DESTINATION SPACE!

UK spaceports and launchers

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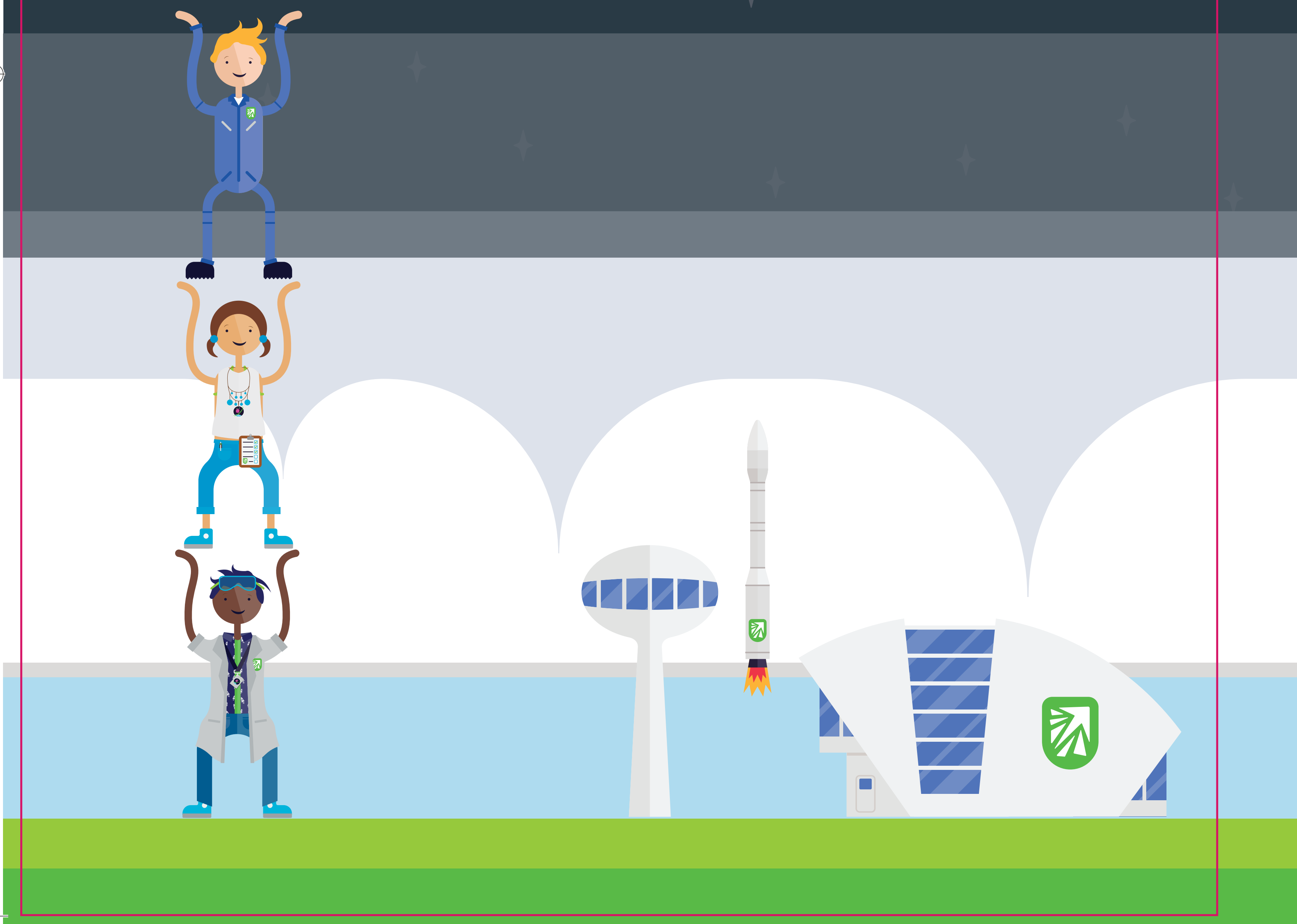

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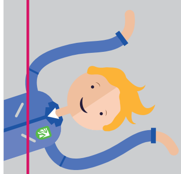
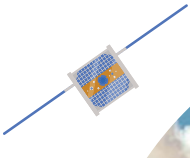




UK spaceports and launchers

'LaunchUK' aims to enable small satellite launch and suborbital spaceflight from the UK.

The space industry is rapidly growing and evolving. A key driver is the demand for small satellites which provide data, communications and even platforms to conduct scientific experiments.

The UK is set to be a key player on this international stage, expanding not only our own access to space, but providing an attractive investment opportunity for the new generation of international commercial space companies.

Spaceports in the UK

The UK is renowned for its space industry expertise with a skilled workforce and engineering capacity that sets the UK as a world leader in the manufacture of small satellites.

The UK is also in a great position to launch small satellites into polar and sun-synchronous orbits. The emergence of spaceports within the UK will allow UK companies to offer a complete package from concept, to launch. In this way, the UK can keep up with demand, maximise the productivity and return on its excellent space industry, and attract new investment so as to continue to harness UK skills in space technology, creating new jobs and opportunities.

Where will UK spaceports be?

Several locations in the UK are developing their spaceport ambition including:

- Campbeltown Airport, Scotland
- Glasgow Prestwick Airport, Scotland
- Snowdonia (Llanbedr Airport), Wales
- Cornwall Airport Newquay, England
- Shetland, Scotland
- Sutherland, Scotland
- Western Isles, Scotland

Plans are now underway to develop a vertical launch sites in Sutherland, Western Isles and Shetlands. Horizontal launch sites are proposed at Cornwall, Snowdonia, Prestwick and Campbeltown.

