

proxima

# → THOMAS PESQUET: REACHING FOR THE STARS

European Space Agency

# European Space Agency

From the beginnings of the 'space age', Europe has been actively involved in spaceflight. Today it launches satellites for Earth observation, navigation, telecommunications and astronomy, sends probes to the far reaches of the Solar System, and cooperates in the human exploration of space.

Space is a key asset for Europe, providing essential information needed by decision-makers to respond to global challenges. Space provides indispensable technologies and services, and increases our understanding of our planet and the Universe. Since 1975, the European Space Agency (ESA) has been shaping the development of this space capability.

By pooling the resources of 22 Member States, ESA undertakes programmes and activities far beyond the scope of any single European country, developing the launchers, spacecraft and ground facilities needed to keep Europe at the forefront of global space activities.

The Member States are: 20 states of the EU (Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Luxembourg, Netherlands, Poland, Portugal, Romania, Spain, Sweden and the United Kingdom) plus Norway and Switzerland.

Seven other EU states have Cooperation Agreements with ESA: Bulgaria, Cyprus, Latvia, Lithuania, Malta, Slovenia and Slovakia. Croatia is negotiating a Cooperation Agreement. Canada takes part in some programmes under a Cooperation Agreement.



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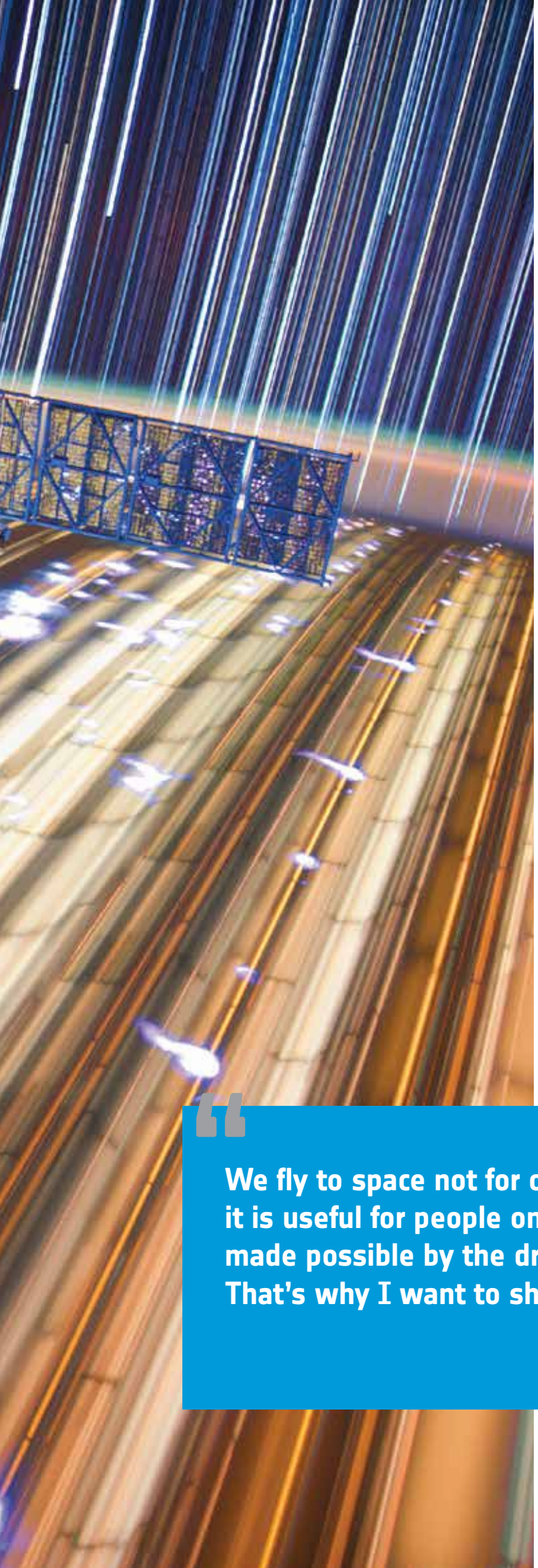
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Inspiring the next generation

# → SPACE FOR EVERYONE

## Mission overview




↑ Montage of star trails and city lights seen at night from the International Space Station



**ESA astronaut Thomas Pesquet is set to go into space on a long-duration mission packed with science and education activities. For six months, his home and workstation will be some 400 kilometres above Earth. He will serve as a flight engineer for Expeditions 50 and 51 to the International Space Station (ISS).**

Thomas will be launched on a Russian Soyuz spacecraft from Baikonur Cosmodrome in Kazakhstan in November 2016, returning to Earth May 2017. He will share the ride with Russian cosmonaut Oleg Novitsky and NASA astronaut Peggy Whitson.

A former aerospace engineer turned airline pilot, Thomas will travel in the left-hand seat of the Soyuz capsule. In his role as co-pilot, he is trained to assist the Soyuz commander during the trip to space and back, monitoring the systems and taking over when necessary.

The 38-year-old will be the tenth French space voyager and the first French astronaut to fly to the International Space Station since 2008. This is Europe's ninth long-duration mission and has been named Proxima, after the closest star to our Sun, Proxima Centauri.

> **We fly to space not for ourselves, but because we believe it is useful for people on Earth. It's everybody's adventure, made possible by the dreams and hard work of many. That's why I want to share it as much as possible.**
>
> *Thomas Pesquet*

# Proxima key data

| | |
|---|---|
| **Launch site** | Baikonur, Kazakhstan |
| **Launch** | 15 November 2016 |
| **Docking** | 15 November 2016 |
| **Landing** | 15 May 2017 |
| **Spacecraft** | Soyuz MS-03 |
| **Launcher** | Soyuz FG |
| **Mission duration** | 6 months |

(Status as of June 2016)




↑ In front of a Soyuz simulator with crewmates Peggy Whitson and Oleg Novitsky (GCTC)



↑ Getting into the Russian Orlan suit (GCTC)

# Mission name and logo

Thomas's mission is called Proxima, after the closest star to our Sun, continuing the French tradition of referring to stars and constellations in human spaceflight missions. The name was chosen from over 1300 entries to a competition held by ESA in 2015.

The 'x' in Proxima is centred in the middle of the logo to signify the star Proxima Centauri. It also refers to the unknown, as well as Thomas being the tenth French space voyager. The three coloured vertical lines form an outline of the International Space Station and also represent Earth, the Moon and Mars, as well as hinting at the French national flag. The star trails evoke future space travel beyond low-Earth orbit.

Science is the most important part of the Proxima mission – Thomas will conduct a wide range of experiments on the Space Station, an out-of-this world research outpost that serves as a stepping stone for human exploration.

Thomas's brain, bones and muscles will be examined to research the impact spaceflight has on humans. He will be testing a new generation of health sensors that will benefit both future exploration missions and people on Earth.

Thomas's parents and brother are teachers so the astronaut is determined to inspire the next generation of explorers. As an ambassador for science and space-based careers, he is involved in an intensive outreach programme to inspire children. Proxima school activities running alongside Thomas's mission have elements of science or technology in them, from computer coding and growing plants, to chemistry, fitness and nutrition.




↑ Checking his Russian Sokol suit

**Being part of space exploration shows that you are committed to the future. We need to think about the present, of course, and do a better job of taking care of Earth and its inhabitants, but we shouldn't forget about the future.**

*Thomas Pesquet*

## French astronauts

Thomas Pesquet will be the tenth French citizen to fly into space and the fourth French astronaut to visit the International Space Station. This will be the first six-month mission to the Station by a French astronaut.

Jean-Loup Chrétien was the first French person and the first west European to go into space when he visited the Soviet Salyut space station in June 1982. In 1988, while on the Russian Mir space station, he became the first non-American and non-Soviet to do a spacewalk.

