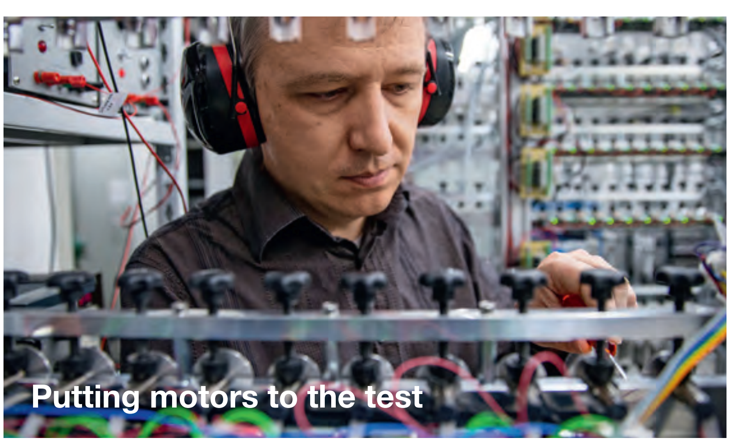
The maxon motor **magazine**

driven

1 // 2015

Heading for new worlds

The Moon, the Sun, and Mars in the spotlight



Putting motors to the test

Traveling in time and space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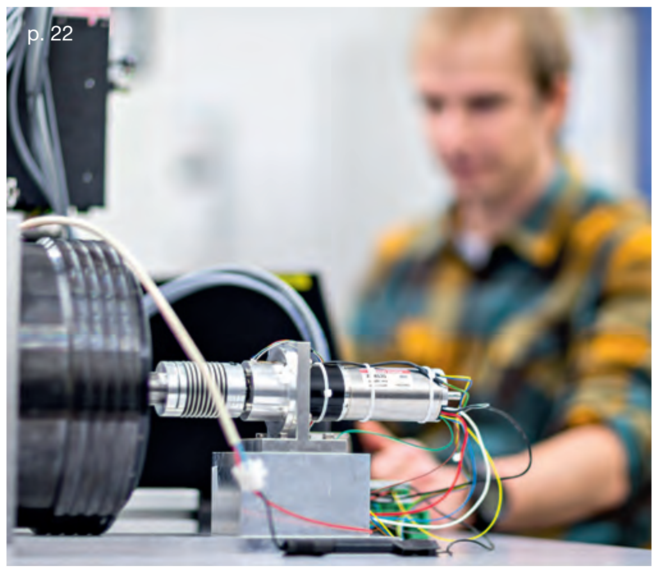
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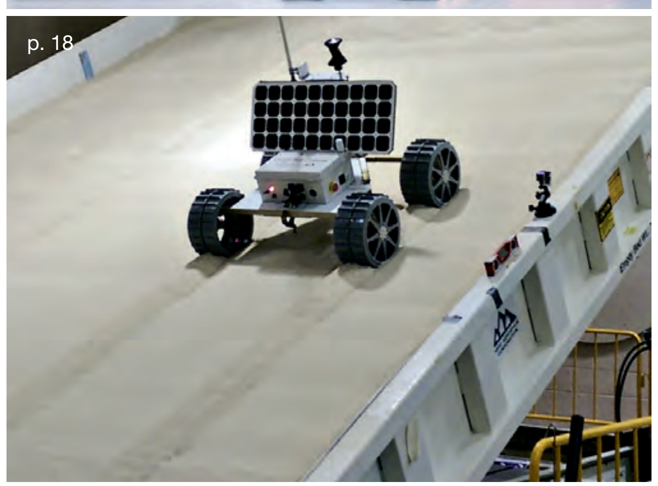
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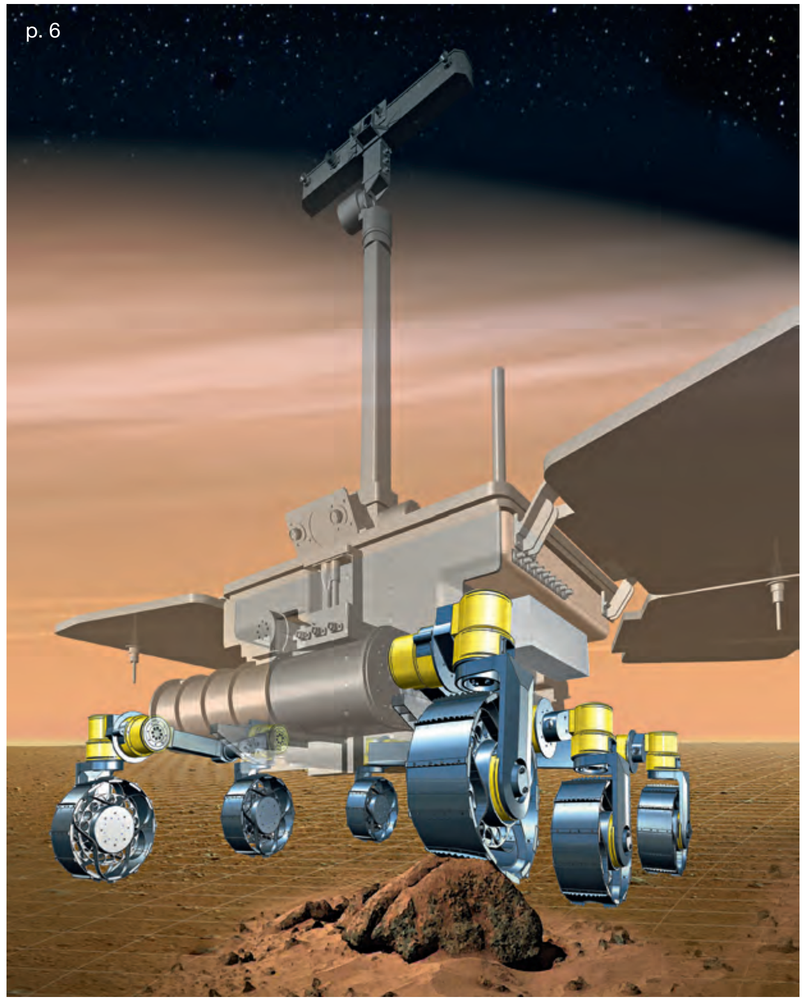
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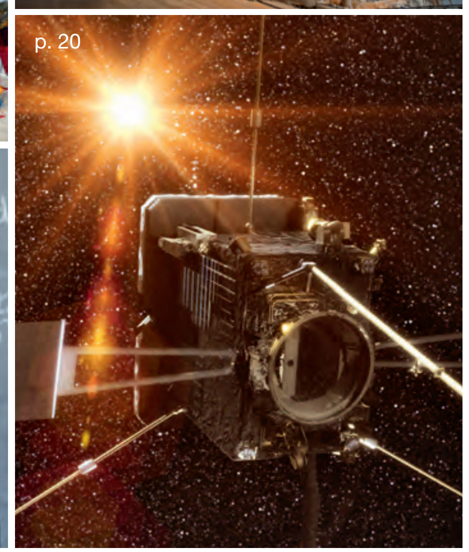
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Photos: ESA/Equinox Graphics, maxon motor ag, MDA Corporation, NASA/Bill Ingalls, NASA/JPL-Caltech/Cornell University/Arizona State University

Editorial

Heading for **new worlds**


Eugen Elmiger, CEO, maxon motor ag

We live in an exciting time where science is exploring some big questions. What is the origin of water? And of life? How did our solar system form? Many clues can be found in space or on other planets. This is why we send out more and more sophisticated probes and robots to look for answers.

Learn how ESA is looking for life on Mars with a rover, why biological experiments are conducted on the ISS, and how a private company is planning to fly to the Moon. Always on board: maxon motors. Their quality and the extensive know-how of our engineers make our motors an indispensable part of space exploration. Nowhere is reliability more important than in the depths of space.

Happy reading!

The current tablet edition with interactive and multimedia features can be found in the Apple App Store, on Google Play and now also in the Windows Store.

Our new Aerospace sales team

Better service with a specialized sales team

Photos: ESA, maxon motor ag

Stefan Dillier, Fabian Bucher, and Roger Villiger, head of the team (from the left).

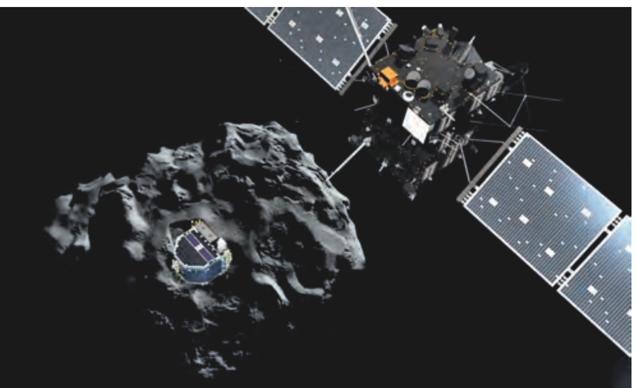
To sharpen its focus in aerospace, maxon motor has assembled a new sales team at its headquarters in Switzerland. The new team caters exclusively to the aerospace sector, i.e. applications in passenger aircraft, helicopters, or space missions, to name a few. Customers all over the world will benefit in a variety of ways.

Products and services are being developed specifically for the aerospace industry. From now on, specialists on the sales team will handle consultation and customer service for these products. These specialists are working closely with the aerospace technical project management team, which has been flanking the relevant projects for a long time.

Roger Villiger, head of the Aerospace sales team, is looking forward to the new challenge: "We believe that the aerospace industry has great potential for growth, and we are looking forward to interesting customer projects. The industry's high requirements to power density, robustness, and uncompromising quality are a very good match for maxon."

Do you have any questions about aerospace projects?
Contact:
aerospace@maxonmotor.com

193
million kilometers

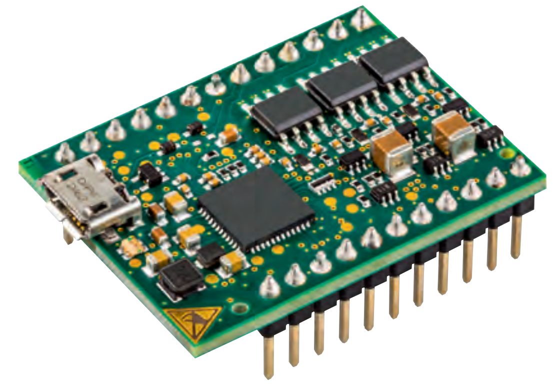


That's the distance between the comet 67P/Churyumov-Gerasimenko and the Sun in August 2015, the shortest on the comet's path through our solar system. The comet is accompanied and continuously monitored and analyzed by the European space probe Rosetta. It is the first time in history that a probe is present when a comet becomes active. Comets are lumps of frozen rock that have been around since the universe was young. They only thaw when they approach the Sun. This creates their characteristic tail.

The question is whether the increased irradiation from the Sun will be sufficient to reactivate the lander Philae that successfully touched down on the comet in November last year. The minilab has been hibernating since then and is waiting for its solar panels to deliver power. Philae's measurements are going to keep scientists busy for years. It is already clear that our water is quite dissimilar from that on the comet. This insight has revived the debate on how Earth came by its water in the first place.

maxon motor delivered several motors for various tasks to the Rosetta mission. Brushed DC micro drives were used to unhitch the lander from the probe and extend an instrument on the comet.

NEW PRODUCTS



ESCON Module 24/2 servo controller

ESCON Module 24/2 servo controller

The size of a stamp, with all that's needed

maxon motor adds a miniaturized plug-in module to expand its successful ESCON range of servo controllers. It is suitable for controlling brushed and brushless DC motors with up to 48 W continuous output power and 144 W peak power. Even though the servo controller is only the size of a stamp, it has outstanding control characteristics for speeds up to 150,000 rpm. The ESCON Module 24/2 offers a wide range of built-in operating modes, such as current control as well as open or closed-loop speed control. The analog and digital inputs and outputs are freely configurable.

