Glossary

Airlock Soviet spacecraft required an airlock between the living area and a chamber from which a cosmonaut could exit to perform a space walk. The U. S. Apollo and Gemini spacecraft had no airlock or exit chamber, depressurizing the whole cabin and exiting direct from there. Equipment inside the U. S. craft was designed to work in vacuum, while that in the Soviet craft could not survive in a vacuum. The U. S. craft would of course be re-pressurized once the astronaut returned from the space walk and the hatch was closed.

Ascent Stage The Apollo Lunar Module was comprised of a Descent Stage and an Ascent Stage. The Ascent Stage comprised the living cabin, the ascent engine plus equipment and resources necessary for the journey from the Moon's surface to the Command and Service Module in orbit above. See Figs. 4.6 and 4.12.

Atlas rocket The Atlas rocket family started out as an Intercontinental Ballistic Missile (ICBM). Atlas rockets launched the Mercury capsule into orbit, including the first American to orbit Earth, John Glenn, and three other astronauts, Scott Carpenter, Wally Schirra and Gordon Cooper. More powerful versions of the Atlas also launched the Ranger (hard-landing) and Surveyor (soft landing) Moon probes. Surveyor used the version with the Centaur upper stage fueled by liquid hydrogen and liquid oxygen. The success of the Centaur upper stage led to the same fuel combination being used for the second and third stages of the Saturn V. The Atlas continues to be a workhorse launch vehicle of the U. S. Department of Defense and (to a lesser extent) of NASA.

Ballistic A rocket or missile is said to be in ballistic flight when its rocket engines are not in use. Its trajectory is then determined only by forces such as gravity and air drag.

BE-4 rocket engine The BE-4 engine is under development by Blue Origin, designed to be used in its New Glenn rocket. Seven BE-4 engines will power the first stage. The BE-4 has also been sold to the United Launch Alliance to be used in its Vulcan rocket. The BE-4 uses liquid methane and liquid oxygen as fuel, developing a thrust of about 2,400 kN at sea level, which is about five times that of engine used in the New Shepard rocket.

P. Norris, *Returning People to the Moon After Apollo*,
Springer Praxis Books, https://doi.org/10.1007/978-3-030-14915-4

Blue Origin Amazon founder and Chief Executive Officer Jeff Bezos has been funding his Blue Origin rocket company to the tune of $1 billion a year. The rockets are reusable and intended to fly humans to space. See BE-4, New Shepard and New Glenn elsewhere in this glossary, and Chapter 10.

Canadarm The robotic arm attached to the exterior of the ISS is used to move heavy or bulky objects around the outside of the station, controlled by an astronaut inside it. It was provided by Canada, hence its name.

Centaur rocket stage The Centaur was the first operational rocket stage fueled by liquid hydrogen and liquid oxygen and built by General Dynamics (now United Launch Alliance). It is comprised of one or two RL-10 engines built by Pratt & Whitney (now Aerojet Rocketdyne). Its first successful flight was in 1962, and variants of it are still in use today.

Chandrayaan India's series of robotic Moon probes are called Chandrayaan ("Moon vehicle" in Sanskrit). *Chandrayaan-1* was launched into orbit around the Moon in 2008 at an altitude varying between 90 and 170 miles (150 and 270 km). It stopped sending back information after ten months. *Chandrayaan-2* is scheduled for launch in 2019 and will include a lander with a rover, as well as a probe in orbit around the Moon – see Chapter 12.

