fives

TECHDAYS AEROSTAR

Sensors, compensations and dashboarding on machines 4.0

February, 2nd 2023

Presented by Pierre-Albert Landel

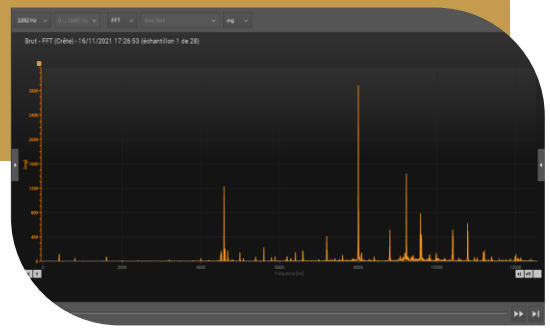
Pierre-albert.landel@fivesgroup.com

SUMMARY

SENSORS & ACTUATORS

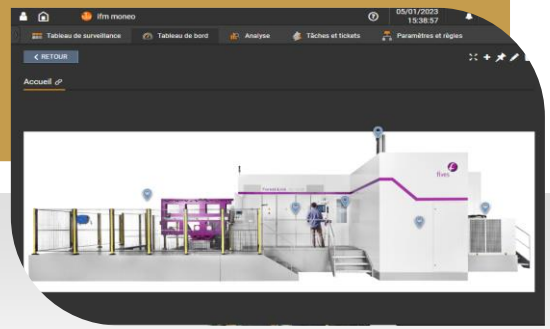
IO-Link inside

VIBRATIONS MONITORING



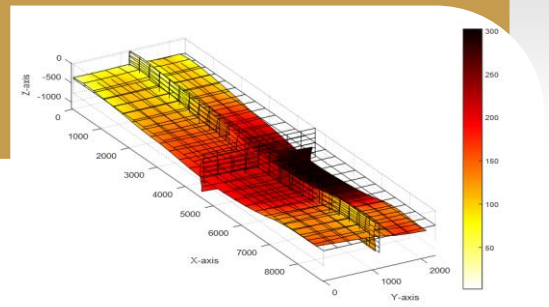
Integrated protection & maintenance

DATA COLLECTION



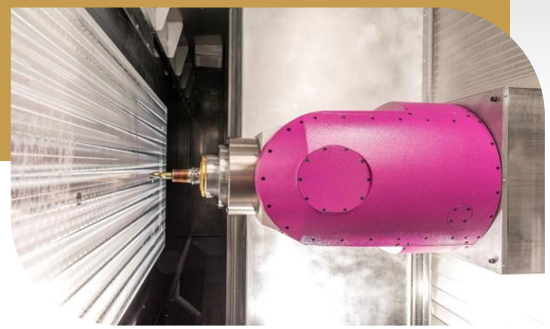
Dashboarding

PRECISION



Volumetric compensation

DILATATION



Temperature compensation

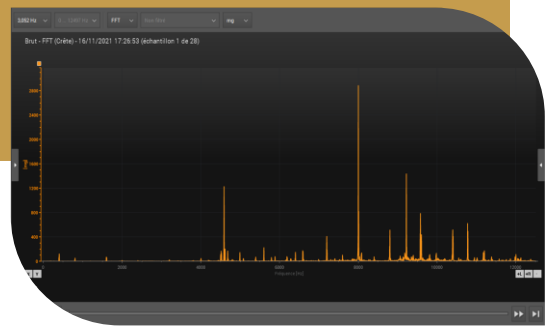
HIGH PRECISION MACHINES

SUMMARY

SENSORS & ACTUATORS

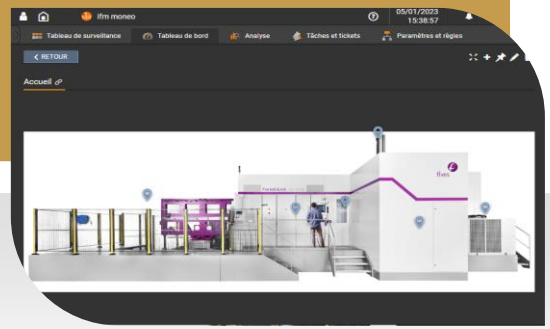
IO-Link inside

VIBRATIONS MONITORING



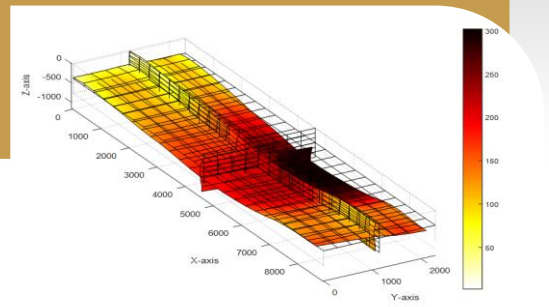
Integrated protection & maintenance

DATA COLLECTION



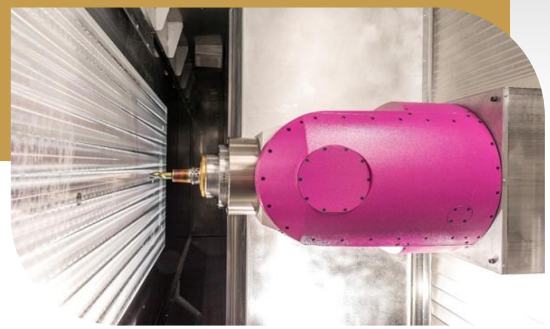
Dashboarding

PRECISION



Volumetric compensation

DILATATION



Temperature compensation

HIGH PRECISION MACHINES

IO-LINK
WHAT IS IO-LINK ?

IO-Link :
Normalized point-to-point communication on 3-wire, between master and sensors / actuators on 20m max.

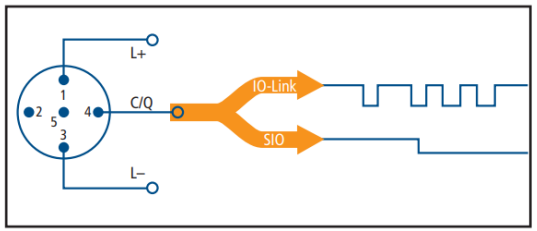
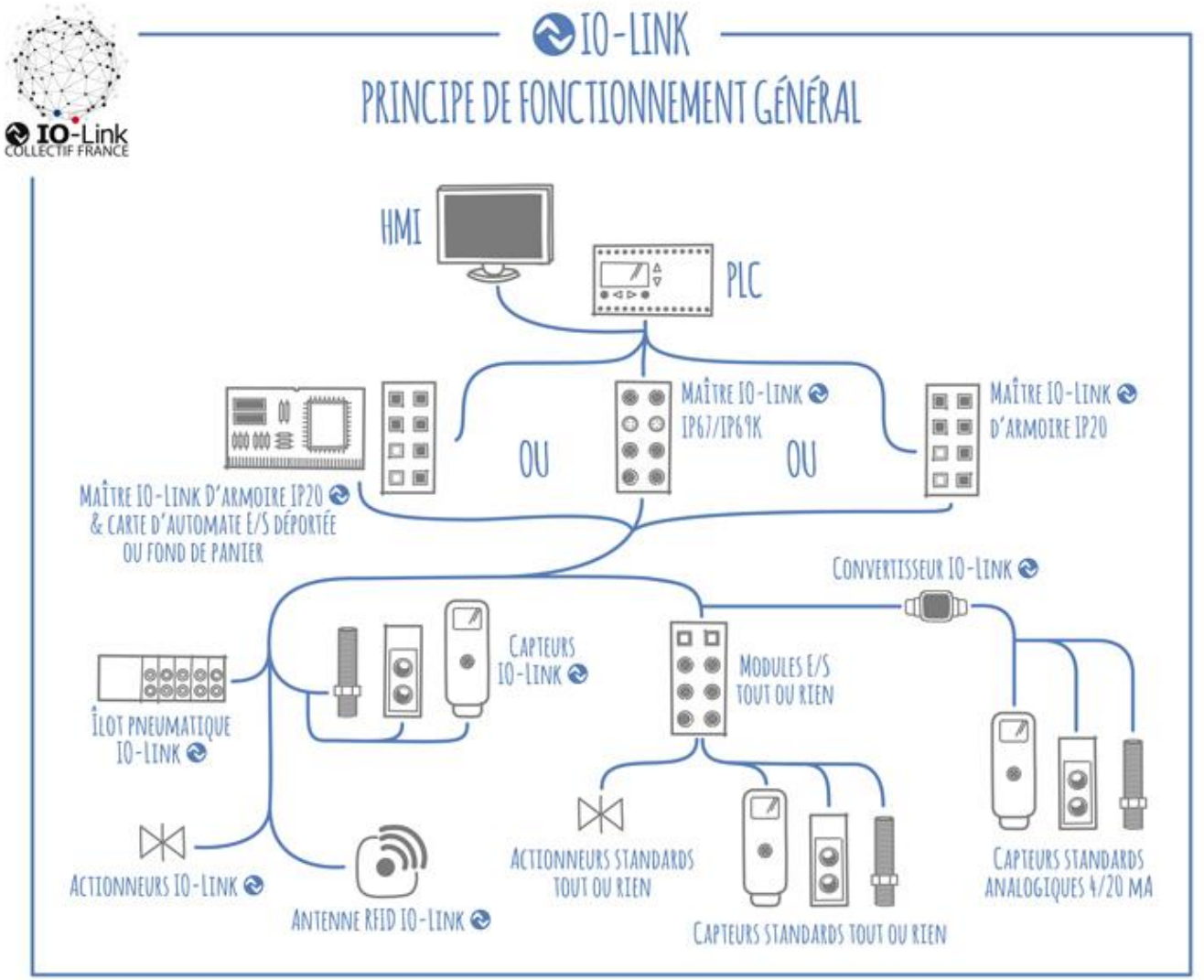


