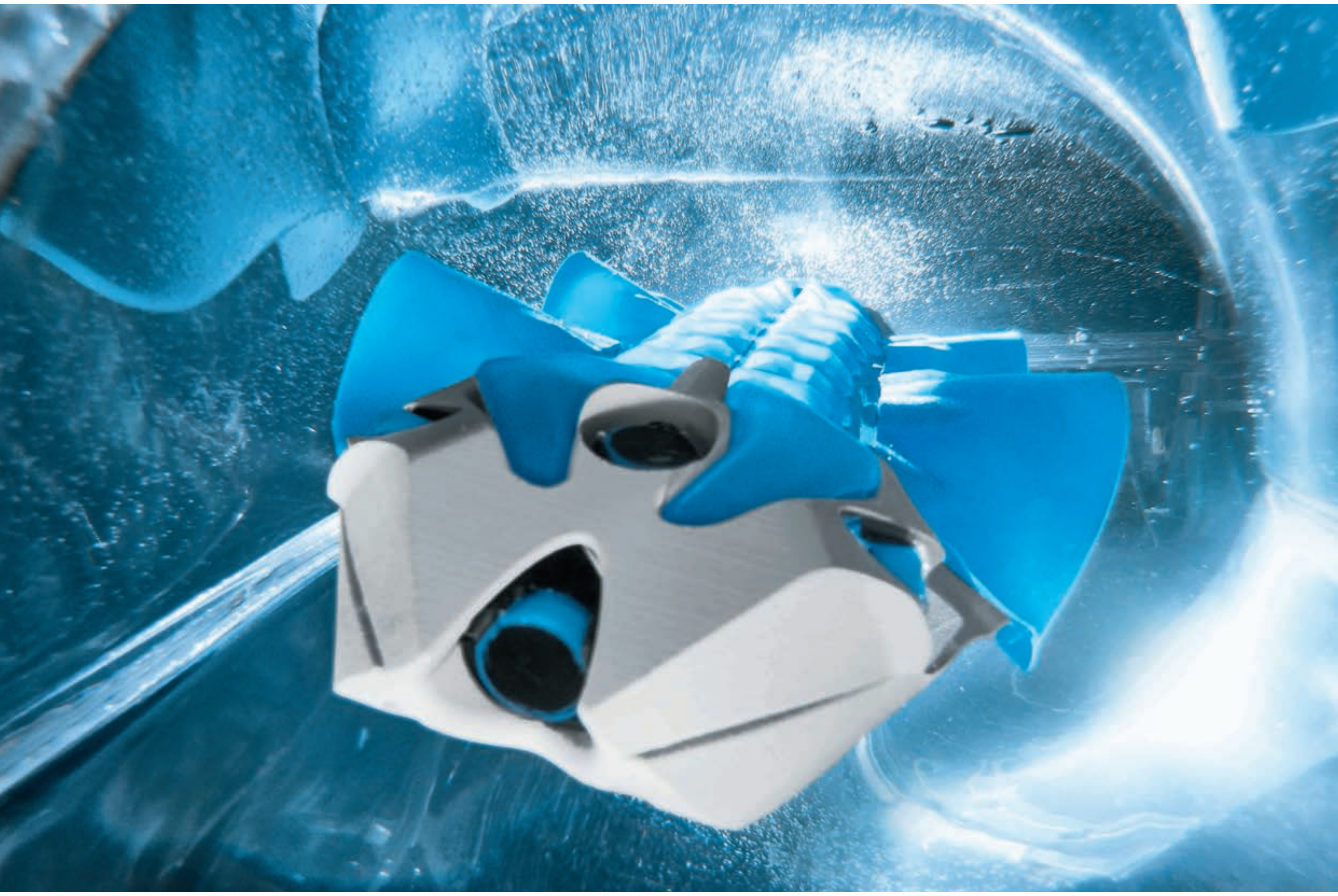
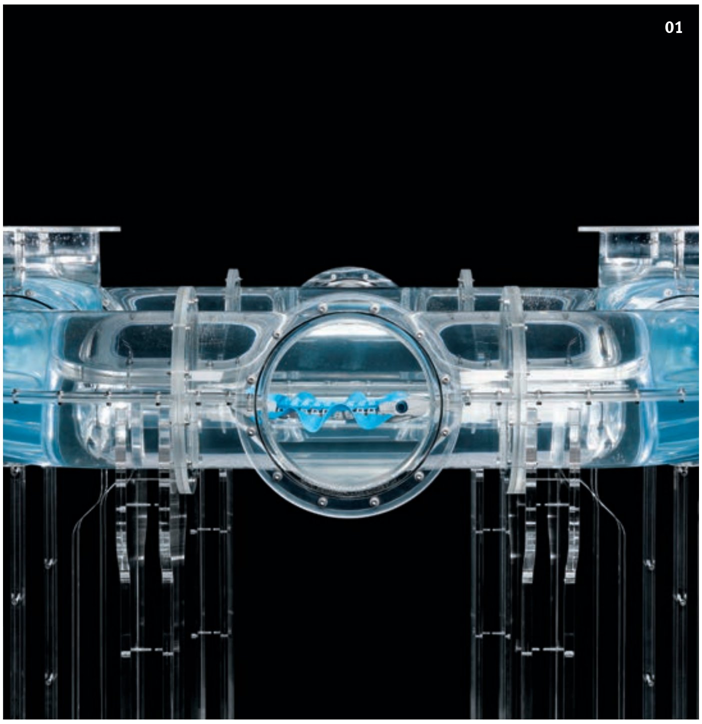
