Journey into Space
ETH is reaching for the stars

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Ready for the future of teaching 34 Sports education heads outdoors 40
Profile of alumna Bettina Heim 45

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FOCUS

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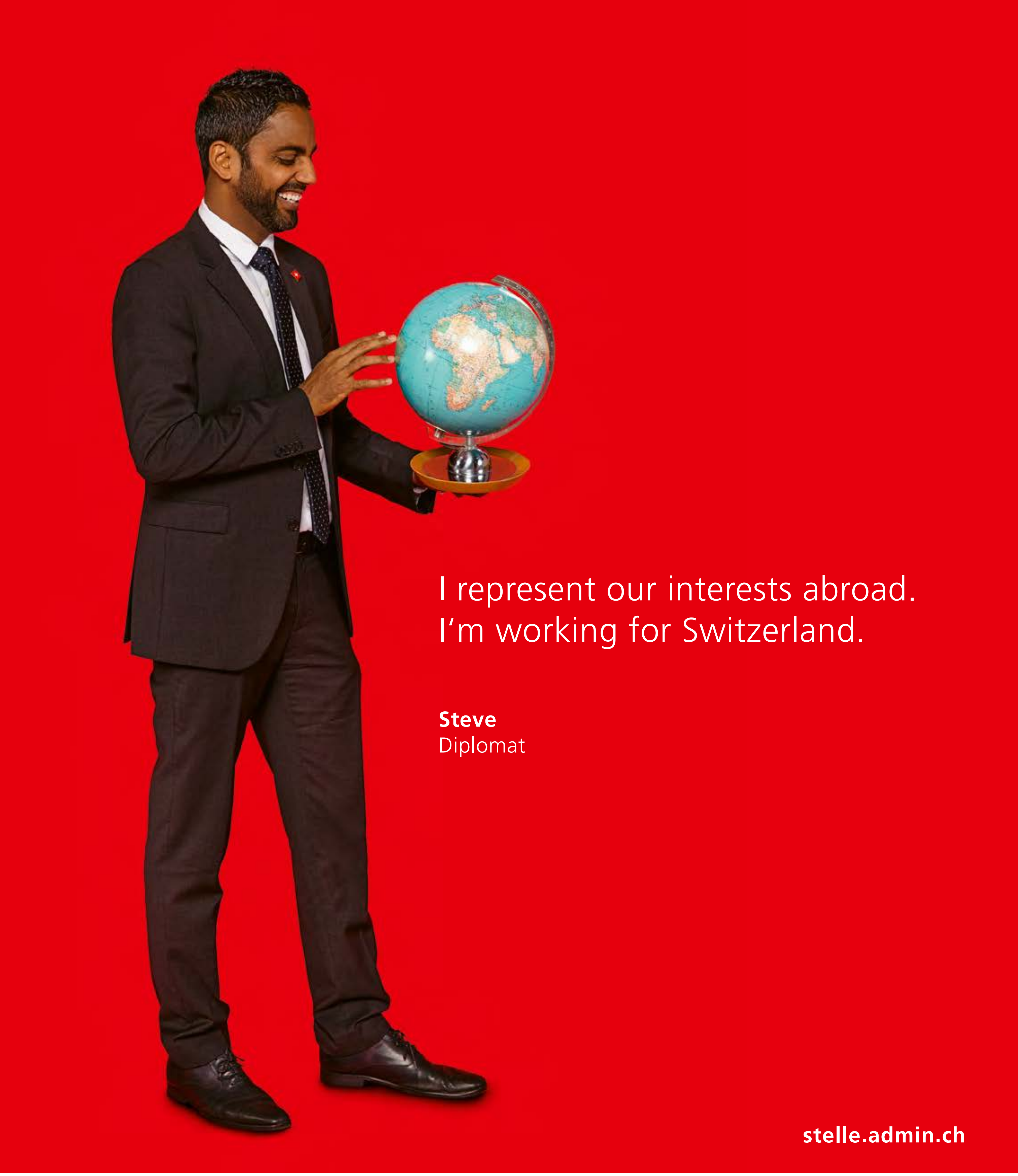
ETH zürich



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Dear readers,

Do you feel as I do when you gaze up at the starry sky? I still find myself awed by its splendour and mystery. Much of the cosmos remains hidden from us, yet science continues to make significant strides in revealing its secrets. Thirty years ago, Swiss Nobel laureates Didier Queloz and Michel Mayor discovered the first exoplanet. Since then, we have discovered more than 5,000 planets outside of our solar system!

As well as igniting our curiosity, space plays a crucial role in addressing global challenges. Satellite observation has become indispensable in helping us monitor climate change and in providing timely warnings of impending storms. That's why ETH Zurich has stepped up its efforts in this field with two major initiatives. The Centre for the Origin and Prevalence of Life (COPL), led by Didier Queloz, conducts research into the fundamental question of the origin of life. Equally ambitious, the ETH Zurich Space initiative, helmed by former NASA head of Science Thomas Zurbuchen, seeks to strengthen collaboration within the scientific community and to forge new partnerships with industry and the space agencies ESA and NASA. This year also saw the launch of our brand new Master's programme in space systems – and you can read feedback from the first cohort in this issue.

The launch of all these initiatives was only possible thanks to the university's long-standing collaboration with space agencies and our involvement in landmark missions, from the development of the James Webb Space Telescope to the seismometer for the InSight Mars mission. Ongoing research projects include the search for Earth-like exoplanets and the quest to detect gravitational waves.

Join us on an extraordinary voyage of discovery; I'm sure you'll find this issue of *Globe* an inspiring read!

Joël Mesot,
President of ETH Zurich

Image: Alexandra Compain-Tissier

Image: ESA & NASA / Solar Orbiter / EUI team; data processing: E. Kraaikamp (ROB)

COVER:

75 million kilometres…

That's how close ESA's *Solar Orbiter* was to the Sun when it took this image in 2022. Captured at a resolution of more than 83 million pixels, it shows our star in unprecedented detail. The outermost part of the Sun's atmosphere, the corona, reaches a temperature of around 1 million degrees Celsius – and no spacecraft has ever ventured so close as the *Solar Orbiter*. Over the course of two decades, ETH physics professor Louise Harra was involved in every phase of the project.

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4 | 2024

Image: Michel Büchel / ETH Zurich

40

Image: Markus Bertschi / ETH Zurich

45

NEW + NOTED

6 News from ETH Zurich

8 Made of mud

10 **ZUKUNFTSBLOG** A war over land and soil

FOCUS

16 **WHY WE NEED SPACE EXPLORATION** An interview with Thomas Zurbuchen

20 **THE QUEST TO EXPLORE SPACE** Scientists on the hunt for signs of life and gravitational waves

22 **THE VIEW FROM SPACE – AND WHAT IT TELLS US** Unleashing the full potential of Earth observation satellites

26 **LAUNCH OF MASTER'S IN SPACE SYSTEMS** New study programme from ETH sparks huge interest

30 **GETTING SMART IDEAS OFF THE GROUND** Switzerland helps space start-ups take off

COMMUNITY

32 Connections to ETH

34 **TOOLS TO TACKLE THE PROBLEMS OF THE FUTURE** A vision for teaching at ETH Zurich

37 **IN PERSON** Johannes Bohacek investigates the molecular basis of stress in the brain

REPORT

40 **NATURE'S CLASSROOM** Aspiring sports teachers spend a challenging weekend in the great outdoors

PROFILE

45 **FROM LOOP JUMPS TO QUANTUM LEAPS** ETH physicist Bettina Heim develops software for quantum computers

48 **DISCOVER**

50 **THINK TANK** Biometrics for artworks

NEW + NOTED

Image: Adobe Stock

As the ice masses on Earth melt, this is changing the way our planet rotates.

Climate change alters Earth's rotation

A research team at ETH Zurich, led by Professor Benedikt Soja, has discovered a link between global warming and our planet's rotation. As polar ice sheets in Greenland and Antarctica melt, the amount of water in the oceans increases, particularly near the equator. This redistribution of the Earth's mass influences how it rotates, much like a figure skater who puts out their arms to slow down a pirouette. These changes follow the law of conservation of angular momentum. Furthermore, as the Earth's rotation slows, the days grow longer, meaning that climate change affects not just how fast our planet spins, but also how long each day lasts.

The team has shown that climate change could lengthen the day by a few milliseconds a year. Interestingly, the Moon, which has influenced Earth's rotation for billions of years, is slowly taking a back seat, meaning humans could one day shape Earth more than these natural processes.

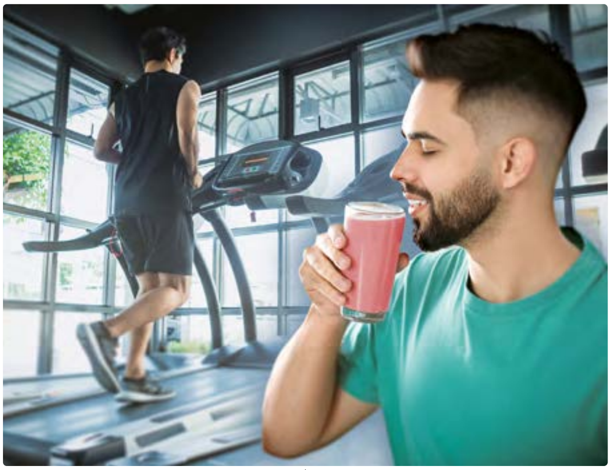
What's more, the same study shows that climate change also shifts the position where the axis of rotation meets the Earth's surface. Referred to as polar motion, this movement is in the range of about 10 metres per century and is influenced not only by the melting of the ice sheets but also by shifts within the Earth's interior.

The team conducted their study using an AI approach known as physics-informed neural networks. By factoring in physical laws, these networks enable accurate modelling of polar motion. Using this approach, doctoral student Mostafa Kiani Shahvandi was able to provide the first ever comprehensive explanation of the various causes of long-term polar motion.

The changes in Earth's rotation may be small, but they are important for precise space navigation. Even minimal deviations could have a significant impact on space missions. ○

Eat or exercise?

Image: Adobe Stock, montage



Countless temptations can keep us from exercising.

The brain chemical orexin is crucial when it comes to choosing between exercise and eating. In experiments with mice, ETH Zurich researchers found that animals with a functioning orexin system were significantly more likely to choose a running wheel over the "milkshake bar", compared to mice whose orexin system was blocked. Interestingly, when given just one option – either the running wheel or the milkshake – both groups behaved similarly. This implies that orexin plays a central role in deciding whether to exercise or eat, rather than just controlling hunger or the urge to move. The researchers suspect orexin has a similar function in humans. This could open up new approaches to overcoming inhibitions to exercise and combating the global obesity epidemic. ○

Record-breaking laser pulses

Science and industry often require short, powerful pulses of laser light rather than a continuous beam. Responding to this need, a research team led by ETH Professor Ursula Keller has developed a groundbreaking laser that produces the strongest pulses ever created by a laser oscillator. With an average power of 550 watts and a peak power of 100 megawatts, the laser is particularly suitable for materials processing and precision measurements. This innovative laser is based on an optimised arrangement of mirrors within the laser as well as improvements to a special mirror that causes the laser to emit pulses. The high laser power is generated without the use of separate amplifiers. This reduces system noise to a minimum, which is of benefit when making sensitive measurements. Researchers hope this advance will pave the way for new applications in science and industry. ○

Image: Moritz Seidel / ETH Zurich

A glimpse inside the record-breaking laser.


ABB
GÜDEL

Image: Michael Lyrenmann / Gramazio Kohler Research / ETH Zurich

Made of mud

It is perfectly possible to construct entire houses out of clay or mud – materials that are not only sustainable and readily available but also cheap. The problem is that current methods are slow and labour-intensive, which pushes up costs. Now, however, ETH researchers from Gramazio Kohler Research, the ETH Robotic Systems Lab and the ETH Chair of Sustainable Construction have developed a robotic method of additive manufacturing with earth-based materials that does not require the addition of cement. In a process known as impact printing, the robot rapidly deposits portions of clay or similar material from above. On impact, these clumps of material bind together, so that minimal additives are required. Furthermore, unlike 3D printing with concrete, the process does not require pauses to allow the material to solidify. This new method can be used to build walls and column-like structures. Individual groups are now developing similar processes for surface finishing and investigating the use of other materials for additional applications. Plans are underway for a spin-off that would bring this new robotic additive-manufacturing technology to market. ○

Video: Printing with earth-based materials
⟶ youtu.be/M9kc0L1zlaA

Project page for impact printing
⟶ ethz.ch/impact-printing

A war over land and soil

The war in Ukraine is also a war over soil. Sebastian Dötterl explains why Ukraine's arable land is so valuable.

