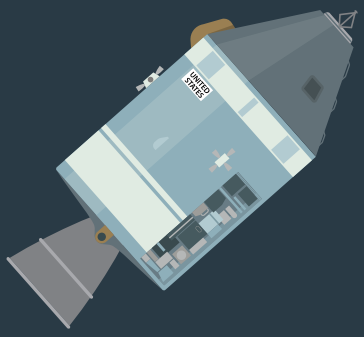
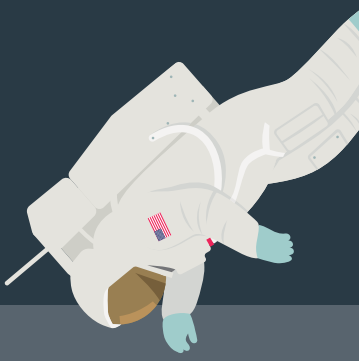
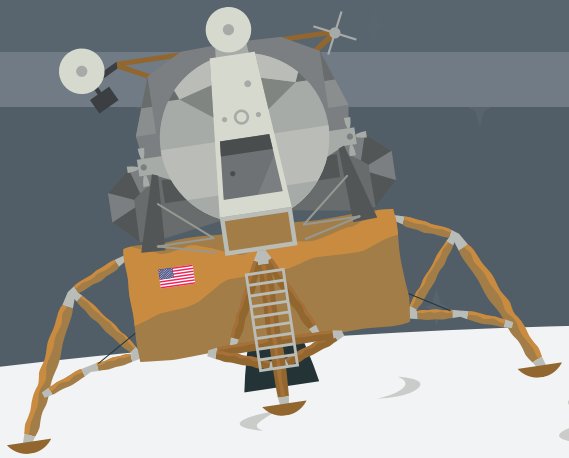
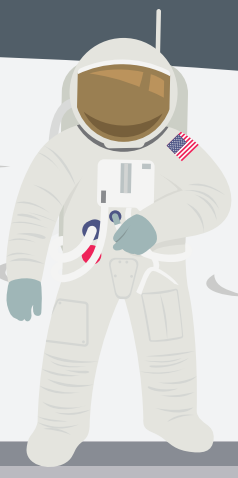
DESTINATION SPACE!







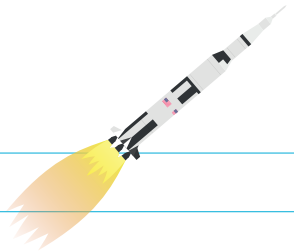


The Moon Training Handbook

Image credit: NASA

DESTINATION SPACE!

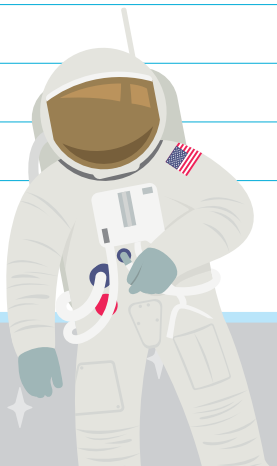
CONTENTS

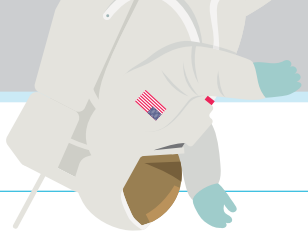


Introducing the Moon

Getting to the Moon

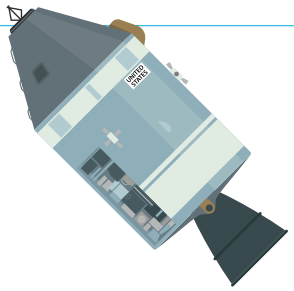
Exploring the Moon

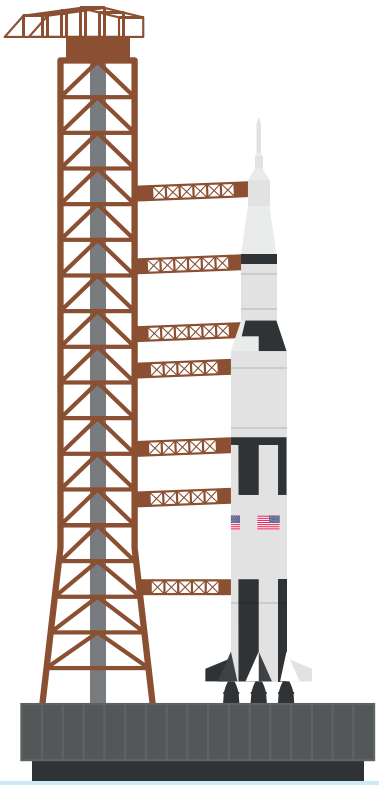


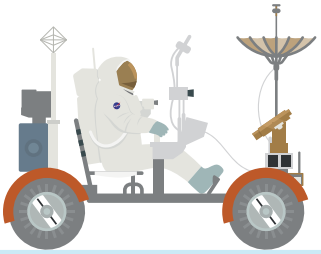


The Future

Family Show and Further Information







Exploring the Moon

Celebrating 50 Years of Moon missions

Introduction

The UK Association for Science and Discovery Centres (ASDC) is delighted to be working in partnership with The UK Space Agency to share some of the most exciting developments in space exploration and space science with families, schools and communities across the UK.

50 years of the Moon

Fifty years ago, the first two humans landed on the Moon, made possible by a team of more than 400,000 men and women here on Earth. ASDC and The UK Science and Discovery Centres and Museums are celebrating this remarkable achievement as part of our wider National STEM Programme, 'Destination Space.'

Destination Space

Destination Space is a UK-wide STEM programme, created and led by The UK Association for Science and Discovery Centres, funded by the UK Space Agency, and with expertise from a host of partners. Phase 1 shared the stories and science of human spaceflight and Tim Peake's mission.

Overall 914,616 children and adults took part at 20 Science Centres and Museums across the UK. This included 152,348 school children in curriculum-linked workshops with their teachers, and 75,741 children and adults who met and spoke with a space scientist or engineer. A further 1,135,786 people visited Destination Space exhibitions, bringing the overall total to 2,050,432 people.

ASDC is delighted to be extending and developing this national programme in Phase 2, to engage, inspire and involve families, school groups and communities across the UK with the stories and science of future space missions, and the latest achievements of the UK's world-leading space sector.

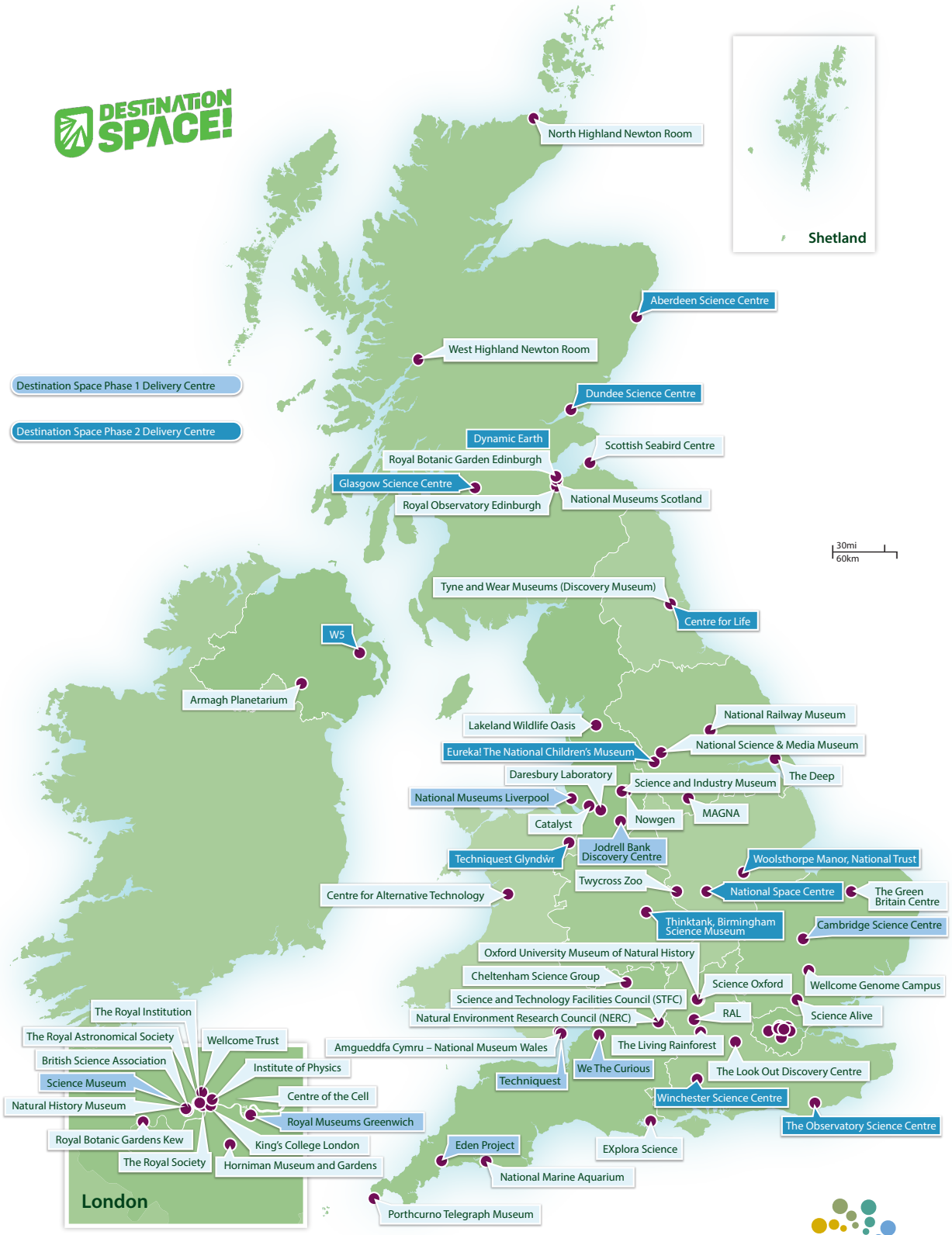
Acknowledgements

This programme has been made possible by the generous support from the UK Space Agency. We thank them for their excellent advice and support throughout. We would also like to thank the following people on the project team for creating this handbook and training staff across the UK: from ASDC Dr Penny Fidler, Andy McLeod, Dr Jaclyn Bell, Shaaron Leverment, Helen Cooke.

From the National Space Centre and National Space Adacemy: Sophie Allan, Josh Barker, Chloe Hopkinson, Dr Kierann Shah, Tori Tasker.

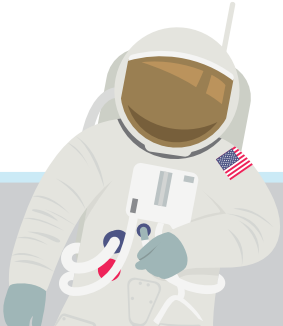
Image credit: NASA

The UK Science and Discovery Centre Network



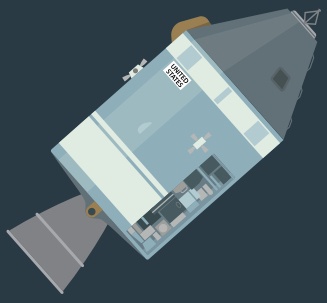
www.sciencecentres.org.uk

UK Association for Science and Discovery Centres

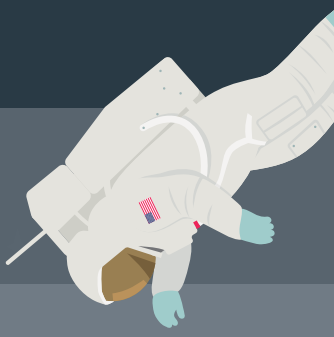


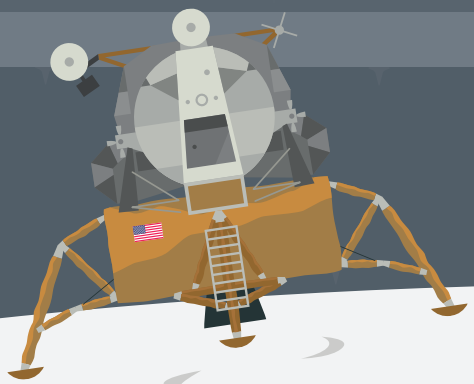
DESTINATION SPACE!

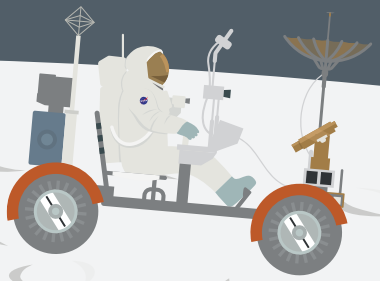
DESTINATION SPACE!

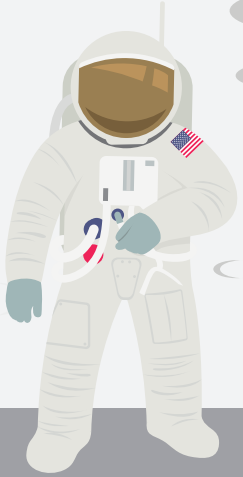


Introducing the Moon









What is the Moon?

The ultimate spin-off

Overview

The Moon is a natural satellite to Earth, and our closest celestial neighbour.

How was the Moon formed?

The favoured theory for the formation of the Moon is based on the Giant Impact Hypothesis, which involves an ancient body, about the size of Mars colliding with the Earth about 4.5 billion years ago. We call this object 'Theia', after the Greek titan who gave birth to the Moon goddess. The collision produced debris, or ejecta, which eventually collected in orbit around Earth to form the Moon.

There have been many theories about how the Moon was formed. The Captive Theory proposes that it was a wandering body, caught by Earth's gravity, while the Accretion Theory suggests that it was created simultaneously with the Earth. The Fission Theory is based on the idea that the Moon was somehow 'thrown out' by the Earth spinning. These theories have been largely discredited thanks, in no small part, to the Apollo Missions of 1969-1972.

What does the Moon do?

If viewed from the celestial north pole, the Moon orbits around Earth anticlockwise. This is the same direction as the Earth spins (rotates) on its axis. The Moon also spins, taking around 27 days to complete one rotation. This is the same time as it takes to orbit the Earth once, a process known as tidal locking. This is why we always see the same face of the moon when we view it from Earth (the near side of the Moon).

If we did not have the Moon, our nights would be darker and our tides would be weaker. More importantly, scientists believe our tides, and other gravitational influences of the Moon that stabilised our axis and climate over long timescales, have been crucial for the evolution of life on our planet.

The Moon in popular culture

The Moon has been the subject of debate, scientific enquiry, observation, history and wonder for as long as humans have been able to look up at the night sky. Because of this, there are countless stories and myths throughout various cultures, from exposure to the Moon offering healing properties, to lunar eclipses being demonstrations of fights between the Sun and the Moon.

During the Apollo era, the Moon was a reachable goal. It remains the only celestial body, other than the Earth, upon which humans have set foot.

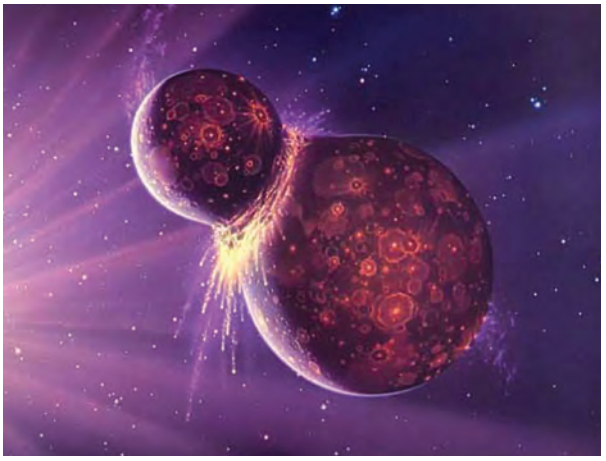


Image credit: NASA

How does the Moon affect our planet?

Overview

Our natural satellite does much more than just illuminate the night sky. Removing the Moon would affect Earths tides, rotation, orbit around the Sun, and the wobble of our planetary axis.

How does the Moon create tides?