Chang'e China's series of robotic Moon probes are named after the Moon goddess. *Chang'e-1* was launched in 2007 and orbited the Moon for 1 year 4 months. The images it sent back were used to make a detailed map of the Moon. *Chang'e-2* was an identical probe launched in 2010. Having spent 8 months orbiting the Moon, and 8 months at the L2 Lagrange point 1 million miles from Earth, where Earth and Sun gravity are equal, *Chang'e-2* headed out into the Solar System to intercept the asteroid Toutatis. It passed within 2 miles (3.2 km) of Toutatis in December 2012, whizzing by at a speed of 6.7 miles/second (10.5 km/sec, 24,000 mph) and capturing detailed images of the asteroid's surface. *Chang'e-3* was launched in 2013, orbited the Moon for a week, then landed in Mare Imbrium on the front face of the Moon. It deployed a rover called Yutu or jade rabbit (who in legend accompanied the Goddess Chang'e to the Moon). *Chang'e-4* is similar to *Chang'e-3* and in early 2019 landed and deployed a rover on the lunar far side. The *Queqiao* (*Magpie Bridge*) satellite was launched in May 2018 and is located above and behind the Moon so that it can relay radio signals from *Chang'e-4* and its Yutu rover. *Chang'e-5* is scheduled to return samples from the Moon's surface to Earth in about 2020. See also Chapter 11.

Circumlunar A space mission that goes around the Moon and straight back to Earth (without going into orbit around the Moon) is called circumlunar. The most famous such mission was *Apollo 13* in 1970, which had to return as fast as possible to Earth after an oxygen tank exploded in the Service Module.

Clementine NASA's first mission to the Moon after *Apollo 17* was the 1994 Clementine robotic probe developed jointly with the Department of Defense. Clementine spent three months orbiting the Moon, taking detailed images and scientific measurements, then was due to head for the asteroid 1620 Geographos when a failed thruster left it in Earth orbit instead, ending its mission a month later.

Command Module The Apollo Command Module was the living quarters for the three astronauts during the mission to the Moon that could last up to 12 days – see Chapter 3.

Command Module Pilot The Command Module Pilot remained in orbit around the Moon while his two companions landed on the surface in the Lunar Module.

Communications satellite Satellite that links two Earth-bound terminals or that broadcasts TV to many terminals. They are particularly useful for linking or broadcasting to parts of Earth that are otherwise difficult to reach such as islands, remote regions, ships at sea and aircraft in flight. Many are in geostationary orbit, about 22,000 miles (36,000 km) high, where they appear stationary from Earth's surface.

CORONA spy satellite The Central intelligence Agency with technical support from the Department of Defense launched nearly 150 CORONA satellites in the 1960s to take images of the Soviet Union and other countries of interest. The satellites returned the exposed film to Earth in one or more re-entry capsules. About 70 percent of the satellites returned usable imagery. CORONA was designed to take wide-area pictures rather than highly detailed ones – the Air Force Gambit satellites performed that role. The Soviet Zenit satellites worked on a similar principle to CORONA.

Cosmodrome Soviet and Russian space launch sites are called cosmodromes – see Fig. 12.1.

Cosmonaut Russian astronauts are called cosmonauts.

Descent Stage The Apollo Lunar Module was comprised of a Descent Stage and an Ascent Stage. The Descent Stage was comprised of the descent engine with its fuel tanks, the landing structure (with spider's legs), scientific equipment to be left on the Moon's surface and (*Apollo 14, 15, 16* and *17*) the lunar rover. See Fig. 4.11.

Docking Spacecraft that join up in space so that they become a single vehicle are said to "dock." Examples include the Command and Service Module docking with the Lunar Module and extracting it from the Saturn V third stage on the way to the Moon, and the Command and Service Module docking with the Ascent Stage of the Lunar Module when it returns from the Moon's surface.

Earth orbit An object in space regularly circling another object is said to be in orbit around it. For a manmade object to orbit Earth it needs to get above the bulk of the atmosphere, i.e., about 100 miles up, and to travel at 17,500 mph (28,000 kmph) or more.

European Space Agency (ESA) ESA undertakes space missions on behalf of its 22 member countries. Increasingly ESA also undertakes space missions for the European Union. (About a quarter of ESA's 2018 budget of $6.4 billion – 5.6 billion Euros – was provided by the European Union.) A recent highlight was the two-year-long rendezvous of ESA's Rosetta probe with a comet. ESA is a partner in the ISS, as well as the Hubble Space Telescope and its planned successor, the James Webb Telescope, and is supplying the Service Module for NASA's Orion capsule (see Chapter 12).

