All About

Human Spaceflight

(Spaceflight with a Human Crew)

Aimee Wallace

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Human Spaceflight

Edward White on a spacewalk during the Gemini 4 mission

Human spaceflight is spaceflight with a human crew and possibly passengers. This makes it unlike robotic space probes or remotely-controlled satellites. Human spaceflight is sometimes called **manned spaceflight**, a term now deprecated by major space agencies in favor of its gender-neutral alternative.

The first human spaceflight was accomplished on April 12, 1961 by Soviet cosmonaut Yuri Gagarin. The only countries to have independent human spaceflight capability are Russia, United States and China. As of 2010, human spaceflights are being actively launched by the Soyuz programme conducted by the Russian Federal Space Agency, the Space Shuttle program conducted by NASA, and the Shenzhou program conducted by the China National Space Administration.

The US will lose governmental human spaceflight launch capability upon retirement of the Space Shuttle, expected in 2011. Under the Bush administration, the Constellation program included plans for canceling the Shuttle and replacing it with the capability for spaceflight beyond low Earth orbit. In the 2011 United States federal budget, the Obama administration proposed canceling Constellation. Under the new plan, NASA would rely on transportation services provided by the private sector, such as Space X's Falcon 9. The period between the retirement of the Shuttle and the initial operational capability of new systems (either Constellation or the new commercial proposals), similar to the gap between the cancellation of Apollo and the first Space Shuttle flight, is often referred to as the human spaceflight gap.

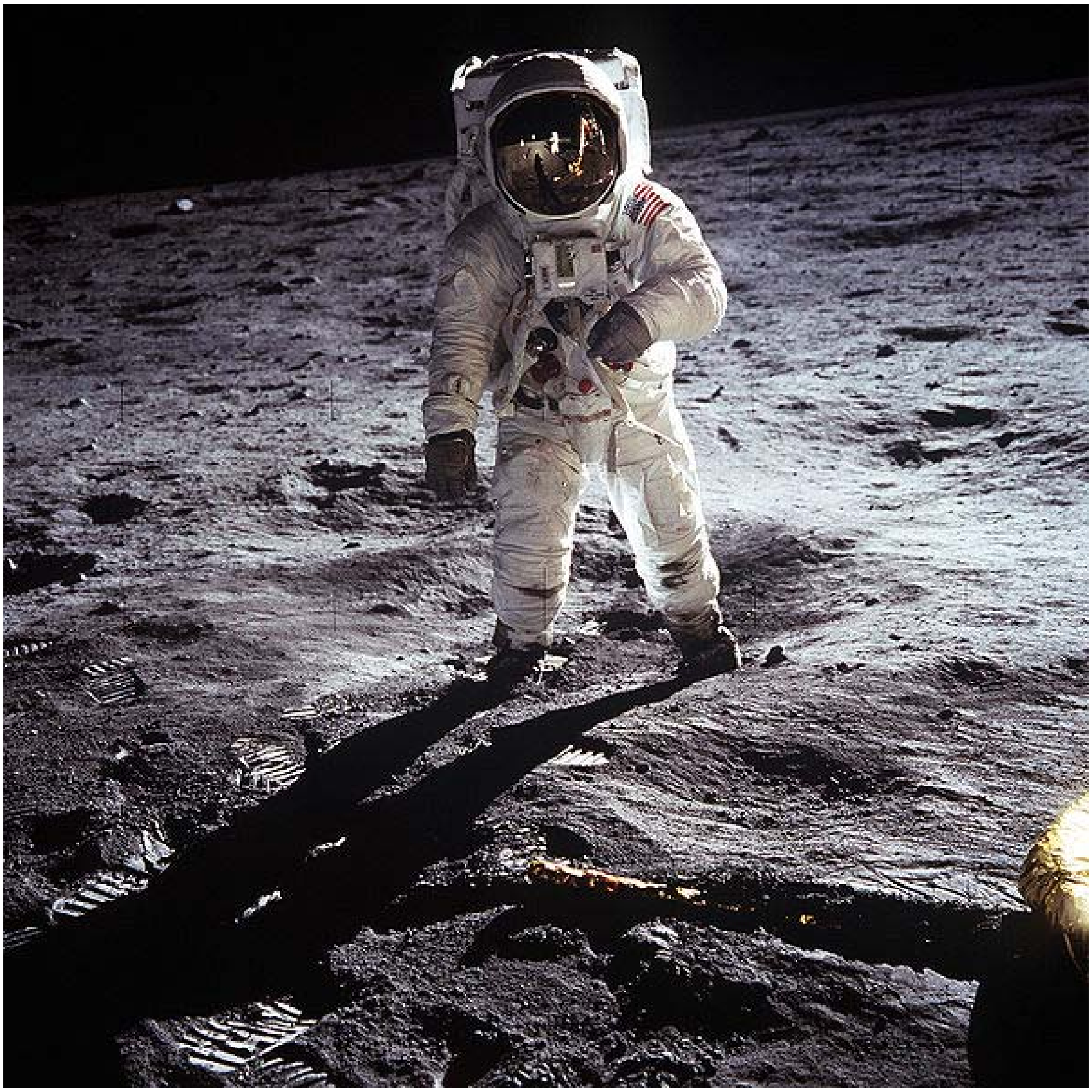
In recent years there has been a gradual movement towards more commercial forms of spaceflight. A number of non-governmental startup companies have sprung up in recent years, hoping to create a space tourism industry. For a list of such companies, and the spacecraft they are currently building. NASA has also tried to stimulate private spaceflight through programs such as Commercial Crew Development (CCDev) and Commercial Orbital Transportation Services (COTS). With its 2011 budget proposals released in early February 2010 , the Obama administration is moving towards a model where commercial companies would supply NASA with transportation services of both crew and cargo to low Earth orbit. The vehicles used for these services would then serve both NASA and potential commercial customers. NASA intends to spend $6 billion in the coming years to develop commercial crew vehicles, using a model similar to that used under COTS.

History

First human spaceflights

Yuri Gagarin, the first man in space, in his space suit during the Vostok 1 mission

The first human spaceflight took place on April 12, 1961, when cosmonaut Yuri Gagarin made one orbit around the Earth aboard the Vostok 1 spacecraft, launched by the Soviet space program and designed by the rocket scientist Sergey Korolyov. Valentina Tereshkova became the first woman in space on board Vostok 6 on June 16, 1963. Both spacecraft were launched by Vostok 3KA launch vehicles. Alexei Leonov made the first spacewalk when he left the Voskhod 2 on March 8, 1965. Svetlana Savitskaya became the first woman to do so on July 25, 1984.



Buzz Aldrin on the surface of the Moon during Apollo 11

The United States became the second nation to achieve manned spaceflight, with the suborbital flight of astronaut Alan Shepard aboard *Freedom 7*, carried out as part of Project Mercury. The spacecraft was launched on May 5, 1961 on a Redstone rocket. The first U.S. orbital flight was that of John Glenn aboard *Friendship 7*, which was launched February 20, 1962 on an Atlas rocket. Since 1981 the U.S. has conducted all its human spaceflight missions with reusable Space Shuttles. Sally Ride became the first American woman in space in 1983. Eileen Collins was the first female Shuttle pilot, and with Shuttle mission STS-93 in July 1999 she became the first woman to command a U.S. spacecraft.

The People's Republic of China became the third nation to achieve human spaceflight when Yang Liwei launched into space on a Chinese-made vehicle, the Shenzhou 5, on October 15, 2003. The flight made China the third nation to have launched its own manned spacecraft using its own launcher. Previous European (Hermes) and Japanese (HOPE-X) domestic manned programs were abandoned after years of development, as was the first Chinese attempt, the Shuguang spacecraft.

The farthest destination for a human spaceflight mission has been the Moon. The only missions to the Moon have been those conducted by NASA as part of the Apollo program. The first such mission, Apollo 8, orbited the Moon but did not land. The first Moon landing mission was Apollo 11, during which—on July 20, 1969—Neil Armstrong and Buzz Aldrin became the first people to set foot on the Moon. Six missions landed in total, numbered Apollo 11–17, excluding Apollo 13. Altogether twelve men walked on the Moon, the only humans to have been on an extraterrestrial body. The Soviet Union discontinued its program for lunar orbiting and landing of human spaceflight missions on June 24, 1974 when Valentin Glushko became General Designer of NPO Energiya.

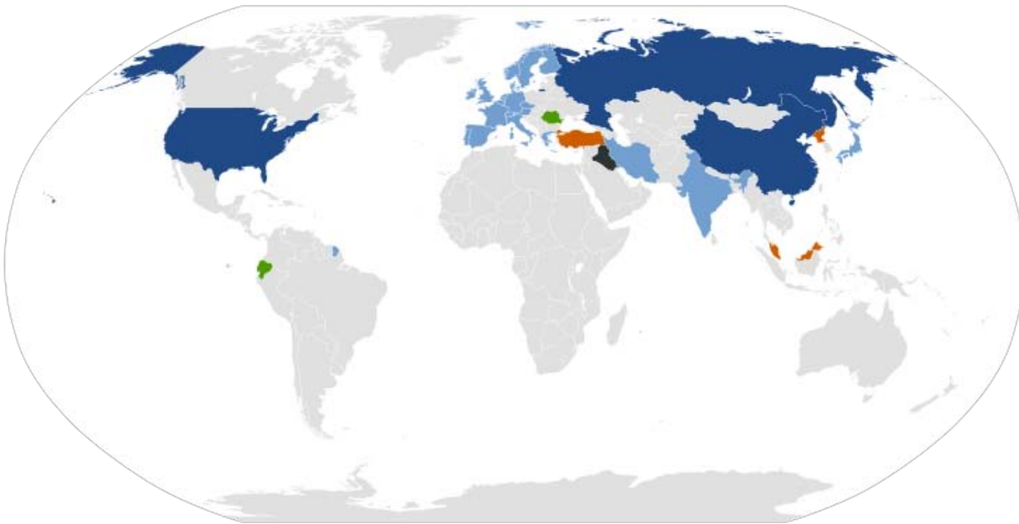
The longest single human spaceflight is that of Valeriy Polyakov, who left earth on January 8, 1994, and didn't return until March 22, 1995 (a total of 437 days 17 hr. 58 min. 16 sec. aboard). Sergei Krikalyov has spent the most time of anyone in space, 803 days, 9 hours, and 39 seconds altogether. The longest period of continuous human presence in space lasted as long as 3,644 days, eight days short of 10 years, spanning the launch of Soyuz TM-8 on September 5, 1989 to the landing of Soyuz TM-29 on August 28, 1999.

For many years beginning in 1961, only two countries, the USSR (later Russia) and United States, had their own astronauts. Citizens of other nations flew in space, beginning with the flight of Vladimir Remek, a Czech, on a Soviet spacecraft on March 2, 1978. As of 2010, citizens from 38 nations (including space tourists) have flown in space aboard Soviet, American, Russian, and Chinese spacecraft.

Space programs

As of 2010, human spaceflight missions have been conducted by the former Soviet Union/(Russia), the United States, the People's Republic of China and by the private spaceflight company Scaled Composites.

Several other countries and space agencies have announced and begun human spaceflight programs by their own technology, including India (ISRO), Ecuador (EXA), Japan (JAXA), Iran (ISA) and Malaysia (MNSA).



Countries which have human spaceflight agendas.

Currently the following spacecraft and spaceports are used for launching human spaceflights:

- Soyuz with Soyuz rocket—Baikonur Cosmodrome
- Space Shuttle—Kennedy Space Center
- International Space Station (ISS)—Assembled in orbit; crews transported by the previous two spacecraft
- Shenzhou spacecraft with Long March rocket—Jiuquan Satellite Launch Center

Historically, the following spacecraft and spaceports have also been used for human spaceflight launches:

- Vostok—Baikonur Cosmodrome
- Mercury—Cape Canaveral Air Force Station
- Voskhod—Baikonur Cosmodrome
- X-15—Edwards Air Force Base, (two internationally recognized suborbital flights in program)
- Gemini—Cape Canaveral Air Force Station
- Apollo—Kennedy Space Center (Apollo 7 at Cape Canaveral Air Force Station)
- Salyut space station—Baikonur Cosmodrome
- Almaz space station—Baikonur Cosmodrome (Almaz was a series of military space stations under cover of the civilian name Salyut)
- Skylab space station—Kennedy Space Center
- Mir space station—Baikonur Cosmodrome
- SpaceShipOne with White Knight—Mojave Spaceport

Numerous private companies attempted human spaceflight programs in an effort to win the $10 million Ansari X Prize. The first private human spaceflight took place on June

21, 2004, when SpaceShipOne conducted a suborbital flight. SpaceShipOne captured the prize on October 4, 2004, when it accomplished two consecutive flights within one week. SpaceShipTwo, launching from the carrier aircraft White Knight Two, is planned to conduct regular suborbital space tourism.

Most of the time, the only humans in space are those aboard the ISS, whose crew of six spends up to six months at a time in low Earth orbit.

NASA and ESA now use the term "human spaceflight" to refer to their programs of launching people into space. Traditionally, these endeavors have been referred to as "manned space missions."

National spacefaring attempts

Successfully executed manned programs are in **bold**.
Suborbital spaceflights are in *italics*.

Nation/Organization	Space agency	National term	First launched astronaut	Date	Spacecraft	Launcher
Soviet Union	Soviet space program (OKB-1 Design Bureau)	cosmonaut космонавт (Russian) kosmonavt	Yuri Gagarin	April 12, 1961	Vostok spacecraft	Vostok
United States	National Aeronautics and Space Administration (NASA)	astronaut	Alan Shepard	May 5, 1961	Mercury spacecraft	Redstone
China	China space program	宇航员 (Chinese) yǔhángyuán 航天员 (Chinese) hángtiānyuán	...	1973 (abandoned)	Shuguang 1	Long March 2A
China	China space program	宇航员 (Chinese) yǔhángyuán 航天员 (Chinese) hángtiānyuán	...	1981 (abandoned)	Piloted FSW	Long March 2
ESA	European Space Agency (ESA)	astronaut spationaut spationaute (French)	...	1992 (abandoned)	Hermes	Ariane V
Iraq	...	رجل فضاء (Arabic) rajul faḍā’ رائد فضاء (Arabic) rā’ib fa ḍā’ ملاح فضائي (Arabic) mallāḥ faḍā’iy	...	2001 (abandoned)	...	Tammouz 2 or 3
Japan	Japan Aerospace Exploration Agency (JAXA)	宇宙飛行士 (Japanese) uchūhikōshi	...	2003 (abandoned)	HOPE-X	H-II

China	China National Space Administration (CNSA)	taikonaut 太空人 (Chinese) tàikōng rén 宇航员 (Chinese) yǔhángyuán 航天员 (Chinese) hángtiānyuán	Yang Liwei	October 15, 2003	Shenzhou spacecraft	Long March 2F
India	Indian Space Research Organisation (ISRO)	vyomanaut gaganaut aakashagaami □□□□□□□□: (Sanskrit) brahmāndagaami □□□□□□□□□□□□□□: (Sanskrit) antarikshyaatri □□□□□□□□□□□□□□□: (Sanskrit)	...	2016 (approved)	Orbital Vehicle (OV)	GSLV Mk II
Iran	Iranian Space Agency (ISA)	فضانورد (Persian) faza navard	...	2017 (planned)	ISA manned spacecraft	...
ESA	European Space Agency (ESA)	astronaut spationaut spationaute (French)	...	2020 (approved conceptually but full development not begun)	ARV phase-2 (may be changed to CSTS)	Ariane V
Japan	Japan Aerospace Exploration Agency (JAXA)	宇宙飛行士 (Japanese) uchūhikōshi	...	2025 (planned)	HTV-based spacecraft	H-IIB
Romania	Romanian Cosmonautics and Aeronautics Association (ARCASPACE)	astronaut astronaut (Romanian)	...	TBA (approved)	Stabilo-mission8	ARCASPACE air-balloon

Safety concerns

Planners of human spaceflight missions face a number of safety concerns.

Life support

The immediate needs for breathable air and drinkable water are addressed by the life support system of the spacecraft.

Medical issues

Effects of microgravity

Medical data from astronauts in low earth orbits for long periods, dating back to the 1970s, show several adverse effects of a microgravity environment: loss of bone density, decreased muscle strength and endurance, postural instability, and reductions in aerobic capacity. Over time these deconditioning effects can impair astronauts' performance or increase their risk of injury.

In a weightless environment, astronauts put almost no weight on the back muscles or leg muscles used for standing up. Those muscles then start to weaken and eventually get smaller. If there is an emergency at landing, the loss of muscles, and consequently the loss of strength can be a serious problem. Sometimes, astronauts can lose up to 25% of their muscle mass on long term flights. When they get back to ground, they will be considerably weakened and will be out of action for a while.

Astronauts experiencing weightlessness will often lose their orientation, get motion sickness, and lose their sense of direction as their bodies try to get used to a weightless environment. When they get back to Earth, or any other mass with gravity, they have to readjust to the gravity and may have problems standing up, focusing their gaze, walking and turning. Importantly, those body motor disturbances after changing from different gravities only get worse the longer the exposure to little gravity. These changes will affect operational activities including approach and landing, docking, remote manipulation, and emergencies that may happen while landing. This can be a major roadblock to mission success.

Radiation

Without proper shielding the crews of missions beyond low Earth orbit (LEO) might be at risk from high-energy protons emitted by solar flares. Lawrence Townsend of the University of Tennessee and others have studied the most powerful solar flare ever recorded. That flare was seen by the British astronomer Richard Carrington in September 1859. Radiation doses astronauts would receive from a Carrington-type flare could cause acute radiation sickness and possibly even death.

Another type of radiation, galactic cosmic rays, present further challenges to human spaceflight beyond LEO.

Radiation damage to the immune system

There is also some scientific concern that extended space flight might slow down the body's ability to protect itself against diseases. Some of the problems are a weakened immune system and the activation of dormant viruses in the body. Radiation can cause both short and long term consequences to the bone marrow stem cells which create the blood and immune systems. Because the interior of a spacecraft is so small, a weakened immune system and more active viruses in the body can lead to a fast spread of infection.

Isolation

During long missions, astronauts are isolated and confined into small spaces. Depression, cabin fever and other psychological problems may result that impact crew safety and mission success.

Astronauts may not be able to quickly return to Earth or receive medical supplies, equipment or personnel if a medical emergency occurs. The astronauts may have to rely for long periods on their limited existing resources and medical advice from the ground.

Reentry safety

Reliability

Fatality risk

As of 2009, 18 crew members have died during actual spaceflight missions (see table). Over 100 others have died in accidents during activity directly related to spaceflight missions or testing.

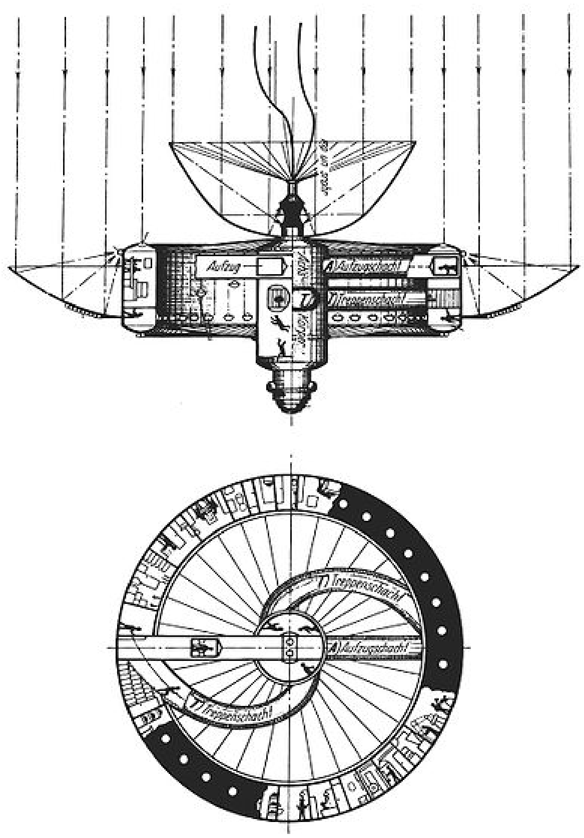
Year	# of Deaths	Mission	Known or likely cause
1967	1	Soyuz 1	
1971	3	Soyuz 11	Asphyxia
1986	7	Space Shuttle Challenger	(mission never reached space)
2003	7	Space Shuttle Columbia	Asphyxia from cabin breach, trauma from object impact, or burns from re-entry heat

Chapter- 2

History of Spaceflight

Spaceflight, particularly human spaceflight, has long been a dream of humankind, but it was only in the 20th century that it became a reality.

Background



Description of a space station in Hermann Noordung's *The Problem of Space Travel* (1929).

The realistic proposal of spaceflight 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. This paper was highly influential on Hermann Oberth and Wernher Von Braun, later key players in spaceflight.

In 1929, the Slovene officer Hermann Noordung was the first to imagine a quite complete space station in his book *The Problem of Space Travel*.