Tides are the rise and fall of water caused by the Moon and its gravitational pull on Earth's oceans, rivers and lakes. As the Moon orbits the Earth it pulls the oceans with it, creating high and low tides. The Sun can also cause this effect, although it is only half as strong as the force produced by the Moon. It is believed that the tides were vital in helping early life, food and populations spread. Without the tides, oceans would be calmer and the circulation of nutrients would cease, threatening thousands of species.

Do spring tide happen in spring?

When there is a new or full Moon visible in the sky this means the Earth, Moon and Sun are aligned. This alignment causes tidal bulges from both the Sun and the Moon to be added together and we get what are called 'spring' tides. This happens twice per month and has nothing to do with the seasons or time of year. Generally, spring tides occur a couple of days after a new or full Moon and result in higher and lower tides than usual.

What is a lunar eclipse?

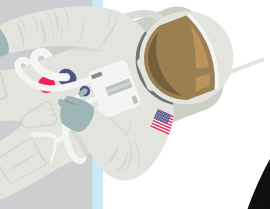
A lunar eclipse is the phenomena that happens when the Earth passes directly between the Sun and a full Moon. The Earth's shadow blocks the light coming from the Sun, meaning there is no light for the Moon to reflect. This results in a lunar eclipse, of which there are three types: total, partial and penumbral.

Lunar eclipses don't happen every time there is a full Moon, instead they occur between two to four times per year, since it is only when the Moon is in the same plane as the Earth that it passes through a portion of its shadow.

The Moon illusion

When the Moon is closer to the horizon it seems to appear larger than when it is higher up in the sky. This is an optical illusion called the 'apparent distance hypothesis'. In reality the Moon is never any bigger than it usually is. You can demonstrate this illusion by holding up a 5 pence piece at arms length and, with one eye closed, moving the coin so that it entirely covers a full Moon when it is sitting high up in the night sky. Do the same when you think the Moon looks particularly large (usually when it is near to or on the horizon) and you will notice that the 5 pence piece will still cover it, proving that the size of the moon never changes.

Image credit: NASA



Glowing Moon Model

The Moon in miniature

Overview

This beautiful, glowing model of the Moon can be used to start the conversation about the Moon's surface features and what can be seen by the naked eye from Earth.

What does it show?

The surface of the Moon is dominated by lighter craters and darker basalt seas.

Many of the Moon's craters are thought to have been created billions of years ago by large asteroid impacts during a period known as the Late Heavy Bombardment.

Both the Earth and the Moon would have experienced thousands and thousands of large asteroid impacts during this period, however, much of the evidence of this on Earth has been erased by active plate tectonics and erosion by water, glaciers and wind.

The darker, smoother patches are called 'mare' or basalt seas (mare is the Latin word for sea, as early astronomers mistook them for oceans).

Why is this important?

Even with city lights, you can see mountains and craters on the Moon. With a simple pair of binoculars or a telescope, the Moon comes to life!

In total, there were six missions that landed astronauts on the surface of the Moon. Each of these missions landed in different locations, although all are on the side of the Moon facing us. Buzz Aldrin and Neil Armstrong landed on the edge of the Sea of Tranquility.

How to run the activity:

The glowing Moon model can be used in the family show, as a prop to introduce the Moon. It is particularly attractive in a darkened room.

It can also be used in the Earth-Moon scale demo, if the Earth is scaled up appropriately. Very roughly, the Earth model would need to be four times the size of the model Moon. The models would also need to be approximately 30 times the diameter of the Earth apart from each other.

Image credit: ASDC

Moon Phases

How our view of the Moon changes through the month

Overview

Our view of the Moon from Earth changes across the month. Try these two activities to demonstrate the reason for the changing phases.

What's happening?

The half of the Moon pointing towards the Sun is illuminated. However, as the Moon orbits around the Earth we can't always see all of the illuminated portion. Instead we see only part of the illuminated portion. This is what makes up the phases of the moon.

The Moon takes nearly 28 days to orbit the Earth. When all of the Moon is visible it is called a Full Moon, when none of it is visible it is called a New Moon. When it is growing it is called waxing and when it is getting smaller it is called waning.

The Moon wheel activity

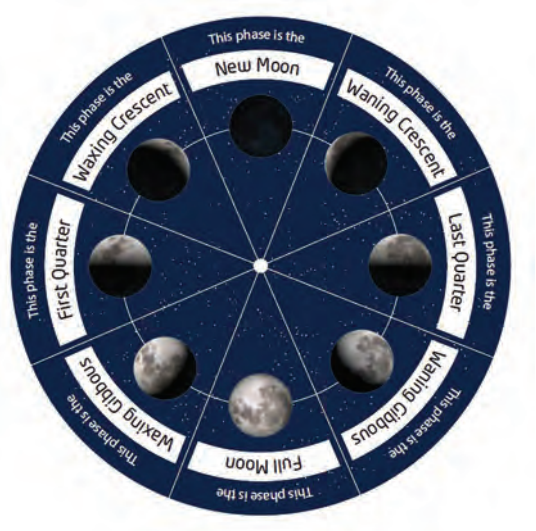
This Moon wheel kit can be used to show the sequence of the phases of the moon in combination with the Sun and Moon demo. Each time you demonstrate a new phase, ask children to find the correct stickers and stick them onto the wheel.

Image credit: NASA and ASDC

Sun and Moon activity

In this participatory demonstration, a group of children stand at the centre of the room, being the Earth. Someone holds the bright torch, and is the Sun, and the presenter walks around them holding the Moon so everyone can see how the phases vary. Dim the lights for maximum effect, and ask the audience how much of the Moon directed towards the Earth is visible or illuminated.

As each phase is demonstrated the audience should be guided to affix the appropriate sticker to their wheel. Once the full orbit is completed and all the stickers are in place the wheel can be cut out and clipped together. The audience can then take away and use their wheels.



Moon Scale Demo

Can you correctly guess the distance between the Earth and the Moon?

Overview

Space is incredibly big and it can be very difficult to get a perspective on just how extensive it is. This simple hands-on demonstration gives the participants a sense of the scales involved.

What does it show?

This activity challenges participants to think about the scale of objects and distances in space. Participants will first have the chance to guess the distance of the Moon from the Earth on a scaled representation; the demonstrator will then show the actual distance. The true scaled distance often surprises people and gets them thinking.

Why is this important?

The size and extent of space is something that is poorly understood by almost everyone, including many experts. The enormous distances involved in space and space travel are one of the elements that make it so tricky. Once people understand just how big space is, it can really highlight the difficulties faced when exploring space. This activity demonstrates just how big the distance is between the Earth and the Moon. This will hopefully prompt people to think about space differently and appreciate the challenges of scale and distance.

How to run the activity

For this activity at least one scaled Earth is needed; depending on the amount of room available or the number of people participating the demonstrator(s) may wish to use more than one. Select a volunteer to place the scaled Moon at a distance that they think is appropriate. This could also be done with more than one volunteer taking part as a little competition. Once people are happy with their placement the demonstrator should reveal the correct distance. The easiest way to do this is with a piece of string that is 30 times the scaled Earth's diameter. While this isn't 100% accurate it is extremely close and of course will scale with Earth models of any size. This can then lead to discussions of the distance of other objects from the Earth, such as the Earth/space boundary, the International Space Station (ISS) orbital height or the distance from the scaled Earth to the Sun.

Key Distances

Earth Diameter= 12,756 km (equatorial)

Moon Diameter = 3,474 km

Distance between = 384,400 km (average)

Image credit: NASA/NOAA 2015 (National Oceanic and Atmospheric Administration)

A Piece of the Moon

That fell to Earth as a meteorite

Overview

This small piece of rock was once part of the surface of the Moon until an impact blasted it into space, where it eventually fell to Earth as a meteorite.

What is it?

This is a Lunar meteorite, a bit of rock that was launched away from the surface of the Moon when it was itself struck by a meteorite. Bits of rock like this drift through space, and can end up on a collision course with Earth. Some, like this one, survive the fall through our atmosphere and are found on the Earth's surface.

Why is this important?

Lunar meteorites give us a chance to analyse a lot more rock than the amount that was bought back on the Apollo missions. While these missions bought back a large amount, much of it is incredibly precious and NASA are very careful about how they use it. Meteorites like this one are far more common and are much easier to find and use. This means they can be studied, and we can hold in our hands little pieces of rock from the Moon.

Where did it come from?

This meteorite has the designation NWA 11444 and fell on the border between Mauritania and Algeria in North Africa. We don't however know the exact location on the Moon that this meteorite originated from.

Image Credit: ASDC

What is it made of?

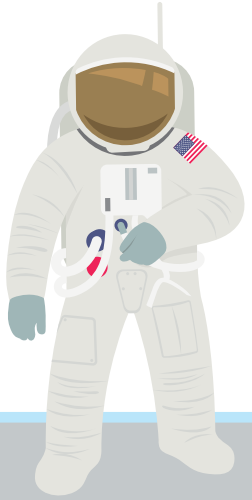
Upon collection in 2017, this piece was analysed by the Open University and was confirmed to be a Lunar breccia. This type of rock is often formed on impact by meteorites, when the energy of the impact causes different types of rock at the impact site to bind together. Within the samples many fragments of basalt and brown basaltic glass can be found.

Is it possible to get more?

Lunar meteorites aren't too tricky to get hold of so if your centre wished to obtain more, we can provide you a good contact to supply some.

Borrow the Moon

STFC run an exciting 'Borrow the Moon' loan box programme, that allows schools to borrow actual pieces of moon rock and other meteorites. This is aimed at schools though could be provided to support a Science C entre dependent on availability. Loans are usually for one week and applications are online.



The Story Begins

1957 - 1967: A (very) brief guide to the first decade of human spaceflight

Overview

The first ten years of human spaceflight was replete with challenges, triumphs and politics, but humanity finally got the chance to look back at our own planet.

Round 1: USSR

The early space firsts were achieved by the USSR, but the USA was never far behind. On 4 October 1957, Sputnik 1 – a simple, beachball sized object became the first artificial satellite to be placed in orbit. This single act, and mounting tensions between the USSR and the USA, launched the Space Race.

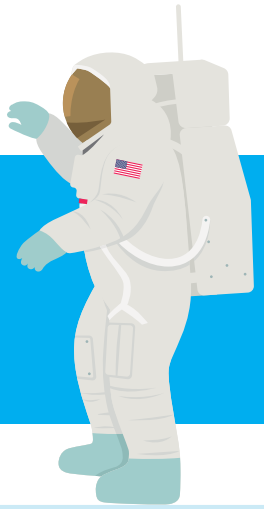
Four years later, on 12 April 1961, the USSR got their next first by successfully sending cosmonaut Yuri Gagarin into space in the Vostok capsule. Just a month later, US Astronaut Alan Shepard gained his astronaut wings on board a Mercury capsule.

NASA was making progress with its space programme, and alongside the all male Mercury 7 project there was some interesting, privately funded work taking place involving possible female astronauts. The 'Mercury 13' project involved 13 women undergoing the same training as their male counterparts. While they performed excellently in their tests, and several were competitive with the Mercury 7, the programme was stopped and NASA declared that it would not be sending women in to space.

The space race stepped up a level on 25 May 1961 with US President John F. Kennedy boldly announcing that the US would put humans on the Moon by the end of the decade. To paraphrase – "not because it is easy, but because it is hard."

On 16 June 1963 the USSR achieved another first by launching the first woman into space – Valentina Tereskova. And in 1965, cosmonaut Alexei Leonov successfully completed the first spacewalk. Five days after this, the new US Gemini programme was launched, and just a short while later, Astronaut Ed White performed the first US spacewalk.

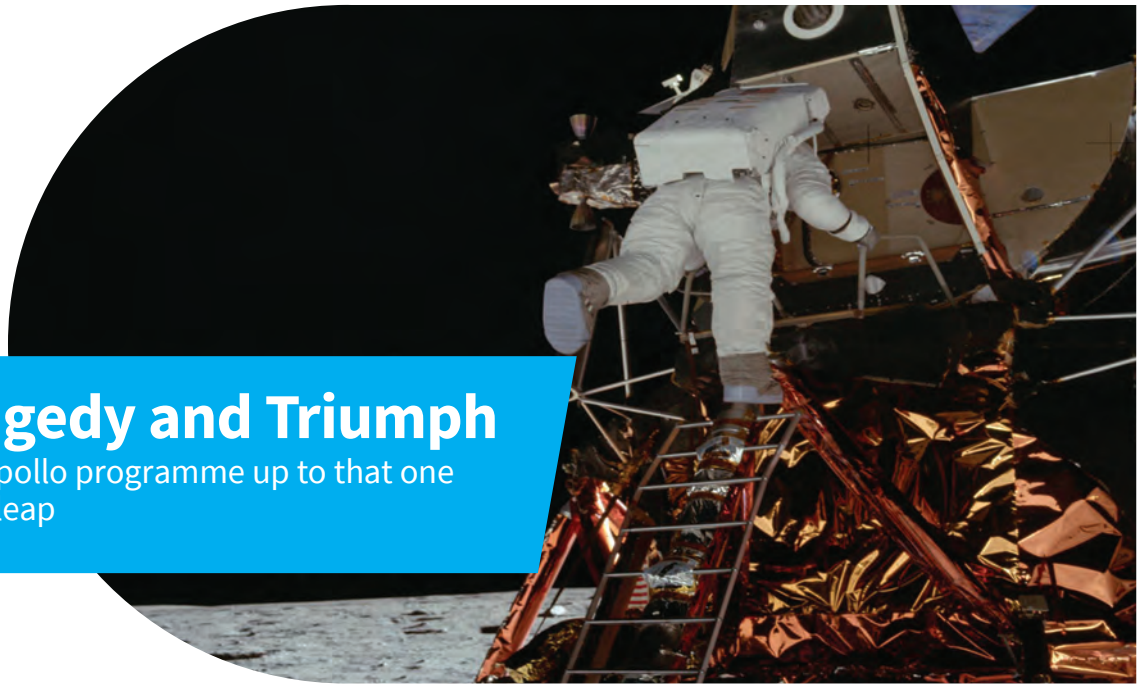
With both the USSR (Luna 9) and the US (Surveyor) landing robotic craft on the Moon and proving the surface was solid enough to walk on, the scene was set for the final challenge. The Apollo programme was soon to take centre stage.



Did you know?

Alexei Leonov's landmark spacewalk nearly ended in disaster. While exposed to the vacuum of space his spacesuit expanded and he was unable to get back inside his Voshkod capsule. He had to open a valve on his suit to allow the pressure to bleed off and barely made it back inside.

Image credit: NASA



Tragedy and Triumph

The Apollo programme up to that one giant leap

Overview

With the space race in full swing and a swathe of early Soviet milestones the USA was focused on one thing: conquering the Moon.

Gods of Space

Named for the Greek God who rode across the sky in his chariot, Project Apollo was the third human spaceflight programme for the US, with renowned rocket engineer Wernher von Braun at the helm and NASA general manager Abe Silverstein overseeing the whole project.

The programme introduced a rocket family that would become synonamous with the Moon – the Saturn family of rockets. As the Gemini programme wound down the Saturn I rockets flew multiple test flights.

In January 1967, tragedy struck the Apollo program as all three Apollo 1 astronauts, Gus Grissom, Roger Chaffee and Ed White, died during a launch pad test. Crewed Apollo missions were suspended for almost two years whilst the safety of the program was reviewed and design changes to the craft and the space suits were made. During this time further un-crewed flights were made, including the first test flights of the enormous Saturn V rocket.

Image credit: NASA

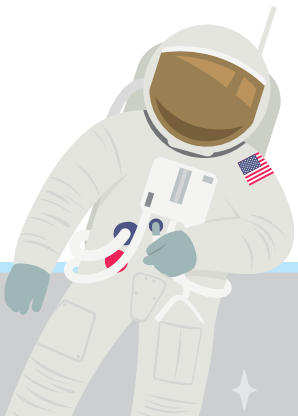
On 11 October 1968, NASA was ready to launch a crewed mission again. Apollo 7 fulfilled Apollo 1's mission of testing the Command and Service Module (CSM) in Low Earth Orbit (LEO).

Apollo 8 astronauts, Frank Borman, James A. Lovell, Jr. and William A. Anders, were the first astronauts to fly in the Saturn V rocket, as well as becoming the first humans to enter lunar orbit on 24 December 1968. The Earthrise was seen for the first time.

