BECKHOFF

ICALEPCS 2021

XPlanar by Beckhoff – Magnetic Levitation for any Application

October 15, 2021

Introduction Beckhoff Automation

BECKHOFF

Introduction Beckhoff Automation

BECKHOFF

Sales & Support: 1500 experts!

IPC
234,000
(incl. 53,000
CX ARM based)

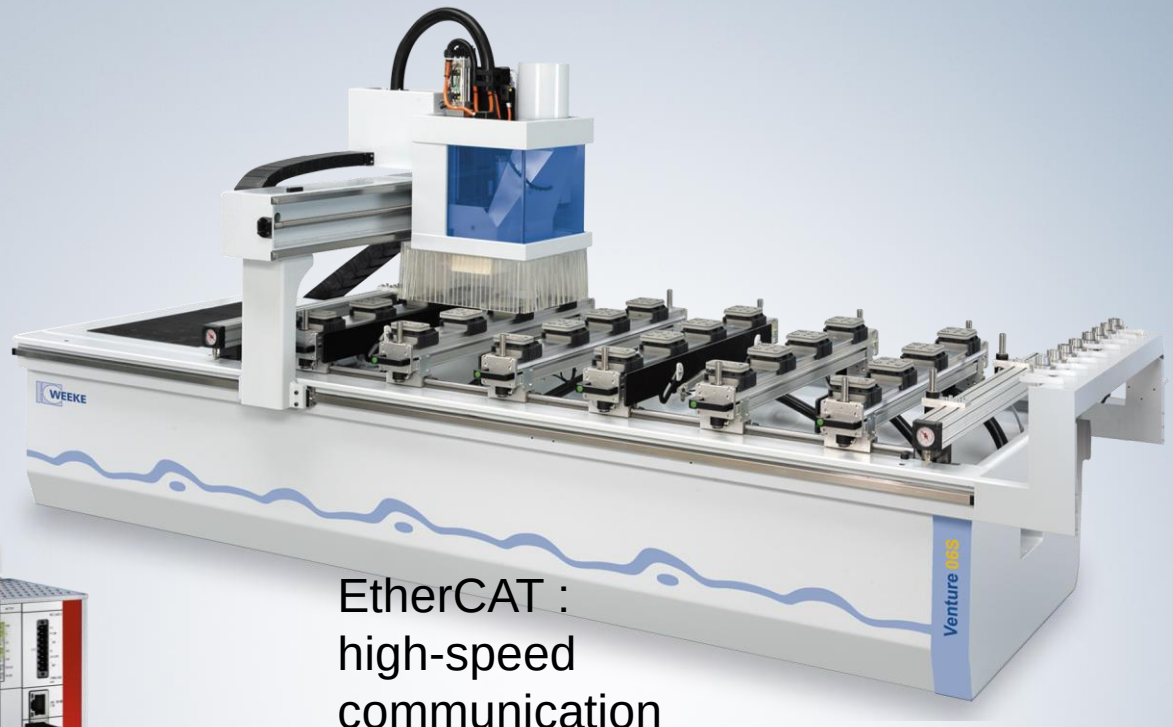
I/O
5,700,000

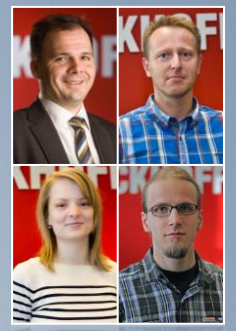
Motion
98,000 Motors
57,000 Drives
+79,000 Servo/
Stepper-Terminals

Automation
320,000
incl. 138,000
Supplements

Beckhoff Automation
Controls for machines: PC-based Automation

BECKHOFF





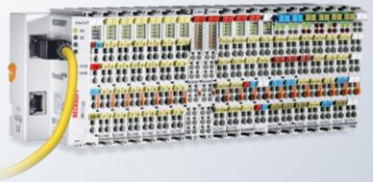
Expertise & Support

Control Panel

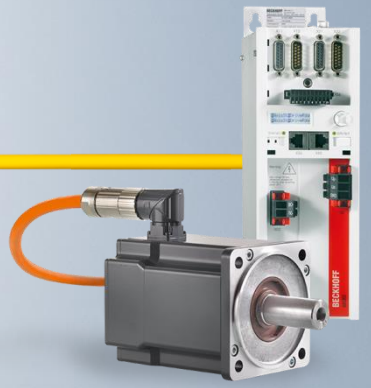
Industrial PC

EtherCAT : high-speed communication

TwinCAT: control & real-time software



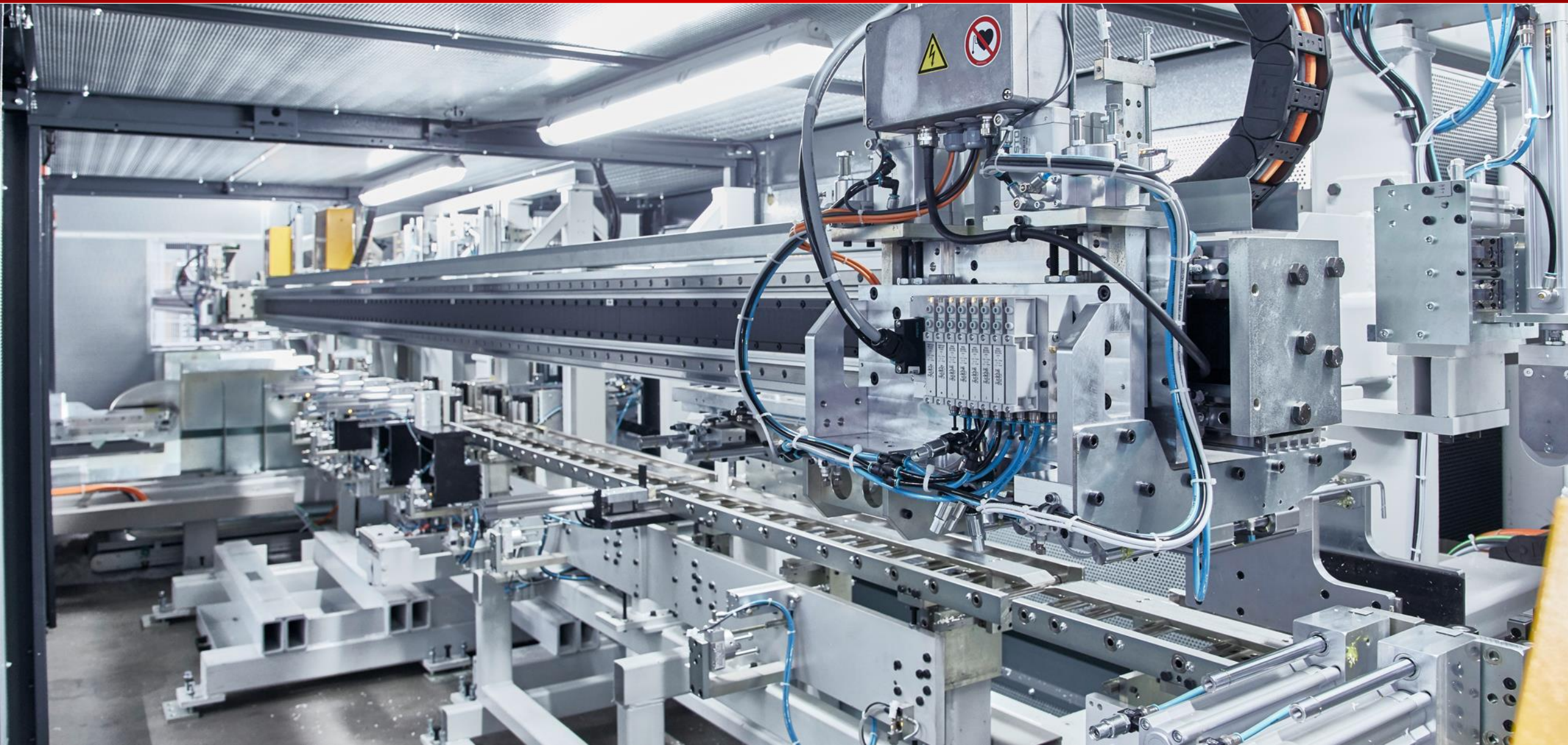
Bus Terminals



Drive Technology

Schirmer Maschinen GmbH

BECKHOFF



Beckhoff: System solutions for Wind Energy Generation

BECKHOFF

European XFEL, Germany
High-performance X-ray laser

BECKHOFF

Beckhoff Automation
Controls for science: Grand Magellan Telescope, Chile/USA

BECKHOFF

European Southern Observatory ESO
Very Large Telescope (VLT), Paranal Observatory, Chile