SEBASTIAN DÖTTERL is an assistant professor in the Department of Environmental Systems Science at ETH Zurich.

Russia's war of aggression continues to bring suffering to the people of Ukraine. Since the outbreak of hostilities in February 2022, there have been many insightful analyses about Russia's imperialist ambitions in Ukraine. Yet I would argue that another aspect has not received the attention it deserves. Whatever its ideological dimensions, this is also a war over two of our century's most important resources: arable land and mineral deposits.

FERTILE SOIL It's no secret that the southern and eastern parts of Ukraine are rich in rare earths, ores and other metals, and that the country as a whole has a wealth of fertile arable land. Less well known is how these resources are spread across Ukraine, and why this is the case. Just as a country's ore reserves are dictated by its geology, the fertility of Ukrainian soil derives from its uniquely thick humus layer and an extremely fertile material known as loess. This fertile soil – often referred to as "black earth" due to its colour – is also found in other parts of the world. But nowhere else in Europe is it as prevalent as in southern and eastern Ukraine and neighbouring parts of Russia – in other words, precisely the regions Russia has laid claim to. By way of comparison, the humus-rich layer in Switzerland's soil is often less than 20 centimetres thick, whereas in Ukrainian agricultural land it can often be as deep as 60 centimetres and in some places over a metre – all that across an area roughly six times the size of Switzerland.

BUFFERINGAGAINSTCLIMATEIMPACTS Ukraine's arable land looks set to become even more valuable in the future. That's because almost all types of crop production lead to some kind of soil degradation, which has a negative impact on soil fertility and yield. As a result, much of Europe's soil is already heavily degraded and thus less resilient to environmental impacts such as climate change. Ukraine's black earth will be able to compensate for this kind of damage and yield loss for many decades to come.

In fact, climate change will make these advantages even starker. Today's most common climate scenarios suggest that areas of Ukraine are likely to suffer far less from the negative effects of climate change than the countries of central and western Europe. With European farmers facing an increased threat of drought and extreme weather events, Ukrainian land will become even more valuable.

VAST UNDERGROUND TREASURE Back in autumn 2022, the Canadian think tank SecDev estimated the value of mineral deposits in Russian-occupied regions of Ukraine at more than 12 trillion US dollars. Of the 30 raw materials that the EU lists as being of particular strategic importance, 22 are to be found in large quantities in Ukraine. These include natural resources such as coal, oil and iron ore, but also lithium, titanium, magnesium, uranium and many other materials.

Due to Ukraine's geology, most of the country's largest ore reserves – including lithium, for example, which is essential for electromobility – are located in the eastern and southern regions. That puts them right at the heart of the current fighting or in territories now claimed by Russia. It seems to me that whoever controls these regions has a crucial ace up their sleeve – playable in the game of power politics against both industrialised nations and countries with low domestic food production. ○

Read more blog posts at:
⟶ ethz.ch/zukunftsblog-en

The thick, fertile layer of dark-coloured humus is clearly visible in this Ukrainian trench.

Image: Anatolii Stepanov/AFP; Keystone/AFP/Anatolii Stepanov

Chemical recycling of plastics

Image: Shibashish Jaydev / ETH Zurich

Most drink bottle caps are made of polypropylene.

Chemical recycling offers a promising way to make the management of plastic waste more sustainable. Unlike mechanical recycling, which degrades the quality of the plastic, chemical recycling breaks plastics down into their basic building blocks, which can then be reassembled into new, high-grade products.

ETH Zurich researchers have now formulated the key principles required to improve this method further – and the key, they say, lies in how the plastic melt is stirred. Polyethylene and polypropylene are heated in a steel tank and mixed with hydrogen and special catalysts. Through careful stirring, the polymers are broken down into short-chain molecules to be used as liquid fuels or lubricants.

The team, led by ETH Professor Javier Pérez-Ramírez, also developed a mathematical model of the entire process that can be used to determine optimal stirring speed and geometry. Scientists can harness this knowledge to boost the efficiency of chemical recycling and to set new standards for transitioning this process from the lab to industrial applications. ○

A hydrogel to combat endometriosis

Endometriosis affects approximately 10 percent of all women and is linked to the backflow of menstrual blood into the abdominal cavity, causing inflammation and pain. Researchers from ETH Zurich and the Swiss Federal Laboratories for Materials Science and Technology (Empa) have come up with an innovative hydrogel implant that can prevent endometriosis while also acting as a contraceptive. The implant blocks the fallopian tubes, preventing the backflow of menstrual blood and also acting as a barrier to sperm. Just 2 millimetres in size, the implant swells after insertion and is not rejected by the body. Another advantage is that the implant can be dissolved using UV light or a special solution, eliminating the need for surgical removal. The research team, led by Inge Herrmann, is currently conducting preclinical studies of the implant and has already initiated the patent application process, paving the way for a swift transition from laboratory to market. ○

Image: Adobe Stock

Endometriosis affects approximately 10 percent of all women.

Image: Wolfram Scheible / MPI-IS

The robot leg reproduces human jumping mechanics.

Artificial muscles: the future of robotics?

Robots are powered by motors, a technology that is already 200 years old. This prompted ETH Professor Robert Katzschmann and the Max Planck Institute for Intelligent Systems to develop a new kind of robotic leg. Propelled by artificial, electrohydraulic muscles, the new leg can jump high in the air and automatically adapt to uneven terrain. The electrohydraulic actuators, which resemble freezer bags filled with oil, use static electricity to change the position of the oil in the bags. This serves to bend or extend the leg in a manner similar to muscle function. As well as enabling nimble and adaptive movements, this technology also generates less heat, thus eliminating the need for heat sinks and improving energy efficiency. The researchers envisage particular benefits for soft robotics applications that require agile and responsive movements. ○

Preventing cancer metastasis

When cancer becomes life-threatening, metastases are usually to blame. A team of ETH researchers led by Professor Andreas Moor has investigated how colorectal cancer cells establish themselves in the liver and identified the surface proteins that facilitate this process. The team discovered that colorectal cancer cells possess specific proteins called semaphorins, which dock onto plexin proteins on the surface of liver cells. This interaction between plexin and semaphorin triggers fundamental alterations in the cancer cells, enabling them to adapt to their new environment and take root in the liver. In the process, the cancer cells change their form and acquire properties that fuel metastatic growth. Studies have shown that colorectal cancer patients whose tumours exhibit high levels of semaphorins face an elevated risk of liver metastasis. The implications of this research extend beyond colorectal cancer treatment, potentially offering insights into other types of cancer where plexin plays a role, such as pancreatic cancer and melanoma. By developing methods to inhibit the interaction between plexin and semaphorin, the researchers hope to create a roadblock in the metastatic process, potentially preventing the formation of life-threatening secondary tumours. ○

ETH IN SPACE

FOCUS | The ETH Zurich Space Initiative demonstrates ETH’s bold commitment to expanding and promoting space research and teaching, driving innovation in this field. The success of this programme hinges on effective networking and collaboration with partners worldwide.

Text Karin Köchle and Noe Lüthi

Image: Nicole Wächter

THE SECRETS OF COSMIC DUST

Cosmic dust, though present throughout space, remains one of the universe's most enigmatic materials. At ETH Zurich, research group leader and ERC grant recipient Veerle Sterken is unlocking the secrets of these microscopic building blocks of stars and planets. Combining computer simulations, laboratory investigations and in situ measurement data from space missions, her team seeks to deepen our understanding of our solar system and its immediate interstellar neighbourhood. Fortunately, we don't need to journey into space to admire clouds of cosmic dust – they're visible to the naked eye in our Milky Way.

Why we need space exploration

Thomas Zurbuchen, Director of ETH Zurich Space, explains how Switzerland can do a better job of exploring and exploiting space – and how there's still enormous potential to be tapped.

Text Christoph Elhardt and Karin Köchle

Thomas Zurbuchen, your interest in space stretches back many years. Do you still feel a sense of awe at what's out there?

THOMAS ZURBUCHEN: Absolutely, and that only grows the more I learn about it! The night sky I admired as a kid was much simpler than the one I look at today. Now I know there's at least one planet for every star, and that the whole of space is rippling with gravitational waves. Right now, we're working on a mission to measure those gravitational waves with a space antenna, part of which is being built at ETH Zurich.

People find space research fascinating. Why do you think that is?

We all share an innate curiosity and a desire to understand nature. Even as children, we are constantly asking what and why, and how things work. But it also stems from our eagerness to push boundaries. In a sense, escaping Earth's gravity is our way of showing defiance. That childish curiosity is something we need to rekindle.

But what about all the problems on Earth that could be solved with the money that is currently spent on space research?

I would argue we invest too little in this area, especially in Switzerland, because many of the solutions to those problems actually come from space! For example, climate change – one of the biggest challenges we currently face on our planet – is a huge topic at ETH. And data from space is actually helping us understand the changes our world is going through.

In what ways exactly?

Satellite data can be used to predict major storm events. And data from space also improves our understanding of landslides, helps us protect forests and enables us to track pollution in our oceans. This data is a vital tool for people working in Earth and climate observation.

You've been at the helm of ETH Zurich Space since August 2023. How do you rate the progress so far?

We've achieved good things already, both in terms of promoting innovation and on the teaching and research front. But, of course, we had good foundations to build on: ESA BIC Switzerland – a support programme run by the European Space

Image: Daniel Kellenberger / ETH Board

THOMAS ZURBUCHEN was head of Science at US space agency NASA from 2016 to 2022. In August 2023, the Swiss-American astrophysicist took charge of the ETH Zurich Space initiative as Professor of Space Science and Technology. The goal of this initiative is to expand ETH's research and teaching activities and to strengthen collaboration with the space industry.

Agency and ETH Zurich – has been a tremendous success. We're currently assisting 21 start-ups that are involved in space technology. And our new Master's degree programme in Space Systems was launched this autumn, which is fantastic.

What's your vision for the ETH Space initiative?

Over the next five years, we aim to establish our new Master's degree programme as one of the best in the world and to look at incorporating new teaching content in core studies and continuing education. I envisage us having two or three major projects on the go by the end of that period: an Earth observation satellite with at least some components built at ETH, for example, or perhaps an ETH robot landing on the Moon. We're also aiming to develop an innovation cluster in the Swiss space sector by bringing together established companies and finding funding to help start-ups grow. I also hope we can build a stronger network with fellow universities, because Switzerland is really too small for us all to be competing with one another.

Why is space research important to Switzerland?

Space research is the perfect match for Switzerland. It's all about quality and great engineering, two things which Switzerland is famous for. It's also a fast-growing market, and Switzerland has a real opportunity to position itself as a place where companies can thrive. We need to ensure that Switzerland seizes that opportunity, hones its competitive edge and enhances its presence on the international stage. The goal is to capitalise on Switzerland's uniqueness and to offer things that nobody else can do. Switzerland already plays a leading role in many other areas, such as timekeeping and sensor manufacturing. We have such brilliantly qualified people in our universities and companies, and that's a real selling point.

How can we unlock all the potential that Switzerland has to offer?

For a start, we need closer collaboration between established companies, start-ups and universities. That's something the ETH Space initiative can really help with. At the same time, we need a new kind of no-blame culture, because that's the only way we can achieve great things. We need to remove the stigma around taking risks and making mistakes. And we need to aim so high that we will inevitably fail sometimes but nonetheless learn from those failures. That takes people who believe in the future and are ready to grapple with the big challenges. We need to be offering them more financial support – and that's where both ETH and the government should be lending a hand.

How important is space to research at ETH?

Observations from space play an increasingly important role in many areas of research at ETH, such as physics, Earth sciences and construction. We should be able to understand that data ourselves and to have a say in how we observe our planet. That means getting experiments from ⟶

> “Data from space helps us understand how our world is changing.”

the laboratory into space as quickly as possible, which is why we’re aiming to expand our collaboration with space companies and to take on a leading role in major missions run by ESA, NASA and other space agencies.

Space is becoming more accessible, largely thanks to commercial players. How do you feel about that?

The cost of launching into space has been falling for some time, and that’s a trend which looks set to continue. As a result, it’s getting easier and cheaper for researchers to get their experiments onto the Moon or into space. One of the advantages we have today is that we can build on existing systems, which means we don’t need to make new satellites to perform space experiments.