1969 was a landmark year for the project. Apollo 9 successfully tested the command, service and lunar modules together. Apollo 10 was a full test run of the Lunar Exploration mission and astronauts Thomas P. Stafford, John W. Young and Eugene A. Cernan did everything but land on the Moon.

And then, on 20 July 1969 history was made – with "one small step for man, one giant leap for mankind."

Following Apollo 11, Apollo 12, 14, 15, 16 and 17 also successfully went to the Moon. In 1972 the final three planned missions were cancelled due to budgetary constraints.



Journey to the Moon

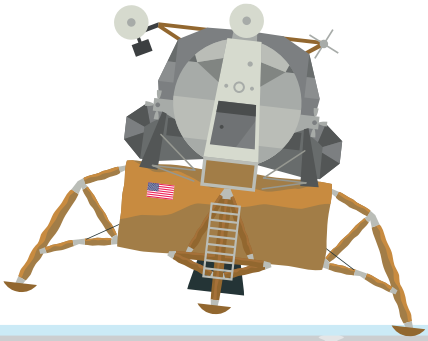
"It's been a real smooth countdown."
(Neil Armstrong around T-55 seconds)

Overview

In the race to become the first nation to put a human on the Moon, NASA began recruiting astronauts for the Apollo program. Project Apollo was the third United States human spaceflight program after Projects Mercury and Gemini. Following a successful trial run with Apollo 10, NASA was now ready to attempt a landing on the Moon.

How far from the Earth is the Moon?

The distance from the Earth to the Moon was first determined by ancient Greek astronomer and mathematician Aristarchus of Samos (c. 270 BC). He calculated that the Moon was 60 Earth radii away (approximately 386,243 km). Since the Apollo program, retro reflectors have been used to accurately calculate that distance, where on average, the Moon sits 384,400 km away from the Earth.



Planning a journey to the Moon

At the beginning of the Apollo program, NASA engineers had to choose the best way to get to the Moon. They decided to use a technique called lunar-orbit rendezvous. One spacecraft would carry the crew to lunar orbit and remain there whilst the other would take two astronauts down to the lunar surface.

The day of launch

Kitted out in their spacesuits, Armstrong, Aldrin and Collins headed to Launch Pad 39A, taking the lift 300ft up to reach the entrance to the command module. After being helped into their seats, the crew still had over two hours until launch to carry out their checks.

It was 16th July and the weather was perfect. At T minus 3 minutes and 10 seconds the fully automated launch sequence was initiated. Between T minus 50 seconds and T minus 10 seconds all power was switched over to internal power sources. Finally, at T minus 8.9 seconds ignition of the first stage engines began and at T minus 0 seconds the 3,000 ton Saturn V rocket blasted off, beginning its journey to the Moon.

Blast-off

Almost a million people had come to Cape Kennedy to watch the crew take off from launch pad 39A, and very quickly their cheers were drowned out by the overpowering sound of the Saturn V lifting off.

Two minutes and 42 seconds into flight and the first stage boosters were jettisoned, causing the rocket to become two thirds lighter. In under 12 minutes, the crew had made it into Earth orbit.

On their journey to the Moon, the crews living quarters were in the command module. The lunar module housed their equipment. It would take them almost 76 hours to reach and enter into lunar orbit.

Apollo Timeline

Apollo 1: The first mission

Gus Grissom, Ed White and Roger Chaffee were selected to fly the first Apollo mission. While rehearsing for their mid-February mission however, a fire broke out in the command module and all three crew members died. Readouts showed temperatures inside the command module reached 1,371 degrees Celsius.

Apollo 8: Journey to the 'dark side'

In December 1968, William Anders, Frank Borman and James Lovell became the first humans to ever leave low earth orbit. This was the first mission launched atop a Saturn V rocket and on Christmas Eve the crew travelled around the Moon, visiting its 'dark side' and witnessing the first Earth-rise seen by humankind. It was Anders who took the iconic photograph of the half-lit Earth above the lunar horizon.

Apollo 10: The dress rehearsal

In May 1969, Eugene Cernan, Thomas Stafford and John Young began their journey to the moon. This mission was a dress rehearsal for Apollo 11, essentially going through the lunar landing without actually landing. The Apollo 10 crew travelled further from Earth than any other human has ever travelled.

Apollo 11: The Eagle has landed

Apollo 11 was NASA's fifth crewed mission to the Moon. It was the first mission to land two humans on the Moon. The mission launched from Kennedy Space Centre on July 16th at 13:32 UTC. It took Neil Armstrong, Edwin 'Buzz' Aldrin and Mike Collins three days to get there and on July 20th, Neil and Buzz climbed into the lunar module to begin their descent to the lunar surface. They landed the 'Eagle' on July 21st at 02:56:15 UTC.

The Apollo program continued to send astronauts to the Moon until 1972.

Image credit: NASA

Google Moon

www.google.co.uk/moon
Like Google Earth - but for the Moon

Overview

Google has teamed up with NASA's Ames Research Centre in Silicon Valley, California, to create Google Moon to allow people across the Earth to explore the Moon. www.google.co.uk/moon

What is it showing?

You can use Google Moon to explore the Moon's surface and to find the six marked Apollo landing sites. Zoom in closer to see each landing site in detail. Click on the individual markers and you will be shown a description of each experiment, piece of equipment and point of interest.

Stories to share

Where did the data come from?

The data to create this has come from the U.S. Geological Survey and their Geologic Atlas of the Moon as well as the Apollo Lunar Surface Journal and the Lunar Chart Series.

What can you see?

You can select your view, choosing from:

1 Apollo: this shows you all the Apollo landing sites, experiments, moonwalks and information.

2 Visible: this shows you the Moon's surface and you can zoom in and out.

3 Elevation: This gives you the topography, with colour-coded height and depth, from about 8 km high to 8 km deep.

The highest point on the Moon is 10,786 metres.

The highest peak on Earth is Mount Everest at 8,848 metres.

The lowest point on the Moon in one of the craters is about 9 km, compared to the lowest point on Earth, the Mariana Trench at about 11 km.

What else can it do?

The newer version of Google Moon can offer:

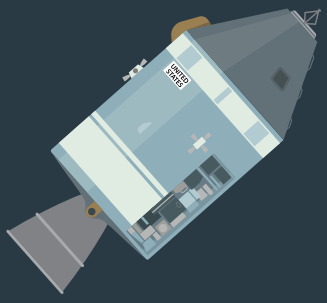
- Tours of lunar landing sites, narrated by Apollo astronauts
- 3D models of rovers and landers
- 360-degree photo panoramas
- Rare TV footage of the Apollo missions

How to run the activity

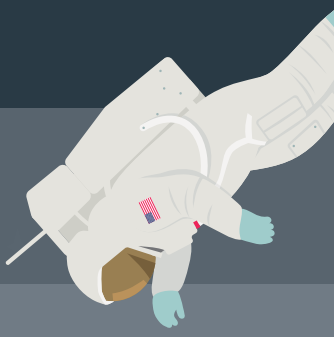
Display Google Moon on computers in your Science Centres and use it in your schools workshops to explore the surface and help students understand the landing sites and current missions.

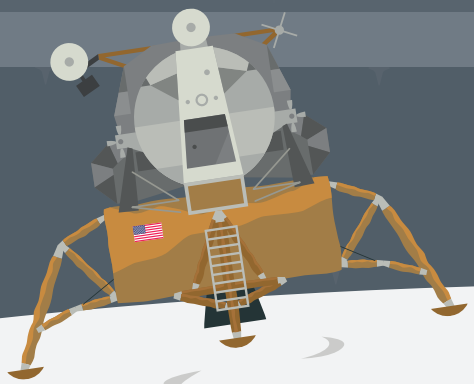
Image credit: Google and NASA

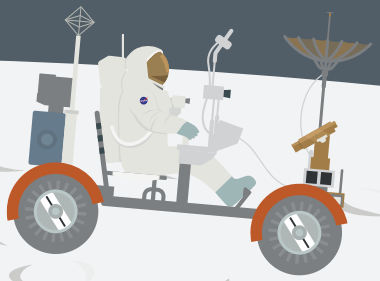
DESTINATION SPACE!

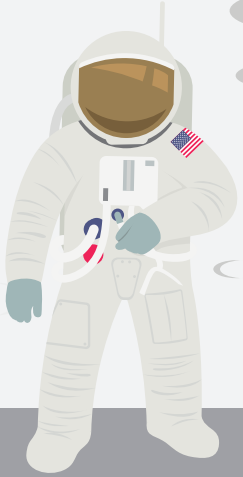


Getting to the Moon









Mighty Saturn V

The rocket that sent humans to the Moon

Overview

The iconic Saturn V was the pinnacle of decades of development by NASA. Here are some key facts about the mighty NASA workhorse.

1. It was huge!

To date, the Saturn V is still the largest rocket ever launched (although the new Space Launch System in development by NASA promises to potentially beat it). Standing at 111 metres tall, it was bigger than Big Ben!

2. It came in three stages

It takes a lot of energy to fight the forces of gravity and air resistance to get a rocket into space. The more mass a rocket has, the more energy you need to achieve this. By making the Saturn V into three separate rocket stages, joined together on launch, each stage could be ejected once it had used up its fuel. This meant that there was now less mass for the next engines to move, saving a huge amount of fuel.

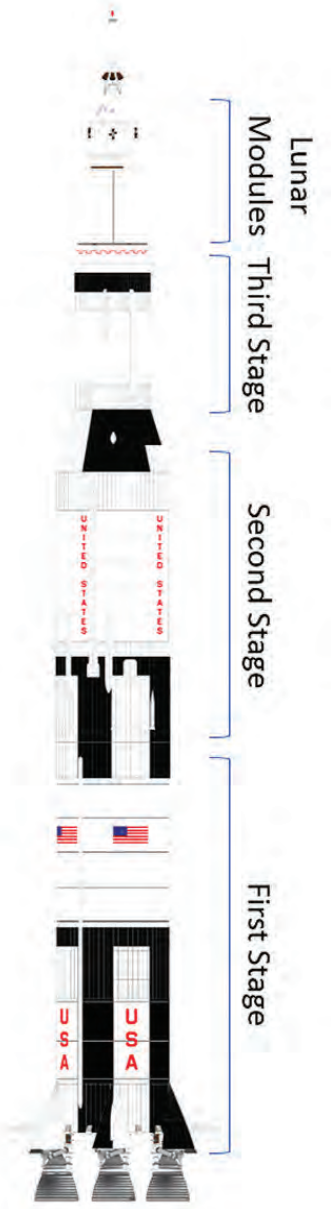
3. It was a heavy beast

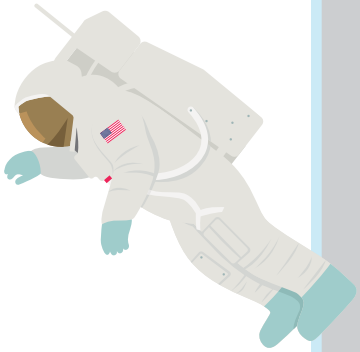
When fully fuelled on the launch pad, the Saturn V had a mass of 2,970,000 kg. The Lunar payload (comprising the Command Module, Service Module and Lunar Module) accounted for less than 2% of this mass!

Image credit: NASA

4. It guzzled fuel

The first stage of the Saturn V was powered by five F-1 rocket engines and consumed 20 tons of fuel per second!

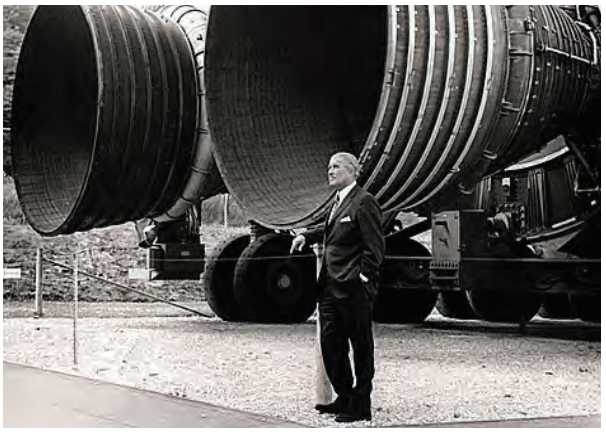




DESTINATION SPACE!

First stage: S-IC

Built by Boeing, the S-IC (S one C) stage comprised of a fuel (kerosene) tank, oxidiser tank (with no oxygen in space you must take your own liquid oxygen) and five enormous F-1 engines. Each engine produced a thrust of up to 7,700,000 Newtons – that is more than forty times the thrust of a modern Boeing 747 in just one engine. After firing for 168 seconds it had accelerated the rocket to an altitude of 68 km and a speed of 2.76 km per second.



Second stage: S-11

Built by North American Aviation, the second stage was powered by liquid hydrogen and liquid oxygen. It had five J-2 engines, each providing a thrust of more than 4 million Newtons and burnt for 367 seconds, taking the payload out of the upper atmosphere. By the time this stage separated, the rocket was now 176 km high and moving at a speed of 6.99 km/s.

Third stage: S-IVB

The final stage of the Saturn V was built by the Douglas Aircraft Company and had a single J-2 engine which fired just twice – once to place it in an Earth orbit, and once to attain translunar injection (to set it on a trajectory to intercept the Moon). Once this trajectory was established, the Apollo modules were released from the special Lunar Module adapter that opened like flower petals.

Interstage adapters

To hold the stages together on launch, and to make sure that stage separation worked well, the stages were joined by interstage adapters. These are the round rings of metal you often see falling away from later stages in iconic photographs.

Did you know?

The Command Module turned around to grab the Lunar module.

To fit in the rocket and preserve the aerodynamics for launch, the command module was initially 'facing the wrong way'. Once on the way to the Moon, the command module separated from the third stage, turned around and docked with the lunar module, removing it from the lunar module adapter.

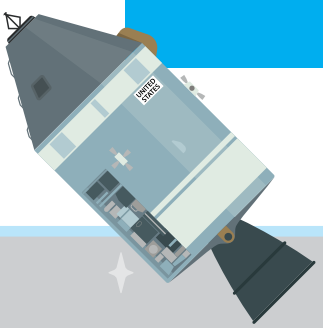


Image credit: NASA

Hidden Heroes

The 400,000 strong backup team

Overview

It took 400,000 people to make those iconic first steps and the missions that followed. From the invention of un-crash-able computers to point perfect mathematics, here are a few of our favourites.

Margaret Hamilton

This is Margaret Hamilton, a self-taught computer programmer who was named the lead software engineer for Project Apollo.

The programming was done by punch cards – long cards with strategically placed holes to encode data. Early programs had to be hand written before being punched into the cards to be fed into the reader. In the image, she stands beside all 5 foot of handwritten codes!

Did you know? Less powerful than a kid's calculator!

The Apollo Guidance Computer (AGC) had approximately 64 kilo bytes of memory and a processing speed of 0.043 Mega Hertz. That makes it less powerful than the most basic calculators commercially available! It allowed astronauts to enter simple commands by typing in pairs of nouns and verbs, to control the spacecraft. They were, however, un-crash-able!

The 'Hidden Figures'

How do you accurately travel a quarter of a million miles to the Moon and make sure you can get into orbit? Or hit a re-entry window that is the equivalent of the thickness of a sheet of paper if the Earth were the size of a basketball? The answer is orbital mathematics and NASA employed an army of talented mathematicians and engineers to

work out, by hand, the exact parameters needed for success.

Amongst these were the 'Hidden Figures' of Katherine Johnson, Dorothy Vaughn and Mary Jackson – now immortalised in book and film.

Houston, we've had a problem

When an oxygen tank exploded aboard Apollo 13 before they even got to the Moon, getting home safe became the primary mission.

Taking refuge in the lunar module to preserve precious resources for re-entry, the three crew members were producing more carbon dioxide than the two-person module was designed to deal with. Somehow, mission control had to come up with a way to attach a square carbon dioxide scrubber from the command module, to a round opening in the lunar modules filtration system using only materials on board. Engineers and astronauts including Ken Mattingly, worked together to create the 'mailbox' solution and ultimately, the crew returned safely back to Earth.

