Switzerland in space
Cutting-edge research and high-tech solutions – for everyday life

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Swiss Confederation

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What is the significance of space for science, technology and industry in Switzerland?

Switzerland has been an integral and active partner in the European space adventure since its very beginning. It has been the aim of our skilled scientists and entrepreneurs to make cutting-edge science happen and to transfer the resulting applications into the economy for the benefit of society. The pride we feel of being a founding member of the European Space Agency (ESA) has been equaled by our determination to work even harder for the advancement of European space during our co-presidency together with Luxemburg of ESA's Ministerial Council from 2012 to 2016. A major highlight during this period was certainly the decision to develop Ariane 6 thus guaranteeing the continuation of an autonomous European access to space at competitive conditions. Our commitment has led to higher political attention at European, as well as at national level of what Switzerland does in space.

Space is a global business. European States working together can and do achieve far more than any single one actor on its own. This is why we have chosen ESA to be our only space agency. Together with the excellence and commitment of our space community ESA has enabled Switzerland to play important roles in scientific missions and industry consortiums. In the following pages, you will (re) discover the numerous Swiss and European success stories in space through the eyes of those who make space happen here on the ground and of course in space, and the important contribution that science and space technologies make to people's lives.

Operational applications based on telecommunication, navigation and Earth observation satellites contribute to a better understanding of our planet, a more efficient traffic management on land, at sea and in the air, or to bridge the digital divide, just to name a few. The key drivers of Switzerland's action in space include scientific and technological progress, enabling us to not only position our country as a competitive and reliable partner in specific niches, but also to contribute to the competitiveness of European space industry as a whole. One of the striking examples are the payload fairings for the European Ariane and Vega launchers.

It cannot be sufficiently emphasized how harsh and unforgiving the Space environment is. Its exploration and exploitation pushes our scientists and entrepreneurs to explore their limits. It is an exciting and challenging area with prospects that can be unknown at the start in which success depends on the combination of skills and expertise to get it right. The demand for space systems that function reliably for years on end means that the resulting technologies are the best possible, simultaneously offering transfer possibilities to non-space markets. The key to sustainable development in this sector, as in others, lies in the advancement of technology and the innovation capacity of industry. Thanks to the stringent requirements of space projects in all aspects – from programme management to quality control – space industry creates jobs and growth well beyond the space sector itself.

Johann N. Schneider-Ammann
President of the Swiss Confederation 2016
Head of the Federal Department of Economic Affairs, Education and Research EAER

“Space is helping us understand our world better.”

Space has become an essential part of modern society. Scientists use space missions to research the universe and our solar system and its planets. Satellite-assisted communication, meteorology, navigation, cartography, and earth observation have brought space into our everyday lives. They have given us reliable weather forecasts, safe landings, functioning mobile phones and satellite navigation systems, television programmes from around the world, and the digital revolution in photography. Satellites send us climate data and help us to manage the risks associated with natural disasters. They monitor unstable mountain slopes and vulnerable infrastructure, helping farmers to increase yields.

Space also plays an important role in Switzerland’s policy, from industrial and infrastructure policy to targeted international cooperation in Switzerland’s interest. Switzerland was a founding member of the European Space Agency (ESA). For 40 years, our country has been at the forefront in developing rockets and research programmes. We are helping to build a competitive, independent Europe in space that serves society and responds to its needs. The European satellite navigation system Galileo is an example of this.

Our space policy guarantees access to space for science and the economy. A long series of international treaties and agreements ensure that we all have access to the resulting data. Our space policy is in line with our foreign policy, sharing the same active dedication and solidarity. In this context, Switzerland is committed to the peaceful, secure, and sustainable use of outer space. Internationally, it supports development of guidelines to prevent proliferation of space debris from becoming a threat to the space industry and people down on earth. Space technologies help us to analyse global problems and seek solutions in the areas of climate change, environmental protection, food security, and prevention of natural and technological disasters.

For Switzerland, space is not only synonymous with innovation, cutting-edge technology, precision, and scientific excellence, it also stands for value creation, thanks to European and global cooperation. This brochure aims to present the Swiss space sector to a wider audience and show how it benefits us all in our everyday lives. I hope you enjoy reading it.

Didier Burkhalter
Federal Councillor
Head of the Federal Department
of Foreign Affairs FDFA

Swiss Space Policy

Space activities play an important role in our society. Alongside their scientific contributions to the exploration of Planet Earth and of the Universe, they have made their way into our daily lives: satellite telecommunication, navigation assistance on land, sea and in the air, or even Earth observation from space for weather forecasts or for a better understanding of climate change have become indispensable.

Switzerland has been active in this fascinating and demanding domain since the beginning of the space era. The country has found its place in the European space community, and is thus in a position to also safeguard its interests globally. Switzerland aims to be a serious, competitive and reliable partner. Its strong position is thanks to its long-standing competences such as innovative capacity and precision.

Engaging in space constantly challenges inventiveness in research and in industry. Space is a vital contribution to the prosperity of our country. It includes activities with high added-value, which will also be of benefit for future generations.

Principles of the Swiss space policy

Switzerland is active in space, focusing on:

- development and exploitation of space-based applications with the aim of improving the quality of life for its citizens;
- long-term safeguard of its commitment to space research for the benefit of innovation and the knowledge society;
- provision of key scientific, technological, and industrial contributions enabling the country to position itself as a competitive, reliable, and indispensable partner.

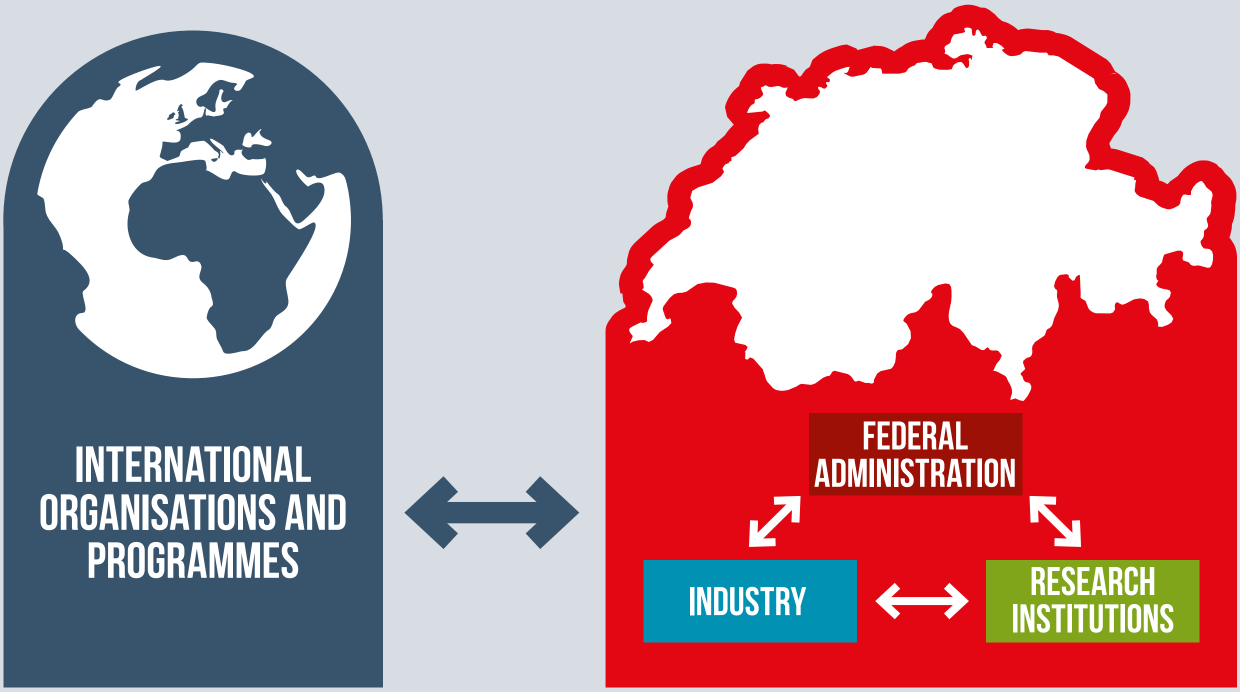
Implementation

Switzerland safeguards its national interests via chosen international collaborations, in particular through selective participation in programmes and activities of the European Space Agency (ESA), and some further European and international space activities. In addition, complementary national activities contribute to position research institutions and industry favourably with regard to future procurement opportunities in institutional European programmes. They contribute to strengthen the existing competences in established and new scientific and technological domains.

It is the Federal Council that decides on the Swiss space policy. Such decisions are based on recommendations formulated by the Federal Commission for Space Affairs. The responsibility for preparing and implementing the national space policy lies with the Swiss Space Office of the State Secretariat for Education, Research and Innovation (SERI), in close cooperation and coordination with the Ministries and Federal Offices which have space related tasks.

The Confederation creates the boundary conditions to enable for Swiss actors to become successful in science, research, technology and industry in the European and international environment. However, the research institutions and companies are, together with their employees, ultimately the ones creating the Swiss successes in space.

Context and main actors for Swiss space activities



Thomas Hurter, member of the National Council
President of the Federal Commission for Space Affairs

„Space has become an indispensable part of our lives. Many of the daily applications we use have been developed thanks only to space activities. Switzerland's participation in space programmes allows our small but highly innovative country to play a leading role in the progress of science and technology. This is even more important because the significance of space will further increase, in particular in sectors such as energy, environment, traffic, transport and security."

Space adventure – selected historical Swiss contributions

1960

Early days of European cooperation in space: Meyrin, Switzerland – Delegates of the Intergovernmental Conference of Space Research. Switzerland was among the nations that created the European Space Research Organisation (ESRO), one of the organisations that paved the way for Europe to enter space. © ESA

1986

Up close in deep space: Giotto, ESA's first deep-space mission, passes closest to the famous Halley's comet with a mass spectrometer from the University of Bern on board. For the first time the instrument made in situ measurements of a comet's dust and gas. © ESA

1990

Reaching for the sun: Launch of the ESA/NASA Ulysses mission. During its almost 18 years of uninterrupted observations of the sun and the heliosphere, Ulysses has made fundamental contributions to our understanding of the sun and our local interstellar neighbourhood. The mission, the longest in ESA's history, included the Solar Wind Ion Composition (SWICS) instrument from Switzerland. © ESA

1995

Beyond our solar system: Michel Mayor and Didier Queloz of the University of Geneva discover the first planet outside the solar system in orbit around the nearby star 51 Pegasi. © ESA

2008

Onboard Columbus: SOVIM, an instrument to observe and study the irradiance of the sun with high precision, stability and accuracy was among the first experiments on board the European Columbus research laboratory attached to the International Space Station ISS. The Swiss instrument was from the Davos Physical Meteorological Observatory. © ESA

2009–2010

Hands-on education and training: 'Swisscube', a cubesat, launched in 2009 with the scientific aim of observing airglow, was manufactured entirely in Switzerland and has enabled around 200 students from the Swiss Federal Institute of Technology in Lausanne (EPFL) and Universities of Applied Sciences to collaborate closely. A team from the University of Applied Sciences and Arts of Southern Switzerland launched the educational Tisat-1 in 2010. © EPFL

2012

Protection for another European launcher: The maiden flight of the European Vega launcher, with its payload protected by a Swiss fairing, built by RUAG Space. Swiss payload fairings continue to provide reliable services on board European and American launch vehicles. © ESA

1969

From Bern to the Moon and back: During the first landing on the Moon, astronauts deploy the Solar Wind experiment devised by Johannes Geiss, a professor at the University of Bern, to study the sun's continuous flux of charged particles or the so-called 'solar wind'. This experiment helped to resolve the competing theories about the origins of the solar system, planetary atmospheres and solar wind dynamics. © NASA

1975

One roof for space: Creation of the European Space Agency (ESA), of which Switzerland is a founding member. This was the result of a merger between the ESRO and the European Launcher Development Organisation (ELDO). That also allowed for the scope of the new agency's remit to be widened to include operational space applications systems such as telecommunications satellites. © ESA

1978

European astronaut selection: Swiss-born Claude Nicollier is selected in the first group of ESA astronauts to fly on board the US Space Shuttle. Nicollier was a crewmember on four Space Shuttle flights in 1992, 1993, 1996 and 1999, and logged more than 1000 hours in space, including a spacewalk to install new equipment on the Hubble space telescope. © ESA

1979

Launcher payload protection – swiss-made: The maiden flight of the European Ariane-1 launch vehicle, featuring a Swiss payload fairing. Ariane-1 was designed primarily to put two satellites into orbit at a time, thus reducing costs. As the size of the satellites grew, Ariane-1 began to give way to the more powerful Ariane launchers. RUAG launcher fairings continue to enjoy success for their reliability to this day. © ESA

2002

Launch of the most advanced gamma-ray observatory INTEGRAL: The **Inte**rnational **G**amma-**R**ay **A**strophysics **L**aboratory (INTEGRAL) Science Data Center attached to the University of Geneva receives the spacecraft's scientific data within seconds and provides alerts, processed data and analysis software to the worldwide scientific community. INTEGRAL was designed to gather some of the most energetic radiation that comes from space. © ESA

2004

Launch of Rendez-vous with a comet: Rosetta was the first ever spacecraft designed to chase, go into orbit around, and land on a comet. It studied the comet 67P/Churyumov-Gerasimenko with a combination of remote sensing and in situ measurements, with key Swiss instrumentation on board, namely the Rosetta Orbiter Spectrometer for Ion and Neutral Analysis (ROSINA) from the University of Bern. © ESA

2008

Swiss precision in space: In preparation for deployment of the Galileo System, ESA initiated development of two on-board clock technologies in the 1990s: the Rubidium Atomic Frequency Standard (RAFS) and the Passive Hydrogen Maser (PHM). After the Rubidium clocks had been flown on the first Galileo test satellite launched in 2005, the first PHM clock undergoes in-orbit testing on board the second Galileo test satellite, GIOVE-B. © ESA

2012–2016

First chair: Switzerland and Luxembourg are formally elected as co-presidents of ESA's Ministerial Council. © ESA

2013

Launch of the 4th Automated Transfer Vehicle (ATV), Albert Einstein: Named following a Swiss proposal, it is one of the five ATV spacecraft developed by ESA that have made an essential contribution to the resupply of the ISS. Important ATV components were built by Swiss industry, including the spacecraft structure (RUAG Space), protection against micro meteorites (APCO Technologies), and electronic components (Syderal). © ESA

2013

Selection of CHEOPS (CHaracterising ExOPlanet Satellite) as the first small mission developed in the framework of ESA's scientific programme. The consortium of 11 countries participating in the mission is led by the principal investigator Willy Benz, a professor at the University of Bern. The mission is in its implementation phase with a scheduled launch in 2018. © ESA

Reliable weather forecasts and climate data thanks to satellites

Alex Rubli
MeteoSwiss

When TIROS 1 produced the first weather satellite images in 1960, the excitement must have been tremendous – meteorologists had been developing theories about weather fronts for half a century, and now, for the first time, they could actually see the bands of clouds and low-pressure vortices corroborating their theories. Today it is impossible to imagine modern meteorology and climate research without satellites.

