INTRODUCTION

Welcome to the amazing world of space

Ever since the first humans gazed up into the night sky we, as a species, have been fascinated by the stars, the planets, the universe and our place within it.

Over the centuries, our knowledge and understanding of the science of space has grown by an amazing extent. We are now able to recognise distant planets, detect gravitational waves from black holes, and monitor near-Earth objects that may be on a collision course with our own planet.

We have also created vehicles that have allowed humans to travel into space, orbit the Earth, and explore the Moon. We have constructed space stations that allow astronauts to live in space for prolonged periods. And we have developed new technologies which could allow us to venture further, beyond the Moon, to explore other planets.

The aim of this book is to give you a good understanding of the science of space – our relationship with the Sun and the other planets in the Solar System, our galaxy the Milky Way, and the universe as a whole. The first section of the book focuses on the exploration of space from Earth – the science of astronomy – and how we have developed our understanding of the universe.

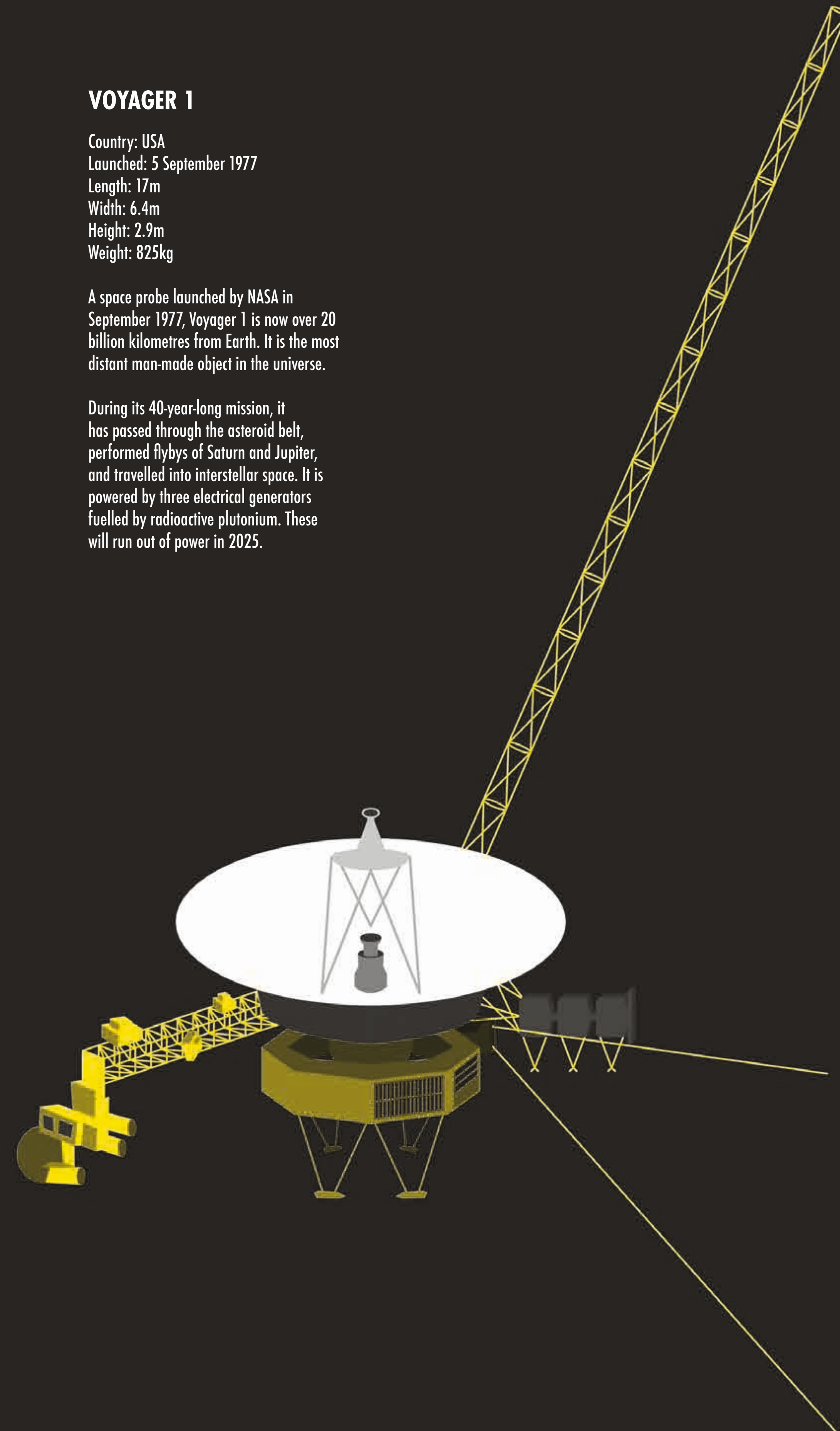
The second section investigates space travel, and how we have used spacecraft and probes to explore physically the nature of our neighbouring Moon and local planets. In parts of this book you may find some scientific terms that you are unfamiliar with. The first time these are used they are highlighted in CAPITALS, and all of these words and phrases are explained in the glossary at the end of the book.

VOYAGER 1

Country: USA
Launched: 5 September 1977
Length: 17m
Width: 6.4m
Height: 2.9m
Weight: 825kg

A space probe launched by NASA in September 1977, Voyager 1 is now over 20 billion kilometres from Earth. It is the most distant man-made object in the universe.

