

Saturn V rocket blasts off the launchpad



Earth's Pacific Ocean

Penguin Random House

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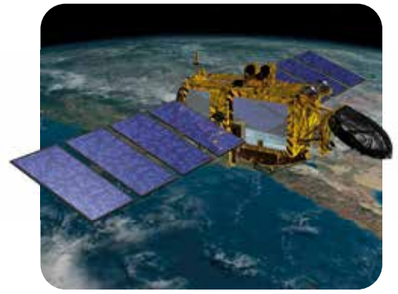
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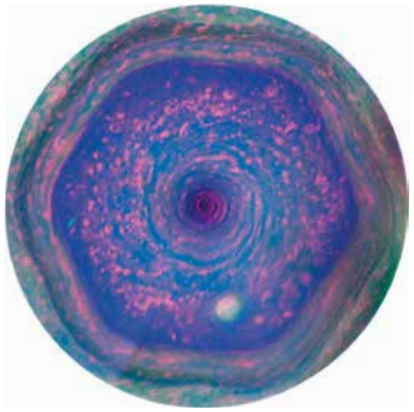
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Earth-orbiting satellite



Close-up, false-colour view of Saturn's north pole



Jupiter outweighs all seven other planets combined

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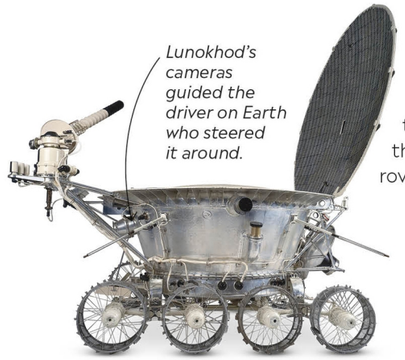


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Space age exploration

Robotic spacecraft have been exploring the Solar System since 1959. Far from home, in conditions no human could endure, they have investigated the planets, a host of moons, two dwarf planets, asteroids, comets, and the Sun. Mostly about the size of a family car, they carry scientific instruments that test conditions on other worlds, and transmit their findings home, making far distant worlds familiar.

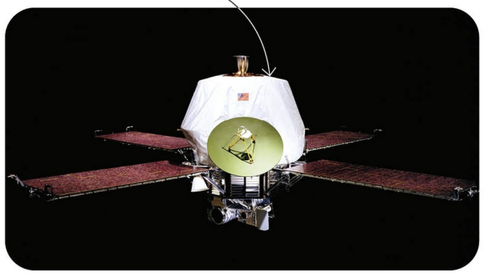


Lunokhod's cameras guided the driver on Earth who steered it around.

Early exploration

The first missions to another world were the Luna craft sent by the Soviet Union to the Moon. Luna 1 was the first to leave Earth's gravity, in 1959. Luna 9 was the first to soft land on the Moon, in 1966. Lunokhod 1 (left) was the first rover to explore the Moon. It landed in 1970 and roved across 10.5 km (6.5 miles) of its surface.

Mariner 9 started returning images of Mars in January 1972.



Mariner missions

Between 1962 and 1973, US Mariner missions made the first flybys of Venus, Mars, and Mercury. Mariner 9 (right) was the first craft to orbit another planet, arriving at Mars in 1971. The final mission, Mariner 10, was the first to visit two planets, Venus and Mercury.

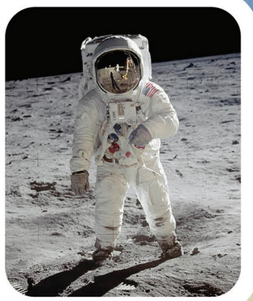
EYEWITNESS

Mae Jemison

US astronaut Mae Jemison (b.1956) broke barriers as the first black female astronaut when she flew NASA's space shuttle Endeavour in 1992. She was one of the agency's first "mission specialists" – astronauts trained to carry out scientific experiments in space.



Robotic explorations of the planet... has truly revolutionized our knowledge of the solar system.



