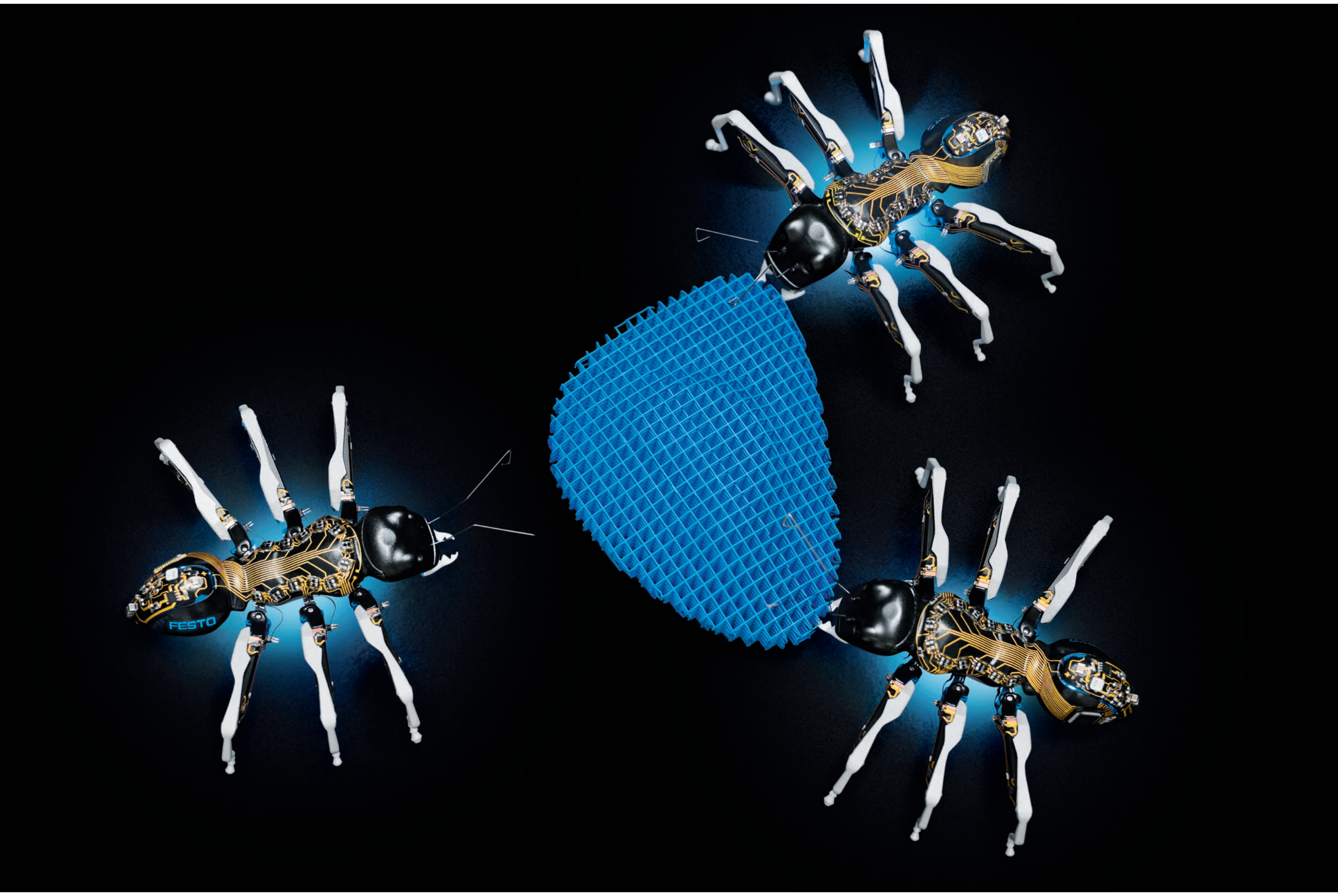