The first rocket to reach space was a German V-2 Rocket, on a test flight in June 1944.

Space Race

Orbital space flight, both unmanned and manned, was first developed by the Soviet Union and the United States during the Cold War, in a competition dubbed the *Space Race*.

The race began on July 29, 1957, when the US announced at the convention of the 1957-1958 International Geophysical Year, its intent to launch an artificial satellite known as Vanguard by the spring of 1958. The Soviets reacted on July 31 by announcing they would launch a satellite in the fall of 1957. They succeeded in launching Sputnik 1 on October 4, 1957. After a series of Vanguard failures, the US succeeded in launching its first satellite, Explorer 1 on February 1, 1958. This carried scientific instrumentation and detected the theorized Van Allen radiation belt.

The US public shock over Sputnik 1 became known as the Sputnik crisis. On July 29, 1958, the US Congress passed legislation turning the National Advisory Committee for Aeronautics (NACA) into the National Aeronautics and Space Administration (NASA) with responsibility for the nation's civilian space programs. In 1959, NASA began Project Mercury to launch single-man capsules into Earth orbit, and chose a corps of seven astronauts introduced as the *Mercury Seven*.

Yuri Gagarin, the first man in space, in his space suit in preparation for the Vostok 1 mission

On April 12, 1961, the USSR announced the successful launch and return of its first *cosmonaut* (their chosen term for space travelers), Yuri Gagarin who made a single orbit aboard Vostok 1. On May 5, 1961 the US launched its first Mercury astronaut Alan Shepard in a capsule he named Freedom 7, but on a suborbital flight.

John Glenn, Jr., as he enters his Friendship 7 spacecraft (NASA)

The US public was becoming increasingly shocked and alarmed at the widening lead obtained by the USSR, so President John F. Kennedy announced on May 25 a plan to land a man on the moon by 1970, launching the three-man Apollo program. In January

1962, NASA announced a two-man spacecraft program named Project Gemini to support Apollo.

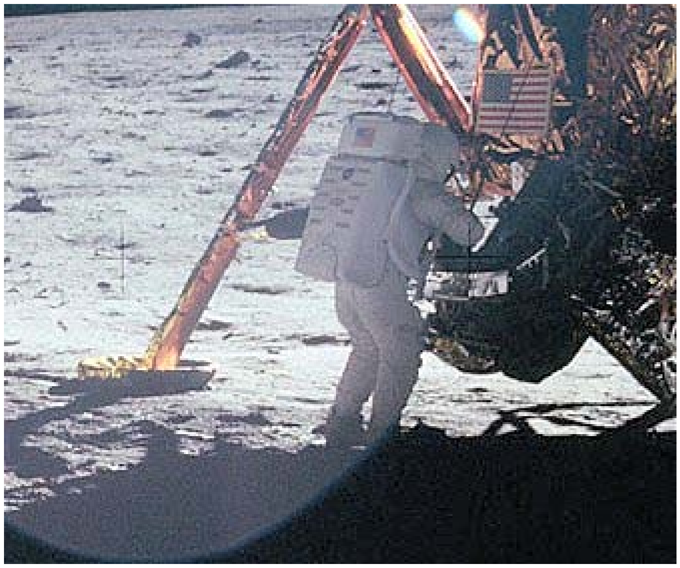
After one more suborbital Mercury flight, the US launched John Glenn to make three orbits in Friendship 7 on February 20, 1962. Project Mercury launched a total of six astronauts by May 16, 1963. The Soviets launched five more cosmonauts, including the first woman in space, the civilian parachutist Valentina Tereshkova in Vostok 6 on June 16, 1963, though this was done for political propaganda rather than a commitment to women's equality.

The Soviet government pressured its chief spacecraft designer, Sergey Korolyov, to quickly produce greater space achievements in competition with the announced Gemini and Apollo plans. Rather than allowing him to develop his plans for a crewed Soyuz spacecraft, he was forced to make modifications to squeeze two or three men into the Vostok capsule, calling the result Voskhod. Only two of these were launched. Voskhod 1 was the first spacecraft with a crew of three, who could not wear space suits because of size and weight constrictions. Alexei Leonov made the first spacewalk when he left the Voskhod 2 on March 8, 1965. He was almost lost in space when he had extreme difficulty fitting his inflated space suit back into the cabin through an airlock, and a landing error forced him and his crewmate to be lost in dangerous woods for hours before being found by the recovery crew.

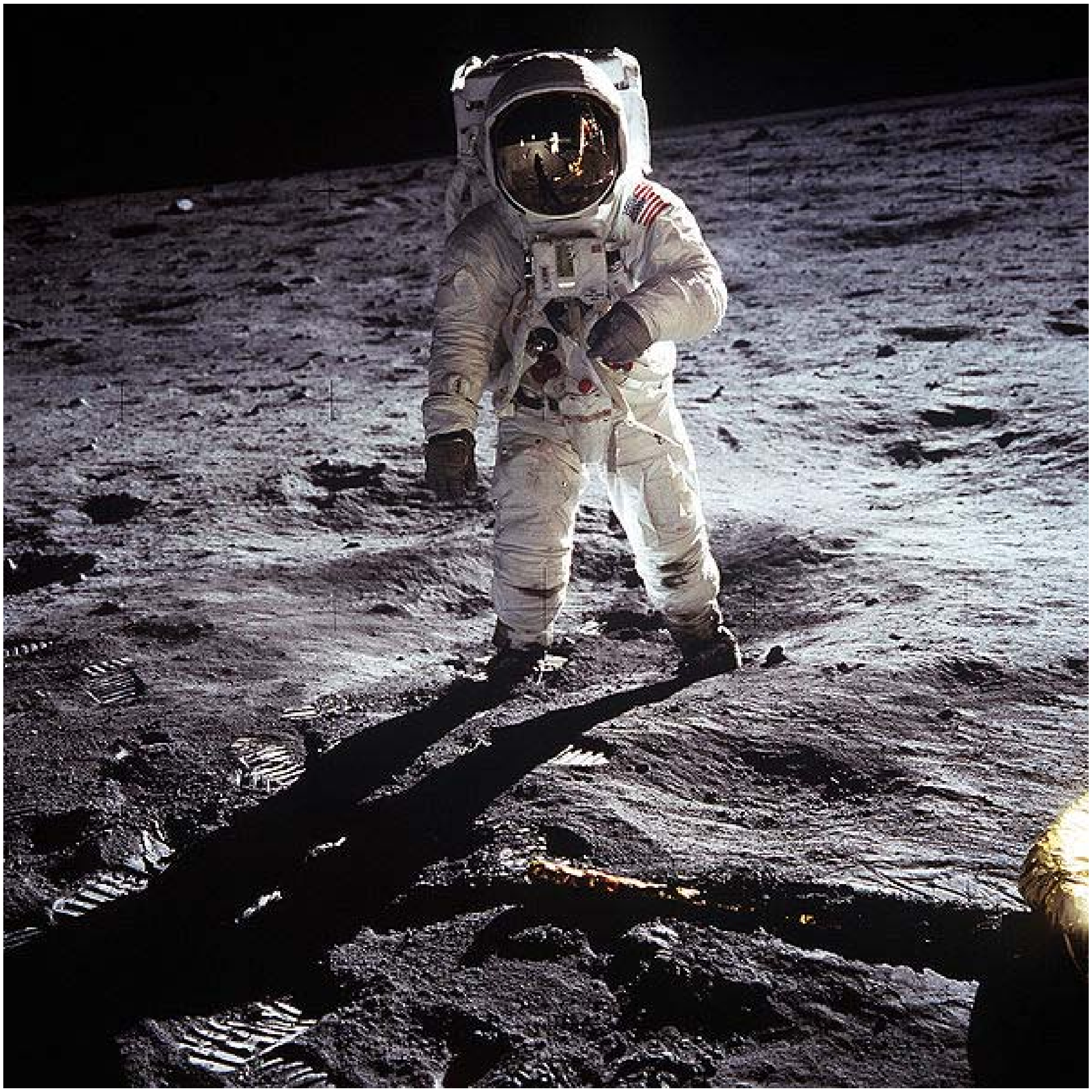
The start of manned Gemini missions was delayed a year later than NASA had planned, but ten largely successful missions were launched in 1965 and 1966, allowing the US to overtake the Soviet lead by achieving space rendezvous (Gemini 6A) and docking (Gemini 8) of two vehicles, long duration flights of eight days (Gemini 5) and fourteen days (Gemini 7), and demonstrating the use of extra-vehicular activity to do useful work outside a spacecraft (Gemini 12).

The USSR made no manned flights during this period, but continued to develop its Soyuz craft and secretly accepted Kennedy's implicit lunar challenge, designing Soyuz variants for lunar orbit and landing. They also attempted to develop the N1, a large, manned moon-capable launch vehicle similar to the US Saturn V.

As both nations rushed to get their new spacecraft flying with men, the intensity of the competition caught up to them in early 1967, when they suffered their first crew fatalities. On January 27, the entire crew of Apollo 1, "Gus" Grissom, Ed White, and Roger Chaffee, were killed by suffocation in a fire that swept through their cabin during a ground test approximately one month before their planned launch. Then on April 24, the single pilot of Soyuz 1, Vladimir Komarov, was killed in a crash when his landing parachutes tangled, after a mission cut short by electrical and control system problems. Both accidents were determined to be caused by design defects in the spacecraft, which were corrected before manned flights resumed.



Neil Armstrong works at the LM in one of the few photos taken of him from the lunar surface. NASA photo AS11-40-5886.



Buzz Aldrin poses on the Moon allowing Neil Armstrong to photograph both of them using the visor's reflection.

The US succeeded in achieving President Kennedy's goal on July 20, 1969, with the landing of Apollo 11. Neil Armstrong and Buzz Aldrin became the first men to set foot on the Moon. Six such successful landings were achieved through 1972, with one failure on Apollo 13.

The N1 rocket suffered four catastrophic unmanned launch failures between 1969 and 1972, and the Soviet government officially discontinued its manned lunar program on June 24, 1974 when Valentin Glushko succeeded Korolyov as General spacecraft Designer.

Both nations went on to fly relatively small, non-permanent manned space laboratories Salyut and Skylab, using their Soyuz and Apollo craft as shuttles. The US launched only one Skylab, but the USSR launched a total of seven "Salyuts", three of which were secretly Almaz military manned reconnaissance stations, which carried "defensive" cannons. Manned reconnaissance stations were found to be a bad idea, since unmanned satellites could do the job much more cost-effectively. The United States Air Force had planned a manned reconnaissance station, the Manned Orbital Laboratory which was cancelled in 1969. The Soviets cancelled Almaz in 1978.

In a season of detente, the two competitors declared an end to the race and shook hands (literally) on July 17, 1975 with the Apollo-Soyuz Test Project, where the two craft docked and the crews exchanged visits.

Post-Space Race US and Russian programs

US Space Shuttle

The Space Shuttle Columbia seconds after engine ignition, 1981 (NASA).

Although its pace slowed, space exploration continued after the end of the Space Race. The United States launched the first reusable spacecraft (Space Shuttle) on the 20th anniversary of Gagarin's flight, 12 April 1981. On 15 November 1988, the Soviet Union attempted to duplicate this with the Buran shuttle, its first and only reusable spacecraft. It was never been used again after the first flight; instead the Soviet Union continued to develop space stations using the Soyuz craft as the crew shuttle.

Sally Ride became the first American woman in space in 1983. Eileen Collins was the first female Shuttle pilot, and with Shuttle mission STS-93 in July 1999 she became the first woman to command a U.S. spacecraft.

The longest single human spaceflight is that of Valeriy Polyakov, who left earth on January 8, 1994, and didn't return until March 22, 1995 (a total of 437 days 17 hr. 58 min. 16 sec. aboard). Sergei Krikalyov has spent the most time of anyone in space, 803 days, 9 hours, and 39 seconds altogether. The longest period of continuous human presence in space lasted as long as 3,644 days, eight days short of 10 years, spanning the launch of Soyuz TM-8 on September 5, 1989 to the landing of Soyuz TM-29 on August 28, 1999.

International Space Station

Recent space exploration has proceeded, to some extent in worldwide cooperation, the high point of which was the construction and operation of the International Space Station. At the same time, the international space race between smaller space powers since the end of the 20th century can be considered the foundation and expansion of markets of commercial rocket launches and space tourism.

The United States continued missions to the ISS and other goals with the high-cost shuttle system, which will be retired in 2010. It also continues other space exploration, including major participation with the ISS with its own modules. It also plans a set of unmanned Mars probes, military satellites, and more. The Constellation space program, begun by President George W. Bush in 2004, aimed to launch a next-generation multifunction Orion spacecraft by 2018. A subsequent return to the Moon by 2020 was to be followed by manned flights to Mars, but the program was canceled in 2010 in favor of encouraging commercial US manned launch capabilities.

Russia, the successor to the Soviet Union, has high potential but smaller funding. Its own space programs, some of a military nature, perform several functions. They offer a wide commercial launch service while continuing to support the ISS with a several of their own modules. They also operate manned and cargo spacecrafts which will continue after US Shuttle program ends. They are developing a new multi-function PPTS manned spacecraft for use in 2018 and have plans to perform manned moon missions also. The program aims to put a man on the moon in the 2020s, becoming the second country to do so.

Programs of other nations

Later, cosmonauts and astronauts from other nations flew in space, beginning with the flight of Vladimir Remek, a Czech, on a Soviet spacecraft on March 2, 1978. As of 2007, citizens from 33 nations (including space tourists) have flown in space aboard Soviet, American, Russian, and Chinese spacecraft.

China, India, and Japan are increasingly capable of competing in space research and activity. These nations form the main players in the Asian space race.

European Union

The European Space Agency has taken the lead in commercial unmanned launches since the introduction of the Ariane 4 in 1988, but is in competition with NASA, Russia, Sea Launch (private), China, India and others. The ESA-designed manned shuttle Hermes and space station **Columbus**, were under development early on in Europe, however these projects were canceled, and Europe did not become the third major "space power".

Europe has launched various satellites, has utilized the manned Spacelab module aboard US shuttles, and has sent probes to comets and Mars. It also participates in **ISS** with its own module and the unmanned cargo spacecraft ATV.

Currently ESA has a program for development of an independent multi-function manned spacecraft CSTS scheduled for completion in 2018. Further goals include an ambitious plan called the Aurora Programme which intends to send a human mission to Mars soon after 2030. A set of various landmark missions to reach this goal are currently under consideration. The ESA has a multi-lateral partnership, and plans for spacecraft and further missions with foreign participation and co-funding.

China

The People's Republic of China, while possessing less funding than Europe's ESA and the United State's NASA, has achieved manned space flight, currently operate a commercial unmanned launch service, and owns multiple satellites. There are plans for a Chinese space station and a program to send unmanned probes to Mars in the near future. China stands poised to become the third *space power*.

China's first attempt at a manned spacecraft, Shuguang. was abandoned after years of development. But on October 15, 2003, it became the third nation to achieve human spaceflight when Yang Liwei launched into space on Shenzhou 5. This flight demonstrated China's capability to build its own manned spacecraft and launch vehicle.

The aggressiveness of China's progress has raised concerns by other nations. The US Pentagon released a report in 2006 detailing concerns of China's growing presence in space, including its capability for military action. In 2007 China tested a ballistic missile designed to destroy satellites in orbit, in violation of an international consensus against military maneuvers in space.

India

ISRO, India's national space agency, maintains an active space program and leads the group of Asian nations in major achievements and future plans. It operates a small commercial launch service and launched a successful unmanned lunar mission dubbed Chandrayaan-1 in October, 2007. India has plans for a further unmanned mission to the Moon in the near future, as well as a missions to Mars by 2012. The ISRO is currently developing a small shuttle system. With the recent success and a developing missions for manned inter-planet flights by 2025 to 2030, India has positioned itself as a contender for the third *space power*.

Japan

Japan's space agency, JAXA, is the third major player in the Asian space race. While not maintaining a commercial launch service, Japan has deployed a module in the **ISS** and operates an unmanned cargo spacecraft, the H-II Transfer Vehicle.

JAXA has plans to launch a Mars fly-by probe. Their lunar probe, SELENE, is touted as the most sophisticated lunar exploration mission in the post-Apollo era.

Although Japan developed the HOPE-X, Kankoh-maru, and Fuji manned capsule spacecraft, none of them have been launched. Japan's current ambition is to deploy a new manned spacecraft by 2025, and to establish a Moon base by 2030.

Other nations

Iran recently announced plans to begin its manned program in 2021.

Chapter- 3

Vostok 1 (First Human Spaceflight)

Vostok 1
Восток-1

Mission insignia

Mission statistics

Mission name	Vostok 1 *Восток-1*
Spacecraft name	Ласточка (*Lastochka* - Swallow)
Spacecraft type	Vostok 3KA
Spacecraft mass	4,725 kg (10,420 lb)
Crew size	1
Call sign	Кедр (*Kedr* - Siberian Pine)
Booster	Vostok 8K72K
Launch pad	45°55′13″N 63°20′32″E / 45.9203°N 63.3422°E, Gagarin's Start, Baikonur Cosmodrome

Launch date	April 12, 1961 06:07 UTC
Landing site	51°16′14″N 45°59′50″E / 51.270682°N 45.99727°E
Landing	April 12, 1961 07:55
Mission duration	01:48
Number of orbits	1
Apogee	327 km (203 mi)
Perigee	169 km (105 mi)
Orbital period	89.34 minutes
Orbital inclination	64.95°

Crew photo

Yuri Gagarin in Sweden.

Related missions

Previous mission	**Subsequent mission**
Sputnik 10	Vostok 2

Vostok 1 (Russian: **Восток-1**, *Orient 1* or *East 1*) was the first human spaceflight, part of the Vostok program. The Vostok 3KA spacecraft was launched on April 12, 1961. The flight took Yuri Gagarin, a cosmonaut from the Soviet Union, into space. The flight marked the first time that a human entered outer space, as well as the first orbital flight of a manned vehicle. Vostok 1 was launched by the Soviet space program, and was designed by Soviet rocket scientists guided by Sergey Korolyov under military supervision of Kerim Kerimov and others.

Crew

Position	Cosmonaut
Pilot	Yuri Gagarin First spaceflight

Backup crew

Position	Cosmonaut
Pilot	Gherman S. Titov

Reserve crew

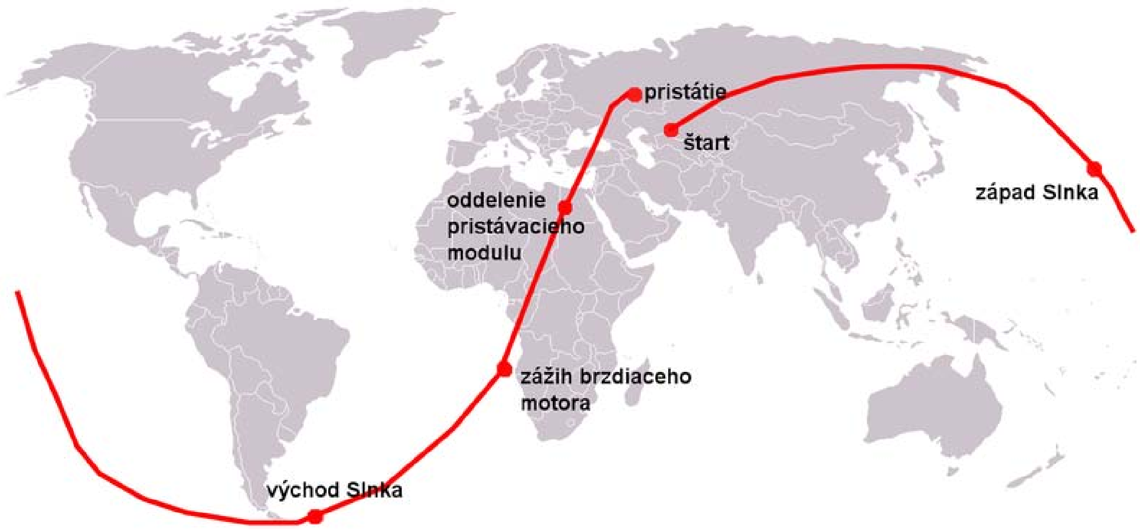
Position	Cosmonaut
Pilot	Grigori Nelyubov

Mission parameters

- **Mass:** 4,725 kg (10,420 lb)
- **Perigee:** 169 km (105 mi)
- **Apogee:** 327 km (203 mi)

- **Inclination:** 64.95°
- **Period:** 89.34 minutes

Mission highlights



Path of Gagarin's complete orbit; the landing point is west of takeoff point because of the eastward rotation of the Earth.

Gagarin orbited the Earth once in 108 minutes . He returned unharmed, ejecting from the Vostok capsule 7 km (23,000 ft) above the ground and parachuting separately to the ground since the capsule's parachute landing was deemed too rough for cosmonauts to risk.

Ground controllers did not know if a stable orbit had been achieved until 25 minutes after launch.

