

# The Benefits of Magnetic Levitation in Neutron Choppers

September 18, 2012

ISIS Design of Neutron Instruments Meeting (DENIM)

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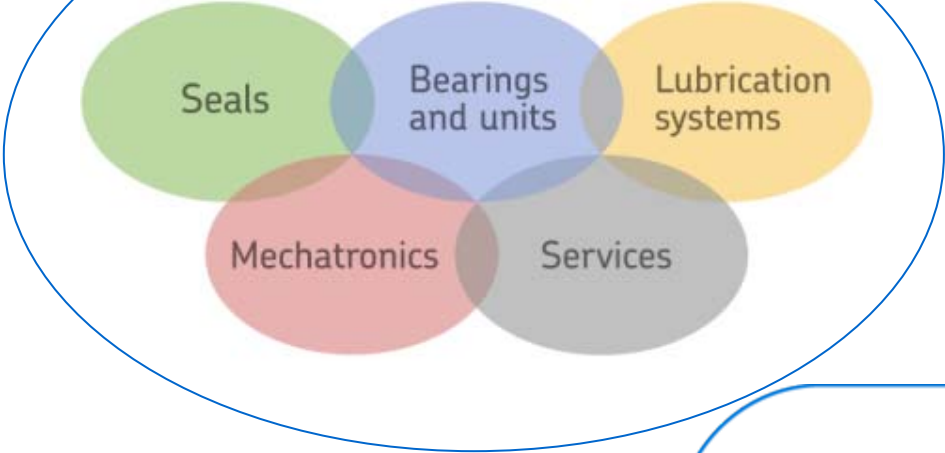
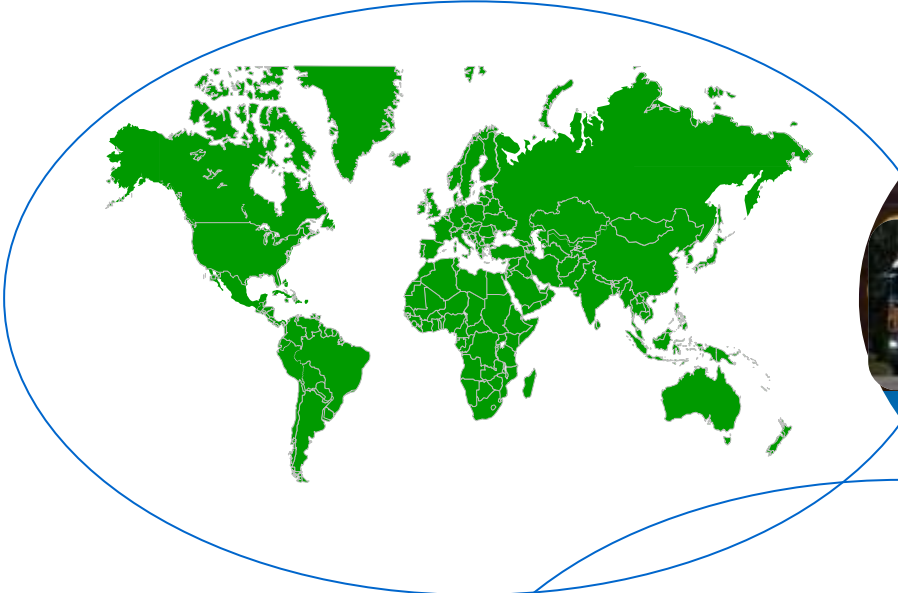
# Introduction to SKF