Switzerland has been using weather satellites systematically since 1977, when the European Space Agency (ESA) sent its Meteosat 1 satellite into orbit. Switzerland was one of the founding members of the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT), an interstate body established in 1986. Since then, EUMETSAT has worked together with ESA to ensure the smooth operation of the European weather satellites. Switzerland is also the depositary state for the EUMETSAT Convention.

Satellites make our lives safer

Nowadays, weather stations receive satellite images every 15 minutes. These provide meteorologists with an accurate overview of the weather situation and are an indispensable tool for making weather forecasts and issuing weather alerts in particular. Satellite images make it possible to determine the exact position of weather fronts. The data provide information on cloud structure, and meteorologists can predict the potential for thunderstorms based on this. Thanks to satellite data, meteorologists can measure the temperature of clouds and the cloud top, which can be used, for example, to warn pilots if their aircraft is in danger of icing. Is there more fog on the way? Or is it clearing up? Is the cloud cover starting to dissipate? Will a clear winter sky make the roads slippery? Meteorologists also use satellite data to answer questions like these.

Weather satellites are becoming increasingly efficient. Numerical weather models are also being further developed, which are fundamental today for forecasting the weather. These models are fed with millions of pieces of satellite data every day, which means that the weather satellites also have their role to play in ensuring that forecasts are even more accurate and reliable – not only in the short term, but for several days or even weeks in advance.

Satellites help us to understand climate change

Satellites also make an important contribution to climate observation. For the past 40 years they have been taking regular measurements that help us to understand climate change better. Satellites observe a number of different climate-relevant variables, accurately measuring the composition of the atmosphere, cloud structure, snow cover, glacier extent, soil moisture, or sea level.

Satellite data are part of the Global Climate Observation System (GCOS). Swiss institutions participate in a number of international initiatives working to create comprehensive data sets from satellite data. For example, MeteoSwiss determines long-term solar radiation in a time series for the EUMETSAT climate observation initiative. The Swiss Federal Laboratories for Materials Science and Technology (EMPA), the Federal Institute of Technology in Zurich (ETH Zurich), and the University of Zurich have been mandated by ESA's Climate Change Initiative to analyse data on greenhouse gas emissions, clouds, and glaciers.

Satellite data also make other services possible that directly benefit everyone, such as Switzerland's interactive solar atlas implemented by MeteoSwiss, swisstopo, the Swiss Federal Office of Energy (SFOE) and Meteotest. The website www.sonnendach.ch is for all those interested in finding out if the roof of their house can be used to generate solar energy and how much heat and electricity can be produced too.

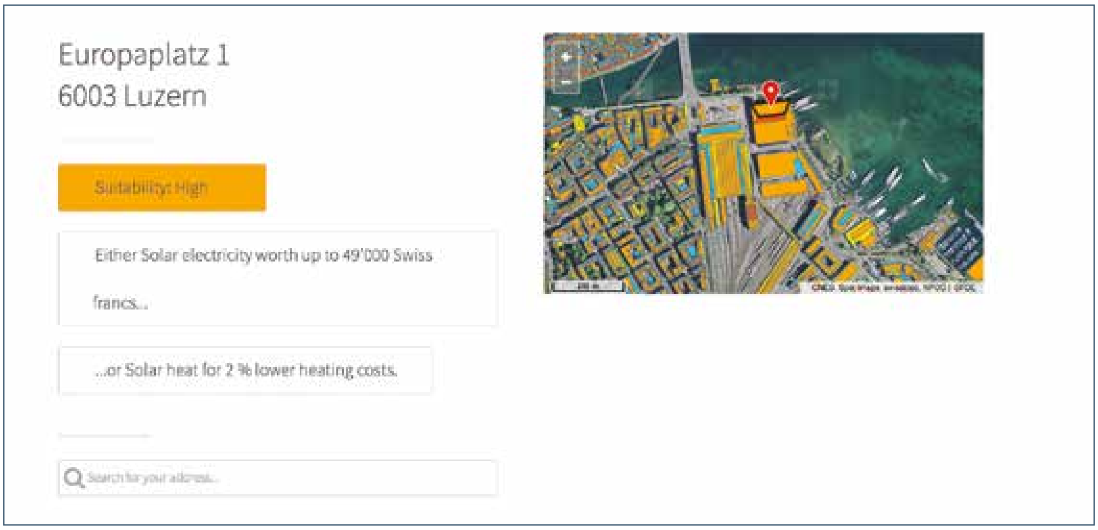
MSG satellite image of weather systems in the northern hemisphere © EUMETSAT

Economic and social benefits

Satellite data make weather forecasts significantly more reliable than those based 'only' on conventional observation. The EUMETSAT Polar Systems – Second Generation (EPS-SG) satellites alone will generate savings of up to Euro 63 billion in Europe. The satellites were developed jointly by ESA and EUMETSAT. They are expected to deliver weather data from a polar orbit between 2021 and 2042.

This data will enable meteorologists to issue bad weather alerts earlier, so that people and farmers can take precautions to reduce the potential damage to their homes and crops, prevent crop losses, and even save lives. The economy also benefits from more reliable weather forecasts. The aviation sector, for example, has managed to make significant savings, thanks to weather forecasts, such as by reducing flight delays and fuel consumption.

Excerpt from the solar atlas
(source: http://www.bfe-gis.admin.ch/sonnendach)
© SFOE, swisstopo, MeteoSwiss



Safer landing thanks to the EGNOS satellite navigation system

skyguide

Satellite navigation is already having an impact on flight procedures and this will increase in the coming years. The potential of new navigation technologies such as the European Geostationary Navigation Overlay Service (EGNOS) lies primarily in their more accurate positioning. This enables safer landings of aircraft and helicopters as well as more efficient air traffic management. Pollutant and noise emissions are reduced, as are fuel consumption and airport operators' costs.

The European EGNOS satellite navigation system complements the United States' Global Positioning System (GPS). It improves the accuracy and reliability of navigation signals. Aircraft and helicopters no longer have to rely on the instrument landing system, especially when making a runway approach in poor visibility. Thanks to the high-performance satellite system and appropriate onboard equipment, pilots making a landing can follow a three-dimensional flight path from the start of the descent until touching down on the runway.

Phased introduction

EGNOS is being gradually introduced at all airports in Switzerland and at Swiss Air Rescue (Rega) helicopter bases. Each new implementation procedure is tailored to the needs of individual airports and airspace users. Operators are not only able to increase safety and capacity but also to reduce the costs of technical infrastructure needed on the ground for landing approaches.

How does EGNOS work?

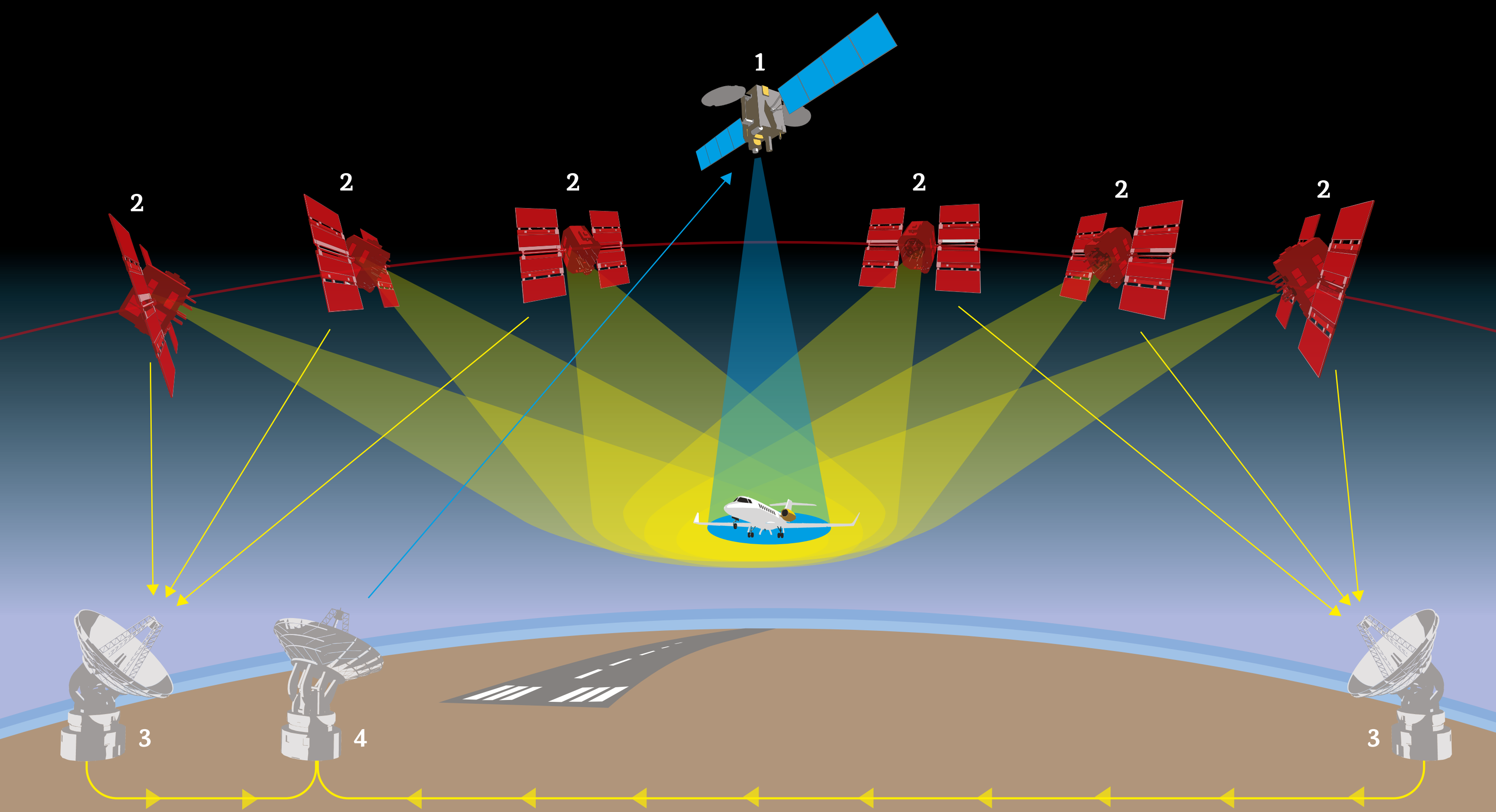
EGNOS consists of three geostationary satellites, which are 'fixed' at a point above the equator and always emit signals in the same region, as well as a network of ground stations. The system continuously verifies GPS signals and immediately transfers its corrections to EGNOS receivers. Thus EGNOS increases the accuracy of the GPS signal so that aircraft and helicopters can be navigated accurately even in narrow valleys and when landing.

EGNOS is a joint project of the European Space Agency (ESA), the European Union (EU) and the European Organisation for the Safety of Air Navigation (EUROCONTROL), which developed it as the European Tripartite Group (ETP). It is Europe's first venture into satellite navigation and a precursor to the European satellite navigation system, Galileo, which it will complement in the future. Galileo should be fully operational by 2020 and its 30 satellites will cover the globe. European Satellite Services Provider (ESSP), a company based in Toulouse, operates and markets EGNOS on behalf of the EU.

In Switzerland a national platform has coordinated flight procedure projects since 2008 and provides a framework for their implementation. In addition to skyguide, the Federal Office of Civil Aviation (FOCA), the Air Force, the international airports of Zurich and Geneva, regional airports, Rega and the airlines Swiss and easyJet are represented on this platform.

"The EGNOS system is a huge step forward for us," says Rega chief pilot Heinz Leibundgut. "Thanks to EGNOS we can navigate much better in difficult terrain, even in poor visibility and during night missions. This is an enormous advantage particularly in Switzerland. EGNOS means Rega can frequently also undertake missions in difficult weather conditions. It increases safety for pilots and passengers while speeding up rescue operations."

Thanks to EGNOS, Rega was able to perform the first helicopter precision approach in Europe. © Rega



Procedure based on GPS and EGNOS

1 European Geostationary Navigation Overlay Service (EGNOS)
2 Global Positioning System (GPS)
3 Reference stations
4 Master control station

The role of skyguide

Skyguide has been a member of the EGNOS Operators and Infrastructure Group (EOIG) since the start. EOIG provided ESA and its member states with the necessary expertise in specific areas and advised them on technical and operational flight safety issues, enabling them to develop a satellite system that meets the highest safety and efficiency demands for flight operations. Skyguide is a shareholder in ESSP along with the national flight safety agencies of Germany, France, the United Kingdom, Italy, Portugal and Spain.

> Skyguide is the Swiss air traffic control authority. It is responsible for the safe, smooth and cost-effective management of civil and military air traffic in Switzerland and in the adjacent airspace assigned to its control. In addition to overflights, skyguide manages air traffic at the two major international airports of Geneva and Zurich and at the 12 regional airports in Switzerland.