Mission Control

Based at the Johnson Space Centre in Houston, Texas, the Mission Operation Control Room (MOCR) comprised of four 'trenches' of monitors and had 20 console positions that were permanently staffed during a mission.

These positions included:

The Life Systems Officer (surgeon) - monitored heart rate information from the crew and continually asked questions to check on their welfare.

CAPCOM (Capsule Communicator) – generally this was the only role that would communicate directly with the astronauts. It was always filled by fellow astronauts since it was believed that they were more able to understand the situation in the spacecraft and communicate clearly with the crew.

Flight Director – with overall responsibility for the whole mission. This was a high stress role since the Flight Director managed the flight controllers and had to be aware of everything that was happening. One of the best-known Apollo Flight Directors is Gene Kranz (below) who was Flight Director for several missions and famously brought the Apollo 13 crew home.

Did you know?

There was once a mini mutiny!

Get a cold in space and you will be miserable with no gravity to help mucus drain. The crew of Apollo 7, the first Apollo mission to carry humans into space, discovered this when they contracted a cold in space. After a miserable few days testing the Apollo hardware, the crew broke protocol and refused to wear their helmets for re-entry so that they could keep blowing their noses on the way down. This mini mutiny was not without repercussions though – none of the crew ever flew in space again.

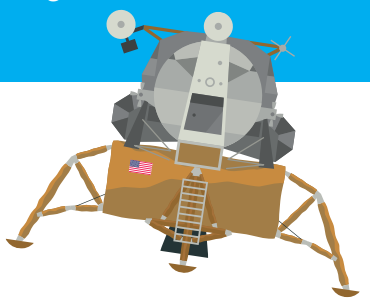


Image credit: NASA

Ethanol Rocket

A speedy mini-rocket

Overview

This mini rocket uses a light-weight plastic water bottle (500 ml) with a nozzle. The bottle has a small amount of ethanol in it, which is vapourised then ignited, and the mini rocket fires off. In this demo we use a piece of guttering as a rocket launching track.

How it works?

The small amount of fuel is vaporised and mixes with the oxygen in the air and is then ignited. The combustion produces carbon dioxide and water vapour and energy in the form of heat. The heat causes the gas inside the bottle to expand, forcing the gas through the rear nozzle at high speed. This propels the rocket along.

How to run the activity

1. Lay the rocket launching track (the guttering) down on a table or the floor, facing away from any people and doors.
2. Add 2 - 4 ml of ethanol to the bottle and screw on the nozzle. Place your finger over the end of the nozzle and shake the bottle vigourously for 30 - 60 seconds to vaporise the ethanol fuel and to mix it with the air and oxygen inside the bottle.
3. Keeping your finger over the end of the nozzle, place the bottle in the rocket launching track and pick up the lighter.
4. Remove your finger from the end of the bottle (there may be a small hiss or spray from the pressure of the vaporised fuel) and quickly bring the open flame to the nozzle. The mixture in the bottle will ignite and your rocket will shoot it down the track.
5. Following launch, the rocket will be warm to the touch but safe to handle. The experiment can be re-run a second time with the addition of more fuel. However, make sure there is enough new air (oxygen) in the bottle.

Slow motion video of reaction

This mini rocket burns quickly and fires fast. To showcase the reaction inside, turn the lights down and film the launch with a high-speed camera on a smartphone and play back in slow-mo.

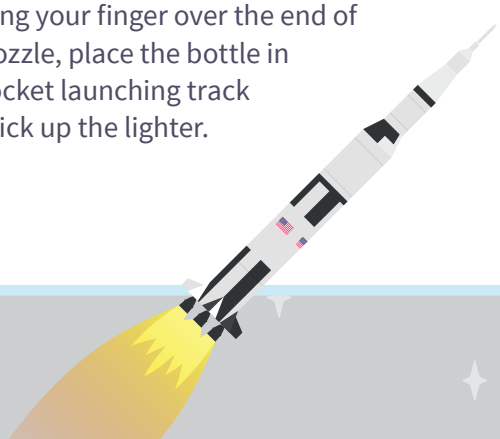
This should capture the reaction occurring within the rocket and the footage can be exported to a presentation to show what is happening. If it is safe to do so, you can ask teachers and other adults to film using their own phones.

Health & Safety

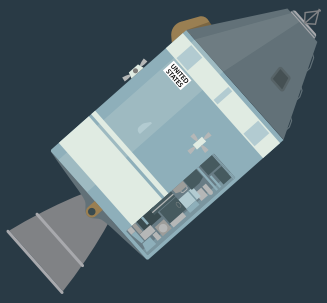
Take care when using, transporting and storing ethanol as it is flammable.

The audience and demonstrators should never sit or stand in front of the bottle.

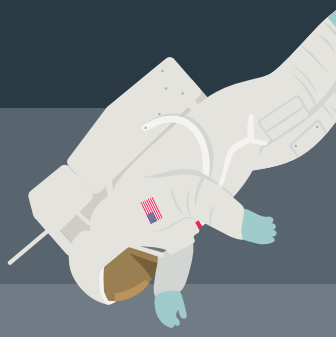
After the demonstrations have been carried out, carefully dispose of any liquid left inside the bottle and leave the lid off to allow the air to refresh inside. Each time, check the bottle for any defects, melted patches, cracks etc.

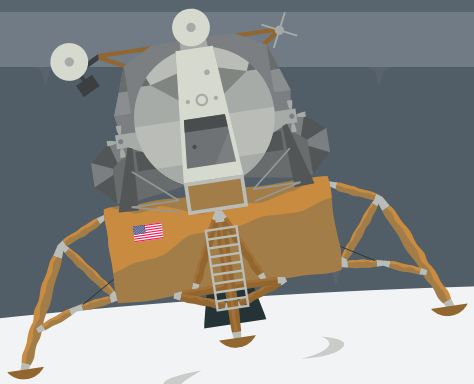


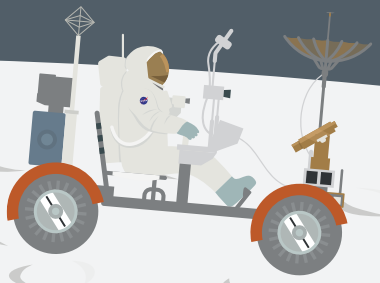
DESTINATION SPACE!

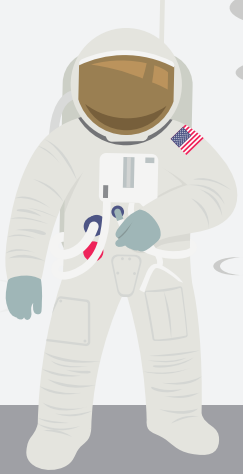


Exploring the Moon







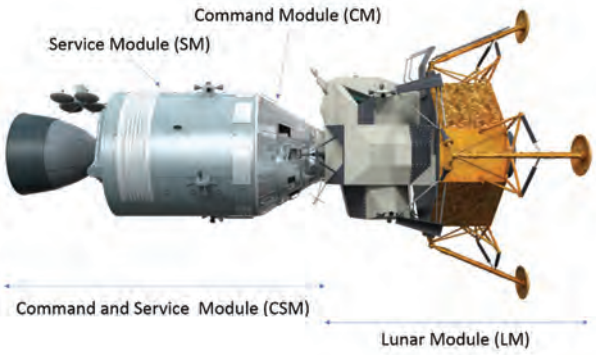


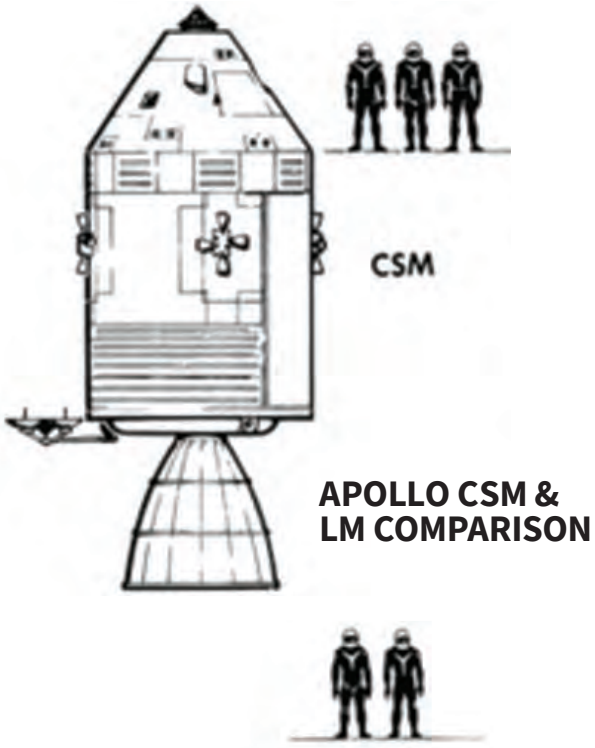
The Apollo Spacecraft

The little craft that could

Overview

The Lunar Module (the space-faring vessel that landed humans on the Moon) is well recognised, but it was just part of a larger spacecraft. In fact, the Apollo spacecraft comprised of two main units – the Command and Service Module (CSM) and the Lunar Module (LM).





APOLLO CSM & LM COMPARISON

Overview:

The Command and Service Module (CSM) carried the astronauts to the Moon, and remained in orbit with one crew member on board while the other two astronauts took the Lunar Module (LM) down to the surface of the Moon.

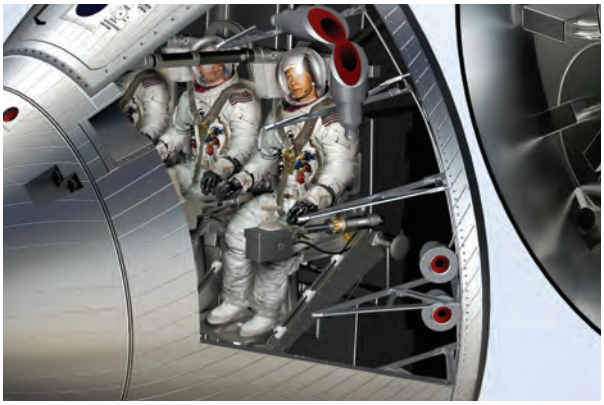
During their three day journey to the Moon, the astronauts stayed in the CSM – and it was pretty cramped as you can see in the adjacent image.

Command and Service Module (CSM)

This module consisted of two parts – the Service Module (SM) and the Command Module (CM).

The SM was an unpressurised cylinder 7.5 metres long which carried the propulsion system, electrical power system (hydrogen fuel cells which turned combined hydrogen and oxygen and generated power from this chemical reaction), fuel tanks and experimental packages for later missions.

The Command Module was the only piece of the spacecraft that would return to the Earth. Covered in an ablative (burns away carrying thermal energy with it) coating, this module was extremely cramped, giving the astronauts just under six cubic metres of space – about the same as the back of a mid-sized van.



When two astronauts departed for the Lunar surface, the Command Module pilot would remain in orbit aboard the Command Module. Here they would photograph the surface of the Moon and conduct their own scientific investigation as well as prepare for the return journey to Earth.

The Lunar Module (LM)

Pronounced 'LEM', the LM carried two astronauts to the surface of the Moon and acted as their accommodation for the duration of their stay. It also had cameras mounted to the outside to video the first steps on the Moon, and on some missions even had a compartment for the Lunar Roving Vehicle (LRV).

The LM was split into two sections, the complete decent stage (with a thruster that was fired to slow down decent and provide a soft landing) and the ascent stage (the upper part of the LM – which was propelled off the surface of the Moon by its thruster following the firing of explosive bolts).

Then, in orbit around the Moon, it rendezvoused with the CM, ready for the journey back home.

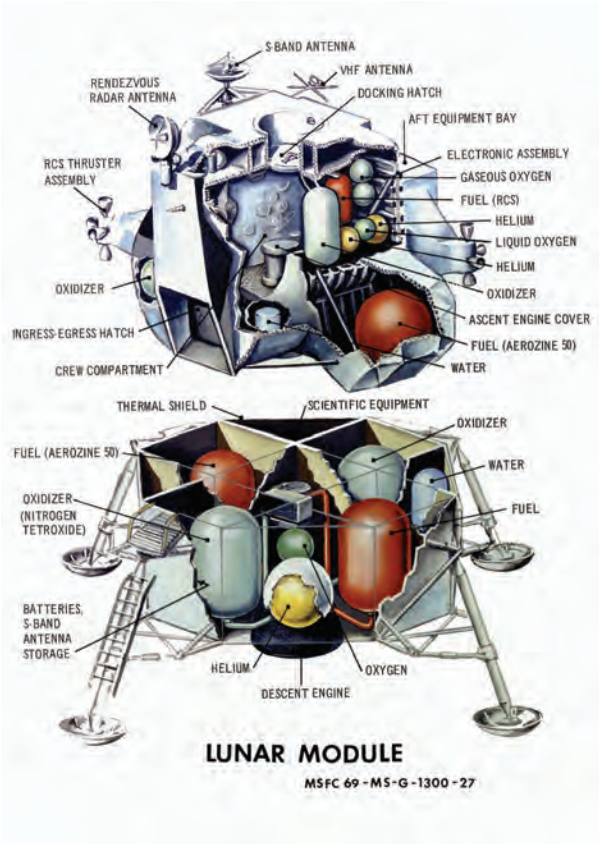
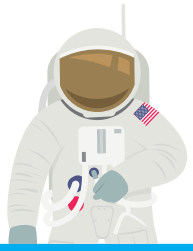


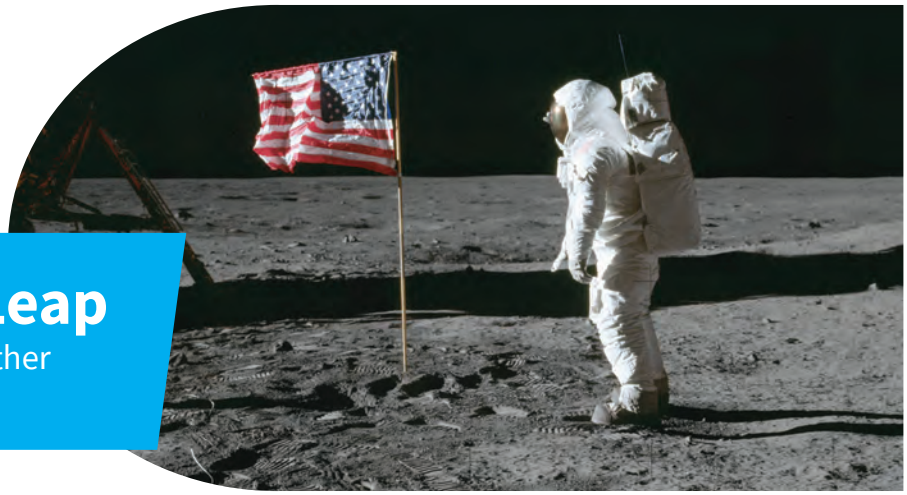
Image credit NASA

Did you know?

NASA is working on a bigger version!

The Orion Multi-Purpose Crew Vehicle is an American-European spacecraft intended to carry a crew of four astronauts to beyond low Earth orbit (currently in development as part of NASA's Space Launch System).





One Giant Leap

The first steps on another celestial object.

On 20 July 1969, Apollo 11 astronauts Neil Armstrong and Buzz Aldrin were the first humans to land on the Moon.

Launch

Apollo 11 launched on 16 July 1969 from Kennedy Space Centre's Launch Complex 39A at 13:32 UTC. In the top of the Saturn V rocket sat the three Apollo 11 astronauts, Michael Collins, Buzz Aldrin and Neil Armstrong. Just twelve minutes after launch the rocket entered Earth's orbit. After one and a half orbits the trajectory towards the Moon was set.

Landing

After three days of travel, the astronauts were able to settle into lunar orbit. Armstrong and Aldrin climbed into their spacesuits and performed several checks inside the lunar module over a few days before setting off on their lunar descent. A hundred hours into their flight, Armstrong and Aldrin did their final preparations, undocking Eagle, the lunar module, from Columbia, the command service module. The Eagle descended to the lunar surface using its engines until Armstrong was required to take manual control to ensure a successful landing in the Sea of Tranquility with only 25 seconds of fuel left. Although this was four miles off the planned landing site, it was a successful and historic landing.

