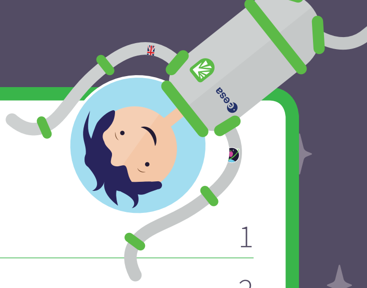
DESTINATION SPACE!

Join The Crew

Training Handbook



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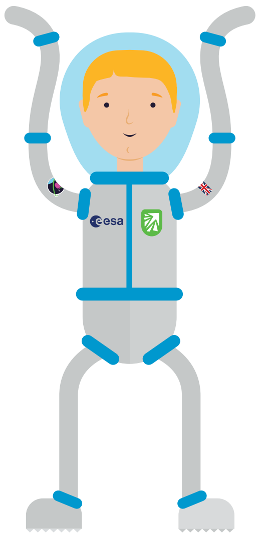

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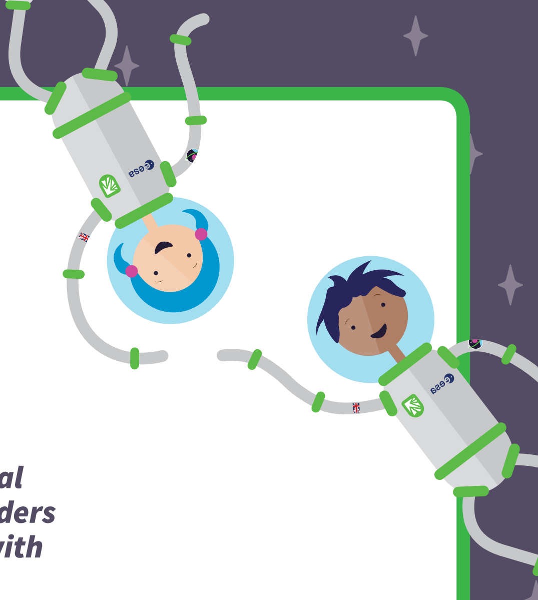


WELCOME TO THE ‘DESTINATION SPACE’ PROGRAMME

Tim Peake, the European Space Agency’s first British Astronaut, is scheduled to blast-off into space and spend six months living and working aboard the International Space Station. To celebrate this fantastic event and the wonders of human space flight, the UK Space Agency has partnered with the UK Association for Science and Discovery Centres (ASDC) to deliver a national programme of astronauts and adventure for families and schools at Science Centres across the UK.

The UK Space Agency is at the heart of UK efforts to explore and benefit from space. It is responsible for all strategic decisions on the UK civil space programme and provides a clear, single voice for UK space ambitions.

ASDC is the national organisation that brings together the UK’s major science engagement organisations to play a strategic role in the nation’s engagement with science. Within our network are over 60 of the nation’s largest publically accessible Science Centres, Discovery Centres, Science Museums and scientific bodies. Together our vision is for a society where people of all backgrounds and in all parts of the UK are inspired and fully involved with the sciences.

The ‘Destination Space’ programme is being delivered by 20 partner Science Centres across the UK. Everyone is invited to join in and take part in the family astronaut show or team up with friends for our school workshops and other activities to celebrate Tim Peake’s mission and the people that make living in space possible.

This exciting interactive family and schools programme has created a series of exceptional hands-on activities, experiments, schools workshops, a family show, meet-the-expert sessions, digital activities and a variety of events. They all focus on Tim’s mission and the endeavours of human space flight, giving young people the confidence, curiosity, and interest to continue to explore and ask questions long after they leave the science and discovery centres. This national project is led by ASDC in collaboration with the National Space Centre in Leicester, Jodrell Bank Discovery Centre in Cheshire and Science Museum in London.

‘Destination Space’ is a two-year national programme to inspire curiosity and young minds with the wonders of human spaceflight, and to promote the importance of Science, Technology, Engineering and Mathematical skills that make spaceflight possible. The programme also allows families and schools to find out about the creative, talented team behind Tim and his mission, as well as the technology needed to travel to, live on and return from the International Space Station. Tim will be carrying out a comprehensive science programme on the Space Station, much of which people will find out about through ‘Destination Space’.

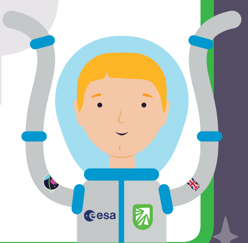
Destination Space continues online at ***www.DestinationSpace.uk*** with the latest images, videos, resources, transmissions from space and games relating to Tim’s mission. You can even test which member of the crew you could be.

Additional information

Please ensure you locate, read and understand the Health and Safety information available online at ***www.destinationspace.uk***

Tim’s Space Timeline

12th April 1961
First human in space. Yuri Gagarin orbits the Earth aboard Vostok 1 and returns safely



THE ASSOCIATION FOR SCIENCE AND DISCOVERY CENTRES NETWORK

Destination Space participating centres

WWW.SCIENCECENTRES.ORG.UK

UK Association for Science and Discovery Centres

principia

DESTINATION SPACE!

DESTINATION SPACE PARTNERS AND ACKNOWLEDGEMENTS

This programme would not have been possible without the efforts and input of a large number of people across the space science and science engagement communities. Everyone involved in the project, from the initial conception and advisory phase to development and delivery is contributing to bringing the excitement, wonder and inspiration of human spaceflight and Tim Peake's Principia mission to families and school children across the UK.

The project would particularly like to thank the following people for their dedication and hard work over the course of this project:

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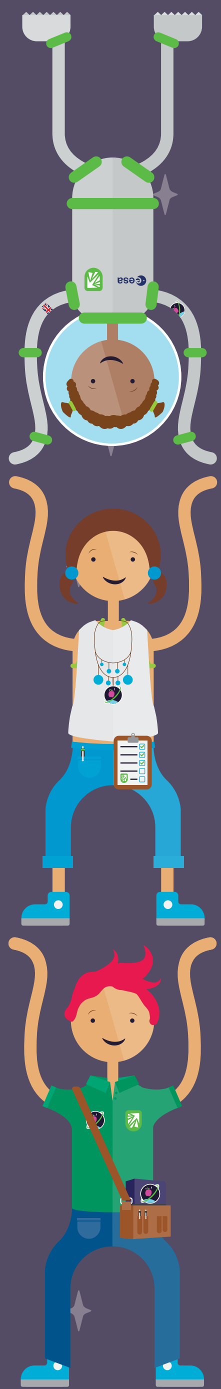

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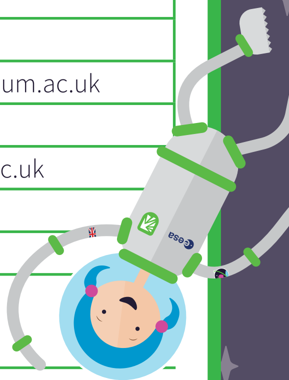

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- ***National Space Centre***
- ***Museum of Science and Industry***
- ***Jodrell Bank Discovery Centre***
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- ***Cambridge Science Centre***
- ***Techniquest Glyndwr***
- ***Centre for Life***
- ***Winchester Science Centre***
- ***Dundee Science Centre***
- ***W5***
- ***Eden Project***

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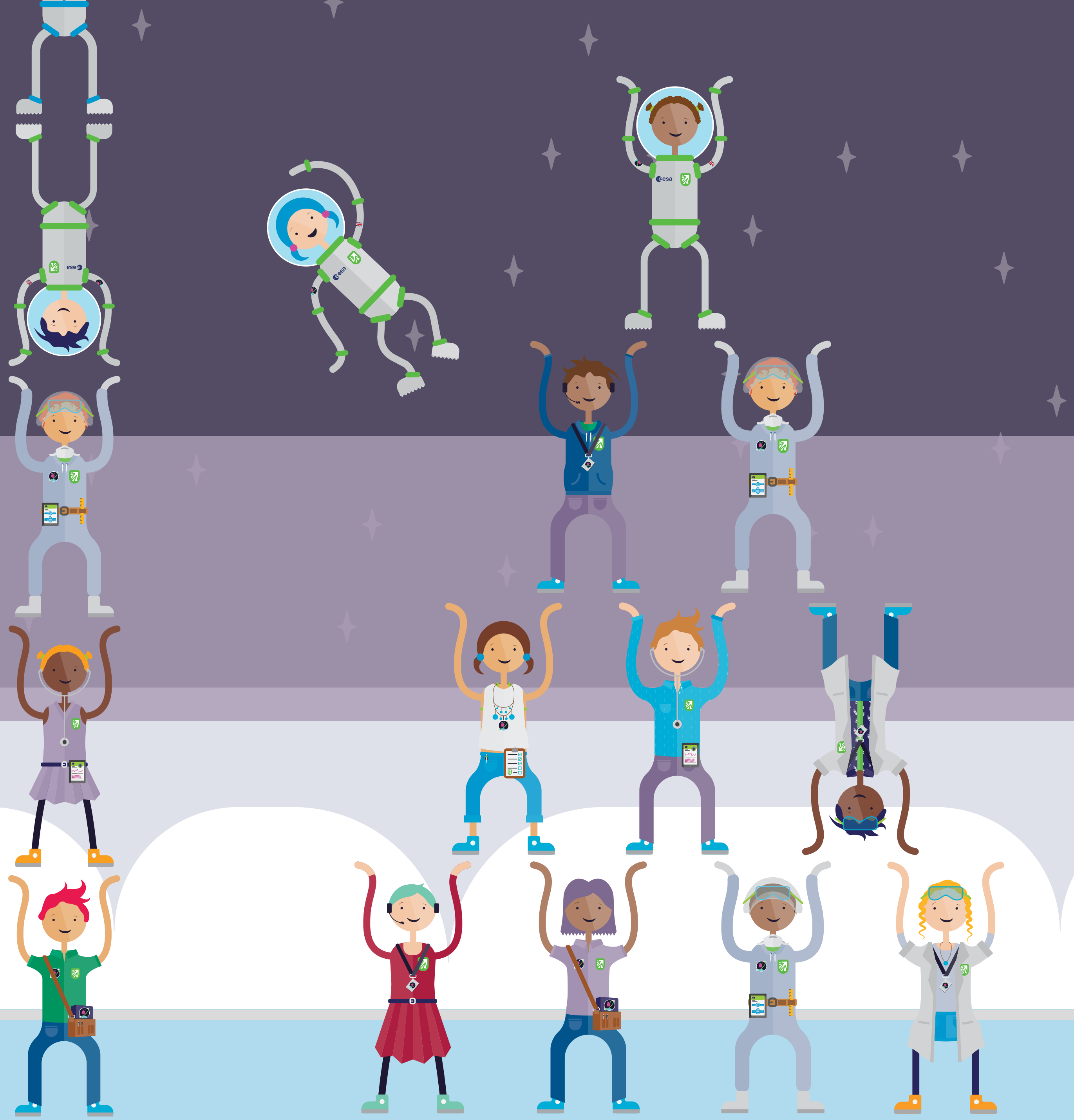
DESTINATION SPACE!

TRAINING FOR SPACE:

Stories and Equipment Briefing Sheets



INTRODUCING TIM PEAKE

Tim Peake is the first British European Space Agency (ESA) astronaut. He is not the first British astronaut; that accolade belongs to Dr Helen Sharman who travelled to the Mir space station in 1991.

Tim was selected as an ESA astronaut in 2009. He completed his Astronaut Basic Training in November 2010 and received Eurocom certification in September 2011, allowing him to be responsible for communication between astronauts in orbit and Europe's Mission Control Centre.

In 2011, Tim was part of an experiment where he lived underground in a cave for a week in order for human behaviour and performance in extreme environments to be studied. In 2012 he spent 12 days in a specially designed habitat called NEEMO, 19m below the sea in order to test technologies and research for future missions.

In 2012, he also completed his training and certification for undertaking spacewalks in both the Russian Orlan spacesuit and US Extravehicular Mobility Unit (EMU).

Tim has spent some of his training at the European Astronaut centre in Cologne, Germany preparing for his Principia mission, a long-duration flight to the International Space Station (ISS). He will be the first British ESA astronaut to have visited the ISS. Prior to this assignment being announced, in 2013 he had been lead EUROCOM for Luca Parmitano's mission to the ISS.

Tim has also taken part in training at Houston and Huntsville in the United States, Star City near Moscow in Russia, Tsukuba in Japan and Montreal in Canada as part of his advanced training.

Prior to being selected as an astronaut Tim had a long career in the British army where he achieved the rank of Major. He joined the army straight after school and served as a pilot in Yugoslavia, Kenya and Canada.

Tim is due to launch to the ISS in December 2015 (correct at time of writing, this could change). He will stay there for approximately six months. He will carry out a variety of scientific experiments onboard the ISS and use ESA's Columbus laboratory module while he is there, as well as having to do more routine tasks such as maintenance and cleaning. He is also committed to doing as much outreach as possible and will share his experience via social media channels.

Credit: Tim Peake Flickr

Tim Peake

Born: 7th April 1972 in Chichester, West Sussex
Education: Chichester High School for Boys, West Sussex. After school Tim went on to train at the Royal Military Academy Sandhurst as an officer in the British Army Air Corps.

18th May 1991
First British Astronaut. Helen Sharman launches aboard Soyuz TM-12

58
Women in space

Tim's Space Timeline

TRAINING FOR SPACE

Introduction

Tim will spend approximately six months living and working on the International Space Station (ISS) for his Principia mission, but those six months required six years preparation. Although the highlight of any astronaut's career is living and working in space, the majority of their efforts go into the preparation needed to survive and thrive during a mission.

Tim was selected to join the European Space Agency's astronaut programme in 2009. However it wouldn't be until 2013 that Tim was officially assigned to a space mission. Even then he still had a wait ahead of him since the mission he was assigned to wouldn't launch for at least another two years. Despite waiting many years to finally fly into space, Tim and his fellow astronauts have been kept extraordinarily busy with their intensive training program and the packed media, outreach and engagement schedules they need to follow.

Ground Based Training

Some parts of space can be an incredibly alien environment with some conditions that are extremely difficult to replicate on the Earth. To counteract this astronauts train in a variety of environments to replicate different aspects of working in space. The first of these environments is one we have a lot of familiarity with, the ground. While safely operating on the ground astronauts can focus on other elements of their training. One introductory element to this is the theory work with which their training begins.

During the initial stages of training, astronauts have to go back to school to gain a basic knowledge in several key subjects. These subjects are similar to those taught in all schools, with some unique additions. Mathematics and the physics of rocketry are not surprising requirements, however psychology and Russian may not be expected. Technical subjects like maths, physics and engineering form a key baseline to an astronaut's knowledge. Despite working alongside huge teams responsible for the calculation of orbital paths, designs of experiments and engineering tasks, astronauts need a thorough understanding of what they are doing. This is necessary so that they are able to have some level of autonomy, allowing them to efficiently use their time in space.

Psychology and politics often feature on an astronaut's syllabus. During their mission in space astronauts are subjected to huge psychological stresses. The International Space Station is a confined environment; the internal space is the size of a standard five -bedroomed house. This living space has to accommodate six astronauts, each staying for approximately six months at a time. Unlike living in an actual five-bedroomed house, each bedroom is the size of a large cupboard. They can't go for a walk or get far away from their colleagues if they find themselves in a stressful situation. This means that without careful consideration there is a chance that tensions can escalate and cause issues. Giving astronauts psychological training can give them the tools to prevent these situations arising, and prepare them for a situation where there is an incident.

Language skills are vital to an astronaut bound for the ISS. Half of the station was built and is run by the Russians and the other half by NASA, ESA and JAXA. The crew must be proficient in russian and english so that they can communicate with each other and the ground, especially in emergency situations. Most of the procedures and labels are bi-lingual and all of the important ground communications are translated.

In addition to these classroom based skills, astronauts undertake a lot of physical and situational training. From survival training (in case the Soyuz descent module bringing astronauts back to Earth lands in a remote, inhospitable environment) to exercising while being studied by doctors to ensure they are fit and healthy, an astronaut never has time to get bored.

Astronauts will also undertake unique testing and training as and when opportunities arise. In 2011, Tim spent a week living in an underground network of caves to allow scientists to study the effect of confinement and isolation on behaviour and performance.

Simulator Training

Familiarity in an alien environment is very important and as such all astronauts spend a lot of their time training on exact replicas of the craft and technology they will be using. By the time an astronaut is strapped into the Soyuz space craft ready to Launch, they will know the location and operation of every switch, button and lever.

Tim travelled to the Canadian Space Agency headquarters to train on the operation of the CANADARM 2 robotic arm that is used for tasks outside the ISS. To do this he had to complete many tasks while using an exact replica of the control box and interface he will be using while working in space. At the Avionics Systems Laboratory at NASA's Johnson Space Center they train in the full size Cupola trainer, while flying over a simulated Earth.

The Gagarin Cosmonaut Training Centre hosts exact replicas of the Soyuz space craft. Astronauts strap themselves in for hours at a time, just as they will be once they launch, and practice every aspect from launch sequence tasks, emergency action, docking manoeuvres and controlling the Soyuz itself. While the buttons may be in Russian, by the time they are finished, international astronauts will know exactly what everything does.

And at the European Astronaut Centre in Cologne, Germany, astronauts train in a replica of the Columbus module. Everything is identical to the real module, including the placement of experiments and cameras that they will use on board. Here they can also use a virtual reality headset system to virtually move through the ISS and get used to seeing it from all of the angles possible in microgravity.

Underwater Training

One of the most unexpected skills that is learnt during astronaut training is Scuba Diving. The ability to scuba dive is utilised extensively while astronauts train for Extra Vehicular Activity (spacewalks) because it shares key elements with doing space walks. First of all both require a suit to be worn for survival. The suit protects the wearer from the environment, a diver from the water and an astronaut from space. In both scenarios the individual has to breathe oxygen, so familiarity with how these systems work is important. Finally while submerged in water, careful weighting can result in neutral buoyancy. The diver will float rather than sink or float to the surface. This enables the diver to practice what it would be like to operate in the microgravity environment in orbit.

Activities that take the astronauts outside of the comfort of the spacecraft can occur and through the use of giant swimming pools astronauts can rehearse and train for these. The astronaut training facilities around the world have huge pools of water that contain submerged replicas of the space station. Astronauts can suit up, usually in space suit analogues, and go through the actions needed during spacewalks. This gives them vital hands on experience, allowing them to perform these operations when needed in orbit.

These underwater training activities are a useful tool for both astronauts and scientists. While the astronauts can use them to train for space exploration, scientists and engineers can use the environment to test new tools or equipment, methods for working, and setups for activities.

One facility that Tim is familiar with is NASA's Extreme Environment Mission Operations (NEEMO) which is submerged 19 meters below the ocean. Tim was part of the 16th mission conducted in this facility, spending 11 days testing a potential mission to land a crew on an asteroid. During this time Tim and his crewmates lived in the underwater facility and tested new spacewalking methods. The benefit of facilities like this is that the participants not only have to deal with the harsh environments associated with exploration but they also get to experience similar living conditions that they will find themselves in on the ISS. In the deep water environments, the return to the surface is not straight forward and so aquanauts can only return at the end of their mission or in emergencies.

Astronauts also need to be able to withstand large g-forces (where you feel a force several times greater to what you experience as weight due to the gravitational pull on the surface of the Earth). On launch and during re-entry, astronauts can expect to pull around four 'gs' (four times the effective weight force due to gravity) but in case of emergency they must train to be able to survive even higher g-forces. To do this they train in giant centrifuges that spin them around, generating up to eight 'gs' of force.

Additional information

For more information on centrifuge training please refer to centrifuge briefing sheet.

Training in the Air

The ground based training is extremely useful for astronauts, but to prepare an astronaut for flight, some experience of weightlessness is needed. This iconic feature of space exploration can be incredibly difficult to replicate down here on Earth. While analogues can be constructed, such as the neutral buoyancy under water, producing the full effect requires a novel solution. The only way to do it while under the influences of the Earth's strong gravitational field is to plummet back towards the Earth under freefall.

In a gravitational field such as Earth's, falling without the influence of any other forces will put the subject in free fall. People experience instances of microgravity every day, when going down in a lift or over a bump in the road. For a fraction of a second, the lift or car is accelerating downwards due to gravity, but the person is also moving downwards with the same acceleration. The lift or car is falling away from them at the same rate that the person is falling towards them – they are in freefall for a split second.

However these short durations of microgravity are not enough to prepare astronauts for space. Astronauts prepare themselves for feeling weightless on-board a specially modified aircraft that can fly parabolas, often referred to as a 'Vomit Comet'. This plane flies a parabolic (following a curve freefalling under the pull of gravity) flight path up and down repeated many times each session. As the plane flies over a peak, everyone on-board is exposed to around 20 seconds of microgravity since the plane is freefalling towards the ground. The pilot then pulls up out of the descent, into an upwards curve. This pushes everyone down onto the floor of the plane, and they are subjected to around 1.8 gs of force (almost twice the force of gravity experienced on Earth's surface).

Additional information

See microgravity information sheet for more details.

Conclusion

As we have seen there is an enormous amount of preparation that is required to train an astronaut. Tim Peake has spent 6 years preparing for his 6 month stay aboard the International Space Station. He has studied and been examined in technical skills, languages and physical training. He has rehearsed everything so many times that using the equipment available to him is second nature. And as much as is possible on the Earth he has experienced a taste of what life will be like on the ISS.

Astronaut training is a long and difficult journey designed to prepare an individual to work in one of the harshest environments we know. However living and working on the ISS will be a new, exciting and inspirational experience for Tim, and everyone following his exploits on planet Earth.

FLIGHT SUIT

Tim's PR outfit

Programme Use: Across the programme

Overview

Astronauts who are preparing for space are often seen in these blue overalls. These are their PR clothes and provide a standard uniform for all media engagements. The patches supplied are specific to Tim's Principia mission.

How it works

1 *What is this patch?*

Each ESA astronaut mission has a specific emblem and this patch is the one for Tim's mission - Principia, named for the work 'Principia Mathamatica' by Sir Isaac Newton, in which he outlined his Laws of Motion. The patch was designed by 13 year old Troy Wood who won a Blue Peter competition to design the patch. Features of the patch include:

- A Soyuz rocket launching, the craft Tim Peake will launch in.
- An apple falling, from the story about Newton first thinking about gravity after an apple fell from a tree.
- The light reflection on the apple is in the outline of the International Space Station, Tim's destination.
- The British Isles can be seen on the section of the Earth shown.
- The colours of the Union Flag can be seen in the outer border of the patch.
- The golden ring around the patch represents an orbital path.

2 *What is this patch?*

This patch features the logo for ESA, the European Space Agency, and the flags of its member states. Clockwise starting top left, the flags are: United Kingdom, Sweden, Switzerland, Germany, Austria, Belgium, Denmark, Spain, Estonia, Finland, France, Greece, Hungary, Republic of Ireland, Italy, Luxembourg, Norway, Holland, Poland, Portugal, Czech Republic, and Romania.

3 *Why this patch?*

Tim is British, and as such will wear the Union Flag to show this. Other astronauts wear the flag of their nation.

4 *What is this patch?*

The ESA Astronaut Corps name badge gives the astronaut's full name and shows they are ESA astronauts.

5 *What is this patch?*

Sometimes you will see an astronaut wearing this patch too. This shows that they are a member of ESA's European Astronaut Corps.

Links to Tim's mission

This blue flight suit is what Tim is most often seen in during public appearances whilst on Earth. While different space agencies may have their own variations, this is the standard appearance for European Space Agency astronauts.

Once in space, Tim will generally wear polo shirts and trousers and will wear space agency branded shirts for broadcasts.

Additional information

For supplier information, risk assessments, and additional resources please see digital content on ***www.destinationspace.uk***

CENTRIFUGE

Generating g-forces by spinning

Programme Use: Across the programme

Notice: This is optional kit

Overview

During launch aboard a Soyuz-FG rocket, astronauts can experience forces of up to 4.2 g (that is, over four times the effective force they experience on the surface of the Earth due to gravity). To experience this astronauts train in a centrifuge that spins them around at high speed, producing effective forces of up to 8 times those experienced on the Earth's surface.

This demonstration explains the principles behind that training.

How it works

1 ***What do we mean by 1g of force?***
Gravity is a force that accelerates objects towards the centre of the Earth– if you were to drop an object from a hot air balloon (and could ignore the effects of air resistance) it would get faster at a rate of 9.81 m/s every second. Newton's second law states that F = ma (The force an object experience when they accelerate is equal to the object's mass multiplied by its acceleration). An astronaut standing on the Earth is pulled down towards the centre of the Earth with a force equal to the acceleration due to gravity multiplied by their mass – we call this their weight. When an astronaut experiences 1g of force, they are experiencing the same force as their weight at the surface of the Earth.

2 ***Why do you feel a force when you spin?***
An object moving on a circular path experiences a centripetal acceleration which acts towards the centre of the circle ($F = mv^2/r$ where F is the centripetal force, m is the mass of the object, v is the object's velocity and r is the radius of its circular motion). An astronaut sat in the centrifuge will feel the reaction force equal to this centripetal force due to being pushed by the cabin. We all experience this force in our everyday lives when we go around a bend in a vehicle or when riding rollercoasters.

3 ***How fast do you need to spin for the reaction force to equal 1g?***
It depends on how big your centrifuge is. The force depends on the radius of your centrifuge and the rate at which it rotates. If the centrifuge was 1m in radius you would need to rotate at a rate of once every 2 seconds to experience 1g (or the equivalent force to that of gravity pulling you down on the Earth). Since the force is proportional to v^2, if you double the speed, you quadruple the force.

4 ***Why do astronauts feel this force when they take off and land?***
When a rocket launches it accelerates upwards, causing the bottom of the rocket to push into the astronauts. From the point of view of the astronauts, the rocket accelerating upwards towards them is equivalent to the astronauts accelerating towards the stationary rocket with that same acceleration. The resulting force the astronauts feel from this acceleration acts to effectively increase their weight, and to pull fluids towards the bottom of their body. One way to limit the effects of this g-force on an astronaut is to have them launch in a laying down position. In this direction, the force acts through their body front to back, avoiding the nasty effects of blood draining towards their feet or rushing towards their head.

Experiments to try

Put some water in a bucket and swing the bucket over your head. If you swing fast enough the water will not fall out since the reaction force is equal to or greater than the acceleration due to gravity. This forces the water to follow the trajectory of the bucket. You can also try putting a cup of water on a tray with some string attached and do the same thing.

During launch aboard a Soyuz-FG rocket, astronauts can experience up to 4.2 g (that is, over four times the effective force they experience on Earth due to gravity).

To withstand this astronauts train in a centrifuge that spins them around at high speed, producing an acceleration towards the centre of the centrifuge of up to 8 g. One way to limit the effects of this g-force on an astronaut is to have them launch in a laying down position. In this direction, the force acts through their body front to back, avoiding the nasty effects of blood draining towards their feet or rushing towards their head.

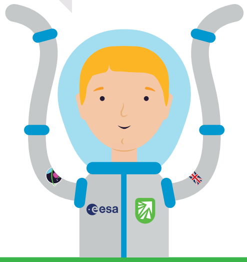
Additional information

For supplier information, risk assessments, and additional resources please see digital content on ***www.destinationspace.uk***

Tim's Space Timeline

17th July 1975
Apollo-Soyuz mission:
A joint US and Russian mission

77
Total person-years
spent in space



REACTION TIMERS

Think Fast

Programme Use: Busking

Notice: This is optional kit

Overview

Astronauts need to have exceptionally good (very short) reaction times when piloting spacecrafts. With this equipment you can test whether your visitors are quick enough to be an astronaut.

How it works

1 ***Why is there delay when testing reaction time?***
When you experience something through your senses (such as seeing or hearing something) it takes a small amount of time for that information to travel along nerves to get to your brain. Information travels along nerves at around 100 metres per second (200 mph). Your brain then takes time to process the information, before sending another signal to your muscles to do something.

2 ***What can affect reaction times?***
Some drugs, such as alcohol can slow down a person's reaction times. Some, such as caffeine can improve them, but only for a short while. Fatigue and disorientation can also increase reaction times.

3 ***Can you improve your reaction time without drugs?***
Reaction times depend a lot on genetics (which means some people are naturally better at it than others) however by practising, you can improve your reaction times by about 10-20%. The best way to improve your reaction time though is to try to stay calm and relaxed. This is what astronauts do. Stress and panic can stop you functioning properly in a crisis and that could be the difference between life and death in an emergency.

Experiments to try

1 ***Quick enough to be an astronaut?***

- Set up a reaction time league at your Centre where visitors can be in competition to get the best time.
- Allow visitors to compare their reaction times to that of astronauts.
- Have visitors try the reaction timer in two situations. Firstly have them do it normally, then put pressure on them and see if stress and distraction increases their times.

2 ***A simple reaction timer***

A simple reaction timer can be made using a ruler. Have one person drop the ruler between the others fingers and thumb (without warning the person they are about to do this) and the other person catch it. See who can catch it in the shortest distance (the shorter the distance the ruler falls the shorter the time it takes to catch it).

Want to try more?

There are more experiments you can try involving reaction times and other aspects of astronauts training through the MissionX – Train like an astronaut activities also running to support Tim's mission.
For more information please visit
www.trainlikeanastronaut.org/mission-data

Additional information

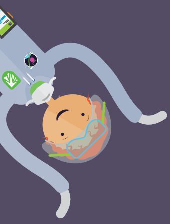
For supplier information, risk assessments, and additional resources please see digital content on ***www.destinationspace.uk***

www.destinationspace.uk

DESTINATION SPACE!

GETTING INTO SPACE:

Stories and Equipment Briefing Sheets



GETTING INTO SPACE

It will only take Tim about 8 and a half minutes to get into space, launched by a Russian Soyuz-FG rocket. Strapped into his couch within the Soyuz spacecraft he and his two crewmates will be sat on the very tip of a rocket loaded with a quarter of a million kilograms of fuel and oxygen. If something goes wrong, it has the potential to go spectacularly wrong, and yet the Soyuz-FG has the best safety record of any rocket used to take humans into space.

Once he has made it into space, Tim should arrive at the ISS in six hours. However, if anything unexpected occurs mission control may opt for a slower two day journey.

So how far away is space? How does the rocket work? And why is getting into space so dangerous and costly?

How far away is space?

Space is not as far away from the surface of the Earth as most people think. How we define where space begins is not as straightforward as it sounds. It would be simple to say that space begins where the atmosphere ends, but the atmosphere is not a static entity. It is dynamic, expanding and contracting with solar heating effects. And while the atmosphere does get thinner as you gain altitude, there is no obvious point where it becomes as thin as the near vacuum of space.

There is, however, an official definition of where space begins. The Fédération Aéronautique Internationale, the governing body for air sports, aeronautics and astronautics has accepted an altitude of just 100km above the surface of the Earth as the official space distance. This is known as the Kármán line.

Named after the engineer that first calculated this altitude, the Kármán line is the altitude at which the atmosphere becomes so thin, that in order for a plane to be able to create enough lift to counteract the gravitational field pulling it back towards the centre of the Earth, its speed must exceed the velocity required to orbit. Beyond this line you officially gain your astronaut wings.

The Soyuz-FG Rocket

Tim will journey to the ISS aboard a Soyuz TMA-M spacecraft launched by a Soyuz-FG rocket. The Soyuz rockets are the most reliable human launching rockets in the world and are currently the only method of transporting astronauts and cosmonauts to the ISS.

Standing just under 50 metres tall (49.5m) the Soyuz – FG rocket comprises a core stage and four liquid fuelled strap-on boosters. The core stage uses a combination of kerosene and oxygen propellants. Sitting on the launch-pad it has a mass of 305,000 kg with 251,350 kg of this mass being fuel and oxidiser. It launches three astronauts and up to 7,100 kg into low Earth orbit.

Time to launch

Tim will launch from the Baikonur Cosmodrome in the deserts of Kazakhstan.

A simplified launch procedure is as follows:

1. The crew will arrive at the launch site over five hours before scheduled lift off time. They will spend an hour of this time putting on their sokol space suits with the help of technicians.

2. 3 hours before launch, the crew is transported to the launch pad and with two and a half hours still to go, the crew climb aboard the Soyuz to conduct pre-launch tests. All the while, the rocket itself is being filled with fuel and oxidiser ready for launch.

3. At T-5 minutes, on-board systems are switched to on-board control, the crew shut their helmets and switch to suit air and the launch key is inserted in the launch bunker.

4. T-2 minutes 30 seconds sees the pressurisation of all of the rocket's tanks begin and 15 seconds later the fuel and oxidiser drains are closed. In the final minute before lift-off, the umbilical towers that carry the pipes to supply the rocket are withdrawn and at T-20 seconds the launch command is given and the engines are turned on. Finally, the launch tower disconnects from the rocket, and the rocket lifts off.

5. After 8 and a half minutes of hurtling towards space aboard the rocket, the Soyuz capsule will separate from the rocket and the crew will spend up to 3 days orbiting the Earth, gradually matching the orbit of the the ISS before docking.

An uncomfortable time

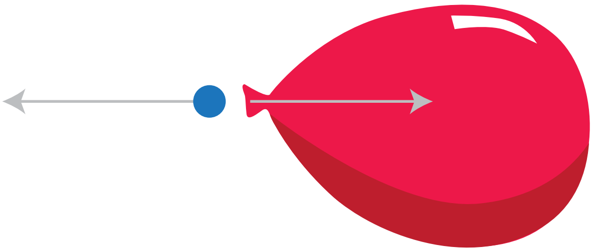
During launch aboard a Soyuz-FG rocket, astronauts can experience up to 4.2 G (that is, over four times the effective force they experience on Earth due to gravity). To withstand this astronauts train in a centrifuge that spins them around at high speed, producing an acceleration towards the centre of the centrifuge of up to 8 G. One way to limit the effects of this g-force on an astronaut is to have them launch in a laying down position. In this direction, the force acts through their body front to back, avoiding the nasty effects of blood draining towards their feet away from their brain or rushing towards their head.

How do rockets work?

Rockets work on the principal of Newton's 3rd law. This states that "for every action there is an equal and opposite reaction." That is, if a force is exerted on an object, it exerts an equal and opposite force back on whatever is pushing it. We see this simply by standing on the floor. Gravity is pulling us down towards the centre of the Earth and makes us push on the floor. Since we do not move downwards through the floor, there must be an equal and opposite force pushing us back up (because a resultant, or overall force, in one direction makes an object change velocity!).

See Newton's Third Law demonstrations under rocket demonstrations

It is now possible to expand this idea to a balloon. When you blow up a balloon, the overpressure produced by forcing the air in and the latex material compressing the air inside, means it is at a much higher pressure than the air outside. If you let go of the balloon, this higher pressure air is forced out behind the balloon. This ejected air pushes back on the balloon with a force equal to the one it was pushed out with, but acting in the opposite direction.



This results in an overall motion for the balloon in the opposite direction. In the diagram below the blue circle represents the expelled air.

While much more complicated than a balloon, the Soyuz-FG rocket works on the same basic principle, however instead of its propellants being air molecules forced out of the back, it is propelled by forcing the products of the combustion (burning) of the kerosene fuel.

(It should be noted here that kerosene is not a single fuel, but rather a mixture of 4 hydrocarbons: dodecane ($C_{12}H_{26}$), tridecane ($C_{13}H_{28}$), tetradecane ($C_{14}H_{30}$), and pentadecane ($C_{15}H_{32}$)).

The simplified combustion equation for kerosene is:

KEROSENE + OXYGEN → CARBON DIOXIDE + WATER + ENERGY

FUEL + OXYGEN → CARBON DIOXIDE + WATER + ENERGY

The heat generated by this exothermic (giving heat out) process also causes the gasses to expand and be ejected at an even greater pressure, increasing the force that they subsequently exert back on the rocket. And while one single expelled molecule will not significantly affect the rocket, billions of them being forced out at once will add up to a huge opposite force – this is what we observe to be the rocket's thrust.

What if something goes wrong?

Unfortunately, getting into space is extremely dangerous and astronauts have been lost on launch.

On January 28 1986, the NASA Space Shuttle Challenger broke apart 73 seconds into its flight, killing all seven crew on board. Investigations concluded that an o-ring seal in the shuttle's right solid rocket booster failed, allowing hot pressurised gasses to escape and destroy the joint connecting it to the external fuel tank. Once this had happened, the solid rocket booster began to detach, causing huge aerodynamic forces that caused the shuttle to violently shake itself apart.

With no crew escape system on board the shuttle there was no way for the astronauts to survive. Those who survived the initial disintegration of the shuttle would sadly have been killed on impact with the Atlantic Ocean.

However, the Soyuz-FG rocket does have an emergency escape system called the ***SAS (Sistema Avariynogo Spaseniya)***. On photographs of the Soyuz, this is the little 'extra rocket' that you see perched upon the top of the Soyuz-FG.

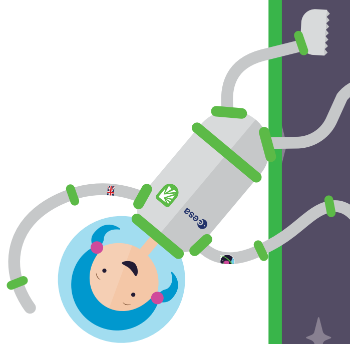
Should anything go wrong whilst on the launch-pad, or in the early part of the journey to space, this system is activated. Escape motors fire for up to 6 seconds, carrying the top two sections of the Soyuz spacecraft (sat at the top of the rocket) away from the main body of the rocket. This system is automatic, but for safety does have a manual override for safety teams to use on the ground should the need arise.

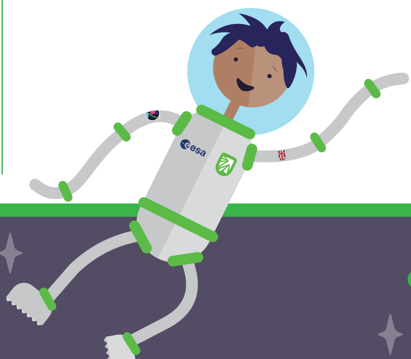
Once clear, the descent module is then separated from the rest of the Soyuz, a separation motor fires, and the descent module falls out of the bottom of the SAS, deploys its parachute and lands as normal.