The spacecraft attitude control was run by an automated system. Medical staff and spacecraft engineers were unsure how a human being might react to weightlessness, and therefore the pilot's flight controls were locked out to prevent Gagarin from taking manual control. (Codes to unlock the controls were placed in an onboard envelope, for Gagarin's use in case of emergency.) Vostok could not change its orbit, only spacecraft attitude (orientation), and for much of the flight the spacecraft's attitude was allowed to drift. The automatic system brought Vostok 1 into alignment for retrofire about 1 hour into the flight.

Retrofire took place off the west coast of Africa, near Angola, about 8,000 km (5,000 mi) from the desired landing place. The liquid-fueled retrorockets fired for about 42 seconds. Because of weight constraints, there was no backup retrorocket engine. The spacecraft carried 10 days of provisions to allow for survival and natural decay of the orbit in the event the retrorockets failed.

Commemorative monument, Vostok-1 landing site near Engel's, Russia.

After retrofire, the Vostok equipment module unexpectedly remained attached to the reentry module by a bundle of wires. The two halves of the craft were supposed to separate ten seconds after retrofire, but this did not happen until 10 minutes had passed. The spacecraft went through wild gyrations before the wires burned through and the descent module settled into the proper reentry attitude.

The FAI rules in 1961 required that a pilot must land with the spacecraft to be considered an official spaceflight for the FAI record books. At the time, the Soviet Union insisted that Gagarin had landed with the Vostok; the government forced the cosmonaut to lie in press conferences, and the FAI certified the flight. The Soviet Union admitted in 1971 that Gagarin had ejected and landed separately from the Vostok descent module.

The landing site coordinates are 51°16′14″N 45°59′50″E / 51.270682°N 45.99727°E, this is 4 km East of Smelovka, Province of Saratov, Russian Federation, and 29 km South South West of Engel's. At this location is a monument park. The central feature in the park is a 25 meter tall monument that consists of a silver metalic rocketship rising on a curved metalic column of flame, from a wedge shaped, white stone base. In front of this is a 3 meter tall, white stone statue of Yuri Gagarin, with one arm raised in greeting and the other holding a space helmet. The statue is wearing a spacesuit.

When Soviet officials filled out the FAI papers to register the flight of Vostok 1, they stated that the launch site was Baykonur at 47°22′00″N 65°29′00″E / 47.3666667°N 65.4833333°E. In reality, the launch site was near Tyuratam at 45°55′12.72″N 63°20′32.32″E / 45.9202°N 63.3423111°E, 250 km (160 mi) to the south west of "Baykonur". They did this to try to keep the location of the Space Center a secret. In 1995, Russian and Kazakh officials renamed Tyuratam Baikonur.

The re-entry capsule is now on display at the museum of RKK Energiya in Korolyov.

Officially the U.S. congratulated the Soviet Union on its accomplishments.

Mission timeline

Yuri Gagarin in Vostok 1

- **Wednesday, April 12, 1961** The Soviet press later reported that minutes before boarding the spacecraft, Yuri Gagarin made a speech: *"Dear friends, known and unknown to me, my dear compatriots and all people of the world! Within minutes from now, a mighty Soviet rocket will boost my ship into the vastness of outer space. What I want to tell you is this. My whole life is now before me as a single breathtaking moment. I feel I can muster up my strength for successfully carrying out what is expected of me."* Gagarin actually recorded this speech—"a stream of banalities prepared by anonymous speechwriters"—in Moscow.

- **Countdown begins** Yuri Gagarin is in the Vostok 1 spacecraft on the launchpad. His television picture appears on television screens in the launch control room from an onboard television camera. Sergey Korolyov speaks into a microphone:

*"*Zarya *calling* Kedr *(Gagarin's call sign). The countdown is about to start."* Gagarin replied, *"Roger. Feeling fine, excellent spirits, ready to go."*

- **06:07 UTC** Launch occurs from the Baikonur Cosmodrome Site No.1; after Gagarin's flight that launch pad became known as Gagarin's Start. At ignition and liftoff, Sergey Korolyov radios, *"Preliminary stage..... intermediate..... main..... LIFT OFF! We wish you a good flight. Everything is all right."* Gagarin replies, "Poyekhali! (*Off we go!*)."

- **06:09 UTC** Two minutes into the flight and the four strap-on booster sections of the Vostok rocket have used up the last of their propellant, they shut down and drop away from the core vehicle. (T+ 119 s)

- **06:10 UTC** The payload shroud covering Vostok 1 is released, this uncovers the window at Gagarin's feet with the optical orientation device *Vzor* (lit. "look" or "glance"). (T+ 156 s)

- **06:12 UTC** Five minutes into the flight and the Vostok rocket core stage has used up its propellant, shuts down and falls away from the Vostok spacecraft and final rocket stage. The final rocket stage ignites to continue the journey to orbit. (T+ 300 s)

- **06:13 UTC** The rocket is still firing, pushing Vostok 1 toward orbit. Gagarin reports, *" .. the flight is continuing well. I can see the Earth. The visibility is good. ... I almost see everything. There's a certain amount of space under cumulus cloud cover. I continue the flight, everything is good."*

- **06:14 UTC** The rocket continues to fire, starting to pass over central Russia now. Gagarin reports, *"Everything is working very well. All systems are working. Let's keep going!"*

- **06:15 UTC** Three minutes into the burn of the final rocket stage and Gagarin reports, *"*Zarya-1, Zarya-1*, I can't hear you very well. I feel fine. I'm in good spirits. I'm continuing the flight..."* Vostok 1 is moving further downrange from the Baikonur Cosmodrome. He is reporting back to *Zarya-1* (the Baikonur ground station) and must be starting to move out of radio range of that station.

- **06:17 UTC** The Vostok rocket final stage shuts down, ten seconds later the spacecraft separates and Vostok 1 reaches orbit. (T+ 676 s) Gagarin reports, *"The craft is operating normally. I can see Earth in the view port of the* Vzor*. Everything is proceeding as planned"*. Vostok 1 passes over Soviet Union and moves on over Siberia.

Part of the Vostok 1 control panel

- **06:21 UTC** Vostok 1 passes over the Kamchatka peninsula and out over the North Pacific Ocean. Gagarin radios, *"...the lights are on on the descent mode monitor. I'm feeling fine, and I'm in good spirits. Cockpit parameters: pressure 1; humidity 65; temperature 20; pressure in the compartment 1; first automatic 155; second automatic 155; pressure in the retro-rocket system 320 atmospheres..."*

- **06:25 UTC** As Vostok 1 begins its diagonal crossing of the Pacific Ocean from Kamchatka peninsula to the southern tip of South America, Gagarin asks, *"What can you tell me about the flight? What can you tell me?"*. He is requesting information about his orbital parameters. The ground station at Khabarovsk reports back, *"There are no instructions from No. 20 (Sergey Korolyov), and the flight is proceeding normally"* They are telling Gagarin that they don't have his orbital parameters yet because the spacecraft has been in orbit for only 6 minutes, but the spacecraft systems are performing well.

- **06:31 UTC** Gagarin transmits to the Khabarovsk ground station, *"I feel splendid, very well, very well, very well. Give me some results on the flight!"*. Vostok 1 is nearing the VHF radio horizon for Khabarovsk and they respond, *"Repeat. I can't hear you very well"*. Gagarin transmits again, *"I feel very good. Give me your data* *on the flight!"* Vostok 1 passes out of VHF range of the Khabarovsk ground station and contact is lost.

- **06:37 UTC** Vostok 1 continues on its journey as the Sun sets over the North Pacific. Gagarin crosses into night, northwest of the Hawaiian Islands. Out of VHF range with ground stations, communications must now take place via HF radio.

- **06:46 UTC** Khabarovsk ground station sends the message "KK" via telegraph (on HF radio to Vostok 1). This message means, "Report the monitoring of commands." They were asking Gagarin to report when the spacecraft automated descent system had received its instructions from the ground control. Gagarin reported back at 06:48 UTC.

- **06:48 UTC** Vostok 1 crosses the equator at about 170° West, traveling in a south east direction and begins crossing the South Pacific. Gagarin transmits over HF radio, *"I am transmitting the regular report message: 9 hours 48 minutes (Moscow Time), the flight is proceeding successfully. Spusk-1 is operating normally. The mobile index of the descent mode monitor is moving. Pressure in the cockpit is 1; humidity 65; temperature 20; pressure in the compartment 1.2 ... Manual 150; First automatic 155; second automatic 155; retro rocket system tanks 320 atmospheres. I feel fine..."*

- **06:49 UTC** Gagarin reports he is on the night side of the Earth.

- **06:51 UTC** Gagarin reports the sun-seeking attitude control system had been switched on. The sun-seeking attitude control system is used to orient Vostok 1 for retrofire. The automated orientation system consisted of two redundant systems: an automatic/solar orientation system and a manual/visual orientation system. Either system could operate the two redundant cold nitrogen gas thruster systems, each with 10 kg (22 lb) of gas.

- **06:53 UTC** The Khabarovsk ground station sends Gagarin the following message via HF radio, *"By order of No.33 (General Nikolai Kamanin) the transmitters have been switched on, and we are transmitting this: the flight is proceeding as planned and the orbit is as calculated."* They are telling Gagarin that Vostok 1 is in a stable orbit. He acknowledges the message.

- **06:57 UTC** Vostok 1 is over the South Pacific between New Zealand and Chile when Gagarin sends this message, *"...I'm continuing the flight, and I'm over America. I transmitted the telegraph signal "ON".*

- **07:00 UTC** Vostok 1 crosses the Strait of Magellan at the tip of South America. News of the Vostok 1 mission is broadcast on Radio Moscow.

- **07:04 UTC** Gagarin sends spacecraft status message, similar to the one sent at 06:48. The message is not received by ground stations.
- **07:09 UTC** Gagarin sends spacecraft status message, the message is not received by ground stations.
- **07:10 UTC** Passing over the South Atlantic, the Sun rises and Vostok 1 is in daylight again. Vostok 1 is 15 minutes from retrofire.
- **07:13 UTC** Gagarin sends spacecraft status message, similar to the one sent at 06:48. Moscow picks up this partial message from Gagarin, *"I read you well. The flight is going..."*
- **07:18 UTC** Gagarin sends spacecraft status message, the message is not received by ground stations.
- **07:23 UTC** Gagarin sends spacecraft status message, the message is not received by ground stations.

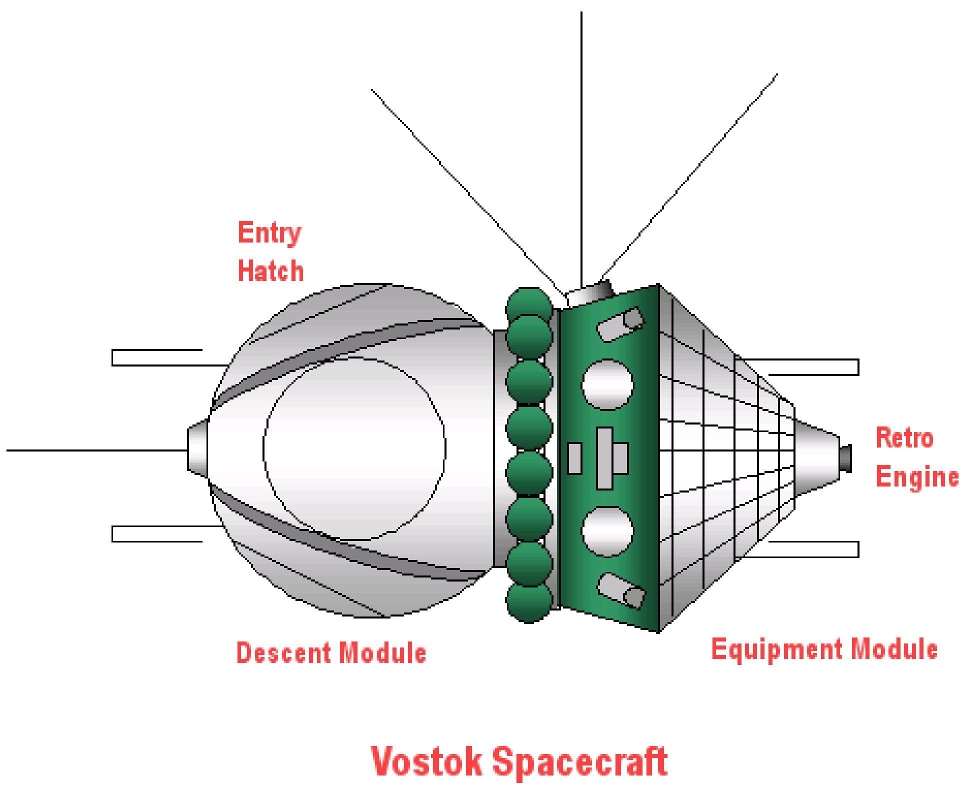


Diagram of Vostok spacecraft

- **07:25 UTC** Vostok 1 is in retrofire attitude. The retros are fired for about 42 seconds as the spacecraft nears Angola on the west coast of Africa. Retrofire takes place about 8,000 km (5,000 mi) from the planned landing point in Soviet Union.

- **07:25 to 07:35 UTC** Ten seconds after retrofire, commands are sent to separate the Vostok service module from the reentry module (*sharik*). One bundle of wires fails to release and the two sections of the spacecraft remain attached for another 10 minutes. Vostok 1 crosses the west coast of Africa and continues over central Africa heading towards Egypt.

- **07:35 UTC** The two halves of the spacecraft begin reentry and go through wild gyrations as Vostok 1 nears Egypt. Finally, the wire bundle burns through and releases the reentry module. Gagarin telegraphs "Everything is OK" despite continuing gyrations; he later reported that he did not want to "make noise" as he had (correctly) reasoned that the gyrations did not endanger the mission (and were apparently caused by the spherical shape of the reentry module).

- **07:35 to 07:55 UTC** Reentry continues over Egypt and out over the Mediterranean, near the west coast of Cyprus and then central Turkey. Continuing to drop lower, Vostok 1 crosses back into the Soviet Union on the Black Sea coast near Krasnodar. Gagarin experiences 8 g (Gagarin's own report states "over 10 g") during reentry but remains conscious.

- **07:55 UTC** Vostok 1 is still 7 km from the ground. The hatch is released and two seconds later Gagarin ejects from Vostok 1. At 2.5 km (8,200 ft) altitude, the main parachute is deployed from the Vostok spacecraft. The Vostok 1 lands at 07:55 UTC. Two schoolgirls witness the Vostok landing and described the scene: *"It was a huge ball, about two or three metres high. It fell, then it bounced and then it fell again. There was a huge hole where it hit the first time."*

The Vostok 1 capsule on display at the RKK Energiya museum.

- **08:05 UTC** Gagarin, because his parachute opened at a much higher altitude than Vostok 1 (7 km (23,000 ft) vs. 2.5 km), lands about 10 minutes after his spacecraft. Both he and the spacecraft land via parachute 26 km (16 mi) south west of Engels, in the Saratov region at 51°16′14″N 45°59′50″E / 51.270682°N 45.99727°E. A farmer and her daughter observed the strange scene of a figure in a bright orange suit with a large white helmet landing near them by parachute. Gagarin later recalled, *"When they saw me in my space suit and the parachute dragging alongside as I walked, they started to back away in fear. I told them, don't be afraid, I am a Soviet like you, who has descended from space and I must find a telephone to call Moscow!"*.

Chapter- 4

Vostok (spacecraft)

Vostok

model of Vostok spacecraft with 3-rd stage of launcher

Type	Space capsule
Manufacturer	Korolev
Designed by	Sergei Korolev
Maiden flight	May 15, 1960
Introduced	1960
Retired	June 19, 1963
Status	Last 7 flights cancelled
Primary users	Soviet space program
Built	10+
Variants	Voskhod spacecraft, Foton

The **Vostok** (Russian: **Восток**, translated as *East*) was a type of spacecraft built by the Soviet Union's space programme for human spaceflight.

Development

The Vostok spacecraft was originally designed for use both as a camera platform (for the Soviet Union's first spy satellite program, Zenit) and as a manned spacecraft. This dual-use design was crucial in gaining Communist Party support for the program. The basic Vostok design has remained in use for some forty years, gradually adapted for a range of other unmanned satellites. The descent module design was reused, in heavily-modified form, by the Voskhod programme.

Design

The craft consisted of a spherical descent module (mass 2.46 tonnes, diameter 2.3 meters), which housed the cosmonaut, instruments and escape system, and a conical instrument module (mass 2.27 tonnes, 2.25 m long, 2.43 m wide), which contained propellant and the engine system. On reentry, the cosmonaut would eject from the craft at about 7,000 m (23,000 ft) and descend via parachute, while the capsule would land separately.

There were several models of the Vostok leading up to the manned version:

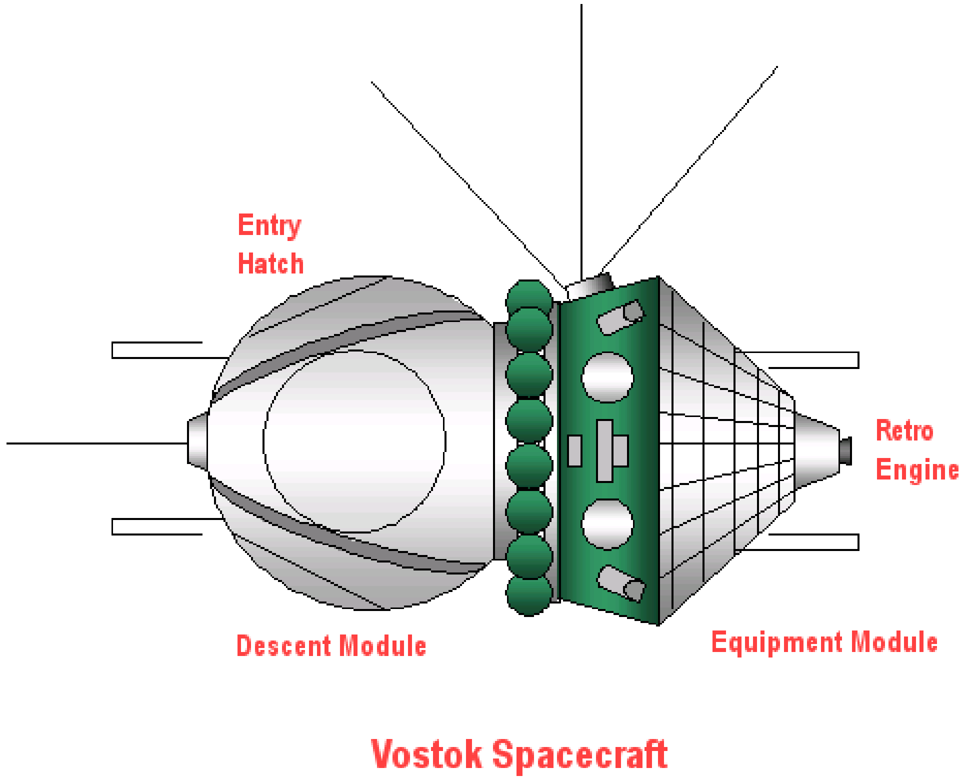
Vostok 1K

Prototype spacecraft. Used to test basic systems and prove the concept. Flew six unmanned test missions in 1960.

Vostok 2K

Photo-reconnaissance and signals intelligence spacecraft . Later named Zenit spy satellite.

Vostok 3KA



Vostok spacecraft

The Vostok 3KA was the spacecraft used for the first human spaceflights. They were launched from Baikonur Cosmodrome using Vostok 8K72K launch vehicles. The first flight of a Vostok 3KA occurred on March 9, 1961. The first flight with a crew -- Vostok 1 carrying Yuri Gagarin -- took place on April 12, 1961. The last flight -- Vostok 6 carrying the first woman in space, Valentina Tereshkova -- took place on June 16, 1963.

A total of 8 Vostok 3KA spacecraft were flown, 6 of them with a human crew.

Specifications for this version are:

Reentry Module: Vostok SA. Also known as: *Spuskaemiy apparat - Sharik* (sphere).

- Crew Size: 1
- Length: 5 m
- Diameter: 2.3 m
- Mass: 2,460 kg
- Heat Shield Mass: 837 kg
- Recovery equipment: 151 kg
- Parachute deploys at 2.5 km altitude
- Crew seat and provisions: 336 kg

- Crew ejects at 7 km altitude
- Ballistic reentry acceleration: 8 *g* (78 m/s²)

Vostok Sharik

Equipment Module: Vostok PA. Also known as: *Priborniy otsek*.

