> FLOODED PARADISE
Is NZ the real Atlantis?

> GATEWAY TO THE STARS
We visit an arctic spaceport

> HEAD TRANSPLANT
Impossible surgery or life saver?

AUSTRALIAN

# SCIENCE ILLUSTRATED

# Rogue Planets

Lost in space, could these wandering worlds be home to life?

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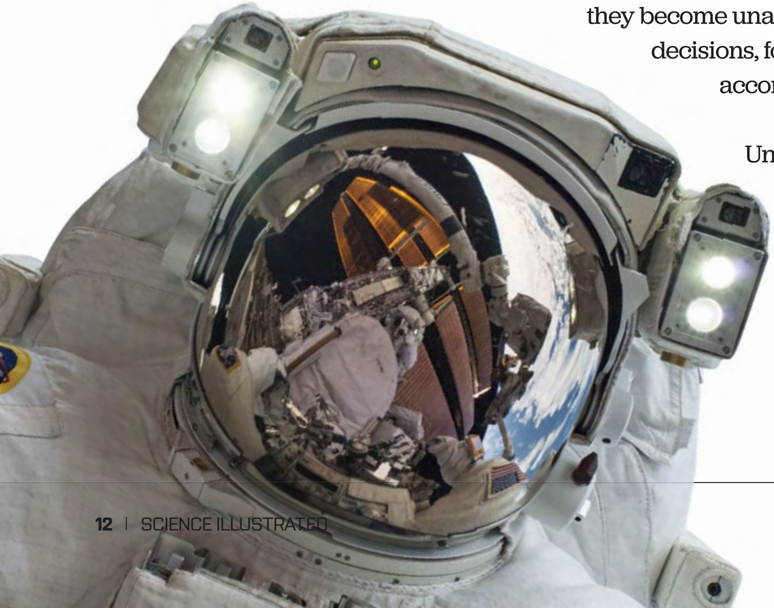
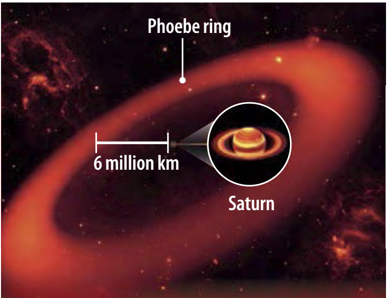
# RADIATION MAY HARM ASTRONAUTS' BRAINS

There is bad news for future Mars travellers: The cosmic radiation outside Earth's atmosphere is so intense that it harms the brain cells of astronauts, so they become unable to make complex decisions, focus, and remember, according to experiments carried out at the University of California. Mice were subjected to radiation resembling cosmic radiation, and as a result, they developed a type of dementia.



NASA

NASA




Saturn is surrounded by a huge ring located six million km away from the planet.

# SATURN'S NEW RING IS GROWING

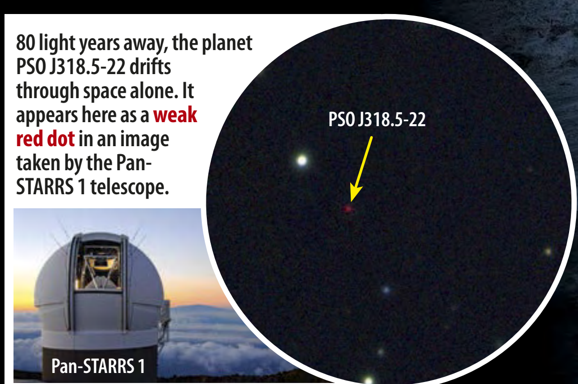
**ASTRONOMY** In 2009, astronomers discovered that apart from the known rings, Saturn is surrounded by an outer, almost invisible ring, which is considerably bigger than any of the others. Scientists have now realised just how huge the ring is: almost 7,000 times bigger than Saturn itself, and 30% bigger than astronomers expected.

NASA's infrared WISE telescope has mapped out the ring, which has been named the Phoebe ring. The new, infrared images reveal that the ring begins six million km from Saturn and stretches to a distance of at least 16.2 million km from the planet.

# IS OUR UNIVERSE FULL OF ROGUE PLANETS?

Billions of lonely, rogue planets wander the Milky Way. They have been ejected by their stars and must now exist without their light or heat. And yet, new calculations suggest that these planets could still support an ocean of life...

By Henrik Bendix




80 light years away, the planet PSO J318.5-22 drifts through space alone. It appears here as a **weak red dot** in an image taken by the Pan-STARRS 1 telescope.

UNIVERSITY OF HAWAII

Billions of planets have been ejected by their stars and are speeding through the universe all by themselves.

SHUTTERSTROCK

In a well-organized universe, planets orbit stars, just like Earth orbits the Sun. Some planets are large, others are small, but they are all orbit a star. However, the universe keeps surprising us, and it turns out that planets do not always follow the rules. Some of them have "run away" from their star, speeding through the universe all on their own. Much to the astonishment of scientists, our own galaxy, the Milky Way, contains billions of these rogue planets.

## EINSTEIN REVEALS THE PLANETS

An international team of astronomers aimed a telescope at the centre of the Milky Way, and via a computer system, they monitored 50 million stars. The astronomers did not focus on the stars themselves, but on their light.

According to Einstein's general theory of relativity, the light from a remote star can be bent and even amplified by a massive object such as a planet passing in front of the star. Suddenly, it looks as if the star is shining more brightly. Known as the gravitational microlensing effect, the phenomenon is used by astronomers to search for the rogue planets.

A planet the size of our Solar System's largest, Jupiter, amplifies the light from a remote star for less than two days, so the scientists focused on these brief events. Having double-checked with colleagues in Chile, the astronomers could confirm a total of seven cases of starlight briefly being amplified by rogue planets.