Figure 3: Pin assignment of IO-Link device

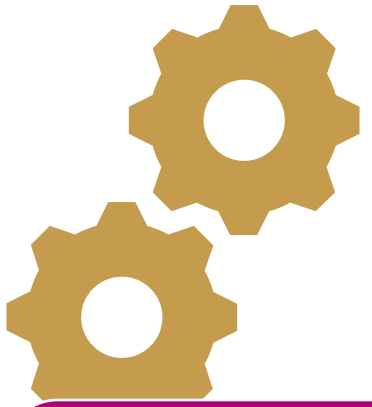
IODDfinder

Open standard used by many manufacturers, including:

ifm
SIEMENS
EUCHNER
HIGH PRECISION MACHINES
ABB
Schneider Electric
HAWE HYDRAULIK



IO-LINK
IMPLEMENTATION ON FIVES' MACHINES

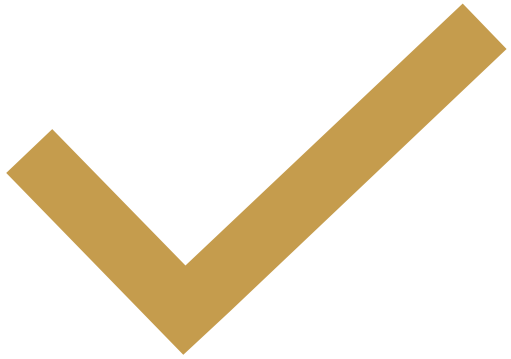


Identify

- Define meaningful data per functional sub-assemblies

Implement

- Select manufacturer and sensor
- Develop PLC block
- Perform implementation

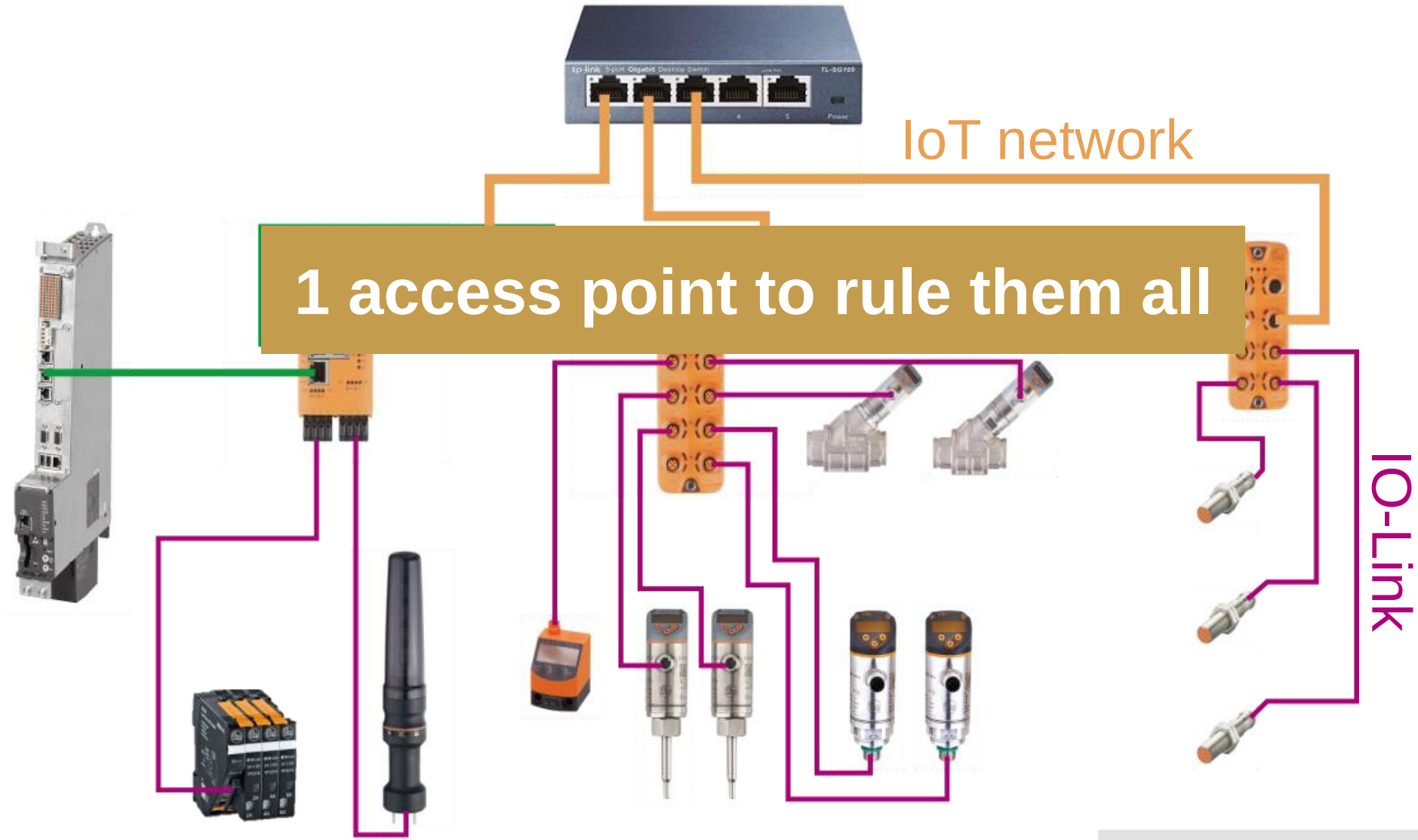


Qualify

- Test sensor on machine
- Check manufacturer spare part availability

HIGH PRECISION MACHINES

IO-LINK
FIVES' PHILOSOPHY



Machine 4.0 Ready !

HIGH PRECISION MACHINES

IO-LINK
FIT MACHINE SENSORS TO YOUR NEEDS

Define your configuration with us !

HIGH PRECISION MACHINES

… your idea !