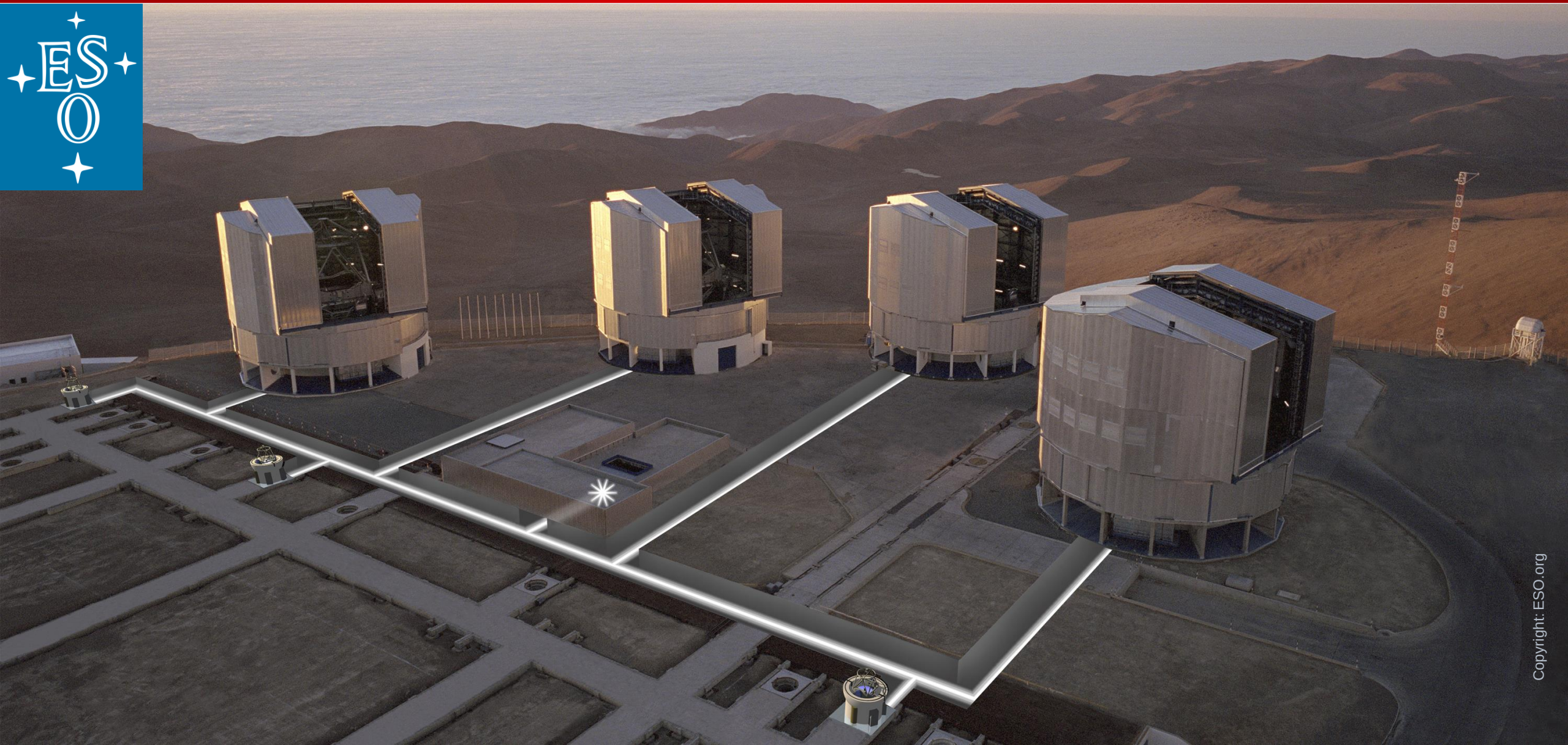
BECKHOFF

European Southern Observatory ESO
Very Large Telescope (VLT), Paranal Observatory, Chile

BECKHOFF

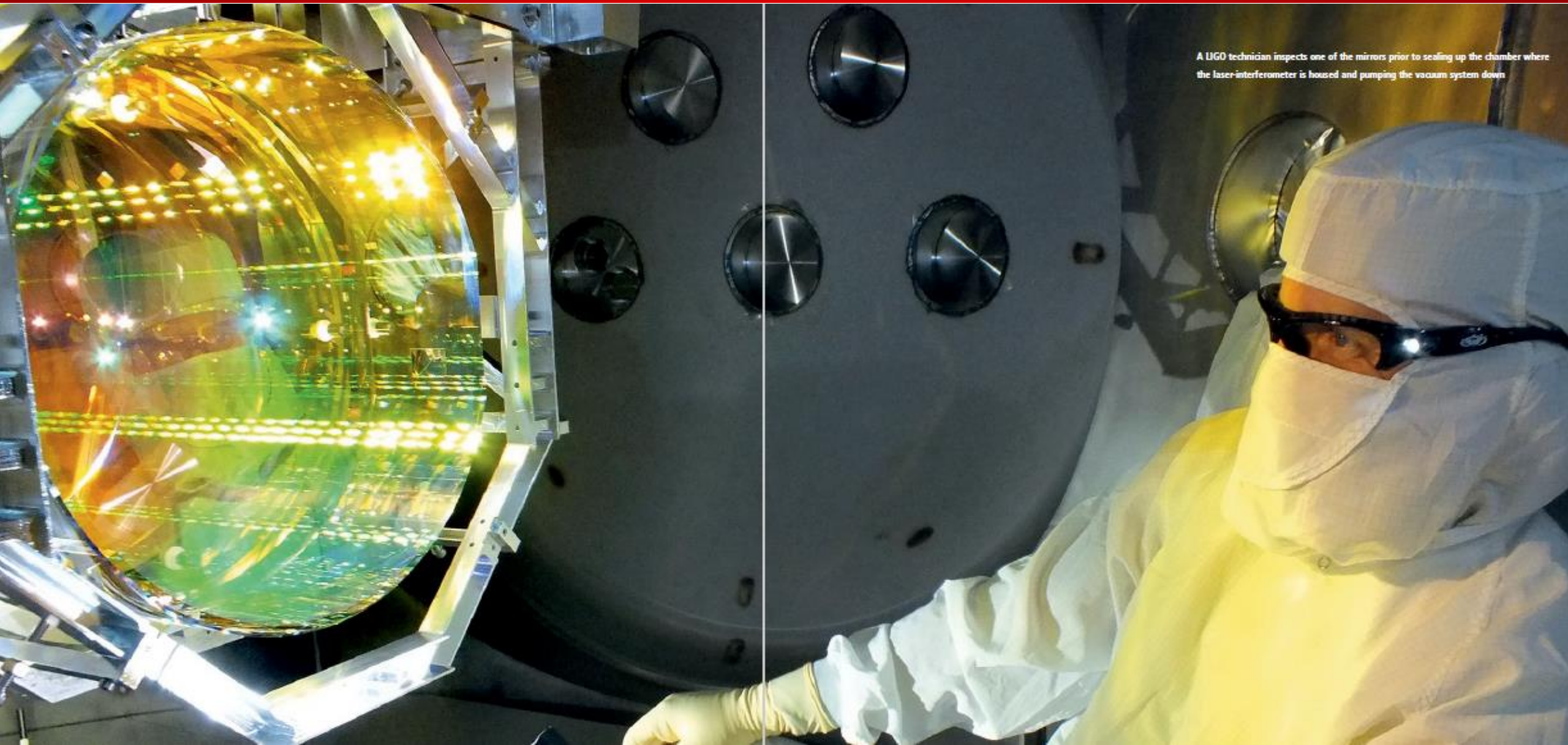
European Southern Observatory ESO
Very Large Telescope (VLT), Paranal Observatory, Chile

BECKHOFF



LIGO Observatories put PC-based control and industrial Ethernet to work for laser interferometers

BECKHOFF



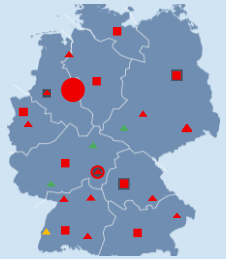
A LIGO technician inspects one of the mirrors prior to sealing up the chamber where the laser-interferometer is housed and pumping the vacuum system down


PRADA
Emirates
FLY BETTER
OMEGA
TOYOTA
Emirates
FLY BETTER
skycity
5G
TOYOTA
OMEGA
OMEGA
PRADA