Claudie Haigneré was the first French woman in space when she visited the Russian Mir space station for 16 days in 1996. In 1999, she became the first woman qualified to command a Soyuz capsule during reentry. In 2001, she became the first European woman to board the International Space Station. Claudie is ESA's first female astronaut.

Jean-Pierre Haigneré, Léopold Eyharts and Michel Tognini flew on missions to Mir. Patrick Baudry, Jean François Clervoy, Léopold Eyharts, Jean-Jacques Favier, Philippe Perrin and Michel Tognini flew on the US Space Shuttle as mission or payload specialists. Léopold Eyharts was the last French astronaut to serve on the Space Station, working two months there in 2008.

France is the European Space Agency's largest contributor. ESA conducts rocket launches from the Guiana Space Centre near Kourou in French Guiana and ESA's headquarters are in Paris, France.

## Ground support

Day and night, a worldwide network of control centres support the astronauts living and working on the International Space Station. In Europe, operators at the Columbus Control Centre in Oberpfaffenhofen, near Munich, Germany, are the direct link to Thomas in orbit. They are there to help him 24 hours a day, seven days a week – they know where everything in the Station is located and how everything works. Teams are constantly adjusting tasks to make sure that Thomas can fulfil his mission.

Simultaneously, researchers on ground can control and monitor experiments performed in the European Columbus laboratory from their offices. Dedicated connections with eight User Support and Operation Centres across Europe make this possible.




↑ Columbus Control Centre control room

# → THOMAS PESQUET

## The youngest of ESA's new generation of astronauts




> I like everything about being an astronaut. It reminds me a lot of my previous life as an airline pilot. I had the second best job in the world, and now I have the best one.
>
> *Thomas Pesquet*

**Thomas Pesquet is the youngest member of the European astronaut corps. With his assignment, all six ESA astronauts from the class of 2009 will have flown to the Station within seven years of graduation.**

When ESA called for candidates from its Member States to reinforce the European astronaut corps, more than 8000 people applied. Thomas and five others passed a demanding year-long selection process and became proud members of the European astronaut class 2009.

## With flying colours

Thomas Pesquet was born in Rouen, France, on 27 February 1978. He has been dreaming of going to space ever since he was a child, playing with a Space Shuttle his father had made out of cardboard boxes and pillows.

By pursuing his passions and interests throughout his education and career, Thomas acquired the experience and skills to be an astronaut. He studied aerospace engineering, majoring in spacecraft design and control, and worked as a spacecraft-dynamics engineer and as a research engineer on space mission autonomy. An avid private pilot in his spare time, he was selected in 2004 for Air France's flight-training programme and became a pilot for the airline in 2006. He has logged more than 2500 flight hours on commercial airliners and became an instructor on the Airbus A320.

Thomas sees many parallels between flying an airplane and a spacecraft: both require detailed technical knowledge, leadership, team work as well as good communication and analytical skills. Together with his love for learning and his motivation and positive attitude, these skills have served Thomas well in his new job and will help him make the Proxima mission a success.

After graduating as an astronaut, Thomas worked as a Eurocom, communicating with astronauts during spaceflights. He was also in charge of future projects at the European Astronaut Centre, including initiating cooperation with new partners such as China.

He is a black belt in judo and enjoys basketball, jogging, swimming, squash and outdoor sports such as mountain biking, sailing, skiing and mountaineering. He also has extensive experience in scuba diving and skydiving.










↑ Spacewalk training in NASA's training pool

## Training

The first stages of training at ESA's European Astronaut Centre in Cologne, Germany, supplied Thomas with an astronaut's toolbox of knowledge: scientific, engineering and medical skills, as well as orbital mechanics, Russian language and survival training. For all astronauts, the challenge is trying to retain the wealth of information and maintain a good balance in all sorts of topics.

After finishing basic and pre-assignment training, Thomas embarked on the next phase of his space journey, starting assigned crew training. It takes International Space Station astronauts two and half years of intensive preparations to be ready for launch.

Then the pace increased for Thomas, training almost without break, travelling between all international partners' sites. An intense schedule took him to Houston, USA, Star City near Moscow, Russia, Tsukuba near Tokyo, Japan, and Montreal, Canada.

As Soyuz flight engineer, Thomas requires a great amount of 'flying hours' in the Russian spacecraft simulator, so he trained until he felt at home in the cockpit and can operate the Soyuz flawlessly in any situation.

Thomas has been trained also on Space Station systems in full-size mockups, where he learnt how everything works and how to fix systems in case of breakdowns. He also learned how to run experiments and technology demonstrations, and got to know every corner of Europe's Columbus laboratory.

Thomas learnt to use the robotic arm to help dock spacecraft visiting the Station. He prepared for spacewalks, known as Extravehicular Activities (EVAs), in huge water tanks to simulate working in weightlessness outside the Station. If the opportunity arises, he is fully qualified to venture into outer space.

The ESA astronaut also took part in space-mission analogues for his orbital journey. Thomas joined a 12-day exploration mission to a simulated asteroid at the Aquarius base, the world's only undersea research station. Much like in space, he had to deal with confined living quarters and a total reliance on life-support systems, 20 m below the sea off the coast of Florida, USA. He also participated in ESA's CAVES training course, as part of an international team of astronauts living underground for a week and exploring a cave system in Sardinia, Italy.

Thomas went through survival courses in extreme environments, preparing himself to face all kinds of situations in prolonged isolation and under psychological stress. The courses help astronauts to be mentally prepared to handle emergencies, such as spacecraft depressurisation and fire or toxic spills, as well as landing in remote or hostile regions.







1 Training for basic medical procedures and techniques

2 Fitness training

3 Exploring the underworld as part of the ESA's CAVES training

4 Training with Expedition 50/51 crewmate Oleg Novitsky, at NASA's Johnson Space Center

5 Collecting wood during winter survival training. Thomas's Soyuz spacecraft could land in a cold, remote area so the crew need survival skills while they wait for rescue

6 When a Soyuz spacecraft returns to Earth there is always the possibility that it could land in water. Thomas underwent survival training near Star City, Russia










↑ From left to right, Peggy Whitson (NASA), Oleg Novitsky (Roscosmos), Thomas Pesquet (ESA)

# → CREWMATES

## Sharing the mission

**The International Space Station has been a workplace for humans since 2000. Because Soyuz capsules ferry only up to three astronauts at a time and have a limited operational lifetime, rotating shifts of new arrivals and departures are part of the Station's routine.**

Keeping the Station permanently crewed requires careful planning. A few times a year, like clockwork, three astronauts leave as a new trio arrives. Crew rotations on the International Space Station are called 'Expeditions'. Each astronaut stays in space for about six months and serves in two adjoining expeditions.

Thomas is part of Expeditions 50 and 51. As a crew member for Soyuz MS-03, he will serve as flight engineer with Soyuz commander Oleg Novitsky and NASA astronaut Peggy Whitson.

Thomas is thrilled to fly to space and back with such a talented and experienced crew. Peggy is one of NASA's most experienced astronauts, having already completed two missions totalling 376 days in space and six spacewalks lasting more than 39 hours in total. She helped build the Space Station. Oleg has a military background and is an experienced pilot, diver and paratroop instructor. This will be his second trip to the ISS.

The crew rotation system allows greater flexibility for operational tasks and maintenance of Station systems, and increases the time spent on research compared to former three-person crews.

# Crew shifts




**Expedition 50**
Nov 2016 - Mar 2017

| | | |
|---|---|---|
| Commander ← | Shane Kimbrough | |
| Flight Engineer 1 ← | Andrey Borisenko | |
| Flight Engineer 2 ← | Sergey Ryzhikov | |
| Flight Engineer 3 ← | Peggy Whitson | → Commander |
| Flight Engineer 4 ← | Oleg Novitsky | → Flight Engineer 1 |
| Flight Engineer 5 ← | Thomas Pesquet | → Flight Engineer 2 |
| | Alexander Misurkin | → Flight Engineer 3 |
| | Nikolai Tikhonov | → Flight Engineer 4 |
| | Mark Vande Hei | → Flight Engineer 5 |

**Expedition 51**
Mar - May/Jun 2017




# Space Station facts

- More than **200 people** have visited the International Space Station.
- USA Astronaut Scott Kelly and Russian cosmonaut Mikhail Korniyenko spent the longest amount of time aboard the Space Station in one mission: **340 days**.
- Astronauts have performed just over **190 spacewalks** to build and maintain the Station.