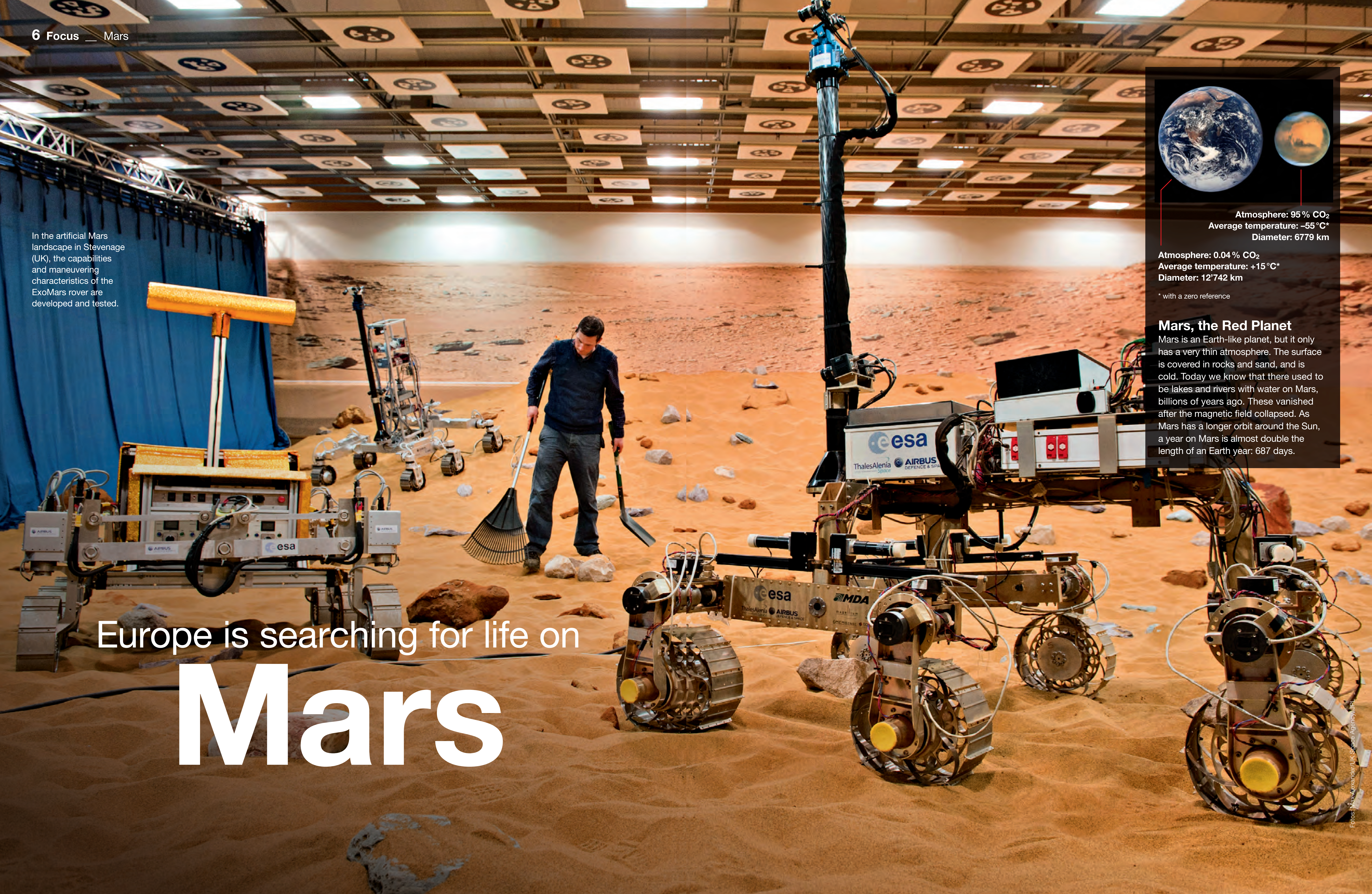
DC-max motors

The cost-effective alternative

The new DC-max motors by maxon bridge the gap between high performance and a cost-optimized design. Equipped with neodymium magnets and state-of-the-art winding technology, they achieve great ratings in all categories and are superior to the previous RE-max motors, at a much lower price. With the new DC-max drives, maxon motor offers its customers a motor with an unprecedented price/performance ratio. The DC-max is available in the two sizes, 16 and 22 millimeters (diameter). From fall 2015, it can be configured online like the DCX-series motors.

DC-max 16
Ø 16 mm, precious metal or graphite brushes

DC-max 22
Ø 22 mm, precious metal or graphite brushes



In the artificial Mars landscape in Stevenage (UK), the capabilities and maneuvering characteristics of the ExoMars rover are developed and tested.

Europe is searching for life on Mars

Atmosphere: 95 % CO_2
Average temperature: –55 °C*
Diameter: 6779 km

Atmosphere: 0.04 % CO_2
Average temperature: +15 °C*
Diameter: 12'742 km

* with a zero reference

Mars, the Red Planet

Mars is an Earth-like planet, but it only has a very thin atmosphere. The surface is covered in rocks and sand, and is cold. Today we know that there used to be lakes and rivers with water on Mars, billions of years ago. These vanished after the magnetic field collapsed. As Mars has a longer orbit around the Sun, a year on Mars is almost double the length of an Earth year: 687 days.

Fotos: Max Alexander/UK Space Agency, JPL

Was there once life on Mars? Or does it perhaps still exist under the surface? The ExoMars rover may hold the key to solving this great puzzle. maxon is supplying dozens of motors for the project, and breaking new ground with the wheel drives.

A hundred years ago, many people believed that there was a civilization on Mars. Today we know better. Nevertheless: It is quite possible that there was once life on Mars. In the early days of the planet, more than three billion years ago, the environmental conditions were not as harsh as they are today. They were similar to conditions on Earth, where microorganisms already existed. Even today, the possibility of undiscovered life forms on Mars cannot be ruled out. Below the surface or in the ice of the polar caps, bacteria would be protected against the radiation of space and the large temperature fluctuations. Why not?

Perhaps we will soon know more, when the rover of the European Space Agency (ESA) lands on Mars in January 2019. This rover, which is part of the ExoMars mission, will look for traces of existing or extinct life. It is equipped for this task with a drill that can reach a depth of two meters below the surface to take samples. These are broken down inside the vehicle and are analyzed chemically and biologically for traces of life. The rover is more advanced than its predecessors from NASA, which were used primarily to search for water (see p. 10).

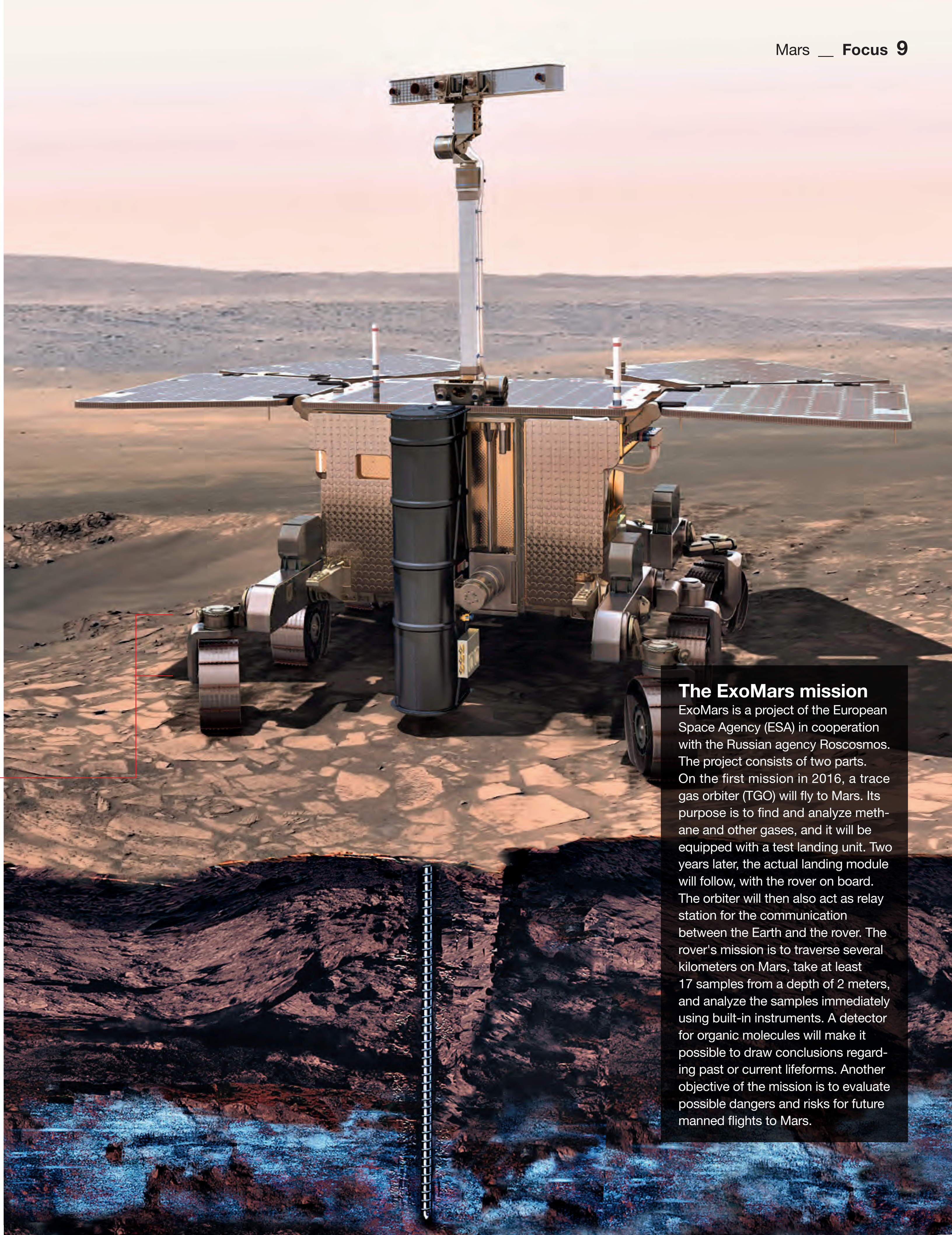
Great leaps in technology

The trip to Mars remains a technological challenge. Devices have to withstand massive temperature fluctuations, cosmic radiation and huge dust storms while still working perfectly. Nothing of this is entirely new for maxon motor. After providing drives for the first three Mars rovers for the U.S. space agency NASA – Sojourner, Spirit and Opportunity – the Swiss company has extensive experience with meeting these demands. Nevertheless the European project will not be an easy ride, as Robin Phillips, aerospace project manager at maxon motor, explains: "There has been significant technical development since the last rovers." Additionally, this is the first time that maxon is supplying entire drive modules, consisting of a DCX motor, gearhead, encoder and brake, all fit into a compact housing. Eighteen of these modules are installed in the vehicle chassis, where they drive and control the six wheels individually. Another new factor is that maxon is handling all drive tests, thus reducing the workload for the customer (see article on p. 22). Robin Phillips says: "In recent years, maxon has made great progress and obtained important know-how. Today, we are capable of handling such a challenge and playing an even more important part in a Mars mission."

Motors from maxon have already been on board NASA's first three Mars rovers.

The Canadian company MDA is responsible for the chassis and has set stringent requirements regarding the weight, torque and speed of the motors. After all, the rover has to overcome obstacles up to 25 cm high and inclines of 26 degrees. It will be able to move

Photo: ESA



The ExoMars mission

ExoMars is a project of the European Space Agency (ESA) in cooperation with the Russian agency Roscosmos. The project consists of two parts. On the first mission in 2016, a trace gas orbiter (TGO) will fly to Mars. Its purpose is to find and analyze methane and other gases, and it will be equipped with a test landing unit. Two years later, the actual landing module will follow, with the rover on board. The orbiter will then also act as relay station for the communication between the Earth and the rover. The rover's mission is to traverse several kilometers on Mars, take at least 17 samples from a depth of 2 meters, and analyze the samples immediately using built-in instruments. A detector for organic molecules will make it possible to draw conclusions regarding past or current lifeforms. Another objective of the mission is to evaluate possible dangers and risks for future manned flights to Mars.

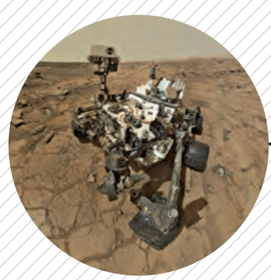
Past **rover missions** to Mars

There have been four rover missions to Mars, all conducted by NASA. All four rovers were equipped with drive systems by maxon motor.

Sojourner
The first Mars rover landed on July 4, 1997. Service life: three months. For the drives, the steering, and the scientific devices, maxon supplied eleven DC motors, 16 mm in diameter.

Spirit/Opportunity
The two twin rovers were sent to Mars individually and landed there in January 2004. Spirit collected data for six years; Opportunity is still active and has since discovered traces of water in rock layers. Both rovers were equipped with 35 maxon DC motors - for example for driving the wheels, the control system and the robotic arm.

Phoenix
This stationary Mars probe landed on Mars on May 25, 2008, took rock samples from the ground with its robotic arm and analyzed them. It found frozen water. maxon supplied nine brushed motors of type RE 25, with special ball bearings for aligning the solar panels.



Curiosity
This rover landed on Mars in August 2012. It surpassed its predecessors, and not just in terms of technology. It is as big as a small car and is powered by a radionuclide battery. Curiosity analyzed the Mars' surface and atmosphere. To this end, maxon motor equipped it with magnetic encoders mounted on the drive axes.

