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SmartBird

Inspired by nature

SmartBird – inspired by nature

Preamble

Humankind, nature and diversity
Modelled on nature: at Festo, the diversity of biological processes provides inspiration for strategic learning and promotes successful, innovative action. Even the individuality of a small herring gull fosters openness, which at Festo is the key to human and technological efficiency. The engineers have deciphered bird flight; with their SmartBird model they are realising new perspectives for the automation technology of tomorrow.

In Richard Bach's modern-day fable "Jonathan Livingston Seagull", a herring gull with human characteristics sets out in search of new insights. Jonathan wants to learn, experience and understand. Along his path to inspiration, his the love of flying quite literally lends him "wings".

In his quest for perfection, Jonathan draws on his full potential. He succeeds in overcoming his fear in his exploits of aerial acrobatics.

Humans and organisations strive for superior goals. Compelling ideas and inspiring values bring to life their special potential for achievement. This is the fuel for the engine of innovation at the family company Festo.

Festo's Bionic Learning Network learns from nature – and SmartBird learns above all from the herring gull. All the knowledge and skills it requires are already at hand in the natural model. With the Bionic Learning Network – an open association of renowned universities, institutes and development companies – Festo is giving shape to sustainable innovation processes within the enterprise:

a fundamental technical principle is first of all derived from nature. Following its bionic adaptation, it is strategically implemented in an energy-efficient application.

Learning to fly

Day after day, Jonathan Livingston Seagull works on perfecting his flying skills. Despite many adversities he sets off time and again with passion and resolve. On each new flight, Jonathan acquires fresh knowledge; he hones his flying skills and experiments to vary the nuances. His willingness to learn is the impetus of his personal desire for freedom.

For the learning enterprise Festo, this means not only constantly perfecting its own behavioural patterns, but also maintaining an open mind for learning opportunities. By learning, the company's employees not only expand their knowledge, but can also more fully exploit their creative potential.

Jonathan is able to grasp the mechanisms on which learning process are founded, despite great hardship. He can discard former behavioural patterns in order to be free for new impulses. His endeavours as an individual ultimately make way for a concerted movement among his colony of seagulls.

Festo likewise subscribes to the principle of learning from one another and for one another. As with the herring gulls in the fable, a spiral of learning evolves – the

basis for a strong organisation. Self-organising, self-controlling and self-renewing in accordance with market requirements, Festo encounters a changing environment openly, dynamically and innovatively and offers its customers high-quality products and services.

Flying together

Jonathan undergoes transformation from an inquisitive student into an enthusiastic teacher who leads the flock along the path to knowledge. One of his students in turn becomes a highly motivated teacher who sets out to liberate the young gulls from outmoded patterns of thinking.

Festo also thinks and acts from a holistic perspective. With the common corporate objectives in mind, Festo therefore offers diversified opportunities for learning. Festo supports the process from the student to the teacher with its central international learning portal, the Virtual Academy. Training and consulting for manufacturing partner companies are secured on the other hand by the business unit Festo Didactic, with its world-leading range of offers in industrial training and education. Young students also benefit from the Festo Educational Fund, which accompanies them when they embark on their careers and creates knowledge transfer networks.

From the herring gull to SmartBird

Thinking without barriers fosters technical evolution. Jonathan lives for flying. He is a pioneer of his time and stands out from the mob. To experience something out of the ordinary, he ventures into new dimensions.

In a figurative sense, Festo's SmartBird is a student of Jonathan. Just as the seagull breaks new speed records, Festo has also registered a breakthrough by deciphering the flight of birds. Modelled on the herring gull, SmartBird is a biomechatronic and cybernetic holistic design – a flight model which like a bird is capable of taking off, flying and landing merely by flapping its wings. The fascination of SmartBird is the result of the intelligent integration of various disciplines: mechanics, drive technology, fluid dynamics, control and regulation technology and condition monitoring. It is this scientific transfer to practical application that enables SmartBird to fly.

Flying in freedom

Being able to fly like a bird is an age-old dream of humankind. Festo is turning this dream into reality. With carefree exuberance, SmartBird takes to the air.

Seagulls impress beach-goers with their daring flight manoeuvres. Whether alone or collectively in a flock, they seem to be in effortless control of the air. They fly, sail and glide until they suddenly plunge and then skilfully pull out of their dive. The purpose of it all is to secure mere survival for themselves and their offspring.

Jonathan is above all of this. His purpose in life is to experience the expanses of the ocean and the sky without limitations. His openness and untiring diligence finally enable him to transcend the bounds of physicality: he is free to move through space and time.

Festo likewise endeavours to responsibly lead the enterprise into a secure future for coming generations – like Jonathan, on the basis of visionary ideas and future-oriented values.

From intuitively flapping wings ...

Birds move through the air solely with the aid of their wings. Pure muscle power enables them to overcome the air resistance. Their sensory organs intuitively measure, control and regulate the necessary sequence of movements. The downward stroke of a bird's outstretched wings displaces air to the rear. As well as providing forward thrust, this movement generates lift; the wings' feathers lie close together to form a closed surface. On the upward stroke, the wings are slightly bent and twisted, so that the air can flow almost unimpeded between the feathers.

... to mechanical movement

Inspired by the flapping wings of the herring gull, Festo with its bionic technological model is demonstrating for the first time the technical adaptation of bird flight: the gull-like SmartBird takes off, flies and lands entirely autonomously. The key element of this artificial bird is an active articulated torsional drive unit that combines lift and propulsion in a single function. SmartBird thus attains unprecedented efficiency in flight with flapping wings – in approximation of its model from nature.

A bird's-eye view

Seagulls take a sublime view of the world. Jonathan extends his horizon to become a wanderer between the worlds – for the gull is the ultimate embodiment of freedom. Even seagulls in the here and now fearlessly conquer new territory. In southern England, young birds from seagull colonies leave their traditional habitat by the sea and move inland.

SmartBird from Festo is likewise opening up new domains. Manifold scientific findings from its development can be transferred to the field of automation. These technical advances will open up new dimensions in freedom to humankind and unleash fresh perspectives.


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Decoding the flight of birds
For many centuries, scientists from around the world have endeavoured to solve the mystery of how birds fly. In their respective eras, they have gained valuable insights and left lasting impressions. The engineers at Festo have now succeeded in decoding the flight of birds.

Jonathan regards flying as a life art. He lives for flying, and to this end he assumes the unusual role of a scientist. Close to the surface of the sea, he experiments to perfect his gliding. To increase his speed, while nose-diving he varies the beat of his wings and the angle of their inclination. He overcomes setbacks and fear of death, to finally triumph by setting a record unparalleled in the history of his gull colony.