This system was successfully used in September 1983. 90 seconds before the launch of what would have been Soyuz T-10a, a fire broke out due to the failure of a valve in the propellant lines. The rocket was quickly engulfed, but the automatic SAS trigger failed as the wires were burnt. Two launch controllers were able to send radio commands from the launch blockhouse and the SAS was triggered 12 seconds after the fire began. After being subjected to g-forces of up to 17 G, Cosmonauts Titov and Strekalov landed safely 4km away from the launch vehicle, which exploded seconds after the successful escape.

Safe journey!

So while launch is indeed one of the most dangerous times for an astronaut, Tim is in the safe hands of the most successful human spaceflight launch system in the world, with an emergency escape system and an excellent safety record.





Credit: ESA–S. Corvaja

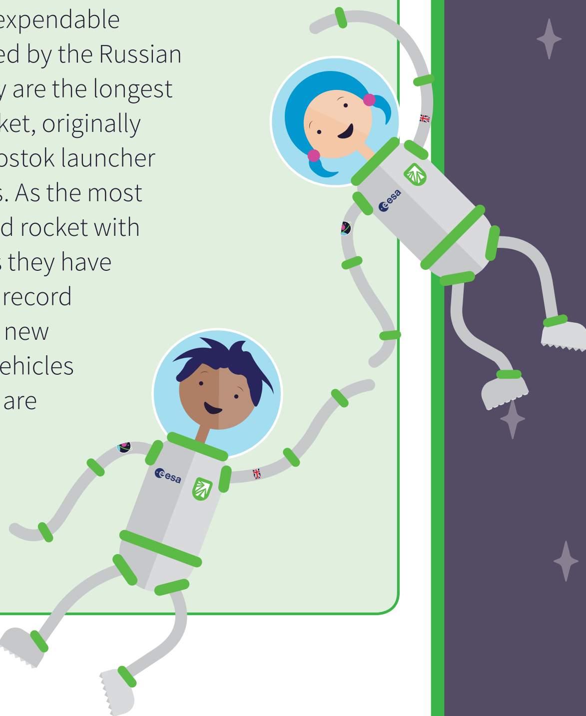
SOYUZ ROCKET

Launching Tim into space

Programme Use: Across the programme

Overview

Soyuz rockets are expendable launch vehicles used by the Russian space agency. They are the longest serving type of rocket, originally derived from the Vostok launcher from the late 1960s. As the most frequently launched rocket with over 1700 launches they have an excellent safety record and until the USA's new commercial crew vehicles are in service, they are the only way to get people to the ISS.



How it works

1 ***Are all Soyuz rockets the same?***

Different launch specifications require the Soyuz rocket to be configured in slightly different ways. The configuration used to launch astronauts to the ISS is called the Soyuz-FG.

2 ***What is the rocket like?***

Standing just under 50 metres tall the Soyuz – FG rocket comprises a core stage and four liquid fuelled strap-on boosters. The core stage uses a combination of kerosene and oxygen propellants. Sitting on the Launchpad it has a mass of 305 000 kg with 251 350 kg of this mass being fuel and oxidiser. It can launch up to 7 100 kg into low Earth orbit.

It is an example of a three stage rocket. The first stage is the strap on rocket boosters you see near the bottom of the rocket. The second stage is the large kerosene and liquid oxygen powered middle section and the third small stage boosts the Soyuz space craft until separation. After this, the Soyuz spacecraft will use its own thruster systems for manoeuvring in space.

3 ***Where are the astronauts?***

On launch, the astronauts are strapped in to the central section of the Soyuz spacecraft which sits within the uppermost white section, or 'Nose Fairing'.

4 ***In photos, sometimes the rocket is grey sometimes white, is there a difference?***

When the lower half of the rocket looks white, like in the above image, it is actually frost from the cold liquid oxygen that is in the rocket ready to mix with the fuel to help it burn. It is actually painted grey on the bottom half.

5 ***What is the tiny rocket on the top for?***

This is the Escape Tower. It is able to launch the astronaut's capsule away from the main rocket in the event of an emergency on the launch pad or in the first few minutes of flight.

Launch Timeline

Tim will launch from the Baikonur Cosmodrome in the deserts of Kazakhstan.

The crew will arrive at the launch site over five hours before scheduled lift off time. They will spend an hour of this time donning their space suits with the help of technicians.

3 hours before launch, the crew is transported to the launch pad and with two and a half hours still to go, the crew climb about the Soyuz to conduct pre-launch tests. All the while, the rocket itself is being filled with fuel and oxidiser ready for launch.

At T-5 minutes, on-board systems are switched to on-board control, the crew shut their helmets and switch to suit air and the launch key is inserted in the launch bunker.

T-2 minutes 30 seconds sees the pressurisation of all of the rocket's tanks begin and 15 seconds later the fuel and oxidiser drains are closed. In the final minute before lift-off, the umbilical towers that carry the pipes to supply the rocket are withdrawn and at T-20 seconds the launch command is given and the engines are turned on. Finally, the launch tower disconnects from the rocket, and the rocket lifts off.

After 8 minutes 30 seconds of hurtling towards space aboard the rocket, the Soyuz capsule will separate from the rocket and the crew will spend up to 3 days orbiting the Earth, gradually matching the orbit of the ISS before docking.

Additional information

For supplier information, risk assessments, and additional resources please see digital content on ***www.destinationspace.uk***

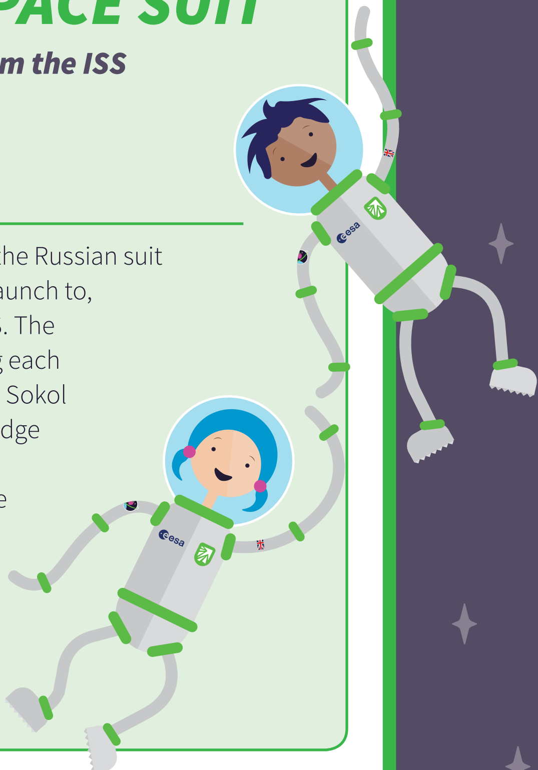
SOKOL SPACE SUIT

Survival to and from the ISS

Programme Use:
Across the programme

Overview

The Sokol space suit is the Russian suit that Tim wears during launch to, and return from, the ISS. The programme is providing each centre with an excellent Sokol costume (to our knowledge the first specifically produced replica) to use across the programme for promotion, engagement and PR.



How it works

1 *Why does Tim need a space suit during launch and landing?*
Launch and landing are the two most dangerous times for an astronaut. When Tim's Soyuz spacecraft rides the Soyuz-FG rocket into space, it will be riding an enormous explosion the whole way. The pressures and forces, as well as possible micrometeoroid strikes can potentially cause damage to the craft allowing the atmosphere inside to leak out, exposing the astronauts to the vacuum of space. On re-entry, with temperatures of around 1600°C acting on the entry module, similar problems arise. This was seen with the crew of Soyuz 11. During re-entry their spacecraft became depressurised, and when the ground team went to recover the crew, all three had died due to exposure to vacuum conditions.

2 *Why does the Sokol suit look so different from the suits worn during a spacewalk?*
The Sokol suit is essentially a survival suit. It is designed purely to keep an astronaut alive long enough for them to fix the problem, or get back down to Earth. The Sokol suits do not have a built in life support system but instead is connected directly to the spacecraft. EVA suits have a backpack which provides life support.

3 *How does the suit protect an astronaut?*
The suit is designed to maintain air pressure by being connected to life support systems within the Soyuz craft. Astronauts get into the suit through an entrance hole in the stomach area of the suit. Once inside an astronaut seals the air-tight bladder by gathering together the excess of fabric around this hole through which they climbed. This is then tied shut with a rubber band and an inner pressure layer in the suit ensures that the pressure inside can be maintained. The suit is designed to support life inside the suit for a total of 30 hours in a pressurised environment and around two hours in an unpressurised one.

The suit is designed to cause minimum interference to an astronauts movements and work in a pressurized cabin but is able to provide life support including, oxygen, electrical power, ventilation and temperature via the Soyuz. The suit comes with a small portable life support pack. However, this is only a short temporary resource until an astronaut can connect to the Soyuz. Although not designed for an EVA the Sokol suit bears a number of similarities to a spacewalking suit.

The suit is connected via pipes to equipment within the Soyuz craft which provides the suits life support systems. A regulation valve can be found on the chest. Padded areas around the knees and inbuilt fabric soles help to keep pressure and make the suit more hardwearing.

4 ***What is the suit like?***

The suit consists of two main layers, an outer restraint layer of white nylon canvas with royal blue trim, and an internal pressure bladder of rubber and rubberized material. The helmet is built into the suit giving it a soft hood with a hinged plastic visor.

Additional information

For supplier information, risk assessments, and additional resources please see digital content on ***www.destinationspace.uk***

WHOOSH BOTTLE

Rocket in a bottle

Programme Use:
Family show, 7-11 and 11-14 workshops

Notice: The bottle should not be used if cracks can be seen. Keep audience at a safe distance

Overview

To get to the ISS, astronauts are riding a controlled combustion reaction into space. While there are many different types of rocket, they all work on the same fundamental principles and this demonstration shows the simplest rocket motor.

How it works

1. ***What do we put into the whoosh bottle?***
   Just like a real rocket we use a fuel and an oxidiser so that combustion can take place. The fuel is industrial methylated spirits (IMS) and the oxidiser is the oxygen already present in the bottle (approximately 20%).

2. ***What happens when the mixture is lit?***
   When the mixture is lit, the IMS reacts with the oxygen in a combustion reaction. This produces carbon dioxide and water vapour. The combustion reaction also produces a lot of heat energy which causes the product gases to heat up and expand, being forced out of the neck of the bottle creating the characteristic 'whoosh'.

3. ***Why don't we light the whoosh bottle 'upside down' like a real rocket?***
   If the whoosh bottle was lit with the neck towards the floor, the gases escaping, through Newton's third law of motion would propel it up. However the bottle is not aerodynamically shaped and its flight would be very unpredictable. As a result, this is not a safe version of this demonstration to do in front of an audience.

Experiments to try

Demonstrating a simple rocket

Explain that this demonstration shows the basic principles of how a rocket works. All rockets are effectively a vessel that you fill with a fuel and oxidiser that will allow combustion to take place. Instead of keeping the propellants separate, this simple version will directly combine them.

The oxidiser we are using is the oxygen in the air in the bottle. The fuel is industrial methylated spirits (IMS).

Add 30ml of IMS to the bottle and put a plastic cup on the top (to prevent any of the liquid escaping). Spend the next 30 seconds shaking and rotating the bottle to get as much of the ethanol evaporated as possible. While doing this you can hug the bottle to increase the temperature, and explain what is happening.

After 30 seconds, remove the cup and pour out any remaining IMS, replace it in the IMS bottle and screw the lid back on. Put the plastic cup back on the top of the whoosh bottle and stand it on the ground at least 3 metres away from the audience.

Light a splint on the end of a metre ruler and remove the cup from the top of the bottle. Standing at arm's length, count down from 5 and light the whoosh bottle by putting the splint about 2 cm into the top of the neck. Stand back and observe the whoosh.

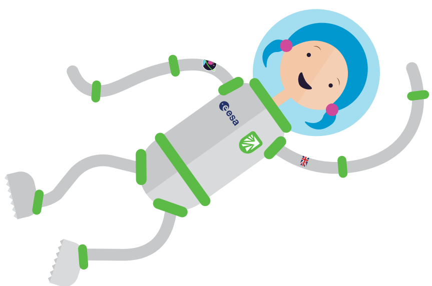
Once the demonstration is complete, pick up the bottle and empty the liquid left inside into a beaker. Note that the liquid is water left in the bottle after the reaction

Reiterate the following:

FUEL + OXYGEN → CARBON DIOXIDE + WATER + ENERGY

Pass the bottle around the audience so that they can feel how warm it has become as a result of the combustion reaction that took place.

As you pack away, check the bottle for signs of damage, particularly around the neck. If it is damaged, then replace the bottle.



Links to Tim's mission

All rockets use the same principles to get off the ground. While the fuel used is different (for example the space shuttle main engines ran on liquid hydrogen, whereas the Soyuz FG that Tim will launch on runs on kerosene) the use of combustion to provide an expanding gas to produce a thrust force is uniform. A key area in the reducing the cost of space exploration is to find more efficient (and in the case of burning kerosene, less environmentally unfriendly) fuels.

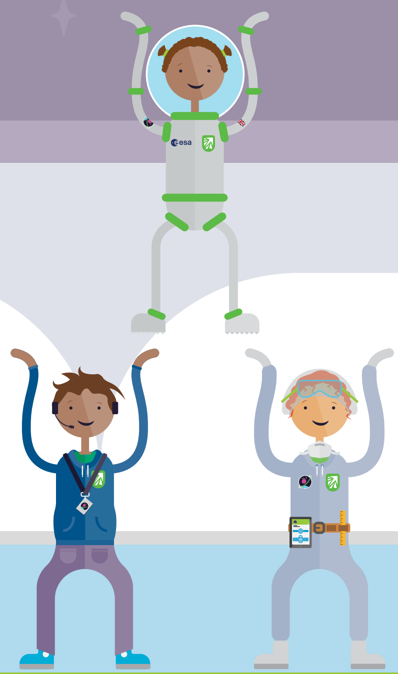
For more information on how rockets get into space, please refer to the hovercraft briefing sheet.

Safety note

It is vital that you are fully familiar with the health and safety details of these demonstrations before you begin.

Additional information

For supplier information, risk assessments, and additional resources please see digital content on ***www.destinationspace.uk***



OXYGEN AND HYDROGEN DEMOS

Riding a controlled explosion into space

Programme Use: family show, 7-11 and 11-14 workshops

Overview

To get into space we need two things; a lot of energy and a large amount of thrust to fight gravity. For Tim's mission this is achieved through riding a controlled combustion reaction to the ISS and combustion can be demonstrated excellently with oxygen and hydrogen.

Usage Notice

Combustion danger! Wear goggles, keep public a safe distance back, provide ear defenders for volunteers.

How it works

1 ***What is combustion?***
Combustion is the scientific word for burning. It is a chemical reaction that requires fuel, something to provide oxygen (an oxidiser) and an ignition source to take place.

2 ***What is produced during combustion?***
Depending on your fuel and how completely it burns, various products can be made. However most combustion reactions can be simplified to this equation:

FUEL + OXYGEN → CARBON DIOXIDE + WATER + ENERGY

3 ***What fuel does the Soyuz FG rocket use?***
Unlike the Space Shuttle (and these demonstrations) which use hydrogen as the fuel, the Soyuz-FG rocket that Tim will launch on will be loaded with 251 350 kg of fuel (kerosene) and oxygen. In addition it has 4 liquid fuelled strap on boosters.

Experiments to try

1 ***Pringles rocket***
You will need: Pringles can (empty or full – ensure foil lid has been removed), screwdriver/scissors, lighter, bladder/balloon of hydrogen gas, tubing.

Remove the foil lid from pringles can and replace the plastic lid. Puncture the can twice with one hole in centre of the metal base and one in the side of the can about one inch from the plastic lid.

Place the can upside down with the plastic lid resting on the floor and the metal base pointing up

Using the tubing and hydrogen bladder purge the air from the can replacing it with hydrogen. Insert the tubing into the hole on the side of the can (this should now be at the bottom) the hydrogen will then fill from the bottom evacuating the air through the top of the can.

Once evacuated (this is a judgement call, use plenty of gas to be sure) remove the tubing.

Light the hydrogen via the hole at the top of the can. At this point a faint flame will be visible as the hydrogen burns. As this happens the hydrogen inside is being used therefore being replaced by air drawn into the tube via the hole on the side of the can.

Once sufficient air has entered the can and mixed with the hydrogen, the hydrogen oxygen mix will be correct to react (forming water - explosively).

The reaction will be set off through the combination of the correct mix (two parts hydrogen to one part oxygen) and the flame will ignite the mixture. The plastic lid being the weakest point will be the point of release and this will propel the can into the air.

2 ***Exploding hydrogen/oxygen bubbles***
You will need: Bowl, balloon, oxygen gas, hydrogen gas, tubing with closable valve, long lighter, water, washing up liquid.

Fill the balloon with mixture of gas, one part hydrogen to one part oxygen. Attach the balloon to the tubing and close the seal.

Note: Using two parts hydrogen to one part oxygen produces a much bigger bang, but this may be too loud for your presenting area.

Fill the bowl with water and add the washing up liquid. Submerge the tubing outlet and bubble the gas through the water.

Remove the tubing and balloon containing any excess gas once sufficient bubbles have formed. Set aside the balloon.

Scoop one handful of bubbles and scrape the back of your hand against bowl to remove excess bubbles. If you like you may wish to moisten your arms with water.

Ignite the bubbles with the lighter.

Links to Tim's mission

All rockets use the same principles to get off the ground. While the fuel used is different (for example the space shuttle main engines ran on liquid hydrogen, whereas the Soyuz FG run on kerosene) the use of combustion to provide an expanding gas to produce a thrust force is uniform. A key area in the reducing the cost of space exploration is to find more efficient (and in the case of burning kerosene, less environmentally unfriendly) fuels.

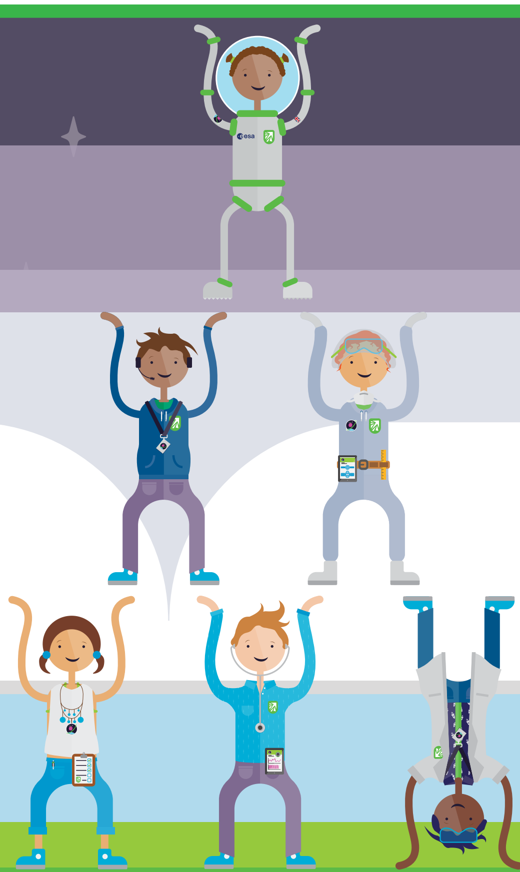
For more information on how rockets get off the ground please refer to the hovercraft briefing sheet.

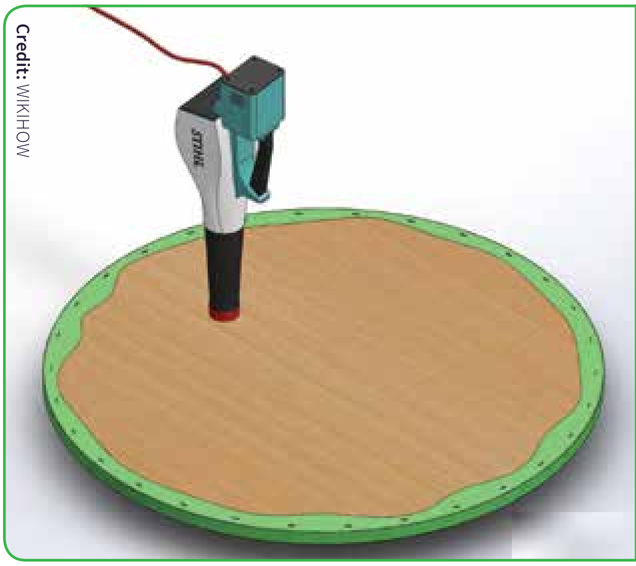
Safety note

It is vital that you are fully familiar with the health and safety details of these demonstrations before you begin.

Additional information

For supplier information, risk assessments, and additional resources please see digital content on ***www.destinationspace.uk***





Credit: WIKIHOW

HOVERCRAFT

Rocket science: Newton's laws in action

Programme Use: Family show, 11-14 workshop

Overview

Rocket science is a term that is often used to describe something very difficult, but the basics of rocket science boil down to a simple set of rules – Newton's laws of motion. The hovercraft provides an engaging and extremely fun way to demonstrate these laws and to link this to what makes the Soyuz-FG rocket (the rocket that takes astronauts to the ISS) get off the ground.

How it works

1 ***What are Newton's laws of motion?***

Sir Isaac Newton discovered three laws which described the way all objects will move and interact with each other.

First law: An object will continue to stay at rest, or move with the same speed and direction unless acted upon by an overall force.

Second law: If you exert a force on an object, it will speed up (accelerate) and the acceleration depends on the object's mass and the force. This is also known as $F = ma$ (Force = mass x acceleration).

Third law: For very action there is an equal and opposite reaction.

2 ***Why do we need a hovercraft to demonstrate these laws?***

If you push the hovercraft along the floor, Newton's first law suggests it should keep going with the same speed and direction, but this does not happen. Contact with the floor produces friction, which acts as the overall force to slow the hovercraft down. The hovercraft removes most of this friction and allows effective demonstrations of Newton's laws.

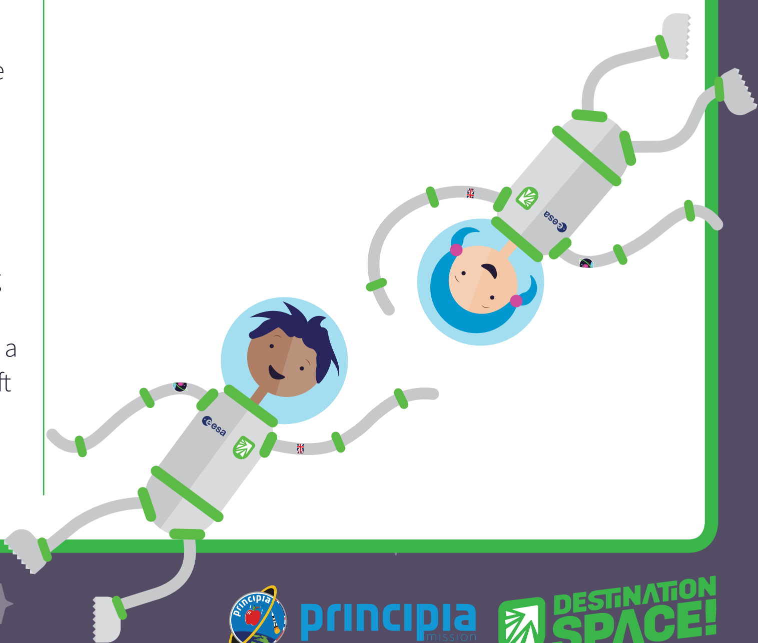
3 ***How does the hovercraft work?***

The hovercraft consists of a wooden board with a skirt attached underneath it and a valve connecting the board to the skirt. The skirt has holes below it that allow air to filter out underneath the skirt when a leaf blower is attached to the valve. As the hovercraft rises on a layer of air, the contact with the ground is largely removed and as a result the friction force becomes much less.

4 ***How do Newton's laws explain how a rocket works?***

When the Soyuz-FG launches, a combustion (burning) reaction takes place in the engine causing products of carbon dioxide and water vapour to heat up and expand. They are forced out of the back of the rocket, each one being pushed away with a certain force. Newton's third law states that each one of these molecules pushes back on the rocket with an equal and opposite force, so a thrust is produced on the rocket.

Since billions of molecules are being pushed out of the back of the rocket per second, their combined forces provide a huge thrust. Newton's third law explains why we need billions of these molecules. If the molecules need to produce a force great enough to launch a rocket, and each molecule has only a tiny mass which can only exert a tiny force, then consequently, billions of molecules per second are needed to produce a big enough force, and therefore a big enough acceleration on the rocket to get it off the ground.



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Experiments to try

1 Newton's first law

Push the empty, unloaded hovercraft along the floor and note how quickly it stops.

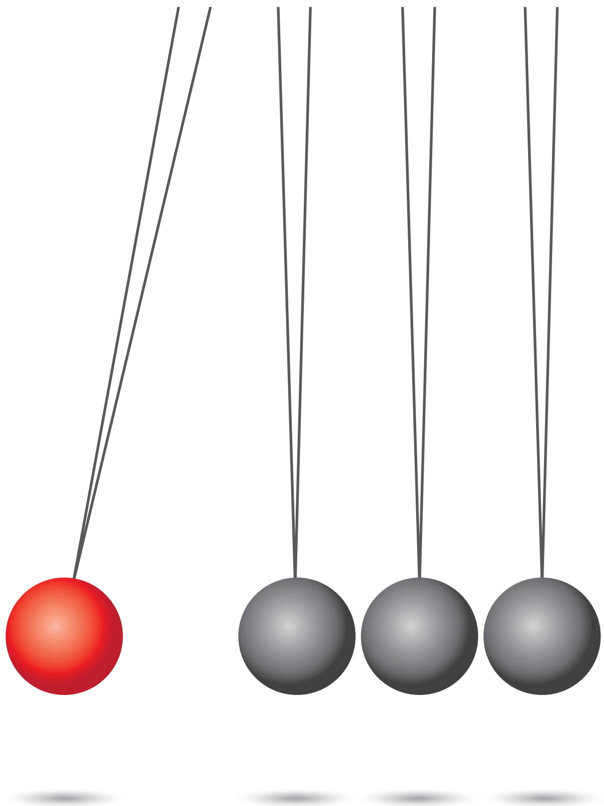
Select a member of the audience to sit on the hovercraft. Get them to sit as centrally as possible and to keep one hand on the leaf blower.

Select a couple more members of the audience (depending on the space you have) and spread them out. Explain that we are now going to play some human football and ask them to 'pass' the hovercraft back to you very gently. Turn on the leaf blower and gently push the hovercraft to one of the volunteers – be careful to watch that it does not get too fast.

2 Newton's second and third laws

Select a new volunteer (someone fairly light but obviously strong enough to throw the heavy medicine ball). Hand them the medicine ball and explain to them that this is their exhaust molecule. Position them so that they are about a metre in front of where you will stand, and facing you (with at least 2 metres of space behind them). Ask them to throw you the ball when you ask, and tell them that you will pass it back to them and they should throw it back to you once they have caught it.

When they throw the ball to you, they will move back due to Newton's third law, but only a little (due to Newton's second law) since their mass is large and the force acting on them is small. By throwing the ball again they receive an extra force (just like a real rocket) and will speed up.



Links to Tim's mission

There is a lot of research being conducted into fuels for space exploration. In this field there are two main areas of focus; generating enough thrust to get off the ground, and once in space generating the biggest increase in speed for the smallest mass of fuel (an property known as specific impulse). When a rocket is ready to launch, over 90% of its mass is fuel. If we could find a way of generating the same thrust for a lower mass of fuel, space travel would become much cheaper.

F=ma (newton's second law) is used to measure an astronauts mass whilst in space. Normal scales float! The astronaut uses a device which pulls them into a rack using a known force. Acceleration is measure and the mass is calulated.

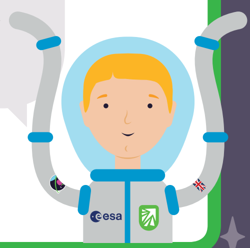
Additional information

For supplier information, risk assessments, and additional resources please see digital content on ***www.destinationspace.uk***

Tim's Space Timeline

21st June 2004

First privately funded human spaceflight. SpaceShipOne went on to win the Ansari X Prize for creating a non-government, reus-able manned spacecraft that flew above the Karman line but not into orbit.



MAGNETIC SOYUZ

Pin the spacecraft on the ISS

Programme Use: 5-11 storytelling, 7-11 workshop

Overview

A microgravity environment has many adverse effects on an astronaut. Once in a freefall orbit of the Earth there is no up or down, and no difference between a floor and a ceiling. This can make astronauts feel sick and disorientated until they get used to this strange environment. This demonstration shows students how even simple tasks are difficult when they are disorientated.

How it works

The magnetic image of the International Space Station and magnet Soyuz is to be used in the 5-7 storytelling workshop when the children have reached the ISS in the Soyuz and need to dock. In the 7-11 workshop it is used during the training part of the workshop. On arrival they may be feeling dizzy and space sick as they are not used to being weightless, so the presenter will select 3 volunteers, give them each a magnetic Soyuz and then spin them a few times so they become dizzy. They will then ask them to place the Soyuz Rocket in the correct location on the image of the ISS.

Links to Tim's mission

On arrival at the ISS many astronauts suffer from the effects of microgravity and feel dizzy. This can take time to get used to. To help prepare for this, Tim has trained on the 'Vomit Comet', an aircraft that flies in a parabolic (freefall curve under gravity) arc that means the plane falls away from him at the same rate that he falls towards the Earth. In short, he becomes weightless for the 20 second parabolic period of the flight However, even multiple 20 second microgravity experiences will not entirely prepare him for the effects of long term microgravity.

Additional information

For supplier information, risk assessments, and additional resources please see digital content on ***www.destinationspace.uk***

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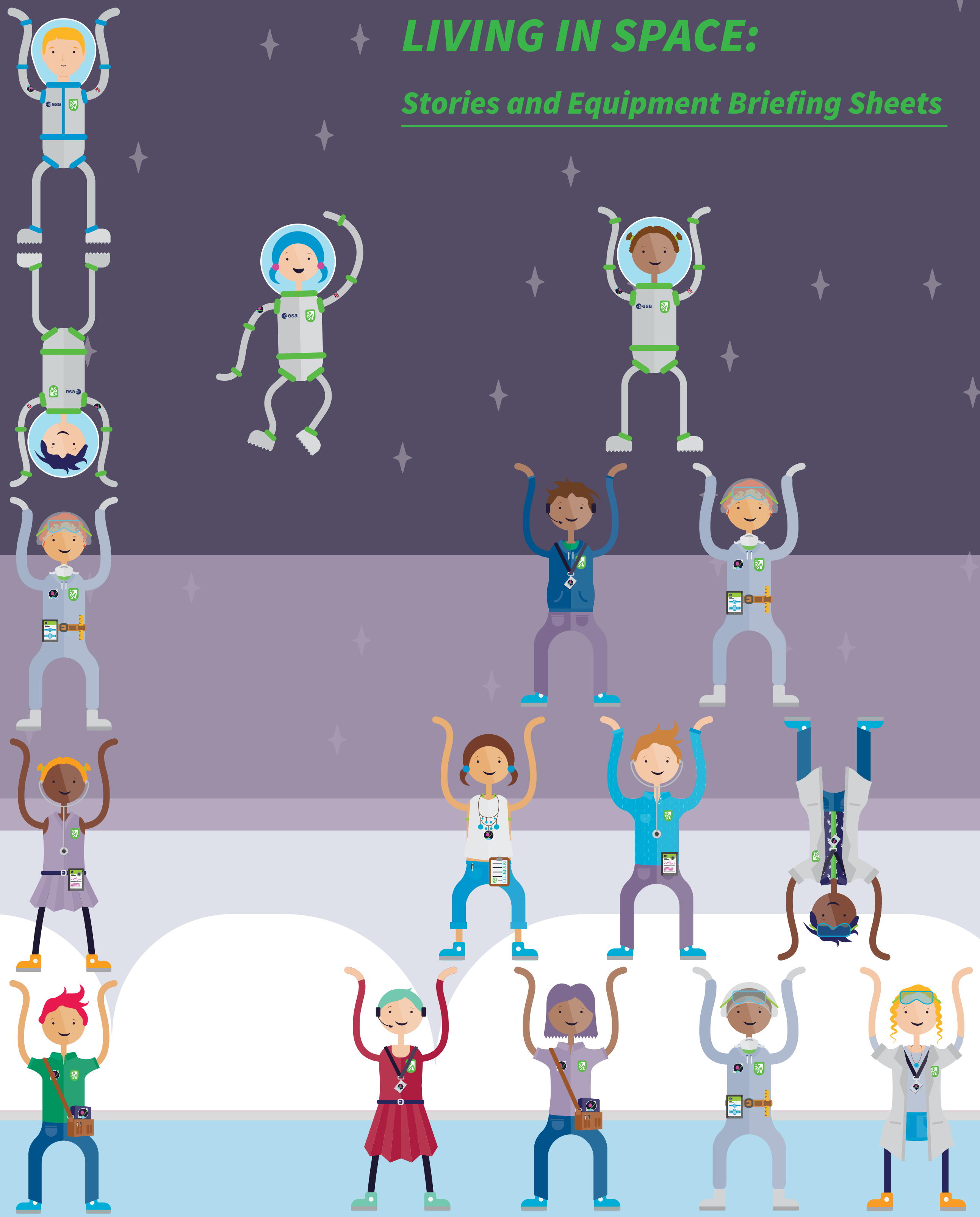
LIVING IN SPACE:

Stories and Equipment Briefing Sheets



LIVING IN SPACE

For most astronauts, a mission to space will last for approximately six months. During this time they will call the International Space Station (ISS) home and most consider their fellow crewmates as a temporary family.

Many trials and challenges accompany living in the strange and unfamiliar environment of Earth's orbit. Years of training are put in place to try to prepare every potential space traveller for living in space but there are some things that are just too different for us to accurately replicate on the Earth.

Living in space is an on-the-job learning experience. Every day, astronauts can get more and more familiar with the space environment and the complications it can bring, both physically and mentally. It's not all bad news though; the ISS and its microgravity environment give an astronaut an experience that is literally out of this world.

The Dangers of Living in Space

Space is a hostile environment with a host of potential dangers. An astronaut relies on the ISS to provide all the life support systems for them that space does not provide as well as to protect them. Astronauts must work with their crewmates and mission controllers to safely maintain their protective bubble in the vacuum of space.

Having lived on the surface of the Earth for all our lives we don't often realise just how much we rely on the air that is constantly pushing in around us, but without it we would swiftly be forced to notice. The virtually non-existent air pressure in space means that there is no readily available supply of oxygen, a big problem when it comes to breathing.

Humans have evolved on the Earth below an ocean of atmosphere extending hundreds of kilometres above us. At sea level, this atmosphere pushes on us with a force of 101,000 Newtons on each square metre of surface area. But we do not get crushed because we are internally pressurised, with gases in our organs, tissues and even dissolved in our blood exerting an equal force outwards.

In a low pressure environment (such as the vacuum of space) these internal bodily gases would expand to equalise with the low pressure outside, with potentially fatal consequences. Although a human's skin is fairly well equipped for resisting this expansion, there are other areas of the body that are more susceptible to the effects of decompression. Rapidly expanding air can force its way out of the lungs so quickly that it can blow out the teeth that get in the way out of the mouth. Add to this the fact that water boils at below body temperature in a vacuum and the chances of unaided human survival are not looking good.

The atmosphere protects us in other ways, reducing exposure to dangerous and damaging forms of energy in space such as solar radiation, ultraviolet and cosmic rays. Much of this protection is lost when orbiting approximately 400km above the Earth's surface and bathing in the sun's rays without protection. In direct sunlight in space, you would be suffering at a temperature of about 120°C.

As well as keeping dangerous things out, our atmosphere is also brilliant at insulating planet Earth and keeping it relatively warm. Without an atmospheric blanket energy can radiate into space resulting in a chilling temperature of around -130°C in the shade.

To deal with all of these hazards an astronaut has to rely entirely on the ISS to provide all the life support and protection they need to survive. Outside of the station an astronaut depends on their spacesuit to act like their own personal spacecraft. However, there are some things that we just cannot currently protect an astronaut from and the microgravity environment of the ISS is one of them.

Physical Effects of Microgravity

Living in a constant state of freefall without the effects of gravity (see microgravity briefing sheet) has a huge impact on the human body, and with each ISS mission we learn more about the human ability to adapt to space. Some of these effects can impact the day-to-day life of an astronaut whilst others might only be noticed upon their return to ground.

Space Adaption Syndrome

Space Adaption Syndrome (SAS) is often referred to as Space Sickness and it can have a profound effect on new arrivals to the ISS. Here on the Earth we rely heavily on gravity, not just to keep our feet on the ground but also to help us to figure out things like 'where is the ground?', 'which way is up?', and 'where are my limbs?'. Without the effect of gravity around to act as a signal, the weightlessness of space can be a very confusing place to find your feet.

Here on Earth we are able to keep our balance with the use of a network of fluid filled channels found within the inner-ear. This is known as the vestibular system and can identify the pull of gravity relaying this information to the brain for processing. Without the effect of gravity working on this system an astronaut lacks some of the information they rely on normally to tell them which way is up and which way is down.

This results in a malady that can be similar in many ways to the motion sickness that some experience on Earth, such as travel sickness. This occurs when our balance sensors and eyes provide inconsistent information and the brain becomes confused as to how to interpret these signals. When an astronaut first arrives on the ISS it is not uncommon for them to feel some form of space sickness with symptoms such as nausea, vertigo and headaches a regular problem. Luckily, the brain quickly adapts to processing this mismatch of information and most astronauts are relieved of their symptoms within a few days of being on-board.