- Length: 2.25 m
- Diameter: 2.43 m
- Mass: 2,270 kg
- Equipment in pressurized compartment
- RCS Propellants: Cold gas (nitrogen)
- RCS Propellants: 20 kg

- Main Engine (TDU): 397 kg
- Main Engine Thrust: 15.83 kN
- Main Engine Propellants: Nitrous oxide/amine
- Main Engine Propellants: 275 kg
- Main Engine Isp: 266 s (2.61 kN·s/kg)
- Main Engine Burn Time: 1 minute (typical retro burn = 42 seconds)
- Spacecraft delta v: 155 m/s
- Electrical System: Batteries
- Electric System: 0.20 average kW
- Electric System: 24.0 kW·h

- Total Mass:4,730 kg
- Endurance: Supplies for 10 days in orbit
- Launch Vehicle: Vostok 8K72K
- Typical orbit: 177 km x 471 km, 64.9 inclinaton

Reentry

The Vostok capsule had limited thruster capability. As such, the reentry path and orientation could not be controlled after the capsule had separated from the engine system. This meant that the capsule had to be protected from reentry heat on all sides, thus explaining the spherical design (as opposed to Project Mercury's conical design), which allowed for maximum volume while minimizing the external surface. Some control of the capsule reentry orientation was possible by way of positioning of the heavy equipment to offset the vehicle center of gravity, which also maximized the chance of the cosmonaut surviving g-forces while in a horizontal position. Even then, the cosmonaut experienced 8 to 9g.

Chapter- 5

Project Mercury

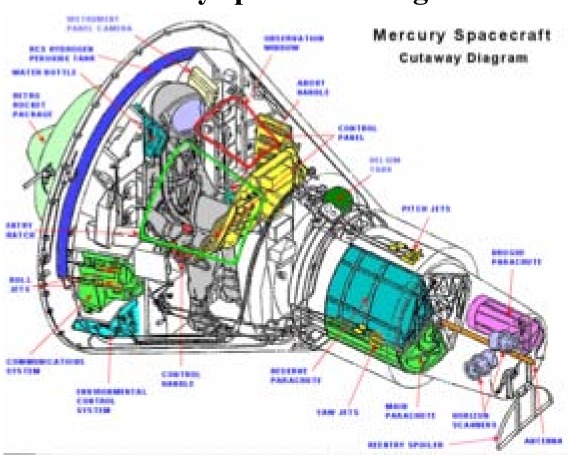
McDonnell Mercury spacecraft

The Mercury spacecraft with escape tower

Description		
Role:	Suborbital and orbital spaceflight	
Crew:	one pilot	
Dimensions		
Height:	11.5 ft	3.51 m
Diameter:	6.2 ft	1.89 m
Volume:	60 ft³	1.7 m³
Weights (MA-6)		
Launch:	4,265 lb	1,935 kg
Orbit:	2,986 lb	1,354 kg

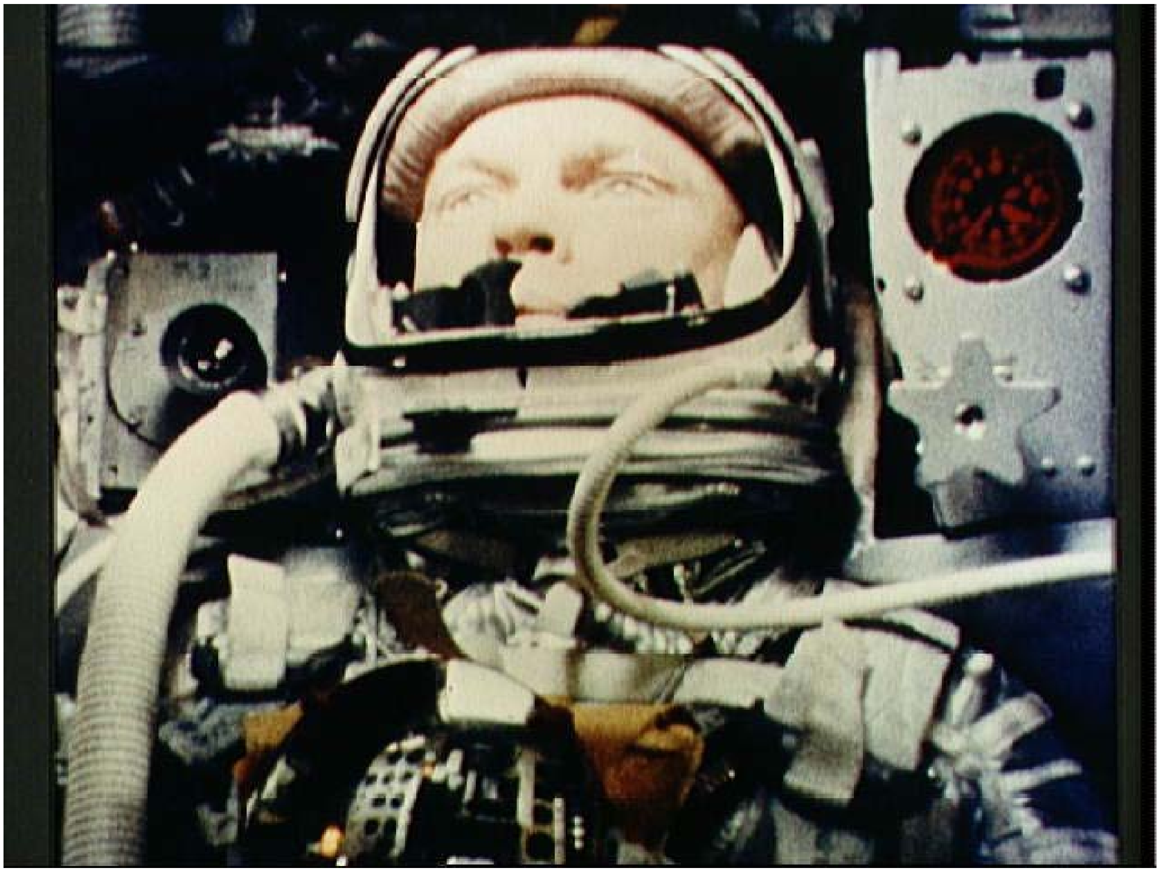
Post Retro:	2,815 lb	1,277 kg
Reentry:	2,698 lb	1,224 kg
Landing:	2,421 lb	1,098 kg
Rocket engines		
Retros (solid fuel) x 3:	1,000 lbf ea	4.5 kN
Posigrade (solid fuel) x 3:	400 lbf ea	1.8 kN
RCS high (H_2O_2) x 6:	25 lbf ea	108 N
RCS low (H_2O_2) x 6:	12 lbf ea	49 N
Performance		
Endurance:	34 hours	22 orbits
Apogee:	175 miles	282 km
Perigee:	100 miles	160 km
Retro delta v:	300 mph	483 km/h

Mercury spacecraft diagram



Mercury spacecraft cutaway

Project Mercury was the first human spaceflight program of the United States. It ran from 1959 through 1963 with the goal of putting a human in orbit around the Earth. The Mercury-Atlas 6 flight on February 20, 1962, was the first American flight to achieve this goal.



John Glenn during the first orbital manned Mercury flight in 1962

The program included 20 unmanned launches, followed by two suborbital and four orbital flights with astronaut pilots. Early planning and research were carried out by the National Advisory Committee for Aeronautics, but the program was officially conducted by its successor organization, NASA. Mercury laid the groundwork for Project Gemini and the follow-on Apollo moon-landing program.

The project name came from Mercury, a Roman mythological god often seen as a symbol of speed. Mercury is also the name of the innermost planet of the Solar System, which moves faster than any other and hence provides an image of speed, although Project Mercury had no real connection to the planet.

The Mercury program cost approximately $384 million, the equivalent of about $2.9 billion in 2010 dollars.

Goals and guidelines

The goals of the program were to orbit a manned spacecraft around Earth, investigate the pilot's ability to function in space and to recover both pilot and spacecraft safely. NASA also established program guidelines: existing technology and off-the-shelf equipment should be used wherever practical, the simplest and most reliable approach to system design would be followed, an existing launch vehicle would be employed to place the spacecraft into orbit, and use of a progressive and logical test program. Project requirements for the spacecraft were that it must be fitted with a reliable launch escape system to separate the spacecraft and its crewman from the launch vehicle in case of impending failure, the pilot must be given the capability of manually controlling spacecraft attitude, the spacecraft must carry a retrorocket system capable of reliably providing the necessary impulse to bring the spacecraft out of orbit, a zero-lift body utilizing drag braking would be used for reentry, and that the spacecraft design must satisfy the requirements for a water landing.

Research and development

On October 7, 1958, T. Keith Glennan, the first administrator of NASA, approved the Mercury project. On December 17 Glennan announced Project Mercury publicly.

Mercury spacecraft at McDonnell in St. Louis, Missouri

On December 29, 1958 North American Aviation was awarded a contract to design and build Little Joe boosters for mercury launch escape system test flights. In January 1959 McDonnell Aircraft Corporation was chosen to be prime contractor for the Mercury spacecraft, and the contract for 12 spacecraft was awarded in February. In April seven astronauts, known as the Mercury Seven or more formally as Astronaut Group 1, were selected to participate in the Mercury program.

In May 1959 North American Aviation delivered the first two Little Joe boosters, and in June the Big Joe booster was delivered. In July the planned use of Jupiter boosters was canceled in favor of Redstone boosters for suborbital flights. In October General Electric delivered to McDonnell the ablative heat shield designated for installation on the first

Mercury spacecraft. In December the launch vehicle for Mercury-Redstone 1 was ready to begin static tests installed on a test stand at ABMA.

In January 1960 NASA awarded Western Electric Company a contract for the Mercury tracking network. The value of the contract was over $33 million. Also in January, McDonnell delivered the first production-type Mercury spacecraft, less than a year after award of the formal contract. On February 12, Christopher C. Kraft, Jr. was appointed to head the Mercury operations coordination group. Kraft was asked to, "come up with a basic mission plan. You know, the bottom-line stuff on how we fly a man from a launch pad into space and back again. It would be good if you kept him alive." In April, the first spacecraft was delivered to Wallops Island for the beach-abort test. The test was completed successfully on May 9.

Spacecraft

Because of their small size, it was said that the Mercury spacecraft were worn, not ridden. With 1.7 m^3 of habitable volume, the spacecraft was just large enough for the single crew member. Inside were 120 controls: 55 electrical switches, 30 fuses and 35 mechanical levers. The spacecraft was designed by Max Faget and NASA's Space Task Group.

Despite the astronauts' test pilot experience NASA at first envisioned them as "minor participants" during their flights, causing many conflicts between the astronauts and engineers during the spacecraft's design. Nonetheless, contrary to other reports, the project's leaders always intended for pilots to be able to control their spacecraft, as they valued humans' ability to contribute to missions' success. John Glenn's manual attitude adjustments during the first orbital flight were an example of the value of such control. The astronauts requested—and received—a larger window and manual reentry controls.

Mercury 8 spacecraft in Hangar S at Cape Canaveral

During the launch phase of the mission, the Mercury spacecraft and astronaut were protected from launch vehicle failures by the Launch Escape System. The LES consisted of a solid fuel, 52,000 lbf (231 kN) thrust rocket with three engine bells mounted on a tower above the spacecraft. In the event of a launch abort, the LES would fire for one second, pulling the spacecraft and astronaut away from the booster and a possible explosion. The spacecraft would then descend on its parachute recovery system. After booster engine cutoff (BECO), the LES was no longer needed and was separated from the spacecraft by a solid fuel, 800 lbf (3.6 kN) thrust jettison rocket that fired for 1.5 seconds.

After a successful liftoff, the spacecraft fired three small clustered solid-fuel, 400 lbf (1.8 kN) thrust rockets for 1 second to separate the spacecraft from the launch vehicle. These rockets were called the posigrade rockets.

The spacecraft were only equipped with attitude control thrusters; after orbit insertion but before retrofire they could not change their orbit. There were three sets of high and low powered automatic control jets and separate manual jets, one for each axis (yaw, pitch, and roll), and supplied from two separate fuel tanks, one automatic and one manual. The pilot could use any one of the three thruster systems and fuel them from either of the two fuel tanks to provide spacecraft attitude control. The Mercury spacecraft was designed to be completely controllable from the ground in the event that something impaired the pilot's ability to function.

The spacecraft had three solid-fuel, 1000 lbf (4.5 kN) thrust retrorockets that fired for 10 seconds each. One was sufficient to return the spacecraft to Earth if the other two failed. The firing sequence (known as ripple firing) required firing the first retro, followed by the second retro five seconds later (while the first was still firing). Five seconds after that, the third retro fired (while the second retro was still firing).

Mercury heat shield and retrorocket pack

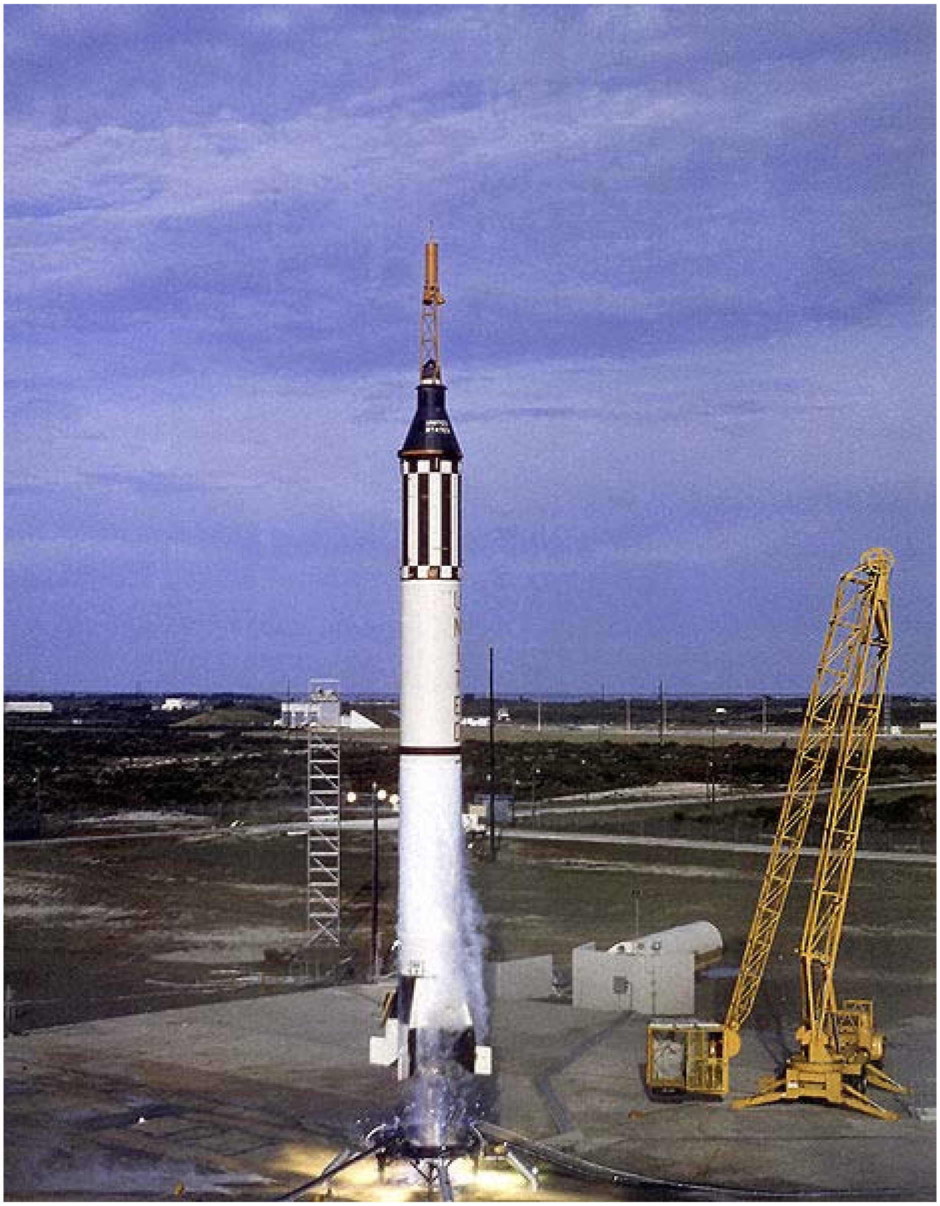
There was a small hinged metal flap at the nose of the spacecraft called the spoiler. If the spacecraft started to reenter nose first (another stable reentry attitude for the spacecraft), airflow over the spoiler would flip the spacecraft around to the proper, heatshield-first reentry attitude, a technique called shuttlecocking. During reentry, the astronaut would experience about 8 g-forces on an orbital mission, and 11–12 gs on a suborbital mission.

Initial designs for the spacecraft suggested the use of either beryllium heat-sink heat shields or an ablative shield. Extensive testing settled the issue – ablative shields proved to be reliable (so much so that the initial shield thickness was safely reduced, allowing a lower total spacecraft weight), and were easier to produce — at that time, beryllium was only produced in sufficient quantities by a single company in the U.S. — and cheaper.

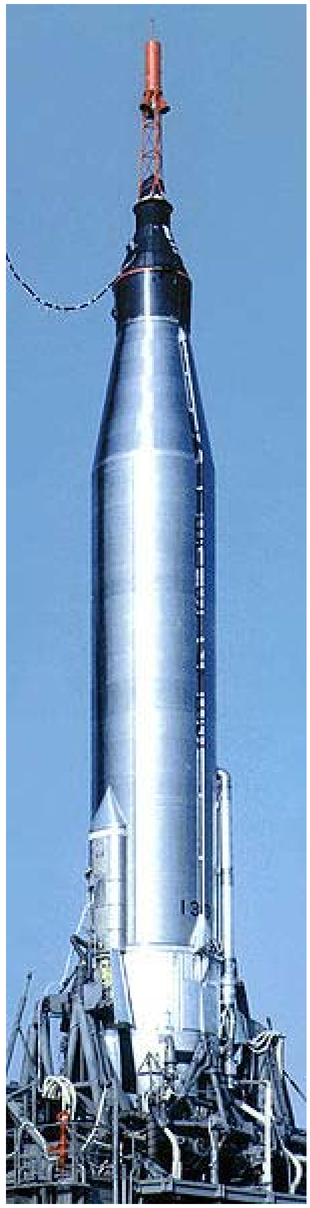
NASA ordered 20 production spacecraft, numbered 1 through 20, from McDonnell Aircraft Company, St. Louis, Missouri. Five of the 20, Nos. 10, 12, 15, 17, and 19, were not flown. Spacecraft No. 3 and No. 4 were destroyed during unmanned test flights. Spacecraft No. 11 sank and was recovered from the bottom of the Atlantic Ocean after 38 years. Some spacecraft were modified after initial production (refurbished after launch abort, modified for longer missions, etc.) and received a letter designation after their number, examples 2B, 15B. Some spacecraft were modified twice; for example, spacecraft 15 became 15A and then 15B.

A number of Mercury Boilerplate spacecraft (including mockup/prototype/replica spacecrafts, made from non-flight materials or lacking production spacecraft systems and/or hardware) were also made by NASA and McDonnell Aircraft. They were designed and used to test spacecraft recovery systems, and escape tower and rocket motors. Formal tests were done on test pad at Langley and at Wallops Island using the Little Joe and Big Joe rockets.

Boosters



Mercury-Redstone 4



Mercury-Atlas 9

The Mercury program used three boosters:

- Little Joe – eight suborbital robotic flights, two carrying monkeys. Launch escape system tests.
- Redstone – four suborbital robotic flights, one carrying a chimpanzee; two piloted suborbital flights.
- Atlas – four suborbital robotic flights; two orbital robotic flights, one carrying a chimpanzee; four piloted orbital flights.

Little Joe and a Mercury boilerplate were used to test the escape tower and abort procedures. Redstone was used for suborbital flights, and Atlas for orbital ones. Starting in October, 1958, Jupiter missiles were also considered as suborbital launch vehicles for the Mercury program, but were cut from the program in July 1959 due to budget constraints. The Atlas boosters required extra strengthening in order to handle the increased weight of the Mercury spacecraft beyond that of the nuclear warheads they were designed to carry. Little Joe was a solid-propellant booster designed specially for the Mercury program. The Titan missile was also considered for use for later Mercury missions; however, the Mercury program was terminated before these missions were flown. The Titan was used for the Gemini program which followed Mercury.

The Mercury program used a Scout booster for a single flight, Mercury-Scout 1, which intended to launch a small satellite designed to evaluate the worldwide Mercury Tracking Network. The rocket was destroyed by the Range Safety Officer after 44 seconds of flight.

Manned flights

The Mercury Seven astronauts with an Atlas model July 12, 1962. L to R: Grissom, Shepard, Carpenter, Schirra, Slayton, Glenn, Cooper

Wernher von Braun and astronaut Gordon Cooper in the blockhouse during MR-3 recovery operations May 5, 1961.

Astronauts

The first Americans to venture into space were drawn from a group of 110 military pilots chosen for their flight test experience and because they met certain physical requirements. NASA announced the selection of seven of these – known as the Mercury Seven – as astronauts on 9 April 1959, though only six of the seven flew Mercury missions, after Slayton was grounded due to a heart condition.