This first set of sites all intend to support the UK's developing small satellite launch operations, and horizontal launch sites could be used for suborbital passenger spaceflight in the future. The spaceports have announced plans to work with various launch companies such as Orbex, Lockheed Martin and Virgin Orbit.

Several companies, working with their partners and the UK government, hope to be the first to launch a UK rocket from a UK spaceport, with proposed spaceports with ambitions to be operational by the early 2020s.

Image: Liftoff of Space Shuttle Atlantis. Launches often attract visitors to watch them. Credit: NASA

What is a spaceport?

Similar to an airport but for spacecraft

Image: Baikonur spaceport, Kazakhstan. Credit: NASA

Similar to an airport for aircraft, spaceports launch, and for horizontal spaceports, receive spacecraft. With an increasing demand for low-cost access to space, and with governments and companies across the globe becoming increasingly reliant on small satellites, new and proposed spaceports are being developed around the globe.

Early spaceports

Most of the early spaceports came from the desire to test rockets for military and scientific reasons.

The world's first spaceport is the Baikonur Cosmodrome. Built in Kazakhstan, it was from here that Sputnik 1 was launched into orbit in 1957 and Yuri Gagarin became the first human in space in 1961. Tim Peake was also launched into space from Baikonur in December 2015.

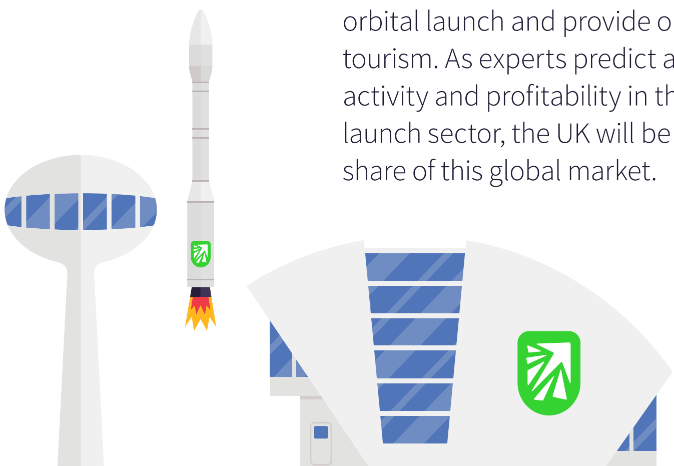
Modern spaceports

Modern spaceports now take a variety of roles due to increasing diversity in the missions that national and commercial space organisations want to fly.

Spaceports may be designed for horizontal or vertical launch, for human or uncrewed missions, with the requirements of the launch vehicles varying with the size of the payloads.

Rapid advances in consumer electronics have transformed satellite technology, driving down the costs of the payload with the ever-decreasing size of satellites that can now be built. Space tourism is also now becoming a realistic, commercial enterprise. These drivers are attracting public and (increasingly) private companies who are keen to capitalise on space-based opportunities.

In the UK, we are hoping to build several spaceports that will eventually fulfil this role of orbital launch and provide opportunities for space tourism. As experts predict a future of increased activity and profitability in the commercial space launch sector, the UK will be able to capture a large share of this global market.



Types of launch

Horizontal vs vertical

When we think of space travel, we often imagine a rocket launching vertically upwards, but the UK is also exploring horizontal launch.

A new solution

Horizontal launches involve specialised aircraft that take off horizontally. Requiring less thrust and less fuel to reach high altitudes, once the horizontal launch craft can go no higher, it will either switch to a rocket engine or deploy a rocket-powered craft that has "piggy-backed" on it in order to power the satellites into space and into orbit.

Vertical launches are still the preferred method of spaceflight for heavier payloads, but horizontal launches can be carried out more frequently using existing airport facilities which have been adapted so it's important that the UK creates opportunities for both launch types.

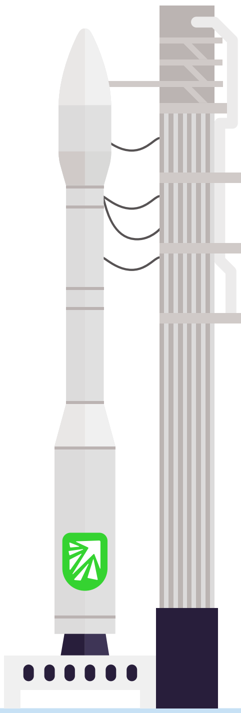
For example, Newquay aerodrome in Cornwall has been proposed as a spaceport site for horizontal launch. It will use a 2.7km runway.

Will we still launch vertically?

The UK has a long history of vertical launch, including launching larger rockets from Woomera in Australia. The UK also works with other countries, utilising their launch sites and rockets for our payloads.

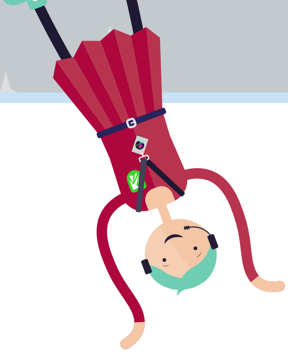
The rockets used to launch satellites into space from the UK will be much smaller than the Russian-built Soyuz, or ESA's Ariane 5 or Vega rockets, because the payload of the smaller satellites is lighter and requires less fuel.

Sites of vertical launches are a source of space tourism in their own right, due to the spectacle of rockets taking off and powering into space, so it is exciting that spaceports are being developed in northernmost Scotland as vertical launch sites.



Top image: Virgin Orbit Cornwall. Credit: Virgin Orbit

Bottom image: render of Sutherland spaceport. Credit: Orbex



Whoosh Rocket

A speedy mini-rocket

With rockets set to launch from UK shores, this activity can help people understand the basic principles of rocketry.

What does it show?

