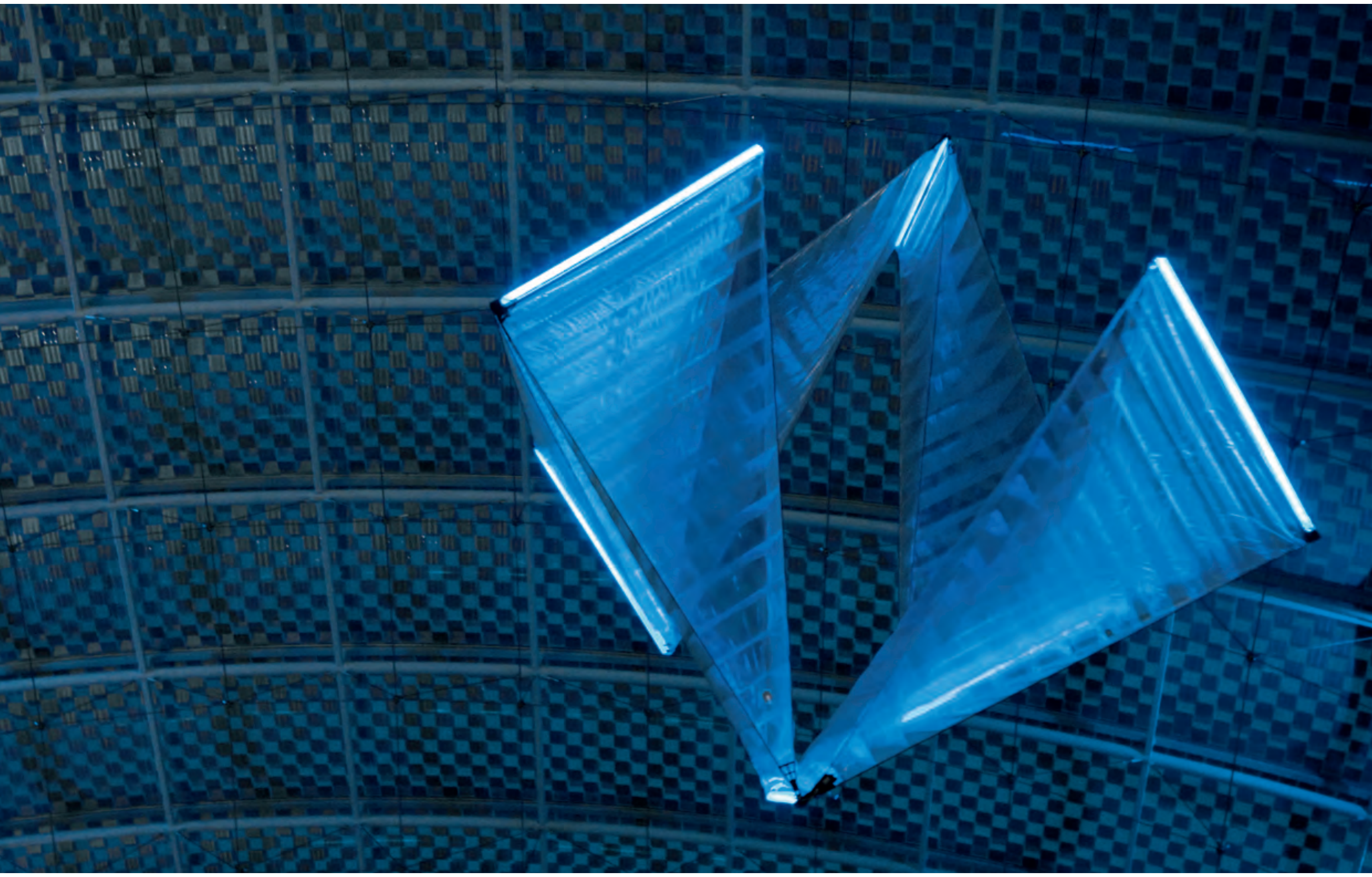
SmartInversion



Propulsion by turning inside-out

Airborne geometrical band with inversion drive

SmartInversion is a helium-filled flying object that moves through the air by turning inside-out. This constant, rhythmically pulsating movement is known as inversion and gives the flight model its name. With the intelligent combination of extreme lightweight construction, electric drive units and control and regulation technology, inversion kinematics can be indefinitely maintained to produce motion through the air.

Inversion kinematics after Paul Schatz

The shape of this flying object is based on the geometrical band devised by Paul Schatz. This Swiss artist and technician dissected a cube into two star-shaped units and an invertible geometrical band; this band comprises an articulated ring of six members that detaches itself from the two stationary units at the corners and constantly turns inside-out, taking on different geometrical shapes in the process.

With the geometrical band Schatz discovered that the principle of kinematics, which until then had been based on rotation and translation (linear motion), could be extended by a further mode: inversion.

Setting new standards in automation technology

As part of its Future Concepts programme, Festo is constantly searching for new or not yet widespread concepts of movement and propulsion. In cooperation with renowned universities, institutes and development companies, Festo transfers mathematical and scientific processes to industrial application. With SmartInversion, the engineers and designers are now investigating where and how geometrical inversion can be put to use in technology.