During its 40-year-long mission, it has passed through the asteroid belt, performed flybys of Saturn and Jupiter, and travelled into interstellar space. It is powered by three electrical generators fuelled by radioactive plutonium. These will run out of power in 2025.



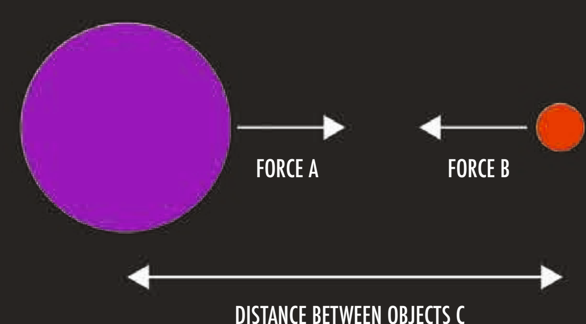
GRAVITY

Johannes Kepler's Laws of Planetary Motion were ground-breaking discoveries which provided the first truly accurate descriptions of the movement of the planets around the Sun. Later, the British scientist Isaac Newton investigated the forces that he believed were responsible for Kepler's planetary observations.

Newton's discoveries led him to propose his law of universal gravitation, which he developed when he was 23 years old. He later followed this with his three universal laws of motion. His scientific discoveries were so revolutionary that they would have a lasting influence on astronomy and physics through the centuries after his death and until the present day.

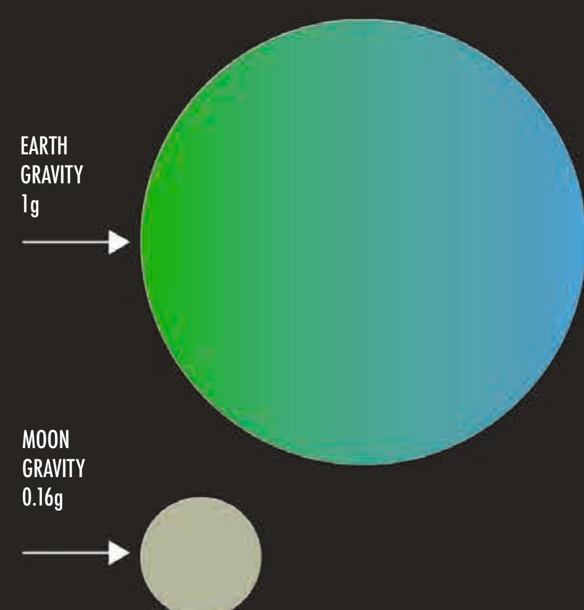
Isaac Newton described GRAVITY as a force of attraction that is generated by all objects with mass, from the smallest atom to the largest star.

He showed that the gravitational force between a pair of objects depends on the total mass of the two objects, and the distance between them. The greater the total mass, the greater the force of attraction. The more distant the objects, the smaller the force of attraction. In the diagram on the right, the forces on each of the objects (A and B) are equal. If the distance between them (C) is greater, the forces are smaller.



Although every object is attracted to every other object, in practice the forces between them are almost imperceptable because the masses are small. Gravity is much more noticable when there is a large mass. For example, everything on Earth is dominated by the effects of the Earth's own gravity.

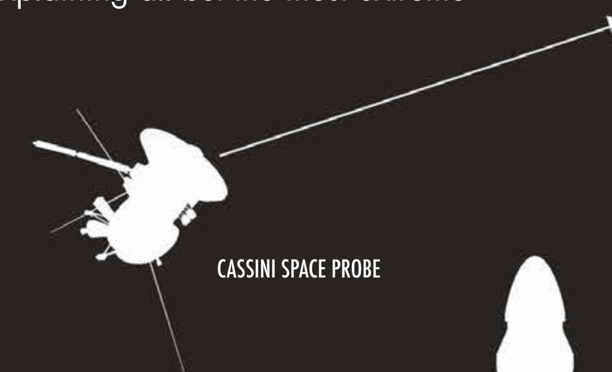
Because the Moon is much less massive than the Earth, the effects of gravity on the Moon's surface are much smaller. As you can see in the diagram on the right, the gravitational force on the smaller Moon is 0.16 times that experienced on the larger Earth.



MOTION

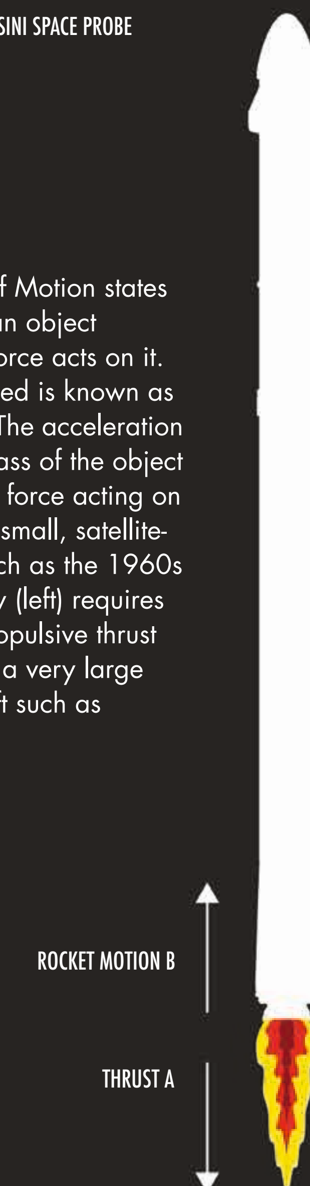
Newton presented his laws of motion in 1686, in his book Principia Mathematica Philosophiae Naturalis – the Mathematical Principals of Natural Philosophy. These laws describe and predict the way in which everything in the universe moves and interacts as the result of gravitational attraction. Though Albert Einstein's theory of relativity has since superseded the theories contained in the Principia, in practice Newton's theories are more than adequate for explaining all but the most extreme astronomical situations.