Magnetic Bearings - how they work

Advantages of Magnetic Bearings for Neutron Choppers

SKF Neutron Chopper Experience Base

# SKF Knowledge



# SKF Magnetic Systems Unit – Covering the Globe



**Calgary, Canada**  
SKF Magnetic Bearing HQ  
Eng, Sales and Service

**Vernon, France**  
S2M HQ  
Eng, Sales & Service

**Moscow**  
Sales

**Philadelphia**  
Sales & Service

**Middle East**  
Sales

**Tokyo**  
Sales



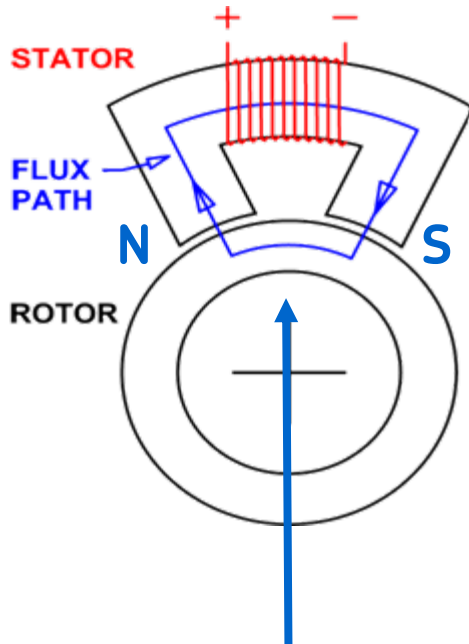
Introduction to SKF

**Magnetic Bearings - how they work**

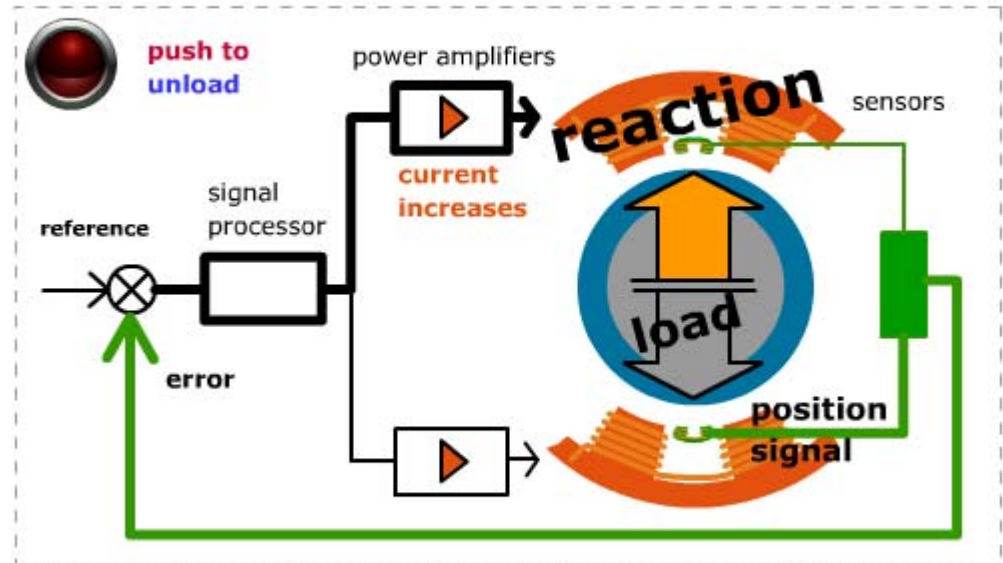
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# Technology – how it works



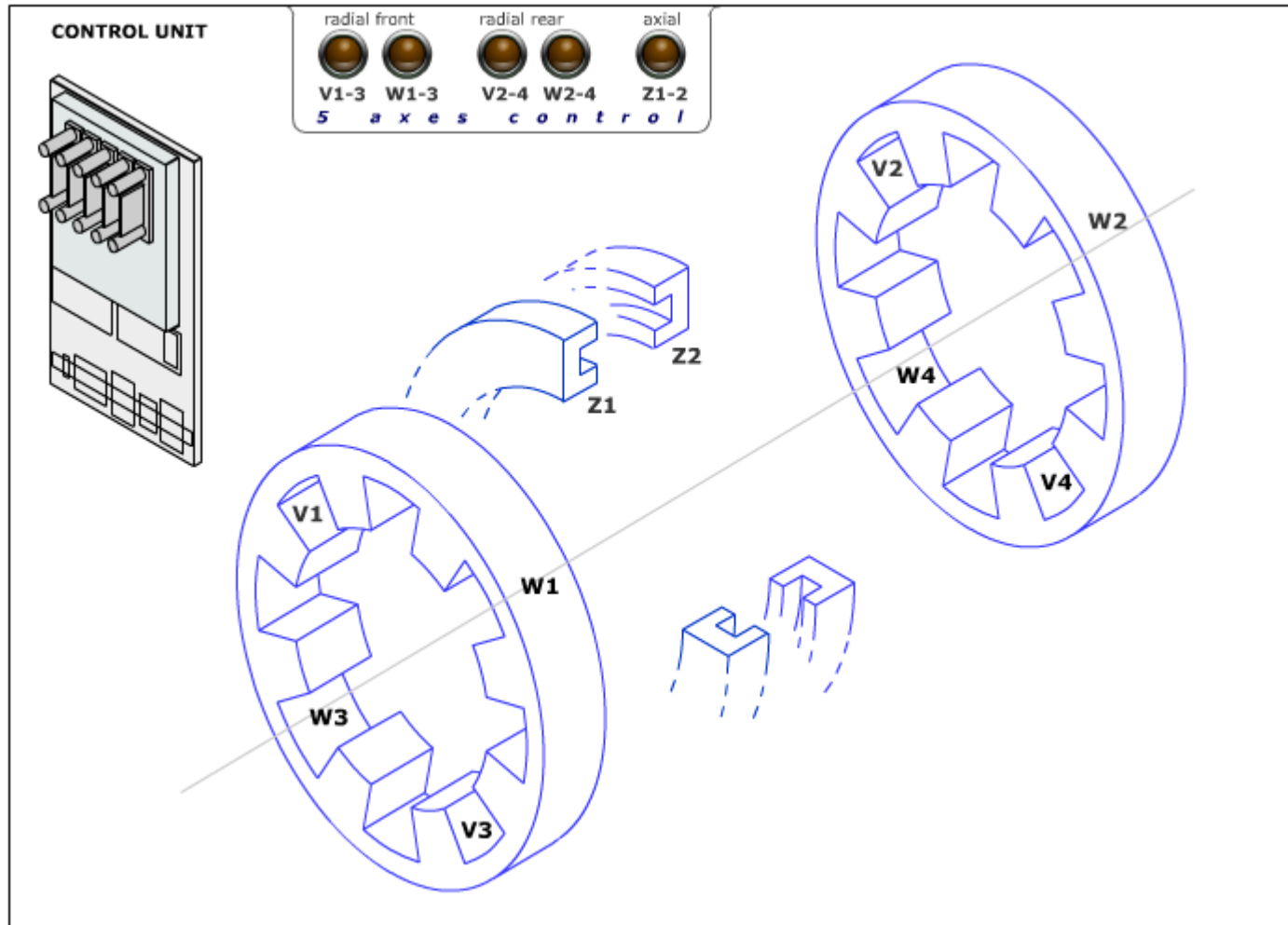
Electro Magnet creates an attraction force