Buzz Aldrin on the Moon, photographed by Neil Armstrong

Sending astronauts to the Moon

Twelve American men have walked on the surface of the Moon, arriving two at a time on Apollo landing craft. The first, Apollo 11's Eagle, touched down on 20 July 1969. Just over six hours later, on 21 July, Neil Armstrong became the first man to step onto the lunar surface, followed by Buzz Aldrin. Their trip to the Moon and back was 1.5 million km (953,054 miles).

The Apollo 11 spacecraft was carried inside the upper part of the rocket.

Lower sections contained fuel and engines. These detached and fell away as the rocket climbed higher and reached Earth orbit.

A Saturn V rocket blasted off from Cape Canaveral, USA, on 16 July 1969, launching Apollo 11 on its journey to the Moon.

Cameras provided views of Mars's north polar region.



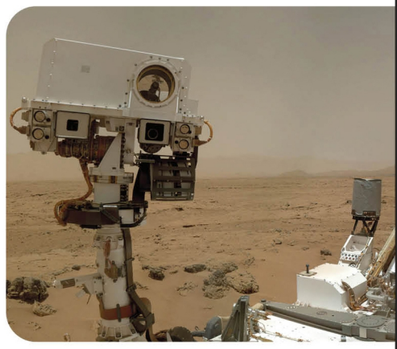
Artist's impression of Phoenix landing in 2008

Landing craft

Spacecraft use parachutes and small rockets to control their descent and make a soft (controlled) landing. The first soft landing on a planet was made by Venera 7 on Venus in 1970, but it survived for just under an hour in the corrosive atmosphere. Mars is more hospitable – four craft have successfully landed and worked there for longer periods.

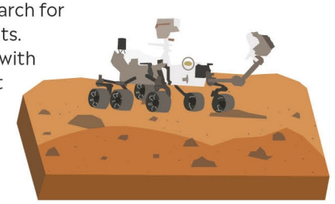
Bristling with equipment

Each spacecraft carries a dozen or so scientific instruments including several cameras, as seen here on the Curiosity rover on Mars. In this selfie taken by another camera, the large round eye is ChemCam, which includes a laser and telescopic camera. Below are two rectangular-shaped cameras, and at either side of them, a pair of navigation cameras.



PERSEVERANCE ROVER

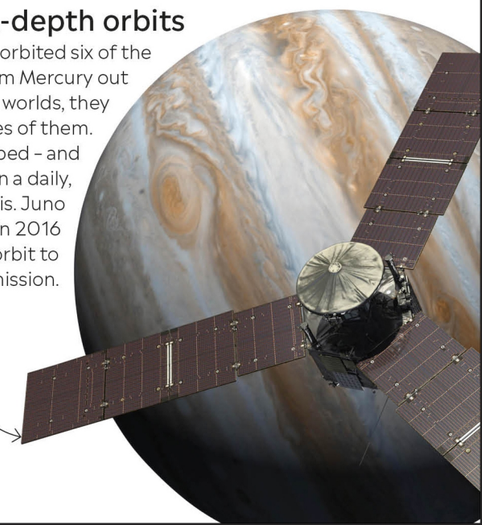
NASA's Perseverance rover touched down on Mars in 2021, on a mission to search for past life and habitable environments. The six-wheeled rover is equipped with an array of cameras, drills to collect rock samples, and instruments to analyse the minerals it finds.