Business facts and figures as of October 2021

BECKHOFF

Verl, Germany

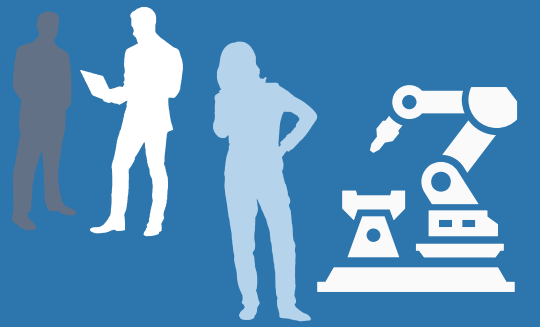


Headquarters

4900

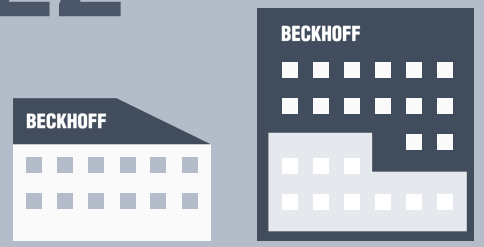
Employees worldwide (actual)

1900



Engineers

22

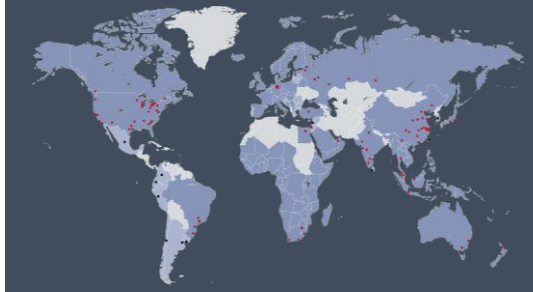


Sales and business locations in Germany

39

International subsidiaries

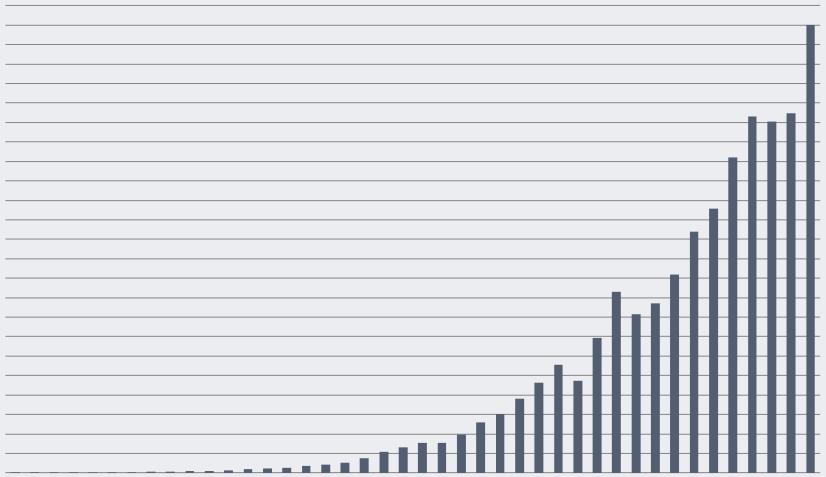
>75



Represented in more than 75 countries worldwide by cooperation partners

€1150 million
(expected 2021)