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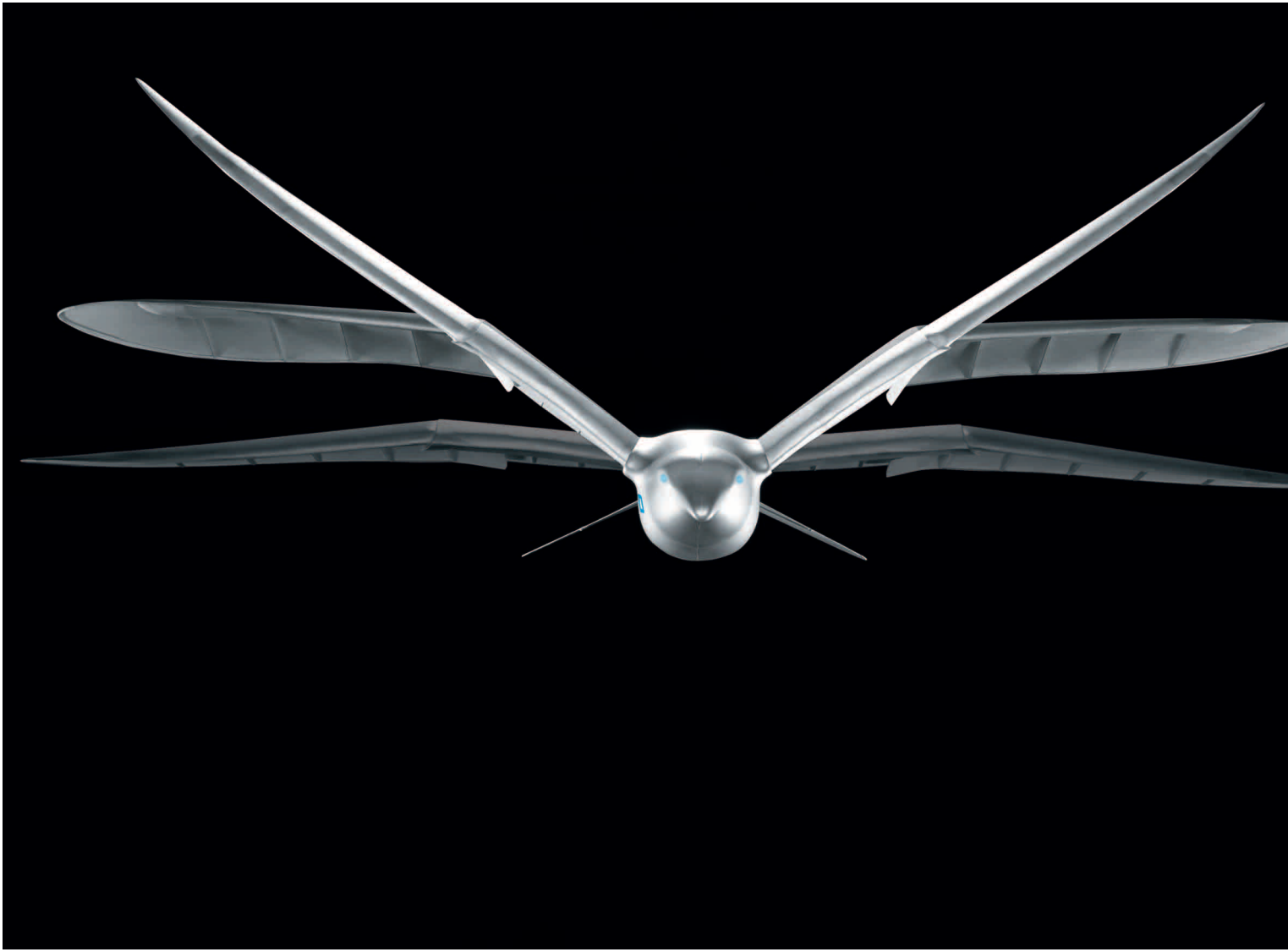
SmartBird's precursors

In the fifteenth century, Leonardo da Vinci designed the first flapping-wing models based on the bird. Around four hundred years later, Otto Lilienthal in his scientific treatises analysed the art of flight of the seagull. A so-called ornithopter, an aircraft with single-joint flapping wings, was recently presented by the University of Toronto. In 2010 a pilot covered about 150 metres in the ornithopter by muscle power alone, once the device had been towed off the ground to become airborne.

Time to fly

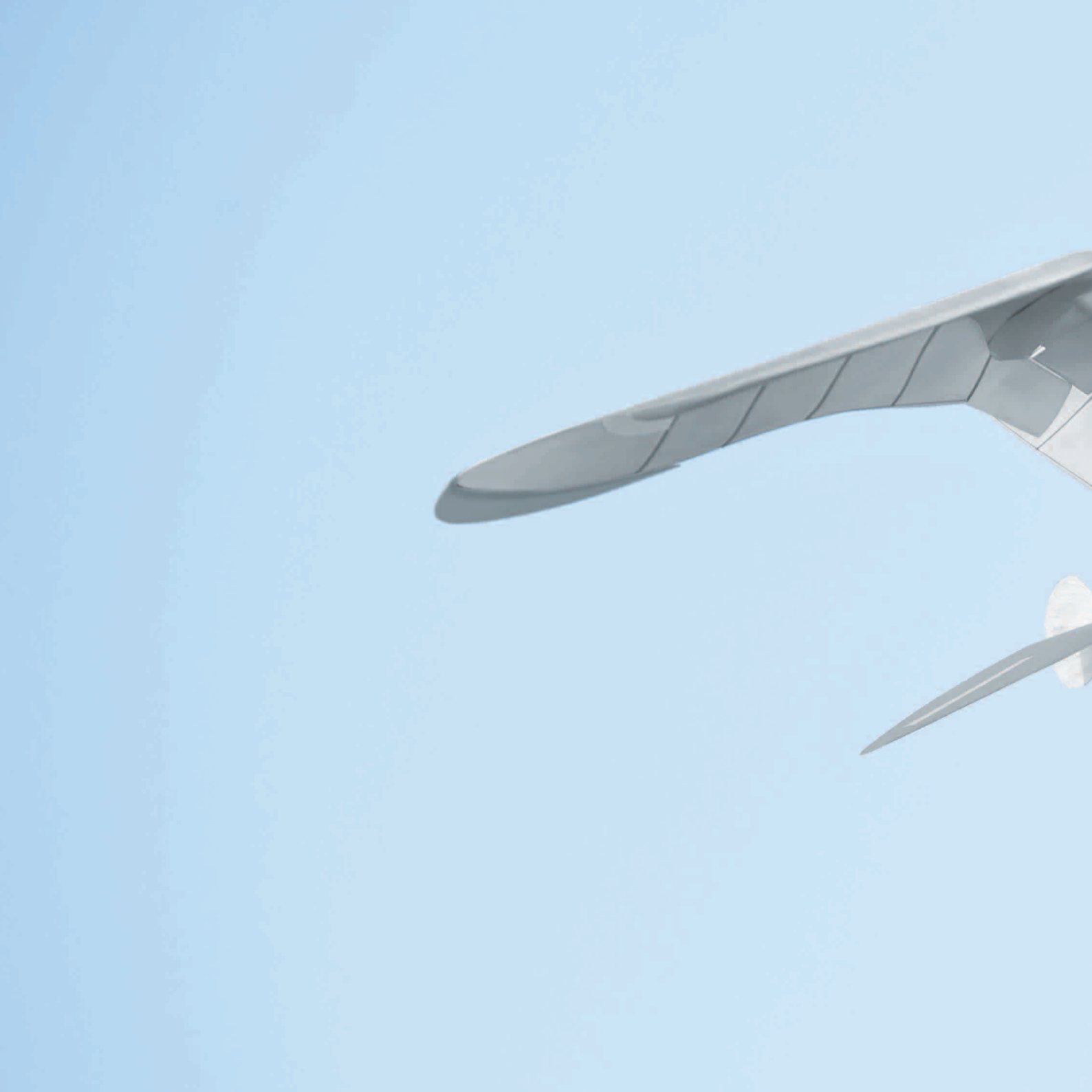
2011 is SmartBird's year of birth. When Jonathan set his own individual speed record, he sensed the beginning of a new era. For Festo too, the scientific deciphering of bird flight signifies the dawn of a new age. In the Bionic Learning Network, Festo's scientists implement valuable

