FAULHABER

motion

02.2022

THE MAGAZINE WITH DRIVE

Colorful and precise

AMAZING
color variety

Dear readers,

75 years of FAULHABER – On September 9, we celebrated this milestone in our company history with a festive party, which all of us are sure to remember for a long time. The first article will be a revue of the event, and we will reveal why the party started on Daimlerstraße and ended on Faulhaberstraße.

In an interview, Hubert Renner will give us a personal review of challenging times in the past and his views on the future of FAULHABER. This interview marks the beginning of a series in which all managing directors will be portrayed one after the other.

In this issue of motion, you will also learn how the student research group led by Aqeel Shamsul, with the help of FAULHABER, managed to develop an automated miniature laboratory that can efficiently and cost-effectively carry out a variety of experiments on microbial cultures and simple higher organisms in space on board a so-called "CubeSat."

From the depths of space we venture on to the depths of the subsoil together with "Pipetronics" and learn everything about the tasks as well as the development and production of modern sewer renovation robots.

The innovative dosing system colorDoS from HNP Mikrosysteme illustrates how color can be introduced at the last moment in injection molding, shortly before the component is produced, and how switching colors is possible in record time. The FAULHABER drive plays a key role in microliter-precise feeding of the liquid colorant.

And last but not least I would like to bring your attention to two important pieces of news. Developers should definitely take a look at the FAULHABER Drive Calculator. This new web tool will revolutionize the way suitable drive systems for applications are selected. Speaking of drive systems – with the new FAULHABER L series we are presenting a complete solution for the field of linear drive systems for the first time.

Enjoy reading.

Sincerely

Karl Faulhaber
Geschäftsführer

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– 01|75 –

FAULHABER celebrates **75th anniversary** in Schönaich

The success story of FAULHABER starts at the end of the 1940s when a young engineer by the name of Dr. Fritz Faulhaber founds "Feinmechanischen Werkstätten" in Schönaich, Germany. During his previous development work on the revolutionary camera model "Vitessa" for the renowned company Voigtländer, he already had the idea of using an electric motor to transport film. As he couldn't find a motor small enough and with the necessary efficiency and performance when battery-operated, Dr. Fritz Faulhaber worked on his own solution in the mid-1950s and, with the ironless, self-supporting, skew-wound design, invented an innovative drive technology that would solve not only his camera problem, but also lay the foundation for the future of miniaturization in many application areas worldwide and form the basis for the success of the company in the next 75 years.

What FAULHABER has learned from these exciting past 75 years is how important corporate courage and foresight were and are – not only for FAULHABER, but also for the many customers whose applications would not have been possible without this forward-thinking. What made this success possible are the people who work at FAULHABER around the world. For everyone who works at the Schönaich site, the anniversary was a long-awaited and well-deserved opportunity to celebrate this achievement together.

On Friday, September 9, 2022, the festival area opposite the company headquarters was ready to welcome the guests. At the entrance, they were surprised with a gift bag that not only had the motto "75 Years of Motion" imprinted, but which also invited the guests to put words into action with a jumping rope and a yo-yo. The bag also contained the hot-off-the-press anniversary brochure for those who preferred reading over moving.

"75 Years of Motion" was also the motto of the numerous attractions on the fairground. On bouncy castles, crate climbing, and many other stations, the young and old visitors could put their talent for motion to the test. To supply the energy needed, there were various options to get hydrated or get a bite to eat with a wide range of culinary options available.

The visitors also had the opportunity to watch various artists carry out a bubble performance or perform magic tricks, as well as listening to the band play in the marquee. Many also took the opportunity to get a tour of the premises. Here the employees could

proudly present their workplace to their families The visitors could either walk around on their own or get a guided tour.

Also among the many well-wishers was Ms. Anna Walther, mayor of the municipality of Schönaich. She emphasized the importance of the company for the municipality and the business location of Schönaich, praised FAULHABER for the company's commitment to the location at its roots and, by stating that FAULHABER is one of the first German companies to produce climate-neutrally at the Schönaich location, highlighted the commitment of the company in terms of sustainability.
As a special thank you, together with Managing Director Lutz Braun, she unveiled a street sign with the new name of the street that will lead to the Schönaich site in the future: Faulhaberstraße – a road to the future – because that is what FAULHABER has stood for over 75 years.

https://75.faulhaber.com/en/

– 75 | 75 –

INTERVIEW SERIES

Passion in motion – What drives us

#01

Hubert Renner
MANAGING DIRECTOR

Embracing change as an opportunity. This has been the credo of Hubert Renner from the first day when he started his journey at FAULHABER as a toolmaker in 1983. His talent for analytical thinking and his hands-on approach were evident from the start. As a result, he was put into positions of responsibility early on and was promoted to more and more demanding positions over time. In his positions as assistant assembly manager, production manager and authorized signatory as well as CEO for four production sites, Mr. Renner has played a crucial role in shaping the company over many years. He has been a member of the FAULHABER management team as Managing Director since 2022.

Passion for change

Mr. Renner, do you remember the production conditions at FAULHABER back in 1983 when you started working for the company?

Back then, production at the Mozartstraße site was characterized by manual workstations. In Schönaich, only brushed motors were produced, the production of which was divided into three divisions (winding, assembly production, and final assembly) based upon the production process. Most of the time, the inquiries and orders exceeded our delivery capacity. For example, when a customer ordered 100 motors (which was a large order back then!), often we could only "allocate" 50 units. There were no computers in the entire company in those days. All the planning of the individual parts and assemblies took place by means of index cards. We had an index box each in purchasing, the warehouse, and production planning. All entries on the index cards were made by hand. So in a worst case scenario, we had four different stock levels for the same part: one in purchasing, one in the warehouse, one in production planning, as well as the actual stock, which was often determined by the production planner on site before confirming the order.

So the demand was greater than the supply?

The demand for FAULHABER motors continued to go up in those days. A milestone was achieved when we received an order for over 700,000 motors that had to be delivered within a year. This was twice our regular production volume. The strong growth and the resulting positive business development enabled us to subsequently construct the new building on Daimlerstraße, where we moved in 1990.

What steps did production take to keep up with the increasing demand?

With more womanpower and manpower. The introduction of a so-called "housewives shift" was part of the solution. While we only worked in single shifts before, this step gave us an additional four hours a day of production capacity. In essence, this was how our double shift operation got underway. The workstations were arranged one after the other. Some of the assembly workers were sitting shoulder to shoulder. The Managing Director at the time, Mrs. Klingberg, had to be gently convinced that her Mercedes needed to be removed from the garage in order to immediately set up two Arburg injection molding machines.

Was there already competition back then?