Newton's First Law of Motion states that any object in motion or at rest will remain so, unless a force acts on it. For example, once a space probe such as Cassini (right) has escaped the influence of Earth, it will continue coasting through space continuously, until either its engine fires or it enters the influence of another massive object, such as another planet.



The Second Law of Motion states that the speed of an object changes when a force acts on it. The change of speed is known as ACCELERATION. The acceleration depends on the mass of the object and the amount of force acting on it. For example, a small, satellite-carrying rocket such as the 1960s British Black Arrow (left) requires a much smaller propulsive thrust to accelerate than a very large manned spacecraft such as Gemini-Titan.

The Third Law of Motion states that, whenever a force acts on an object, there is an equal and opposite reaction. For example, when a rocket fires its engine the fiery hot thrust A moves one way, and the rocket itself moves in the opposite direction B.



INSIDE THE SUN

OUTSIDE THE SUN

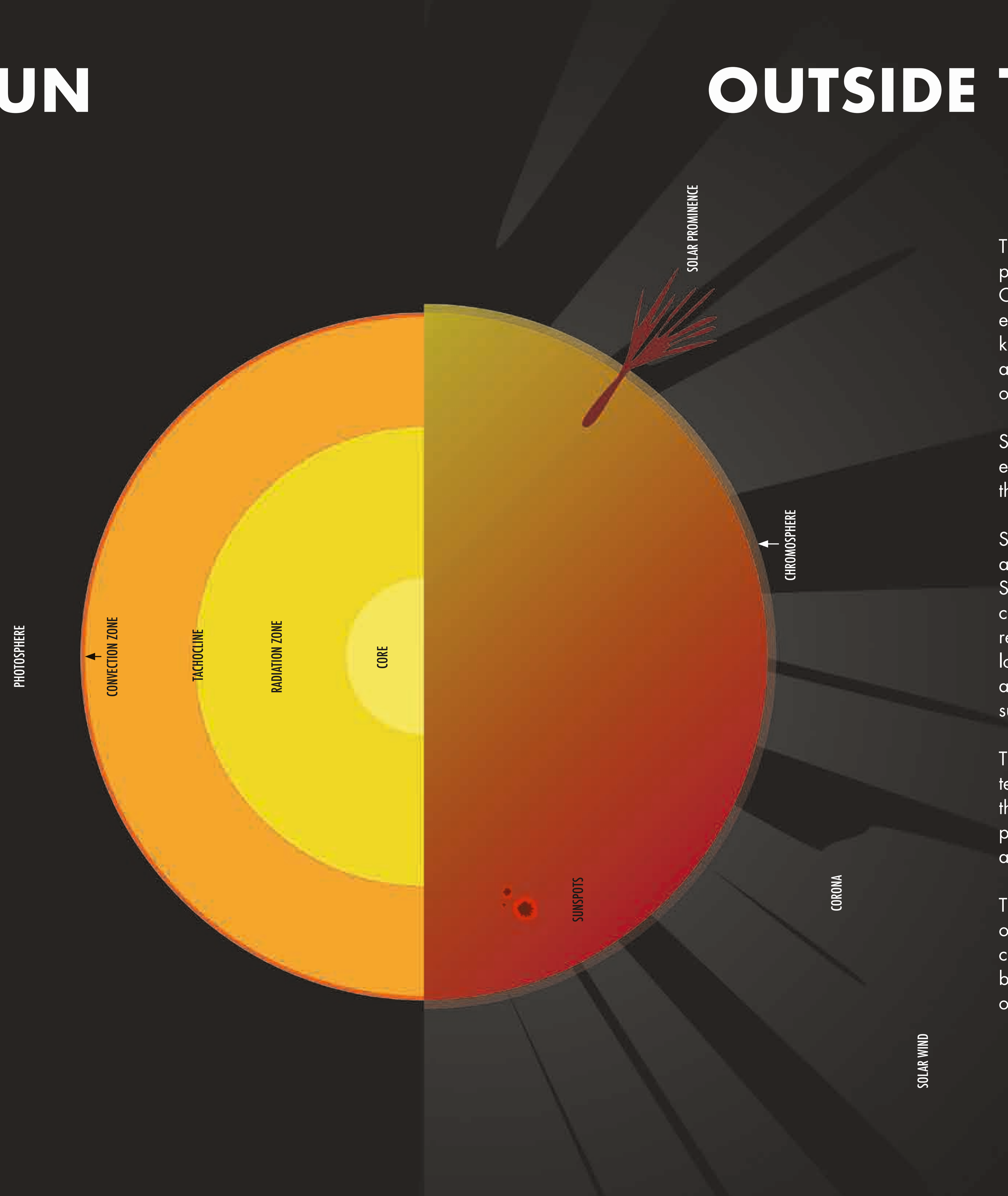
The core of the Sun is a sphere of very hot, high density and high pressure matter, called PLASMA. Within the core, hydrogen atoms join together to form helium in a process called nuclear fusion. In this reaction, a proportion of matter is converted into pure energy. The heat involved is huge – the core reaches temperatures of over 15 million degrees.