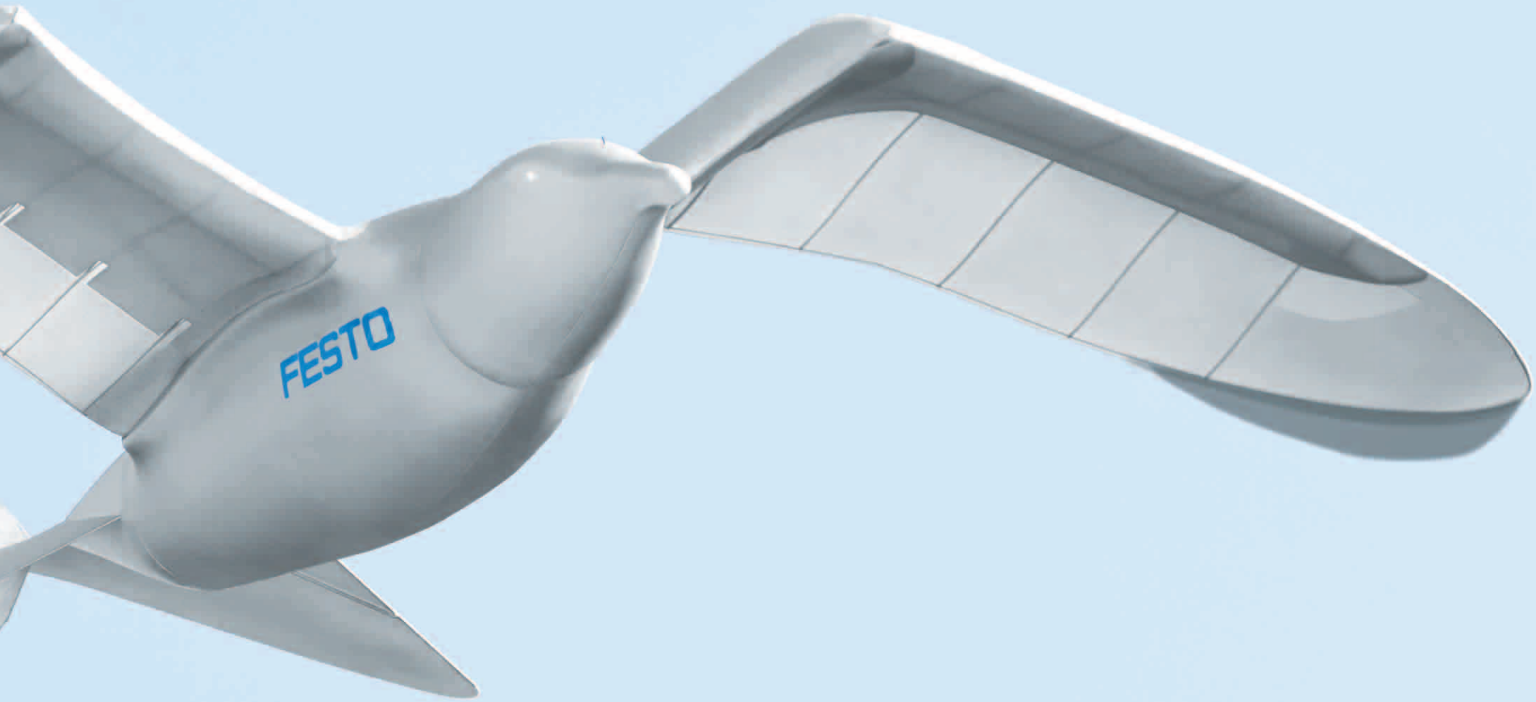


knowledge and experience gained from previous bionic projects. AirRay and AirPenguin, for example, expedited the development of the artificial bird. SmartBird flies just like its natural model. A lightweight and powerful technical approximation of the herring gull, it is extremely agile and has outstanding aerodynamic characteristics.

Flight acrobatics and automation

A distinctive characteristic of SmartBird is its active wing torsion, with no lift or propulsion aids. In combination with complex control technology, an articulated torsional drive unit – like the sensory organs of a seagull – effects the specific rotation of the wings during their upward and downward strokes. The torso and the tail section are movable and thus increase SmartBird's manoeuvrability and agility. With the new findings it provides in aerodynamics, airflow behaviour, lightweight construction and drive technology, SmartBird is paving the way for pioneering solutions. Learning from SmartBird means learning about the effective use of energy and resources. Its versatility borrowed from nature will be reflected in the future of factory and process automation – in intelligent lightweight construction, in functional integration and in the control and optimisation of highly complex processes in the dimensions of space and time.

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Biology and technology
A gull-like creature darts through the air. The human hand from which the bird has autonomously taken off feels its airflow. The creature executes diverse flight manoeuvres and ends up back in the hand of the engineer. This evolutionary act of engineering art is made possible by the human-technology interaction achieved by Festo.

Accompanied by seven chosen seagulls, Jonathan exuberantly demonstrates his perfected flight acrobatics to the flock. They fly in close formation, wing tip to wing tip, as if they were one single bird. Jonathan wants to show the other gulls that they too have the ability to overcome their own limitations.


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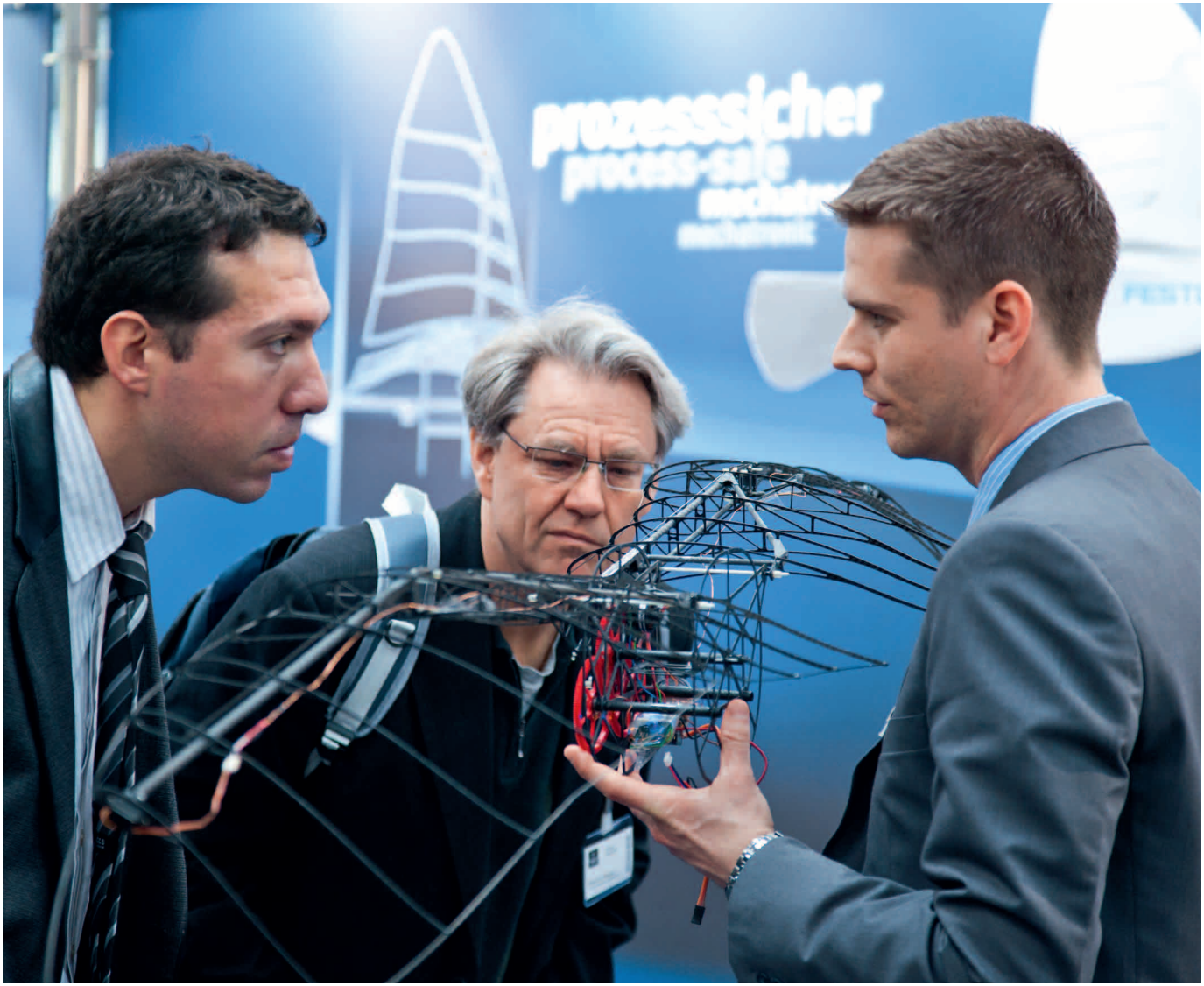
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process-safe


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At Festo too, the creative potential and ideas of each and every employee harmonise to the benefit of all. SmartBird's flight requires technologies that are coordinated right down to the last detail. The processes must reliably mesh throughout.