Motor module
This is a maxon complete solution from a single source. The module consists of a brushed DCX 22 L motor, a GP 22 HD planetary gearhead, a magnet brake, and a Hall sensor. Everything fits into a compact housing. This is the first time maxon developed, built, and delivered a complete drive unit. With its ironless winding, the DCX drive has several advantages. For example, the motor is easy to control, powerful, energy-efficient and very durable. To ensure a long service life in the atmosphere of Mars, maxon is equipping the motor with special brushes.

sideways and even walk, moving its legs like a spider. No rover in the past has had even remotely comparable mobility. "It is really magical to participate in scientific projects such as this," says Ryan McCoubrey, senior rover engineer at MDA. He is happy to have found a good partner in maxon. "They are world-renowned for their precision motors and have valuable experience from the NASA missions, whereas we contribute our knowledge of flight systems and process management. Together, we are a very strong and effective team."

> 60 maxon employees are involved in the development of the rover.

For the first time, brushless motors are flying to Mars

maxon motor has been an official participant of the ExoMars mission since 2011, but the first developments started several years earlier. Today around 60 employees are involved, more than in any other aerospace project. After all, maxon is not supplying only motors for the rover's wheels. 16 different combinations of motors, gearheads and encoders are used –, for example in the analysis instruments and the drill unit.

The latter is being developed, tested and supplied by Selex ES, a company of the Finmeccanica group. It is a great challenge for the engineers, says Francesco Rizzi: "It is very difficult to develop a drill unit that is capable of coping with all imaginable known and unknown types of rock." The drill has to function perfectly on Mars and but simultaneously meet very strict limits regarding its size, dimensions and power consumption. The whole package must weigh less than 21 kg and use less than 80 W. The motors also have to be particularly light, efficient and powerful. That is why brushless EC motors by maxon will be used on Mars for the first time; they will drive the drill head. These motors have the necessary power and long service life to fulfill this task. Additional brushed DC motors will be responsible for positioning the drill and taking the samples.

In the coming months, Selex ES will test the rover extensively under realistic Mars conditions at the University of Padova. The rocket launch, landing and driving on the Mars surface will also be simulated. The flight unit will be handed over to ESA at the end of 2016. Until then, the engineers still have a few challenges to face, "but this is normal for projects where we can't build on experience and have to meet such high requirements," says Francesco Rizzi. "Together we will succeed, not least because we have the great maxon team and its technical expertise on our side."

EC 22
This brushless DC motor with a diameter of 22 millimeters has no cogging torque, offers outstanding control characteristics and a great efficiency. It has a high short-term overload capacity and quickly sheds heat.

maxon EC 22
Ø 22 mm, brushless, 50 W

Photos: NASA, NASA/JPL/Caltech/University of Arizona, NASA/JPL/Caltech/MSSS, maxon motor ag

In a cleanroom, technicians prepare the InSight Mars lander for drive and leak tests.

Investigating **the secret** of rocky planets

To learn about Earth's past, scientists are turning their gaze to Mars. They send a robotic probe to take the Red Planet's pulse and temperature.

Photos: DLR, maxon motor ag, NASA/JPL, NASA/JPL/Caltech/Lockheed Martin

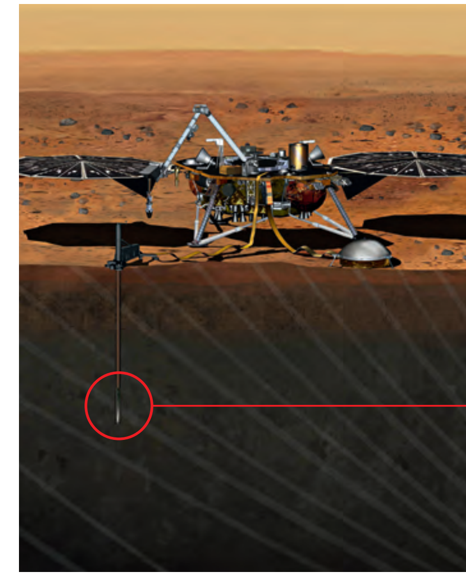
Our Earth is alive, active, and constantly changing. Its surface has been in motion since the planet's formation. Continental plates drift apart and collide, forming mountains, oceans, and plains. Literally no stone is left unturned – only change is permanent.

To learn more about the early days of Earth, geologists therefore need to look to Mars. The Red Planet does not have tectonic plates and hardly any geological activity. The surface is still as it was four billion years ago – albeit there used to be lakes and rivers, as we now know. Mars is interesting to researchers because it underwent the same basic formation process as our Earth. Both started out as balls of liquid fire and, through the process of planetary differentiation, turned into terrestrial planets, also called rocky planets. Heavy metals gravitated to the center, where they formed the red-hot iron core. Above, the mantle was formed, enclosed by the crust, which cooled down and solidified. Venus and Mercury also are rocky planets, while Jupiter, Saturn, Uranus and Neptune are gas giants.

A bolt drives itself into the ground

To learn more about Mars and its structure, NASA is sending a robotic probe called InSight in 2016. InSight will remain stationary after landing. One of it instruments will record seismic activities caused by quakes or comet strikes.

A second instrument, called HP³, will enter five meters deep into the ground to measure the planet's heat. It is a bolt, lovingly dubbed "Mole" by its developers. In the words of Judit Jänchen, it works "like a nail that drives itself into the ground." Jänchen is a project manager at the German space agency, which developed HP³. Inside the Mole, there is a maxon-built drive, consisting of a DCX 22 motor and a GP 22 HD planetary gearhead, that has to stand up to extremely high requirements. This is because Mars, with its temperature fluctuations, sand storms, and thin atmosphere, is a very unfriendly place for technology. On top of that, the DC motor is going to be exposed to forces of up to 400 g. The motor's task is to wind up a spring, which then releases with great force, executing a powerful downwards punch. This causes the bolt to drive itself into the ground step by step. The process takes several hours. Once embedded, the device stays in place.



The maxon drive system that drives the HP³ bolt into the ground on Mars is exposed to loads of up to 400 g.

Temperature profile helps researchers

The measurement is performed using a cable equipped with temperature sensors dragged along by the Mole. It is used to generate an exact temperature profile of the ground on Mars over a two-year period, to determine the surface heat flow. "This quantity is a fundamental parameter when you want to characterize a planet", says Judit Jänchen. Information on the porosity and density of the ground can also be derived from the penetration speed of the Mole. Both results are of great interest for terrestrial geophysics. "This gives us a better understanding of the formation and evolution of rocky planets."

Download the tablet issue 1 // 2015 to see how InSight is going to deploy its instruments on the surface of Mars. magazine.maxonmotor.com

As tough as they come

The DCX 22 is the champion among maxon's brushed motors. It can be configured online with ease and excels with its enormous power and energy efficiency, which can be decisive when operated on a battery. For the InSight mission, the drive was reinforced to survive the brutal impacts. Additional weld rings and joints at the bearings ensure that the drive withstands up to 400 g. The gearhead used with the motor is a GP 22 HD, an extremely robust unit that is often used in deep drilling.

maxon DCX 22
Ø 22 mm, graphite brushes

maxon GP 22 HD
Ø 22 mm, 3-stage

Traveling in **time and space**

What were the key events in the history of space travel? And what happened on Earth at the same time? What's in the cards for the future of humanity?

First man in space

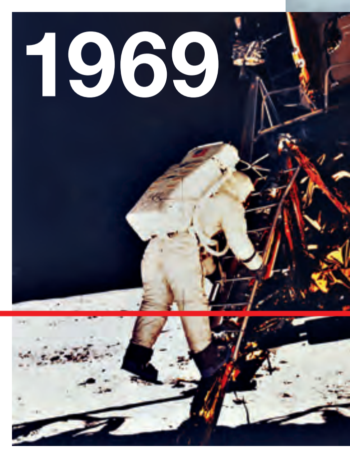
In April 1961, Yuri Gagarin embarks on a trip around the planet Earth on board a Soyuz rocket. Duration: 100 minutes.

Berlin Wall is built

In August, the GDR starts to build the Berlin Wall. It symbolized the Cold War between NATO and the Warsaw Pact.

First Moon landing

In July, Neil Armstrong and Edwin Aldrin are the first men on the Moon. In the same year, Charles Conrad and Alan Bean follow on the Apollo 12 mission. Between 1969 and 1972, twelve people walked on the Moon.

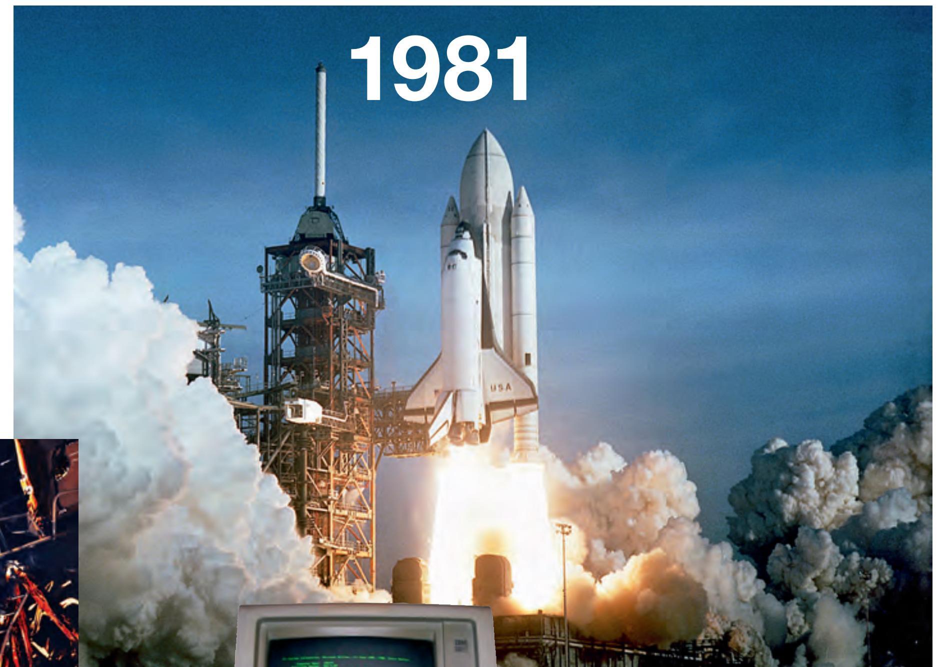


Arpanet is online

The Arpanet goes online. It was developed by the Advanced Research Projects Agency (ARPA) and is a precursor to the modern Internet. The goal is to create a decentralized network to interconnect the US universities that work for the Pentagon.

Virgin flight of the Space Shuttle

In April, the Columbia Space Shuttle is the first manned carrier system to be sent into space. 30 years later, in 2011, the Space Shuttle program is phased out on grounds of cost and safety.



Personal computer

In August, IBM presents the first personal computer, the IBM PC. This has a lasting effect on the future development of computers.

Hubble looks into space

Starting in April, the Hubble space telescope orbits Earth at an altitude of 600 kilometers. Since then, the "flying observatory" has delivered a constant stream of fascinating photos of remote stars and galaxies.

German Reunification

The GDR is history. In October, the German Reunification ends the division of the country after 40 years.

Pathfinder probe lands on Mars

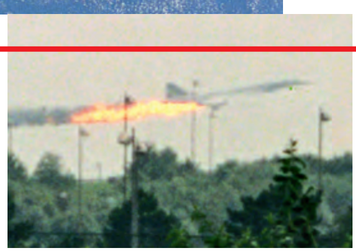
On board: the Rover Sojourner, the first vehicle on Mars. After landing in July, the rover travels the sandy landscape for almost three months, sending data and images back to Earth. It is driven by maxon DC motors.

Deadly car crash

Diana, Princess of Wales, dies in a car crash in a Paris tunnel together with her partner Dodi Al-Fayed.

Photos: akg-images/Archive Photos, ESA, Keystone/AP PA/Neil Munns, Keystone/dpa/Volkmar Hoffmann, Keystone/Laif/Paul Langrock/Zenit, NASA, NASA/JPL, Wikimedia

ISS goes into operation
In November, the International Space Station (ISS) starts its operation at an altitude of approximately 400 kilometers. Since then, it has been orbiting Earth at 27,581 km/h. On ISS, drive systems by maxon motor are used for laboratory equipment, among other things.



End of the Concorde
113 people die when a French Concorde crashes near Paris in July. Air France terminates its operation of the Concorde.