Image credit: NASA

"Houston, Tranquility Base here. The Eagle has landed." – Neil Armstrong

First steps

Although, Armstrong and Aldrin were scheduled to sleep after landing, they decided to prepare for their EVA (extra vehicular activity) instead. Six hours later, Armstrong stepped onto the Moon's surface declaring:

"That's one small step for [a] man, one giant leap for mankind"

Aldrin joined him 20 minutes later. During this EVA, Aldrin deployed the Early Apollo Scientific Experiments Package and gathered over 20kg of surface samples to bring back to Earth.

Overall, Armstrong and Aldrin spent a total of 2 hours and 36 minutes on the surface of the Moon before firing the engines to join Michael Collins in Columbia in orbit around the Moon.

The Apollo 11 Moon landing was the grand finale of the Space Race but the start of humankind's exploration of space.

Did you know?

The first meal eaten on the Moon consisted of bacon squares, peaches, sugar cookie cubes, pineapple grapefruit drink and coffee.

Moon Footprint

Buzz Aldrin's iconic photo of his footprint on the Moon

Overview

This specially printed mat allows children to see how their foot measures up, and to ask questions about the Moon's surface.

What is it showing?

On July 20, 1969, Neil Armstrong took humankind's first step on the Moon. However, this photograph was taken by the second person to step on the Moon, Buzz Aldrin.

The printed Moon footprint, allows families to compare their foot and start conversations about what it felt like to be walking on the Moon and what the surface of the Moon is like.

Buzz Aldrin photographed this footprint in the lunar soil as part of an experiment to study the nature of lunar dust and the effects of pressure on the surface. The dust was found to compact easily under the weight of the astronauts leaving a shallow but clear impression of the boots, characteristic of a very fine, dry material.

Can you still see the first footprints?

Yes, the footprints of Neil Armstrong and Buzz Aldrin are still there and should remain so for thousands of years as there is no wind or weather to blow them away.

Image credit: NASA

In 2011, closeup shots from NASA taken by a lunar orbiter 15 miles above the surface showed footprint and rover tracks on the Moon's surfaces from Apollo landings 1969 - 1972.

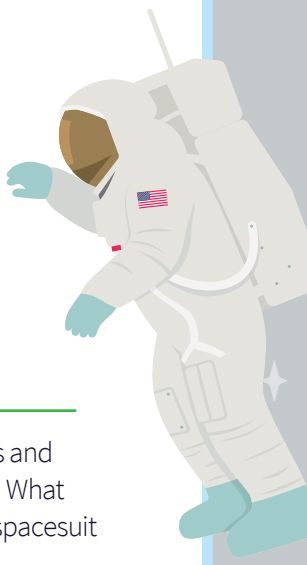
How soft is the Moon's surface?

When the first astronauts landed in 1969, they didn't know how solid the surface would be, and how deep the lander would sink.

It turned out to be solid enough, and the two astronauts spent 2½ hours walking on the Moon. Overall, their lander was on the surface for 21 hours, 36 minutes which allowed them to get seven hours of sleep.

Where are the boots now?

The astronaut's spacesuits are at the Smithsonian's National Air and Space Museum in Washington. However the over-boots that made this print were left on the Moon.



How to run the activity

Use the mat to stimulate conversations and to prompt questions. Whose footprint? What is the surface made of? Where are the spacesuit boots now?

The Smell of the Moon

Experience the distinctive smell of the Moon

Overview

The Moon is somewhere most of us would like to visit if we could. To give us a sense of what it's like this aroma matches what Neil and Buzz described the Moon smelling of.

What is it showing?

Neil Armstrong and Buzz Aldrin walked on the Moon in July 1969. Once they returned to Earth, they did their best to describe the experience to everyone else. One element highlighted by Buzz Aldrin was the distinctive smell of gunpowder on the Extra-Vehicular Activity suits used on the surface of the Moon.

Why is this important?

The smell of the Moon is an interesting experience as it's not one the crew of Neil and Buzz would have experienced during their space walk activities. However, upon returning to the capsule after their mission they noted a distinctive aroma. This activity is to give people a sense of that smell to help them imagine what it may have been like to go on that incredible mission.

How to run the activity

To run the activity using the smell of the Moon kit you will need the box of aroma and a well-ventilated area. Give the audience some context around the mission to the Moon explaining how Neil and Buzz could only smell this aroma once they were back in the Lunar Module. During their spacewalks the isolated environment of the suit and helmet separated them from it. Once they got back inside and took off their helmets, they could experience the smell coming from the outside of their space suits. You can then invite audiences to smell from the box of aroma. The aroma is provided from a sponge soaked in an aromatic oil within the box. The sponge will need to be recharged with fresh oil after 1-2 months of use.

Image credit: NASA and ASDC

Roaming the Moon

The Apollo 15 Landing Site

Overview

This custom-printed mat features a high-resolution image of the Apollo 15 landing site featuring the tracks and imprints of the mission vehicles and equipment.

What is it showing?

This image is taken from 25 km above the lunar surface. It shows an area smaller than 1 square kilometre, allowing us to see the tracks left by astronauts walking and driving the Lunar Roving Vehicle (LRV). In the centre of the image you can see the main landing site with the Lunar Module descent stage. Buggy tracks lead from here to the various sites the astronauts visited, and you can see the Lunar Roving Vehicle (LRV) parked and abandoned, just over 100 m to the East of the Lunar Module.

To the West of the descent module, the tracks lead to ALSEP (Apollo Lunar Surface Experiments Package), a collection of scientific instruments set up by the astronauts in each Apollo mission that landed on the Moon. This sent back data about the solar wind, seismic activity, fluctuations in magnetic field and ionisation of gases near the lunar surface for over five years after the astronauts left the site.

Image credit: NASA

Why is this important?

Apollo 15 was the first mission to land on the Moon with a specially designed LRV. This allowed the astronauts to travel much farther from the landing site than previous missions. You can see on the mat that the tracks of the LRV lead to various other locations beyond the image on the mat. Dave Scott, Mission Commander, and Jim Irwin, Lunar Module Pilot, were able to sample mare deposits, search for ancient crustal rock and explore a lunar rille (long, narrow channel), for the first time. The battery-powered Apollo 15 LRV travelled a total of 27.76 km at a top speed of about 13 km/h.

There is a small amount of erosion on the Moon due to solar wind and micrometeorites. But with no atmosphere, no active volcanoes and no surface running water, these tracks will remain, unless disturbed by future visitors, for millions of years.

How to run the activity

One way of using this activity is to use the scale and information provided to ask audiences what they would have visited, given the time and distance constraints. Is there anything interesting you would explore? Where would you take samples from if you were on this exciting mission?

Working on the Moon

Lunar science and the difficulties the astronauts faced

Overview

Wearing a set of inflatable splints, visitors use the picker to simulate the difficulties of working on the Moon.

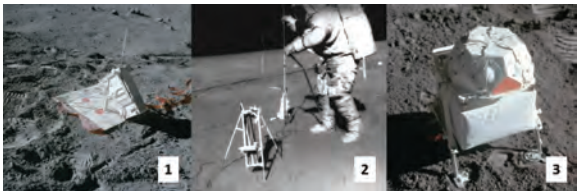
What does it show?

Each Apollo crew spent between one and three days on the Moon. During this time, their main tasks were to photograph the surface and conduct a series of science experiments. However, trapped within their bulky, restrictive space suits, this was extremely difficult and took a massive physical toll on the astronauts.

To demonstrate how difficult this was, visitors compete, one wearing a set of inflatable splints simulating a space suit, to pick up the most Moon rocks in a set time

Stories to share

Following on from the simple experiments left by Apollo 11, each subsequent mission placed and conducted a set of experiments on the Moon called ALSEPs (Apollo Lunar Surface Experiment Package). Some of the highlights included:



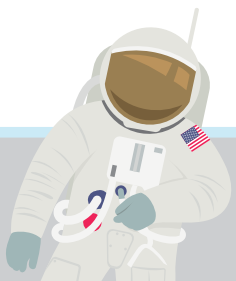
More information on the science experiments and a great video of astronauts falling over while working can be found on www.Moon50.uk and www.DestinationSpace.uk

1. The Active Seismic Experiment (ASE)

Used during Apollo 14 and 16, this package allowed the internal structure of the Moon to be determined to several hundred feet underground. A set of three geophones (devices that convert ground vibrations into electronic signals that can be analysed) were laid out in a line. During both missions, astronauts used a Thumper (impactor) to detonate one of 22 small charges. During Apollo 16, a mortar fired a set of four explosives up to 900 metres away. The vibrations produced as a result allowed scientists to understand the density, composition and structure of the surface of the Moon.

2. The Heat Flow Experiment (HFE)

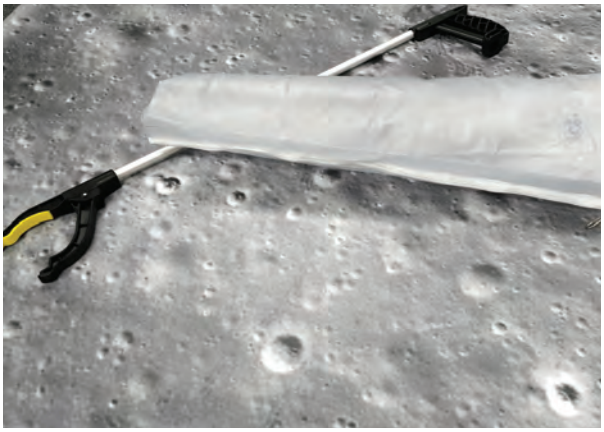
Used during Apollo 15 and 17 (a connection broke during Apollo 16) this experiment involved drilling two holes to a depth of 1.6 – 2.3 metres. The temperature was measured at several depths



and from this the heat flow from the centre of the Moon estimated. The value was, as expected, extremely small.

3. The Solar Wind Spectrometer (SWS)

Deployed during Apollo 12 and 15, this device measured the composition of the solar wind.



How to run the activity:

1. Explain to visitors that as well as deploying experiments on the Moon, astronauts needed to take soil and rock samples to return to Earth for analysis. Ask them why they think this was a difficult task and discuss some of the problems that working in a space suit posed: difficult to move around, easy to lose your balance, and a bulky suit inflated with air.
2. Show the litter picker and explain that since it was so hard to bend in the suits, astronauts used a device much like this to help them pick up samples. Demonstrate how to operate it by scattering your 'Moon rocks' (balls of rolled up paper work well for this) and picking one up.
3. Get a member of the audience to come up and hand them the picker and a bag or bucket (they may stand this on the ground if they prefer). Challenge them to stand on the spot and pick up as many 'Moon rocks' as they can in 30 seconds and deposit them into the bag or bucket. Count up how many they managed.
4. Now, using the same volunteer, or choosing another from the audience, place the inflatable splints on their arms and legs (if you wish to for time saving purposes you can just do the arm). Carefully inflate the splints using the balloon pump until movement is restricted, but the volunteer is still comfortable. Ask them how it feels to move in the splints and explain that just like the Apollo astronauts, the bulk makes it much harder to move.
5. Get them to repeat the previous activity and compare this result to the last one. Ask the volunteer how they found the task and whether they are feeling tired.

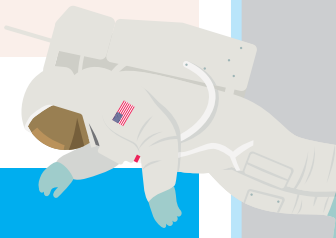
Image credit could run along here in 9pt font size

Equipment needed

- Set of inflatable splints with inflating tube
- Balloon pump
- Litter picker
- Bag or bucket
- Rolled up paper / fake Moon rocks

Health & Safety

Do not overinflate the splints as this could in theory restrict blood flow. Aim to get the splints inflated so that there is still give in them when you squeeze them and ask the volunteer to tell you if they are becoming uncomfortable.



Did you know?

Only one scientist went to the Moon!

The final Moon mission, Apollo 17, included Dr Harrison Schmitt, a geologist. His knowledge and field work experience meant that he was able to spot and take samples of interesting Lunar rocks that other astronauts might miss. When the astronauts climbed back into the LEM, they were covered in extremely fine regolith – a talcum powder-like material that got everywhere!

The Moon in VR

Take a virtual joyride in a lunar buggy

Overview

Apollo 15 VR is a free virtual reality experience available on android smartphones that allows users (with the use of Google Cardboard or a VR headset) to follow in the footsteps of the Apollo 15 crew.

You will need

Download Apollo 15 VR onto your Android phone, you will also need a VR headset (available on-line for £15). Alternatively, you may wish to provide the cardboard headsets and encourage visitors to use their own phones - or perhaps sell them in your shops as a suggested activity.

How to navigate in VR

In order to select what you want to look at, where you want to go, and any activities that you want to do on the Moon, there is a dot in the centre of your field of vision. This acts as a pointer.

As you move around the moon in VR, you are looking for circles with an eye, footprint or other icon next to them. These indicate that there is something interesting to do here.

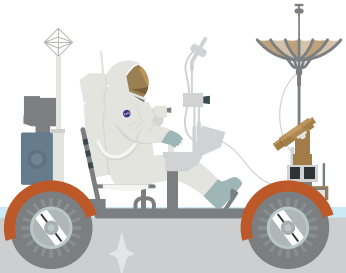
Select the icon by moving your head so that the dot is centred on the icon for a few seconds.

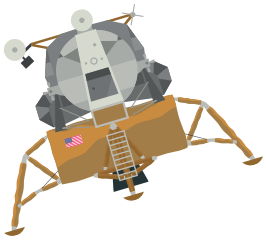
Image credit: Screen grab from Apollo 15 VR

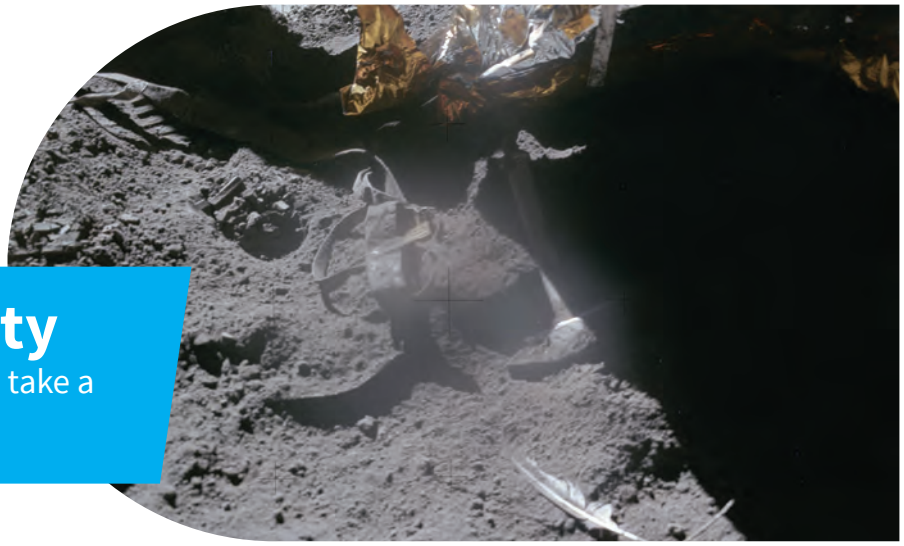
What can you do?

Once you have opened the App, you will be inside the Apollo 15 Lunar Module as it descends towards the Moon. Upon landing, you can exit the Lunar Module and take a bit of a walk around the landing site using the navigation method mentioned before.

You can also go back to the Lunar Module and select the Lunar Roving Vehicle (the moon buggy). Doing this will cause it to un-stow from the Lunar Module, and by aiming your pointer at the accelerator lever, you can go for a joyride on the Moon!







Lunar Gravity

Feeling heavy? Time to take a trip to the Moon…

Overview

Gravity is the force that occurs when massive objects like planets and moons have a strong pull on other objects. We see the effect the moon's gravitational pull has on Earth through the variation in oceans tide levels. But how strong is the Moon's gravity when you're walking on its surface?

Is there gravity on the Moon?

The Moon is much smaller than Earth, and as a result of its size the gravity felt on the Moon is much less, about 16.6% or one sixth of what you would feel on Earth. This means that if you weighed 66 kg on Earth, you would weigh just 11 kg on the moon.

