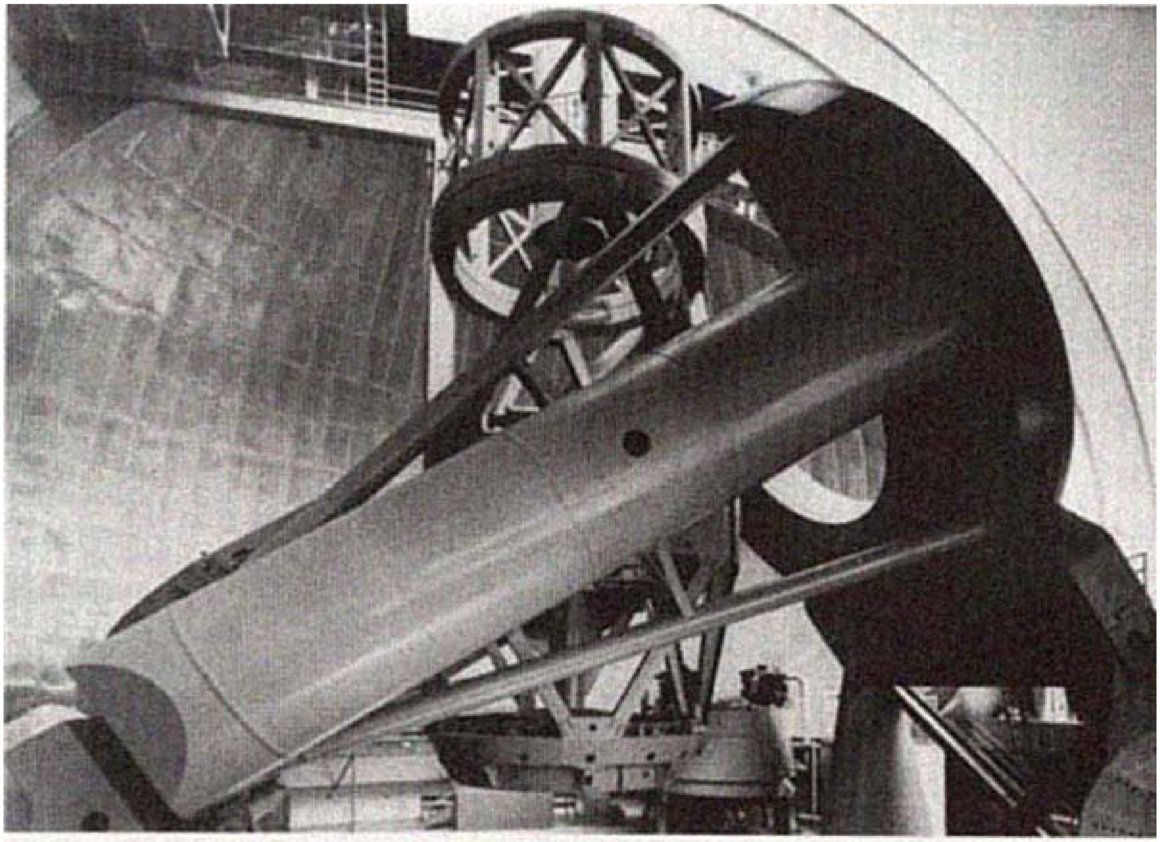
Space Science

A picture showing part of the Milky Way

Space science is an all-encompassing term that describes all of the various science fields that are concerned with the study of the Universe, generally also meaning "excluding the Earth" and "outside of the Earth's atmosphere". Originally, all of these fields were considered part of astronomy. However, in recent years the major sub-fields within astronomy, such as astrophysics, have grown so large that they are now considered separate fields on their own. There are eight overall categories that can generally be described on their own; Astrophysics, Galactic Science, Stellar Science, non-Earth Planetary Science, Biology of Other Planets, Astronautics/Space Travel, Space Colonization and Space Defense. The Library of Congress and Dewey Decimal System have a major classification "Descriptive Astronomy" which they use instead of placing descriptive works into their huge "Geography" collections. Space science should not be confused with space research and space exploration.

Astronomy

Astronomical methods



Mt. Palomar's 200-inch Hale Telescope, pointing to the zenith, as seen from the east side.

Palomar Telescope

Astronomical methods are the equipments and techniques used to collect data about the objects in Space. Galileo's first astronomical method was to find and buy the best telescope of the time and then point that telescope to the heavens. Methods can be categorized according to the wavelength they are attempting to record.

Radio astronomy includes radio telescopes; devices that receive and record radio waves from outside the Earth. They record cosmic microwave background radiation resulting from the Big Bang, Pulsars and other sources. Optical astronomy is the oldest kind of astronomy. X-ray observatories include the Chandra X-ray Observatory and others. gamma ray includes the Compton Gamma Ray Observatory and others. Neutrino astronomy observatories have also been built, primarily to study our Sun. Gravitational wave observatories have been theorized.

A space telescope is a telescope orbiting or travelling from the Earth, such as the Hubble space telescope. RXTE is Long Exposure Time Astronomy used to study millisecond pulsars and pulsar deceleration.

Spectroscopy

Astronomy teaching tools include Planetariums and others.

Descriptive astronomy

Galileo's second astronomical method was to describe what he saw in the telescope. Descriptive Astronomy is the highest sub-category of Astronomy used by the Library of Congress and Dewey Decimal systems to classify any knowledge related to describing celestial objects. Because we are seeing today portions of the Universe as they actually looked millions or billions of years ago we should have a historical section within Descriptive astronomy: **History of The Universe** includes the size, shape and structure of the historical universe), **Cartography of The Historical Universe**, Early Universe and others. **The Current Universe** includes size shape and structure of the current Universe, cartography of the current Universe and others.

Cartography of Space Bodies. Recording photographic or similar images of the Earths surface from space is a well developed science, yet still expanding because of advances in the actual resolution of images taken from space or atmosphere and because of advances in digitizing and manipulating the images. Most of these advances are being applied to the cartography of space-located bodies, even though acquiring the original images of those bodies is extremely complicated and expensive, usually requiring long distance probes to carry the cameras.

Visible matter in the universe is apparently organized geographically into structures with large amounts of space between them; either the space between planets, the space between stars or the space between galaxies. Even galaxies themselves are not spread uniformly but appear to be located in filaments. Therefore The Universe can be divided geographically into regions that follow this structure. **The Filaments of Galaxies** are the furthest visible structures.