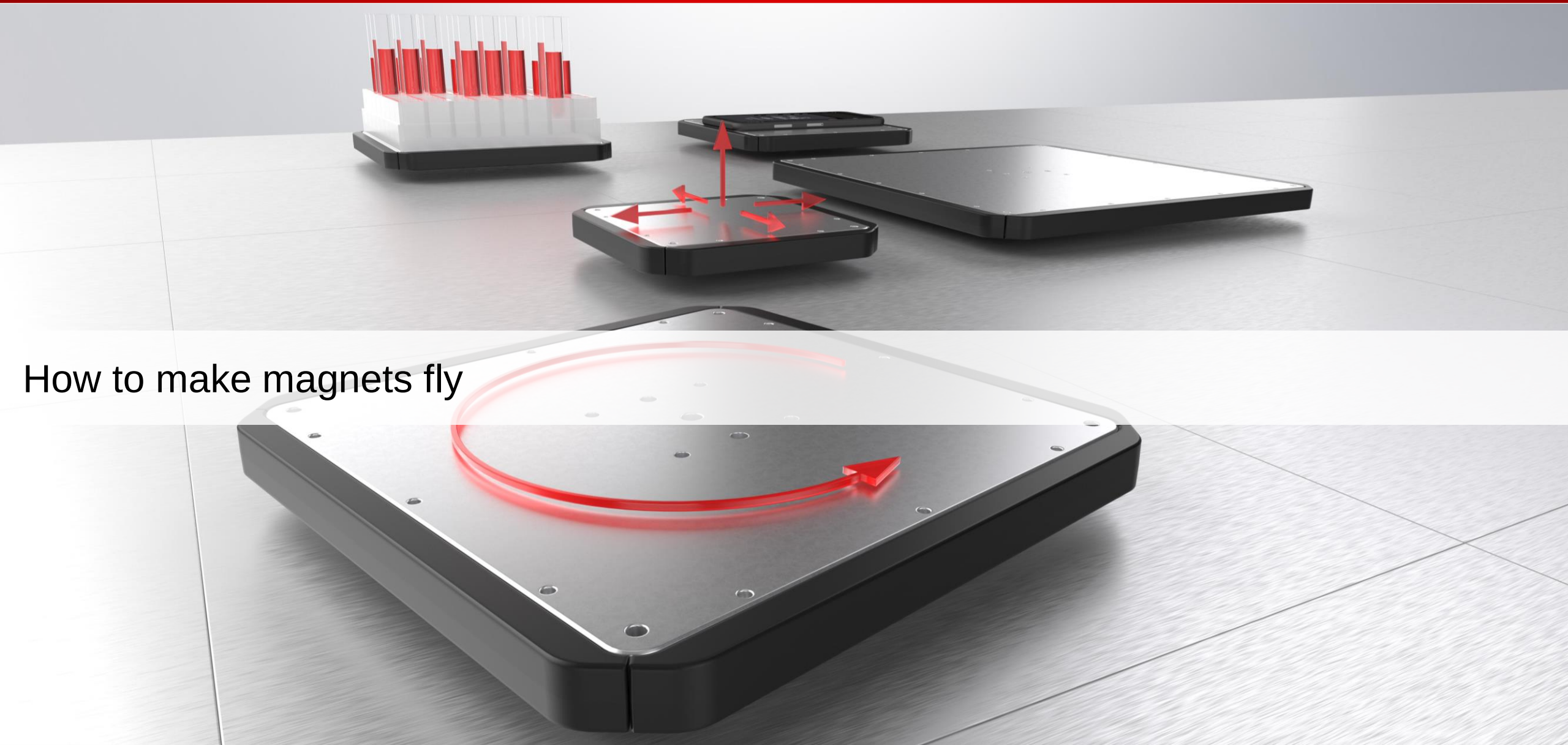
+25%



Sales worldwide 2021

Different Planar Motor Approaches

BECKHOFF

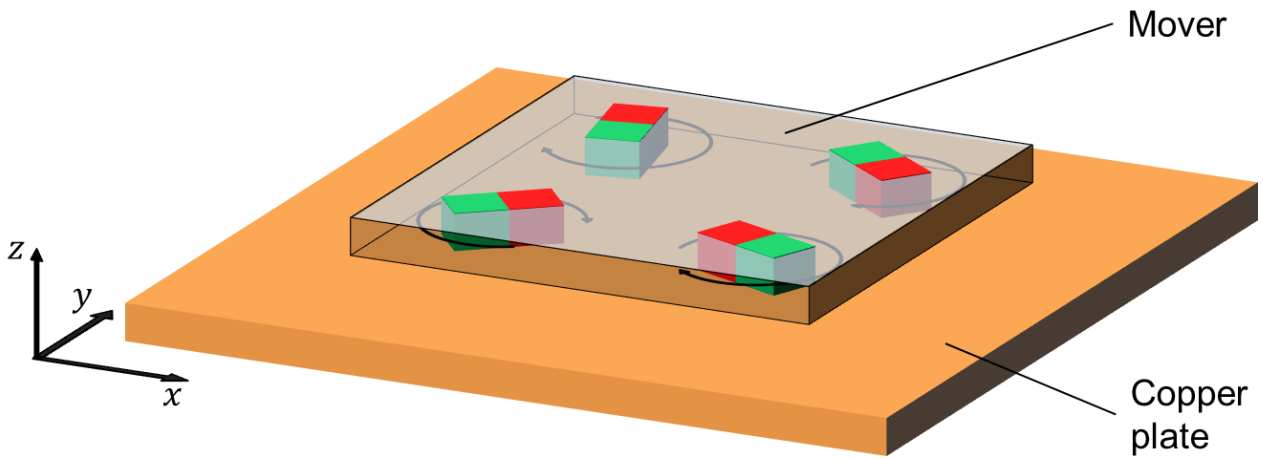


How to make magnets fly

Hoverboard

BECKHOFF

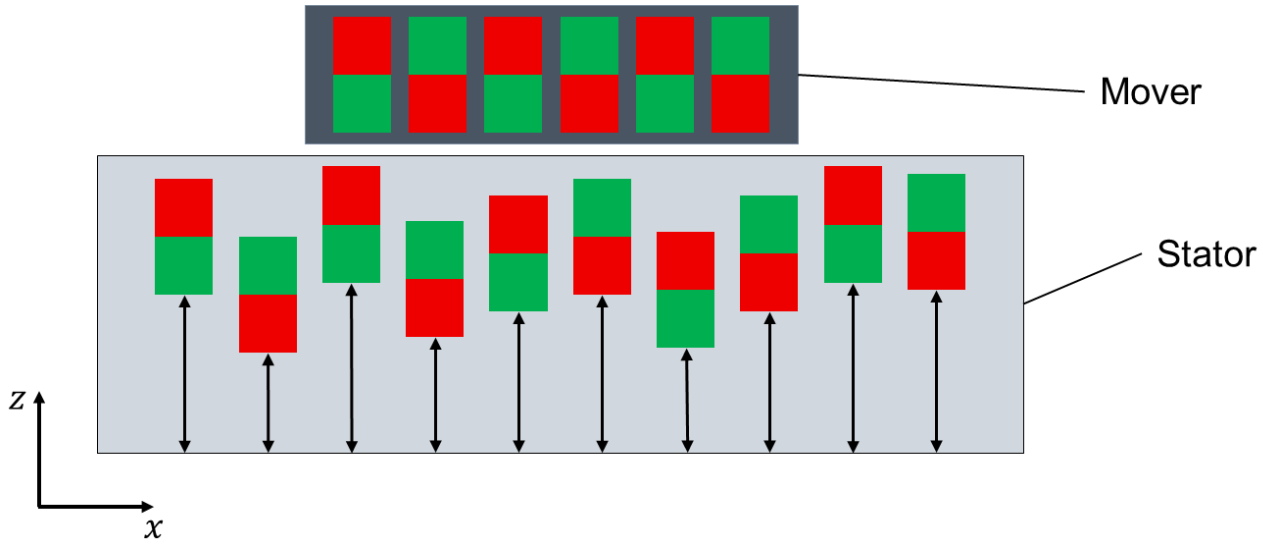
- Mover with rotating magnets
- Copper plate stator
- Eddy currents in the copper generate a repulsive force on the mover
- Pros
  - Strong forces
  - Simple stator
- Cons
  - High energy consumption
  - Mover needs a cable supply
  - Mechanics in the mover
  - Position feedback hard to realize
  - Heat generation in the copper



Repulsion of Permanent Magnets

BECKHOFF

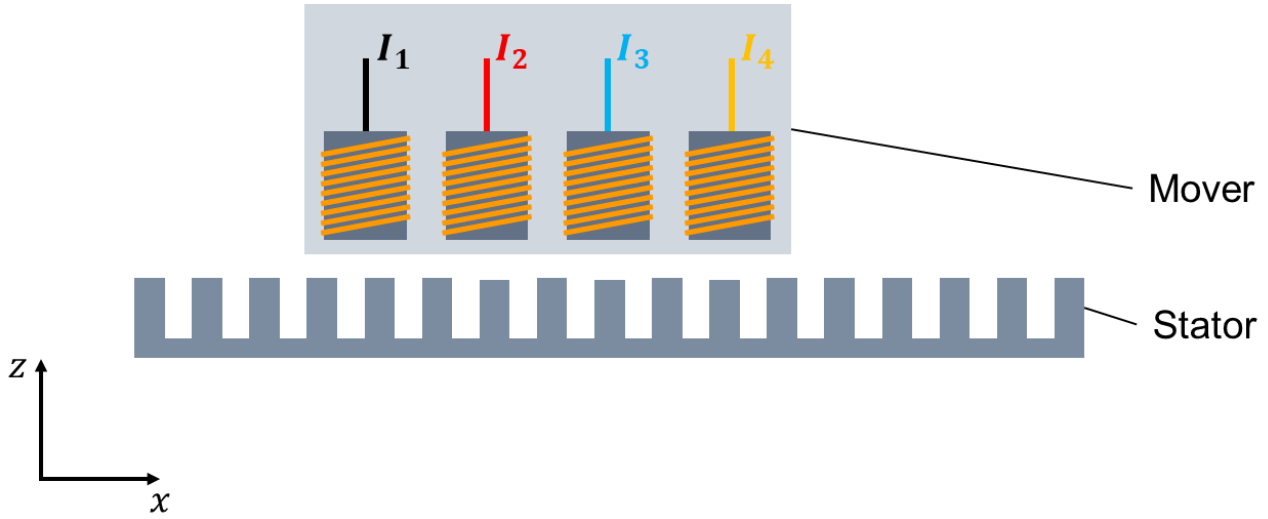
- Interaction between permanent magnets in the stator and in the mover
- Stator magnets are adjusted mechanically to generate the desired force
- Pros
  - Strong forces
  - Mover is attracted to stator in case of power outage
- Cons
  - Complex control
  - Mechanics in the stator
  - Position feedback is hard to realize

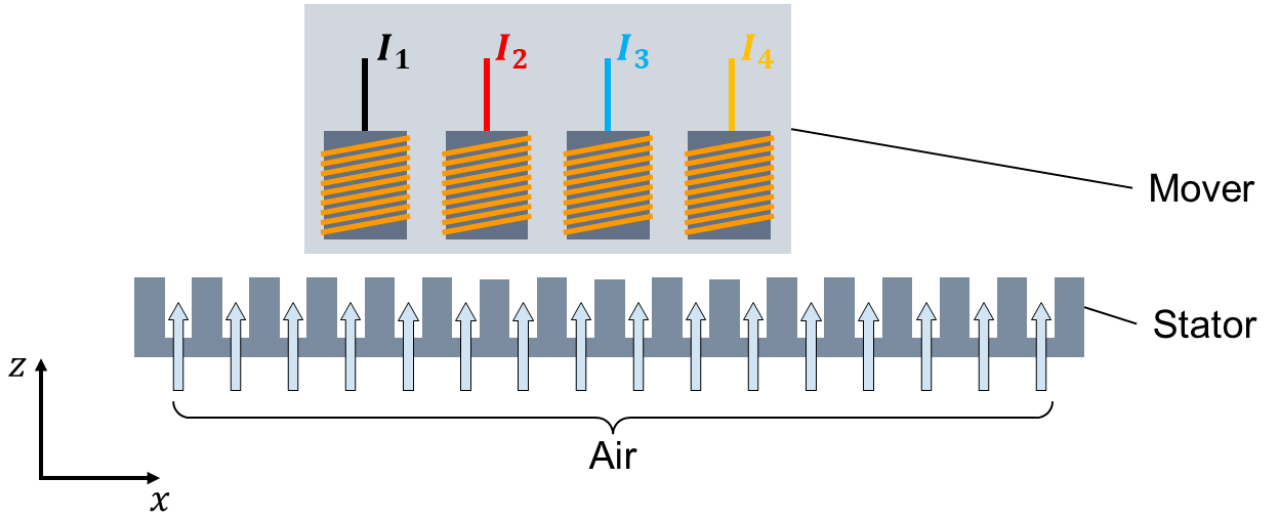


Planar reluctance motor

BECKHOFF

- Coils in the mover
- Iron comb structure in the stator
- Energize the mover coils so that the mover is attracted to the next spike in the comb structure
- Levitation due to air bearing
- Pros
  - High precision
  - Strong forces
- Cons
  - Mover needs a cable supply
  - Limited area
  - Compressed air