Process tailored

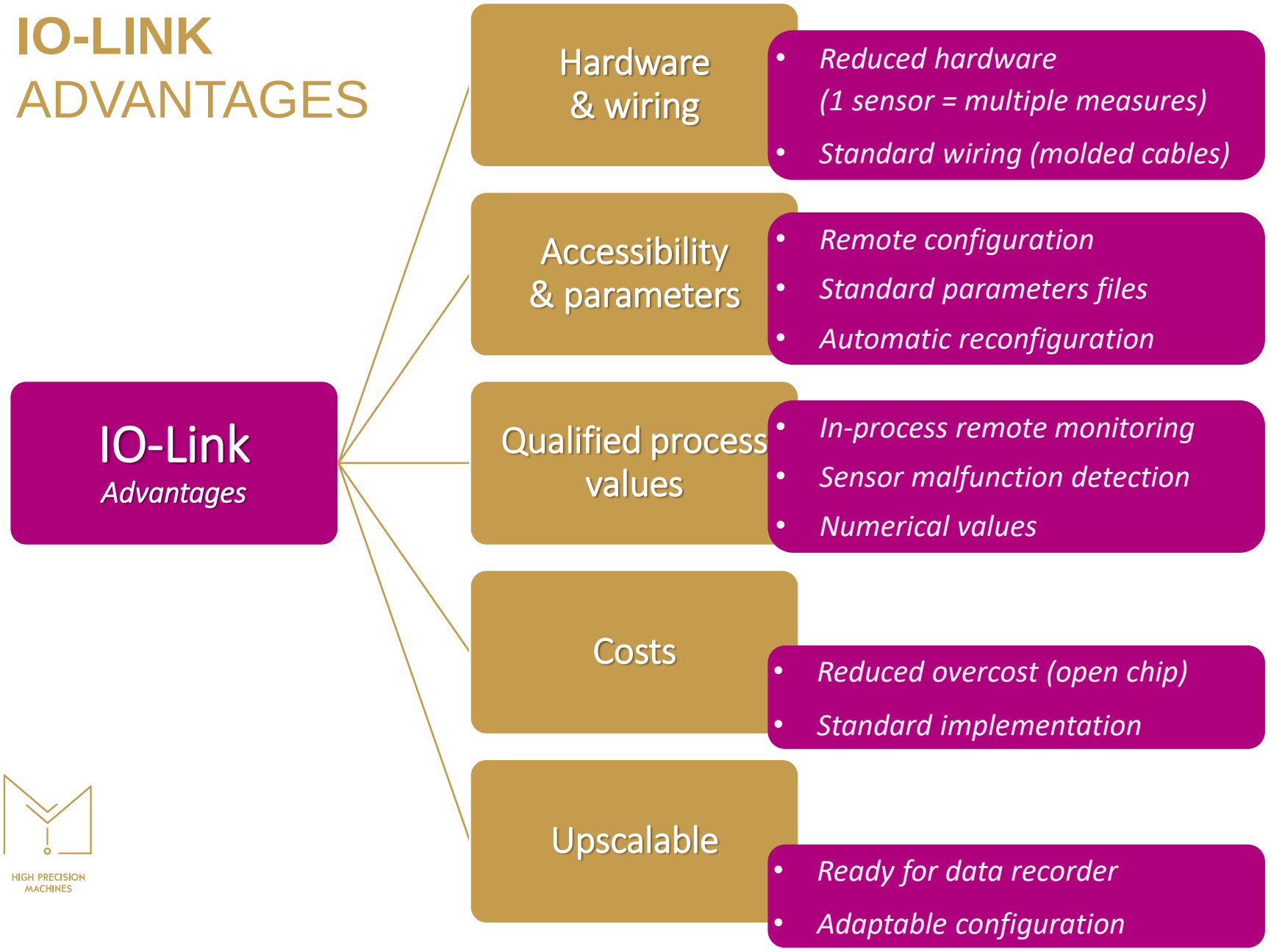
Green configuration

Standard configuration

Connect

Data acquisition

IO-LINK ADVANTAGES



Better reliability !

Reduced wiring…

Better accessibility !

Lower downtime !

Improved diagnostic !

