# DRIVEN

by maxon

# The 4th planet

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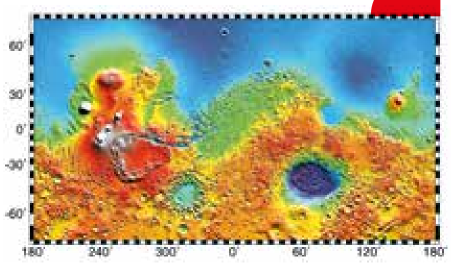



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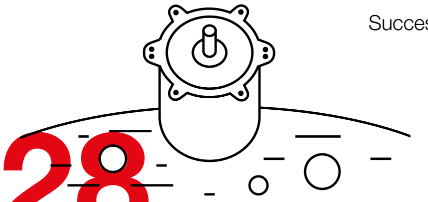


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## Legal & contact information


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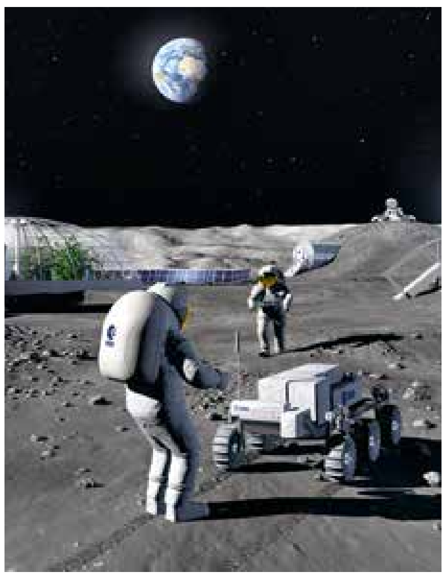

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Ulrich Claessen,
Group CTO maxon

# The fascination of Mars missions

The successful launch of NASA's Perseverance Mars mission on July 30, 2020, was a highlight of the summer, as maxon had been working with NASA for 3 years on actuators for this mission.

In recent years, our company has taken space projects to a new level: All development and manufacturing processes have been improved to meet the high demands of our customers. As a result, maxon has a unique portfolio of drives for use on Mars and we are now working on developing these further for the next generation of missions.

Without a doubt: Space is fascinating. If life were to be found on Mars, it would be a paradigm shift in our knowledge of how life originates.

I hope you enjoy reading this magazine.

# Bionic dad

**“I will never forget the day the people from maxon contacted me and told me that they will sponsor my bionic prosthesis. It was a surreal moment,” says Danny Florence from the UK, as he puts on his Hero Arm from Open Bionics for the first time and tries it out. As a child, he lost both legs and a hand to meningitis. Still, getting a prosthesis wasn't something he thought about much. Aesthetic models had little to no function, and bionic hands were too expensive. But then his son Joshua was born, and Danny realized how much more he’d be able to do if he had two hands, and the benefits it would have for bonding with his child. He applied for a 3D-printed bionic prosthesis from British manufacturer Open Bionics, launched a fundraising campaign, and finally came into contact with maxon. Our company has been cooperating with Open Bionics since 2015 and supplies DCX 12 motors with custom gearheads for their Hero Arm. “Seeing the arm for the first time was just overwhelming,” says Danny. “The prosthesis is very smart, and I got the fingers to work pretty much straight away. It'll take some practice to make it feel perfectly natural though.”**


Photo: Open Bionics

Emirates Team New Zealand

# Green light for the 2021 America's Cup

**Good news from New Zealand: The teams taking part in the America's Cup have agreed that the regatta will take place as planned in 2021. The 36th edition of the prestigious sailing competition will be held from March 6 to 21. This was by no means a given, as the preliminary regattas in Europe had to be canceled due to the COVID-19 pandemic. The defending champions, Team New Zealand, transported their high-tech AC75 boat "Te Aihe" there and back without ever putting it in the water. Since late May, the boat has been back in New Zealand, where the team has been testing new components and techniques in preparation for the next race in the America's Cup World Series in December 2020. maxon is proud to be an official supplier of Emirates Team New Zealand, supplying drive combinations comprising a DC motor (480 W) and a 42 mm gearhead, with EPOS motor control. This type of drive was selected because of its superlative power density and its ability to withstand extreme environments.**


Unmanned flight

# maxon takes to the air

Unmanned aerial vehicles or UAVs, drones, mini helicopters: Whatever you want to call them, they are useful for much more than just amateur photography. They offer enormous potential for future applications in the areas of inspection, agriculture, security, and small-scale freight. The market is young and highly dynamic, with a lot of startups. maxon is taking an active role too. Following the industry's initial ventures and a few high-profile crashes, the requirements placed on unmanned aerial vehicles and their components have increased. maxon has the necessary high-quality drives and the knowledge to develop specialized drone motors.

In 2019, a number of initial models were constructed for special projects, together with matching controllers. Since then, many tests have been carried out in the laboratory and designs have been revised. New drives for customer projects are currently in development. At the same time, the aim from the very beginning was to learn as much as possible from experts. This is why maxon's aerospace people have been working closely with drone specialists and Swiss colleges such as the EPFL in Lausanne, as well as with propeller manufacturers and customers. In the drone market, the motor is not the only thing that matters. What is far more important is the perfect interplay of BLDC motors, motor controllers, and matching propellers. That is the only way to get the most out of the system in terms of thrust and energy efficiency. This system concept is also becoming increasingly important in other markets. This is one reason why maxon has established business units that specifically focus on Aerospace, Industrial Automation, Medical, and Mobility Solutions. The specialized staff understand the requirements for systems in those areas. Incidentally, the most talked-about drone at the moment is controlled by six maxon DC motors. Find out more on page 22.

For more information

**aerospace.maxongroup.com**

Solar Orbiter

# Will the Sun reveal its secrets?

On February 10, 2020, the European Space Agency (ESA), successfully launched a rocket carrying the Solar Orbiter space probe. Scientists hope that the mission, which will last five years, will provide them with new insights into the Sun. In particular, they are looking to learn more about the solar wind and the complex dynamics behind solar flares. Astrophysicists still know surprisingly little about our closest star. The Solar Orbiter will come as close as 42 million kilometers to the Sun, which is about a fourth of the average distance between the Earth and the Sun. Temperatures will rise to over 500 degrees Celsius, which is why a large heat shield protects the valuable instruments on board, allowing a view of the Sun only when measurements are being taken. One of those instruments is the X-ray telescope (STIX), which will make the first ever observations of the smallest solar eruptions, known as nanoflares. STIX is fitted with an aluminum attenuator that slides in front of its 30 detectors as required – with the aid of two modified DC motors with diameters of 13 millimeters. The micro drives are wired in parallel and can be activated together or individually. This ensures that they will run smoothly for the entire mission. The design is based on the motors used in the ESA's ExoMars rover.

Photos: Emirates Team New Zealand, ESA/ATG medialab

Update

# Cybathlon 2020 goes global

The Cybathlon event will happen this year, but in a new, virtual format that will bring together participants from all over the world. Due to the COVID-19 pandemic, the organizers at ETH Zurich first had to postpone the competition in Switzerland and then ultimately cancel it. The event will now happen in the new format on November 13 and 14. The participating teams will stay in their home countries and will construct their obstacle courses themselves. The pilots will each go through the course separately, instead of side by side. The races will be broadcast in a live stream. People with disabilities will compete against each other in six disciplines, supported by assistance systems such as exoskeletons, bionic prostheses, and motorized wheelchairs. In addition to the races, viewers will be treated to many exciting reports, interviews, and discussions on the topic of inclusion and technology. maxon has supported the Cybathlon as a presenting partner right from the beginning and will continue to do so, even in difficult times. Exciting reports about the Cybathlon and the teams can be found on maxon's corporate blog

**www.drive.tech**

For all the latest about the event

**cybathlon.com**


Photo: maxon group

# New Products

**Mini-MACS6-AMP-4/50/10**
master controller

MiniMACS6-AMP-4/50/10

## Multi-axis controller for highly dynamic positioning tasks

maxon's new multi-axis controller, the MiniMACS6-AMP-4/50/10, offers precise and highly dynamic control of up to six DC motors or four BLDC motors (400 W continuous power). The controller is an economical and compact solution for autonomous robots or shuttle systems. It features optional programming with the comprehensive APOSS automation software. It also has bus interfaces that permit efficient data exchange with higher-level control systems.


**ENX 22 EMT**
22 mm

ENX 22 EMT

## The encoder that doesn't forget

With the launch of the 22 EMT encoder, maxon has introduced an absolute multi-turn encoder with a record-breaking size of just 22 millimeters. This encoder is based on patented Wiegand wire technology. That means it can record the revolutions of the motor shaft even when it is not supplied with power. The major advantage of this technology is that it works without a backup battery or complex gearing, and is highly robust. This encoder replaces time-consuming homing procedures, without requiring any additional external measurement systems. It can also be used for commutation. The 22 EMT encoder provides a very high resolution of 16 bits (multi-turn) and 17 bits (single-turn). It is available with BiSS-C and SSI interfaces and will be compatible with the IDX motors and drives, EC-4 pole and EC-i motors, and DCX (from 22 mm).

The maxon online shop has more than 5,000 products, selection aids, combination tools, and comprehensive product information:

**shop.maxongroup.com**

**Welcome to the Red Planet, a cold desert world with a thin atmosphere, seasons, and polar ice caps. It has ravines and extinct volcanoes that testify to a more active past. No other planet in our solar system has been the subject of more research and exploration. Yet still it draws us back again and again.**


Rendering: Sciepro/Science Photo Library

**⌀ DISTANCE FROM THE SUN**
227.94 million km

**TYPE OF PLANET**
Terrestrial

**1 MARTIAN YEAR**
687 Earth days

**AVERAGE TEMPERATURE**
-55 °C


**GRAVITY**
About a third of Earth's gravitational pull

**WEIGHT**
On Mars, someone weighing 70 kilograms would feel like they weighed 26.6 kilograms.

**POPULAR DESTINATION**
Humans have sent almost 50 spacecraft to Mars. Most of them never made it all the way. The first to succeed was the Mariner 4 probe on a flyby mission in 1965. See page 26 for more about Mars landings.

**TWIN MOONS**
Mars has two moons: Phobos and Deimos

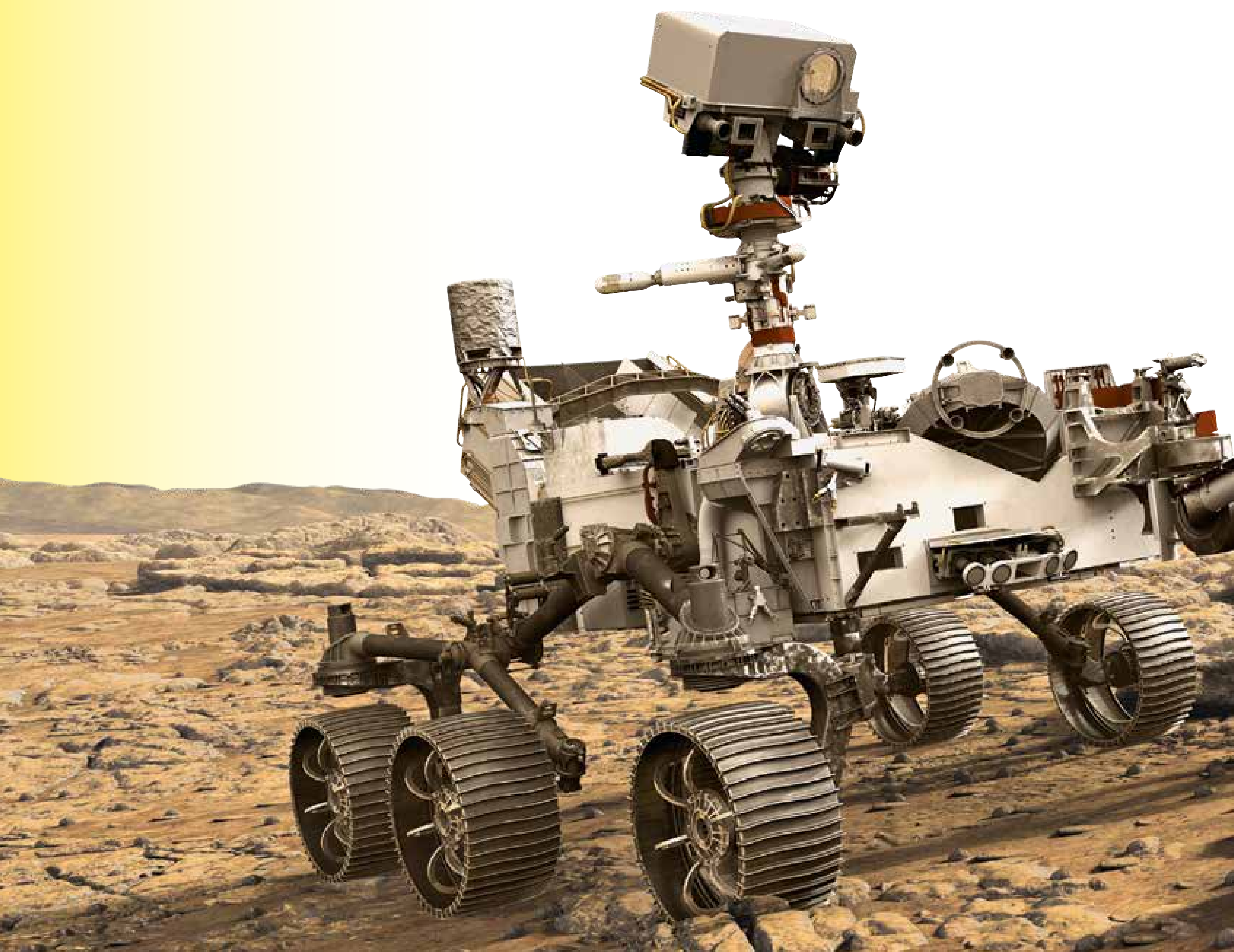
**BRING A SPACESUIT** Mars has a very thin atmosphere, consisting mainly of carbon dioxide (CO2), argon (Ar), nitrogen (N2), and a small amount of oxygen. The atmosphere on Earth is more than 100 times as dense.