As well as having trouble getting used to the fact that they cannot feel the difference between 'up' and 'down' astronauts can also sometimes find that they 'lose their limbs'. Part of the nervous system is responsible for an important practice known as proprioception. The proprioceptive system uses the influence of gravity on muscle and joints to help our brains determine the location of the different parts of our bodies in space without looking at them. Think about when you have played a sport with some kind of bat or racket; it is possible to make contact with the relevant ball without having to look at both the ball and bat. The proprioceptive senses make it possible to figure out where limbs are without having to use visual data.

In weightlessness some of the information for this system is missing. This often means that if an astronaut is not actively using their limbs, they may sometimes lose track of where their arms and limbs are in relation to the rest of them, leaving them with a strange sensation of not being able to feel them.

Physiological changes

For the duration of their stay a space traveller has to deal with a number of differences between life on Earth and life in microgravity. On Earth it takes a lot of effort for the human heart to force blood up the body against the force of gravity. In space the fight isn't nearly as difficult but the heart still pumps as hard to begin with. Due to this, astronauts get red, puffy faces as more of their blood is able to make its way to their heads. This lack of gravitational effect also makes astronauts feel like they have a cold with a very blocked nose as mucus stays stuck in their nose and throat. This greatly reduces their sense of taste and smell. Fluid will build up in the chest area and the body interprets this as over-hydration leading to a more frequent need to urinate and mineral loss.

Astronauts become taller in space as the shock absorbing, cartilage discs between a person's vertebrae in their spines are able to expand to their full size without the force of gravity to compress them. This can make up to a few inches of difference in a person's height, although it does increase an astronaut's risk of a slipped disk upon their return to Earth. This can also cause the spinal cord to stretch which is another reason astronauts suffer from headaches.

The rough skin on the soles of the feet is lost in space as rough and tough skin is only needed to project the soles of your feet when they are used regularly to walk and stand. However astronauts get new areas of tough skin on the tops of their feet where they hook their feet under rails to steady them.

Perhaps the most significant physiological change is the loss of muscle mass and bone density. Astronauts don't have much use for their muscles and skeleton in the microgravity environment. Without much use the body starts to break down some of the muscles it doesn't think it needs anymore. Couple this with the fact that an astronaut's internal chemistry means that bones waste away much quicker in space and the result is that astronauts probably wouldn't be able to hold up their own head, let alone walk, when they return to Earth. To counter this all astronauts must complete at least two hours of exercise everyday with specially designed gym equipment. This helps to slow down some of the wastage but astronauts are still weaker when they return home.

Psychological Effects

Although the psychological effects of spaceflight have not been as well studied, there is certainly significant mental as well as physical strain on an astronaut. An astronaut's job brings with it a large amount of stress and pressure. Astronauts live in a confined environment on the ISS and must deal with living in close quarters with only their crewmates for a long time. In addition, they must deal with being away from their family and friends with only voice and video communications.

The day-to-day routine of an astronaut sees them having to complete many important activities, which may include science experiments, technology installation, repairs and day-to-day chores. This requires concentration and drive to perform well every day.

Seeing sunrise and sunset out the window every 90 minutes and other factors mean that an astronaut's circadian rhythm (the physical, mental and behavioural changes that follow a roughly 24-hour cycle, in response to light and darkness) may be disturbed. If this is affected it can result in psychological stress and changes to the neurobehavioral responses that can lead to conditions such as anxiety, insomnia and depression.

Effect on Routine Tasks

Space can make the most mundane of day-to-day tasks very different, perhaps even requiring special equipment and training. Below are a few examples.

Eating

Most food available on the ISS is dehydrated, vacuum packed or tinned and carefully packaged. Food cannot really be mixed in space thanks to weightlessness. Instead astronauts tend to eat from the bag so that not too much food can be lost to make a mess. For a similar reason food that is crumbly is not allowed. Fresh food is a rare occurrence on the ISS as supply craft are the only way of getting items to the crew.

Going to the Toilet

In microgravity it is very easy for both liquid and solid waste matter to escape which is a health issue for the crew. A specially designed toilet which needs special training is therefore needed on the ISS (see space toilet briefing sheet).

The space toilet has different ways of collecting liquid and solid waste but both require suction to make sure that no waste can escape. The liquid waste that is collected is recycled, whilst solid waste is collected and packed onto waste vessels that will be burnt up when the waste vessel is released and enters the atmosphere. Without the effect of gravity acting on the liquid in their bladders, astronauts tend to find it more difficult to tell when they need to go to the toilet and therefore have to go more often to be safe.

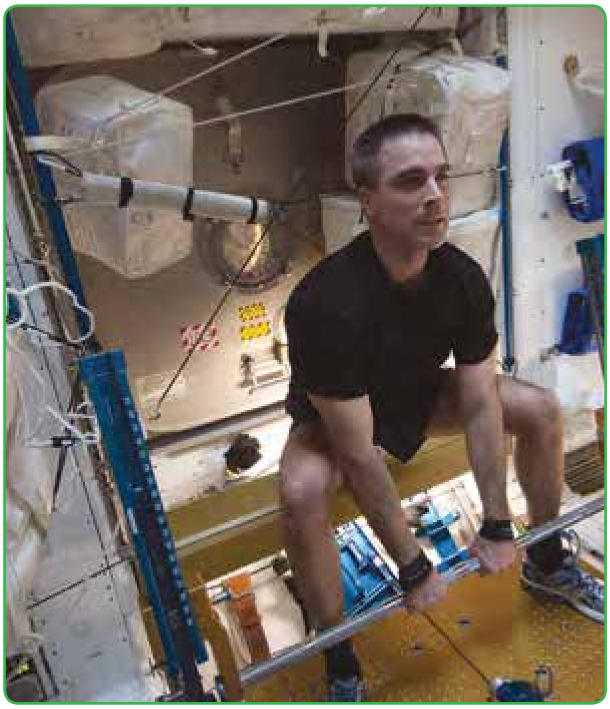
Keeping clean

Liquids act very differently in space. In weightlessness the surface tension of water means that this liquid naturally forms a spherical shape held by its own surface tension. It can move along surfaces in giant, globular water droplets instead of taking up the shape of its container as we see on Earth.

Therefore, it is not possible for the normal ways of washing, such as baths and showers, to be used on-board the ISS. Running water is difficult to control and can potentially be a hazard to the equipment on the spacecraft. A shower was installed on Skylab, an earlier space station, and there were plans for one on the ISS. However constraining the water and keeping it clean proved to be more trouble than it was worth. This means that astronauts must rely on simple wet wipes to keep clean.

Exercise

Astronauts must complete workouts every day but it is difficult to lift weights when things don't have a weight in microgravity. Instead special resistance workout equipment has been designed for use on the ISS and activities such as the treadmill require an astronaut to be held in place with elastic material whilst working out. An astronaut's exercise is designed and strictly monitored by mission controllers back on Earth.



Sleeping in space

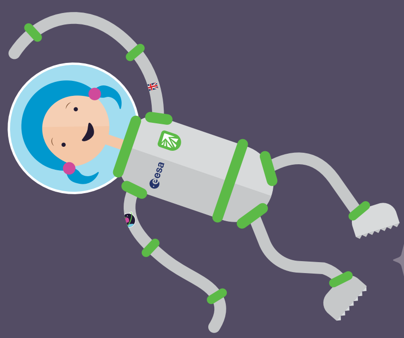
According to a number of space travellers, orbit is one of the most comfortable places to sleep. Without the effect of gravity to hold you to a bed astronauts, instead, must strap themselves into sleeping bags which are attached to the wall in their bunk. Astronauts still continue to float whilst they are sleeping meaning that there are no uncomfortable pressure points and so all of their muscles relax. In fact, sleeping crew in space often look like zombies in space as their arms relax and their arms float up in front of them.

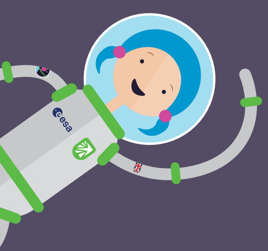
Relaxing in space

Confined on the station, recreational activities are somewhat limited. Reading and watching movies is not much different to down here on the Earth, but sports are a different matter. Many crew members make up their own space sports with special microgravity rules. And famously, Canadian astronaut Chris Hadfield recorded several songs whilst on an ISS mission.

The crew can call and email their friends and family in their free time. One of the big ways to relax and use up free time on the station is to admire the extraordinary views, especially those available from the large Cupola viewing bay. Windows on the ISS let crew look back to planet Earth and out to the stars and as a result photography is a good interest to have whilst in space.

Life in orbit can be difficult and dangerous, but is also truly special and unique. The experiences and activities undertaken, the camaraderie with a small elite crew and the overview effect gained by looking back at our planet, seeing it as a whole entity rather than a collection of countries and factions, provides an amazing, unforgettable experience.





MICROGRAVITY

Understanding why astronauts float

Programme Use: Across the programme

Overview

It is often said that “In space there is no gravity”, but is a common misconception. The Earth’s gravity field is certainly acting upon the ISS, since it is this force that keeps the ISS in its orbit around the Earth. Without gravity acting upon the ISS, it would shoot off into space. At the altitude of the ISS, around 400 kilometres, the Earth’s gravity is still 90% as strong as it is on the surface. So how come the astronauts float around? Why don’t they feel this gravity?

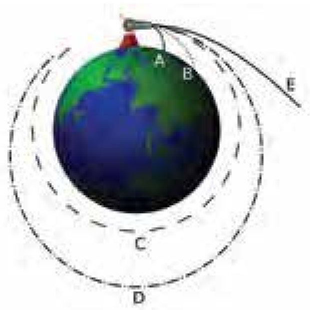
How it works

1 *What is an orbit?*

Newton’s cannon is a thought experiment devised by Sir Isaac Newton to help describe why orbits occur. Imagine a giant cannon firing a cannon ball. The ball has velocity in its initial direction but is pulled down by gravity and as a result falls back towards the Earth on a curved path, finally hitting the ground. Now imagine the cannon is so powerful that it shoots the ball with so much speed that the curve of its path matches the curve of the Earth. The Earth curves away beneath the ball as it falls. In this example, the ball would continue to fall forever around the Earth, never reaching the ground - this cannonball has gone into orbit. The ISS is doing the same thing, constantly falling around the Earth, but it is travelling so fast, it will never hit the ground. The ISS and everything on-board is in a constant state of freefall.

2 *What is freefall?*

Most people experience instances of microgravity in their everyday lives. For example, when a car goes over a bump in the road, or when a lift starts to go down people often feel their stomach lurch and have the impression of being lifted up. This is because as the car/lift falls back to Earth, both them and their passenger are falling back to the Earth at the same rate – technically, the car/lift is falling away from their passengers at the same rate the passengers are falling towards them. So, when an object is freely falling under gravity anything



within it will float around, just like the astronauts on the ISS.

3 *Why do we use the term microgravity?*

You might hear people referring to ‘no gravity’ or ‘zero-G’, but the official term for the weightlessness experienced when in orbit is microgravity. This is because there are very small disturbances from onboard thrusters, machines and the astronauts. Everything on the ISS still experiences the forces of gravity from the objects around it. The experiments that are most sensitive to gravity are placed in the middle of the ISS where this effect is the smallest.

4 *What training is needed?*

Without going into orbit, freefall can only be recreated temporarily on Earth. Astronauts prepare themselves for feeling weightless on-board a specially modified aircraft more commonly referred to as ‘the Vomit Comet’. This plane flies a parabolic (following a curve freefalling under the pull of gravity) flight path up and down repeated several times each session. As the plane flies over a peak, everyone on-board is exposed to around 20 seconds of microgravity since the plane is freefalling towards the ground. The pilot then pulls up out of the descent, into an upwards curve. This pushes everyone down onto the floor of the plane, and they are subjected to around 1.8 G (almost twice the force of gravity experienced on Earth’s surface).

Additional information

For supplier information, risk assessments, and additional resources please see digital content on ***www.destinationspace.uk***

Credit: ESA/NASA

INTERNATIONAL SPACE STATION

An orbital laboratory

Programme Use: Across the programme

Overview

The International Space Station (ISS) is a marvel of human engineering and international cooperation. Providing a permanently crewed research laboratory in orbit, science research can be carried out that just is not possible on the Earth. This sheet is designed to give an overview of the place Tim will call home for six months.

The Station

The ISS is not the first crewed space station, but it is the largest and has had crew living aboard consistently since 2nd November 2000. With the solar panel array, the ISS is about the size of a football pitch. It was funded and built collaboratively by the spaceagencies of Canada, Japan, Russia, United States, and, contributing members of the European Space Agency. It holds the record for the longest continual habitation of a space platform.

Station construction began in November 1998 with the launch of Russia's Zarya module. The space shuttle was used to haul the large modules into orbit and constuct the ISS. In 2003 the Space Shuttle Columbia was lost which delayed this process, but it was completed in 2011. After construction of the ISS was complete, the space shuttle was retired from service, leaving the Russian Soyuz spacecraft as the only means of getting astronauts up to the ISS.

Credit: ESA/NASA

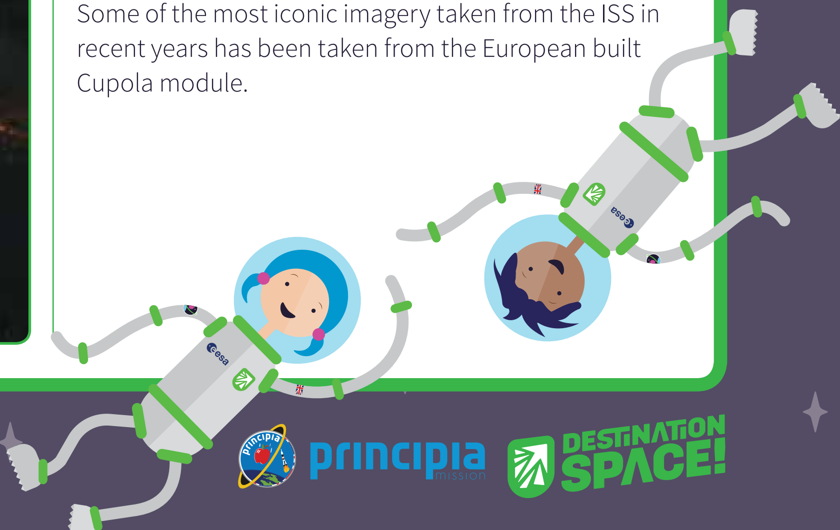
European involvement

The European Space Agency (ESA) is responsible for the Columbus laboratory. Forming a key part of the Station's research capability, it is fitted with ten interchangeable racks where experiments can be 'slotted in' to be conducted in the microgravity environment of orbit. Columbus is a multifunction laboratory that specialises in research in fluid physics, materials science and life sciences.

In addition, ESA built and flew the Automated Transfer Vehicles (ATV). These uncrewed supply ships were launched on a European Ariane-5 rocket and could carry up to seven tons of cargo to the ISS. Since the tiny amount of atmospheric drag experienced at the ISS's orbital height of around 400km is enough to gradually slow the ISS, the ISS loses about 2km of orbital altitude a month. The ATVs used their thrusters to boost the station into a higher orbit, a role that can also be filled by the uncrewed Russian Progress supply craft.

European scientists and engineers contribute to equipment and design across much of the International Space Station. More than a third of pressurised Station elements are designed and built in Europe.

Some of the most iconic imagery taken from the ISS in recent years has been taken from the European built Cupola module.



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This is a dome structure with a panoramic window that is used as a control room for astronauts operating the Stations robotic arm. Cupola's circular top window is 80cm in diameter making it the largest window ever to fly in space, while six side windows open the view to all directions. The windows are covered by protective flaps which are closed every night and in the event of space debris causing concern to mission control.

The future

NASA and Roscosmos (the Russian space agency) have agreed that the ISS will continue operation until 2024. Despite recent political tensions between the two organisations (as of publication of this handbook) both agencies have tenuously agreed to work together on designing and building a replacement.

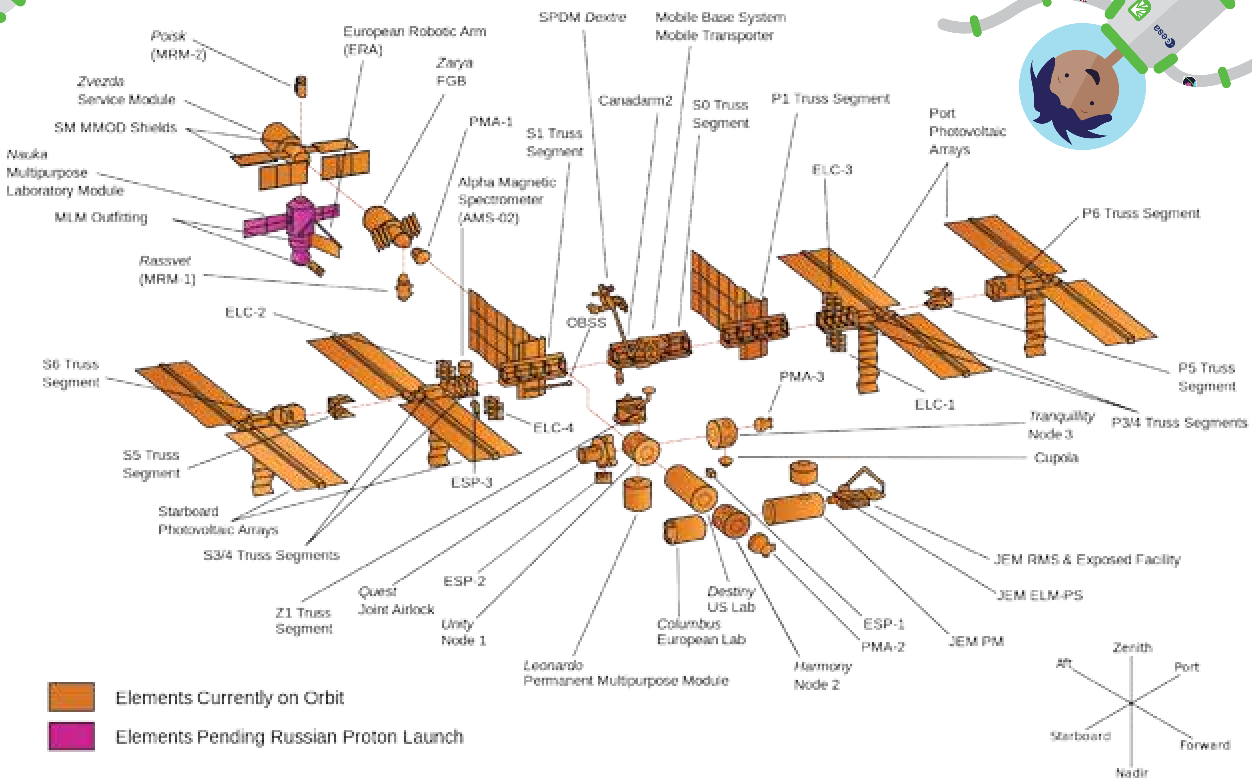
Experiments to try

Try to give a sense of scale by comparing the ISS to known places or things. The ISS is approximately 108.5 meters by 72.8 meters, this is slightly larger than a full sized football pitch. It weighs around 450 tons, that's almost 65 Elephants, or two and a half blue whales. The ISS travels at 7.66 km/s, fast enough to orbit the entire Earth in 91 mins.

Under the right circumstances you can see the ISS with the naked eye as a bright star-like object moving quickly across the sky from west to east. You will need a clear sky and need to be looking late evening, during the earliest hours of darkness or before sunrise. This is so that while you, on the surface of Earth are in darkness, the ISS, 400km above you, is still lit by the sun. The most important factor is whether or not the ISS is actually there. Using websites such as ***www.principia.org.uk,*** you can see if the ISS will be over your part of the planet at an appropriate time. There are also apps that can tell you this, as well as point you to exactly the right part of the sky. You can get more information, as well as sign up to alerts at ***spotthestation.nasa.gov***.

Additional information

For supplier information, risk assessments, and additional resources please see digital content on ***www.destinationspace.uk***



AUGMENTED REALITY

Interactive International Space Station

Programme Use: Across the programme

Overview

To help you explore the International Space Station, Destination Space has developed an Augmented Reality app for mobile phones and Tablet computers. Look at how the International Space station is constructed and see if you can spot Tim Peake onboard.

How to install the app

There are two versions of the App that are available, one for Apple iOS devices and one for Android devices.

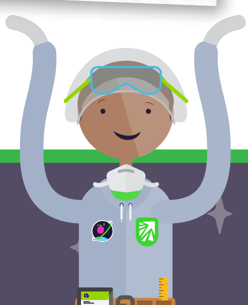
Installation

From the Destination Space website, follow the links to the 'mission modules'. From here select the 'Spot astronauts in space' module. Scroll down the page to see the two links for the app and select the required app.

The application should auto install. Once the app has installed, launch the app and allow the app to use your device camera.

Using the app

Once the app is launched, point the device camera at the AR target that can also be downloaded and printed.



Make sure you can see the whole of the image and then a virtual International Space Station should appear.

There are two ways to control the station:

1. Move the camera around the image or closer or farther away from the image
2. Use your fingers to 'pinch' gesture the image to zoom in or out, and swipe you finger along the bottom of the screen to rotate horizontally or swipe down the side of the screen to rotate vertically.

Task

Tim is onboard the International Space Station, see if you can find him.

Clue: Tim can get a great view of Earth from where he is sitting.

Trouble shooting

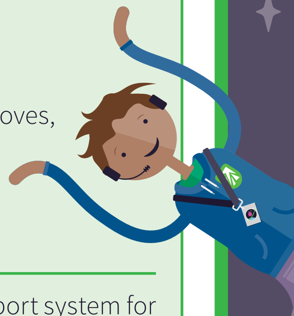
Because the app has not been installed via the Apple app store or Google Play store, your device may state that the app is not trusted and will not allow it to run until authorised.

Please see online guidance to resolve this

Apple iOS guidance:
https://support.apple.com/en-gb/HT204460

Android device:
http://www.howtogeek.com/howto/41082/install-non-market-apps-on-your-android-device/

CARBON DIOXIDE FILTER



Keeping the air breathable

Programme Use: 11-14 workshop

Notice: Sodalime: mild irritant, wear gloves, Bromothymol blue: do not ingest.

Picture to left is from Apollo 13

Overview

The ISS acts as a totally sealed life support system for the astronauts on board. Every resource, including air is precious and recycled as much as possible. Carbon dioxide (CO_2) must be removed from the air. Students can investigate the best material for this job.

How it works

1 *How do you set up the carbon dioxide filter?*
Once a material has been selected for testing, it is ready to be placed in the filter. Unscrew the top end cap and add a small amount of wire wool to the filter to allow circulation of the air around the scrubbing agent. Screw the end cap back on and attach the straw mouthpiece. The filter is now ready to be tested.

2 *How do you test the filter?*
In order to monitor how much carbon dioxide remains in the air an indictor must be used. For this experiment bromothymol blue has been selected. Place the bottom tube of the filter into a boiling tube full of the indicator making sure it rests near the bottom of the boiling tube. Breathe normally, exhaling through the filter and allowing the air to bubble through the indicator. The indicator will change from a blue/green to yellow as more carbon dioxide is bubbled through. By timing how long it takes for the indicator to turn yellow, you can compare the scrubbing agents – a longer time to turn yellow signifies more carbon dioxide is being absorbed by the scrubbing agent and so it is taking longer for enough carbon dioxide to dissolve in the indicator and force a colour change.

3 *How does the indicator work?*
Bromothymol blue is an indicator used to measure the acidity of a substance. As carbon dioxide dissolves into the indicator it forms carbonic acid. The more carbon dioxide that dissolves, the more carbonic acid is formed and so the more acidic the sample becomes.

Experiments to try

All of the experiments are detailed within the digital resources for the 11-14 workshop.

Links to Tim's Mission

The ISS is fitted with carbon dioxide filters that contain a substance called zeolite. These are a class of materials that adsorb (allow molecules to stick to the surface of it) both water and CO_2. The reason these molecules stick is that the atoms on the surface of the Zeolite are not completely surrounded by other atoms and so have the ability to attract molecules and hold onto them.

Eventually the Zeolite will become full of adsorbed gases rendering it useless as a scrubbing agent, but this is not a problem since when the Zeolite is heated the gases are released. By heating the zeolite and venting these gasses out into space, the zeolite can be reused.

This activity is based on the famous Apollo 13 carbon dioxide emergency. 56 hours into their mission to the Moon, the number 2 oxygen tank of the service module exploded damaging the service module's other oxygen system causing it to become useless to the mission. Aborting the lunar landing, the focus of the mission became bringing the astronauts home safely. Having to use the lunar landing module as a life boat, a problem arose.

The lunar lander was only supposed to be able to sustain two astronauts for a day and a half, not three astronauts for the four days that a return journey would take.

The carbon dioxide filters in the lunar module became quickly saturated, with the only other filters available those from the command module – which were incompatible with the lunar module's system. Ingenuity prevailed and mission control was able to rig a system that allowed the command module filters to be used and allowing the mission to become NASA's 'successful failure'.

Additional information

For supplier information, risk assessments, and additional resources please see digital content on ***www.destinationspace.uk***

LIFESAVER BOTTLE

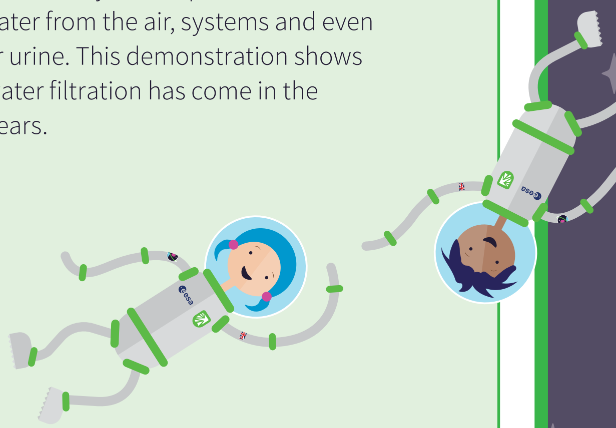
Recycling water in space

Programme Use:

Family show option, 5-7 storytelling

Overview

Sending resources into space is very expensive. To extend the useful life of the resources on the ISS, as much is recycled as possible. Astronauts recycle water from the air, systems and even from their urine. This demonstration shows how far water filtration has come in the last few years.



How it works

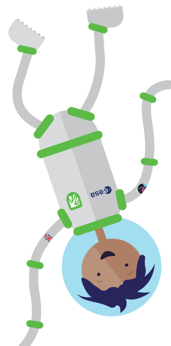
1 ***How much water does a human need each day?***
Two thirds of the human body (by weight) is composed of water. You lose water through sweating, urinating and even breathing. Even if you are not doing much you need about 2.25 litres of water a day to survive.

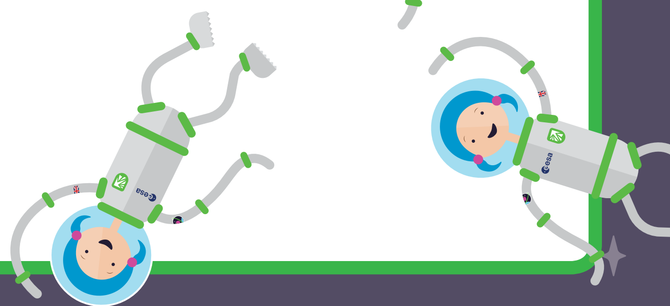
2 ***Why do we need to recycle water on the ISS?***
With six astronauts needing a minimum of 2.25 litres of water a day just to survive (not including hydrating food and the water needed for systems on the ISS) it would be necessary to send huge amounts of water up to the ISS on every supply mission. And what if a mission went wrong? Would we leave our astronauts stranded without water? As a result it is necessary to recycle as much water as possible.

3 ***Do they recycle urine?***
Yes, human urine can be recycled into clean, drinkable water.

4 ***How does the lifesaver filter work?***
Unlike on the ISS we have the effect of gravity to help us. Water is first poured through the sponge at the top which filters out any large particles. Once the bottle is filled the handle is pumped to increase the pressure in the centre of the bottle. This forces the water in the middle through a series of filters, as small as 15 nanometres (0.000000015m) filtering out everything from flecks of material, to bacteria and viruses. The water then drains into the flow compartment (where the nozzle is) to be consumed.

5 ***Is the water out of this bottle really safe to drink?***
Yes. The Lifesaver systems filtration technology complies with all British, US and European Drinking Water Regulations for Microbiological Reduction, as tested and certified by the London School of Hygiene and Tropical Medicine.
Also the Lifesaver bottle uses FAILSAFE™ technology, this means that when the cartridge has expired it shuts off, preventing the user from drinking contaminated water.





Experiments to try

Cleaning waste water

Mix up a sample of 'waste water' by adding soil or crumbled muffin into the water.

Unscrew the cap at the bottom (making sure the drinks top it pushed down) and make sure the filter sponge is placed at the top of the opening. Pour the mixture through the sponge until the bottle is two thirds full and scrape off any collected particulates from the sponge.

Now screw the bottom on tightly, and pull out the pump at the bottom of the bottle. Give it 5 or 6 full pumps to force the mixture through the filters.

Turn the bottle upside down over a clear glass and pop open the drinks top allowing the now clear liquid to drain in.

Take a sip of the water to show how clean it is.

Additional information

For supplier information, risk assessments, and additional resources please see digital content on ***www.destinationspace.uk***

Links to Tim's mission

Up to 85% of the water used on the station is recycled. The ISS has two water recycling systems on board. The Russian Zvezda module has a system that can process waste water from crew systems and water vapour from the atmosphere. This water is usually used to generate oxygen for their systems through electrolysis.

The Tranquillity module has a water recovery system consisting of a Urine Processor Assembly and a Water Processor Assembly. The Urine Processor Assembly uses a low pressure vacuum distillation process. First a centrifuge is used to separate heavy particulates from the urine (this is necessary because in microgravity they won't separate unaided).

Water from the Urine Processor Assembly and from waste water sources (condensation from air conditioning units etc.) are combined to feed the Water Processor Assembly that filters out gasses and solid materials before passing through filter beds and then a high-temperature reactor to cause any impurities to react with materials and bind to them.

Tim's Space Timeline

12th April 1981

First Space Shuttle launch. Mission STS-1 takes 54.5 hours and orbits the Earth 37 times

SPACE FOOD

Fine dining in microgravity

Programme Use: Across the whole programme

Overview

Astronauts need to eat, but getting items into orbit is extremely expensive and storage space on the ISS is at a premium. As a result, food supplies are carefully considered, weight must be kept to a minimum and space must be saved where possible. Despite these points, astronauts have a wide variety of choice in what they eat.

How it works

1 *What is different about these foods?*
The foods on the ISS are the same as we would have, though they are often vacuum packed or dehydrated to help with storage and preservation. Dehydrated foods are then rehydrated before eating. In addition, due to the effects of microgravity astronauts have a much duller sense of taste and smell and often request spicy foods to counteract this.

2 *What food can astronauts eat on the ISS?*
In theory, an astronaut can eat whatever they like on the ISS. However, some foods are more suited to eating in space. For example, most bread makes lots of crumbs, which could float around and not just be an annoyance, but could cause real problems if they got into the electronics of the ISS or were breathed in by another astronaut. Because of this, tortillas are often used for sandwich type foods at they don't make crumbs, and the Russian cosmonauts have small bread cubes so that they don't have to cut or tear the bread.

Liquids need to be restrained in drinking pouches to avoid globules of drink floating around the ISS. These pouches have valves that allow them to be attached to the water dispensers on board so that the pouch can be filled with hot or cold water.

Astronauts also have to eat healthily, and so while they do get a say in what they eat, everything is nutritionally checked beforehand to make sure that they are eating a healthy, balanced diet.

For more on drinking in space see Space Teacups briefing sheet.

Links to Tim's mission

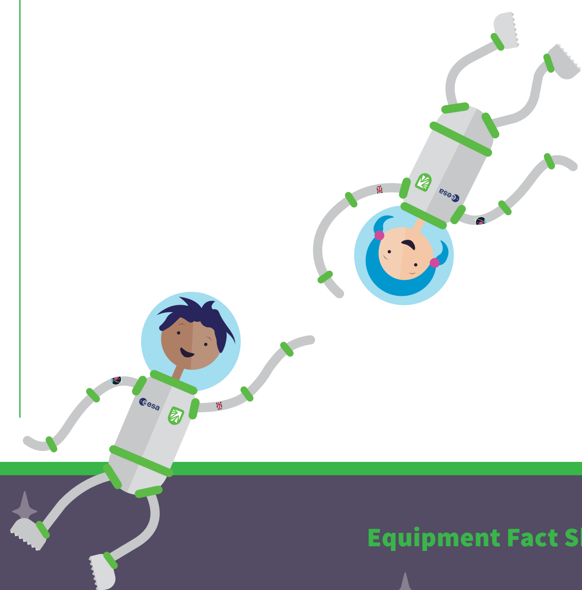
School groups in the UK were offered the chance to design a meal for Tim to eat on board the ISS as part of the UK Space Agency's Great British Space Dinner competition. Some of the food that won the competition include:

- A full roast dinner in a pie shaped like an astronaut helmet.
- A three course ice lolly consisting of tomato and basil soup, spicy mackerel curry and Eton mess.
- A full English breakfast in the form of a square burger.

These ideas provided some of the inspirations for Heston Blumenthal's meals for Tim.

Additional information

For supplier information, risk assessments, and additional resources please see digital content on ***www.destinationspace.uk***



SPACE TEA CUPS

A British astronaut needs their tea

Programme Use:
Can be mentioned across the programme

Notice: This is an information sheet – the equipment is not provided

Overview

In a microgravity environment drinking can be difficult. Liquids will either float away or try to crawl up the sides of their container, so astronauts drink through a straw attached to a bag. Luckily for Tim, six special espresso cups were designed and delivered to the ISS to counter these effects, so he can still have a proper cup of tea.

How it works

1 *Why do astronauts need these?*
A lot of care and effort is taken to make the astronauts comfortable and happy, otherwise, long periods of time spent in space can be psychologically straining. Small comforts that make the astronauts feel at home are of great value. On top of that, a lot of interesting fluid dynamics science is being learnt from items such as these cups.

2 *Do they not already have cups? If not, how do astronauts drink?*
Normally liquids would need to be held in a sealed bag and drunk through a straw. With so much delicate electrical equipment around the ISS, you don't want liquids floating around out of control. Astronauts do occassionally play with spheres of water but they are always very careful when doing so.

3 *Why are these cups so special?*
In order to act as much like a normal cup and be open at the top so you can sip from them, these cups use the surface tension of the fluid to hold them in place. On Earth liquids take the shapes they do because of two forces, gravity and their own surface tension. The surface tension is almost completely negligible compared to gravity, but you can see it in action if you over-fill a glass and look at the bulge of water above the top of the rim. However in microgravity, the surface tension is the main force shaping the liquid. If it is free of any surfaces then it will form a sphere, but if there is a surface in contact with the liquid it will cling to it and spread across the surface. The special shape of these cups keeps the liquid in and uses capillary action to draw it up the narrow channel to the pointed side of the cup. From there astronauts are able to sip the liquid into their mouths in a fashion quite similar to that on Earth.

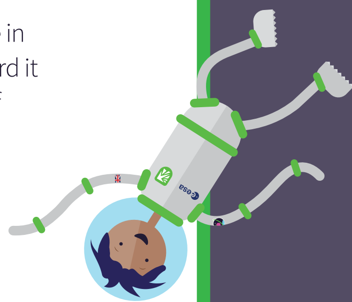
4 *What science can be learnt from all this?*
Along with leading to a better understanding of the motion of the fluids, the ISS espresso machine (ISSpresso) that was designed to make coffee also aids investigation into colloids (substances suspended in a liquid), of which coffee and tea are examples.

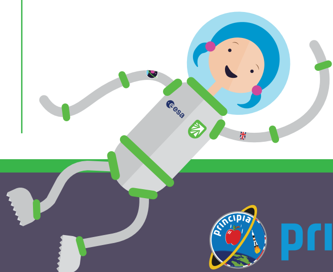
Experiments to try

1 Liquid behaviour in orbit:

Do this outside, or somewhere you don't mind spilling water. Take a liquid container with a hole in the side, near the bottom. A cup or plastic bottle with the lid removed will work. Covering the hole, fill it with water. Show that when you uncover the hole the liquid pours out. Now drop the liquid filled container, into a bucket ideally, from as high as you can reasonably manage. As the container falls the water will stop pouring out of the side.

This is because the water and container are in freefall, just as the ISS and everything aboard it is. The liquid no longer needs to pour out of the hole and is, relative to the container, floating about inside the container. This is what is happening aboard the ISS.





Experiments to try (cont.)

2 Surface tension:

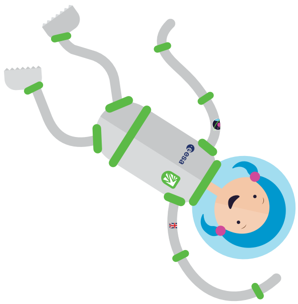
Take a dry cup and place on an even surface. Fill to the brim with water so the surface is flat. Now add water a very small amount at a time, perhaps with a dropper. The surface of the water will begin to bulge above the brim of the cup. This bulge is a meniscus, specifically a convex meniscus. The surface tension, a result of the attraction between water molecules, is holding the water in the cup and clinging to the rim of the cup. You can create a concave meniscus simply by pouring some of the water out. Look at the surface of the liquid within the cup and it will be gripping to the sides as if climbing up the interior of the cup. This is capillary action. How far up it reaches is limited by gravity, in orbit though, it would continue to climb the cup and cover as much of it as it could.

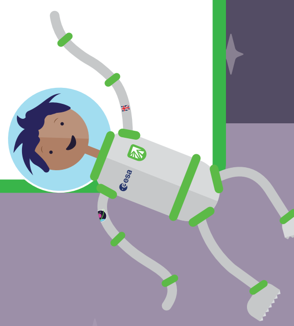
Additional information

For supplier information, risk assessments, and additional resources please see digital content on ***www.destinationspace.uk***

Links to Tim's mission

ESA astronaut Samantha Cristoforetti became the first person to use this prototype space cup after installing the ISSpresso zero-g coffee machine, and while they are used by astronauts as a home comfort, their use and the experiments that are run using the related ISSpresso machine will further our understanding of fluid dynamics and colloidal suspensions. This increased understanding could lead to improvements to space related systems, but also manufacturing and medical processes here on Earth.