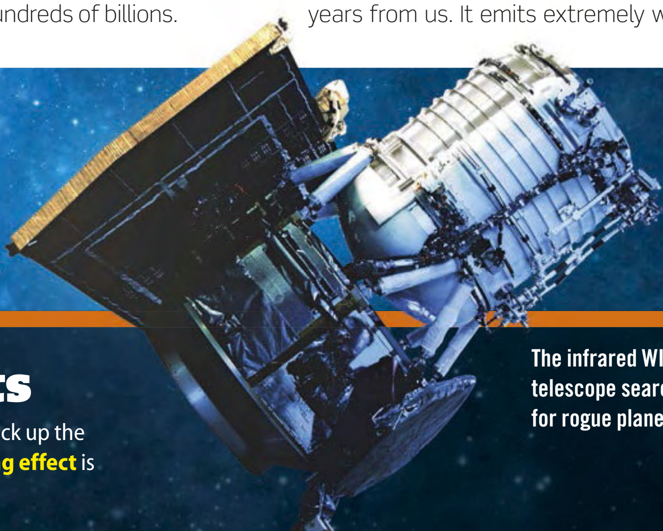
Though seven planets doesn't sound like a lot, it was more than enough to enable the astronomers to start calculating how many of these Jupiter-like, rogue planets exist in the Milky Way. Surprisingly, our galaxy contains almost twice as many rogue planets as stars – in the order of hundreds of billions.

## SLIGHT HEAT RADIATION EMITTED

At night, when we can see the other planets of the Solar System, it is so, because they reflect the light of the Sun, but planets without stars cannot shine as brightly. Still, it is not impossible to take a closer look at them, as they emit a little heat, and the heat radiation can be detected by special telescopes.

Although the rogue planets do not receive heat from a star, they are not completely cold. They slowly emit heat in the form of thermal infrared radiation. When a planet is formed, pressure and temperature in its interior rise, and radioactivity can also heat the planet.

By studying images taken by the Pan-STARRS 1 telescope, located in Hawaii, astronomers have discovered a planet, which has been named PSO J318.5-22. The planet is rogue, and located about 80 light years from us. It emits extremely weak ▶



The infrared WISE telescope searches for rogue planets.

NASA

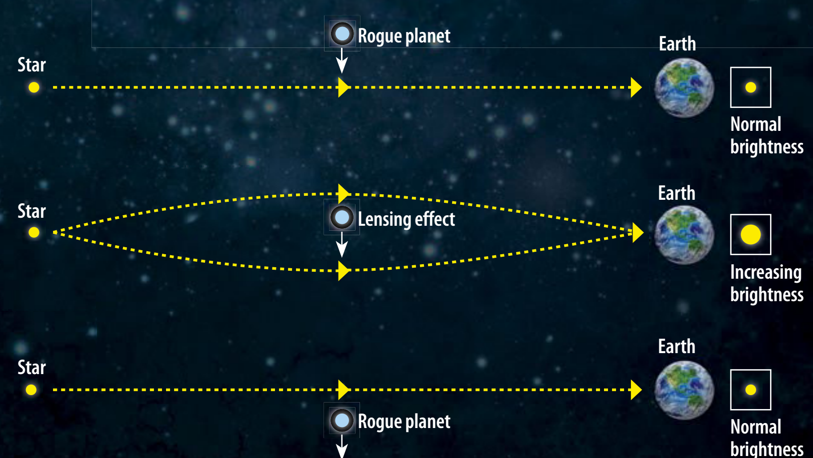
## Starlight reveals planets

Massive objects can function as a type of lens, which will briefly pick up the light from a remote star. The so-called **gravitational microlensing effect** is used in the search for planets which do not orbit a star.

**1** The light from remote stars is **captured by telescopes**. Astronomers observe whether the brightness is constant or not.

**2** A planet passes in front of the star, and the **light is bent** around the planet. When light comes from several directions, brightness increases.

**3** It typically takes **a few days** for a large planet to pass in front of the star. Afterwards, the brightness goes back to normal.



The distances within the Milky Way are so immense that a collision with a rogue planet is almost impossible.
CREATIVE COMMONS

## Earth is not in danger of collision

The Milky Way is full of rogue planets, but we need not worry about one of them suddenly colliding with Earth, because while the Milky Way contains billions of these objects, there is also lots of space. That said, the closest rogue planet is probably closer to Earth than the closest star, Proxima Centauri. But that star is located approximately **42,000 billion km** away from us. The distances of the universe are simply so immense that the risk of a collision with a wandering planet is extremely small.

It is much more likely that a rogue planet will be adopted by a new star. On its way through space, the planet may be captured by the gravity of a star and begin to orbit the star. The theory can explain why mysterious planets have been observed in orbits unusually far away from their stars.

infrared light. It can only be observed, because its mass is 6.5 times Jupiter's, making this planet an absolute heavyweight.

### PLANETS THROWN FROM THE NEST

Where these billions of rogue worlds come from remains a mystery, but astronomers have several theories. According to one, the planets formed alone from a cloud of dust and gas in the same way as stars originate. According to another theory, they form like the Solar System's planets, - from a disc of matter surrounding a young star. But at some point in their evolution, they were ejected from their stellar system – like when a baby bird is thrust out of the nest by its bigger siblings.

Scientists tend to support this theory, and quite a few astrophysisists are even convinced that our solar system contained more planets in its youth, four billion years ago. In the beginning, the Solar System was probably a very unstable and chaotic place, in which the planets had not yet found their present-day orbits.

**2018**

**is the year in which the James Webb telescope will intensify its search for rogue planets.**

According to a well-established model of our Solar System's development, the gas giants Jupiter and Saturn first moved towards the Sun, only to lose momentum and drift out to their present orbits. En route, they interrupted the orbits of other planets, and computer simulations carried out by American astrophysicist David Nesvorny show that a planet the size of Uranus or Neptune may have been ejected from the Solar System due to Jupiter's gravity.