Early malfunction detection

Easy implementation

Agile system

HIGH PRECISION MACHINES

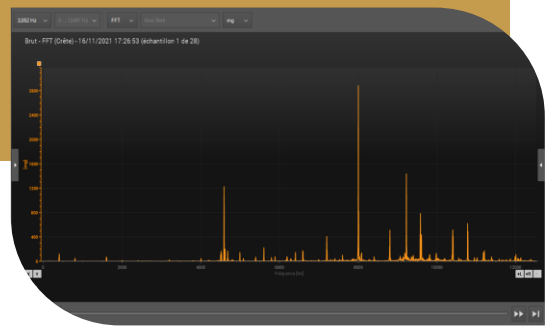
fives

SUMMARY

SENSORS & ACTUATORS

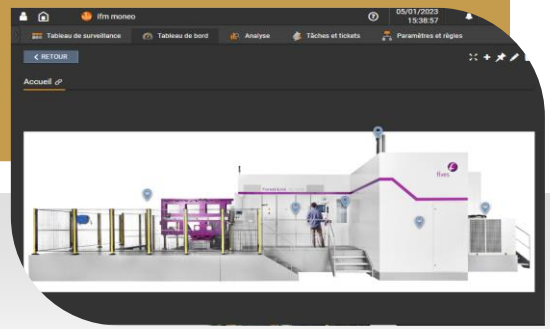
IO-Link inside

VIBRATIONS MONITORING



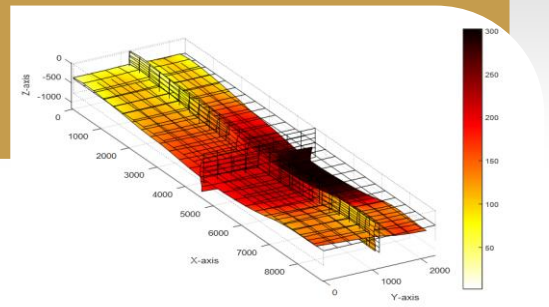
Integrated protection & maintenance

DATA COLLECTION



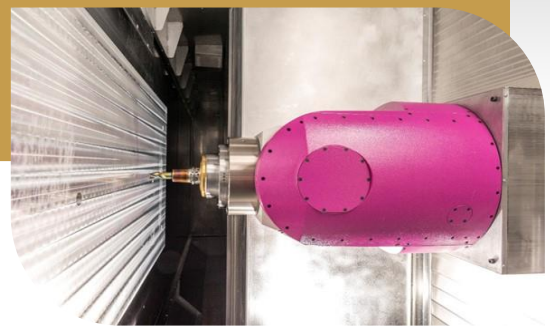
Dashboarding

PRECISION



Volumetric compensation

DILATATION



Temperature compensation

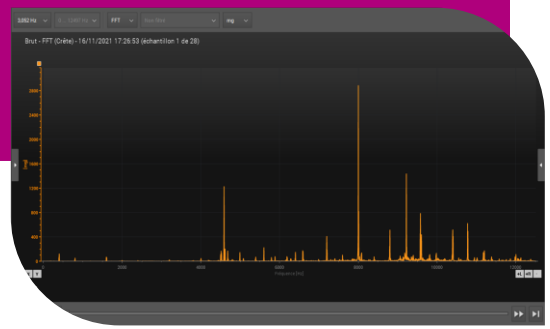
HIGH PRECISION MACHINES

SUMMARY

SENSORS & ACTUATORS

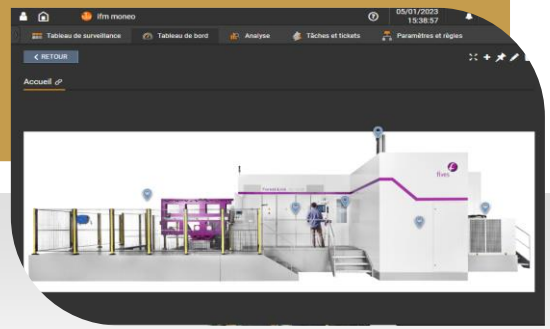
IO-Link inside

VIBRATIONS MONITORING



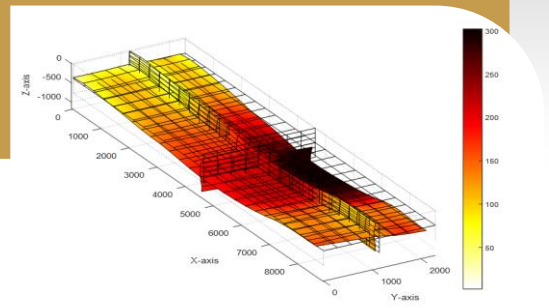
Integrated protection & maintenance

DATA COLLECTION



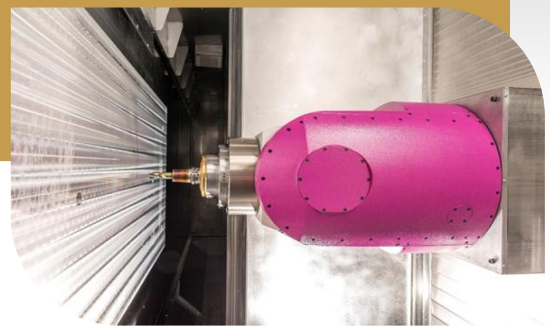
Dashboarding

PRECISION



Volumetric compensation

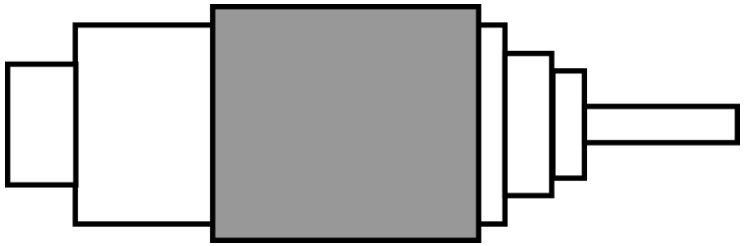
DILATATION



Temperature compensation

HIGH PRECISION MACHINES

VIBRATIONS MONITORING
WHY IS IT IMPORTANT ?

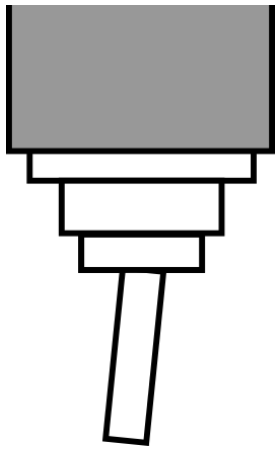


Energy for spindle rotation inertia and friction

Energy for cutting

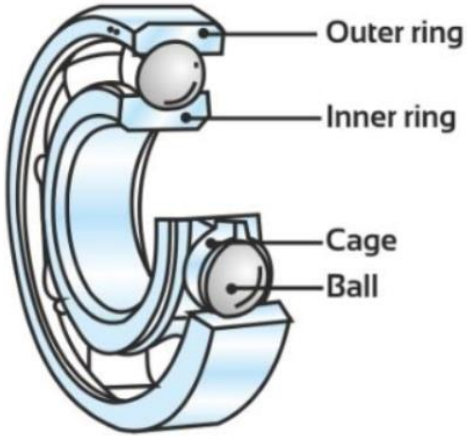
Energy loss in vibration

Collision

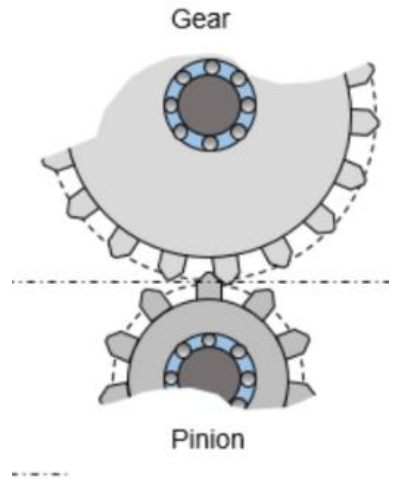


Counterbalancing

Tool breakage



Bearings

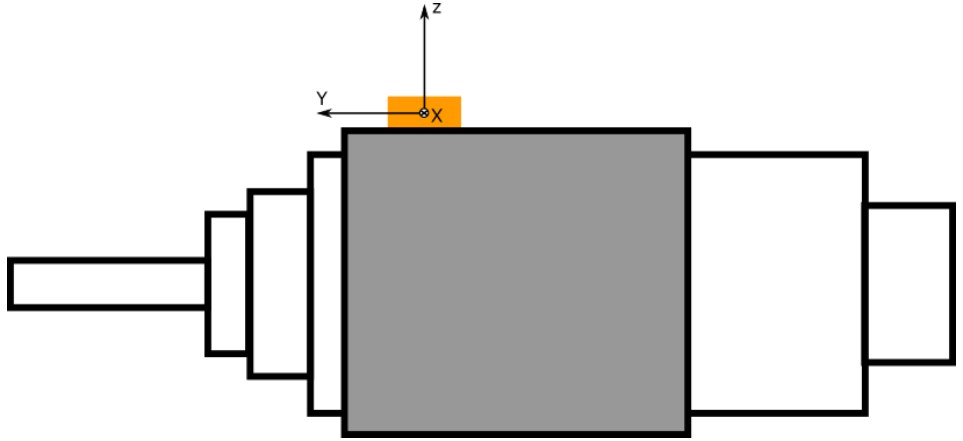


Gearboxes

HIGH PRECISION MACHINES

VIBRATION MONITORING
THE MAGIC BEHIND - SENSORS

Frequency range
[45Hz – 4500Hz]
(can go up to 10kHz)



3-axes accelerometer as close as possible to the spindle front bearing.

HIGH PRECISION MACHINES

Possible monitoring of spindle internal accelerometers (option)

VIBRATION MONITORING
THE MAGIC BEHIND - COMPUTATION

100

kHz

Sampling frequency

T

Acceleration
Velocity
Displacement

Filters
RMS
Peak

FFT

Acceleration
Velocity
Displacement

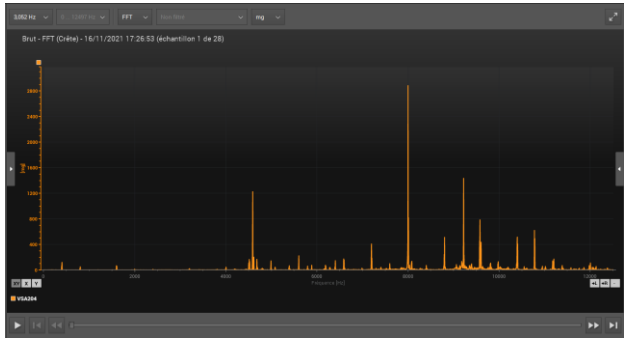
Enveloppe
Filters
RMS
Peak

H

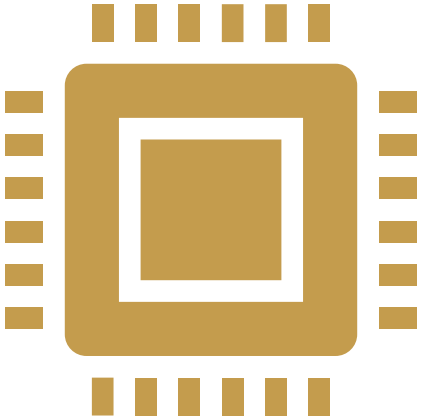
Historical
Counters

HIGH PRECISION MACHINES

Ready for monitoring and first analysis !



VIBRATIONS MONITORING
VALIDATION PROCESS



Select

- Define hardware configuration
- Position sensor on machine
- Define KPIs to monitor

Test

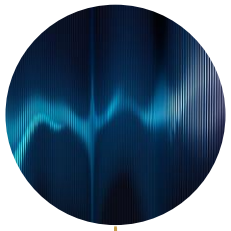
- Test sensor response
- Set thresholds
- Test machines reactions

Follow

- Adjust program cutting conditions
- Adjust monitoring if needed
- Support production
- Perform first analysis if needed

HIGH PRECISION MACHINES

VIBRATIONS MONITORING
IMPLEMENTATION ON FIVES' MACHINES



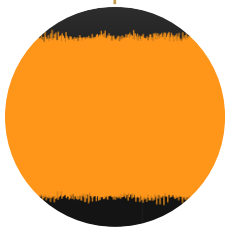
Vibration monitoring

Secure machine

- **Shocks detection**
- **Tool balancing** check before milling

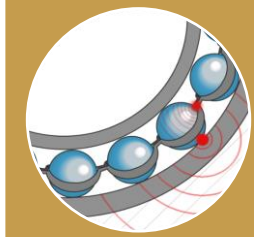
Improve part quality

- **Continuous vibration monitoring** in process
- **Tool breakage** check in process
- **Adjustable indicators** (rough, finishing, drilling…)