Credit: NASA

SPACE TOILET

A serious engineering challenge

Programme Use:
Can be mentioned across the programme

Notice: This is an information sheet

Overview

Mundane tasks on Earth can be much more complex in space and often require equipment that is expensive and much more advanced than their counterparts on Earth. There are many differences between an Earth and space toilet, and astronauts train extensively to make sure that they can safely and hygienically use this space latrine.

How it works

1 ***What is the problem with going to the toilet in space?***

Microgravity causes a number of problems for the crew of the ISS. In microgravity it is very easy for both liquid and solid waste matter to float up and escape. This is an incredibly serious issue as contamination could cause health complications for the crew.

It is also more difficult for an astronaut to go to the toilet. Maintaining a correct position on the toilet is very difficult, and without gravity to pull on the urine in the bladder, astronauts get less notice of when they have to go to the toilet. As a result, to be on the safe side astronauts go to the toilet more often.

2 ***How does the space toilet work?***

The ISS currently houses two toilets, one in the Russian and one in the US segment. The toilets on the ISS are valued at around $19 million.

The collection of liquid and solid waste is carried out differently and requires different equipment. Liquid waste is collected via a tube with an attachment.

These attachments are designed differently for men and women to take into account their differing anatomy. To ensure that all liquid waste is collected the tube has suction to make sure the waste is taken into a collection tank. The piping for this section of the toilet must be replaced frequently to prevent bacteria build up in the tubes.

Solid waste is collected into a metal container that makes up part of the toilet. Before attending to their business an astronaut must ensure that the toilet is switched on and providing suction. The solid disposal requires an astronaut to precisely aim through a 4 inch aperture.

Before each visit a new, specially designed, plastic bag is attached just below the seat. The suction of the toilet prevents anything escaping once it has been released. After an astronaut has finished they detach the bag which snaps shut and is then sucked into the metal tank below. The toilet is then thoroughly cleaned. Astronauts must secure themselves in position in whatever way they find most comfortable so that their position is not compromised during their visit.

A range of toilet paper to suit the differing tastes of astronauts from different nations is provided, mounted to the side of the toilet cubicle.

3 What happens to the waste?

Human waste can pose a serious health hazard for astronauts aboard the ISS and therefore it must be handled and disposed of safely. Liquid waste is handled separately from solid waste.

Urine is collected into a holding tank where it can go on to be recycled and purified with all other forms of reclaimed water (e.g. condensation from the air conditioning systems) on board the ISS. The water recovery system is an essential part of the kit aboard the space station and can recycle around 85% of the water it reclaims (see water filter briefing sheet).

Solid waste is not recycled. It is instead packaged before being stored in an aluminium container attached to the space toilet. When this is full it is detached, replaced, and loaded onto a cargo vehicle which will be released from the ISS and burn up in Earth's atmosphere.

4 What training is needed?

As a space toilet is slightly different from one on Earth, so astronauts must be space toilet trained. NASA astronauts must complete positional training exercises on a training toilet equipped with a camera to check their positioning. Once they have successfully completed this section of the training they can then move on to the functional training toilet.

Additional information

For supplier information, risk assessments, and additional resources please see digital content on ***www.destinationspace.uk***

BALLOON TOILET DEMO

Why microgravity makes going to the toilet difficult

Programme Use: 5-7 storytelling

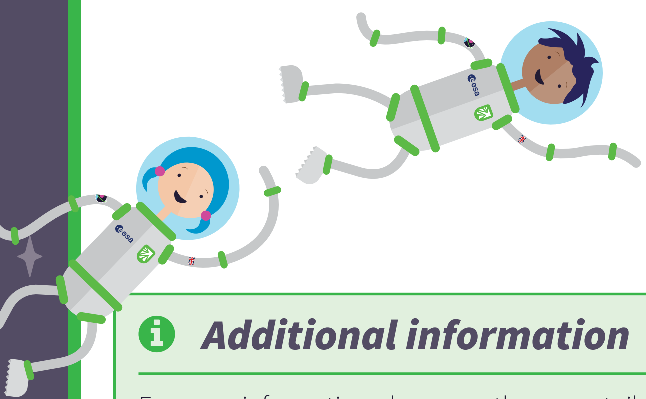
Overview

Since everything floats in a microgravity environment, going to the toilet is a difficult task. In this activity students will get to think about how important it is that human waste products are hygienically and efficiently collected and disposed of and that in space, vacuum cleaners may have another use.

How it works

This is aimed at demonstrating that the complexities of going to the toilet on the ISS, the need for suction in containing human excrement and the effects of microgravity.

The demonstration uses brown balloons to simulate solid human waste. These are released in to the audience while a volunteer uses a vacuum cleaner to capture the balloons with suction and place them in the clear bags ready to be packed onto a supply craft to burn up in the atmosphere.



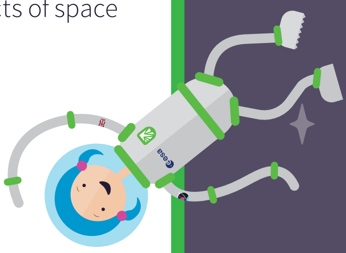
Additional information

For more information please see the space toilet information sheet.
For supplier information, risk assessments, and additional resources please see digital content on ***www.destinationspace.uk***

Links to Tim's mission

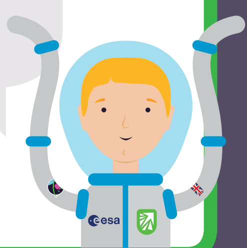
Real space toilets are intended to capture all the waste from astronauts to ensure it does not float around in the microgravity environment and pose a health hazard, or cause damage to the ISS. While not used anymore, early astronauts collected their faeces in bags to be returned to Earth and studied to investigate the effects of space travel on the human body.

Tim has undergone training in the use of the space toilet, including making sure that he can safely and hygienically position himself on the multi-million dollar device.



Tim's Space Timeline

18th March 1965
First space walk.
Alexey Leonov conducts the first EVA (extra vehicular activity) in space during the Voshkod 2 mission



BUNGEE CORDS

Exercising in microgravity

Programme Use: 7-11 workshop

Overview

On Earth we constantly work against gravity to stay upright. As a result our muscles are constantly doing a lot of work. In space, microgravity makes everything much easier and so astronauts lose muscle mass and bone density (see living in space story). In order to combat these effects they must exercise, and they use elastic and resistive devices to do this.

How it works

1. ***Why can't you lift weights to keep you fit in space?***
   In order to keep fit your muscles need to apply a force to something in order to use energy. In space, weights do not weigh anything, so the force required to lift them is negligible. You won't burn much energy doing this in space.

2. ***Why can't you use a running machine normally to keep you fit in Space?***
   On Earth when you run or walk you work against gravity each time you lift your foot. When your foot touches the ground you push off the ground to lift yourself up, but gravity pulls you back down. It is this continually pushing against gravity which is hard work. In orbit you don't feel the pull of gravity, so you won't stay in contact with the treadmill.

3. ***What is a Bungee rope?***
   A bungee rope is just like a piece of elastic. The more you stretch it, the bigger the force is that tries to return it to its original position.

4. ***What determines how much force the bungee rope exerts?***
   Hooke's law tells you how much force the rope exerts. Hooke's law says the force gets bigger the more the rope is stretched. There is also a factor which depends on what the rope is made of, so not all ropes will give the same force for the same amount of stretch.

5. ***How are bungee ropes used to exercise in space?***
   The bungee rope needs to be attached to the astronaut and to somewhere fixed on the ISS. Astronauts can attach the ropes to hold them onto the treadmill to hold them in place as they run. Astronauts mimics weightlifting by using hydralic system to work against resistance. This can be simulated using bungees.

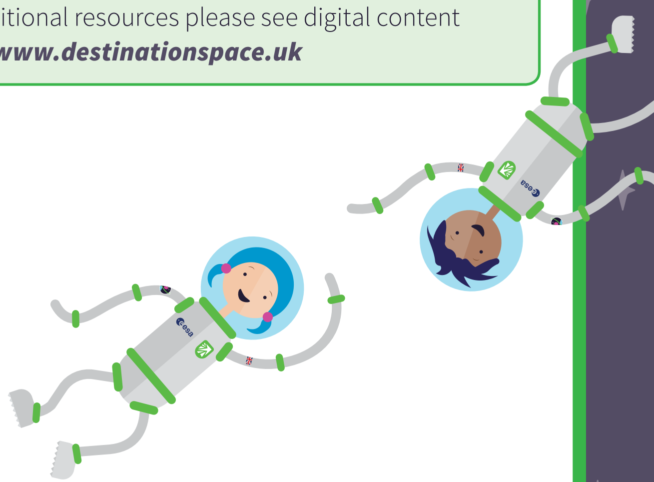
Experiments to try

Hang weights off an elastic band or a spring (or the bungee cord if possible) and see how much the length extends for different weights attached to it.

Try exercising by holding the bungee rope in your hands and stretching and contracting it continually. See who can do the most stretches to a particular length in a particular time.

Additional information

For supplier information, risk assessments, and additional resources please see digital content on ***www.destinationspace.uk***



BERNOULLI BLOWER

Working with floating objects

Programme Use: 5-7 storytelling

Overview

In the microgravity environment on-board the ISS, items will float around. While this is difficult to replicate on Earth, for the 5-7 storytelling workshop we can simulate objects floating around in microgravity using this simple but effective demonstration.

How it works

1 ***How do we make objects 'float' above the hairdryer?***
Switch the hairdryer on and hold it so that the air stream is moving upwards. Take the ball and hold it lightly in position in the air stream. When you let go of the ball, it will come to a floating rest in the airstream at a position where the force on the ball due to the moving air is counteracted completely by the weight of the ball acting downwards.

2 ***Why doesn't the ball fly out of the stream if the hairdryer is tipped slightly sideways?***
The ball stays surprisingly stable due to the Bernoulli Effect, whereby if the ball moves to one side, the air can flow past it faster, reducing the air pressure on that side, drawing the ball back into place. In addition, the pressure of the air outside of the stream is higher than the pressure of the moving air stream which also pushes back on the ball when it attempts to leave the moving air stream.

Experiments to try

1 During Storytelling

In the storytelling workshop students will use the Bernoulli blower and have to try to move the ball across the stage to deposit it in a net.

You can also tip the hairdryer at an angle to see at what point the forces due to the airstream and pressure are no longer big enough to counter the weight of the ball. At this point the ball will fall out of the airstream.

2 Bernoulli catch

Try throwing the ball gently at a volunteer with the hairdryer. Can they catch the ball in the airstream?

Links to Tim's mission

A familiarity with working in a microgravity environment is important for all astronauts training to go to the ISS. While this particular training exercise is not one that is used, it does give students an opportunity to get as close to working with objects in microgravity as we can.

To prepare him for living and working in microgravity Tim has been training in a giant neutral buoyancy pool. Wearing a full space suit and loaded with weights, the up-thrust force of the water is countered by his weight to allow him to float as if he is in space. In this pool he has been working with full scale models of the ISS, learning how to do tasks during a spacewalk.

In addition, astronauts can experience a short period of microgravity by training on the Vomit Comet. This aircraft flies in a parabolic trajectory (a curved path dictated by the gravitational pull of the Earth). During the freefall phase astronauts experience the same microgravity that they do in space allowing them to truly experience this strange environment (see microgravity sheet).

Additional information

For supplier information, risk assessments, and additional resources please see digital content on ***www.destinationspace.uk***

SLEEPING BAG

How to stay put while sleeping

Programme Use: 5-11 storytelling

Overview

In microgravity everything floats, and astronauts claim that they have their most comfortable sleep while in space as a result. Without the effect of gravity acting on their limbs they are able to fully relax. However astronauts could easily drift around while sleeping on the ISS, and the solution to this problem is beautifully simple.

How it works

1. ***Why have a sleeping bag on the ISS?***
   Sleeping in weightlessness requires the astronauts to be secured in some way otherwise they will drift around and could injure themselves. Additionally, many people find it comforting to be held in place, much like having the weight of a duvet on you when sleeping on Earth.

2. ***Why have arm holes?***
   As well as needing to secure themselves in the sleeping bag, just like on Earth, the astronauts may like to read or do other tasks before going to sleep, so being able to get your hands out and access the things around you is useful.

Experiments to try

The bottom section of this sleeping bag can be removed, so the sleeping bag can be put on a bit like a cagoule, this way visitors can try the bag on and see how easy it is to reach their hands through the holes and zip themselves up.

Links to Tim’s mission

While away from home on the ISS, the sleeping bags provide comfort, security and familiarity. With six people living in such a confined space, an astronaut’s tiny sleeping compartment is their only personal space.

It is important that sleeping quarters are well ventilated to prevent the astronauts waking up deprived of oxygen and with the danger of asphixiation due to a bubble of their own exhaled carbon dioxide forming around their heads.

A regular sleep cycle is important onboard the ISS. Astronauts work and sleep according to a daily time plan and are usually scheduled for eight hours of sleep at the end of each mission day. They may wear eyeshades to keep out the light while they are sleeping.

Most astronauts find they need less sleep in space than on Earth (because their body is under less stress) and report that they sleep very well.

Additional information

For supplier information, risk assessments, and additional resources please see digital content on ***www.destinationspace.uk***

ATV SOLAR CELLS

Powering ESA's uncrewed supply ship

Programme Use: Busking and artefact handling

Overview

Despite generating power through solar panels and recycling water and air on board the ISS, regular supplies of fresh water, air, fuel and food are required to keep the crew alive and the space station functioning. For six years the European Automated Transfer Vehicle (ATV) was used to fulfil some of these missions. The Science Centres in the Destination Space programme has been given solar cells from the un-flown ATV 6 craft to use for busking and artefact handling.

How it works

1 ***How does a solar cell (photovoltaic cell) work?***
To find out how a solar cell works, please refer to the Photovoltaic cell briefing sheet

2 ***What was it used for?***
The ATVs were an expendable cargo spacecraft that were designed to replenish the ISS with fuel, water, air, food, fresh clothes and experiments or equipment required. The ATV could carry three times more supplies than the Russian progress spacecraft which is still used today.

The ATV was also used to re-boost the orbit of the ISS which is required at regular intervals to ensure it remains in orbit.

The ATVs remained docked to the ISS for six months to be used as a waste collection module, for any waste that needed to be removed from the ISS. After 6 months, loaded with nearly 7 tonnes of waste, they separated from the ISS and were programmed to follow a steep flight path that caused the spacecraft to burn up in the Earth's atmosphere high above the Pacific Ocean.

3 ***How did they get to the ISS?***
ATV's were launched into space by an Ariane-5 rocket (ESA's main space rocket system). Once in space it used a GPS and a star tracker system to guide it to the International Space Station. The whole process including the docking was fully automatic, with safe guards that would allow flight engineers to take control of the spacecraft if there were any problems. The ISS crew were also able to abort the approach.

4 ***How many were launched?***
In April 2012 the European Space Agency announced that the ATV programme would end after the fifth ATV was launched. No additional ATV flights were funded.

Additional information

For supplier information, risk assessments, and additional resources please see digital content on ***www.destinationspace.uk***

LIST OF ATV FLIGHTS

	Name	Launch date	ISS docking date	Deorbit date
ATV-001	Jules Verne	9 March 2008	3 April 2008	29 September 2008
ATV-002	Johannes Kepler	16 February 2011	24 February 2011	21 June 2011
ATV-003	Edoardo Amaldi	23 March 2012	28 March 2012	4 October 2012
ATV-004	Albert Einstein	5 June 2013	15 June 2013	2 November 2013
ATV-005	Georges Lemaître	29 July 2014	12 August 2014	15 February 2015

PHOTOVOLTAIC CELLS

Powering the ISS

Programme Use: 11-14 workshop optional activity

Overview

Giant solar panels are used to take energy from the Sun and convert it into electrical power for use on the ISS. This activity (an optional swap-in for the 11-14 workshop) allows students to investigate the optimum position for the solar panels.

How it works

1. ***How does a solar panel generate electricity?***
   Solar panels are made of silicon which is a semiconductor. Photons ('particles' of light) hit the silicon and cause electrons to be released. The movement of electrons is electric current. However, the silicon needs to be arranged in a particular way to make the electrons flow the right way. Some of the silicon will have too many electrons (n-type) and some of the silicon will have too few electrons (p-type). Electrons will flow from the n-type to the p-type. This will cause the n-type to become positively charged and the p-type to be negatively charged. This creates an electric field between the two types of silicon that ensures that the electrons which are being knocked off the atoms by the photons move in the correct direction.

2. ***How do the electrons gain their energy?***
   The photoelectric effect is when a photon hits an atom and gives its energy to one of the electrons. This will either raise the electron to a higher energy level in the atom or, if there is enough energy, it will mean the electron can move completely clear of the atom. If you shine a light on a photovoltaic material a current can be observed coming from the material and this is the photoelectric effect. However, please note that you need to use the correct wavelength of light with the correct material for this to work.

3. ***Why does the angle of the solar cell matter?***
   If the light source is incident on the solar cell at right angles to the cell it will maximise its power output. At other angles the power output will be lower. The light can be thought of as having a component at right angles to the cell and a component parallel to the cell when it comes in at an angle. It is only the component at right angles which is seen by the solar cell. Mathematically, the power varies with the cosine of the angle of incidence.

Experiments to try

See photovoltaic cells activity guide online at ***www.destinationspace.uk***

Links to Tim's mission

The International Space Station is powered entirely by solar panels. There is no access to any other useful source of power in space. A lot of other spacecraft use solar power, although some use nuclear power, particularly when venturing far from the Sun (where the power of the Sun's rays is much weaker). Solar power has the advantage of being clean, there is a (virtually) unlimited supply and there is no issue with clouds in space!

Additional information

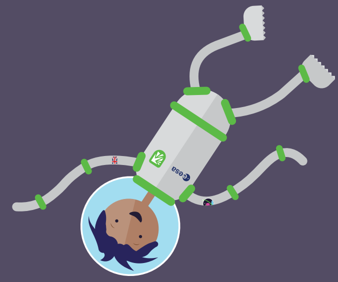
For supplier information, risk assessments, and additional resources please see digital content on ***www.destinationspace.uk***

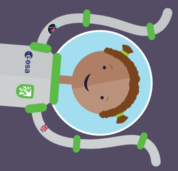
www.destinationspace.uk

DESTINATION SPACE!

WORKING IN SPACE:

Stories and Equipment Briefing Sheets





WORKING IN SPACE

The International Space Station is a unique environment – it's the only place where long term experiments can be done in microgravity. There is a huge range of research being conducted on the ISS, such as biology, testing new technologies, or making observations of the Earth. Different experiments require different levels of astronaut interaction. Some need an astronaut to run, others, like observing cameras, will run without any human input once they are installed. An astronaut's time is carefully scheduled so that all the maintenance tasks and experiments get done.

Research modules

The ISS has three modules where most of the science research is carried out; Destiny, Kibo and Columbus. Destiny is the American science module, Kibo the Japanese science module and Columbus the European one. However, experiments can also be carried out in other modules, and even on the exterior of the station. 'Indoor' experiments are usually run inside experiment facilities that are housed in racks called International Standard Payload Racks (ISPRs). Each experiment facility has a removable experiment container, making it easy to install and change.

Types of research

Biology and Biotechnology

Microgravity affects living things at a cellular level. Without the effects of gravity, cells grow differently and the effects can be dramatically different to cells grown on Earth. Various experiments on-board the ISS have studied cell cultures to see how they grow in microgravity and what this can tell us about the ways cells grow and are controlled.

Experiments have also been conducted to see if living things can survive in the vacuum of space. Part of a sample of tardigrades (very tough tiny creatures less than half a millimetre in size that are sometimes referred to as 'Water Bears') successfully reanimated, after being stored outside the ISS, exposed to the cold, vacuum and radiation of space.

More recently, live mice have been flown up to the ISS to see how microgravity affects their bodies. Microgravity has a detrimental effect on muscles and bone, causing them to degrade and weaken. This experiment helps

scientists better understand the effects of long-term space flight for astronauts, as well as simulating the effects for people on Earth who are unable to move for long periods of time for a variety of reasons.

Earth and Space Science

From its low Earth orbit of around 400 km above the planet's surface, details on the Earth such as glaciers, agricultural fields, cities, and coral reefs are easily visible with high resolution cameras. This information can be combined with other sources of data, for example from orbiting Earth Observation satellites, to compile a very detailed, changing picture of our planet. Scientists can use this data to monitor how human behaviour and natural phenomena are altering the Earth.

The ISS also has a number of instruments that take observations from space, such as detecting cosmic rays, x-rays from space, hunting for dark matter and observing the Sun. A camera also records the Earth's atmosphere in high-detail to spot the tell-tale glow of a meteor falling to Earth, to measure how often meteors fall and what they are made of.

Human Research

Being in space for long periods poses many health risks to astronauts (see Living in Space for more information). Whilst on-board the ISS, the astronauts themselves are test subjects. There are a number of experiments studying various aspects of the astronaut's health, such as their muscles and bones, back pain, cardio-vascular system, skin, behaviour, psychology, sleep-cycle, immune system, digestive system, nervous system, vision and how they are affected by space radiation.

The results of these experiments will help scientists and engineers develop methods to combat related ailments. The hope is that humans will be able to spend longer in space, eventually able to travel for the years required to explore further into the Solar System, whilst still remaining healthy and functional. In March 2015 astronaut Scott Kelly and cosmonaut Mikhail Kornienko launched to the ISS to spend nearly a whole year aboard – twice as long as the usual six months astronauts spend there but still some way short of the absolute single spaceflight record of 438 days. Scientists are keen to find out what effects this extended period in space will have on their bodies because a journey to Mars may involve a total spaceflight time in excess of two years.

Physical Sciences

The ISS is the only place to study long-term effects in the apparent absence of gravity. Gravity's effects are ever-present on Earth, but without it, other effects begin to dominate. This allows scientists to better understand the forces underlying physical systems. On-board the ISS, experiments are being conducted investigating flames, fluids, plasmas and ice crystals. New materials are also being tested, such as synthetic muscle to build robots and novel metal alloys.

Technology

The space station uses and tests a whole host of new technologies to keep the crew alive and healthy. These new technologies will be required for extended space travel in the future. Examples include new types of clothing, life support systems, management of microorganisms and allergens, new power systems, radiation shielding, 3D printing, robotics and a whole host of new materials for thermal regulation and protection from radiation and micrometeoroids.

Since 2009, the ISS has used a water recycling system that collects moisture out of the air, waste water from washing and astronauts' urine and converts it into drinkable water. It's not a perfect system, but it allows astronauts to reuse about 85% of their water. This has dramatically reduced the amount of fresh water that needs to be supplied to the ISS from Earth.

Tim's research

Whilst Tim is on-board the ISS, there will be over 30 ESA experiments running, along with many more Roscosmos, NASA and JAXA (Japanese Space Agency) experiments. Most of these experiments are already running- however new experiments will also be started during Tim's mission. Tim has trained to run many of these experiments, even though there's no guarantee he will be involved in all of them. These experiments are correct at the time of writing, but may change.

Here are some examples of the ESA experiments:

- Study how skin ages in microgravity
- Try to determine the cause of 'space headaches'
- If a particular type of bacteria is more resistant to the space environment than others
- Seeing how seedlings grow in microgravity in a variety of light settings
- Creating a 3D map of the radiation dose across the ISS
- Demonstrating control of a robot (Eurobot) on Earth from the ISS
- Testing the identification of maritime vessels using a space-based automatic identification system

Benefits of ISS research

People around the world are already reaping the benefits of ISS research in many small ways, without evening knowing it. "People do not realize how much their lives today have been made better by the space station," said NASA International Space Station Chief Scientist Julie Robinson.

Here are some examples:

- There have been many advances in medicine, such as new treatments for asthma and osteoporosis.
- Farmers in the US are starting to monitor their crops using imagery from the ISS.
- Technology that was used to build the Canadarm 2 (the robotic arm that assists astronauts with tasks outside the station – also known as MSS, or Mobile Servicing System) has been adapted to develop robotic assistance during brain surgeries.
- Children in Chiapas, Mexico, have been provided with a water purification plant at school, modelled on the water recycling system aboard the ISS. Powered by solar energy, it provides clean, safe drinkable water for the school children.

As an astronaut, Tim will be conducting unique research for scientists across the planet. The ISS is not just a wonder of human engineering, international cooperation and a symbol of what can be done if humans really put their mind to it, it is also humanity's flagship microgravity research station. Tim is an astronaut, and for the duration of his mission he will also be a scientist and engineer. It will be interesting to see what rewards the research he conducts reap for human spaceflight and the planet as a whole.

Tim's Space Timeline

24th April 1967

Cosmonaut Vladimir Komarov dies during the Soyuz 1 mission when his capsule's parachute fails to open on landing. This is the first death of an astronaut in flight

VACUUM DEMOS

The effects of exposure to space

Programme Use: Family show option, 7-11 workshop

Overview

In space, no one can hear you scream (even if you were able to breathe).This is because there is no air to transmit the sound waves. While an exaggeration of what would actually happen, this equipment shows to amazing effect how dangerous a difference in air pressure is.

How it works

1 ***What do we mean by air pressure?***
The force of the air molecules around us impacting with a surface produces a pressure (pressure = force/ area). We can see the effect of this with a glass of water and a piece of card (see demo).

2 ***What is the air pressure in space?***
Space is nearly a perfect vacuum. This means that there are very few molecules present in the gas (just a few molecules per cubic metre) and the air pressure is effectively zero.

3 ***Why is this dangerous for humans?***
Humans have evolved on the Earth below a sea of atmosphere. This atmosphere is pulled towards the centre of the Earth by gravity with each layer of atmosphere exerting a force on the next due to its weight and the weight of the layers above. As a result, the air pressure at the surface of the Earth is very high, pushing on us with a lot of force. In order to be balanced with this force, humans have an internal pressure that equals the pressure outside of them. Being internally pressurised brings problems when we are exposed to areas of extremely high, or in the case of space, extremely low air pressure.

4 ***What would happen if a human was suddenly exposed to the vacuum of space?***
There are several problems for a human exposed to the vacuum of space. The first is that with no oxygen present you would start to asphyxiate (suffocate) immediately. The second problem is that since the air pressure outside is so low, the pressurised gases inside your body will start to expand. Your skin acts as quite a good pressure suit, squeezing your internal mass and preventing much of that expansion. The gas in your lungs however would expand incredibly quickly and force its way out of your mouth, quite possibly blowing out your teeth in the process.

Another consequence of low air pressure is the effect that it has on the boiling point of water. As the air pressure drops, water will boil at a lower temperature, meaning that when exposed to the vacuum of space the liquid inside of you would want to boil. Again, your skin acting as a pressure suit will suppress much of this however your saliva would begin to boil away.

Although the demonstrations are dramatic, they are exaggerations. Not only would your skin prevent you from ballooning up in size or exploding, but the ISS and the space suits used for EVA are designed to minimise the effect of leaks and give the astronauts enough time to perform a repair.

5 ***Why does water boil at a lower temperature at lower pressures?***
The simplified explanation is that boiling is effectively large scale evaporation. Even at room temperature a standing puddle of water will gradually lose molecules from the surface as some of them will have enough energy to leave. Others will be 'bounced back' by the atmosphere above them. The lower the air pressure (and therefore the fewer the molecules above the water) the fewer molecules will be bounced back, increasing the rate of evaporation and therefore allowing the water to boil at a lower temperature.

Experiments to try

1 Marshmallows in syringes

Explain that a syringe can be used to reduce the pressure of the air inside it. Start with the plunger on about 3ml of air and put your thumb over the end. Ask whether air can get in or out. It cannot so the number of molecules of air in the syringe stays constant.

Now, keeping your thumb over the end of the syringe pull the plunger out to about 8ml. Ask what will happen to the air molecules inside (they will spread out). This means that there will be fewer molecules impacting with each unit of area of the syringe so the air pressure will be lower.

Now take a small marshmallow. This represents an astronaut – full of air and 'squishy' like a human. Take the plunger out of the syringe and insert the marshmallow. Move the plunger down so that it is just touching the top of the astronaut (don't squash the marshmallow as this will ruin its elasticity). This leaves a very small amount of air in the syringe. Place your thumb over the end again and pull out the plunger as far as it will go. The air trapped inside the marshmallow expands in an attempt to balance the pressure of the air inside the marshmallow to the lower outside pressure in the syringe. This is an exaggeration of what would happen to a real astronaut exposed to the vacuum of space.

2 Using the vacuum chamber

This experiment can be conducted using either a partially inflated balloon (with an alien face drawn on it for effect) or a couple of large marshmallows. Explain that the balloon/marshmallow represents a human, full of air pressurised at sea-level air pressure.

Place the balloon/marshmallow into the vacuum chamber and place the plastic cover on top. Make sure there is a good seal and that the vacuum pump is attached to the valve on the chamber.

Switch on the vacuum pump and draw the air out of the chamber, reducing the air pressure in the chamber. Watch as the balloon or marshmallow expands and explain that this is happening because the gasses inside the item are expanding to reach the same pressure as the, now, low pressure gas outside. Again, explain that this is an exaggeration of what would really happen to a human in space without a space suit.

Additional information

For supplier information, risk assessments, and additional resources please see digital content on ***www.destinationspace.uk***

ASTRONAUT COSTUME

Feeling the part

Programme Use: 5-7 storytelling

Overview

If an astronaut is going to do a spacewalk outside of the ISS, they need to be protected from the extremes of temperature, the vacuum and the lack of oxygen. A spacesuit acts as their own personal spacecraft providing everything they need to survive. This costume is used in the finale of the age 5-7 storytelling show.

How it works

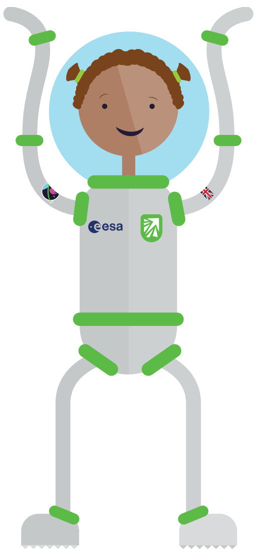
This suit is not intended to be accurate, but is used as a costume during the under 7s storytelling show.

When the children encounter a problem that requires them to leave the space station they must pull together an Extra Vehicular Activity (EVA) suit.

In order to build the suit the audience will get advice from experts who will give two criteria for each part. The presenter will suggest three possible choices from this costume and the samples (see Equipment and Material Samples briefing sheet) in the following sets:

	EQUIPMENT AND MATERIAL SAMPLES NEEDED			
	Choice 1	***Choice 2***	***Choice 3 (Best option)***	***Suit part***
Suit	Tissue Paper	Plastic Tube	Fabric	Jump suit
Feet	Flip Flops	Football Boots	Soft Boots*	Soft Boots
Hands	Mittens	Net Gloves	Gloves*	Gloves
Air supply	Net bag	Balloon	Air Tank*	Air Tank & Backpack
Helmet	Clear Perspex	Opaque Perspex	Tinted Perspex	Helmet

*These samples are from the costume itself.



Additional information

For supplier information, risk assessments, and additional resources please see digital content on ***www.destinationspace.uk***

MATERIALS

Design a space suit

Programme Use: 5-7 storytelling

Overview

When designing anything for use in an environment as extreme as space, material selection is extremely important. In the 5-7 storytelling show, these seemingly everyday materials and pieces of equipment will be investigated for their properties to see if they fit some of the requirements of parts of a space suit.

How it works

Investigating the materials

The students need to investigate the properties of different materials and decide on appropriate examples for making an Extra Vehicular Activity suit (an EVA suit, aka a spacesuit) for an emergency spacewalk.

During the story we need to go outside of the space station and this requires a suit. The experts we have already met will give advice on what we'll need for the space suit, giving us two important requirements. These samples will meet only one requirement each, while the correct parts (see the Astronaut Costume briefing sheet) will meet both requirements. It is the audience's job to identify which is the most suitable piece of equipment, or material from the three offered up by the presenter.

For more details please see 5-7 storytelling activity.

Links to Tim's Mission

In reality space suits are precisely engineered and extremely robust pieces of equipment that preserve the life of the astronauts wearing them and contribute to the construction and maintenance of orbital equipment.

The spacesuit is also an icon of human spaceflight. Easily recognised and a symbol of adventure and heroism, the classic spacesuit is typically an Extra Vehicular Activity (EVA) suit. With its large tinted helmet, chunky boots and gloves, and large backpack the EVA suit has been a popular image since the early days of the space race.

Material choice is extremely important in human space flight. Materials need to be able to stand up to extreme conditions including UV exposure, micrometeoroid impacts and extremes of temperature. In addition, and particularly important for the design of space suits, materials must be comfortable to work in and not restrict mobility too much. A great deal of consideration must go into selecting and developing materials for space applications.

Additional information

For supplier information, risk assessments, and additional resources please see digital content on ***www.destinationspace.uk***

EVA SUIT SWATCH

A cross section of a space suit

Programme Use: Across the programme

Overview

There are two types of EVA (Extravehicular Activity) suits in use on-board the ISS. These are spacesuits that astronauts must wear when working outside the ISS. The EMU (Extravehicular Mobility Unit) suits are used by NASA and European astronauts and the Roscosmos cosmonauts use their own Orlan suits. Both have been carefully designed with many layers of fabric, each one playing a key role in preserving the life of the astronaut working outside of the ISS. These swatches use everyday materials to simulate a cross section of a real spacesuit.

How it works

To find a guide on how to make a simulation cross section of an EVA suit consisting of swatches of different materials, each representing a layer of an EVA suit please go to: ***www.destinationspace.uk/resources***

The layers and swatches are described below.

Thermal regulation

The first three layers an astronaut will don are layers for maintaining their temperature. This includes the 'thermal control undergarment' and the 'liquid cooling and ventilation garment'. The first is a simple cotton cloth layer. The second is a stretchy material, covered in plastic tubes full of water. The water is pumped around the layer, warming up from the astronaut's body temperature. The water is then pumped into a compartment in the astronaut's backpack, where the excess heat escapes into space. This prevents the astronaut from overheating when they are completing physical activities. A swatch of lightweight cotton material and some rubber tubing in the kit represents this layer.

Airtight seal

The next layers are the bladder layers. These are tight, strong, coated fabrics which ensure the suit remains airtight. These are represented in the kit by a swatch of rubber. Spacesuits have to be pressurised as the human body cannot survive in the vacuum of space. The suits are not inflated to the pressure we are used to, however. The air pressure at sea-level is around 1,000 millibars. A suit inflated to that pressure would become rigid, like a well-inflated balloon. The astronaut's arms and legs would be stuck straight out and they would be unable to bend them. Suits are instead inflated to about 300 millibars – the air pressure one would experience approximately 900 metres above sea level. To ensure the astronaut has enough oxygen to breath at this lower pressure, the suits are inflated with pure oxygen, rather than ordinary air.

Keeping out the cold

Next comes several layers of insulating material. The purpose of these is to isolate the astronaut in the suit from the extreme temperature conditions outside the suit. When not in direct Sun, the temperature at that altitude above the Earth is about –150˚C. When directly facing the Sun, the temperature soars to 120˚C. The suit needs to be able to cope with these extremes and everything in between. This is achieved with several layers of Mylar, a shiny material that reflects infrared radiation (radiated heat). This is what this swatch is made of and it represents all of these insulating layers. Mylar is actually the brand name for a special type of stretched polyester film.

Fire resistance

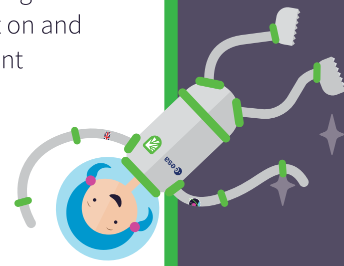
The next swatch is the beta cloth, a fire resistant material representing the fire resistant layer of the space suit.

Micrometeoroid protection

Finally the outer layer of a space suit is a layer of Kevlar, or similar material. This is the same material that bulletproof vests are made from and it protects astronauts against strikes from micrometeoroids. The swatch representing this layer is made of Kevlar (another brand name!). Micrometeoroids, although tiny, travel at an average speed of around 10 kilometres a second (relative to the orbiting astronaut) – that's about 22,500 mph! At these incredible speeds, even an object the size of a grain of sand could puncture a hole in a space suit, if not properly protected.

Links to Tim's mission

While Tim may not perform a spacewalk during his time on the ISS, he has trained in how to put on and work in an EVA suit. Hours of training in a giant neutral buoyancy pool prepare him for conducting a spacewalk.



Additional information

For supplier information, risk assessments, and additional resources please see digital content on ***www.destinationspace.uk***

INSTANT SNOW

Space nappies

Programme Use:
7-11 workshop, family show, busking

Notice: The instant snow should not be ingested

Overview

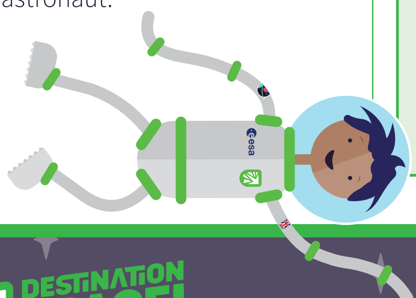
The microgravity environment of space presents many potential dangers. Liquids act very differently forming into floating spheres bound by their own surface tension. An astronaut in a space suit has no way of controlling where this liquid can go and as a result this material was developed to present a solution to the dangers of floating liquids.

How it works

1 *What is the instant snow made of?*
The powder is a chemical known as a Super Absorbent Polymer (SAP). These chemicals are designed to absorb hundreds of times their own weight in water. This particular chemical is called Sodium Polyacrylate (SPA).