The hammer and feather experiment

Communications were very different back in July 1969. On a moon walk during the Apollo 15 mission, David Scott performed an experiment that was streamed live on television. In one hand he held an aluminium hammer weighing 1.32 kg, in the other a 30 g falcon feather. He dropped both items at the same time and, as predicted by Galileo in 1589, both items hit the ground simultaneously. This proved the theory that objects released together will always fall at the same rate, regardless of how heavy they are.

Image credit NASA

Activity: Packing for the Moon

To demonstrate the difference between the Earth's gravity and the Moon's gravity you could run this activity as part of a family show at your centre:

1. Take two small and identical suitcases that can easily be lifted by any member of the public.
2. Keep one suitcase empty and set this offstage, out of sight of the audience.
3. Bring a volunteer from the audience on stage to help you pack some essential items for a journey to the Moon.

   For this you could include a mix of items such as bottles of water, packets of food, medicine, spacecraft manuals, maps of the lunar surface, tools and some optional home comforts teddy bears, photographs, a Sony Walkman, etc. (The heavier the items the better).
4. Help the volunteer pack the suitcase with items they and the audience think should be taken to the M oon.
5. Once the suitcase is packed, demonstrate how heavy it is before moving it offstage to switch with the empty one.
6. Next, you've landed on the Moon. Call up another volunteer to help with the suitcase. They will be surprised when the suitcase seems weightless!

Thus demonstrating how the same item can feel much lighter on the Moon than on Earth due of its lower gravitational pull.The videos can be found on www.Moon50.uk.

What we left behind

What humans have left on the Moon

Overview

Many of the spacecrafts that have landed on the moon, as well as the astronaut's moon buggies, experiments and rubbish are still up there. To lighten the spacecrafts on the way home, and make room for moon rocks, much has been left behind. This includes the descent stage of the Apollo 11 'Eagle'.

Stories to tell

There have been a host of missions to the moon. Twelve astronauts have walked on the moon in six Apollo missions from 1969 – 1972.

There have also been numerous robotic spacecrafts (without people) that have landed or been intentionally crash-landed on the moon. These include the first human-made object to reach the surface of the moon, the Russian Luna 2 in 1959, and the most recent, the Chinese Chang'e 4 which landed on the far-side of the moon in 2019.

How many spacecrafts have we left on the moon?

About 70! Some landed softly and safely and gathered data before ceasing their missions, others were part of the Apollo astronaut missions, for example the descent stages that were no longer needed, or the ascent stages or Saturn booster rockets that were intentionally crashed once they had served their purpose.

What else is up there?

- About 70 Space crafts (or parts thereof)
- 3 Moon buggies
- 12 pairs of boots
- A small silicon disc bearing a goodwill message from 73 world leaders micro-etched on its surface, left on the moon by Apollo 11 astronauts
- American flags
- TV cameras and fittings
- Various shovels and rakes
- Empty space food bags
- Bags of urine and faeces
- Sick bags and wet wipes
- Personal hygiene kits
- Nail clippers
- A feather and a hammer
- A host of experiments
- A mission patch from Apollo 1 in memory of the 3 American astronauts who died on the launch pad
- Cosmonaut medals in memory of 2 Russian cosmonauts
- A gold olive branch

Where do I find the full list?

There are over 700 items, largely from the Apollo missions, but also spacecraft from the ESA, Japanese, Indian, Chinese and Soviet missions. The full itemised list is on the NASA website, search for 'NASA Catalogue of Manmade Material on the Moon'. Together they weigh over 180,000kg (on earth). Perhaps it will be re-used one day by people exploring the moon.

Image credit: NASA/Harrison Schmitt, Apollo 17 1972

Lasers at the Moon

Retroreflectors: The Apollo era kit still in use today

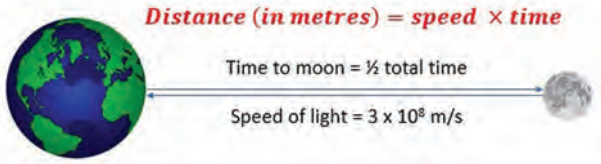
Overview

While each Lunar landing had its own scientific objectives, the Lunar Laser Ranging Experiment is still in use today.

What was it?

The Lunar Laser Ranging Experiment is an ongoing scientific program that involves firing intense laser pulses at the surface of the Moon to monitor its distance from Earth.

By measuring the time taken for light (which has a finite speed of 300 million m/s) to get to the Moon and back, the total distance can be calculated.

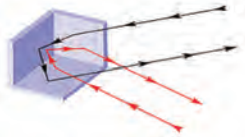


Apollo 11, 14 and 15 extended and improved this research by providing retroreflectors on the surface of the Moon –providing irrevocable proof of humanity's visits on the Moon. These retroreflectors can even be seen in high resolution imagery taken by orbiting spacecraft.

Image credit: NASA or ASDC

Stories to tell

The retroreflectors are like giant cat's eyes (like those used on roads) or bike reflectors. They were made up of 300 individually mounted 'optical corners' – extremely shiny squares that ensure light is reflected back along the path it entered.



The placement of the reflectors was also important as they had to be angled to make sure lasers from the Earth would be able to hit them.

Thanks to these we now know that the Moon is crawling away from the Earth at a rate of 4cm a year – the result of Earth's tidal bulge pulling on the Moon and speeding it up!

Demo idea

While no kit is provided for this, you could use bike reflectors and a strong torch to give the idea of the principles of this experiment.

Did you know?

Laser light will spread out from the source, causing its intensity to drop as it gets further from the Earth. By the time it hits the Moon, the beam spreads out over a 6.5km wide circle!

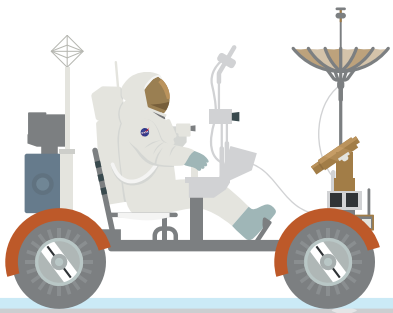
Misson Patch Badges

Overview

Mission patches go down in history as a representation of the astronauts and their missions. The Apollo astronauts themselves were set the task of designing their own mission patch. Each Apollo mission patch is steeped in symbolism, from the Eagle holding the olive branch representing a peaceful landing, to the three horses representing Apollo riding through space to the Moon.

Apollo 11

The Apollo 11 mission patch, designed by Michael Collins, Neil Armstrong and Buzz Aldrin, shows an eagle about to land holding an olive branch in its talons. It represents a peaceful landing by the United States.



Apollo 12

In the Apollo 12 mission patch, the Navy colours, gold and blue, are prominent as all three Apollo 12 crew members were Navy Commanders.

Apollo 13

The Apollo 13 mission patch was inspired by the ideas of the crew members but ultimately designed by artist Lumen Winter. It symbolizes the Greek God Apollo in the form of three horses riding across the sky towards the Moon.

Apollo 14

The Apollo 14 mission patch shows an astronaut pin, the Earth and the Moon. The silver astronaut pin is given to those who are accepted into the astronaut corps. A gold astronaut pin is given after their first spaceflight.

Apollo 15

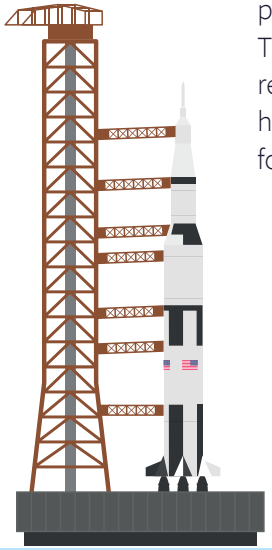
The Apollo 15 mission patch badge was inspired by ideas from the crew, but like the Apollo 13 patch, was then designed by an artist/designer, Emilio Pucci. The mission patch features three birds, each representing the three crew members working together to have a successful mission.

Apollo 16

The Apollo 16 mission patch features an eagle sitting upon a red, white, and blue American shield, reflecting the theme of patriotism. The theme, as chosen by the Apollo 16 crew, was embedded into the mission patch design by NASA graphic artist, Barbara Matelski.

Apollo 17

The Apollo 17 mission patch was designed by artist, Robert McCall. As the final Apollo mission, the mission patch conveys the message of future promise in space exploration. The Apollo and eagle imagery represent a nation and the human civilization looking forward to the future.



Equipment needed

- Badge maker
- Template
- Plastic covers
- Metal front
- Metal back (with pin)
- Scissors/cutting guide

How to make your own mission patch badge:

1 Cut out your template so it fits to the badge maker

2 Get creative with your mission patch!

3 Place a metal front into the badge maker

4 Place the designed mission patch on top of the metal front

5 Cover with a plastic cover

6 Swivel this section of the badge maker so it is sitting underneath the badge press

7 You should now have an empty badge slot in front of you

8 Place the metal back (with pin) into this slot so the pin is facing downwards. You should see a zigzag facing you.

9 Press the handle down so that it presses onto your badge design.

10 Swivel the badge slot so that your metal back can now be pressed.

11 Press the handle down

12 Your badge should be complete!

Image credits for mission patches: NASA

The Journey Home

It's going to be a bumpy ride

Overview

After spending 22 hours on the moon, Neil and Buzz prepared the lunar module for launch. Now they just needed to rendezvous with Mike and descend back down to Earth.

Launching from the moon

On July 21st 1969, Armstrong and Aldrin began their journey to lunar orbit. Neither had slept much and they now had to fly the top half of the lunar module to reach Collins, who had been waiting for them in the command module Columbia.

At 18:54 BST, they left the lunar module descent stage behind at Tranquillity Base and began their lunar-orbit rendezvous. This meant docking the Eagle with Columbia whilst orbiting the moon: a tricky task, especially since rendezvous would take place on the side of the moon that communications with mission control couldn't reach.

Docking with Columbia

Reaching a vertical speed of around 50 miles per hour the Eagle sped towards Columbia, docking at 22:35 BST. This didn't go as smoothly as planned and the spacecraft started to spin. However, Armstrong and Collins quickly brought the situation under control.

Image credit: NASA

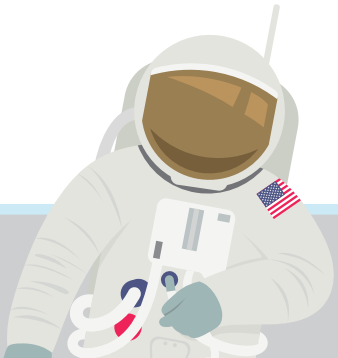
The three crew were reunited and now that they were back in the command module they had no use for the lunar module so they separated it, ahead of schedule.

The crew sat down for a meal before firing their main engine to escape the Moon's gravitational pull. By now, Columbia had made 31 orbits of the moon and it had roughly 236,642 miles left to travel until it was home.

The crew slept while mission control took over, and on July 24th 1969 the command module entered the Earth's atmosphere at a velocity of 25,000 miles per hour. Columbia's heat shield rose in temperature and when it hit 2760°C it caused radio transmissions to stop for almost four minutes.

Splashdown

At 17:44 BST Columbia's main parachutes deployed, and the crew landed in the mid-pacific six minutes later. President Nixon was on the recovery ship, 15 miles from where the crew landed, to welcome them home. They were quarantined, putting on isolation suits before they emerged from the hatch, to make sure they didn't bring back any contaminants.



Moon Memories

Newspapers, TV and personal memories

Overview

On July 20 – 21 1969, over 500 million people around the world watched the TV broadcast as Neil Armstrong took humanity's first step on the Moon.

What is it showing?

The Moonwalk was broadcast on TV and reported in local and national papers around the world. Neil Armstrong stepped onto the Moon in what was the middle of the night in the UK (3:56 am on the night of 20th - 21st July) and 10:56 pm on the 20th in America. They had landed on the Moon several hours earlier at 9.18pm BST.

This copy of an original newspaper shows how it was reported, along with all the social history and other stories of the day.

Why is this important?

Communications were very different back in July 1969. BBC1 and ITV were broadcast only in black and white, TVs were expensive and many families in the UK rented their sets.

Yet, humans had managed to get to the Moon, and broadcast the images to the earth!

In the UK they were relayed to BBC London via Goonhilly Satellite Earth Station in Cornwall.

Many parents woke their children in the middle of the night to see it live. If they didn't have a TV, children were carried down the street in their pyjamas to a neighbour's house to watch it. It was also the very first overnight British TV broadcast.

The first images were grainy and hard to make sense of, especially for younger children. However, most people heard Neil Armstrong's famous words "That's one small step for man, one giant leap for mankind".

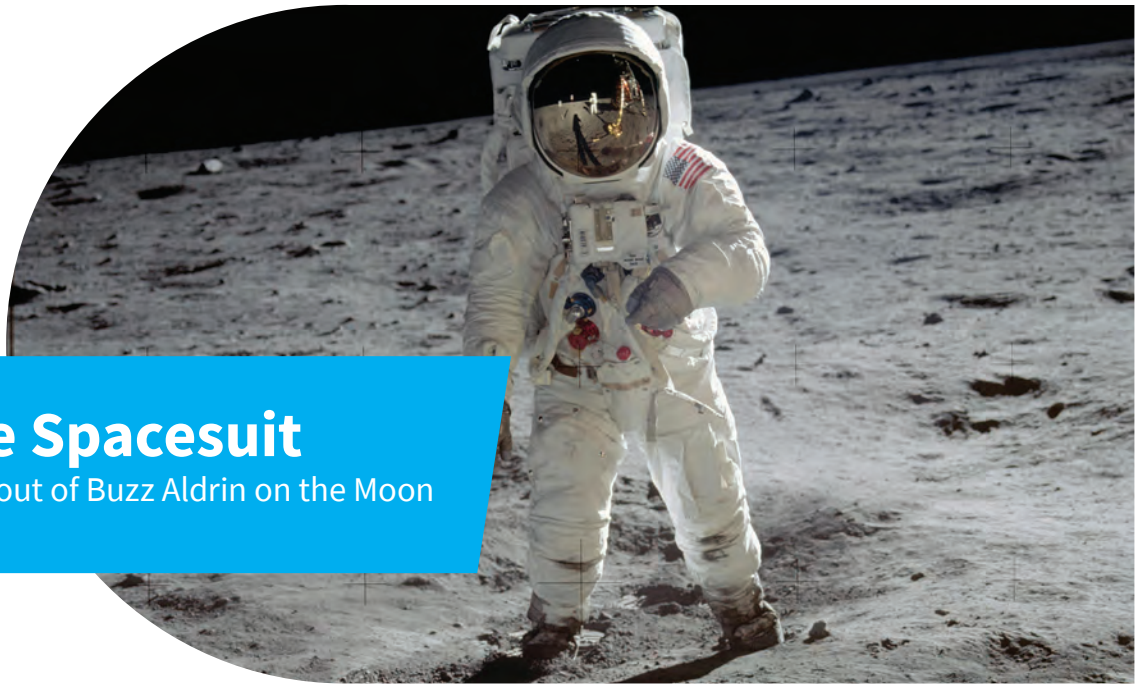
Neil Armstrong himself maintained he had infact said "That's one small step for a man, one giant leap for mankind".

Newspaper and Memories Board

Use the newspaper to stimulate discussions, especially intergenerational conversations. Many people over the age of 53 will remember the Moon landing. Ask for their personal stories and consider putting up a 'Memories Board' in your centre where people can write and share what they remember. You could also try to get hold of your local paper for this date.

You can watch the original video of the moon landing on the NASA website, simply google 'NASA Apollo 11 video'. The videos can also be found on www.Moon50.uk.

Image credit: NASA Broadcast TV image



The Spacesuit

A cut-out of Buzz Aldrin on the Moon

Overview

This iconic photo is of Buzz Aldrin on the Moon. Your kit contains a life-size cut-out of Buzz wearing the Apollo spacesuit of 1969.

What is it showing?

Neil Armstrong had the privilege of being the first human on the Moon. However, because he had the camera, many of the iconic images like this one are of Buzz Aldrin. Meanwhile Michael Collins was up in the command module orbiting the Moon to enable their safe return.

Stories to tell

The earlier NASA spacesuits were silver and astronauts looked rather like a child's idea of a spaceman. These were for use inside a spacecraft and were re-designed in the wake of the Apollo 1 tragedy, where a fire killed three astronauts on the launchpad.