Satellite data and Swiss know-how increase yields and reduce risks for rice farmers

Michael Anthony
sarmap SA

Asia is the world's rice bowl. Some 90 per cent of rice is grown in Asia, where it is a staple food eaten two to three times a day. Unfortunately, droughts and flooding damage harvests time and again, leaving rice bowls empty. Since 2015, satellites have been helping to provide early warning and to measure the extent of flooding. This information helps to improve food security while allowing farmers to receive compensation more quickly when crops fail.

The RIICE project

The satellites capture data on rice-growing areas in Asia, making it possible to forecast yields with a precision of up to 90%. The processed satellite data are fed into a rice growth simulation model developed by the International Rice Research Institute (IRRI), which is based in the Philippines. The Sentinel-1A satellite maps the earth's rice fields every 12 days. The images make it possible to monitor crop growth and assess damage from natural disasters.

Switzerland provides the technical know-how. The satellite data are processed in Switzerland before government-associated research institutes in partner countries gradually take over the processing of the data themselves as part of the RIICE project (Remote Sensing-based Information and Insurance for Crops in Emerging Economies). Since 2013, the private sector, academia, and government agencies have been working internationally in a public-private partnership to use the remote-sensing satellite imagery to forecast crop yields and make the information available for insuring rice fields. The Swiss Agency for Development and Cooperation (SDC) and the Swiss remote-sensing company sarmap, which is based in Ticino, are working on the RIICE project together with IRRI, the German insurance company Allianz, and the German Agency for International Cooperation (GIZ). The aim is to map all the rice-growing areas in Asia, forecast yields, and record the actual harvests.

Sentinel-1A

The 2.3-tonne satellite Sentinal-1A has a radar eye that can see through all weather conditions and any amount of cloud cover to transmit images of the earth's surface at 5x5 m spatial resolution. It orbits the earth at 693 km altitude at a speed of approximately seven km per second (about 25,000 km per hour). Sentinal-1A has been sending images to earth since October 2014. It was developed by ESA and is being operated in the framework of the EU's Copernicus programme.

Key RIICE statistics

90% of the world's rice is harvested and consumed in Asia.
30% of the total crop yield (in USD) in Asia comes from rice.
In Asia rice is grown on 18 million hectares. RIICE has already mapped almost half of this area.
RIICE is working with five governments in Asia to use the rice information to provide insurance coverage for crop failures.
RIICE is the only initiative which provides regular information on plant growth and harvest forecasts in rice fields across Asia.

Satellites improve food security and help get aid to where it is needed fast

The satellite data directly benefits food security and contributes to the fight against poverty. RIICE is not only able to reduce or even prevent crop losses thanks to this data. It can also help in specific ways to get aid to where it is needed more quickly in the wake of natural disasters. And it ensures that rice farmers' claims for compensation are paid more swiftly. The radar sensors of the Sentinel satellites can instantly detect damage to crops at any moment, in all weather conditions, through any amount of cloud cover.

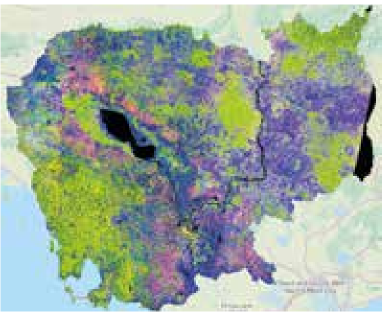
When, for example, a typhoon devastated large parts of the southern Indian state of Tamil Nadu in November 2015, the data was invaluable in allowing the authorities to get an idea of the scale of the disaster and send relief to the affected area. Such a quick response was only possible thanks to the satellite data.

Satellite technology is not only useful for emergency relief. It also provides crucial information for agricultural insurance providers, making it possible to quickly and efficiently calculate losses from crop failure. This benefits the farmers, who receive their insurance money early enough to reinvest in new seeds without having to take out a new loan and incur new debts.

The Sentinel-1A satellite © ESA

17-SEP-2015_26-SEP2015
27-SEP-2015_06-OCT-2015
07-OCT-2015_16-OCT-2015
17-OCT-2015_26-OCT-2015
27-OCT-2015_05-NOV-2015
06-NOV-2015_15-NOV-2015
16-NOV-2015_25-NOV-2015
26-NOV-2015_05-DEC-2015
06-DEC-2015_15-DEC-2015

The image shows the start of the rice season in Cambodia in November 2015 and shows in conjunction with the table on the right when and where the rice fields were planted. © Copernicus data (2015)
Background map ©OpenStreetMap contributors



The image, composed of various data sets captured over Cambodia during the 2015 harvest season, displays surface differences in varying colours: the dark blue areas are water, settlements and infrastructure are white, different shades of green represent forests of various types and thickness, and the light blue to purple areas show farmland at different stages of cultivation.
© Copernicus data (2015)
Background map ©OpenStreetMap contributors

Copernicus: Global observation for the environment and security

Copernicus is the EU's Earth observation programme. Based on ground-, air- and satellite-based observations, it provides geoinformation services for environmental monitoring and security. The observations from space are mainly carried out by the Sentinel satellites specifically developed for Copernicus. The main users of such information services are European, national and regional authorities as well as business and research. The Copernicus services support a wide range of applications in land use, the marine environment, the atmosphere, disaster and crisis management, climate change and security.

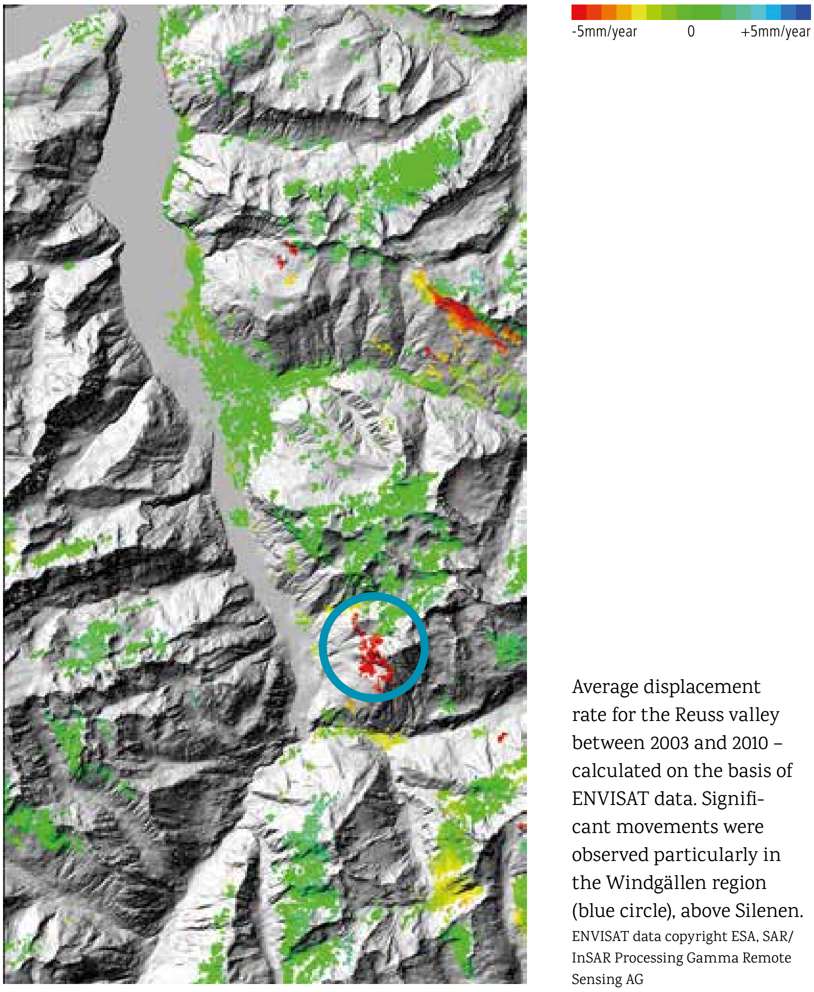
The Copernicus initiative was launched jointly by the EU and ESA in 1998. Switzerland has since been involved in developing satellites and information services within the framework of various EU and ESA programmes. The EU launched the operational programme in 2014, with major parts of the implementation being delegated to existing organisations in which Switzerland is involved such as ESA, EUMETSAT, the European Environment Agency (EEA), and the European Border and Coast Guard Agency (FRONTEX).

Detecting natural hazards early, thanks to satellite radars

Urs Wegmüller
Gamma Remote Sensing AG

Satellites have been observing the glaciers, slopes, and cliffs for more than 20 years. But they have also been viewing Alpine infrastructure (railways, dams, buildings) using satellite radar interferometry. These methods allow us to detect natural hazards early on, to keep up to date with the risk potential, and to draw up a list of imminent dangers and update it regularly.

Radar interferometry opens up a world of possibilities for us to create hazard maps and moving maps of natural events such as volcanic eruptions, earthquakes, landslides, unstable cliffs, changes in the permafrost, and ice avalanches. It can also chart movements in the terrain caused by humans, for example mining for gas and petroleum extraction, in abstraction of ground water, or construction of buildings.



Average displacement rate for the Reuss valley between 2003 and 2010 – calculated on the basis of ENVISAT data. Significant movements were observed particularly in the Windgällen region (blue circle), above Silenen.
ENVISAT data copyright ESA, SAR/InSAR Processing Gamma Remote Sensing AG

Reliable data to the millimetre

The radar waves allow us to determine the topography and movements in the terrain reliably. The satellite radar system records data on the area under observation at regular intervals – under almost all weather conditions and in high quality. This means that even minimal changes of a few millimetres or centimetres can be established. Between 2002 and 2012, Switzerland used the European Space Agency's (ESA) environmental satellite ENVISAT. The Sentinel-1A satellite became operational in 2014.

With minimal effort, previous movements in the terrain can be reconstructed by comparing several radar pictures taken at different times. The new generation of satellites are even able to capture movements in real time. Using data that have been collected over years, we can create an inventory of possible hazards; the risk potential can then be updated with current data. Ground-based interferometry sensors are also used for up-to-date local surveillance. They can perform measurements every minute, which also means they can be used for early warning systems.

Working in Chli Windgällen

We ran a pilot experiment using satellite-based displacement measurements in the Reuss valley between Sisikon and Wassen, particularly in the area of Chli Windgällen. Thanks to comprehensive data from a 20-year series of measurements taken by both the ERS and ENVISAT satellites we could generate retrospective readings and interpret them in geological terms. This allowed us to calculate movements in the terrain with a measurement accuracy of 1 mm/year and spatial resolution of about 20 meters for linear motion without having fixed measuring points beforehand. The mandate for this was issued by the Swiss Federal Railways, which uses the results for their monitoring set-up on the main artery linking northern and southern Europe.

These methods are also used in the Alpine region in Switzerland for mapping landslides and cliff instability. We assessed data from various radar satellites extensively in a mandate from the Federal Office for the Environment, which then used the information to create hazard maps with various danger levels.

ESA's environmental satellite ENVISAT.
Operational between 2002 and 2012 © ESA

Satellite radar interferometry
This is a method whereby satellites send radar waves to the Earth's surface where they are reflected. This allows us to make very accurate distance measurements between the satellite and the Earth's surface. If a slope is in movement, the distance between the satellite and the Earth's surface will change from one measurement period to the next. Interferometric methods of analysis calculate these differences in distance with high precision and create a map based on this.

These methods give us new possibilities to monitor uninhabited areas where there are no other measurement networks. Thus radar interferometry is also particularly well-suited for monitoring slopes that were previously stabilised by permafrost, but which are now melting due to climate change and are starting to move.

Space is part of daily life and an economic driver for Swiss industry

Peter Guggenbach
President of the Swiss Space Industries Group (SSIG)

Raoul Keller
Director of the Swiss Space Industries Group (SSIG)

Swiss companies are playing a leading role in space. Very few space missions can accomplish their goals without cutting-edge technology from Switzerland. This benefits Switzerland not only as a centre of research and education but also as an industrial centre. The space sector creates sustainable high-quality jobs in Switzerland, ensures transfer of know-how, and promotes development and applications in other industrial sectors.

Switzerland's space sector is a strategically important growth industry. It obtains high-value orders and develops structures such as payload fairings for launchers, satellite structures, precision mechanisms, on-board electronics, space transponders, engine components, new materials, payload fairing, measurement technology, and scientific and medical instruments. These developments often lead to profitable applications for everyday use here on earth. Activities in space also shape our communication, infrastructure, and mobility on earth.

The impact of the space sector on everyday life

Space technology is part of our daily life, even if we are not aware of it: every time we watch TV, make phone calls, write emails, or rely on our car's GPS system, we are using developments from the space sector. In the last two years, more than 270 applications developed within the framework of European Space Agency (ESA) programmes found their way into other areas. For example, Earth observation satellites help to understand the complex interrelations of ecosystems at the global level, monitor the environment, and use resources more efficiently (see page 14). Accurate weather forecasts are inconceivable without satellite data (see page 10).

The space sector is also economically profitable. Switzerland contributed 3% towards the costs of the ESA/EUMETSAT weather-satellite programmes, and thereby obtained the right to use all the functions of the satellites (which were partly built in Switzerland). The overall economic benefit over the next 20 years is expected to be 15 to 60 times the EUR 3 billion that will have been invested in the satellite programme. Among ways Switzerland uses satellite data is to protect the nation's population and infrastructure from landslides and weather hazards (see page 16).

The European Commission's Copernicus programme makes satellite data available for environmental protection and civil security worldwide. Switzerland not only produces key components for satellites but also uses Copernicus data, for example, for climate change research (see page 15).

PulsEar, a heart-rate monitor developed by the CSEM, the Swiss Center for Electronics and Microtechnology, is another example. The PulsEar sensor is integrated in an ordinary earphone and displays users´ heart rates in real time on the iPhone. The PulsEar technology was originally developed for ESA in order to monitor human behaviour during long-term missions in space.

PulsEar – the earphone that measures your heart rate © CSEM

Structure of the european Intermediate eXperimental Vehicle IXV, built by RUAG Space, handled by APCO Technologies' Mechanical Ground Support Equipment © ESA

Jobs for highly specialised professionals

ESA space programmes create jobs in Switzerland for highly qualified professionals and at the same time promote exchange of knowledge and cooperation between research and industry. The space industry employs people who have graduated from higher-education institutions as well as specialists from a wide range of fields. The industry brings in expertise in electronics, optics, precision engineering, aerodynamics, thermodynamics, computer science, material sciences, and 3D printing processes.