**INHOSPITABLE**
Today, the planet can't support life as we know it. Scientific missions therefore search for signs of earlier life.

**RUSTY PLANET**
Iron minerals in the Martian soil and on the surface oxidize, coloring the landscape in red and orange. This is why it is called the Red Planet.

# In search of signs of life on Mars

**Mars once had liquid water and an atmosphere—was there life too? To answer this fundamental question, NASA is sending the Perseverance rover, a robot of unparalleled complexity. The world will be watching live.**



Will it work once again, despite all the obstacles? Mars missions may seem to be routine now, yet it's still the case that only a few craft make it to the planet's surface intact. The European Space Agency (ESA) had a painful demonstration of that in 2016 when their lander Schiaparelli smashed into pieces on the Red Planet. Nevertheless, US space agency NASA has so far taken four robotic vehicles to Mars successfully. It is now looking to make history again with the Perseverance rover in February 2021. For the first time, we on Earth will see live images of a Mars landing, supplied by high-resolution video cameras. We will feel as if we ourselves are landing on our neighboring planet.

It will still take a while, however, before people land on Mars. This is why robots need to do the work for now, and Perseverance has quite a lot of it in store. It will land in the Jezero Crater, which was once filled with water, with the task of investigating whether the area was once habitable. At the same time, the rover will search for signs of earlier life, known as biosignatures. It is equipped with a variety of measuring instruments for this purpose.

Its third task is to pave the way for human missions with a technology demonstration: An instrument named MOXIE will extract oxygen from the small amount present in the Martian atmosphere. This technology would be crucial for human missions, as oxygen is not only required for breathing, but can also be used for making fuel.

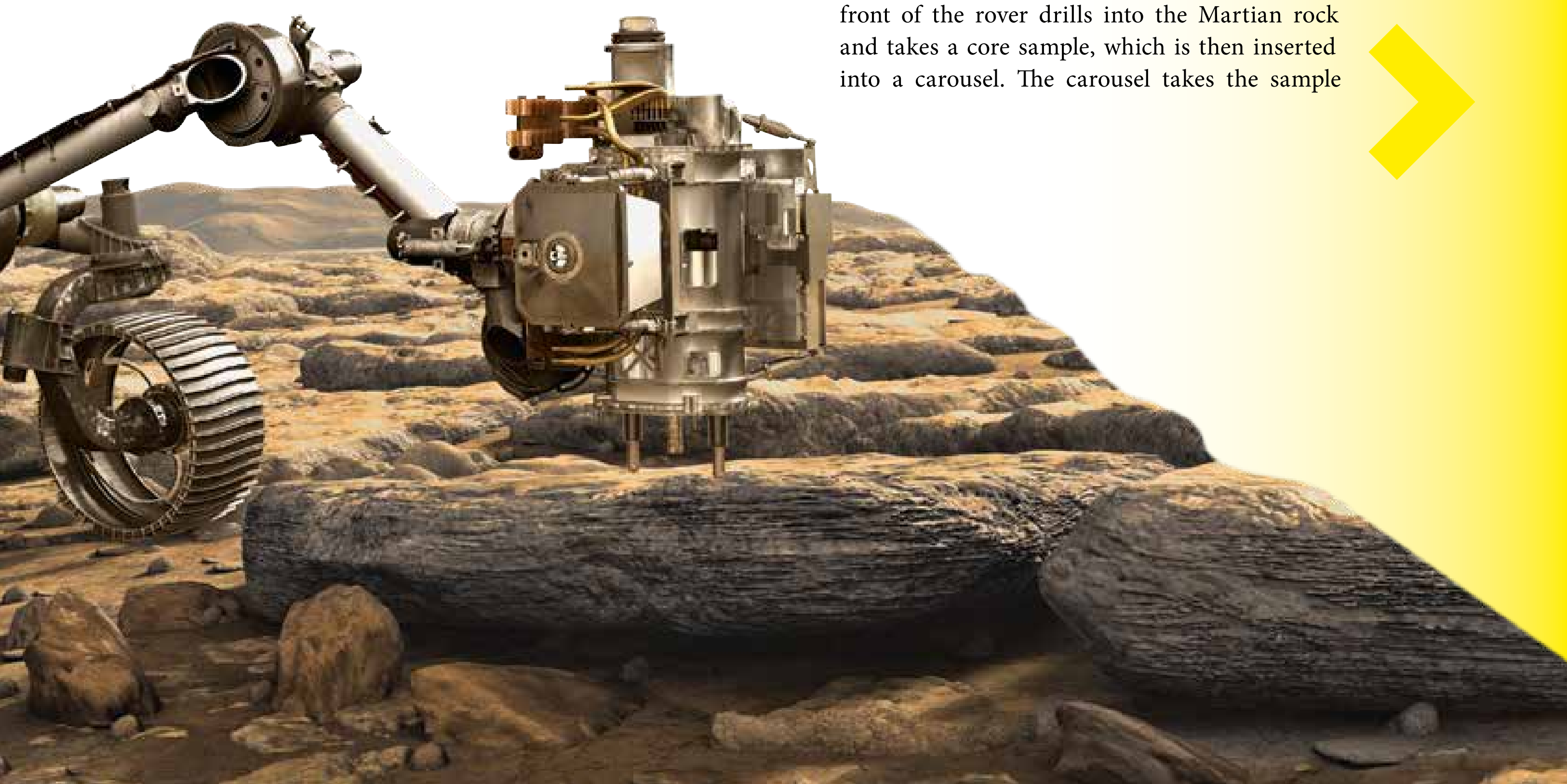
### The secret of life

We now come to the fourth mission, the most spectacular and most technically demanding: Perseverance will take up to 30 soil samples, place them in individual vessels, seal the vessels, and then finally deposit them at a suitable location so a later mission can collect the samples and bring them back to Earth. For scientists, it doesn't get much better than this: getting clean samples from Mars

> **"Other industries with similar requirements, such as the medical sector, also benefit from the space missions"**
>
> **Robin Phillips,**
> **Head of maxon's SpaceLab**

and being able to investigate them here, with all the latest techniques available. As NASA puts it, these samples have the potential to tell us more about the basis and origin of life in our solar system.

Three systems have to work together seamlessly for the sampling to succeed. First, the big robotic arm at the front of the rover drills into the Martian rock and takes a core sample, which is then inserted into a carousel. The carousel takes the sample



inside the rover. There, the third system takes over. It is another robotic arm, a much smaller one called SHA. This arm takes the sample from the carousel, moves it to the volume assessment and scanning stations, then to the sealing station, and finally into temporary storage—all autonomously.

This is where maxon comes in. Several BLDC motors are being used to handle the samples. Some of them are installed in the SHA robotic arm, which transports the samples from station to station; others are used when sealing the sample tubes and positioning them.

### The key to success is still the same

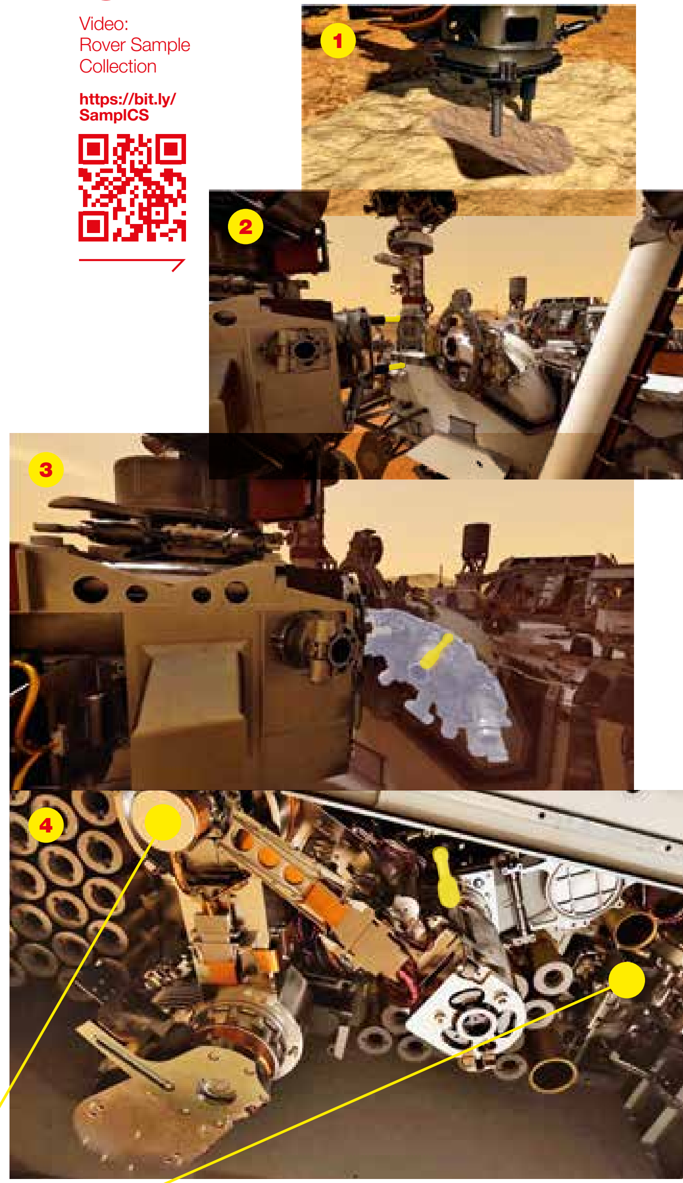
Just like the more than 100 maxon drives that have previously done work on Mars, the Perseverance motors are based on standard catalog products: specifically, nine brushless DC motors of the EC 32 flat type and one of the EC 20 flat type, in combination with a GP 22 UP planetary gearhead. Naturally, modifications were required so that the drives could meet the high demands of the mission. Nevertheless, the basis of the drives is no different from the models that are used in all kinds of applications on Earth.

### Close collaboration between maxon and JPL

maxon's engineers have modified and repeatedly tested the motors and gearheads for three years, working closely with the specialists at the Jet Propulsion Laboratory (JPL), which handles all unmanned missions for NASA. The space experts from Pasadena

Video:
Rover Sample
Collection

**https://bit.ly/SamplCS**




**1** The drill head takes a soil sample.

**2** The sample is moved into the carousel on the rover

**3** The carousel takes the sample inside the rover.

**4** The small robotic arm moves the sample to stations for visual inspection, sealing, and deposition.

**EC 32 flat DC motor**
Ø 32 mm, brushless

Rendering, video stills, photos: NASA/JPL-Caltech

# M

**THE MISSION**

Perseverance will search for signs of earlier life (biosignatures) on Mars, take rock and soil samples, and prepare them for return to Earth. It will also conduct experiments to pave the way for human missions.

**THE JOURNEY**

| | |
|---|---|
| Launch vehicle | Atlas V-401 |
| Launch site | Cape Canaveral Air Force Station, Florida (USA) |
| Landing date | February 18, 2021 |
| Landing site | Jezero Crater |