Explorer satellites Early NASA scientific satellites were given the general purpose title "Explorer" followed by a series number. The large number of these satellites made it impossible to tell their function from the name, so most were also given informal mission-related names, for example Explorer-51, launched in 1973 was called Atmosphere Explorer-C.

Extra-Vehicular Activity (EVA) Exiting from a spacecraft in space is officially called an extra-vehicular activity (EVA) by NASA. When the spacecraft is in orbit, the EVA is popularly known as a "space walk". On the surface of the Moon the EVA is sometimes referred to as a "Moon walk."

F-1 engine Developed by Rocketdyne in close collaboration with NASA's Marshall Space Flight Center, five of the F-1 engines were used in the first stage of the Saturn V rocket. The propellant used was a refined form of kerosene and liquid oxygen. See Chapter 2.

Falcon 9 Falcon 9 is SpaceX's current workhorse rocket. The first stage is comprised of 9 Merlin engines burning rocket-grade kerosene and liquid oxygen. The second stage contains a single modified Merlin engine. Since 2015, having separated from the second stage, the first stage can make a controlled return to the ground, either to the launch site or to a floating platform, so that it can be reused. Falcon 9 can lift about 23 tons to low Earth orbit, although that has to be reduced (by as much as a third) if the first stage is to be recovered. There have been nearly 20 launches per year in 2017 and 2018, with about three-quarters involving recovery of the first stage. The first stage of the Block 5 version introduced in 2018 can be re-flown up to ten times (the previous version could only re-fly once).

Falcon Heavy Strapping three Falcon 9 rockets together gives the Falcon Heavy, which can lift 64 tons to low Earth orbit. Development took longer than predicted by SpaceX, leading to the first launch in 2018. SpaceX had planned to upgrade the Falcon Heavy to carry humans but now says that no significant further upgrades to Falcon Heavy will take place. Instead, SpaceX is developing the Super Heavy and Starship rocket and spaceship. See Chapter 10.

Gemini spacecraft The two-person Gemini capsule was an intermediate development between the single-person Mercury and the three-person Apollo capsules. Ten Gemini spacecraft were launched in 1965-66, testing techniques such as docking, rendezvous in orbit, space walks (EVA) and two-week long stays in space, all essential for the Apollo Moon missions. Gemini also gave many Apollo astronauts their first space experience. The prime contractor was McDonnell Aircraft Corporation, which had also been the prime for Mercury.

Gravity field The force of gravity exerted by Earth would be identical wherever you are on the surface if Earth were a perfect and uniform sphere. Earth, however, has bulges and regions of heavier material that change the force of gravity. The sum total of all these variations is called the gravity field. The Moon's gravity field is even more uneven than Earth's.

Heavy-lift launcher Heavy-lift is a loose way to describe the most powerful rockets. As more powerful rockets become available, what was a "heavy-lift" rocket becomes a "medium lift" one.

Intercontinental Ballistic Missile (ICBM) Missiles that can hit a target beyond about 3,500 miles (5,500 km) are said to be intercontinental in their range. A missile is "ballistic" if it coasts for most of the journey, having been boosted up to high speed initially by its rocket motor.

International Space Station (ISS) Astronauts undertake scientific and technical tasks in the ISS orbiting Earth about 250 miles (400 km) out in space. It took 13 years to assemble all the parts, which in total weigh more than 400 tons. It has been continuously occupied since November 2, 2000, and is expected to continue operation until at least 2025. Continued funding of the station makes it difficult for NASA and the other partners to fund a human Moon landing mission – see Chapters 10 and 12.

Indian Space Research Organization (ISRO) ISRO is the civil space agency for the government of India, and reports via the Department of Space to the Prime Minister. Its annual budget is about $1.5 billion and it has about 15,000 staff.