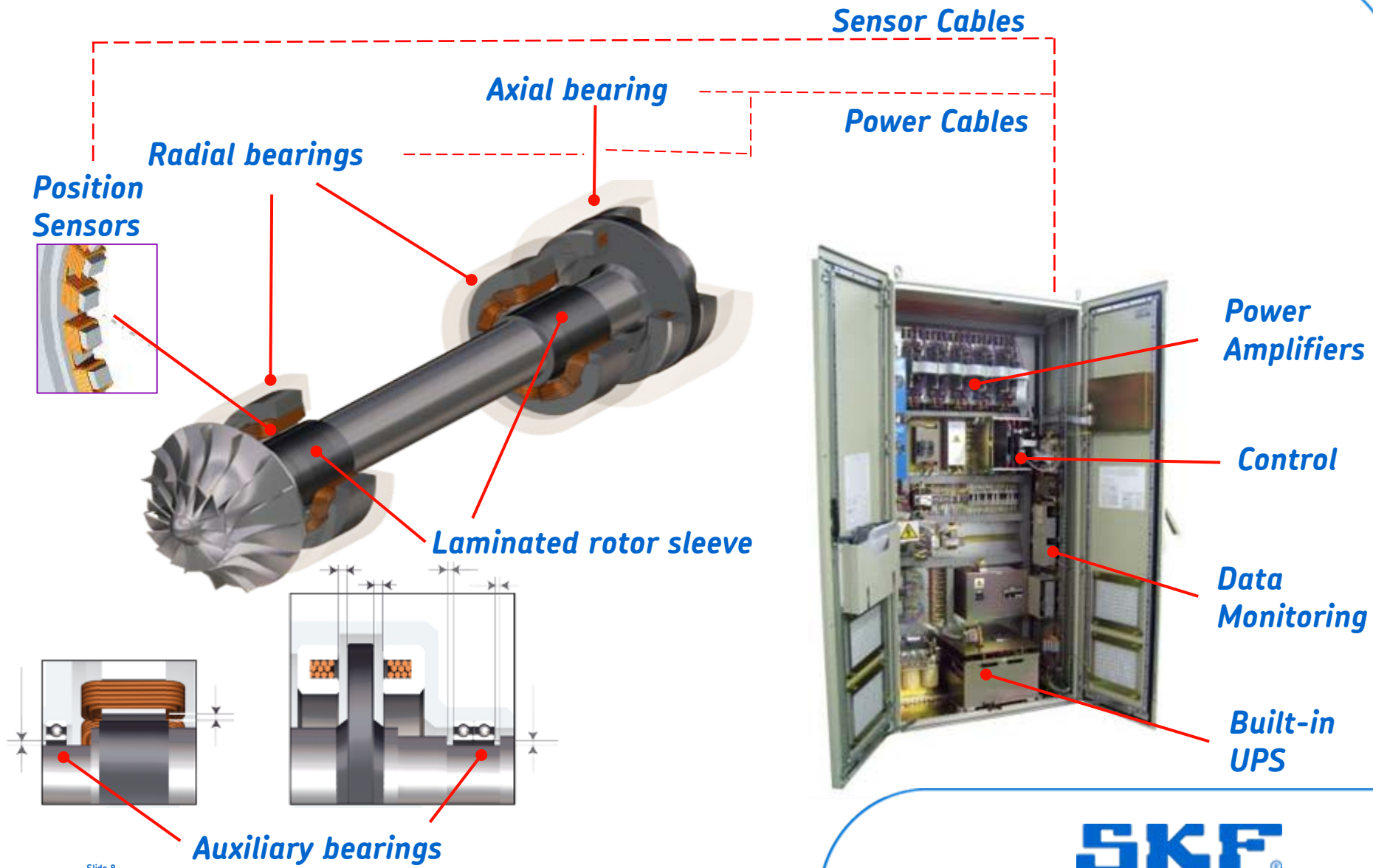
Available System Operating Data:

