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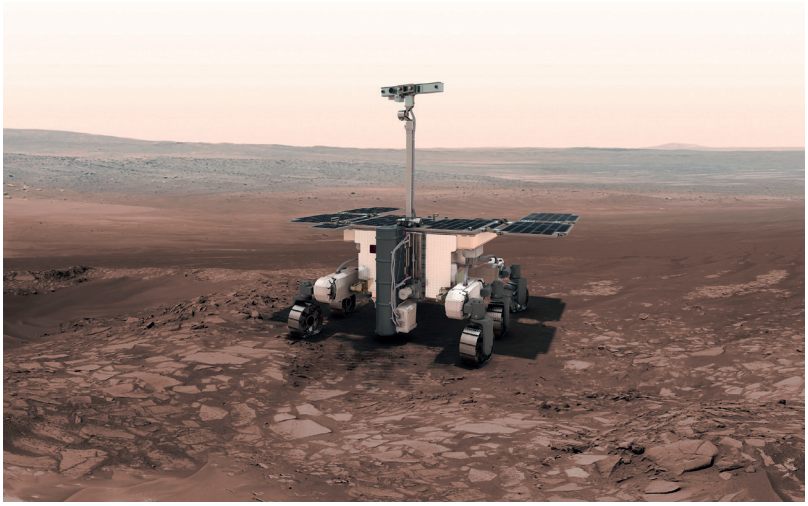
Physicists in Industry (4)

Motors, Mars and Mobility



Swiss Technology to drive the new ESA Mars mission 2020.
(Animation: ESA).

Physicists in Industry (4)

Motors, Mars and Mobility

Our interview partner is the physicist Dr. Ulrich Claessen, who is head of R&D at ***maxon motor ag*** in Sachseln, in the Swiss Canton of Obwalden. In the preface, he writes:

Machines and motion are fundamental elements of technology. For many years, electrical drive technology was found mainly in the fields of factory automation and railway vehicle traction. Over the past few decades, it has become commonplace in all areas of society. Today, the term small drives (drives with less than 1 kW power) stands for a global billion-dollar market.
The ongoing trend towards miniaturization has also changed electrical drive technology. New magnetic materials and high-quality mechanical designs have greatly improved the power density, efficiency and service life of small precision drives. For battery-operated devices, the high efficiency (80 - 90%) of small motors is a decisive advantage.

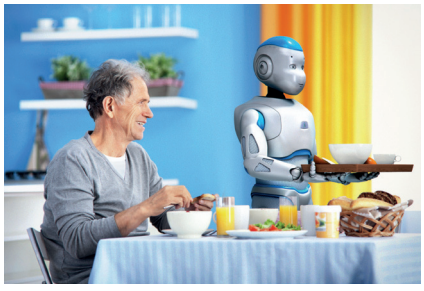
Q: Mobility is one of the main societal focal points in the coming years, not only in public transport and industrial sectors, but also in private life. This means that drive units of all types, sizes and power ratings are needed. How can and will *maxon motor* participate in this?

The core competence of *maxon motor* is the development of customer-specific drive solutions. Each drive problem first has to be thoroughly understood. Here it always helps to have a good comprehension of physics. The various components, i.e. motor, gearhead, feedback sensor and controller, have to be optimally configured to provide the needed motion (load chart, operating point, losses, ambient conditions).

Q: How will mobility develop in the coming decades?

Today four directions of impetus are responsible for the strong growth in the market for precision drive technology: Smart & connected machines, Medical devices and medical robotics, Electromobility and automotive, Industrial automation and Industry 4.0.

- **Smart & connected machines and robots**
  Humanoid robots require precision drives with very high power density and resilience if they are to match the abilities of the human body (upright gait, moving the arms and hands, grasping with fingers, moving the legs, etc.). Paired with sensors and artificial intelligence, robots will in future become workers and helpers in our day-to-day lives.



- **Medical devices and medical robotics**
  Controlled administration of medication (e.g. insulin) directly into the human body is a field of innovation in medical technology (drug pumps, patch pumps, needle-free injection, implantable pumps). Cardiac pumps support the activity of the heart in patients with an insufficiency, or replace the heart completely (artificial heart).
  A growing number of surgery robots are performing high-precision minimally invasive surgery under the watchful eyes of a surgeon. Another current topic is intelligent walking aids, such as motor-driven prostheses and exoskeletons.

- **Electromobility and automotive**
  In conventional vehicles with a combustion engine, the electric motors of today already control a range of convenience functions (seats, mirrors, lane departure warning) and auxiliary operations (pumps, injection procedures, etc.). With the rise of electromobility, electrical power traction has become a part of our vehicles. Another focus is battery technologies.

- **Industrial automation and Industry 4.0**
  Manufacturing processes are being networked with sensors, actuators and bus systems (Internet of Things and Industry 4.0). As a result, the demand for decentralized drive technology is increasing.

maxon motor is the worldwide leading provider of precision drives and systems, with manufacturing facilities in Switzerland, Germany, Hungary and South Korea. The company has 2400 employees and a turnover of 400 Million Swiss Francs (2015). At the headquarters in Sachseln, in the Swiss Canton of Obwalden, approx. 1200 employees develop and manufacture customized and high-quality drive solutions. The areas of application range from medical technology to industrial automation, from test and measurement technology to communication solutions and safety engineering, as well as applications for the automotive industry and the aerospace industry.