Those filaments are made of superclusters, tending to line up in filaments. Our Milky Way Galaxy is a galaxy in what is called **Our Supercluster of Galaxies** by the National Geographic Society. Some 150 million light-years across, Our Supercluster is a great aggregation of perhaps thousands of smaller clusters of galaxies. The largest of these smaller clusters is called the Virgo Cluster. According to National Geographic, The Virgo Cluster contains the center of mass of Our Supercluster. Although The Milky Way Galaxy is a part of Our Supercluster, it is not a part of the Virgo Cluster. Our Milky Way Galaxy is part of a cluster called the Local Group. Gravitationally, our Local Group plays a small role in Our Supercluster because it is a small and distant cluster from the center. A much larger cluster within in Our Supercluster is the Ursa Major Cluster. The following objects are located within Our Supercluster but not within the Local Group;

they are objects 100,000,000 light-years to 10,000,000 light-years from the Sun: M49, M51, M58, M59, M60, M61, M63, M64, M65, M66. National Geographic magazine has produced a very good drawing of this region in its Map of the Universe Supplement, October 1999 issue.

Local Group: Our Milky Way Galaxy is one of about 30 galaxies called the Local Group. The Local Group is about 4 million light-years across. In the Local Group our Milky Way Galaxy plays a large gravitational part because our galaxy is the second largest galaxy in our Local Group, second only to the Andromeda Galaxy. All of the other galaxies in our Local Group are gravitationally bound either to the Andromeda Galaxy or to our Milky Way Galaxy. Inside of our local group but outside of our Galaxy are objects 4,000,000 LY to 1,000,000 LY from the Sun: M31, M32, M33.

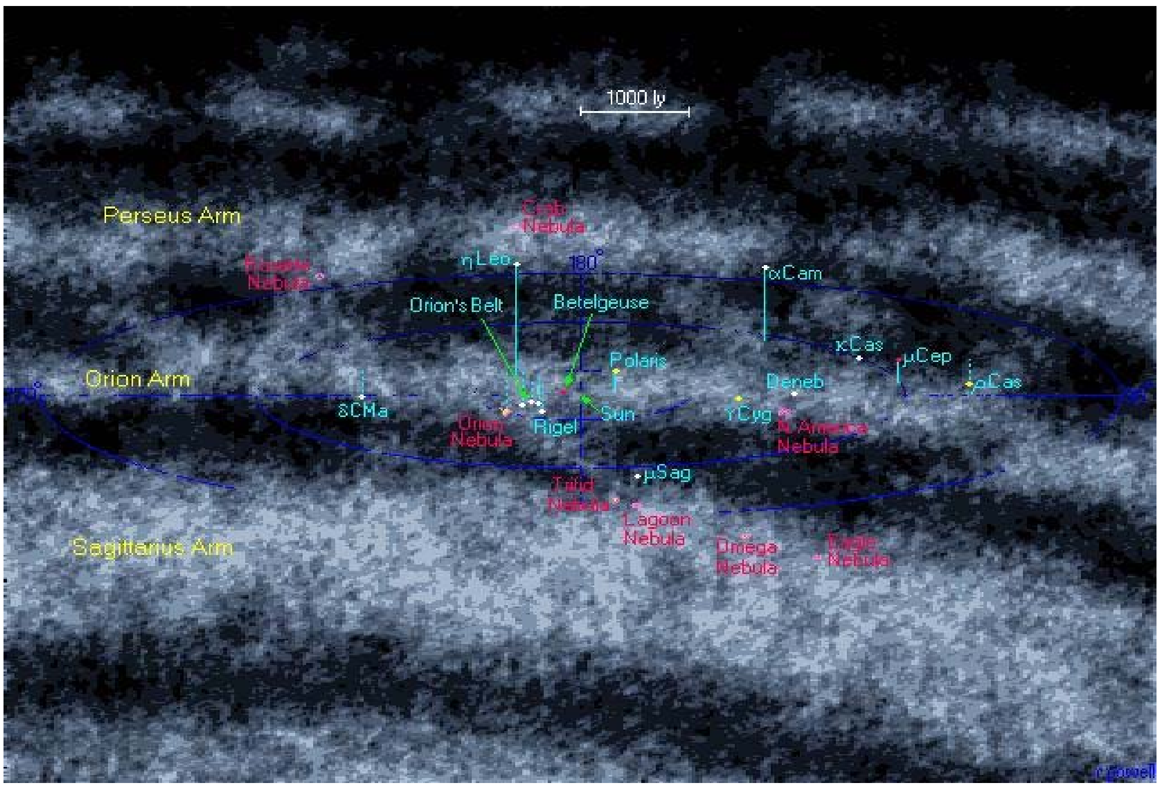


Image of the Orion and neighbouring arms

Milky Way Galaxy: Our Milky Way Galaxy is a massive mass-containing structure 100,000 light-years across and 30,000 light-years tall. Most of its billions of suns are organized into several structures called "arms". Our Sun is located in what is called the "Orion Arm". The next arm outside of us is called the "Perseus Arm". The Crab Nebula M1 is located in the Perseus Arm. The arm outside of the Perseus Arm is called the Outer Arm. Palomar 1 is located in the Outer Arm. The next arm inside of us is called the Sagittarius Arm. The Ring Nebula M57 and the Carina Nebula (NGC 3372) are located in the Sagittarius Arm. The next arm inside of the Sagittarius Arm is called the Crux

Arm. The inner arms are much shorter, obviously from being shifted by gravitational forces. Arms beside each other today may have at an earlier time been one.