Would you go into space yourself?

Absolutely! Going into space used to require five long years of preparation, and I wasn’t willing to sacrifice that amount of time. But if someone told me I could join one of today’s space missions after just a couple of months of training, then I would jump at the chance. Especially if I were able to conduct an important experiment in space, such as testing one of ETH’s quantum sensors.

There’s recently been a lot of talk about returning to the Moon. What can we hope to gain from that?

It generally comes down to three things: research, national interest – i.e., prestige and innovation – and inspiration. The exact importance accorded to each of these three factors depends on the country. China, for example, has a strong national interest in showing off its strength, but it’s also a research powerhouse. India needs the Moon programme as a source of national inspiration and as a way of fostering innovation. If I had a billion euros, I would invest part of it in going to the Moon. But my primary goal would be to promote science, rather than simply getting people there.

How long before we have a permanent base on the Moon?

China aims to achieve that by 2035, which puts it ahead of anyone else. The Americans were the first to get there, in 1969. But nowadays it’s not about leaving footprints and flags. We should be using the Moon as a research lab and perhaps also exploiting it for its resources.

If China becomes the first country to have a permanent lunar base, will it then share its research data with other partners?

The international community hasn’t yet been able to come up with a universally accepted set of rules governing lunar collaboration. These rules would need to cover the exploitation of whatever resources we might find on the Moon and set out how data should be freely shared. We need to find a consensus on all these issues – regardless of who gets there first. As a neutral country, Switzerland could very well end up playing a key role in this international discussion.

Thinking beyond the Moon, when are we likely to see a human mission to Mars?

It’s largely a question of money, luck and regulatory issues. Mars is a far more challenging destination than the Moon, because it may harbour life. It’s vital that we don’t end up permanently polluting the Red Planet as well. And we also need to ensure that future generations can continue our research. But there are still major technical challenges to be resolved. For example, how will astronauts cope with such harsh radiation over long periods of time? And how will we get them safely back to Earth?

What’s the point of even going to Mars, apart from satisfying our curiosity?

Science on Mars is much more interesting than on the Moon. You can look at Mars as a kind of “broken Earth”. It used to boast oceans and a thick atmosphere. What caused that to change? And what we learn from this? As with the Moon, national interests and just plain curiosity play a big role here. When astronauts first set foot on the Moon, it inspired the whole world and paved the way for new technologies that we still use today. It will be a similar story when we reach Mars. ○

⟶ space.ethz.ch

Image: Marco Tempest / ETH Zurich

GIANT STEPS FOR A SMALL ROBOT

An international team led by Anna Mittelholz and Simon Stähler is currently investigating the use of a robot to explore the Moon on future lunar missions. Developed at the Robotics Systems Lab and based on ETH's SpaceHopper, the 10-kilogram LunarLeaper is equipped with geophysical instruments and cameras that will enable it to search for what may be volcanic cave systems under the surface of the Moon.

The quest to explore space

ETH Zurich is involved in a number of space missions – from satellite-based searches for signs of life on exoplanets to the hunt for gravitational waves with the LISA space antenna. These projects rely on strong partnerships with the aerospace industry.

TEXT Michael Keller

The James Webb Space Telescope

Image: NASA

The largest and most powerful space telescope to be launched since Hubble, the JWST comprises a mirror, four infrared instruments and a sunshield to screen it from the sun's rays. It enables us to peer deep into space and back in time to the early universe.

Mission	Launched successfully in 2021
ETH contribution	The ETH Institute for Particle Physics and Astrophysics coordinates the participation of Swiss research and industry.

ETH TECHNOLOGY Contamination control cover and connector cables for the Mid-Infrared Instrument (MIRI), produced by the MRI Consortium.

SpaceHopper

Image: Dominik Lindegger

A three-legged exploration robot designed to hop across the surface of asteroids and other low-gravity celestial bodies.

Mission	LunarLeaper – the successor to SpaceHopper – is tailor-made for exploring the Moon.
ETH contribution	A team of ten ETH students developed SpaceHopper from scratch in a two-semester focus project.

LUNARLEAPER builds on the design for SpaceHopper and complements the methods used for exploring lava tubes on the Moon. See picture series on page 19.

LIFE – Large Interferometer for Exoplanets

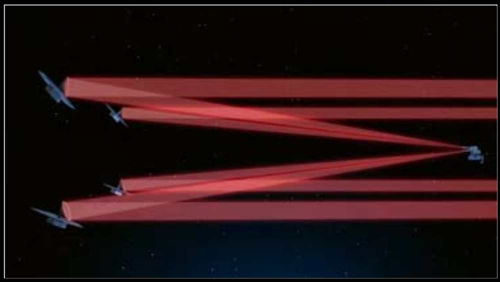


Image: ETH Zurich/Life Initiative

This array of five satellites forms a powerful infrared telescope to study Earth-like planets and track down traces of life in their respective atmospheres.

Mission	Planned for 2040
ETH contribution	LIFE is an international space mission initiated and led by the ETH Centre for Origin and Prevalence of Life.

InSight

Image: NASA

An unmanned NASA mission to land geophysical instruments on Mars and investigate the interior of the Red Planet.

Mission	Successfully landed in 2018; final contact December 2022
ETH contribution	On-board seismometer with data-acquisition and control electronics developed by ETH. For four years, this instrument detected Marsquakes and meteorite impacts, transmitting the data back to ETH Zurich.

Various ETH groups evaluated the data. Analysis of a powerful Marsquake enabled scientists to calculate the thickness of the Martian crust.

LISA Pathfinder

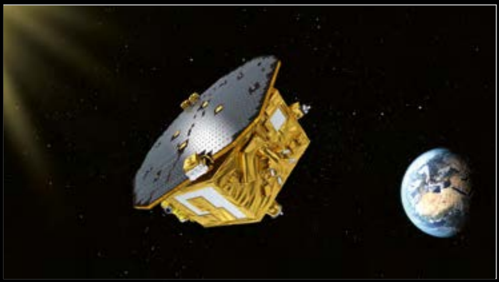


Image: ESA – C. Carreau

A preliminary space probe for ESA's LISA mission: a space antenna to detect gravitational waves, as posited by Albert Einstein.

Mission	Successfully completed in 2017
ETH contribution	The ETH Seismology and Geodynamics research group is part of international ESA consortiums for the preparatory and main LISA missions.

ETH TECHNOLOGY Front-end electronics for the gravitational reference sensor, the heart of the LISA measurement system.

The Laser Interferometer Space Antenna (LISA) is the future observatory for gravitational waves in space. From 2037, it will provide new insights into the Big Bang, the development of the universe and Einstein's theory of relativity.

Earth-observation satellites deliver data for a wealth of applications – from monitoring climate change and documenting war crimes to planning disaster relief and assessing snow depth. ETH researchers are also big beneficiaries.

TEXT Barbara Vonarburg

The view from space – and what it tells us

Orbiting at an altitude of 700 kilometres, satellites of the European Space Agency (ESA) transmit radar signals down to Earth. These are scattered by the planet's surface and reflected back to the satellite, yielding images of the terrain even when the sky is overcast. Right now, Konrad Schindler and his team are interested in images of Ukraine. "Satellites fly over the country every couple of days, which gives us a kind of slow-motion video," says Schindler, head of the Institute of Geodesy and Photogrammetry at ETH Zurich. "If the signal hits a heap of rubble where there were once intact buildings, then it bounces back in a different form." This is because smooth surfaces reflect radio waves more effectively than rough surfaces.

Not that the naked eye could make much sense of this stream of freely accessible images. That's the job of an automatic monitoring system that harnesses the power of artificial intelligence. "The system uses statistics to identify patterns in the data," Schindler explains. This is an example of machine learning, whereby an AI system is trained with reference images that clearly show, for example, the difference between a building that has been destroyed and one that is still intact.

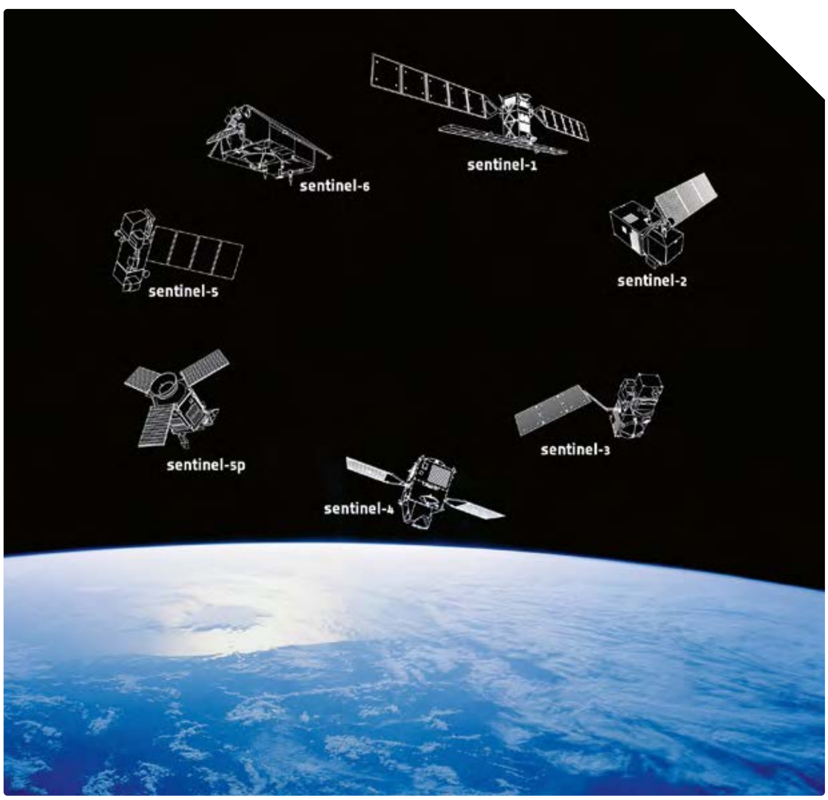
These reference data were provided by UNOSAT, the United Nations Satellite Centre. Here, experts painstakingly inspect high-resolution images from commercial sources in order to identify damage to buildings and thereby document war crimes such as the bombing of civilian infrastructure. "Our monitoring system is certainly not designed to replace these people," says Schindler. "But its ability to cover large areas gives them useful guidance on where to take a closer look."

MAPS FOR AID ORGANISATIONS The mapping of war damage is one of two projects on which ETH researchers have collaborated with the International Committee of the Red Cross (ICRC). "The second one sought to answer what might seem like a very simple question – namely, where are the people?" Schindler explains. When the ICRC launches relief operations or vaccination campaigns in the wake of natural disasters, it needs data on population density. In less developed countries, this is often lacking – and that's when the Red Cross falls back on the population maps that Schindler's group creates from satellite data.

ETH researchers use this powerful cocktail of satellite observation and machine learning across a wide range of areas. In collaboration with the Swiss start-up ExoLabs, for example, they have developed a system that delivers a faster and more accurate assessment of snow cover than that from conventional sources. The researchers began by feeding the system with estimates of snow depth in Switzerland based on satellite images and digital elevation maps. Using comparisons with precise data gathered by aircraft and meteorological ground stations, the system learned how to improve the satellite-based estimates. Now it provides daily snow depth maps, a service that will soon be launched on a commercial basis.

A global map of tree heights has already been made freely available. Also based on satellite data, this is primarily used for environmental purposes. "Obviously, you can't see the bottom of a tree from space, but the reflected signal contains detailed content, particularly in the infrared range, from which a lot of information about vegetation can be obtained," Schindler explains. Using reference data from a laser scanner on board the International Space Station (ISS), a computer program has learned how to derive tree heights on the basis of illumination patterns of the area under observation. A laser pulse bouncing back from a treetop takes minimally less time to return to the ISS than one reflected from the ground below. This difference is enough to calculate the height of local vegetation.

EARLY-WARNING SYSTEM FOR FORESTS "The global mapping of canopy heights also provides interesting information on the age of the vegetation," says Verena Griess, Professor of Forest Resources Management and head of the Institute of Terrestrial Ecosystems at ETH Zurich. She and her team are using satellite data to discover more about tree health. "Climate change has propelled us into an era of rapid change," says Griess. "This also applies to our forests, where problems caused by pests, blowdown, fire and drought are very much on the rise." Using satellite data, the researchers plan to set up an early-warning system that will alert us to ⟶



ESA's Sentinel satellites are civil Earth observation satellites. They are also used by ETH researchers.