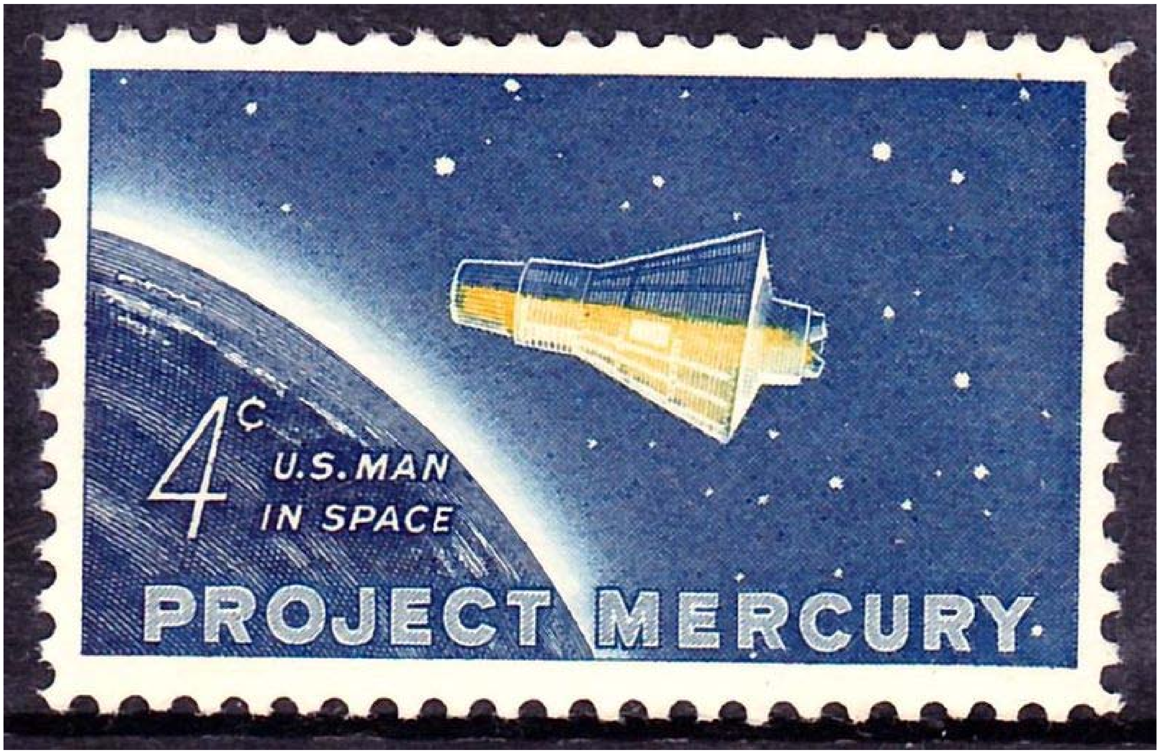
- Malcolm Scott Carpenter, USN (born 1925)
- Leroy Gordon "Gordo" Cooper, Jr., USAF (1927–2004)
- John Herschel Glenn, Jr., USMC (born 1921); first American to orbit the Earth
- Virgil Ivan "Gus" Grissom, USAF (1926–1967); Died during Apollo 1 pre-launch test
- Walter Marty "Wally" Schirra, Jr., USN (1923–2007)
- Alan Bartlett Shepard, Jr., USN (1923–1998); first American in space
- Donald Kent "Deke" Slayton, USAF (1924–1993); grounded in 1962 due to irregular heartbeat, reinstated in 1972 and flew on the Apollo-Soyuz Test Project in 1975.

Beginning with Alan Shepard's *Freedom 7* flight, the astronauts named their own spacecraft, and all added "7" to the name to acknowledge the teamwork of their fellow astronauts.

Mercury mission insignias

Mercury program monument at LC-14

Flight patches that purport to be patches from various Mercury missions are available to the public. In reality, these patches were designed by private entrepreneurs several years after the Mercury program. When mission patches were created by crews in the Gemini program, this caused a public demand for Mercury flight patches, which was filled by these entrepreneurs. The only patches the Mercury astronauts wore, however, were the NASA logo and a name tag. Each manned Mercury spacecraft was decorated with a flight insignia featuring the spacecraft name (*Freedom 7*, etc.).



Project Mercury Issue of 1962

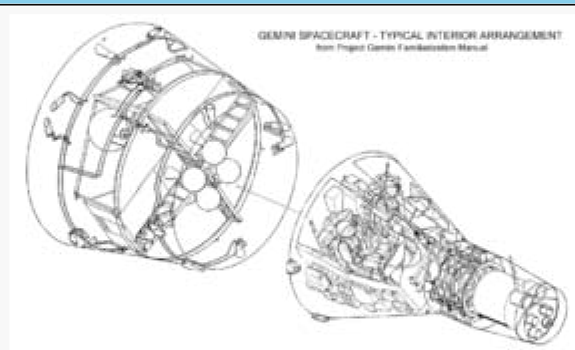
Project Mercury stamp

In 1962, the US Post Office honored the Mercury-Atlas 6 flight with the Project Mercury commemorative stamp, the first U.S. postal issue to depict a manned spacecraft. The stamp first went on sale in Cape Canaveral, Florida on February 20, 1962, the same day as the Project Mercury launch putting the first U.S. astronaut into orbit.

Chapter- 6

Project Gemini

McDonnell Gemini spacecraft		
 Gemini 7 in orbit, as seen by the crew of Gemini 6.		
Volume:	90 ft³	2.55 m³
Weights		
Retrograde module:	1,303 lb	591 kilograms (1,300 lb)
Equipment module:	2,815 lb	1,277 kilograms (2,820 lb)
Total:	8,490 lb	3,851 kilograms (8,490 lb)
Rocket engines		
Retros (solid fuel) x 4:	2,500 lbf ea	11.12 kN
Reentry Control System (N_2O_4/MMHH) x 16:	25 lbf ea	111 N

OAMS (N_2O_4/MMHH) x 2:	85 lbf ea	378 N
OAMS (N_2O_4/MMHH) x 6:	100 lbf ea	445 N
OAMS (N_2O_4/MMHH) x 8:	25 lbf ea	111 N
Performance		
Endurance:	14 days	206 orbits
Apogee:	250 miles	402 kilometres (250 mi)
Perigee:	100 miles	160 kilometres (99 mi)
Spacecraft delta v:	728 ft/s	222 m/s
Gemini spacecraft diagram		
 Gemini spacecraft diagram (NASA)		
McDonnell Gemini Spacecraft		

Project Gemini was the second human spaceflight program of NASA, the civilian space agency of the United States government. Project Gemini was conducted between Projects Mercury and Apollo, with ten manned flights occurring in 1965 and 1966.

Its objective was to develop techniques for advanced space travel, notably those necessary for Apollo, whose objective was to land humans on the Moon. Gemini missions included missions long enough for a trip to the Moon and back, the first American spacewalks, and new orbital maneuvers including rendezvous and docking. All manned Gemini flights were launched from Cape Canaveral, Florida atop Titan II GLV boosters.

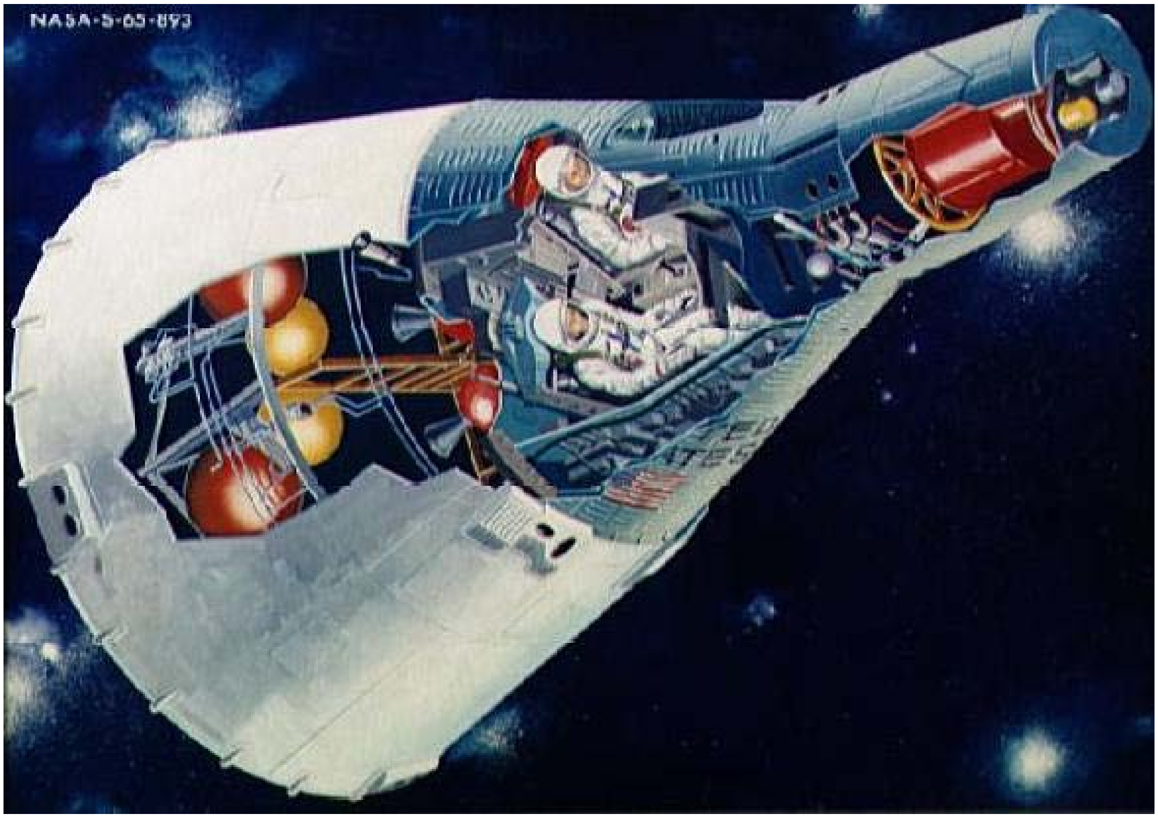
Program objectives

After the existing Apollo program was chartered by President John F. Kennedy on May 25, 1961 to land men on the Moon, it became evident to NASA officials that a follow-on to the Mercury program was required to develop certain spaceflight capabilities in support of Apollo. Originally introduced on December 7 as *Mercury Mark II*, it was re-christened Project Gemini on January 3, 1962. The major objectives were:

- To demonstrate endurance of humans and equipment to spaceflight for extended periods, at least eight days required for a Moon landing, to a maximum of two weeks
- To effect rendezvous and docking with another vehicle, and to maneuver the combined spacecraft using the propulsion system of the target vehicle
- To demonstrate Extra-Vehicular Activity (EVA), or space-"walks" outside the protection of the spacecraft, and to evaluate the astronauts' ability to perform tasks there
- To perfect techniques of atmospheric reentry and landing at a pre-selected location
- To provide the astronauts with zero-gravity, rendezvous, and docking experience required for Apollo

Spacecraft

Replica of a Gemini spacecraft at the Neil Armstrong Air and Space Museum



A cutaway of the Project Gemini spacecraft

Gemini's primary difference from Mercury was that the earlier spacecraft had all systems other than the reentry rockets situated within the capsule, most of which were accessed through the astronaut's hatchway. In contrast, Gemini housed power, propulsion, and life support systems in a detachable Equipment Module located behind the Reentry Module, which made it similar to the Apollo Command/Service Module design. Many components in the capsule itself were reachable through their own small access doors.

The original intention was for Gemini to land on solid ground instead of at sea, using a Rogallo wing paraglider rather than a parachute, with the crew seated upright controlling the forward motion of the craft. To facilitate this, the paraglider did not attach just to the nose of the craft, but to an additional attachment point for balance near the heat shield. This cord was covered by a strip of metal which ran between the twin hatches. However, this design was ultimately dropped, and parachutes were used to make a sea landing as in Project Mercury. However, the capsule was suspended at an angle closer to horizontal, so that a side of the heat shield contacted the water first. This eliminated the need for the landing bag cushion used in the Mercury capsule.

Early short-duration missions had their electrical power supplied by batteries; later endurance missions used the first fuel cells in manned spacecraft.

The "Gemini" designation comes from the fact that each spacecraft held two crewmen, as "gemini" in Latin means "twins". Gemini is also the name of the third constellation of the Zodiac and its twin stars, Castor and Pollux.

Unlike Mercury, which could only change its orientation in space, the Gemini spacecraft could translate in all six directions, and alter its orbit. It was designed to dock with the Agena Target Vehicle, which had its own large rocket engine which was used to perform large orbital changes.

Gemini was the first American manned spacecraft to include an onboard computer, the Gemini Guidance Computer, to facilitate management and control of mission maneuvers. It was also unlike other NASA craft in that it used ejection seats, in-flight radar and an artificial horizon—devices borrowed from the aviation industry. Using ejection seats to propel astronauts to safety was first employed by the Soviet Union in the Vostok craft manned by cosmonaut Yuri Gagarin.

The Gemini program cost $5.4 billion.

Team

Gemini was designed by a Canadian, Jim Chamberlin, formerly the chief aerodynamicist on the Avro Arrow fighter interceptor program with Avro Canada. Chamberlin joined NASA along with 25 senior Avro engineers after cancellation of the Arrow program, and became head of the U.S. Space Task Group's engineering division in charge of Gemini. The prime contractor was McDonnell Aircraft, which had also been the prime contractor for the Mercury capsule.

In addition, astronaut Gus Grissom was heavily involved in the development and design of the Gemini spacecraft. He writes in his posthumous 1968 book *Gemini!* that the realization of Project Mercury's end and the unlikelihood of his having another flight in that program prompted him to focus all of his efforts on the upcoming Gemini Program.

The Gemini program was managed by the Manned Spacecraft Center, Houston, Texas, under direction of the Office of Manned Space Flight, NASA Headquarters, Washington, D.C, Dr. George E. Mueller, Associate Administrator of NASA for Manned Space Flight, served as acting director of the Gemini program. William C. Schneider, Deputy Director of Manned Space Flight for Mission Operations, served as mission director on all Gemini flights beginning with Gemini VI.

Guenther Wendt was a McDonnell engineer who supervised launch preparations for both the Mercury and Gemini programs. His team was responsible for completion of the complex pad close-out procedures just prior to spacecraft launch, and he personally closed the hatches before flight. The astronauts appreciated his taking absolute authority over, and responsibility for, the condition of the spacecraft and developed a good-humored rapport with him.

Astronauts

The following astronauts flew on the 10 manned Gemini missions:

Group	Astronaut	Service	Mission
Astronaut Group 1	L. Gordon Cooper	USAF	Gemini V
	Virgil "Gus" Grissom		Gemini III
	Walter M. Schirra	USN	Gemini VI-A
Astronaut Group 2	Neil A. Armstrong	Civilian	Gemini VIII
	Frank Borman	USAF	Gemini VII
	Charles "Pete" Conrad	USN	Gemini V
			Gemini XI
	James A. Lovell	USN	Gemini VII
			Gemini XII
	James A. McDivitt		Gemini IV
	Thomas P. Stafford	USAF	Gemini VI-A
			Gemini IX-A
	Edward H. White II		Gemini IV
	John W. Young	USN	Gemini III
			Gemini X
Astronaut Group 3	Edwin "Buzz" Aldrin	USAF	Gemini XII
	Eugene A. Cernan	USN	Gemini IX-A
	Michael Collins	USAF	Gemini X
	Richard F. Gordon	USN	Gemini XI
	David R. Scott	USAF	Gemini VIII

Mission	Commander	Group	Flight #	Pilot	Group	Flight #
Gemini III	Grissom	1	2	Young	2	1
Gemini IV	McDivitt	2	1	White	2	1
Gemini V	Cooper	1	2	Conrad	2	1
Gemini VI	Schirra	1	2	Stafford	2	1

Gemini VII	Borman	2	1	Lovell	2	1
Gemini VIII	Armstrong	2	1	Scott	3	1
Gemini IX	Stafford	2	2	Cernan	3	1
Gemini X	Young	2	2	Collins	3	1
Gemini XI	Conrad	2	2	Gordon	3	1
Gemini XII	Lovell	2	2	Aldrin	3	1

Crew selection

Deke Slayton, as head of the Astronaut Office, had the main role in the choice of crews for the Gemini program. With Gemini it became a procedure that each flight had a primary crew and backup crew, and that the backup crew would rotate to primary crew status three flights later. Slayton also intended for first choice of mission commands to be given to the four remaining active astronauts of the Mercury Seven: Alan Shepard, Grissom, Cooper, and Schirra. (John Glenn had retired from NASA in January 1964 and Scott Carpenter, who was blamed by some in NASA management for the problematic reentry of *Aurora 7*, was on leave to participate in the Navy's SEALAB project and was grounded from flight in July 1964 due to an arm injury sustained in a motorbike accident. Slayton himself continued to be grounded due to a heart problem.)

In late 1963, Slayton selected Shepard and Stafford for Gemini 3, McDivitt and White for Gemini 4, and Schirra and Young for Gemini 5 (which was to be the first Agena rendezvous mission). Backup crew for Gemini 3 was Grissom and Borman, who were also slated for Gemini 6, to be the first long-duration mission. Finally Conrad and Lovell were assigned as backup crew for Gemini 4.

Delays in the production of the Agena Target Vehicle caused the first rearrangement of the crew rotation. The Schirra and Young mission was bumped to Gemini 6 and they now were the backup crew for Shepard and Stafford. Grissom and Borman now had their long-duration mission assigned to Gemini 5.

The second rearrangement occurred when Shepard developed Ménière's disease, an inner ear problem. Grissom was then moved to command Gemini 3. Slayton felt that Young was a better personality match with Grissom and switched Stafford and Young. Finally, Slayton tapped Cooper to command the long-duration Gemini 5. Again for reasons of compatibility, he moved Conrad from backup commander of Gemini 4 to pilot of Gemini 5, and Borman to backup command of Gemini 4. Finally he assigned Armstrong and Elliot See to be the backup crew for Gemini 5.

The third rearrangement of crew assignment occurred when Slayton felt that See wasn't up to the physical demands of EVA on Gemini 8. He reassigned See to be the prime commander of Gemini 9 and put Scott as pilot of Gemini 8 and Charles Bassett as the pilot of Gemini 9.

The fourth and final rearrangement of the Gemini crew assignment occurred after the deaths of See and Bassett when their trainer jet crashed, ironically into a McDonnell building which held their Gemini 9 capsule in St. Louis. The backup crew of Stafford and Cernan was then moved up to the new prime crew of the re-designated Gemini 9A. Lovell and Aldrin were moved from being the backup crew of Gemini 10 to be the backup crew of Gemini 9. This cleared the way through the crew rotation for Lovell and Aldrin to become the prime crew of Gemini 12.

Along with the deaths of Grissom, White, and Roger Chaffee in the fire of Apollo 1, this final arrangement helped determine the makeup of the first seven Apollo crews, and who would be in position for a chance to be the first to walk on the Moon.

In his autobiography *Deke!* Slayton relates that he would probably have replaced Aldrin with Cernan, the backup pilot for Gemini 12, on Apollo 11 if the second use of the Astronaut Maneuvering Unit (AMU) had been on Gemini 12. (The first use was by Cernan on Gemini IX-A.) Cernan makes a similar claim in his autobiography.

As it happened, despite these random substitutions and similar ones in Apollo, and a different number of unmanned flights in both programs, Slayton's rotation philosophy dominated to create a curious coincidence: most of the Gemini astronauts who went on to fly in Apollo occupied an Apollo mission numbered one more than their corresponding Gemini mission:

- Schirra commanded Gemini 6 and Apollo 7.
- Borman and Lovell flew together on Gemini 7 and Apollo 8.
- David Scott flew on Gemini 8 and Apollo 9.
- Stafford and Cernan flew together on Gemini 9A and Apollo 10.
- Collins flew on Gemini 10 and Apollo 11.
- Conrad and Gordon flew together on Gemini 11 and Apollo 12.
- Lovell commanded Gemini 12 and Apollo 13.