- Shaft displacement
- Bearing current (related to force)
- Key phase (shaft angular position)

# How Magnetic Bearings Work



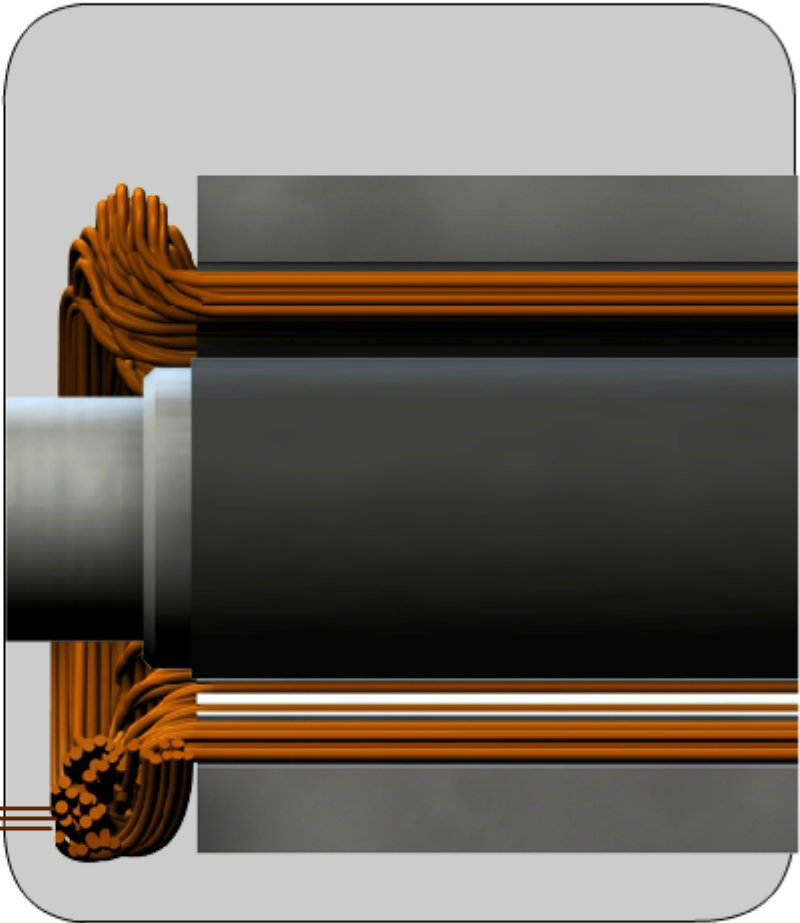
# The Components of a Magnetic Bearing System