J-2 engine Five of Rocketdyne's J-2 engines powered the second stage of the Saturn V rocket, and one powered the third stage. Like the RL-10 engine that powered the Centaur rocket stage, the J-2 used liquid hydrogen and liquid oxygen as propellants, but was ten times more powerful – see Chapter 2.

L1 spacecraft The Soviet L1 spacecraft was intended to carry two cosmonauts around the Moon and then straight back to Earth – a circumlunar mission. Derived from the Soyuz spacecraft and launched on the Proton (UR-500) launcher, two test versions of the L1 completed the circumlunar trip in October and November 1968, some carrying small animals and plants, but no human passengers ever made it. After the success of NASA's *Apollo 8* in December 1968 carrying three astronauts into orbit around the Moon, the L1 program was quietly ended without its existence ever being made public – see Chapter 8.

L3 Spacecraft The L3 was the manned payload to be launched towards the Moon by the Soviet N1 rocket. It consisted of two main parts: the LOK mother ship that carried the cosmonauts to and from Earth and the LK spacecraft that would land on the Moon's surface.

Launch Escape System Above the Apollo spacecraft on top of the Saturn V rocket was a small rocket assembly called the Launch Escape System. If the Apollo spacecraft was in danger during the first few minutes of flight this system would be fired and would lift the spacecraft clear of the Saturn V. See Fig. 3.3.

LK spacecraft The LK spacecraft was the Soviet equivalent of the Apollo Lunar Module. At about 5½ tons it weighted about a third of the Lunar Module (Fig. 8.13) and was designed to carry a single cosmonaut from the Soyuz-type LOK capsule in orbit around the Moon down to the Moon's surface and back. Prototypes, called T2K, were successfully tested in Earth orbit three times in 1970-71. A number of engineering models of the LK remain (Fig. 8.12). See Chapter 8.

LOK Spacecraft The LOK was a variant of the Soyuz capsule and was designed to carry two cosmonauts to the Moon and back. It was intended to go into orbit around the Moon using its built-in rocket engines with the LK lunar lander attached, then to dock with the LK when it returned from the Moon's surface, and then leave lunar orbit and return to Earth.

Long March rockets China's main space launch vehicles are usually given the name Long March (LM) in the West (Changzheng in Chinese pinyin). Various versions of the LM-2, LM-3 and LM-4 rockets have been in use since the 1980s using mainly storable propellants. (The main exception is that the upper stage of some versions of the LM-3

uses liquid hydrogen and liquid oxygen.) The new LM-5, LM-6 and LM-7 rockets are discussed in Chapter 11.

Longjiang Two Chinese robotic microsatellites were launched to the Moon in May 2018 as secondary passengers on the launcher that carried the Queqiao relay satellite to the Moon. *Longjiang-1* suffered a failure, but *Longjiang-2* successfully entered lunar orbit and sent back images taken by a camera supplied by Saudi Arabia, including at least one Earthrise picture. The main mission of the Longjiang satellites is radio astronomy, to take advantage of being shielded from Earth's radio signals when behind the Moon.

Lunar Gateway NASA plans to create an inhabited space laboratory in orbit around the Moon, frequently referred to as a Lunar Gateway. See Chapter 10.

Lunar Module The Apollo Lunar Module was the spacecraft that carried two astronauts to the surface of the Moon and then back to the Command and Service Module that waited in orbit around the Moon. See Chapter 4 and Fig. 3.10.

Lunar Module Pilot The two-man crew of a Lunar Module was comprised of the Commander and the Lunar Module Pilot.

Lunar Orbiter Five robotic Lunar Orbiter spacecraft launched in 1966 and 1967 took detailed images of the Moon in preparation for the Apollo missions. They also enabled analysts back on Earth to examine details of the Moon's gravity field by observing how the trajectories of the Lunar Orbiters varied as they circled the Moon.

Lunar Reconnaissance Orbiter This was a NASA robotic probe launched in 2009 to provide detailed imagery of the Moon and to analyze the chemistry of the lunar surface. Its eccentric orbit typically brings it to within 12 miles (20 km) of the surface, with a high point of about 100 miles (160 km). See Fig. 7.2.