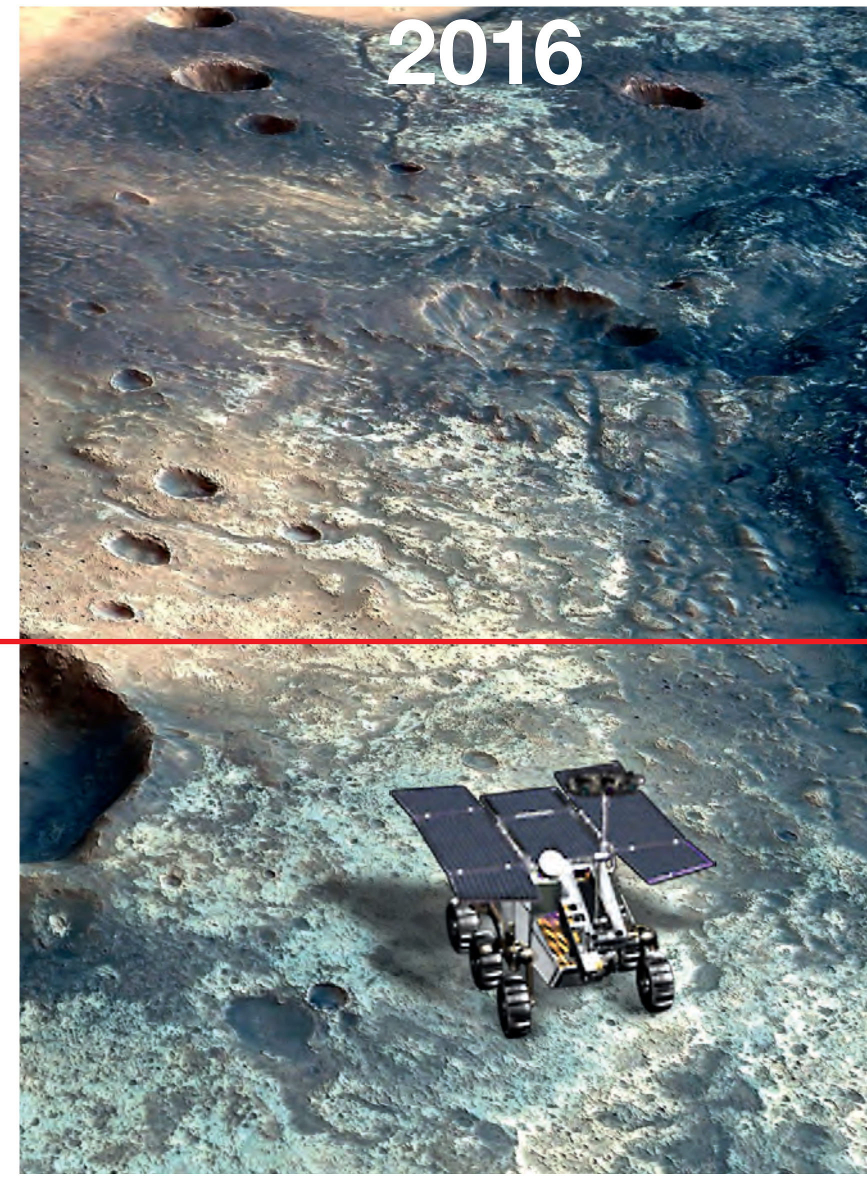
Mars rovers land
In January, the Mars rovers Spirit and Opportunity touch down on Mars to look for traces of water. The maxon motor drive systems on board power a variety of components, for example the wheels and the robotic arms of the rovers. Opportunity is still going strong today.

Olympic Summer Games in Athens
108 years after the first modern Olympics in 1896, the Summer Games are held in the Greek capital for the second time in 2004.

SpaceX launches Dragon
The era of private space exploration starts: The US company SpaceX develops the Dragon capsule, which supplies ISS with materials from May onwards. Drive systems by maxon motor control the position of the solar sails, among other things. The head of SpaceX, Elon Musk, wants to send manned Dragon capsules into space in 2017, at the latest.

Spectacular auction
In May, a version of the famous painting The Scream by Edvard Munch is sold at Sotheby's New York. The final price is 119.9 million US dollars.

ExoMars mission
Under the name ExoMars, a probe will be launched to our neighbor planet in 2016. A Mars rover is to follow two years later. It will take rock samples from a depth of two meters. Once again, maxon motor is a partner in the mission and delivers DCX precision drives for the ExoMars rover.



Solar Orbiter
ESA's Orbiter will get closer to the Sun than any space mission before. Its goal is to gain detailed information about the activities on the surface of the Sun. Drive systems by maxon are used to adjust the heat shield (see p. 20).

The Orion spacecraft
Start of NASA's first manned Orion mission to orbit the Moon. Later, the spacecraft is to be used as a manned transport vehicle to Mars.

First humans on Mars
Experts estimate that the 2030s might be the decade in which the first people set out on a journey to Mars. That, however, is still science fiction.

Photos: ESA, ESA/AOES Medialab, ESA/R. Lockwood, Keystone/AP/Itsuo Inouye, NASA, Reuters/Andreas Kisgergely, Wikimedia/Edward Munch/The Munch Museum Oslo

Suddenly, everyone wants to go to the Moon

For decades, it seemed like the world had lost interest in Earth's smaller companion. Now, the science and business communities have rediscovered the Moon. Several landing missions are planned for the coming years, and an American university is leading the way with their rover.

Rover Andy
Size: 102 cm
Mass: 33 kg
(weighs only about 5 kg on the Moon)
Velocity: 18 cm/s
Max. inclination: 30°
Max. size of obstacles: 15 cm

It seemed like the Moon had lost its luster. After the end of NASA's program for manned missions to the Moon in the early 1970s, the major aerospace agencies focused on other priorities: the International Space Station, Mars, and exploring the galaxy with the Hubble Space Telescope and Cosmic Background Explorer, to mention just a few. Now, after four decades, the Moon is back in the spotlight. China, Japan and India have already conducted missions of their own, and other governments, businesses, and even individuals are reaching for the lunar surface. But a small company teamed with a robotics powerhouse university might just lead the way.

Setting sights on Google's grand prize

Astrobotic Technology, a start-up based in Pittsburgh, USA, wants to send a lander and rover to the Moon in the summer of 2016. The success of this mission would be a small sensation – the first private space mission to soft land on the Moon. Astrobotic, partnered with Carnegie Mellon University to compete as Team Astrobotic, would also win the Google Lunar XPrize, a competition initiated by Google. The grand prize of 20 million dollars goes to the first private company that lands on the Moon, travels 500 m across the surface, and sends high-definition video images back to Earth. The deadline has been postponed several times and is now the end of 2016. Astrobotic is a young company founded in 2008 by robotics pioneer Dr. William "Red" Whittaker, director of the Field Robotics Institute. It is a spin-off of Carnegie Mellon University's world-renowned Robotics Institute, with which it still cooperates closely. The company's long-term goal is to cost-effectively deliver payloads to the Moon for goverments, universities, business ventures, and nonprofits.

Rover looks for caves on the Moon

On the inaugural mission, Astrobotic's Griffin lunar lander will deliver the Andy exploration rover to the Moon's surface. Built by a team of researchers and students at Carnegie Mellon University, Andy has its sights set on exploring caves. Planetary scientists believe that a certain type of hole discovered on the Moon, called a skylight, could provide entry to underground cave systems. Such caves would be ideal for future human bases, as they offer protection from radiation, micrometeorite strikes, and temperature swings.

It remains to be seen whether Andy can win the Google prize. Astrobotic is planning to carry other Lunar XPrize candidates on the mission – provided they pay for a ticket on the lander. Negotiations are in progress. If all goes as expected, Mankind may soon witness a NASCAR-style rover race on the Moon.

Today, Astrobotic and CMU are clearly in the pole position, evidenced by the three milestone prizes totaling $1.75M that Google awarded to Astrobotic in January, in the categories of Landing, Mobility, and Imaging. All teams competing for the Mobility prize had to demonstrate that their rovers can function under vacuum conditions and in the other harsh environments of the Moon. The Andy rover impressively demonstrated these abilities in multiple tests and to the XPrize judging panel.

High torque is critical

During the nine-month development of Andy, the researcher and student team in Pittsburgh focused on building a rover that is economical and practical, using standard components wherever possible. The four wheels are driven by brushless maxon EC 4-pole motors with GP 32 HD planetary gearheads. "This combination gives us more than enough torque to conquer all obstacles," says Jon Anderson, a Robotics Masters student at CMU and technical lead of Andy's development. The team made small modifications to lubricants and circuit boards to withstand the anticipated operating conditions in space. The team values maxon motor's extensive experience with space projects. "maxon motors are proven in space. The Mars rovers Spirit and Opportunity each have 35 maxon DC motors driving their wheels, steering, and some science instruments. While we have a lot of obstacles to overcome on our way to the Moon, having a proven partner like maxon to supply our motors makes our job a lot easier," says Anderson.

The fascination with the Moon

Even though the Moon looks gray and barren, it is still a very interesting target for space exploration. Potential deposits of water ice could be mined for drinking water, for irrigation, or even to produce fuel. Sublunarean caves could provide shelter for human explorers and infrastructure. The Moon could be a powerful jumping-off point for future exploration of our solar system.

Photos: Carnegie Mellon University, maxon motor ag

Andy's drives
The brushless EC-4pole 22 used in Andy is a true powerhouse. The rotor has two pole pairs for very high power density and high torque. The motor is combined with the planetary gearhead GP 32 HD, which was developed specifically for use in harsh environmental conditions.

maxon EC-4pole 22
Ø 22 mm, brushless
90 W

Download the tablet issue 1 // 2015 to see how the rover Andy easily conquers inclines and obstacles.
magazine.maxonmotor.com

Closer to the Sun

Without the Sun, there would be no Earth and no life. However, our knowledge about our home star is still very limited. This is about to change. In 2017, ESA will send its Solar Orbiter into space, equipped with a thick heat shield.

Download the tablet issue 1 // 2015 to see how the Solar Orbiter is built. magazine.maxonmotor.com

maxon RE 13
Ø 13 mm, precious metal brushes, 1.2 W

The Solar Orbiter's heat shield has apertures that briefly let the instruments look at the Sun.

Photos: ESA/Anneke Le Floc'h, ESA / Equinox Graphics, maxon motor ag

It is a cautious approach. Step by step, the Solar Orbiter will change its trajectory and swing by Earth and Venus to reduce its distance from the Sun to only 45 million kilometers. No other human-made object was ever this close. The way back to Earth would be thrice as long. Not a pleasant place for the Solar Orbiter: At the front, temperatures rise up to 520 °C under the ceaseless pounding by solar radiation. All other sides are surrounded by the eternal cold of outer space. This combination makes for an incredibly challenging environment.

The secret of solar eruptions

Solar Orbiter is a joint project of the European Space Agency ESA and the US agency NASA. It is going to be an important milestone in the exploration of the Sun. Even though the Sun is responsible for the development of the planets in our solar system, and even though it influences the weather as well as life in general, we know far too little about it. For example, what causes the solar winds? Or solar eruptions? What forces are behind the formation of the heliosphere, the cloud of charged particles that extends past the outer reaches of our solar system?

It is going to take a while until scientists will have answers to these questions. In 2017, an American rocket will take the probe into space. Then it will travel for three years until it can begin its work. Solar Orbiter is going to provide a new perspective of the Sun, its surface, and the polar caps. For this purpose it is equipped with around a dozen cameras and measuring instruments. Some of these systems and subsystems are being developed and built in Lausanne, Switzerland. The company Almatech is involved, for example, in the development of STIX, an X-ray telescope for the observation of solar eruptions. It is expected to yield new insights into the acceleration of electrons and their projection into the depths of outer space.

Sunglasses for instruments

Just like people should not look directly at the Sun, measuring instruments also need protection. After all, the intensity of the radiation on board the Solar Orbiter is 13 times higher than on Earth. The primary means of protection is a state-of-the-art heat shield that remains directed at the Sun at all times. A few holes can be opened for measurements. However, the instruments need to be protected too. In the case of STIX, this is provided by permanent beryllium protective filters and the use of an aluminum grid during solar eruptions. This grid can be placed in front of the 32 X-Ray detectors by means of two maxon RE 13 motors. The brushed DC drives are wired in parallel, enabling them to be used together or individually. This ensures a service life of ten years – the planned duration of the mission.

At Almatech, four engineers are continuously working on the detector system, which is called STIX-DEM. "It's a challenge to develop a device that has never been built before and to test it to prove that it is going to function reliably," says Senior Project Manager Fabrice Rottmeier. "At the same time, it's a great experience and very motivating to be part of a scientific research program that investigates questions about the origin of the universe and the origin of life."

Lightweight drives as an advantage

Weight is a critical factor for space projects. maxon motors come into their own here. Rottmeier: "With maxon drives we were able to build a shield that weighs less than 200 grams and survives vibrations, for example during the launch, without problems." The renowned reliability and high quality of maxon motors were another selection criterion. He adds: "The support from their engineers is very flexible and all around great."

On the mechanical impact tester, the drive units for the wheels of the ExoMars rover are tested for radial and axial shock resistance. The station can generate impact loads of up to 2500 g.

Putting motors to **the test**

Drive systems by maxon motor need to take a lot of abuse, such as high vibration, extreme temperatures, and brutal impact loads during the upcoming ExoMars missions. That is why maxon motor has an in-house development laboratory where motors and gearheads are subjected to harsh testing.