This mini rocket uses an ordinary plastic bottle with a nozzle attached. The bottle has a small amount of ethanol in it which is vaporised, mixed with oxygen from the air and then ignited.

This combustion produces carbon dioxide, water vapour and energy in the form of heat. The heat causes the gas inside the bottle to expand, forcing the gas through the rear nozzle at high speed. This propels the rocket along.

This is the same as in full-scale rocket launches, when kerosene or another rocket fuel ignites in the rocket engine and provides propulsion to launch the rocket into space.

How to run the activity

Lay the rocket-launching track (the guttering) down on a table or the floor, facing away from any people and doors.

Add 2-4 ml of ethanol to the bottle and screw on the nozzle. Place your finger over the end of the nozzle and shake the bottle vigourously for 30-60 seconds to vaporise the ethanol fuel and to mix it with the air and oxygen inside the bottle.

Keeping your finger over the end of the nozzle, place the bottle in the rocket-launching track and pick up the lighter.

Remove your finger from the end of the bottle (there may be a small hiss or spray from the pressure of the vaporised fuel) and quickly bring the open flame to the nozzle. The mixture in the bottle will ignite and your rocket will shoot down the track.

Following launch, the rocket will be warm to the touch, but safe to handle. The experiment can be re-run a second time with the addition of more fuel. However, make sure there is enough new air (oxygen) in the bottle.

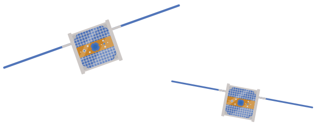
Slow motion video of the reaction

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

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

Health and Safety

Take care when using, transporting and storing ethanol, as it is flammable.
The audience or demonstrators should never sit or stand in front of the bottle.
After the demonstrations have been carried out, carefully dispose of any liquid left inside the bottle and leave the lid off to allow the air to refresh inside. Each time, check the bottle for any defects, melted patches, cracks etc.



Where in the world to put a spaceport

What features do the major launch sites have in common?

The drywipe globe gives us a full world map that we can draw on and easily wipe clean then draw on again. Use this to discuss requirements of launch sites.

What does it show?

The drywipe globe shows country boundaries and can be easily annotated, cleaned and re-annotated.

There are currently only 32 rocket launch sites in existence around the world for commercial or government-led launches. Many other sites are used for small sounding rockets and are not capable of launching larger payloads, such as satellites, into successful orbits.

This activity invites people to see if there are common factors between several well-known launch sites.

How to run the activity

Label the following launch sites on the globe:

1. Cape Canaveral, Florida, USA
2. Wallops Island, Virginia, USA
3. Tanegashima, Kagoshima Prefecture, Japan
4. Sriharikota, Andhra Pradesh, India
5. Baikonur, Kazakhstan (leased to Russia)
6. Kourou, French Guiana, a French territory in South America
7. Xichang, Sichuan, China
8. Jiuquan, Gobi desert, Inner Mongolia
9. Plesetsk, Mirny, Russia
10. Reagan Test Site, Marshall Islands, Pacific Ocean

Invite people to look at the positions of the launch sites on the globe and see what they notice about them.

They should notice that:

- **a** They are often sited close to the equator (within the Tropics of Cancer and Capricorn).
- **b** They are often on the eastern coast of their respective landmasses.

Discuss the following reasons why these launch sites have these common features:

- **a** The Earth's own rotation can be harnessed to provide some of the energy required to get a rocket into orbit. This rotational energy is at its greatest near the equator. Launching from here can reduce the amount of energy (and therefore fuel) needed to get into orbit.
- **b** Geostationary orbits need to be over the equator. By launching close to the equator, less energy is needed to launch geostationary satellites.
- **c** The reason many orbital launch sites are on eastern coasts is because they will launch eastwards to take advantage of the Earth's rotation. Placing the launch site on the east coast means that rockets will take off over the sea. If an emergency occurs, the rocket can be made to abort its flight over the sea rather than over a populated inland area. Baikonur is not on the coast, but to the east of the launch site there is a large sparsely populated area of the Kazakh desert.

Where to put UK spaceports?

An activity looking at proposed UK spaceport sites

The UK has grand plans to become a world leader in the provision of a complete space solutions package, from satellite design and construction to launch. To do this it will construct several spaceports, but the siting of these involves a huge number of considerations.

Why build UK spaceports?

The aim of UK spaceports will be to launch small satellites into space or to facilitate space tourism and science, such as experimentation in microgravity.

Currently, the UK relies on other countries to get our satellites and experiments into space. A UK spaceport would not replace these existing collaborations, but would bolster our capabilities and allow us to design, build, launch and operate them here in the UK.

Polar launches

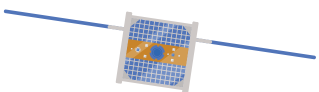
Most of the global launch sites mentioned on the previous page, launch large objects into geostationary orbit or even further afield. UK sites will specialise in launching smaller satellites into polar orbit, where a satellite passes above or nearly above both poles. In these launches north-south clearance is more important than east-west clearance so the geographical location of the UK is perfect.

The satellite applications section has more detail about the different types of orbit and the applications of these.

What makes a good spaceport site?

When selecting the locations for spaceports, there are several factors that must be considered. The first is safety. Space exploration now feels commonplace, but nevertheless public safety must always be paramount. To minimise risk, spaceports are often built away from large centres of population. It is also important that the spacecraft has access to clear flightpaths. Some of the biggest spaceports launch over the sea, or over uninhabited regions for this reason.

Spaceports must also provide not only a place to launch, but the infrastructure to get the craft into space. The pieces of the spacecraft, crew and support staff must be able to reach the launch site. For safety, rockets are fuelled as close to launch as possible, so this is one of the services that is usually operated by the spaceport. Therefore, while building remotely increases safety, ensuring the location is not too remote is an important consideration, as there must be good or easily-constructible transport links for a spaceport to be successful.