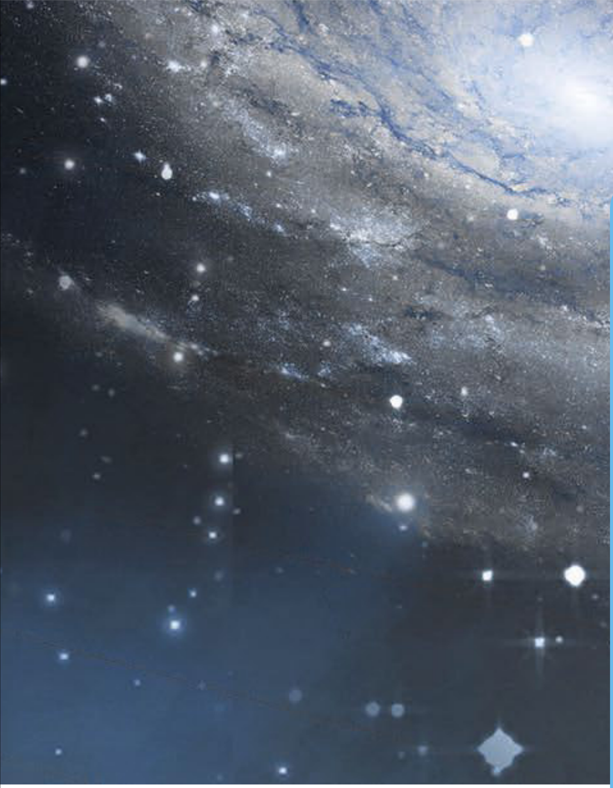
Other models indicate that smaller planets the size of Mars were also ejected from the Solar System in connection with Jupiter's and Saturn's migration.

So, one or more planets that formed in the young Solar System and were later ejected could now be drifting through space on their own. Other stellar systems may also have lost planets in the turbulent past, and so, the number of rogue planets could indeed be as high as indicated by the astronomical estimations.

### LIFE MAY ORIGINATE FAR FROM A STAR

The rogue planets live cold, dark lives without any connection to a star, but astronomers still think that they could still support some form of life.

On Earth, the vast majority of all organisms depend on energy from the Sun, but some microorganisms can survive without sunlight, as they have found another energy source. That is true for microbes thriving in the darkness of the deep oceans



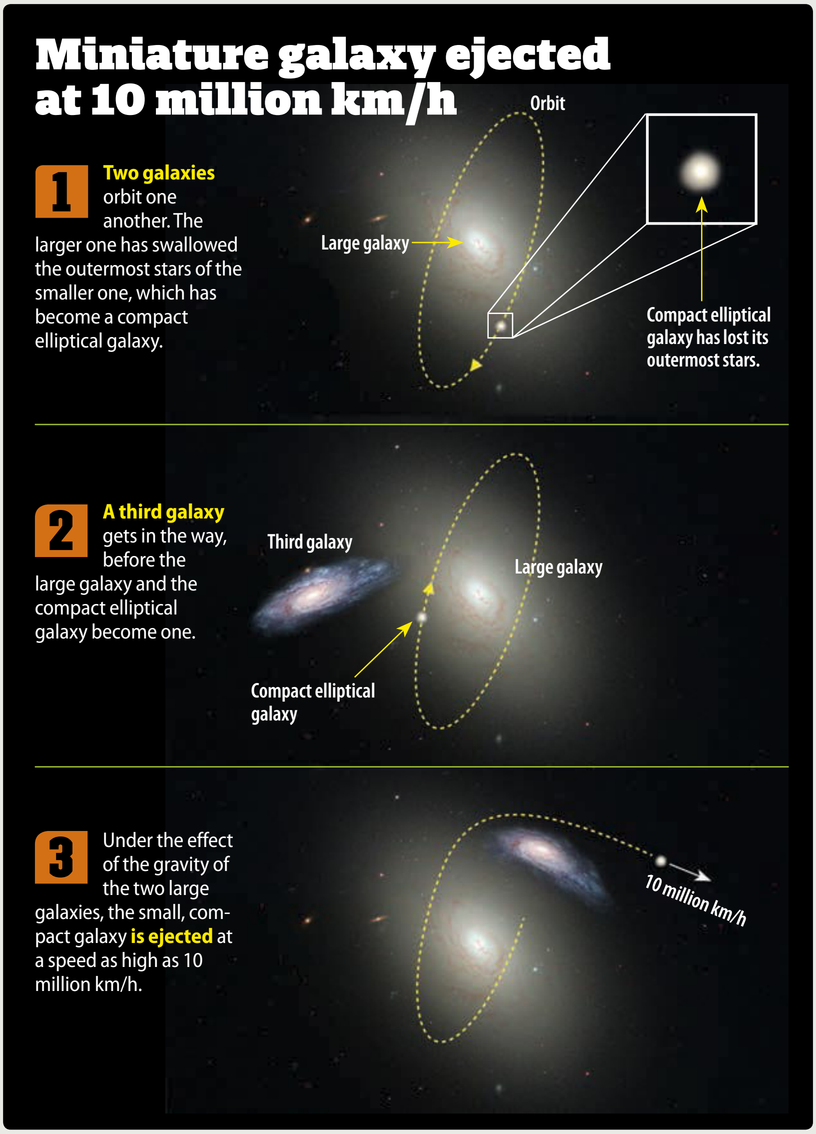
# How about a rogue Galaxy?

**Not only planets, but also entire galaxies can be rejected. Two Russian astronomers discovered that in 2014, when they decided to search for a particularly rare type of galaxy.**

Even huge systems such as galaxies can go rogue. In 2014, Russian astronomers discovered 195 rare compact elliptical galaxies, which have lost most of their stars, so only the innermost ones remain. Eleven of these are located far away from the galaxy clusters in which galaxies are normally to be found.

According to scientists, the compact galaxies were once large, but they collided with even bigger galaxies that swallowed their outermost stars. Subsequently, a third large galaxy passed by, and as the two big galaxies interacted, the compact elliptical galaxy was accelerated away, to wander through space.

## Miniature galaxy ejected at 10 million km/h




close to hydrothermal vents, where warm, nutrient-rich water flows out of cracks in the ocean floor.

Similarly, rogue planets could support life, as long as their interiors produce enough geothermal heat to keep water liquid. According to the calculations of two American scientists, a planet that is at least 3.5 times heavier than Earth could still have an ocean under its ice sheet. The heat from the interior of the planet can keep the water liquid, but only if the ocean is covered by ice, which can function as an insulating blanket.

Smaller planets could also have such an ocean, but only if they hold much more water than Earth or used to have a thick carbon dioxide atmosphere, which has subsequently frozen and come to cover the surface like an extra blanket.