The 21 companies of the Swiss Space Industries Group (SSIG) employ over 900 professionals whose work is directly related to space technology. The companies' annual turnover is CHF 270 million. In addition, several thousand people in Switzerland – particularly professionals working in companies in the machine, electrical engineering, and metals industries which supply key components to the space industry – work indirectly to serve the space industry.

Swiss on-board electronics: Mass memory and formatting unit for ESA's EarthCARE mission, built by Syderal SA © Syderal

No Ariane rocket launch without Swiss hi-tech

Hendrik Thielemann
RUAG

Switzerland is on board every European carrier rocket flight – often with a payload fairing. This nose cone protects the spacecraft and makes sure that the satellites pass through the Earth's atmosphere safely. It dampens the sound of the rocket launch, protects the spacecraft from overheating, and keeps dirt away.

It only takes around three and a half minutes for an Ariane rocket to leave the Earth's atmosphere – about 120 km upward. But it has to endure quite a lot in those few minutes. For example, the engine noise is so loud that a person in the immediate vicinity would not survive. The high airspeed causes enormous aerodynamic loading, and the outer shell of the spacecraft heats up to around 700°C. All of this would be far too much for the sensitive satellites to endure – journeying into space on the tip of the rocket's nose – were it not for a special kind of protection made in Switzerland – the payload fairing, a 17-metre-long aerodynamic hood which provides reliable protection for satellites encapsulated underneath at the upper stage of the rocket.

The Swiss aerospace company RUAG Space is a global market leader when it comes to safely managing the first three minutes after a rocket launch. It provides the payload fairings for the European carrier rockets Ariane and Vega, which contributes significantly to the rocket programme securing an autonomous European access to space. The Ariane rocket is also commercially very successful, thanks to Swiss hi-tech, bringing around one half of the biggest commercial telecommunications satellites from around the world into space.

Partner from day one

Switzerland has partnered the Ariane programme from the outset. A RUAG Space payload fairing was even in use during the first launch on 24 December 1979. In addition to Ariane, since 2012 Europe has had a second carrier rocket – Vega – which is also equipped with a Swiss payload fairing. While the almost 60-metre-high 'heavy transporter' Ariane 5 can transport two large telecommunications satellites weighing a total of 10 tonnes and more into a geostationary orbit, the roughly 30-metre-high Vega brings small to medium-sized payloads into a low Earth orbit. This makes Vega particularly well suited to transporting satellites for Earth observation, meteorology, and research.

RUAG Space engineers can look back over a history of over 250 successfully completed flights. This kind of reliability is likewise in demand in the United States, the world's leading space-faring nation, where Swiss technology is also being employed. The currently most important US carrier rocket for transporting large satellites into space, Atlas V, has been flying since 2003 with a Swiss-made carbon fibre hood. RUAG Space is currently developing the payload fairings for the next generation of Ariane 6 rockets in Europe and the Vulcan rocket in the USA.

The payload fairing for a Vega rocket is packed for transportation at RUAG Space in Zurich © RUAG

The Ariane Programme

The programme to develop and build European launch vehicles began in 1973. The main aim was to enable Europe to independently access space, thereby reducing its dependence on other space-faring nations. The European Space Agency (ESA) has since developed five generations of Ariane rockets – work on the sixth generation began in 2014 – and provided funding for construction of a european launch pad in Kourou, French Guiana.

Their constantly improving performance and high reliability has meant that most commercial satellites are launched today by Ariane rockets. The Ariane programme also played an important part in supplying the International Space Station (ISS). The rockets launched five automated transport vehicles which took supplies and experiments up to the ISS between 2008 and 2014 (see page 30).

Launch of an Ariane 5 rocket on 18 June 2016 at the European spaceport in French Guiana with two satellites on board. The rocket nose is protected by a RUAG payload fairing © ESA

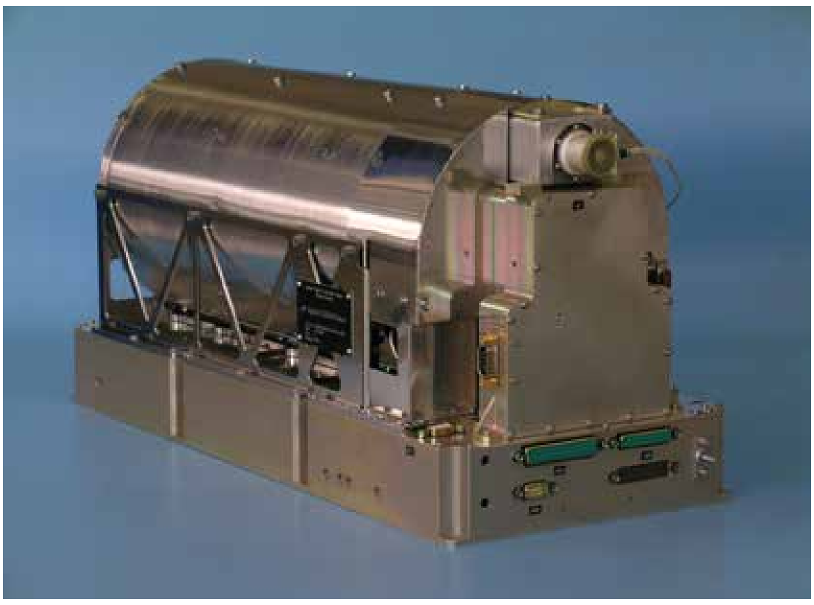
Swiss atomic clocks improve the accuracy of our satellite navigation systems

Pascal Rochat
Spectratime

Satellite-based navigation systems are so much part of our lives that it is hard to imagine everyday activities like hiking and driving without them. Activities such as surveying, farming, and the management of land, sea and air traffic also depend on these systems. And it goes without saying that we expect the data they provide to be accurate to within a few metres or even centimetres.

To produce such exact data, satellite navigation systems use precisely synchronised, stable and highly accurate atomic clocks. The navigation satellite signals are used along with a 'time stamp' from the atomic clocks to determine accurate positioning. Since the signals sent by the satellites are transmitted at the speed of light (300,000 km/s), even the slightest of errors affects the accuracy of the positioning measurement. If an atomic clock in a satellite is 'off' by as little as a nanosecond (a billionth of a second), it makes a difference of 30 cm. The clocks must also withstand strong vibrations during the launch and when the satellites are released from the launcher's upper stage. As they travel into space and orbit the Earth, atomic clocks are also subjected to extreme temperature changes. Once in space, no maintenance can be carried out on them.

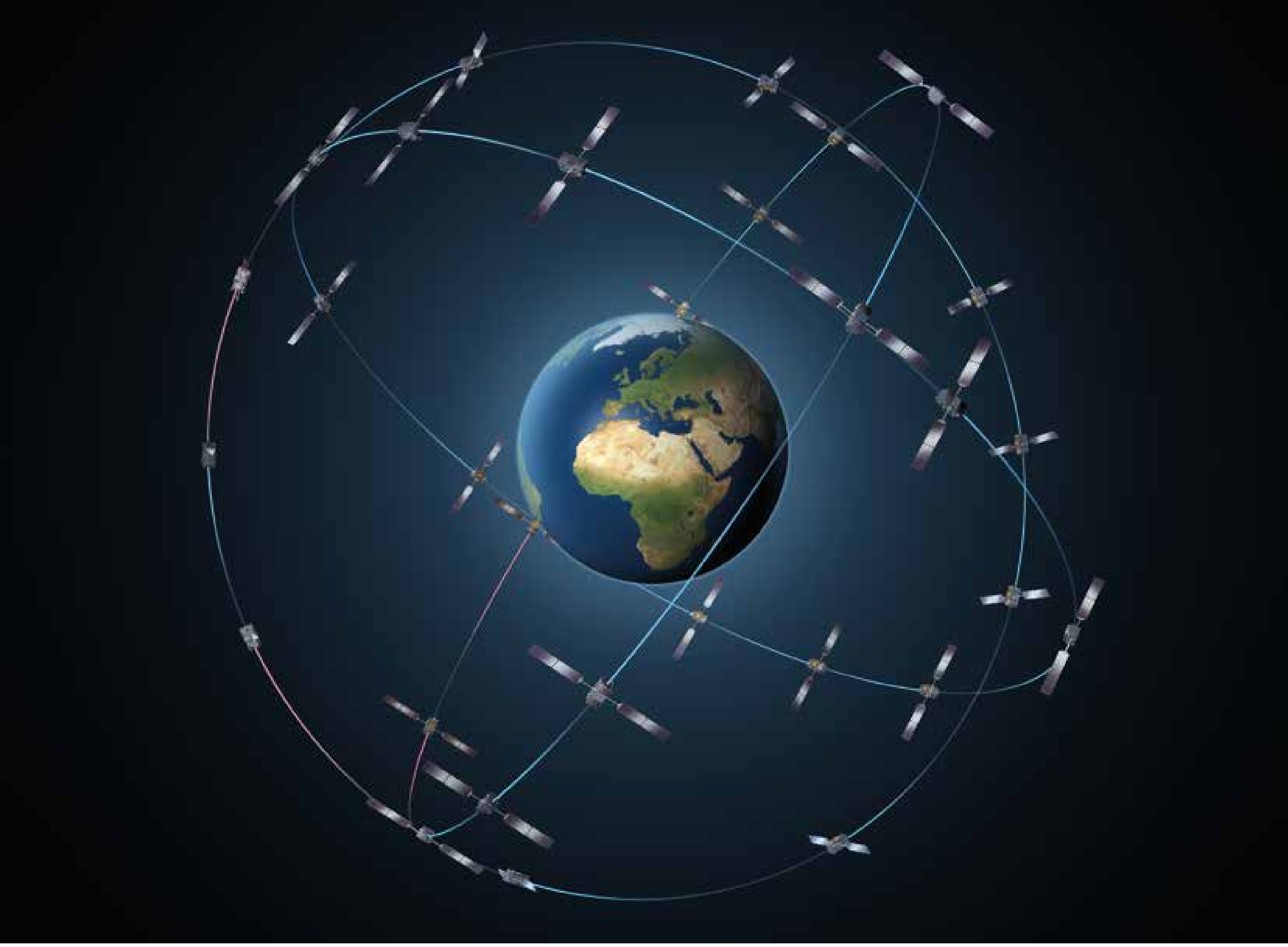
Atomic clock by Neuchâtel-based company Spectratime, interior casing by Argotec, Aargau. © Spectratime



Atomic clocks 'made in Switzerland'

Atomic clocks bear little resemblance to our idea of an ordinary clock with a dial and hands. They need an oscillator like an ordinary clock, but – instead of a pendulum – they use oscillations in the energy level of an atom. Spectratime, a company based in Neuchâtel, designed two different clock types for the European satellite navigations system Galileo. The clocks are based on rubidium and hydrogen atoms. The latter type is the most precise clock in space. In three million years they only lose or gain a single second. Every satellite carries a backup clock of each type. The satellites transmit the current time and their position back to Earth. A receiver device can then calculate its exact position based on how long it took for the signals to arrive. Global positioning relies on at least four satellites to transmit signals which are synchronised to a billionth of a second.

Atomic clocks in space are also used for telecommunications, radio astronomy and measuring physical effects at the limit of what can be measured. Moreover, many everyday applications on Earth also rely on the highly accurate time signals from space that atomic clocks transmit everywhere on the planet. To begin with, they are used to establish Coordinated Universal Time (UTC). Communication networks cannot be synchronised without such reference signals, or power grids might collapse at peak times or mobile phone and internet communications would become unreliable or slow down. Paying by credit cards in shops and electronic trading of securities are among many other activities which would not be possible without atomic clocks and satellite signals from space.



The complete Galileo constellation with eight satellites in each of three orbital planes (plus two reserve satellites in each orbital plane). © ESA

The European satellite navigation systems Galileo and EGNOS
Galileo will end European users' dependence on the USA' Global Positioning System (GPS). Upon completion (scheduled for 2020), Galileo will consist of a constellation of 24 satellites on three orbital planes. Each of the orbital planes will also have two reserve satellites. This constellation will ensure that at any given point in time at least four satellites are 'visible' from anywhere on Earth, allowing positioning accuracy to within a metre.

The European Geostationary Navigation Overlay Service (EGNOS), a regional navigation system, has already been in operation since March 2011. It improves the accuracy and reliability of GPS signals and can be received over Europe and North Africa. With its development at the European Space Agency (ESA) complete, EGNOS was handed over to the EU in 2009, and the EU now manages the service's operation. EGNOS signals are particularly useful in guiding aircraft during landing approaches in poor weather conditions (see page 12).

Switzerland is involved in the development and operation of both systems. Switzerland and the EU signed a cooperation agreement in December 2013. The agreement has been applied provisionally since 1 January 2014. Switzerland ratified the agreement in 2015. Ratification is still under way within the EU.

The European Space Agency (ESA)

From the start of the space age, Europe has been active in space. Whilst it was initially mainly a matter of scientific curiosity, today, the motivation for Europe's diverse space activities is much broader: space brings at the forefront technology and services which are essential for a modern society, it expands our knowledge of the universe and of our own planet, it provides up-to-date information enabling us to respond to global challenges, it creates highly skilled jobs and strengthens the European industry's competitiveness and capacity for innovation.

The European States recognised early on that the breakthrough in space would only be possible though cooperation. European States had been working together on the development of launchers and on scientific satellites already since the early 1960s. With the foundation of the European Space Agency ESA in 1975, these activities were brought together under one organisation, with Switzerland being among the 10 founding States.

Today, ESA has 22 Members States with Canada as an associated Member participating in various programmes, and Slovenia having signed an association agreement in 2016. ESA is an independent, intergovernmental organization. It maintains a close relationship with the European Union; the two are linked through a framework agreement.