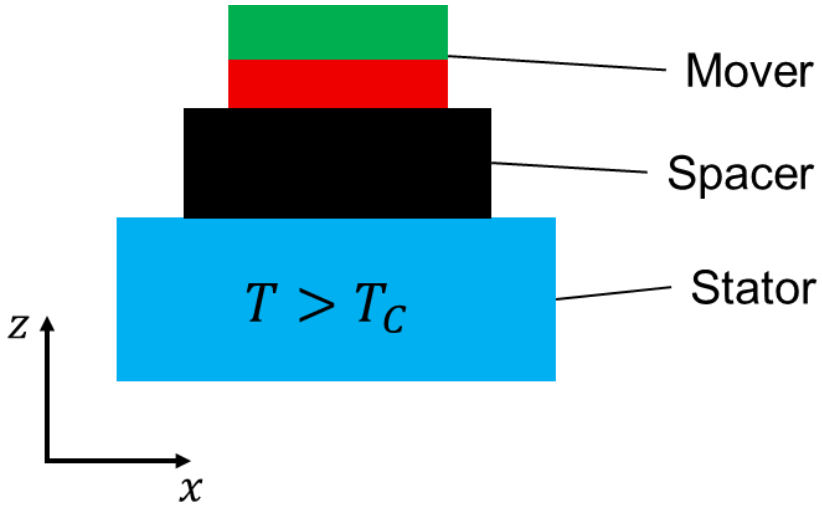


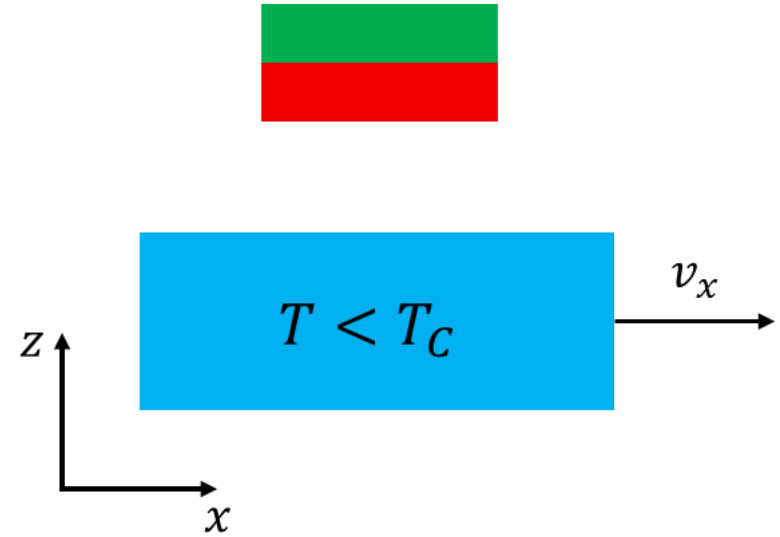


Supraconductivity

BECKHOFF

- Supra conducting stator
- Permanent magnet mover
- Movement is achieved by moving the stator
- Pros
  - No control of the mover is necessary
  - Strong forces
  - High levitation height
  - Low power consumption
- Cons
  - Low temperatures < -200 °C
  - Poor dynamics
  - Mechanics to move the stator
  - Spacer is needed for the the initial distance
  - Bulky construction

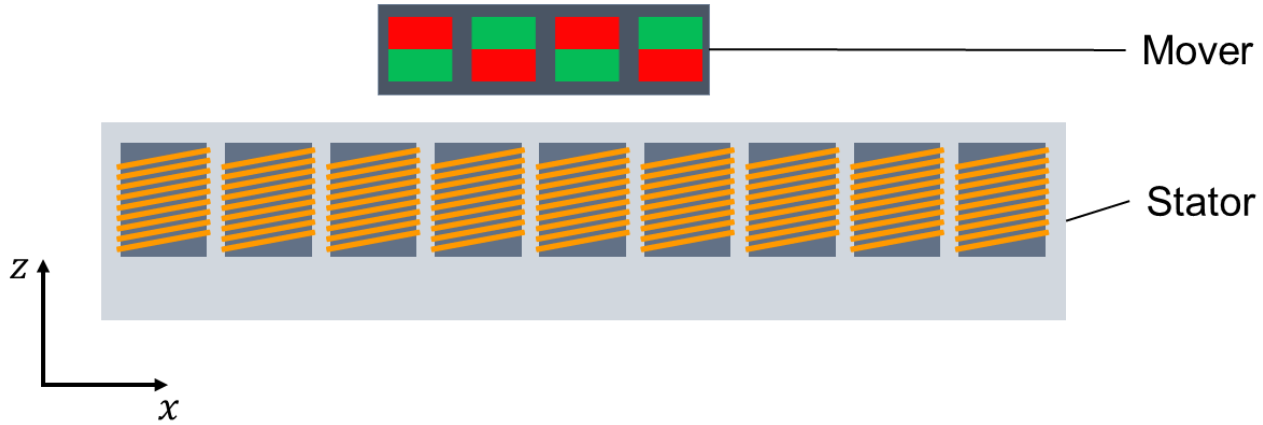


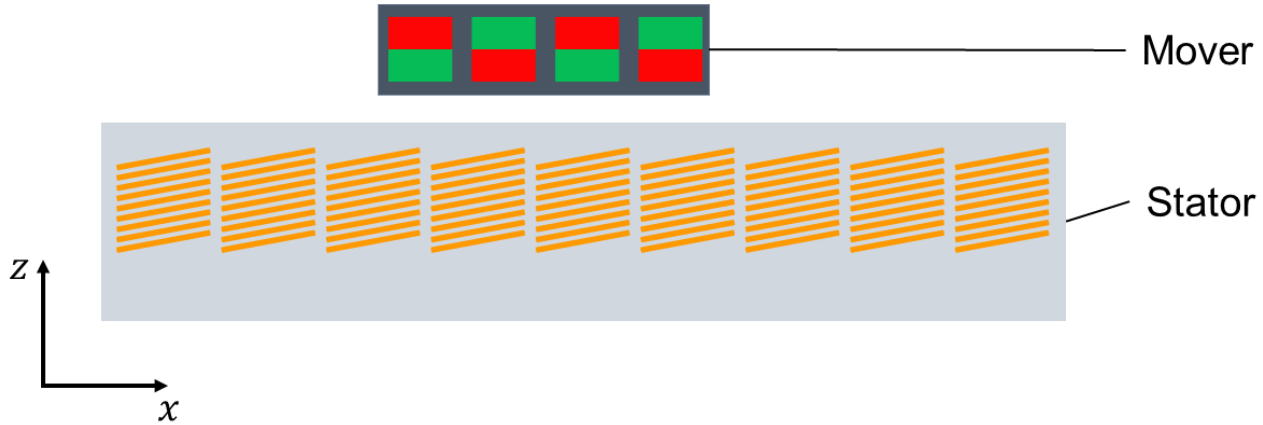


Lorentz Force

BECKHOFF

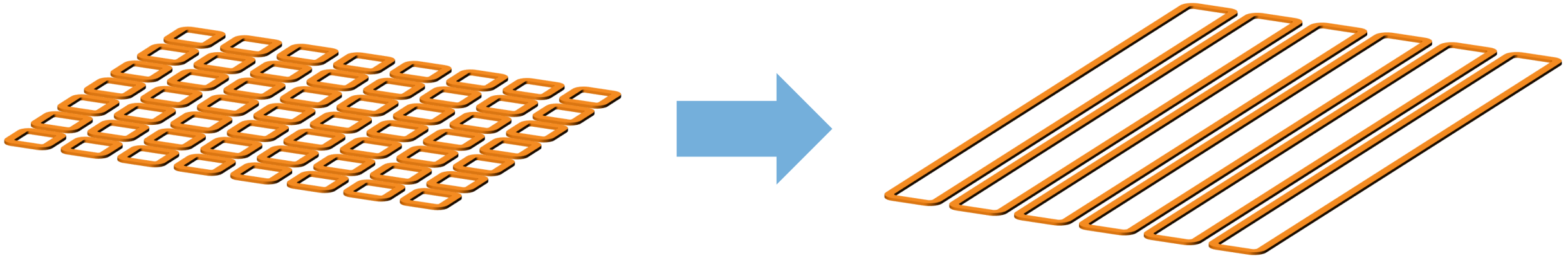
- Coils in the stator
- Permanent magnets in the mover
- Current in the coils can be adjusted so that the mover is flying
- Ironless coils due to the attraction beteween magnets and iron
- Pros
  - Purely passive mover
  - Modular
  - Individual control of multiple movers
- Cons
  - Small forces
  - High requirements for the control