Up to 2500 g – it is hard to imagine the enormous forces that act on an object under this kind of acceleration. Or in this case, on a maxon motor drive system. For comparison, an astronaut experiences gravitational acceleration of around 3 g to 4 g during launch. The average maximum in aerobatics is 8 g.

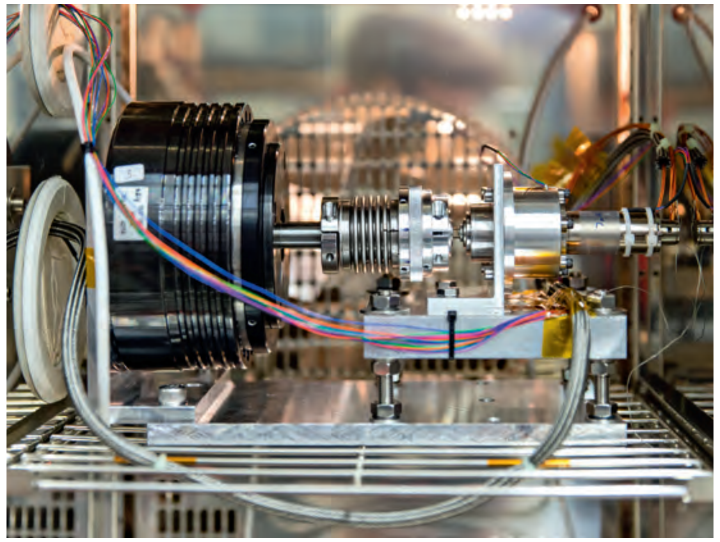
Let's get back to Earth though. In the maxon motor development lab in Obwalden (Switzerland), motors and gearheads are very thoroughly tested. The laboratory has all kinds of technical equipment, such as vacuum chambers, various climate-temperature systems, and a mechanical impact tester. This last unit generates the extreme g-values mentioned above to test the motors' impact resistance. The device was purchased specifically for maxon HD (heavy duty) motors. Currently, the drive systems for the ExoMars mission – or to be more precise, the motor-gearhead combinations for the wheel drives of the rover – are being tested (see p. 6 to learn more about the ExoMars rover).

Two years and longer service life

The laboratory itself is already impressive. The endurance testing room even tops it, with its endless rows of racks, all loaded with different motors and controllers. The service lives of more than a thousand motors are tested here. Some drives run for more than 20,000 hours. The tests are checked almost daily by the laboratory's development engineers.

Photos: maxon motor ag / Philipp Schmidli

Martin Odermatt, development engineer at maxon, is testing a motor.



In this temperature chamber, an ExoMars drive is tested for performance at various temperatures.

Oil immersion for motors

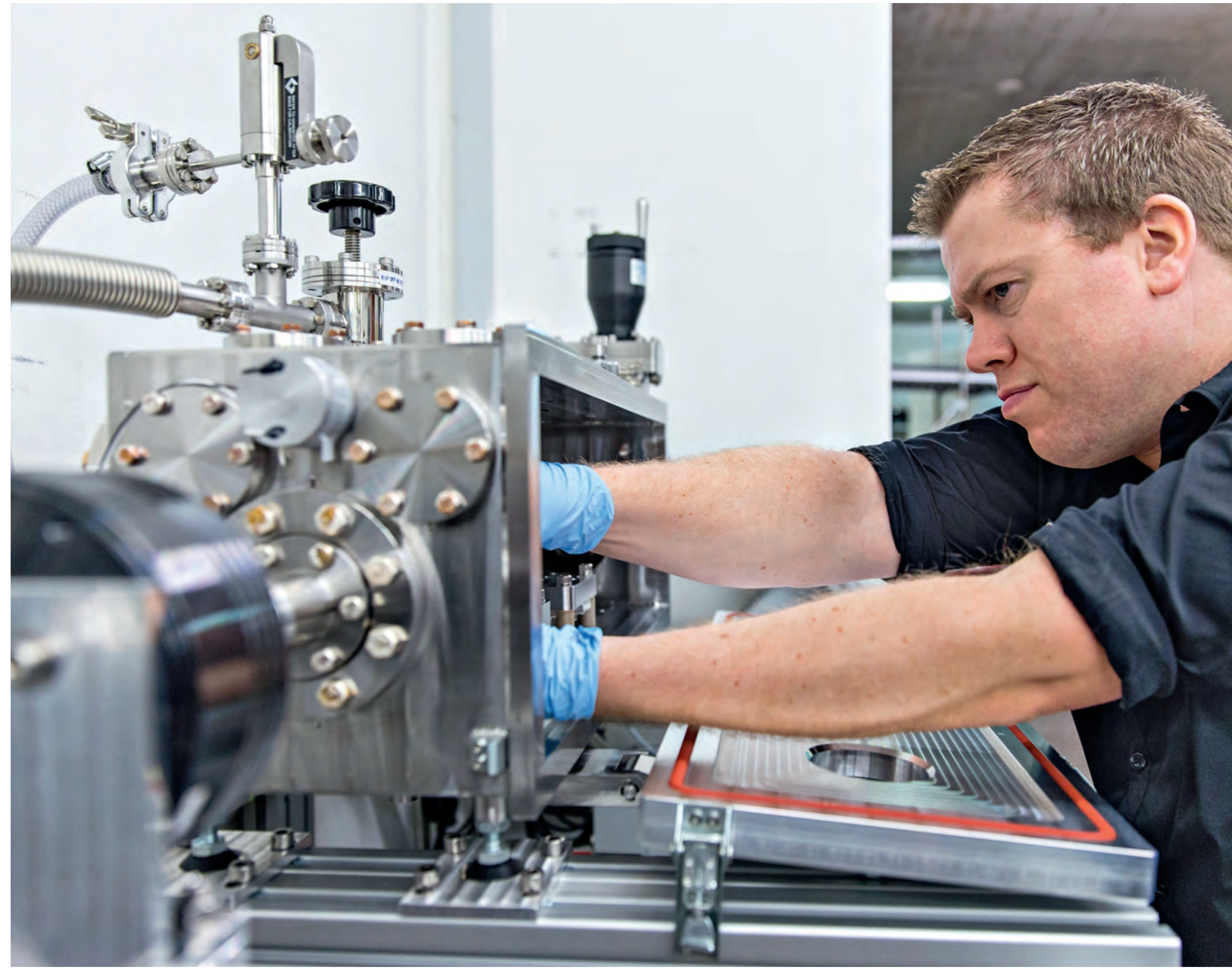
Some motors are immersed in oil baths of up to 200° C a particularly hard test. These are maxon HD drives that have been developed specifically for operation in oil. With slight modifications, they can also be operated in air at 200° C. One field of application is deep drilling. Only HD drive systems are able to withstand the high temperatures, extreme pressures, and strong vibration in this environment. Continuous testing is critical to ensure that these drives work flawlessly at depth.

Mars atmosphere in the lab

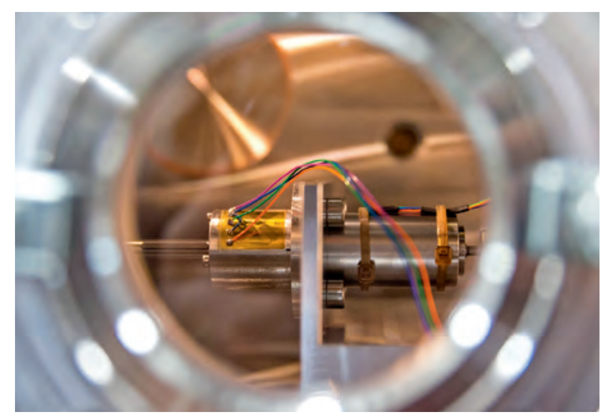
The robust maxon motors are also suitable for use in the aerospace industry. The lab therefore has a vacuum chamber capable of simulating the characteristically thin Mars atmosphere, in addition to generating high vacuum. “In the chamber, the motors are exposed to exactly the same environmental conditions as on the surface of Mars. This is the only way we can guarantee to the customer that our drives are going to work flawlessly in this remote location”, explains Nico Steinert, development engineer at maxon motor. The high vacuum unit with its futuristic appearance was built specifically for the ExoMars mission. It is used to test the motors and gearheads that will be used on Mars in 2018. The chamber is able to generate pressures of $< 10^{-6}$ mbar and temperatures between –150 and +200° C.

The in-house development lab enables maxon motor to thoroughly test its drive systems to detect and remedy potential problems early on. The development of our drive systems is thus an ongoing strive for even more excellence, and quality is guaranteed at all times.

Download the tablet issue 1 // 2015 to see how a motor stands up to high vibration. magazine.maxonmotor.com



Nico Steinert, development engineer at maxon motor, installs an HD motor with a custom ExoMars gearhead in the vacuum chamber.



The vacuum chamber is able to simulate the thin atmosphere of Mars, which consists of 95 percent carbon dioxide (CO_2) at a pressure of 8 to 10 mbar.

400 kilometers above the Earth

The International Space Station (ISS) is a masterpiece of technology. The world's highest research laboratory also has drive systems from maxon motor on board – for example in experimental robots.

The International Space Station has been orbiting Earth for the past 15 years. It is being used as an international research station, operated jointly by the US-American space agency NASA, the Russian space agency Roscosmos, the European Space Agency (ESA), as well as the space agencies of Canada (CSA) and Japan (JAXA). Since it was commissioned in November 2000, a total of 216 astronauts have flown to the space station to expand it and work on a variety of research projects. More than 900 experiments from 63 countries have been conducted since 2001. These include research on how plants orient themselves in zero gravity, why humans suffer muscle and bone loss in space and how the cells of the human immune system react to a weightless environment. It is already known that the immune system of the astronauts weakens in space. In fact, the immune system in space is comparable with the lower immune system in old age, explains Alexandra Deschwanden, head of the Biotesc team of the Lucerne University of Applied Sciences and Arts (see interview on p. 30). Early in January 2015, the team sent two research projects to the ISS on board the SpaceX Dragon capsule.

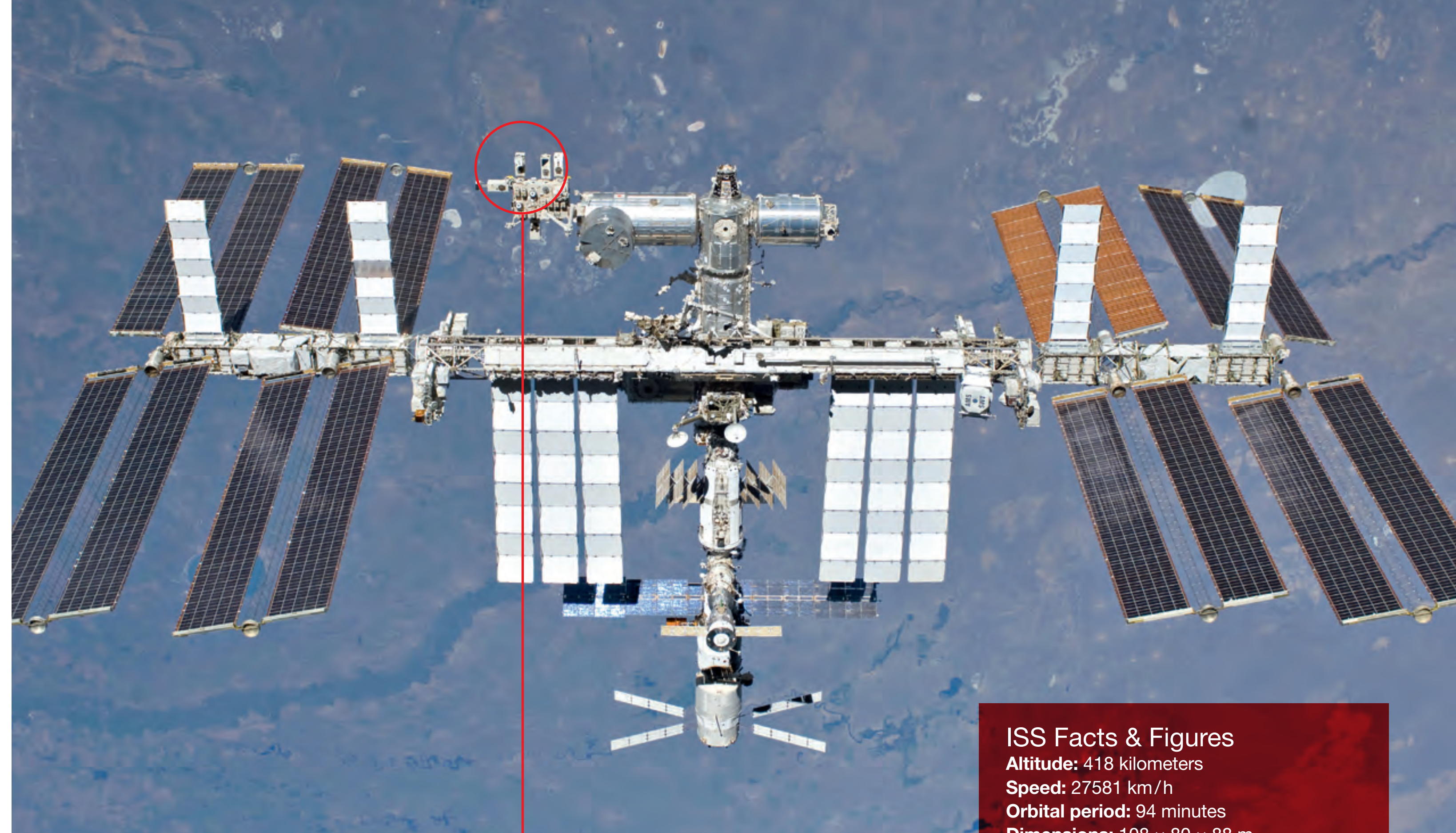
Technical equipment, such as various laboratory devices, is essential for the experiments on board the ISS. Robots that can perform the tasks of astronauts or assist them also play a decisive role.