Today, ESA's activities cover practically all space domains, namely

- » Launchers
- » Space Science
- » Human and robotic exploration
- » Earth Observation
- » Navigation
- » Technology, Telecommunications and Integrated Applications
- » Space Situational Awareness

Alongside its own programmes, as decided and funded by Member States, ESA also manages activities for third parties, for example the development of the next generation of weather satellites for EUMETSAT or the construction of the satellite constellations for the EU Galileo programme (Navigation) and Copernicus (monitoring of the environment). Further, ESA has entered into Public Private Partnerships with numerous commercial providers in the satellite communications sector. The Agency is also responsible for the development of the Ariane and Vega launchers, which are themselves commercially exploited by Arianespace.

ESA's annual budget is EUR 5.3 billion (2016), the most significant part of which flows back to the Member States in the form of research and development contracts. The competences and products developed by the participating institutes and companies bear witness to the economic benefit; the return being many times higher than the contribution of the Member States. ESA, with its headquarters in Paris, employs around 2,200 people who come from all Member States and are stationed at the different technical centers in Europe.

ESA Member States (dark grey), associated and cooperating States (light grey) © ESA

ESA Director General Johann-Dietrich Wörner
© ESA

"Space is important to a modern society. Space contributes to industrial competitiveness and, in so doing, generates jobs and growth. Space is about cooperation as a means of achieving success. Space inspires people to pursue education and embark on fascinating, fulfilling careers.

ESA is the space agency for Europe, and it is ready to take specific actions for its Member States. We see the diversity of our Member States as an asset, with each bringing its own particular competences. For example, Switzerland not only provides key technologies and products to European space programmes – it has also made essential contributions to the coordination of space activities in Europe.

Switzerland hosted ESA's Ministerial Council in Lucerne on 1 and 2 December 2016, an opportunity to show the public in our Member States that space is relevant to every citizen, that it contributes to the growth of our economies and to our overall competitiveness while enriching and improving our daily lives through innovation, information, interaction and inspiration."

ESA chairmanship: Switzerland in charge for Europe

Balz Abplanalp
Diplomatic adviser for the ESA co-chairmanship, FDFA

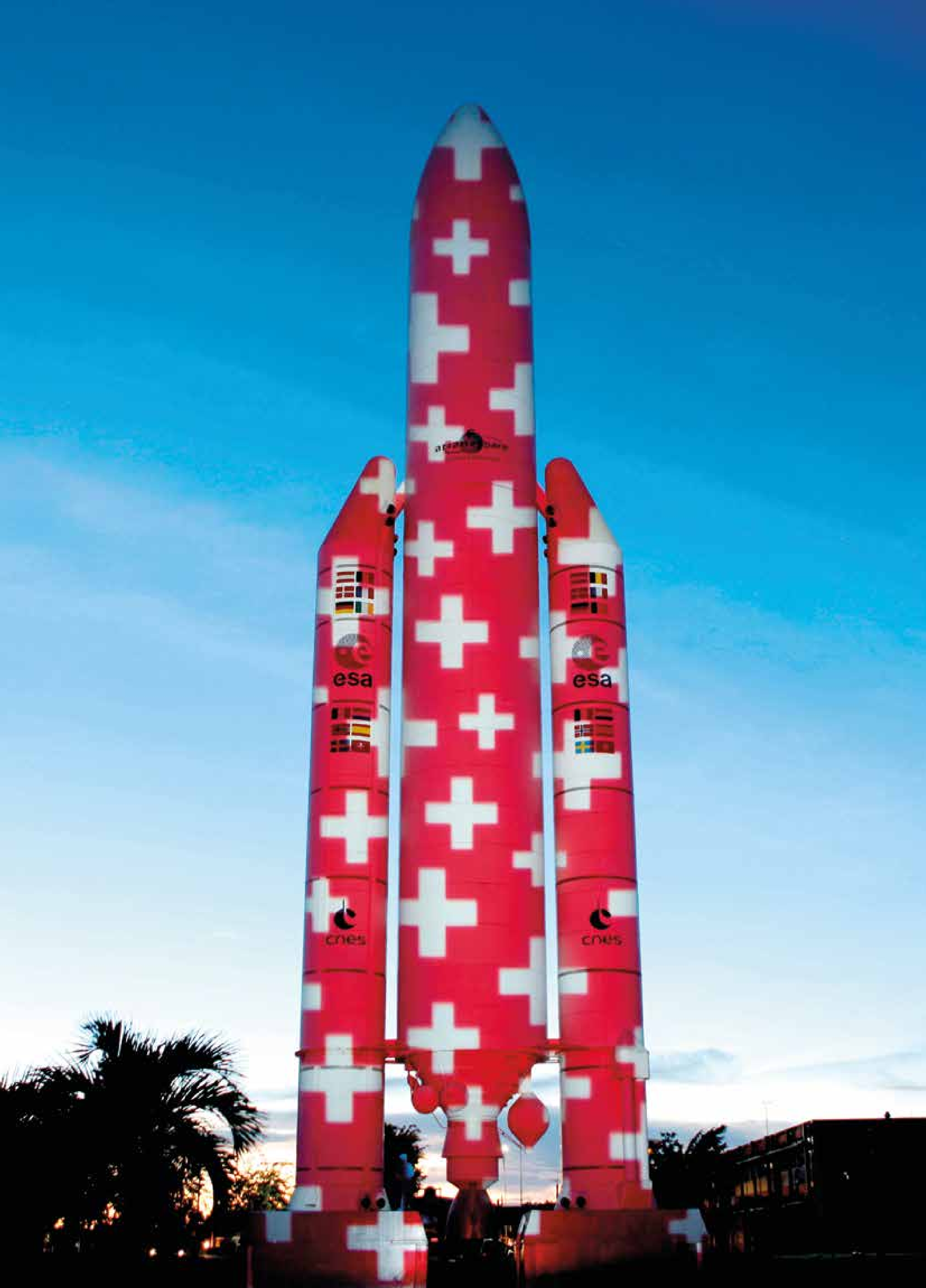
Switzerland's access to outer space has been ensured by the European Space Agency (ESA) for over 40 years. It joined Luxembourg recently in co-chairing the organisation's ministerial council for the first time from 2012 to 2016. Both countries agreed to a simple division of tasks from the start, with EU-member Luxembourg being responsible for relations between ESA and EU, while Switzerland took charge of all ESA programmes. Luxembourg's Deputy Prime Minister Etienne Schneider (from the end of 2013) co-chaired with Mauro Dell'Ambrogio, the Swiss State Secretary for Education, Research, and Innovation (SERI).

ESA's ministerial council is where the 22 member states set out the organisation's strategic, programmatic, and financial policies for the upcoming period. Together with the ESA director general, the co-chairmanship was tasked with preparing a set of space programmes that met the needs and wishes of all member states. If successful, the ministers will grant sufficient funding for the long-term programmes that need new financial resources every few years. An example is the 12-year ESA Rosetta mission, which succeeded in placing a robotic lander on a comet for the first time ever on 12 November 2014.

Despite the recent economic crisis, ministers at the 2012 council in Naples and the 2014 council in Luxembourg committed funds of over EUR 15 billion for ESA's programmes. This large financial commitment reflects the ministers' conviction that investing in innovations for research and space infrastructure provides a major boost to economic growth in Europe. Its contribution to Europe's competitiveness in this field also reflects favourably on Switzerland's co-chairmanship, which has helped to bring about key decisions behind the scenes. For example, it led the lengthy negotiations on developing the new carrier rocket Ariane 6 and successfully negotiated between ESA member states and the industry sector. Developing Ariane 6 will create a number of high-skilled jobs in the next few years. They include jobs in Switzerland, which is actively involved in the programme. This will also help boost the Swiss location as a centre for industry and research.

ESA will be able to retain its status as an intergovernmental organisation in the future, thanks to political resolutions on developing ESA adopted at the ministerial councils in Naples and Luxembourg. This strengthens ESA as an institution and boosts its position as an independent and essential cooperation partner for the EU. This is also in Switzerland's interest.

Switzerland's co-chairmanship of ESA has thus achieved its political objectives and helped strengthen space-travel stakeholder networks in research and industry. ESA ministerial council in Lucerne from 1 to 2 December 2016 has marked the close of the co-chairmanship.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A look behind the scenes at the European Space Agency (ESA)

Interview by
Kamlesh Brocard,
scientific adviser at the Swiss Space Office, State Secretariat for Education, Research and Innovation (SERI)

Interview with Maurice Borgeaud, Head of the Science, Applications and Future Technologies Department of ESA's Earth Observation Programmes Diretorate

You are now working at ESA. What motivated you to pursue a career in the space sector?

As an undergraduate I was already fascinated by space and satellites. I specialised in microwaves, digital signal processing, radar, and antennas. I wanted to know more about space in order to better understand the earth and our environment. My PhD thesis was about development of models to predict interactions between radio waves and different types of Earth terrains such as vegetation, ice, and snow. I discovered early on that I preferred working in an international environment.

What is your department's role within ESA?

As an international agency, ESA must be present worldwide, attentive to its 22 member states, and responsive to their national strategies. ESA is also tasked with supporting European industry, research, and development to ensure they remain competitive and can play leading roles in space technology and developments in the space sector.

To this end, we also work with space agencies outside Europe, including the US, Russian, Japanese, and Chinese space agencies, to explore opportunities for cooperation and coordinate joint activities. I also represent ESA on the board of the International Charter on Space and Major Disasters. In the event of a disaster, the ESA Center for Earth Observation (ESRIN) makes satellite data and information freely available to relief agencies.

What is your typical day like?

Every day brings new and different challenges. My responsibilities are varied and demanding, and this also makes my job rewarding. They range from Earth sciences to preparing future Earth observation missions and associated technology, and to developing new applications, for example, for the EU's Copernicus programme.

We also want to ensure that our satellite data not only benefit science but also enable the downstream industry to develop and market new services and products. Another goal is for data to be used in climate-change monitoring and global sustainable development, for example, in the areas of food security, water management, and urban development.

Because my department is spread over three ESA sites in Frascati (Italy), Noordwjik (the Netherlands), and Harwell (the UK), I am often on the road.

What do you see as the biggest challenges for the future?

One of our major goals is to make Earth observation data available to the general public. Weather forecasts are a good example: here in Europe, weather forecasts services are provided by EUMETSAT, based on data from satellites developed by ESA. We have to ensure that these data can be used both by the scientific community and by industry for innovation and further applications. And last but not least, the data are important for decision makers in a wide range of fields to ensure sustainable development of our planet. A growing number of partners in Europe and around the world means, that ESA is presented with new opportunities for cooperation but also with new challenges.

For example, the role and responsibilities of ESA will have to be better defined. ESA must be strengthened as a research and development agency, as a space architect for future missions, and as a procurement agency for all European space programmes.

What advice would you give young people who are considering a career in the space sector?

When I was teaching at the Swiss Federal Institute of Technology in Lausanne (EPFL), I had 40 to 50 students every year who attended lectures on remote sensing of the Earth and on space in general. But despite their enthusiasm very few of them have ended up working in this sector. Mobility or reluctance to move abroad was often the cause of this. Speaking from my own experience, I can confidently say that a stay abroad is definitely worth it.

Maurice Borgeaud, Head of the Science, Applications and Future Technologies Department of ESA's Earth Observation Programmes Directorate © ESA

There are various opportunities at ESA to help young people embark on a career in the space sector. For example, we have a Young Graduate Trainee (YGT) programme for bachelor's or master's degree graduates, and a programme for post-doctoral scientists and freshly minted engineers. The National Trainee Programme (NTP) offers additional opportunities. Hiring young people is strategically important for us, because a large number of ESA staff members will reach retirement age over the next few years.

ESA tries to ensure that the number of staff from each member state is proportional to that state's contribution to the overall budget. Achieving this balance is not always easy, especially for Switzerland, which is why I would like to take this opportunity to encourage Swiss nationals to apply for a position at ESA!

Let me close with two quotes. Antoine de Saint-Exupéry said: "We do not inherit the earth from our parents; we merely borrow it from our children." And the EU Commission writes: "Space is not only an adventure; it is also an opportunity. Europe cannot afford to miss it." By developing new satellites, we want to contribute to a better understanding of the Earth and the environment.

1977–1982	Studied electrical engineering at EPFL
1982–1987	Master's and PhD at the Massachusetts Institute of Technology (MIT), Cambridge, Massachusetts, USA
1988–1989	DLR, German Remote Sensing Data Centre (DFD), Oberpfaffenhofen, Germany
1989–2002	European Space Research and Technology Centre (ESA)
1994	Sabbatical at NASA Jet Propulsion Laboratory (JPL), Pasadena, California
2002–2004	Swiss Space Office (SSO), Programme Manager for Earth Observation, Telecommunications, Navigation
2004–2010	EPFL, Director of Swiss Space Centre,
Since 2011	ESA, Head of the Science, Applications and Future Technologies Department of ESA's Earth Observation Programmes Directorate

Switzerland on board the International Space Station (ISS)

Oliver Botta
State Secretariat for Education, Research and Innovation (SERI)

The International Space Station (ISS) is one of the greatest projects ever realised by humanity. Switzerland participates actively in the programme, which means its space industry and researchers at scientific institutions have access to this unique infrastructure in Earth's orbit.

The ISS symbolises peaceful international cooperation in space. It is a joint project among NASA (USA), which spearheaded the programme, the space agencies of Canada, Japan, and Russia, and the European Space Agency (ESA). The ISS integrates its partners' contributions in a shared space infrastructure used for research and development of technology as well as preparing for future joint exploration missions.