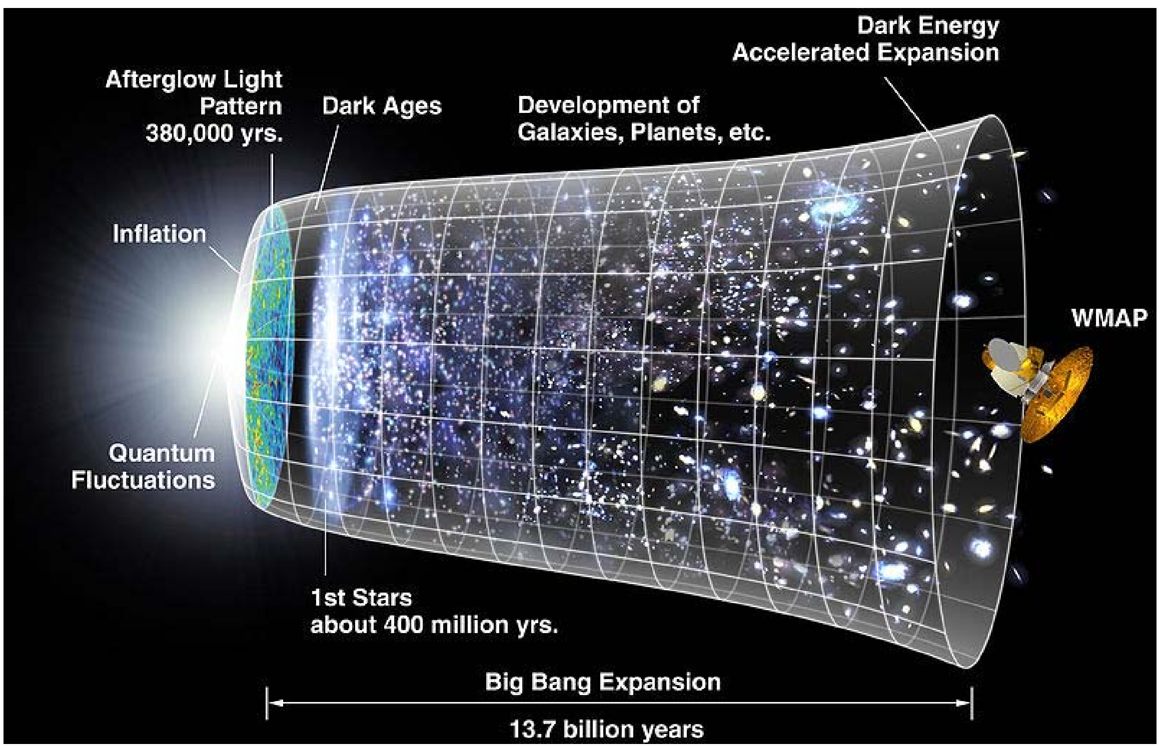
Orion Arm: The Orion Nebula M42 is located in our Arm. **Celestial Objects 1000 LY to 100 LY from the Sun**: M39, M44, M45. **Celestial Objects 100 LY to 16LY From the Sun**. **Celestial Objects less than 16 LY from the Sun**: List of nearest stars

Nearby-Stars Solar Systems: By measuring the extremely small movements of nearby stars astronomers have been able to prove that there are planets going around these Suns, therefore these suns have become "Solar Systems".

Solar system includes **Scientific Study of Solar System Planets**, Venus, Mercury, Saturn, Jupiter, Uranus, Neptune, Mars, and Moon

Further reading can be found in the Library of Congress Classification QB495-903 Descriptive astronomy (Dewey 523) Galileo's second astronomical method was to describe what he saw in the telescope.

Physics of the universe / Astrophysics



Timeline of Origin of Space

After first looking at the planets, then second describing what he saw, Galileo's third astronomical method was to theorize about the reasons for what he saw in the telescope, specifically to theorize that the Earth goes around the Sun. The Physics of the Universe can be divided into several broad categories:

Astrophysical Theory includes general relativity and others.

Astrophysical Processes includes baryonic and others.

Physical Processes, General includes Mechanics, Electromagnetism, electromagnetic forces, Statistical Mechanics, Thermodynamics, Quantum Mechanics, relativity, gravity and others.

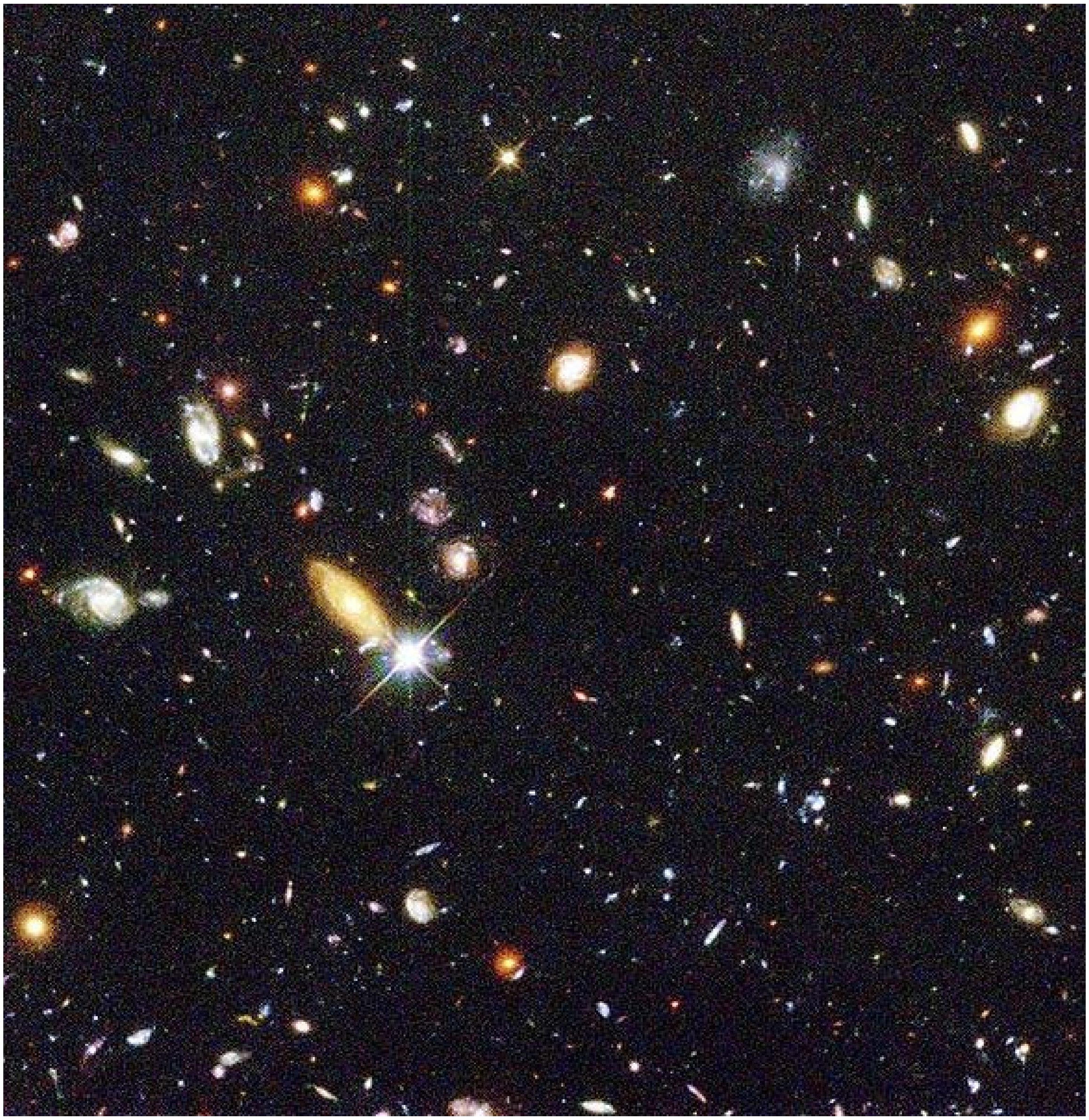
Origins Of The Universe Universe Theories of the Origins of the Universe, Big Bang Theory, Early Universe, Evidence, Cosmic Microwave Background, Dark Ages, **Interstellar Medium**, voids, Filaments of Galaxies, galaxy clusters and others.