Not so much in the beginning, but, among other things, the quickly expanding market soon brought with it a few high-growth competitors. Orders were no longer allocated, but had to be tendered for. In order to enable a cost structure that allowed us to remain competitive in terms of pricing, the production was systematically and consistently automated. Almost all assemblies and large parts of the final assembly were partially or fully automated within 10 years. The number of variants continued to go up. Customer-specific drive solutions have been and still are at the core of FAULHABER's success. The enormous number of parts and ID numbers at all levels of the parts list could no longer be organized with index cards – at the end there were 2–3 index boxes next to each other! The solution was a PPS system, which we introduced in 1991. From that day forward computers were a must.

How have the market requirements influenced the development of new drive technologies?

The growing significance of electronics also in drive technology and the falling prices of electronic components with increasing volume created new uses for small motors. FAULHABER massively increased its product development capacities and introduced a number of new motor lines. Various brushless drives, flat rotor motors, stepper motors, integrated encoders, and the necessary motion controllers and speed controllers have become core components of our product portfolio. For production, this naturally led to an increasing number of assembly lines.

How did FAULHABER manage to economically organize such a wide ranging production portfolio?

The extreme number of variants could no longer be economically organized by maintaining stocks of salable products. The solution was production-on-demand. This entailed significantly smaller batch sizes, which could not be economically automated across all levels of the parts lists. In order to achieve an economical cost structure, we laun-

ched the production sites in Hungary and Romania, which we have expanded consistently. Our business had evolved from a motor supplier to an order- and customer-specific drive system supplier.

Didn't producing at multiple locations also have its share of problems?

For production organization, on-demand production across multiple locations has been and remains to be very challenging. Our answer to this issue is "SITE-SYNCHRONIZED PRODUCTION." We used radar charts to evaluate and consistently improve the performance of all sites in the production network. CIP programs, shop floor management, kanban structures, reduction of throughput times, flexible capacities, U-lines are just a few features. I am particularly pleased that our successful implementation of site-synchronized production was recognized in 2018 by winning first place in the "Factory of the Year" competition in the category "Outstanding small-batch production."

How important is it to FAULHABER that all employees are qualified across all sites?

For us, every employee is an important investment. Every employee who has trained at FAULHABER for 3–4 years is subsequently qualified for more than 100 jobs. This is implemented consistently at every location. Every production facility at every location has been uniformly equipped and organized. This is an important prerequisite for synchronized production across locations. Whether in Hungary, Romania, Switzerland, or Germany – the distinctive FAULHABER production environment is obvious right away. This also includes systematic training. When you have trained someone for 3 years, then that is an absolute investment, because it takes an incredibly long time until the specific know-how with the great variety and the many different product lines has been internalized to the extent that it can be used productively.

Let's talk about the current global situation – how crisis-proof is FAULHABER?

Darwin was convinced that it's not the strongest species that's ultimately successful, but the most adaptable one. This realization from the theory of evolution is also a good guideline for companies. It's no different for us at FAULHABER: in the past, we frequently had to adapt to new framework conditions.

The COVID-19 pandemic and its consequences have caused and continue to cause an unprecedented disruption to the global supply chain; and I'm not just talking about toilet paper (laughs). Suddenly, materials weren't and aren't available anymore. Delivery times, e.g., for electronic components have increased from what used to be 16 weeks to 52–104 weeks – how can we possibly know which parts and how many we need in 1–2 years?

The invasion of Ukraine by Russia creates new uncertainties, especially in terms of raw materials and in the energy sector. New challenges arise for production and production planning, the management of capacities, materials, and for the entire organization. Flexibility, which FAULHABER had to have many times before, is once again called upon and is the most promising solution. This will require various paradigm shifts. While the industry maxim was "just in time" in the past, we now need new and updated methods in order to maintain deliverability.

You mention a paradigm shift – what exactly do you mean by that?

Let's talk about vertical integration, for example: when parts and products cannot be procured externally with any measure of certainty, we need to think hard about whether we can produce them in-house. Geared parts, internally geared gear housings, or turned parts are examples

which we have already successfully integrated. Other parts are currently under consideration. Parts and components that are not feasible for in-house production must be kept in stock. A good example is semiconductors and ball bearings. Forecasting is the definition of the type and volume of stockpiling. Flexible capacities throughout the process chain are necessary in order to be able to process interrupted deliveries in a timely manner.

In times of uncertain material supply, the ability to deliver comes before cost minimization. Establishing and strengthening regional suppliers, reducing our dependency on individual supplier countries or companies, and entering purchasing associations are other possible solutions.

We try to understand the changing needs of the markets in all sales regions at an early stage and incorporate our findings into our forecasting, our investments, and projects.

This is how we ensure the best possible decisions on material procurement, capacity management, and production line upscaling.

How do you decide which areas to invest in?

We have successfully established working communication between all sales managers and regions – from field sales managers to top management, everyone involved contributes important information that helps us to make the right decisions. This is the basis upon which we plan our investments. Never before have we invested the way we have this year, and we will continue on this trajectory in the years to come.

The homogeneous, family-oriented shareholder structure helps us here – FAULHABER has always been ready to invest the necessary capital into good ideas. The trust put into the company by the shareholders is reciprocated by the trust of the employees into the shareholders and company. This was and still is an extremely important success factor.