↑ Thomas with his crewmates at the Gagarin Cosmonaut Training Center in Star City, Russia

↓ Inside the Soyuz capsule (GCTC)



# Astronauts or cosmonauts?

A person that travels in space can be called an astronaut or a cosmonaut – they refer to the same thing. Cosmonaut is the Russian word for astronaut, derived from the Greek words kosmos, meaning 'universe', and nautes, meaning 'sailor'. While the term astronaut is used mainly in English-speaking countries, cosmonaut refers to Russian space travellers. The French use the word 'spationaute' to refer to space travellers.

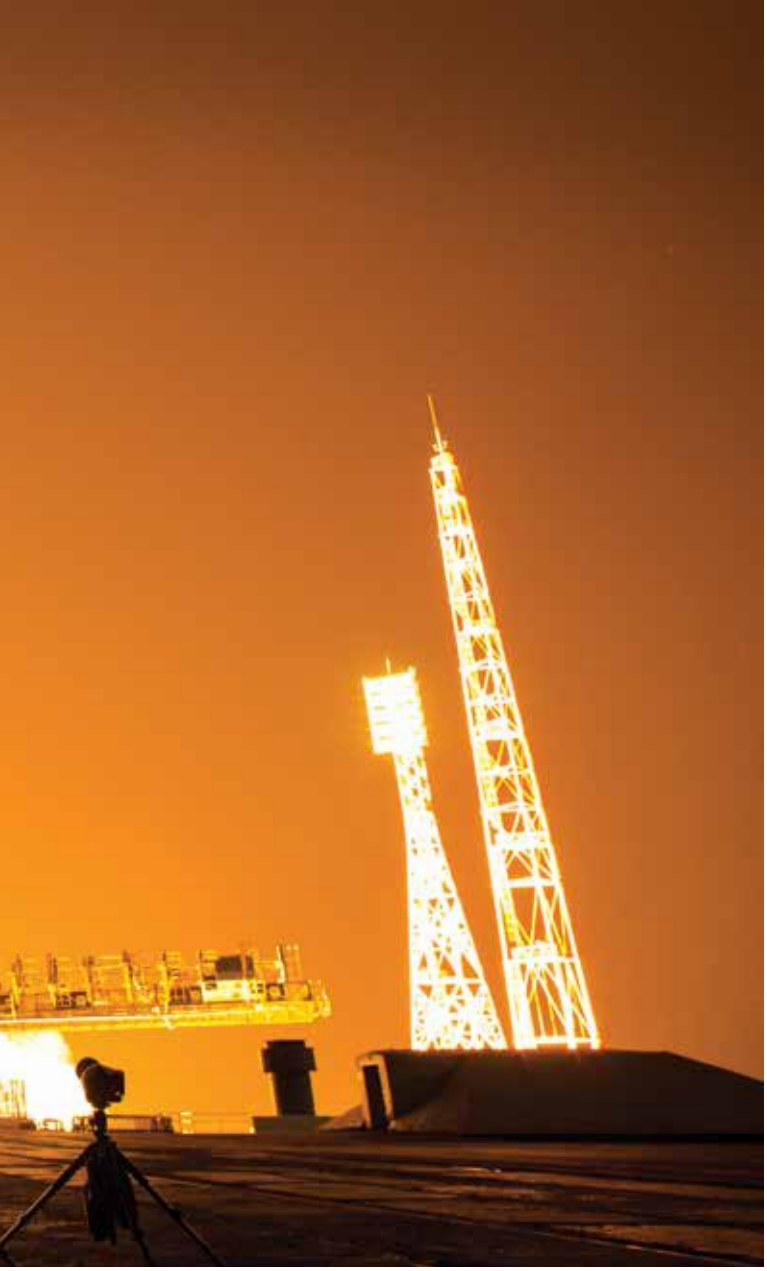
# → A VOYAGE WITH SOYUZ

## The workhorse for space

↑ Night liftoff of the Soyuz launcher from the Baikonur Cosmodrome, in Kazakhstan (NASA)

## Soyuz ascent and orbit insertion

| | T + 00:00<br>**Liftoff** | T + 01:58<br>**First-stage separation** | T + 02:38<br>**Escape tower and fairing separation** |
|---|---|---|---|
| |  |  |  |
| Altitude: | 0 km | 42 km | 85 km |
| Speed: | 0 km/h | 6100 km/h | 8300 km/h |
| Range: | 0 km | 39 km | 109 km |



**The Soyuz has been used for human spaceflight missions longer than any other launch system. The Russian workhorse is currently the only way astronauts can travel to the International Space Station.**

The Soyuz spacecraft shares the same name as its launcher – Soyuz means 'union' in Russian – and can manoeuvre, rendezvous and dock automatically or by manual control. Conceived in the 1960s as part of the Soviet space programme during the space race with the United States to land the first man on the Moon, Soyuz spacecraft continues to ferry astronauts to low-Earth orbit.

## Launch

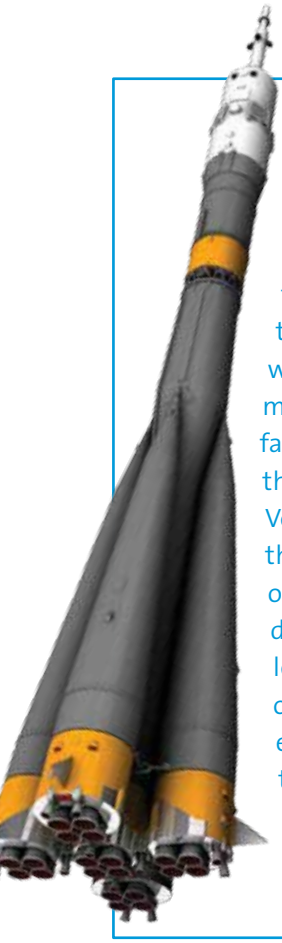
On launch day, the vehicle is loaded with propellant and the final countdown sequence starts three hours before liftoff. Four boosters, each about 20 m in length, provide the main thrust in the first two minutes of flight before they are jettisoned.

In less than five minutes, 225 tonnes of RP-1 fuel and liquid oxygen are consumed. RP-1 is a highly refined form of kerosene, similar to jet fuel. Nearly ten minutes into flight, at an altitude of about 210 km and at speeds of about 25 000 km/h, the Soyuz enters Earth orbit.

Some orbital corrections are required before the spacecraft enters the same orbit as the International Space Station flying at an altitude of 400 km and a speed of about 28 000 km/h. While in orbit, chasing the Space Station, the Soyuz crew perform system checks and keep in touch with controllers at the Russian Mission Control Centre.

| T + 04:48<br>Second-stage separation | T + 08:48<br>Third-stage separation and orbit insertion |
|---|---|
| 176 km | 208 km |
| 13 500 km/h | 25 000 km/h |
| 500 km | 1640 km |

> **The Soyuz is a complex machine. You have to learn to do the work of five to six people simultaneously – and in Russian!**
>
> *Thomas Pesquet*



## Soyuz launcher

Soyuz rockets have launched spacecraft and satellites into orbit for nearly half a century – they are the most-used launch vehicles in the world. They have logged over 1700 manned and unmanned launches, far more than any other rocket. Its three-stage design goes back to the Vostok launcher, which was used for the first manned spaceflight in 1961 of cosmonaut Yuri Gagarin. The basic design of the Soyuz launcher excels in low cost and high reliability. At the top of the 51 m-high Soyuz FG rocket, an emergency escape system connected to the Soyuz spacecraft can be used to quickly release the crew module in case of rocket failure up to about three minutes after launch.