Image: ESA

distressed woodland even before such damage is visible to the human eye. This system could also be used to detect the first signs of forest fires in sparsely populated areas, or to show where remedial measures are required in Switzerland to safeguard the protection against natural hazards that forestry affords. Satellite data could also identify areas that are suitable for timber extraction or that require conservation due to their high biodiversity. "Our aim is to ensure that the right decision is made for each place," Griess explains.

Researchers are now working on a model that will be able to automatically identify tree species from satellite images. Trained on data from locations where species such as beech, spruce or larch are known to be growing, the model gradually learns to identify the corresponding patterns in satellite images. Using hyperspectral sensors, satellites can also collect information on tree health that is invisible to the human eye. This includes measuring the concentration of certain substances in the leaves and monitoring any changes that might indicate the early stages of a pest infestation.

Two-dimensional satellite images can also be enriched with 3D data from laser scanners either on board satellites, aircraft or drones, or located on the ground. ETH recently inaugurated its Alps supercomputer, which will speed up data analysis and improve the training of AI models. "This technology adds yet another string to our bow, alongside our outstanding students and the excellent collaboration between university professorships and other member institutions of the ETH Domain," says Griess. "Switzerland now has a real wealth of expertise in this area, concentrated to a degree you won't find anywhere else."

GPS TECHNOLOGY REPURPOSED The health of woodland trees can also be investigated using signals from GPS satellites. When a GPS receiver is placed under a tree and another one at a distance, the difference in the signals received can serve to calculate how much biomass the tree contains. "It's amazing what you can do with a technology that was developed for something entirely different – in this case, navigation," says Benedikt Soja, Professor of Space Geodesy.

In collaboration with MeteoSwiss, Soja and his team have installed low-cost GPS receivers at several weather stations located throughout Switzerland. They measure the level of water vapour in the atmosphere by detecting the corresponding delay in the propagation of radio signals transmitted by satellites. This data is then used to calculate the humidity above a weather station and thereby improve rain forecasts.

At the same time, the analysis of such data over a longer period of time also yields information on climate change. A warmer atmosphere absorbs more moisture – i.e., more water vapour. "This in turn intensifies climate change, because water vapour is also a greenhouse gas – in fact, the most abundant of all," Soja explains. "This makes it very easy to determine the local impact of climate change on the atmosphere." GPS measurements show that, on average, some regions have become wetter and others drier.

Researchers are harnessing another technique to track the melting of ice sheets in Greenland and Antarctica. Two satellites flying in tandem measure the Earth's gravity field, which varies according to how much mass is present at a particular location. "This means we can measure any changes in this mass from space," explains Soja. This data can be further refined with the help of other satellites that measure altitude. "The polar regions are seeing massive ice melt. We're losing hundreds of gigatons of ice each year – the equivalent of a gigantic 3,000-metre-high cube the size of the city of Zurich – and this is causing sea levels to rise," says Soja. "Satellite observation is the best way of tracking the impact that climate change is having on the Antarctic and Greenland ice sheets." ○

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⟶ form.ethz.ch

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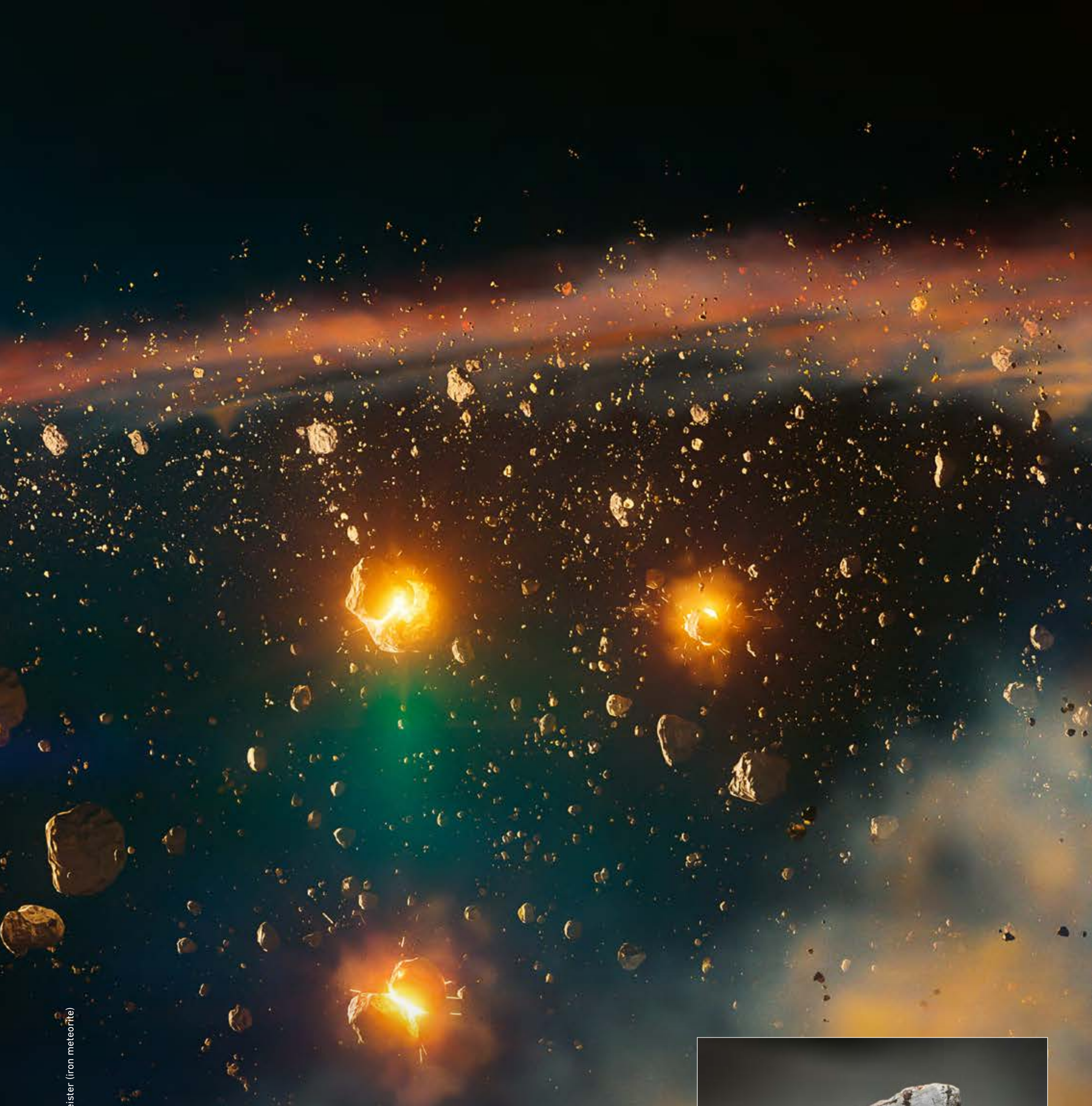
⟶ space.igp.ethz.ch



TIME CAPSULES FROM SPACE

Asteroids are relics of our solar system's origin, remnants of the process by which pieces of rock were formed from gas and dust 4.5 billion years ago. Some of these fragments coalesced into planets; others continue to orbit the Sun as asteroids. Occasionally, one of these reaches Earth as a meteorite, offering a precious resource to scientists. A research team led by Professor Maria Schönbächler, a cosmochemist at ETH, has analysed metallic asteroid cores as part of PlanetS, one of Switzerland's National Centres of Competence in Research. These findings offer important insights into the history of our solar system.

Image: Tobias Stierli, flaeck / PlanetS (background); Aurelia Meister (iron meteorite)

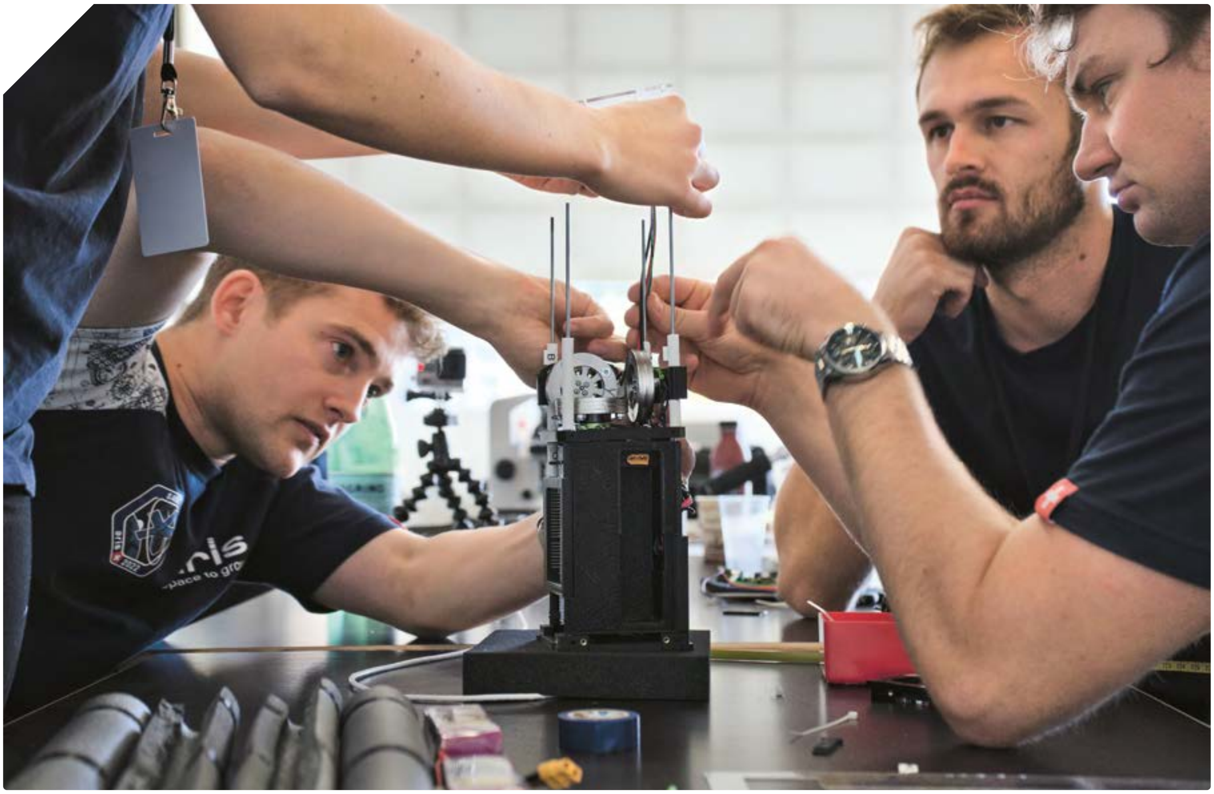


Image: SAGE

Launch of space systems degree programme

Few courses of study at ETH Zurich have attracted quite as much attention as the new Master in Space Systems. Teachers and students strapped in for the programme's launch this autumn.

TEXT Peter Rüegg

The ARIS SAGE CubeSat team assembles a prototype of the cube-shaped satellite.

Long before the lecture is due to start, the small E41 lecture hall in ETH's Main Building is already close to capacity. There's an air of excitement among the students as they await the arrival of their lecturer, who is due to give his first class in the ETH Master's programme in space systems.

Thomas Zurbuchen arrives punctually, coffee in hand. He kicks off his lecture with a challenge: his students can expect to benefit from his deep connections in the space industry, but in return he expects them to carve out a niche for themselves in the industry once they complete their Master's degree – just as many of his former students did when Zurbuchen was head of Science at NASA. Several of his former protégés work at SpaceX, and one was the Mission Systems Engineer on the DART mission, which aimed to demonstrate NASA's ability to intercept an asteroid. "That's the kind of excellence I expect from you – or even better!" he says.

It was actually Zurbuchen's promptings that first led to ETH Zurich offering a Master's degree programme in Space Systems. In 2023, he presented ETH Zurich with his vision of a course of studies designed to train the next generation of space industry professionals. His idea struck a chord, both within ETH and among students, drawing an enthusiastic response not only from ARIS – a student association dedicated to advancing space exploration – but also from students studying astrophysics and planetary sciences. The programme was launched in mid-September 2024 with a cohort of 28. The initial offering of 30 places attracted 90 applications, 35 of which were accepted, with 7 candidates who subsequently withdrew.

A quick round of introductions in this first lecture highlights the difference in backgrounds: first up is a materials scientist, followed by a mechanical engineer, an Earth scientist, a physicist, a biochemist and a computer scientist.