Above the core is a layer known as the RADIATION ZONE, where energy moves very gradually outwards. It takes over 170,000 years for energy to travel across the radiation zone.

Above the radiation zone is the CONVECTION ZONE, within which solar matter and energy move much more rapidly. Plasma currents transport heat from the base of the convection zone to the surface of the Sun, where they transmit their heat, cool, and sink back down again.

The boundary between the two zones is called the TACHOCLINE. The interaction of the two works like a dynamo, generating and amplifying huge magnetic forces.

The visible outer surface of the Sun is known as the PHOTOSPHERE. The Sun's heat and light energy is transmitted into space from the photosphere.



The layer above the photosphere is known as the CHROMOSPHERE. This layer extends approximately 2,000 km from the photosphere, and curiously gets hotter at its outermost edge.

SOLAR PROMINENCES are high energy releases of plasma from the Sun's surface.

SUNSPOTS are highly magnetic areas on the surface of the Sun. Their magnetic field causes the Sun's surface to reduce in temperature. The lower temperature means the area appears darker than the surrounding photosphere.

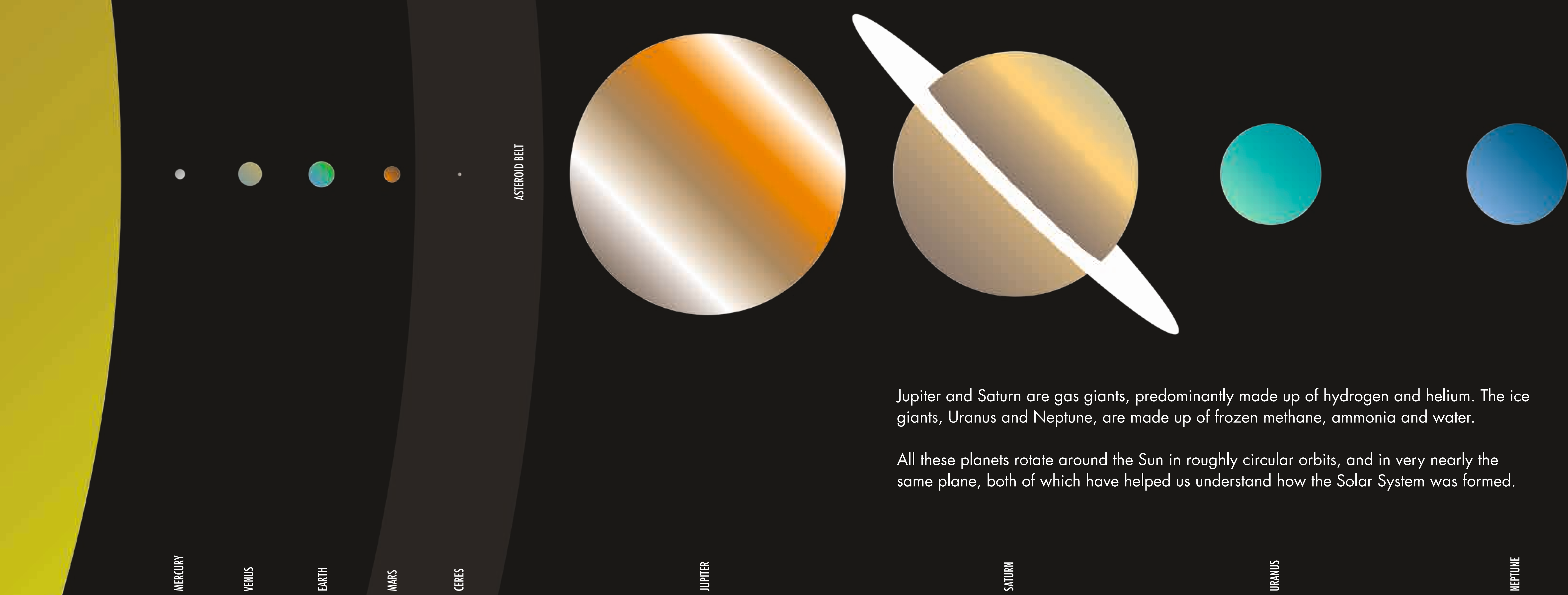
The CORONA is a very high temperature layer of plasma that extends out into space. Its position and thickness depend on activity on the Sun's surface.

The SOLAR WIND is made up of plasma that flows from the corona, away from the Sun, beyond the planets, to the edge of the Solar System.

THE INNER SOLAR SYSTEM

Millions of objects are in orbit around the Sun, but only eight of these objects are classed as planets. These are the terrestrial planets Mercury, Venus, Earth and Mars, and the giant planets Jupiter, Saturn, Uranus and Neptune.

The terrestrial planets are mainly made up of rock and metal. Beyond the orbit of Mars lies the ASTEROID BELT, which is formed of millions of rock and metal particles. The dwarf planet Ceres is also found here.



Jupiter and Saturn are gas giants, predominantly made up of hydrogen and helium. The ice giants, Uranus and Neptune, are made up of frozen methane, ammonia and water.