# MOTOR/GENERATOR

Power generation




- 1
- 2
- 3
- 4
- 5
- 6
- 7
- 8
- 9
- 10




# VIBRATION CONTROL

ON / OFF




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START / STOP




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Speed



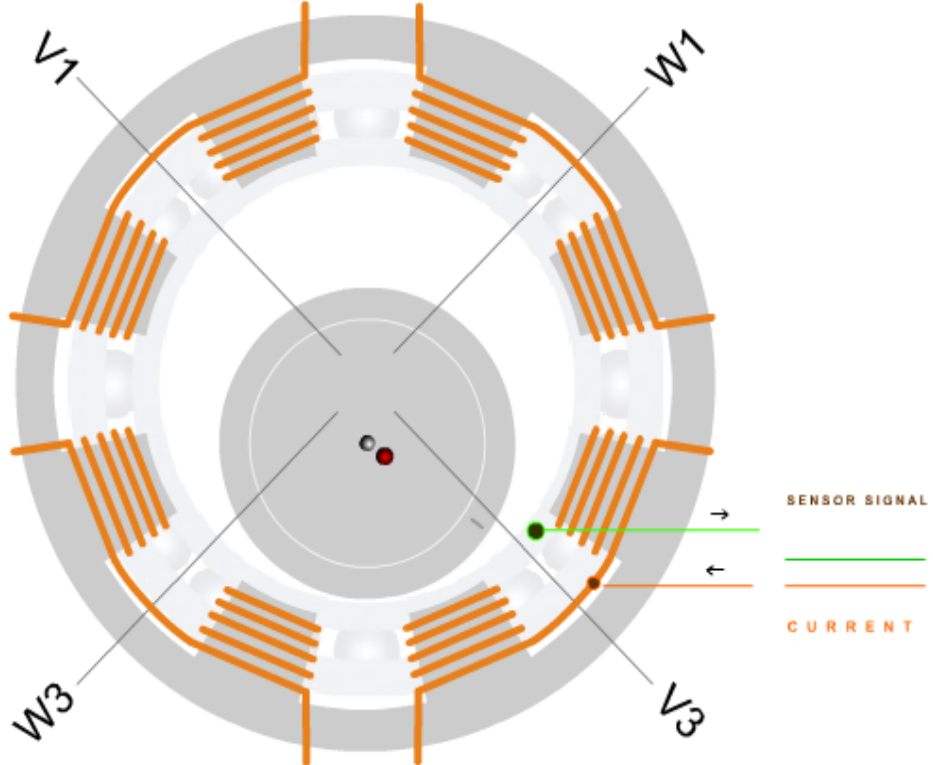
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Rotation around inertial line



ON / OFF

STATUS no levitation



**Unbalance**



**Damping**



(c) Bruno Wagner  
22.07.2001



# Rotordynamic Modeling and Simulation

Modeling and simulation tools are used to perform the following analyses:

- Model definition (rotor, AMB, auxiliary bearing, seals, controller)
- SISO tuning
- MIMO tuning
- Simulations (force impulse, signal injection, drop tests, etc.)
- Stability analysis
- Unbalance response analysis
- Compliance analysis
- Radial exciter analysis
- Voltage and force saturation analysis

# Markets and Products

## Oil & Gas



- Turboexpanders**
- Upstream natural gas treatment
  - Ethylene manufacturing



- Compressors**
- Upstream natural gas production, storage, reinjection
  - Natural gas transport



- Compressors**
- Polyethylene manufacturing
  - Refinery



- Electric drives**
- Natural gas production, storage, reinjection
  - Natural gas trans,

## Industrial gas



- Turboexpanders**
- Air separation



- Laser Gas Blowers**
- Laser Manuf. Units

## Power Gen.



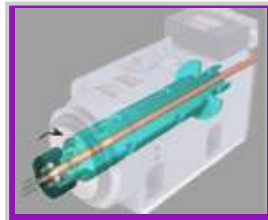
- Turbogenerators**
- 9MW
  - Hydraulic turbines

## Turbo + PM



- Turbomachines with S2M PM motors /generators**
- Air compressors
  - Turbogenerators
  - Chillers

## Machine tool



- Electrospindles**
- Copper tube grooving
  - Grinding
  - Milling

## Vacuum



- Turbomolecular pumps**
- Semicon manufacturing
  - General vacuum
- \* Including license mfg.