Astrophysical Plasma includes plasma and *quasineutrality* and others.

Cosmic Plasmas Between Stars, (Diffuse Plasmas) includes intergalactic space, intergalactic medium, interstellar medium, interplanetary medium, heliospheric current sheet, interplanetary medium, Solar wind and others.

Cosmic Plasmas Inside Stars, (Dense Plasma) includes Stars, plasma physicists, active galactic nuclei, fusion power, magnetohydrodynamic, X-rays, bremsstrahlung, Cosmology, reionized, ambipolar diffusion, Particle Physics and others.

Cosmology



Galaxies in the Hubble Deep Field

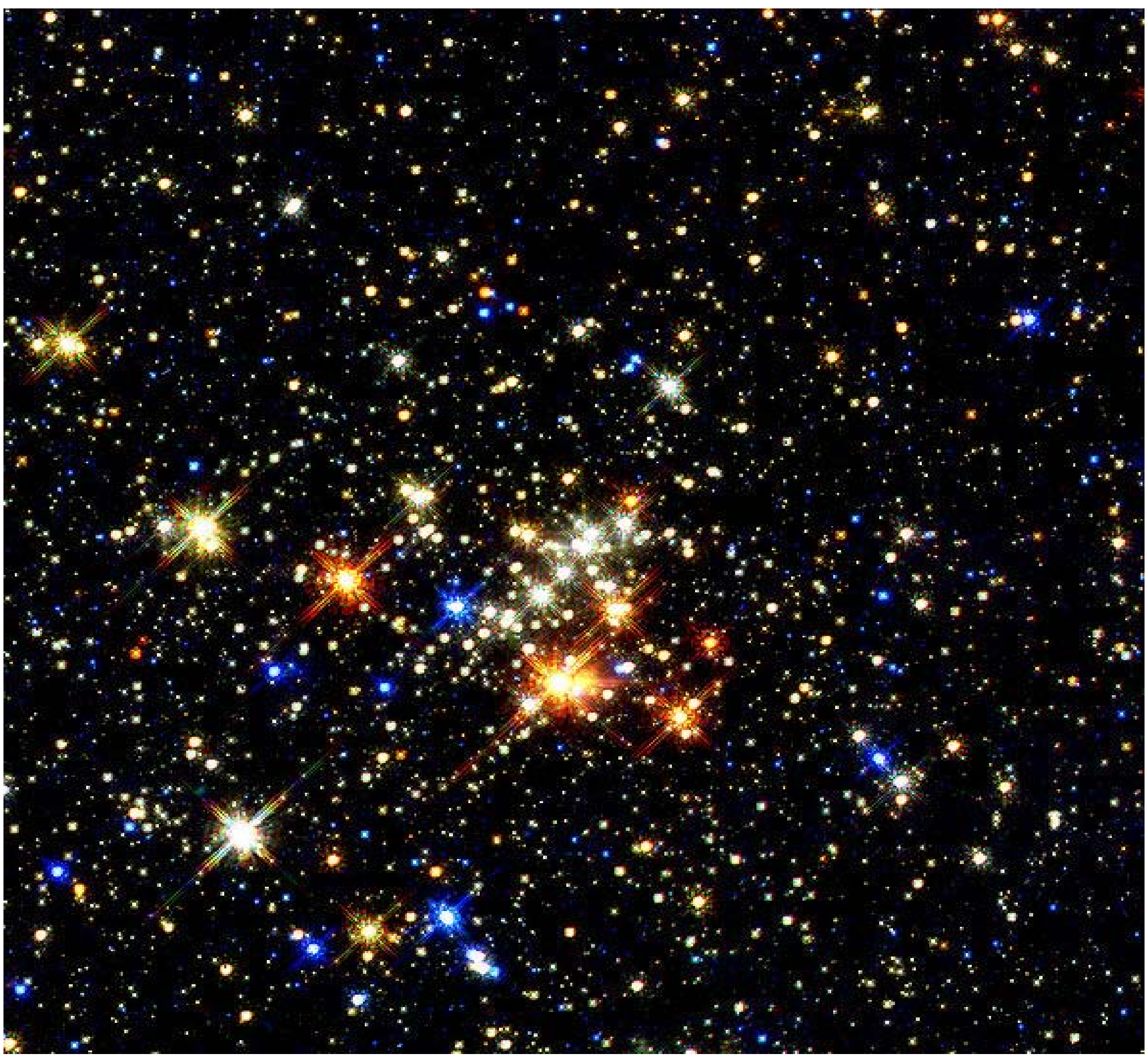
Physics can explain the underlying physical science of any galaxy, yet many aspects of galaxies are not best described through their physics. **Galactic physical science** is the general term for all physical sciences that can be applied to any galaxy in the Universe or to a particular galaxy.

Galaxy Formation and Evolution includes Galaxies, elliptical galaxies Giant Galaxies, **Spiral Galaxies**, M31 The Andromeda Galaxy and others.