**THE FACTS**

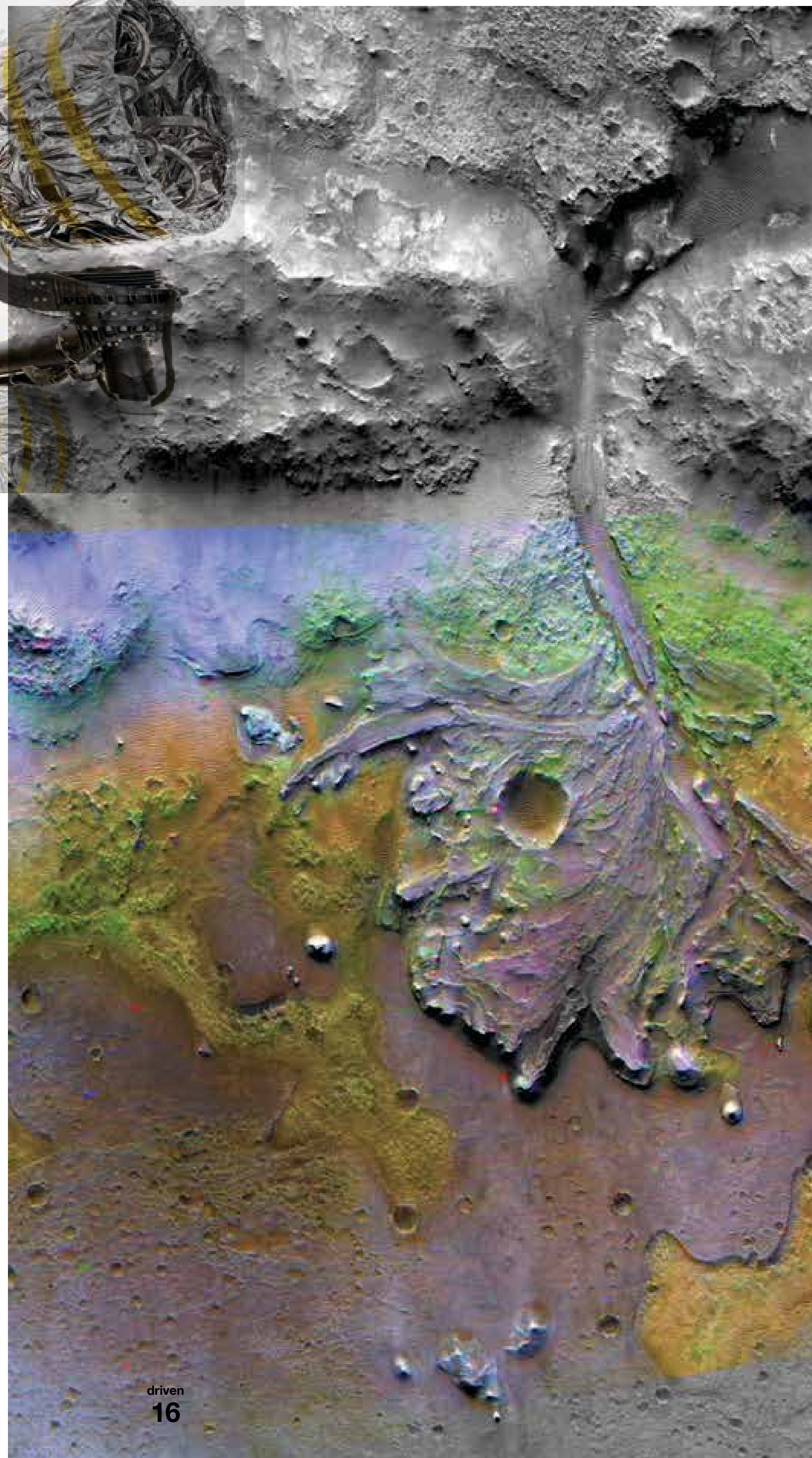
| | |
|---|---|
| Planned duration of mission | At least one Martian year (687 Earth days) |
| Weight | 1025 kilograms |
| Length | 3 meters |
| Height | 2.2 meters |

were frequent visitors at the Swiss headquarters of the electric motor experts. "We've learned a lot from this collaboration," said Robin Phillips, head of the maxon SpaceLab. This can be seen specifically in higher quality standards and new test procedures and processes. "Customers from other industries, like the medical sector, where requirements are often similar, also benefit from this know-how."

Phillips and his team will pay close attention to the landing of the Perseverance rover and its activities, as much will depend on the functioning of the maxon drives. In his words, "We are involved in absolutely critical applications. If the robotic arm on which our BLDC motors are mounted doesn't move, or if the gripper doesn't work, then the entire mission will be a failure."

**1**

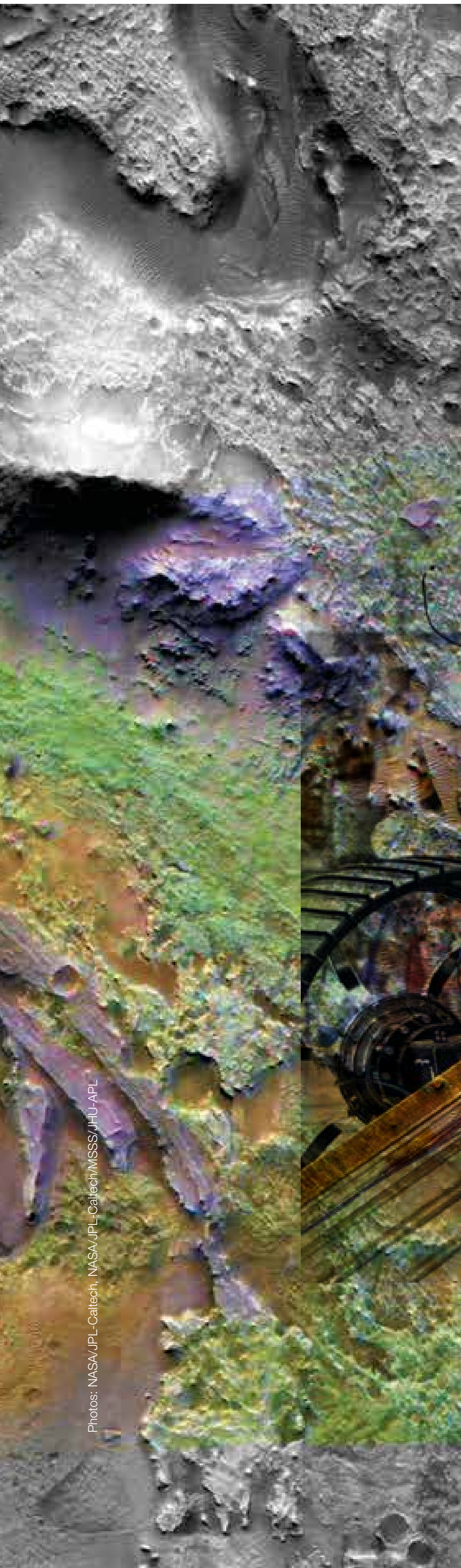

**2**



**1** The Perseverance rover is placed on a turntable in the Kennedy Space Center to find its center of gravity.

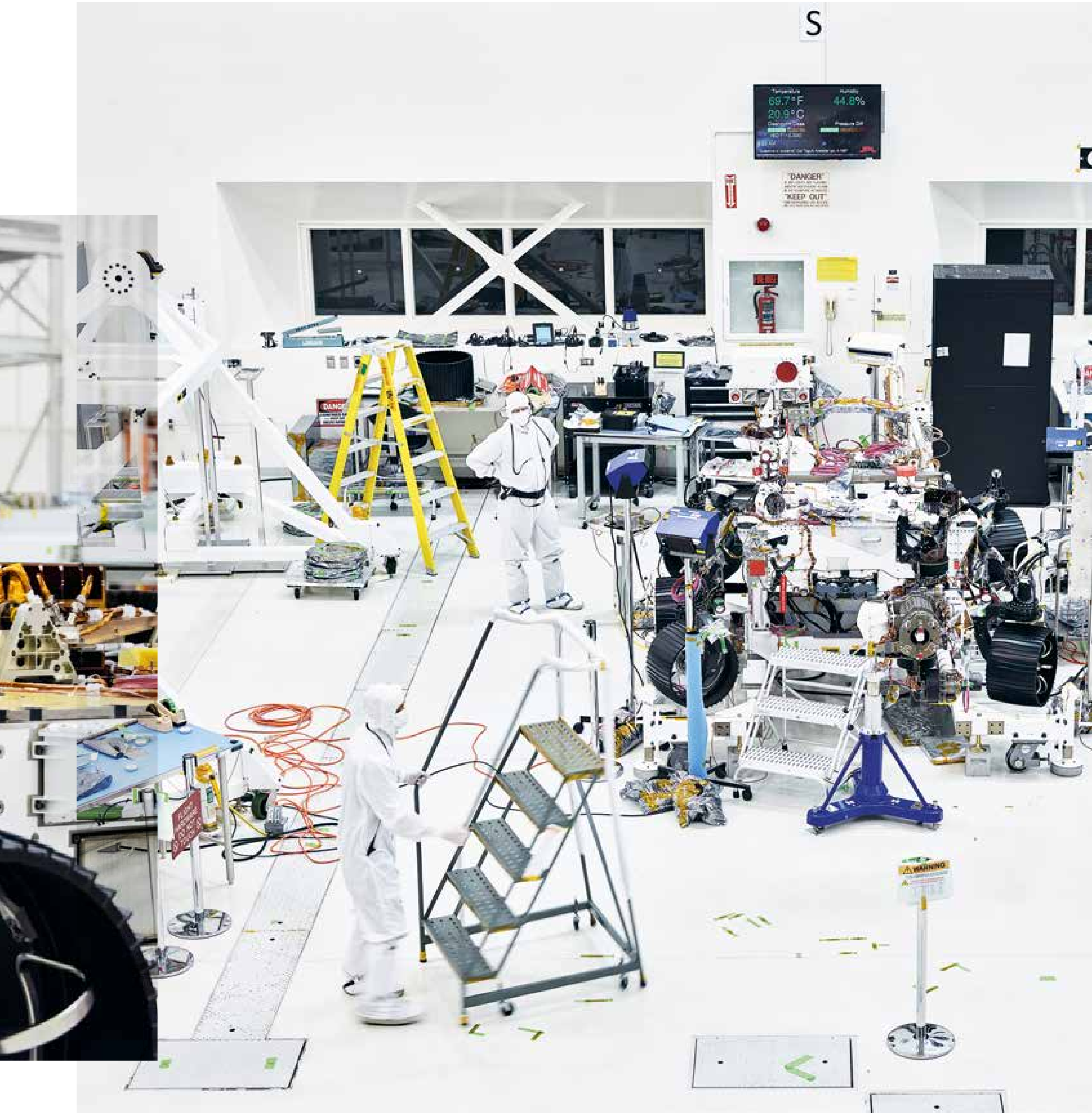
**2** A satellite image of the Jezero Crater on Mars, where Perseverance will land.

**3** An engineer fastens the helicopter to the underside of the rover. After arrival on Mars, the aerial vehicle will be set down on the ground with the aid of a maxon drive.



Photos: NASA/JPL-Caltech, NASA/JPL-Caltech/MSSS/JHU-APL

# 3

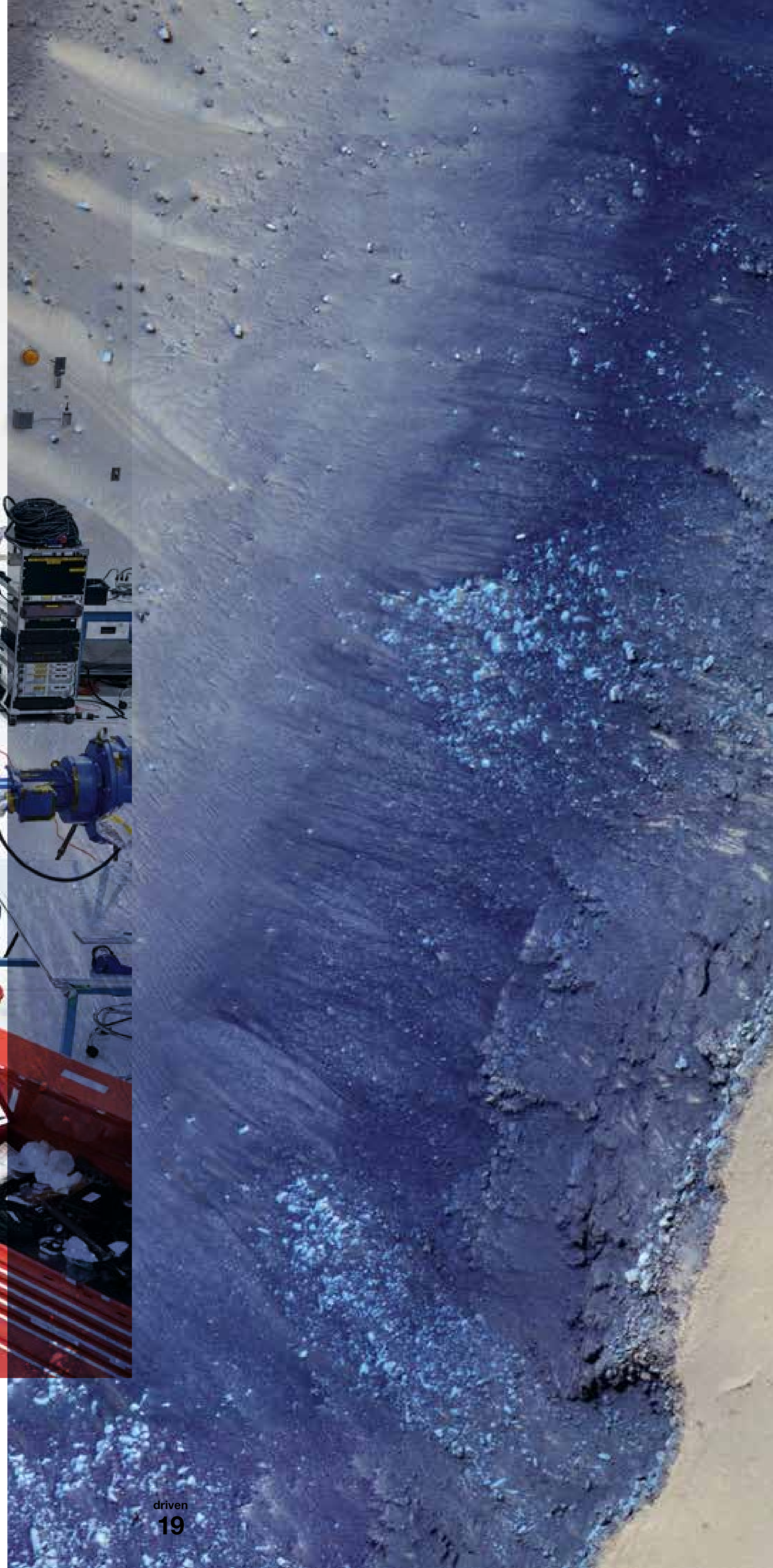



# 4

**4** JPL engineers test the instruments of the Mars rover, wearing protective suits so that no particles from the Earth end up on the Red Planet.

**5** This image shows the Cerberus Fossae region of Mars, a volcanic plain with many valleys.

5



Photos: NASA/JPL-Caltech/University of Arizona, Spencer Lowell / Trunk Archive

6

**6** The rover is stowed in the shell, which is connected, in turn, to the module that is responsible for energy and control during the journey through space.