## Semicon



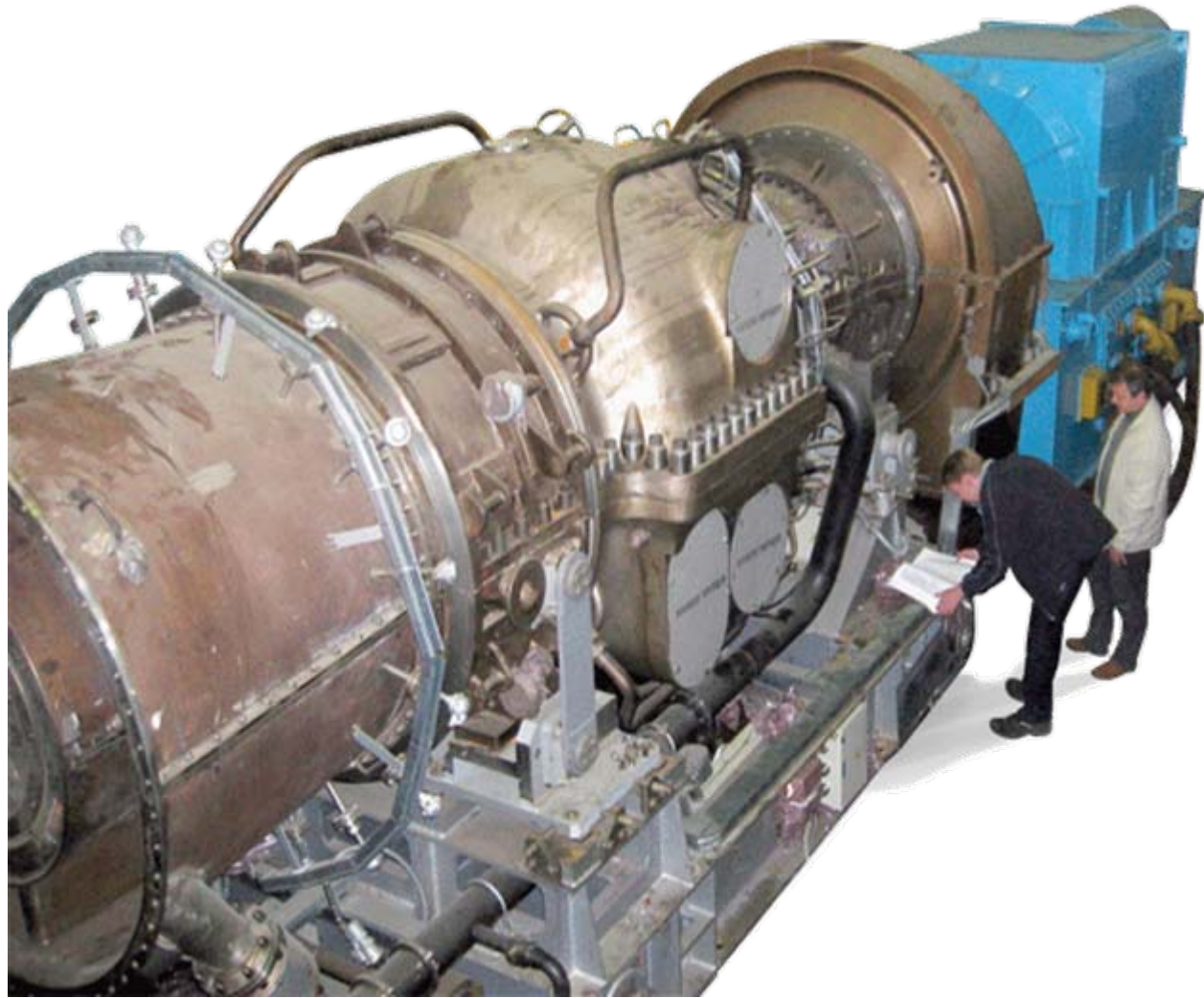
- Rapid Thermal Processors**
- Silicon chip manuf.

## Nuclear Science



- Rotating Filters**
- Disk Choppers
  - Fermi Choppers
  - T-zero Choppers

# Magnetic Bearings: no longer a niche technology!



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# Technology Advantages

## Contact Free and Oil Free

- No friction
- No wear
- No lubricant, no lube oil system
- Operation in vacuum, severe environments
- High peripheral speed
- Environmental friendly
- Energy efficient (lower operating costs)



## Smaller Footprint

- Less civil work (reduction of 20% to 60%) and less weight

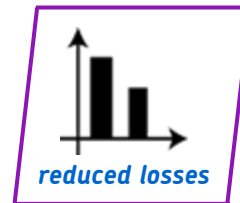
## Monitoring

- Bearing loads and process loads
- Rotor displacement
- Safety shutdowns
- Built-in condition monitoring (no external CoMo hardware required)



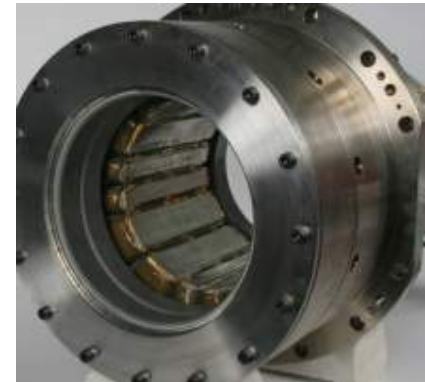
## Increased Up-Time

- Highest bearing reliability
- MTBF ++
- Maintenance free concept (lower maintenance costs)