Lunokhod The Soviet Union had two successful robotic Moon rover probes, Lunokhod-1 in 1970-71, carried to the Moon on *Luna-17,* and Lunokhod-2 in 1973 *(Luna 21).* An earlier Lunokhod was destroyed during launch in February 1969. See Chapter 8.

Mascons Areas on the Moon where the pull of gravity is greater than average, typically associated with the circular seas or mares – see Chapter 4.

Mercury spacecraft The one-person Mercury spacecraft, built by McDonnell Aircraft, carried America's first astronauts into space in the early 1960s. There were six manned Mercury flights starting with the suborbital flight of Alan Shepard in May 1961 (see Chapter 1). The first American to orbit the Earth, John Glenn, was in *Mercury 3* in February 1962. Two 1961 test flights carried a chimpanzee – one suborbital in January the other into orbit in November.

Merlin engine The SpaceX Falcon 9 rocket is powered by nine SpaceX Merlin engines. The propellant is rocket grade kerosene and liquid oxygen. See Chapter 10.

Mission Control Once in space, the Apollo missions were managed from Apollo Mission Control in the Manned Spacecraft Center in Houston, Texas. Working a shift system, teams of experts provided support to the crew in space, aided by further teams in industry and other NASA centers around the country.

Moore's law The seemingly inexorable improvement in electronics since the 1960s follows a pattern first articulated by Gordon Moore of Intel – hence the name Moore's law. See Chapter 9 and Fig. 9.2.

N1 rocket The nearest Soviet equivalent of the Saturn V rocket was the N1. Although heavier than the Saturn V, the N1 could only carry a payload of just under 100 tons into orbit compared to Saturn V's 130 tons. There were four failed launch attempts: on February 21, 1969, the engines shut down 70 seconds into the flight.; on July 3, 1969, the rocket rose 700 feet (200 m) high then fell back onto the launch pad and exploded; on June 27, 1971, the engines shut down after 51 seconds; and on November 23, 1972, the rocket exploded after 104 secs. See Chapter 8 and Figs. 8.14 and 8.15.

NACA The National Advisory Committee for Aeronautics (NACA) was founded in 1915 to undertake aviation research in the United States and was merged into the newly created NASA in 1958.

National Aeronautics and Space Administration (NASA) NASA is responsible for America's civilian space program plus research in aviation and aerospace. It was created by President Eisenhower in 1958 to provide a federal agency to deal with non-military space matters.

New Shepard The New Shepard rocket developed by Blue Origin is able to carry up to six passengers to an altitude of about 62 miles (100 km) and then return to Earth to be reused. The passenger capsule descends on a parachute with small rockets ensuring a smooth touchdown. The rocket lands upright, using its engines to control its descent. Test flights have been undertaken since 2015 and first operational flights are planned for 2019. The rocket is named after the first American to make a suborbital flight beyond 100 kilometer altitude, Alan Shepard in the Mercury capsule.

Orbit rendezvous For two objects to remain close together for an extended period of time (i.e., to rendezvous) in space their orbits have to be identical. This means that when they are together their speed in every direction (up/down, forward/back, sideways) has to be identical. To avoid using unnecessary fuel, two objects in space need to gradually align their orbits to steadily reduce their separation.

Orbital bombardment system The Soviet Union investigated the possibility of placing a nuclear-armed missile in orbit able to be commanded to hit a target on Earth if and when required. The concept was called the GR-1 orbital bombardment system. It was part of the justification for developing the N1 rocket, but was terminated in 1965 due to lack of military interest.

Orion The crewed spacecraft to be carried by NASA's new Space Launch System is called Orion – being developed by Lockheed Martin for NASA and incorporating a Service Module built by Airbus for the European Space Agency. See Chapter 10.

Payload The cargo and/or passengers carried by a rocket is called the payload. The name derives from the fee paid to carry the cargo or passengers to space.