Our research station in space

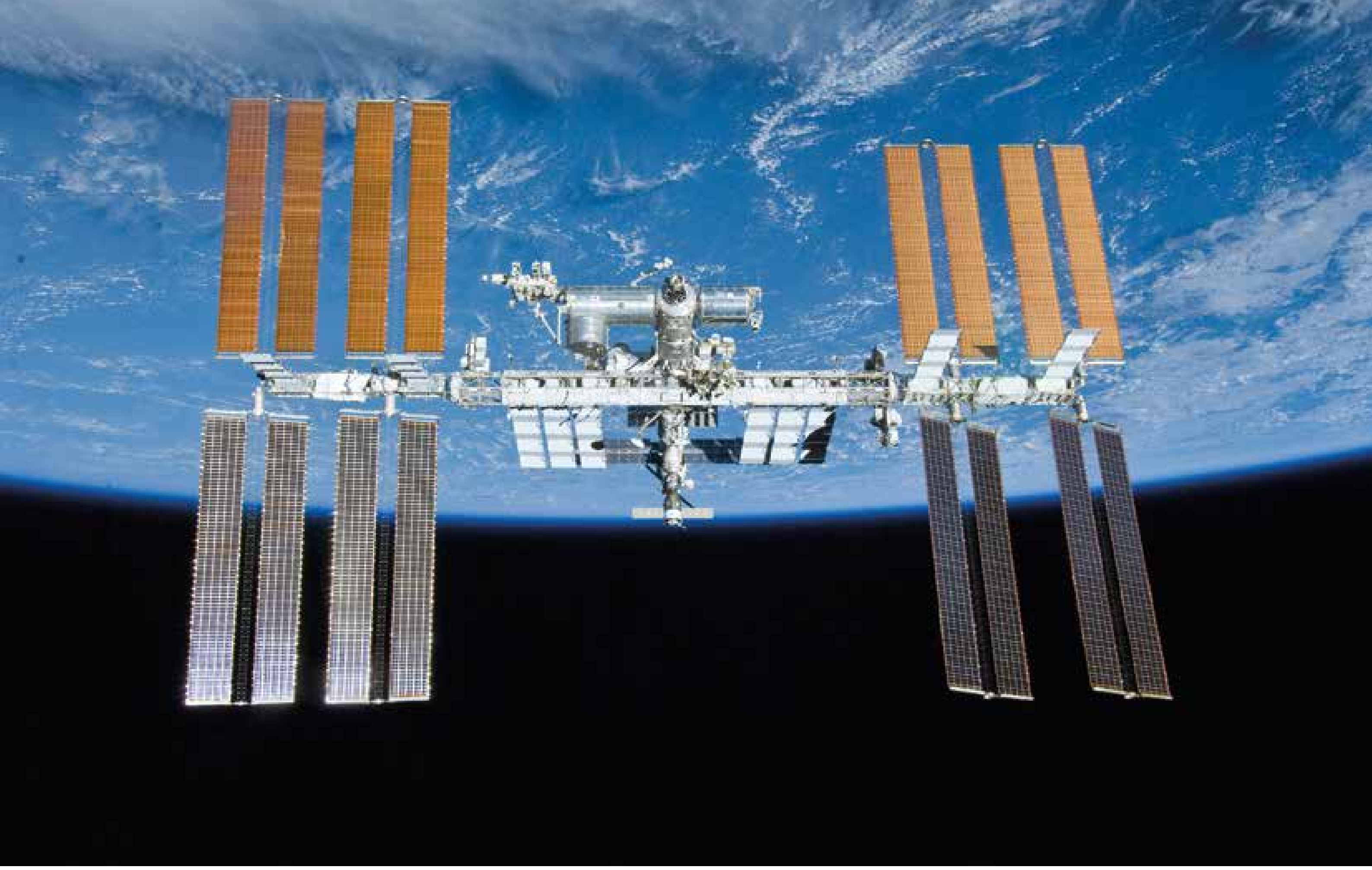
The ISS has been operational since 2011, but it was already used to some extent for research projects during its construction phase (1998–2011). The first crew went on board on 2 November 2000. The plan is to keep the ISS operational until at least 2024, which would mean people will have been present in Earth's orbit for more than 20 years without interruption. Experiments are carried out on the ISS in a wide range of disciplines – biology, medicine, materials science, astrophysics, basic research in physics (in relation to relativity theory, for example), and Earth observation. This research leads to direct applications on Earth. For example, research on the ISS has yielded results that have led to innovative methods for treating osteoporosis in elderly people. Aircraft companies use new kinds of alloys – which the ISS helped to develop, test and characterise – to build quieter, more efficient engines.

European contributions to the ISS are the Columbus laboratory module, the Automated Transfer Vehicle (ATV), the Cupola observatory module, the European Robotic Arm (ERA), and the ESA European Astronaut Corps. Columbus was docked to the ISS in 2008, and has since served as a laboratory for scientific experiments. The ATVs have already completed their five flights. The missions carried equipment for experiments, supplies, and fuel to the ISS. ESA's participation entitles European astronauts to undertake long-term missions, remaining on board the ISS for up to six months and carrying out extensive research programmes.

Besides the scientific community, Swiss industry is also involved in the ISS. It has made various contributions to the development of Columbus, Cupola, and the ATV. For example, the main structure of the ATV was made by RUAG. Switzerland is keen to enable the scientific community to use the ISS as a research platform. ESA runs the Swiss User Support and Operations Centre (USOC) in Hergiswil in the canton of Nidwalden, which provides valuable space biology services to help scientists plan, develop, validate, and conduct experiments.

Researchers would not be able to carry out their projects successfully without the help of this user support and operations centre. The Aerospace Biomedical Science and Technology Competence Centre, which is part of the Lucerne University of Applied Sciences and Arts and shares its premises with the USOC, has developed and flown several experiments for the ISS. The next project involving Switzerland plans to send an ultra-stable atomic clock from Neuchâtel to the ISS as part of the Atomic Clock Ensemble in Space (ACES) experiment.

ESA astronaut Samantha Cristoforetti preparing the BIOLAB research facility for the TripleLux-B experiments on board the ISS Columbus module. The TripleLux experiments were developed by the Universities of Zurich and Berlin to study immune system responses in muscle cells. Implementation on board the ISS was planned and supported by the Swiss USOC in Hergiswil. © ESA



The International Space Station in orbit, photographed from a space shuttle after it undocked in May 2010. The pressurised modules are clearly visible in the middle, and so is the large horizontal truss on which the great wings bearing the solar panels are mounted. A Soyuz spacecraft is visible at one of the zenith port on the station. The European research module Columbus is attached to the starboard side of the station. © NASA

KEY FIGURES

Mass of the ISS: approx. 420 tonnes
Size:
» Length: 72.8 m
» Width: 108.5 m
» Height: 20 m
» Pressurised volume: 916 m3 (approximately equal to that of a Boeing 747)
Orbit altitude: between 409 and 416 km
Orbital inclination: 51.65° to the equator
Speed: 7.66 km/s
Crew: six (minimum three during crew change)

Costs:
» Development and operating costs (calculated over 30 years): USD 100 billion
» ESA contribution: EUR 8 billion
» Swiss contribution: about 2.5% of ESA's contribution

Supply spacecraft:
» Manned: Soyuz (Russia) (1998-2011: Space Shuttle, USA)
» Unmanned: Progress (Russia), HTV (Japan), Dragon, Cygnus (both USA) (2008–2014: ATV, ESA)

Scientific experiments:
» Scientific experiments can be carried out both inside the ISS or mounted externally on the ISS or on its truss structure.
» Statistics: (as of September 2015)
  – Total number of experiments that have been carried out on board the ISS: around 2060
  – ESA experiments: about 295
  – Experiments with Swiss participation: 18

ROSINA – Rosetta's Swiss pearl

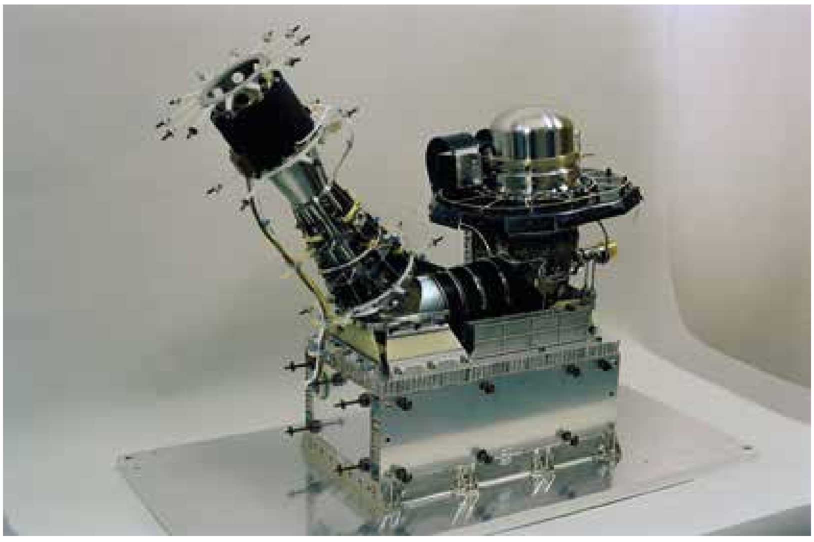
Kathrin Altwegg
Astrophysicist and professor of space research and planetary sciences at the University of Bern, ROSINA project manager

The European Space Agency (ESA) announced the successful end of the Rosetta mission at midday on 30 September 2016. The space probe executed its 'controlled descent' with 67P/Churyumov–Gerasimenko as planned, taking with it the Swiss mass spectrometer Rosetta Orbiter Sensor for Ion and Neutral Analysis (ROSINA) developed at the University of Bern. This marked the end of ESA's by far craziest mission to date.

The mission was launched in 2004, on a 10-year journey towards the comet, clocking more than six billion kilometres on its way. For more than two years it orbited the pitch-black boulder into outer space, sending us data and images of this small and insignificant – yet highly exciting – comet. This included measurements taken by ROSINA, an extremely sensitive and high-precision mass spectrometer with unprecedented capabilities.

ROSINA was developed at the University of Bern and then built mainly by Swiss industry. The challenges were significant and pushed all those involved to their limits. Eight PhDs were written about it, and a number of masters students played their part in ROSINA's creation. In return, they were able to benefit from sophisticated technology and international collaboration. Today we can proudly say that it was worth it.

Rosina's double focusing mass spectrometer (DFMS).
© ESA/Rosetta/Rosina



Answers to the great questions of life's origins and future

Researching comets enables us to draw conclusions about the genesis of our solar system, the sun and other planets. They are deep-frozen witnesses to our past. Thanks to comet research, it is possible for us to identify the source of the Earth's water, how life probably came to exist on this planet, and even perhaps elsewhere in the universe. In so doing, we are trying to answer one of the fundamental questions of life – where did we come from and where are we going to? – with the help of scientific methods.

ROSINA plays a key role in this. It is capable of chemically analysing the comet's gas with high precision and sending back unique data continuously for a two-year period. Never before has such an accurate and sensitive mass spectrometer been used in deep space. The findings we can deduce from ROSINA change our understanding of how the solar system began. We now know that the Earth's water did not originate from comets, but comets probably shaped the Earth's atmosphere.

The discovery of a rich palette of organic material ranging from hydrocarbon chains to amino acids gives a boost to the theory that comet strikes may have triggered life on Earth. And, if this happened on our planet, could it also have occurred in other places with conditions similar to Earth? Even if in all probability we are unlikely to be able to communicate with extraterrestrials, at least it would mean that we are not alone!

Mission accomplished – after 30 years

Initial ideas for the Rosetta mission were already being elaborated in 1985. After almost ten years of planning, a nine-year building phase followed before the probe – with its ten instruments and landing unit – lifted off on 2 March 2004 in the direction of 67P/Churyumov-Gerasimenko.

By August 2014, Rosetta was in the immediate vicinity of the comet – and never as close as in the last days of the mission. It accurately placed its tiny landing unit, Philae, on the surface of the comet on 12 November 2014 – an event that attracted more global attention than any other space mission before.

Artist's impression of Rosetta and Philae at the comet.
© ESA/ATG medialab; Comet image: ESA/Rosetta/NavCam

Mission: Rosetta
Start: 2 March 2004, Ariane 5, French Guiana
3 gravity assist flybys: 2005, 2007, 2009
1 Mars flyby: 2007
Flyby of Štein's asteroid: September 2008
Flyby of Lutetia asteroid: 2010
Hibernation mode: June 2011 – 20 January 2014
Arrival at 67P/Churyumov-Gerasimenko: August 2014
Philae lander: 12 November 2014
Perihelion passage: 13 August 2015
End of mission (Rosetta landing on comet): 30 September 2016

ROSINA: (Rosetta Orbiter Sensor for Ion and Neutral Analysis):

- Double-focusing mass spectrometer (DFMS), 16 kg, about 10 million mass spectra data
- Reflectron time-of-flight mass spectrometer (RTOF): 15 kg, about 10 million mass spectra data
- Comet pressure sensor (COPS): 1.5 kg, continuous measuring of gas density from July 2014 until end of mission
- Data processing unit (DPU): redundant 386 processors with 3 megabyte programme memory

Scientific highlights from ROSINA

- Deuterium found in comet water disproves the theory that comets brought water to Earth.
- Nitrogen molecules give a temperature of -250 °C for formation of comets.
- Argon (a noble gas) in the Earth's atmosphere probably originates from comets.
- Amino acid glycine and an array of organic molecules support the theory that comets contributed to the existence of life on Earth.
- Number of ROSINA publications 2014–16: 42

CHEOPS: A small satellite but a unique opportunity for Switzerland

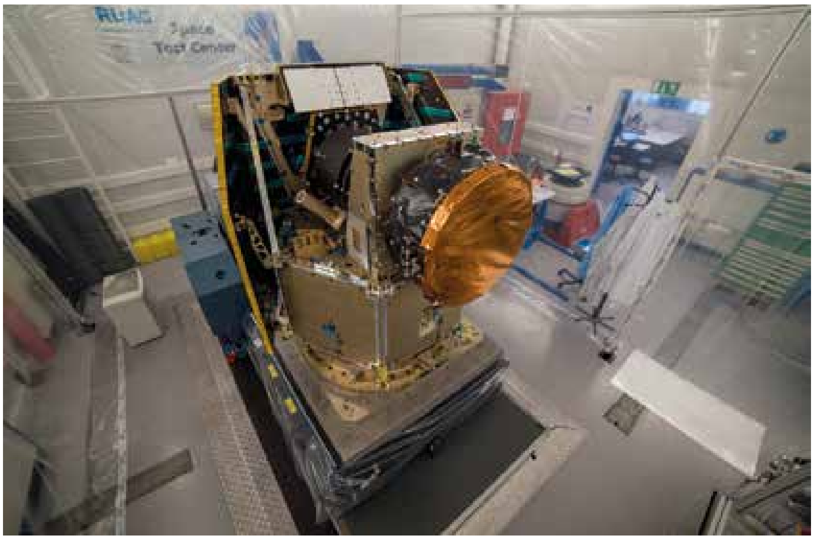
Willy Benz
Professor and head of NCCR PlanetS, Principal Investigator CHEOPS mission

A small 'Swiss' satellite will use its telescope to discover what planets outside our solar system are made of. The CHEOPS (CHaracterising ExOPlanets Satellite) space mission is run jointly by Switzerland and the European Space Agency (ESA).