At the helm of the programme is geophysicist Simon Stähler, Curriculum Director of the Master in Space Systems. From the start, his job has been to translate Zurbuchen's vision into reality, to develop the curriculum and to decide which academic departments should be involved and which new lectures need to be devised.

A SYSTEMS APPROACH At the heart of the course is systems engineering. Students learn about the key subsystems of a spacecraft and how they interact. The goal is to give them the knowledge they need to put together a scientific instrument and, on that basis, design an entire spacecraft. "We want to encourage students to think in terms of systems," says Stähler. These budding systems engineers also have to know what to do if the scientific instrument that was originally planned suddenly expands because mission researchers decide they want a bigger camera. "It's all about learning how to estimate costs and how to ensure they don't spiral out of control," says Stähler.

The lecturers lay the groundwork for this by explaining how engineers and scientists need to find a common language. "If a researcher says they need the instrument to be twice as big, it's possible they just want a higher resolution, and there are more ways to achieve that than by simply doubling the size of the instrument," says Stähler. He speaks from experience, having worked on NASA's InSight mission, which explored the interior of Mars.

CONCRETE OVER ABSTRACT The students on the course will primarily work on concrete projects and develop instruments for space missions in collaboration with industry partners. The course organisers received proposals for space missions from potential partners in mid-September, and students have already started coming up with ideas – including, for example, a method for measuring snow depth in the Alps using satellite-borne radar. Calculating the size and cost of such a satellite is also part of the students' brief.

"We are not looking to produce theoreticians," says Florian Kehl, a lecturer at the Department of Earth and Planetary Sciences, who also teaches on the new Master's programme and specifically builds laboratory courses to provide students with practical hands-on experience. The degree course will combine theory and practice while encouraging close collaboration with business and industry. "We reached out to space companies and asked what kind of graduates they need and designed things on that basis," he explains.

A further novelty is that the students will be expected to tackle these projects in interdisciplinary groups. "We're not interested in having a team that consists entirely of mechanical engineers or solely of Earth scientists," says Kehl. ⟶

GROWING INTEREST The new ETH Master's programme in Space Systems has attracted considerable interest not only from students at Swiss universities, but also from around the world. "Dozens of international candidates have already expressed an interest," says Stähler. "We're even getting enquiries from students at universities that are known for their aerospace engineering courses, such as Milan, Toulouse and Munich." ETH began accepting international applications in November.

Stähler emphasises, however, that the focus of the ETH programme is different to that of Toulouse, Munich or Milan: "We don't have anyone here who is learning exclusively how to work on rocket engines. ETH doesn't yet have any professorships in that area."

PREPARING WITH ARIS Maximilian Leeb is one of the students who was accepted for the course. With Bachelor's degrees in Chemistry and Mechanical Engineering in his pocket, his goal now is to ramp up his knowledge in the field of space systems. The aspect of the course that appeals to him most is the systems engineering approach, and he likes the emphasis on practical skills rather than just theoretical knowledge – a point echoed by fellow student Chloé Pilloud: "I'm hoping we get lots of new input on the current state of the space industry as well as a sense of how it's evolving worldwide."

Pilloud is currently the president of the ARIS association, a position that has given her an opportunity to indulge her enthusiasm for space. "Being the president of ARIS is a real learning experience. The association gives me plenty of opportunity to grow in this role and to learn more about myself in the process," she says. Pilloud is also enjoying developing her own leadership style, something she can also put to good use on the Master's programme: "We're doing all sorts of projects, some of which already involve industry, so we need to be well versed in all the technical aspects, but project leadership is very important, too."

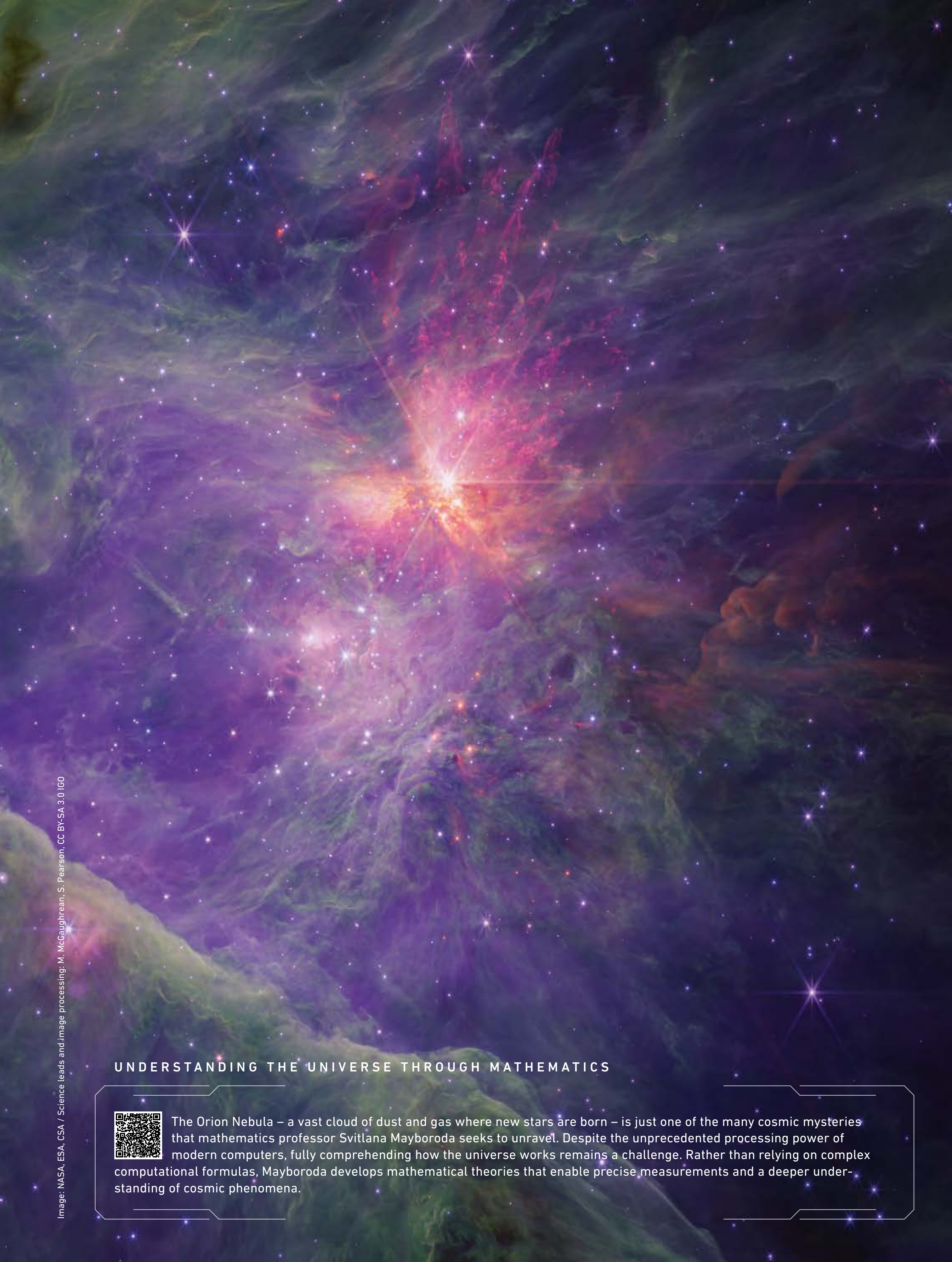
Leeb also has experience with ARIS: he joined the association while studying chemistry and continued working there right up until the end of his Bachelor's in Mechanical Engineering. During that time, he worked on a hybrid rocket engine and a number of rockets. He heartily recommends ARIS to any students interested in space flight. "It doesn't really matter what subject you're studying – you can still get involved in ARIS. If you have a passion for space travel, then the door is always open!" he says. "I've benefited so much from working there, both in terms of my courses and in many other ways."

Nonetheless, he says students should be careful not to let their enthusiasm for ARIS projects cause them to neglect their studies. "You have to be conscious that getting too heavily involved with an association like ARIS might end up affecting your grades," he cautions.

Neither he nor fellow student Pilloud currently have a specific career in mind, and Leeb is unsure where he might be in five years' time. "I can imagine being in an aerospace-related business where I can apply my knowledge of systems engineering. That's what interests me most," he says. "And Thomas Zurbuchen does a great job of teaching it!" Pilloud, meanwhile, dreams of becoming an astronaut. "And I'm hoping this degree programme will help make that dream come true!" she says. ○

ROCKET BUILDERS AND DEEP-SEA ROBOTS ARIS – a German acronym for Academic Space Initiative Switzerland – was founded at ETH Zurich in 2017 by students from various Swiss universities with the goal of building a functioning rocket. Currently, the association has 220 active members and over 500 alumni. ARIS has since expanded the focus of its work to include not only rockets and engines, but also a cube-shaped satellite, a controllable drogue parachute and an underwater robot.

⟶ aris-space.ch



UNDERSTANDING THE UNIVERSE THROUGH MATHEMATICS

The Orion Nebula – a vast cloud of dust and gas where new stars are born – is just one of the many cosmic mysteries that mathematics professor Svitlana Mayboroda seeks to unravel. Despite the unprecedented processing power of modern computers, fully comprehending how the universe works remains a challenge. Rather than relying on complex computational formulas, Mayboroda develops mathematical theories that enable precise measurements and a deeper understanding of cosmic phenomena.

Getting smart ideas off the ground

Space start-ups in Switzerland enjoy the support of ESA BIC Switzerland, a business incubation centre set up by ESA and run by ETH Zurich. The programme helps researchers take their first steps towards commercial success.

TEXT Corinne Johannssen ILLUSTRATION Tiago Leitao

Automated construction machinery

ETH spin-off Gravis Robotics develops technology that brings large construction machines to life. The company's product range includes a walking excavator that can autonomously navigate rough terrain and operate in hazardous environments – potentially even on the Moon.

⟶ gravisrobotics.com

Ultrafast and robust

ETH spin-off Menhir Photonics specialises in ultrafast, ultraprecise lasers. The company's lasers are so robust that they can withstand vibrations, impacts and variations in ambient pressure. This makes them ideal for use in the aerospace industry. Other applications include research labs and telecommunications.

⟶ menhir-photonics.com

Robots on patrol

Spin-off company Ascento develops robots for the security sector. These agile, two-wheeled robots use space data for orientation and navigation. They are designed to patrol large sites, day and night, in all weather conditions. The robots get help from features like smart software, a 360-degree camera, a thermal-imaging camera and LEDs.

⟶ ascento.ai

The mobility of the future

ETH spin-off Transcality builds digital twins of transportation systems. With the help of these complex real-time models, it is possible to analyse urban traffic flow and simulate future mobility concepts. The technology is based on satellite data and methods from the field of artificial intelligence.

⟶ transcality.com

Data to boost crop yields

ETH spin-off Terensis combines satellite images from space with growth models to build a digital twin of crops in the field. This virtual image of reality shows the condition of cultivated plants in real time and combines this information with local meteorological data. On this basis, it is possible to predict crop yields and to forecast weather risks such as drought or frost.

⟶ terensis.io

Start-up funding

The ESA Business Incubation Centre Switzerland (ESA BIC CH) supports start-ups that either adapt space technology for use on Earth or modify terrestrial technology for applications in space. ESA BIC Switzerland is operated by ETH Zurich in conjunction with the European Space Agency (ESA). Funding from the ETH Foundation has helped numerous entrepreneurs launch their own start-up. This support includes Pioneer Fellowships and grants from the Excellence Scholarship & Opportunity Programme (ESOP).

Better battery performance

ETH spin-off BTRY develops rapid-charging solid-state batteries that can perform in extreme temperatures. They can withstand very high heat levels, such as those reached in sensors that monitor for steam leaks. But they are also suitable for use at very low temperatures – in equipment for transporting medicines, for instance, or in systems used in space.

⟶ www.btry.ch

Metal foam for heat management

ETH spin-off Apheros produces metal foams for a range of applications, including thermal management. With their extremely large surface area, porous microstructure and high thermal conductivity, these foams are more efficient than conventional cooling solutions. Combined with their lightweight nature, this makes them ideal for potential space applications.