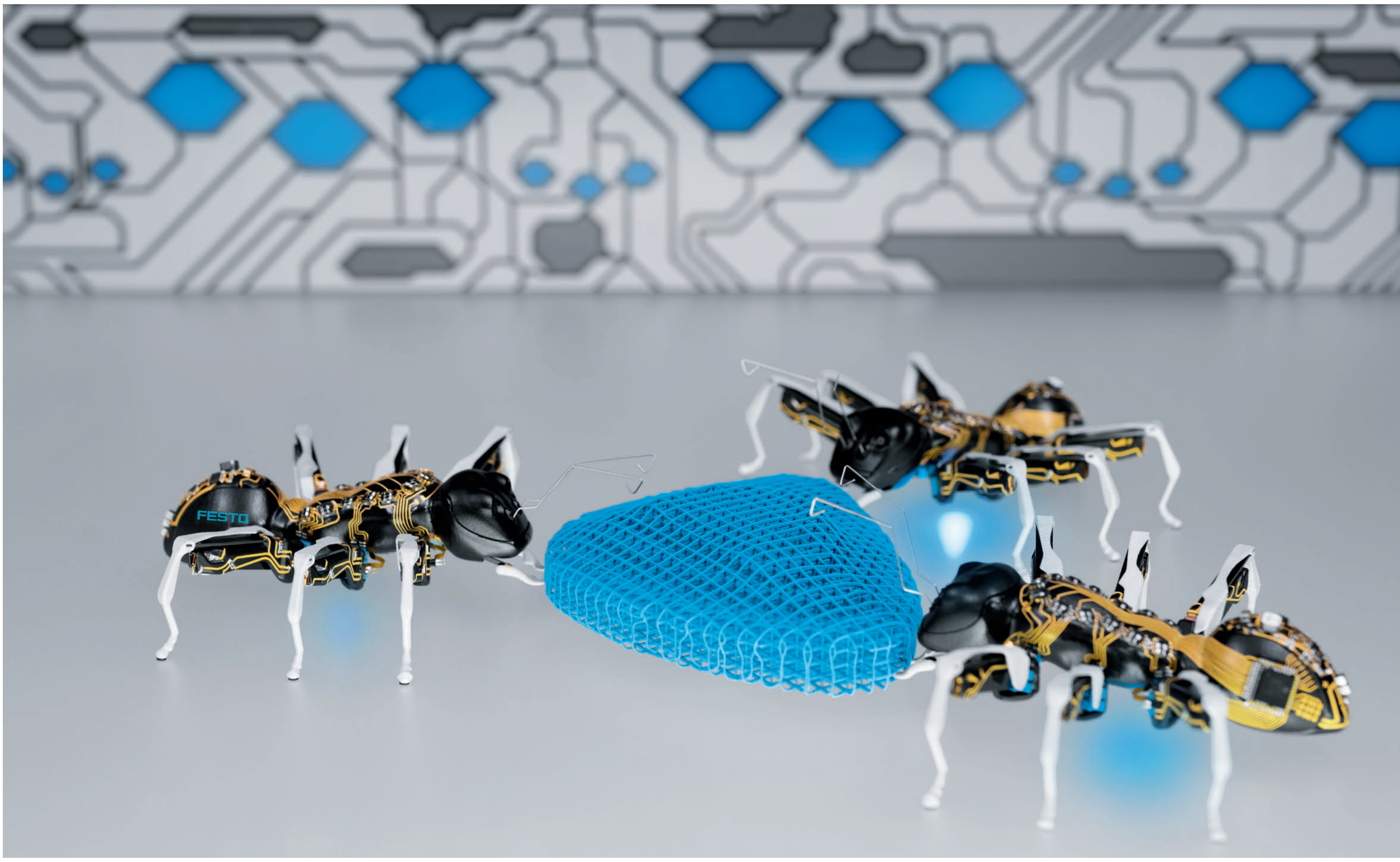
BionicANTs