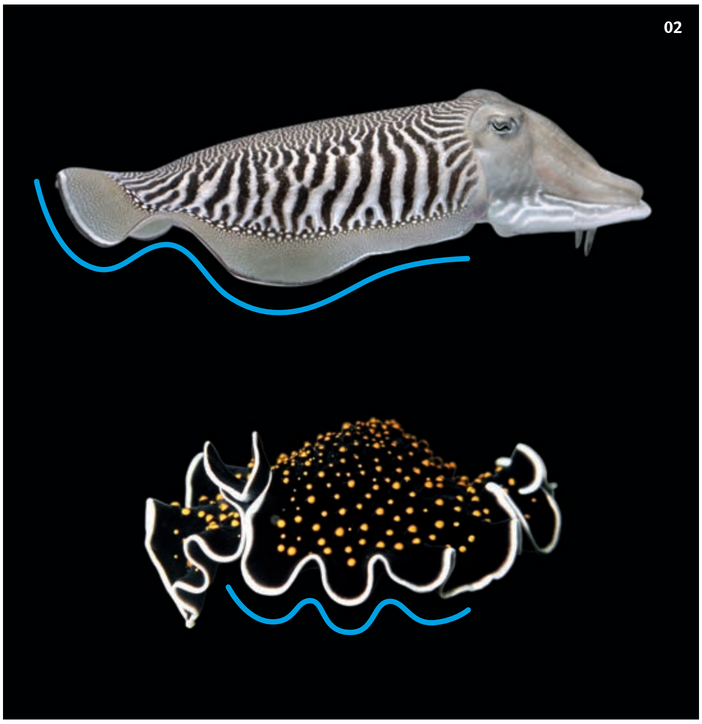
BionicFinWave
Underwater robot with unique fin drive