Proton (UR-500) rocket The Proton is the most powerful Russian rocket currently in use (see Table 9.1). Originally called the UR-500, more than 400 Protons have been launched since the first one in 1965.

R-7 rocket Developed by Sergei Korolev, the R-7 was the world's first ICBM and was the basis for the Vostok rocket that launched the first artificial satellite, *Sputnik-1,* in 1957 and the Soyuz rockets still in use today – see Fig. 8.5. Because of its cryogenic propellant (liquid oxygen), the R-7 was poorly suited to the role of military missile, and only a handful were ever deployed.

Radar A radar (radio detection and ranging) transmits a radio signal and detects the (usually much weaker) signal echoed back by a target. This allows the radar to work

out the direction, distance, velocity and even the shape of the target. Civil aircraft, ships and spacecraft usually contain a device called a transponder that boosts the power of the echo so that it can be detected at a much greater distance – see Chapter 5.

Raptor engine SpaceX is developing the Raptor engine to power its Super Heavy / Starship rocket. Using liquid methane and liquid oxygen as propellants, Raptor will have more than double the thrust of SpaceX's existing Merlin engine. See Chapter 10.

Reconnaissance satellite The original motivation for an American space program was to get images of the Soviet Union. Satellites that contain a camera to collect images of Earth below are labeled as "reconnaissance" or "Earth observation" or "remote sensing" or sometimes "spy." The overhead imagery (some taken by aircraft, some by satellites) of the world on Google Earth and its imitators has familiarized us with the concept. The American CORONA and Soviet Zenit satellites of the 1960s provided accurate information about missile deployment of both the superpowers, enabling them to trust each other enough to sign up to the Strategic Arms Limitation Treaty that drastically slowed the escalation of the nuclear arms race. "Trust, but verify" as President Ronald Reagan famously said – reconnaissance satellites do most of the "verify" bit.

Re-entry When a spacecraft is returning to Earth from space, it meets strong resistance when it encounters the atmosphere. The air resistance slows the spacecraft down, and the temperature increases. The atmosphere is detectable out to about 400 miles (600 km), but it provides significant resistance to a returning spacecraft from only about 100 miles (160 km) up, that point being considered the re-entry point. It varies in altitude over the course of a day and due to changes in the intensity of radiation and charged particles from the Sun (notably over the eleven-year solar cycle).

Robotic probe An unmanned space probe is said to be "robotic." It usually contains a computer that controls its actions, and this can in turn usually be reprogrammed from Earth.

Rocket engine A rocket engine works on the principle that by pushing a gas out one end, the engine will move in the other direction – in accordance with Newton's Third Law of Motion (for every action there is an equal and opposite reaction). The gas can be simply stored and then ejected or can be the result of a chemical reaction (for example kerosene burning oxygen). Rocket engines using chemical fuels were invented more than a thousand years ago in China (steam rocket engines seem to have been known to the Greeks and Romans). Unlike internal combustion or jet engines, rocket engines work in a vacuum, hence their use in space.

Roscosmos Roscosmos is a state-owned corporation responsible for Russia's civil space programs. It was created in 1992 as a government agency and given its corporation status in 2015, when it absorbed much of the state-owned space industry.

Rover Early space probes that landed on other Solar System bodies such as the Moon and Mars stayed stationary at their landing spot. Later, a wheeled vehicle (often called a "rover") was added to the probe so that some at least of the scientific instruments could travel across the surface of the body. Typically part of the vehicle remains stationary, acting as a communication hub for the rover and performing scientific experiments that were too complex to be carried out on the rover. A rover was also carried by the later Apollo missions to the Moon (*Apollos 14* through *17*) to carry the astronauts, their equipment and the rocks and dust they collected.

RS-25 engine Built by Aerojet Rocketdyne the RS-25 is a reusable rocket motor powered by liquid hydrogen and liquid oxygen, three of which are comprised of the main engine of the space shuttle. A total of 46 reusable RS-25 engines were flown during the space shuttle program. Those that remain in the NASA inventory are now slated to be used once only in the Space Launch System currently under development – see Chapter 10.