⟶ apheros.ch

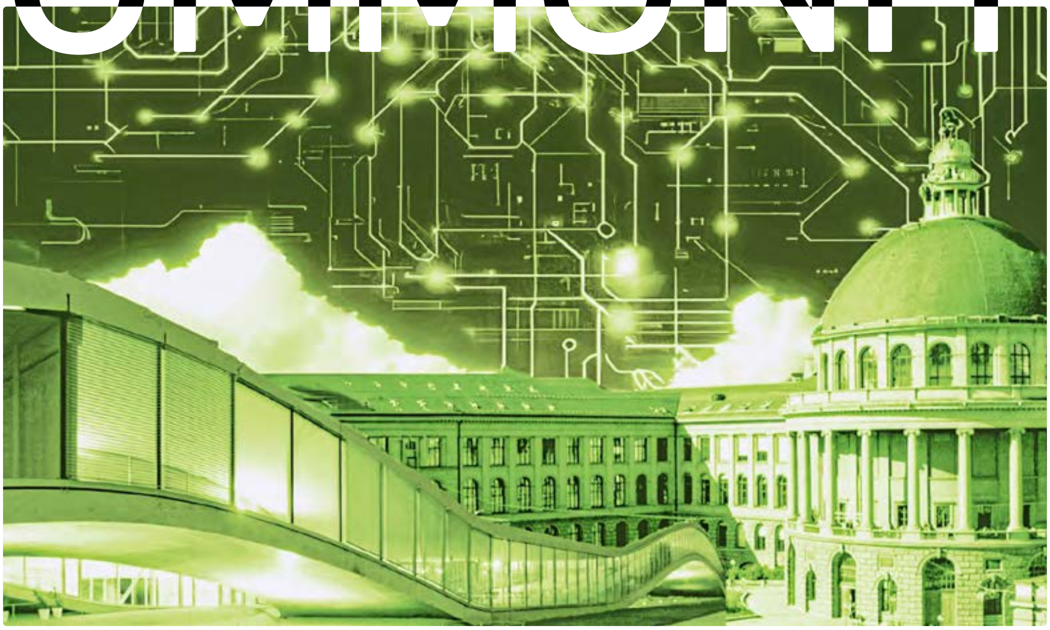


Image: ETH Zurich

ETH Zurich and EPFL have teamed up to propel Swiss AI research to new heights. This AI-generated montage juxtaposes EPFL's Rolex Learning Center with ETH Zurich's main building, symbolising their collaboration.

ETH Zurich and EPFL join forces to boost AI

ETH Zurich and EPFL are stepping up their efforts to position Switzerland at the forefront of global artificial intelligence research. The newly established Swiss National AI Institute (SNAI) aims to create a nationwide platform for AI-driven education, research and innovation. The SNAI will help accelerate implementation of the Swiss AI Initiative, which has received 20 million Swiss francs from the ETH Board for the 2025–2028 period. Additional funding for the institute and its projects will come from ETH, EPFL and external sources.

From its inception, the SNAI will benefit from the expertise of over 70 AI-related professorships across Switzerland, thanks to its affiliation with the ETH AI Center and EPFL AI Center. One key project involves Switzerland's first national foundation model for languages, which will embody Swiss values such as trustworthiness, transparency and open source principles.

The SNAI will work closely with the Swiss Data Science Center (SDSC) and the Swiss National Supercomputing Centre (CSCS). The CSCS develops and operates Alps, a cutting-edge Swiss supercomputer for scientific research with extreme computing and data requirements (see page 38). ○

New makerspace for students

Thanks to generous support from the Georg H. Endress Foundation, ETH Zurich is set to expand its Student Project House (SPH) with a Life Sciences Makerspace. This will enable the SPH to attract students from previously underrepresented disciplines such as chemistry and biosciences, providing them with a unique opportunity to develop methodological skills outside of their programme of study, to network with fellow students and to explore and advance their own ideas.

This donation means that students will now be able to pursue their ideas in a hands-on environment, according to Sarah Endress, President of the Foundation. She is confident this will lead to a wealth of exciting experiences and new approaches that will ultimately have a positive impact on the broader economy. ○

ETH as knowledge generator

ETH Zurich celebrated its 169th anniversary on November 16, welcoming guests from politics, business and academia. The event began with some opening words from ETH Rector Günther Dissertori, followed by a ceremonial speech by Federal Councillor and ETH alumnus Albert Rösti. In his address, ETH President Joël Mesot reaffirmed the university's historical role as a bridge-builder and emphasised the need for unity over division.

This year, ETH Zurich awarded honorary doctorates to five outstanding researchers: Jason W. Chin, Scott E. Denmark, Helen H. Hobbs, Maria Leptin and Susan Trumbore. In addition, the title of Honorary Councillor was bestowed upon economist Andréa M. Maechler and entrepreneur and ETH alumnus Walter Fust. ○

Image: Alessandro Della Bella / ETH Zurich

Federal Councillor and ETH alumnus Albert Rösti completed a degree in agricultural sciences in 1994. In his ETH Day address, he reflected on the symbiotic bond between Switzerland and ETH Zurich.

The right tools to tackle the problems of the future

Where does the future of university education lie? ETH Zurich sets out its vision in a new strategy paper. One thing is clear: the production of specialised knowledge alone is not enough.

TEXT Michael Walther

Resilience, adaptability and the ability to handle failure are essential for solving the problems of the future, which is why ETH will be promoting these qualities even more strongly in the years ahead. That's a key takeaway from "Vision for teaching at ETH Zurich", a strategy paper approved by the ETH Executive Board in summer 2024. The paper explores the challenges the university sector is likely to face in 10 to 15 years' time and considers how teaching at ETH Zurich should address them.

The paper provides a roadmap to guide long-term strategic discussions and decisions regarding issues such as teaching infrastructure and staff. It was prepared by a number of working groups in response to growing student numbers and stagnating funding levels. "ETH aims to continue providing high-quality teaching," says ETH Rector Günther Dissertori. "We must therefore ask ourselves where the future of university education lies." The paper identifies four key factors.

FOR THE GOOD OF SOCIETY Knowledge must flow faster from academia to society and industry, and vice versa. Society looks to ETH graduates to employ their knowledge and expertise for the common good. ETH should aim to become an even stronger platform of exchange between academia, industry and society. At the same time, however, the university should not abandon the close relationship between teaching and basic research.

Image: ETH Zurich

Project-based learning in groups makes students more agile in their approach to knowledge.

KNOWLEDGE ALONE IS NOT ENOUGH The goal of studying is to attain understanding. Specialised knowledge is still important, but so too is the "why" that lies behind it. Students need to understand how knowledge can be used and to what end. ETH aims to teach people how to handle new technology but also how to recognise its limits. This can be achieved through project- and problem-based learning in groups where students practise dealing with the unknown and thereby learn where knowledge reaches its limits. "This type of learning promotes a deep understanding of the principles and methods used in their subject field and encourages students to be more agile in their approach to knowledge," says Dissertori.

MORE FLEXIBLE CURRICULA When designing curricula, ETH will take into account that education is becoming more diverse and knowledge now ages more quickly. "The classic Bachelor's-Master's-job or Bachelor's-Master's-doctorate paths will become less clear-cut," says Dissertori. "Students may want to gain professional experience earlier and will also need to refresh their knowledge more quickly following graduation." To this end, today's tightly regimented curricula must become more flexible and varied. In future, study programmes and their curricula will need to evolve more quickly.

A FORUM FOR THE EXCHANGE OF IDEAS For ETH Zurich, the campus remains indispensable as a place of learning. As the paper says: "The university of the future will remain a place where people come together to research, teach and learn how to overcome challenges and solve problems." The campus is vital for research- and project-based teaching, for integrating students into the academic community, and for facilitating an exchange of ideas across disciplinary boundaries. ETH also needs the campus as a platform of exchange between academia and industry – as is already the case in its numerous continuing-education programmes, for example.

Ultimately, though, the key to achieving these goals is for ETH to continue attracting leading specialists and top-notch lecturers, ancillary staff and students. "When it comes to teaching, the human factor is still the most important," says Dissertori. ○

PHILANTHROPY

DONALD TILLMAN
Managing Director of
the ETH Foundation

A life lived for science

Many of you will know the name of Lucien Trueb, who died last year. Lucien was research and technology editor at the *Neue Zürcher Zeitung* for many years, and I was fortunate enough to get to know this passionate promoter of science. Again and again, I was struck by his immense breadth of knowledge. It is said that the age of the polymath is long gone, but Lucien Trueb could easily have passed for one. An ETH alumnus, he completed a doctorate in electrochemistry in 1960 and went on to publish extensively as a journalist while also writing numerous books. Well into his old age, he continued to volunteer for the ETH Foundation, translating texts into English. Even now, Lucien remains present in much of the work we do. He and his partner, Yoshiko Yasukawa, already benefactors during their lifetime, donated their estate to the ETH Foundation. In this way, they continue to support ETH – or, as Lucien liked to say, its "brilliant minds" – especially in chemistry, physics and materials science. We honour the couple's memory. ○

→ ethz-foundation.ch/en/legacies

Image: Hannes Heinzer

Nurturing young talent

The Excellence Scholarship & Opportunity Programme (ESOP) continues to attract top-tier talent to ETH Zurich. Open to the top 2 to 3 percent of each year's graduates, it enables exceptional Master's students to focus entirely on their studies and research. Fully funded by donations, the programme attracts talented individuals from all over the world. This year's cohort of 58 Excellence Scholars comprises students from 23 countries, including first-time participants from Bangladesh, Ghana, Slovakia and Taiwan. ○

Image: Hannes Heinzer / ETH Foundation

ETH Rector Günther Dissertori (pictured front left) was on hand to greet the talented young scholars at the ESOP Welcome Day 2024.

Czech President visits ETH Zurich

ETH Zurich recently hosted Czech President Petr Pavel, kicking off his two-day state visit to Switzerland. ETH President Joël Mesot welcomed the Czech leader, his wife Eva Pavlová and Swiss President Viola Amherd. The visit included the opening of the Swiss-Czech Biotechnology and Pharmaceutical Forum, an event organised by the Czech Embassy, Switzerland Global Enterprise, and Swiss business association Economiesuisse. Also on the agenda was an informal meeting with Czech students and researchers at ETH. ○

Image: Nicola Pitaro / ETH Zurich

Pictured from left to right: Jana Havrdová (Czech Chamber of Commerce), Ruth Metzler (Switzerland Global Enterprise), Petr Pavel (President of the Czech Republic), Viola Amherd (President of the Swiss Confederation), Eva Pavlová and Christoph Mäder (Economiesuisse).

IN PERSON

Neuroscientist Johannes Bohacek investigates the molecular basis of stress in the brain. He originally wanted to become a psychotherapist.

JOHANNES BOHACEK is Professor of Molecular and Behavioural Neuroscience at the Department of Health Sciences and Technology.

→ bohaceklab.ethz.ch

When is stress harmful, and when is it useful?

The body's reaction to a stressful situation can be vital for survival. It alerts us to danger and quickens our responses. However, excessive or chronic stress can exhaust our energy reserves. This can quickly become harmful, damage the cardiovascular system and pose a threat to our mental health.

Can your research help prevent this?

As someone working in basic research, I'm looking to understand what occurs in the brain during an acute stress reaction. The brain is a highly complex organ, and there's still a lot of work to do in this area, so don't expect an immediate solution from us. In the long term, however, our fundamental research should support the development of new therapies.

Is there one big goal you'd like to achieve?

My dream is that we can discover a molecule or circuit in the mouse brain that can boost stress resilience, and that this will offer a biological way of helping those who struggle to cope with stress. But, realistically, what we're doing is only a small piece of a large puzzle. Working in basic research is like being part of a vast anthill: when one of us finds a grain of sugar, we all benefit.

Originally, you studied psychology. Do you still find that knowledge helpful today?

At the start of my studies, I actually wanted to become a psychotherapist. And I sometimes joke that I now do similar work as a research group leader! Seriously, though, it's important to recognise the strengths and weaknesses of everyone on the team and to make sure they're considered in the context of team dynamics. That can often be a really interesting challenge.

And how do you deal with stress yourself?

Exercise and social interaction are my key stress relievers. I set aside time for both. That means doing sports, spending time with my two little girls and socialising with friends and loved ones. But, like everyone else, I often find it stressful squeezing everything in alongside a busy work schedule. Perhaps the real key to happiness is accepting and enjoying a full, busy life. ○

TEXT Karin Köchle

Image: Annick Ramp / ETH Zurich

Pushing boundaries at Cybathlon 2024

Image: Nicola Pitaro / ETH Zurich

Cybathlon 2024 participants celebrate their achievements.