**7** Slopes deep in the south of Mars are coated with frost in winter, giving researchers insights into the planet's seasons.

7

**The European rover will take off in 2022.** More than 50 drive systems from maxon are installed in the ExoMars rover that the European Space Agency (ESA) is sending to Mars. The rover, named Rosalind Franklin, was originally planned to launch in 2018, but the mission was postponed, initially until 2020, and it is now scheduled for the year 2022. Many different combinations of drive systems comprising DC and BLDC motors, gearheads, and encoders are responsible for moving and controlling the rover, driving its drill, and moving its solar panels, camera head, and much more.

Photos: NASA/JPL-Caltech, NASA, JPL/University of Arizona, Airbus Space

# "We will get incredibly valuable data"

For the first time, a helicopter will take off from the surface of Mars. Aerospace engineer Matt Keennon explains how this impossible mission became a reality.

**Interview** Manuel Bühlmann

**Matt Keennon**
aerospace engineer and project manager at AeroVironment Inc.

**For the first time in human history, a helicopter is going to be used on Mars. AeroVironment was involved in building the helicopter. Are you nervous?**

Am I ever! There are so many unknowns, from the launch to the landing on Mars. Operating a helicopter in such a hostile environment is absolutely unprecedented. The entire team—JPL, NASA Ames, NASA Langley, and us here at AeroVironment—made a huge effort to work out all the risks and reduce them to a minimum.

**How did you get the idea for a Mars helicopter?**

The idea of having an aerial vehicle take off from the surface of Mars goes back several decades. In 1993, Romanian scientists published a study on a solar-powered vertical takeoff aircraft for Mars. In the late 1990s, NASA ran a competition for students in which the participants had to develop a concept for a Mars helicopter. The current Mars helicopter, Ingenuity, was the brainchild of Bob Balaram from JPL, who has been working with us for more than 20 years now. He is the head engineer on this project and has directed it right from the beginning.

**What findings are scientists hoping to gain from the flights and the flight images?**

Although each of the flights will be less than two minutes in duration, they will provide incredibly valuable data that will help us better understand the environment on Mars in a whole new way.

**The air on Mars is extremely thin and is comparable with conditions on Earth at an altitude of 30 kilometers. In your estimation, how likely is it that the little drone will actually take off on the Red Planet?**

I'm very confident that the helicopter will take off from the surface of Mars and will fly, provided it arrives safely. AeroVironment has already constructed solar and battery-powered aircraft that have flown successfully at that altitude with that same low air density. Those aircraft flew with propellers that are very similar to the rotor blades on the Mars Ingenuity helicopter.

**What was the biggest challenge for the engineers in this groundbreaking project?**

If you ask the electrical engineers, they will say designing the electronics was the most difficult part. The mechanical engineers will say the mechanical design was the most difficult. The software engineers will say the software and so on, until we've gone through all the engineering disciplines. Every member of our development team—whether at JPL, maxon, or AeroVironment—has worked hard to make this historic undertaking a reality. Ultimately, nothing beats good teamwork.

**How many people are involved and how long has this pioneering project been running?**

Development began on this Mars helicopter innovation project in 2013. Over the course of time, there have probably been several hundred people working on it. Dozens of companies have also been involved. Like maxon, they had to develop custom-made components, tested to incredibly strict specifications. It wasn't always easy to meet the requirements of the mission, but we got there.

# W

**WHO? HOW? WHAT?**
**Facts & figures**

**CONTROL** The helicopter has autonomous control. There is no way to steer it remotely. The time delay involved in sending radio signals between the Earth and Mars makes that impossible.

**ROUTE PLANNING** For each flight, there will be a specific flight plan that will be programmed from Earth and loaded into the helicopter before it takes off. On the day of the flight, the helicopter will take off at the predetermined time and then make its own decisions for the precise, fast-calculated flight control commands needed to execute the overall flight plan and land safely.

**FLIGHT PROFILE** Take off, climb three meters, laterally yaw (rotate) to look around, and then slowly descend to land safely. A more advanced flight plan would include lateral translation of up to 150 meters over the Martian terrain, and then returning to the starting point before landing.

**ANALYSIS** The plan is to use the two days following a flight to transmit the collected data, including the color photos taken, and to plan the next flight. The flight routes will become more complex from one flight to the next. There are 30 experimental windows in which the flights can be carried out. A total of five exploratory flights are planned.

Video: Ingenuity flying on Mars

**https://bit.ly/ingenfly**

### Why maxon?

maxon has extremely valuable experience in the space sector, and also played an important part in the success of the Nano Hummingbird aircraft from AeroVironment in the early 2000s. That was the first hummingbird robot to use a maxon 8 mm brushed DC motor for its drive.

### What requirements do the DC motors have to meet?

Aspects such as weight, length, operating voltage, efficiency at a specific torque and speed, service life under a specific load, storage temperature, operating temperature, and resistance to dust ingress, to name just a few.

### How would you describe working with maxon?

Working with maxon was and is fantastic in every way. Through our intensive collaboration, we've been able to build up a huge body of knowledge. The little DC motors are the most difficult component in this project.

### What direction could future Mars helicopters take?

There are a lot of ideas for future Mars helicopters, but none of them are definite yet. I'm sure the Mars helicopter Ingenuity will be an important first step toward a much larger and much more complex helicopter that will have capabilities that we can't even imagine today.

# Starring

**Drive system**
**EC 20 flat BLDC motor**
**GP 22 UP gearhead**

⟶ Perseverance rover
p. 12


**DCX 19 S**

⟶ Moon factory
p. 42

**Drive system consisting of two brushless EC-4pole 30 motors and a GPX 42 UP gearhead**

⟶ Rendezvous in space
p. 44

# Mars landings at a glance

**Landing on the Red Planet is one of the greatest challenges of space travel. Here you can see all the successful missions together with their landing sites—marked on a map that shows the relative elevations of Mars in a range of colors.**

### PHOENIX – 2008

**This stationary probe took rock samples from the ground with its robotic arm and analyzed them. Mission duration: five months.** **MAXON DRIVES ❯** Nine RE 25 DC motors with specially designed ball bearings, to align the solar panels and move the robotic arm.

### VIKING 1 – 1976

**NASA achieved its first successful landing with Viking 1. The robot kept working for more than six years and took the first photographs of the surface of Mars.**

### PATHFINDER/ SOJOURNER – 1997

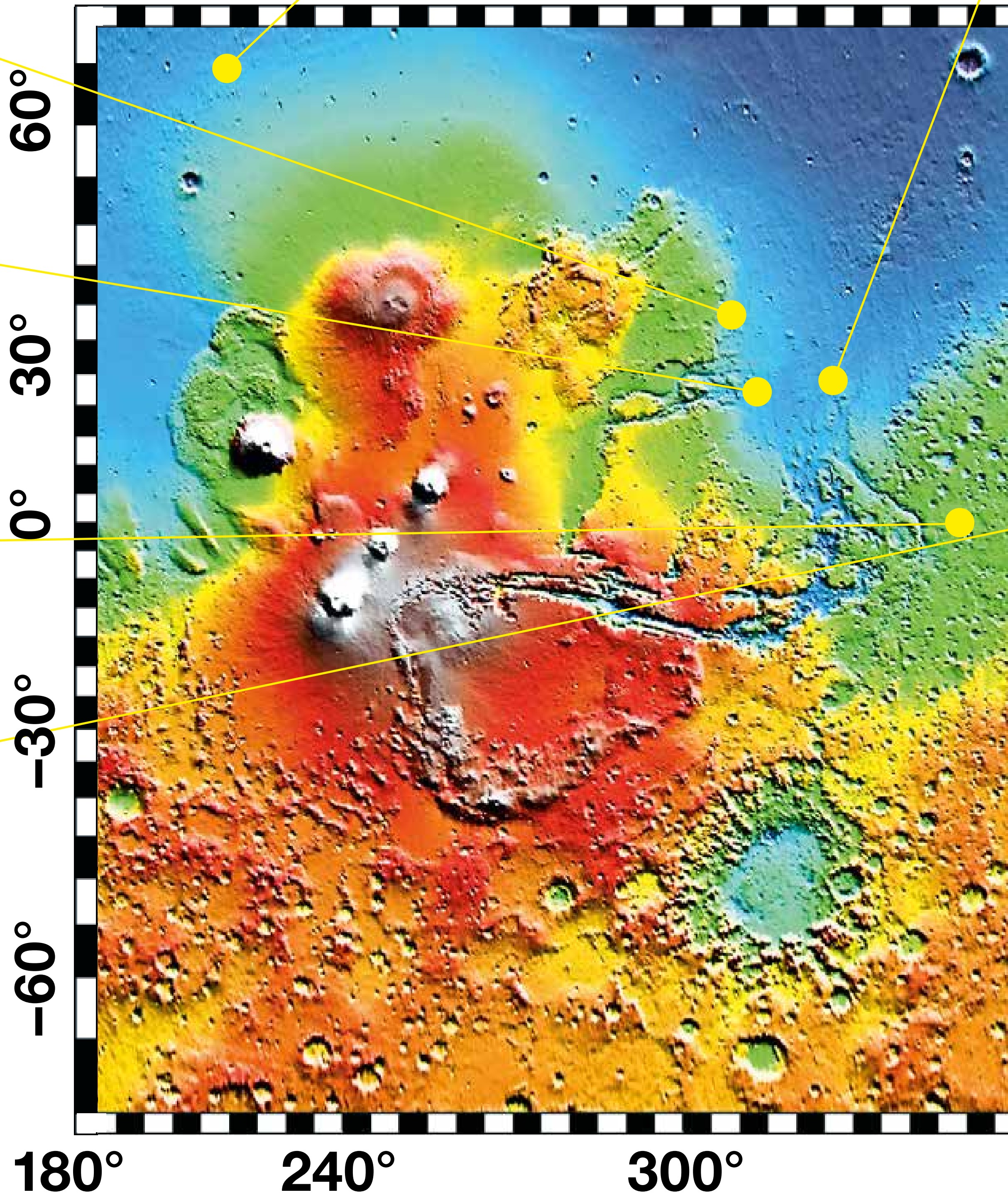
**NASA's Pathfinder probe brought the first rover to Mars, named Sojourner. The landing took place on July 4, 1997. Mission duration: three months.** **MAXON DRIVES ❯** 11 DC motors with a diameter of 16 millimeters for the drives, steering, and scientific devices.

### MARS 3 – 1971

**This Russian mission was made up of an orbiter and a lander. The latter achieved the first soft landing on Mars. However, transmission stopped after a few seconds.**

### OPPORTUNITY – 2004

**Opportunity landed on January 25, shortly after Spirit. 15 years and 45 kilometers of travel later, its mission finally came to an end.** **MAXON DRIVES ❯** 35 DC motors with diameters of 20 and 25 millimeters for wheel drive, control, a robotic arm, and more.



## EXOMARS – 2023 (PLANNED)

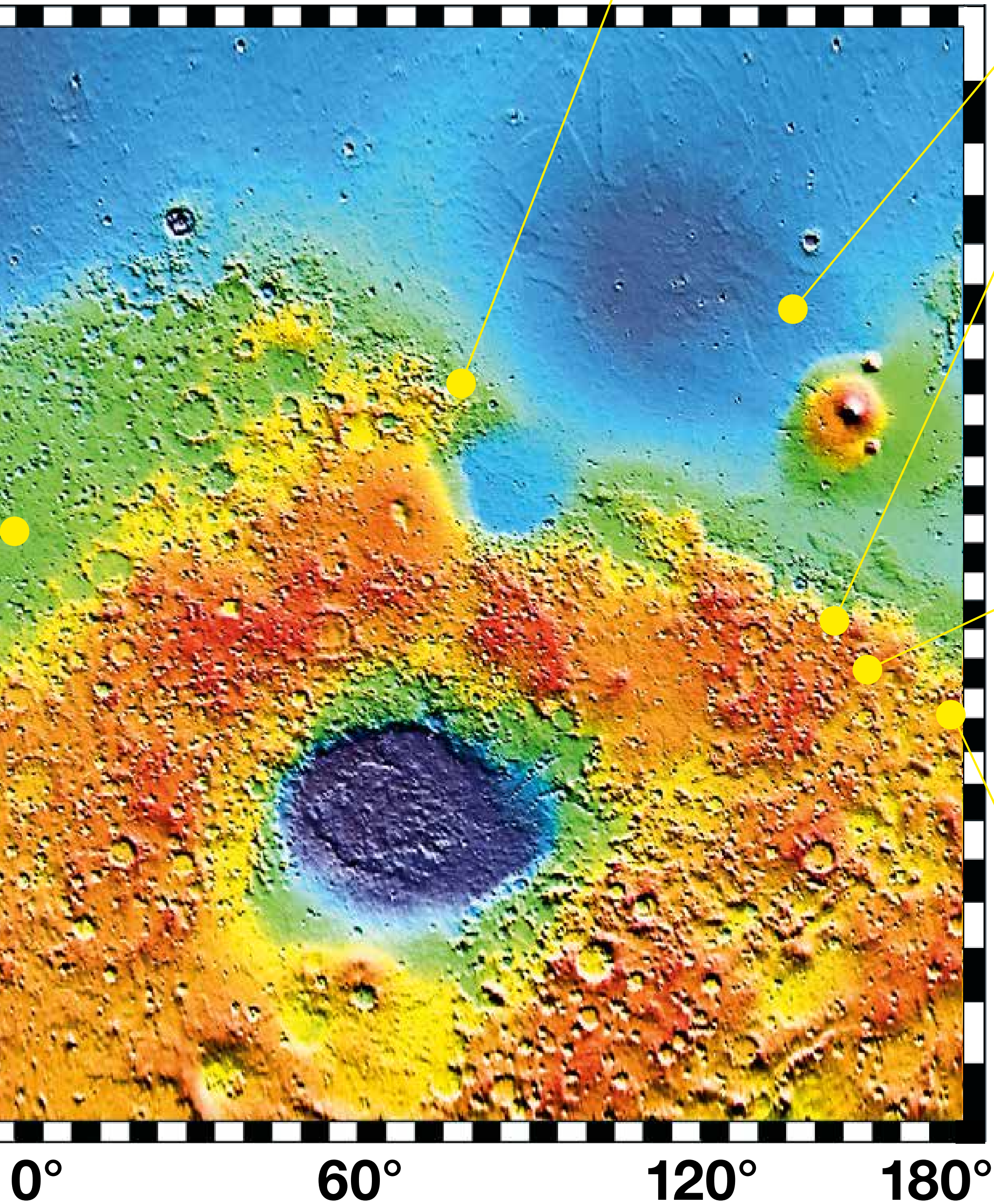
**The rover from the European Space Agency (ESA), called Rosalind Franklin, was originally intended to start operations in 2018, but the mission had to be postponed several times. The journey is now set to begin in 2022, with the landing planned for 2023.**

**MAXON DRIVES** › 50 drive systems. These include a wide variety of combinations of DC and BLDC motors, gearheads, and encoders for propulsion and control of the vehicle, for the drill, and for the analysis systems.