Conversion of existing sites such as airports is something that is common, due to the supporting infrastructure that is already in place. It also ensures regeneration of areas that may have fallen on hard times due to the abandonment of a site. Old military test ranges and even existing airports have previously been converted into spaceports.

How to run the activity

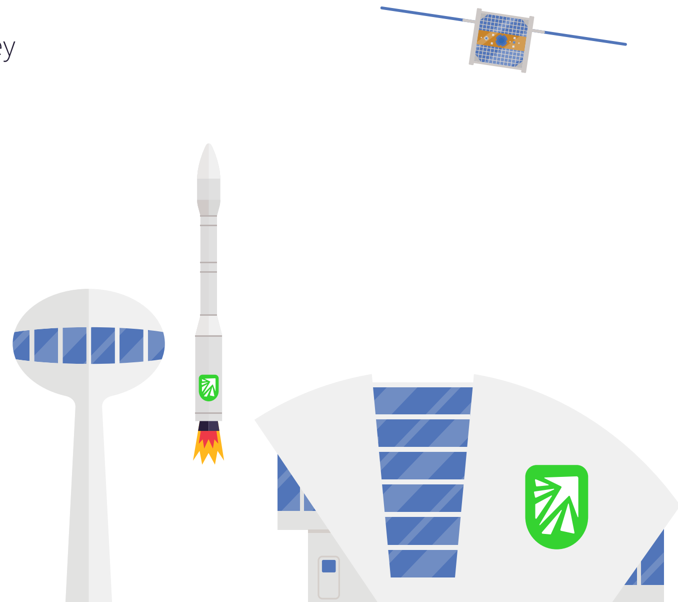
The magnetic map of the UK and the spaceport magnets are a great tool to discuss spaceport positioning with the audience.

Ask visitors to suggest areas in the UK where they might want to put a spaceport, and generate discussion about whether the site would be usable.

Consider whether the launch goes out to sea rather than over a populated area, whether it is sited away from a large residential area due to potential accident risk and noise, and discuss good tranport links.

Alternatively, you can place the currently considered UK sites and discuss the pros and cons:

1. Campbeltown Airport, Scotland
2. Glasgow Prestwick Airport, Scotland
3. Snowdownia (Llanbedr Airport), Wales
4. Cornwall Airport Newquay, England
5. Shetland, Scotland
6. Sutherland, Scotland
7. Western Isles, Scotland



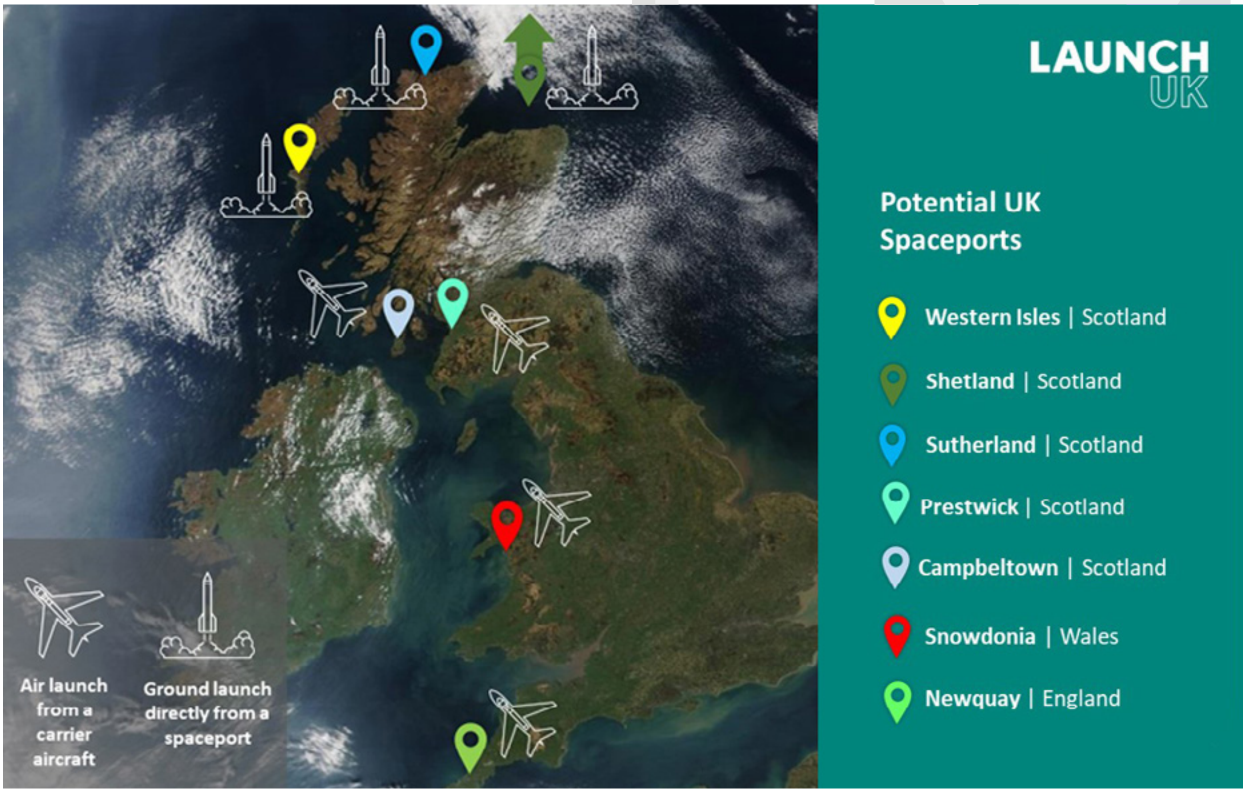


Image: Map of proposed UK Spaceport sites. Credit: UK Space Agency

A history of UK spaceflight

Celebrating the UK's space pedigree

Since the founding of the British Interplanetary Society in 1933, the UK has had a strong and influential presence in global space flight efforts – both independently and as a key player in global partnerships.