Reduce machine wear

- **Excessive vibrations limitation** (fatigue)
- **Best spindle rotation range** identification
- Indicator to **tune milling program to machine**



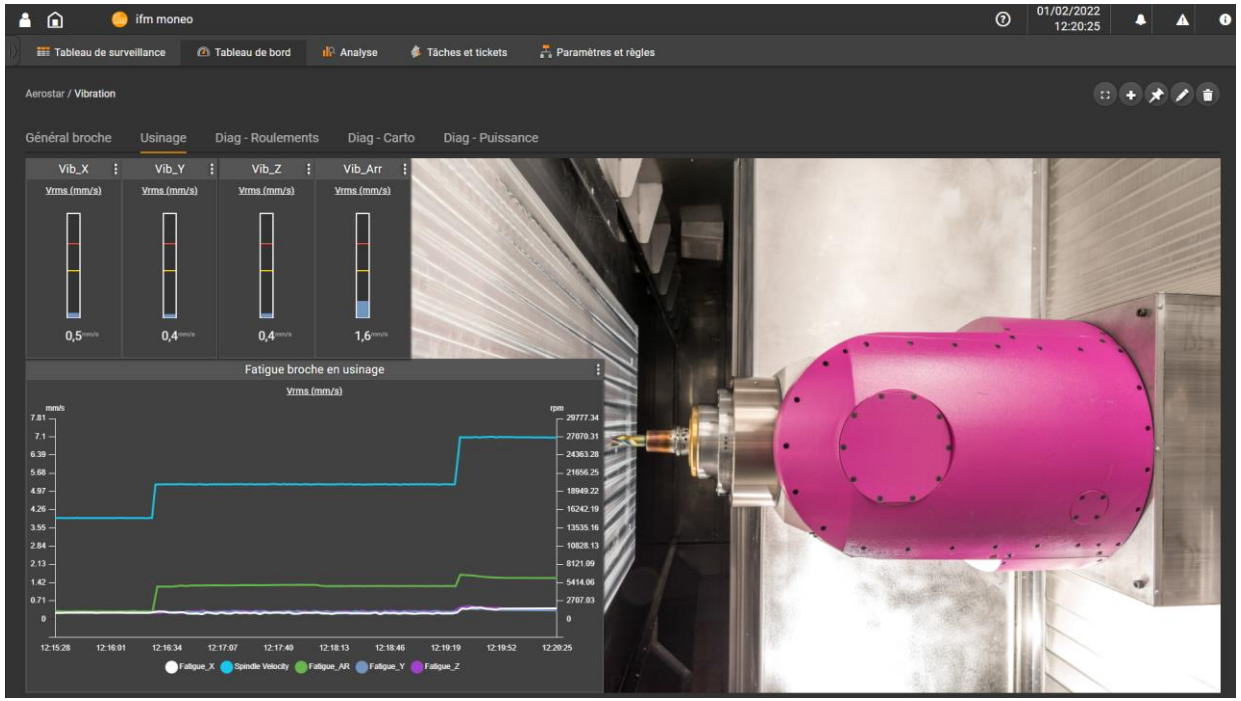
Plan the maintenance

- **Integrated spindle KM0**
- **ISO 17243 indicators (LTSC and STSC)**
- **Automated bearings diagnostic** (inner & outer rings, bearing track)

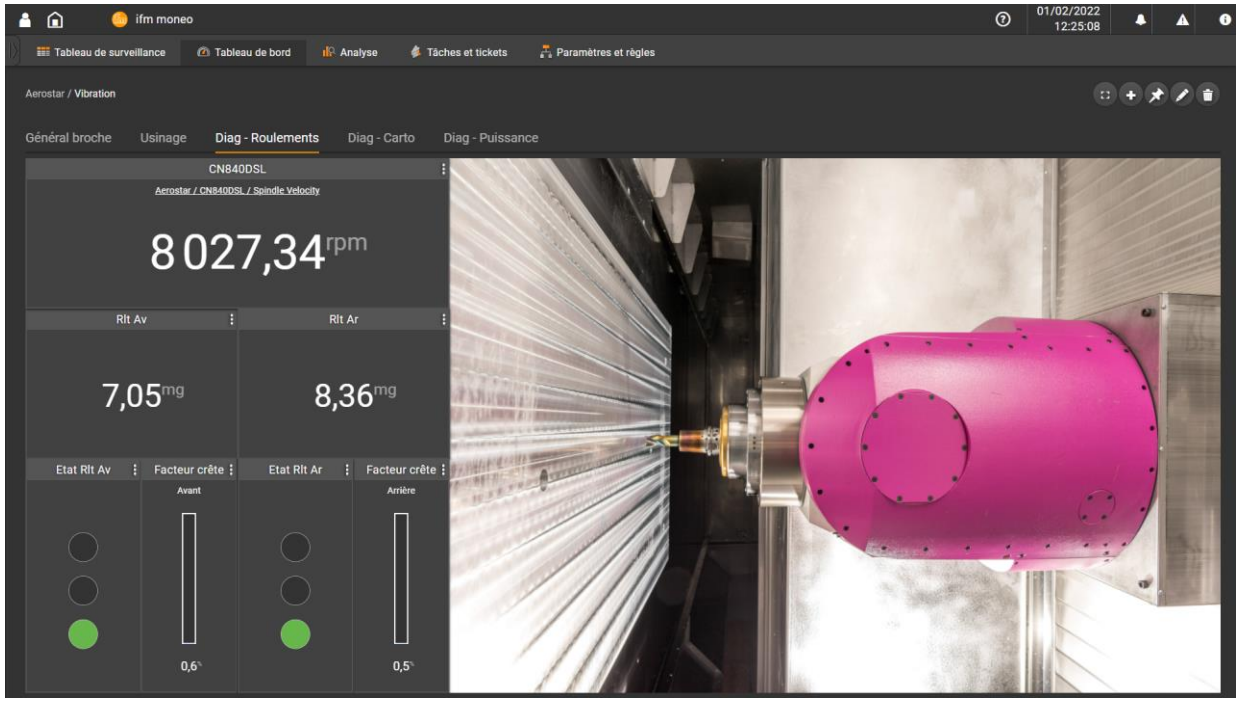
HIGH PRECISION MACHINES

Indicators and functions may vary between hard and soft materials cutting.
Hard material cutting still under development.

VIBRATION MONITORING
BECOME SIMPLE !



For process



For maintenance

HIGH PRECISION MACHINES

Easy indicators with integration to data acquisition systems (Fives CortX, IFM Moneo, …)

VIBRATION MONITORING
READY FOR RETROFIT…

Qualified replacement solution for systems no more available on the market.