### HUBBLE REPLACEMENT COULD SOLVE MYSTERY

We will get an idea of whether the scientists' theories hold water, when new, improved telescopes are put into service in the years to come. The James Webb telescope replaces Hubble in 2018, and it will be able to take more and sharper images of the rogue planets. Also, astronomers expect a lot from the future Wide-Field Infrared Survey Telescope, which can use the microlensing effect to search for wandering worlds. According to the mission schedule, the new telescope will be launched in 2024. SCI

The TEXUS 51 research rocket is launched from the hostile Arctic landscape surrounding the Esrange Rocket Range.

# ARCTIC AEROSPACE

Europe's biggest rocket range, the Esrange Space Centre, is located among reindeer and vast, snow-covered expanses near the Swedish mining city of Kiruna. Starting in 2020, humans and satellites will be launched into space from the Arctic wilderness.

By Gunver Lystbæk Vestergård. Photos: Jesper Rais


**Europe's new spaceport is in Sweden**

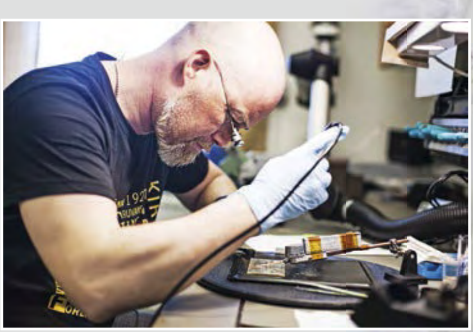
- **SPACE RESEARCH**
  The solar wind at Mercury
- **ROCKET LAUNCH**
  Research missions to space
- **SPACE TOURISM**
  100,000 visits to the site a year

## Space university specialises in solar weather

Some of the world's leading solar wind experts are working at the Swedish Institute of Space Physics (IRF) in Kiruna. Right now, the space university's instruments are orbiting Venus, Mars, Saturn, and more – just like the IRF is monitoring solar particles in Earth's atmosphere.

Solar wind consists of charged particles emitted by the Sun, which create auroras, and other effects in the atmosphere, or disrupt satellite communication. Every object orbiting the sun is subject to solar wind. Outside Kiruna, there is a satellite dish with a 32 m diameter, which uses radar to monitor electron clouds produced by solar wind in our atmosphere. The dish is a part of a Scandinavian radar network known as EISCAT. The radars can see space junk down to 20 mm and up to 1,500 km away. The IRF contributes small weather stations and particle detectors to ESA and NASA missions such as to the BepiColombo, Europe's first mission to Mercury (due to launch in 2017).

The instruments can measure magnetic fields and capture ions from solar wind.



The Swedish Institute of Space Physics builds instruments, that are going to orbit Mercury.

ESA tests the BepiColombo craft, which is to orbit Mercury.

ANNEKE LE FLOC'H/ESA

At the Esrange Space Centre, 40 km outside Sweden's northernmost city of Kiruna, two biomedical scientists are working with a cell microscope. With intense concentration, they are trying to focus on just one of the 100,000 cancer cells on the small plastic disc: a huge task, when the cells and the microscope are actually located 260 km into space, having travelled there at a speed of 7,200 km/h.

Sascha Kopp of Germany and Thomas Corydon of Denmark are rehearsing, while the world's first space microscope that can photograph cells in a state of weightlessness is still on the ground. The cylinder-shaped microscope will eventually be placed in a shining, rose-coloured TEXUS "sounding rocket" and launched to the edge of space.

Kiruna is already home to a space university, a space high school, and the world's biggest civil satellite receiver station, and Esrange is Europe's leading rocket range. But the Swedish ambitions reach beyond research rockets launched from the Arctic landscape, where reindeer and dog sledges must share the few roads, and auroras light the night sky. Sweden has initiated the vision of Space Kiruna, which is going to launch people and satellites into space from Europe.

### TRIAL AND ERROR

Sascha Kopp keeps on turning the knob to adjust the focus of the cell microscope during the rehearsal. Two deep worried lines appear on Thomas Corydon's forehead. Only greyish black blots can be seen on the computer screen. They are struggling, and the six simulated minutes of weightlessness are coming to an end. But with seconds to ▶

Esrange's satellite dishes are scattered across the Arctic landscape.

Scientists are testing the microscope, which will register how cells react in a weightless environment.

# The tiniest astronauts light up

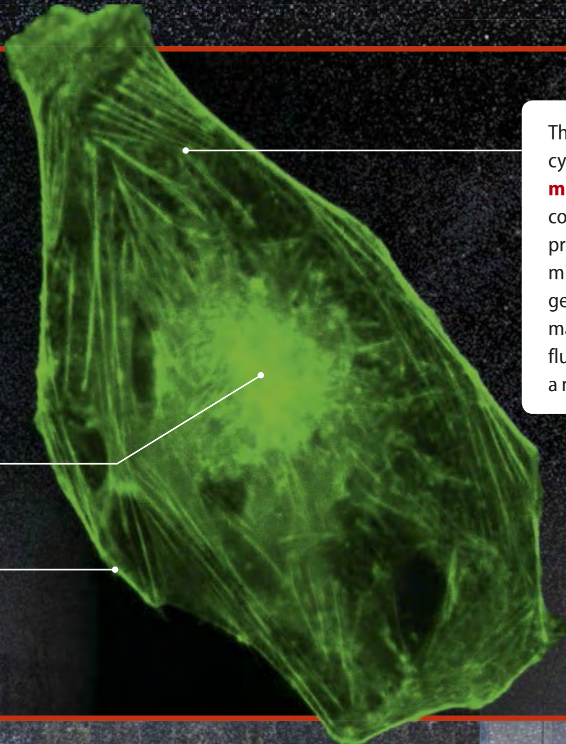
**In order to find out how the human body will react to long space missions, scientists are sending different cell types into space.**

On the TEXUS 52 mission in April 2015, cancer, immune, and brain cells were tested in zero-g (or more correctly, free-fall). Space medicine experts discovered that human cells perform poorly in this state, which affects the immune system, brain, heart, and muscles. The key to understanding the bizarre cell behaviour in space may be found in cells' internal scaffolding, the cytoskeleton, which supports a cell like the pegs of a tent. The cytoskeleton collapses in free-fall, sending a signal to the protein factory, the ribosome, that something has changed. This makes the ribosome produce different types of proteins than it does on Earth; proteins that scientists can study. If humans are to go on space missions of several years, scientists need to learn more about the behaviour of those cells.