## PERSEVERANCE – 2021 (PLANNED)

**Curiosity's successor is scheduled to land in the Jezero Crater in February, with the task of searching for signs of former life. The rover will also collect soil samples and deposit them for later missions. In addition, it will carry with it the first Mars helicopter.**

**MAXON DRIVES** › For handling of the samples in the rover: nine EC 32 flat BLDC motors and one EC 20 flat motor in combination with a GP 22 UP gearhead. For the helicopter: six DCX 10 motors.




Map: NASA/JPL/GSFC

## VIKING 2 – 1976

**The second lander of the twin Viking mission also made it to Mars successfully. The stationary probe worked for 1316 days.**

## INSIGHT – 2018

**The robot landed on November 26, 2018, and shortly after that, it opened its solar panels with the aid of DC motors. Another drive operates the hammering mechanism in the "mole," which the probe uses to dig into the ground.** **MAXON DRIVES** › Two DC motors for the solar panels and an advanced DCX motor for the temperature probe.

## CURIOSITY – 2012

**The rover landed on Mars in August 2012. It surpassed its predecessors, and not just in terms of technology. Curiosity weighs 900 kilograms and is powered by a radionuclide battery.**

**MAXON DRIVES** › Precise encoders for the drive axes.

## SPIRIT – 2004

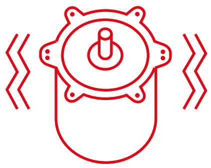
**The rover landed on January 4—shortly before its twin Opportunity. Spirit sent data back to Earth for six years before it finally became stuck in the sand.** **MAXON DRIVES** › 35 DC motors for wheel drive, control, a robotic arm, and more.

# 5 challenges that an electric motor has to overcome on Mars

**Outer space is unforgiving. This is why precision drives embarking on a trip to other planets need to meet extremely high quality standards.**

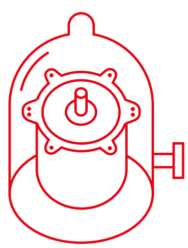
**Every Mars drive from maxon is based on a catalog product and is modified for the specific mission. That's because the DC motors, gearheads, and encoders face brutal conditions during liftoff, the long journey through space, and the mission on the Red Planet. Robin Phillips, Head of SpaceLab, explains the properties a drive needs to have to qualify for a journey to Mars.**

Illustrations: Anita Allemann



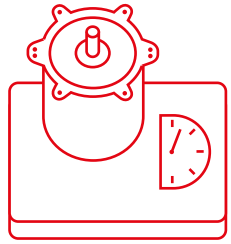
## 1 Vibration and shock

The first challenge is to survive the rocket launch. This means that the motor must be resistant to shock and vibration. The vibration is not as strong as people might think: A little more than on a passenger plane, but not much more, and only for a few minutes. Shocks, on the other hand, are something that we need to deal with on a regular basis when working with standard products. These occur mainly during staging, which is when the first stage separates from the rest of the rocket. The resulting forces would destroy normal motors because the rotor would become separated from the stator. That's why we need to reinforce our drives, for example by encapsulating the rotor and using special welds, special retaining rings, and optimized materials.



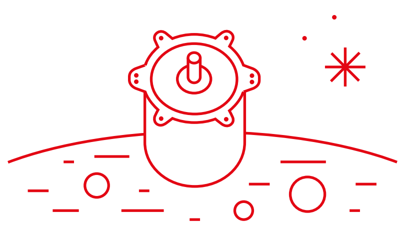
## 2 Vacuum and radiation

The trip to Mars takes about six months. During this time, the drives need to survive the vacuum and radiation. The most damaging radiation doesn't come from the Sun, but from high-energy particles from outside the solar system, which can damage the electronics. That's why we need specially hardened electronics for the Hall sensors on the motors. To be extra safe, we're installing them in pairs for redundancy. In a vacuum, the durability of components is important. You can't use a glue that undergoes changes in its chemical properties and loses its adhesiveness after a few days in a vacuum.



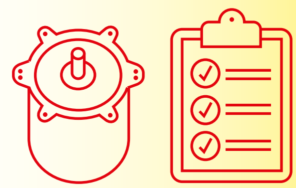
## 3 Weight reduction

Rockets can carry only a limited mass to other planets. To be as light as possible, we also resort to unusual shapes and use thinner housings, or titanium instead of steel. We also often use the smallest possible drive sizes, because we know that the operating time required is usually shorter than for industrial applications. Higher wear is therefore acceptable.



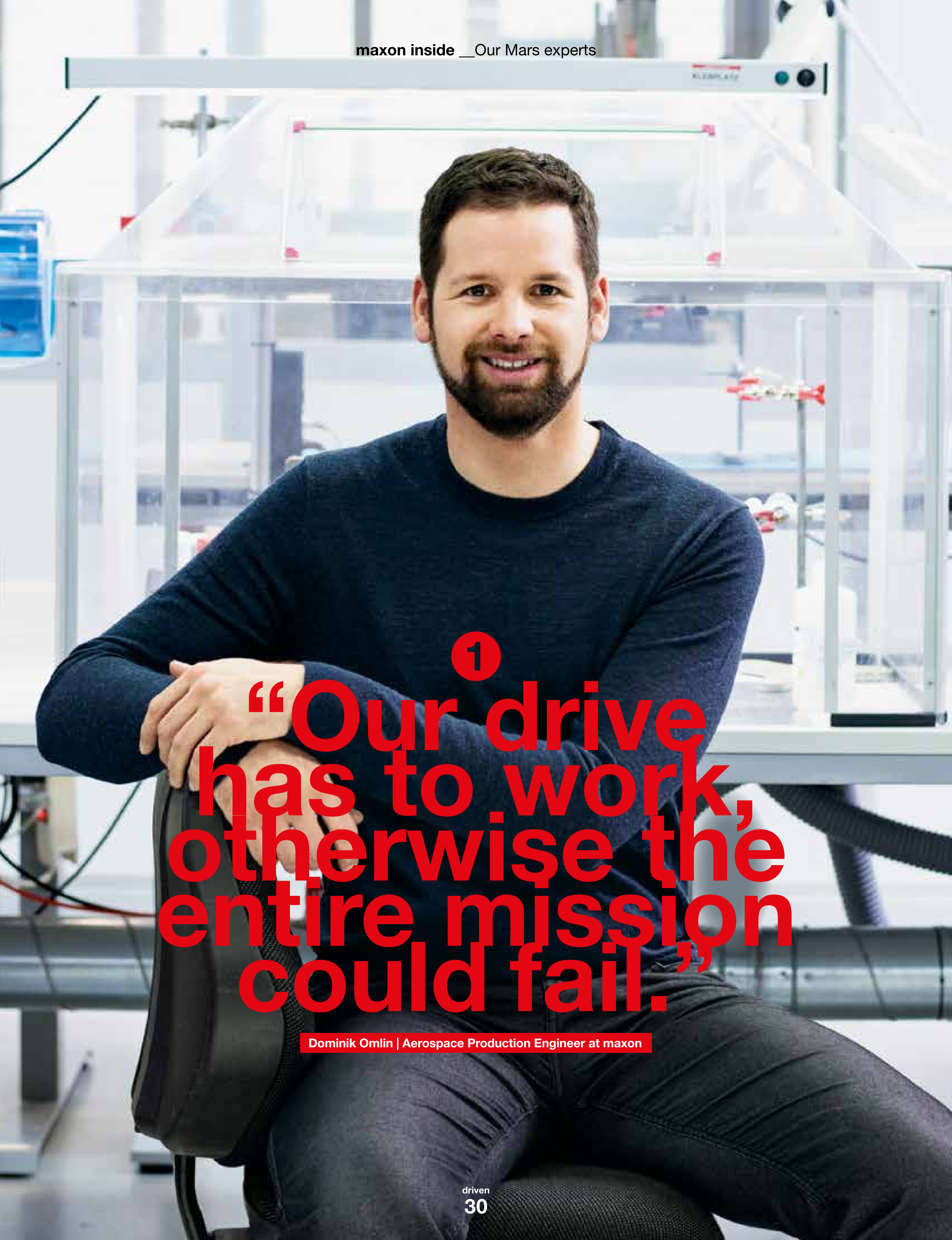
## 4 Atmosphere of Mars

After arriving, the motor must work flawlessly for the entire duration of the mission: Due to the thin atmosphere, the lubricants need to be resistant to outgassing and need to retain their properties. Especially for brushed DC motors, it is also necessary to use the right brush mixture. No patina forms on Mars, which is why we developed special brushes impregnated with a lubricant (silver graphite with 15% $MoS_2$). That's one of the most important modifications, because regular brushed motors fail after only a few hours in a vacuum.



## 5 Quality tests

While drives used on Earth are also tested, there are limits to those tests due to financial considerations. This is different with a Mars mission, where any kind of risk is unacceptable. Here it pays to test every single component. We also test every assembly, and the tests are comprehensively documented. This is how we prove to our customer that the motor is exactly as we promised. The models used on mission must be identical to the units that were qualified, because these were exposed to the same strains in tests as in real life. They were put on a shaker, exposed to temperature cycles, and subjected to durability tests. If the drives pass all these tests, then we can be confident that the design is good. The only remaining step is to build all the other drives in the exact same way—hence all the documentation. The process takes a lot of effort, but it's worth it: The history of space missions shows that anything that's overlooked will cause problems—and outer space is unforgiving.



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# "Our drive has to work, otherwise the entire mission could fail."

**Dominik Omlin | Aerospace Production Engineer at maxon**

❷

# “For me, projects like the Mars helicopter are a dream come true.”

**Florbela Costa | Technical Project Manager at maxon’s SpaceLab**

3

# “Inspiration doesn’t come from a blank sheet of paper.”

**Robin Phillips | Head of maxon’s SpaceLab**

## 1 Dominik Omlin. Aerospace Production Engineer

"When making motors for Mars, nearly everything has to be done by hand. Every move and every assembly step have to be documented and has to be right—we can't afford to make mistakes. We're working with materials that you can't just get from the warehouse. At the back of my mind, I'm aware that on Mars there is no way to fix things. Our drive has to work, otherwise the entire mission could fail. So we talk to each other about everything, discuss the next steps, and work with strict double checking by a second person. Our team in Special Production assembles motors and drive combinations for space applications. But not only that. We also handle orders for the medical sector, robotics, and other industries. Every project is different, so we have broad knowledge of the maxon motor range. As an aerospace production engineer, I have many tasks. These include creating detailed process descriptions, producing the drives, training employees, and working closely together with the engineering department. Sometimes I'll spend several hours in the cleanroom, where the motors are protected from particles. I can concentrate on my work there. That's not always easy when you have someone looking over your shoulder—which was the case for the Mars 2020 project. The specialists from JPL, our client, worked closely with us and visited us at our headquarters several times. We discussed the challenges with them and worked together to find solutions. Yes, I am proud to be a small part of these space missions. I can see how very grateful the customers are for what we do. That makes the work even more satisfying."