BionicFinWave
Autonomous navigation through a pipe system filled with water





Nature teaches us in impressive fashion what the optimal drive systems for particular swimming movements look like. With the beating wings of the manta ray, the recoil principle of the jellyfish and the adaptive structure of a fish's tail fin, Festo has already technically reproduced several of these fascinating forms of movement from the animal world.

For the BionicFinWave, the bionics team has now been inspired by the undulating fin movement, which is used, among other creatures, by the wild marine planarian, the cuttlefish and the Nile perch.

Unique swimming manoeuvres in all directions
The common feature of these creatures is their fins running lengthways. They run from head to tail and are located either on the back, the stomach or on both sides of the body. In order to propel themselves, the fish use their fins to generate a continuous wave, which advances along their entire length. This undulation pushes the water behind, creating a forward thrust. Conversely, the creatures can also swim backwards in this way and, depending on the wave pattern, create uplift, downforce or even lateral thrust.

Using this undulation principle, the BionicFinWave now manoeuvres itself independently through a pipe system made of acrylic glass. At the same time, the autonomous underwater robot is able to communicate with the outside world wirelessly and transmit data – such as the recorded sensor values for temperature and pressure – to a tablet.

Flexible silicone fins from a cast
To move along, the BionicFinWave uses its two side fins, which are completely cast from silicone and make do without struts or other support elements. This makes them extremely flexible and thus able to implement the fluid wave movement of their biological role models in a way that is true to nature.

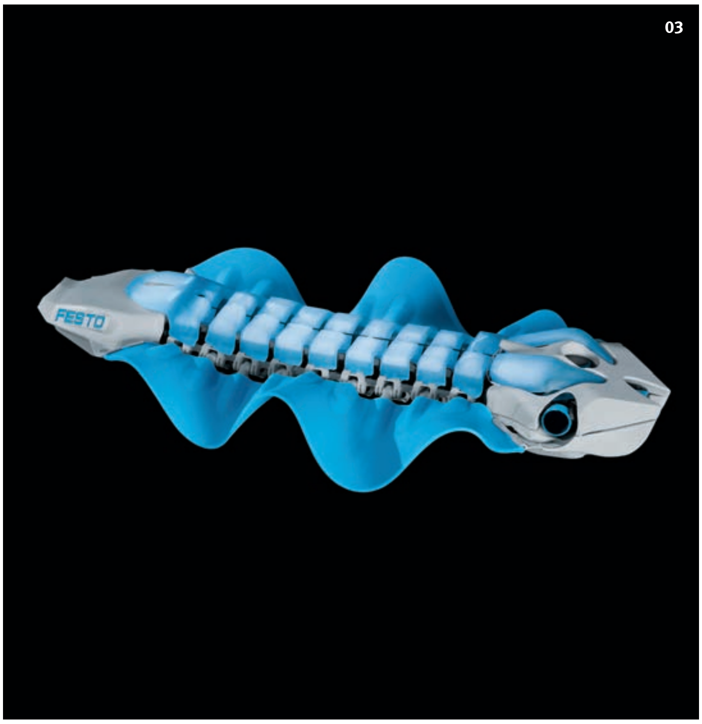
For this purpose, the two fins on the left and right are each fastened to nine small lever arms, which have a deflection angle of 45°. The lever arms in turn are driven by two servo motors located in the body of the underwater robot. Two attached crankshafts transfer the force to the levers in such a way that the two fins can move individually. They can thereby generate different wave patterns.

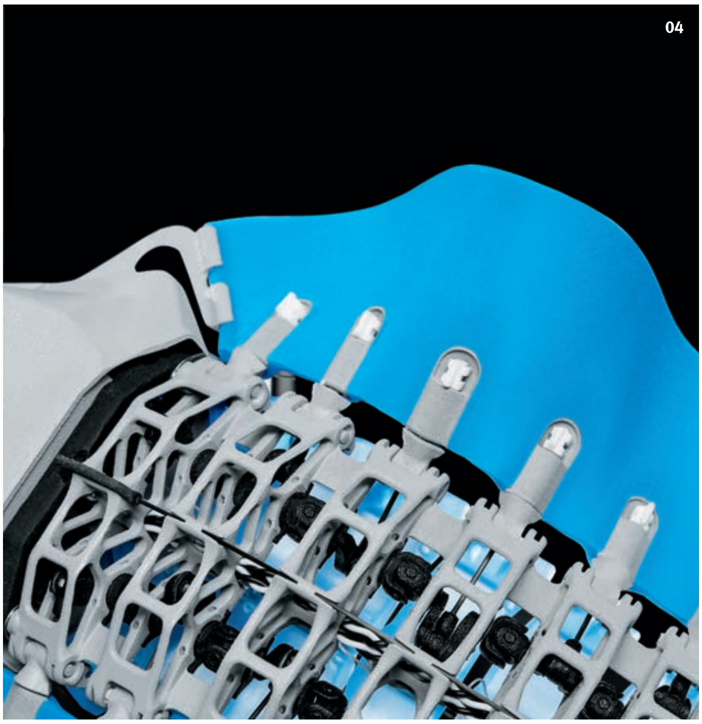
01: Bionic technology platform: used in liquid media