Early space exploration

Following World War II, the UK performed some of the first tests of the space-capable V-2 rockets. As early as 1946, British engineers were developing plans to build the first crewed suborbital spacecraft.

In the 1950s Britain's space odyssey truly began. Based at a rocket site in Australia, the British Skylark rocket began a 50-year campaign to deliver small payloads to the edge of space. These sounding rockets (capable of travelling at many times the speed of sound, but not of entering orbit) proved to be arguably the most successful of their type and laid the groundwork for bigger and more capable rockets.

The 1960s saw the UK enter the satellite industry. The Ariel program saw the launch of six research satellites into orbit. Having collaborated with NASA, we forged a strong partnership that still exists today. This early era of rocketry saw the launch of Prospero X-3. This joint research and communications satellite was a landmark moment for British space science: the first British satellite to be launched by a British rocket, Black Arrow.

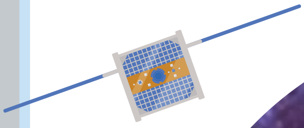
Britain then provided the first stage of the experimental European Europa rocket mission, which used the Blue Streak missile as its base. While the rocket was marred by technical difficulties, Britain's first stage performed perfectly on each test flight.

British innovation

The following decades saw the UK move away from rocket technology and focus on our ability to build satellites. However, we still retained our innovative spirit and engineering excellence. The UK space industry has forged an international reputation for building excellent satellites. As this reputation has grown so has our involvement in the global space market.

And now, through young, innovative space start-up companies and supported by the upcoming construction of space ports, the UK is ready to once again make its mark on the spaceflight industry.

Top image: Skylark rocket. Credit: Wikipedia Bottom left: Bluestreak rocket at National Space Centre. Credit: National Space Centre



Space law

Protecting space companies, the environment and people as our space industry grows

Launching things into space means starting from the land and travelling through the air, creating a set of legal responsibilities for operators. The use of space is governed by international law, meaning that payloads such as satellites are also subject to regulations.

Who governs spaceports?

Any spaceport in the UK will be subject to UK laws. As the UK has never had a spaceport before, a lot of new laws and regulations need to be put in place, which started with the Space Industry Act 2018. This established who will regulate UK spaceports and that their primary duty is to secure public safety as well as complying with all other existing environmental, planning and health and safety legislation. The act also requires spaceflight activities in the UK to be licensed.

The UK Space Agency, Department for Transport and Civil Aviation Authority continue to work closely together to develop the secondary legislation, guidance, and regulator for launch following Royal Assent of the Space Industry Bill. The new regulator is expected to be established and accepting and accessing applications and monitoring activities in early 2021.

Why do we need laws?

Having laws in place means that spaceport operators will have a legal obligation to conduct their work in a way that considers environmental and safety assessments. If they break the law, they could be fined or even forced to stop operating. A legal framework is also needed so that spaceport operators can insure their vehicles and payloads. Insurance companies will not cover activities if they are illegal or if legality is in doubt.

What other space laws are there?

International space law is very important. It ensures that different countries can have satellites and spacecraft operating in space without conflict. The basis of all international space law is the 1967 UN Treaty on Outer Space. This means that all space law takes into account Article I of the treaty, which states that the exploration and use of outer space is carried out in the interests of all countries. It also encourages international cooperation.

Article 1

The exploration and use of outer space, including the Moon and other celestial bodies, shall be carried out for the benefit and in the interests of all countries, irrespective of their degree of economic or scientific development, and shall be the province of all mankind.

The business case for spaceports

Why does the UK need its own spaceports?

As technology evolves and reduces the cost of access to space, there is an exciting opportunity for the UK to thrive in the new space age.

Space sector growth is down to business

Government's spaceflight programme, LaunchUK, aims to establish commercial spaceflight from the UK and grow these new UK markets for small satellite launch and suborbital spaceflight. This will support the Government's aim of growing the UK's global market share of the space sector by 10% by 2030.

Historically, space exploration and satellite usage have been led by national governments. Today, the sector is growing because of investors convinced by the business case for the space industry, such as the build or operation of spacecraft or opportunities for using the data collected by earth observation satellites for commercial uses.

Smaller satellites, smaller launchers

The European Space Agency's 2002 trailblazing Earth observation satellite, Envisat, was the size of a bus and weighed over 8 tonnes. Recently, technology in satellites has become increasingly smaller, meaning that most satellites are now small satellites (smallsats) and microsatellites. CubeSats are just 10cm x 10cm x 10cm and weigh not much more than a kilogram. These lighter payloads require less fuel and have smaller rocket requirements, all resulting in less expense for launching smaller satellites.

UK Spaceports for satellite launch

When UK companies use foreign launch sites, they must transport their payloads to these destinations, costing money and increasing the overall satellite cost. It also puts the satellite and its instruments at risk of damage during transportation. Having launch sites in the UK will greatly reduce this cost and risk, meaning UK space businesses can reduce their running costs, becoming more profitable.

Having smaller and less expensive satellites also means that you can make more of them more often. This is only worth doing if there is a way to get them to space regularly and reliably. Horizonal launches from UK spaceports will support regular, easy access to space for UK companies, allowing new satellite technology to be launched quickly and keeping satellite networks up-to-date.