## 3 Robin Phillips. Head of SpaceLab

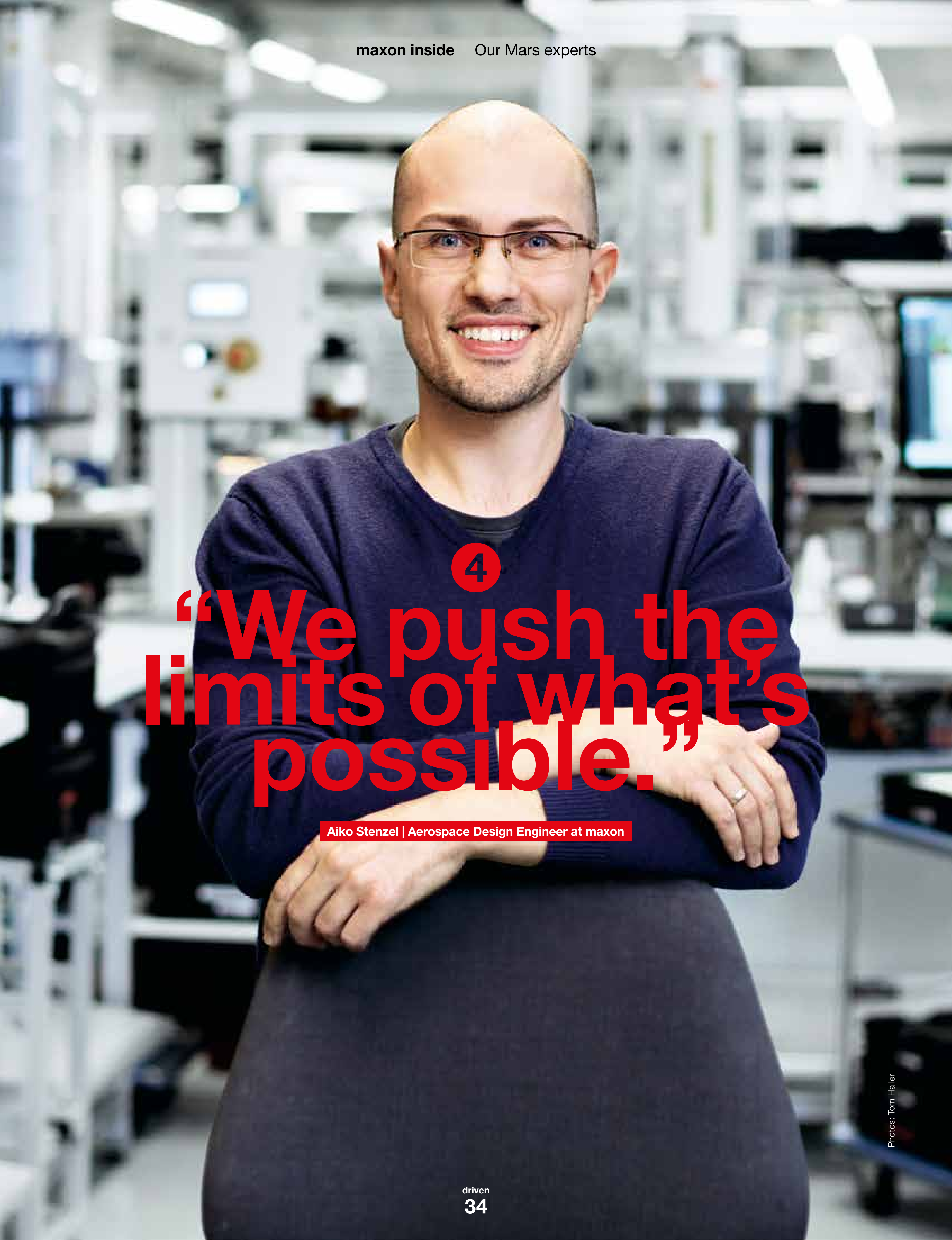
"I believe that inspiration doesn't come from a blank sheet of paper. That's why I have collected a lot of interesting motors and components at my workstation. It was one of these components that gave me the key idea for the brushless drive that is now used in NASA's Perseverance rover. This vehicle will collect samples on Mars, and our motors will handle those samples. So they are critical for the success of the mission. Yes, it makes me proud to contribute to something that will help humanity learn about the solar system in which we all live. Space missions are the expeditions of discovery of our time, and can only be achieved with the highest technical standards. Our precision drives often carry out important tasks on such missions. Mistakes are not an option, and that's what makes it exciting. As head of the SpaceLab, I'm always on the lookout for new technologies for our company. I also work to create an environment for people where they can do their work as perfectly as possible. Happily, we at maxon are getting better all the time in that regard. We used to simply deliver the drives with the specified modifications and the customers were responsible for what happened next. We now have expertise in space applications and have established quality assurance processes that meet the expectations of the industry. Customers from other industries where requirements can be just as demanding, like the medical sector, also benefit from this know-how. Space projects require a lot of patience. I've been doing my job for more than ten years, but it's only now that my drives are slowly coming into use. That makes it all the more satisfying when everything works."

## 2 Florbela Costa. SpaceLab Project Manager

"I can't wait till the first helicopter from NASA flies on Mars. As a technical project manager in Aerospace, I was responsible for the DC motors used to control the helicopter, in its swashplate to be exact. For me, projects like these are a dream come true. Especially in cases such as this, when we're able to meet the tight deadlines and our products get positive results in all the qualification tests. It makes me very proud to be part of such an incredible operation. Something like this can only be done by many people working together, of course. In my role, I act as a link between the customer and the various departments at maxon. I make sure we meet requirements—in terms of quality, deadlines, and cost. I like being in contact with all the people involved at maxon, from development through to production. I also like space projects, as the aerospace industry has always fascinated me. They are different from other applications, above all because of their generally higher quality requirements for things like resistance to vibration and temperature. Consequently, everything needs to be analyzed and tested. Parts used in our standard motors are reevaluated to make absolutely certain that they will function in space or on other planets. It's a lot of work, but it's worth it."

## 4 Aiko Stenzel. Aerospace Design Engineer

"For the last seven years, I've had the privilege of building brushed DC motors for various Mars missions. It all started with the ExoMars project for the ESA, where I was responsible for 13 different drives. These included the innovative wheel drive on the rover, which can lift its wheels on rocky terrain. We developed a new, purely magnetic cogging torque brake for that. The idea is to stop the rover rolling down slopes. However, the most exciting project so far was the Mars helicopter for NASA. I had the opportunity of developing a maxon DCX 10 drive for control of the rotor blades. Six of these small direct current motors were needed. The biggest challenge was the extreme weight requirement. We had to take off every tenth of a gram we could, so that the helicopter can fly in the thin atmosphere on Mars. It's great that we were able to find a solution with enough power to adjust the rotor blades, despite the weight reduction—and which could handle all the vibration and temperature fluctuations as well. The main difference between space drives and ones on Earth is that we push the limits of what's possible: in the engineering, the materials, and the processes. For example, we developed a special hardening process for the manufacture of shafts, to make them tougher. On top of that, there is always a lot of documentation required: detailed bills of materials, weight specifications, center of gravity calculations, surface area calculations for plastic parts, etc. It's good that many other customers can also benefit from our experiences in the space sector. For instance, we developed special welding techniques for the Mars drives which are now being used in our standard commercial production. The maxon catalog will soon also include the magnetic holding brakes that we designed for ExoMars. Pretty cool, right?"



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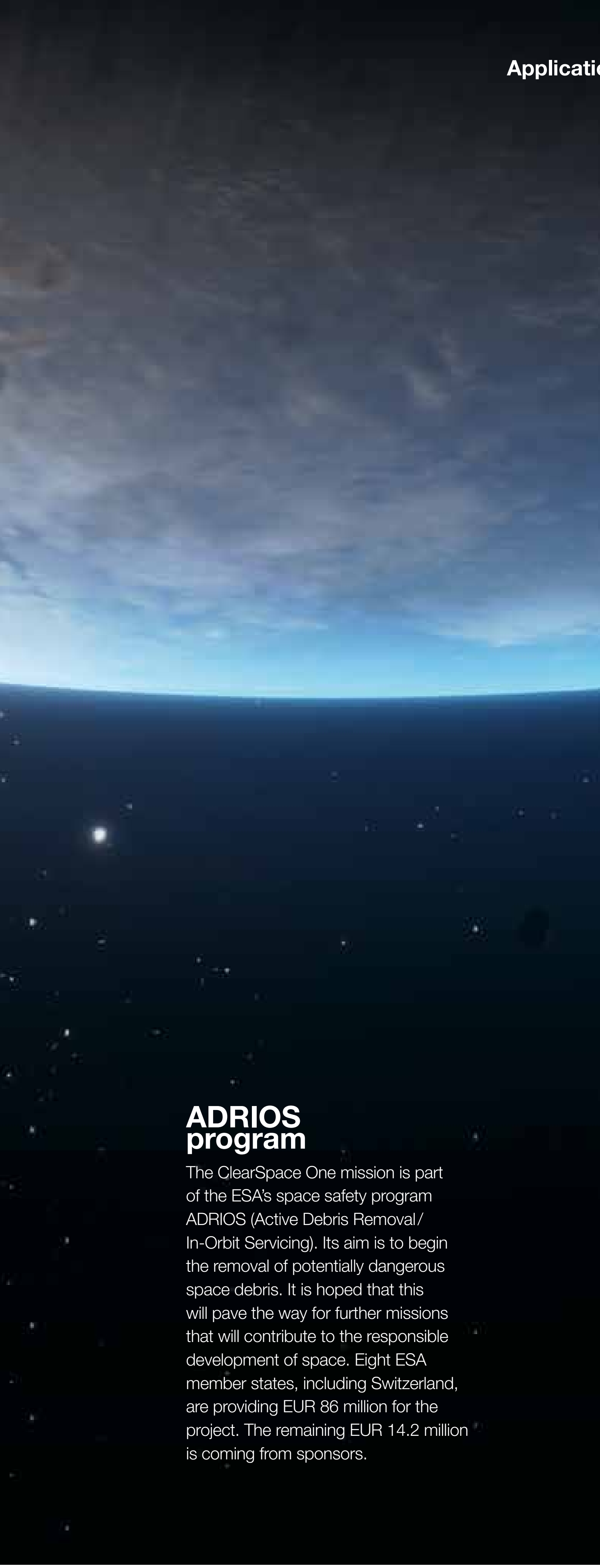
# "We push the limits of what's possible."

**Aiko Stenzel | Aerospace Design Engineer at maxon**

Photos: Tom Haller

# Trap the trash

A spin-off from the Swiss Federal Institute of Technology in Lausanne (EPFL) has been given responsibility for a EUR 100 million project by the European Space Agency, ESA. ClearSpace SA now heads a consortium developing the first debris removal mission in the Earth's orbital field.



## ADRIOS program

The ClearSpace One mission is part of the ESA's space safety program ADRIOS (Active Debris Removal/In-Orbit Servicing). Its aim is to begin the removal of potentially dangerous space debris. It is hoped that this will pave the way for further missions that will contribute to the responsible development of space. Eight ESA member states, including Switzerland, are providing EUR 86 million for the project. The remaining EUR 14.2 million is coming from sponsors.

**Text** Luca Meister

Our lives are becoming more and more dependent on space technologies. We use satellites for meteorology, communications, navigation, and observation of disaster areas. According to the European Space Agency, ESA, around 40% of modern-day mobile applications rely on satellite and space technology. However, this infrastructure is at risk.

95% of all objects in low-Earth orbit, which is to say at altitudes between 200 and 2000 kilometers, are defective and no longer controllable. They are space debris—such as jettisoned rocket stages, solar panels (including those from satellites), tools, paint chips, and particles of solid fuel. This debris poses a risk to active satellites and to future space missions and their crews. Even the International Space Station has had to maneuver to avoid space debris on several occasions.

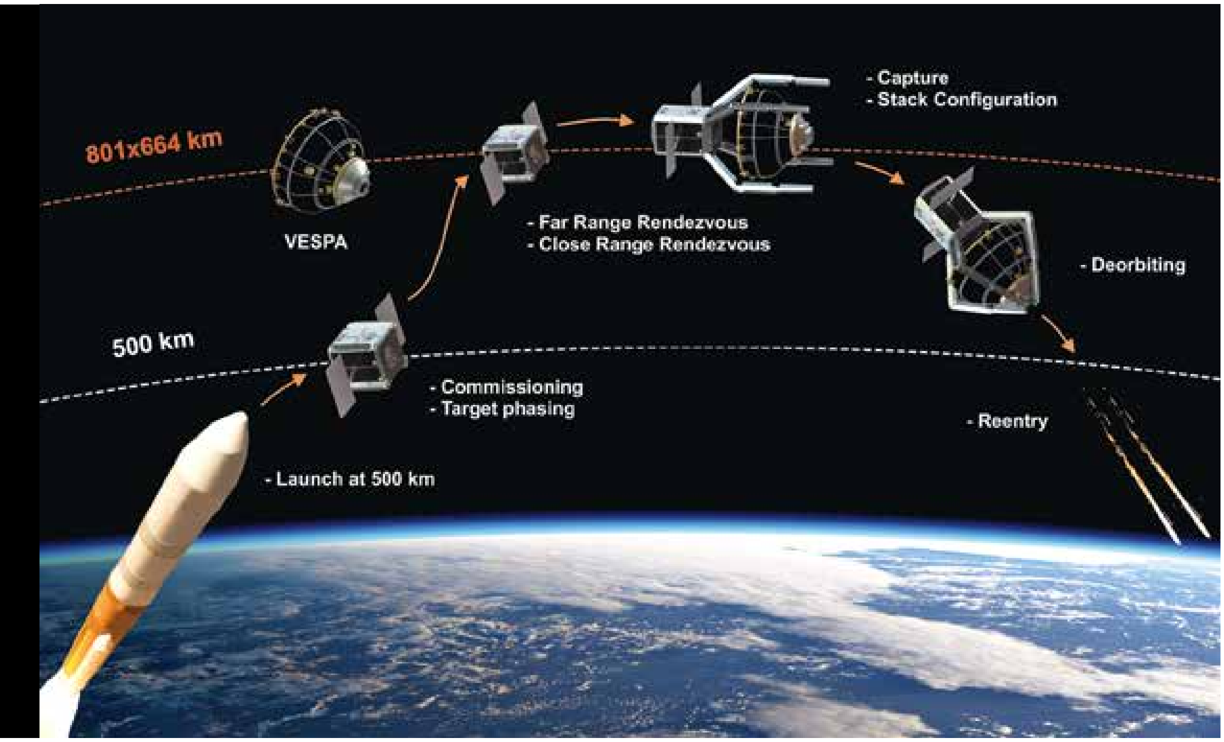
### Constellations of mini-satellites

The situation is becoming more urgent due to the new satellites that continue to be placed in orbit. Whereas only 50 spacecraft were sent into orbit each year between 2009 and 2012, 800 are scheduled for the current year, and the trend is upward. In the future, most of the new arrivals in space will be nanosatellites, as part of network constellations. For example, the company OneWeb began to build a constellation of around 650 mini-satellites in 2019. Their aim is to enable internet access even in the most remote locations on Earth. Projects like this, as well as the emerging field of space tourism, necessitate the removal of space debris.