Cooperative behaviour based on a natural model



BionicANTs
Highly integrated individual systems to solve a common task



With one eye for detail and the other on the big picture: for the BionicANTs, the Festo engineers have not only taken the delicate anatomy of the natural ant as a role model. For the first time, the cooperative behaviour of the creatures has also been transferred to the world of technology using complex control algorithms.

Like their natural role models, the BionicANTs work together under clear rules. They communicate with each other and coordinate both their actions and movements. Each ant makes its decisions autonomously, but in doing so is always subordinate to the common objective and thereby plays its part towards solving the task in hand.

Stimulus for production of the future
In an abstract manner, this cooperative behaviour provides interesting approaches for the factory of tomorrow. Future production systems will be founded on intelligent components, which adjust themselves flexibly to different production scenarios and thus take on tasks from a higher control level.

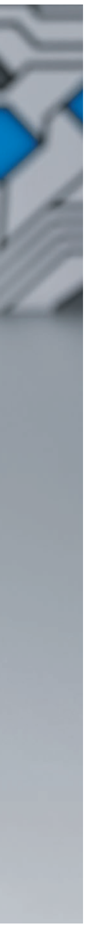
The BionicANTs demonstrate how individual units can react independently to different situations, coordinate with each other and act as an overall networked system. By pushing and pulling together, the artificial ants move an object across a defined area. Thanks to this intelligent division of work, they are able to efficiently transport loads that a single ant could not move.

Functional integration in the smallest of spaces
However, not only the cooperative behaviour of the artificial ants is amazing – even their production method is unique. For the first time, laser-sintered components are subsequently embellished with visible conductor structures in the so-called 3D MID process. The electrical circuits are attached on the surface of the components, which thereby take on design and electrical functions at the same time. In this way, all the technical components can be fitted into or on the ant’s body and be exactly coordinated with each other. After being put into operation, an external control system is no longer required. It is possible, however, to monitor all the parameters wirelessly and to make a regulating intervention.

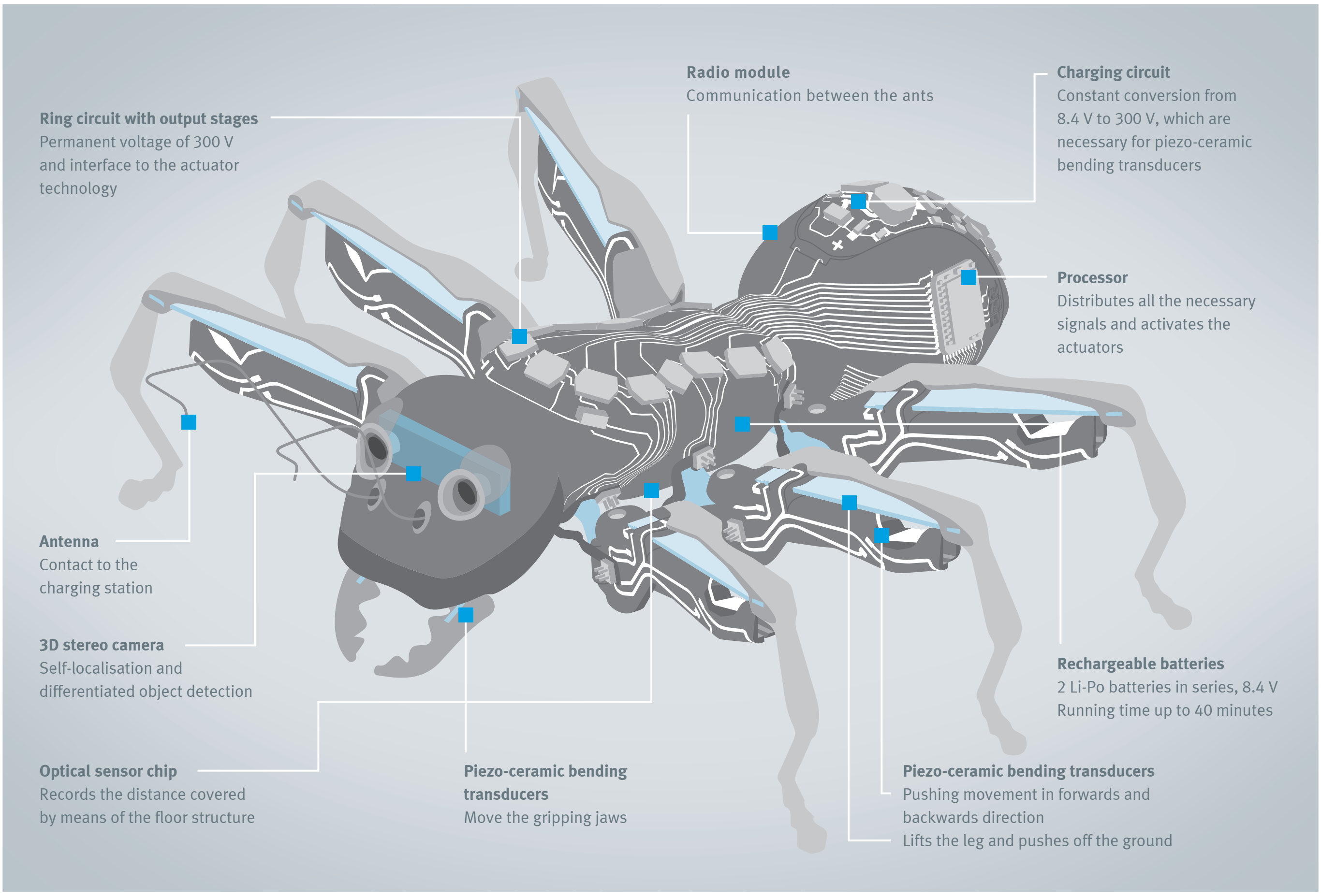
01: **Well-conceived name:** 'ANT' stands both for the natural role model and for Autonomous Networking Technologies