HIGH PRECISION MACHINES

VIBRATION MONITORING
DEVELOPPEMENT ROAD

Hard Metal Cutting

Ski slope management

Creation of low frequencies specific indicators

Process applications

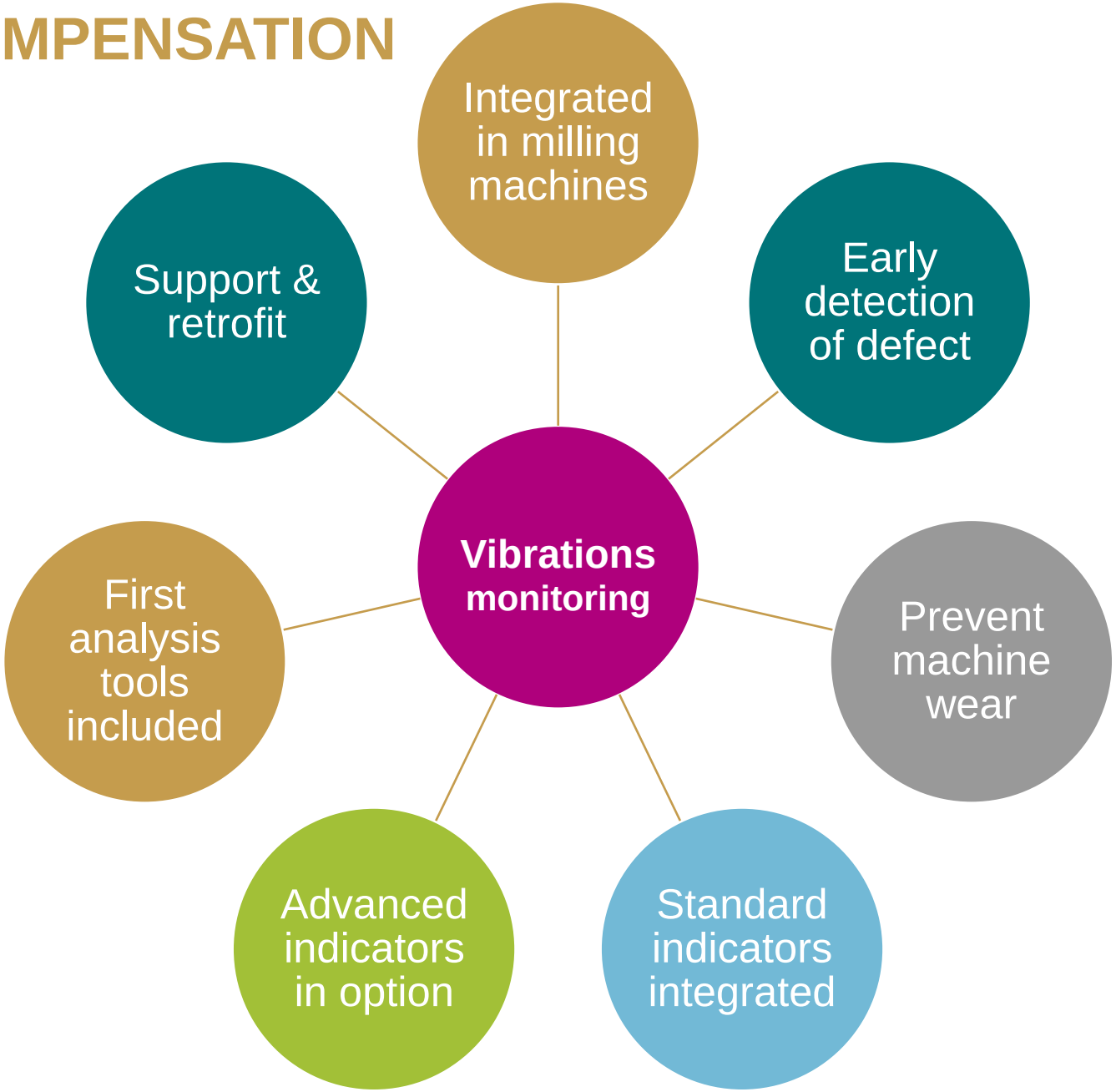
Indicators to improve milling quality

Rails monitoring

Adaptative milling

HIGH PRECISION MACHINES

VOLUMETRIC COMPENSATION
CONCLUSION



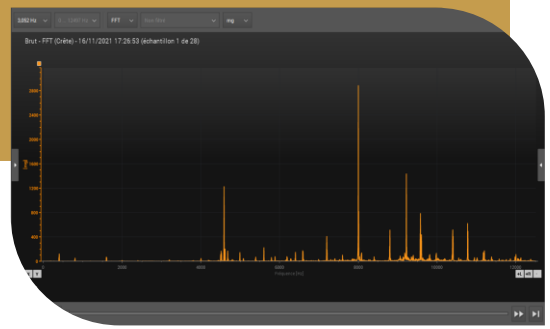
HIGH PRECISION MACHINES

SUMMARY

SENSORS & ACTUATORS

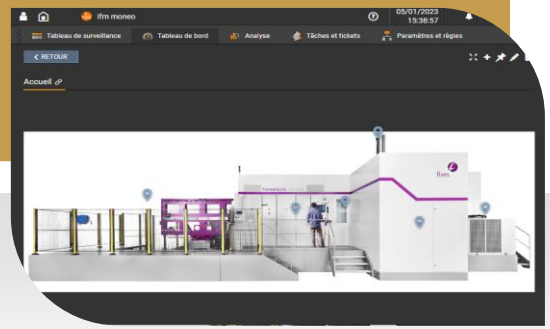
IO-Link inside

VIBRATIONS MONITORING



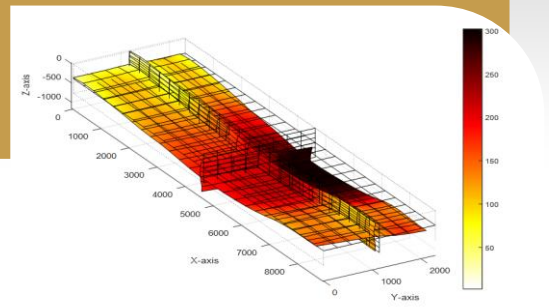
Integrated protection & maintenance

DATA COLLECTION



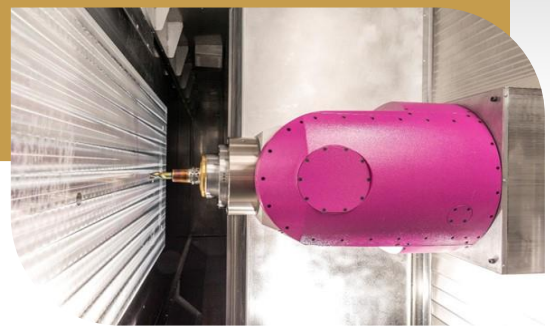
Dashboarding

PRECISION



Volumetric compensation

DILATATION



Temperature compensation

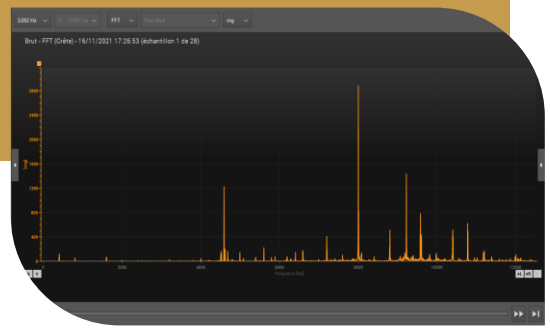
HIGH PRECISION MACHINES

SUMMARY

SENSORS & ACTUATORS