All these planets rotate around the Sun in roughly circular orbits, and in very nearly the same plane, both of which have helped us understand how the Solar System was formed.

BLACK HOLES

One of the most mysterious phenomena in the universe is another type of super massive entity, which is even more dense than neutron stars. Most BLACK HOLES are created when very large stars collapse, in a similar process to neutron stars. These are known as STELLAR BLACK HOLES.

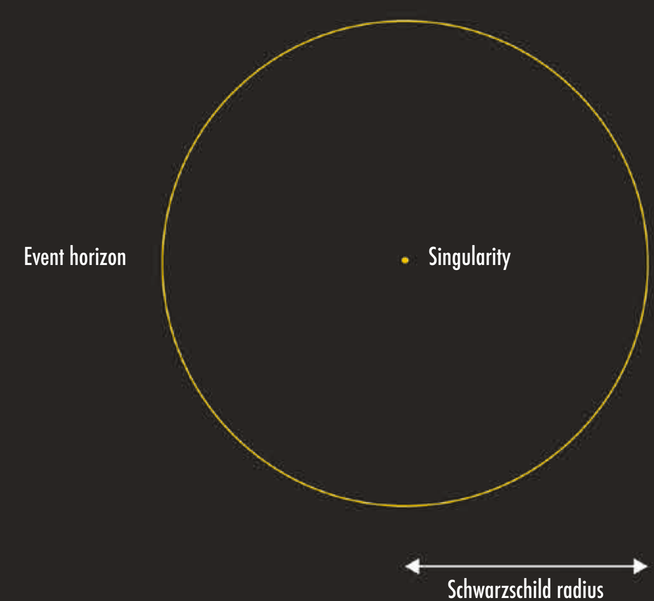
Unlike neutron stars, the matter making up a black hole has been squeezed down into a much smaller volume at its very centre. This point is known as the SINGULARITY.

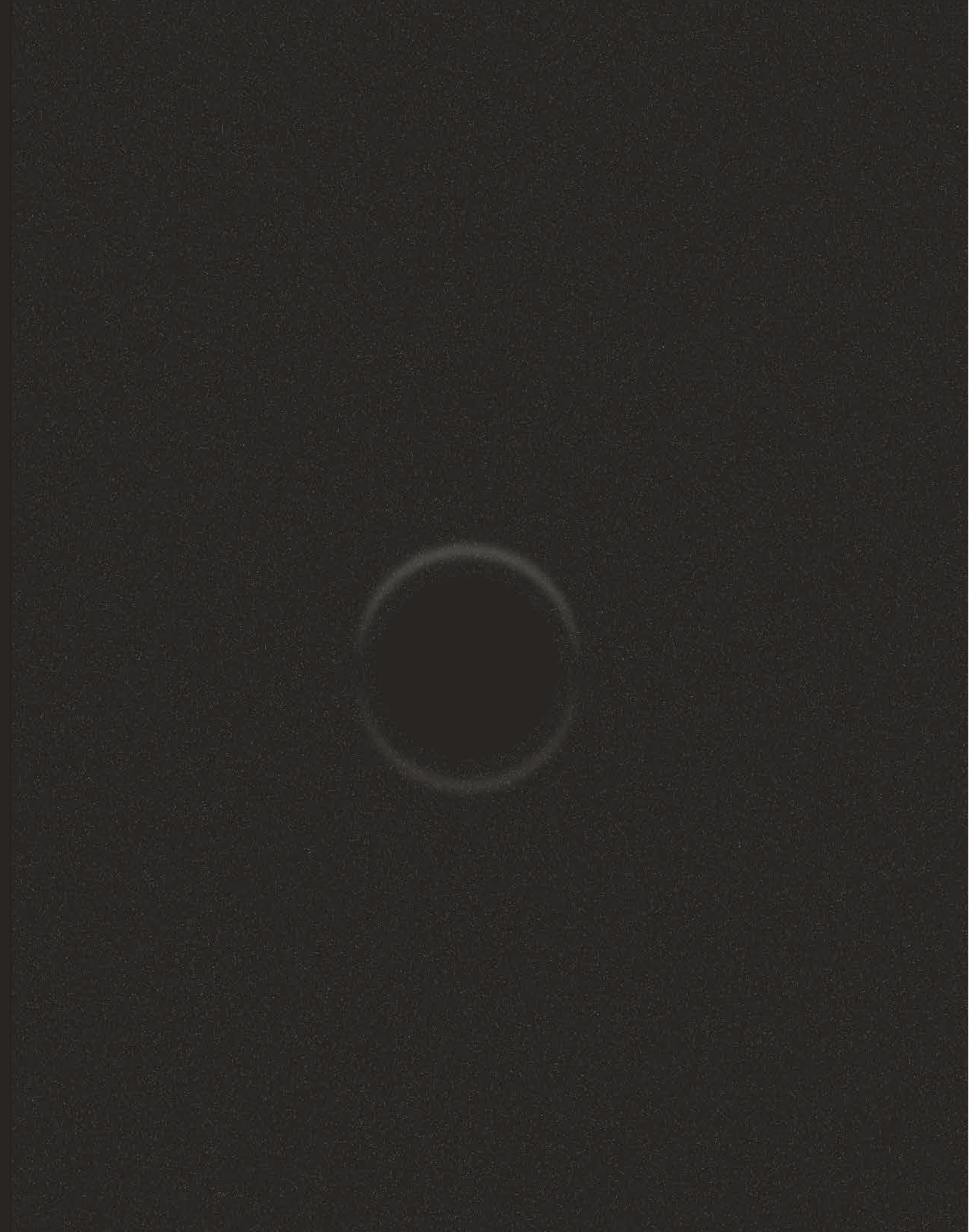
This is so dense that its gravity affects not just matter but also light. Within an area around the singularity, known as the EVENT HORIZON, it sucks in everything. This is why black holes appear black, because no light can escape. The path of light passing outside the event horizon is bent, rather like when light passes through a lens. This is known as GRAVITATIONAL LENSING. The picture on the right illustrates the strange curves of light visible around a black hole, which are caused by gravitational lensing.