The only exceptions to this pattern were:

- McDivitt, who commanded Gemini 4 and Apollo 9
- Young, who flew Gemini 3, Gemini 10, Apollo 10 and Apollo 16
- Armstrong, who commanded Gemini 8 and Apollo 11

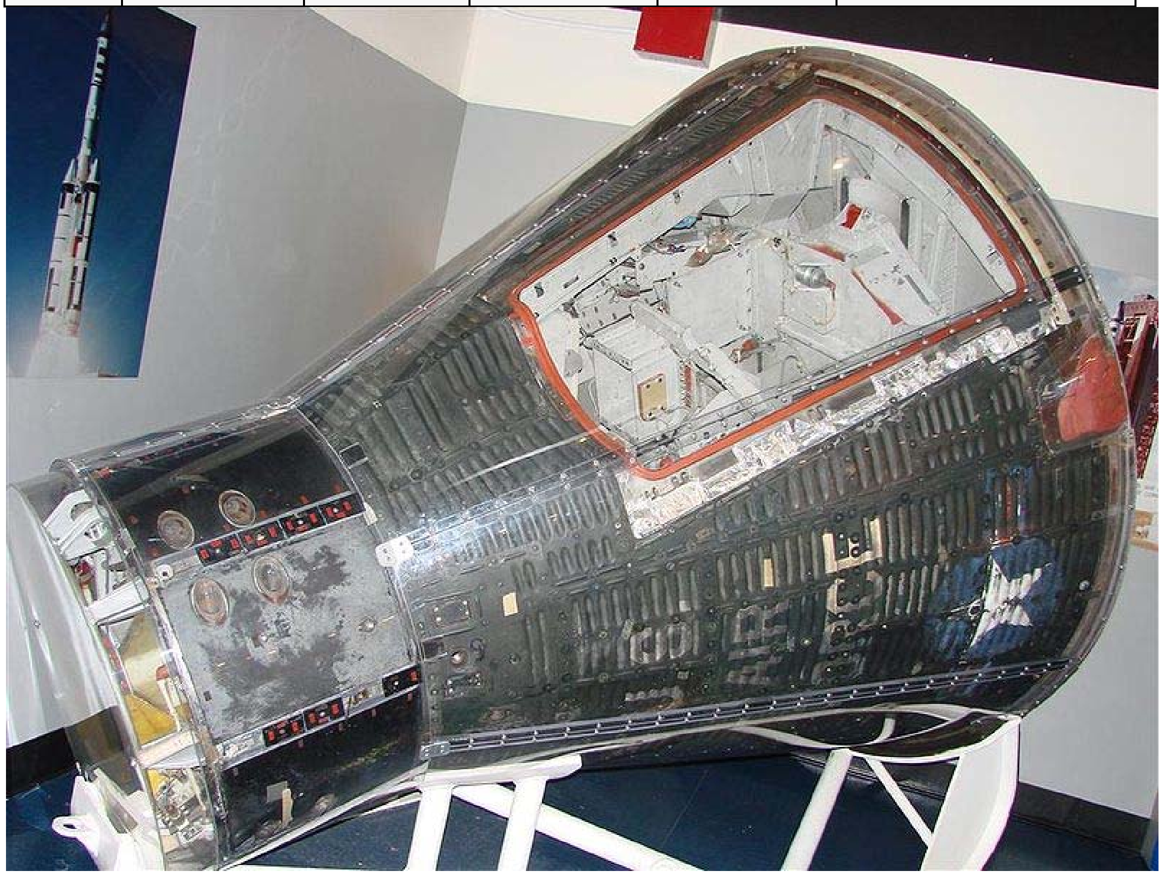
Missions

Liftoff of Gemini 6A from Pad 19 with astronauts Walter Schirra and Thomas Stafford aboard (15 December 1965)

There were 12 Gemini flights, including two unmanned flight tests. All were launched by Titan II rockets.

Unmanned events					
Mission	**LV Serial N^{o}**	**Mission Dates**	**Launch Time**	**Duration**	**Remarks**
Gemini 1	GLV-1 12556	8–12 April 1964	16:01 UTC	03d 23h	First test flight of Gemini
Gemini	GLV-2	19 January	14:03 UTC	00d 00h 18m	Suborbital flight to

2	12557	1965		16s	test heat shield



Gemini 2 on display at Air Force Space and Missile Museum

<table>
<caption>Manned events</caption>
<tr><th>Mission</th><th>LV Serial Nº</th><th>Command Pilot</th><th>Pilot</th><th>Mission Dates</th><th>Launch Time</th><th>Duration</th></tr>
<tr><td rowspan="2">Gemini III</td><td>GLV-3 12558</td><td>Grissom</td><td>Young</td><td>23 March 1965</td><td>14:24 UTC</td><td>00d 04h 52m 31s</td></tr>
<tr><td colspan="6">First manned Gemini flight, three orbits.</td></tr>
<tr><td rowspan="2">Gemini IV</td><td>GLV-4 12559</td><td>McDivitt</td><td>White</td><td>3–7 June 1965</td><td>15:15 UTC</td><td>04d 01h 56m 12s</td></tr>
<tr><td colspan="6">Included first extravehicular activity (EVA) by an American; White's "space walk" was a 22 minute EVA exercise.</td></tr>
<tr><td rowspan="2">Gemini V</td><td>GLV-5 12560</td><td>Cooper</td><td>Conrad</td><td>21–29 August 1965</td><td>13:59 UTC</td><td>07d 22h 55m 14s</td></tr>
<tr><td colspan="6">First week-long flight; first use of fuel cells for electrical power; evaluated guidance and navigation system for future rendezvous missions. Completed 120 orbits.</td></tr>
<tr><td>Gemini VII</td><td>GLV-7 12562</td><td>Borman</td><td>Lovell</td><td>4–18 December</td><td>19:30 UTC</td><td>13d 18h 35m 01s</td></tr>
</table>

				1965		
	When the original Gemini VI mission was scrubbed because its Agena target for rendezvous and docking failed, Gemini VII was used for the rendezvous instead. Primary objective was to determine whether humans could live in space for 14 days.					
Gemini VI-A	GLV-6 12561	Schirra	Stafford	15–16 December 1965	13:37 UTC	01d 01h 51m 24s
	First space rendezvous accomplished with Gemini VII, station-keeping for over five hours at distances from 0.3 to 90 m (1 to 300 ft).					
Gemini VIII	GLV-8 12563	Armstrong	Scott	16–17 March 1966	16:41 UTC	00d 10h 41m 26s
	Accomplished first docking with another space vehicle, an unmanned Agena stage. While docked, a Gemini spacecraft thruster malfunction caused near-fatal tumbling of the craft, which, after undocking, Armstrong was able to overcome; the crew effected the first emergency landing of a manned U.S. space mission.					
Gemini IX-A	GLV-9 12564	Stafford	Cernan	3–6 June 1966	13:39 UTC	03d 00h 21m 50s
	Rescheduled from May to rendezvous and dock with augmented target docking adapter (ATDA) after original Agena target vehicle failed to orbit. ATDA shroud did not completely separate, making docking impossible. Three different types of rendezvous, two hours of EVA, and 44 orbits were completed.					
Gemini X	GLV-10 12565	Young	Collins	18–21 July 1966	22:20 UTC	02d 22h 46m 39s
	First use of Agena target vehicle's propulsion systems. Spacecraft also rendezvoused with Gemini VIII target vehicle. Collins had 49 minutes of EVA standing in the hatch and 39 minutes of EVA to retrieve experiment from Agena stage. 43 orbits completed.					
Gemini XI	GLV-11 12566	Conrad	Gordon	12–15 September 1966	14:42 UTC	02d 23h 17m 08s
	Gemini record altitude, 1,189.3 kilometres (739.0 mi) (739.2 mi) reached using Agena propulsion system after first orbit rendezvous and docking. Gordon made 33-minute EVA and two-hour standup EVA. 44 orbits.					
Gemini XII	GLV-12 12567	Lovell	Aldrin	11–15 November 1966	20:46 UTC	03d 22h 34m 31s
	Final Gemini flight. Rendezvoused and docked manually with its target Agena and kept station with it during EVA. Aldrin set an EVA record of 5 hours 30 minutes for one space walk and two stand-up exercises, and demonstrated improvements to previous EVA problems.					

Gemini-Titan launches and serial numbers

Gemini 6A launch. USAF serial number location on Titan II.

The Gemini-Titan launch vehicles, like the Mercury-Atlas vehicles before them, were ordered by NASA through the U. S. Air Force and were in reality missiles. The Gemini-Titan II rockets were assigned U.S. Air Force serial numbers, which were painted in four places on each Titan II (on opposite sides on each of the first and second stages). U.S. Air Force crews maintained Launch Complex 19 and prepared and launched all of the Gemini-Titan II launch vehicles.

The USAF serial numbers assigned to the Gemini-Titan launch vehicles are given in the tables above. Fifteen Titan IIs were ordered in 1962 so the serial is "62-12XXX", but only "12XXX" is painted on the Titan II. The order for the last three of the 15 launch vehicles was cancelled on July 40, 1964, and they were never built. Serial numbers were, however, assigned to them prospectively: *12568* - GLV-13; *12569* - GLV-14; and *12570* - GLV-15.

All Gemini Launches from GT-1 through GT-12.

Current location of hardware

Spacecraft

Gemini 1

Destroyed

Gemini 2

Air Force Space & Missile Museum, Cape Canaveral Air Force Station, Fla.

Gemini III

Grissom Memorial, Spring Mill State Park, Mitchell, Ind.

Gemini IV

National Air and Space Museum, Washington D.C.

Gemini V

Johnson Space Center, NASA, Houston, Texas

Gemini VI

Oklahoma History Center, Oklahoma City, Okla.

Gemini VII

Steven F. Udvar-Hazy Center, Chantilly, Va.

Gemini VIII

Armstrong Air and Space Museum, Wapakoneta, Ohio

Gemini IX

Kennedy Space Center, NASA, Cape Canaveral, Fla.

Gemini X

Kansas Cosmosphere and Space Center, Hutchinson, Kan.

Gemini XI

California Museum of Science and Industry, Los Angeles, Calif.

Gemini XII

Adler Planetarium, Chicago, Ill.

Trainers

Gemini 3A - St. Louis Science Center, St. Louis, Mo.

Gemini MOL-B - National Museum of the United States Air Force, Wright-Patterson Air Force Base, Dayton, Ohio

Gemini Trainer - U.S. Space & Rocket Center, Huntsville, Ala.

Gemini Trainer - Goddard Space Flight Center (Visitor Center), NASA, Greenbelt, Md.

Gemini Trainer - Louisville Science Center, Louisville, Ken.

6165 - National Air and Space Museum, Washington D.C. (not on display)

El Kabong - Kalamazoo Air Museum, Kalamazoo, Mich.

Gemini Trainer - Kalamazoo Air Museum, Kalamazoo, Mich.

TTV-2 Royal Museum, Edinburgh, Scotland

Trainer - Pate Museum of Transportation, Fort Worth, Texas

MSC 313 - Private residence, San Jose, Calif.

Rogallo Test Vehicle - White Sands Space Harbor, White Sands, N. M.

TTV-1 - Stephen F. Udvar-Hazy Center, Chantilly, Va.

unnamed - U.S. Air Force Space Museum, Cape Canaveral Air Force Station, Fla.

unnamed - U.S. Air Force Space Museum, Cape Canaveral Air Force Station, Fla.

Gemini Trainer - BDL Aerospace and Flight Museum, NAS Whidbey Island, Oak Harbor, Wash.

Trainer - U.S. Astronaut Hall of Fame, Titusville, Fla.

MSC-307 - USS Hornet Museum, Alameda, Calif.

Proposed applications

McDonnell Aircraft was one of the original bidders on the prime contract for Apollo, but lost out to North American Aviation. McDonnell later sought to extend the Gemini program by proposing a derivative which could be used to fly a cislunar mission and even achieve a manned lunar landing earlier and at less cost than Apollo, but these proposals were rejected by NASA.

Military

The United States Air Force had an interest in the system, and decided to use its own modification of the spacecraft as the crew vehicle for the Manned Orbital Laboratory. To this end, one of the unmanned Gemini spacecraft was refurbished and flown again atop a mockup of the MOL, sent into space by a Titan III-M. This was the first time a spacecraft went into space twice.

The USAF also had the notion of adapting the Gemini spacecraft for military applications, such as crude observation of the ground (no specialized reconnaissance camera could be carried) and practicing making rendezvous with suspicious satellites. This project was called Blue Gemini. The US Air Force did not like the fact that Gemini would have to be recovered by the US Navy, so they intended for Blue Gemini eventually to use the paraglider and land on three skids, something from the original design of Gemini.

At first some within NASA welcomed sharing of the cost with the USAF, but it was later agreed that NASA was better off operating Project Gemini by itself. MOL was cancelled in 1968 and Blue Gemini too was cancelled without any use by military astronauts.

Other proposals

Other Gemini derivatives were proposed, including Big Gemini, Gemini LOR, Gemini Lunar Lander, Gemini-Centaur, Gemini Ferry, Gemini Transport, Gemini - Saturn I, Gemini - Saturn IB, Gemini - Saturn V, Gemini Pecan, Extended Mission Gemini, Gemini - Double Transtage, Gemini Satellite Inspector, Gemini Lunar Surface Rescue Spacecraft, Gemini Observatory, Gemini Para glider, Rescue Gemini, Winged Gemini, Gemini LORV and Gemini Lunar Surface Survival Shelter.

Chapter- 7

Notable Human Spaceflights

Soyuz TMA-20

Soyuz TMA-20
Союз TMA-20

Mission insignia

Mission statistics

Mission name	Soyuz TMA-20 Союз TMA-20
Spacecraft name	Soyuz-TMA
Crew size	3
Call sign	Варяг ("Varangian")
Launch pad	Baikonur Cosmodrome
Launch date	December 15, 2010 19:09 GMT
Landing	May 16, 2011

Crew photo

From left to right: Coleman, Kondratyev and Nespoli

Related missions

Previous mission	Subsequent mission
Soyuz TMA-01M	Soyuz TMA-21

Soyuz TMA-20 is a manned spaceflight to the International Space Station (ISS) and is part of the Soyuz programme. It lifted off from the Baikonur Cosmodrome on December 15, 2010. The link up of Soyuz TMA-20 with the ISS is planned on 17 December, following a two day autonomous flight. The three person crew of Soyuz TMA-20, Dmitri Kondratyev, Catherine Coleman and Paolo Nespoli represent the partner organizations of Roscosmos, NASA and the European Space Agency (ESA) in the ISS program.

Crew

The Soyuz TMA-20 prime and backup crews conduct their ceremonial tour of Red Square on 26 November 2010.

The Soyuz TMA-20 crew was confirmed by NASA on November 21, 2008.

Position	Crew Member
Commander	Dmitri Kondratyev, Roscosmos Expedition 26 First spaceflight
Flight Engineer 1	Catherine Coleman, NASA

	Expedition 26 Third spaceflight
Flight Engineer 2	Paolo Nespoli, ESA Expedition 26 Second spaceflight

Backup crew

Position	Crew Member
Commander	Anatoli Ivanishin, RSA
Flight Engineer 1	Satoshi Furukawa, JAXA
Flight Engineer 2	Michael Fossum, NASA

Tallest crew member

European astronaut Paolo Nespoli (height: 188 centimeters) is believed to be the tallest crew member ever to fly onboard Soyuz spacecraft. According to president of RKK Energia, Vitaly Lopota, a custom-built seat and related hardware had to be manufactured due to Nespoli's height.

Transportation damage

The Soyuz spacecraft suffered damage to its container during transport to the Baikonur cosmodrome on October 5, 2010, according to Interfax news agency. Engineers spotted damage after it was shipped by rail from Russia to Kazakhstan. After initial inspections of the damage, Russian sources said that it was not immediately clear whether the spacecraft will have to be returned to the RSC Energia factory in Moscow. Later, Russian officials replaced the damaged descent module with a new one flown aboard a cargo plane. The replacement module was originally part of the Soyuz TMA-21 spacecraft.

The Soyuz TMA-20 rocket launches from the Baikonur Cosmodrome carrying Kondratyev, Coleman and Nespoli to the International Space Station.

Despite the transportation damage, RSC-Energia president Vitaly Lopota told news media that the mission will take place in December. Roskosmos spokesman Alexander Vorobyov also told Interfax that the December launch date would not be affected because a reserve spacecraft will be available at Baikonur for the mission, if required.

Launch and docking

Launch

On 12 December 2010 the Soyuz TMA-20 payload section was integrated with the Soyuz FG rocket and the emergency escape system allowing the State commission to declare that the Soyuz TMA-20 mission was fully assembled. Rollout to the launch pad began in the morning of December 13, 2010.

The Soyuz FG rocket with Soyuz TMA-20 spacecraft blasted off from Baikonur Cosmodrome's Site 1 at 19:09 GMT (22:09:25 Moscow Time) on 15 December 2010 and successfully reached orbit ten minutes later.

Docking

The Soyuz TMA-20 spacecraft approaches the International Space Station.

The Soyuz TMA-20 spacecraft docked with the Rassvet module's docking port at 20:12 GMT on December 17. The docking occurred as the space station flew over western Africa at an altitude of 224 miles.

In preparation for the day's docking activities, the automated rendezvous sequence aboard Soyuz TMA-20 began about 17:49 GMT. The Soyuz TMA-20 engines were fired at 18:09 GMT and another impulse firing occurred around 18:28 GMT. Within minutes the Kurs rendezvous equipment on both the Soyuz and station was activated to support the linkup. The television camera on the nose of the Soyuz spacecraft was turned on at 19:29 GMT to provide views of the docking.

After checking that there are no leaks between the two spacecraft, the hatch between the Soyuz TMA-20 spacecraft and the space station was opened at 23:02 GMT. The new crew of Kondratyev, Coleman and Nespoli entered into the space station. The welcome ceremony to mark the arrival of the new crew was held shortly when the live television downlink communications session started.

Soyuz TMA-19

Soyuz TMA-19
Союз ТМА-19

Mission insignia

Mission statistics

Mission name	Soyuz TMA-19 Союз ТМА-19
Crew size	3
Call sign	Olympus
Booster	Soyuz-FG
Launch pad	Site 1/5, Baikonur Cosmodrome
Launch date	15 June 2010 21:35 UTC
Landing	26 November 2010 04:46 GMT
Orbital period	88.8 minutes

Orbital inclination	51.62 degrees (initial orbit)

Crew photo

From left to right: Wheelock, Walker and Yurchikhin

Related missions

Previous mission	Subsequent mission
Soyuz TMA-18	Soyuz TMA-01M

Soyuz TMA-19 was a manned spaceflight to the International Space Station and is part of the Soyuz programme. It was launched 15 June 2010 carrying three members of the Expedition 24 crew to Space Station, who remained aboard the station for around six months. TMA-19 was the 106th manned flight of a Soyuz spacecraft, since the first mission which was launched in 1967. The spacecraft remained docked to the space station for the remainder of Expedition 24, and for Expedition 25, to serve as an emergency escape vehicle. It undocked from ISS and landed in Kazakhstan on the 26 November 2010. It was the 100th mission to be conducted as part of the International Space Station programme since assembly began in 1998.

Crew

The Soyuz TMA-19 prime and backup crews conduct their ceremonial tour of Red Square on 31 May 2010.

The Soyuz TMA-19 crew was confirmed by NASA on 21 November 2008. The mission Commander is Fyodor Yurchikhin of the Russian Federal Space Agency, who is making his third spaceflight. The other two crew members are Shannon Walker and Douglas H. Wheelock of the United States National Aeronautics and Space Administration and are designated flight engineers. TMA-19 is Wheelock's second spaceflight, and Walker's first.

Position	Crew Member
Commander (Center Seat)	Fyodor Yurchikhin, RSA Expedition 24 Third spaceflight
Flight Engineer 1 (Left Seat)	Shannon Walker, NASA Expedition 24 First spaceflight
Flight Engineer 2 (Right Seat)	Douglas H. Wheelock, NASA Expedition 24 Second spaceflight

Backup crew

Position	Crew Member
Commander	Dmitri Kondratyev, RSA
Flight Engineer 1	Paolo Nespoli, ESA
Flight Engineer 2	Catherine Coleman, NASA

Launch

A Soyuz-FG launches Soyuz TMA-19 from Baikonur Cosmodrome, 15 June 2010.

Soyuz TMA-19 was launched by a Soyuz-FG carrier rocket flying from Site 1/5 at the Baikonur Cosmodrome in Kazakhstan. The launch occurred successfully on 15 June 2010, with the rocket lifting off at 21:35 UTC. After its separation from the last stage of the Soyuz-FG rocket, Moscow Mission Control Center began controlling the Soyuz TMA-19 spacecraft. Nine minutes into the ascent, the spacecraft settled into a preliminary orbit of 200.16 by 259.16 km (124.37 by 161.03 mi) with the inclination 51.62 degrees toward the Equator. The Soyuz spacecraft successfully deployed the solar arrays for power generation and the antennas for navigational and communication systems. Telemetry data received from the Soyuz confirmed that the spacecraft was performing nominally.

Soyuz TMA-19 launches into orbit en route to the ISS (10 mins 39 secs).

Prior to launch, assembly of the rocket and spacecraft had been underway for several months. The Soyuz-FG rocket arrived at Baikonur on 11 March 2010, along with a Soyuz-U which was slated to launch Progress M-06M. The spacecraft itself was shipped from Korolyov on 16 April 2010, arriving at Baikonur by train three days later. Upon delivery, the spacecraft was moved to Site 254.

On 11 June 2010, final inspections of the spacecraft were conducted, and the spacecraft was then encapsulated in its payload fairing to form the upper composite of the rocket. The next day, the upper composite was integrated with the upper stage of the rocket that was to launch it, and subsequently the launch escape system. This assembly work took place at Site 112 of the Baikonur Cosmodrome. Once this was complete, the upper stage was attached to the remainder of the rocket in the MIK. A State Commission met of 12 June to approve rollout, which was authorised.

Rollout to the launch pad began at 01:00 UTC (5 a.m. Moscow Time) on 13 June 2010, with the rocket departing the MIK propelled by a locomotive. Rollout lasted around two hours, with the rocket travelling 2 kilometres (1.2 mi) from the MIK to the launch pad. The winner and runner-up in the patch design competition were present to observe the rollout. Rollout operations were completed by 05:00 UTC (9 a.m. Moscow Time), when the rocket was erected on the launch pad.