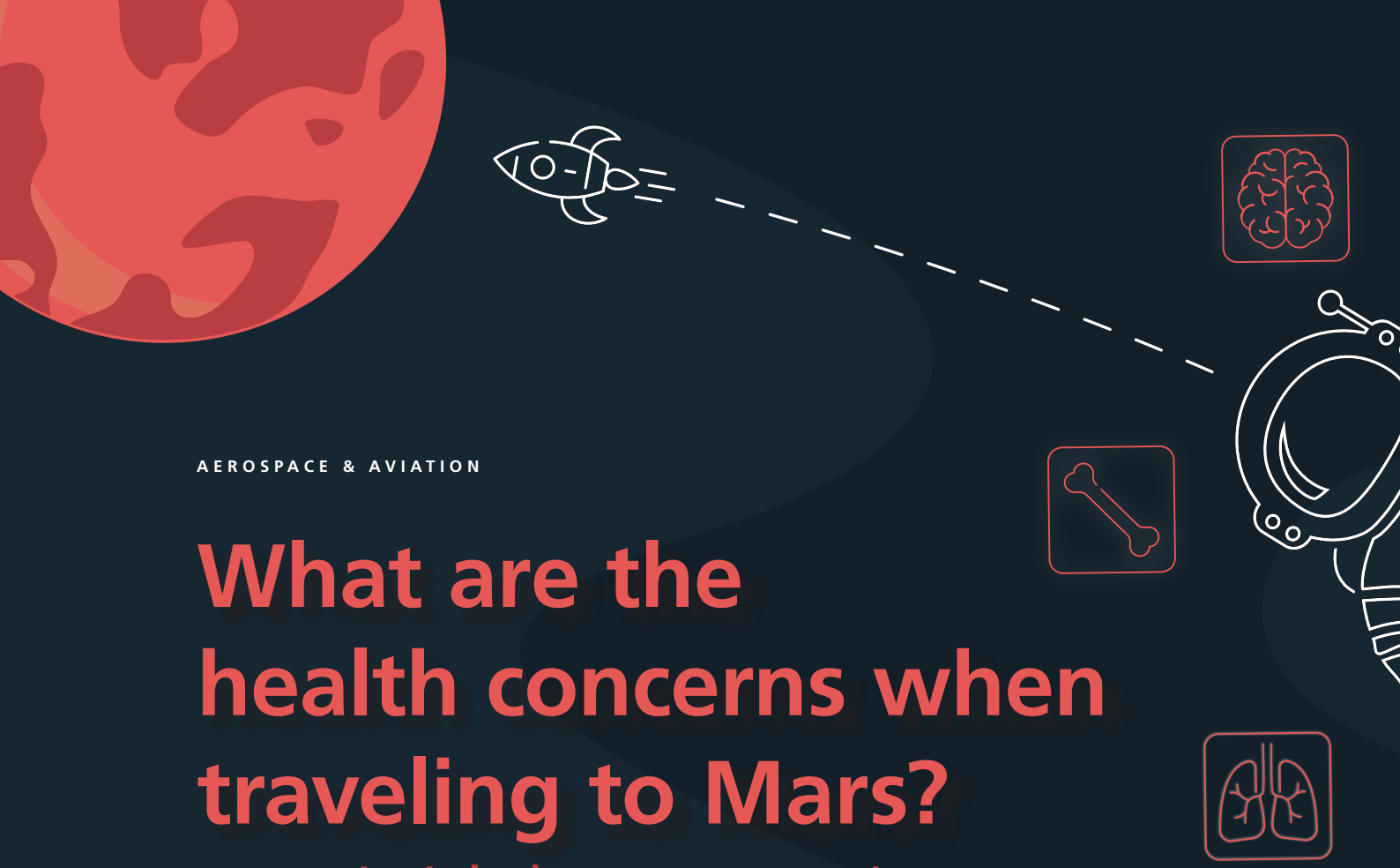
Let's look at clean room production, for example, which we have just started in Germany. There we produce the first medical products that are implanted in the body and products for the automation of semiconductor production – they have to be super precise and clinically clean. If these projects develop well, in 3–4 years we might have 50, 60, 70 jobs in cleanroom production in Schönaich.

Where do you think FAULHABER will be headed in the future?

In my view, we have to see the current challenges as opportunities. Our target market strategy helps us to analyze the most important future growth markets.

The future lies in robotics and industrial automation, for example. No matter where we turn today, be it logistics, the agricultural industry, or medical and laboratory technology, robotics is a huge market and all robots need motors and they need motors with low power consumption because mobile robots usually don't want to drag a cable behind them, but would like to work flexibly and freely in the room, which means they need a battery. If there is a battery inside, power consumption is critical. When power consumption is critical, then we and our FAULHABER technology are the frontrunners.
These are success factors for the markets of the future – we are FAULHABER!

www.faulhaber.com/en/motion/

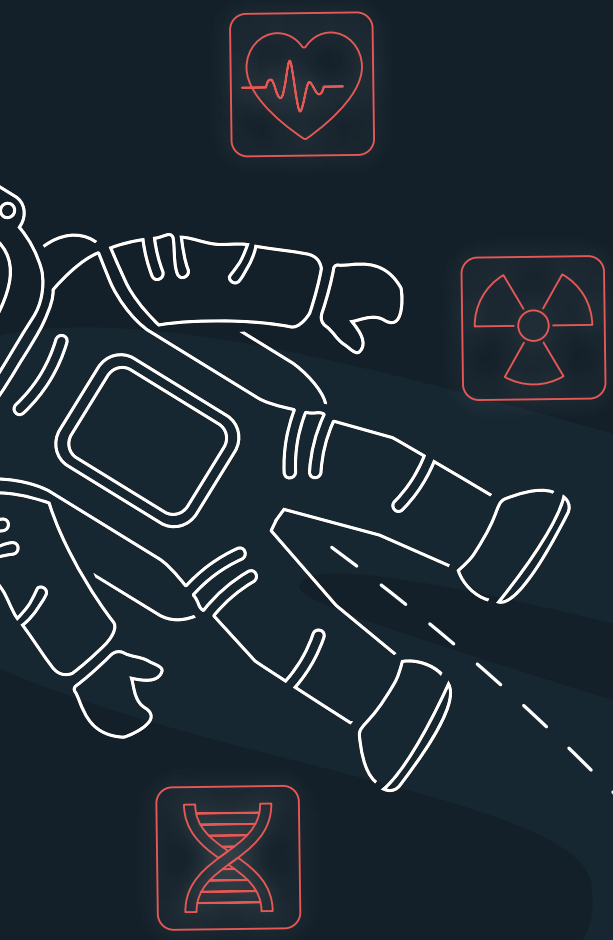


AEROSPACE & AVIATION

What are the health concerns when traveling to Mars?

A mini laboratory in a mini satellite is looking for answers

Space is a hostile environment. This – in addition to the vast distances – makes manned space travel pretty difficult. Central problems include weightlessness and exposure to cosmic radiation. Anyone planning long-duration journeys through the universe needs to be aware of and fully understand the effect that these problems have on biological processes. Space exploration with human subjects is, however, very expensive and extremely complex. The British BAMMsat project has therefore developed a minilab that is transported into space with a minisatellite in order to conduct scientific studies there with the minimal resources available. A motor from FAULHABER is on board.