### Final approach and docking

Thomas's flight will take the Soyuz fast-track to the Space Station. His Soyuz will execute a 'same-day rendezvous', docking after just four orbits, less than six hours after launch.

Rendezvous and docking are automated, but the Soyuz crew can execute these operations manually in case of anomalies. The Soyuz spacecraft completes a series of trajectory corrections and manoeuvres to align with one of four available Russian docking ports on the Space Station.

Once docked with the Station, the crew equalises air pressure between Soyuz and the orbital outpost. After removing their flight suits, they open the hatches to enter what is to be their new home for the next six months.

### Emergency exit

A Soyuz space capsule ferried the first crew to the International Space Station in November 2000. Nowadays, one Soyuz for each group of three astronauts has always been at the Station to serve as a safe house and lifeboat should they have to return to Earth unexpectedly. Although the Space Station is the most heavily shielded spacecraft ever, even a piece of space debris as small as a coin could threaten the crew's lives.

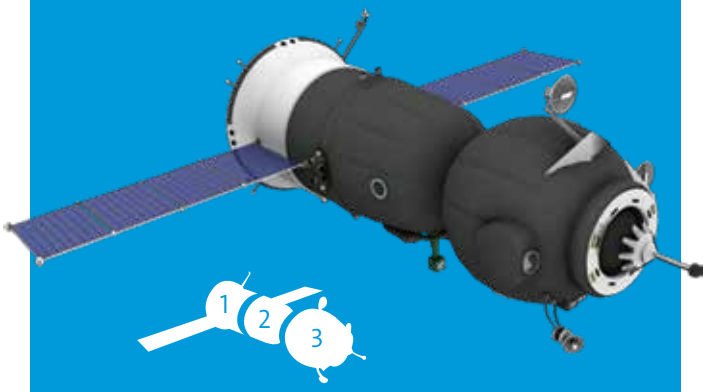
## Soyuz spacecraft

Thomas Pesquet flies on Soyuz MS-03, a modernised version of Russia's legendary manned transport. It is the final planned upgrade of the Soyuz spacecraft, with more efficient solar panels, a new advanced flight-control computer, more accurate navigation and an upgraded propulsion system.

1 **Service module**
Contains oxygen and propellant, attitude-control thrusters, electronics for communication and guidance and navigation control systems. Astronauts have no access to this module and all functions are controlled remotely.

2 **Descent module**
The only module to return to Earth and designed to withstand the stresses of reentry into our atmosphere.

3 **Orbital module**
Used only in space and acts as living quarters. It is equipped with a toilet.




> **Flying a spacecraft is like flying an airliner. The pace is the same as for a long-haul flight, and even manual flying is similar.**
>
> *Thomas Pesquet*

Space debris is tracked from the ground, and the Space Station can be manoeuvred to avoid it if needed. If that is not possible, astronauts can shelter in their Soyuz spacecraft. If an object hits the Station, the astronauts would be in their capsules ready to return to Earth.

## Undocking and reentry

After living and working on the Space Station for nearly 190 days, Thomas will return to Earth in the Soyuz capsule with his crewmates. Closing the Soyuz hatch will signal the end of his Proxima mission, and the astronauts will land on Earth less than four hours later.

Around three hours after undocking, when Soyuz is at a distance of 19 km from the Space Station, the spacecraft's main engine fire for about four minutes. This 'deorbit burn' slows the spacecraft and decreases its orbit. Shortly afterwards, at an altitude of 140 km and less than 30 minutes before landing, the Soyuz spacecraft separates into three parts.

The orbital and service modules burn up on reentry in the denser layers of Earth's atmosphere. The remaining descent module naturally rotates and places its heat shield towards the direction of travel, so that it absorbs most of the heat caused by friction with the atmosphere.

Reentry begins at an altitude of about 100 km, when the speed at which the capsule travels is reduced dramatically and the crew is pushed back into their seats feeling forces of up to 5 *g*, the equivalent of five times their body weight.

## Landing and rescue

Parachutes deploy to reduce speed even more and the astronauts sit in custom-fitted seats with shock absorbers that reduce the shock of impact. At the last moment, retrorockets fire before touchdown to limit the landing speed to around 5 km/h.

After touchdown, the crew deploy a communication antenna so that rescue teams can pinpoint their location. Soyuz descent modules are not reusable, but some of the equipment, including the control panel, can be removed and reused.

Once back on Earth, Thomas will fly straight to the European Astronaut Centre, the home base of all ESA astronauts in Cologne, Germany. This early access to Thomas allows ESA's medical team to monitor his health very closely and to start his fitness and rehabilitation programme quickly. Scientists also benefit from continuing with their scientific examinations soon after landing.



↑ On the way back to Earth, the separation of Soyuz modules takes place before reentry into the atmosphere, at around 140 km altitude. The orbital and service modules disintegrate and burn up (ESA/NASA)



↑ Three hours after leaving the Station, a system of parachutes is deployed in precise sequence. The reentry capsule enters a stable descent at a speed of around 7 m/s (NASA)



↑ ESA astronaut Andreas Mogensen minutes after landing back to Earth in September 2015. He is being carried to a nearby medical tent to stand up after 10 days in space

# → ALL THE SPACE YOU CAN USE

## The International Space Station



## Did you know?

- The International Space Station can be seen as a **bright moving star** from most places on Earth with the naked eye. Opportunities for observation arise in clear skies up to three hours before sunrise or after sunset, about **ten days per month**.
- The Station has more liveable space than a conventional **six-bedroom house**, with a 360-degree bay window called Cupola, two toilets and fitness facilities.
- The Station has been **inhabited for 16 years**. No other space station has been inhabited for longer or received more visitors.


NASA

**The International Space Station is a shining example of broad cooperation, uniting Europe, USA, Russia, Japan and Canada in one of the largest partnerships in the history of science. The orbital station is one of the greatest engineering works ever achieved by mankind. This human outpost in Earth orbit is a stepping stone for further space exploration.**

The endeavour has brought humanity together to live and work in space uninterrupted for close to two decades. The orbiting complex is the size of a football field – enough room for the crew and an array of scientific facilities. This weightless laboratory allows experiments to be run efficiently like no other low-gravity platform on Earth.

Intensive research and effective use of this laboratory leads to new applications and benefits for people on Earth, from space to your doorstep.