In-depth orbits

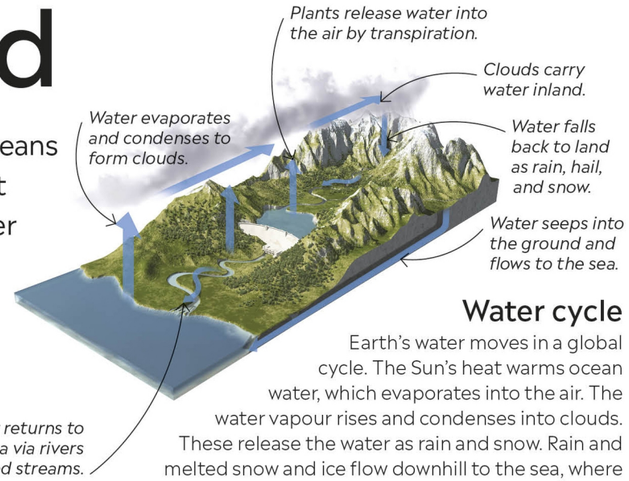
Spacecraft have orbited six of the Solar System planets, from Mercury out to Saturn. By circling these worlds, they can make systematic studies of them. Whole planets can be mapped – and changes recorded – on a daily, monthly, or yearly basis. Juno (right) arrived at Jupiter in 2016 and moved into a polar orbit to start its scientific mission.

Three solar panels around Juno's hexagonal body provide electrical power.



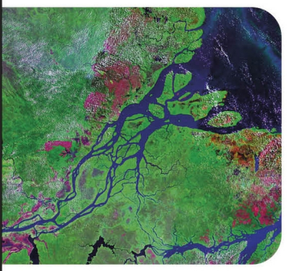
Water **world**

Earth's water makes our planet unique. Oceans and seas of liquid salty water cover about 70 per cent of Earth's surface. Fresh water in lakes and rivers, as well as frozen in glaciers, ice sheets, and icebergs brings the total to more than 80 per cent. The movement of water plays a huge role in shaping Earth's surface.



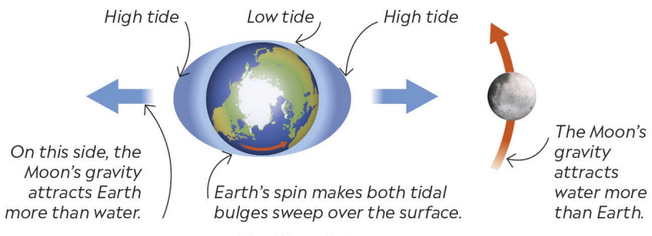
Water cycle

Earth's water moves in a global cycle. The Sun's heat warms ocean water, which evaporates into the air. The water vapour rises and condenses into clouds. These release the water as rain and snow. Rain and melted snow and ice flow downhill to the sea, where the cycle starts again.



Amazon River

Rivers hold less than one per cent of Earth's water, but have a big effect on its landscape, carrying about 20 billion tonnes of sediment to the oceans annually. The Amazon (left) delivers a fifth of all river water reaching the sea.



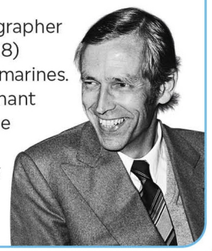
Daily tides

The Moon's gravity pulls on the oceans. The pull is stronger nearer to the Moon, so a bulge of water forms on the side nearest to the Moon, and on the opposite side. As Earth turns, the bulges create daily changes in the sea level – our high and low tides.

EYEWITNESS

Jacques Piccard

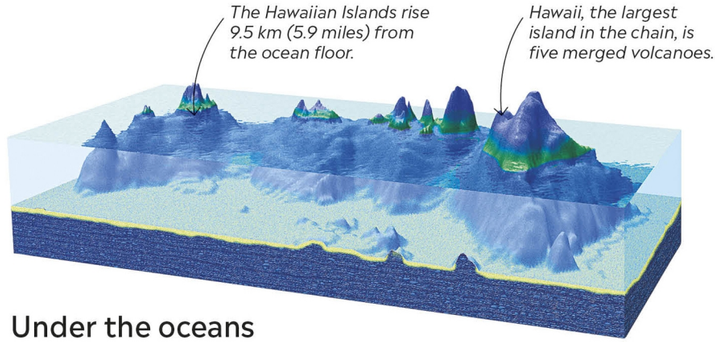
Swiss engineer and oceanographer Jacques Piccard (1922–2008) specialised in designing submarines. Piccard and US Navy Lieutenant Don Walsh descended to the deepest point on Earth – almost 11 km (7 miles) below sea level in 1960.