The size of the event horizon depends on the mass of the black hole, and is known as the SCHWARZSCHILD RADIUS, after the German physicist Karl Schwarzschild. Stellar black holes usually have Schwarzschild radii of between 10 - 30km.

Over time, black holes can grow by attracting more matter, or combining with other black holes. The very largest, known as supermassive black holes, can reach masses billions of times larger than that of the Sun. These are found in the centre of virtually all galaxies. In the case of the Milky Way, the supermassive black hole is known as Sagittarius A*, and it is 4,000,000 times the mass of the Sun.

As supermassive black holes pull matter towards their centre, discs form around the event horizon. Because of friction, these reach very high temperatures and release huge amounts of radiation, which can be detected with x-ray telescopes.





APOLLO

The Apollo programme – the successful series of missions which sent astronauts to the Moon – is one of the greatest achievements in human history.

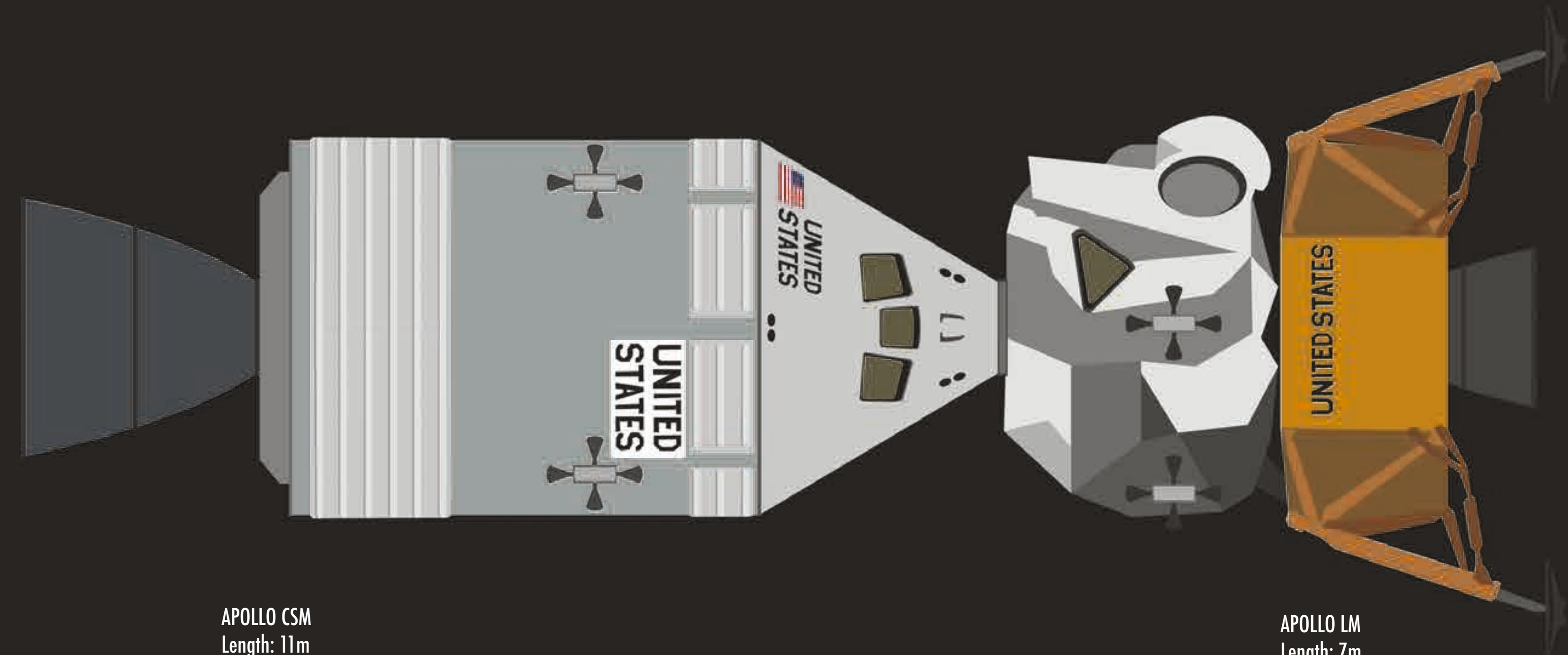
A new, much larger rocket was required to launch the large and complex command and landing modules into space and to the Moon. This rocket (details on p. XX) is still the largest, heaviest and most powerful ever launched.