Intra-Galaxy Processes, General includes Black Hole, Globular Clusters, Satellite Galaxy, Retrograde Rotation, Halo stars, High Velocity Clouds, Monoceros Ring, **accretion disc**, Gravitation, Angular momentum, Centripetal force, tidal effects, Viscosity, orbital momentum, Accretion disk, Active galactic nuclei, Protoplanetary discs, Gamma ray bursts and others.

Milky Way Galactic Physical Science is the overall science containing all the physical sciences related directly to the Milky Way Galaxy: Halo stars, Milky Way High Velocity Clouds, Milky Way Monoceros Ring, Milky Way **accretion disc**, Milky Way Gravitation, Milky Way Angular momentum, Milky Way Centripetal force, Milky Way tidal effects, Milky Way Viscosity, Milky Way orbital momentum, Milky Way event horizon, Milky Way black hole and others.

Stellar science



Quintuplet Cluster- Very young and near the Galactic Center

Physics is the underlying physical science of any star, yet many aspects of stars are not best described through their physics. **Stellar science** is the general term for ALL physical sciences that can be applied to any star in the Universe or to a particular star. **Solar science of the Sun** Sun is the overall science containing all of the physical sciences related directly to our local Sun.

Stellar-Processes, General Stellar dynamics, stars, Stellar Evolution, event horizon, black hole, x-rays, nuclear fusion and others. In astronomy, **stellar evolution** is the sequence of changes that a star undergoes during its lifetime; the hundreds of thousands, millions or billions of years during which it emits light and heat. Over the course of that time, the star will change radically.

Stellar evolution is not studied by observing the life cycle of a single star—most stellar changes occur too slowly to be detected even over many centuries. Instead, astrophysicists come to understand how stars evolve by observing numerous stars, each at a different point in its life cycle, and simulating stellar structure with computer models.

Stellar evolution begins with a giant molecular cloud (GMC), also known as a stellar nursery. Most of the 'empty' space inside a galaxy actually contains around 0.1 to 1 particle per cm^3, but inside a GMC, the typical density is a few million particles per cm^3. A GMC contains 100,000 to 10,000,000 times as much mass as our Sun by virtue of its size: 50 to 300 light-years across.

Very small protostars never reach temperatures high enough for nuclear fusion of hydrogen to begin; these are brown dwarfs of less than 0.1 solar mass. Brown dwarfs heavier than 13 Jupiter masses (M_J) do fuse deuterium, and some astronomers prefer to call only these objects brown dwarfs, classifying anything larger than a planet but smaller than this a sub-stellar object. Both types, deuterium-burning or not, shine dimly and die away slowly, cooling gradually over hundreds of millions of years. The central temperature in more massive protostars, however, will eventually reach 10 megakelvins, at which point hydrogen begins to fuse by way of the proton-proton chain reaction to deuterium and then to helium. The onset of nuclear fusion leads over a relatively short time to a hydrostatic equilibrium in which energy released by the core prevents further gravitational collapse. The star thus evolves rapidly to a stable state.

New stars come in a variety of sizes and colors. They range in spectral type from hot and blue to cool and red, and in mass from less than 0.5 to more than 20 solar masses. The brightness and color of a star depend on its surface temperature, which in turn depends on its mass.

A new star will fall at a specific point on the main sequence of the Hertzsprung-Russell diagram. Small, cool red dwarfs burn hydrogen slowly and may remain on the main sequence for hundreds of billions of years, while massive hot supergiants will leave the main sequence after just a few million years. A mid-sized star like the Sun will remain on the main sequence for about 10 billion years. The Sun is thought to be in the middle of its lifespan; thus, it is on the main sequence. Once a star expends most of the hydrogen in its core, it moves off the main sequence.

MaturityAfter millions to billions of years, depending on its initial mass, the continuous fusion of hydrogen into helium will cause a build-up of helium in the core.

The later years and death of stars:

Low-mass star Some stars may fuse helium in core hot-spots, causing an unstable and uneven reaction as well as a heavy solar wind. In this case, the star will form no planetary nebula but simply evaporate, leaving little more than a brown dwarf. But a star of less than about 0.5 solar mass will never be able to fuse helium even after the core ceases hydrogen fusion. There simply is not a stellar envelope massive enough to bear down enough pressure on the core. These are the red dwarfs, such as Proxima Centauri, some of which will live thousands of times longer than the Sun. Recent astrophysical models suggest that red dwarfs of 0.1 solar masses may stay on the main sequence for almost six trillion years, and take several hundred billion more to slowly collapse into a white dwarf. (S&T, 22)

Mid-sized stars Once a medium-size star (between 0.4 and 3.4 solar masses) has reached the red giant phase, its outer layers continue to expand, the core contracts inward, and helium begins to fuse into carbon. In stars of less than 1.4 solar masses, the helium fusion process begins with an explosive burst of energy generation known as a helium flash.

Helium burning reactions are extremely sensitive to temperature, which causes great instability. Huge pulsations build up, which eventually give the outer layers of the star enough kinetic energy to be ejected as a planetary nebula. At the center of the nebula remains the core of the star, which cools down to become a small but dense white dwarf, typically weighing about 0.6 solar masses, but only the volume of the Earth.

White dwarfs White dwarfs are stable because the inward pull of gravity is balanced by the degeneracy pressure of the star's electrons. (This is a consequence of the Pauli exclusion principle.) With no fuel left to burn, the star radiates its remaining heat into space for thousands of millions of years. In the end, all that remains is a cold dark mass sometimes called a black dwarf. However, the universe is not old enough for any black dwarf stars to exist.