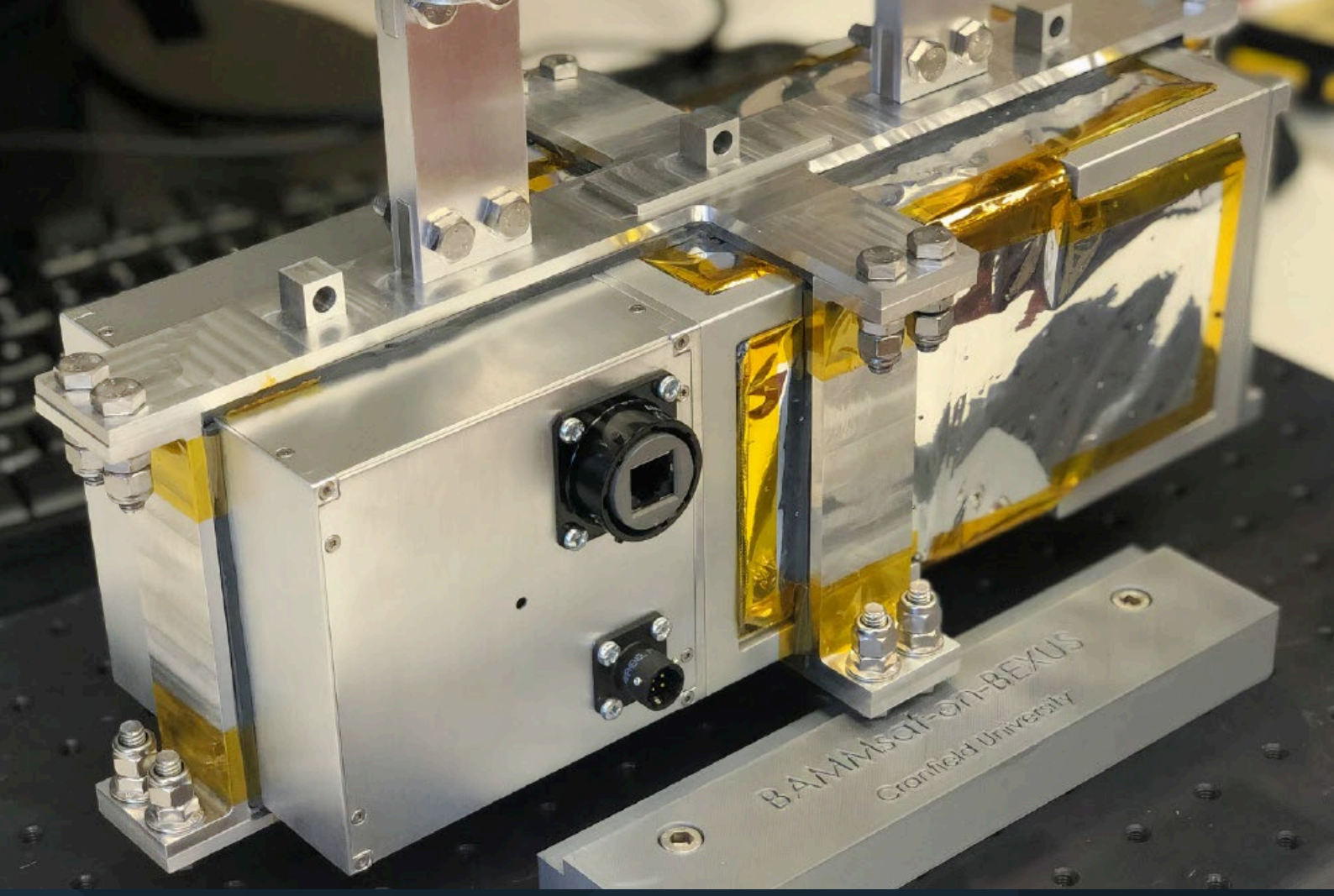


The moon, which is soon to be revisited by several space-faring nations, is a mere stone's throw away. Even with the technology of the 1960s and 1970s, the journey to the earth's satellite took just three days. However, the next major destination for manned space flight is Mars. A spacecraft needs nine months to reach our neighboring planet – the roundtrip would therefore take one and a half years. During this time, the crew would be exposed to zero gravity and the high levels of radiation encountered in space. What effect such long-term conditions have is nowhere near fully researched.

"The impact of zero gravity and exposure to cosmic radiation can only be partially investigated here on earth," says Aqeel Shamsul who supervises the BAMMsat project at the Cranfield University, England. "Experiments in space pose particular challenges and require rather expensive rocket transport, including astronaut time and logistics. This in turn restricts the possibilities for research on biological systems under space conditions."

CubeSats – The low-cost aerospace segment

A number of years ago, a student working group headed by Aqeel Shamsul set itself the goal of finding a practical and low-cost solution to this dilemma. The idea was to develop an automated miniature laboratory that can autonomously conduct a variety of experiments on microbial cultures and simple higher organisms. The dimensions were predefined: The test setup had to fit inside a "3U CubeSat".



BAMMsat System

CubeSats – or cuboid satellites – have been used since 2004. They are standardized cuboid modules for small-scale satellites with a low launch weight and correspondingly low launch costs. They heralded the beginning of a kind of low-cost aerospace segment. The smallest CubeSat has the designation 1U (one unit). It measures around 11×10×10 centimeters and weighs a maximum of 1.33 kilograms. A 3U CubeSat measures 34×10×10 centimeters and weights four kilos. Several CubeSats, also satellites of different sizes, can be launched together on a rocket and the transport costs shared.

A nematode as test pilot

The minilab of the BAMMsat team fits inside a 3U casing, which is roughly the same size as a shoe box for a pair of flat ballet pumps. The experiments are conducted on specimens of Caenorhabditis elegans. This is a nematode which measures just one millimeter in length and normally lives in soil in temperate climatic zones. 83 percent of its genes are comparable with human genes, which is why it is frequently used on earth for studies in areas such as gerontology, muscle physiology and radiobiology. In space, the cells of C. elegans react to zero gravity and exposure to radiation in a similar way to human cells.

A key element of the miniature space laboratory is a round disk with several chambers in which the biological specimens are kept. The chambers have inlet and outlet openings through which minute quantities of fluid can be fed in or withdrawn. This allows the nematodes to be supplied with food and their excretions to be removed. Furthermore, various pharmaceutical substances are also fed in to study their effect under space conditions.

By rotating the disk, the chambers can be moved in front of a microscope lens. A spectrometer can determine biochemical properties of the material inside the chamber, such as the proportion of proteins. In this way, it is possible to perform many different experiments in the same system – a novelty for such instruments. Instead of nematodes, the chambers could also contain microbial cultures, for example. The data from the experiments is collected by the on-board computer and sent to earth.

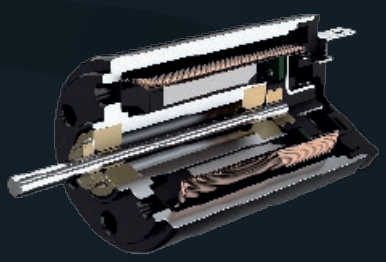
Torque for the rotating disk

"One of the most important aspects of this projects was to keep weight to a minimum," explains Aqeel Shamsul. "This allowed us to fit the module inside the 3U CubeSat and ensure the project's economical feasibility. A key element here was the drive for the specimen disk. It not only has to be extremely small and light, but also has to deliver a high torque and operate extremely precisely during the entire mission time of several months to one year."

The BAMMsat team had originally planned to use a stepper motor for this task. Experts of the British FAULHABER subsidiary EMS brought a different solution into play: The brushed DC-motor of the SR series with a diameter of 22 millimeters proved ideal for the special requirements of the application. An encoder of type IEH3-4096 provides the basis for the finely tuned control; a planetary gearhead type 20/1R maximizes the torque. This ensures that the specimen chambers always move to the desired position and that the experiments can be conducted as planned.