Satellite An object circling a body through the force of gravity is said to be a satellite of the body. The Moon is the only natural satellite of Earth. Manmade objects orbiting the Earth are said to be "artificial" satellites.

Saturn 1B rocket The Saturn-1B ("one-bee") rocket carried unmanned versions of the Apollo Command and Service Module and (separately) the Lunar Module into orbit to test their designs in 1966-68. The first stage was built by Chrysler Corporation and the second stage by Douglas Aircraft. The second stage, known as the S-IVB, was also used on the much more powerful Saturn V rocket.

Saturn V rocket The Saturn V carried the Apollo spacecraft to the Moon. Its first stage was powered by five Rocketdyne F-1 engines burning rocket grade kerosene in liquid oxygen and built by Boeing. The second stage was comprised of five Rocketdyne J-2 engines using liquid hydrogen and liquid oxygen as propellant and built by North American Aviation. The third stage, called the S-IVB, used a single J-2 engine and was built by Douglas Aircraft. Fourteen Saturn Vs were launched, all successfully. Three are on display in Huntsville, Houston and Cape Canaveral. See Chapter 2.

Service Module A Service Module is frequently split off from other parts of a spacecraft (robotic or manned) and contains the generic resources and equipment needed by every spacecraft, such as generating and storing electrical power, radio communications, propulsion, pointing and guidance equipment, temperature control, oxygen and carbon dioxide scrubbing (human missions), etc.

S-IVB The S-IVB ("ess-four-bee") was the third stage of the Saturn V and the second stage of the Saturn 1B. See Chapter 2.

Space Launch System (SLS) NASA's new heavy- lift rocket is called the Space Launch System (SLS). Its development is a key feature of the proposed Lunar Gateway program. The Orion spacecraft is being developed in parallel to be carried into space by the SLS. See Chapter 10.

Soyuz The word Soyuz is confusingly used to describe the rocket of that name and the manned spacecraft that it carries into space. Developed in the 1960s by the Korolev group, the Soyuz spacecraft was designed to carry three people into space for stays up to two weeks long and capable of maneuvering in space and enabling the crew to undertake space walks. With many gradual improvements the spacecraft continues to be the mainstay of the Russian human space program. The Soyuz rocket was derived from the R-7 long-range missile. There have been more than 1,700 launches of the various forms of the Soyuz rocket, and it continues to be used for human and robotic spaceflights. The Soyuz rocket is usually launched from Baikonur in Kazakhstan, but one version can be launched from Europe's launch site at Kourou in French Guiana in South America, which is close to the equator and thus increases the weight of payload it can place in orbit due to the more rapid Earth rotation at the equator.

Space walk Wearing a spacesuit, an astronaut is able to leave the spacecraft, i.e., to take a "space walk." NASA's name for this is "extra-vehicular activity (EVA)". If the space walk takes place on the Moon instead of in outer space it is commonly referred to as a Moon walk. The spacesuit acts as a miniature spacecraft, although with enough oxygen, electrical power, etc., for only a few hours.

SpaceX Founded by Elon Musk in 2002, SpaceX is one of the most successful space rocket companies in the world. Its Falcon 9 rocket, whose first stage can be recovered and reused, launches commercial, military and NASA spacecraft. Its Falcon Heavy rocket is the most powerful in the world. It is headquartered in Hawthorne (southwestern Los Angeles), California. See Chapter 10.

Sputnik Meaning "satellite" in Russian, the 184 pounds (83.6 kg) *Sputnik-1* was the world's first artificial satellite when launched by the Soviet Union on October 4, 1957. Launched a month later and weighing half a ton, *Sputnik-2* had a pressurized cabin and carried the dog Laika into space. A total of ten satellites launched by the Soviet Union were given the Sputnik designation, most of which tested systems for carrying animals into space and safely returning them to Earth. They also performed pioneering scientific measurements of magnetic fields, charged particles, radiation, temperatures and other characteristics of space.