02: **Well-conceived concept:** Numerous components, technologies and functions are combined in each ant in the smallest of spaces

01



02



The BionicANTs also come very close to their natural role model in terms of design and constructional layout. Even the mouth instrument used for gripping objects is replicated in very accurate detail. The pincer movement is provided by two piezo-ceramic bending transducers, which are built into the jaw as actuators. If a voltage is applied to the tiny plates, they deflect and pass on the direction of movement mechanically to the gripping jaws.

New application of piezo technology

Festo also makes use of the benefits of piezo technology for the legs on the artificial ants. Piezo elements can be controlled very precisely and quickly. They require little energy, are almost wear-resistant and do not need much space. Three trimorphic piezo-ceramic bending transducers, which serve both as an actuator and a design element, are therefore fitted into each thigh. By deflecting the top bending transducer, the ant lifts its leg. With the pair underneath, each leg can be exactly deflected forwards and backwards. To increase the relatively low lift, the team developed a flexible hinge joint, which extends the ant's step size significantly.

Highly complex control algorithms for cooperative behaviour

With two rechargeable batteries on board, the ants can work for 40 minutes before they have to link up with a charging station via their feelers. All actions are based on a distributed set of rules, which have been worked out in advance using mathematical modelling and simulations and are stored on every ant. The control strategy provides for a multi-agent system in which the participants are not hierarchically ordered. Instead, all the BionicANTs contribute to the process of finding a solution together by means of distributed intelligence. The information exchange between the ants required for this takes place via the radio module located in the torso.

Camera system and floor sensor working together

The ants use the 3D stereo camera in their head to identify the gripping object as well as for self-localisation purposes. With its help, each ant is able to contextualise itself in its environment using landmarks. The opto-electrical sensor in the abdomen uses the floor structure to tell how the ant is moving in relation to the ground. With both systems combined, each ant knows its position – even if its sight is temporarily impaired.