2 *What liquids need to be absorbed in space?*
Although good at absorbing liquids the use of SAPs is reserved for one particularly unique task for our orbiting astronauts. We find SAPs in a piece of clothing called the maximum absorption garment (MAG). This item of clothing is one of the first that is put on when an astronaut is preparing for a spacewalk. It is basically a space nappy.

3 *Why do highly trained astronauts need to wear nappies?*
It takes several hours and supporting crew members to get two astronauts ready to go out on a spacewalk. Therefore, once you have gone through the airlock (which takes about 30 minutes) and are doing your spacewalk, you can't just nip back inside to go to the toilet. Spacewalks can last for up to 8 hours, and so astronatus wear maximum absorbancy garments. In addition, if an astronaut were to have an accident in their suit, globules of urine could potentially make their way up to the helmet, and with no way of removing them, even a small amount could potentially drown an astronaut.



Experiments to try

Demonstrate absorption ability

Take a small amount of powder, enough to cover the bottom of an old 35mm film canister. Add to it half a film canister of water and get people to observe what happens. The powder will absorb water and expand. The powder can be poured out and touched allowing the audience to feel the moisture trapped inside. This experiment can be scaled up fairly easily for bigger displays or kept small for smaller events and busking.

Links to Tim's mission

The danger of free floating liquids in space was demonstrated in July 2013 during a spacewalk. Shortly after leaving the ISS, ESA astronaut Luca Parmitano noticed cold water from a leak inside the suit building up on the back of his head. Gradually the water continued to trickle in, covering his eyes, nose and part of his mouth. Staying extraordinarily calm under pressure, Luca was able to navigate back to the airlock, and just in time. Another few minutes and he would likely have drowned.

Additional information

For supplier information, risk assessments, and additional resources please see digital content on ***www.destinationspace.uk***

METEORITES

Ancient Space Rocks

Programme Use: Optional extra

Notice: The equipment is not in the core kit but may be purchased separately

Overview

Meteorites are fragments of rock and/or metal that fall to Earth from space. They are the oldest objects in the solar system, around 4.5 billion years old, and provide insight into the materials that made up our own planet. They also pose a danger to those on board the ISS.

How it works

1 *What types of meteorites are there?*

There are three main types of meteorite and they are classed according to the amount of iron they contain.

- Iron meteorites are almost completely metal. They are thought to be the cores of asteroids that melted early in their history.
- Stony-iron meteorites are a combination of stone and iron in almost equal quantities. They have an attractive speckled appearance as a result.
- Stony meteorites have a relatively low amount of iron in them and are almost completely silicate based. The majority of meteorite falls discovered on Earth have been stony meteorites.

2 *Where do meteorites come from?*

Most meteorites start life as an asteroid (or as part of one) and they are the leftover material from the formation of the Solar System. These asteroids mostly lie in an orbit between Mars and Jupiter known as the asteroid belt.

A small number of rare meteorites come from the Moon and Mars and are much younger, being just 2,500 million years old from the Moon, and 10.5 million years old from Mars. We know where they have come from because their composition matches lunar rock brought back from the Apollo missions and Martian rock samples analysed by Mars landers including the Viking probes in 1976.

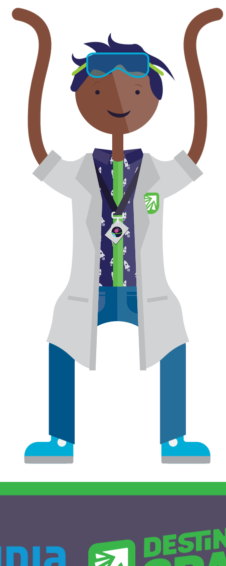
3 *Why do they burn up in the atmosphere, and when does a meteoroid become a meteorite?*

Meteorites are called a meteoroid until they enter the atmosphere at phenomenal speeds. Pulled towards the Earth by gravity, they are typically accelerated to speeds of over 11km/s. As a meteoroid crashes through the atmosphere, it compresses the gases in front of it, causing heating and sometimes engulfing the object in a spectacular envelope of superheated plasma. At this point it becomes a meteor. If any fragments reach the ground, they are then referred to as meteorites.

4 *How dangerous are they?*

Large meteorite impacts are rare. Most rocks that approach the Earth will burn up in the atmosphere before they impact the ground.

Without the slowing effect of an atmosphere, in space even tiny meteoroids (micrometeoroids) are dangerous. The more relative kinetic (movement) energy a micrometeoroids has, the more dangerous it is, and since kinetic energy increases with the square of the velocity a meteoroid has, this plays the biggest role (that is, if they are moving twice as fast they have four times the energy). As a result, both the ISS and astronaut's space suits have to have very strong layers built into them which can withstand impacts from these micrometeoroids.



Experiments to try

Becoming a meteorite hunter

Visitors can be provided a selection of rocks (some of which are meteorites) and investigate the following qualities:

1 Mass

Meteorites are very dense and so tend to be very heavy. By either comparing in the hand or using a set of scales, the masses of the meteorites can be investigated.

2 Visual inspection

Stony and stony-iron meteorites appear black on the outside. They are also smooth with a slight 'bobbling' on the outside. This is caused by the outer layer melting as it heats up during its journey through the atmosphere. This 'bobbling' is caused by gases trapped within the meteorite expanding as they get hotter and bubbling through the melted rock. We call this the fusion crust. Similarly, iron meteorites get melted by the extreme temperatures of impact. They resemble a melted piece of metal and are usually black or a very dark metallic grey. For meteorites that have a cut and polished cross-section it is possible to make a further visual inspection. Meteorites contain chondrules. These are small circular 'mini rocks' that are around a millimetre in size, contained within the structure of the meteorite, and represent the very first grains formed within the meteorite.

3 Magnetism

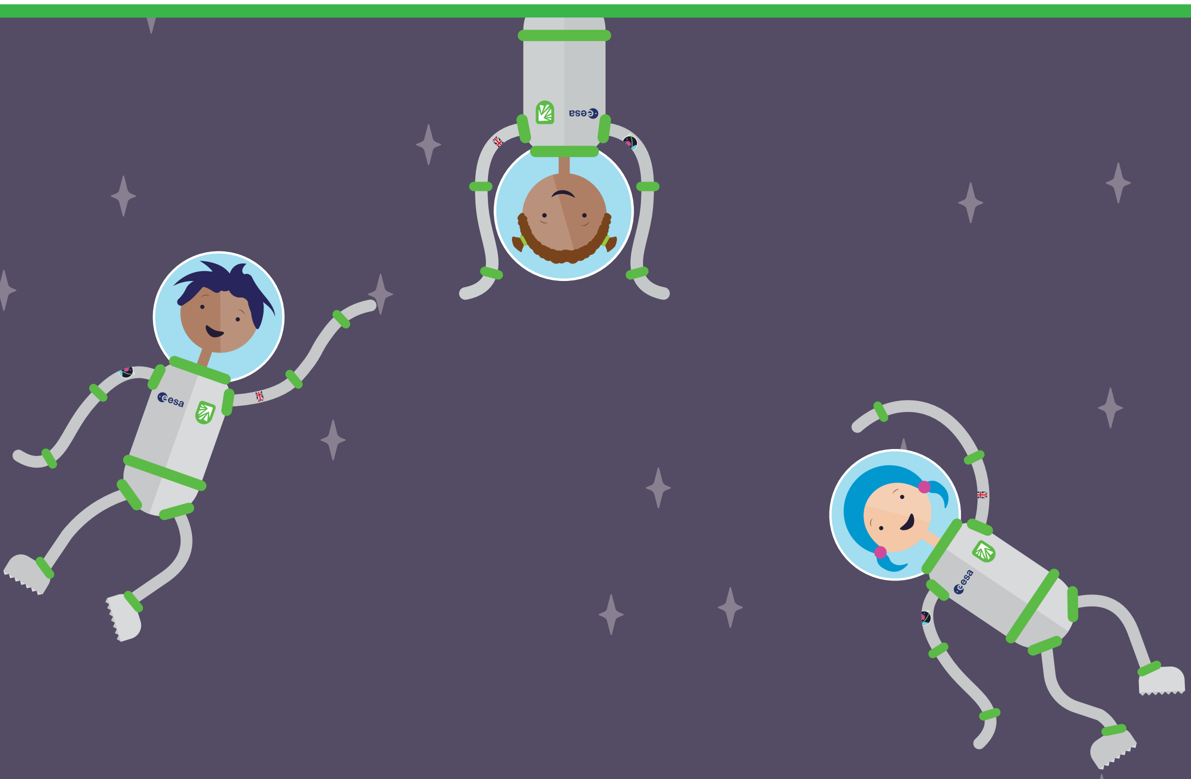
Due to their iron content, iron and stony-iron meteorites are magnetic. Participants can be handed a magnet to explore which rocks present in front of them are magnetic or not.

4 Collect micrometeorite material

Spray a hose pipe on to the roof of a shed and collect the runoff in a bucket from the drainpipe. Filter the debris and use a neodymium magnet to collect micrometeorites and view under a microscope.

Additional information

For supplier information, risk assessments, and additional resources please see digital content on ***www.destinationspace.uk***



COMPRESSED AIR ROCKET

Demonstrating the dangers of space junk

Programme Use: Family show, 5-7 storytelling

Overview

The ISS is in a Low Earth Orbit (LEO) around the Earth. However, the Earth is shrouded in a huge cloud of debris, or 'space junk' as it is often referred to. But why is it a danger to the ISS and its crew? With the compressed air rocket launcher you can demonstrate the danger of this space junk and another high speed danger – micrometeoroids.

How it works

1 *Where does space junk come from?*
Space junk is the collection of inactive, broken and in some cases smashed remnants of previous space activities. This includes inactive satellites, the upper stages of launch vehicles, and even frozen clouds of water and tiny flecks of paint. To add to this problem, collisions between pieces of space junk will often produce yet more debris, and the problem continues to grow.

2 *How much space junk is there?*
Over 30 000 pieces of space junk larger than 10cm and half a million between 1cm and 10cm are estimated to orbit the planet. There are also millions of pieces smaller than 1cm. Until 2007 most space junk was the result of accidental collisions. However in 2007, the Chinese military tested an anti-satellite missile by destroying the weather satellite Fengyun 1-C, an act which is thought to have doubled the amount of debris in orbit.

3 *If most of the space junk is small, why do we worry?*
The amount of damage an object will do when it impacts another object depends on its mass and its relative speed. Objects in a low Earth orbit travel at speeds of around seven kilometres per second. And since the kinetic energy (or moving energy) of an object is proportional to its mass multiplied by the square of its speed (KE = ½ mv2), it is the speed of the object that has the biggest effect on its kinetic energy. This means that a pound coin in orbit can have the same kinetic energy as a 500kg car driving along the motorway!

4 *How does the compressed air rocket launcher work?*
The compressed air rocket launcher has a tyre adapter at one end to allow air to be pumped in without escaping. The other end has a rotating tube that can be manually aimed. Before this tube there is a ball valve with a handle allowing the presenter to release the compressed air. A rocket is made by wrapping paper around the launch tube so that it forms a tube marginally wider than the launch tube.

Instructions for the paper rocket can be found within the digital resources online at www.destinationspace.uk

Experiments to try

Demonstrating the effect of velocity on kinetic energy (paper rocket through a box)

- Firstly, use the instructions on the website to make a rocket for the compressed air rocket launcher.
- Take this rocket and pretend to throw it at the audience and mention that they would probably not fear for their lives.
- Place the rocket on the launch tube and make sure the hand pump is connected to the launcher. Make sure the ball valve is in the closed position.
- Pump the hand pump to pressurise the launcher to 60 psi using the pressure gauge on the pump.
- Aim the rocket at a cardboard box and ensure the audience is sat at least 2 metres away and the box is not in the line of sight of any public. Warn the public that this may be loud.
- Count down from 5 and on zero, open the valve fully, as quickly as possible.

- The compressed air will rapidly expand to equalise with the pressure of the air outside of the launcher. As it expands, there is only one place for it to go – out of the launch tube. The paper rocket gets in the way and is forced off at speeds of up to 60 miles per hour. The effect of its kinetic energy can be seen as it tears through the cardboard box.

Links to Tim's mission

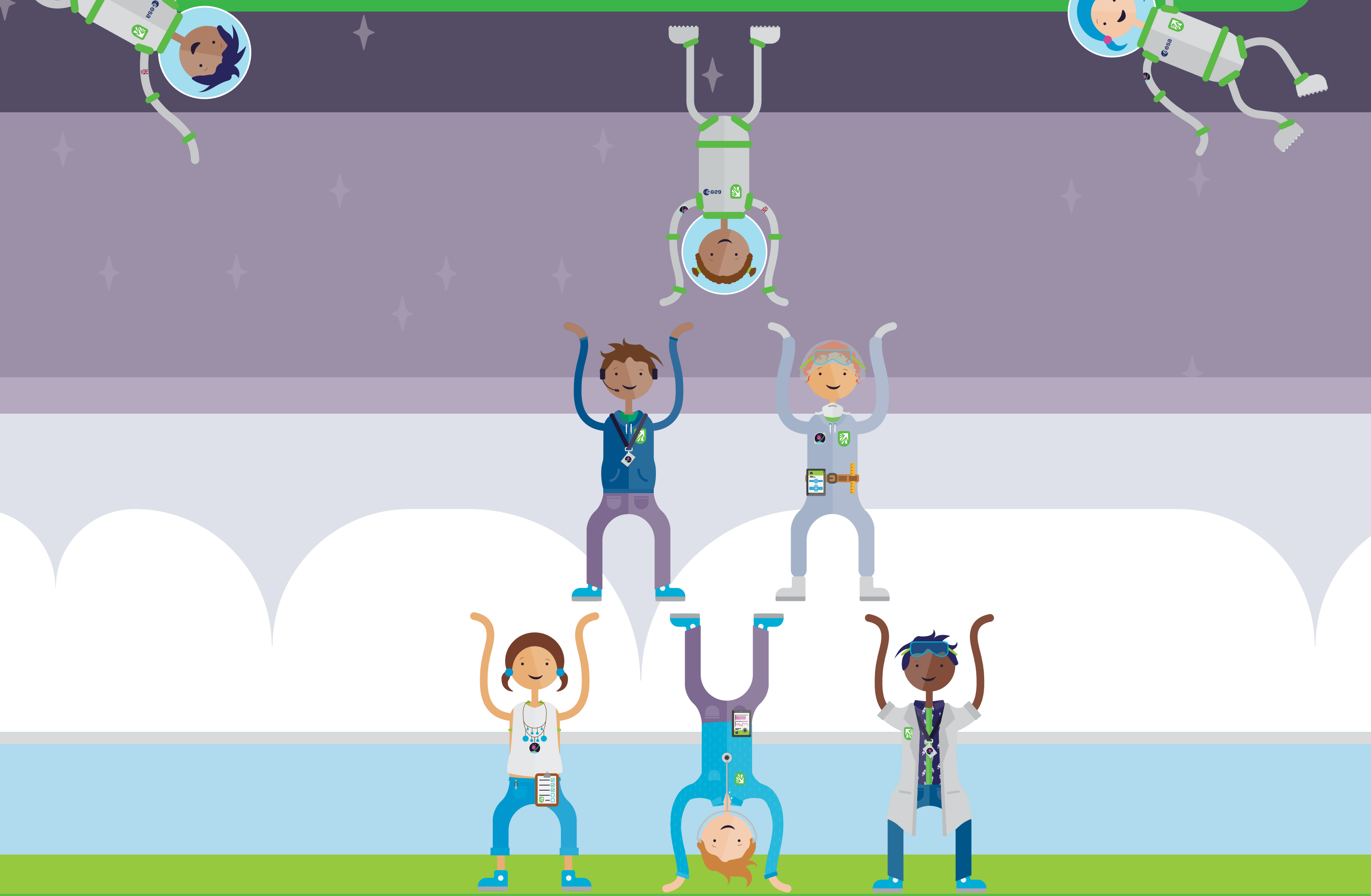
Space junk is a real concern for all those involved with ISS operations. Small debris will have a sandblasting effect on the ISS – it can erode away material over time and cause minor surface damage. Inhabited sections of the ISS are shielded by a Kevlar based material designed to protect it from most impacts, but if the ISS was to be struck by a sizable piece of space junk, then the lives of the astronauts would be at risk.

Objects as small as 10cm can be tracked from the Earth by a combination of radar and optical satellites. RAF Fylingdales Radar Installation in North Yorkshire is part of a network of stations across the planet that tracks this space junk and predicts its orbit. If a piece presents a risk to the ISS and its crew the ISS can, and has previously, fire its boosters to move it out of the way of the debris. If there is not enough time for a manouvere to take place, astronauts will head to the docked Soyuz Spacecraft that act as a life boat so that should an impact occur they can return to Earth.

If the ISS hull was breached by an impact, the crew will still have several hours before the air pressure has reduced to a level where the ISS systems will start to overheat (the crew would still be fine) and the crew have to evacuate the ISS. The crew respond to a leak by isolating each module in turn (working from the end of the space station back towards to Soyuz) until they find which module the leak is in. at this point the ground teams would work with the crew to decide what to do next, it may be possible to fix the leak or to leave the module isolated, allowing the rest of the ISS to continue to function.

Additional information

For supplier information, risk assessments, and additional resources please see digital content on ***www.destinationspace.uk***



ROBOT ARM

Performing remote tasks in space

Programme Use: 7-11 and 11-14 workshops

Overview

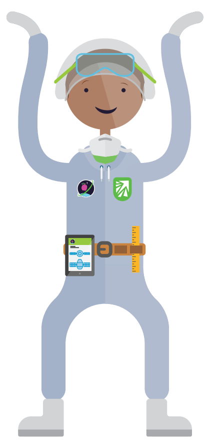
Working outside of the ISS is dangerous and should be limited as much as possible. Astronauts and mission control can control robotic components, to safely perform tasks suitable for robots. This equipment allows students to attempt to do the same.

How it works

1 ***Are robots used on the ISS?***
While the ISS does have a test robot called Robonaut, it mainly uses a robotic arm for work outside the ISS. This can be used to either attach astronauts to, to enable them to easily get into position for tasks, or to physically install equipment. The ISS has a robotic arms called Canadarm2 and Dextre which is an attachment for Canadarm2. Canadarm2 is over 17 metres long and can move along the station, attaching itself to the most convenient point for a specific task. Dextre is a smaller, two armed system that can be used with the Canadarm2 for activities requiring more precision.

2 ***How are they operated?***
The robotic arms are operated by mission control or by astronauts on board the ISS using remote control. Astronauts need extensive training to be able to operate them safely.

3 ***Why do we use robotic arms?***
Astronauts can use the robotic arm, tethering themselves to it in order to move more easily to the locations they need to work at. Tasks such as moving modules or capturing vehicles can only be done by the robotic arm. By using robotic arms, the risks associated with a spacewalk are avoided.



Experiments to try

In the workshops
Students follow task cards to combine problem solving with control of the robotic arm. They are asked to move objects from one the start area to the target. As the task continues, they are asked to move more, ever increasingly difficult to handle shapes.

Want to try more?

For more information please see 7-11 and 11-14 workshop digital resources.

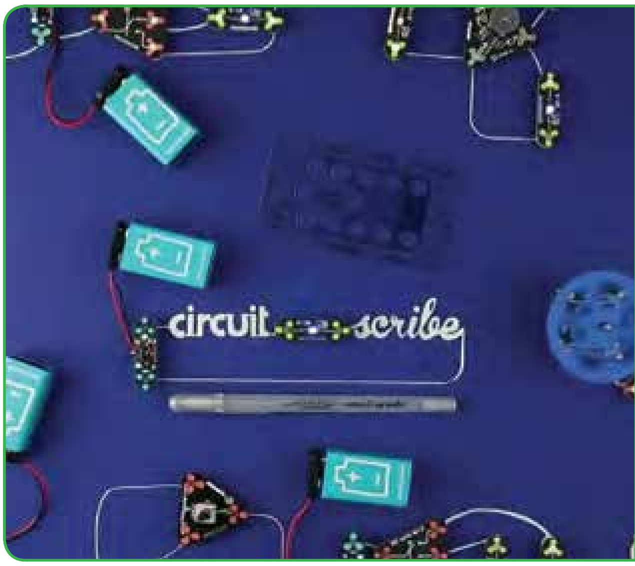
Links to Tim’s mission

Robotic ‘helpers’ are considered to be a vital part of future long duration space missions. As well as the robotic arms on board the ISS, ‘Robonaut 2’, a humanoid robot designed as a test bed for future robotic developments, is being used on the station. The most recent version, Robonaut 2, had legs delivered in 2014.

While not yet radiation hardened for use outside of the spacecraft, this prototype shows that full humanoid robots may soon become a key factor in human space flight.

Additional information

For supplier information, risk assessments, and additional resources please see digital content on ***www.destinationspace.uk***



CIRCUIT SCRIBE

Drawing circuits for the ISS

Programme Use: 11-14 workshop

Overview

Between relays for the power produced by the solar panels, individual subsystems on board and the ever changing experimental packages on board there is an awful lot of electrical wiring up on the ISS (over eight miles of electrical wiring for the electrical power system alone). These pens allow students to experiment with circuits by drawing them and then connecting components.

How it works

1. ***How do the pens work?***
   The circuit scribe pens contain a conductive silver ink that when connected to a battery will allow a current (flow of electrons) to pass through it.

2. ***How do I attach the components?***
   The components are mounted on a plastic piece that has magnets in the feet. By placing a magnetic board underneath the template paper, and using the included stencil to draw in the connections, these feet clamp to the ISS template allowing the circuits to be tested.

3. ***How far will the pens go?***
   This depends upon the surface that is being drawn on and the thickness of the lines. On gloss paper, each pen can draw about 150 metres of line.

Experiments to try

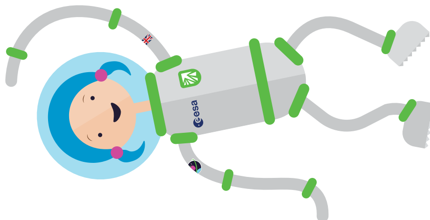
Try drawing series and parallel circuits and evaluate which type is best for certain scenarios on the ISS. Students can even write their name as part of the circuit.

Additional information

For supplier information, risk assessments, and additional resources please see digital content on ***www.destinationspace.uk***

Additional information

For full details of the activities please see digital resources for 11-14 workshop.



Links to Tim's mission

To install a new piece of equipment or to make repairs, astronauts will often have to become space electricians, following instructions set by engineers on the ground. While astronauts are not expected to be professional electricians, they do receive training in wiring and electronics. Usually any complex rewiring tasks will be pre-planned and astronauts will specifically train for this, following the instructions of the engineers.

To further complicate the issue, the wiring on the ISS is not restricted to the inside of the structure. In 2006, STS-116 Astronauts Sunita Williams and Robert Curbeam conducted a series of spacewalks to rewire the system that transfers power from the solar arrays. With increasing power demands due to new modules it was necessary to install new solar panels and rewire the external truss electronics, a task made considerably harder by the restrictions of working in a pressurised space suit and further hampered by one of the retractable solar panels getting stuck. However they were successful and the increased power capability allowed more modules and equipment to be installed on the ISS.

MIRROR AND TORCH

Simulating an ISS emergency

Programme Use: 5-7 storytelling

Overview

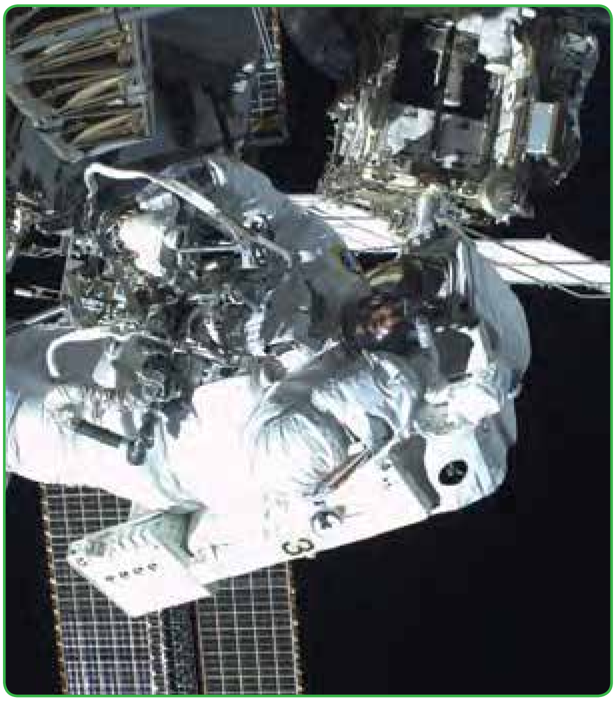
Astronauts may be required to go outside the ISS to make repairs, carry out maintenance or to install new equipment to the ISS. For the 5-7 storytelling show this equipment can be used to simulate manually moving the solar panels on the ISS.

How it works

This is aimed at demonstrating that problems occur on the ISS and there may be a need to conduct a spacewalk to fix a problem on the outside of the ISS. In this demo the volunteer that is dressed in the space costume will be given a mirror to simulate the solar panels on the ISS. Two other volunteers will be needed to be the Sun and an astronaut on the ISS, respectively. The volunteer conducting the spacewalk must try to position the mirror so that the torch light (Sun) can be seen by the astronaut on the station.

Additional information

More information on this activity can be found within the digital resources for the storytelling workshop online at ***www.destinationspace.uk***



Links to Tim's mission

During an EVA (Extravehicular Activity, a spacewalk), astronauts usually remain attached to the ISS by tethers. Tethers are like ropes. One end is hooked to the astronaut, the other to the outside structure of the ISS. These are for safety, as tethers stop astronauts from floating away into space. Astronauts also use tethers to keep tools from floating away, by tethering tools to their spacesuits. The hooks on the tethers require two separate actions to open them, to ensure they are not opened accidentally.

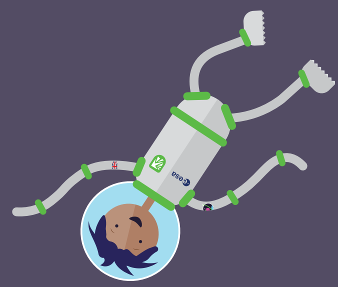
If their tether breaks and astronauts float away from the station they can rescue themselves by using their jetpack called 'SAFER' (Simplified Aid for EVA Rescue). This is worn like a backpack and is essentially a jetpack. It uses small thrusters to let an astronaut move around in space and is controlled with a small joystick.

Spacewalks are dangerous and only conducted when necessary, but if something does go wrong with the ISS, then the astronauts need may need to perform a spacewalk to solve the problem.

Additional information

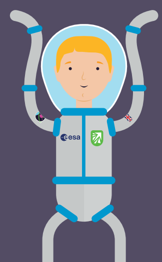
For supplier information, risk assessments, and additional resources please see digital content on ***www.destinationspace.uk***

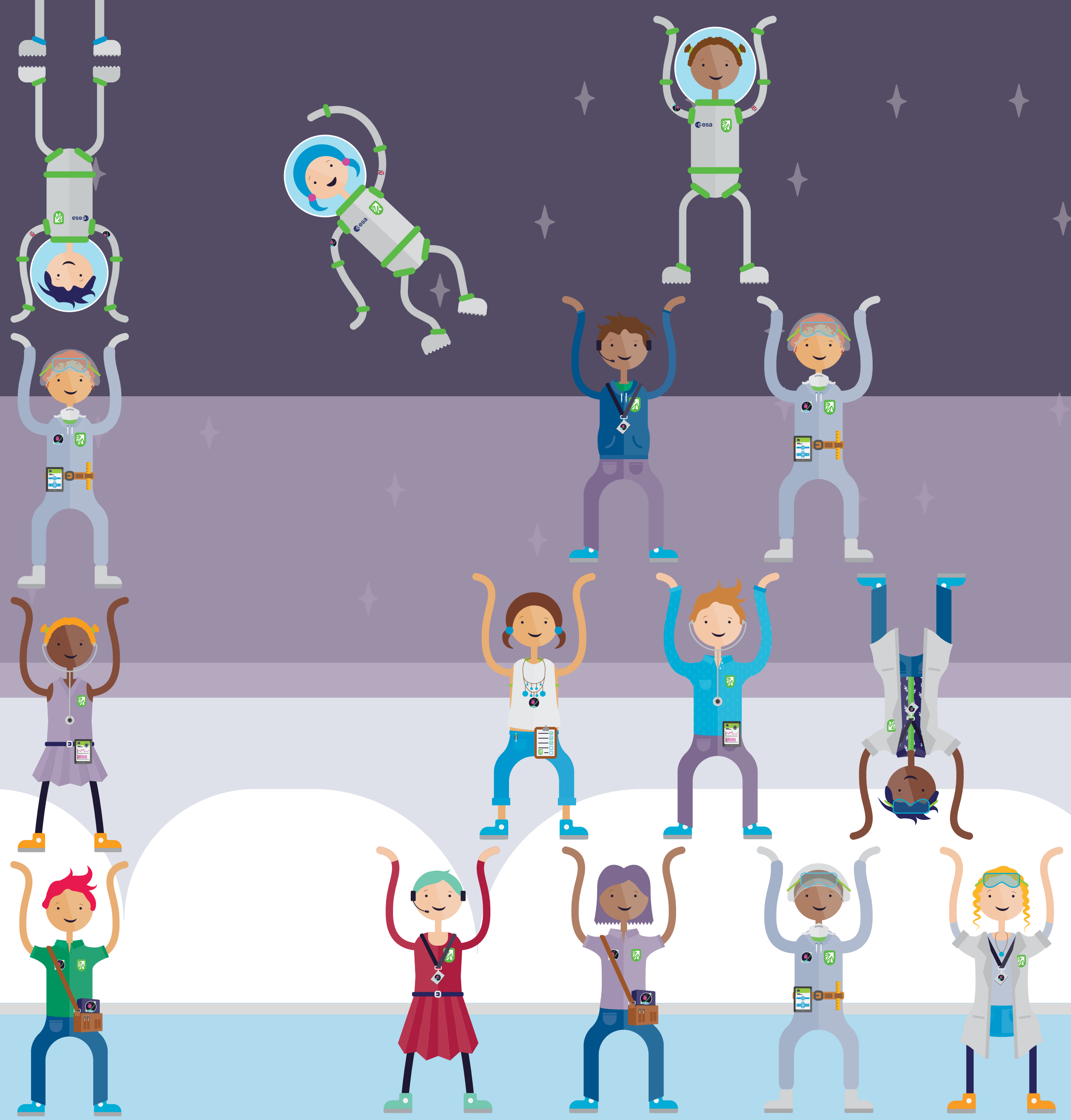
DESTINATION SPACE!



GETTING BACK FROM SPACE:

Stories and Equipment Briefing Sheets





GETTING BACK FROM SPACE

Introduction

It takes an enormous amount of energy to get the Soyuz spacecraft (the craft that takes astronauts to space) into orbit and docking with the ISS. All of the energy required to fight against the pull of gravity is supplied by the combustion reaction of kerosene and oxygen in the rocket engines. As the rocket gains speed and altitude, it gains kinetic and gravitational potential energy as a result. In order to come back down to Earth, it has to lose this kinetic and gravitational potential energy, and as it enters the atmosphere, it does so in spectacular fashion.

It takes up to two days to get to the ISS, but once Tim and his two crew mates undock from the ISS, it will take much less time to get back. If all goes to plan, three and a half hours after undocking with the ISS his capsule will touch down on the flat steppe of Kazakhstan, and his first space mission will be complete.

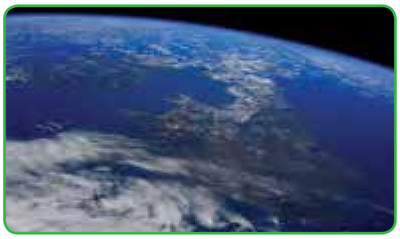
Saying Goodbye to the ISS

The run up to a return to Earth is rather long. Several hours of checks are made on the docked Soyuz spacecraft to ensure that it is fit for return, including electrical and communications checks. When the all clear is given, the returning astronauts put their Sokol space suits (the suits astronauts wear for launch and landing) on and clamber back into their Kazbek launch couches. With a final goodbye, the hatch is closed and sealed and final checks are made.

The separation command is given, opening the hooks and latches which hold the Soyuz spacecraft to a docking port on the International Space Station. After three minutes, these have all opened and the Soyuz begins to drift away from the ISS. Once it gets to a distance of about 30 metres, thrusters fire for 15 seconds to ensure a clean separation and the Soyuz begins its slow descent towards the Earth.

Two and a half hours after separation the thrusters fire for 4 minutes and 21 seconds in a 'de-orbit' burn. This slows the Soyuz down and places it into a lower, re-entry orbit.

Credit: ESA/NASA



Nearly three hours after separating from the ISS, the descent module (the central module of the Soyuz spacecraft where the astronauts are strapped in to their couches) separates from the orbital and propulsion modules. Shortly thereafter the Soyuz reaches 'entry interface'.

The descent module has its own navigation and control system which enables the crew to manoeuvre the vehicle after the Orbital and Propulsion Module has been jettisoned. The Soyuz commander can pilot the module using a rotational hand controller that manages the firing of eight hydrogen peroxide thrusters on the vehicle's exterior.

Re-entry

At an altitude of around 122 kilometres, the descent module hits 'entry interface' with the atmosphere. The astronauts are now only 23 minutes away from landing.

Credit: ESA/NASA

At this point, extreme compression of the tenuous gases in Earth's upper atmosphere slamming into the spacecraft results in those gases experiencing a massive rise in temperature. This is called Ram Air Compression (not "friction") and it starts to heat up the outside of the module to incredibly high temperatures. The hot plasma (a gas where the temperature is high enough for electrons to escape their atoms leaving them ionised) formed by the compression causes the leading edge of the module to heat up to over 1600°C.

This extreme temperature means that the spacecraft needs a TPS, or Thermal Protection System, to be protected from damage. There are two methods commonly used to protect spacecraft on re-entry; single-use ablative heat shields or multi-use heat tiles/ other composites. Ablative heat shields are the method that Soyuz uses, whereas re-usable tiles/composites were used by the Space Shuttle and will likely be used in the next generation of manned spacecraft.

Soyuz's ablative heat shield system works by having layers of protective material that ablate, or peel away, during re-entry. As the outer layer peels away they carry with them the thermal energy from the hot plasma layer, leaving a cooler surface behind. Once this surface gets sufficiently hot, it too will peel away and the process continues to repeat itself.

The TPS system employed by the space shuttle involved the use of seven different materials with different thermal properties placed in various locations around the shuttle. These included reinforced carbon-carbon panels; used where the re-entry temperature would be greatest and High-Temperature Reusable Surface Insulation (HRSI) tiles used on the underside of the shuttle. These tiles acted as heat sinks, absorbing and re-radiating large amounts of thermal energy but not transferring it through conduction to the internal shuttle structure.

During re-entry the atmosphere acts to decelerate the spacecraft – for Soyuz, the maximum deceleration is normally around 4g but can peak at over 8g for what's called a ballistic re-entry. During the deceleration, the Soyuz's kinetic and gravitational potential energy are being lost and converted into enormous amounts of thermal energy.

Landing


Credit: NASA/Bill Ingalls

Eight minutes after beginning re-entry, the descent module hurtles through the air at 230 metres a second (514 miles per hour). It needs to slow down significantly before landing. It's at this stage that the descent module's navigation and control system are disabled; from this point on it's the job of the parachutes to slow the craft.

Four parachutes open, 15 minutes before landing. The first to open are two pilot parachutes, followed quickly by a drogue chute. The drogue, measuring 24 square meters, slows the craft to 80 metres per second (179 miles per hour).

The main parachute is the last to emerge. It is the largest, with a surface area of 1,000 square metres. Once open, the drogue chute is cut loose. Not only does the main parachute slow the craft down, it tilts the descent module to angle of 30˚ (relative to the ground), in order to allow heat to escape. It then tilts the craft back to vertical before landing. The main parachute slows the Soyuz to a speed of 7 metres per second (16 miles per hour), but this is still too fast for a comfortable landing.


Credit: NASA/Bill Ingalls

Finally, one second before touchdown, six small engines on the bottom of the module fire, slowing the craft one last time.

In order to ensure the landing is a soft as possible, the crew's seats are lined with cushioning material. Each seat has been individually moulded to fit each astronaut's body. This ensures a tight, comfortable fit when the module lands. (However astronauts still report that landing is similar to a controlled car crash.)

After landing, the astronauts must wait in their seats for another 10 to 20 minutes before the descent module's hatch is opened. Then they are pulled out, and placed in reclining seats. They are carried to a medical tent where, under medical supervision, they can attempt to stand up for the first time in months.

What's it like?

Astronaut Doug Wheelock in an interview to ABC news: ***goo.gl/hufeRx***

"It's incredibly bumpy and hot and cramped. It's kind of like going over Niagara Falls in a barrel but the barrel is on fire."

"You have a lot of G-forces pushing you down. You're watching parts of your spaceship burn up outside of your window. It's a little alarming visually. And then, of course, the heat shield on the Soyuz is ablative. It melts off and chunks roll off as you're coming through the atmosphere so, consequently, [it] gets thinner and thinner."

"They train you to keep your hands and arms inside of your body enclosure to make sure you don't break anything. You get as small as you can. When you hit, some people stick the landing. We bounced. We hit again and rolled over. It depends on the winds and things like that."

After landing: "A lot of people feel a tingling in the bottoms of their feet. The nerve endings in your feet are feeling your body weight for first time in months."

Video

Soyuz undocking, reentry and landing explained: goo.gl/NpZ2N0


Credit: NASA

SOYUZ SPACECRAFT

Tim's space vehicle

Programme Use: Across the programme

Notice: This is an information sheet

Overview

Tim will launch into space in a Russian Soyuz TMA-M spacecraft (hereafter referred to as the Soyuz) sat atop a Soyuz-FG rocket. This rocket and spacecraft combination is currently the only method available to ISS partner space agencies to get astronauts to (and return them safely from) the ISS.