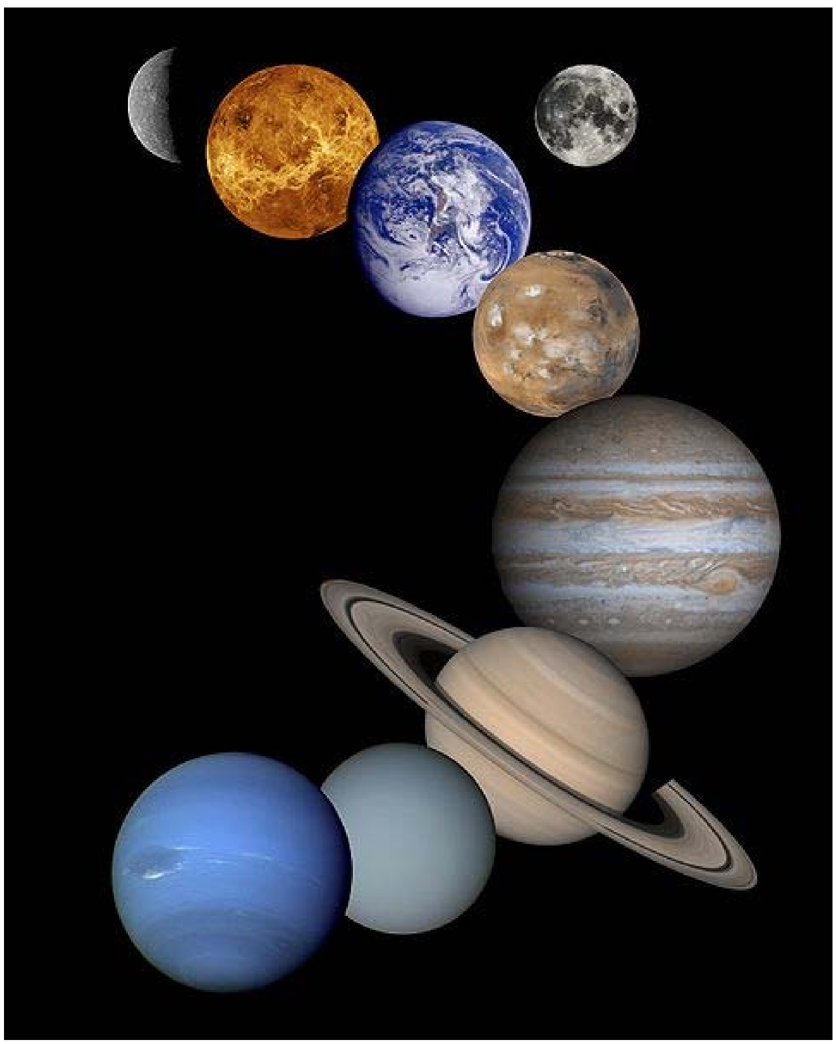
Supermassive stars After the outer layers of a star greater than five solar masses have swollen into a gigantic red supergiant, the core begins to yield to gravity and starts to shrink. As it shrinks, it grows hotter and denser, and a new series of nuclear reactions begin to occur. These reactions fuse progressively heavier elements, temporarily halting the collapse of the core.

Neutron stars

It is known that in some supernovae, the intense gravity inside the supergiant forces the electrons into the atomic nuclei, where they combine with the protons to form neutrons. The electromagnetic forces keeping separate nuclei apart are gone (proportionally, if nuclei were the size of dust motes, atoms would be as large as football stadiums), and the entire core of the star becomes nothing but a dense ball of contiguous neutrons or a single atomic nucleus.

Black holes: It is widely believed that not all supernovae form neutron stars. If the stellar mass is high enough, the neutrons themselves will be crushed and the star will collapse until its radius is smaller than the Schwarzschild radius. The star has then become a black hole.

Non-Earth planetary science



Solar System Planets

Planetary Processes, General includes Planetary science, Planets, Extrasolar Planet, Dwarf Planets, Comets, Asteroids and others.

Geophysics is the study of the Earth by quantitative physical methods, especially by seismic, electromagnetic, and radioactivity methods, therefore **Planetary Geophysics** is the study of the planets by quantitative physical methods, especially by seismic, electromagnetic, and radioactivity methods. It includes the branches of: Seismology (earthquakes and elastic waves), planetary gravity, geodesy, Tectonophysics (geological processes in the planets), Mineral Physics and others. Geophysics can be both a part of physics and a part of Geology.

Geodesy of The Solar System, also called **geodetics** of the solar system, is the scientific discipline that deals with the measurement and representation of the planets of the Solar System, their gravitational fields and geodynamic phenomena (polar motion in three-dimensional, time-varying space. The science of geodesy has elements of both astrophysics and planetary sciences. The shape of the Earth is to a large extent the result of its rotation, which causes its equatorial bulge, and the competition of geologic processes such as the collision of plates and of vulcanism, resisted by the Earth's gravity field. These principles can be applied to the solid surface of Earth (orogeny; Few mountains are higher than 10 km, few deep sea trenches deeper than that because quite simply, a mountain as tall as, for example, 15 km, would develop so much pressure at its base, due to gravity, that the rock there would become plastic, and the mountain would slump back to a height of roughly 10 km in a geologically insignificant time. Some or all of these geologic principles can be applied to other planets besides Earth. For instance on Mars, whose surface gravity is much less, the largest volcano, Olympus Mons, is 27 km high at its peak, a height that could not be maintained on Earth. The Earth geoid is essentially the figure of the Earth abstracted from its topographic features. Therefore the Mars geoid is essentially the figure of Mars abstracted from its topographic features. Surveying and mapping are two important fields of application of geodesy.

Physics is the underlying physical science of any planet, yet many aspects of planets are not best described through their physics. **Planetary science** is the general term for ALL physical sciences that can be applied to planets in the Universe or else to a particular planet. **Planetary science of the Earth** is the overall physical science containing all the physical sciences related directly to our Earth. Planetary Science can be broadly divided into several major sciences: Geology, Oceanography and Atmospheres.

Geology of Solar System Planets contains Geology of Mercury, Geology of Venus, Geology of the Moon, Geology of Mars, Geology of Jupiter, Geology of Saturn, Geology of Uranus Geology of Neptune, Geology of Pluto