A key component of the Apollo programme was the development of a new type of fire-retardent spacesuit to be worn by astronauts during launch and re-entry as well as on the Moon's surface. The suits needed to provide protection from the vacuum of space and the extreme temperatures outside the spacecraft. They also needed to be flexible enough to allow adequate mobility, especially whilst walking on the Moon. The suits have many layers, including a water-cooled undergarment.

Image credit: NASA

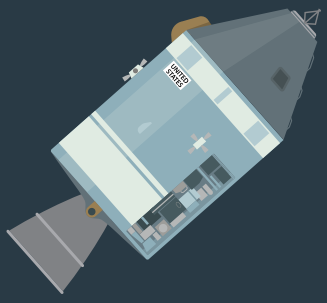
How do these compare to the Sokul suits?

The modern Sokul suits are not for use outside a spacecraft, except in an emergency. They are pressure suits, worn by astronauts like Tim Peake, during the journey to and from space.

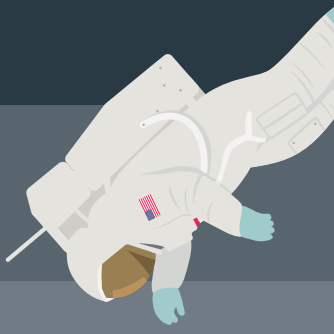
How to run the activity

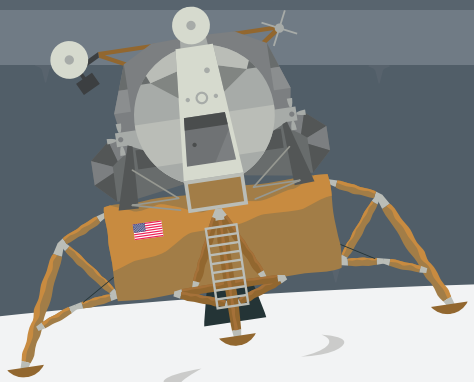
The life-size cut-out (Buzz was 5'8") is a low-cost way to bring the Moon landing alive. They are great for selfies, and for showing more detail of the suit. You can adapt them to be more rigid by adding a wooden structure, or even cut out the helmet and insert a see-through acrylic bowl so people can put their face through for photos.

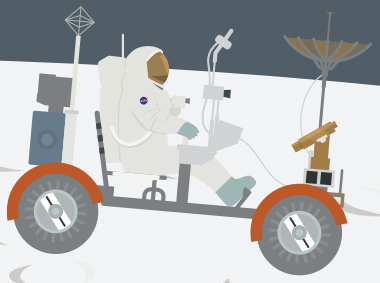
DESTINATION SPACE!

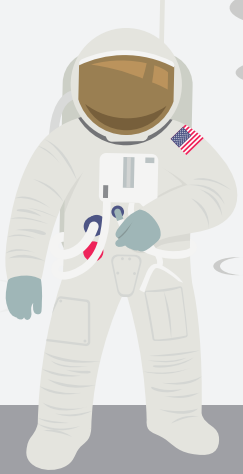


The Future









Why haven't we been back?

Overview

The Apollo Moon landings are arguably one of humanity's greatest achievements. But since Apollo 17 returned in 1972, no other humans have even orbited the Moon. So why haven't we been back?

Changing Ambitions

The end of the Second World War, and the continued threat of war between global superpowers, set the stage for countries to establish their place within the global community. The USA and USSR led the competition to be the most dominant nation on Earth and space was one of the areas they competed in to show their technical prowess and political power. This period is referred to as the 'Space Race'. This rivalry ensured enormous support within each country for their own space programmes. When the USSR pulled ahead, launching the first ever animal and then the first ever human into space, the US administration vastly increased NASA's budgets, making them the highest they have ever been as a percentage of US spending. The desire to beat the USSR to the Moon pushed NASA to deliver something truly incredible.

The touch down of Apollo 11 on the lunar surface was seen as the end of the Space Race, and subsequently the rivalry broke down and created opportunities for the USA and USSR to become a little more collaborative in space, beginning with the first docking in space of an American Apollo capsule with a Soviet Soyuz craft in 1975. Without the drive of competition for supremacy, budgets were reduced to allocate money elsewhere, and national objectives for space changed. It is often said that the biggest reasons humans have not returned to the lunar surface are budgetary and political, rather than scientific or technical challenges.

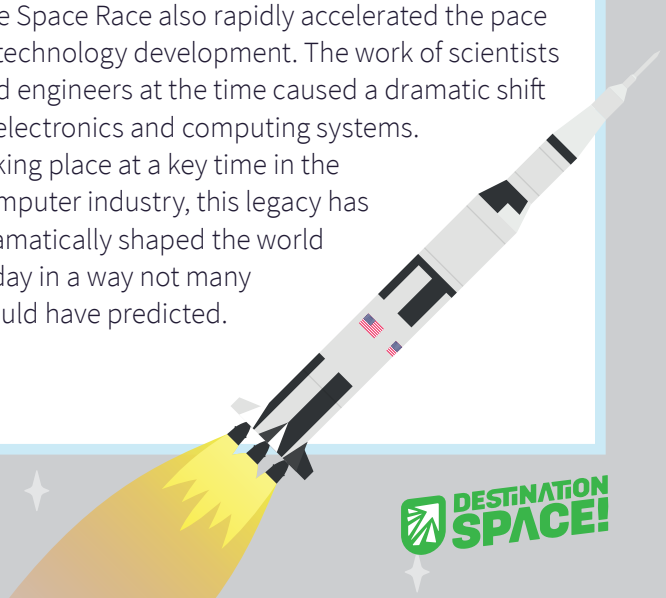
Image credit NASA

Changing Goals

Humanity's exploration of space has continued to develop. Research has been carried out and milestones achieved, but the focus of crewed missions has changed. Many organisations across the globe began to recognise the huge value of utilising space for satellite technology. Organisations such as NASA worked on how to reduce the cost of access to space to take advantage of these new opportunities.

NASA developed a low-cost reusable spacecraft called the Space Shuttle, which fulfilled many roles including deploying satellites as well as taking astronauts into space to work on short missions and even to build space stations. The increased launch costs coupled with lower budgets encouraged a focus on getting the most out of the shuttle and low Earth orbit operations.

The Space Race also rapidly accelerated the pace of technology development. The work of scientists and engineers at the time caused a dramatic shift in electronics and computing systems. Taking place at a key time in the computer industry, this legacy has dramatically shaped the world today in a way not many would have predicted.



Modern Moon Missions

Recent Exploration

Overview

Recent exploration of the Moon, and the future scheduled and proposed missions, come from a variety of different nations and organisations.

SELENE

The Japan Aerospace Exploration Agency (JAXA) launched their lunar mission SELENE (also nicknamed Kaguya) in 2007 to explore the Moon's origin and evolution. SELENE provided us with far greater understanding of the lunar landscape, through improved lunar topography maps, a gravity map of the far side of the Moon and insight into the interior of select craters. Onboard SELENE were 13 scientific instruments. These included one terrain camera, several spectrometers, a lunar radar sounder and other instruments to understand the makeup of the lunar surface. Through JAXA's "Wish Upon the Moon" campaign, SELENE took 412,627 names and messages etched upon a sheet and carried within the spacecraft to the Moon.

Chandrayaan-1

Launched by the Indian Space Research Organisation (ISRO) in 2008, Chandrayaan-1 was India's first mission to the Moon. Its mission was to orbit the Moon and provide a more detailed understanding of the geographical and chemical characteristics of the lunar surface. It is best known for helping to discover evidence of water molecules on the Moon. A collaborative mission, the spacecraft featured 5 Indian developed instruments and 6 other instruments developed all over the world. Space agencies involved in included NASA and ESA, alongside research intuitions such as the Bulgarian Academy of Science and the Rutherford Appleton laboratory in the UK. Chandrayaan-2 is planned to be launched in 2019 and will include an orbiter, lander and rover, which is planned to soft land near the lunar south pole: an area of interest due to the occurrence of water ice.

LCROSS

NASA's Lunar Crater Observation and Sensing Satellite (LCROSS) mission's objective was to give us more insight into the possibilities of water on the Moon. Launched with the Lunar Reconnaissance Orbiter on 18 June 2009, evidence for the presence of water ice was found in the vapor plume and debris ejected by the LCROSS spent Centaur stage (part of its Atlas V carrier rocket) as it was deliberately crashed into the crater Cabeus near the lunar south pole. The LCROSS mission confirmed the presence of water ice on the Moon.

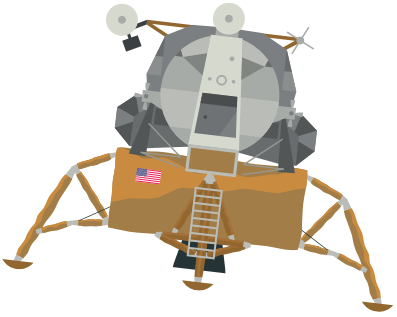


Image credit Cnsa Handout/EPA

Modern Moon Missions

Recent Exploration, Commercial SpaceFlight and the Gateway to the Moon

Chang'e Project

The Chinese Lunar Exploration Program (CLEP), (also known as the Chang'e Project) is a series of robotic Moon missions. Chang'e 4 (Chang'e is the Chinese Moon goddess) is the first spacecraft to land on the far side of the Moon, touching down on 3 January 2019. The spacecraft consists of a lander and a lunar rover as well as a communications satellite and microsatellite. The scientific instruments onboard Chang'e 4 were developed in collaboration with international partners (e.g. Germany, the Netherlands, Saudi Arabia and Sweden). Among other things, Chang'e 4 is measuring lunar structure and composition and investigating how solar wind affects the Moon. The Chang'e 5 and Chang'e 6 missions are expected to involve lunar sample return.

Orion Spacecraft

The first crewed test flight of the Orion spacecraft is scheduled for June 2022. The spacecraft will sit on top of NASA's new Space Launch System rocket and will take up to four astronauts on a free-return trajectory flight around the moon. This will be the first time humans have been back to the Moon since 1972.

SpaceX's #dearMoon

Planned to launch in 2023, this space tourism and art project will take a group of accomplished artists on a flyby to the Moon. Following a similar trajectory to that of Apollo 13, the mission, called #dearMoon, is expected to take a total of 6 days. The spacecraft, called Starship, will be launched on top of a Super Heavy Rocket (formerly known as the Big Falcon Rocket). This rocket will dwarf that of the Falcon Heavy, which was used to launch a Tesla car into space on 6 February 2018 and was watched live by millions worldwide.

The Space Gateway

In a partnership between ESA, NASA, Roscosmos (the Russian Space Agency), the Canadian Space Agency and JAXA, plans have been endorsed to build a Gateway, or outpost, around the Moon. This Gateway will act as a base, supporting both human and robotic exploration of the lunar surface. Assembly of the Gateway is due to start in the early 2020's, with the first module being carried up by an Orion spacecraft in 2024 following its test flight in 2022.

Once the Gateway is built, the Orion spacecraft will then be used to carry astronauts to and from the Gateway. This is anticipated to happen around 2026, two years after the first European service module is assembled. Similar to the International Space Station, astronauts will be able to live onboard the Gateway for up to three months at a time. This mission is the next big step in human exploration.

Long term visits to the Moon

Very recently, NASA announced Commercial Lunar Payload Services (CLPS) contracts to deliver robotic payloads to the Moon. The plan is to take steps towards long-term scientific study and human exploration of the Moon.

Image credit NASA

Lunar Bases

Could we live on the Moon?

Overview

One way to make space exploration easier would be to provide a permanent base on the Moon that can be used as a staging ground.

Why is this important?

Since the discovery of water on the Moon, the possibility of longer-term human missions have become more of a reality. A lunar base would not only allow for exploration of the Moon, but provide opportunities to test and develop technologies that will help pave the way for future missions to Mars and beyond. NASA and ESA are both considering different solutions to this issue.

Orbiting the Moon

One of the purposes of the the Lunar Orbital Platform Gateway would be to faciliate lunar and deep space operations. Vehicles might ferry between the station and the surface of the Moon, or the orbiting station could act as refuelling stop for missions headed further out into our solar system.

Exploring the surface

ESA are looking at a base built on the lunar surface itself. Some of their researchers are currently looking at the best methods and materials for building such a base, and some have suggested that using the lunar soil may be the best idea. Current plans see inflatable modules laying out the base arrangement and then surrounding these with lunar soil to protect the astronauts from the temperature changes and radiation found on the surface of the Moon. These base ideas are still in the early phases of design, but it is likely that, as our reliance on space grows, sustainability within space will be increasingly in demand. Bases like these could provide a solution.

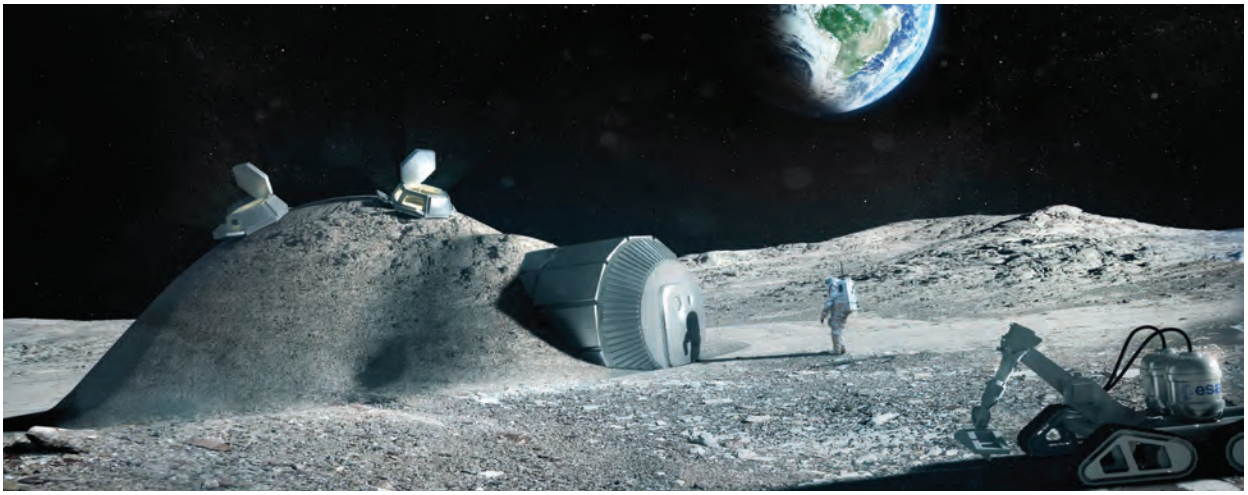


Image credit: NASA (top), ESA

Museum of the Moon

Luke Jerram's beautiful artwork

Overview

Museum of the Moon is a touring artwork created by UK artist Luke Jerram in partnership with a host of organisations including the UK Association for Science and Discovery Centres (ASDC) and the UK Space Agency.

Where has it been presented?

The Museum of the Moon has been presented at Science Centres, museums, music festivals, parks, cathedrals, swimming pools, arts festivals and city-wide celebrations across the UK and around the world. In the UK it has been hosted by the following Science Centres: W5 in Belfast, Centre for Life in Newcastle and Thinktank in Birmingham. It will be presented at the Natural History Museum in London and Jodrell Bank Discovery Centre for the anniversary of the Apollo 11 Moon landing.

Over three million people have flocked to see the artwork so far. It is 7 metres in diameter, and each centimetre of the internally lit spherical sculpture represented about 5 km of the Moon's surface. There are now several copies of this Moon, touring around the world.

Where is the imagery from?

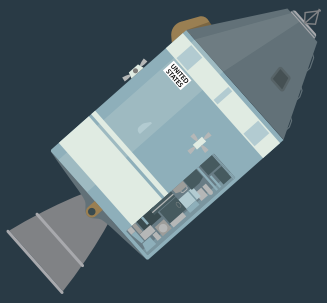
The imagery was taken by the Lunar Reconnaissance Orbiter, a robotic spacecraft currently orbiting the Moon. The data is considered essential for planning future human and robotic missions to the Moon.