With over 34,000 human-made objects currently registered with diameters exceeding ten centimeters, we have reached a critical juncture. If humanity doesn't do anything about it, an estimated 140,000 objects of junk will accumulate in orbit by 2065. This is because the collision of two objects creates a debris field with a multitude of parts. There is a risk of a dangerous chain reaction.

### First debris removal mission by the ESA

Now a Swiss "disposal satellite" is set to do the groundbreaking work of removing a debris object for the first time. Planned for 2025, the ClearSpace One mission, directed by the startup of the same name, will capture the discarded VESPA upper stage (VEga Secondary Payload Adapter) from a rocket launched in 2013 and guide it into the Earth's atmosphere.




ClearSpace's first debris removal mission could proceed as shown here. Currently the company is working with maxon drives consisting of the DCX 22 L direct current motor and the GP 32 HP planetary gearhead.

A 3D animation of all the pieces of debris orbiting the Earth can be viewed at

**stuffin.space**

The prototype of this space cleaner will use a "chaser" consisting of four robotic arms to grab and move the disused upper stage at an altitude of 720 kilometers. Twelve maxon drives operate the tentacle-like arms of ClearSpace One. After that, the captured rocket stage will be positioned such that it can be decelerated out of orbit. This procedure will use jet engines on several sides. During a controlled reentry, both the VESPA and the ClearSpace One will burn up in the atmosphere—the biggest "incineration plant" ever.

The idea is that future disposal satellites will repeat this procedure as often as possible. They will also carry away heavier objects in low-Earth orbit to free up space for subsequent space operations.

### Ten years of experience with space debris

The researchers at the EPFL Space Center in Switzerland have been working on space debris capture systems since 2010. The engineering knowledge they have gained over the years went into the development of ClearSpace One. In 2017, the project was spun off, resulting in the founding of ClearSpace SA, which began its operations in the maxon lab at the EPFL. As Luc Piguet, CEO and cofounder of ClearSpace SA, observed, "The maxon lab is a hub for technology transfer, making it ideal for startups." The growing team at ClearSpace has been enhanced by specialist consultants from leading space agencies and companies with mission experience. The advisory board includes luminaries such as Jean-Jacques Dordain, former Director General of the ESA, and Swiss astronaut Claude Nicollier.

It is remarkable for a startup to be given responsibility for a EUR 100 million project. In 2019, ClearSpace prevailed single-handedly against Airbus, Thales Alenia Space (France), and Avio (Italy). Luc Piguet said, "Although we had great confidence in the application we submitted, we were surprised to be allowed to take the lead over a project consortium on our own." He remained pragmatic, however: "We've taken economic considerations into account right from the beginning." The costs incurred by each de-orbit should be as low as possible. This won over the ESA. Piquet added with a modest smile, "We're taking on a big responsibility."

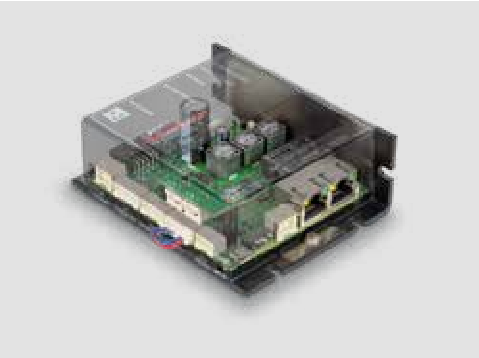
Photos: ClearSpace

## Dual loop control:

# Oscillations and gear backlash no more

Can loads be positioned dynamically, with high precision and no oscillation, despite mechanical backlash and elastic components? Yes—using an intelligent system.

Jürgen Wagenbach,
Head of Customer
Support, Motion Control
at maxon



The EPOS4 50/5 positioning controller from maxon.

Moving loads with an electrical drive is usually done with a system that uses an encoder on the motor shaft to provide the position and velocity information for control. High encoder resolution and precise detection of the motor shaft reaction are essential for dynamic position control. From the point of view of the application, however, it is ultimately the precision of the output-side load movement that is critical for the quality and dimensional accuracy of the goods produced. Gearheads, spindles, and drive belts can have a negative effect on this. Depending on the direction of movement, the gear backlash may result in a different load position on the output side. Elasticity may cause delays and oscillations at the start or stop of the movement. The first solution that comes to mind is to mount the encoder on the output shaft, instead of the motor shaft. However, rather than success, this results in even worse system performance.

In the case of a mechanism with backlash or elasticity, dynamic and precise load positioning requires the use of a system in which control is based on two encoder systems:

- One rotary encoder, the auxiliary encoder, is rigidly connected to the motor shaft. It should already be part of the motor combination.
- Another encoder, the main encoder, is connected to the moved load on the output side.

To process the signals from these two encoder systems, dual loop control is required. maxon's EPOS4 positioning controllers augment this dual loop control with a second-order filter and a gain scheduler to counteract mechanical resonance and gear backlash. The EPOS Studio commissioning software provides a Regulation Tuning tool which automatically determines parameters for the complex controller structure. It also plots the transfer function of the drive.

## Control architecture

EPOS4 uses a cascade control structure for the dual loop control (see **Figure 1**):

- The innermost control loop provides field-oriented control (= FOC) of motor current based on the motor current measurement as a feedback signal.
- The middle control loop (auxiliary control) controls the motor speed based on the encoder on the motor shaft.
- The outermost control loop (main control) controls the position of the load based on the encoder system on the load.

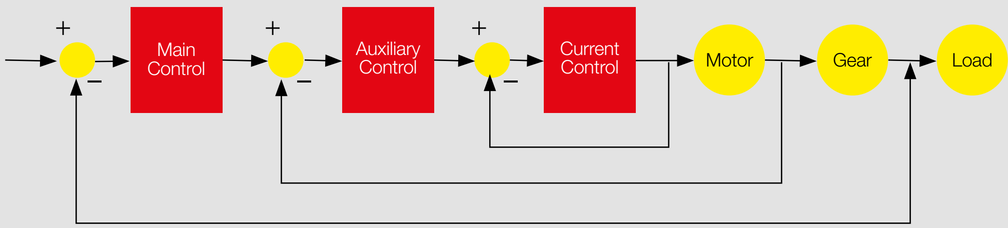



**Figure 1** Dual loop architecture consists of three integrated feedback loops.

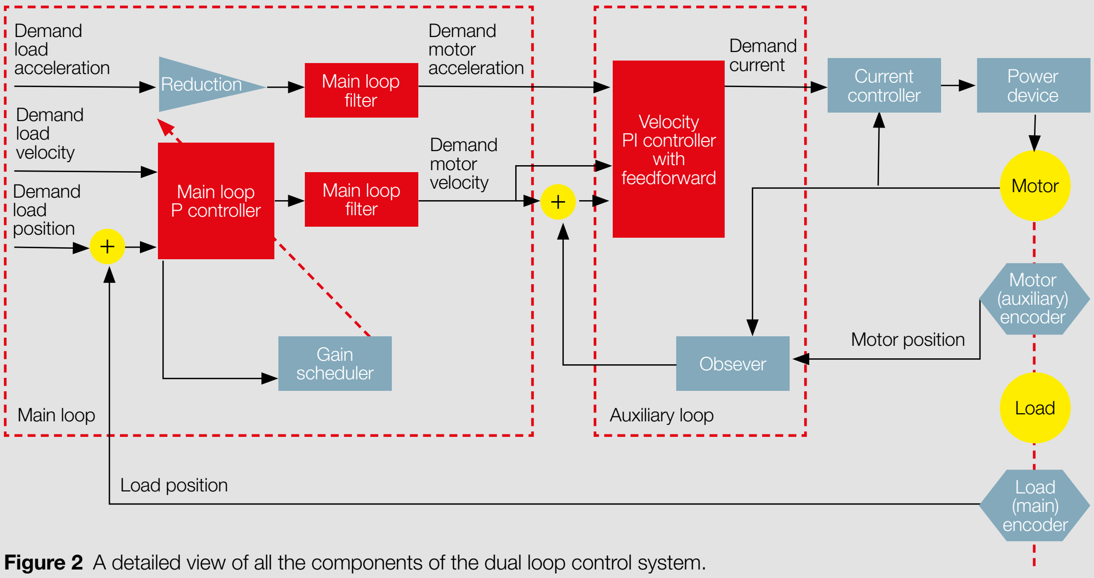



**Figure 2** A detailed view of all the components of the dual loop control system.

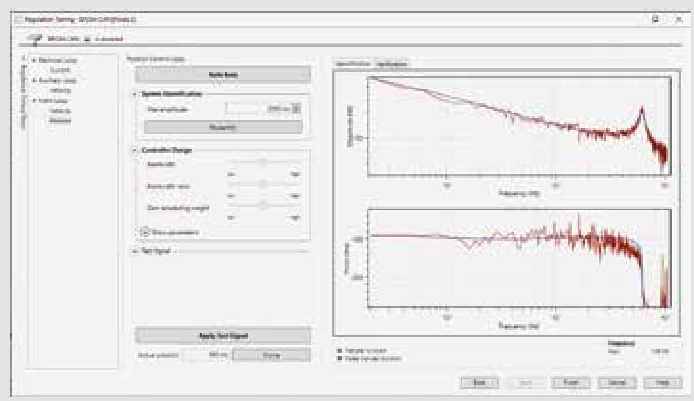


**Figure 3** Example of a transfer function identified using EPOS4, with resonance.

A detailed view of the EPOS4 dual loop control structure is shown in **Figure 2**.

## Main control loop

The main control loop is made up of a proportional (P) controller, a gain scheduler, and a second-order filter (the main loop filter). A path planner supplies the desired position of the load and its desired velocity and acceleration as input variables for the main control loop. Another input variable is the current position of the load, as measured by the encoder on it.

• Gain scheduler

The EPOS4 dual loop control uses the gain scheduler to eliminate negative effects from gear backlash. The gain scheduler does this by automatically adjusting the P gain of the main control loop. If the tracking error—the deviation of the actual load position from the desired position—is too large, a high P gain will be applied, resulting in rapid reduction of the error. As the tracking error becomes smaller, the P gain is reduced as well, so that oscillation does not occur in the drive, despite gear backlash.

• Main loop filter

If there is a certain amount of elasticity between the motor and the load due to couplings, belts, or long spindles, resonant frequencies could cause amplifying oscillations. These could increase to the point where control becomes unstable. In order to prevent this, the EPOS4 dual loop controller uses a second-order filter, of the notch filter type. This filter suppresses the resonant frequency range in the output signal from the main control loop, thereby preventing harmonic oscillations in the drive train.

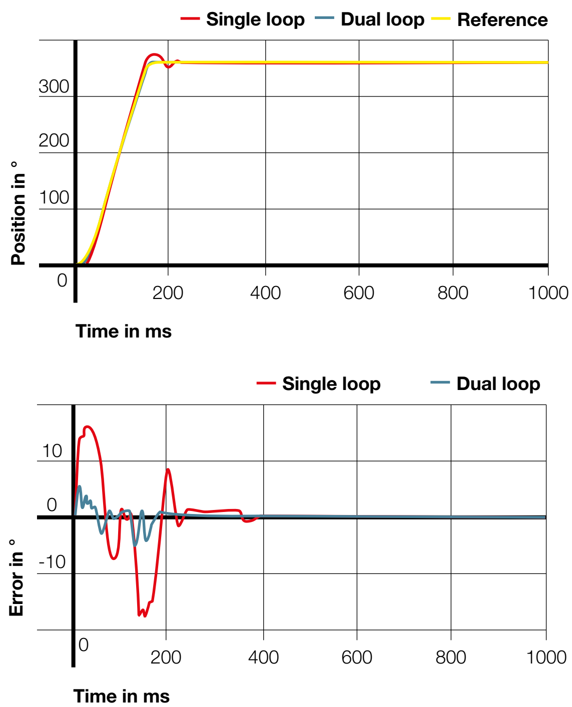



**Figure 4** Load position profile of a system with gear backlash: reference response (top) and tracking error (bottom).

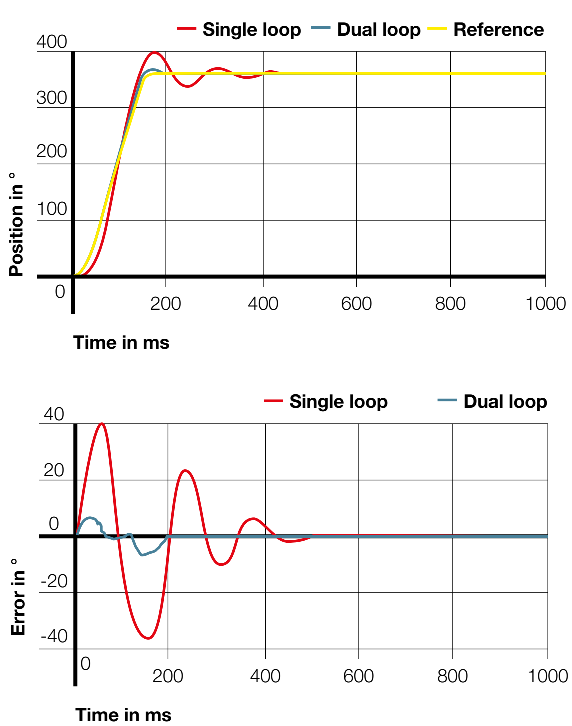



**Figure 5** Load position profile of a system with elasticity. Reference response (top) and tracking error (bottom).

## Auxiliary control loop

The auxiliary control loop consists of a proportional-integral (PI) controller with feed forward (FF), and an observer that estimates the motor speed from the position data of the motor encoder and the motor current measurements.