How it works

1 *What is the Soyuz used for?*

The Soyuz spacecraft is located right at the tip of the rocket on launch and the only part of the rocket actually capable of housing astronauts. Once in orbit it is able to dock with the ISS and once docking procedures have completed the astronauts can get on-board. The Soyuz stays attached for the duration of a stay as it acts as a 'lifeboat' for the ISS. Three crew members can fit in the Soyuz and there will always be enough docked with the station at any time for all crew members to be able to evacuate in an emergency. At the end of a mission, astronauts re-enter the Soyuz which is then released from the station. Astronauts arrive back safely onto the surface of Earth with the help of the Soyuz.

2 *What is the spacecraft like?*

The Soyuz is made up of three main parts; the orbital module, the descent module and the propulsion module.

The orbital module is a spherical pressurized vessel used by the crew during the orbital phase of the mission (once the Soyuz has got into space and is heading for the ISS). In its front side, it has installed the docking mechanism, the hatch and the rendezvous antennas to facilitate docking, while in the back is the hatch that separates it from the descent module.

The descent module is the central part of the Soyuz. It is equipped with all the required means for the safe re-entry of the astronauts including the shock absorbing couches, controls and displays, life support provisions, batteries, parachutes, and landing rockets. Tim will launch into space and return to Earth while strapped into this module.

The service module contains the orbital thrusters as well as the majority of the scientific and communications systems of the Soyuz. This part of the Spacecraft is not accessible for astronauts.

3 *How much room do the astronauts have?*

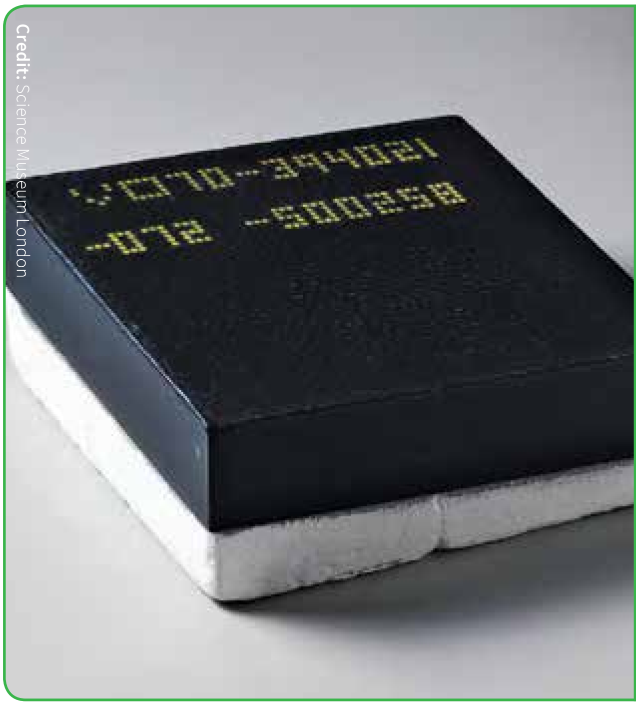
Conditions are a little cramped on the Soyuz. Between the orbital and descent modules astronauts have nine cubic metres of habitable volume (about the same amount of living space as a large van). It is even more cramped at launch, when three fully suited astronauts get strapped into their custom made launch couches, tucking their legs up under them. They launch lying on their backs to reduce the effects of acceleration on launch and so getting into position is no easy task.

Links to Tim's mission

The Soyuz spacecraft has existed in various forms since 1967 (when it could only launch two astronauts). While the onboard systems are regularly updated and modified the basic design is remarkably unchanged. However it has successfully been a workhorse of human spaceflight, with an excellent safety record (no fatalities since 1971). While it may be cramped and uncomfortable to begin with, Tim will be in good hands for his journey to, and from, the ISS.

Additional information

For supplier information, risk assessments, and additional resources please see digital content on ***www.destinationspace.uk***



Credit: Science Museum London

THERMAL PROTECTION TILE

Keeping cool on re-entry

Programme Use: Family show

Notice: Blowtorch – take care not to burn yourself, wear eye protection

Overview

The descent module of Tim's Soyuz spacecraft will experience temperatures in excess of 1,600°C as it punches through the atmosphere on its way back to Earth. Thermal protection systems must be used to prevent this heat energy destroying the spacecraft. This piece of equipment (which is used on a shuttle) can be used to demonstrate one of the methods used to protect spacecraft from these effects.

How it works

1 *Why does the descent module get so hot on re-entry?*

As the descent module slams into the Earth's atmosphere a combination RAM compression heating (caused by the rapid compression of air in front of the hurtling module) starts to heat up the air in front of the module. As a result, hot plasma (a gas where the temperature is high enough for electrons to escape their atoms leaving them ionised) causes the leading edge of the module to heat up to over 1600°C.

2 *How is Soyuz protected from this re-entry temperature?*

The descent module is surrounded by an ablative heat shield system. This works by having layers of protective material that peel away during re-entry. As the outer layer peels away it carries with it the thermal energy from the hot plasma, leaving a cooler surface behind. Once this surface gets sufficiently hot, it too will peel away and the process repeats.

3 *What is this tile used for?*

This tile is a Thermal Protection System (TPS) tile that was used as part of the Russian version of the Space Shuttle (The Buran). Since the Buran was a re-usable space vehicle, the thermal protection could not be ablative in nature – it needed to be reusable and easily replaceable. As a result, the Buran was covered in series of TPS tiles made from fibrous ceramic material.

This material is designed to have a very low thermal conductivity, so heat does not easily travel through it into the spacecraft. The material is also very good at radiating heat away, so it cools down very quickly.

Experiments to try

1 *Thermal protection*

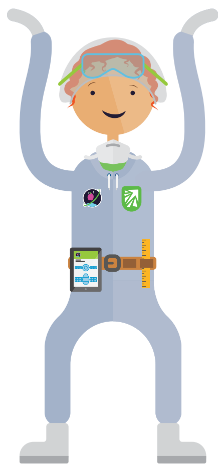
You will need: Thermal protection tile, blowtorch, thermal imaging camera (optional)

Hold one corner of the thermal tile.

Turn on the blowtorch and heat the corner of the tile diagonally opposite from your hand, making sure to point the flame away from you.

The corner being heated will begin to glow with heat, and yet it will not transfer to your hand!

If you have a thermal imaging camera, get a member of the audience to hold this and focus on the corner you are heating – the heat will stay confined to that corner.



Experiments to try (cont.)

2 Protecting chocolate

Place the tile on a tripod stand and place a flat bottomed chocolate on top.

Heat the bottom of the tile – the chocolate will not melt.

This can be projected with a camera or works well as a busking activity.

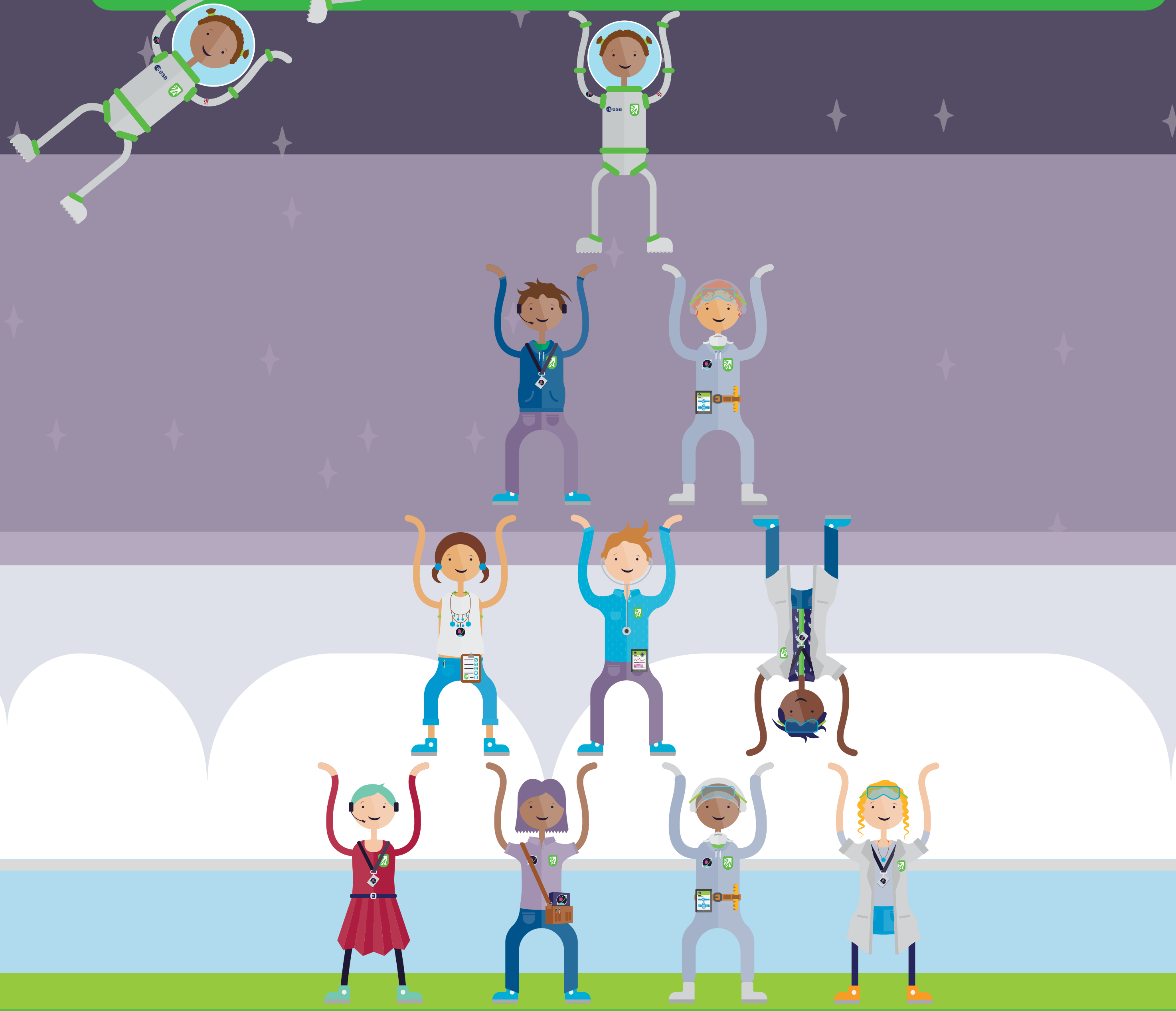
Links to Tim's mission

Apart from launch, re-entry is the most dangerous time for an astronaut. As Tim returns to Earth and blasts through the atmosphere, he will be able to see the super-heated plasma stream pass the window, as well as the glowing embers of the ablative shield material as it comes away from the front of the craft.

For more information please see the getting back to Earth story.

Additional information

For supplier information, risk assessments, and additional resources please see digital content on ***www.destinationspace.uk***



THERMAL IMAGING CAMERA

Watching heat in action

Programme Use:
Optional addition to the family show

Notice: For those centres that have this kit

Overview

The infrared camera can be used in conjunction with the thermal tile re-entry demonstration to visibly show the low thermal conductivity of the tile. For centres that do not have a thermal imaging camera, a video of this is provided in the digital resources found online at www.destinationspace.uk.

How it works

1 *Why is this different from a normal camera?*
Rather than detecting visible light, like our eyes, this camera detects a different kind of light called infrared (IR) radiation. Occupying a different section of the electromagnetic spectrum, we often refer to infrared radiation as heat.

2 *If we wanted to measure temperature why don't we just use a thermometer?*
To get accurate readings for temperature a thermometer can be used, however, a thermometer is often too specialised. While a thermometer enables us to get accurate single point readings the IR camera enables us to visualise and study a whole scene. Using this tool we can investigate properties such as conduction and insulation in a much more visually spectacular way than we could by simply using a thermometer.

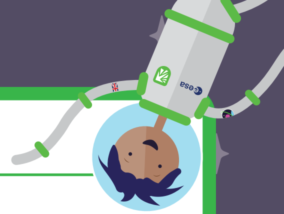
Experiments to try

1 *Which materials make the best insulators?*
Point the camera at the audience and ask them what they notice. Where the audience has skin showing they appear to be very bright (the brightest colours correspond to the hottest temperatures). This is because skin is a poor insulator and lets plenty of heat escape.

Areas of hair, tops of heads or beards, often appear darker as they trap heat inside allowing less heat to be detected. This leads on nicely to the idea behind wearing clothes. Clothes trap in heat so clothed areas will appear darker when observed using the camera. We can also investigate different styles of clothing. Thick jumpers will appear darker (cooler) than t-shirts since they are better insulators.

If you can find someone wearing glasses in the audience use this to highlight how different materials transmit different types of light. Glass allows visible light to pass through; however using the camera you can see it reflects the infrared back, not allowing it to be transmitted through the glass.

This demonstration can be extended. Ask for two volunteers from the audience, have one stand in a bin bag (pulled up to waist or beyond depending on size) and have the other wrap themselves in a mylar survival blanket (this can be obtained from camping shops). Point the camera at them and you will be able to see a big difference; the blanket will be opaque whereas the bin bag will be virtually transparent. You will be able to see the volunteer's legs through the bag.



Experiments to try (cont.)

2 Observe thermal conductivity

Ask a volunteer to take off their shoes. Get them to stand still for a few moments and point the camera at their feet. You should see that they are brighter (hotter) than the floor. Then ask them to take a step back and you will see a footprint left behind – the result of thermal conduction between their feet and the floor.

The infrared camera can also be used during the thermal tile demonstration. Get a volunteer to aim the camera at the corner that is being heated and you will see that the infrared does not travel far from this spot. The spot being heated gets incredibly hot, but the thermal tile does an incredible job of not conducting the heat – it is an excellent insulator.

Links to Tim's mission

Infrared imaging can be used to examine the thermal conducting and insulating properties of materials used in the construction of the ISS. Since there is a huge temperature difference between the side in direct sunlight and the side in the shade, it is important to make sure that heat is able to easily conduct around the body of the station to avoid damage due to expansion and contraction of the station during changes of temperature.

Additional information

For supplier information, risk assessments, and additional resources please see digital content on ***www.destinationspace.uk***


Credit: NASA/Bill Ingalls

PARACHUTES

Safely returning to Earth

Programme Use: 5-7 storytelling, busking

Overview

Once the descent module (the part of Tim's spacecraft that returns him back to the Earth) has stopped burning up on re-entry, it is down to parachutes to bring him gently back to the ground. This demonstration allows visitors to get a feel for air resistance, and the importance of a parachute in the safe return of astronauts.

How it works

1. ***What force slows you down as you move through the air?***
The force which slows you down is air resistance. The air contains billions of tiny molecules that are too small for humans to see. An object moving in the atmosphere will experience a dragging force due to all of these molecules bashing into the object – this is known as air resistance or drag.

2. ***What determines the amount of drag?***
The size of the drag force depends on the surface area of the moving object, its shape and the speed at which it is moving. The larger the surface area, the more surface there is for air molecules to bash into, increasing the drag force. This is why parachutes are so big – they provide a big force working against gravity. The faster an object moves, the bigger the drag force as well, meaning most objects will reach a terminal velocity (or maximum velocity) as they fall through the air. This velocity is when the drag force and the force due to gravity become equal. The smaller the surface area, the faster the terminal velocity.

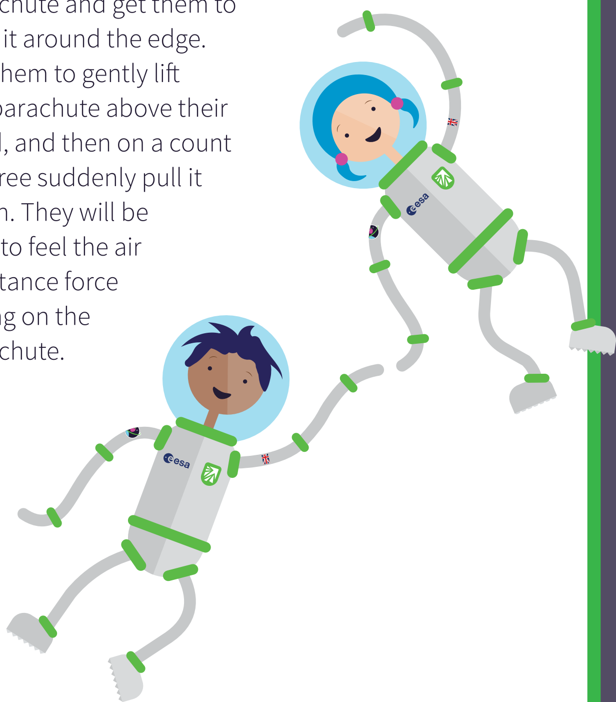
3. ***Why do parachutes have holes in them?***
Parachutes have holes in them to ensure the air flows around them properly. If there are no holes the air flow can become chaotic and disturb the motion of the object attached to the parachute. This can cause the object to move in unpredictable ways – in the worst case the object and the parachute can end up the wrong way up, in which case the parachute is no use any more.

Experiments to try

Drop an object with and without a parachute attached. You should see the object with the parachute attached falls much slower.

Try dropping an object attached to a parachute with and without holes in it. Look to see if the motion is smoother in one case than the other.

Gather people around the giant parachute and get them to hold it around the edge. Get them to gently lift the parachute above their head, and then on a count of three suddenly pull it down. They will be able to feel the air resistance force acting on the parachute.



Additional information

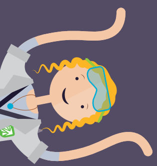
For supplier information, risk assessments, and additional resources please see digital content on ***www.destinationspace.uk***

www.destinationspace.uk

DESTINATION SPACE!

SHOWS, SCHOOL WORKSHOPS AND ACTIVITIES:

Scripts and Briefing Sheets



FAMILY SHOW

Summary

This is a 30 to 40 minute show aimed at family groups visiting your centre. This is a suggested guideline and you are free to change the text and demonstrations used. Suggested swap options will be discussed later on in this document.

This show explores what life is like for an astronaut from training, to living and working on the ISS and then returning safely back to the Earth. This story will be told using the following demonstrations:

Oxygen and hydrogen bubbles (or whoosh bottle), hovercraft and Newton's third law, Lifesaver water filter bottle, compressed air rocket launcher and the thermal insulation tile blowtorch demonstration (with an infrared camera if you have one).

Suggested activities

Other suggested activities that would fit well within this narrative:

- ***Space nappies*** – magic snow
- ***Dangers of a vacuum*** – vacuum demonstrations
- ***Whoosh bottle*** – can be substituted for the oxygen and hydrogen demonstration.

For specific details of all of these pieces of equipment, please refer to the briefing sheets.

Equipment needed

Oxygen and hydrogen demo:

- Balloon prefilled with oxygen and hydrogen and sealed
- Tray with water and bubble mix
- Metre ruler with a wooden splint on the end
- Matches/lighter
- Hovercraft demonstration:
- Hovercraft and leaf blower
- Heavy ball to throw

Recycling water:

- Lifesaver bottle
- Plastic box or bowl to pour over
- Plastic jug of 'waste water'
- Glass to pour the water into

Space junk dangers:

- Compressed air rocket launcher
- Bike pump
- Paper rocket
- Cardboard box

Coming back safely:

- Buran shuttle tile
- Blow torch
- IR camera (if you have one)

SCRIPT

Introduction

Slide 1 – Welcome slide

- Hello and welcome to the Destination Space family show! My name is ***[your name]*** and today we are going to look at what life is like for an astronaut living in space. We are also going to look at the thousands of people that make these missions possible

- And to introduce the show we have a message from someone who has trained to go into space.

Bring up slide 2 – Tim intro video

- Thanks Tim!

- Out of interest who here has heard of NASA? So lots of you have heard of the American Space Agency, but what about ESA? ESA is an organisation made up of 22 countries which work together on space missions - from sending astronauts to space to robotic exploration. And the UK Space Agency? Well the UK Space Agency is our own, British space agency, which works with ESA (the European Space Agency). And ESA have their own astronauts, men and women from lots of different countries. And we are so excited about Tim Peake's Principia mission because Tim is the first British ESA astronaut!

- But where is Tim going/where did Tim go?

Bring up slide 3 – ISS video

- This is the International Space Station or ISS as it is known for short.

- It is going around the Earth (orbiting) at a height of 400km and is humanity's laboratory in space. It has permanently got astronauts on-board conducting science experiments and performing maintenance on the station. And it is a true international project with the American, European, Russian, Japanese and Canadian space agencies involved.

Bring up slide 4 - experiments

- And Tim will spend most of his time conducting many experiments himself including looking into things like sleeping patterns in space, how his metabolic rate changes, study how skin ages in microgravity, looking at how bacteria respond to the space environment and many more!

Bring up slide 5 – training montage

- Now Tim started basic astronaut training in September 2009, so he has gone through six years of basic, and specialised training in everything from working in a weightless environment (click), controlling the space craft used to get to the ISS (click), living in a confined environment under the sea to simulate living in space (click) and much more.

- And following all that training the time comes to get into space! But how do we get there?

Getting into Space

Bring up slide 5 – Soyuz launch pic

- Yes, we need a rocket. And the rocket Tim will use/used is called the Soyuz-FG. This Russian rocket is 50 metres tall (the height of about 35 cars stacked on top of each other) and Tim will be/was sitting in just this top little bit, (click to bring up Soyuz) that houses the Soyuz spacecraft that ferries astronauts to the ISS.

Bring up slide 6 – How does the rocket work?

- And how does the rocket get the astronauts into space? Well what do we see coming out of the back of the rocket?

- That's right, fire! And all rockets work on basically the same principal – riding a big, continuing explosion into space.

- Now does anyone know what the science word for burning is? It's combustion. And to get combustion we need all the parts of the fire triangle.

Bring up slide 7 – fire triangle

See Oxygen and Hydrogen Briefing sheet for in depth demonstration specifics

Note: you can substitute the whoosh bottle here if you prefer – see whoosh bottle briefing sheet

- We are going to look at this fire triangle in action. First we need a fuel. Now the Soyuz-FG uses kerosene (heating oil) as its main fuel, but some rockets use one of the gasses I have put in this balloon; hydrogen.

Take pre-prepared oxygen and hydrogen balloon

- And what other gas do we need for things to burn?

- We need oxygen, and is there any oxygen in space? No! So our rocket needs to supply its own oxygen, which I also added to this balloon.

Bring up slide 8 – Soyuz engine

- Instead of using balloons, the Soyuz has two huge fuel tanks holding a quarter of a million kilograms of fuel and oxygen between them. They are combined in the motor here (point to motor) but we are going to trap it in bubbles instead.

Bubble oxygen and hydrogen through the tray of bubble mixture

So we have our fuel and oxygen, but what else do we need?

Select volunteer from the audience

We need an ignition source, some heat to start the combustion reaction. So for this I will need a brave volunteer.

Ok, you are going to ignite our mixture. If you can please take this ignition stick…

Hand them meter ruler with splint on end

And this can get loud, so can you please wear these ear defenders and fashionable goggles…

And audience, you may want to cover your ears for this as well!

Hand them ear defenders and goggles

Ok, I am going to light the end of our ignition stick, and we will count down from 5. At zero, I would like you to touch the end of the ignition stick to the bubbles. Are you ok to do that?

Alright, lets count down…5,4,3,2,1 – Zero!

Bubbles are lit

Brilliant! Can we please have a big round of applause for our brave volunteer!

Volunteer sits back down

So, there is our combustion reaction. But how does this make our rocket move?

As I stand here on the ground, why don't I go floating off?

That's right – gravity is pulling me down towards the Earth. And to get into space we have to fight this gravity. Now as I stand here, am I going down?

No I am not. This means that the Earth is pushing back on me. I push down on the Earth and the Earth pushes back. And what can we say about the size of these two forces, or pushes?

Yes! They have to be the same.

Bring up slide 9 – Newton

- This is what a famous scientist called Isaac Newton said in his famous third law of motion:
- For every action there is an equal and opposite reaction.
- But let's put this to the test…with…a HOVERCRAFT!

Bring up slide 10 – Hovercraft and Newton's Laws

- This hovercraft will let us demonstrate Newton's 3rd Law. By raising up on a bed of air, we can get rid of a pesky force that makes this experiment difficult. What force is this?
- Yes friction. To demonstrate this I will need a brave volunteer from the audience

If in a large space, can get several volunteers to 'pass' the hovercraft around

- Please sit right in the middle of the hovercraft. Now if I try to push you (push the hovercraft) you won't go anywhere because the friction with the floor stops you. But if we raise you up on a bed of air (switch on hovercraft and give a light push) friction is now lower and you drift gently away!
- Turn off hovercraft.
- Let's hear it for our volunteer!
- So how does this link to our rocket?

Bring up slide 11 – Newton's 3rd law

- Well, the fire we see coming out of our rocket is made up of all of the things produced during the combustion of the fuel and oxygen – things like carbon dioxide and water vapour. They are being pushed out of the back of the rocket.
- Can I have another volunteer please? (pick someone relatively light who looks like they can throw the heavy ball)
- Please sit in the centre of the hovercraft. Again I am going to turn the hovercraft on, but this time, I would like you to throw me this ball. I will catch it and throw it back to you, and we will keep passing it between us ok?

Turn on hovercraft and set it at rest. Move into position and begin playing catch. Every time they throw the ball, they should move in the opposite direction

Turn off hovercraft and ask volunteer to sit down

- Let's have a round of applause for our volunteer!

- So why did they move backwards when they threw me the ball? Well, they forced the ball away from them (click to show molecule moving away from rocket) and as a result of Newton's third law, the ball pushed back with an equal and opposite force. And each time the ball was thrown they received a new equal and opposite force, increasing their speed – just like our rocket. But our rocket is throwing billions of particles behind it every second, each one pushing back on the rocket.
- And that is how Tim will get/got into space.

Bring up slide 12- Soyuz launch clip

- So once Tim gets/got up there, what is his life like/will his life be like?
- Well, life in space is very different from life on Earth.

Living in space

Bring up slide 13 - microgravity

- Sophie add in Newtons second law and how you measure an astronauts mass.
- Because the astronauts float around (and if you would like to know why come and see me at the end) it looks like a lot of fun.
- But this has problems. Tim will lose muscle since he won't use his legs much. Fluid that is normally pulled towards his feet will now gather in his head and chest causing his face to go puffy, and these two effects combined are known as puffy-head-bird-leg syndrome.
- For reasons we still don't understand calcium leeches out of the bones and causes them to become brittle. And there are many other problems that he will experience. As a result, medical professionals will monitor the health of Tim and the other astronauts.

Bring up slide 14 – medical careers

- But despite these differences, astronauts still have to do every day things in space.

Bring up slide 15 – Life in space

- They have to eat, being careful not to let anything drift away. They have to drink, and of course they have to go to the toilet – training for a while on how to use this specially designed space toilet. I'll give you a clue to how it works: What would happen to human waste in space if you went to the toilet normally? It's disgusting but yes it would float around. So to stop this from happening, the space toilet has a hose with a special adapter for liquid waste to go into, and a compartment for solid waste to go into. And they both rely on suction to stop any waste escaping.

Recycling

- It costs a lot of money to get supplies up to the ISS and as a result, most water is recycled – even urine!

- Ewww! I hear you say! Well filter technology has become so good, I am willing to take this lovely mix of waste water and urine (show jug of dirty water), filter it, and drink it!

- Like on the ISS waste water will go through several filtration steps. Here, we first separate out the larger particles.

> Pour liquid into lifesaver bottle THROUGH the blue sponge ***[while nestled in the bottle]*** over a box
>
> Screw the pump end in and make sure that the bottle top is pressed down and the cover is in place

- Now the water inside is still dirty. As I pump the bottle I compress gas inside.

> Pump the bottle 6 times

- Once I open the top, this compressed gas forces the water through the micro-filters and removes any remaining particles.

> Open the top and pour the liquid into a glass

- As you can see, the water we get is much, much cleaner than the water that went in, in fact…

> Take a sip of the water

- Any harmful particles, as well as bacteria and viruses have been filtered out of the water and it is completely safe to drink!

Bring up slide 16 – water filtration on the ISS

- The ISS has two water filtration systems, one in the Russian Zvezda module and one in the American Tranquillity module and these allow around 85% of the water used on board to be recycled.

Space Dangers

- And while Tim will/is living in space, there are also factors beyond his control that could pose a threat.

Bring up slide 17 – space junk

- This image shows all of the stuff that is orbiting the Earth. This includes broken satellites, material from previous missions and rocks that get pulled in towards the Earth by gravity.
- But why is all of this a problem?
- Well with virtually no atmosphere, things in orbit around the Earth are able to move very fast – at tens of thousands of kilometres per hour.
- And objects that are moving have a type of energy called kinetic energy, or moving energy.
- Imagine you are walking along and bump into someone – will it hurt badly?
- No, probably not, but what if you are running and bump into them, will it hurt more or less?
- Yes, it will hurt more! When do you think you have more kinetic energy, when you move faster or slower?
- Yes, so the faster an object is going, the more kinetic energy it has. And this is a problem in space because even something really small, if moving really fast, can have a lot of kinetic energy.

Pick up paper rocket

- Take for example this paper rocket. Now it is not very heavy, and if I threw it very gently at you, do you think it would hurt much?
- Well, the point might! But you wouldn't be running for your life!
- But if I put the rocket on this device, we'll see if we can make it go a bit faster.

Place rocket on the compressed air launcher

- This is my compressed air rocket launcher. I have a valve at the front that I can open and close, and currently it is closed.
- As I pump air into the launcher…

Pump up the launcher to 60 psi

- …I squash the gas together and so it is at high pressure. What do you think will happen when I open the valve at the front and let the air out?
- Yes! The rocket will be pushed by the escaping air as it spreads out to equalize with the outside air.

Aim rocket at cardboard box

So let's see what this will do to the kinetic energy of our rocket…

Count down: 5, 4, 3, 2, 1 - then open valve very quickly

Would you be running away from my rocket now? By making it go so fast, in this case at about the same speed as a car travelling on the motorway, I gave the rocket a lot of kinetic energy, which meant it could do a lot more damage!

Bring up slide 18: micrometeorite damage

And if, instead of a box, we have the ISS and instead of the rocket we have a piece of space junk, then even small objects can cause a lot of damage to the ISS and put Tim and the rest of the crew in danger.

Debris smaller than 1cm can be absorbed by the protection systems of the ISS and debris bigger than 10cm is being tracked from Earth by specially trained teams. However the debris between 1cm and 10cm are currently untrackable…

Bring up slide 19: Tracking Debris

And if a piece of debris is predicted to pass near the ISS and the ISS cannot perform an evasive manouvere, the astronauts on board get into the Soyuz spacecraft that are permanently docked to the ISS, ready to return to Earth if necessary. The ISS itself can fire thrusters and boost itself up and out of the way of the debris if possible.

So between conducting science experiments, keep healthy, maintaining the ISS and making sure the crew are safe, Tim will be very busy in space, but astronauts do have time for a bit of fun!

Bring up slide 20 – ISS fun

And of course, plenty of opportunity to look back at his home planet and see us all, from space.

Bring up slide 21 – World view pic/vid

And after 6 months in space, it will be/is time for Tim to come back to Earth.

Bring up slide 22 – coming home (Soyuz de-orbit and re-entry)

He will climb/climbed back into his Soyuz spacecraft with his two crew mates, and undock from the ISS. They will fire thrusters to slow them down and begin to spiral back to Earth. They will separate their descent module from the other two modules of the Soyuz, ready to enter the atmosphere of the Earth. As they slam into the atmosphere at thousands of kilometres per hour, they squash the air in front of them, causing it to heat up rapidly (becoming a superheated plasma).

And this is the really dangerous part – the outside of the descent module will heat up to over 1,600°C! That's 160 times hotter than boiling water! And this is where our engineering really comes in…

Bring up slide 23 – engineers

- To survive re-entry, the descent module needs a thermal protection system. There are two main types. The Soyuz uses something called ablative technology. As the material heats up, it falls away from the module, carrying the heat energy with it.

- The other system can be well demonstrated using a blow torch to represent the superheated plasma.

- Here I have a piece of the thermal protection system from the Russian spacecraft Buran. It has been specially designed to be a bad conductor of heat, and to radiate, or lose heat very quickly.

Optional: If you have an infrared camera

Switch on IR camera

- This camera does not use the light that we can see. Instead it looks at infrared, or heat radiation. This means that we can use it to show us how heat is flowing through the thermal protection tile. In fact, can I have another member of the audience please who does not mind taking off their shoes?

Select volunteer with easy to remove shoes

- Ok, can you please stand on the spot there? Now if we point the camera at your feet we can see that they are much warmer than the floor, and that is why they look brighter. Now can you please take a big step back?

- Look! There are footprints on the floor. Even though you were only standing there for a few seconds, heat from your feet has been conducted into the floor!

- Ok you may put your shoes back on and sit down – can we get a round of applause for our volunteer please?

- Now I need a volunteer to hold the camera for me.

Select volunteer from the audience

- So we could easily see the conduction of heat into the floor using the infrared camera, and we can do the same for our thermal protection tile here…

- Now I will need my goggles for this!

Put on goggles

- Now if I turn on the blow torch…

Turn on and ignite blowtorch

- This is burning at about 1,500°C, so a similar temperature to what the descent module will experience. But when I hold the thermal tile to it, you would expect that the heat would conduct up towards my hand and burn me, but it does not! In fact, my hand feels very comfortable indeed.

- The material that the tile is made of is doing an excellent job of insulating – it is not conducting the heat very well at all.

- But even better, if I turn off the blow torch…

Turn of the blow torch and set it aside

- We can see that there is still a lot of heat stored in the tile, but it is being quickly radiated away. In fact, this material radiates heat away so well that after only a few seconds…

Hold the hot end

- I can hold the same spot that I was burning!

Put down tile, collect camera from volunteer and ask them to sit down

Note: If you have an infrared camera you can get a member of the audience to film this demonstration so you can see the heat staying confined to one area. If you do not, a video is provided within the digital resources)

- Round of applause for our volunteer please!

- So because of these properties of this material, it can protect a spacecraft from the extreme temperature of re-entry.

- And what does it look like for an astronaut?

Bring up slide 24 – Soyuz portal plasma

- Pretty spectacular!

- So with Tim safely back to Earth, the next astronauts will replace him and continue the adventures in space. But being an astronaut is not a job alone. Most astronauts start out as scientists, engineers, doctors or mathematicians. You don't just become an astronaut, you do a job you are passionate about and keep fit and healthy for years before you are even considered. And for every astronaut there are thousands of people working in the space industry and beyond.

Bring up slide 25 – Space careers

- From scientists and engineers, to technicians and doctors. From physicists and chemists, to computer programmers and mechanics, thousands of people work in amazing jobs to keep us exploring space. And all of these jobs use science skills.

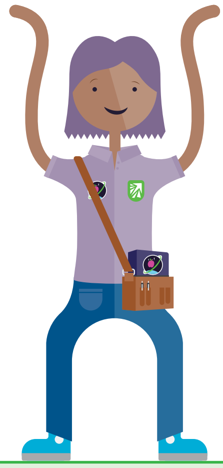
Bring up slide 26 – Tim's view from space

- And so I hope you have enjoyed this show, and that it has given you a glimpse into what it takes to make space our destination. To finish with I would like to ask a question of some of the younger people in the audience.
- Hands up if you would like to work in the space industry?
- Well if you work hard and stay interested in science, technology, engineering and maths then maybe, in the future you will ***#jointhecrew***

Bring up final slide

- Thank you very much for taking part ladies and gentlemen, I hope you enjoyed the show and please enjoy the rest of your day at ***[science centre name]***.

5-7 YEAR OLD SCHOOLS SHOW



Synopsis

We've been invited to the International Space Station! We'll need to get some expert help to prepare for travelling to and living in space. We'll launch a rocket and dock with the International Space Station, then we can experience life in orbit through a series of challenges. But a sudden emergency requires us to test and select materials and equipment to get us out of the space station to fix the problem. Once repaired, the group take in the view of Earth before finding a way to safely return to the ground.

Equipment needed

- Paper Rocket
- Compressed Air Rocket Launcher
- ISS Board and Magnetic Soyuz Capsules
- Lifesaver Water Bottle
- Container* with water*
- Earth*
- Hair Dryer
- Basket Case game (ping pong balls and net with stand)
- Brown balloons**
- Vacuum cleaner (Charged)
- Clear Bags**
- Sleeping Bag
- Mirror
- Torch
- Parachute

*Not Supplied
**Consumable supplied, may need replenishing eventually

Astronaut Costume made up of:

- White jump suit
- White boots
- White Gloves
- Backpack
- Helmet

Material and Equipment Samples consisting of:

- Tissue Paper**
- Plastic tube
- Fabric Sample
- Football boot
- Flip Flop
- Mitten
- Net Glove
- Balloon**
- Net Bag
- Air Tank Prop
- Clear Perspex Sample
- Opaque Perspex Sample
- Tinted Perspex Sample

SCRIPT

Introduction

- Hi, my name is … and you're here to find out a bit about going to space. I don't know if you know, but there is a space station up there we call the International Space Station or ISS for short. On the ISS astronauts do lots of science experiments that help us down here on Earth. Some of those astronauts are part of the European Space Agency, or ESA. ESA are the people that can send astronauts up into space and soon they'll be sending/they've just sent a British astronaut up there called Tim Peake. You might've seen him on TV talking about all the work he's been doing. I thought we should do an ESA mission of our own and go up to the International Space Station, are you up for that? Even Tim Peake can't do all the work on his own though. ESA is made up of lots of different people doing lots of different jobs using skills that you use in your science lessons, such as problem solving, teamwork and testing. Here are some of the experts that might be able to help us while we're up there.

Pointing out individuals:

- This is Name, he/she is a Mission Planner. They look after planning the astronauts' days and making sure they've got everything they need. They'll be a good person to go to when we don't know what to do.
- This is Name, he/she is a Flight Surgeon, which means they are the astronauts' doctor. Just like on Earth they look after the astronauts bodies and help them if they are ill. They can help us keep ourselves healthy.
- This is Name, he/she is an engineer. They build the tools and machines that astronauts use. They can help us choose the right equipment to work with.
- This is Name, he/she is a scientist. They decide what experiments the astronauts do in space. They can help us with our work while we're in space.
- And this is Name, he/she is a flight controller. They are in charge of everybody else and make sure they're looking after the International Space Station. They'll tell us what to do and make sure that we are doing our jobs properly.
- If we're going to go to space, we'll need a rocket, and I have a rocket here

Produce paper rocket.