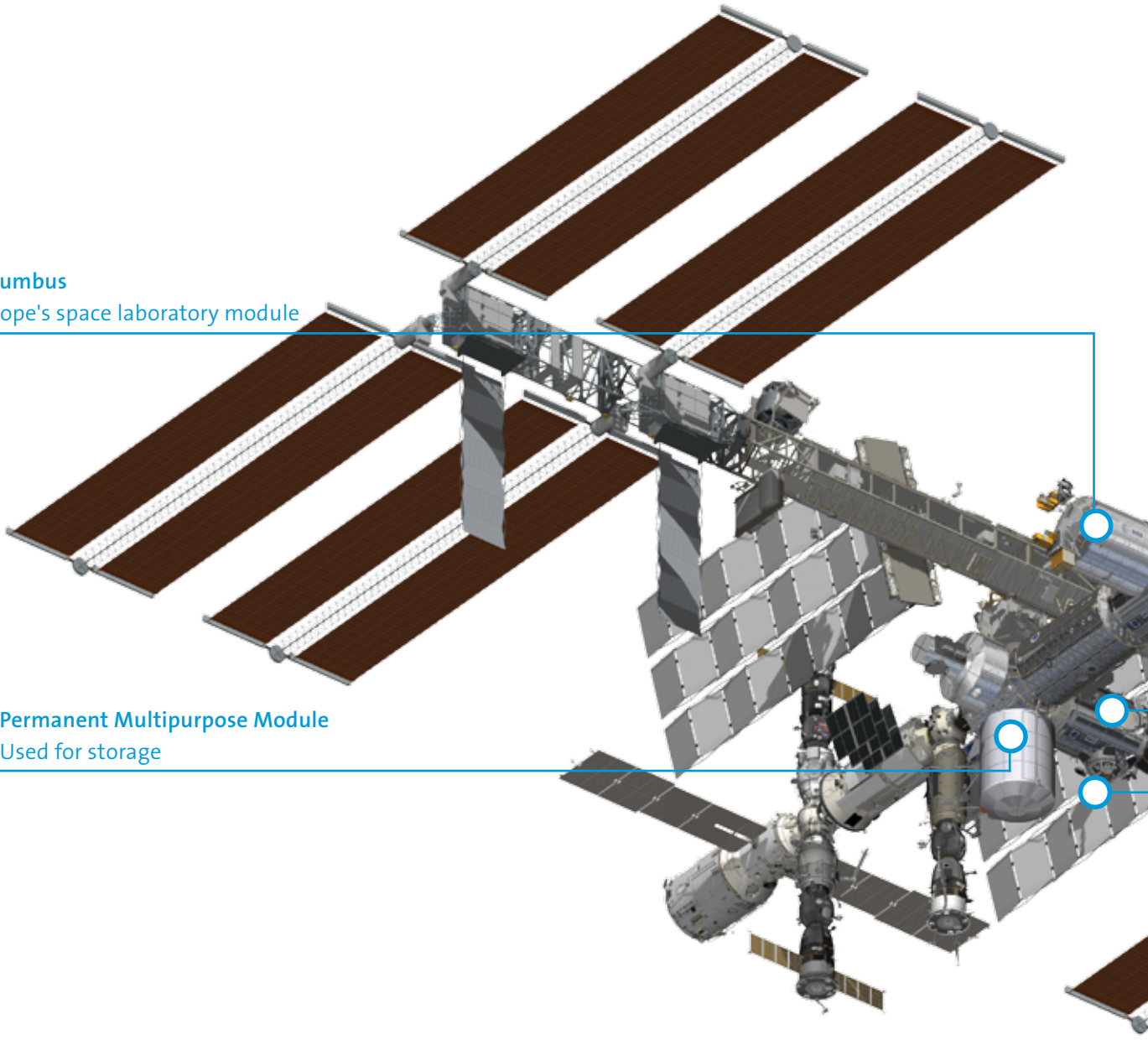
## A free-falling research laboratory in space

For decades, experiments in space have answered many scientific questions, inspired technological development and, sometimes, resulted in unexpected outcomes. The International Space Station was completed after nearly 13 years of construction and now the number of scientific activities concerning the effects of long-duration microgravity on humans has reached a record high.

Gravity affects almost everything we do on Earth. Freefalling around the planet, the astronauts on the Space Station live in microgravity. Up there, scientists are conducting pioneering investigations, testing theories, and pushing the boundaries of our knowledge.

The high-flying international laboratory is packed with sophisticated facilities that support a wide range of research in human physiology, biology, fundamental physics, materials sciences, Earth observation and space science.

The orbital outpost offers a unique view of Earth for collecting scientific data. Observations of glaciers, agricultural fields, cities and coral reefs can complement satellite data to create a comprehensive view of our planet. Science in space supports competitive technology developments and fosters scientific research and education.




# European parts of the International Space Station

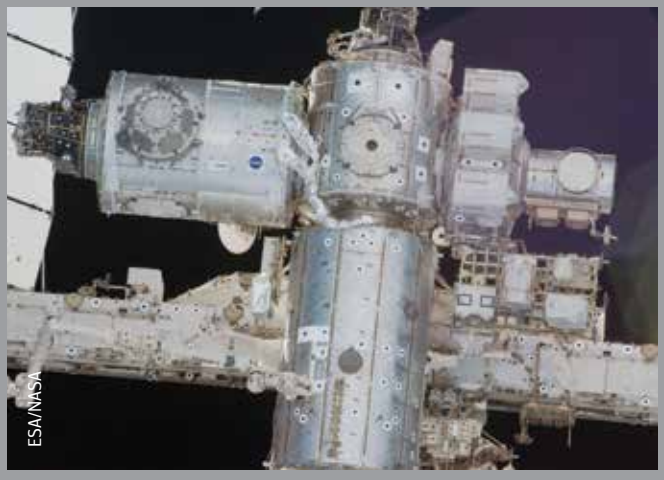
## Columbus

The Columbus laboratory is the first permanent European research facility in space. Since 2008, this multifunctional lab has been generating scientific data across a range of disciplines. External platforms are supporting experiments and applications in space science, Earth observation and technology.

## Harmony and Tranquility

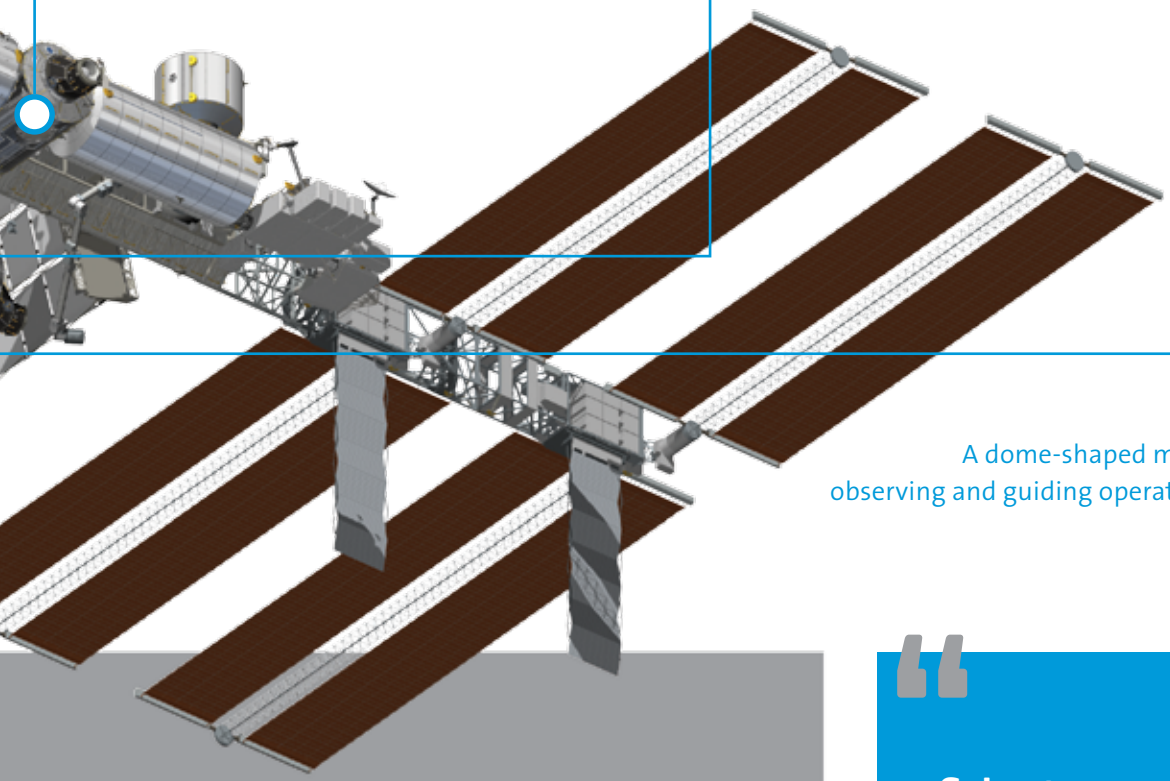
Node-2 Harmony is a connecting module between Columbus, Destiny and Kibo laboratories. It also has three docking ports for visiting vessels. Node-3 Tranquility, connects to Node-1 Unity and houses life-support and exercise equipment for six crewmembers as well as accommodating Cupola and more docking ports.