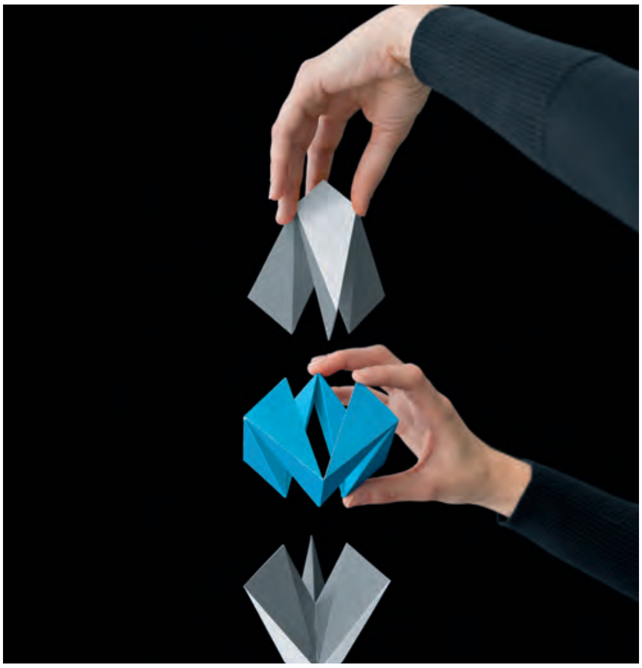
Inspiration for new drive concepts

Festo had previously concentrated on solutions based on the mechanical principles of rotation and translation. Rotary drives, servo motors and pneumatic and semi-rotary electric drive units operate on the principle of rotation. Linear axes and parallel grippers are examples of translational kinematics. This morphology could be extended by the principle of inversion.

Initial applications of the ideas of Paul Schatz already exist in industry, for example in the form of internal mixers or as oloid mixers for aerating and circulating standing waters.

Efficient: extremely light design for optimal flight characteristics

Intuitive: simple interactive control of highly complex processes



Model for the flying object: the geometrical band after Paul Schatz

An airborne geometrical band

To produce the invertible geometrical belt, the three “petals” of the docking station open up like a flower. The middle section – the helium-filled geometrical band – detaches itself from the star-shaped base, which remains in position as a docking station.
The helium compensates for the weight of the geometrical band and provides the flying object with buoyancy. 2,130 litres of helium are required to generate approximately 2,334 grams of buoyancy, so that the object can move through the air. The forward propulsion is generated by the inversion of the object; this principle can thus be referred to as an inversion drive.

Lightweight design with six identical prisms

The geometrical band is composed of six identical prisms. Each prism consists of two carbon-fibre end rods and four peripheral rods, likewise of carbon fibre; these together form the outer framework. Each of these structures is enclosed by a gas-tight membrane. The six individual prisms are filled with helium. Within each prism, 14 bulkheads keep the outer membrane in position, thereby maintaining the precise shape of the prism with geometrically correct angles.

Rhythmic alternation between expansion and contraction

The flying object is kept in motion by the pulsatory drive mechanism. The inversion is effected by the interplay between diastole and systole – in other words the rhythmic sequence of expansion and contraction.

Two phases of advance, two phases of rest: drive by inversion

In the course of a full rotation of the inversion process, the centre opens up and assumes the form of a triangle pointing downwards. In the next inversion phase, an upward facing triangle is formed. During these two phases, the geometrical band generates thrust and moves forward.

The triangle then closes twice in succession; SmartInversion generates no thrust during these two phases and remains stationary. In an analogy from nature, this is comparable to the peristaltic propulsion of a jellyfish.

Inversion with no dead centre

To support the inversion process, the three servo motors are coordinated in parallel by an onboard unit. Depending on the phase, two of the servo units advance and one operates in retrograde.

During certain phases, however, the servo motors are required to operate in contrary motion. For this purpose, the mathematical model of the geometrical band is stored in four phases in the onboard unit, which controls the servo motors by this means. Inversion without a dead centre is thereby ensured, so the inversion process can be initiated at any point.

Process-safe operation with condition monitoring

While SmartInversion is in motion, data such as battery charge level and power consumption are recorded and analysed in real time. The principle of permanent diagnostics guarantees Festo process-safe operation in automation technology.

Inspiring: pulsatory drive by turning inside-out

Process-safe: continuous real-time diagnostics

Technical data

- Edge length: 1.82 m
  At greatest extension approx. 4.75 m from edge to edge
- Helium volume: 2.130 m^3
- Mass: 2.334 kg
- Framework structure: highly rigid carbon-fibre tubing
- Drives: proportional servo motors
- Battery: two-cell 8.4 V lithium polymer accumulator, capacity 450 mAh
  Remote radio control, 2.4 GHz, bidirectional
- Onboard unit: LM3S5749 processor, ARM Cortex
- Flight duration: approx. 15 minutes

Paul Schatz
Paul Schatz was born on 22nd December, 1898 in Constance, Germany. Already as a twelve-year-old, he replicated large aircraft prototypes on a reduced scale in balsa wood. After the First World War, Paul Schatz initially studied engineering at the Technical University of Munich and in Hanover. Following his apprenticeship as a wood sculptor he also undertook intensive study of Rudolf Steiner's anthroposophy, which gave him renewed access to the natural sciences and mathematics.

Through his artistic dealings with matters of space and the zodiac, Paul Schatz discovered the invertible nature of the Platonic solids in 1929. In particular, the invertible cube that he derived from these geometrical principles and its inherent rhythmical movement constituted the basis of the entire subsequent scientific activity of Paul Schatz.

The Paul Schatz Foundation and the Paul Schatz Society
The Paul Schatz Foundation (based in Basel) and the Paul Schatz Society (based in Stuttgart) have assumed the task of preserving the estate of Paul Schatz and making it accessible to the public. The Archives with the scientist's written, sculptural and technical heritage are located in Basel. The German Paul Schatz Society promotes these objectives, above all with projects in Germany.

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