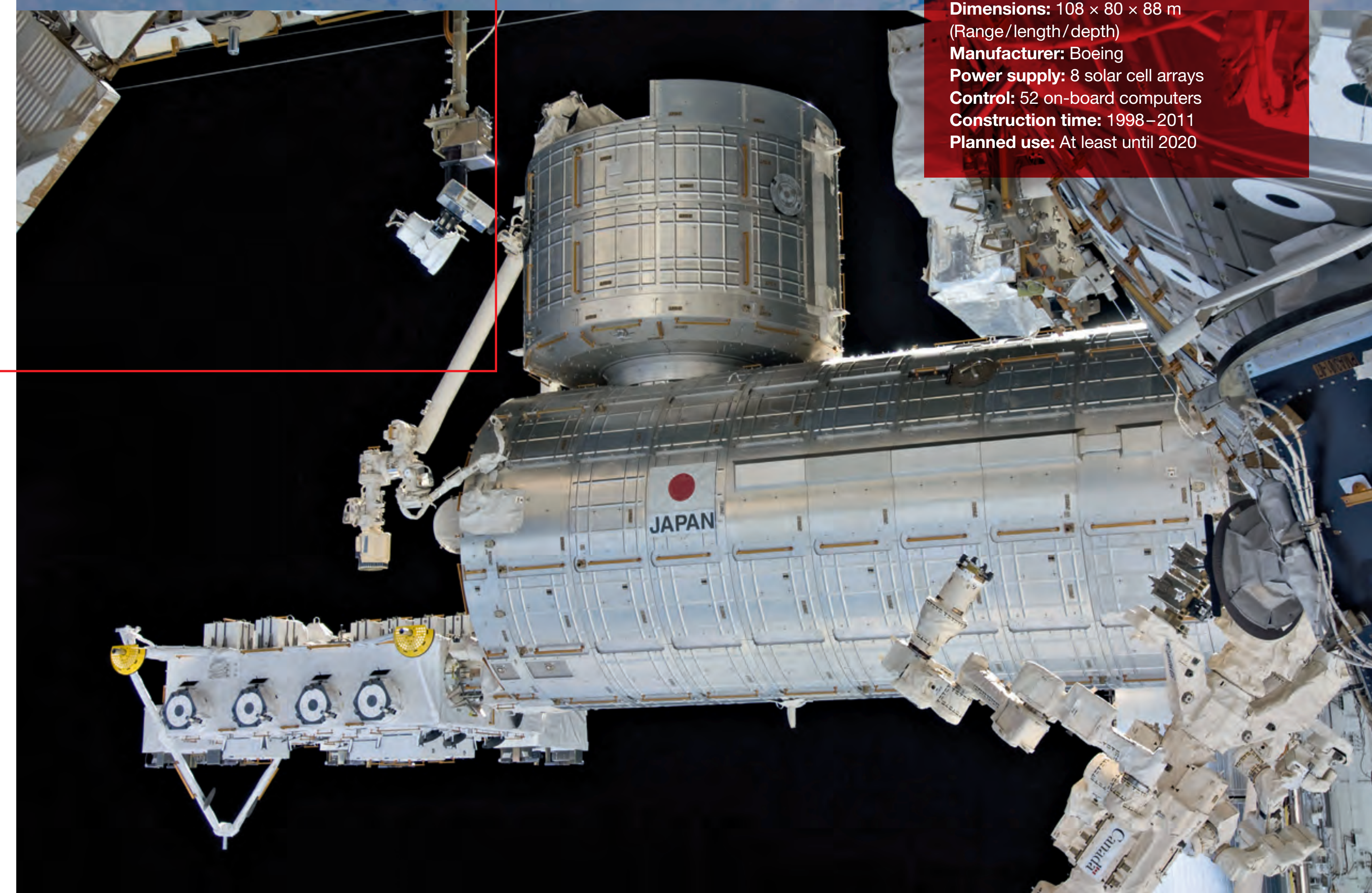
Special robot experiment

One such experimental robot, called "REX-J" (Robot Experiment on JEM), had been in use in Kibo, the Japanese module of the ISS, from 2012 to 2013. It was developed by the JAXA space agency. The objective of the experiment is to develop a new generation of robots (astrobots) capable of moving across the surface of the space station and inside it, to lift loads or to perform inspections. What makes the robot unique is its special locomotion system, which uses tether mechanisms to anchor the robot. By means of hooks, the tethers are attached to the existing handrails used by the astronauts to secure themselves during ex-

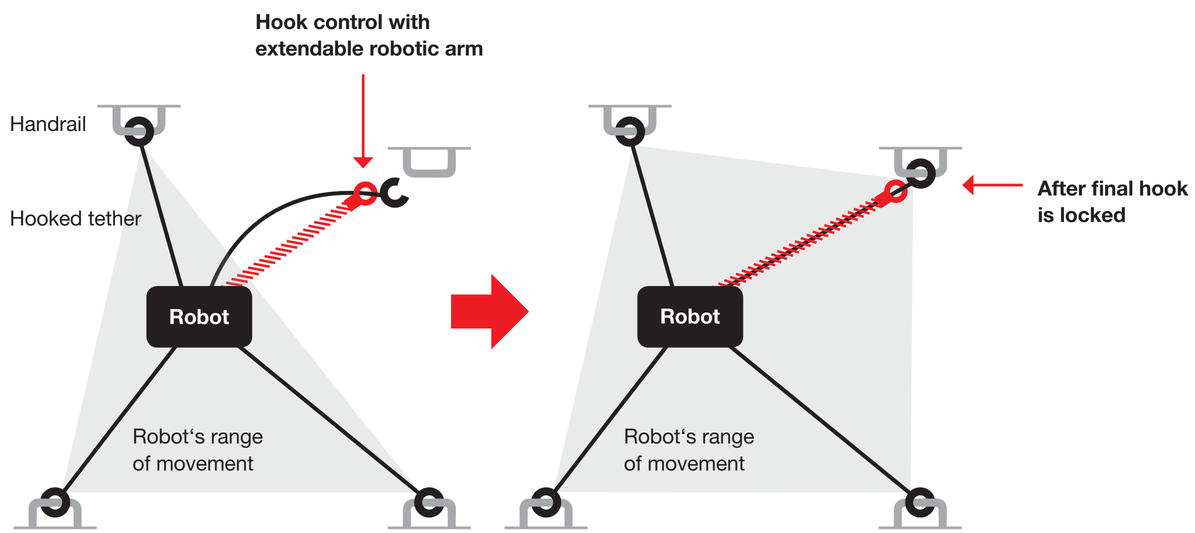
maxon EC-max 16
Ø 16 mm, brushless

Photos: maxon motor ag, NASA





ISS Facts & Figures
Altitude: 418 kilometers
Speed: 27581 km/h
Orbital period: 94 minutes
Dimensions: 108 × 80 × 88 m (Range/length/depth)
Manufacturer: Boeing
Power supply: 8 solar cell arrays
Control: 52 on-board computers
Construction time: 1998–2011
Planned use: At least until 2020



The REX-J robot moves like a spider on the outside of ISS using gripping bars for support. It hooks in with a robotic arm and moves along cables of variable length.

travehicular activity on the ISS. The mobile robot is equipped with an extendable arm. At the end of the arm, there is a robotic hand capable of attaching the tether cables to different anchoring points. This allows the robot to move across a surface like a spider. The robot is operated from the ground control center, so that no support from the ISS crew is required.

Drives for precision movements

The REX-J is equipped with several drive systems made by maxon motor – and so is the robot's extendable arm. The wrist joint has two degrees of freedom, vertical and horizontal. The wrist joint and extendable arm contain brushless EC max motors, planetary gearheads and encoders. The control electronics for the motors are located at the end of the arm, and the cables for driving and controlling the unit are routed internally. Additional maxon drive systems are used in the rotary mechanism of the robot, in the robot arm, and in the cable spool (wind-up mechanism).

All experiments with REX-J have been completed successfully. JAXA is already planning develop the robot system further, with the aim of using such robots for a range of different tasks in space in the future. These include monitoring ISS devices and performing visual inspections of the space station to detect damage to the outer hull. Another long-term goal is to build mobile astrobots that can assemble large structures to produce energy in space.

Download the tablet issue
1 // 2015 to see REX-J in action.
magazine.maxonmotor.com

Photos: ESA/NASA, ESA Astronaut Alexander Gerst, Dörr GmbH

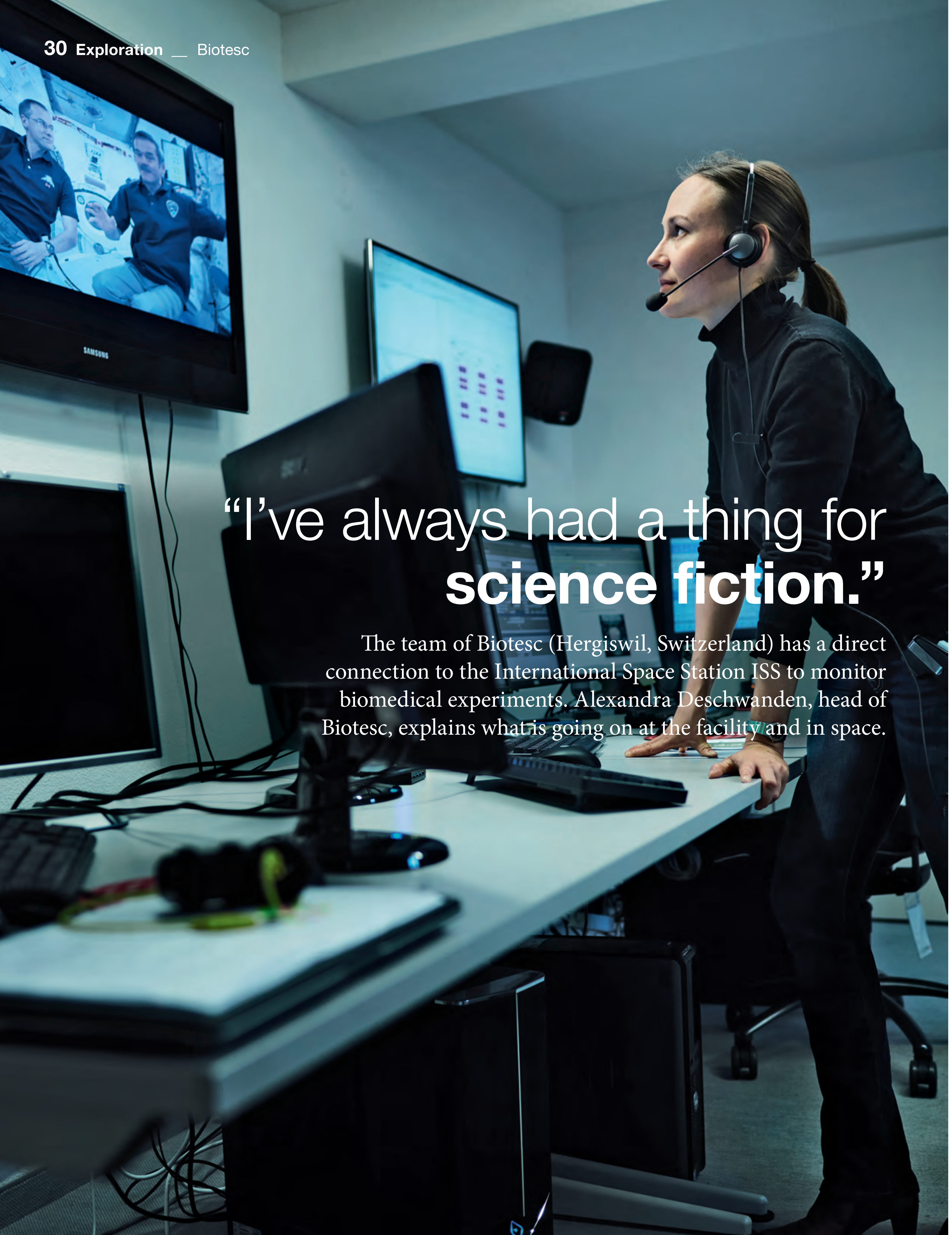
CONTEST

The ISS is looking at...?