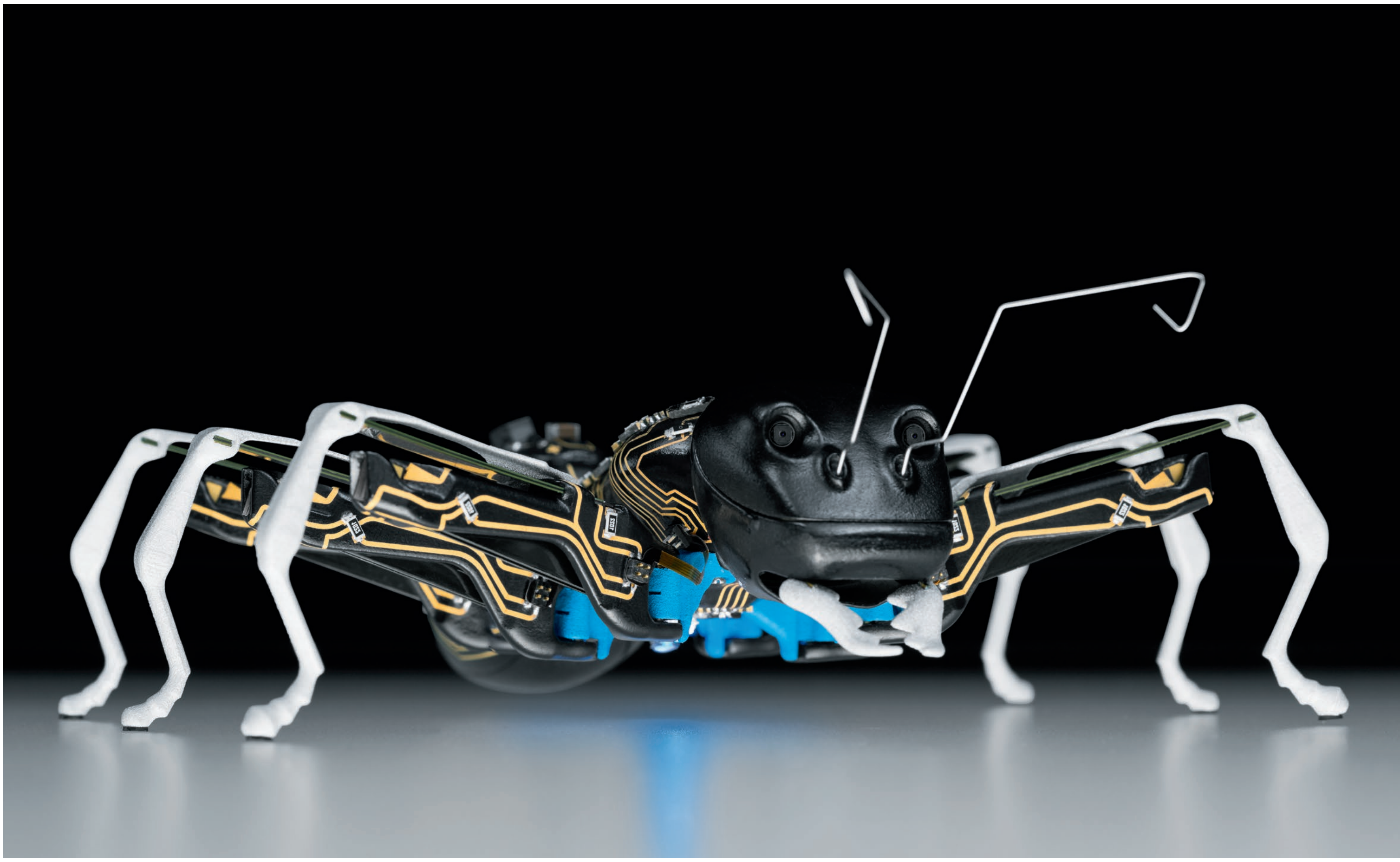
BionicANTs

Cooperative behaviour based on a natural model

Special features belonging to ants
Ants are seen as industrious workers that can carry a hundred times their own body weight. They live in big colonies with a clear ranking order and set rules. In an ant colony, every creature knows which tasks need to be fulfilled. In this way, they can complete work together that a single ant could not manage on its own.

Technical benefits for Festo
Festo took a close look at this cooperative behaviour and transferred it to the BionicANTs. The artificial ants demonstrate in an abstract manner how self-organising individual components communicate with each other and solve a complex task working as an overall networked system.

BionicANTs
Development platforms for new technologies and production methods



Over 2,900 patents worldwide and 100 new products a year speak for themselves: Festo has always offered its customers innovative automation solutions whilst keeping an eye on the production and working worlds of the future. The Bionic Learning Network provides new approaches and impetus for this. In association with universities, institutes and development firms, Festo is specifically occupied with transferring natural phenomena to engineering.

Over millions of years of evolution, nature has developed the widest range of optimisation strategies to adapt to its environment, which can often be applied to Festo's core business. One of the most significant developments is how individual animals communicate with each other.

Engineers have been able to implement the special behaviour of ants by combining various technologies. They are the basic design principle for the highly integrated microsystems, which are also equipped with their own intelligence for acting at a local level. The ants thus illustrate possible production scenarios of tomorrow and the future beyond.

Testing complete systems that are networked
A fundamental change is taking place in the world of production. The future is calling for ultimate flexibility and convertibility. In future, the trend will increasingly move in the direction of customised products. The small quantities and high level of variety associated with this require technologies that continually adapt to changing conditions. The components in industrial facilities of the future must therefore be able to coordinate themselves. Tasks that are now managed by a central master computer will be taken over by the components in future.