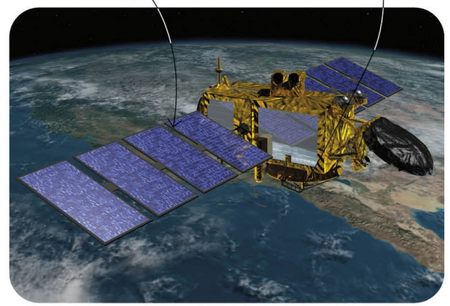
Frozen water

More than three-quarters of Earth's fresh water is ice – in glaciers, ice sheets and shelves (above), icebergs, mountain-top coverings, and soil. Most of it is in the ice sheet covering Antarctica – if it melted, sea levels would rise by about 60 m (197 ft).



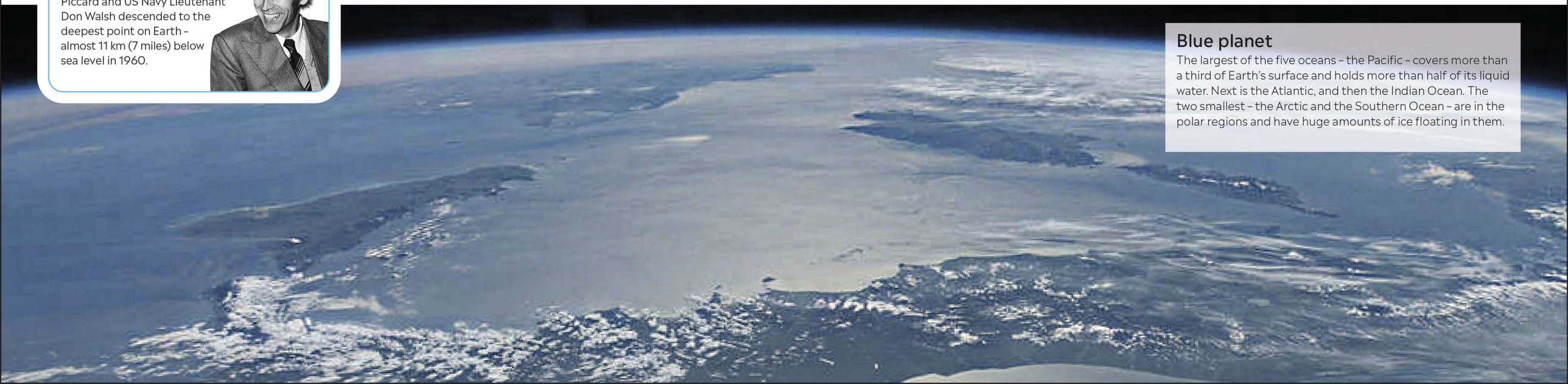
Under the oceans

The ocean floor is mostly flat plains, but it also has mountains and trenches. The Mariana Trench plunges 11 km (6.8 miles) below the Pacific Ocean's surface. The Mid-Atlantic Ridge is Earth's longest mountain range. Deep-sea volcanoes that break through the water's surface make islands such as Hawaii.



Water watch

Satellites orbiting Earth monitor its land, oceans, and ice. Jason-3 (above) measures the height of the ocean surface as part of a wider study of changes in sea levels and the effects of climate change. The Aqua satellite studies the water cycle, and CryoSat measures changes in the thickness of the ice sheets.



Blue planet

The largest of the five oceans – the Pacific – covers more than a third of Earth's surface and holds more than half of its liquid water. Next is the Atlantic, and then the Indian Ocean. The two smallest – the Arctic and the Southern Ocean – are in the polar regions and have huge amounts of ice floating in them.