Supporting the global space sector

UK spaceports won't just be available for UK companies. They'll also be able to sell launch opportunities to international companies and other national governments that don't have their own access to space. This will bring overseas income to the UK and encourage international collaboration with other countries.

Getting off the ground

What is in a rocket?

For almost the entirety of human history we have been confined to the ground. What does it take to leave our planet and get into space?

Gravity gets us down

Taken almost for granted, gravity is the universal force that holds us onto the planet's surface. Escaping our planet's gravitational pull is something we only managed to achieve in the last 200 years. In that time, we have progressed from the Montgolfier Brothers' paper balloon to the giant rockets we ride into space.

Energy vs elegance

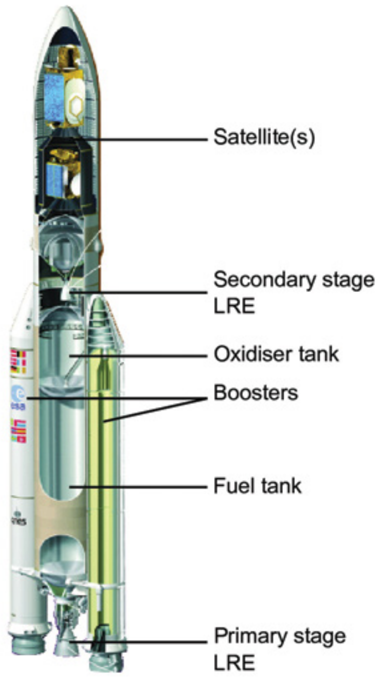
Powered flight through the air was achieved through an elegant balance between airflow and lift and a relatively small input of energy to move along. To get into space we have to sacrifice the airflow and lift generated by the atmosphere. This means that our energy requirements become much greater.

To provide the enormous amounts of energy to push rockets into the air, we use the chemical reaction, combustion. The explosive combination of fuel and oxygen has so far powered all our space exploration.

Explosive energy

Combustion's main advantage over other reactions is its simplicity. If the ingredients are mixed in the right proportions, the resultant reaction can be controlled.

While simple, the use of combustion means we must sacrifice some efficiency. To lift large payloads into orbit requires large amounts of fuel which, is itself, is added payload. Due to this complicated relationship a rocket is generally 85% fuel and just 15% rocket. Most of this material comprises the engines and fuel tanks, leaving usually just 1-4% of the mass available for what you want to send to space. Until recently, almost all these rockets have been single-use: an expensive way to get all our heavier payloads into space.



Bottom right: ESA's Ariane V rocket showing how fuel and oxidiser tanks make up the majority of a rocket. Credit: European Space Agency

Reaction Engines

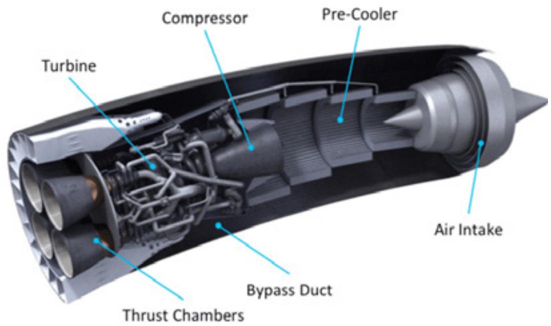
Pioneering new engine technology for direct access to space

Reaction Engines is a British aerospace company with big ambitions. The SABRE engine is their unique combination of jet and rocket engine technology, which creates a reusable, fuel-efficient propulsion system capable of reaching space.

The SABRE engine

SABRE (Synergetic Air-Breathing Rocket Engine) is currently in development and is very experimental.

Using liquid hydrogen as its fuel, it is designed with two modes of operation. In air breathing mode, it sucks in air like a conventional jet engine, with a capability of going 5.4 times the speed of sound (almost twice as fast as conventional jet engines). In rocket mode, it will switch to using liquid oxygen as a propellant (instead of the oxygen in the air) producing speeds of up to 25 times the speed of sound and unlocking access to space.



The pre-cooler

SABRE will be able to attain higher speeds than a conventional jet engine is thanks to its innovative pre-cooler. As air is drawn into a jet engine it is compressed. This compression causes it to heat up to temperatures that would destroy the light weight materials necessary for a spacecraft to reach orbit. SABRE has a system of extremely fine tubing, through which helium (that has been cooled by the engine's extremely cold hydrogen fuel) is pumped. Due to the enormous surface area of the fine tubes, the heat from the compressed gas can transfer into the helium coolant, allowing a drop in temperature of 1000 degrees celsius in less than 1/25 of a second.

Skylon

Once the engines have been tested and proven, the next step will be to integrate these into a fully functional spacecraft. Reaction Engines are currently working on the Skylon concept (pictured in the headline image) to pioneer the use of their supercooled, air breathing, hybrid engines.

Top image: Artistic render of a hypersonic aircraft geometry base on the Skylon concept. Creative Common Share Alike 3.0 License
Bottom image: Cutaway image of SABRE engine. Credit: Reaction Engines

Fire Tornado

A model of an air breathing engine

Jet engines like SABRE guzzle and compress air, increasing the amount of oxygen available and therefore the rate of combustion, providing a larger thrust. This demo shows a similar way in which you can increase the amount of flame.

What's happening

A burning container of fuel sits within a mesh bin on a rotating table. When the bin is stationary, a modest flame is observed. But spin the bin and you get a fire tornado!

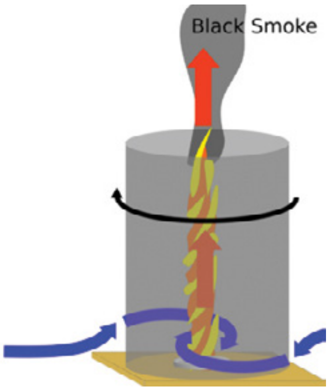
As the fuel burns, it heats the air above it, causing it to rise and draw the flame with it. Fresh, colder air is drawn in from the bottom to replace it.