In order to make complete systems like these possible – and ones that are networked – Festo is continuing with intensive development of technologies such as precision engineering and microsystem technology. In these areas, a variety of materials and production methods are also being tested, which will make functional integration in such a small space possible for the first time. The research platforms of the Bionic Learning Network are thus the ideal way of not only investigating natural principles but of implementing them using new methods.

01: **Ideal platform:** Research basis for testing new technologies

02: **Highly integrated components:** design and electrical functions in one

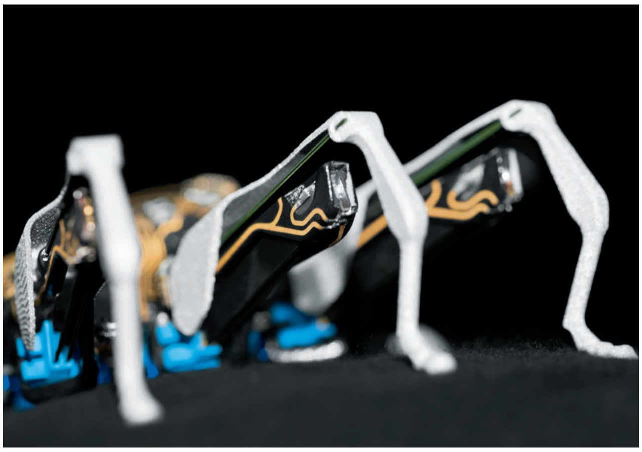
03: **Precise control:** piezo-ceramic bending transducers in leg actuator technology

04: **Unique combination:** 3D MID technology on laser-sintered shaped parts

01

02

03



04

Use of new production technologies

Selective Laser Sintering (SLS) is an additive manufacturing technique that Festo has already tested and developed further in numerous bionic projects. The bodies of the BionicANTs are also made of polyamide powder, which is melted layer by layer with a laser. For the first time, however, Festo is now combining sintered components with 3D MID technology.

3D Moulded Interconnect Devices feature spatial conductive tracks, which are visibly attached to the surface of shaped parts and act as circuit boards for electronic and mechatronic subassemblies. They make do without any cables and only require a small amount of effort to be assembled.

Well-known areas of application for MID technology are automotive construction, medical and telecommunication engineering and the aerospace industry. For the first time, Festo is now producing miniature robots with the technology, thus acquiring new knowledge about a manufacturing method that could soon take hold in product development.

Developing tried-and-tested skills

In the field of piezo technology, Festo already has many years' experience. Festo Microtechnology AG in Switzerland is a competence centre for piezo production. Festo also produces proportional valves here, in which the technology for flow and pressure regulation is integrated.

The piezo valves made by Festo are used as seat comfort valves in vehicles, among other things. They can also be found in laboratory automation and medical technology; they are able to provide an exact dose of the air and oxygen supply in mobile breathing apparatuses. Their low energy consumption means that batteries seldom need to be changed. Finally, the switching operation runs almost without a sound, meaning patients are not further restricted.

Piezo-ceramic actuators are meanwhile used mainly as pressure sensors and for energy recovery purposes. Yet their use in miniature robots is extremely rare. With the BionicANTs drive concept, Festo demonstrates once again how a familiar form of technology can be used in new ways.

Technical data

Length: ....135 mm
Height: ....43 mm
Width: ....150 mm
Weight: ....105 g
Step size: ....10 mm

Material, body and legs: .... polyamide, laser-sintered
Material, feelers: ....spring steel
3D MID: ....laser structuring and gold plating by Lasermicronics
Actuator technology, gripper: .... 2 trimorphic piezo-ceramic
.... bending transducers (32.5 × 1.9 × 0.7 mm)
Actuator technology, legs: .... 18 trimorphic piezo-ceramic
.... bending transducers (47 × 6 × 0.8 mm)

Stereo camera: ....Micro Air Vehicle (MAV) lab of the
.... Delft University of Technology
Radio module: .... JNtec
Opto-electrical sensor: ....ADNS-2080 by Avago Technologies
Processor: .... Cortex M4
Rechargeable batteries: ....380 mAh Li-Po batteries in series, 8.4 V

Project participants

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