When the cells are viewed through a microscope, their internal structure can clearly be seen.

## CELL SCAFFOLDING STUDIED IN SPACE

**Scientists are studying the cells' internal scaffold, the cytoskeleton, to understand cell behaviour in space. The cytoskeleton consists of a number of "tent poles" that behave in a special way in zero-g.**





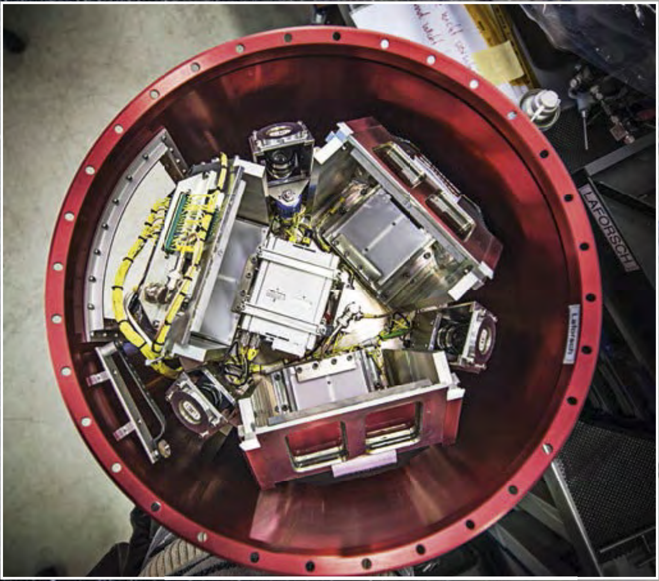
## Space centre launches rockets and balloons

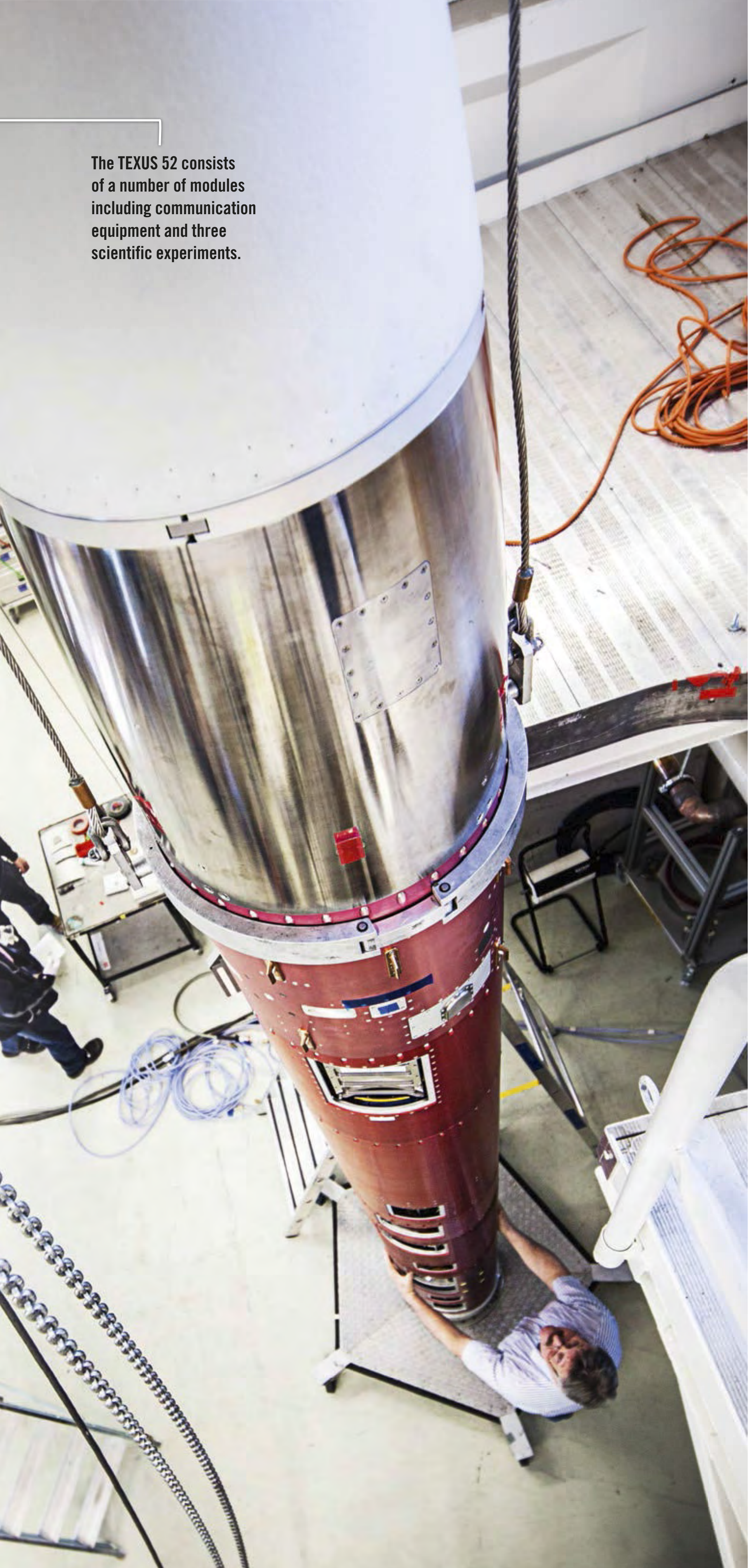
More than 500 rockets and 550 stratosphere balloons have been launched from the Esrange Space Centre since 1966. The rockets land north of Esrange in a 5,600 km² wilderness area.

ALLAN HØJEN

◀ Airbus engineers are assembling the TEXUS 52 rocket, mounting the parachute module on top of the control system module.

▼ This experiment will study predators' behaviour in free-fall. The containers hold tadpoles and daphnia.





The TEXUS 52 consists of a number of modules including communication equipment and three scientific experiments.

spare, Sascha Kopp manages to focus on a cell and produce a delicate green cobweb on the screen. The rehearsal reveals weaknesses in the design of their experiment. The two scientists will pre-focus the microscope on three cells before launch. If the microscope and the cells do not move during the rocket launch, the scientists can concentrate on taking good pictures during the minutes of weightlessness, before the rocket falls back to Earth.