The minilab passed its baptism of fire in the fall of last year. On October 21 in northern Sweden, a balloon carried it into the stratosphere. It stayed there for five hours during which time all on-board systems successfully passed testing conducted under conditions similar to those encountered in space. Then, braked by a parachute, the CubeSat module landed undamaged in Finland. The first launch by rocket is planned for 2024; the BAMMsat team intends to produce further modules and thereby make low-cost bioresearch in space practicable. "I believe with our technology we can make a significant contribution to the further development of manned space flight," says Aqeel Shamsul. "That aside, our minilab opens up completely new and above all financeable possibilities for conducting extensive series of biochemistry experiments under space conditions."

BAMMsat
The BAMMsat team is made up of students from Cranfield University and the University of Exeter in England. They work jointly with the German Aerospace Center (DLR), the Swedish National Space Agency (SNSA) and the European Space Agency (ESA).



FAULHABER 2232 ... SR
DC-MICROMOTORS

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Colorful and precise

AMAZING color variety

Plastic has many advantages. One of them is that it can be imbued with any color. Whether pale eggshell, noble royal blue or gaudy orange – there is no limit to the colorful diversity of plastic parts. The coloring process can even take place "at the very last moment", just before injection molding of the actual part. With the dosing system colorDoS from HNP Mikrosysteme, it is also possible to switch between colors in record time. The FAULHABER drive plays a key role in microliter-precise feeding of the liquid colorant.

How many injection-molded plastic parts have I seen or physically handled today? Anyone who in the evening has asked themselves this question and tried to count the exact number of parts will end up going to bed very late. Plastic can be found everywhere in our world, and injection molding is the universal, cost-effective production method used to form it into almost any shape: The raw material, plastic granulate, is heated until it is flowable and is then injected into a mold. Remove any burrs and sprues – done.

Even if we decide not to count the exact number of plastic parts and just consider what has caught our eye, the range of colors we have seen during the day is sure to be enormous; the world of plastic is as colorful as the world of flowers and butterflies.

There are various ways of imbuing the neutral raw material with this optical diversity. If parts of identical color are produced in large quantities, it is often preferrable to leave coloring of the raw material to the plastic suppliers from the chemical industry. The granulate then already has the color of the final product. In many sectors and product areas, quantity is less important than the flexible and fast response to customer wishes, also with regard to coloring.

Dosing is key

In this case, the method of choice is to add the liquid colorant to the flow of granulate directly at the feed into the screw conveyor – so-called dosing of the injection-molding machine. In the cylinder, the granulate is simultaneously heated, thoroughly mixed and transported to the mold via the rotating screw. A dosing system is responsible for ensuring that the colorant is uniformly distributed in the granulate. The screw of the injection-molding machine in conjunction with the ram pressure then ensures that the colorant is mixed in thoroughly. Precise dosing is crucial for color quality. Here, the dosed quantities can be extremely small.

"We developed our compact dosing system colorDoS especially for processes where color needs to be changed quickly," explains Olaf Lang from Technical Sales at HNP Mikrosysteme in Schwerin (Germany). "Between 0.02 and 100 grams of colorant can be dosed per shot."

The sophisticated technology of HNPM ensures not only highly precise dosing of the individual colors, but also prevents so-called color carryover. Thanks to the special design of the dosing nozzle and hose couplings, it is possible to switch between different colors quickly, smoothly and without cleaning time. A micro annular gear pump is responsible for the fine

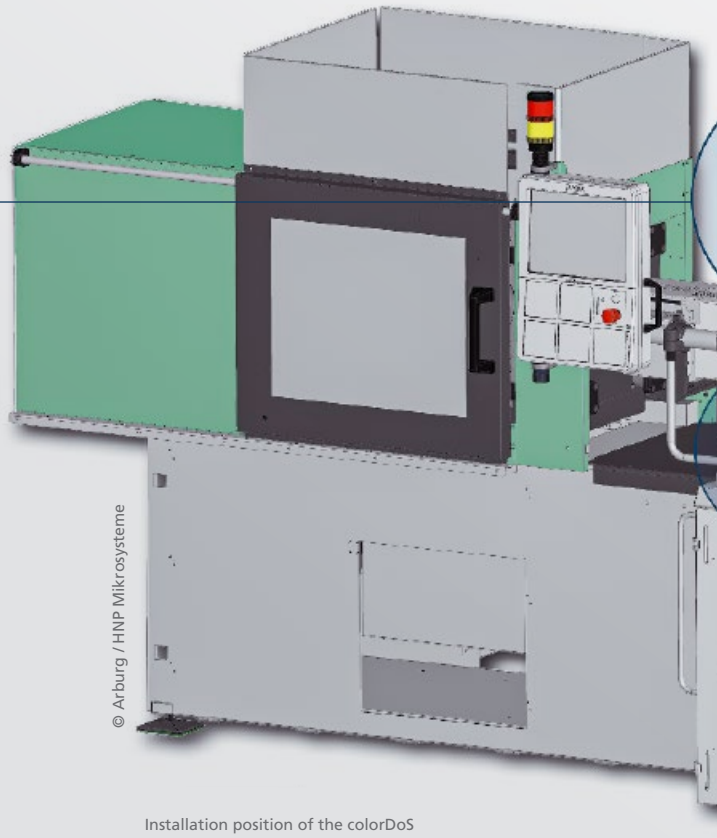
dosing. This is a miniaturized gerotor pump with an external and an internal rotor. The internal rotor has one tooth less than the external annular gear. The chambers created by this setup have a fixed displacement volume. The media are dosed volumetrically. The colorant quantity can be adjusted by changing the speed while maintaining the same dosing time.

Repeatability is an extremely important factor. To ensure that the products always have the same color, the quantity of colorant per shot must always be the same.

A mzr-7245 modular pump is used in the colorDoS. The smallest dosing quantity is 20 microliters per shot. This is less than one drop, but the special geometry of the dosing nozzle ensures that this tiny quantity is delivered with high precision and repeatability. "This is where the quality of the pump drive plays a crucial role. Apart from the motor, the analog Hall sensors too are of particular importance," emphasizes Lutz Nowotka, drive specialist at HNPM. "We have been using micromotors from Schönaich for many years. For colorDoS, we opted for a BX4 series brushless DC-servomotor from FAULHABER."

Compact dosing system for liquid paint

© HNP Mikrosysteme



© Arburg / HNP Mikrosysteme

Installation position of the colorDoS dosing system using the example of the Allrounder 320 from Arburg

Speed determines the color

"The quantity of colorant depends on speed and dosing time," explains Olaf Lang. "The faster the rotors rotate, the more colorant is fed in during the same period time, whereby the speed of the pump is adapted to the dosing time of the injection-molding machine. The cycle time also includes cooling and ejection of the workpiece. Then the pump stops briefly. Colorant dosing is therefore an extremely dynamic process."