After a series of test launches, including one mission to the moon which did not land (Apollo 10), Apollo 11, carrying astronauts Neil Armstrong, Buzz Aldrin and Michael Collins, launched from Cape Canaveral in July 1969. After launch, their command/service module (CSM) extracted and docked with the Lunar module (LM), which was stored in the rocket section below. With both modules in their docked configuration (right) they travelled to the Moon and entered lunar orbit. Armstrong and Aldrin then descended to the Moon's surface in the lunar module. Neil Armstrong was the first of the pair to step onto the Moon, uttering the famous words, "One small step for man, one giant leap for mankind". Aldrin joined him, and together they took photographs, and collected samples of moon rock and dust.

They then re-entered the lander, launched the ascent stage and returned to join Michael Collins in the CSM for their return to Earth.

Five more successful Apollo missions followed. The final three missions included the transportation of a moon vehicle along with the Lunar lander. This electrically-powered lunar rover vehicle (LRV – right) allowed the astronauts to travel further on the Moon's surface, travelling nearly 8km away from their landing site.

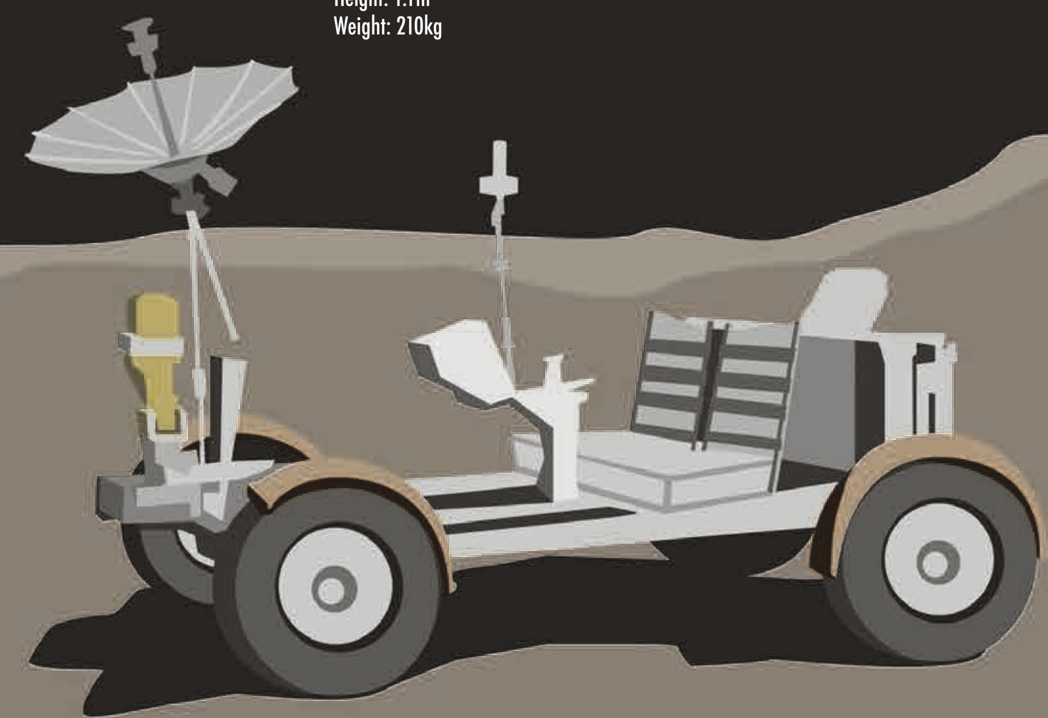
The final Apollo mission, Apollo 17, returned to Earth in December 1972. It was the last time an astronaut stood on the surface of the Moon.



APOLLO CSM
Length: 11m
Diameter: 3.9m
Weight: 14,690kg

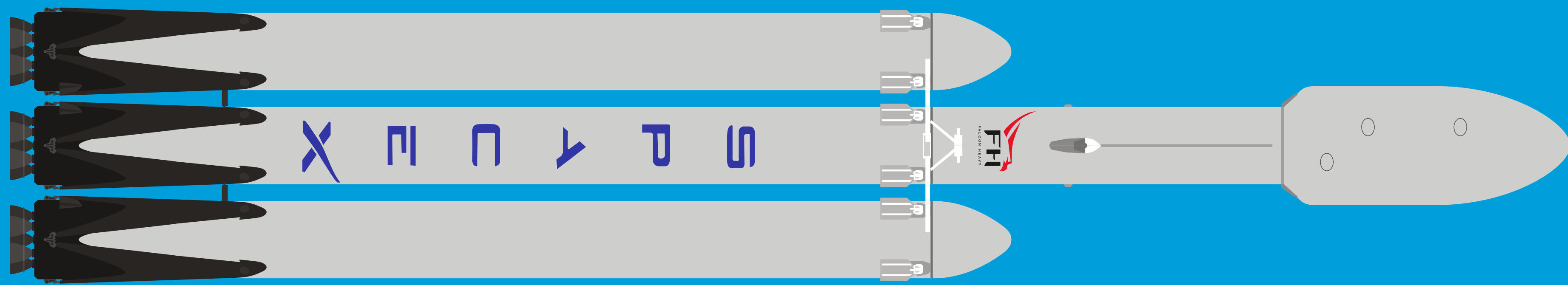
APOLLO LM
Length: 7m
Diameter: 9.4m
Weight: 15,200kg