02: Natural role models: the wave-shaped fin movement on the cuttlefish and wild marine planarian

03: Unique drive: the undulating motion of the flexible silicone fins

04: Delicate mechanical system: the 3D-printed crankshaft with attached lever arm





In order to swim in a curved line, for example, the outer fin moves faster than the inner one – similar to the chains on a digger. A third servo motor on the head of the BionicFinWave controls the flexure of the body, which helps it to swim up and down. So that the crankshafts are suitably flexible and supple, a cardan joint is fitted between each lever segment. For this purpose, the crankshafts including the joints and the connecting rod were made out of a single piece of plastic with the 3D printing method.

Optimally designed body with integrated onboard electronics
The remaining elements in the BionicFinWave's body are also 3D-printed, which enables its complex geometries in the first place. With their cavities, they act as flotation units.

At the same time, the entire control and regulation technology system is watertight and installed safely. Thus, besides the circuit board with a processor and remote module, the front of the body also houses a pressure sensor and ultrasound sensors. They constantly measure the distances to the walls as well as the temperatures in the water, thus preventing collisions with the pipe system.

Intelligent interaction of a wide range of components
A prerequisite for this autonomous and safe navigation was to develop small, efficient as well as watertight and water-resistant components that can be coordinated and controlled with the corresponding software.

Festo was thus able to technically implement an undulating fin drive that is particularly suitable for a slow and precise movement and whirls up water less than a conventional screw drive does, for example.

New impetus and approaches
With the bionic technology platform, Festo is once again creating impetus for future work with autonomous robots and new drive technologies used in liquid media. It would be conceivable to develop concepts like the BionicFinWave further for tasks like inspections, measuring sequences or data collections – for instance for the water and sewage technology or other areas in process automation. In addition, the knowledge gained during the project can be used for the manufacturing methods of soft-robotics components.

Technical data

Body
- Length: .... 370 mm
- Height: .... 50 mm
- Width: .... 190 mm
- Weight: .... 430 g
- 3D printing method: .... Selective Laser Sintering (SLS) ....and Digital Light Processing (DLP)

Onboard electronics:
- Processor: .... ARM® Cortex®-M4-based STM32F4
- Radio module: .... JNtec
- Servo motors: .... 3× Savöx SH 264 MG
- Inertial sensor system: .... Bosch Sensortec – BNO055 (9 axes)
- Pressure sensor: MS5837
- Ultrasound sensor system: ... Inoson – with a frequency of 2MHz .... and a measurement accuracy of 2 to 4 mm, ... with a measuring range of 20 to 700 mm

Project participants

Project initiator:
Dr Wilfried Stoll, managing partner,
Festo Holding GmbH

Project management:
Dr Heinrich Frontzek, Dr Elias Knubben, Sebastian Schrof,
Festo AG & Co. KG

Project team:
Cedric Alt, Mart Moerdijk, Konstantin Lehleiter, Nathanael Peltzer,
Thomas Trapp, Micha Purucker, Jochen Spohrer, Christian Trapp,
Philip Steck, Paolo Ruegg,
Festo AG & Co. KG

Model construction:
Felix Fuchs,
Felix Fuchs Design

Material modification, further development and production of the air pockets with bioluminescent effect using the DLP process:
DREIGEIST, Nuremberg

Festo AG & Co. KG

Ruiter Strasse 82
73734 Esslingen
Germany
Phone +49 711 347-0
Fax +49 711 347-21 55
cc@festo.com
→ **www.festo.com/bionics**