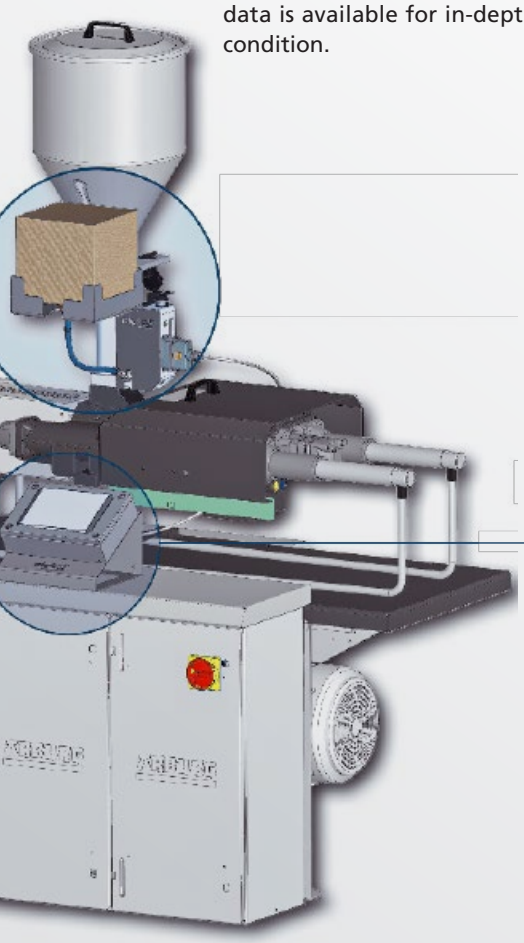
Precise positioning through Hall sensors

In addition to the high torque of 96 mNm, the strengths of the motor with the designation 3268… BX4 CS also include the small installation space, an extremely long service life and the integrated, high-precision motion control. "The analog Hall sensors enable precise positioning of the drive and therefore also of the rotors at 3000 positions per revolution. As a result, our pump doses with high precision even in the microliter range," explains Nowotka. "Here, good speed control and high torque even at extremely low speeds play a key role. The smallest of motion impulses must be implemented without jolts and jerks."

Via the serial interface, the controller receives detailed information about operation of the drive. Standby current, speed, position, deviation and temperature are captured with the utmost precision; the data is available for in-depth analysis of the device condition.

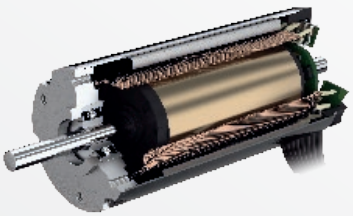
Maintenance requirements can be detected early on when they first appear on the horizon, well before a failure becomes imminent. This ensures consistent dosing of the colorant for each shot as well as reliable operation.

The user also benefits from other advantages of the colorDoS system. Its display control communicates directly with the injection-molding machine and indicates e.g. the time remaining until the next container change. The color code management system can be used to store recurring colorant recipes. An alarm manager warns of a low colorant level and stops the injection-molding process in the event of a fault. According to HNPM, however, the core component of colorDoS – and other dosing systems – is the in-house designed micro annular gear pump that is driven by a FAULHABER motor.



Display control for the dosing system colorDoS

© HNP Mikrosysteme



FAULHABER BX4 CS
BRUSHLESS DC-SERVOMOTORS

www.faulhaber.com/en/motion/
www.hnp-mikrosysteme.de

Trenchless renovation

As is the case with any type of infrastructure, sewers require regular maintenance. But the often narrow pipes below the ground are difficult to access. Instead of unearthing them at great expense, users of trenchless renovation procedures use specialized robots that carry out the work in the interior of the pipelines. Pipetronics is a market and technology leader when it comes to the development and manufacture of sewer robotics. Markus Lämmerhirt, a member of the management board, talks about the highly specialized industry.

How did your work in underground sewers start?

I had studied precision engineering – called mechatronics today – and in 1990 I interned for a semester at D.T.I., an engineering office for special machinery construction. At the time, the company was developing a machine that was capable of milling off projecting parts of residential connection lines in pipes with a diameter of 150–300 mm. This cleared the path for an inspection camera. I was tasked with testing and improving the prototype.

From left to right: SR 300 spatula robot, eCutter EF 250 electric milling robot, SR 300 pressing system

How did your first own idea come about?

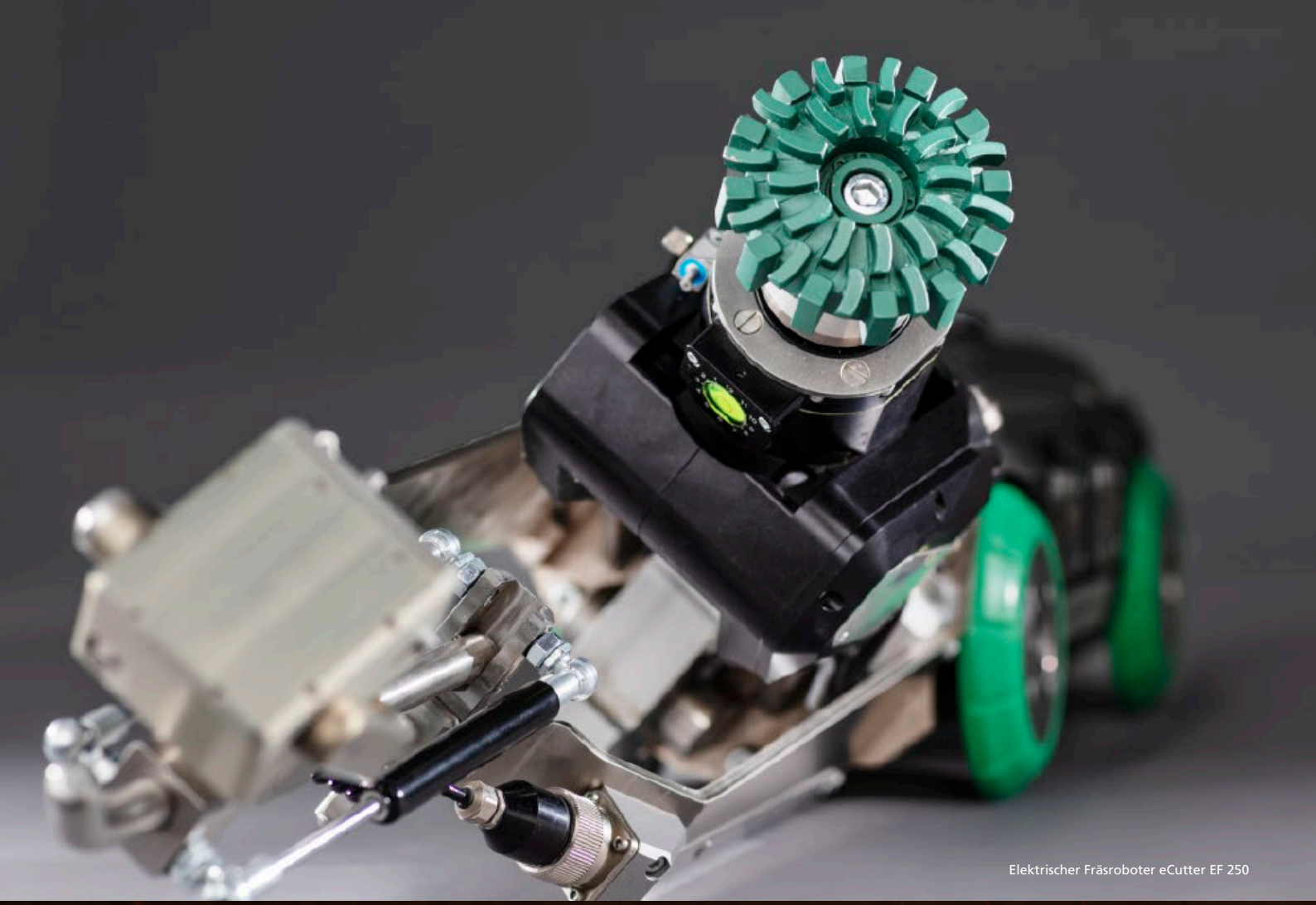
While the customer approved the aforementioned prototype, the device was difficult to work with. As part of my degree thesis, I had the idea for a milling robot. This product was further developed at D.T.I and the first robots for sewer repairs were born. In 2000, I and the sales manager acquired the sewer robotics division from D.T.I. for the company we owned back then.