SmartBird's interior

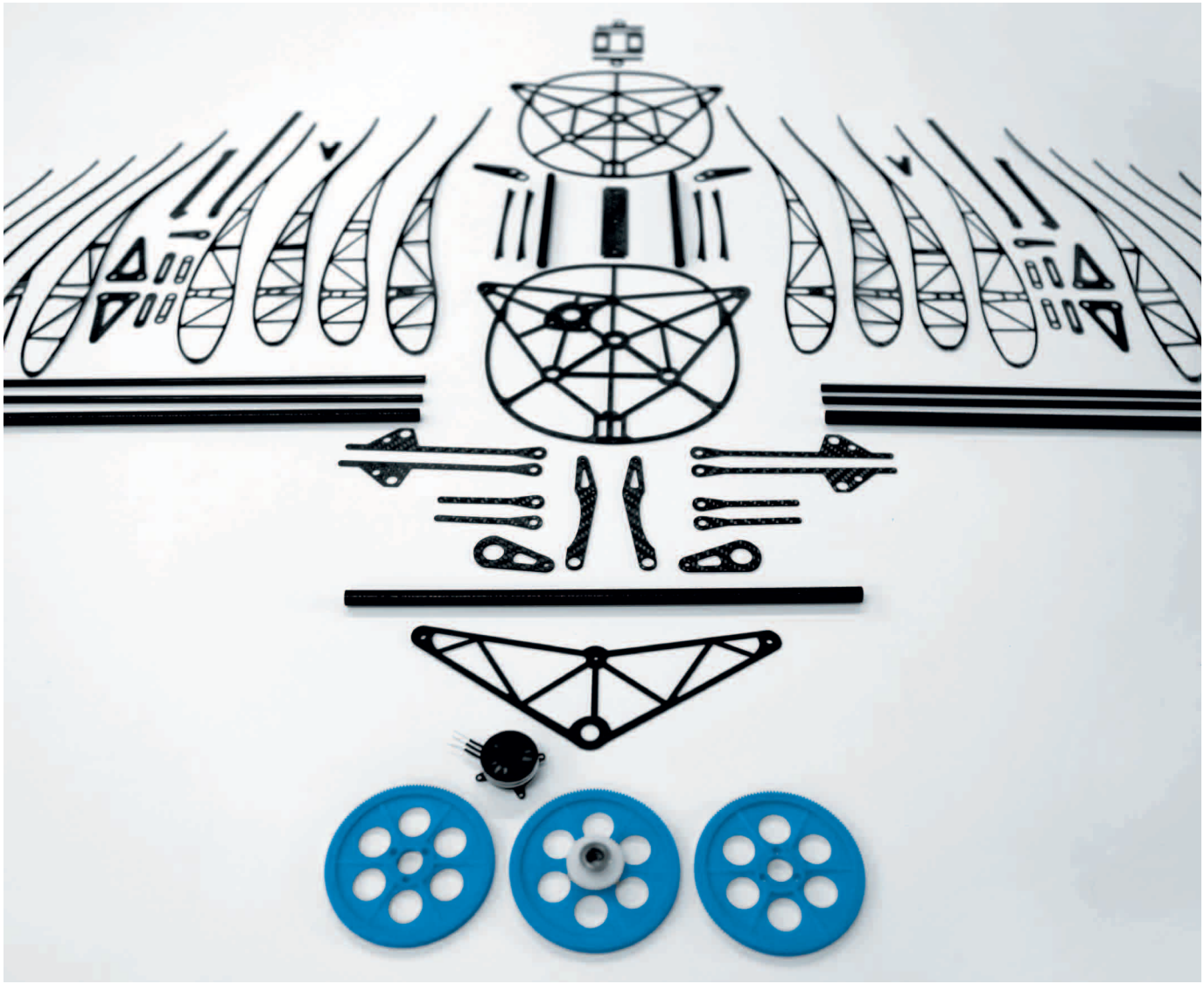
As in a bird's body, the internal workings of SmartBird are contained within its torso section: the battery, engine, transmission, crank mechanism and control electronics. The role of the spine is assumed by a fibreglass tube, to which the structural components for the head, the torso and the wing suspension are attached. The wings are activated by an external motor via a spur gear. Sensors determine their exact position at all times, so that the force of their movement and their angle of torsion can be precisely adjusted.

Moving intelligence

Since SmartBird's crank mechanism does not have a dead centre, it flies like a seagull with smooth, harmonious movement of its wings. It owes its agility and manoeuvrability to the intricate arrangement of its electric drive units and push rods, which allows the torso to bend aerodynamically with simultaneous weight displacement. Its tail section acts as an elevator and rudder and increases the lifting force. On curves the tail section bends, and during phases of straight flight it serves to stabilise the bird.

Winged wonder

The movement of SmartBird's wings is modelled on that of the herring gull. Their motion consists of two components. The wings, comprising arm and hand sections, beat up and down, and their amplitude increases from



the torso to the wing tips; this movement is conveyed by a trapezoidal joint. At the same time, the wings twist upward during the up-stoke, whereby the correct angle of inclination is crucial. The extent and timing of the twist are controlled by a servomotor. The arm wing thus generates lift, and the hand wing propulsion. This active articulated torsional drive is a feature unique to SmartBird that combines the two movements into a single function.

Intuition

Jonathan does not want to be bound by mediocrity. In his flying exploits, he discovers the loop, the slow roll about his own axis and the inverted spin. He practises his aerial acrobatics to perfection. Like a computer, he registers new impressions at lightning speed and immediately transforms them into new ideas.