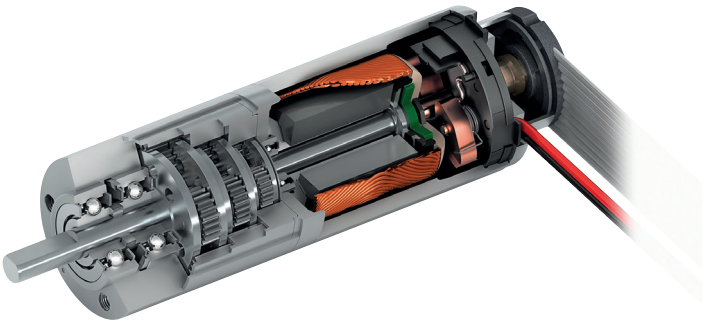
Even today, maxon makes half of its revenue from drives for medical technology. It is expected that the field of robot technology - an area that used to be the domain of university research - will show strong growth.

Q: Where are technical advances needed and how can Switzerland contribute?

Technological advances are constantly being achieved in the power density and in the precision of mechanical execution. Even in applications that use customary brush motors with graphite brushes as a conventional slide contact, not all phenomena are fully understood. However, today the focus is no longer on the individual components, but instead on the complete drive with integrated controller.

What is Switzerland's contribution?

“Switzerland is the Silicon Valley of robotics,” says ETH Professor Roland Siegwart. Switzerland is strong in the fields



of smart & connected machines, robotics and medical robotics, microrobotics, motion control, autonomous motion, drones and unmanned air vehicles.
The long tradition of the Swiss clock industry has also given Switzerland a head start in precision mechanical engineering and precision manufacturing methods.
In magnetic materials, progress currently tends to be continuous, but increased remanence is always an advantage, as this means the motor gets stronger (an adequately high coercive field strength is also important, to ensure that the motor is not demagnetized during operation). Today China dominates the development and production of rare earth magnets.
The development of sensors for rotor position detection is based on magnetic or optical principles. It is important to have sensors with robust mechanical and electrical designs that are not sensitive to interference and offer a good signal quality.
Today, Asia is the main location in the business for low-cost drive technology. The manufacturing costs in Switzerland are too high for this market segment. But if we succeed in lowering the direct costs of the drives, by means of new materials and new manufacturing methods, it will be an important step towards improving the competitiveness of Switzerland.

Q: With the motors for the Mars rover, *maxon motor* has drawn attention from all over the world. How important are such challenges that go to the limits of what is technically possible?

For more than 20 years, *maxon* has faced the challenges involved in producing drives for use in outer space. The drives are "off the shelf," but need to be reconfigured for the ambient conditions in space (low temperatures down to minus 120 °C, large temperature fluctuations, operation under vacuum conditions or CO_2 atmosphere, high stress caused by impact, vibration and acceleration). The joining methods (welding, adhesive bonding, soldering) have to be validated in test series. Each manufacturing step has to be controlled and verified. Future Mars missions by ESA (Exo Mars) and the Jet Propulsion Lab (Mars 2020) are already in planning, and once again *maxon motor* will be on board.

Q: Our readers are physicists. What recommendations do you have for physics graduates?

In the field of drive technology, physicists compete with ETH engineers and graduates of universities of applied sciences, who have more practical experience in a company, and usually more experience in mechanical engineering and manufacturing methods. The recurring topic is costs and how to reduce them.
For physicists who plan a career in the industry, I recommend starting with internships in the industry as early as possible and developing an interest in applied research. The reknown physicist Rudolf Peierls once said: "If you want to work in a technical field, you really have to be interested in it."
For physicists, I see advantages in their fundamental comprehension of electrical and mechanical phenomena. Heinz Maier-Leibnitz, famed university professor of the Technical University Munich, always emphasized: "Once you understand something well, it can become the starting point for something new."
A challenging topic, even for physicists, is the configuration and simulation of motors and magnet circuits. Finite element analysis for simulation of the electromagnetic and mechanical forces that take effect has become very important. Prediction of vibration characteristics and noise generation is an important topic.
Today, physics graduates have the option of working in a start-up company first. Here they can gain valuable experience at a young age, without being ground by the mills of the larger companies' personnel recruitment processes.

Q: What are the limits of mobility? Last year's Nobel Prize in chemistry was awarded for nano-mobility. In fact, EMPA (Swiss Federal Laboratories for Materials Science and Technology) was involved in this (see *SPG Mitteilungen* Nr. 51, page 18). Will there be a molecular motor by *maxon motor* one day?

Molecular machines that work in cells and organisms as nature's robots are a fascinating field of study.
Today, the smallest motor by *maxon* still has a diameter of 4 mm. For smaller dimensions, there are other actuator principles (MEMS, piezo) that have advantages for micromotion. *maxon motor* is mainly active where a market is forming. Completely new technologies that are still in the basic research stage are best developed to a first level of maturity in a start-up. If this development is successful, these companies then become candidates for a takeover, if the company owners want this.

Ulrich Claessen (born 1956 in Bremerhaven/Germany) studied Physics in Tübingen and Munich. In Munich he worked with Frederick Koch (Semiconductor Subband Physics) and Hans Jörg Mang (Nuclear Models). PhD Thesis in 1986 from Munich Technical University. Executive MBA from St. Gallen University in 1998.
From 1987 to 1990 he worked at Siemens Research Labs Munich on transistor modelling for CMOS Analogue Integrated Circuits.
In 1991 Ulrich Claessen went to Switzerland to work for ABB Transportation Systems. At ABB he was responsible for Vehicle Control Engineering.
In 2000 he started to work for CSEM (Centre Suisse d'Electronique et de Microtechnique) und built up a Research Center for Microrobotics in Alpnach/Obwalden. The center won the 2007 Swiss Innovation Award for developing a Microfactory. In 2007 Ulrich Claessen was employed by *maxon motor ag* in Sachseln/Obwalden and became Research & Development Director.