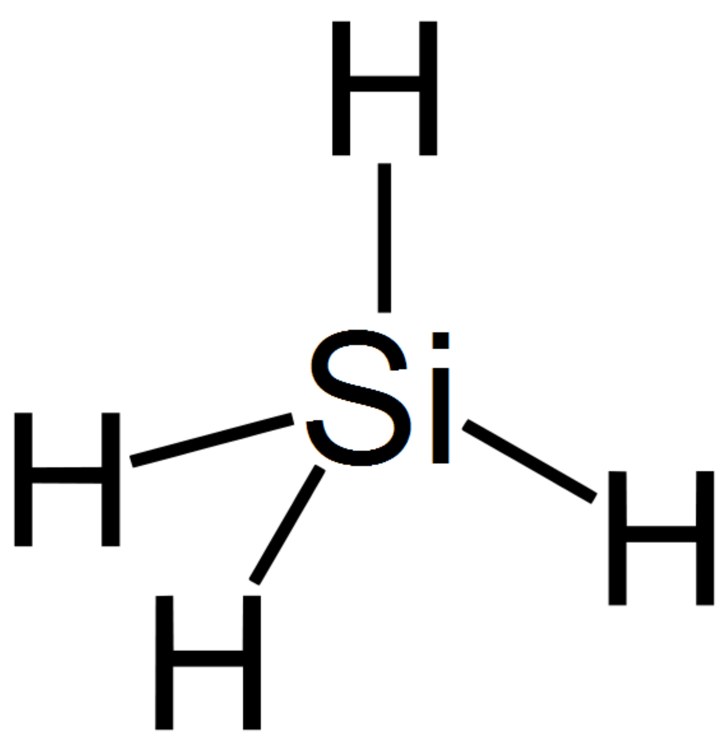
Geology of Other Planets Planetary geology (sometimes known as Astrogeology) refers to the application of geologic principles to other bodies of the solar system. However, specialised terms such as *selenology* (studies of the Moon), *areology* (of Mars), etc., are also in use. Most of the geological sciences related to the Earth can be directly applied to the study of non-Earth planets: **Geology Fields or related disciplines** Structural geology, Geomorphology., Economic geology, Mining geology, Geodetics, Geomorphology, Geophysics, Historical geology, Hydrogeology or geohydrology, Mineralogy, Paleoclimatology, Sedimentology, Seismology, Stratigraphy, Structural geology, Volcanology,**Hydrology**. Geothermometry (heating of the earth, heat flow, volcanology, and hot springs), Hydrology (ground and surface water, sometimes including glaciology).

Extrasolar Geology is currently a young science because only recently have extrasolar planets been found.

Atmospheres of Solar System Planets refers to the application of meteorological principles to other bodies of the solar system including the application of: Atmospheric electricity and terrestrial magnetism (including ionosphere, Van Allen belts, telluric currents, Radiant energy, etc.), Meteorology and Climatology. Aeronomy the study of the physical structure and chemistry of the atmosphere.

Atmospheres of Extrasolar Planets is currently a young science because only recently have extrasolar planets been found. Astronomers are currently theorizing that the recently discovered extrasolar Jupiter-sized planets have continuous surface winds of many thousands of miles per hour caused by their highly elliptical orbit which brings them close to their parent star.

Exobiology / Extraterrestrial life



Silicon Based Life. A picture of silane, the silicon-based analogue of methane.

Earth telescopes can resolve some surface features of the nearby planets and so far, no life can be seen through the telescopes. However, Earth telescopes cannot resolve the surface features of any planet outside the solar system, so the search for life on other planets continues. While no incontestable evidence has been found for life outside of Earth, the scientific study of the theoretical basis for life on other bodies is progressing. Some scientists are trying to theorize which kinds of stars would have planets that hold life. Because life has overall fragile parameters for survival the general consensus is that only older stars would have planets circling them with life. From this they theorize which sections of our Milky Way Galaxy would most likely hold life. Other scientists theorize the quantity of civilizations that might exist in a galaxy and others are actually listening for the possible radio chatter of extraterrestrial technical civilizations. These sub-sciences of exobilogy can be categorized as follows:

Habitable Zone Astrobiology is discussed in Galactic Habitable Zone and Solar System Habitable Zone.

Astrobiochemistry Exogenesis Most scientists hold that if extraterrestrial life exists, its evolution would have occurred independently in different places in the universe. An alternative hypothesis, held by a minority, is panspermia, which suggests that life in the universe could have stemmed from a smaller number of points of origin, and then spread across the universe, from habitable planet to habitable planet. These two hypotheses are not mutually exclusive. **Alternative biochemistry** includes **Alternative Carbon Biochemistry** where water is not the Solvent of Carbon Chains: Life forms based in ammonia rather than water are also considered, though this solution appears less optimal than water. Also included is **Alternative Non-Carbon Biochemistry**: Non-carbon based chemistry Silicon is usually considered the most likely alternative to carbon, though this remains improbable. Silicon life forms are proposed to have a crystalline morphology, and are theorized to be able to exist in high temperatures, such as planets closer to the sun.

Astrobiosphere is the entire area of a planet that supports life and includes Biosphere, Theory of Biosphere, Planetary Habitability Extrasolar planets Astronomers also search for extrasolar planets that would be conducive to life, especially those like OGLE-2005-BLG-390Lb which have been found to have Earth-like qualities.

Plants On Other Planets includes Extremophiles, Theoretical Astrobotany, Life On Jupiter, Life on Mars scientific theory, Independently in 1996 structures resembling bacteria were reportedly discovered in a meteorite, ALH84001, thought to be formed of rock ejected from Mars. This report is also controversial and scientific debate continues.

Humanoids-On-Other-Planets includes Humanoids-On-Other-Planets Origins-Speculations And Scientific Theory Panspermia. Extraterrestrial life along with the biochemical basis of extraterrestrial life, there remains a broader consideration of evolution and morphology.

Humanoids-On-Other-Planets Technical Civilizations includes Humanoids-On-Other-Planets Technical-Civilizations, Speculation And Theory.

Humanoids-On-Other-Planets Technical-Civilizations, Migrations Most scientists hold that if extraterrestrial life exists, its evolution would have occurred independently in different places in the universe. An alternative hypothesis, held by a minority, is panspermia, which suggests that life in the universe could have stemmed from a smaller number of points of origin, and then spread across the universe, from habitable planet to habitable planet.

Humanoids-On-Other-Planets Technical-Civilizations, Quantity of Drake Equation

Humanoids-On-Other-Planets-Civilizations On Local Stars includes Search For Humanoids-On-Other-Planets-Civilizations On Local-Stars, SETI

Space exploration through space travel

Orion approaching the ISS

Astronomy is exploration of space through instruments based on Earth. Space Exploration through space travel is exploration of space by travel through it, either in person or by drone. Closely associated with Space travel is Space Station, either manned or unmanned. All man-made satellites are a form of unmanned or manned space stations.

Unmanned Space travel includes the sciences of Spacecraft Propulsion, Rocket launch technology, Rocket, Astrodynamics, Unmanned space missions, and others.