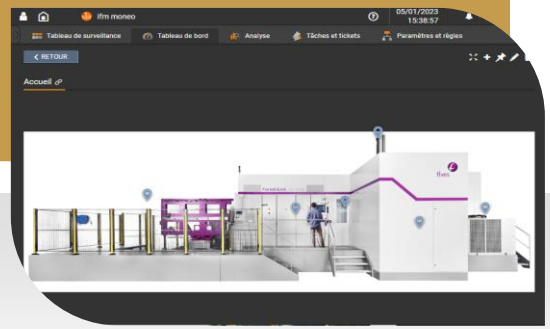
IO-Link inside

VIBRATIONS MONITORING



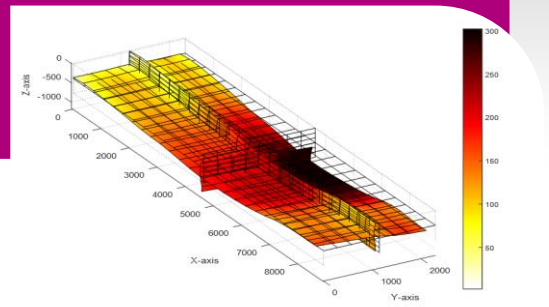
Integrated protection & maintenance

DATA COLLECTION



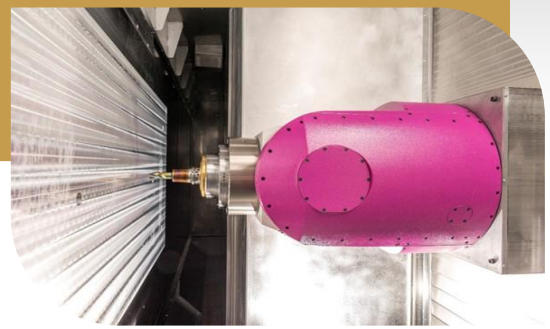
Dashboarding

PRECISION



Volumetric compensation

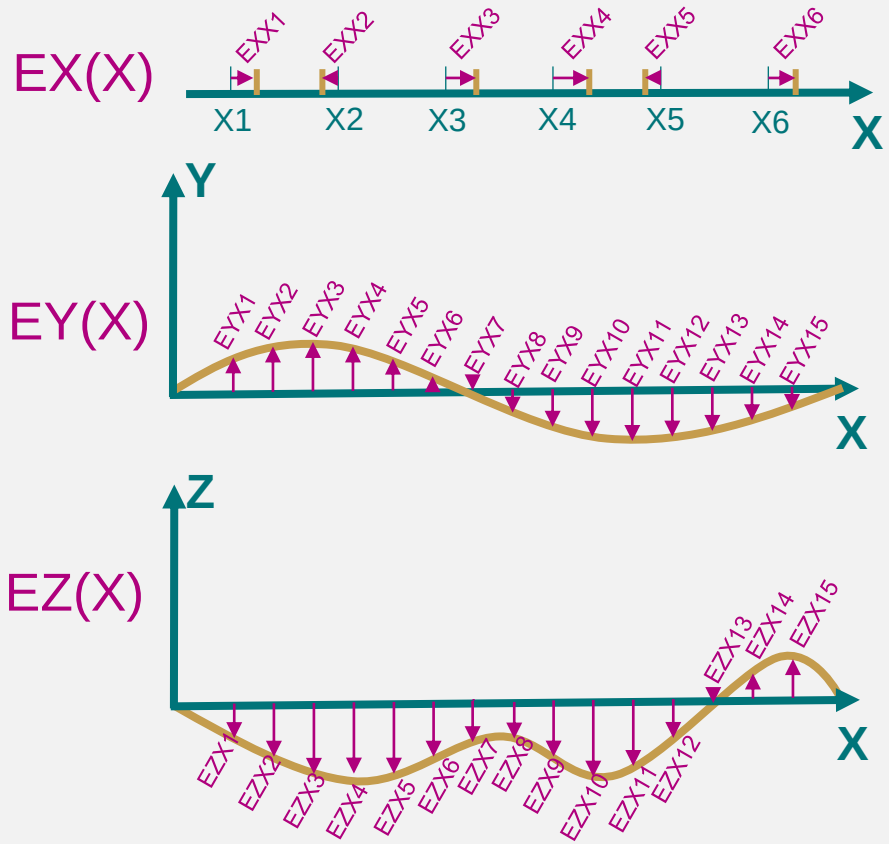
DILATATION



Temperature compensation

HIGH PRECISION MACHINES

VOLUMETRIC COMPENSATION
TRADITIONAL COMPENSATIONS



Calibration

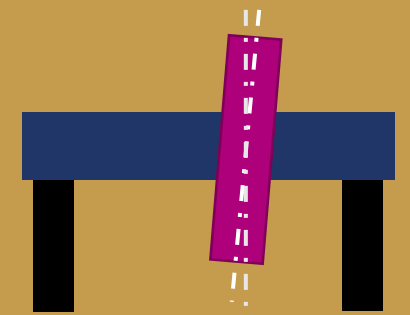
Cross-axis compensation

Conventional

1 machine
= 3 cartesian axes
= 9 (3 positional errors / axis)
+
3 squareness errors

---

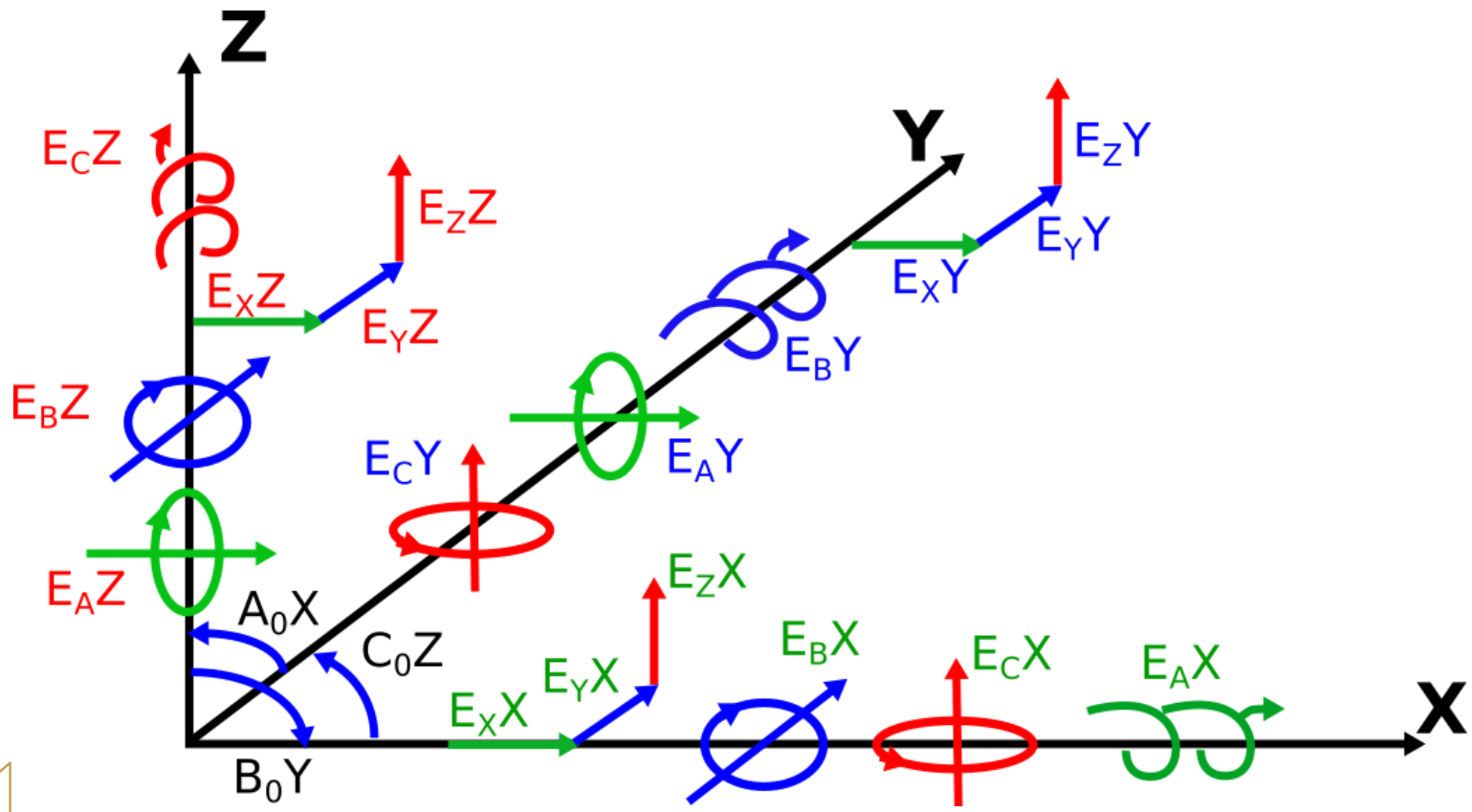
12 errors



Rotational error not evaluated

HIGH PRECISION MACHINES

VOLUMETRIC COMPENSATION
VCS MODEL



VCS model

1 machine
= 3 cartesian axes
= 3 positional errors / axis
+
3 rotational errors / axis
+
3 squareness errors