Seagulls react intuitively to change by means of sensory perception. With SmartBird, this task is assumed by on-board electronics. A microcontroller calculates the optimum setting of the servomotors to control the wing torsion, which in turn is synchronised with the stroke motion by means of sensors. In addition, the wing position and torsion can be monitored by radio, and the torsion can even be optimised in real time. SmartBird can easily adapt to new situations within a fraction of a second, with extremely high efficiency.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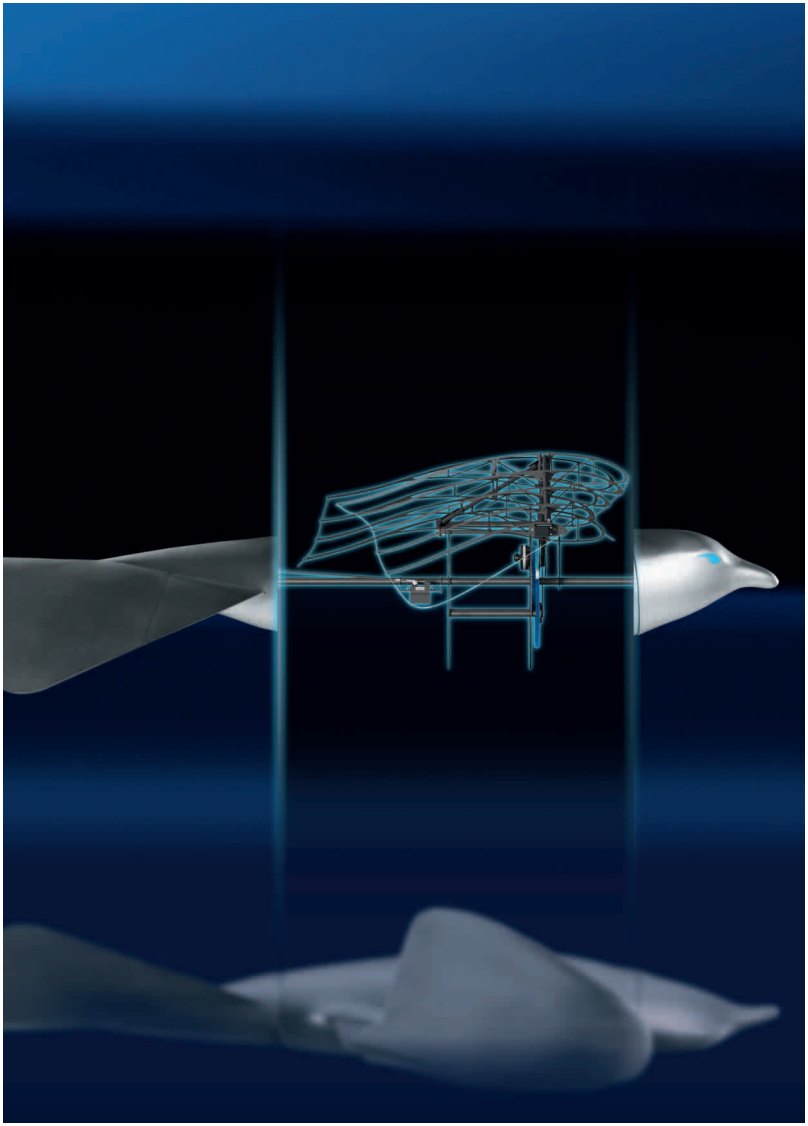
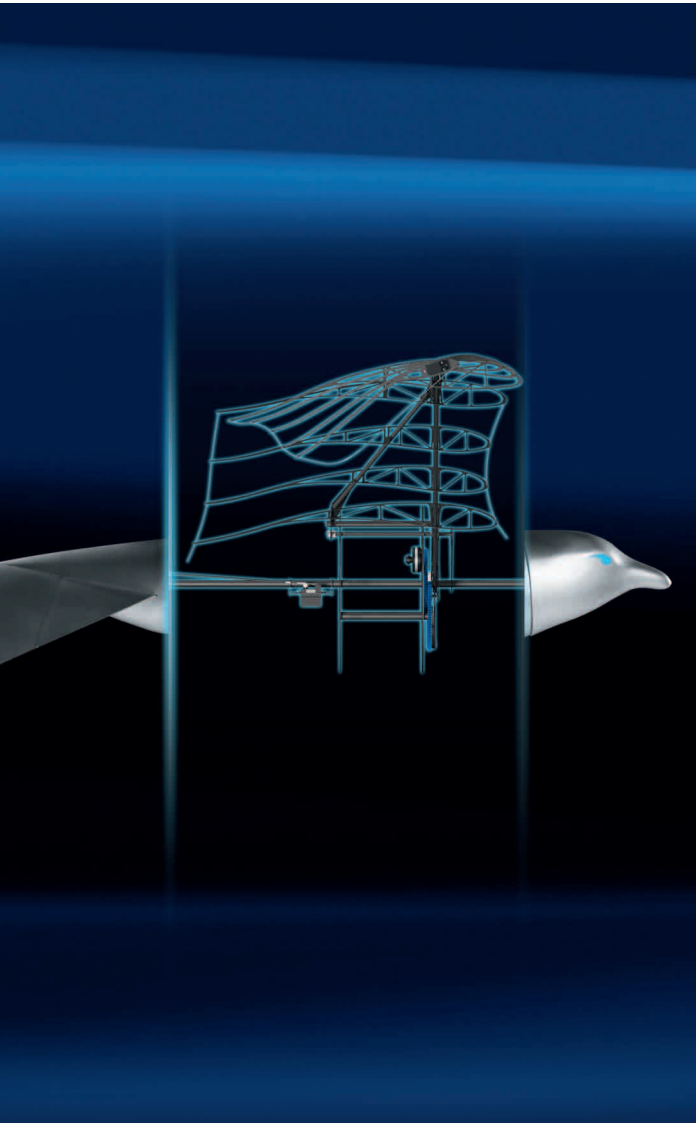
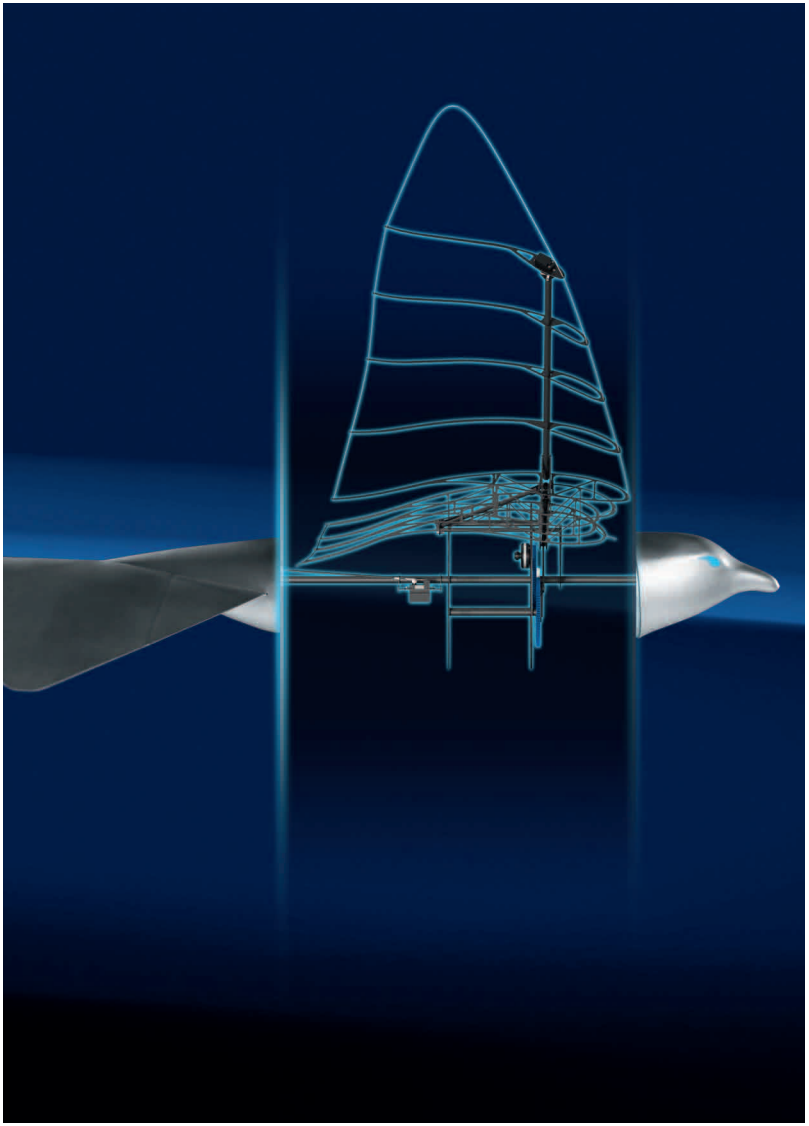


Maximum efficiency

SmartBird from Festo is characterised by extreme lightness and optimal resource efficiency. The precisely coordinated movement of its wings lends this artificial bird three-dimensional motion – without the need for an external drive unit. SmartBird puts airflow phenomena to use with unprecedented aerodynamic efficiency.

At first, Jonathan seems hampered by his natural limitations. In the course of time, however, he manages to exploit his flying skills to attain a maximum degree of efficiency. His metaphysical insights finally reward him with access to a further dimension: freedom in space and time.



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The measure of efficiency of Festo's SmartBird is its optimised overall efficiency factor. As with all flying devices, this comprises an electromechanical and an aerodynamic component.