It's not just its scientific aims that make CHEOPS different from other space missions. CHEOPS is the first probe in a possible series of 'S-class' ESA missions – missions designed to run on a small budget within a comparatively short time period. It's also the first space mission in which Switzerland shares the leading role with ESA. The University of Bern has overall responsibility for the mission, overseeing contributions by the University of Geneva (leading the ground segment) and institutes from ten ESA member states.

Alongside the scientific community, Swiss industry is heavily involved in CHEOPS through the supply and testing of hardware and software. The National Centre of Competence in Research (NCCR) PlanetS is providing coordination and manpower to help with the scientific exploitation of the mission on a national level.

The CHEOPS Structural Qualification Model (SQM) undergoing vibration tests at the RUAG Space Test Center in Zurich.



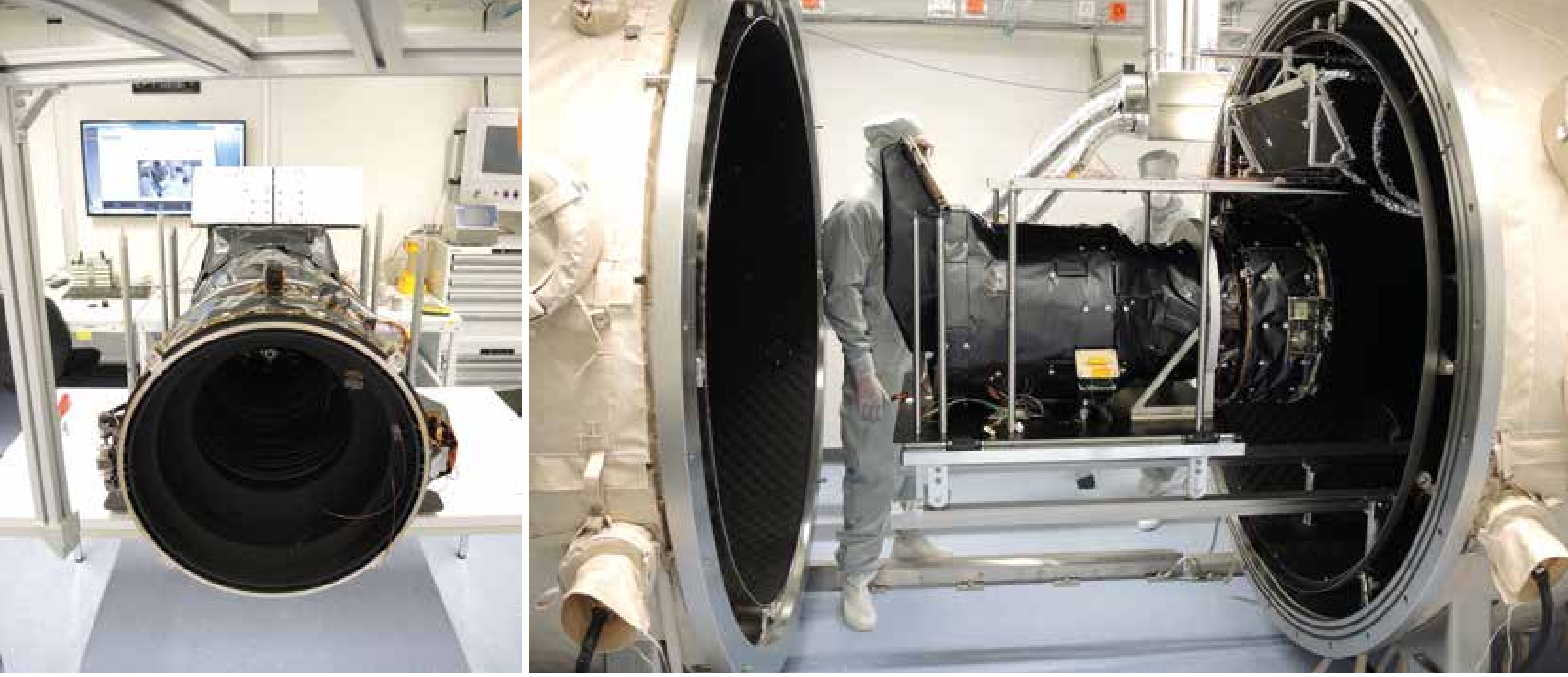
Aims of the CHEOPS mission

ESA first decided to launch CHEOPS (a small, ultra-high precision photometric telescope) in 2012 to learn more about planets already known to exist. It will search for transits by planets outside our solar system (exoplanets). A transit is the passage of a planet across the face of its central star during which the planet covers a fraction of the stellar surface proportional to its own size. CHEOPS's telescope by monitoring the light of the star over time very accurately can therefore measure the planet's diameter. Together with the knowledge of the mass it is possible to obtain information about what the planet is made of: if it is rocky like Earth, icy like Neptune, or gaseous like Jupiter. Therefore, the CHEOPS mission is an important step in characterising the physical nature of a planet.

Space pioneer Switzerland

The discovery of the first planet orbiting a star like Earth orbits the sun by two Swiss astronomers in 1995 sparked a true revolution in astronomy. Some 20 years later, several thousand planets have been discovered, ranging in size from smaller than the Earth to the size of giant planets larger than Jupiter. Today planets are recognised as common objects in the universe, and scientific interest is focused on their physical and chemical characteristics.

Having developed leading ground-based instruments used to detect these planets outside our solar system, Switzerland is now venturing into space to obtain more information about them. It assumes an unprecedented leading role to plan, develop, and carry out European space missions. With this move, Switzerland is ensuring it continues to play the leading role it adopted early in the search for new planets and signs of life outside our solar system.



CHEOPS's structural and thermal model (STM) in the laboratory at the University of Bern. Left: Front view shows the baffle entry and radiator ensuring thermal control of the instrument. Right: the instrument is being placed in the thermal vacuum chamber for environmental tests.
© CHEOPS Team / University of Bern

CHEOPS is a small satellite with a mass of about 280 kg. Its payload consists of a single telescope with a primary mirror of 32 cm diameter with a large external baffle to minimise stray light. Telescope and baffle together measure about 1.5 meters in length and weigh close to 60 kg. The satellite will be placed in a sun-synchronous polar orbit at an altitude of 700 km. In this orbit, the satellite flies around the Earth in about 90 minutes from the North Pole to the South Pole and back. Facing away from the sun, CHEOPS will observe stars visible over the night-side of the Earth. All elements have been optimised to allow CHEOPS to monitor the light of stars over several hours to a precision of 0.002%.

Over 3.5 years, CHEOPS will generate data on the size and characteristics of the atmosphere of a total of about 1,000 neighbouring stars known to host planets. Its launch is scheduled for 2018 – following a remarkably short development period of approximately five years.

An observatory for cosmic rays

Martin Pohl
Department of Nuclear and Particle Physics (DPNC), Centre for Astroparticle Physics (CAP), University of Geneva

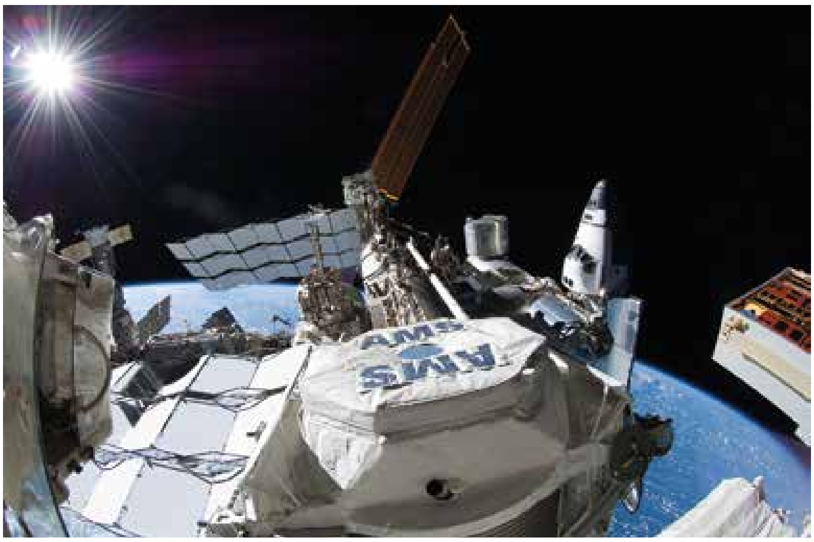
Where do cosmic rays come from, and how do they affect life on Earth? Scientists are looking for answers to this question using a particle detector, the Alpha Magnetic Spectrometer, on the International Space Station (ISS). Switzerland has been involved since the very start of this experiment.

Cosmic rays are part of our environment, since the Earth is constantly exposed to ionising radiation from space. Atomic nuclei, electrons, and other particles are released into the Milky Way, where they are accelerated to high velocities. They are electrically charged and ionise the material they penetrate. Basic research into the characteristics of these particles is being conducted on the ISS.

Effect on our daily lives

The ionising particles have an effect on our daily lives. We cannot escape them. They can disrupt radio communications, and influence cloud formation and the composition of the atmosphere. They have an impact on changes in genetic material, and are thus one of the drivers of evolution.

We are protected on Earth by the atmosphere, which is like a one-metre-thick concrete shield, and by the magnetic field, which steers charged particles away from the planet. In space there is no such protection from the health-damaging cosmic rays. In a three-year mission to Mars, the risk of developing a life-threatening cancer rises by up to 19%. The rays are even suspected of exacerbating the risk of developing Alzheimer's disease.



The Alpha Magnetic Spectrometer in 2011, after having been transported to the International Space Station. The Endeavour Space Shuttle can be seen in the background. © NASA

The observatory for cosmic rays

The *Alpha Magnetic Spectrometer (*AMS) has been operating on the ISS since May 2011. It is a modern particle detector and uses the same technology which is used at the particle accelerators at the CERN research centre in Geneva. The AMS measures the energy of cosmic particles to a very high precision. Of particular interest are particles which originate in the Milky Way. They were first discovered over a century ago, but we still do not know exactly where they come from, how they are accelerated, and how they get to Earth.

They may originate at the end of a star's lifetime, when it suddenly becomes brighter before being destroyed in a final explosion. This phenomenon, known as a supernova, can release huge amounts of nuclear material and create fast-moving shockwaves. But particles may also be created by dark matter – an unknown mass that helps hold the universe together – without emitting, absorbing, or reflecting light.

Switzerland involved from the start

The Department of Nuclear and Particle Physics (DPNC) at University of Geneva has decades of experience in developing and using this kind of detector technology. A DPNC research group has been involved in the AMS experiment since it was designed in 1994, along with several hundred other scientists, engineers, and students from 16 countries. After 18 years of planning, construction, and tests, the Space Shuttle Endeavour transported AMS to the ISS on its final flight. Since then, the spectrometer has constantly gathered information, so that we now have the largest ever collection of data on cosmic radiation. Initial analyses indicate previously unknown particle sources. It is planned to continue the experiment for the whole of the ISS's lifetime, *i.e.,* until at least 2024 (see page 30).

The Alpha Magnetic Spectrometer, installed on the truss section of the International Space Station © NASA

Alpha Magnetic Spectrometer AMS-02

Cooperation:
» Universities and research institutions in China, Denmark, Finland, France, Germany, Italy, Mexico, Portugal, Romania, Russia, Spain, South Korea, Switzerland, Taiwan, Turkey, and the USA

Main researchers:
» Samuel C.C. Ting, MIT, Massachusetts Institute of Technology, Cambridge, USA
» Manuel Aguilar-Benitez, CIEMAT, Madrid, Spain
» Sylvie Rosier-Lees, Ph.D., LAPP and Université Savoie Mont Blanc, Annecy-Le-Vieux, France
» Roberto Battiston, INFN di Trento and Università degli Studi di Trento, Trento, Italy
» Shih-Chang Lee, Academia Sinica, Taipei, Taiwan
» Stefan Schael, RWTH Aachen, Germany
» Martin Pohl, DPNC, University of Geneva, Switzerland

Installation:
» Launched: 16 May 2011 with mission STS-134 to the ISS
» First data: 19 May 2011
» Orbit: Altitude 400 km, inclination 52°, period 93 minutes

Data collection:
» 18 billion cosmic particles a year
» To run until at least 2024

Research objectives:
» Characteristics of cosmic rays
» Conventional sources (supernovas, pulsars, etc.)
» Unconventional sources (e.g., dark matter)
» Residual antimatter

Swiss research provides insights into space debris

Thomas Schildknecht
Professor, Astronomical Institute at the University of Bern and director of the Zimmerwald Observatory

DurIng the afternoon of 10 February 2009, the active telecommunications satellite Iridium 33 collided with Kosmos-2251, a disused communications satellite, above Siberia at an altitude of nearly 800 km. The satellites collided at a speed of 11.7 km per second, producing a cloud of more than 2,000 pieces of debris measuring at least 10 cm in diameter. Within a few months, the debris had spread out over a large region in space, creating a risk of further collisions with active satellites.

The event was a wake-up call for all satellite operators and policy makers. It added a new dimension to an issue that has occupied experts and space agencies for nearly 50 years now: the problem of space debris, defunct man-made objects in space. Swiss research provides scientific and empirical bases for creating models and devising measures to stabilise the amount of space debris. It is helping to ensure the safe and sustainable use of space for the future.