Docking

Soyuz TMA-19 spacecraft docked to Rassvet Mini-Research Module 1 (MRM1).

Soyuz TMA-19 arrives at the ISS (16 mins 32 secs)

Soyuz TMA-19 docked with the International Space Station on 17 June 2010at 22:25 UTC. It docked with the aft port of the Zvezda module. Ahead of docking, the ISS handed over attitude control to the Russian Orbital Segment at 19:00 UTC, and at 19:17 maneuvered to provide an optimum attitude for docking. At 20:06, the automated rendezvous sequence started. The Kurs docking systems aboard the Soyuz and the Space Station were activated at 20:52 and 20:54 respectively. TMA-19 began station keeping at around 20:08 UTC, before it commenced its final approach at 20:16.

Twenty minutes after docking, hooks were closed securing the Soyuz to the station. Once this was completed, the ISS returned to its normal attitude. Attitude control was returned to the US Orbital Segment at 23:45 UTC.

Relocation

Soyuz TMA-19 relocates from the Zvezda Service Module's aft port to the Rassvet Mini-Research Module 1.

On June 28, cosmonaut Fyodor Yurchikhin along with NASA astronauts Douglas Wheelock and Shannon Walker boarded their Soyuz TMA-19 spacecraft and undocked from Zvezda Service Module's aft port at 3:13 p.m. EDT. They re docked it to its new location on the Rassvet module 25 minutes later as the two spacecraft were flying just off the coast of the Western Sahara on the west coast of Africa. The repositioning of the Soyuz TMA-19 was temporarily delayed due to an electrical breaker problem that delayed proper orientation of the 4B solar array on the space station's P4 truss. The flight went according to plan.

The event marked the first ever docking to the Rassvet module. The change of location released the Zvezda port for the docking of Progress M-06M.

Undocking and landing

The Soyuz TMA-19 spacecraft departs the International Space Station.

Soyuz TMA-19 lands in Kazakhstan on 26 November 2010.

Soyuz TMA-19 crewmembers after landing.

Soyuz TMA-19 undocked from the space station at 01:19 GMT on 26 November, 2010. The descent module landed on the central steppes of Kazakhstan at 04:46 GMT, four days earlier than originally planned. The landing had been set for 30 November, but Kazakh officials decided to restrict air traffic before the start of the Organization for Security and Cooperation in Europe summit in Astana, Kazakhstan, set for 1-2 December. The landing site was located 84 km away from the city of Arkalyk.

On 25 November, 2010, the crew boarded Soyuz TMA-19 to return to Earth. After closing the hatchway between the Soyuz and the station at 22:14 GMT, they donned their Sokol spacesuits and continued with the power up operations. The crew also activated the Soyuz systems and removed the docking clamps. The undock command was issued at 01:20 GMT when the Soyuz and the station was flying above the Russian-Mongolian border. . The physical separation occurred three minutes later at 01:23:13 GMT

After the separation from the station and at a short distance away, Soyuz TMA-19 executed the so called “separation burn” (a 15 seconds burn) to vacate the proximity of the space station. About two and half hours later, at 03:55:12 GMT, the Soyuz spacecraft performed the deorbit maneuver which lasted for 4 minutes and 21 seconds, while it flew backwards over the south-central Atlantic Ocean on a north easterly trajectory towards Asia. With the deorbit burn nominally accomplished, the recovery forces comprising 14 helicopters, 4 airplanes and 7 search and rescue vehicles were dispatched to the landing zone. At an altitude of 140 kilometers, just above the first traces of the Earth's atmosphere, onboard computers commanded the separation of the three Soyuz TMA-19 modules. With the crew inside the Descent Module, the forward Orbital Module and the rear Instrumentation Module were pyrotechnically nominally jettisoned at 04:21 GMT. Three minutes after the separation, with the heat shield of the Descent Module pointing towards the direction of travel, the Soyuz capsule experienced the first traces of the atmosphere ("entry interface") at 04:23 GMT at an altitude of 400,000 feet above the Earth. Around 04:28 GMT, the flight path of the capsule crossed the Mediterranean, Turkey and the Black Sea before flying over southern Russia and into Kazakhstan.

At an altitude of about 10 kilometers, onboard computers started a commanded sequence to unfurl the parachutes. Two "pilot" parachutes deployed first, extracting a 24-square-meter drogue parachute. The parachute deployment reduced the velocity of the Soyuz capsule from 230 m/s to 80 m/s and assisted in the capsule's stability by creating a gentle spin for the Soyuz spacecraft. Once the drogue chute was released, the main parachutes were deployed. They further reduced the descent to 7.2 m/s. Initially, the Descent Module hung underneath the main parachute at a 30-degree angle with respect to the horizon and for the few minutes before the landing, then following the detachment of the bottom-most harness it hung vertically. At this time, flight controllers reported the Soyuz spacecraft was operating as expected on the automatic sequence. During the same time, they were successful in contacting the crew via the fixed-wing aircraft that served as the central command for the search and recovery forces. The recovery forces spotted the Soyuz TMA-19 around 04:36 GMT. At an altitude of five kilometers, the module's heat shield was jettisoned.

At the end of the 163-day voyage, Soyuz TMA-19's landing was confirmed at 04:46 GMT. The recovery team assisted the crew to exit the capsule. First out of the capsule was cosmonaut Fyodor Yurchikhin followed by NASA astronauts Shannon Walker and Douglas Wheelock.

After the successful landing, the Soyuz TMA-19 crew flew to Kustanai in Kazakhstan for the welcoming ceremony. Wheelock and Walker boarded a NASA jet waiting for them in Kustanai for the trip back to the Johnson Space Center in Houston. Yurchikhin headed for Star City - the home of the Gagarin Cosmonaut Training Center in Russia.

Mission insignia

The Soyuz TMA-19 patch design is based on a drawing by Evgeny Emelianov, the winner of the traditional patch contest organized by the Russian Federal Space Agency. His design shows the ISS and the Earth waiting for the crew to come back.

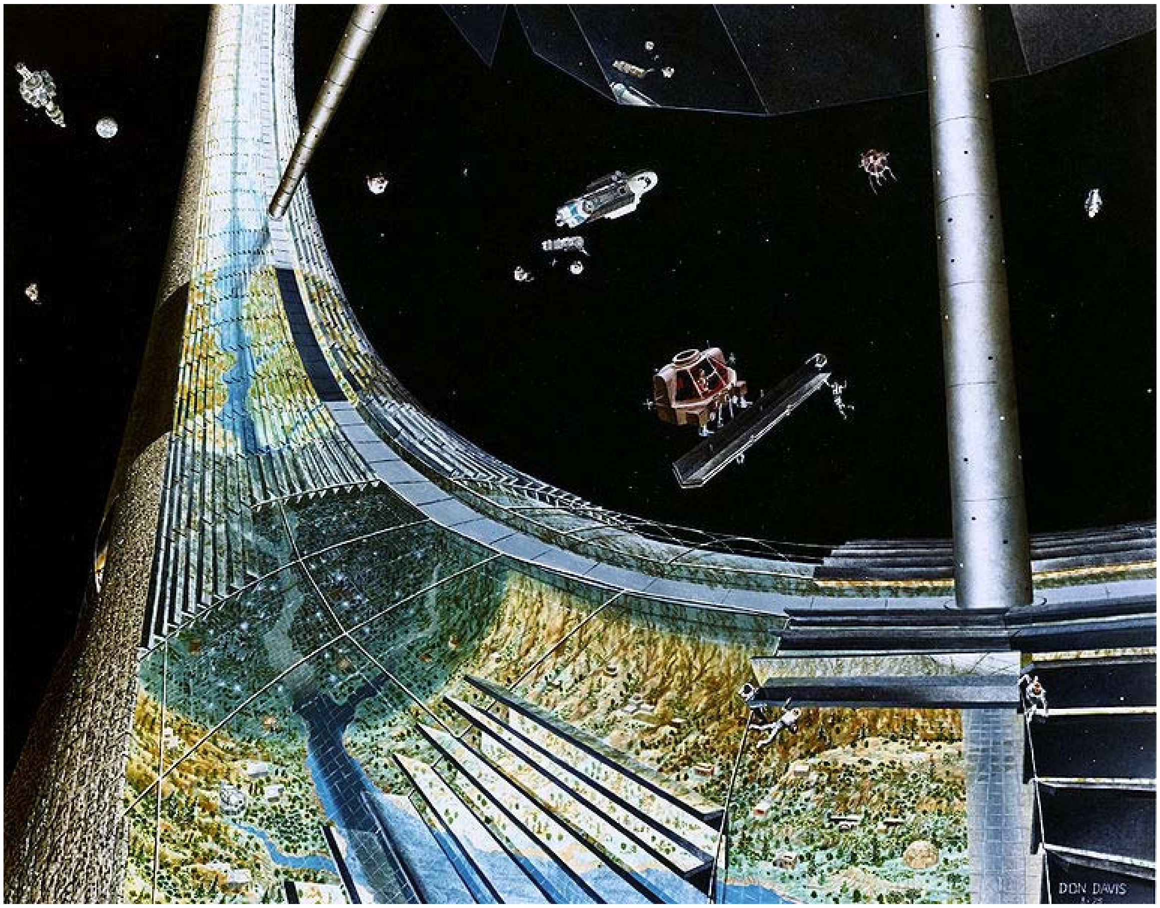
Chapter- 8

Human Adaptation to Spaceflight

Human physiological adaptation to the conditions of space is a challenge faced in the development of human spaceflight.

The fundamental engineering problems of escaping Earth's gravity well and developing systems for in-space propulsion have been examined for well over a century, and millions of man-hours of research have been spent on them. In recent years there has been an increase in research into the issue of how humans can survive and work in space for extended and possibly indefinite periods of time. This question requires input from the whole gamut of physical and biological sciences and has now become the greatest challenge, other than funding, to human space exploration. A fundamental step in overcoming this challenge is trying to understand the effects and the impact long-term space travel has on the human body.

Importance



Space colonization efforts must take into account the effects of space on the body

The sum of mankind's experience has resulted in the accumulation of 58 solar years in space and a much better understanding of how the human body adapts. In the future, industrialisation of space and exploration of inner and outer planets will require humans to endure longer and longer periods in space. The majority of current data comes from missions of short duration and so some of the long-term physiological effects of living in space are still unknown. A round trip to Mars with current technology is estimated to involve at least 18 months in transit alone. How the human body reacts to such time periods in space is a vital part of the preparation for such journeys. On-board medical facilities need to be able to cope with any type of trauma or emergency as well as contain a huge variety of diagnostic and medical instruments in order to keep a crew healthy over a long period of time, as these will be the only facilities available on board a spacecraft to cope with not only trauma, but also the adaptive responses of the human body in space.

Effects on humans

The effects of space conditions on humans can be separated into two areas, the physical and the psychological.

Unprotected effects

The environment of space is lethal without appropriate protection. The greatest threat is from the lack of pressure in the vacuum environment, while temperature and radiation effects also have an influence. In the low pressure environment, gas exchange in the lungs would continue as normal but would result in the removal of all gases, including oxygen, from the bloodstream. After 9 to 12 seconds, the deoxygenated blood would reach the brain, and loss of consciousness would result. Death would gradually follow after two minutes of exposure—though the limits are uncertain. As shown in the film depiction of Arthur C. Clarke's vignette in *2001: A Space Odyssey* (1968), if actions are taken quickly, and normal pressure restored within around 90 seconds, the victim may well make a full recovery.

This painting, *An Experiment on a Bird in the Air Pump* by Joseph Wright of Derby, 1768, depicts an experiment performed by Robert Boyle in 1660.

Humans and other animals exposed to vacuum will lose consciousness after a few seconds and die of hypoxia within minutes, but the symptoms are not nearly as graphic as the imagery in the public media. Blood and other body fluids do boil when their pressure drops below 6.3 kPa (47 Torr), the vapour pressure of water at body temperature. This condition is called ebullism. The steam may bloat the body to twice its normal size and slow circulation, but tissues are elastic and porous enough to prevent rupture. Ebullism is slowed by the pressure containment of blood vessels, so some blood remains liquid. Swelling and ebullism can be reduced by containment in a flight suit. Shuttle astronauts wear a fitted elastic garment called the Crew Altitude Protection Suit (CAPS) which prevents ebullism at pressures as low as 2 kPa (15 Torr). Rapid evaporative cooling of the skin will create frost, particularly in the mouth, but this is not a significant hazard.

A short term exposure to vacuum of up to 30 seconds is unlikely to cause permanent physical damage. Animal experiments show that rapid and complete recovery is normal for exposures shorter than 90 seconds, while longer full-body exposures are fatal and resuscitation has never been successful. There is only a limited amount of data available from human accidents, but it is consistent with animal data. Limbs may be exposed for much longer if breathing is not impaired. Robert Boyle was the first to show in 1660 that vacuum is lethal to small animals. In 1942, in one of a series of experiments on human subjects for the Luftwaffe, the Nazi regime exposed Dachau concentration camp prisoners to vacuum in order to determine the human body's capacity to survive high-altitude conditions.

As well as experimentation with humans and monkeys, a few cases of loss of pressure have occurred in the past, especially in experimentation on spaceflight projects. One such case is discussed in a NASA technical report: *Rapid (Explosive) Decompression Emergencies in Pressure-Suited Subjects*:

> "At NASA's Manned Spacecraft Center (now renamed Johnson Space Center) we had a test subject accidentally exposed to a near vacuum (less than 1 psi) [7 kPa] in an incident involving a leaking space suit in a vacuum chamber back in '65. He remained conscious for about 14 seconds, which is about the time it takes for O_2 deprived blood to go from the lungs to the brain. The suit probably did not reach a hard vacuum, and we began repressurizing the chamber within 15 seconds. The subject regained consciousness at around 15,000 feet [4600 m] equivalent altitude. The subject later reported that he could feel and hear the air leaking out, and his last conscious memory was of the water on his tongue beginning to boil."

There has been one recorded incident of death from decompression in spaceflight, the Soyuz 11 decompression accident, in 1971.

Cold or oxygen-rich atmospheres can sustain life at pressures much lower than atmospheric, as long as the density of oxygen is similar to that of standard sea-level atmosphere. The colder air temperatures found at altitudes of up to 3 km generally compensate for the lower pressures there. Above this altitude, oxygen enrichment is necessary to prevent altitude sickness, and spacesuits are necessary to prevent ebullism above 19 km. Most spacesuits use only 20 kPa (150 Torr) of pure oxygen, just enough to sustain full consciousness. This pressure is high enough to prevent ebullism, but simple evaporation of blood, or of gases dissolved in the blood, can still cause decompression sickness (the bends) and gas embolisms if not managed.

Rapid decompression can be much more dangerous than vacuum exposure itself. Even if the victim does not hold his breath, venting through the windpipe may be too slow to prevent the fatal rupture of the delicate alveoli of the lungs. Eardrums and sinuses may be ruptured by rapid decompression, soft tissues may bruise and seep blood, and the stress of shock will accelerate oxygen consumption leading to hypoxia. Injuries caused by rapid decompression are called barotrauma, and are well known from scuba diving accidents. A pressure drop as small as 100 Torr (13 kPa), which produces no symptoms if it is gradual, may be fatal if it occurs suddenly.

In a vacuum there is no medium for removing heat from the body by conduction or convection. Loss of heat is by radiation from the 310 K person to the 3 K of outer space. This is a slow process, especially in a clothed person, so there is no danger of immediately freezing. (Evaporation of skin moisture in the vacuum would cause immediate cooling but only by a very small amount.) Exposure to the 600 K radiation from the Sun would lead to local heating that would be well distributed by the body's conductivity and blood circulation. Other solar radiation, particularly ultraviolet rays, may cause severe sunburn in a few seconds.

Protected effects

Despite modern technology, some hazards still prove impossible to remove. The most important factor affecting human physical well-being in space is weightlessness, more accurately defined as microgravity environments. Living in this type of environment impacts on three types of human tissue:

- gravity receptors
- fluids
- weight bearing structures

Gravity receptors

Living on earth we constantly feel the gravitational pull and our bodies react automatically to maintain posture and locomotion in a downward pulling world. In microgravity environments, these constant signals the body is adapted to are absent. The otolith organs in the middle ear sensitive to linear accelerations no longer perceive a downwards bias, muscles are no longer required to contract to maintain posture and pressure receptors in the feet and ankles no longer signal the direction of down. These changes can immediately result in visual-orientation illusions where the astronaut feels he has flipped 180 degrees. Over time however the brain adapts and although these illusions can still occur most astronauts begin to see "down" as where the feet are. People returning to Earth after extended weightless periods initially have great difficulty maintaining their balance but recover the ability very quickly, highlighting the remarkable ability of the human body to adapt. Over half of astronauts also experience symptoms of motion sickness for the first three days of travel due to the conflict between what the body expects and what the body actually perceives.

Fluids

The second effect of weightlessness takes place in human fluids. The body is made up of 60% water, much of it intra-vascular and inter-cellular. Within a few moments of entering a microgravity environment, fluid is immediately re-distributed to the upper body resulting in bulging neck veins, puffy face and sinus and nasal congestion which can last throughout the duration of the trip and is very much like the symptoms of the common cold. In space the autonomic reactions of the body to maintain blood pressure are not required and fluid is distributed more widely around the whole body. This results in a decrease in plasma (water in the blood stream) volume of around 20%. These fluid shifts initiate a cascade of adaptive systemic effects that can be dangerous upon return to earth. Orthostatic intolerance results in astronauts returning to Earth after extended space missions being unable to stand unassisted for more than 10 minutes at a time without fainting. This is due in part to changes in the autonomic regulation of blood pressure and the loss of plasma volume. Although this effect becomes worse the longer the time spent in space, as yet all individuals have returned to normal within at most a few weeks of landing.

Weight-bearing structures

The third and most worrying effect of long-term weightlessness involves bones and muscles. Without the effects of gravity, skeletal muscle is no longer required to maintain our posture and the muscle groups used in moving around in a weightless environment are very different to those required in terrestrial locomotion. Consequently some muscles atrophy rapidly. The types of muscle fibre prominent in muscles also change. Slow twitch endurance fibres used to maintain posture are replaced by fast twitch rapidly contracting fibres that are insufficient for any heavy labour. Bone metabolism also changes. Normally bone is laid down in the direction of mechanical stress, however in a microgravity environment there is very little mechanical stress. This results in a loss of bone tissue approximately 1.5% per month especially from the lower vertebrae, hip and femur. Elevated blood calcium levels from the lost bone result in dangerous calcification of soft tissues and potential kidney stone formation. It is still unknown whether bone recovers completely. Loss of bone and muscle make it very difficult for humans to move and even breathe under the weight of Earth's pull upon their return.

Effects of radiation

Weightlessness is not the only factor to affect the human body in space. Without the protection of the Earth's atmosphere and magnetosphere astronauts are exposed to high levels of radiation through a steady flux of cosmic rays which pose a serious health threat. A year in even low-earth orbit results in a dose of radiation 10 times that of the annual dose on earth resulting in a high risk of astronauts developing cancer. High levels of radiation can create 'chromosomal aberrations' in blood lymphocytes. These cells are heavily involved in the immune system and so any damage may contribute to the lowered immunity experienced by astronauts. Over time immunodeficiency results in the rapid spread of infection between crew members, especially in such confined areas. Radiation has also recently been linked to a higher incidence of cataracts in astronauts. Protective shielding and protective drugs may lower the risks to astronauts to an acceptable level, but data is scarce, and longer-term exposure will result in greater risks.

Sense of taste

One effect of weightlessness on humans is that some astronauts report a change in their sense of taste in space. Some astronauts find that their food is bland, others find that their favorite foods no longer taste as good, some astronauts enjoy eating certain foods that they would not normally eat and some find no change whatsoever. The reason for this is uncertain, and several theories have been suggested:

- Congestion: Microgravity may cause fluid buildup in the sinuses, changing the taste in a similar fashion to holding one's nose while eating.
- Physical food degradation: Food in orbit is often stored for some months before being consumed. This and the stellar radiation may cause a breakdown in the groups of chemicals that give food its taste, resulting in bland food.
- Boredom: Menus for the ISS astronauts are planned on a repeating 8-day cycle, which are selected from a menu designed by NASA, and taken into space with the astronaut. This constant repetition may lead to some astronauts getting tired of food that they had previously liked.
- Psychological changes: The loss of taste may be purely psychological.

Astronauts often choose strong-tasting food such as salsa or shrimp cocktail.

Other physical effects

Studies of Russian cosmonauts, such as those on Mir, provide data on the long-term effects of space on the human body.