A bionic precursor

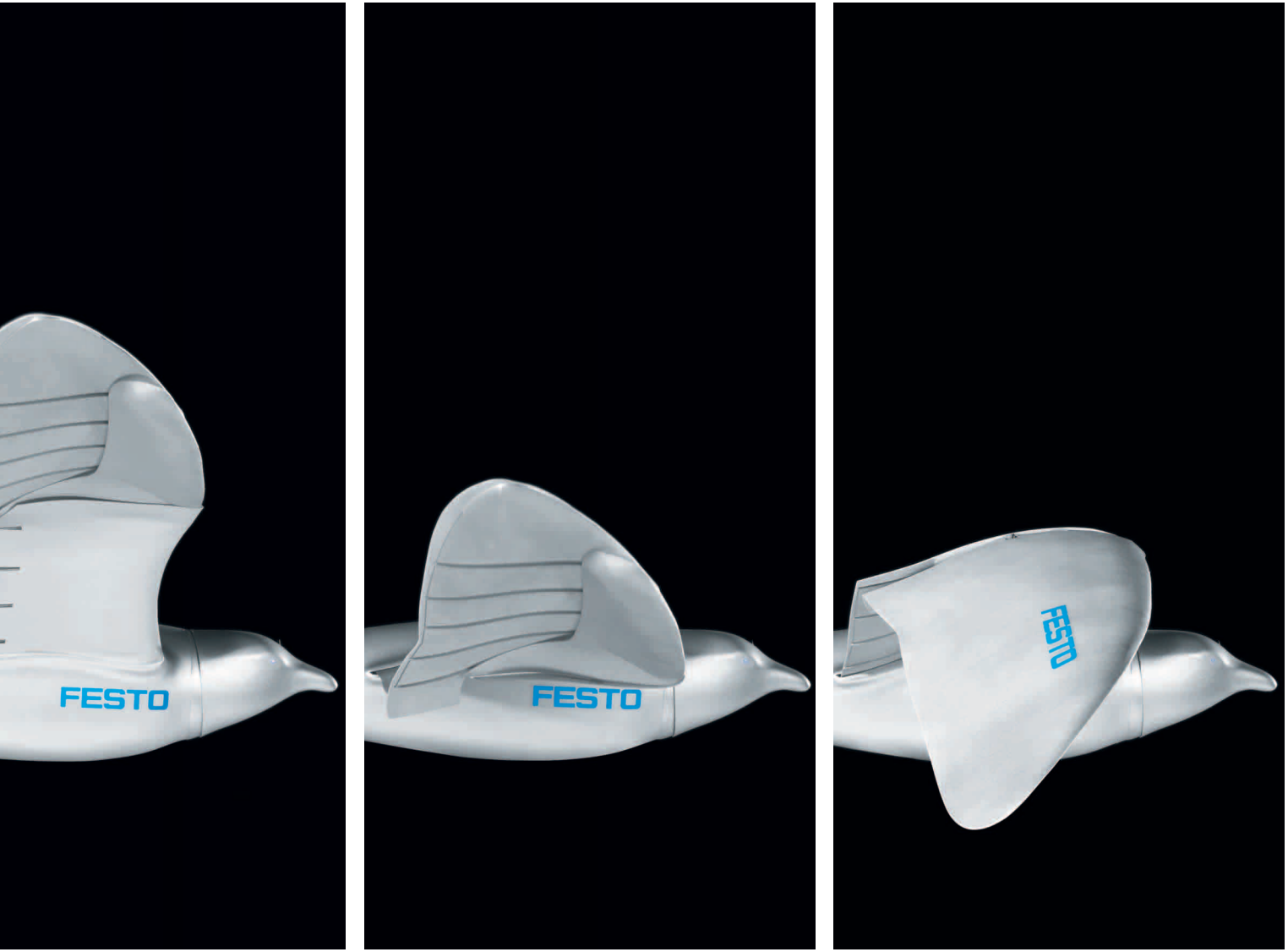
In 1882, the French physiologist Étienne-Jules Marey was the first to identify twelve phases of bird flight within the space of a second. Reconstruction of this sequence of motion was to provide accurate information for the construction of flying machines. Using Marey's historical experimental setup as a bionic foundation, the scientists from Festo reconstructed this circular flight path configuration in modified form for measurements of SmartBird's performance.

Measurements and efficiency

The artificial bird is attached to a rotating boom. If the boom is powered by a motor, the lift and drag of the flight model can be determined. When the bird flies around the circular track under the power of its own wings, the engineers can determine the thrust. With this intricate experimental setup, the thrust and lift can be studied over a broad range of speeds. Measurement of the mechanical power rating of the articulated torsional drive unit is carried out during flight on an absorption dynamometer. The ratio of this quantity to the electrical power rating yields the electromechanical efficiency factor. The aerodynamic component is determined by calculation. SmartBird can attain an exceptionally high aerodynamic efficiency factor of 70 to 80 percent.

New trends

Jonathan Livingston Seagull's incessant feats of acrobatic flight and his daring manoeuvres stand for the experiments, measurements, calculations and deliberations performed day in, day out by Festo's engineers. The secret of SmartBird lies in the active torsion of its wings. Only by this means can the work it expends in beating its wings be converted into highly efficient thrust. Festo succeeded in taking into account the minimal movement of the wing torsion in the design of its innovative articulated torsional drives.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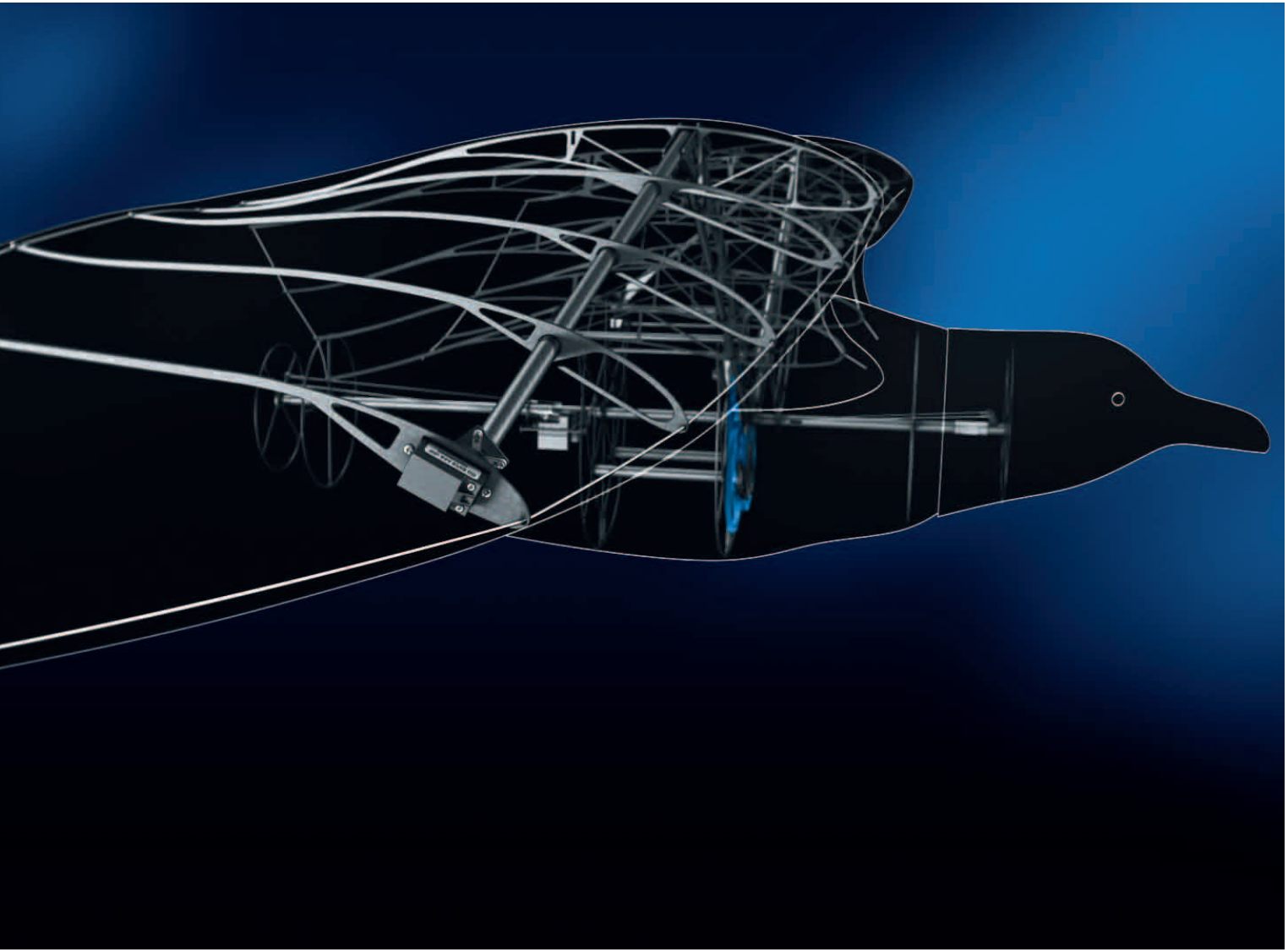
New horizons in automation

From the herring gull to SmartBird, from SmartBird to factory and process automation – there is a purpose to this path of learning. Through their technological knowledge gleaned in the development of SmartBird, the scientists and engineers from Festo are opening up far-reaching, promising perspectives for everyday human life.

SmartBird was born of insights from nature and from Jonathan's inspiration and idealism. Festo's Bionic Learning Network provided both the fertile ground and the framework for this development. Like a natural system, it engages in open exchange with its environment. Together with Festo's experience and willingness to learn, it opens up new perspectives in engineering and inspires its protagonists to pioneering innovations that will be encountered in everyday industrial life in a future characterised by responsibility.