Held at the end of October, the Cybathlon 2024 attracted entries from 24 countries and a total of 67 teams, including 4 from ETH Zurich. The goal of the event is to advance assistive technologies, which are designed to help people with disabilities tackle everyday tasks. The competition featured eight disciplines, including the newly introduced Vision Assistance and Assistance Robot races. Some 6,000 spectators attended the event, with a further 15,500 viewers following events online from home. The next Cybathlon, scheduled to take place in four years, is expected to be held in Asia. ○

Alps supercomputer unveiled

ETH Zurich has officially inaugurated the new Alps supercomputer at the Swiss National Supercomputing Centre (CSCS) in Lugano. The event was attended by Federal Councillor Guy Parmelin and well-known figures from science and politics.

Alps is one of the fastest computers in the world. A collaborative effort between academia, government and industry, it is designed to meet the extreme computing and data requirements of today's scientific research and to fully harness the potential of artificial intelligence. ○

Image: Marco Abram / CSCS

From right to left: Federal Councillor Guy Parmelin, ETH Board President Michael Hengartner, ETH Vice President for Research Christian Wolfrum and CSCS Director Thomas Schulthess at the official inauguration of Alps.

Cancer researcher receives Cloëtta Prize

This year's Cloëtta Prize has been awarded to Andrea Alimonti, Professor of Experimental Oncology at ETH Zurich and the Università della Svizzera italiana, and Director of the Institute of Oncology Research (IOR) in Bellinzona. Alimonti studies how cancer cells age and how they interact with the immune system. Among his most significant accomplishments is the development of a cancer therapy that actively induces aging in cancer cells. This pro-senescence therapy halts the growth of cancer cells, enabling the immune system to attack and eliminate them. Furthermore, he played a crucial role in discovering a new type of immune cell, myeloid-derived suppressor cells. Particularly in the case of prostate cancer, these cells create an environment that is beneficial to cancer cells, promotes their growth and renders standard cancer therapies ineffective.

The Cloëtta Prize is awarded annually by the Prof. Dr. Max Cloëtta Foundation to two individuals who have made significant contributions to medical research or related scientific disciplines in Switzerland. The prize is endowed with 50,000 Swiss francs for each recipient. The other recipient of this year's Cloëtta Prize is Andrea Ablasser, a professor at EPFL. ○

NATURE'S CLASSROOM

TEXT Vinzenz Greiner
IMAGES Michel Büchel

REPORT The Teaching Diploma in Sport at ETH Zurich is the only programme of its kind in Switzerland. Blending outdoor education with the romance of camp life, the course sees students brave cold water and river rapids.

Lisa Stoffel can't stop shivering. Is her hair still wet from being in the river, or is it just the rain? It's hard to tell in this downpour. The rain has barely stopped since they set out this morning and headed for the River Reuss, near the small town of Bremgarten in Aargau. And the single mug of hot alphabet soup she shared earlier with two of her fellow students has done little to warm her up. It's only an hour since 23-year-old Stoffel and the rest of the group were struggling out of their wetsuits after swimming, one after another, some 200 metres down the dark green river. Avoiding rocks and a washed-up tree trunk, they plunged down a small waterfall and through foaming white water before clambering onto an island.

"The adrenaline keeps your mind off the cold while you're in the water!" she says with a laugh. A website that tracks conditions in the Reuss describes it as "only for the hardcore". The water is currently 15 degrees Celsius, 2 degrees warmer than the air. "Perfect!" declares Simon Starkl, an athletically built bundle of can-do energy who normally teaches at an inter-cantonal police academy. Officers from throughout Switzerland have to join Starkl in the water before they can qualify to become a diving instructor. But on this particular Saturday in September, it's 22 students from ETH who are taking the plunge. They are all studying for their sport teaching diploma under the guidance of Hanspeter Gubelmann. The same man who taught Starkl 13 years ago – and who is now standing in front of them, roll call in hand.

NO FEAR OF THE DEEP "Never go anywhere alone – except to the bathroom," Gubelmann jokes. "And be sure to keep warm!" Gubelmann speaks from experience: he has navigated this river countless times with student groups, spending hours on a raft kept afloat by 300 or so empty plastic bottles. One time, a raft had to be rescued, and there have been the occasional bumps and bruises.

Everyone enrolled in the ETH Zurich Teaching Diploma in Sport has to take "Educational Sciences 2, Sport", which involves a weekend on – and in – the Reuss. So far, 400 students have completed the programme, including one student who arrived in a wheelchair following a gymnastics accident. There have even been students with a fear of deep water. "Sorry, but as a teacher, you've got to learn to deal with that," says Gubelmann. This may sound harsh, but ETH's sport diploma has a reputation for being tough. One of seven teaching diplomas offered by the university as an additional certification programme, it qualifies graduates to teach at the secondary school level.

This is certainly not a course for the fainthearted. It involves learning all about the theory and practice of sports education and the legal or other requirements that have to be met, covering everything from volleyball to first-aid courses over a total of 1,800 teaching hours. There are classes in molecular biology, cell biology and even digital football analysis. Health Sciences students can get credits from modules already completed on their study programme. The diploma is also open to students from other fields, though it would almost be like doing a double degree. ⟶

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1
Lisa Stoffel (third from left) listens carefully as Simon Starkl explains the next activity.

2
ETH lecturer Roger Scharpf oversees the forest activities.

3
Embracing the great outdoors: Maurus Pfalzgraf sits by the campfire.

In fact, only one of the group is studying a different subject: 24 year-old Maurus Pfalzgraf, a student in Environmental Sciences. He actually completed two semesters of Health Sciences with the others before switching majors. As a result, he is able to use some of those credits. "But I still have to put in more work than the others," he explains, stifling a yawn after today's early start.

He seems to have hit the jackpot this morning, however, leisurely pitching his tent while Lisa Stoffel's group is already ankle-deep in the river. While Starkl tells the other students to fall into the water like penguins and float like whales – "Use your legs as rudders!" – Pfalzgraf is busy channelling his Boy Scout knowledge to weave a hammock from rope. Later, this will become a drying rack for wet towels, gently swaying beneath one of the dozen moss-covered concrete bridge piles that used to be part of an old military training ground.

Nearby, a pot of broth steams over a fire, peppered with a few flakes of ash. Two students debate exactly what kind of "black-backed beetle" is currently crawling across their palms. The scene is reminiscent of a post-apocalyptic film that features people learning how to build fires and form a functioning community. And, indeed, being part of a group, and learning how to read it and lead it, form a key part of the course, with nature providing the perfect backdrop.

PLAN B While Pfalzgraf has experienced camp life before on secondary school trips, it was always with a roof over his head. Now, as he surveys the outdoor scene, he wonders if teaching PE really is his calling, or whether he should become a trainer and harness his love of canoeing. That, he muses, might just be "the best job in the world".

He's not alone in that sentiment. The group is a diverse mix of athletes – from 800-meter runners to hockey players and kung-fu artists – and not everyone sees themselves in a classroom. Maxine Monnerat, a former midfielder sidelined by a cruciate injury, says the diploma is a good way of keeping her options open. "I could definitely imagine getting into sports diagnostics," she says, hammering the last bent tent peg into place. Later, she'll be part of the team tasked with prepping materials for tomorrow's raft build, while others tackle projects like crafting makeshift furniture and making a pizza oven. After the weekend, Monnerat will recall how she had her heart in her mouth until that first wave proved their handmade raft was actually seaworthy. Meanwhile, Lisa Stoffel, an avid climber, will be whipping up a spicy curry as part of the cooking squad. For her, the teaching diploma is a solid plan B. She is currently engrossed in Starkl's lesson on river currents, watching intently as he uses a clump of grass to illustrate his points. Stoffel admits that it wasn't until she started the course that she realised her childhood dream of teaching PE might actually be the perfect fit.

Roger Scharpf, sporting a cyclist's tan from a recent Geneva to Côte d'Azur trip with students, is fine with the fact that not everyone wants to become a teacher. "Some graduates end up in sports diagnostics, others in physiotherapy or research. And some will become instructors like Starkl or teachers like myself," he says. A secondary school teacher in Aargau and a lecturer at ETH, Scharpf is in charge of the forest activities, while his colleague Gubelmann stands ready by the Reuss, rope in hand, as a safety precaution for the river group.

LEARNING BY DOING Scharpf and Gubelmann began running this outdoor instruction programme a decade and a half ago. The differences in teaching maths and PE had become too stark to ignore, so the two men jumped at the chance to revamp the educational sciences component of the Teaching Diploma in Sport.

Together with the mountain-savvy Gubelmann, Scharpf was keen to apply his experience of Scotland's outdoor education philosophy. Their concept sailed through curriculum approval. "We just went for it," says Gubelmann with a grin.

But why take learning outdoors? Scharpf believes there's something transformative about battling through days of rain. And Gubelmann points to the growing trend of school project weeks, which will make this kind of training increasingly relevant. "Plus, kids these days need more time in nature," he adds. "They spend most of their time indoors."

Getting out into the fresh air makes sense, but why come to a river? "Statistically, most outdoor accidents happen in rivers," Gubelmann explains. "So teachers need those skills." But does it have to be a river as challenging as the Reuss? "We're not ⟶

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Hanspeter Gubelmann has been responsible for the educational science part of the Teaching Diploma in Sport for fifteen years.

5
Maxine Monnerat (left) helps build the raft – but will it be strong enough to survive its maiden voyage?


4

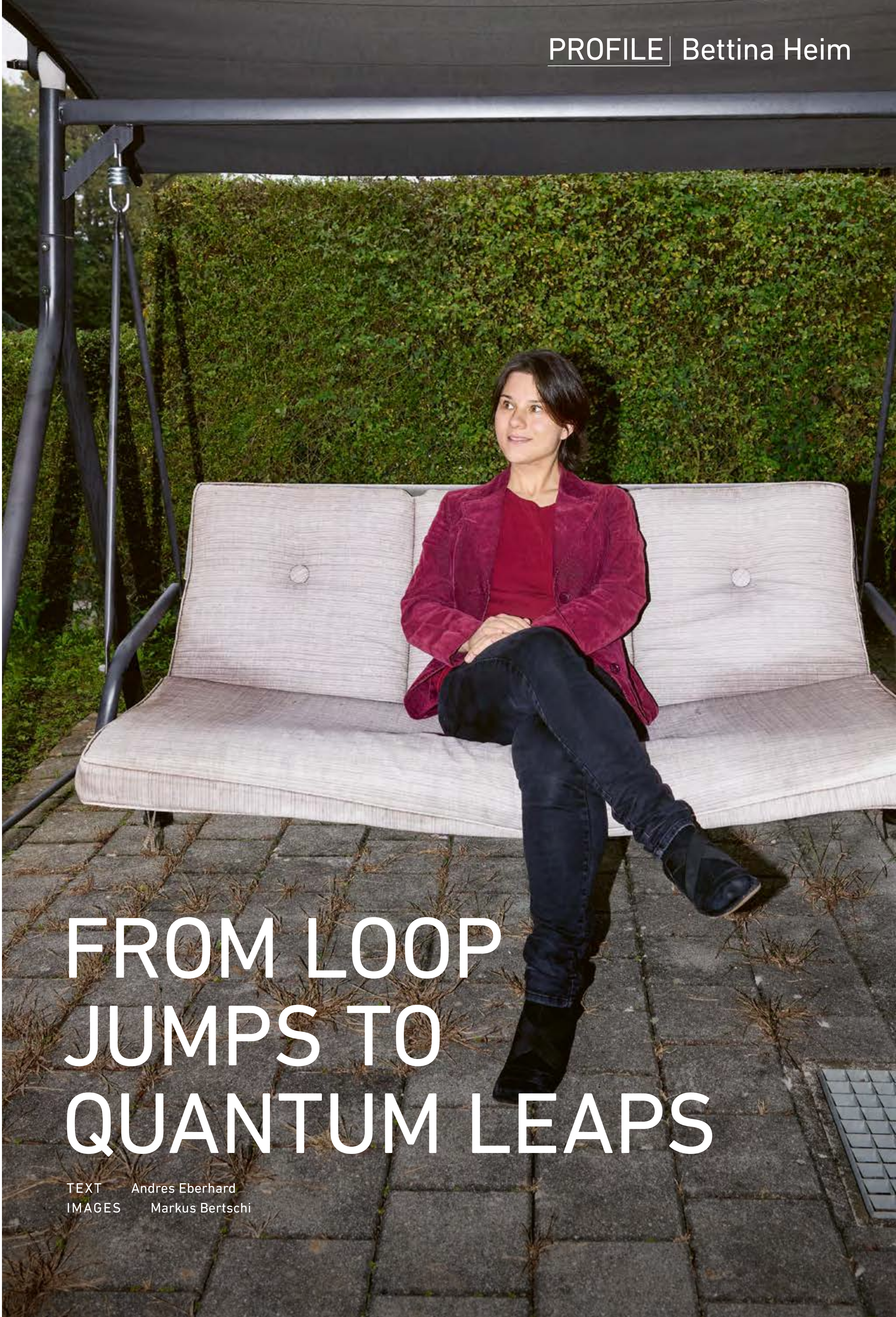

5

Image: Roger Scharpf

here to put people in danger, but to teach them how to assess risk," Gubelmann says, his sports psychologist background coming to the fore. That's where Starkl's expertise pays dividends.