ESA/NASA


ESA/NASA

**Node-2**
Connecting module

**Node-3**
Connecting module



**Cupola**
A dome-shaped module with windows for observing and guiding operations outside the Station

## Cupola

The Cupola observatory is the most recent European module on the Station. The seven-window dome is the crew's panoramic window to Earth, as well as giving astronauts a clear view when controlling outside equipment from inside the Station.



ESA/NASA

**Going to space will give me the opportunity to experience new sensations: floating in weightlessness, seeing the Earth from above and just having the extraordinary privilege of living and working on board the Space Station. I will have to unlearn what I've known for years on Earth and adapt to a totally new environment, where even my body will change.**

*Thomas Pesquet*

# → RESEARCH FOR THE BENEFIT OF HUMANKIND

## European science in space

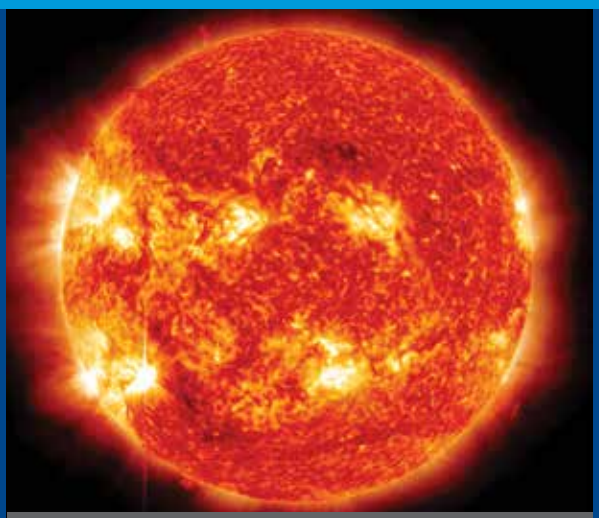
European science will be in full swing during the Proxima mission. Thomas will work on 62 experiments coordinated by ESA and France's space agency CNES. They cover human research, physical sciences and biology, as well as demonstrating new technology on the Space Station.

As with previous French missions to the Russian Mir space station and the International Space Station, the emphasis will be on human physiology. Scientists hope to gain more insight into cognition and motor skills as well as bones and muscle health for future space exploration missions.

Thomas will take full advantage of the Space Station's scientific facilities and perform valuable science for Europe in the European Columbus laboratory. The results will bring benefits to people on Earth and pave the way for future space exploration missions.

Thomas will not only contribute to European science. During Proxima, he will play a role in about 55 other experiments from the US, Canadian and Japanese space agencies.

### MONITORING SPACE ENVIRONMENT



↑ SOLAR will help us learn more about our star (NASA/SOHO)

#### SUN

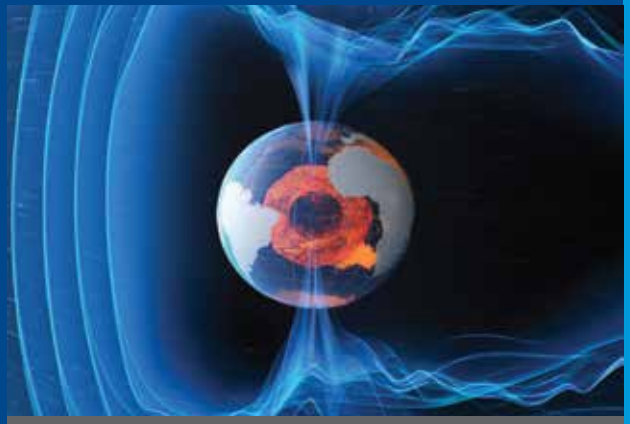
The **SOLAR** facility measures our star's electromagnetic radiation with unprecedented accuracy across a wide part of its spectral range. Its spectrometers make observations in the ultraviolet, visible and infrared wavelengths. One of the primary goals is to measure the solar constant to distinguish between solar impact and human influence on Earth's climate.

#### RADIATION

Radiation levels in space are higher than on Earth, usually as much as 30 to 50 times stronger. The **DOSIS-3D** experiment monitors radiation in the European Columbus module to prevent health problems on long-duration space missions.

#### MAGNETIC FIELD

The **MagVector** experiment measures changes in the strength of the magnetic field that interacts with the Space Station to better understand the effects of Earth's magnetic field on electrical systems.



↑ Earth's magnetic field (ESA/ATG Medialab)

## BIOLOGY

### PLANTS

The **Seedling Growth-3** experiment analyses how plants react to coloured light sources in microgravity. The research will help find alternatives to sunlight when growing crops. Being able to grow crops with little natural sunlight is a key issue for greenhouse producers of fruit and vegetables as well as for astronauts who could be heading to the Moon or Mars and need a healthy diet.

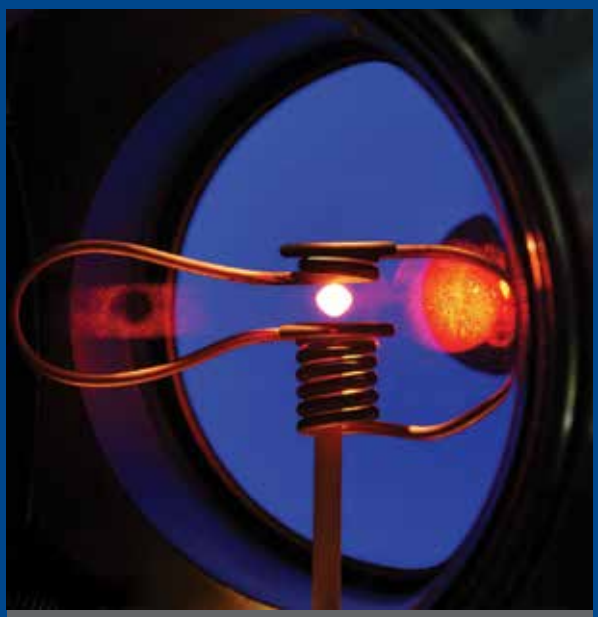


↑ Seedling growth in space in the light chamber (SRON)

## MATERIAL SCIENCE

### METALS

Super-alloy metals are in high demand to optimise industrial casting processes. A set of experiments will investigate the effects of microgravity on metal microstructures, especially on liquid metals when forming alloys. The **Electromagnetic Levitator** facility allows the melting and solidifying of metallic samples with no need for containers in an ultra-high vacuum, as well as in extremely pure gases.



↑ Electromagnetic Levitator (DLR)

### PLASMA

Plasma is an ionised gas. It is considered to be the fourth state of matter, distinct from gas, liquid and solid matter. The **PK-4** experiment, operated by Russian crew in Columbus, investigates the creation of plasma-microparticles in weightlessness to simulate how molecules interact in three dimensions.

### FLUIDS

Fluids and gases are never at rest. Their molecules move incessantly and continuously collide with each other. Scientists are interested in measuring particle motion because this reveals information on how quickly heat spreads in a fluid and how quickly liquids mix. The **SODI-DCMIX-3** experiment will exploit the fact that fluids in microgravity become less dynamic to measure diffusion in liquid mixtures. The **Fluid Dynamics in Space** experiment will also look at the behaviour of fluids under microgravity – in particular, at the slosh of liquid propellants in reservoirs during satellite manoeuvres. The results of this research will help improve the design of propellant tanks of future spacecraft.



↑ Roscosmos cosmonaut Elena Serova with the PK-4 experiment unit in ESA's Columbus laboratory (Roscosmos)

## FEEL THE FORCE

ESA is investigating the limits of human perception and ability to apply fine forces with their limbs and hands in space. Thomas will use a force-reflecting joystick in space (**Haptics/Interact**). The tests will help improve the equipment to support robotic and human interaction in weightlessness, paving the way for future planetary exploration missions where humans and robots will operate in partnership.