Resources

SmartBird, with an overall weight of just 450 grams despite its wingspan of two meters, is extremely light. The engineers have been able to achieve this level of resource-efficiency above all thanks to their well-founded analysis of airflow phenomena and the material-saving use of carbon fibre technology. Festo will implement this acquired knowledge to the benefit of its customers in flow-optimised, energy-efficient product solutions that require only a minimum of installation space.
With refined condition monitoring, the researchers



ensure SmartBird's flight stability and operational reliability at all times, so that the artificial bird can correct its flight by intuitive means. The constant data acquisition and the real-time control of various parameters can likewise be applied in automation. Processes at industrial facilities can thus be perfected without loss of time.

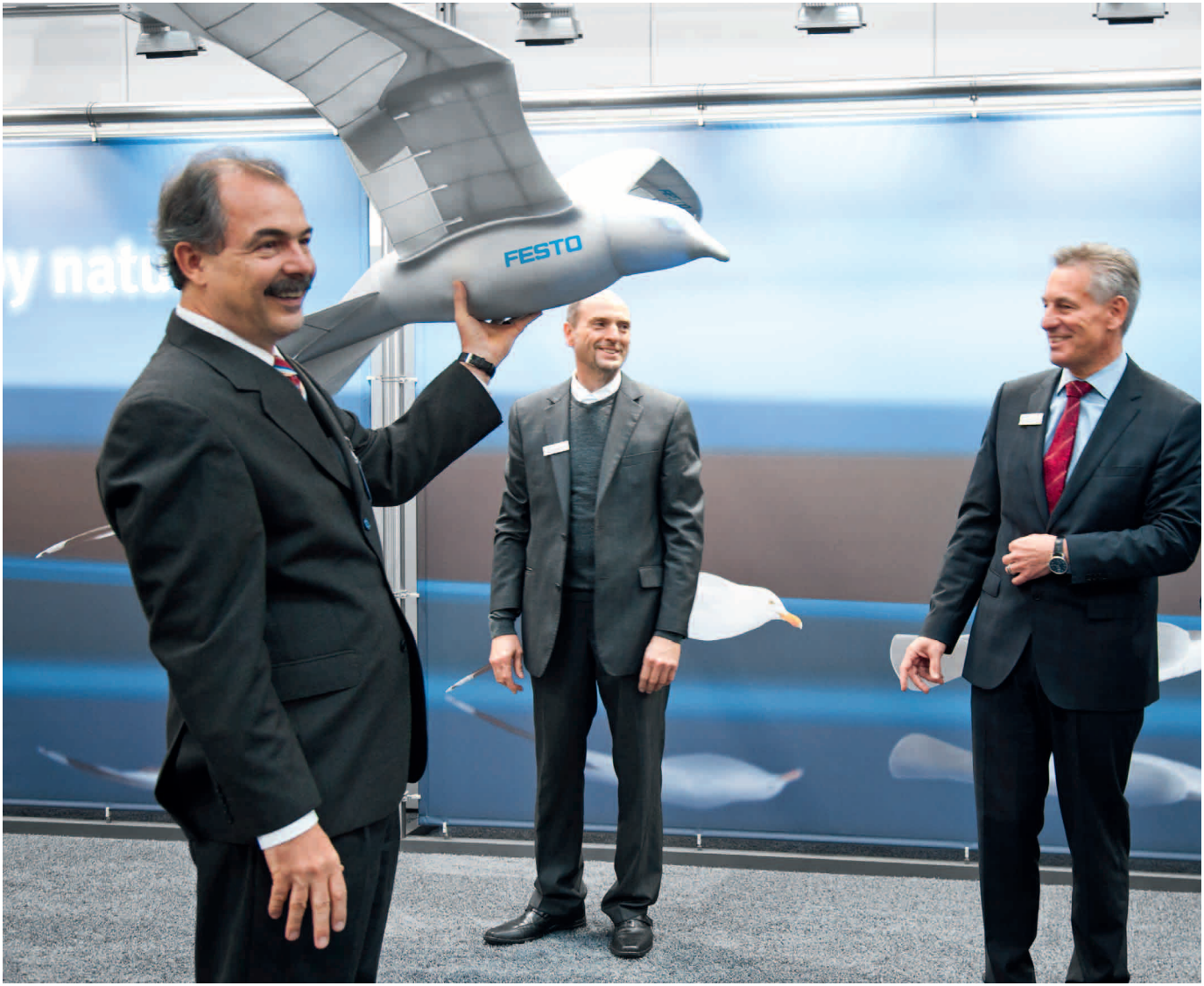
Insights

During flight, SmartBird's active articulated torsional drive combines forward propulsion and lift in a single function. When the rapidity of pneumatics is combined with the precision of electric linear axes, as in this model, new perspectives arise for the development of hybrid drive technologies. Coupled drives for linear and rotary movement can be used for example in process automation or in stroke wing generators. The underlying principle here is the physical reversal of bird flight: a seagull

generates energy with its wings to overcome air resistance and gravity. This energy is already available in flowing water and is derived by means of generators using the same pattern of movement.

Knowledge

SmartBird is a holistic design. As a model for biomechatronics and cybernetics it already today yields a variety of future-oriented solutions and innovations; nevertheless, the learning spiral continues for the scientists from Festo. The conclusion of one period of learning is the beginning of the next. This is the basis of Festo's learning system: the company's employees learn with one another, from one another and above all for one another, so that they can put their creative potential to use for the benefit of all. A successful corporate culture requires a diversity of minds, but unified thought. For Festo, knowledge provides the foundation for venturing into new dimensions and thus for contributing in its role as an active partner to an environment that is undergoing constant transformation.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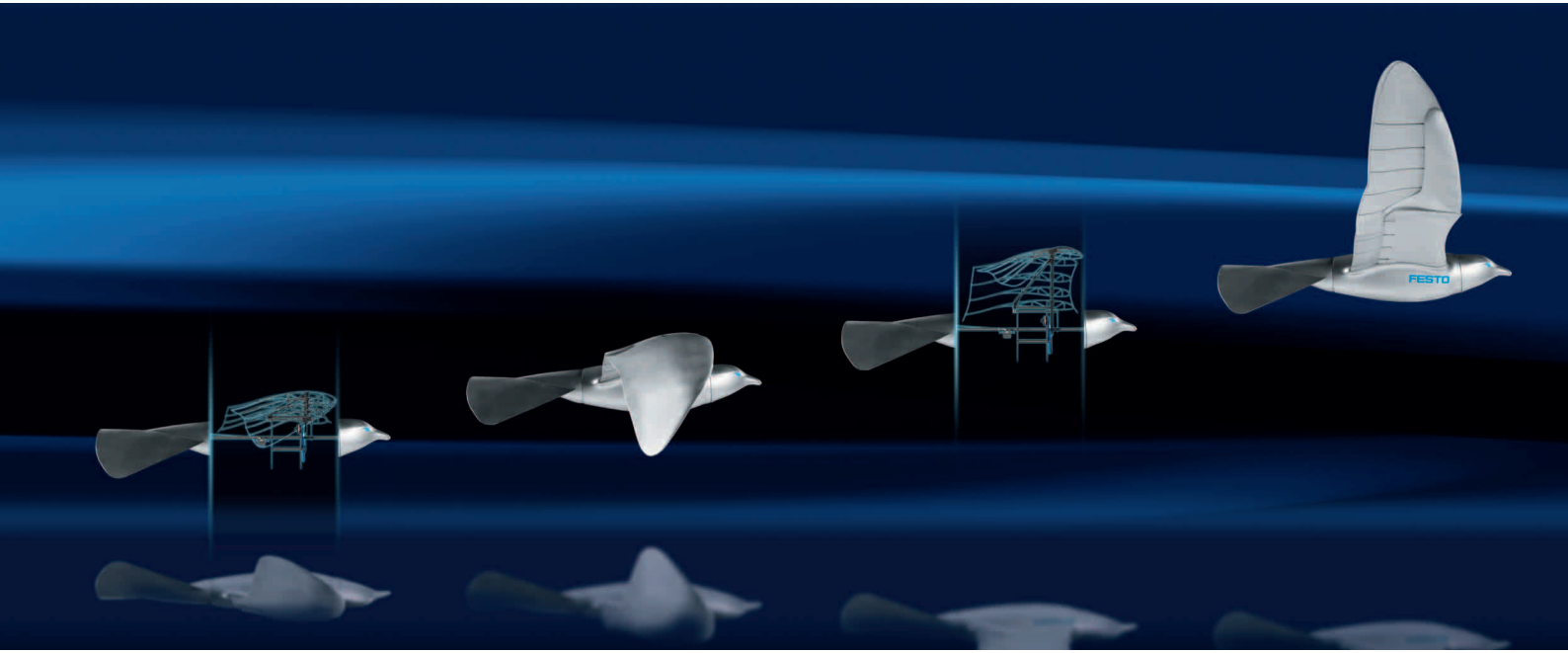
Technical data