## Optimized Parameters

- Active control
- Stiffness and Damping



## Submerged Bearing Solutions

- Eliminate shaft seals (cost advantage)
- No process contamination
- Canned solutions for severe environments

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# Contact Free Rotation

- Magnetic bearings are standard technology for
  - Semiconductor manufacturing
  - Turbomolecular pumps
  - CO<sub>2</sub> Laser gas blowers
  - Neutron choppers
- Lubrication free, high speed rotation...in vacuum
- No activated grease or oil
- Low vibration using auto-balancing software
- Low and consistent drag, helps phase performance



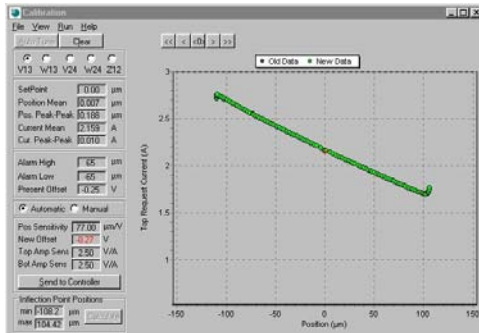


# Availability and Reliability

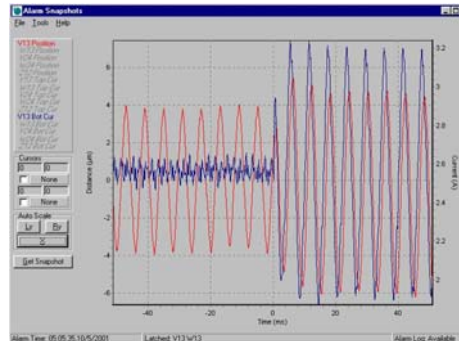
- No contact = no wear = zero maintenance
- Demonstrated Mean Time Between Failures (for full systems):
  - Turbomolecular pumps > 500,000 hours (~57 years)
  - Semiconductor RTP > 1,000,000 hours (~114 years)
  - 3.25M hours for RTP controller alone
- Critical for beam up-time and reducing maintenance of activated parts
- Rotors and actuators have little that can fail if made properly
- Like all electronic assemblies, controllers can fail over time, but...
  - ...they are easily replaced (outside the beam line)

# Condition Monitoring, Intelligent Machines

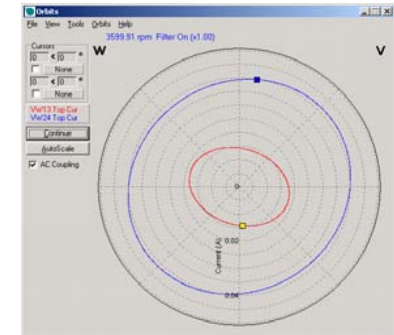
- Inherently intelligent machines
  - Position sensors
  - Force measurement (through currents)
  - Motor data
  - Data processing (AVC, zero vibration)
- Built-in condition monitoring
- Built-in data-logging



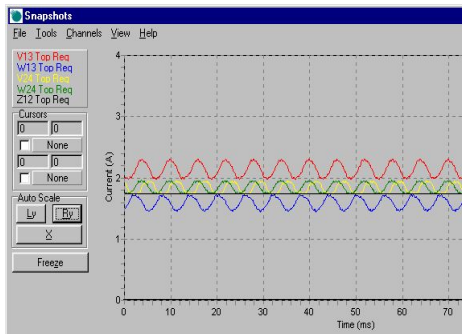
Calibration Screen



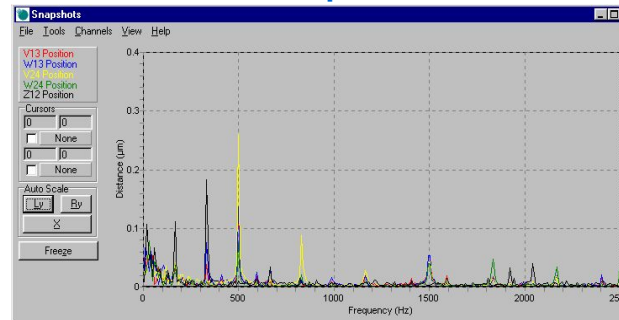
Alarm Capture Screen



Shaft Orbit Screen



Time Domain Screen



Frequency Domain Screen



# Things to Watch For

- Benefits come with a financial premium
  - Low when considered over the machine life-cycle
- Zero friction, but rotor magnetic losses exist
  - Eddy currents in the bearing rotors and motor -> heat
  - Hysteresis losses -> heat
- Without contact, rotor can only radiate heat
  - Carbon-fiber disks have low maximum temperatures, <50°C
  - Water cooling is sometimes required for high-speed machines
  - Any changes in rotor properties with temperature are a challenge
- Highly gyroscopic disk-choppers can pose rotordynamic challenges
  - Bearing control filter can be hard to design
- Crossing rotor flexible modes (1<sup>st</sup>, 2<sup>nd</sup> Bending, etc.) should be avoided if possible (speed limitation)