Manned Space travel further includes the sciences of Microgravity environment, Space transport, Manned space missions, Interplanetary travel, Interstellar travel and Generation ship.

Unmanned space station

There are Astronomical satellites, Biosatellites, Communications satellites, Miniaturized satellites, Navigation satellites, Reconnaissance satellites, Earth observation satellites, Earth observation satellites and others. There are many different kinds of orbits possible for these devices.

Manned Space Station includes the sciences of Space Station and Floating cities.

Space colonization

Space colonization is a colossal science that includes all of the scientific disciplines needed to be able to build colonies on non-Earth planets and planetoids.

Space Colonization Justification includes the sciences of Space and survival.

Space Colony Research And Development Man can practice living on other worlds by building permanently inhabitable cities in extremely hostile environments of the Earth: The poles and the deserts. This is discussed in Biosphere 2 and BIOS-3. Currently manned Earth hostile-environment stations include Amundsen-Scott South Pole Station, Devon Island, Mars Arctic Research Station, Mars Desert Research Station, climate, underwater structures for planets with oceans or very heavy atmospheres and others.

Space Colony Location is the science of figuring out the best planets and the best locations on those planets for colonization. Because water is such a necessity for human survival most searches are for locations close to some kind of water. These issues and other related issues are discussed in Colonization of Mars, Mars Society, Colonization of Mercury, Colonization of Venus, Venusian terraforming, Colonization of the Moon, Artemis Project, Europa, Phobos, Colonization of the asteroids and others.

Space Colonization Habitat science includes Space habitat, Human adaptation to space, Manmade closed ecological system, Planetary habitability, Domed city, Ocean colonization, Underground city and other sub-sciences. Further reading is available at Space Industrialization Dewy 629.44.

Space Colonization Health (Space Medicine Dewey 616.9)

Space Colonization Agriculture includes Biosphere 2 and BIOS-3 and others.

Space Colonization Food Processing includes Space food and others.

Space Colonization Housing includes International Space Station.

Space Colonization Clothing includes Space suits

Space Colonization Construction includes Orbital Megastructures, station-keeping, Amundsen-Scott South Pole Station, Devon Island, Mars Arctic Research Station, Mars Desert Research Station, climate, underwater structures for planets with oceans or very heavy atmospheres and others.

Space Colonization Transportation includes Lunar rover

Space Colonization Materials includes Recycling

Space Colonization Energy includes Renewable energy

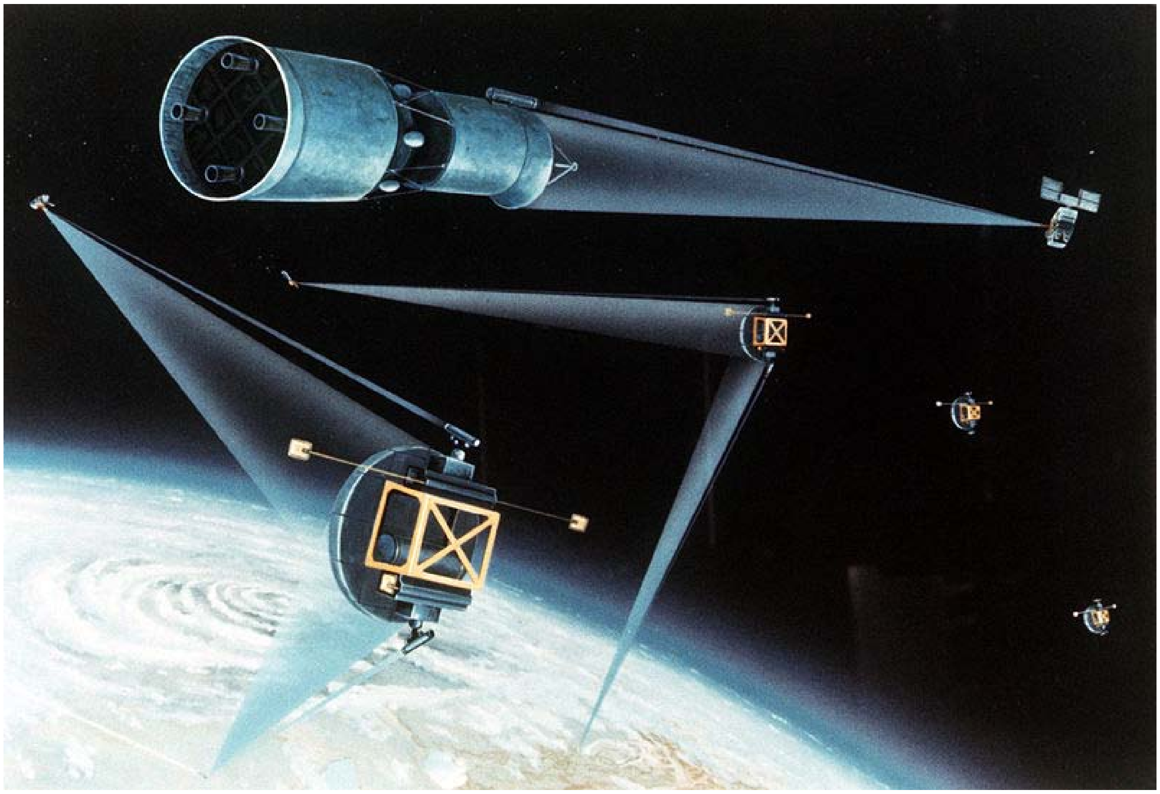
Space Colonization General Manufacturing includes Space Manufacturing

Space Colonization Economics includes Space Frontier Foundation, Private spaceflight and space tourism, solar power satellites, Asteroid mining, space manufacturing,

Space Colonization Operations includes space agencies, Space advocacy, Colonize the Cosmos, Artemis Project, National Space Society, Planetary Society, robotic exploration, search for extraterrestrial life, Space Settlement Institute, Students for the Exploration and Development of Space, NASA, ESA, Project Constellation

'*Space Colonization Law and Protection* includes Space Law

Space defense



Space Lasers

Space Defense is the science of defending the Earth from natural or unnatural threats from Space. Natural threats include Near Earth Asteroids and similar. Other issues are discussed in Missile Defense Command, United States Army Space and Missile Defense Command, Department of Defense Manned Space Flight Support Office, European Aeronautic Defense & Space and Joint Defense Space Research Facility.