- I also have this rocket launcher...

Produce compressed air launcher

- ...but I am going to need some help to launch it.

Get volunteer

You need to pump here to build up the pressure, give it 3 pumps now. Now get ready here, because when these guys say “blast off” you pull this level here to launch our rocket all the way over there, where space is. Are you ready? Audience, are we ready? Then start the count-down…

10… “Quick, get in the rocket…”

9… “Squeeze into your seat…”

8… “Pull the straps on…”

7… “Do up the buckle at the front…”

6… “Put your helmet on…”

5… “Flick some switches…”

4… “Twiddle some dials…”

3… “The engines are going now, make the noise”

2… “Louder”

1… “Hold on tight…”

Blast off! We have lift off!

With the volunteer, launch the rocket

Our rocket has made it up into space and we can separate our little capsule here…

Indicate Soyuz capsule

…now we want to get to the International Space Station here.

Indicate ISS on other side of stage

I need a volunteer to pilot our capsule to the International Space Station.

Get volunteer

To dock with the space station you need to stick our capsule on this target here.

Indicate docking station

That might seem easy, but remember we're floating around in microgravity now, and the first thing that will do is make you dizzy, so we need to get you dizzy first.

Spin volunteer until dizzy

Ok ***[name]***, dock us with the space station! Possibly move the station about to cause confusion. We've docked! Hooray, give ***[name]*** a round of applause! We have arrived at the space station and are ready to experience life on board.

I think it's important to look after our bodies up here in space, just like on Earth. Who do you think we should ask about keeping us healthy?

Flight Surgeon

Yes, that makes sense. Let's see if the Flight Surgeon has any advice for us.

Play video

"Hello! So, you want to stay healthy. Well it's very important to drink plenty of water in space, just like on Earth. But up there, you don't have lots of water, so you'll have to recycle what you've got. That means collecting all the water from the air, and even your wee! I hope you've got a way to clean that dirty water."

On the space station they use filters to clean the water, and luckily, I have a filter here that can clean dirty water. Can I get a volunteer to help me make some dirty water? Have volunteer mix dirt into water, then run it through the lifesaver bottle. The filters in this bottle make that dirty water clean enough for me to drink. Take a sip, offer it to volunteer. Good work, give them a round of applause.

On the space station we're in orbit around the Earth. I bet it's a bit different, so who could we ask about working in orbit?

Scientist

Yes, that makes sense. Let's see if the Scientist has any advice for us.

Play Video

"Hello! So, you want to see what it's like to work in orbit. Things seem to float around and it takes some practice to get used to it. I've set up an experiment for you to practice working with things that are floating around."

I need a volunteer to play this game with me. Get Volunteer The scientist gave me this hairdryer and these ping pong balls. They said we should make the balls float like this and practice getting them into that basket while they float around, give it a go. Let/Help volunteer to get balls into the basket. Good work, give them a round of applause.

If things float about in orbit, I'm a bit worried about going to the toilet, we don't want all that stuff floating about, do we. Who do you think could help us build the right equipment for a toilet that will work in space?

Engineer

Yes, that makes sense. Let's see if the engineer has any advice for us.

Play Video

"Hello! So, you don't want your poo floating around in orbit. On the space station the toilets have to suck, like a vacuum cleaner to take the poo away. Wait, what's that…"

Release balloons

Oh no, some poo has escaped the space toilet, I need a volunteer to help me get it back. Get volunteer The engineer said space toilets suck like a vacuum cleaner, and I've got this one, so can you use it to suck that poo up before it gets in someone's face? Help volunteer to grab the balloon with the suction of the vacuum. Good work, give them a round of applause.

This is all very hard work. I could do with a nap, but I'm not sure what time we get to go to bed. I guess we should check with someone when bedtime will be, who do you think would plan that?

Mission Planner

Yes, that makes sense. Let's see if the Mission Planner has any advice for us.

Play video

"Hello! So, if you want to sleep you need a special bed to stop you floating away. On the space station they sleep in sleeping bags. But they might be a bit different to ones you use for camping. There should be one there to try."

The Mission Planner gave me this very special sleeping bag, I need a volunteer to try it out. Get volunteer and put the sleeping bag over them On the space station sleeping bags like these are fixed to the wall, you get in and can zip yourself up, or read a book, because your arms poke out of these holes. Nice modelling…

Alarm interrupts!

Oh no, there's some kind of an emergency on the space station, let's see if the flight controller has sent us a message about it. Incoming message, either slide or video.

"Hello, this is the Flight Controller. We have a problem. One of the solar panels is in the wrong position and you won't be able to come home until it's fixed. You're going to have to send someone outside of the space station to fix it. But it's not safe out there, you'll need to build a space suit to keep them safe. If you need any help, we're all still here to help you."

Ok, we need a volunteer to do a spacewalk Get volunteer Ok, the Flight Controller said it wasn't safe out there so we need to build you a space suit.

- I don't know where to even start, let's ask the Mission Planner, they should be able to help.

Play video

- "Hello, me again. So, you need to make a space suit. Well, to start you'll need to find a material that is strong, to protect you in space, but also flexible and bendy enough that you can still move around. Have a look around and see what you can find."

Presenter

- So we've got plastic, tissue paper, and fabric. Let's test them.
- Ok, is the plastic strong? Great, what about bendy? Not so much?
- Ok, let's try the tissue paper is that bendy? Great, what about strong? Not so much?
- Ok, what about this fabric, is that strong? Great, is it also bendy? Ok, so which of these three options should we use?
- Fabric!
- Perfect! I think we've got what we need to make the space suit. To volunteer Put this space suit on.
- Hmm, I don't think it's quite ready yet. We'll need something to cover the feet for our spacesuit, I don't know what to use though, let's ask the Flight Controller, they might be able to help."

Play video

- "Hello, me again, ***[name]***. So, you need shoes for your suit. Well, you'll need to find something that covers all of your feet, but won't damage the outside of the space station when you walk on it. Have a look around and see what you can find."

Presenter

- So we've got football boots, flip flops, and soft boots. Let's test them.
- Ok, do the football boots cover your feet? Great, are they smooth and soft on the bottom to protect the space station? Not so much?
- Ok, are the flip flops smooth and soft? Great, and will they cover your feet? Not so much?
- Ok, do these boots cover your feet? Great, and are they soft and smooth on the bottom? Ok, so which of these three options should we use?
- Soft boots!
- Perfect! I think we've got what we need for the feet. ***[To volunteer]*** Put these boots on then.

Hmm, I don't think it's quite ready yet. We'll need something to cover the hands for our spacesuit, I don't know what to use though, let's ask the engineer, they might be able to help."

Play video

"Hello, me again, ***[name]***. So, you need gloves for your suit. Well, you'll need to find something that covers all of your hand, but still lets you move your fingers. Have a look around and see what you can find."

Presenter

So we've got mittens, fingerless gloves, and normal gloves. Let's test them.

Ok, do the mittens cover your whole hand? Great, can you move all your fingers? Not so much?

Ok, can you move your fingers in these fingerless gloves? Great, and will they cover your hole hand? Not so much?

Ok, do these gloves cover your hands? Great, and can you move your fingers? Ok, so which of these three options should we use?

Gloves!

Perfect! I think we've got what we need for the hands. ***[To volunteer]*** Put these gloves on then.

Hmm, I don't think it's quite ready yet. We'll need to be able to breath while in our spacesuit, I don't know what to use though, let's ask the Flight Surgeon, they might be able to help.

Play video

"Hello, me again, ***[name]***. So, you need an air supply for your suit. Well, you'll need to find something that can hold air, but you can control the air coming out. Have a look around and see what you can find."

Presenter

So we've got a net, a balloon, and these bottles. Let's test them.

Ok, does the net hold air? Not so much?

Ok, does this balloon hold air? Great, and can we control the air coming out? Not so much?

Ok, do these bottles hold air? Great, and can we control the air coming out? Ok, so which of these three options should we use?

Bottles!

Perfect! I think we've got what we need for the air supply. ***[To volunteer]*** We'll put them in this backpack and you can put this on.

- Hmm, I don't think it's quite ready yet. We'll need a helmet for our spacesuit, I don't know what to use though, let's ask the scientist, they might be able to help.

Play video

- "Hello, me again, ***[name]***. So, you need a helmet. Well, you'll need to find a material that you can see out of, so you can do your work, but also it will need to block the bright sun to protect your eyes. Have a look around and see what you can find."

Presenter

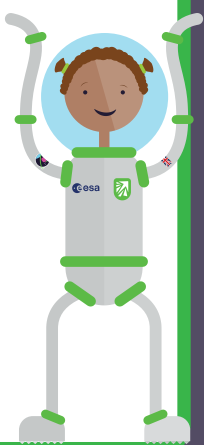
- So we've got clear plastic, dark plastic, and tinted plastic. Let's test them.
- So, can you see through the clear plastic? Great, does it block out this bright torch? Not so much
- Ok, does this dark plastic block the bright torch? Great, and can you see what you're doing? Not so much?
- Ok, can you see through the tinted plastic? Great, and does this torch look a bit dimmer? Ok, so which of these three options should we use?
- Tinted plastic!
- Perfect! I think we've got what we need for the helmet. ***[To volunteer]*** Put this helmet on then.
- I think your spacesuit is ready to go outside now so we can fix the problem, but first, we need to know what to do.
- The solar panels on the space station are for collecting sun light to power the station, but they are in the wrong position to do that, so you need to move them. Before you do that though, we'll need someone to be our Sun

> pick a volunteer and give them a torch,
> instructing them to shine at the mirror

- and we need someone inside the space station to tell us when the panels are in the right place

> Pick a volunteer and instruct them to look at the mirror
> and tell us when they can see the light from the "Sun"

- Ok astronaut, you need to get over to that mirror without letting go or you might float away, so hold on to someone's hand. Audience, you need to help ***[Volunteer]*** get to the solar panel at the back without letting go of them, pass them from hand to hand until they've reached the panel.



Encourage and support the astronaut volunteer to work their way around the audience always holding onto someone's hand, once at the mirror, they need to swivel the mirror so that the other volunteer can see the "Sun"

Play success message on screen

- I think that's in the right position now, let's help our astronaut back over here to the space station.

Same again with the hand holding

- Good team work everybody, we've fixed the panels, let's give everyone a round of applause!
- We're all ready to go home again now, but before we do, would you like to take a look out of the window of the space station to see what our planet looks like from space? There is a special window for this on the space station called the cupola, let's take a look out of it now…

Play video of Earth, ideally including the UK, and with dimmed lights if possible. Allow some time for the audience to enjoy it uninterrupted.

- Wow, what a beautiful place our planet is, I think I'm starting to miss it, shall we go home to Earth? Ok, I'm going to start the countdown again, here we go…

(Could be recorded or just called out)

- 10… "Quick, get in the capsule…"
- 9… "Squeeze into your seat…"
- 8… "Pull the straps on…"
- 7… "Do up the buckle at the front…"
- 6… "Put your helmet on…"
- 5… "Flick some switches…"
- 4… "Twiddle some dials…"
- 3… "Get ready…"
- 2… "Here we go…"
- 1… "Hold on tight…"
- …Oh, wait, it's much quieter this time because we're in space, we don't need a big powerful rocket, all we really need to do is fire our little thrusters to slow down and fall back down to the ground. It's going to get a bit noisier and hot as we come back to Earth, phew. Who's feeling hot? Video of re-entry?

- If we keep falling this fast, it's going to hurt when we hit the ground, we'll need something to slow us down. What do you think we could use to slow us down while falling?

- A Parachute

- It just so happens that I have a parachute here, so quick, spread this out over yourselves, lift it up and catch as much air as you can, so we can drift nice and slowly down to the ground. This is what it looks like when the space capsule comes down with a parachute, landing on the ground, just like we did. So, we've made it everybody, give yourselves a big cheer!

- So, not only have we been up to the International Space Station, found out what it's like to live and work up there, but we've also met some of the different people that it takes to put people in space. I hope you've enjoyed your journey, my name is . . ., thank you very much and good bye!

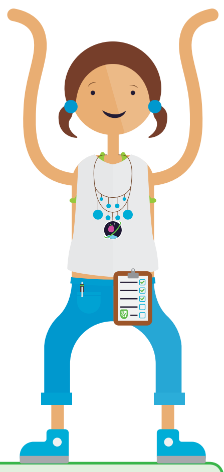
7-11 YEAR OLDS SCHOOL WORKSHOP

Summary

This one hour workshop is aimed at 7 to 11 year olds (KS2 in England and Wales). The premise is that with Tim's mission to the ISS, we are looking to recruit and train the next generation of space scientists. This workshop focuses on some of the key skills needed to be not only an astronaut, but a scientist or engineer working in the space industry.

After a brief bit of training and a demonstration and explanation of how astronauts get off the ground, the simulated mission activities begin.

Through problem solving and experiments students get a chance to use their communication, mathematical, English and team-working skills to control a robot arm and investigate two of the problems facing astronauts in space; floating liquids and the effects of a vacuum.



Additional information

For supplier information, risk assessments, and additional resources please see digital content on ***www.destinationspace.uk***

Equipment needed

- Astronaut training
- Magnetic Soyuz and board
- Bungee cords
- Getting into space
- Whoosh bottle
- Industrial methylated spirits
- Metre ruler with wooden splint

Activity 1 (Robot arm) – 4 stations, each station needs:

- Robot arm
- Progress sheet
- Selection of foam shapes
- Pens/pencils
- Task cards
- Large target sheet

Investigating space dangers (magic snow and marshmallows in syringes) – 4 stations, each station needs:

- Magic snow
- Several mini marshmallows
- Test tube rack
- 4 syringes
- 6 boiling tubes
- Working sheets
- Filter funnel and paper
- Pens/pencils
- Digital scales
- Coloured water
- A syringe
- Demonstrating the effect of vacuum:
- Vacuum plate, jar and pump
- Partially inflated balloon

SCRIPT

INTRODUCTION

Introduction slide is on

Start with students sat on the floor at the front

- Hello everyone and welcome to ***[science centre's]*** Destination Space Workshop. My name is ***[Your name]*** and I am your training commander.
- In this workshop you are going to train for several different roles for the Principia mission to space. Some of them will be Earth based roles and some of them will be astronaut roles, but we hope that all of them will give you an idea of what it is like to work in the space industry!
- And to tell us a little more about the Principia mission we have an introduction from a very important person who has actually trained to go into space…

Bring up slide 2 – Tim intro

- Thanks Tim!

Bring up slide 3 – Tim pic

- That was Tim Peake, the first British European Space Agency Astronaut. Has anyone here heard of the European space agency, or ESA before?
- Has anybody heard of NASA before?

Bring up slide 4 - ESA

- Well ESA is the European version of NASA. Space agencies from 22 member states work together on space missions, from robotic exploration, to astronomy, to human spaceflight.
- And in December 2015 Tim will go/went into space for a 6 month mission to this place…

Bring up slide 5 – ISS intro

- This is the International Space Station or ISS as it is known for short.
- It is going around the Earth (orbiting) at a height of 400km and is humanity's laboratory in space. It has permanently got astronauts on board conducting science experiments and performing maintenance on the station. And it is a true international project with the American, European, Russian, Japanese and Canadian space agencies involved.

TRAINING

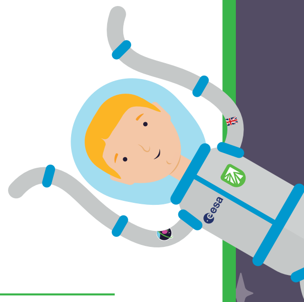
Bring up slide 6 – training montage

- Now Tim started basic astronaut training in September 2009, so he has gone through six years of basic, and specialised training in everything from working in a weightless environment (click), controlling the space craft used to get to the ISS (click), living in an isolated environment under the sea (click) and much more.

- And we are going to start with some astronaut training exercises of our own.

- To do this we are going to split the class into two…

Split the class down the middle



- Ok, this side is team Tranquillity (point to one side) and this side is team Columbus (point to the other side). These are both names of modules on the ISS.

- Now, the first activity we are going to do is fitness based.

Bring up slide 7 – microgravity

- On the ISS, Tim does not feel the gravity from the Earth (and if you want to know why then come and see me at the end). This means that he and the other astronauts on board spend their time floating around.

Play video

Bring up slide 8 – health effects

- Tim will lose muscle since he won't use them much. Fluid that is normally pulled towards his feet will now gather in his head and chest causing his face to go puffy, and these two effects combined are known as puffy-head-bird-leg syndrome.

- For reasons we still don't understand calcium leeches out of the bones and causes them to become brittle. And there are many other problems that he will experience. As a result, medical professionals will monitor the health of Tim and the other astronauts.

- So how do you exercise your muscles in space? Well let's have a test. I need 2 volunteers from each side.

Select volunteers

- Ok one volunteer from each side needs to hold this big ruler out like this. This shows how far each of the people exercising need to move their hands to. Now you (select one of the volunteers from tranquillity) are going to do this. Start with your hands together in front of you and pull them apart so that they spread out as far as the ruler (demonstrate this).

- Whereas you (select one of the volunteers from Columbus) are going to do the same thing, but you have to hold on to this bungee and stretch it out to that length each time (demonstrate this).
- When I say start, you will have 20 seconds to pull your hands apart and back as many times as you can. Remember to make them go all the way or I will not be able to count this!
- And teams, I need you to count how many FULL goes, all the way out and in again your team mate can do – teachers, please help with this.

Count down from 5 and start the stopwatch

- Ok well done!

Point at the volunteer from Columbus

- Wow, you look pretty tired, was that easy?
- Let's see how many each team got (ask for results from class, check with teachers and note this down on your clipboard).
- Very good! Ok volunteers you can sit down – can we have a big round of applause for our volunteers please!
- So, which exercise do you think involved the muscles doing more work? And which exercise would you recommend an astronaut to do in space?

Bring up slide 9 – resistance training

- And this is similar to how astronauts on board the ISS exercise, for at least two hours a day. By using the resistance in the exercise machines, they are able to put a load on their muscles that they would not be able to in the microgravity of space.
- But there is another problem with living in a microgravity environment. Astronauts tend to feel sick for the first few days that they are on the ISS.

Bring up slide 10 – Inner ear

- This is because your inner ear is responsible for telling your brain which way is up or down, and in space it does not work properly, so an astronaut feels like they are constantly spinning round and they can get very dizzy. This makes even simple tasks difficult.
- Again I will need a volunteer from each team.

Select a volunteer and pull chair into the middle of the presenting area facing the screen)

- This session is going to test how well you can perform when disorientated. This means when everything is muddled and confused and in space, with everything floating around astronauts will often feel dizzy and a little bit sick.

Bring up slide 11 – disorientation

- I am going to spin each volunteer round for 20 seconds to make them a bit dizzy. I am then going to hand them this spacecraft called the Soyuz – the same craft that Tim will be in as he journeys to the International Space Station. Your job it to get it as close to the docking target on the board over there as you can, in the smallest time possible.

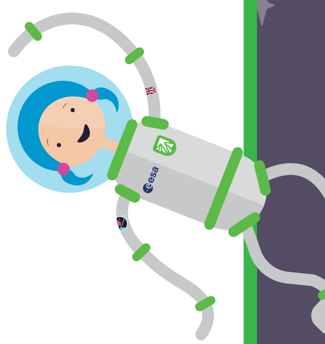
> Select one volunteer and spin them, releasing them to go and timing how long it takes. Repeat with the other volunteer

- Well done to both teams! (Comment on how each team has done).
- So once the training is over it is time to get into space!

Getting Into Space

Bring up slide 12 – Soyuz Launch

- Tim and two other astronauts will go to the ISS on board the Russian Soyuz Rocket. They will be/were in a Soyuz space craft right at the very top, and this spacecraft will take them/took them to the ISS.
- Let's have a look at the launch (play video).



- And what do we see coming out of the back of our rocket?
- Yes fire! And all rockets work on the same principal, now for burning to happen we need three things. Can anyone name me one of them?
- What else do we need?

> Keep asking until you have all three/prompt if necessary

- Yes, we need fuel/oxygen/heat.

Bring up slide 13 – fire triangle

- So for burning to happen we need a fuel (click) we need oxygen gas (click) and we need a heat source.
- Is there any oxygen in space?
- No! So our rocket has to not only take the fuel into space, but also the oxygen needed for burning.
- We can demonstrate the basic idea of our rocket using this…

> ***Note:*** For full details on this demo please see whoosh bottle briefing sheet

Bring out plastic water cooler bottle

This is going to be our rocket engine, and there is already oxygen inside it from the air. But I need to add a fuel (add methylated spirit [IMS]). As I shake the bottle, the fuel is turning into a gas and mixing with the air. If I hug the bottle I can make it warmer and so the fuel will turn into a gas faster.

After about 30 seconds tip out any excess fuel and put a cup on the top. Gather students around and make sure all students are at least 2 metres away and stand the bottle on the floor

I need to put my goggles on for this!

Put on a pair of goggles

Ok, so in this bottle we have the fuel and the oxygen, what else do we need to complete our fire triangle?

Yes – heat! So we will count down from 5 and when we get to zero I will light the bottle. If you don't like noise, you might want to cover your ears.

Turn off the lights and light a splin

5, 4, 3, 2, 1 - go!

Remove the cup and use the lighted splint to light the bottle

And that is our basic rocket. Now it didn't burn for very long, but you can feel just how much energy was given out by that flash of flame.

Pass the bottle round so students can feel the heat

What kind of energy was produced? What did we see and experience?

Yes, we had sound energy, light energy and heat energy produced.

And so Tim will ride/rode a giant controlled explosion into space!

And now, onto your final training…

Class Activities

Bring up slide 14 – tasks

- Working in groups of four (and a couple of threes if necessary) you are going to do two training exercises. (click) One involves controlling a robot arm, but it is not just fun and games. You will have to read the instruction cards very carefully and fill in your training sheet as you go along. This activity will involve communication skills and problem solving, very important skills that you use in your science lessons if you want to work in the space industry!

- ***[CLICK]*** The other activity involves investigating two effects that are really important to understand for astronauts to survive in space. One involves doing an experiment with water and different materials, and one involves looking at if they were to be suddenly exposed to space outside the ISS. This activity has a large poster sheet that you need to complete as a group to take back to school with you.

- Make sure you put your names on everything and read the instructions carefully.

Bring up slide 15 - ISS check list

- And just like real space scientists and engineers, you will need to tick off each task as you go to make sure you understand it.

- You get 15 minutes on each task and at the end of the task you need to follow the tidy up instructions on the task card.

- And once your sheets are complete, put your hand up so I can stamp your group with a pass in that training activity.

- If you get stuck you can ask me or your teachers for help.

Allocate groups to their starting activities

- Ok, good luck everyone, you have 15 minutes on these activities starting… NOW!

Circulate and help where necessary. Set stop watch to count. If you are running short on time you can shorten the time that they have

Give them a 5 minute warning, Stamp any completed work

- Ok everyone, stop what you are doing and make sure you tidy the desks. Any left-over liquids need to be poured into this pot at the front/middle of the desks and put the rest of the equipment for the living in space investigation back in your box.

Students bring their box of kit to the front of the room. Groups about to start this experiment (the one with the water and syringes) need to collect a new box from the front of the room

- Ok, same instructions. You have 15 minutes starting…Now!

As before, circulate, check work and give a 5 minute warning. Same clear down instructions as before

Bring group back to the front and ask them to bring their worksheets and poster with them. Discuss their findings

Discussion and wrapping up

Bring up slide 16 – CanadaArm

- Ok so let's first look at the robot arm. Now this is a simplified version of the CanadaArm2 that is used on the ISS, but why did you think astronauts might use this?
- Excellent ideas! And yes, there are some jobs where a human is not suitable for and so a robot makes their jobs easier.
- And what about the experiments? Can anyone tell me what the word absorb means? Yes, it means to take in water and store it, a bit like a sponge. The water is still in there as a liquid, but it is trapped.
- Who found that material A absorbed the most water?
- Who found that material B absorbed the most water?
- And material C?
- Well, material C is officially the most absorbent…

Bring up slide 17 – SPA

- This material is called sodium polyacrylate and it is also known as magic snow. It can absorb hundreds of times its own mass in water!
- And can anyone suggest why we would want to absorb water in space?
- ***[CLICK]*** Water will float around in balls in space. And when an astronaut is launching, landing or doing a spacewalk (click) any water can be a danger to them, because they might breathe it in and drown! And how do humans in particular produce liquids?
- YES! Through pee! If you are doing a spacewalk you might be out long enough that you need to go to the toilet, but it takes too long to come back into the ISS, take off your space suit, go to the toilet, put your spacesuit

back on and go back outside again. As a result, astronauts need to wear one of these:

Bring up slide 18 – MAG

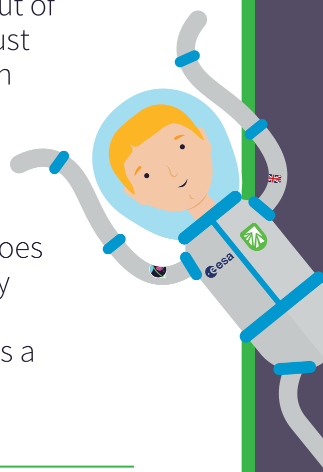
- Yes, it's a space nappy! Or as astronauts call them, a maximum absorbency garment. This makes sure that during launch, landing and space walks, any liquid produced by the astronaut is safely stored away and can't be accidentally breathed in!

- And what about our syringe experiment? What happened to the marshmallow astronaut when the air pressure dropped? Yes, it expanded!

- I have here a demonstration that shows this in even greater detail. This big chamber is called a vacuum chamber and I am going to pump the air out of it in a minute. This here is my astronaut (produce balloon astronaut). Just like us she is squishy and full of gas. Shall we see what happens to her in the vacuum chamber?

- Now, do we think this would happen to a human?

- Well, not exactly. Yes we have gases trapped inside of us, but our skin does a really good job of squashing everything together. But it would get very uncomfortable, and with no oxygen what would happen to us? Yes, we would die. So that is why astronauts have to wear one of these if there is a chance they might be exposed to space.



Bring up slide 19 - Sokol

- The Sokol space suit is worn during launch and landing and is designed to give you a little bubble of air at a pressure to keep you alive until you make it back to Earth, or the ISS.

- So, well done class. Your first stage of training is complete. You have taken on the role of a mission controller, an astronaut, space scientists and medical staff. And there are so many exciting space jobs out there.

Bring up slide 20 – Space careers – play video

- So maybe in 20 years' time some of you will be working on the next big, exciting space missions.

- And with after today's training, maybe you have got what it takes to…

Bring up slide 21 – wrap up

- …***#jointhecrew***

- Thank you very much everyone. I hope you enjoyed that….
  [Wrap up however your centre does]

11-14 YEAR OLDS SCHOOL WORKSHOP

Summary

This one hour workshop is aimed 11 to 14 year olds (KS3 in England and Wales). The premise is that with Tim's mission to the ISS, we are looking to recruit and train the next generation of space scientists and after an initial briefing, this session acts as a simulated space mission for training purposes. This workshop focuses on some of the key skills needed to be not only an astronaut but a scientist or engineer working in the space industry.

After an introduction and explanation of how astronauts get off the ground, the simulated mission activities begin.

Through problem solving and experiments students get a chance to use their communication, mathematical, English, science and team-working skills to control a robot arm and design a circuit system for the ISS and investigate the best materials to solve a carbon dioxide emergency on board.

Additional information

For more information about the activities including set up, please refer to the digital resources online at ***www.destinationspace.uk***

Equipment needed

All of the student activities have worksheets and task cards that need to be provided

Getting into space:

- Oxygen and hydrogen bubbles equipment (alternatively you can do the whoosh bottle demonstration)
- Hovercraft, leaf blower and heavy ball

Activity 1 (Robot arm) – 3 stations, each station needs:

- Robot arm
- Progress sheet
- Selection of foam shapes
- Pens/pencils
- Task cards
- Large target sheet

Carbon dioxide emergency:

- Carbon dioxide filter housing
- Test tube rack
- Scrubbing materials (soda lime, cat litter, rock salt) Bromothymol blue indicator
- Straws
- Wire wool or cotton wool

Making ISS circuits:

- One circuit scribe kit box
- Circuit scribe pen
- Magnetic board
- 8 glossy ISS sheets

SCRIPT

INTRODUCTION

Introduction slide is on

Start with students sat on the floor at the front

- Hello everyone and welcome to ***[science centre's]*** Destination Space Workshop. My name is ***[your name]*** and I am your training commander.
- In this workshop you are going to train for several different roles for the Principia mission to space. Some of them will be Earth based roles and some of them will be astronaut roles, but we hope that all of them will give you an idea of what it is like to work in the space industry!
- And to tell us a little more about the Principia mission we have an introduction from a very important person who has actually trained to go into space…

Bring up slide 2 – Tim intro

- Thanks Tim!

Bring up slide 3 – Tim pic

- That was Tim Peake, the first British European Space Agency astronaut. Has anyone here heard of the European space agency, or ESA before?
- Has anybody heard of NASA before?

Bring up slide 4 - ESA

- Well ESA is the European version of NASA. Space agencies from 22 member states work together on space missions, from robotic exploration, to astronomy, to human spaceflight.
- And in December 2015 Tim will go/went into space for a 6 month mission to this place…

Bring up slide 5 – ISS intro

- This is the International Space Station or ISS as it is known for short.
- It is going around the Earth (orbiting) at a height of 400km and is humanity's laboratory in space. It has permanently got astronauts on-board conducting science experiments and performing maintenance on the station. And it is a true international project with the American, European, Russian, Japanese and Canadian space agencies involved.

Getting Into Space

- So how will/did Tim and his 2 crew mates get into space?
- The only way for astronauts to get to the ISS at the moment is this…

Bring up slide 6 – Soyuz Rocket Sequence

- …This is the Russian Soyuz-FG rocket. It is 50 metres tall and Tim will be/was sitting in just this top little bit, ***[CLICK to bring up Soyuz spacecraft]*** that houses the Soyuz spacecraft that ferries astronauts to the ISS.

Bring up slide 7 – How does the rocket work?

- And how does the Soyuz-FG get the astronauts into space? Well what do we see coming out of the back of the rocket in this video?
- That's right, fire! And can anyone tell me the scientific word for burning?
- Combustion!
- Now combustion is a chemical reaction. What do we mean by a chemical reaction?
- A chemical reaction is a process where one set of chemical substances is transformed into another.
- Can anyone tell me what reactants (or starting chemicals) we need for combustion to take place?

Bring up slide 8 – combustion reaction

[CLICK to bring up fuel + oxygen]

- Yes, we need a fuel and oxygen for the fuel to burn in. And is there any oxygen in space?
- No! So for a rocket to work in space it needs to take its own supply of oxygen up with it.
- And does anyone know what the products are (what we end up with)?

> See Oxygen and Hydrogen Briefing sheet
> for in depth demonstration specifics
>
> ***Note:*** you can substitute the whoosh bottle here if
> you prefer – see whoosh bottle briefing sheet

- ***[CLICK]*** Yes, we get carbon dioxide, water vapour and energy!
- And we can have a look at this combustion reaction in action with the following demonstration…

First we need a fuel. Now I mentioned that the Soyuz FG uses kerosene (heating oil) as its main fuel, but some rockets use what I have here – hydrogen.

Produce balloon

This balloon contains oxygen and hydrogen (our fuel) ready mixed.

Instead of balloons, ***[Click to bring up fuel tanks diagram]*** the Soyuz has two huge fuel tanks holding a quarter of a million kilograms of fuel and oxygen between them. But instead of pumping my fuel and oxygen into an engine, I am going to trap these gasses in bubbles.

Bubble oxygen and hydrogen through the mixture

So we have our fuel and oxygen, but what else do we need?

We need an ignition source, some heat to start the combustion reaction. So for this I will need a brave volunteer.

NOTE: Depending on the space and group you may prefer to ignite the mixture yourself. When you do ensure you are wearing ear defenders.

Select volunteer from the audience

Ok, you are going to ignite our mixture. If you can please take this ignition stick…

Hand them meter ruler with splint on end

And this can get loud, so can you please wear these ear defenders and fashionable goggles…

Hand them ear defenders and goggles

And audience, you may want to cover your ears for this as well!

NOTE: If you prefer you can scoop up the bubbles onto your hand and get the volunteer to light your hand. If you do this make sure you are also wearing ear defenders, wet your hands and arms before-hand and scrape off any bubbles from the bottom of your hand.

Ok, I am going to light the end of our ignition stick, and we will count down from 5. At zero, I would like you to touch the end of the ignition stick to the bubbles. Are you ok to do that?

Alright, lets count down…5,4,3,2,1 – Zero!

Bubbles are lit

Brilliant! Can we please have a big round of applause for our brave volunteer!

Volunteer sits back down

So, there is our combustion reaction.

Bring up slide 9 – rockets and Newton's laws

But how does this make our rocket move? And what does this man (bring up picture of Newton) have to do with it?

Can anyone tell me who this is?

Yes, it's Sir Isaac Newton, one of the great minds of science and the person who first developed the laws of motion that explain how our rocket moves off the launch pad.

He came up with three laws of motion. Does anyone know any of them?

See which laws are known

Well these are his three laws ***(bring up laws of motion box and talk through the laws)*** and it is this third law that we will focus on – every action has an equal and opposite reaction. Or to put it another way, if you exert a force on something, it exerts a force that is equal in size, but opposite in direction back on you!

So let's investigate Newton's laws in a bit more detail… Now Newton's first law states that an object that is moving will keep moving with the same speed and in the same direction unless an overall force is acting on it to change this. But if I take this object…

Turn off hovercraft and ask volunteer to sit down once it has completely deflated

Move over to hovercraft/brig hovercraft out

…And push it along the floor, does it just keep on moving?

No! Does anyone know what force is acting on it?

Yes, friction is acting as the overall force on our object, slowing it down. So, it seems we need to try to minimise the effect of this friction force.

So I am going to use this hovercraft! By raising up on a bed of air, we can minimise the contact the hovercraft has with the ground and so reduce the friction force.

To demonstrate this I will need a brave volunteer from the audience

If in a large space, can use several volunteers to 'pass' the hovercraft around

Please sit right in the middle of the hovercraft. Now if I try to push you ***(push the hovercraft)*** you won't go anywhere because the friction with the floor stops you.

But if we raise you up on a bed of air ***(switch on hovercraft and give a light push)*** friction is now lower and you drift gently away!

If you have the room and the correct floor type, you pass the hovercraft around between students

Turn off hovercraft and wait till it has completely deflated before you let the volunteer stand up

Let's hear it for our volunteer!

Volunteer sits down

So that has proven Newton's first law correct. A hovercraft, when pushed, will just keep on going (more or less!). Newton's second law states that if I keep pushing on the hovercraft with a force, it will accelerate, or get faster. So how does our rocket do that?

Well we need to turn to Newton's third law?

Can I have another volunteer please

Pick someone relatively light who looks like they can throw the heavy ball

Please sit in the centre of the hovercraft. Again I am going to turn the hovercraft on, but this time, I will count down from three, and when I get to zero I would like you to throw this ball to be as hard as you can like this (mime a netball throw straight from the chest).

But before we do this, we should make a prediction. If they throw the ball to me in this direction, I would like you all to point in the direction that you think the hovercraft will go.

Turn on hovercraft and set it at rest. Move into position count down and let the volunteer throw the ball. If not much movement is generated you can switch to the catch method of throwing the ball between you

Ok, well let's see.

Let's have a round of applause for our volunteer.

Turn off hovercraft and wait till it has completely deflated before you let the volunteer stand up

- So why did they move backwards when they threw me the ball? Well, they forced the ball away from them and as a result of Newton's third law, the ball pushed back with an equal and opposite force.

- And this is the same principle for our rocket, except instead of a single ball, our rocket is throwing billions of particles (the products of our combustion reaction) behind it every second, each one pushing back on the rocket with an equal and opposite force. And while those individual forces are very small, they all add up to a large overall force, or thrust, that allows the rocket to fight gravity and get off the ground…

Bring up slide 10 - freefall

- So once Tim gets/got up there, what is his life like/will his life be like?

- Well, life in space is very different to life on Earth.

- Astronauts living on the ISS live in what we call a microgravity environment. This means that they are basically falling towards the Earth, with enough speed in their orbiting direction that they never hit the planet.

Show Newton's cannonball video

- But they still feel the effects of this freefall. Who here has ever felt their stomach lurch when they go down in a lift or go over a bump in the road really quickly?

- Well that is because for a tiny fraction of a second, you and your stomach are both falling back towards the Earth at the same rate due to gravity – you are falling away from your stomach at the same rate as your stomach is falling, so your stomach is momentarily 'floating' inside of you!

Click to bring up astronaut football video

- And while this makes life in space very fun, it also means everyday tasks become more difficult.

Bring up slide 11 – space toilet

- And going to the toilet in space also becomes more complicated. What would happen to your toilet products' if you went to the toilet as you do here on the Earth?

- Ew indeed! They would just…float around

show floating water video

So astronauts have to train in how to use one of these…a space toilet

show space toilet video

And even fizzy drinks are not allowed in space – without the effect of gravity to allow the less dense air bubbles to rise to the top of the stomach, air bubbles will spread out evenly throughout a liquid. This means if you burp in space, you burp a mixture of food and gas!

So now that you have a bit of an idea of what it is like to live in space, we are going to see whether you have what it takes to work as part of a human spaceflight mission.

Brig up slide 12 – activity overview

In groups of 3 or 4 you will take part in 3 activities that will test key skills needed to work in the space industry which are skills you use in science lessons:

- Team working
- Problem solving
- Keeping calm under pressure

All of the instructions are on the task cards at the stations. Read these carefully and your challenge is to complete each task in just 13 minutes!