Long rectacular coils

BECKHOFF



Force Generation on the Magnets

BECKHOFF

- Generated force can be calculated via Lorentz force

$$\overrightarrow{F_L} = \vec{I} \times \vec{B}$$

- Magnetic field of magnets in Y-direction

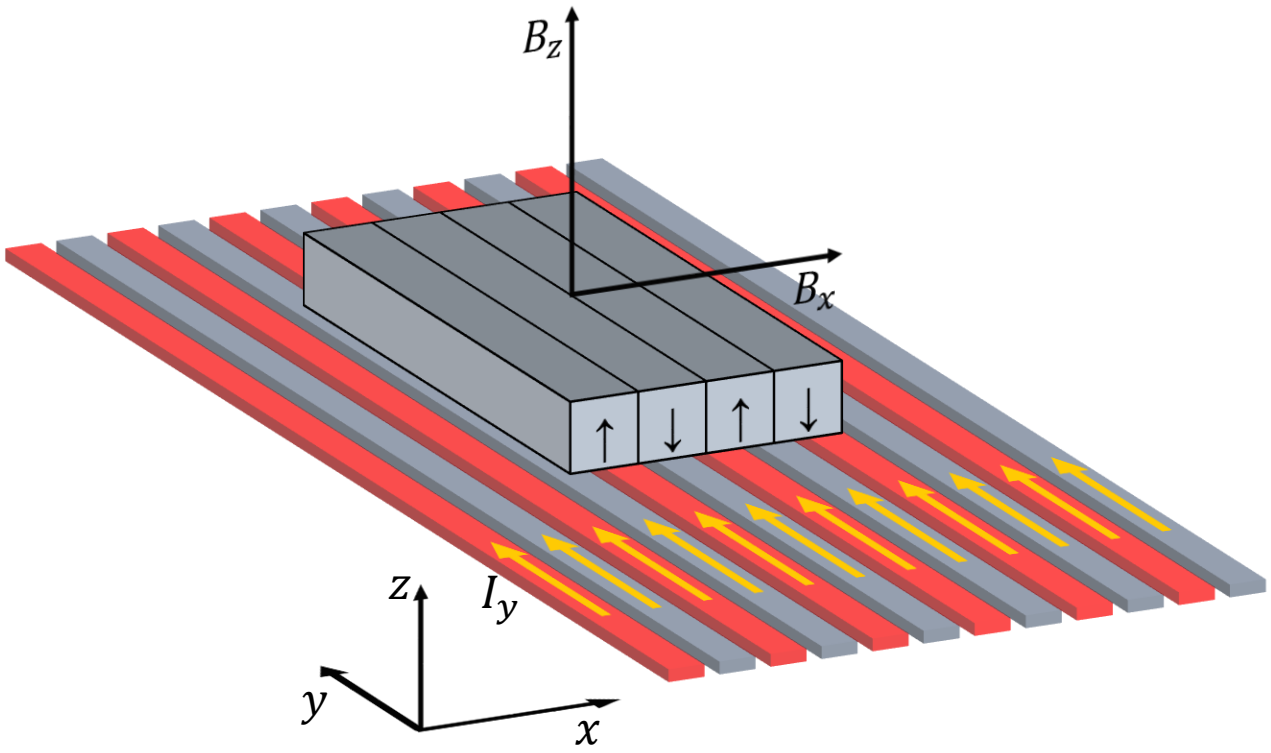
$$\vec{B} = \begin{pmatrix} B_x \\ 0 \\ B_z \end{pmatrix}$$

- Current of conductors in Y-direction

$$\vec{I} = \begin{pmatrix} 0 \\ I_y \\ 0 \end{pmatrix}$$

- Resulting force on the mover

$$\overrightarrow{F_L} = \begin{pmatrix} I_y B_z \\ 0 \\ -I_y B_x \end{pmatrix} = \begin{pmatrix} F_x \\ 0 \\ F_z \end{pmatrix}$$



Force Generation on the Magnets

BECKHOFF

- Magnetic field of magnets in X-direction

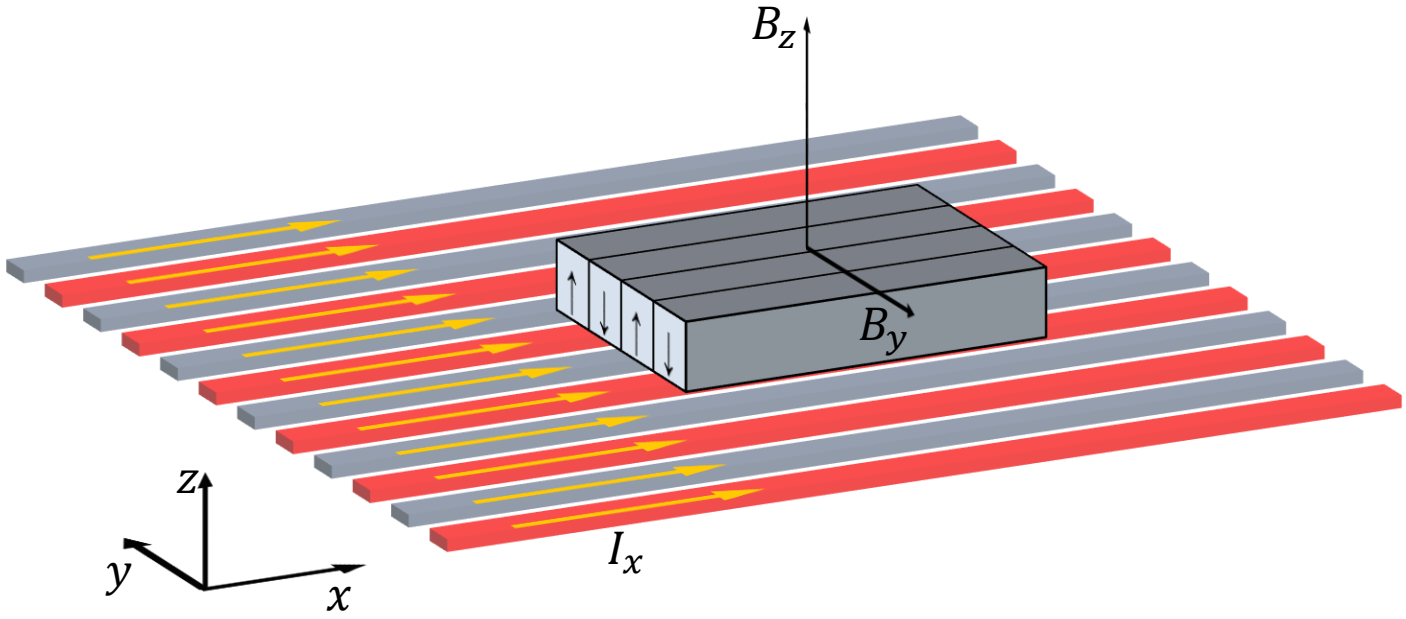
$$\vec{B} = \begin{pmatrix} 0 \\ B_y \\ B_z \end{pmatrix}$$

- Current of conductors in X-direction

$$\vec{I} = \begin{pmatrix} I_x \\ 0 \\ 0 \end{pmatrix}$$

- Resulting force on the mover

$$\overrightarrow{F_L} = \begin{pmatrix} 0 \\ -I_x B_z \\ I_x B_y \end{pmatrix} = \begin{pmatrix} 0 \\ F_y \\ F_z \end{pmatrix}$$



Force Generation on the Magnets

BECKHOFF

- Magnets and conductors in Y-direction

$$\overrightarrow{F_L} = \begin{pmatrix} F_x \\ 0 \\ F_z \end{pmatrix}$$

- Magnets and conductors in X-direction

$$\overrightarrow{F_L} = \begin{pmatrix} 0 \\ F_y \\ F_z \end{pmatrix}$$

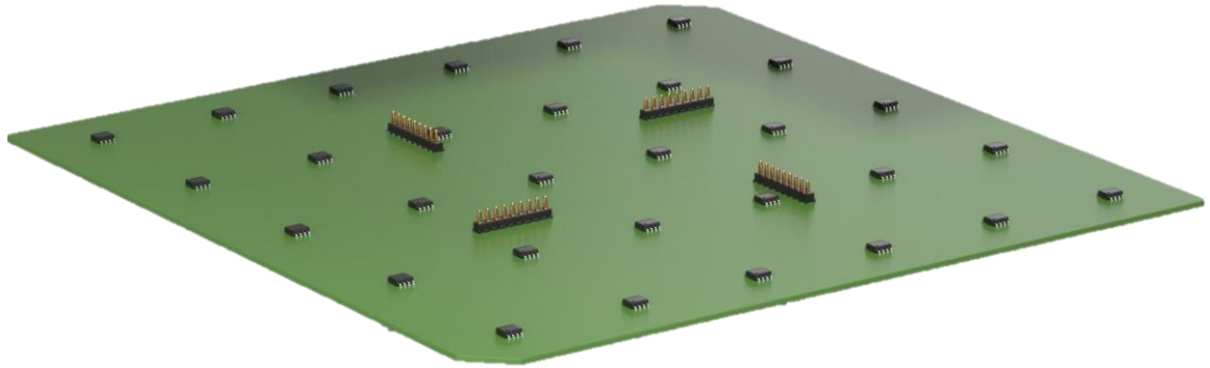
- Put conductors in X- and Y-direction in the stator
- Put magnets in X- and Y-direction in the mover
- To move in X-direction: energize Y-conductors
- To move in Y-direction: energize X-conductors