Other physical discomforts such as back and abdominal pain are commonly experienced with no clear cause. These may be part of the asthenia syndrome reported by cosmonauts living in space over an extended period of time, but seen as anecdotal by astronauts. Fatigue, listlessness, and psychosomatic worries are also part of the syndrome. The data is inconclusive, however the syndrome does appear to exist as a manifestation of all the internal and external stress crews in space must face. The amount and quality of sleep experienced in space is poor due to highly variable light and dark cycles on flight decks and poor illumination during daytime hours in the space craft. Even the habit of looking out of the window before retiring can send the wrong messages to the brain resulting in poor sleep patterns. These disturbances in circadian rhythm have profound effects on the neurobehavioural responses of crew and aggravate the psychological stresses they already experience.

Psychological effects

The psychological effects of living in space have not been clearly analyzed but analogies on Earth do exist, such as Arctic research stations and submarines. The enormous stress on the crew, coupled with the body adapting to other environmental changes, can result in anxiety, insomnia and depression. According to current data however astronauts and cosmonauts seem extremely resilient to psychological stresses. Interpersonal issues can have an enormous influence on a human's well-being and yet little research has been undertaken to examine crew selection issues in relation to this. The Mars Arctic Research Station and Mars Desert Research Station have examined the influence of different crew selections when living in a completely isolated environment and may provide vital data for future experiences.

Future prospects

At the moment only rigorously tested humans have experienced the conditions of space. If off-world colonization someday begins, many types of people will be exposed to these dangers, and the effects on the elderly and on the very young are completely unknown. Factors such as nutritional requirements and physical environments which have not been examined here will become important. Overall, there is little data on the manifold effects of living in space and this makes working to mitigate the risks during a lengthy space habitation difficult. Test beds such as the International Space Station (ISS) are presently being utilized to research some of these risks.

The environment of space is still largely unknown, and there will likely be hazards of which we are not currently aware. Meanwhile, future technologies such as artificial gravity and more complex bioregenerative life support systems may someday be capable of mitigating some hazards.

Chapter- 9

Life Support System

In human spaceflight, the **life support system** is a group of devices that allow a human being to survive in outer space. U.S. government space agency NASA, and private spaceflight company Bigelow Aerospace, use the term **Environmental Control and Life Support System** or the acronym **ECLSS** when describing these systems for their 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.

Human physiological and metabolic needs

A crewmember of typical size requires approximately 5 kg (total) of food, water, and oxygen per day to perform the standard activities on a space mission, and outputs a similar amount in the form of waste solids, waste liquids, and carbon dioxide. The mass breakdown of these metabolic parameters is as follows: 0.84 kg of oxygen, 0.62 kg of food, and 3.52 kg of water consumed, converted through the body's physiological processes to 0.11 kg of solid wastes, 3.87 kg of liquid wastes, and 1.00 kg of carbon dioxide produced. These levels can vary due to activity level, specific to mission assignment, but will correlate to the principles of mass balance. Actual water use during space missions is typically double the specified values mainly due to non-biological use (i.e. personal cleanliness). Additionally, the volume and variety of waste products varies with mission duration to include hair, finger nails, skin flaking, and other biological wastes in missions exceeding one week in length. Other environmental considerations such as radiation, gravity, noise, vibration, and lighting also factor into human physiological response in space, though not with the more immediate effect that the metabolic parameters have.

Atmosphere

Space life support systems maintain atmospheres composed, at a minimum, of oxygen, water vapor and carbon dioxide. The partial pressure of each component gas adds to the overall barometric pressure.

By reducing or omitting diluents (constituents other than oxygen, e.g., nitrogen and argon) the total pressure can be lowered to a minimum of 21 kPa, the partial pressure of oxygen in the Earth's atmosphere at sea level. This can lighten spacecraft structures, reduce leaks and simplify the life support system.

However, the elimination of diluent gases substantially increases fire risks, especially in ground operations when for structural reasons the total cabin pressure must exceed the external atmospheric pressure; see Apollo 1. For this reason, most modern crewed spacecraft use conventional air (nitrogen/oxygen) atmospheres and use pure oxygen only in pressure suits during extravehicular activity where acceptable suit flexibility mandates the lowest inflation pressure possible.

Water

Water is consumed by crew members through drinking, cleaning activities, EVA thermal control, and emergency uses. It must be stored, used, and reclaimed (from waste water) efficiently since no in-situ sources currently exist for the environments reached in the course of human space exploration.

Food

Life support systems often include an indoor plant cultivation system which allows food to be grown within buildings and/or vessels. Often, the system is designed so that it reuses all (otherwise lost) nutrients. This is done, for example, by composting toilets which reintegrate waste material (excrement) back into the system, allowing the nutrients to be taken up by the food crops. The food coming from the crops is then consumed again by the system's users and the cycle continues.

Microbe detection and control

The NASA LOCAD (Lab-on-a-Chip Applications Development) project is working on systems to help detect bacterial and fungal growths in spacecraft used for long-duration spaceflight.

Space vehicle systems

Gemini, Mercury, & Apollo

Space Shuttle

For the Space Shuttle, NASA includes in the ECLSS category systems that provide both life support for the crew and environmental control for payloads. The *Shuttle Reference Manual* contains ECLSS sections on: Crew Compartment Cabin Pressurization, Cabin Air Revitalization, Water Coolant Loop System, Active Thermal Control System, Supply and Waste Water, Waste Collection System, Waste Water Tank, Airlock Support, Extravehicular Mobility Units, Crew Altitude Protection System, and Radioisotope Thermoelectric Generator Cooling and Gaseous Nitrogen Purge for Payloads.

Orion Crew Module

The Orion crew module life support system is being designed by Lockheed Martin in Houston, Texas.

Soyuz

The life support system on the Soyuz spacecraft is called the Kompleks Sredstv Obespecheniya Zhiznideyatelnosti (KSOZh).

Space station systems

Spacelab

Mir

Bigelow Commercial Space Station

The life support system for the Bigelow Commercial Space Station is being designed by Bigelow Aerospace in Las Vegas, Nevada. The space station will be constructed of habitable Sundancer and BA 330 expandable spacecraft modules. As of October 2010, "human-in-the-loop testing of the environmental control and life support system (ECLSS)" for *Sundancer* has begun.

EVA systems

Extra-vehicular activity (EVA) systems primarily consist of the traditional space suit, but can also include self-contained individual spacecraft.

Space suits

Both space suit models currently in use, the U.S. EMU and the Russian Orlan, include Primary Life Support Systems (PLSSs) allowing the user to work independently without an umbilical connection from a spacecraft. A space suit must provide life support, either through an umbilical connection or an independent PLSS.

Chapter- 10

Astronautical Hygiene

Astronautical hygiene is the application of science and technology to the recognition and evaluation of hazards, and the prevention or control of risks to health, while working in a low-gravity environment i.e. in space.

Space medicine has developed as a science since 1948 when Dr. Hubertus Strughold predicted many of the medical problems of working in low gravity for example, neurovestibular disturbances, red blood cell changes. The discipline of astronautical hygiene includes such topics as the use and maintenance of life support systems, the risks of extravehicular activity, the risks of exposure to chemicals, radiation etc., the characterisation of hazards, human factor issues and the development of risk management strategies. Astronautical hygiene works side by side with space medicine to ensure that astronauts will be healthy and safe when working in space. This is especially critical with the planned manned expeditions to the Moon and Mars.

When astronauts return to the Moon and travel farther to Mars, or even other planets, they will be exposed to a number of hazards e.g. radiation, microbes in the spacecraft, planetary surface toxic dust. An "astronautical hygienist" or an astronaut with knowledge of the discipline would provide invaluable data during the voyage on for example, how to assess the risks to health from exposure to chemicals within the spacecraft and the appropriate measures to mitigate exposure. Once on the surface of the Moon or planet the astronautical hygienist would provide information on the nature of the dust, measure the potential levels of exposure while exploring the surface terrain, assess the likely risks to health and thereby determine how to prevent or control exposure. Applying astronautical hygiene knowledge and expertise from the gathered intelligence during the journey would ensure that the health of the astronauts was protected at all time.

The Space Shuttle is to be replaced in 2014 by a new spacecraft the *Orion* to carry astronauts to the International Space Station (ISS). Orion will contain potentially hazardous material such as ammonia, hydrazine, freon, nitrogen tetroxide, volatile organic compounds and it will be necessary to prevent or control exposure to these substances during flight. Astronautical hygienists in the US together with colleagues in the European Union and individual UK astronautical hygienists and space medicine experts are developing the measures that will mitigate exposure to these substances.

Dr. John R. Cain (UK government expert) was the first scientist to define this new discipline. He is a fellow of the Institute of Biology, a fellow of the British Interplanetary Society, a member of the Faculty of Occupational Hygiene and a member of the UK Space Biomedicine Association. For many years, he has been working to develop the discipline of astronautical hygiene with the goal of establishing a school of space medicine and astronautical hygiene in the UK linked with a major university. The establishing of the UK Space Agency to promote and develop space science is one step in achieving this goal.

Hygiene in space

Issues arise when dealing with low gravity environments. On the International Space Station, there are no showers, and astronauts instead take short sponge baths, with one cloth used to wash, and another used to rinse. Since surface tension causes water and soap bubbles to adhere to the skin, very little water is needed. Special non-rinsing soap is used, as well as special non-rinsing shampoos. Since a flush toilet would not work in low gravity environments, a special toilet was designed, that has suction capability. While the design is nearly the same, the concept uses the flow of air, rather than water. In the case of the space shuttle, waste water is vented overboard into space, and solid waste is compressed, and removed from the storage area once the shuttle returns to earth. The current toilet model was first flown on STS-54 in 1993, and features an unlimited storage capacity, compared to only 14 day capacity of the original shuttle toilets, and the new model has an odor-free environment.

Control of gases in spacecraft

Toxic gases are produced as an off-gassing from the astronauts, non-metallic materials e.g. surface coatings, adhesives, elastomers, solvents, cleaning agents, heat exchanger liquids etc. The gases if inhaled above specific concentrations could affect the ability of the crew to carry out their duties effectively

Most of the toxicological data on gas exposure is based on the 8-hour work period of the terrestrial worker and is therefore unsuitable for spacecraft work. New exposure times (astronautical hygiene data) have had to be established for space missions where exposure can be uninterrupted for up to 2 weeks or longer with no daily or weekend periods.

Exposure limits are based on:

- "Normal" spacecraft operating conditions.
- The "emergency" situation i.e. during a failure mode.

In the normal conditions there are found trace contaminant gases such as ammonia from normal off-gassing at ambient temperatures and at elevated temperatures. Other gases arise from the breathing gas supply reservoirs and crew members themselves. In emergencies gases can arise from overheating, spills, a rupture (s) in the coolant loop (ethylene glycol) and from the pyrolysis of non-metallic components. Carbon monoxide is a major concern for space crews; this was evident during the Apollo missions. The emitted trace gases can be controlled using lithium hydroxide filters to trap carbon dioxide and activated carbon filters to trap other gases.

Gases in the cabin can be tested using gas chromatography, mass spectrometry and infra-red spectrophotometry. Samples of air from the spacecraft are examined pre-flight and post-flight for gas concentrations. The activated carbon filters can be examined for evidence of trace gases. The concentrations measured can be compared with the appropriate exposure limits. If the exposures are high then the risks to health increase. The on-going sampling of the hazardous substances is essential so that appropriate action can be taken if exposure is high.

A large number of volatile substances have been detected during flight mostly within their threshold limit values (TLVs) and NASA Spacecraft Maximum Allowable Concentration Limits (SMACs. If spacecraft cabin exposure to specific chemicals is below their TLVs and SMACs then it is expected that the risks to health following inhalation exposure will be reduced.

Spacecraft maximum allowable concentrations (SMACs)

SMACs provide guidance on chemical exposures during normal as well as emergency operations aboard spacecraft. Short-term SMACs refer to concentrations of airborne substances such as a gas and vapor that will not comprise the performance of specific tasks by astronauts during emergency conditions or cause serious toxic effects. Long-term SMACs are intended to avoid adverse health effects and to prevent any noticeable changes in the crews performance under continuous exposure to chemicals in the ISS for as long as 180 days.

Astronautical hygiene data needed for developing the SMACs include:

- chemical-physical characterization of the toxic chemical;
- animal toxicity studies;
- human clinical studies;
- accidental human exposures;
- epidemiological studies; and
- *in-vitro* toxicity studies

Application of astronautical hygiene principles to control exposure to lunar dust

Hazard

Lunar dust or regolith is the layer of particles on the Moon's surface and is <100 um). The grain shapes tend to be elongated. Inhalation exposure to this dust can cause breathing difficulties. It is toxic. It can also cloud astronauts' visors when working on the

Moon's surface. Furthermore, it adheres to spacesuits both mechanically (because of barbed shapes) and electrostatically. During Apollo, the dust was found to wear the fabric of the spacesuit .

Evaluation of risks

During lunar exploration it will be necessary to evaluate the risks of exposure to the moon dust and thereby instigate the appropriate exposure controls. Required measurements may include measuring exospheric-dust concentrations, surface electric fields, dust mass, velocity and charge and its plasma characteristics.

Control

The use of "high-gradient magnetic separation" techniques should be developed to remove dust from the spacesuits following exploration as the fine fraction of the lunar dust is magnetic . Furthermore, vacuums can be used to remove dust from spacesuits.

Mass spectrometry

Mass spectrometry has been used to monitor spacecraft cabin air quality . The results obtained can then be used to assess the risks during spaceflight for example, by comparing the concentrations of VOCs with their SMACs. If the levels are too high then appropriate remedial action will be required to reduce the concentrations and the risks to health.

Deposition of inhaled particles of lunar dust

The extent of the inflammatory response in the lung will depend on where the lunar dust particles are deposited. In 1G deposition in the more central airways will reduce the transport of the fine particles to the lung periphery. On the Moon with fractional gravity, the inhaled fine particles will be deposited in more peripheral regions of the lung. Therefore, because of the reduced sedimentation rate in lunar gravity, fine particles of dust will deposit in the alveolar region of the lung. This will exacerbate the potential for lung damage .

Microbial hazards in space

During spaceflight there will be the transfer of microbes between crew members. Microbial exchange commonly occurs amongst astronauts. Several bacterial associated diseases were experienced by the crew in Skylab 1. The microbial contamination in the Skylab was found to be very high. Staphylococcus aureus and Aspergillus spp have commonly been isolated from the air and surfaces during several space missions. The microbes do not sediment in microgravity which results in persisting airborne aerosols and high microbial densities in cabin air in particular if the cabin air filtering systems are not well maintained. During one mission an increase in the number and spread of fungi and pathogenic streptococci were found.

Proteus mirabilis, an organism commonly isolated from patients with urinary tract infection tends to build up on the urine collection devices. This could be a serious problem during the trip to Mars especially as some of the astronauts may be susceptible to urinary infection. In Apollo 13, the lunar module pilot suffered an acute urinary tract infection which required two weeks of antibiotic therapy to resolve.

Biofilm that may contain a mixture of bacteria and fungi have the potential to damage electronic equipment by oxidising various components e.g. copper cables. Such organisms flourish because they survive on he organic matter released from the astronaut's skin etc. Organic acids produced by microbes in particular fungi can corrode steel, glass and plastic. Furthermore, because of the increase in exposure to radiation on a spacecraft there are likely to be more microbial mutations.

Because of the potential for microbes to cause infection in the astronauts and to be able to degrade various components that may be vital for the functioning of the spacecraft it is important that the risks are assessed and where appropriate the levels of microbial growth controlled by the use of good astronautical hygiene. For example, by frequently sampling the spacecabin air and surfaces to detect early signs of a rise in microbial contamination, keeping surfaces clean by the use of disinfected clothes, by ensuring that all equipment is well maintained in particular the life support systems and by regular vacuuming of the spacecraft to remove dust etc. It is likely that during the first manned missions to the Moon and Mars that the risks from microbial contamination will be underestimated unless the principles good astronautical hygiene practice are applied. Further research in this field is therefore especially important so that the risks of exposure can be evaluated and the necessary measures to mitigate microbial growth are developed.

Microbes and microgravity in space

There are over one hundred strains of bacteria and fungi that have been identified from manned space missions. These microorganisms survive and propagate in space . Much effort is made to ensure that the risks from exposure to the microbes are significantly reduced. Spacecrafts are sterilized as good control practice by flushing with antimicrobial agents such as ethylene oxide and methyl chloride; and astronauts are quarantined for several days prior to a mission. However, these measures only reduce the microbe populations rather than eliminate them. Microgravity may increase the virulence of specific microbes. It is therefore important that the mechanisms responsible for this problem are studied and the appropriate controls are implemented to ensure that astronauts, in particular those that are immunocompromised, are not affected.

Humans in space

The work of Cain ("Spaceflight" Dec 2007) and others have seen the need to understand the hazards and risks of working in a low gravity environment. The general effects on the body of space flight or reduced gravity for example, as may occur on the Moon or during the exploration of Mars include changed physical factors such as decreased weight, fluid pressure, convection and sedimentation. These changes will affect the body-fluids, the gravity receptors and the weight bearing structures. The body will adapt to these changes over the time spent in space. There will also be psychosocial changes caused by traveling in the confined space of a spacecraft. Astronautical hygiene(and space medicine) needs to address these issues in particular the likely behavioral changes to the crew otherwise the measures developed to control the potential health hazards and risks will not be sustained. Any decrease in communication, performance and problem solving for example, could have devastating effects.

During space exploration there will be the potential for contact dermatitis to develop in particular if there is exposure to skin sensitisers such as acrylates. Such skin disease could jeopardise a mission unless appropriate measures are taken to identify the source of the exposure, to assess the health risks, and thereby determine the means to mitigate exposure.

Noise

Fans, compressors, motors, transformers, pumps etc. on the International Space Station (ISS) all generate considerable noise. As more equipment is required on the space station, then more noise will be generated.

The Russian space program has never given a high priority to the noise levels experienced by its cosmonauts (e.g. on MIR the noise levels reached 70 - 72 dB. But they were exceeded as new components were brought on board. Such noise levels may cause cause a temporary reduction in hearing but not a full hearing loss. This could result in hazard warning alarms not being heard against the background noise. To reduce the noise risks NASA engineers are building hardware with inbuilt noise reduction. A depressurized pump producing 100 dB can have the noise levels reduced to 60 dB by fitting 4 isolation mounts. For future space programs it is essential that the noise levels are reduced. The use of hearing protectors are not encouraged because they block out alarm signals. More research is necessary in this field as well as in other astronautical hygiene areas e.g. measures to reduce the risks of exposure to radiation, methods to create artificial gravity, more sensitive sensors to monitor hazardous substances, improved life support systems, more toxicological data on the martian/lunar dust hazards.

Hazards of radiation in space

Space radiation consists of high energy particles such as protons, alpha and heavier particles originating from several sources e.g. galactic cosmic rays, energetic solar particles from solar flares and trapped radiation belts. Space station crew exposures will be much higher than those on Earth and unshielded astronauts may experience serious health effects if unprotected. Galactic cosmic radiation is extremely penetrating and it may not be possible to build shields of sufficient depth to prevent or control exposure.

Trapped radiation

The Earth's magnetic field is responsible for the formation of the trapped radiation belts that surround Earth. The ISS orbits at between 200 nautical miles (370 km) and 270 nautical miles (500 km) i.e. a Low Earth Orbit (LEO). Trapped radiation doses in LEO decrease during solar maximum and increase during solar minimum. Highest exposures occur in the South Atlantic Anomaly (SAA) region.

Galactic Cosmic Radiation

This radiation originates from outside the solar system and consists of ionized charged atomic nuclei from hydrogen, helium and uranium. Due to its energy the galactic cosmic radiation is very penetrating. Thin to moderate shielding is effective in reducing the projected equivalent dose but as shield thickness increases, shield effectiveness drops.

Solar Particle Events (SPEs)

These are injections of energetic electrons, protons, alpha particles into interplanetary space during solar flare eruptions. During periods of maximum solar activity, the frequency and intensity of solar flares will increase. The solar proton events generally occur only once or twice a solar cycle.

The intensity and spectral disruption of SPEs have a significant impact on shield effectiveness. The solar flares occur without much warning so they are difficult to predict. SPEs will pose the greatest threat to unprotected crews in polar, geo-stationary or interplanetary orbits. Fortunately, most SPEs are short lived (less than 1 to 2 days) which allows for small volume "storm shelters" to be feasible.

Other

Radiation hazards may also come from man-made sources for example, medical investigations, radio-isotopic power generators or from small experiments "as on Earth". Lunar and Martian missions may include either nuclear reactors for power or related nuclear propulsion systems. Astronautical hygienists will need to assess the risks from these other sources of radiation and take appropriate action to mitigate exposure.

Laboratory tests reported in the Journal of Plasma Physics and Controlled Fusion indicate that a magnetic "umbrella" could be developed to deflect harmful space radiation away from the spacecraft. Such an "umbrella" would protect astronauts from the super-fast charged particles that stream away from the Sun. It would provide a protective field around the spacecraft similar to the magnetosphere that envelops the Earth. This form of control against solar radiation will be necessary if man is to explore the planets and reduce the health risks from exposure to the deadly effects of radiation. More research is necessary to develop and test a practical system.