Saturn's rings

The most impressive rings of any planet encircle Saturn. They are made of millions of orbiting pieces prevented by Saturn's gravity from combining to form a single moon. The rings extend to many times Saturn's width but average only about 10 m (33 ft) deep, and small moons sweep the gaps in between.

EYEWITNESS

Giovanni Cassini

Italian-born Cassini, the first director of the Paris Observatory, France, was one of the first to observe Saturn. In 1675, he spotted the gap dividing the A and B rings that now bears his name. He also discovered four moons: Iapetus, Rhea, Tethys, and Dione.





Rings within rings

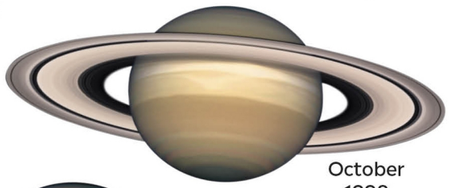
The rings most readily seen from Earth are named A, B, and C. Each consists of individual rings of material. At either side of these three are more recently discovered rings that are almost transparent. The D ring is closest to Saturn, while E, F, and G lie beyond the A ring. There are a small number of gaps between the rings, such as the Cassini Division. They look empty from a distance but are full of material.

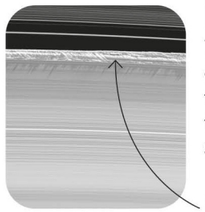


Changing view

Our view of the rings changes as Saturn orbits the Sun. The planet tilts by 27 degrees on its spin axis, and each hemisphere points towards the Sun once per orbit. In these five views, more and more of the southern hemisphere faces the Sun. The rings will lie edge on in 2025, and be wide open once again in 2032.







Ring peaks

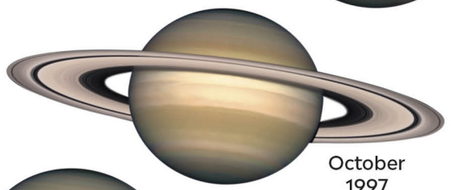
The gravity of moons within the ring system causes kinks and waves in individual rings, or forces pieces into peaks. Cassini imaged these peaks rising up to 2.5 km (1.6 miles) above the edge of the B ring.

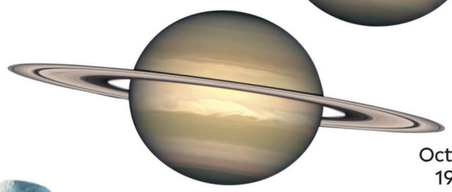
Tall peaks cast long shadows on the B ring.

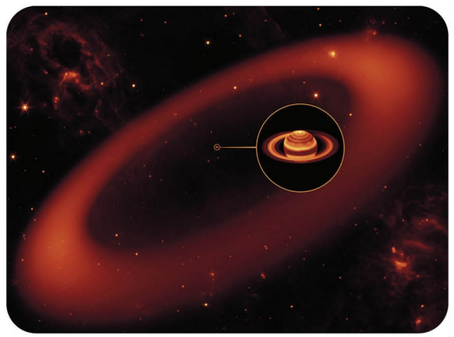
Shepherd moon

Daphnis (right) is just 8 km (5 miles) wide, and orbits within the Keeler Gap. It shepherds material into the ring and maintains the gap, causing ripples on both edges.









Giant dust ring

A huge new ring found in 2009 is tilted from Saturn's main ring system. Made of dust, it starts 6 million km (3.7 million miles) from Saturn and extends twice as far again. It is also very thick, about 20 times Saturn's width from top to bottom. Invisible to the eye, the giant ring is seen here in infrared.

Icy particles reflect sunlight well, making the rings bright and easy to see.



Ring pieces

The pieces that make up the rings are dusty water ice, and range in size from tiny grains to truck-sized boulders. Each follows its own circular orbit in a plane extending out from Saturn's equator. Their origin is uncertain. The pieces could be debris from a moon torn apart by Saturn's gravity, or from a moon destroyed in a collision with another body.