STK rocket Russia's proposed new heavy-lift rocket is known by the Russian acronym STK – see Chapter 12.

Strategic Arms Limitation Treaty (SALT) Throughout the 1960s the United States and the Soviet Union deployed thousands of nuclear weapons on missiles and aircraft, each country trying to ensure that it had more and better weapons than the other. Both countries realized that deploying better weapons simply triggered the same action from the other, and thus did not improve their security. Thanks to the reliable information supplied by surveillance satellites, both countries agreed to halt this wasteful exercise, resulting in the first Strategic Arms Limitation Treaty in 1972.

Super Heavy and Starship SpaceX Chief Executive Officer Elon Musk says that future SpaceX launches of all kinds will use this giant rocket. The first stage Super Heavy and the upper stage Starship will both be re-usable, unlike most other rockets that are used only once. Its payload to Earth orbit will be about 150 tons, and it is intended to carry humans to Mars and back. See more in Chapter 10.

Surveyor NASA landed five Surveyor probes on the Moon's surface in 1966-68 (two more failed on landing), primarily to demonstrate the principle of a soft landing. See Figs. 6.1 and 7.3.

Tiangong Two of China's Tiangong manned space stations have been launched into orbit around Earth. *Tiangong-1* was launched in 2011 and visited by Chinese astronauts on three occasions in 2011, 2012 and 2013 before being mothballed in 2016. It re-entered Earth's atmosphere in 2018, ending up in the south Pacific Ocean. *Tiangong-2* was launched in 2016 and visited for a month by two Chinese astronauts that same year. It has also been visited three times by an unmanned cargo vehicle.

Umbilical tower While on the launch pad, a rocket is attached via umbilical connectors to ground-based electrical power and other resources. In some cases the umbilical connections are housed in a tower alongside the vertical rocket – hence the term umbilical tower.

V2 rocket The first rocket capable of traveling hundreds of miles was the V2 developed in Germany during World War II by a team led by Wernher von Braun. Over 3,000 V2 rockets were launched with a range of about 200 miles (320 km).

Vertical/Vehicle Assembly Building The Vertical Assembly Building was built at Cape Canaveral to allow the Saturn V rocket to be assembled before being transported to the launch pad 3½ miles (6 km) away. Now called the Vehicle Assembly Building it has been used to assemble the space shuttle and soon the Space Launch System. See Chapter 5 and Fig. 3.1.

Voskhod Two Voskhod spacecraft were flown in 1964 and 1965, each establishing a space "first." *Voskhod-1* was the first space vehicle to hold three crew members. *Voskhod-2* carried two crew members and enabled one of them, Alexey Leonov, to perform the first space walk. Voskhod was derived from the Vostok spacecraft and diverted funding away from the development of the Soyuz spacecraft intended to replace Vostok. See Chapter 8.

Vostok Six Vostok one-person spacecraft carried Soviet cosmonauts into space, including the first human in space, Yuri Gagarin (April 12, 1961), and the first woman in space, Valentina Tereshkova (June 16, 1963). During the return to Earth, the cosmonaut had to eject from the capsule at an altitude of 23,000 feet (7 km) and descend to the ground by parachute while the capsule also descended by a separate parachute. The Zenit military reconnaissance satellite was a variation of the Vostok design, returning exposed film and its camera to Earth in place of a cosmonaut.

Zenit rocket The Zenit rocket was the last to be developed in the Soviet Union before it ceased to exist at the end of the Cold War. It was built in the Ukraine. A total of 84 have been launched, of which 74 were wholly or partially successful. About half of the launches took place between 1999 and 2014 through the commercial Sea Launch company. Launches ceased following the 2014 breakdown in relations between Russia and Ukraine. See Chapter 12. Note that the name Zenit was also used for a series of surveillance satellites.

Index

P. Norris, *Returning People to the Moon After Apollo*,
Springer Praxis Books, https://doi.org/10.1007/978-3-030-14915-4