During the rehearsal, the cells moved 60 micrometres, and as the microscope can only be moved 300 nanometres at a time, the scientists must turn the manual dial 200 times to find the cell again, which is almost impossible. The $5 million experiment seems headed for failure.

The TEXUS rocket with the cell experiment is the 52nd TEXUS research launch. At the cone-shaped launch tower a few hundred metres from the workshop, the 13-m-tall TEXUS 51 is dormant. It has been ready for about a week, but high winds delay the launch. The TEXUS rockets, which have been paid for by the German space agency DLR and built by German and Brazilian engineers, cannot be allowed to drift south into inhabited areas. North of the range, an area slightly larger than Luxembourg is deserted apart from a few flocks of reindeer which makes it perfect for rocket impacts.

## FROM CLOUDS IN SPACE TO CELLS

The first sounding rockets did not focus on weightlessness, they studied the clouds of charged particles that collect in the top part of the atmosphere, the ionosphere, when it is affected by solar wind.

Ionospheric research set off the space age in Kiruna with the establishment of the Swedish Institute of Space Physics (IRF) in 1957. Today, exhibition cases in the corridors show that many of the sounding rockets, which have studied the solar wind, included IRF instruments. Today, the IRF is also the headquarters of the development of one of the world's most sophisticated radar systems for mapping out the ionosphere: EISCAT_3D. The system is going to consist of five fields throughout Scandinavia, each made up of approximately 30,000 small antennas. One of the test areas is located at the Esrange Space Centre, which was built in 1964. In the early days, the space centre was owned by the European Space Research Organisation (ESRO, the future ESA), but later, it was

# Tried and Tested

**The TEXUS rocket is the world's oldest active suborbital research rocket and has lifted experiments into space since 1977. The latest (at time of writing), the TEXUS rocket No. 52, was launched from the Esrange Space Centre in April 2015.**


**6 THE ROCKET NOSE** is made of metal, but covered by a plastic layer to protect it against the heat. **The plastic layer melts** and evaporates during launch, when friction causes temperature to rise to 300 degrees.

**5 THE PARACHUTE** is made of thin, synthetic cloth and boasts a 20 m diameter. It **automatically unfolds** 4-5 km above the ground.

**4 A BALANCING RING** harmonises load weight differences, keeping the rocket steady. The balancing ring is a bowel-shaped cavity, in which weights are placed.

**3 A GPS ANTENNA** is located close to the nose, constantly transmitting data to mission control concerning the location of the rocket. A few seconds after launch, the GPS can also calculate **where the rocket will land.** Engineers cannot control the rocket, but are in constant contact with it, receiving data and images from the ongoing experiments.

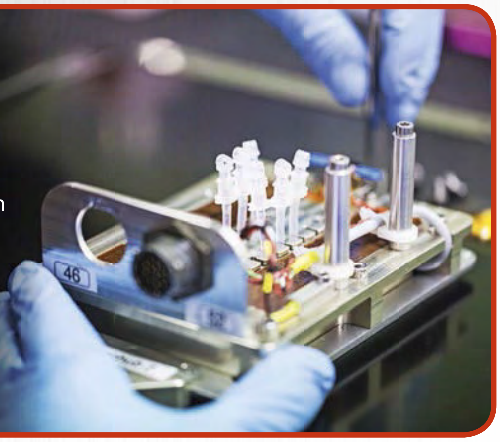
**2 THE SECOND MOTOR** takes over from the first. About one minute after lift-off, the second motor burns out at an altitude of 43 km and is disconnected. The rocket continues to **an altitude of 260 km,** before succumbing to gravity and falling back to Earth.

**1 THE FIRST MOTOR** The fuel consists of aluminium powder mixed with an oxidizing agent. An electric spark ignites a capsule with black powder. In a matter of milliseconds, the entire rocket motor has been ignited, and the force of the huge, controlled **explosion lifts the rocket.** The motor burns out and is disconnected after 14 seconds.

**EXPERIMENT 1**

### Weightless cells are filmed

Cancer, immune, and brain cells are filmed live through a microscope to learn how their interior structures change in free-fall.




**EXPERIMENT 2**

### Future displays are studied

Liquid crystals can flow like liquids but maintain crystalline structures. On Earth, the crystals collapse, but in zero-g, they can grow taller. The crystals are used in LCD displays, and by building figures in free-fall, scientists hope that the crystals will reveal new characteristics.

**EXPERIMENT 3**

### Predator instinct tested in space

In this experiment, predators (tadpoles) tadpoles are allowed to attack daphnia "water fleas" to see how prey and predators interact in free-fall.

> **Esrange will now focus on the growing micro-satellite market.**

taken over by the Swedish Space Corporation (SCC), which is the national Swedish agency. Some 550 sounding rockets and a similar number of stratosphere balloons have been launched from the range since then. The rocket experiments typically involve the testing of equipment that is to be installed on satellites or sent to the International Space Station (ISS). Scientists also test semiconductors and liquid crystals, which reveal unknown characteristics in a state of weightlessness.

A growing share of the experiments are biological or medical such as Corydon's and Kopps' microscope project. Scientists used to believe that microscopic life such as bacteria and human cells do not change in zero-g, but they were wrong. The cells change dramatically, which Corydon's and Kopp's space microscope will contribute to proving.

### NO BADGE, NO LAUNCH

On 23 April, a launch window finally opens, as the wind decreases in intensity. The TEXUS 51 rocket must be woken up. Four hours before the launch at 8 o'clock, the countdown begins. One hour before lift-off, cables and hoses are disconnected, and the rocket's electric ignition is readied. All mobile phones are turned off, as electromagnetic signals could ignite the rocket.

Thirty minutes before launch, the countdown stops. The wind is still a problem, so two weather balloons are launched. The security staff makes sure that nobody is close to the rocket. Anyone going near it on the day of the launch get a badge which must be given back no later than 20 minutes before launch. But badge No. 9 is missing. Phone calls are made to locate it.

The missing badge may prevent the entire launch, but after a few minutes, it is found, and shortly after, the TEXUS 51 roars off from the launch tower. At an altitude of 100 km, the rocket's speed and acceleration precisely cancel out the pull of gravity from the planet below - it is weightless.