**When used properly, magnetic bearings  
are the ultimate bearing technology!**

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# SKF global installations bring experience



77+ neutron choppers delivered and operational

\* Project in progress

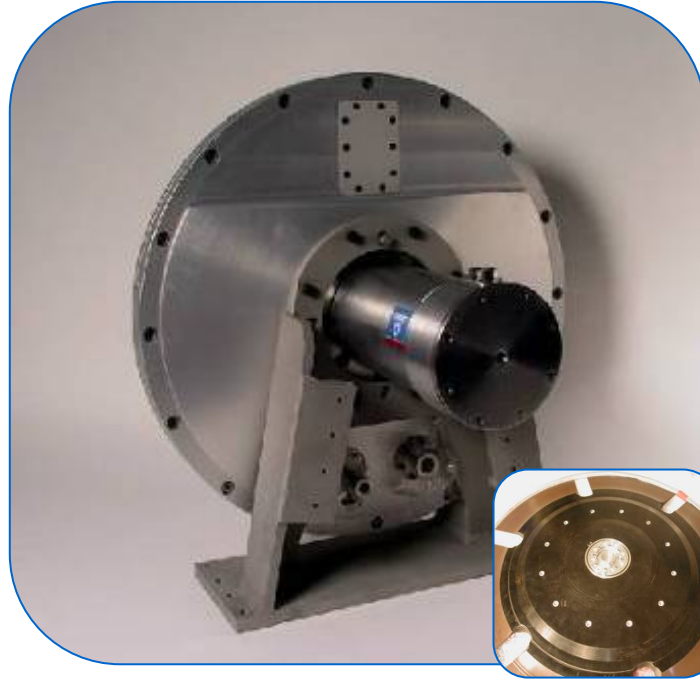
# Drives for neutron choppers

- 7.3 kg Payload
- 36,000 rpm
- $\pm 0.05^\circ$  Phase Control



Fermi (17)

- 6 kg Disk, 30 kg Gen 2
- 20,000 rpm
- $\pm 0.05^\circ$  Phase Control



Disk (56)

- 68 kg Payload
- 10,800 rpm
- $\pm 0.43^\circ$  Phase Control



T-Zero (4)

**RECALL:** all choppers are “Bandwidth Limiting Filters” for neutron beams

# Drive controller



- Fully integrated chopper control (motor, bearings, monitoring, phase control)
- Motors for operation between 10Hz and 600Hz
- Veto signal with window size software configurable
- Precise phase stability and parking
- Compact – 3U/19” rack
- Standard for all chopper types – spares can be shared across all choppers\*
- Each controller is customized by downloading a software file
- Easy to install and use, maintenance free
- User friendly interfaces

\*T-zero requires additional controller hardware

# SKF Collaborates

SKF collaborates with strategic partners to design and supply neutron absorbers (disk, slit package) using  $Gd_2O_3$ ,  $B_{10}$ , Inconel to meet instrument specific requirements.

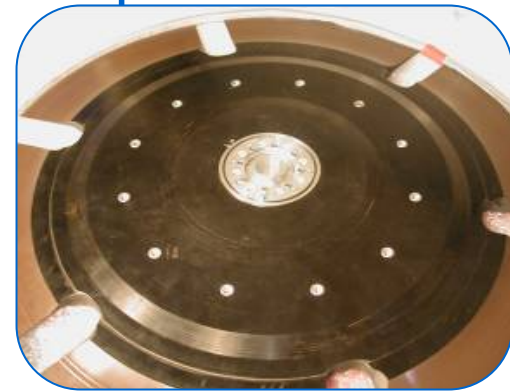
Mirroron – disks and Fermi slit packages

Astrium – disks

SNS- Fermi slit packages

ISIS – Fermi slit packages, heavy disks

JAEA- in progress



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# Meeting Industry Trends

## 5th generation controller

- Based on components from high volume industrial applications
- Increase power, reliability and robustness
- Update electronic components (baseline for next 15-20 years)
- Backward compatible / interchangeable with current system
- Design in progress

## Increased bearing capacity spindle

- Support larger disks
- Support higher speeds
- Backward compatible
- Design in progress



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