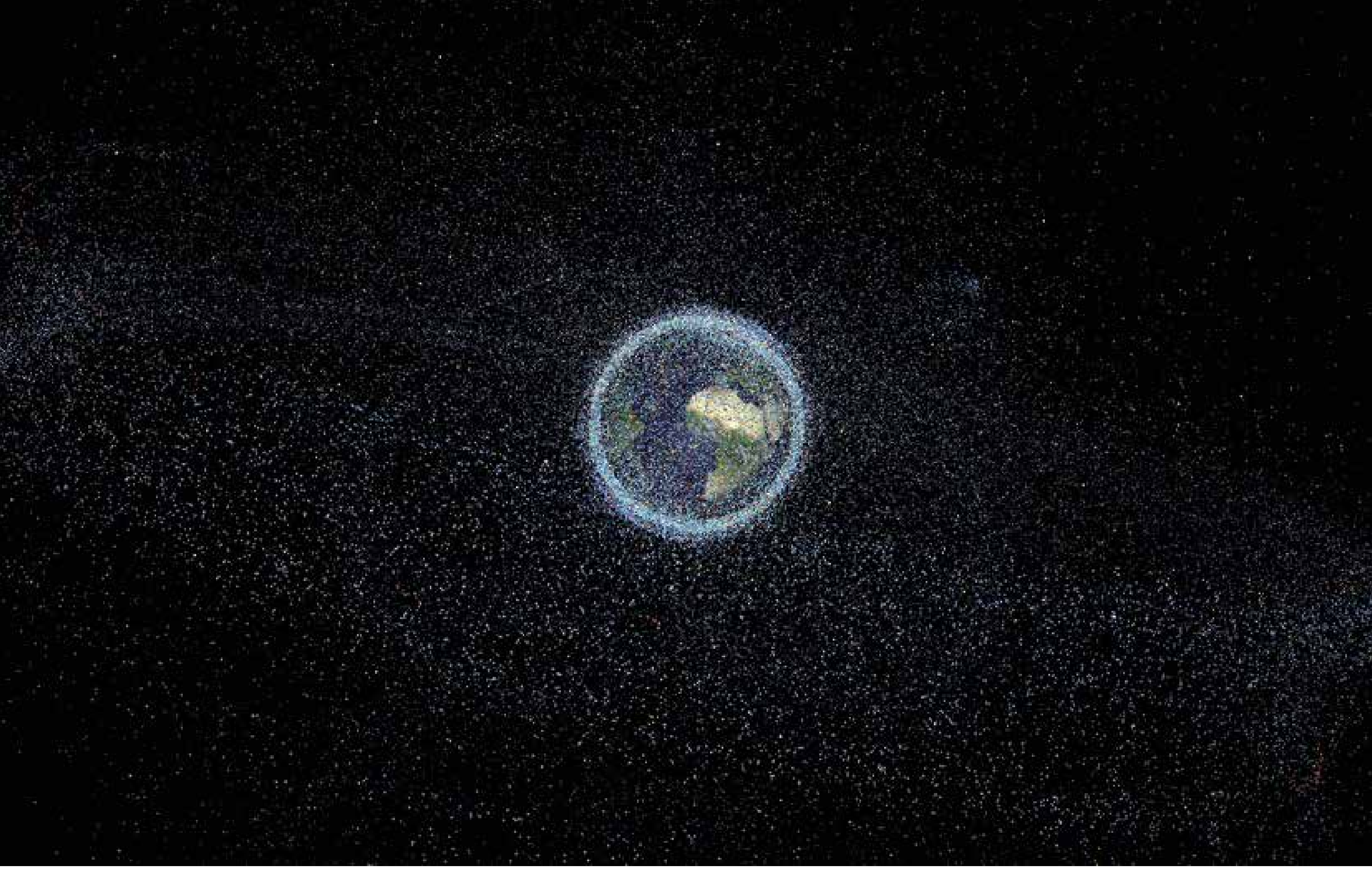
Measuring the orbits of space debris with the laser beam of the 1 m Laser and Astrometry Telescope at the Swiss Optical Ground Station and Geodynamics Observatory in Zimmerwald near Bern. © P. Schlatter

Highly complex measurements at the University of Bern provide insights

To better understand the current population of space debris requires extensive observation using ground-based radar stations and optical telescopes. These measurements enable tracking larger objects to determine their orbits. Today we know the orbits of about 20,000 objects at altitudes of 300 to 40,000 km. Only statistical data is available for objects less than 10 cm in diameter. The measurements indicate a total of about 700,000 space debris items between 1 and 10 cm in size. These fragments may be small, but they can inflict serious damage. A collision with a fragment of 1 cm in diameter releases the energy of an exploding grenade.

Researchers from the Astronomical Institute at the University of Bern are searching small fragments of space debris in high Earth orbits. They use telescopes at the Swiss Optical Ground Station and Geodynamics Observatory in Zimmerwald near Bern and an ESA telescope on Tenerife in Spain. In addition to the regions in which navigation satellites orbit (at about 20,000 km altitude), the geostationary ring at 36,000 km altitude is surveyed in particular interest. Satellites in the geostationary ring remain 'fixed' over a point on the equator, always observing the same section of the Earth's surface (weather satellites) or transmitting signals to the same region (communication satellites). The geostationary orbit is very much used, but also limited, what may give rise to tensions among satellite operators or even States.

Using these measurements, researchers have discovered countless items of debris over the last 20 years, including a new, unexpected population of very light objects. Closer observation of individual objects among this new population suggests that they are bits of foils used for thermal insulation of satellites.



Graphic representation of space debris measuring more than 1 cm in diameter as seen from a distance of three Earth radii (IRAS TUB)

Space increasingly polluted

These results have made a significant contribution to models that describe the current population of space debris and serve as a starting point for calculating future scenarios. All such models indicate that the population of space debris is set to rise sharply in coming decades. Numerous measures will be needed to limit this proliferation, including collision avoidance, disposal of objects away from the critical regions at the end of their mission (for example, by letting them burn up in Earth's atmosphere), and possibly active removal of old, disused satellites and upper stages of launchers with the help of a space robot.

Space debris also a matter of concern for UN outer space committee
Space debris is also an important issue for the UN Committee on the Peaceful Uses of Outer Space (UNCOPUOS). UNCOPUOS is the only worldwide intergovernmental body devoted to space affairs.

The committee is concerned with space science and technology as well as the legal aspects of space activities. It establishes guidelines and regulatory frameworks to ensure the safe, peaceful use of outer space in the long term. This might include clarifying who is responsible when a rocket crashes to earth or when two satellites collide, for example. Intergovernmental dialogue itself contributes to security and stability in space.

At the same time, UNCOPUOS promotes international cooperation with regard to the use of technologies for sustainable development in areas such as water, global health, disaster management and climate change.

In 2018, UNCOPUOS will celebrate 50 years of the first United Nations Conference on the Exploration and Peaceful Uses of Outer Space. Switzerland has been a member of the committee since 2008. From 1969 to 1978, it has ratified four out of five UN treaties on outer space.

The astronaut’s view

Claude Nicollier

I had the great privilege of being on board four Space Shuttle missions as part of the cooperation in human spaceflight between ESA and NASA. It was hard work, yes, but for me personally also a unique experience. It gave me the opportunity to support space research and exploration, and help serve the interests of the countries taking part in this program, as well as their citizens.

I’m thinking in particular about the two missions I had the chance to take part in to maintain and repair the Hubble space telescope. This work helped ensure that this unique telescope – jointly developed by ESA and NASA – could continue being a very productive scientific instrument for research in astrophysics.

Space opens up extraordinary possibilities for us, which we can also use to better our day-to-day lives – particularly when it comes to telecommunication, navigation (air, water, or land), and observing our planet and its atmosphere. At the same time, space offers an almost inexhaustible laboratory for astrophysics and solar physics as well as for research into the near-Earth environment, which is constantly exposed to radiation and particles. Another fascinating area of space research is the impact of microgravity (or weightlessness) on solid objects, fluids, biological processes, and the human body.

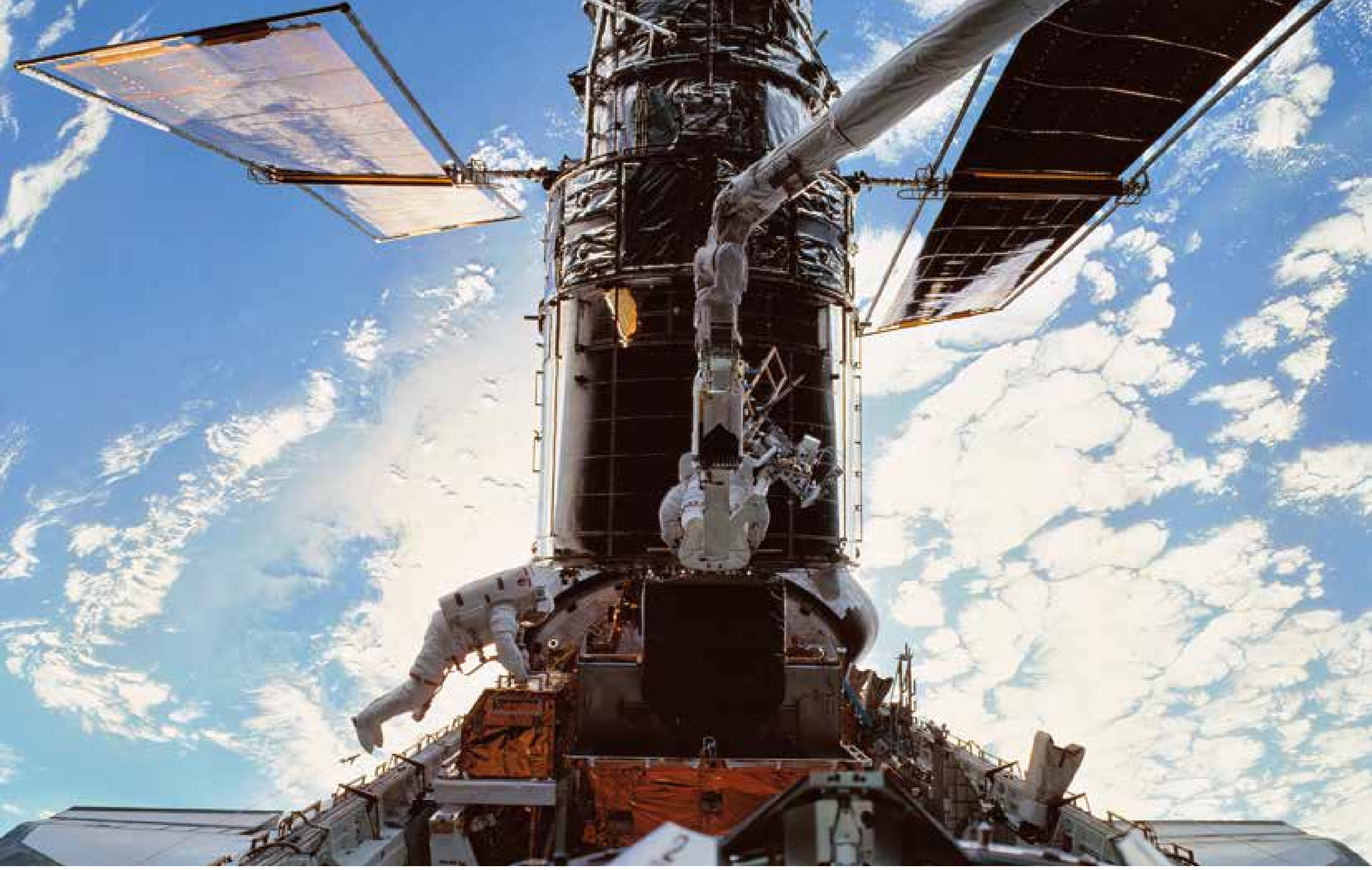
Claude Nicollier in space as he repairs the Hubble space telescope on 23 December 1999. © NASA

“Living in the International Space Station, we finally understood what ‘long term spaceflight’ means...”

Out of the human space, the 15-nation International Space Station (ISS) project was proof, first and foremost, that we can join forces and build large size space structures using human capabilities and robotics. We are currently focusing on the maintenance of the ISS, so that it can continue to function as a laboratory in space in the future. These experiences will benefit all Station operators and partners. It’s true, the ISS is primarily about research, but we learned also a lot beyond pure science. “Living in the ISS, we finally understood what ‘long term spaceflight’ means...”

The future and interests of human spaceflight do not lie in near-Earth orbits alone but are clearly turning to more distant objects in the solar system – including our closest neighbour, the moon. It will be a matter of committing our human capabilities and skills to continued space research beyond Earth and to see if an exploitation of ‘off Earth’ resources is possible.

And last but not least, it will be about finding out if people may one day be able to travel to other planets in the solar system and settle there for the long term. The question is: will human existence be confined to Earth? Or will we head for new frontiers within our solar system, and settle there for long periods of time? Only the future will tell. But the next steps in human space-flight should allow us to find an answer to this question, and there is no doubt that it will be a really fascinating adventure!



Claude Nicollier (viewed from behind, mid-photo, on the robotic arm) installing a fine guidance sensor on the Hubble space telescope 600km away from Earth above Australia on 23 December 1999. Fellow astronaut Mike Foale is on the left. © NASA

Claude Nicollier (born 22 September 1944 in Vevey, canton of Vaud) is the only Swiss astronaut to date. He is also the only European to have undertaken four space shuttle missions. The asteroid Nicollier (no. 14826) is named after him.

After studying astrophysics and training to become an airline pilot, Nicollier started working in 1976 as a researcher at ESA in Noordwijk in the Netherlands. He applied for a space mission and was selected for the first ESA astronaut group in December 1977.

Nicollier flew into space on four space shuttle missions between 1992 and 1999 as part of ESA's cooperation programme with NASA. He took his first spacewalk during the fourth and final mission, installing new instruments and replacing equipment on the Hubble space telescope.

Nicollier has been working as a full professor at the Federal Institute of Technology in Lausanne (EPFL) since 2007. Since 2009 he has led the flight test team for the solar-powered aircraft, Solar Impulse.

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