When spinning, the drawn-in air is forced to rotate and spiral inwards, getting faster as it gets closer to the flame. This temporarily results in more air per second mixing with the fuel vapours. Also, as more air passes over the fuel, the rate of fuel evaporation increases.

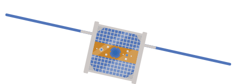
As this spinning flame rises, it forms a vortex – a spectacular fire tornado. Interestingly, while the rate of combustion does slightly increase, it is not as efficient. As the tornado rises, more smoke is created. This is because it is harder for the spinning air to mix with the fuel, leading to a less complete combustion and more soot.

How to run the activity

Cut a piece of sponge just big enough to fit in the bottom of the fire-proof dish. Saturate this sponge with your fuel (lighter fluid or isopropyl alcohol work best for this). Place the dish in the centre of the bin, and the bin in the centre of the lazy Susan. You can use Blu-Tack to secure it down if you wish, though if properly centred this is not necessary.

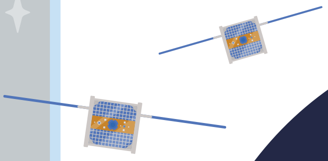


Put on the heat proof gloves and light the fuel with the long lighter. Comment on the height of the flame then set the bin spinning and observe as a vortex forms, drawing the flame up in a dramatic manner.



Please note

This demonstration is not a true representation of a jet engine, but more a starting point to discuss the factors that affect combustion and how we can maximise thrust.



What might happen at UK spaceports?

A host of new opportunities!

UK spaceports will provide regular, low-cost access to space for satellite launches, but spaceport sites may offer other new opportunities.

New research into microgravity

Scientists and engineers sometimes need to test experiments in microgravity (the constant state of freefall that makes it appear as if gravity is not affecting you in orbit). This is hard to do on Earth, but it can be done on special high-altitude flights where the vehicle drops in free fall for a few seconds at a time. UK spaceports, particularly horizontal launch sites, could provide flight opportunities like this.

New companies

New companies have already been set up to work with UK spaceports. Some existing companies are adapting in order to be able to take advantage of them too. Companies like Orbex, Lockheed Martin, Raptor Aerospace and Skyrora are working on vertical launch, whilst Virgin Orbit is working on horizontal launch and Reaction Engines are working on novel propulsion systems.

There are existing companies in the UK like Clydespace and Airbus who build satellites that could be launched from UK spaceports. They will need to be able to transport their payloads to the spaceports and the spaceport operators will need to work with the launcher companies to ensure the smooth handling of payloads onto launchers.

Co-ordinating the timings of when payloads arrive and are prepared for launch will be one of the main jobs of the spaceport operators. They will also need to co-ordinate launch windows and to track the launch vehicles after launch.

There are also opportunities for startup companies to come up with innovative ways of using the increasingly affordable access to space and the data gathered from this access. Catapults and incubators across the UK provide networking hubs between established businesses, academia and startups and it's likely that ideas and collaborations will emerge from these to push the boundaries of what can be done in the UK.

Watching launches

People will definitely want to launch from UK spaceports. Spaceport operators may create viewing points and share information about launches with the public. They may also set up visitor centres. Spaceports may become destinations for tourists and space fans from the UK and all over the world.

Image: Composed satellite photograph of Europe. Credit: NASA

Microgravity

A unique environment producing unique science

Microgravity is an environment that can only be consistently experienced in orbit. This activity introduces some of the effects of microgravity and discusses why microgravity science is so important.

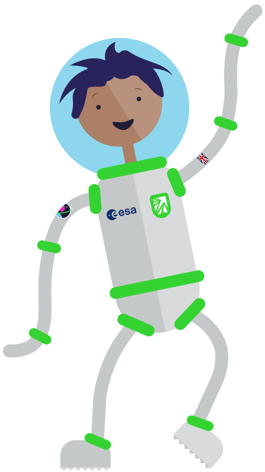
What is microgravity?

Whenever we think of astronauts in space, we picture them floating around as if the Earth is exerting no gravitational force. This is of course not the case. Gravity on the International Space Station is still around 90% as strong as it is on the surface of the planet. So what is going on?

We can temporarily experience microgravity on the Earth with a parabollic flight. If an aeroplane begins to climb, and then throttles back its engines so as to only provide enough thrust to counteract air resistance, then it effectively becomes a projectile: the only overall force acting on it is gravity pulling the aeroplane towards the surface of the Earth.

Gravity affects all particles equally. A small mass and a large mass dropped in a vacuum will fall toward the Earth with the same acceleration, and hit the ground at the same time (as spectacularly shown on the Moon during the Apollo 15 mission). You can demonstrate this with two identical sized balls of equal diameter, and therefore equal air resistance, but different mass.

Our aeroplane is being accelerated towards the ground with the same acceleration as anything inside it. If you are in the plane, the floor is falling away from you as fast as you are falling towards it. Lift up your legs and you will float with respect to the plane. That is, until the plane pulls out of this curve, making you temporarily feel twice as heavy as it rapidly climbs.



An object in orbit is also falling towards the Earth, as is anything inside. It just has enough sideways speed that the curve of its path matches the curve of the Earth and so it never hits the surface. This is what causes microgravity.

What do we research?

While there is no doubt that microgravity is an extremely fun (if often queasy) experience for humans, there is a lot of unique science that can be done in orbit.