APOLLO LRV
Length: 3.1m
Width: 2.3m
Height: 1.1m
Weight: 210kg

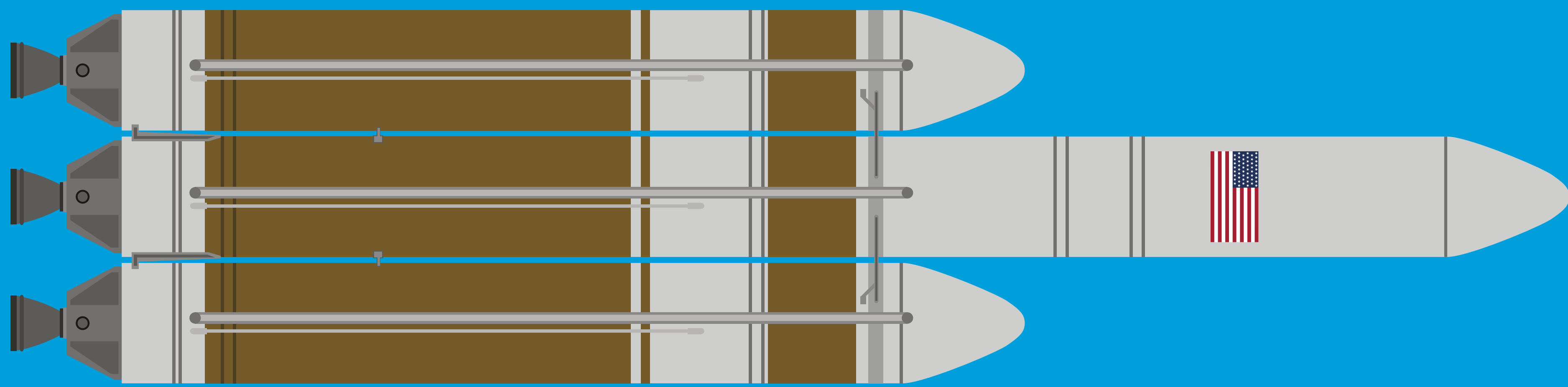


HEAVY LIFT VEHICLES

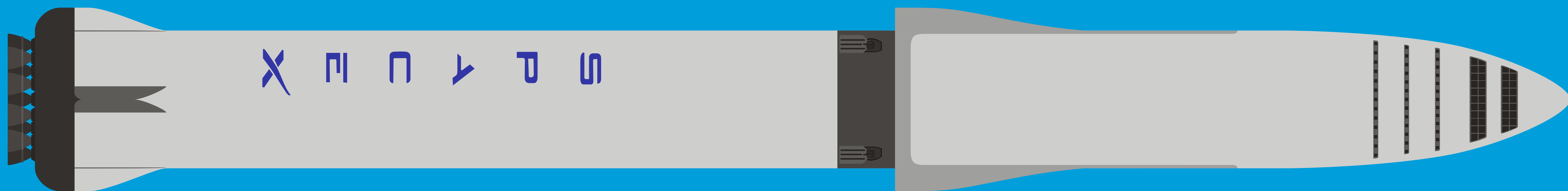
The newest generation of high-power, heavy-lift launch vehicles are being developed for the next steps in human space exploration. Programmes such as the construction of the lunar platform gateway, and missions to the Moon and Mars will require advanced new rocket systems capable of delivering large loads to diverse locations, and often operating unmanned.



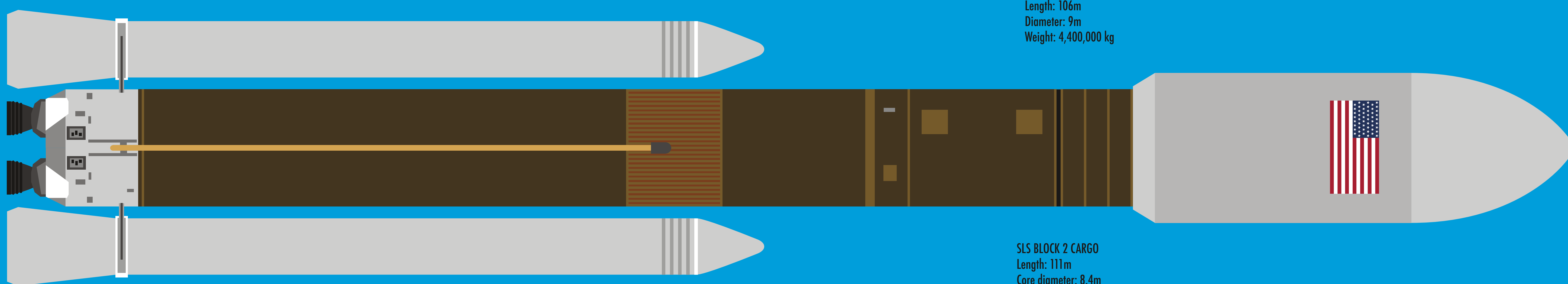
SPACE X FALCON HEAVY
Length: 70m
Core diameter: 3.6m
Overall width: 12.2m
Weight: 1,420,788 kg



DELTA IV HEAVY
Length: 72m
Core diameter: 5m
Overall width: 15m
Weight: 733,000 kg



SPACEX BFR (Proposed)
Length: 106m
Diameter: 9m
Weight: 4,400,000 kg



SLS BLOCK 2 CARGO
Length: 111m
Core diameter: 8.4m
Overall width: 20m
Weight: 4,400,000 kg