"He's a great instructor!" says Stoffel. "And it will be good for my teaching career to be able to say that I'm speaking from experience." She's already envisioning a raft-building project with her future students. For Monnerat, the weekend was all about getting people out of their comfort zone. If she does end up in a classroom instead of working in sports diagnostics, she will definitely be taking the outdoor concept on board. Her own secondary school offered similar outdoor electives, including a bike tour to the Côte d'Azur – the same route Scharpf has spent years cycling with his students.

Scharpf is delighted at the thought that his ideas might be catching on. "There's no copyright on good teaching," he says. "We're happy to share what works." It seems that ETH's method of outdoor sports instruction has made quite a splash in the world of education. ○



FROM LOOP JUMPS TO QUANTUM LEAPS

TEXT Andres Eberhard
IMAGES Markus Bertschi

Bettina Heim won the Swiss figure-skating championships before developing an interest in quantum computing. She studied physics at ETH and now develops software for the computers of the future.

Bettina Heim is at the forefront of efforts to achieve a breakthrough in quantum computing. Employed by US company Nvidia, this 35-year-old former ETH researcher is helping to develop the computers of the future – and it's hard to envision her in a more fitting job. Just like quantum computers, Heim cannot easily be described in terms of either/or attributes – the ones and zeros, or "bits", used by conventional computers. The systems she works on use quantum bits, or qubits, as the smallest unit of information – and qubits can exist in a state of superposition, in which they can be zero and one simultaneously.

Heim, too, manages to be many things at once. A brilliant quantum physicist, she wrote her dissertation on quantum computers while studying for her Bachelor's degree in Physics, a work that was subsequently accepted for publication by the scholarly journal *Science*. Yet Heim is also a gifted figure skater and sportswoman, someone who was attracting attention for her pirouettes, loop jumps and Salchow jumps long before she embarked on her academic and professional career. Aged 21, she won the Swiss Figure Skating Championships, which marked both the culmination and conclusion of her sporting career.

SKATING FROM THE AGE OF TWO Heim is sitting at the dining table of her home in the Swiss canton of Aargau. She and her husband moved in only a week ago, and there are still boxes stacked up all over the house. Every now and then, one of her two Sphynx cats leaps onto the table hoping for a stroke. "I'm just a naturally passionate person," says Heim. "Give me a hobby, and I'll end up transforming it into a career!"

She recalls getting hold of a pair of skates at a flea market when she was two. "And I just wouldn't let go!" she laughs. The ice rink was a short walk from the family home, so her parents let her have her way and supported her new hobby. Later, long after discovering her interest in the natural sciences, Heim would earn money from her figure-skating skills: early on in her degree programme, she gave lessons to people hoping to become more confident on the ice, from two-year-olds to physics professors. Working on a self-employed basis, she dedicated 50 to 60 percent of her time to coaching.

FROM APPENZELLERLAND TO ETH Heim's involvement in the quantum leap of computer technology was far from a foregone conclusion. During the computer gold rush of the 1990s, she was still living in the Appenzell town of Herisau, far from the cutting edge. Her parents worked in sales – tractors and the retail trade – and the family didn't even own a computer until the mid-2000s.

It was only when Heim was about to take her baccalaureate that she realised she was not only a whizz at science but also had a knack for programming. She applied to study physics at ETH and was then awarded an Excellence Scholarship. "That allowed me to give up my job at the rink and focus all my attention on my studies," she says. In her Bachelor's dissertation, she took her first plunge into quantum computing with an investigation into why the world's first commercial quantum computer, D-Wave, fared so poorly in so many areas when pitted against conventional computers. She managed to get her paper published in the scholarly journal *Science*, succeeding straight off at something that others take years to achieve. After finishing her degree, she completed a doctorate under the supervision of Matthias Troyer, then Professor of Computational Physics at ETH. Eventually, she followed her mentor into the tech industry, spending four years

BETTINA HEIM is a team leader at US company Nvidia, where she develops software for quantum computers. After studying physics at ETH and obtaining a doctorate in Computer Physics, she spent six years working for Microsoft in the US, before moving back to Switzerland. Prior to her career in science and industry, Heim was a professional athlete who won the Swiss figure-skating championships and competed in two world championships.

living in Seattle and working for Microsoft. Two years ago, she returned to Switzerland. Her husband feels more at home here, and she wanted to be closer to her mother after the death of her father.

SOFTWARE FOR QUANTUM COMPUTERS At Nvidia, Heim got the opportunity to build her own team from scratch to develop software for quantum computers. "For too long, experts in quantum computing have focused solely on hardware and just assumed that the software would take care of itself," she says. "But normal software wouldn't even work on a quantum computer!" The first significant achievement by Heim and her team was the development of an interface called CUDA-Q, which allows researchers to write programs for quantum computers using conventional programming languages such as Python and C++.

Heim has already set up her office upstairs. The curved widescreen monitor seems surprisingly compact given the field she works in, and her computer is of a normal modern type. "When I need to run quantum simulations, I connect to a powerful computer in our office on Europaallee in Zurich," she says. Heim spends most of her time working from home, just like her colleagues. And with most of the team living in the US, she tends to start work at midday and continue into the late evening. Asked what she learned from her sporting career, she says it taught her how to deal with setbacks. Yet the ice rink was also very much a lone-warrior experience, and she relishes the opportunity offered by her current job to help people get the best out of themselves. The majority of her working day is spent on calls to colleagues, and any programming she wants to do tends to be relegated to her free time or weekends. Heim works hard and has always been passionate about what she does, but she is increasingly aware that it can sometimes be good to take a step back. "I've actually started doing a bit of gardening," she says.

Heim comes straight to the point when asked what she hopes to achieve in her career: "I'd like to help get us to the stage where we can do something useful with quantum computers." It's true that these new computers have not yet proved to be particularly good at anything, and that conventional computers are still far better at most everyday computational tasks. But nobody would deny that the theoretical potential of quantum computing is vast. For example, it would take a normal computer millions of years to find the prime factors of a 2,048-bit number, while a quantum computer, working with qubits, could perform the calculation in a matter of minutes. "There's a perfectly realistic chance that, in a few years' time, quantum computers will be better than conventional computers at tackling certain tasks," says Heim.

But what purpose will they serve? This is a tricky question, and researchers are currently trying to identify ways of putting the technology to practical use. "The aim is not to run Microsoft Word on quantum computers, but to use them to solve very specific problems," says Heim. In other words, quantum computers will never replace ordinary PCs, but they could help shoulder the burden of extremely complex computational tasks.

Many observers remain confident that advances in quantum computing will have a revolutionary impact – for example, by transforming drug development. Heim remains cautious, though she concedes that quantum computers could help drive the machine-learning aspects of AI. "I'm optimistic that quantum computers will eventually live up to their potential, even if it's still hard to say what exactly that potential is," she says. In the meantime, she feels it's an exciting time to be working in this field. "I missed out on the development of computer technology by a generation, but being part of the blossoming of quantum computing is a very similar feeling!" she enthuses. ○

"I'd like to help get us to the stage where we can do something useful with quantum computers."

Bettina Heim

DISCOVER

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⟶ www.brainfair.uzh.ch

○ Exhibition

The prints of Albrecht Dürer

Setting standards, defying norms

Image: Albrecht Dürer, Rhinoceros, 1515; woodcut, 24.3 × 30.8 cm; Graphische Sammlung ETH Zurich

The Graphische Sammlung at ETH Zurich houses almost the entire range of Albrecht Dürer's printed oeuvre. The holdings are of very high quality, even including examples of his rare iron etchings and drypoint prints. The works selected for this exhibition highlight Dürer's relevance to contemporary artistic discourse and honour him as an artist whose printed oeuvre not only defied norms but also set standards.

ETH Zurich, Zentrum campus,
4 December 2024 to 9 March 2025

Find out more:
⟶ gs.ethz.ch/en

Image: Thomas Mann Archive, ETH Zurich

○ Video series

Centenary of The Magic Mountain

What do DJs have to do with Thomas Mann's novel The Magic Mountain? Is it true that the novel only exists thanks to a misdiagnosis and the Rhaetian Railway? And what's the best translation of Seelenzergliederung – "psychoanalysis" or the more literal "dissection of the soul"? It has been 100 years since the publication of this celebrated work. Since then, it has been translated and interpreted numerous times. But how should we read it today?

To mark the novel's centenary, the Thomas Mann Archive has produced four short films that examine its historical and contemporary relevance in an ETH context. With its insights into the history of technology, The Magic Mountain is a rich source of information on technological progress and social upheavals. In the videos, experts take a fresh look at this work.

Find out more about the videos:
⟶ ethz.ch/zauberberg-en

○ Public Tour

Atomic nuclei: the spy within

Nobel Prize tour with chemistry lab visit

With his groundbreaking research into nuclear magnetic resonance spectroscopy, Nobel Prize winner Richard Ernst from Winterthur made a key contribution to the development of modern diagnostics. Yet the path he took was sometimes rocky. The tour takes us behind the scenes of Ernst's life and, together with one of his former colleagues, investigates how his work connects with today's research – including a visit to some giant magnets!

Find out more and book your place:
⟶ tours.ethz.ch/en

○ *focus*Terra Fairy Tale Sundays

Fairy tale geology

Image: *focus*Terra

The Earth's superpowers
An afternoon of experimentation and storytelling.

Together with the Swiss Fairy Tale Society, *focus*Terra invites the whole family on a journey of discovery. Kids will enjoy the fairy tales with musical accompaniment before getting down to activities designed to help them discover the earth's superpowers. The perfect outing for the entire family (for children aged six and over).

*focus*Terra, Zentrum campus
12 January 2025, 2 – 3 p.m.
Followed by a range of kids' activities until 4.30 p.m.

Find out more:
⟶ focusterra.ethz.ch/fairy-tales

○ Recommended reading

A book to fall asleep to

In today's fast-moving digital world, sleep problems are increasingly common. So what are the latest insights from the sleep lab? How can we make use of them? And which tips really help? This book brings together findings from over 15 years of sleep research and draws on the authors' experience of running mindfulness workshops on the subject of sleep. The book also comes with a downloadable sleep log.

Caroline Lustenberger, a neuroscientist and lecturer at ETH Zurich, has spent many years working in sleep research at an international level. Salome Kurth is assistant professor of biology and a sleep researcher. She lectures at a number of universities and gives praxis-oriented research seminars on the subject of sleep.

Beobachter Edition
ISBN: 978-3-03875-573-9

Interview with ETH sleep researcher Caroline Lustenberger:
⟶ ethz.ch/booktip-sleep

Image: Beobachter Edition

Image and video: Nicole Davidson / ETH Zurich

The SmartStamp app is used to verify the authenticity of artworks.

Biometrics for artworks

TEXT Karin Köchle

In the art world, a certificate of authenticity is the traditional guarantee of originality. Typically issued by artists, art dealers or private sellers, these certificates serve to distinguish genuine works from forgeries. The problem is that the actual proof of originality often amounts to little more than a signature on a piece of paper or a label on the back of an artwork – something that has proved all too tempting for fraudsters.

Gregor Kisters, an ETH Master's student in Materials Science and Engineering, has now developed a fail-safe, tamper-proof technology to authenticate art works. The SmartStamp app combines machine learning, artificial intelligence and computer vision to create what amounts to a unique digital fingerprint – essentially biometrics for artworks. With this patented technology, the company behind the app has introduced a new benchmark for the art world. ○

STUDENT PROJECT HOUSE This creative thinkspace and makerspace provides ETH students with support in developing and implementing their own project ideas.

⟶ sph.ethz.ch

Video: SmartStamp
⟶ youtu.be/7_YOrx2XksQ

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