## Auto-tuning procedure

To simplify commissioning, maxon's EPOS Studio software features an integrated auto-tuning wizard to determine and validate the parameters of the dual loop controller. The auto-tuning procedure consists of two experiments that are carried out automatically.

• Experiment 1 triggers oscillations of the motor shaft. These oscillations are used to determine the mass inertia, the torque constant, and the friction in the motor. The parameters for the auxiliary loop controller and observer are then calculated on the basis of the data identified.

• Experiment 2 is used to calculate the parameters for the main control loop and the notch filter. A PRBS signal (= Pseudo-Random Binary Sequence) is used to excite the plant. Based on the resulting input-output data, the transfer function is identified and presented as a Bode plot (see **Figure 3**).

The Bode plot can be exported. It assists control technicians in system analysis in optimizing the mechanical design, and in manual adaptation of the control for specific applications.

## Comparison of single loop control and dual loop control

The following graphs show the differences in reference response and tracking error for a system with gear backlash (**Figure 4**) and a system with an elastic coupling (**Figure 5**). The graphs compare single loop control with an encoder on the load, and automatically tuned dual loop control with an encoder on both the motor shaft and the load.

Dual loop control is a way of making drive systems more precise and more efficient. maxon offers not only all the components required, but also a great deal of experience in consultation—from the initial idea and the system design through to full-scale commercial production.

# Starter kit for a moon factory

Photo: ESA - P. Carril

## Young Engineers Program

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**Text** Luca Meister

Fiber-based materials are suitable for the construction of a future moon base. In their MoonFibre project, researchers developed a miniature system to produce continuous glass fibers under adverse conditions.

The moon is now well known to us, including its dark side. A Chinese probe landed there in 2019. The ESA and NASA are also pursuing plans for new moon missions. If only the transportation costs weren't so high. It costs USD 1 million to bring a liter of water to the moon. Simply delivering the materials for a space station the size of the ISS would come to USD 450 billion. So the aim is to build extraterrestrial infrastructure with locally available materials.

The lunar surface consists of boulders, rubble, and dust. This porous and loose rock is regolith, and is similar in its chemical composition to basalt, which is suitable for the production of mineral fibers.

The Institute of Structural Mechanics and Lightweight Design (SLA) and the Institute of Textile Technology (ITA) at RWTH Aachen University have developed an automated miniature spinning mill for the production of mineral fibers. After analyzing soil samples from the Apollo and Luna missions, regolith simulants were produced and fibers as thin as 17 micrometers were spun from them.

## Versatile

Using the production systems of glass fiber manufacturing as their starting point, the researchers simplified the processes and packed them into a 40-centimeter cube made of carbon-fiber-reinforced materials. In that cube, the moon rock will be melted into glass at 1,450 degrees Celsius. The molten glass will then be drawn out through a nozzle at the bottom of the melting pot to form a continuous fiber. Finally, the continuous fiber will be wound onto a spool. The iBlock should be able to produce up to 180 kilometers of fiber material per hour.

The conventional spinning process is affected by gravity and air pressure. This is where the difficulties lay in adapting it to lunar conditions. In addition to the weaker gravitational force, the extreme temperature fluctuations were also taken into account when designing the plant concept.

The glass fibers obtained from regolith would be very versatile in the construction of a moon base. They could be used to produce fiber-reinforced structures made of concrete and mineral wool, or textiles which, in turn, could be used in the manufacture of clothing, medical equipment, ropes, and cables. Wool material and nonwovens would be used to produce filters, heat and sound insulation, and radiation shielding. There are even plans to cultivate plants on substrates made of moon fibers.

## Scalable to a system

The cube, which weighs only 17 kilograms, can be scaled up to form a system or a small factory. Multiple units, interacting via interfaces, would perform various different functions. In a study conducted by the German Aerospace Center (TLR), which looked into setting up a moon base, these moon fibers were a central component.

The MoonFibre team was one of the three winning teams of students in the ESA project IGLUNA, coordinated by the Swiss Space Center, which took place in Lucerne in July. The fiber spinning concept is to be tested in a sounding rocket before the end of this year. By the way: the winder and the thread guidance are driven by brushless EC 45 flat and EC 20 flat motors (the latter with an extended planetary gearhead). Height adjustment is performed using another actuator, made up of a brushed DCX 19 S motor, a low-backlash planetary gearhead, and an ENX incremental encoder for positioning.

**Text** Stefan Roschi

# RENDEZVOUS IN SPACE

The European Space Agency (ESA) is introducing a new system to ensure easy docking between two objects in space. maxon has developed two special drive systems for this purpose.

Even though it's been done many times before, the docking maneuver between two objects in space is always a delicate and potentially dangerous procedure. The speed is extremely high (about 28,000 km/h in case of the ISS), and corrections are difficult. For example, when the two objects are about to meet, maneuvering thrusters can no longer be used, since their exhaust plumes can cause damage. To prevent harm, cargo transporters are caught by a robotic arm installed in the International Space Station (ISS) and berthed manually. Manned spacecraft, on the other hand, dock directly in a computer-controlled process. In the future, this type of docking maneuver is going to become easier and safer. The European Space Agency (ESA) has commissioned its industry partners to design a new docking system called IBDM (International Berthing and Docking Mechanism). This conforms to the International Docking System Standard (IDSS), a standard on which the leading space agencies worldwide have agreed. The system will therefore be compatible with the ISS and most other spacecraft. The mechanism's first missions will

Photos: SENER, Sierra Nevada Corp

be with the Dream Chaser, a craft that looks like a compact version of the Space Shuttle and will soon perform cargo flights to the ISS. The craft is being developed by the Sierra Nevada Corporation.

## Docking energy is absorbed

The IBDM is an androgynous coupling system. This means that the connector is identical on both sides. It consist of a hard inner ring (Hard Capture System) and a soft outer ring (Soft Capture System) that has six degrees of freedom and force sensors. The outer ring first absorbs the docking energy. Then the final airtight connection is made and secured by mechanical hooks which pull the two spacecraft tightly together.

SENER is in charge of developing and installing the Hard Capture System. The company is currently working on the qualification model, which is due for testing soon. "Then the IBDM needs to be used as quickly as possible on a supply flight for the ISS," says SENER's Gabriel Ybarra. Also, the IBDM will be used in the international Deep Space Gateway space station, which is planned to go into orbit around the moon for the 2025, and could serve as a launch point for manned missions to Mars in the future.

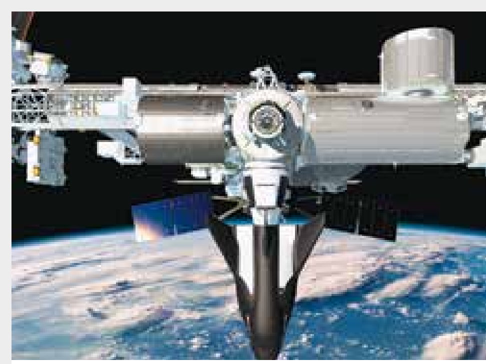
## Dual systems for maximum safety

This is a challenging project for the engineers at SENER: "We first needed to fully understand all the requirements set by ESA and NASA and figure out how to fulfill these requirements. And especially with regard to safety, because the docking mechanism can also cope with manned flights." As well as being lightweight and delivering the required torque, the electrical drives that are used must also be extremely reliable. This is why SENER has been working with the drive specialist maxon for several years.

maxon's engineers have developed two drives for SENER that can be used to execute a huge variety of functions. This first drive consists of two brushless EC-4pole motors and a GPX UP gearhead. Twelve of these actuators power the locking hooks in the IBDM docking mechanism. The second drive combines a flat motor with a planetary gearhead. It is used in eleven places, to manage the plug-in connections and the retaining eyes, as well as other ancillary functions.

As the IBDM docking mechanism is a flight-critical application, redundant drive systems are required. The backup must function even if the primary drive fails. This is often solved by means of a backup motor that can take over in an emergency. This is the approach used for the locking hook actuator. For the other drive system however, the maxon engineers found a different, unconventional solution: an additional stator is used instead of an extra motor. The flat motor therefore has two stators and hence two windings, each of which is capable of independently driving the rotor – an ingenious solution, which guarantees safety while saving space.

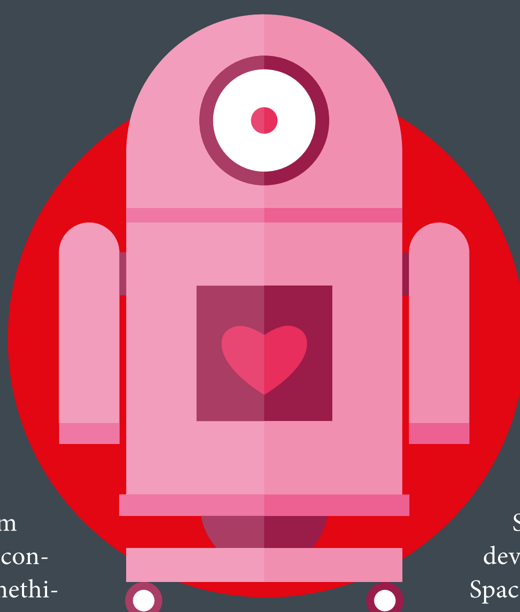
Gabriel Ybarra praises the collaboration with maxon: "The team understands our requirements and is very quick with design modifications." Moreover, both partners have a passion for mechatronic systems. "It feels great to be involved in the entire cycle, from design to production and testing. This makes it extremely interesting. And when the system moves for the first time, it's like watching your children take their first steps."



**Top** An artist's impression of the Dreamchaser docked at the ISS. **Bottom** The IBDM system with its rigid inner ring and flexible outer ring.

# Robots make better astronauts

Text Stefan Roschi



Do you remember Mars One? It was a media project nearly ten years ago, which proposed to take at least four people to Mars – on a one-way ticket. The level of excitement in the media was matched only by the amount of criticism from the experts. The plan was condemned as unrealistic and unethical. Since then, the project has gone quiet and can be considered as having failed. However, even the professionals are having a hard time getting people to Mars (and bringing them safely back again). NASA has now identified the Moon as an intermediate staging point. The US space agency plans to take women and men to the Moon again by 2024 and then establish a permanent presence there – both on the surface and in orbit around it, where a mini-ISS will be set up. This gateway is intended as a starting point for Mars missions. Exactly when is not clear. What's more, there are still many technical challenges that need to be overcome: How do you protect astronauts from cosmic radiation? Can people land safely on Mars and take off again later? How do you produce oxygen and food while you're there? Solutions will be found to all these questions.

It will take time, however. Meanwhile, the private company SpaceX is talking about launching the first uncrewed rockets to Mars in 2022, with people to follow a little later. The flight system required, Starship, is admittedly still in development. Apart from that, SpaceX is known for timetables that can be, shall we say, ambitious. So, for the moment, we are reliant on robots to explore and work on the Moon or on Mars. This is not such a bad thing. The technical advancements made in recent years in projects of this kind flow back into industrial applications that benefit us all. In addition to that, there are now several countries and companies that are capable of sending robots into space. That makes things exciting, and promises many new discoveries. Robot missions are less expensive and safer than human space travel. They definitely engage our emotions, too. It's safe to say that there will be one or two tears of joy shed at maxon when the first Mars helicopter takes off in 2021. We certainly want to see people on Mars sometime, no doubt about it. Until then, however, we'll be passionately cheering on our robot heroes.

Illustration: sidop/iStock


## Contest

# How many maxon DC motors steer the first Mars helicopter?

**All participants with the correct answer will be entered into a draw to win one of five UE Wonderboom portable Bluetooth speakers. Good luck!**

E-mail your answer to:
**driven@maxongroup.com**

**The deadline for entries is January 31, 2021.**
Winners will be notified. maxon employees are not eligible to participate.
No correspondence will be entered into in regard to the contest. All decisions are final.

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www.drive.tech

# Why not take a look at our blog?

The maxon corporate blog **www.drive.tech** has many exciting reports, videos, and technical articles in which maxon experts share their knowledge. Get excited, learn new things, and discuss with our bloggers.

For example this article about how COVID-19 is changing the robot-human relationship.


# On hold

**The ExoMars rover Rosalind Franklin was scheduled to launch in 2020, but the European Space Agency (ESA) had to postpone the mission for two years. That means the roughly 50 drives from maxon also have to wait before they are used. These include the EC 40 brushless DC motor with GP 41 gearhead, which is engraved with the names of all the maxon team members who participated in the project.**