Torso length:	1.07 m	El. power requirem.:	23 W
Wingspan:	2.00 m	Structure:	lightweight carbon fibre structure
Weight:	450 g	Lining:	extruded polyurethane foam
Battery:	lithium polymer accumulator, 2 cells, 7.4 V, 450 mA	Microcontroller:	MCU LM3S81132-bit micro-controller@50 MHz64 kByte flash, 8 kByte RAM
Servo drive:	2x digital servo unit with 3.5 kg actuating force for control of head and tail sections2x digital servo units for wing torsion, with 45 degree travel in 0.03 s	Radio transmission:	868 MHz/2.4 GHz two-way radio transmission based on ZigBee Protocol
		Motor:	Compact 135, brushless



Sensors:	Motor positioning 3x TLE4906 Hall sensors
Accelerometer:	LIS302DLH
Power management:	2x LiPo accumulator cells with ACS715 voltage and current monitoring
LED activation:	TPIC 2810D

Project partners

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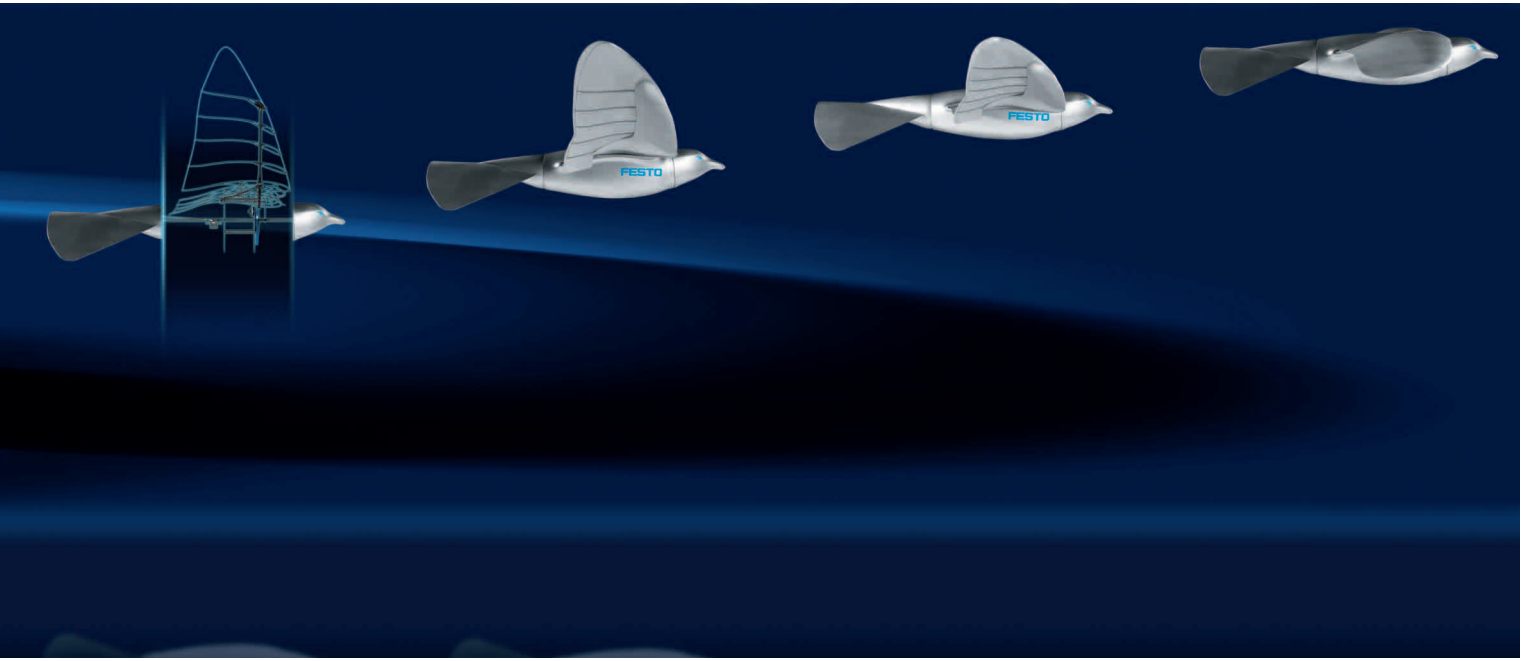

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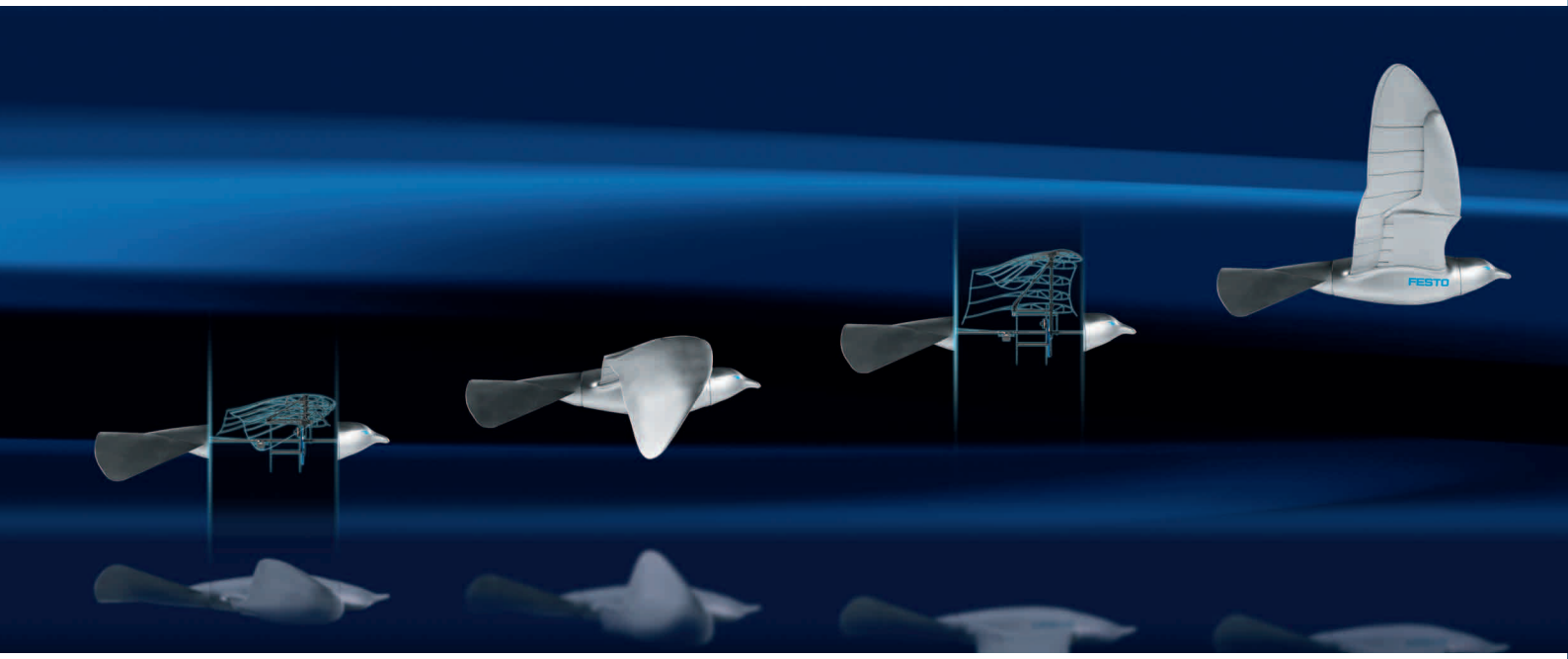
Taxidermist:
Jan Panniger



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