Where were your initial customers from?

Mainly Germany, France, and Switzerland. Trenchless sewer renovation was already popular in these countries early on. At the time, we only had one competitor from Switzerland. As the industry was relatively small, we quickly made a name for ourselves worldwide and soon began exporting to Asia and the USA. The notion of working in the sewer without having to dig up the road is an irrefusable sales pitch. It saves time and money and traffic is not interrupted.

What is your assessment of the condition of the sewage networks in Germany and the world?

The length of the German sewage network is about 600,000 kilometers. According to our estimates, about 18 percent of this requires short-term renovation or replacement. I assume that it is about the same or worse in other countries.



Elektrischer Fräsroboter eCutter EF 250

What are the challenges and trends in sewer robotics?

The machines and devices that work in the sewer require sturdy and durable technology on the smallest possible footprint. Standard solutions are rarely feasible, which is why we develop most of the components ourselves. In terms of operation, we are expecting an increasing shortage of expert personnel. So the idea is to replace humans with intelligent technology that can be operated without specialized training. The trend leans towards automatic traveling to the damaged location and automatic repair.

How did you decide on FAULHABER?

If you need a lot of power in a small package, you need corresponding motors. FAULHABER'S product range includes motors that meet all of our requirements, such as for the robot's drive, which has to pull a very heavy cable, or for the miniature wiper of a small camera.

How do you decide between hydraulic and electric drives?

Hydraulic drives are very solid, but their efficiency is limited for our scope of applications. Add to that the noise pollution and exhaust from the generator and the hydraulic unit. This should be avoided particularly when working in inner cities and residential areas. Electric drives and batteries allow us to operate the robot systems emission-free and almost noiseless.

Which drive technologies will be relevant in the future?

Thus far, we have predominantly used brushed drives because suitable control options for brushless drives in our machines were not available in the past. The controller must be right on the motor, because it cannot be controlled over a 150-m long supply line. Our newest technology works with CAN-Bus, which also enables the controlling of brushless motors. The trend is moving towards bus technology and brushless drives. Brushless motors are subject to less wear, and they can be controlled and programmed.

What would be your wish in terms of drive technology?

Our top priorities are a small installation space and high power density both for the motor and the electronics. And of course combined with robustness and durability.

What are the unique strengths of Pipetronics?

Our core expertise lies in the development and manufacture of robotic systems. Our know-how is based upon decades of experience. That also extends to the vehicle equipment and generator design. We are also offering other innovative products on the market and to the users, such as pinpoint repairs with synthetic resin, for example. And we are continuously investing large amounts into further developments.

What sets you apart from your competitors?

Our technology gives us a lot of flexibility, which enables us to easily integrate special designs into standard products on request.

can conceivably be used in other pipeline systems, such as in the chemical industry, to inspect gas lines, tank systems, or pressure tanks.

Do you think it's possible for humanoid robots to one day open manhole covers and descend down into the sewer?

Anything is possible in principle. But such a technology would be highly complex and expensive. There are simpler solutions that are more expedient in every which way.

Do you think "flying robots" or drones for channels are conceivable?

These types of machines have already been successfully tested for inspection works. But I don't think it makes sense for repairs.

Interview with Markus Lämmerhirt

eCutter EF 250 on eMulti-robot system

Are you looking beyond sewers?

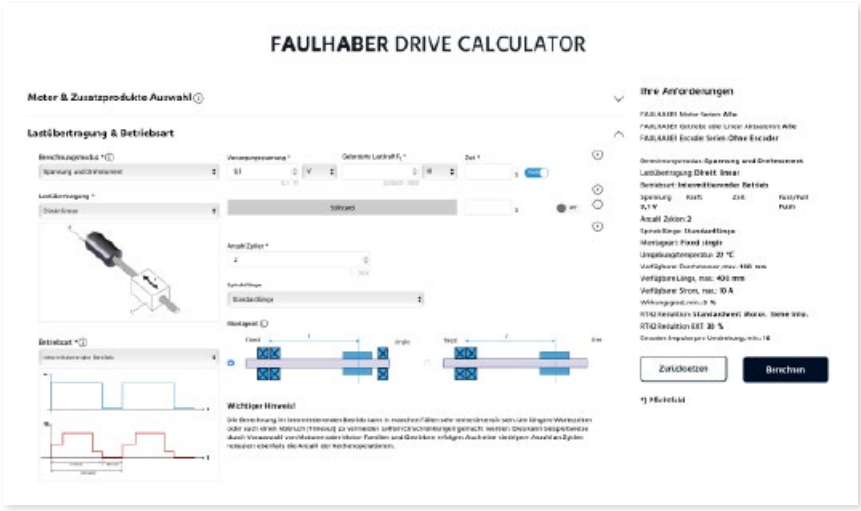
Sewer repair is clearly our core business. But in principle, the technology can also be used for the trenchless renovation of potable water pipes. It

www.faulhaber.com/en/motion/application/
www.pipetronics.com

About Pipetronics GmbH & Co. KG

Pipetronics GmbH & Co. KG, headquartered in Stutensee near Karlsruhe, offers innovative solutions for trenchless sewer renovation. This includes a wide range of electric and hydraulic robots. The high degree of consulting and servicing expertise is supported by the company's five service locations, which also repair the devices. The company also offers individual equipment options for the vehicles and attachments including accessories and a wide range of consumables for sewer repairs. The product range also includes the internal pipe sealing systems RedEx®, Pipe-Seal-Fix, Pipe-Seal-Flex and Pipe-Seal-End as well as the appropriate equipment. Pipetronics is managed by Markus Lämmerhirt, and Markus Brechwald.