Position Feedback

BECKHOFF

- Magnetic field of the mover is much higher than the magnetic field generated by the coils

- Mover magnetic field can be measured by e.g. Hall sensors



Basic structure of the XPlanar tile

BECKHOFF

- The XPlanar tile is a fully integrated drive
  - 240 x 240 x 67 mm^3
- Integration of all necessary electrical components
  - Power supply
  - Feedback
  - Power electronics
  - Stator PCB
- Multiple tiles can be arranged next to each other to form a large area above which movers can fly

The XPlanar Tile

BECKHOFF

XPlanar Hardware Structure

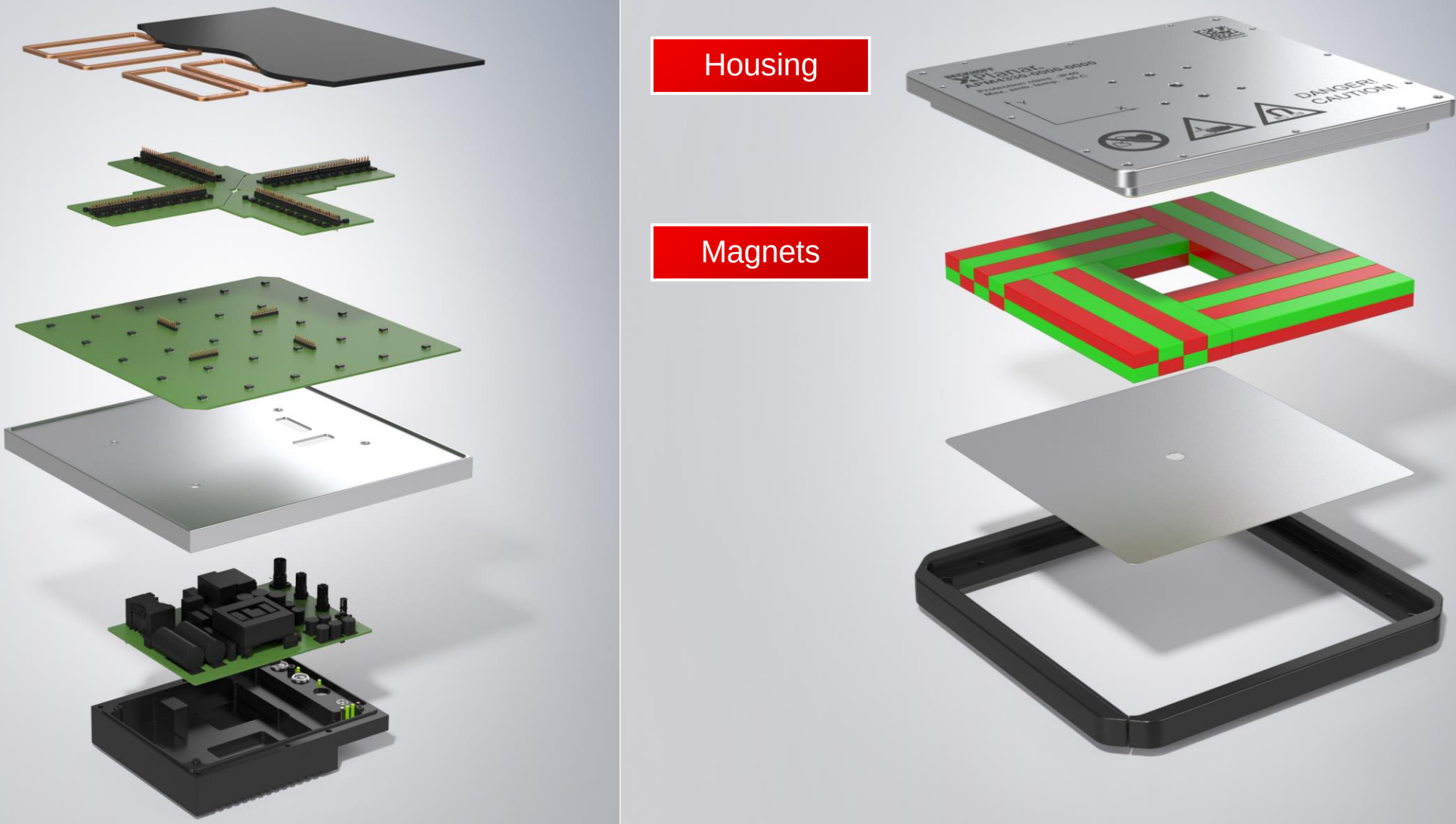
BECKHOFF

Stator Coils

Power transistors

Feedback

Power supply



Housing

Magnets

System Architecture | PC-Based Control

BECKHOFF

TwinCAT
software platform for
control and engineering

Industrial PC
scalable hardware platform

XPlanar mover
free positioning
in 3 sizes

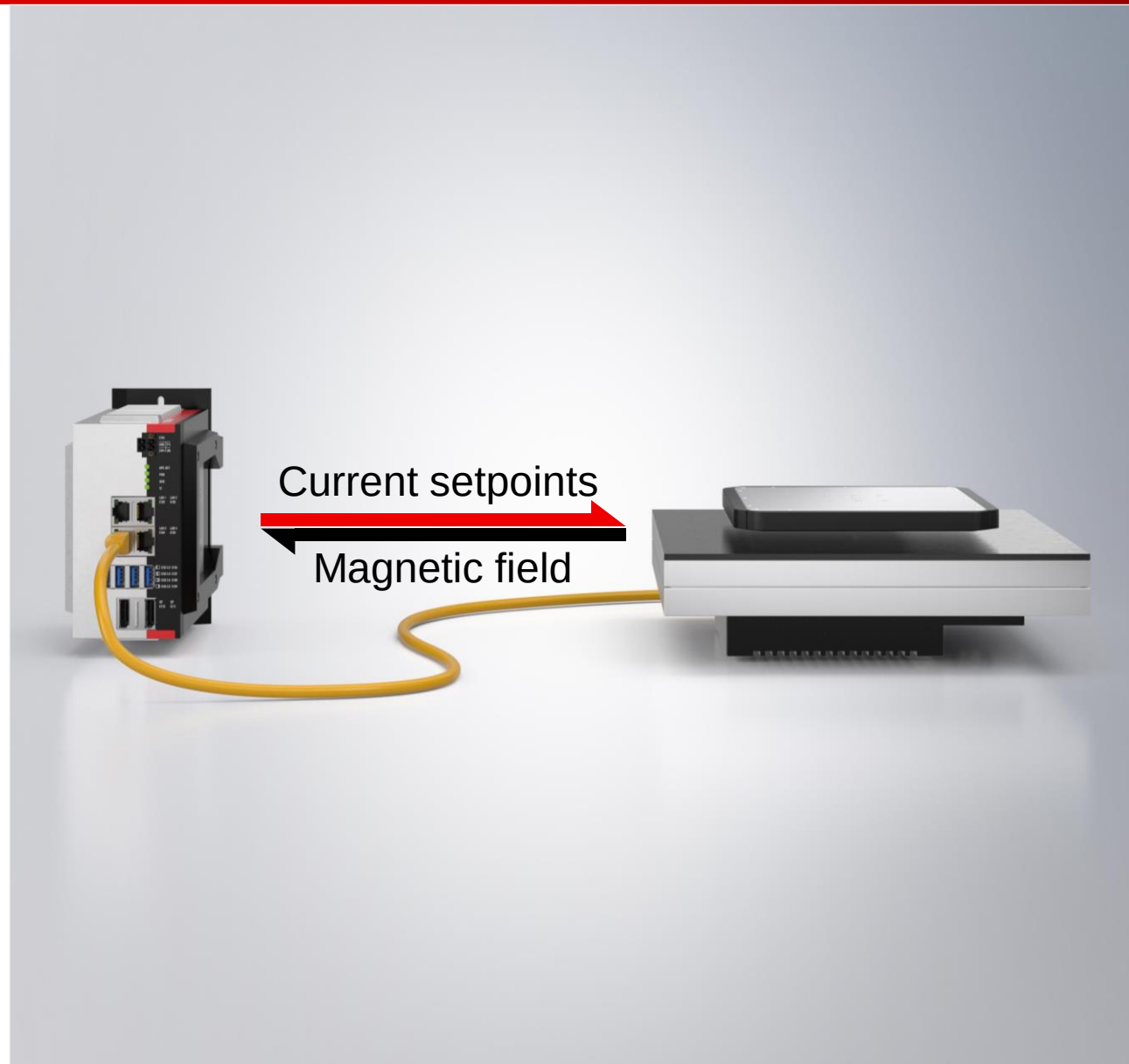
XPlanar tiles
free layout
configuration

EtherCAT G fieldbus
high performance

Benefits of Beckhoff Control System

BECKHOFF

- **EtherCAT**
  - Each tile provides more than 500 Byte of data
    → over 8 kByte for one squaremeter
  - EtherCAT is able to perform the communication in just a few µs