Tell us which country you are looking at. Is it Australia, England, or Brazil? Send your answer to driven@maxonmotor.com to win a reflecting telescope and explore the planets of our solar system.

The deadline is August 31, 2015.

The Delta 30 telescope by Dörr-Danubia is a compact reflecting telescope with a high focal length.



“I’ve always had a thing for **science fiction.**”

The team of Biotesc (Hergiswil, Switzerland) has a direct connection to the International Space Station ISS to monitor biomedical experiments. Alexandra Deschwanden, head of Biotesc, explains what is going on at the facility and in space.

Alexandra, you walk into a villa on a lake in the morning, and a few minutes later you have a live connection to the ISS. There are worlds in between!
Yeah, it’s really weird when you think about it. Hardly anybody has an idea what’s going on at the villa. For me it has become quite normal. And yet, contact with the ISS is always exciting.

What exactly are you doing?
To put it briefly, and among other things, we supervise biomedical experiments on the ISS together with ESA. My team plans the execution of such experiments with up-to-the-minute precision. We also follow the experiments aboard ISS in real time, creating detailed instructions and sequence plans for the ISS crew. Most experiments are first simulated here at the facility to prevent unexpected errors in orbit. Biotesc is also responsible for the hardware – the cubic in which the experiments are conducted.

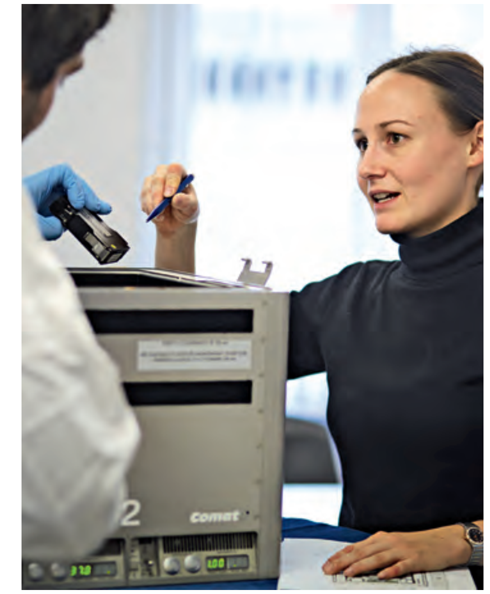
How are the experiments conducted?
They usually take place inside a cubic. Cubics are special boxes for biological experiments aboard the ISS. As the name suggests, they are cubical boxes – small incubators that can be heated up to 37 degrees. The sample containers are places inside. During the experiments, we monitor how, where and when the cubic is connected and when the samples are installed and need to be removed.

Since when are biological experiments conducted in space?
On request of ESA, Biotesc has been planning and monitoring biological experiments by groups of researchers from all over the world since 2000. However, the research group has been conducting biological experiments in zero gravity since the 1970s.

Can you describe the experiments in more detail?
In the most recent experiment sent to ISS on a SpaceX rocket in early January 2015, human immune cells were exposed to zero gravity. The order came via NASA from an American researcher. The experiment was conducted by Italian astronaut Samantha Cristoforetti, and we were looking over her shoulder in order to provide the best possible assistance whenever needed.

What insights are you hoping to gain from this kind of research?
Zero gravity appears to affect the performance of the human immune system. What happens in the cell? What has changed? The research has helped to develop pharmaceuticals that may improve the immune system of older people. The research may also be useful with regard to longer missions in space, to protect the immune systems of astronauts.

What does a day at the control center look like?
I arrive in the morning, before the astronauts’ working day begins. I prepare everything at the control console. The flight control team sometimes also has a few questions about the activities. Then there is a brief meeting at a precisely defined time where we inform the crew about the procedures. Afterwards I wait for the experiment to start. We are frequently connected by video so that I can watch the astronauts and answer questions.



Alexandra Deschwanden and a colleague with the cubic incubator.

Did you ever dream of being so close to space?
That was just inconceivable. However, I’ve always had a thing for science fiction. After graduating in human biology I was looking for a job. I found the job add of ETH Zurich more or less by accident, and I was instantly fascinated by the idea of preparing procedures and experiments for astronauts. In 2013, the research group moved from Zurich or Hergiswil, and our facility became part of Lucerne University.

What else are you planning for this year?
This year we are planning more experiments than ever before, probably seven, including some with human stem cells. We usually have only two to three experiments on average.

Photos: Beat Brechbühl

Application example

Motors for micro-satellites

Selecting suitable motors and gearheads for standard applications is quite straightforward. However, if you add special environments and size constraints, finding the optimal drive system involves additional considerations, and possibly compromises. By way of example, we are looking at a drive for microsatellites.

Von Urs Kafader

Urs Kafader has been supervising the technical training at maxon motor for 19 years. He runs training sessions on the technology and use of maxon products, both for the employees at the maxon headquarters in Sachseln and for the international sales network, as well as for customers. He has a PhD in physics as well as an MBA in production science. He began his career at the Laboratory for Solid State Physics at the Swiss Federal Institute of Technology Zurich.

Photos: CNES, maxon motor ag

Challenge

We are looking for a drive system for a hypothetical micro-satellite research project. Size and weight are the main constraints for the motor. The maximum diameter is 36 mm, with a maximum length of 45 mm. The motor needs a minimum torque of 180 mNm, while the operating speed should be around 200 rpm.

I am also looking for some basic form of position feedback. The goal is to source a motor capable of surviving ~5000 cycles (at 20 s operation/cycle) over a year of operation in a low-earth orbit on a micro-satellite.

At this point, I am wondering what motors you would recommend to meet the size and torque requirements. Could you customize a motor to survive the vacuum and radiation exposure?

Aspects to consider

Power density – speed, torque and dimensions:

The required mechanical power amounts to $\pi/30 * 200$ rpm $* 0.15$ Nm = approx. 3 W. This is very low! The torque load applies for 20 s only, probably with long breaks in between. Hence, it's once-in-a-while operation and we can run the motor in the short-term operating range. The speed is rather low for a motor. A combination with a standard gearhead should be considered, with a reduction ratio around 8000 rpm/200 rpm = 40 : 1. There are motors with diameters below 36 mm that can deliver the necessary torque. However, they do not fulfill the length restriction. The flat motors that are short enough have too large a diameter. A way out of this dilemma is to use a flat motor with a low-stage gearhead.

maxon EC20 flat
Ø 20 mm, brushless, 3 and 5 W

Motors with suitable torque

Motor type	Diameter x Length	Weight	Design	Nominal torque	Thermal time constant winding	Hall sensor states per turn
	mm	g		mNm	s	
EC-i 40, 50 W	Ø 40 x 26	170	slotted, brushless	approx. 50	12	42
EC-i 40, 50 W	Ø 40 x 36	240	slotted, brushless	approx. 80	19	42
EC 45 flat, 30 W	Ø 45 x 16	75	slotted, brushless	approx. 50	12	48
EC 45 flat, 50 W	Ø 45 x 21	110	slotted, brushless	approx. 80	18	48
EC-max 30, 60 W	Ø 30 x 64	305	slotless, brushless	approx. 60	3	6
EC-4pole 30, 100 W	Ø 30 x 47	210	slotless, brushless	approx. 70	4.6	12
EC-4pole 22, 120 W	Ø 22 x 66	175	slotless, brushless	approx. 65	6.5	12
EC 22, 100 W	Ø 22 x 63	128	slotless, brushless	approx. 48	5	6
EC 22 HD, 80 W	Ø 22 x 90	210	slotless, brushless	approx. 58	6	6
RE 30, 60 W	Ø 22 x 68	260	slotless, brushed	approx. 80	16.3	–
DCX 26 L	Ø 26 x 57	170	slotless, brushed	approx. 54	24	–

This table gives a selection of motors (from the selection guide in the maxon catalog page 21–27) that fulfill the torque requirements, as well as some additional parameters that are interesting in our context (all values are approximated).

Service life:

The required service life is about 1700 hours. This should be no problem for any maxon drive.

Ambient conditions:

The vacuum in low earth orbit (150 – 2000 km altitude) is already in the high to ultra-high vacuum range. Brush life might be very strongly affected; a solution with a brushless motor is preferable. Besides, maxon motors have proven several times that they can withstand the vibration during a rocket launch. Weight and size are an important issue in any aerospace application. The lower the better, since all of it needs to be lifted into space, adding cost.

Control

"Some basic form of position feedback" is a rather vague requirement. One could imagine fulfilling it by selecting a brushless EC motor with Hall sensors, in particular in conjunction with a gearhead. The big questions are: What purpose does the position information serve? Is it fed into a position control loop for active position control? Or does it only provide some sort of confirmation that the drive has moved? How about accuracy? All these open questions make it hard to define a suitable feedback sensor.

Motor type selection without gearhead

Assuming that a motor can easily deliver a torque that is twice the continuous torque for a duration of up to one thermal time constant of the winding, we should look for motors with a continuous torque between 80 and 120 mNm and a thermal time constant of around 20 s.

As can be seen, none of the above motors match the size restrictions. Due the higher mass of the iron core, EC motor types with slotted windings have a higher thermal time constant than those with slotless windings. They are better suited for overload operation. The lower weight points in particular to the EC 45 flat motors. The multi-pole EC 45 flat also has a higher number of Hall sensor states per turn of the motor shaft. Depending on the requirements for position resolution, we may be able to do without an encoder.

The brushed DC motor types (RE 30 and DCX 26 L) would be well suited from a torque and thermal time constant point of view. However, reduced brush life in vacuum makes them a bad choice. Nevertheless, it might be worthwhile to explore options for special brushes. Position feedback would require an encoder.

Solutions with gearheads

According to the explanation of gearhead parameters, running a gearhead in overload for 20 seconds is quite long. The rule is 'not more than 1s!' Therefore, we should select gearheads with a continuous torque above 0.18 Nm. Solutions with gearheads will reduce the necessary motor torque by a huge amount.

A glance at the gearhead selection guide in the maxon catalog reveals several possible gearhead candidates. From a torque point of view, the GP 13 A and the GP 16 A and C are quite perfect. However, since no flat motor matches these gearheads, we expect the resulting motor-gearhead combinations to become too long. As a possible alternative, we add the GP 22 A gearhead that can be combined with an EC 20 flat.

The high required output speed of 200 rpm only allows reduction ratios below about 40:1 (assuming a gearhead input speed of 8000 rpm); i.e. only two-stage gears are possible. The required motor torque in the tables matches the 180 mNm load torque at the gearhead output. Only one of the solutions meets the size restrictions.

Again, let me add a few comments. While the GP 13 A is operated within the continuous operation range, the nominal torque of the matching EC 13 motor is not high enough. It runs in the short-term operating range. The overload is not high, but quite long for a motor with a thermal time constant of the winding of 0.6 s only. In addition, there is no encoder available for this motor.

In the solution with the GP 16 A, the load torque is slightly too high for continuous operation. However, there is the ceramic version GP 16 C, which offers sufficient torque and the same motor combinations and dimensions. The combination of GP 16 C and EC-max 16 results in a lightweight solution – though too long – that would remain in the continuous operation range.

Selected solutions with motor-gearhead combinations

Gearhead type	Continuous torque	Reduction	Required motor torque	Brushless motor	Nominal motor torque	Weight of unit Total length
GP 13 A	0,2 Nm (2 stages)	26 : 1 (2 stages)	8,4 mNm	EC 13, 12 W (w/o encoder)	5,5 mNm	29 + 14 = 43 g 54 mm
GP 16 A	0,15 Nm (2 stages)	29 : 1 (2 stages)	7,7 mNm	EC-max 16, 8 W	7,8 mNm	52 + 23 = 75 g 59 mm
GP 16 A	0,3 Nm (2 stages)	29 : 1 (2 stages)	7,7 mNm	EC-max 16, 8 W	7,8 mNm	52 + 23 = 75 g 59 mm
GP 22 A	0,5 Nm (2 stages)	29 : 1 (2 stages)	8,9 mNm	EC 20 flat, 3 W	3,5 mNm	15 + 55 = 60 g 34 mm
GP 22 A	0,5 Nm (2 stages)	29 : 1 (2 stages)	8,9 mNm	EC 20 flat, 5 W	8 mNm	22 + 55 = 77 g 43,5 mm

The only solution that fully complies with the size restrictions is the GP 22 A + EC 20 flat (3 W). However, the motor torque is rather low, resulting in a high overload. Considering that the motor is running in vacuum, there is a high risk of overheating. The EC 20 flat 5 W version is much better suited, however slightly too long.