FAULHABER DRIVE CALCULATOR
A HELPFUL TOOL FOR EVERY DEVELOPER

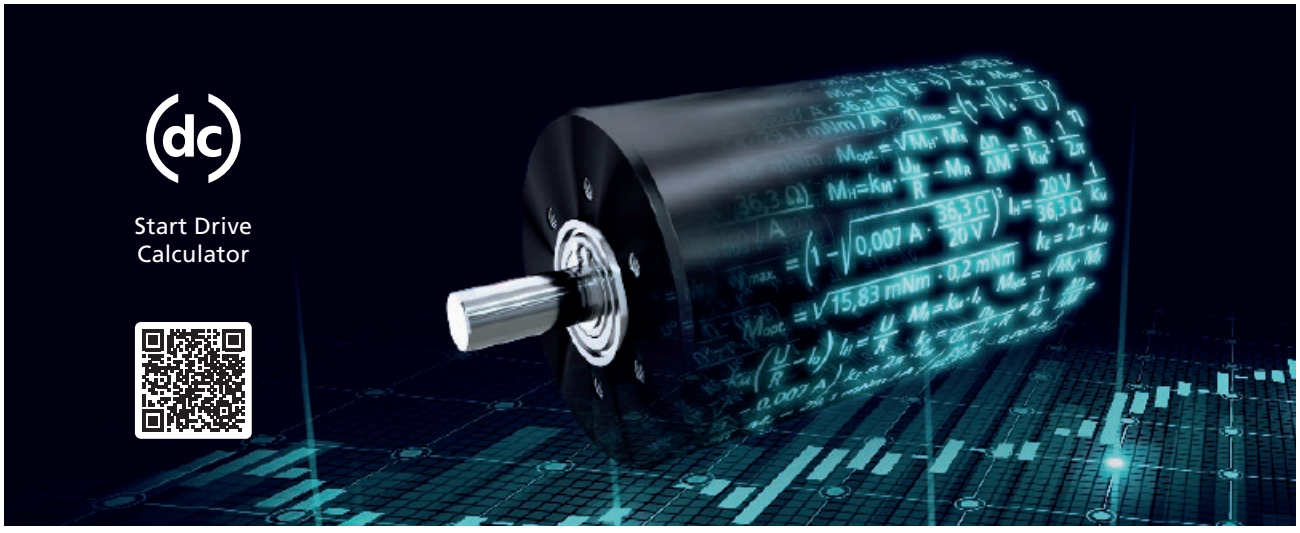


The FAULHABER Drive Calculator is the perfect tool for developers to find a suitable drive system for a specific application in record time. It is easy to use and functional: the modern, clear user interface was designed with optimal usability in mind, and helpful tool tips provide valuable detailed information.

For faster calculation, the program uses global presets with common average values. Of course, the default settings can be adjusted to individual needs, such as to take into account the ambient temperature, supply voltage, or the available space.

The suitable solutions are then shown to the user in a clear list of results, which he or she can further narrow down as needed using powerful filters. The FDC currently enables the calculation of seven drive types and two operating modes.

A detail page for each drive system shows the calculated thermal values and performance diagrams as well as other important information and data. What makes this unique is that the user can change the values on the fly and have them recalculated and displayed immediately. In addition to the calculation, suitable controls are also displayed to complete the drive system. At the end, the user can download the selected solutions as a PDF or request them directly online.



https://www.faulhaber.com/en/drive-calculator/fdc/

TURNKEY SOLUTIONS
FOR LINEAR DRIVE TASKS

The new linear actuators of the FAULHABER L series offer customers a comprehensive complete package from a single source for many different linear drive tasks. The spindle, gearhead, nut, and flange are assembled in Schönaich into a compact, powerful unit that is compatible with all other FAULHABER products. In the design of the FAULHABER L series, great emphasis was placed on flexibility in order to enable specific solutions for a wide variety of applications: There are numerous different spindle sizes and types to choose from. Even the customers' own spindles can be integrated on request. When it comes to the gearhead, customers have the option of choosing from a wide range of evenly distributed reduction ratios – the 22/32L model is fitted with the currently most modern planetary gearhead of the GPT type as standard. With these and many other options, the new linear actuators of the FAULHABER L series are recommended for particularly demanding applications, such as those required in optics, photonics, robotics, or aerospace, as well as for applications in medical technology or for laboratory equipment.

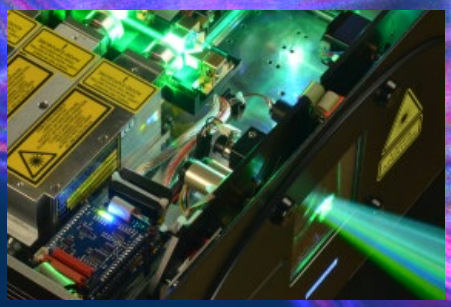
Linear actuators diameter	22 mm / 32 mm
Peak axial force, dynamically, max.	425 ... 1920 N
Continuous output speed, max.	120 mm/s
Continuous input speed, max:.	15000 min^{-1}
Drive output, max.	50 W
Reduction x:1	1 ... 1294

Coming soon!

Linear actuators diameter	6 mm / 8 mm / 10 mm
Peak axial force, dynamically, max.	12 ... 40 N
Continuous output speed, max.	25 mm/s
Continuous input speed, max:.	12 000 min^{-1}
Drive output, max.	0.267 W
Reduction x:1	4 ... 1024

www.faulhaber.com/faulhaber-l/en

OLYMPIC SHOWS AND ARTIFICIAL MOONS



Today, every large event includes an elaborate laser show. Laser projections are used at trade fairs, in advertising, art, and at architectural events. The magically glowing light patterns are made possible by highly complex technology, and at many of the most spectacular installations this technology is provided by Berlin-based LaserAnimation Sollinger. When it comes to the alignment of beams and the creation of effects, motors from FAULHABER play an important role in the company's laser projectors.

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