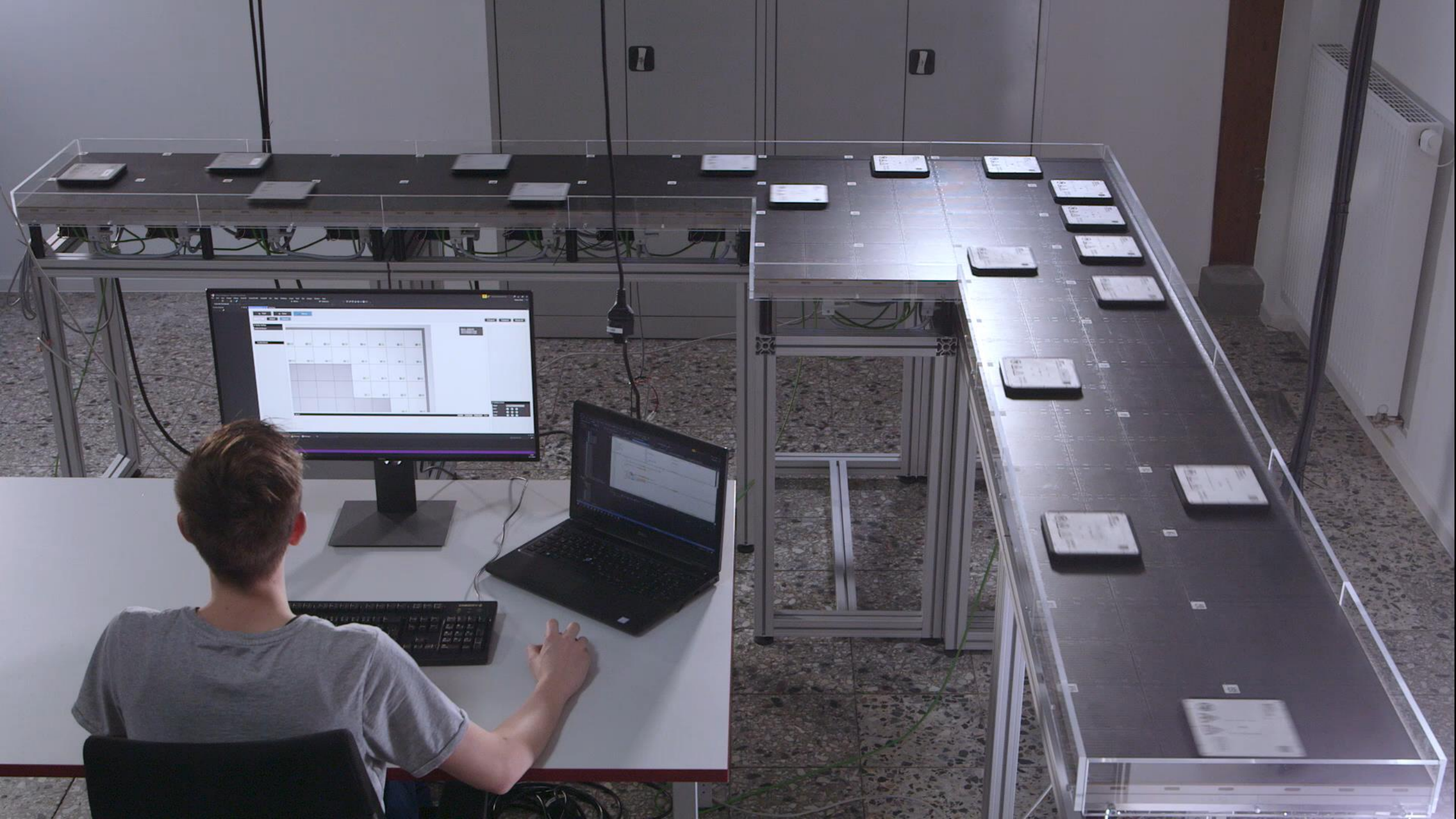


Benefits of Beckhoff Control System

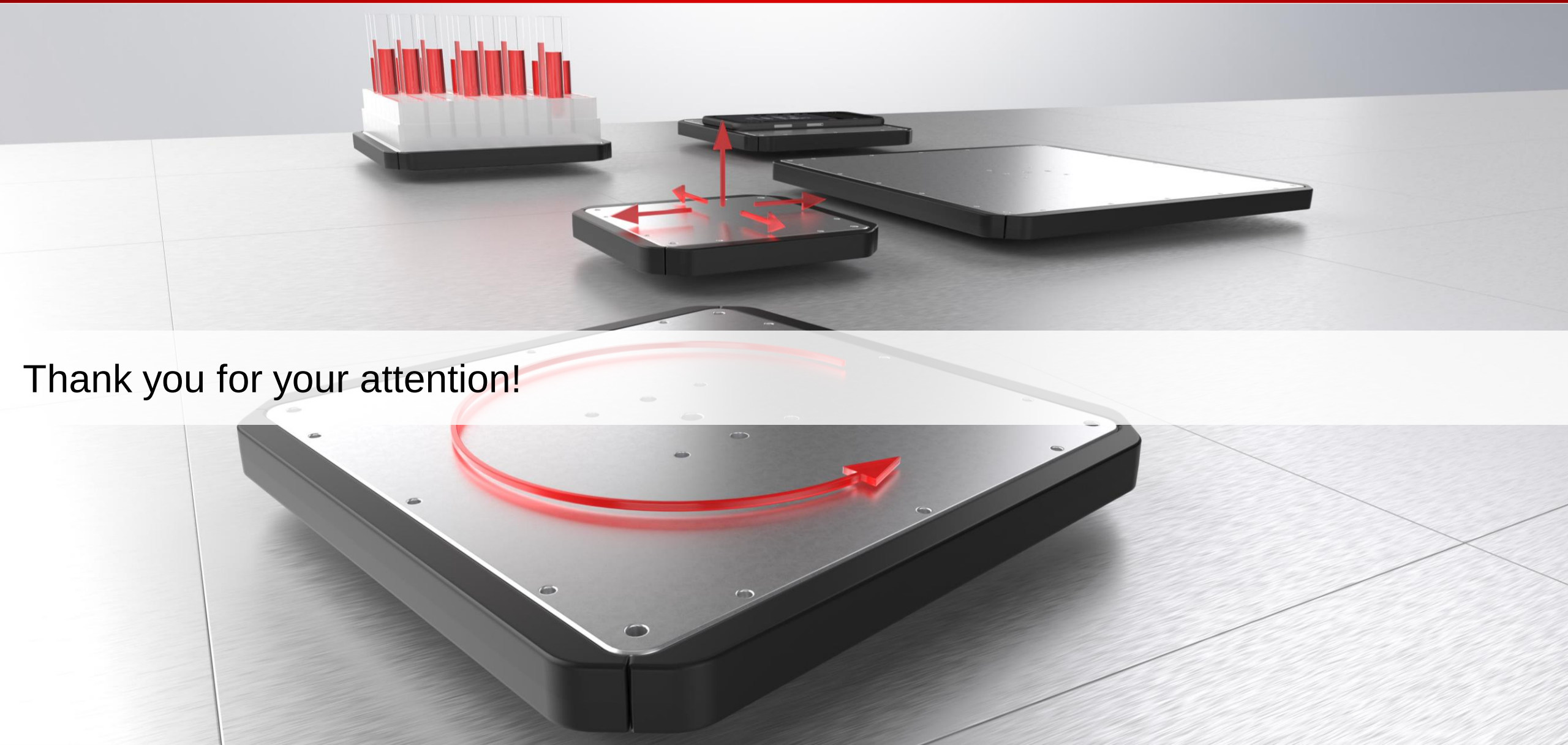
BECKHOFF

- **PC based control**
  - One central intelligence that knows all the data of the complete system
    - Easy multi mover control
  - Deterministic real time allows cycle times << 1 ms
  - XPlanar benefits from manycore technologie
    - Calculations are split over more than 20 CPU cores
  - Special algorithms such as the position feedback or 6D position control can be implemented without restrictions
    - TwinCAT functions allow XPlanar to use e.g. neural networks in real time


XPlanar



BECKHOFF



Thank you for your attention!

Contact

BECKHOFF

Beckhoff Automation GmbH & Co. KG
Headquarters
Huelshorstweg 20
33415 Verl
Germany

Phone: +49 5246 963-0
E-mail: info@beckhoff.com
Web: www.beckhoff.com