Where to see the Moon

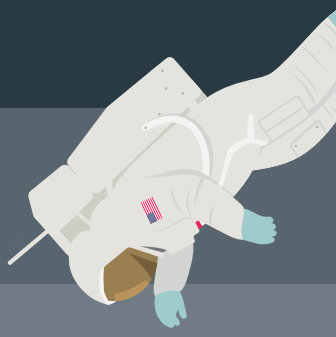
To find out more about the Moon, including tour dates and venues, see www.my-moon.org.

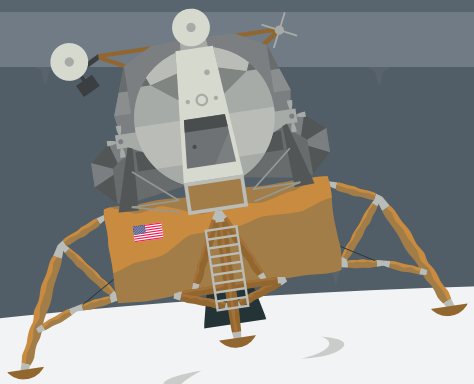
Image credit: Luke Jerram

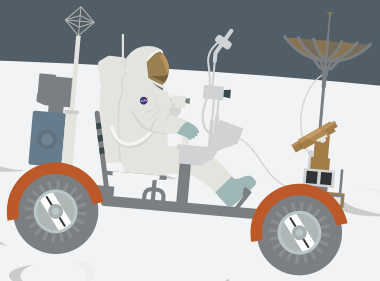
DESTINATION SPACE!

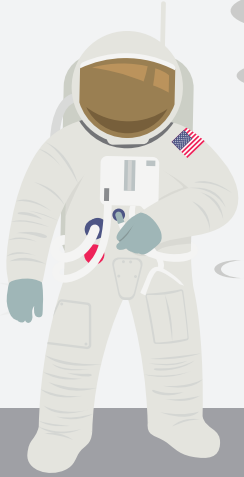


The Family Show









The Family Show

A set of demos and engagement activities for use with family audiences

Overview

This is a suggested narrative covering four demos, and should take 20-30 minutes to deliver. There are lots of other props and demos that could be used to include or extend the show as required.

Introducing the Moon

Slide: The Moon – our constant neighbour in space. It seems so close – as if you could reach out and touch it. But how close is the Moon?

Demo: Earth and Moon to scale (Page 10)

Slide: Since before history has been recorded humans have looked up at the Moon and wondered what it was.

Slide: Civilisations saw shapes on the surface and interpreted them as animals, such as the Chinese jade rabbit who was so virtuous its image was placed on the Moon, and even the face of a man!

Slide: Although the Moon 'shines', it doesn't produce it's own light. Instead, the light from the Sun bounces off it like a mirror. And it is because of this that the Moon seems to change over the course of a month.

Demo: Moon Phases (Page 9)

Slide: But our friendly neighbourhood Moon hasn't always been there. In fact, about 4.5 billion years ago, when the Earth was very young, it was one of dozens of planets fighting for dominance in our inner solar system. A planet called Theia, about the size of Mars, collided with the Earth. Theia was destroyed in the collision, and billions of tons of material were thrown out into space. The gravity of the Earth pulled these into orbit, and the Moon was formed.

Slide: After centuries of stories, the last century saw us humans developing a way of getting things into space – rockets. And it didn't take long for our sights to turn to the Moon.

The 1960's saw a space race taking shape. The USA and the USSR were in competition and tensions were high. The USSR won a lot of the early challenges, with the first man in space – Yuri Gagarin, the first woman in space – Valentina Tereshkova, and the first space-walk with Alexei Leonov – who nearly couldn't make it back into his spacecraft because his space suit expanded in space!

Slide: But in 1961, US President John F. Kennedy made a speech which kicked off the Apollo programme…

Getting to the Moon

Slide: So how do you get humans to the Moon? How do you fight the forces of gravity that are pulling you towards the centre of the Earth? Well, you need a rocket!

Demo: Ethanol rocket (Page 22)

Slide: In fact NASA, the American space agency, needed to build the tallest rocket ever launched – the Saturn V. It was so big, and needed so much fuel, that a single rocket was not enough. So the Saturn V was made up of three stages – when one was done, it fell back to Earth, leaving less mass for the next stage to push against gravity and send humans on a path towards the Moon. And less mass means less fuel and less $!

Slide: After testing all aspects of the mission, including going to the Moon and making it back (though not landing on the Moon), NASA was ready to put not one, but two humans on the Moon for the first time. The crew of Apollo 11 – Commander Neil Armstrong, Lunar Module pilot Buzz Aldrin, and Command Module pilot Michael Collins would make history. Although only two walked on the Moon in this mission, it was the result of the collective efforts of around 400,000 men and women back on Earth!

Slide: On 16 July 1969, they launched from the Kennedy Space Centre in Florida, United States. Just four days later, on the 20 July, Neil Armstrong and Buzz Aldrin climbed into the Lunar Module called the 'Eagle', ready to separate from the Command Module, and descend to the Moon.

Exploring the Moon

Slide: With 21 seconds worth of fuel to spare, Armstrong successfully landed the lunar module on the surface of the Moon, and after spending several hours completing checks and getting ready, Neil Armstrong opened the hatch and made history.

Slide: All the Apollo missions had a set of experiments for the Moon called ALSEPS (Apollo Lunar Surface Experiments Package), and these were slightly different for each mission, but all the missions involved collecting Moon rock to be brought back to Earth to be analysed – and this was hard work! You can see from this image of Harrison Schmitt – the only scientist to walk on the Moon in Apollo 17 just how much effort it was – but what made it so hard – well let's find out!

Demo: Working on the Moon activity (Page 30/31)

Slide: By 1972, the cost of the Apollo programme was becoming too high, and the final three Apollo missions were cancelled. Humans haven't walked on the Moon since. But that doesn't mean we haven't still explored it! In fact space agencies from many different countries have sent spacecraft to the Moon – both in orbit, to image the Moon in amazing detail, or rovers to explore the surface.

Image Credit: National Space Centre

The Future

Slide: And NASA, ESA (The European Space Agency) and other partner space agencies are working together on an exciting new project. The Lunar Orbital Platform Gateway is a planned multinational space Station that would provide access to the Moon and allow potential future missions to venture further out into our Solar system. As a member of ESA, the UK will play a role in the development of some of this technology.

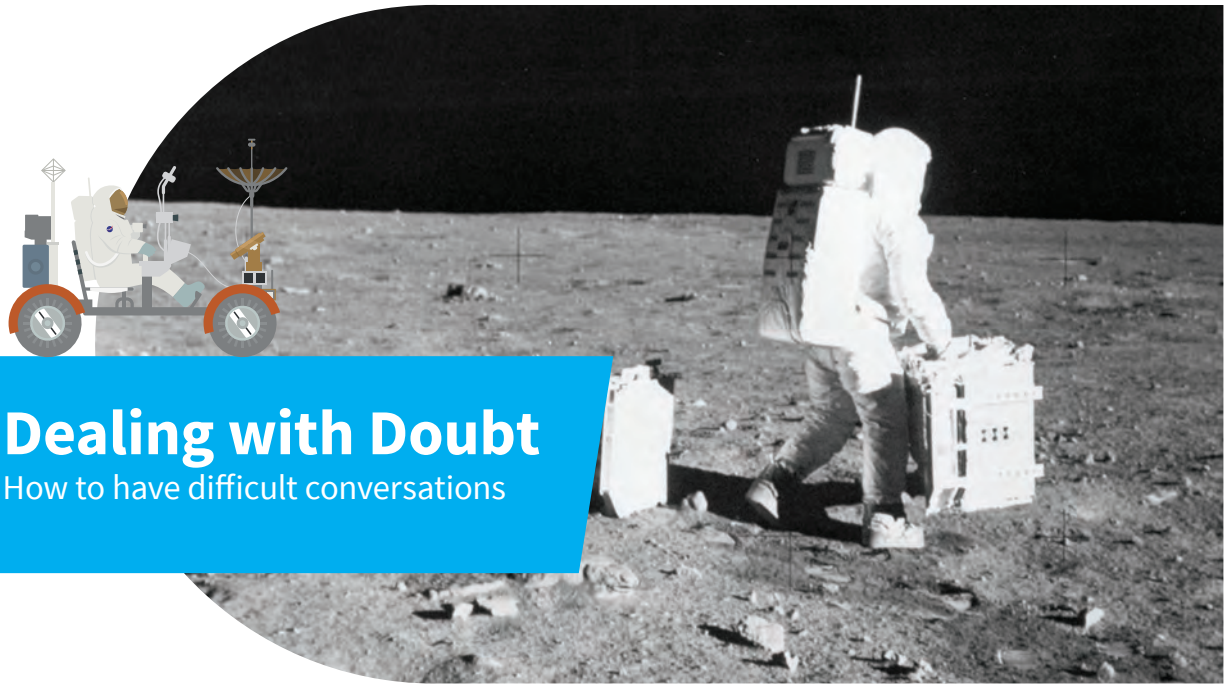
Slide: So, 50 years ago our obsession with the Moon led to humans setting foot on another body in space for the first time. And today, our focus returns to the Moon. And who knows, maybe one of the engineers, scientists or computer programmers working on these missions – perhaps even as an astronaut, is sitting in a Science Centre in the UK, right now, watching this show about our obsession with the Moon.

Additional Demos

- A Piece of the Moon (Page 11)
- Lunar Footprint (Page 27)
- The Smell of the Moon (Page 28)
- Roaming the Moon (Page 29)
- Lunar Gravity (Page 33)

Curriculum Links

- Depending on the demos included, there are various curriculum topics that are relevant in this show. They include Earth, Moon and Sun, Light, Different types of rock, Chemical reactions, Gravity and weight and Forces.
- Throughout the entire programme there is always an opportunity for scientific enquiry, role play, problem solving and communication.



Dealing with Doubt

How to have difficult conversations

Overview

Despite it being 50 years since the first people went to the Moon, and numerous subsequent robotic missions, occasionally you will come across people who believe the landing didn't actually happen.

How can we deal with this?

Whenever we discuss and present the topic of the Moon landings, there is always a chance that we will encounter someone who firmlly believes the Moon landing never happened, and it is all part of a conspiracy. As a science presenter, this can make for quite an uncomfortable conversation. So what can you say?

As with all audience members, it is important to engage, celebrating their interest and their curiosity. Telling somebody they are wrong feels like quite a hostile action, especially when dealing with something they truly believe in and hold an entrenched position. The response would almost always be to defend their position.

Often a much better approach is to explain how other people hold something else to be true.

How do I convince them?

In our experience, often the best idea is not to try to convince the other person. People who hold contrary views to the evidence often do so because they have researched a topic and reached their own conclusion. Studies show that self-realised conclusions are often the hardest to change.

Rather than try to tell someone what the correct version of events is, offer them ways in which they can investigate it themselves.

Isn't it wasting each other's time?

While some conversations can be frustrating, in our experience the best interactions have come when we have taken time to just listen. Often contrary view holders aren't looking to recruit you, they just wish to voice their thoughts. A simple conversation listening to, acknowledging their views, and highlighting why you hold your views, and the evidence that backs them up, can be enough to generate a positive experience for all parties.

You can also bring up the retro-reflectors and other experiments that we still use and were left by the Apollo mission. It is, however, worth practicing your technique with colleagues in a training session.

What if I don't have answers?

No-one holds all the answers. There are a great deal of resources that discuss the questions so feel free to direct people to them to do some further reading.

Space Race Spin-offs

Overview

The intense research for the Apollo missions and the need to protect astronauts in such harsh and extreme conditions led to rapid developments, that have been applied to technologies here on Earth.

Stories to tell

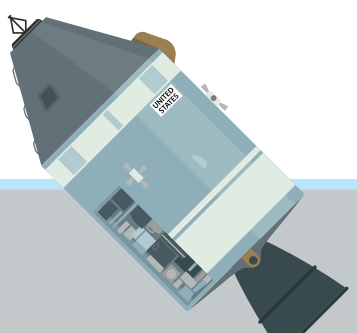
NASA lists around 2000 spin-offs. Many of course are the result of international efforts and partnerships to develop them for the space missions.

Since 1976 NASA has produced a magazine, listing the latest spin-offs: www.spinoff.nasa.gov

Spin-offs include:

- The Joystick: this computer gaming device was first used on the Apollo Lunar Rover.
- The CAT scanner: first used to find imperfections in space components.
- The microchip: innovation for the integrated circuits in the Apollo Guidance Computer led to their development.
- Cordless power tools: drills and vacuum cleaners use technology developed to drill for moon samples.
- Freeze-dried food: preserving nutrients whilst increasing shelf-life.
- Kidney dialysis: using a new chemical process that removes toxic waste from fluids.
- Memory foam: created for seats to soften the landing, and now used widely in mattresses and shock absorbing helmets.
- Water purification technology used on the Apollo spacecraft is now used to kill bacteria, viruses and algae in community water supply systems and cooling towers.
- Flame-Resistant Textiles: After a tragic fire which resulted in the death of three astronauts, NASA worked with private industry to develop fire-resistant textiles for use in space suits and vehicles.
- Insulation: home insulation uses reflective material that was developed to protect spacecraft from radiation.
- Space-blankets: The foil developed for the Apollo mission s also used for emergency blankets.
- Green building materials: Teflon-coated fiberglass strands created for spacesuits are used to make permanent, tent-like, roof structures in buildings.
- Digital Image Sensors: When you take pictures with a phone, you are using more recent space technology.
- Cardiac Pump: people in need of a heart transplant have been kept alive thanks to a cardiac pump that was designed with the help of space expertise in simulating fluid flow through rocket engines.

Image credit: NASA



FAQs and Moon Mysteries!

Is there gravity on the Moon?

Yes, gravity on the Moon is approximately one sixth (~17%) of the strength of gravity experienced on Earth.

Does the Moon have an atmosphere?

Until recently it was believed that the Moon didn't have an atmosphere due to its relatively low gravitational field strength (1.6N/kg compared to Earth's 10 N/kg). However, the Lunar Atmospheric Composition Experiment (LACE) instrument placed on the Moon's surface during Apollo 17 mission detected small amounts of atmospheric gases, including argon, helium, ammonia, carbon dixoide and traces of what could be methane.

How many people have walked on the Moon?

Only 12 people have ever walked on the Moon, all NASA astronauts. These were Neil Armstrong, Buzz Aldrin, Pete Conrad, Alan Bean, Alan Shepard, Edgar Mitchell, David Scott, James Irwin, John Young, Charles Duke, Eugene Cernan and Harrison Schmitt.

How far away is the Moon and how long does it take to get there?

The Moon sits, on average, 384,400 km away from Earth, with its closest approach being just 363,104 km. It took the Apollo 11 crew a total of four days, six hours and 45 minutes to get to the Moon.

Image credit: Charlie Duke

Is the American flag still there?

There are actually six American flags on the Moon. Apollo 11's was knocked over when astronauts returned to the Command Module, however, the remaining five are still standing. The flags have all been bleached white by the Moon's harsh atmosphere.

Anything strange left behind?

Besides flags, experiments, lunar rovers and scientific instruments, Apollo astronauts also left 96 bags of human faeces, urine and vomit on the Moon, as well as a portrait of Charles Duke's family, a gold-plated telescope and 12 cameras.

How did water get on the Moon?

In 2009, NASA discovered water ice trapped under the surface of the Moon, however, scientists still don't know how it got there. Could it have been from icy comets crashing into the lunar surface? It seems we don't yet know why, but the Moon is far wetter than anone had previously imagined.

How many human missions to the Moon have there been?

Between 1968 and 1972, there were a total of nine crewed missions. Six of these landed astronauts on the Moon's surface. Since 1972 humans have not been back to the Moon, however, there are at least eight crewed missions planned by America, Russia, China and Japan from 2022 onwards.

Image credit: NASA

DESTINATION SPACE!

DESTINATION SPACE!

is a partnership of

UK Association for Science and Discovery Centres

UK SPACE AGENCY

www.moon50.uk **www.destinationspace.uk**

DestinationSpaceUK #moon50 @destin_space @sciencecentres

The Association for Science and Discovery Centres, 2019. Registered charity: 1129312.
Company number: 6798106. 30 Queen Charlotte Street, Bristol BS1 4HJ