↑ ESA astronaut Thomas Pesquet using force-reflecting joystick

## CLEANING UP

Keeping the Space Station clean is no easy task. Thomas will evaluate the use of antimicrobial surfaces in space. The aim of the **MATISS** experiment is to reduce surface microbial contamination in astronaut spacecraft by testing agents that reduce the ability of microorganisms to survive on surfaces. Some of the surfaces that will be tested have self-cleaning properties. If successful, some of these surfaces may find use in hospitals and other clinical settings on Earth.

## WATER PURIFICATION

Thomas will test the filter capabilities of a membrane in microgravity and will analyse the microbial quality of Space Station water. The final goal of the **Aquamembrane** demonstration is to revolutionise water purification by means of industrial biotech techniques in space and on Earth. **Aquapad** will help simplify water quality analysis in the Space Station by the demonstrating a cheap, user-friendly and easy-to-interpret method to detect microbes in a potable water sample in space.



↑ ESA astroanut Andreas Mogensen working with the Aquamembrane experiment

## REMOTE CONTROL

To help turn robotics and remote operations into a standard tool for space missions, ESA is linking the Space Station with Earth. Thomas will operate ESA's Eurobot in the Netherlands while orbiting Earth using a laptop and a joystick. The **Meteron SUPVIS-E** activity is the continuation in a series of experiments of increasing complexity. The European astronaut will also test the **Echo** unit, a medical imaging ultrasound scanner that will be operated remotely by a radiologist on Earth. This technique could help bring specialised medical expertise to remote populations on Earth.



↑ The Eurobot rover

## SUITED FOR SPACE

Astronauts can grow by up to seven centimetres as their spines lengthen in weightlessness. As a result, many suffer from backache during long-duration missions. Thomas will wear a suit designed to combat the lack of gravity effects by squeezing the body from shoulders to the feet with a familiar force to that felt on Earth. The **Skinsuit** garment could help people with lower-back problems on Earth.



↑ Thomas testing his Skinsuit on a parabolic flight (CNES/Novespace)

## MARITIME CONTROL

The **Vessel ID system** is the marine equivalent of air traffic control. Attached to Europe's Columbus laboratory, its satellite receiver can identify more than 22 000 ships a day. The data are contributing to develop global maritime surveillance.



↑ ESA astronaut Christer Fuglesang and Thomas Reiter with belt-worn radiation monitors (ESA/NASA)

## SMART SENSORS

Thomas will wear clothing that incorporates sensing devices. **EveryWear** will demonstrate how personal physiological data can be collected from astronauts and transmitted to Earth in real time for medical and scientific purposes. The **EuCPAD** project will test a new radiation dosimetry system for space that can provide continuous, real-time instant information about radiation exposure and could become part of ESA's radiation protection strategy for astronauts.

## WIRELESS SENSING TECHNOLOGY

How does a wireless sensor network function in space? The **Wise-Net** experiment is testing a set of sensors in the Columbus module.



↑ World sea traffic tracked from space (LuxSpace)

## HEAD

Understanding how the neural processes of perception adapt to weightlessness is the focus of the **Brain-DTI** experiment. Thomas's brain will be examined in detail before and after his mission. This research could lead to new tools for research on spatial cognition. He will also record any headaches and other symptoms while in orbit. The results of the **Space Headaches** experiment will help develop measures to reduce migraines.

## HANDS

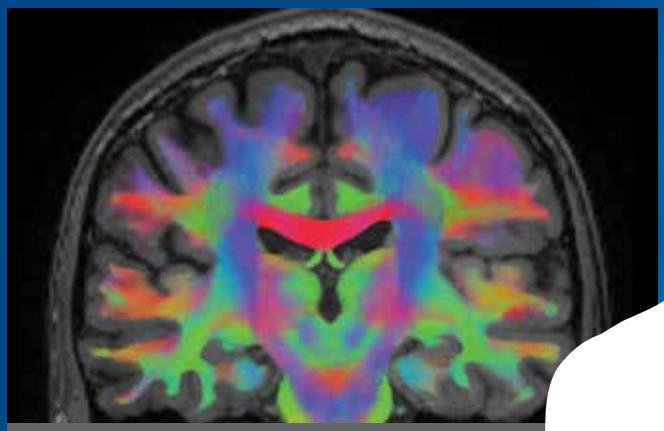
The **GRIP** experiment will study the effects of long-duration spaceflight on Thomas's dexterity by looking at how the central nervous system controls hand movements and forces while manipulating objects in microgravity. The **GRASP** experiment will take advantage of the **Perspectives** equipment to immerse Thomas in virtual-reality. The goal is to investigate how the central nervous system integrates sensory cues and information from different reference frames to coordinate hand movement and visual perception. In particular, the experiment will look into how gravity acts as a reference frame to guide reaching and grasping movements. Both experiments could help patients who have trouble manipulating objects.

## METABOLISM

Humans lose body mass in space. Thomas will measure changes in energy expenditure to derive an equation for an astronaut's needs in weightlessness. The **Energy** experiment will contribute to planning the right amount of food on long-duration missions to the International Space Station and beyond.

## WRIST WATCH

We all have an inner clock – the circadian timing system – that tells us roughly what time of day it is, and makes us sleepy at night. That cycle is disrupted in orbit, where astronauts experience 16 sunrises and sunsets every day. The **Circadian Rhythms** experiment will look at how long-duration spaceflight affects Thomas's biological clock. The findings could help people who work irregular hours on Earth.



↑ Brain scan (University of Antwerpen)



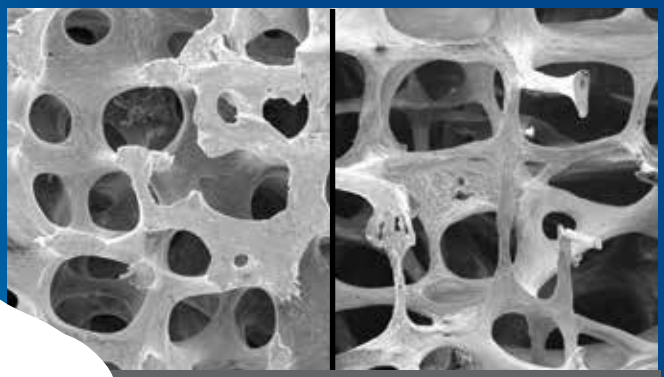
↑ Testing GRIP prototype on weightless parabolic flight