Do you have what it takes?

We shall see…

Allocate starting positions, circulate and help. At 12 minutes, groups pack away kit if relevant and reset for the next group, then move on to the next activity

Bring up slide 13 – well done!

Ok, well done everyone! You successfully built your carbon dioxide filters, repaired the damage on the outside of the ISS and manage to rewire the station!

Can anyone tell me which substance was best to put into the carbon dioxide filters and why?

Can anyone tell me which circuit was best to repair the Columbus module and why?

And who managed to complete all of the tasks on the robotic arm task?

Well, I think I can give you all a pass on this part of your training!

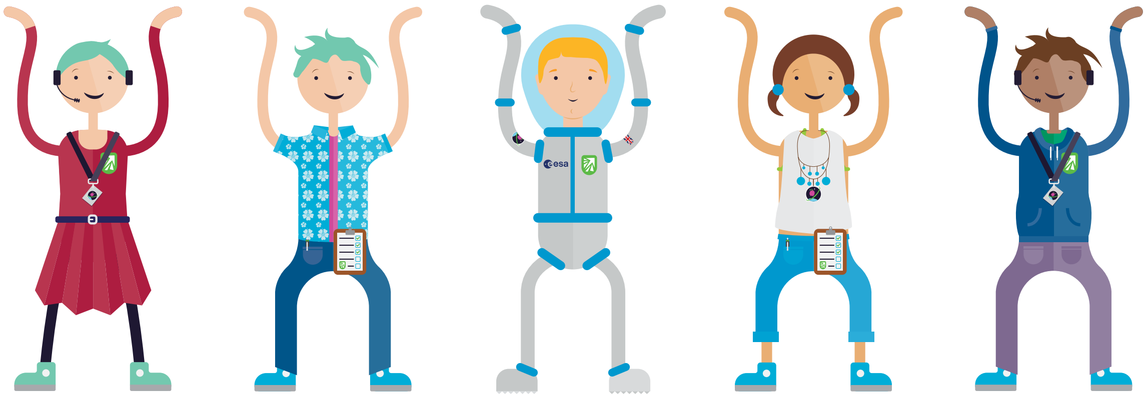
Bring up slide 14 – space careers

- You showed that you have many of the skills needed to work in the space industry, and I say space industry instead of in space because for every astronaut who goes into space, there are thousands of scientists, engineers, technicians, mechanics, programmers, doctors, and many other men and women working on all aspects of these missions to make them possible.
- And if you have ever wondered why it is worth exploring space, let's finish with a message from Tim himself.

Show Tim message

Bring up final finish slide

- Thank you very much for joining us today. You can continue the adventure online and ***#jointhecrew!***



MEET THE EXPERT

In order to inspire your audiences further with the science behind Tim Peake's mission we hope that you will be inviting experts into your centres to showcase the work they do.

These experts can be specialised in any field that is related to human space travel, from a materials technician to an actual astronaut. If there is a link to a STEM subject and you have the contacts to make a face to face meeting between public or school audiences and someone who works in the related sectors happen, the inspirational reach it can have is priceless.

To ensure your visitors and your specialist get the most out of any 'meet the expert' experience, it is vital that the specialist is confident and vibrant enough to engage and communicate their job role and skillset with the audience. Try to ensure that you organise a mixture of male and female inspirational role models.

The aim of this project is to inspire people with the large number of STEM careers that make Tim Peake's mission and human space flight possible. Therefore any meet the expert sessions should be full of energy, inspiration and great stories that will encourage people to look further into a career in STEM or research the history of human spaceflight and Tim's mission.

If suitable, allow your expert to bring in relevant props and to use the Destination Space! equipment to enhance the face to face meetings, and choose a suitable area for your expert to set up. The area should be approachable, visible and welcoming. Your expert will want as many visitors as they feel comfortable with, and the expert should be supported throughout their visit to ensure they have a positive experience.

IDEAS FOR BADGED GROUPS

If you normally offer badged groups a show then there is no reason why you should not use the family show which is part of this project.

If you normally offer a workshop the following activities can be used. The number of activities which you offer can be changed depending on how long the workshop is and the amount of space you have.

The full descriptions of these activities are in the scripts for the school workshops and the equipment briefing sheets so please refer to these for full details.

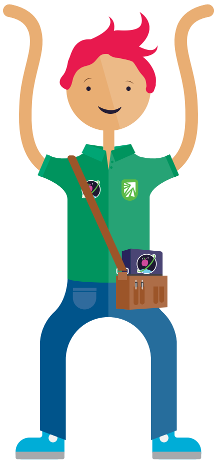
For Brownies and Cubs:

Any of the activities for 7-11 year olds can be used

- Exercise with and without a bungee cord
- Robot arm activity (you may want to write different questions)
- Material absorption experiment
- Marshmallows in syringes
- Water filtering experiment

You could also try:

- Meteorite handling
- Reaction time testing



For Scouts and Guides

Any of the activities for 11-14 year olds can be used

- Making CD hovercraft ***goo.gl/ZRZacb***
- Any of the demonstrations of Newton's third law of motion (see hovercraft briefing sheet)
- Robot arm activity
- Solar power experiment
- Carbon dioxide removal experiment

You could also try:

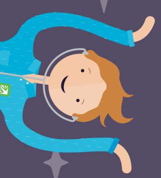
- Meteorite handling
- Parachute design challenge

A scouts astronautics badge already exists.

DESTINATION SPACE!

MARKETING:

Marketing and partner resources



MARKETING RESOURCES

The Destination Space brand identity for partners has been created to provide you with all the assets you need to market, set up and deliver your Destination Space activity.

Partner resources

On the ***Destination Space*** partner resources page you will find all the marketing resources you will need.

You can access this via the main website at ***www.destinationspace.uk***

It includes everything you need including:

- Brand guidelines
- Logo download packs
- Colour and typography guidelines
- Characters
- Partner logos and treatments for use
- Workshop content
- Training guides
- Marketing assets
- Presentation templates
- Stickers and certificates
- Full media kit
- Marketing copy

Usage of resources

We are keen that this project encourages people to share and innovate. As such we are passionate that the project's resources are shared and made openly available for a variety of people to use. For this reason we have licensed everything under ***Creative Commons***.

Name and Strapline

You should use ***Destination Space*** as the title of all your activities associated with this project.

The project strapline is ***Join The Crew***. Where possible, this should appear in your text and marketing materials.

Social Media

You can find Destination Space on social media using the following accounts:

DestinationSpaceUK

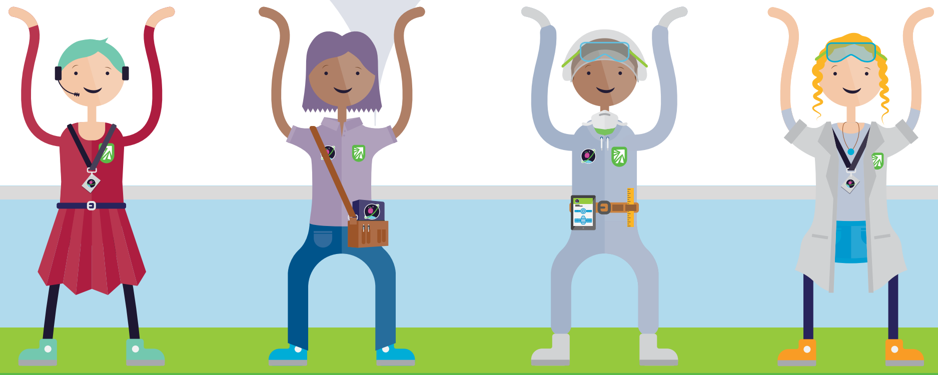
@destin_space

You follow Tim Peake and the UK Space Agency using ths following accounts:

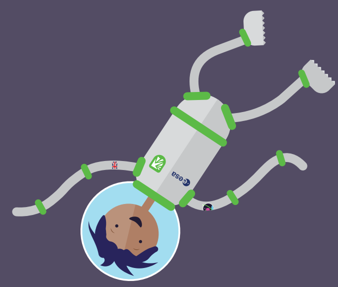
ESATimPeake

@astro_timpeake

@spacegovuk



DESTINATION SPACE!



ADDITIONAL RESOURCES

CAREERS IN SPACE

Working in the space industry doesn't just mean being an astronaut. For every astronaut there are thousands of people working hard behind the scenes to make the mission a success. And it's not just crewed spaceflight; there's robotic exploration, astronomy, Earth observation science and commercial satellites too. The space sector is an exciting and rapidly growing industry. Employers in the space sector include space agencies, like the European Space Agency, or the UK Space Agency, but there are also lots of private companies as well.

Credit: ESA/NASA

What do I need to work in the space industry?

The space industry is certainly looking for experts in the physical sciences. Lots of engineers are required to get things into space and make them work. There are lots of different types of engineer required, such as aerospace engineers, electrical engineers, mechanical engineers and software engineers. Mathematicians are needed too, along with physicists, astrophysicists and astronomers. But it's not just these; there are plenty of opportunities for biologists and medical professionals as well. People working in these areas tend to have a master's level degree. If you love science but a degree is not your chosen path, then many private space based companies offer apprenticeships, or recruit technicians for some of the more hands on roles (where you actually get to assemble things that will go into space).

Don't fancy yourself a scientist or engineer? Don't worry, there are plenty of other ways to be involved! These space agencies and companies need all the things that other organisations need. They need business administration, business strategy, experts in law, communications, cost control, public relations, project management, marketing and much more! These are all important roles.

How to become an astronaut

Still fixated on being an astronaut? There's no one route to follow to becoming an astronaut. One thing is for sure though – it's tough to get picked. Thousands upon thousands of people apply to be astronauts, but only a select few get chosen to enter training.

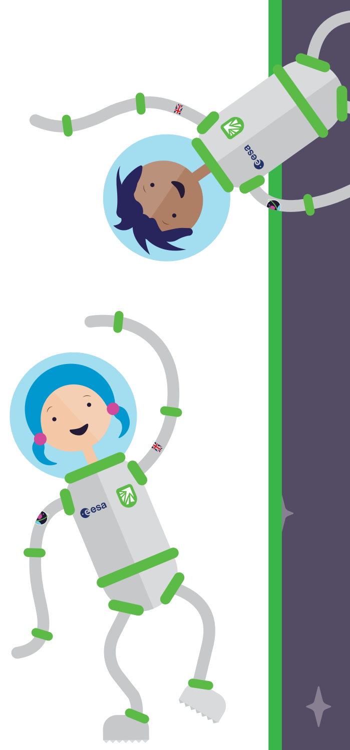
Some people have become astronauts after being in the military, for example by being involved in military aviation. But others have come from medical backgrounds, scientific research, engineering, even deep sea diving. Effectively space agencies are not looking for one specific qualification but a wide range of skills. All astronauts excel in their chosen science, technology, engineering or maths field before even being considered. And fitness is vital too.

What about jobs surrounding the space industry?

Space is obviously a popular topic, so there are a range of jobs about educating people about space, or communicating space topics to the public.

For example, you could write for magazines such as New Scientist, BBC Focus, Sky at Night or COSMOS, or be involved with the media in other ways. Or you could work at one of the space related science centres around the country.

But one thing is clear. The UK space industry is growing with recent figures stating a £11.8 billion turnover and around 37,000 people directly employed in space related jobs, and many more involved in 'down-stream' roles that involve some form of space involvement. Now, more than ever, if you want to work in the space industry, the opportunities are there with 100,000 more planned by 2030.



Additional information

For more information on space careers please see the digital resources found online at ***www.destinationspace.uk***

DIGITAL APPS

The following is a list of digital apps for various platforms that can be used to support activities and given to visitors to enhance their understanding and interest in space.

NASA App

The app provides access to a huge amount of information about NASA, its many missions and the cosmos.
www.nasa.gov/connect/apps.html

ISS Tracker

Enable you to track the ISS.
www.isstracker.com

Space Images

Developed by NASA this app delivers jaw-dropping photos of planets, moons, galaxies and more, along with informative captions.
www.nasa.gov/connect/apps.html

Exoplanet

This app is an interactive, frequently updated catalogue of all known alien worlds.
exoplanetapp.com

Planets

This skywatching app shows you how to spot planets in the night sky from wherever you happen to be.
sciencenetlinks.com/tools/planets-app

Satellite Flybys

This app lets you know when interesting craft such as the International Space Station and NASA's Hubble Space Telescope will be overhead, and it tells you where to look.
itunes.apple.com/us/app/satellite-flybys/id347477413

NASA Space Weather Media Viewer

Keep an eye on the beautiful, complex and ever-changing solar surface with NASA Space Weather Media Viewer, which provides views of the sun from a variety of NASA missions in near.
itunes.apple.com/us/app/nasa-space-weather-media-viewer/id398687618?mt=8

Moon Phase Pro

This app lets you track the ever-shifting visage of Earth's natural satellite, providing up-to-date information about the moon's phases and its rise and set times.
moonphasepro.com

ISS Live

Interact with live streaming data from the International Space Station (ISS), take virtual 3D tours of the Mission Control Center (MCC) and ISS, and view console displays, crew and science timelines for a fun, educational experience with NASA.
itunes.apple.com/us/app/isslive/id502032954?mt=8

Earth Now

NASA's Earth Now is an application that visualizes recent global climate data from Earth Science satellites, including surface air temperature, carbon dioxide, carbon monoxide, ozone, and water vapor as well as gravity and sea level variations.
www.nasa.gov/topics/earth/features/earth20120319.html

World Cities from Space

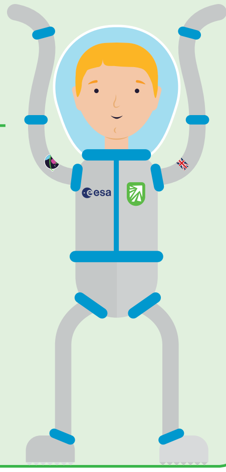
Stunning and very detailed images of world cities from space.
www.citiesatnight.org

GREEN-SCREEN

Take your photo with Tim

Programme Use: Across the programme

Notice:
This is an information sheet



Overview

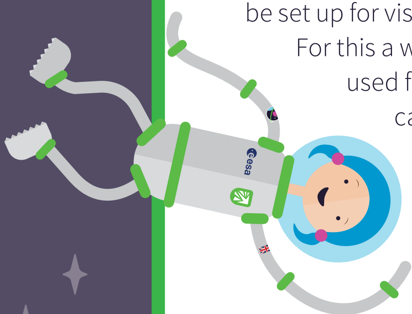
While not provided as a core part of the programme, some centres may wish to make use of available green screen technology to enhance their version of the programme. This sheet details some of the ways that this can be achieved.

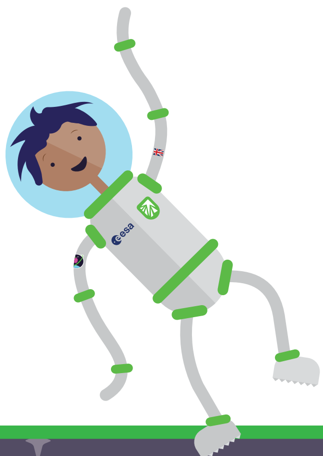
How it works

1 *What is chroma-key?*
It is possible to isolate a single colour value electronically which can then be made transparent to allow other images or video to show through in a photograph, video or livestream. This is often referred to as green-screen, but in actual fact any background with a consistent single colour can be replaced.

A proper green-screen may not be needed. The trouble lies in finding a background made of only a single colour key and shade. This means eliminating any shadows on the background which makes lighting from multiple angles essential.

2 *How do you set up green-screen?*
A permanent/semi-permanent space may need to be set up for visitors to see themselves 'in space'. For this a well-lit area of single colour can be used for people to walk through. An iPad can be used to record the area and there needs to be space for visitors to enter the area and not leave a shadow on the walls. The camera will need to be as still as possible for the best results.





There are a large variety of apps, many of which are free, that are available from the Apple app store. If you are considering a green-screen activity, it would be worth investigating which might be most suitable for your space. Some of the apps available include:

- Do Ink
- Veescope
- Quargo

An iPad can be manned by a member of staff or set-up using a secure case. The visuals can be shown on the iPad screen, or possibly connected to a larger screen or projector for visitors to photograph. By using the in-built education mode, it is possible to restrict the use of the home button and certain areas of the iPad screen.

Space backgrounds are best sourced from official sources such as NASA or ESA (see extra resources).

Additional information

For supplier information, risk assessments, and additional resources please see digital content on ***www.destinationspace.uk***

ASTRONAUT QUESTIONS & ANSWERS

There are many questions that people always wonder about living and working in Space. Here are some of the most common questions and short answers to them.

How do astronauts go to the toilet in space?

A seat belt and foot restraints hold the astronaut on the seat, while high-speed air currents pull the waste into the respective receptacles. There is a small potty like receptacle for solid waste, and a hose for liquid waste. Solid waste is collected and put into one of the cargo ships for disposal and destruction during re-entry. Liquid waste is recycled into drinking water.

How do astronauts sleep in space?

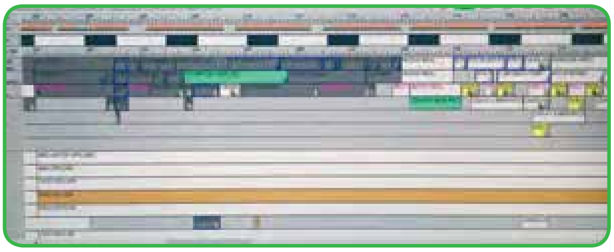
Astronauts cannot lie 'down' in a bed because of the weightlessness. They zip themselves into special sleeping bags that have holes for the arms, which are attached to the wall inside their crew quarters. (Which are the size of a broom cupboard). They end up in a 'Zombie' pose.

How do astronauts wash in space?

There are no showers on the ISS as they don't work in the weightless environment. Water would just stick to your body due to surface tension. Instead the crew use a damp wash cloth to wipe themselves clean.

What time is it in space?

The astronauts onboard the ISS use GMT (all year round). This was chosen as it is a good split between US and Russian time zones. The ISS orbits the earth once every 90 minutes, so they see the sun rise and set 16 times a day.



What do astronauts do in space?

Astronauts on the International Space Station usually work a normal working week. They have a work schedule from about 8am to 7pm Monday to Friday, including a 1 hour lunch break and 2 hours of exercise every day.

They have a morning and evening 'meeting' with all the control centres around the world to talk about the days activities. During the day, they work on experiments, perform maintenance tasks to keep the station working, prepare for visiting vehicles or space walks and talk to the ground crews.

At the weekends they have to do the cleaning and vacuuming. Evenings and weekends are their free time to relax, call and email friends and family, watch TV, play instruments and enjoy the view!

What do astronauts eat in space?

Most food is long lasting (over 2 years), but some fresh fruit and vegetables are included with each cargo delivery. Imagine going hiking and camping for 6 months without going near a supermarket, and you get an idea of the food. A lot of food is flown in a dehydrated state, and the astronauts add warm or cold water to it before eating it. Some food is tinned or thermostabilied in pouches, and others just flown in natural form (like nuts, dried fruit etc.)

How can I become an astronaut?

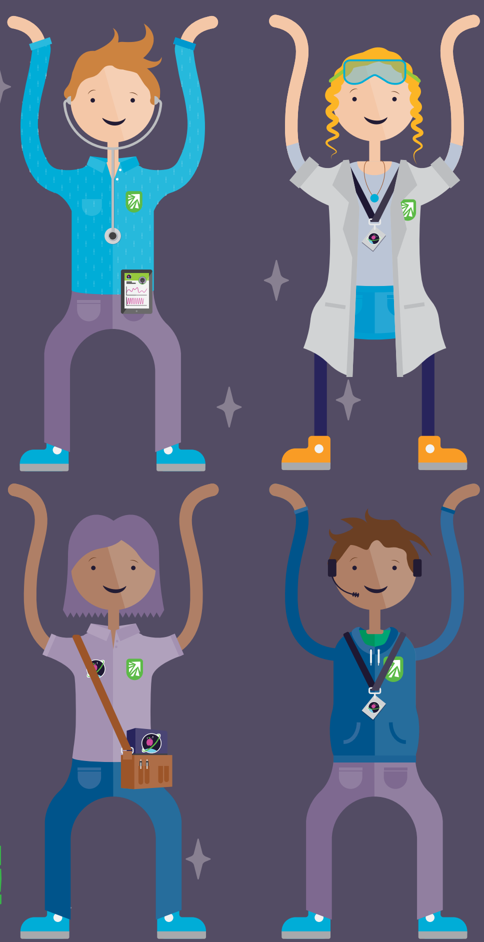
ESA recruits astronauts very rarely (in the past it has been about every 10 years or so). Typically, candidates should be knowledgeable in the scientific disciplines and should have demonstrated outstanding abilities in appropriate fields, preferably including operational skills.

Applicants must have a university degree (or equivalent) in Natural Sciences (physics, biology, chemistry, and mathematics), Engineering or Medicine, and preferably at least three years of related postgraduate professional experience, or flying experience as a pilot. It is a strong asset, but not mandatory, to have studied aeronautics and astronautics. Above all: no matter what you have studied, you should be good at it.

There are many more opportunities to work in the space sector and support Astronauts, (Mission Control, training, medical support, science experiments, engineers etc etc.)

Additional information

For videos on all these topics visit the resources page on ***www.destinationspace.uk***



TIM PEAKE/PRINCIPIA:

Media briefing notes for Destination Space participating Science and Discovery Centres

Key dates:

15th December – Launch (approx. 11am) and docking (approx. 6pm)

- Streaming of launch available here ***www.esa.int/esatv/Television*** or here ***www.nasa.gov/multimedia/nasatv***
- Launching in Soyuz craft, via Soyuz rocket from Baikonour in Kazakhstan
- Fellow crew members launching with Tim:
    - Tim Kopra (USA)
    - Yuri Malenchenko (Russia)

4th May – Return (date correct as of October 2015)

- Returning in Soyuz return module, taking about 3 and a half hours from leaving the ISS to landing on Earth

Tim at a glance:

- Born 1972 (age 43 at launch on 15th December 2015) in Chichester, UK
- Joined the army in 1990, studying at Sandhurst, became an army test pilot in 1994, and has since clocked over 3000 hours flying time in over 30 different types of helicopter and fixed wing aircraft
- Is married and has two sons
- Was selected for ESA astronaut training in 2008, becoming part of ESA's "class of 2009" along with 5 other Europeans. This was ESA's most recent call for astronauts, there hasn't been an astronaut selection for ESA since.

Dos and Don'ts:

- Do point out that Tim Peake is an ESA astronaut, and that the UK is a founding member of ESA.
- Do point out that there is a UK Space Agency, which is "responsible for all strategic decisions on the UK civil space programme and provides a clear, single voice for UK space ambitions". The UK Space Agency is part of the Department for Business, Innovation and Skills (BIS).
- Do remember that Tim is not the first British person to go to space. The first British person to go to space was Dr Helen Sharman OBE, who went to the Russian space station Mir in 1991. Her mission was funded by a group of British companies working with the Soviet Union.
- Do remember that there have been a number of NASA astronauts with dual nationality who can also be considered British astronauts:
    - Michael Foal (US/UK)
    - Piers Sellers (US/UK)
    - Nicholas Patrick (US/UK)
- Do remember that there have been a number of British people who self-funded trips to space who can also be considered British astronauts:
    - Mark Shuttleworth (South Africa/UK)
    - Richard Garriott (US/UK)
- Do point out that despite not being the first British person to go to space, Tim Peake is the first British ESA astronaut, and the first British astronaut whose mission is supported by the British government through the UK contribution to ESA's human spaceflight programme (UK first contributed to the ESA human spaceflight programme in 2012).
- Do point out that Tim's job is to undertake science experiments on the ISS and to undertake any maintenance work on the ISS as necessary
- Do point out that many of the science experiments on the ISS are part of UK-led research
- Do point out that Tim's mission will be supported by a huge number of people on Earth, working for ESA and other space agencies- make the connection to the Destination Space Join the Crew activity ***www.destinationspace.uk/meet-space-crew/find-your-role-space-crew/*** but point out that there are more roles

- Don't refer to Tim Peake as Major Tim Peake, his military title is not used as all ESA astronauts are civilians

- Don't use the term "zero gravity" as it is incorrect (gravity still has an effect in space, in fact it is what keeps objects orbiting around the earth so it cannot be termed "zero"), "microgravity" is the correct term when describing the International Space Station. You can also describe astronauts as "experiencing weightlessness".

- Don't give the impression that the space shuttle is still in use – the shuttle era is of immense importance in the history of human spaceflight but the shuttle has been retired since 2011.

Destination Space Facts

- A project funded by the UK Space Agency, and led by the UK Association for Science and Discovery Centres (http://sciencecentres.org.uk/) Destination Space is being delivered by 20 Science and Discovery Centres across the UK, in all four nations.

- The project has the following aims:

    - To celebrate the mission of the first British ESA astronaut Tim Peake with the public

    - To encourage various audiences to engage with the science and engineering behind Tim's mission as well as the ways that space science and space technology affects our lives

    - To raise an awareness of the diverse careers that link to the space sector, everything from an astronaut to the thousands of people who work in the commercial UK space industry

- Delivery of the project will include special events and programmes relating to Tim's missions at the 20 participating centres – things like Ask the Expert events and fascinating science shows for families and schoolchildren of different ages.

- Delivery of the project started in October 2015 and will continue on during and after Tim's mission.

- The resources for the project include a list of events at different science centres ***www.destinationspace.uk/events/*** and a quiz you can take to find out what role your skills and interests might suit as part of a human spaceflight mission ***www.destinationspace.uk/meet-space-crew/find-your-role-space-crew/***

ESA Facts

- The European Space Agency has 22 member states from Europe and also has a number of international partnerships

- The Columbus Module on the International Space Station is ESA's main contribution to the construction of the ISS. It is a laboratory module, and the home of many ESA experiments.

- The scientific research conducted or supported by the astronauts and cosmonauts on the ISS is varied, but includes medical science, physiology, microbiology, biology, biochemistry, fluid science, Earth observation science, geophysics, radiation studies, materials science, fundamental physics, and spacecraft control systems

- ESA has the following offices in Europe:

    - ESA Headquarters, Paris, France – the administrative hub for ESA

    - ESTEC, Noordvijk, The Nederlands – ESA's space research and technology centre

    - ESRIN, Frascati, Italy – ESA's Earth observation centre

    - ESAC, Madrid, Spain – The European Space Astronomy Centre

    - ESOC, Darmstadt, Germany – ESA's Space Operations Centre

    - EAC, Cologne, Germany – the European Astronaut Centre, where ESA astronauts train

    - ECSAT, Harwell, Oxfordshire, UK – the newest ESA centre, the European Centre for Space Applications and Telecommunications, linking in with UK expertise in these areas. This centre opened in 2015 and will employ 200 people by the end of 2016

- ESA commissions many different types of space research as well as human spaceflight, for example the Rosetta mission which reached comet 67P in 2014, the first mission to put a lander (the Philae lander) on a comet, is an ESA mission.

The UK in space – a few facts and figures

- The UK is a world leader in satellite design, build, and operation in the commercial space sector
- The commercial UK space sector employs roughly 35,000 people and has an annual turnover of around £11bn
- The UK has a number of industries which are not part of the main space sector, but which are classed as “space enabled” as they rely heavily on satellites, including telecommunications – that includes satellite television and satellite enabled mobile communications
- The space sector in the UK is working with more and more areas where satellite data can be helpful, including: agriculture, environmental monitoring, planning, navigation and maritime industries.
- UK universities are involved in world class space science, from cosmology and astronomy through to planetary science and solar system exploration.
- Information on the UK Space Agency is available here ***www.gov.uk/government/organisations/uk-space-agency***

Contacts for more information:

The following contacts at the National Space Centre are available should you have any technical questions about the project kit or content, about the Principia mission, human spaceflight generally, or the UK space sector. Between the 6th of December and the 1st of January these should be your go-to points of contact for this information.

Sophie Allan

Lead Physics Teacher,
National Space Academy
sophiea@spacecentre.co.uk
0116 258 2113 7

Kierann Shah

National Project Manager,
National Space Academy
kieranns@spacecentre.co.uk
0116 258 2125

Josh Barker

Education Presenter,
National Space Centre
joshb@spacecentre.co.uk
0116 258 2113 2

If there is no answer on the above numbers then the following numbers should be able to put you through to one of us or an appropriate colleague:

National Space Centre reception:

0116 2610261

National Space Academy administrator:

0116 258 2147

For any questions relating to the contracts/administration of the project, please contact Penny at ASDC as usual.

GLOSSARY

Automated Transport Vehicle (ATV)

The Automated Transfer Vehicle (ATV) was an expendable cargo spacecraft developed by the European Space Agency (ESA). ATVs supplied the International Space Station (ISS) with propellant, water, air, payloads, and experiments. ATVs also re-boosted the station into a higher orbit. There were five ATVs used between 2008 and 2015. The ATV programme has now ended.

Canadarm2

The Canadarm2 is a robotic arm that is used on the ISS to remotely perform tasks outside of the station.

Centrifuge

This is a piece of equipment that puts an object in rotation around a fixed axis (spins it in a circle), applying a potentially strong force perpendicular to the axis of spin (outward). The centrifuge works using the sedimentation principle, where the centripetal acceleration causes denser substances and particles to move outward in the radial direction. At the same time, objects that are less dense are displaced and move to the center.

Combustion

This is a high-temperature exothermic redox chemical reaction between a fuel and an oxidant (usually atmospheric oxygen). Combustion in a fire produces a flame, and the heat produced can make combustion self-sustaining. A simple example can be seen in the combustion of hydrogen and oxygen into water vapor, a reaction commonly used to fuel rocket engines.

Extra Vehicular Activity (EVA) suit

This is a suit which astronauts wear outside of the ISS while doing a spacewalk (extravehicular activity). There are two designs of suit in use on the ISS, the American EMU (Extravehicular Mobility Unit) and the Russian Orlan-M.

Principia Mathematica

Philosophiæ Naturalis Principia Mathematica often referred to as simply the Principia, is a work in three books by Sir Isaac Newton, published in 1687, 1713 and 1726 respectively. The Principia states Newton's laws of motion, forming the foundation of classical mechanics, also Newton's law of universal gravitation, and a derivation of Kepler's laws of planetary motion. The Principia is "justly regarded as one of the most important works in the history of science".

Principia

This is Tim Peake's mission, which is named after Sir Isaac Newton's Principia Mathematica in which he outlined his Laws of Motion. ESA asked for suggestions to name Tim's mission. More than 4,000 people suggested a name and Principia was suggested 20 times. The mission patch was designed by 13 year old Troy Wood who won a Blue Peter competition to design it.

G- Force

This is a measurement of the type of acceleration that indirectly causes weight. G-force is a type of acceleration that can be measured with an accelerometer. Since g-force accelerations indirectly produce weight, any g-force can be described as a "weight per unit mass". When the g-force acceleration is produced by the surface of one object being pushed by the surface of another object, the reaction-force to this push produces an equal and opposite weight for every unit of an object's mass.

International Space Station

This is a space station, or a habitable artificial satellite, in low Earth orbit. Its first component launched into orbit in 1998, and the ISS is now the largest artificial body in orbit and can often be seen with the naked eye from Earth. The ISS consists of pressurised modules, external trusses, solar arrays and other components. ISS components have been launched by Russian Proton and Soyuz rockets as well as American Space Shuttles.

Kinetic Energy

This is the energy that an object possesses due to its motion. It is defined as the work needed to accelerate a body of a given mass from rest to its stated velocity. Having gained this energy during its acceleration, the body maintains this kinetic energy unless its speed changes. The same amount of work is done by the body in decelerating from its current speed to a state of rest. Kinetic energy is calculated by multiplying half the mass of an object by the square of its speed (KE = ½ mv2).

Magnetism

This is a class of physical phenomena that are mediated by magnetic fields. Electric currents and the magnetic moments of elementary particles give rise to a magnetic field, which acts on other currents and magnetic moments.

Maximum Absorbency Garment (MAG)

This is a piece of clothing astronauts wear during liftoff, landing, and extra-vehicular activities (EVAs) to absorb urine and feces. It is worn by both male and female astronauts.

Meteorites

These are fragments of rock and/or metal that fall to Earth from space. They are some of the oldest objects in the solar system, usually around 4.5 billion years old, and provide insight into the materials that made up our own planet.

Microgravity

This is the correct term for the weightlessness astronauts experience when in Earth orbit. It should be used instead of 'zero-G' or 'no gravity'.

Pathogens

An infectious agent such as a virus, bacterium, prion, fungus, viroid, or parasite that causes disease in its host.

Photoelectric Effect

This is when a photon hits an atom and gives its energy to one of the electrons. This will either raise the electron to a higher energy level in the atom or if there is enough energy it will mean the electron can move completely clear of the atom.

Photovoltaic (PV)

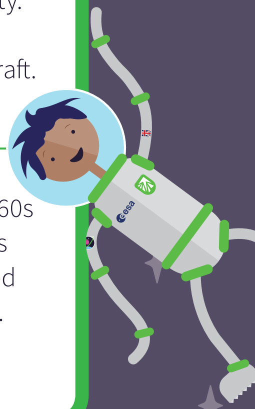
The method of converting solar energy into direct current electricity using semiconducting materials that exhibit the photovoltaic effect. A photovoltaic system employs solar panels composed of a number of solar cells to supply usable electric power.

Sodium Polyacrylate

This is a sodium salt of polyacrylic acid with the chemical formula $[-CH_2-CH(CO_2Na)-]_n$ and broad application in consumer products. It has the ability to absorb as much as 200 to 300 times its mass in water.

Sokol Space Suit

Known as the Sokol IVA suit or simply the Sokol, this is a type of Russian space suit worn by all who fly on the Soyuz spacecraft. It was introduced in 1973 and is still used. The Sokol is not capable of being used outside the spacecraft in a spacewalk or extra-vehicular activity. Instead, its purpose is to keep the wearer alive in the event of an accidental depressurisation of the spacecraft.



Soyuz

A series of spacecraft designed for the Soviet space programme by the Korolyov Design Bureau in the 1960s that remains in service today. The Soyuz spacecraft is launched on a Soyuz rocket, the most frequently used and most reliable launch vehicle in the world to date.

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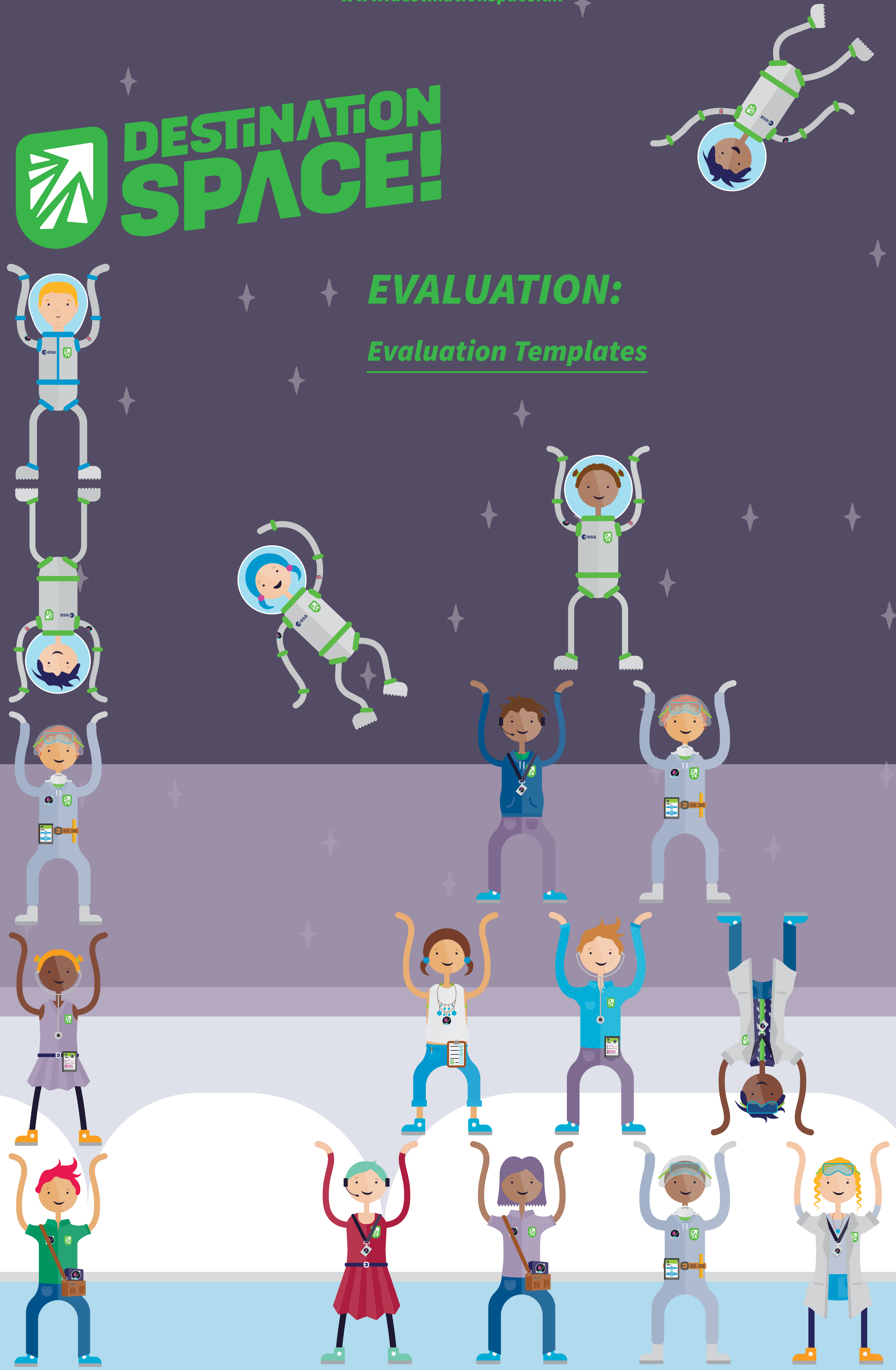
Evaluation Templates



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