Without the influence of gravity, crystals will grow larger, more uniformly and with fewer imperfections than on the Earth. The most accurate clocks (with the exception of atomic clocks) on the Earth use precision quartz crystals and the more perfect the crystal, the more accurate the timing. Current research into protein crystals may even potentially lead to more effective, targeted cancer treatments.

Microgravity research is a relatively young, but exciting field. With cheaper, more regular access to orbit, researchers will have the chance to test far more ideas.

The microgravity box

This activity centres around the microgravity box. This box contains a 4k action camera with 120fps slow motion capability and a fixing point for various vessels. Because it is carefully balanced and has a low centre of mass, dropping this box from height gives a good approximation of microgravity for a fraction of a second. The best results come withing the first few milliseconds after dropping, before air resistance has had a chance to build up. While the effects of drag and short fall time mean we cannot fully replicate the microgravity environment, it does gives us a glimpse of some of the effects which we can then begin to discuss.

The two experiments provided with the box are the candle test and the water test.

A full set of instructions concerning the operating of the camera and viewing/analysing the video is available as an additional digital resource.

Candle test

Make sure there is a suitable 'soft landing' for your experiment. A duvet worked well in preliminary testing.

Fix the candle into the larger jar using velcro and then velcro the jar itself to Tether Spot 1 on the microgravity box.

Take the action camera, turn it on and set it to record at 120fps by pressing the 'power button' twice. Attach this to the camera fixing point.

Swiftly light the candle using the long lighter and carefully screw on the perforated lid. Gain as much height as you can – stand on a table, use a stepladder, or release from a higher floor if you can. Just before you release the box, press the "OK" button on the camera to begin recording.

What does this show?

As the candle falls, the flame will noticibly flatten before it is extinguished by the impact. Flames have their distintive shape due to convection caused by warmer, less dense air rising. Without the effect of gravity, differences in density will not affect a fluid or a gas and so convection has no effect. In fact, in true microgravity, a candle flame is spherical.

Water test

Repeat the demonstration for the candle test, but this time attach the vial of water to Tether Spot 2.

What does this show?

Immediately after release, the edges of the water will start to creep up the side of the container. This is due to the surface tension capillary action which is explained in more detail in the additional notes.

The effects demonstrated in both of these activities can be shown in full using a range of videos filmed on the International Space Station.

Did you know?

Engineers worked out a way to use this surface tension capillary action to an astronaut's advantage in orbit. They were able to design special cups that encourage liquids to flow up a specially designed channel, into the astronaut's mouth.

What has space done for me?

Exploring surprising spinoffs

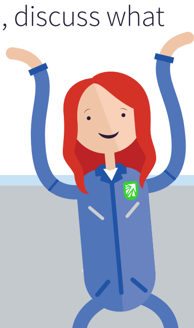
Space exploration is exciting, but people often struggle to see how it affects their daily lives beyond that. This activity will reveal to visitors that a lot of items and technology they use in their every day lives were derived from the space industry, as well as dispelling a few myths.

Spinoffs

Sending spacecraft, robotic missions and humans into space is not easy. The dangers of the space environment, and the difficulties presented by microgravity, radiation, isolation and more, means the development of new advanced technologies is a necessary and common occurrence. Once a technology has been produced for the space industry, it's usually not that long before it will filter down to a public use.

How to run this activity

For this activity, lay several items on a table (see suggested items to the right). Five of these items are true space spinoffs: they were directly developed for the space industry (or at least contain technology that was) and then filtered down to us. Four were developed for every day life, but are now used in the space industry. Visitors are challenged to look at the items, discuss what they are and place them in the right group: spinoff or myth.



Spinoffs

Sunglasses – scratch resistant coatings

Developed to protect equipment, especially space helmet visors, from becoming scratched in space.

Thermal 'space' blanket

Invented by NASA in 1964 to protect astronauts and technology from the extremes of space.

Goal keeping gloves – temperature regulating foam

Originally developed for NASA spacesuit gloves.

Memory foam shoe inserts – memory foam

Invented in the 1960s to improve crash protection and comfort.

Baby formula milk – nutritional additives

Many baby formulas contain an oil called Formulaid™, derived from algae and originally discovered as part of NASA-sponsored nutrition research.

Spin-not

- Fisher space pen
- Velcro
- Teflon
- Cordless power tools – though a cordless vacuum cleaner was designed especially for Apollo Moon missions.

What next?

The future of UK spaceflight and technologies

Spaceports in the UK will soon become a reality, with small satellites going into orbit from UK launch sites. This will present really exciting opportunities for the UK to thrive in the new space-age.

Spin-off technologies

New technology for spaceports could lead to even more 'spin-off' technology like the unexpected developments we mentioned on the previous page. Possible spin-outs include new rocket or aircraft propulsion systems, fuel types, materials for building launch vehicles and systems for monitoring and recording launches and missions. Spin-outs are hard to predict, so there may be something completely new that nobody expected.

What about space tourism?

Although UK vertical launch sites will not be set up for launching people, some methods for horizontal launch are similar to plans for future human space travel. Horizontal launch company Virgin Orbit is a sister company to Virgin Galactic, a space tourism company that will launch from the USA. So, will they also launch people from the UK? Whilst, there are no plans for this to happen at present, the Space Industry Act 2018, the legal basis for spaceports, does allow for space tourism, so watch this space!

Image: Orbex Prime rocket. Credit: Orbex

Education

Another area often overlooked when a new facility or technology emerges is education. Launching rockets from here in the UK is an exceptional opportunity to engage young people with the science and engineering of rockets, not to mention tourism, economics and law. Imagine being able to go on a school trip to see a real rocket launch, or to launch your school's own CubeSat to the edge of space! The resulting need for skilled engineers and technicians is also likely to have an impact on educational provision, particularly for young people living in the vicinity of a spaceport.