Twenty minutes after lift-off, the payload is back on the ground, where it is picked up by a helicopter. Right now, Esrange only launches "sounding rockets" which cannot attain orbit, and so fall back to Earth. The New Esrange, under construction, will be able to launch small satellites into an orbit around Earth. At the moment, European rockets are launched from the US, Russia, or French Guyana, but Esrange focuses on the growing micro-satellite market. The small, square CubeSats are becoming more and more popular among companies and scientists.

Esrange already has lots of satellite experience, as the range includes the world's biggest civil satellite receiver station. The hilltops surrounding Esrange are not only forested, they also include huge satellite dishes with diameters of up to 13 m. Since 1978, when the station started out

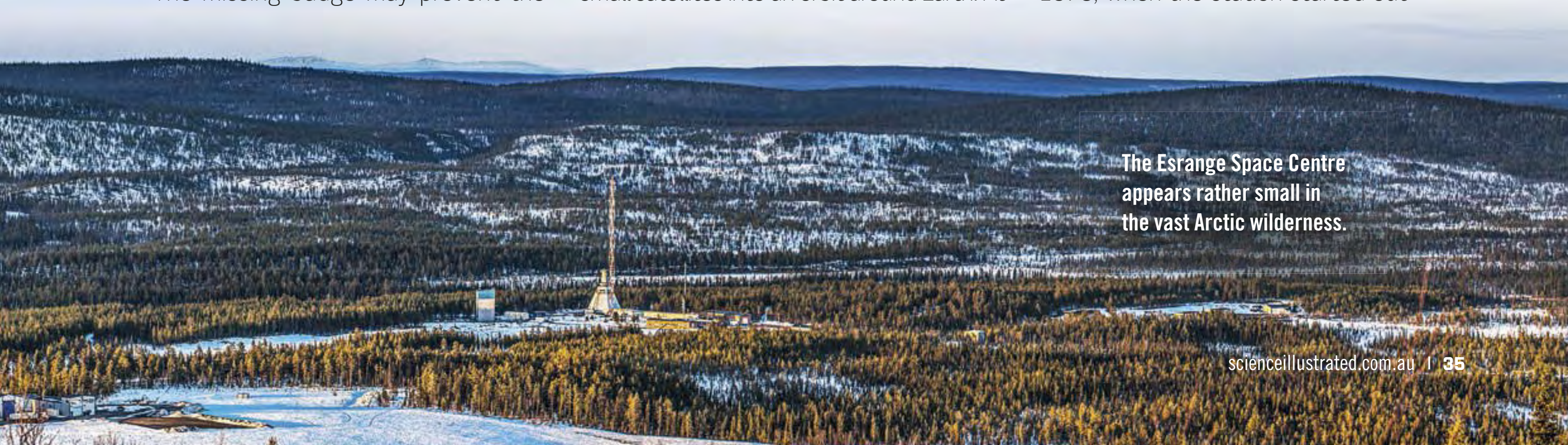
## Dice to be rolled in space

Once, satellites were the size of buses, but today, the smaller ones fit into a backpack. A type of microsatellite known as CubeSat is gaining ground fast at the moment. Just 10cm on a side, they can be combined into larger units. The price of launching a traditional satellite can top $200 million, but a CubeSat can be launched for as little as $20,000, appealing to companies and universities.

From 2020, the New Esrange will launch CubeSats using VLM rockets. With its 3 motors, the rocket will be able to lift about 150 kg into orbit.

**CubeSats weigh about 1 kg each and cost as little as $8,000.**

MONTANA STATE UNIVERSITY/JPL-CALTECH/NASA & CREATIVE COMMONS



**The Esrange Space Centre appears rather small in the vast Arctic wilderness.**


**According to plan, Spaceport Sweden will be Virgin Galactic's European base.**
SPACEPORT SWEDEN

# Space Kiruna may launch tourists into space

## Virgin Galactic is looking into the possibility of launching space tourists from Northern Sweden.

The minds behind Space Kiruna are a group of tourist organisations, scientific institutions, public bodies, and private companies. Together, they aim to attract 100,000+ tourists annually for aurora-watching, rocket launches, space attractions, and space missions aimed at the lucky and wealthy.

Virgin Galactic, which hopes to be able to launch tourists into space at a price of $270,000+ soon, has agreed with Spaceport Sweden to look into the possibility of launching its spacecraft, SpaceShipTwo, from Kiruna. Space Kiruna will also be a space research hotspot, since it will remain the only spaceport for satellite launches in Europe.

**Weightlessness experiences and tourist space missions will be central Space Kiruna activities.**
SPACEPORT SWEDEN

## SPACE KIRUNA WILL BE EUROPE'S LEADING SPACEPORT BY 2020

- **Tourism flights to the border of space offered by companies such as Virgin Galactic and XCOR.**
- **The first satellite launches (not just tracking) from Europe.**
- **Up to 10 space probe launches and 5 balloon launches annually.**
- **The world's biggest satellite receiver station in contact with over 60 civil satellites.**
- **Space high school and university.**
- **Headquarters of the extensive EISCAT_3D radar project, which is going to take the first 3D images of the atmosphere.**
- **Large experience centre known as the Space Visitor and Science Centre.**

with one satellite dish and tracking just one satellite, it has grown by approximately one dish per year to 30.

The vast majority of satellites orbit the poles, not the Equator. So, to be in frequent contact with your satellite, you need to be as close to a pole as possible. Esrange is located 200 km north of the Arctic Circle, and collects data from 60 civil satellites.

## PLANS FOR A SPACE TERMINAL

The satellite station is manned 24/7, but rocket launches are seasonal, taking place in the spring and autumn. As we write this, the annual spring launch windows are coming to an end, so it is quite urgent to get the TEXUS 52 and the cell microscope launched. The first 24 hours after the launch of the TEXUS 51, the tower is still so full of toxic vapour from the rocket motors, that nobody can enter it. They just have to wait.

When the crew finally gets access to the tower, a hatch sticks. The scientific experiments cannot be linked with the two rocket motors and placed in an upright position. It takes approximately 12 hours for engineers to open the hatch.

Luckily, the weather is still nice, and in the middle of the night between 26 and 27 April,

The rockets land in the wilderness and are picked up by helicopter.