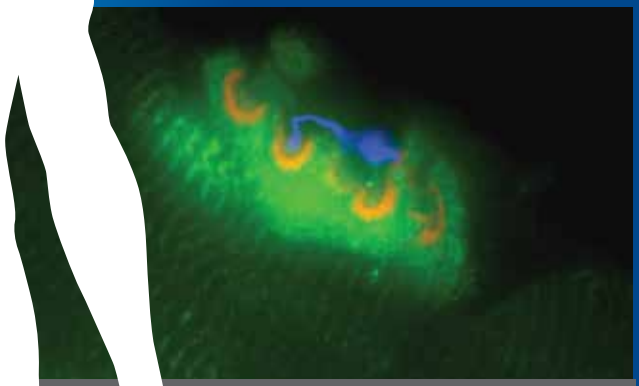

↑ Space food for the Energy experiment



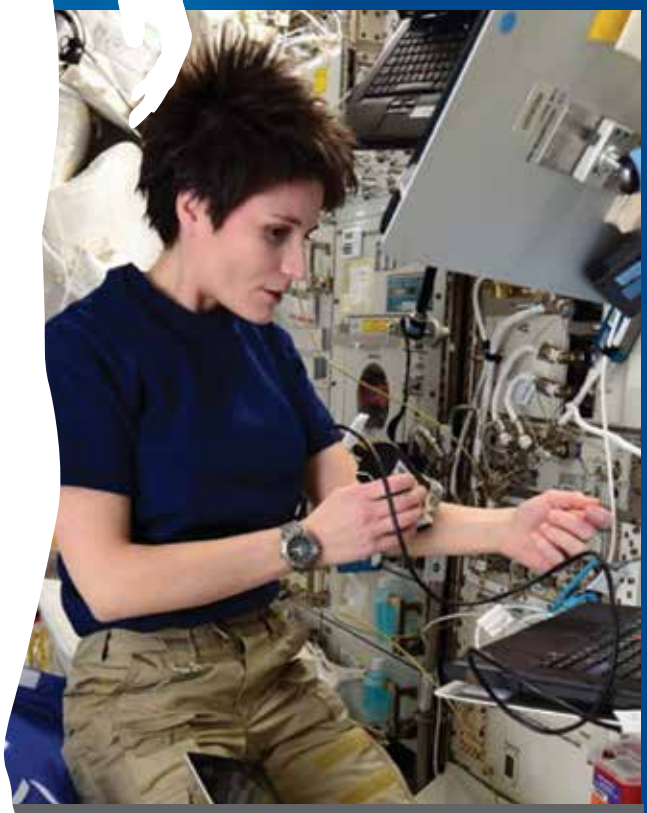
↑ ESA astronaut Alexander Gerst with a thermometer on his forehead to measure his temperature continuously (ESA/NASA)



↑ Comparison of normal (left) and osteoporotic (right) bone architecture (University College London—T. Arnett)



↑ Laser image of a calf muscle (Charité)



↑ ESA astronaut Samantha Cristoforetti running the Skin-B experiment (ESA/NASA)

## BONES

Astronauts lose up to 1% of their bone mass each month in space. The **Early Detection of Osteoporosis in Space** experiment will look at changes in cosmonaut's bone structure. This research will help detect and hopefully prevent osteoporosis in large population segments, especially those over 55 years old.

## MUSCLES

Living in microgravity leads to the loss of muscle mass, function and motor control. The **SARCOLAB-3** experiment will study characteristics of muscles that are particularly affected in space, such as the muscles in the lower leg while moving or keeping balance. By taking samples of Thomas's soft tissue before and after spaceflight, the **Muscle Biopsy** experiment will help to work out how to counteract loss of muscle strength in space. The European astronaut will provide feedback on how his muscles perform before and after his flight.

## SKIN

As we grow older, our skin becomes more fragile and it takes longer to heal from injuries. Astronauts lose more skin cells and age faster during spaceflight. The aim of the **Skin-B** experiment is to gain insights on skin physiology in space and, in particular, the skin-ageing process.

## IMMUNE SYSTEM

More than half of space travellers show significant signs of immune dysfunction after long missions. Using brain scans, monitoring breathing and looking at samples of hair from Russian cosmonauts, the **Immuno-2** experiment looks at how stress affects the immune system.

> **We are not only the operators but also the subjects of experiments – we are guinea pigs.**
>
> *Thomas Pesquet*




**Love for learning is the number one quality expected from an astronaut. You need to study hard and be willing to learn every day, which is what my parents taught my brother and me long ago.**

*Thomas Pesquet*

# → SPACE FOR EDUCATION

## Inspiring the next generation

**One of Thomas's priorities during his stay on the International Space Station is to share his mission with people on Earth. The astronaut hopes that more people will be able to fly to space in the future. In the meantime, a whole set of educational activities will challenge students to join his spaceflight adventure and continue learning. An active blogger and great communicator, Thomas will also pass his message through various social media channels about the importance of fitness, love for learning and care for our planet.**

### Mission-X – train like an astronaut

Mission-X fever is spreading across the planet. Future space explorers will get on their marks and invade gyms to train like astronauts for the 2017 challenge. 'Mission-X: Train like an astronaut' is an educational programme in which thousands of schoolchildren aged 7 to 12 years old from more than 25 countries do science activities and learn how to get fit.

Thomas will kick off the worldwide challenge by talking about regular exercise and nutrition, both on Earth and in space. He will answer questions, give tips on having a healthy lifestyle and share his experiences in weightlessness.

### Chemistry – living with enzymes

Enzymes are biological molecules that help complex chemical reactions occur inside the cells of living organisms. Without enzymes, we wouldn't be able to digest food. With Thomas's help, students on Earth will investigate how the chemical reactions associated with digestion are influenced by microgravity conditions.

Thomas will have two syringes: one containing protein gelatine and another containing pepsin diluted in an acidic liquid. Pepsin is one of the main enzymes that breaks down protein inside our stomachs. Thomas will inject the pepsin solution from one syringe to the other and will take pictures at regular intervals to document how the enzyme breaks down the protein in weightlessness. To help students compare results with Thomas ESA is producing educational kits for schools containing the same materials and ingredients.





↑ Seeds in Space (ESA/NASA)

## Biology – gardening in space

Thomas will be busy growing seeds while in space. A special cargo of mustard, lentil and radish seeds will be waiting for him on the Space Station. He will water them and take pictures at regular intervals to study how the seeds grow in space.

Schoolchildren on Earth will compare notes with Thomas. They will use the same type of seeds and will follow the same procedures. The pupils will learn how space travel impacts growth and whether humans could one day produce their own food in space.

## Physics – crystal clear

Thomas will help students on Earth understand how crystals grow in space. He will start the experiment by preparing a saturated solution and injecting it into a bag containing the initial crystal – potassium sodium tartrate tetrahydrate, also known as Rochelle or Seignette salt. First prepared around 1675 by apothecary Pierre Seignette of La Rochelle, France, this crystal has found use in microphones and earpieces as well as in making mirrors.

Thomas will take pictures of the experiment at regular intervals and will share the results with French students who will receive similar experiment kits. The schoolchildren will learn how gravity influences the growth of crystals.

## Space sciences – watch and learn

Astronaut Thomas Pesquet joins the efforts of teachers on Earth in the quest to explain space science to their pupils. The astronaut will record videos from the International Space Station demonstrating the phenomena that mentors find hard to show during their earthbound lessons.

Some lucky students and teachers will also have the chance to see and talk to the astronaut through live video calls with the International Space Station. Thomas will connect with them for a few minutes to answer their questions.

## Calling occupants of interplanetary craft

Space technology is not all high-tech. Radios operated by amateur enthusiasts can be used to communicate with the International Space Station. As he flies above Europe, Thomas will talk to children using handheld-radios over ARISS, the Amateur Radio on the International Space Station.

An ARISS conversation usually lasts for about 10 minutes, which is the window when the Station flies over a certain area and radio contact is possible from orbit. During that time, students will be able to ask him questions about his life and work in space.



↑ Students can ask questions to ESA astronauts while they are in space (Parque de las Ciencias de Granada)



↑ ESA astronaut Alexander Gerst looking at the Earth from the Space Station's Cupola (ESA/NASA)

## Earth Guardian

From the Space Station's Cupola, astronauts have a privileged vantage point to observe the beauty of our planet. However, its fragility, as well as global threats, are also more obvious when seen from space. Following up on a previous project by ESA astronaut Alexander Gerst, Thomas will stimulate school children to think about environmental protection and sustainable strategies for the future.

ESA will distribute a package of activities related to Earth observation to primary schools in Europe. A European-wide competition will challenge the pupils to demonstrate how they are caring for our planet. Thomas will announce the best three Earth Guardians during his stay in space.

## Computing – Astro Pi

At the end of his mission, ESA astronaut Tim Peake left behind two Raspberry Pi mini computers on the Space Station. Called Astro Pi, each of these credit card-sized computers is equipped with a host of sensors and gadgets.

Students can devise their solutions to coding challenges proposed by ESA. Thomas will load the winning codes, set them running, collect the generated data and then send the results back to Earth for the students to analyse.




↑ ESA astronaut Tim Peake with the Astro Pi computer on the Space Station

## More space fun?

The European Space Agency provides tools to inspire teachers, parents and students throughout Thomas's space adventure. Check it out!

**http://www.esa.int/Education**

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