Which solution is optimal?

It all depends on the relative importance of the requirements. If the stated size restriction is absolute, there is only one solution possible – the GP 22 A with EC 20 flat (3 W). However, the motor will be loaded at its thermal limits, and maybe beyond.

If weight is most important, then the GP 13 with EC 13 is the best solution, however without the possibility of position control and with some overload concerns that would need further investigation. If operation within safe limits and at low temperature increase is important, opt for the GP 22 A + EC 20flat (5 W) or the GP 16 C + EC-max 16.

If the size restrictions can be changed to allow a larger diameter and shorter length, then the EC 45 flat motors might be alternative solutions.

What can we learn from this example?

At low speeds, a solution with a gearhead may be superior to a motor-only solution with regard to size, weight, position resolution, and even cost. When specifying the requirements of the application, try to be as precise as possible. What exactly is "some basic form of position feedback"? Selecting drive units for a particular application is a question of context. It's not just torque and speed that matter, but also operating cycles, the mechanical layout, and the type of control.

maxon GP 22 A
Ø 22 mm, 0,5–1 Nm

Photo: maxon motor ag

Looking for thousands of **exoplanets**

Astrophysicist Sara Seager has dedicated her life to the search for exoplanets. She and her colleagues have great hopes for the new TESS satellite, which is expected to discover dozens of new Earth-like objects.

Every star in the sky is a Sun. If our Sun has planets, then it seems likely that other stars should have planets, too – and they do. Astronomers have found thousands of systems with exoplanets, but none so far like our own Solar System. Some stars have planets orbiting ten times closer to their star than Mercury is to our Sun. Other systems have circumbinary planets that orbit two stars. Some stars have several planets, all of which have lower orbits than our Venus. The most common type of planet is not a giant planet – thought to be the end product of inevitable runaway growth during planet formation – but a planet 2 to 3 times the size of Earth or smaller, a type that has no solar system counterpart and whose formation process is not known. Many of these enigmatic planets have been found by NASA's pioneering Kepler Space Telescope.

Although thousands of exoplanets are known, including many Earth-size planets, technology can't yet tell us if a planet is like Earth with oceans, continents, and breathable air, or instead like Venus, with a massive greenhouse atmosphere making the surface scorchingly hot and completely inhospitable to life.

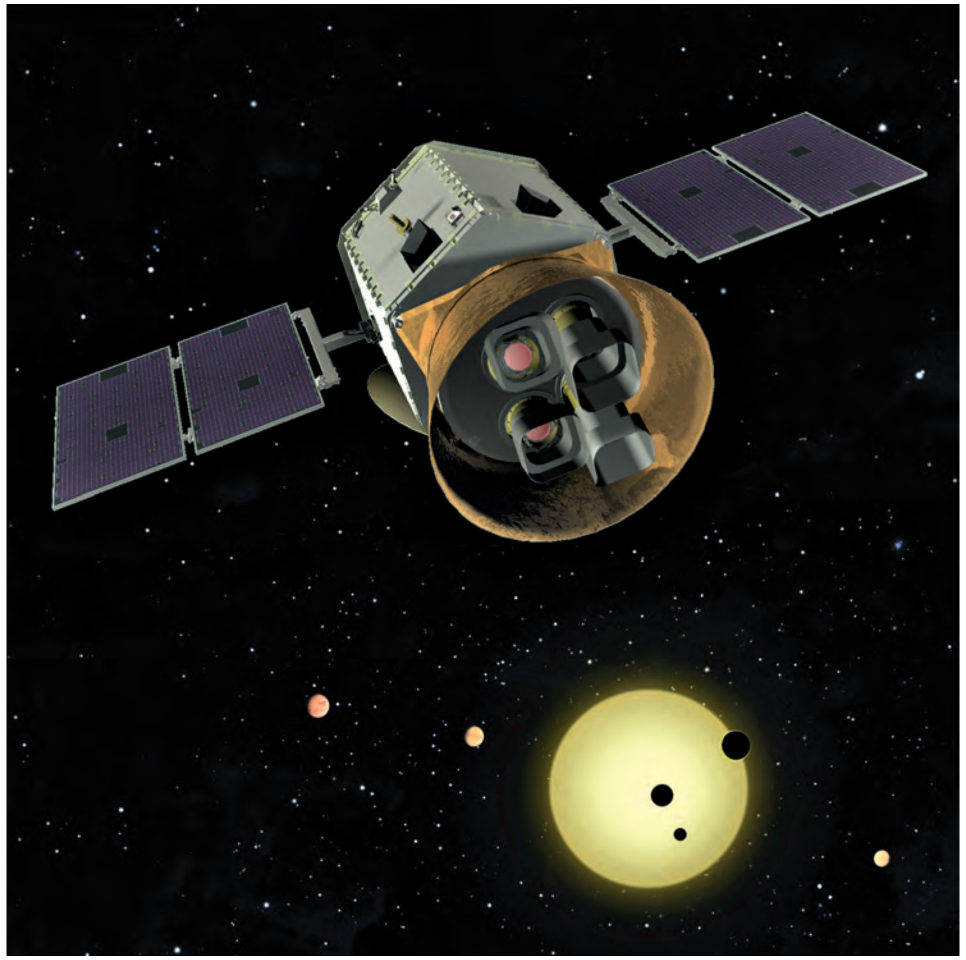
We need to find a way to observe planetary atmospheres, to assess the greenhouse gases and infer a surface temperature. For now, exoplanet observation is limited to a few dozen easy-to-observe candidates that are hot or large or otherwise bright, but totally unsuitable for life as we know it. We would like to have a large pool of rocky planets whose atmospheres can be studied for signs of habitability or even life.

Hundreds of thousands of planets in sight

The MIT-led NASA mission the Transiting Exoplanet Survey Satellite (TESS) is under construction to survey hundreds of thousands of bright, nearby stars for planets. It is set for launch in 2017 aboard a SpaceX Falcon 9 vehicle out of Cape Canaveral, Florida. TESS is expected to find more than a thousand planets smaller than Neptune, including dozens that are comparable in size to Earth. The discovered stars and planets will be bright – bright enough to characterize through follow-up atmospheric observation. TESS will continuously monitor stars for at least 27 days, searching for temporary drops in brightness caused by planetary "transits" when a planet goes in front of the star as seen from the telescope.

A large part of the sky with a large number of stars needs to be monitored to find transiting planets, because only a small fraction of all planets have orbits fortuitously aligned to show transits. The TESS spacecraft can view a large swath of sky, a 24° × 96° patch, by using four wide-field specialized cameras. Each camera consists of a custom-designed lens assembly with a 10.5 cm entrance aperture with special thermal properties and optimized optics, and a CCD detector operating at 600–1000 nm. TESS will spend 26 days on each patch of sky, continuously stepping around the sky until the entire sky has been monitored.

Photos: Chester Beals,/MIT Lincoln Laboratory, MIT

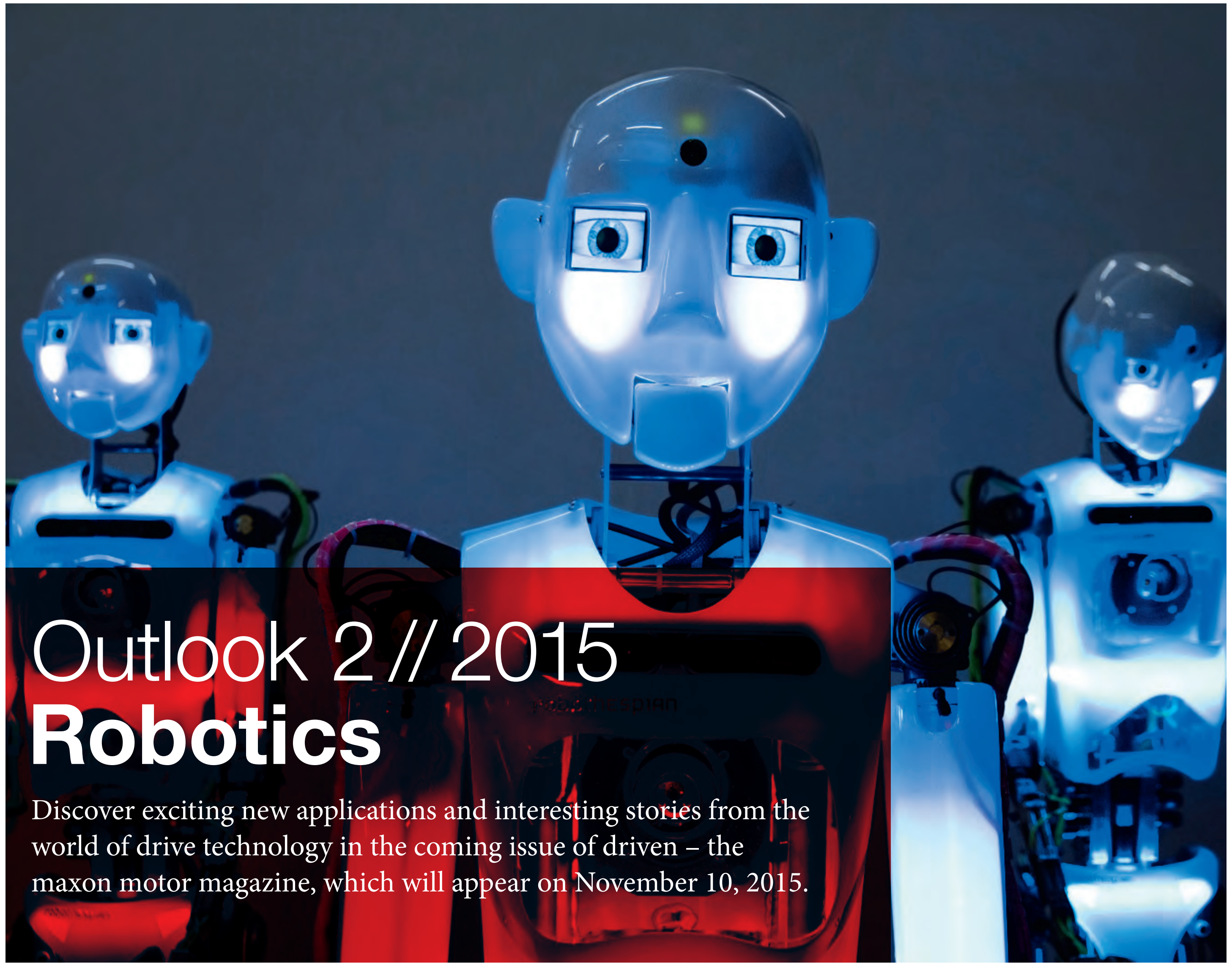


Sara Seager (43), astrophysicist, is a professor of physics and planetary sciences at the Massachusetts Institute of Technology (MIT). Left: Visualization of MIT's Transiting Exoplanet Survey Satellite (TESS).

Without stray light from Earth

To measure a star's brightness as a function of time at a level needed to find planets, continuous monitoring away from the bright Earth is necessary. Low Earth Orbit is not ideal because out of the 90-minute orbit, less than 30 minutes are spent in Earth's shadow and available for TESS science observations. The satellite will therefore be placed into a highly elliptical 13.7-day orbit around Earth. Observations will be made away from the bright Earth, and the data will be downlinked during the closest approach to Earth. The transmitter has a body-fixed high-gain antenna with a diameter of 0.7 m, a power of 2 W and a data rate of 100 Mb s−1.

TESS will undoubtedly find a pool of rocky planets orbiting small stars that are not too hot and not too cold, but just right for life. In the best case scenario, follow-up atmospheric measurements with a next-generation telescope (such as the James Webb Space Telescope (launch in 2018) or one of the ground-based 20 to 40 m telescopes currently under construction) will actually find atmospheric gases that are indicative of life, giving us hints, for the first time, about life beyond Earth.



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Robotics

Discover exciting new applications and interesting stories from the world of drive technology in the coming issue of driven – the maxon motor magazine, which will appear on November 10, 2015.

What aspect of this topic do you find particularly interesting? Let us know on our Twitter channel @maxonmotor.

Imprint

Published by: maxon motor ag
Project manager: Michel Riedmann
Editors: Stefan Roschi, Anja Schütz
Image editing: Heiner Eugster

Realisation: Infel Corporate Media
Project manager and editor: Simona Stalder
Design: Guido Von Deschwanden (Creative Director), Beni Spirig
Photo Editor: Diana Ulrich

Proofreading: CLS 4-Text GmbH

Print: Landenberg-Druck AG

Frequency of publication: Biannual issue as iPad/Android/Windows app and as print magazine (April/November)

Languages: German, English

Print run: 10 000 (German), 4000 (English)

Photo: Engineered Arts limited


The maxon motor magazine
2 // 2014
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The maxon motor magazine
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