Sascha Kopp can finally enter the bunker, from where the rocket and the microscope are controlled. Anxiety has prevented him from sleeping for the past couple of days, but now, he is calm, ready to adjust the dial. Thomas Corydon and Research Director Daniela Grimm have to wait 1000m away in the cafeteria, from where the launch is observed. At last, the TEXUS 52 takes off.

The old saying that a bad rehearsal produces a splendid first performance is true. Sascha Kopp manages to take photos even better than he imagined.

"From the end of the world, we are happy to announce that we are flying!" Thomas Corydon cheers.

The biomedical researchers now enter a race against a new clock – the publication clock. The six minutes of weightlessness were shared with two other teams of scientists, who also used the space microscope for experiments involving brain and immune cells. The first team to publish its results gets the most credit. Cell experiments in space are still a very new field, and each experiment is very likely to result in a new discovery.

The same pioneering spirit exists in connection with the part of the Space Kiruna vision concerning space tourism. A growing number of adventurous rich people buy tickets for brief sightseeing trips to the border of space. Spaceport Sweden in Kiruna is negotiating with companies such as Virgin Galactic and XCOR to be the first outside the US to launch space tourists. Spaceport Sweden expects to be ready to send the first humans into space from European soil in 2020. SCI

After a mission, the rocket motors are scrapped and left in the rocket cemetery.

# 290 KM/H

is the highest speed a skydiver can achieve in a "head down" position. At this speed, acceleration from gravity is cancelled out by the friction of wind resistance.

**Your weight is the force with which Earth gravity affects your body, and is determined by your mass. More mass, more downward pull, and thus more weight.**

SHUTTERSTOCK

# Rocket controlled by laws on Earth and in space

**Newton's three laws apply during a space mission – no matter whether the rocket is on the launch pad, accelerating into orbit on a pillar of fire, or drifting through space, where it is almost unaffected by friction.**


## 2nd law*

$$a = \frac{F}{m}$$

Acceleration

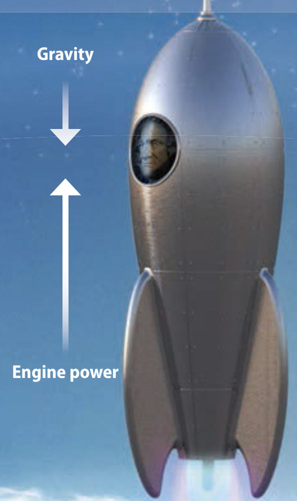
Force

Mass

## 1st law

**An object either remains at rest or continues to move at a constant velocity (speed), unless acted upon by an external force.**

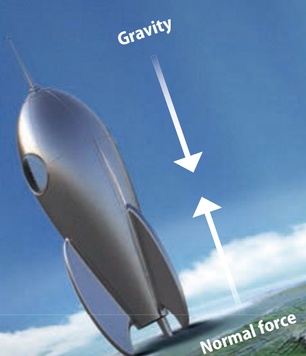
The rocket stands still, but an internal tug-of-war is going on. Gravity pulls it down, while the concrete of the launch pad holds it back. If the rocket drifts in space without being affected by anything, it will move at a constant speed.




## 3rd law

**Action equals reaction**

In space, the rocket is virtually unaffected by friction. If it is going to change speed, the third law comes into play. If the engine releases exhaust gases at a force of 1 million newtons, the rocket will move forward at the exact same force.




### * Force equals mass multiplied by acceleration

The rocket accelerates, because the force from the engines overcomes gravity. The acceleration – how fast the speed increases – can be calculated by subtracting gravity from engine power and dividing the result by the total weight of the rocket.

### Saturn V's acceleration when launched towards the Moon:

$$\frac{34{,}500{,}000 \text{ newtons} - 27{,}500{,}000 \text{ newtons}}{2{,}800{,}000 \text{ kg}} = 2.5 \text{ m/s}^2$$

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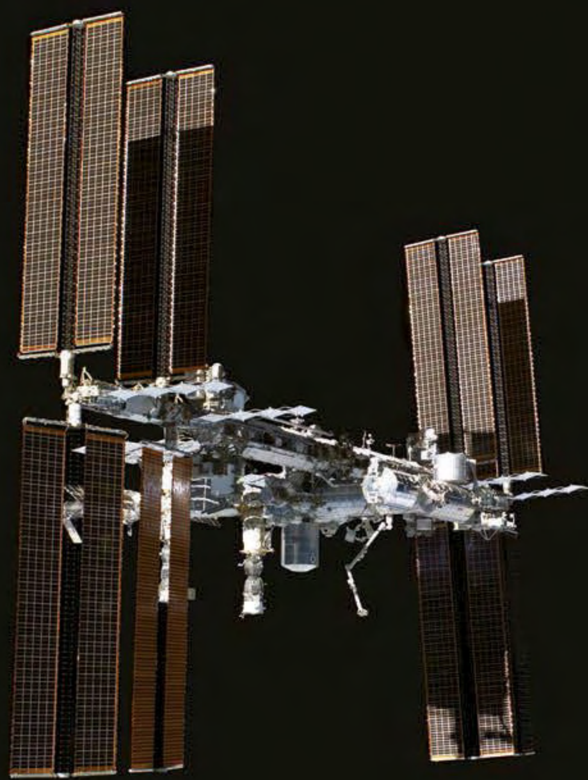

# THE SKY IS NO LONGER THE LIMIT.

**The screens of the Future are available today!**

Screen Innovations has worked with NASA to develop a one-of-a-kind, ambient-light-rejecting, zero-gravity screen to be installed in the International Space Station…

Until now, astronauts on the International Space Station communicated with Mission Control and their families back home on tablet-sized 13-inch displays. Now they will have a large roll-out screen from Screen Innovations, together with a laser projector that should last more than 30,000 hours of use – that's a movie a day for more than 40 years.

The criteria for a screen in space were unique, from the obvious need for extreme lightness and easy storage to trickier requirements such as screen rigidity in zero gravity and the ability to reject the bits of food and other detritus that have a habit of floating around zero-gravity environments.

Although the theatre in your home resides in a more-worldly environment with picture quality taking a front row seat it's nice to know that Screen Innovations also delivers the best down-to-earth solution around.

images courtesy: NASA

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