---

21 errors

Rotational error evaluated

Possible TCP orientation compensation

HIGH PRECISION MACHINES

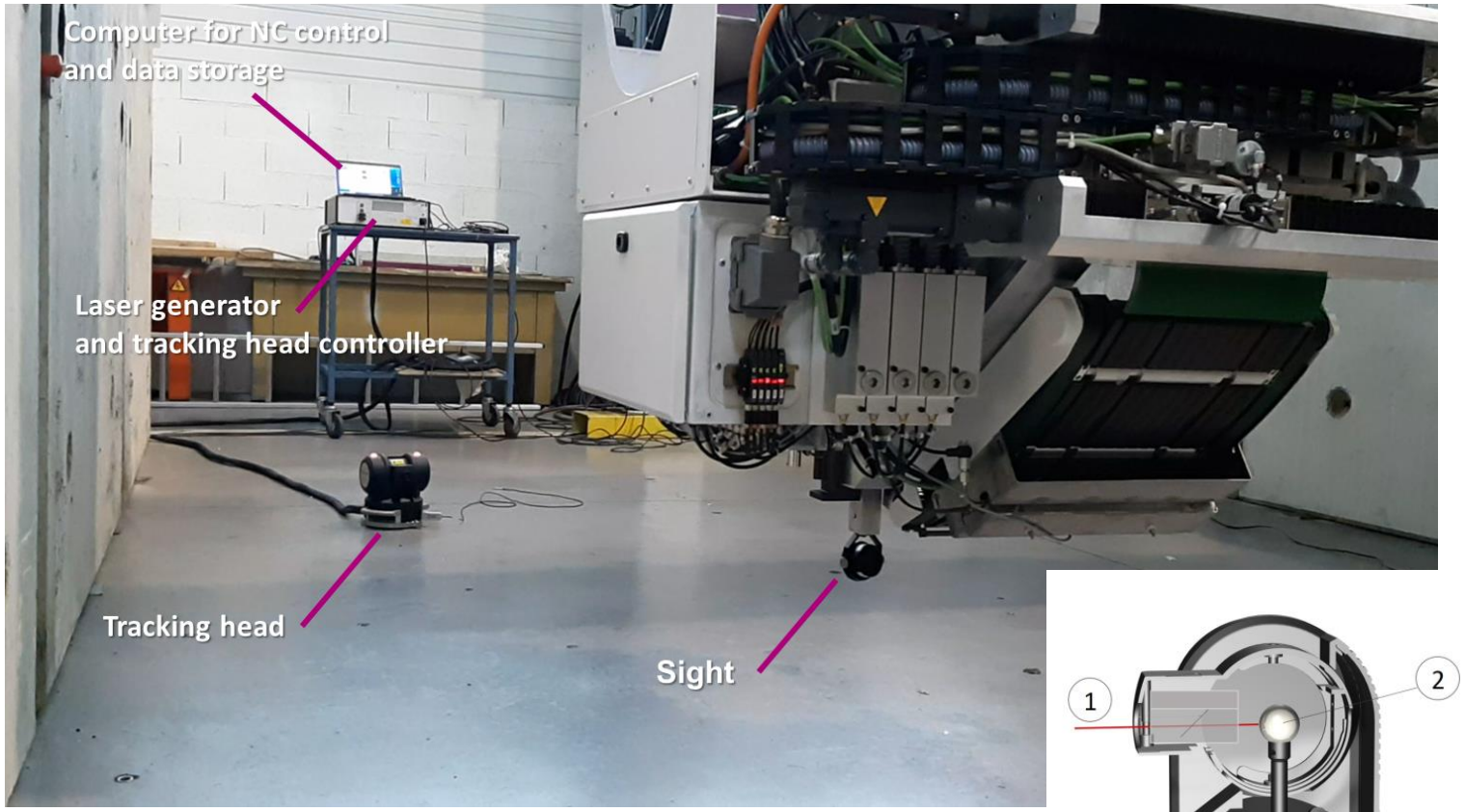
VOLUMETRIC COMPENSATION
MEASURING – LARGE SCALE MACHINES CASE

Touch probe

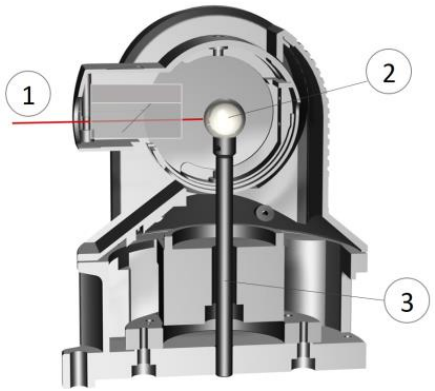
Laser Tracker

Adapted for small volumes

HIGH PRECISION MACHINES

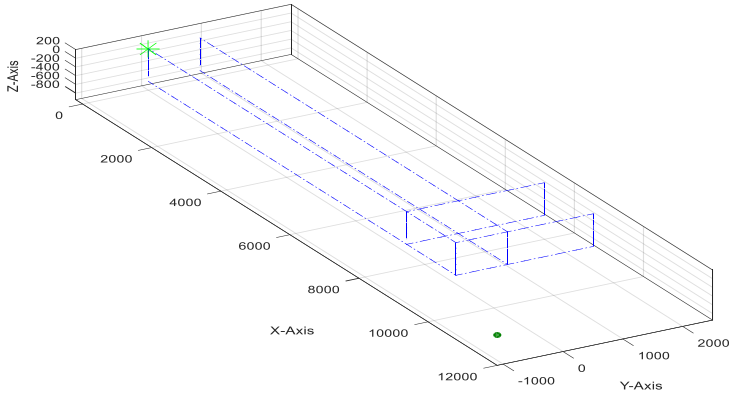


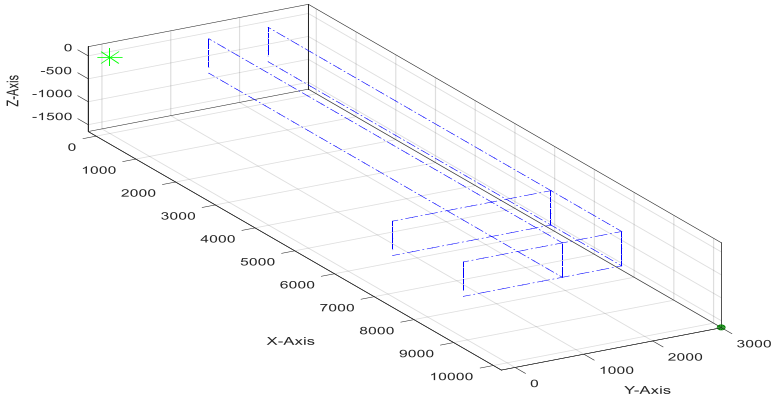
Laser Tracer

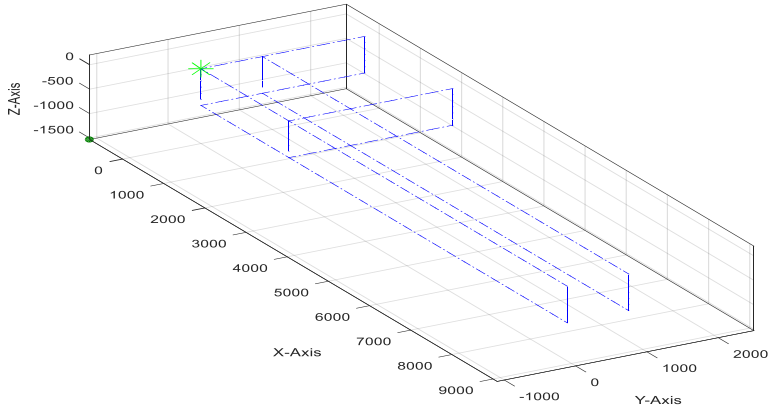


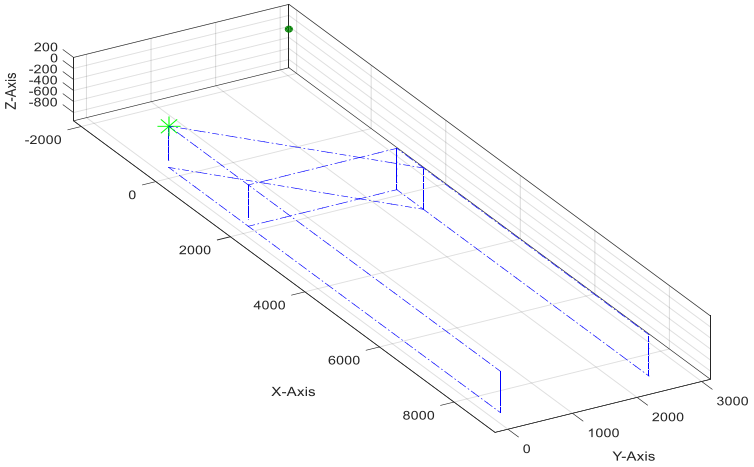
VOLUMETRIC COMPENSATION
MEASURING – LARGE SCALE MACHINES CASE

1. Découpage machine
2. Génération des trajectoires
3. Mesure
4. Calcul des erreurs
5. Génération des tables



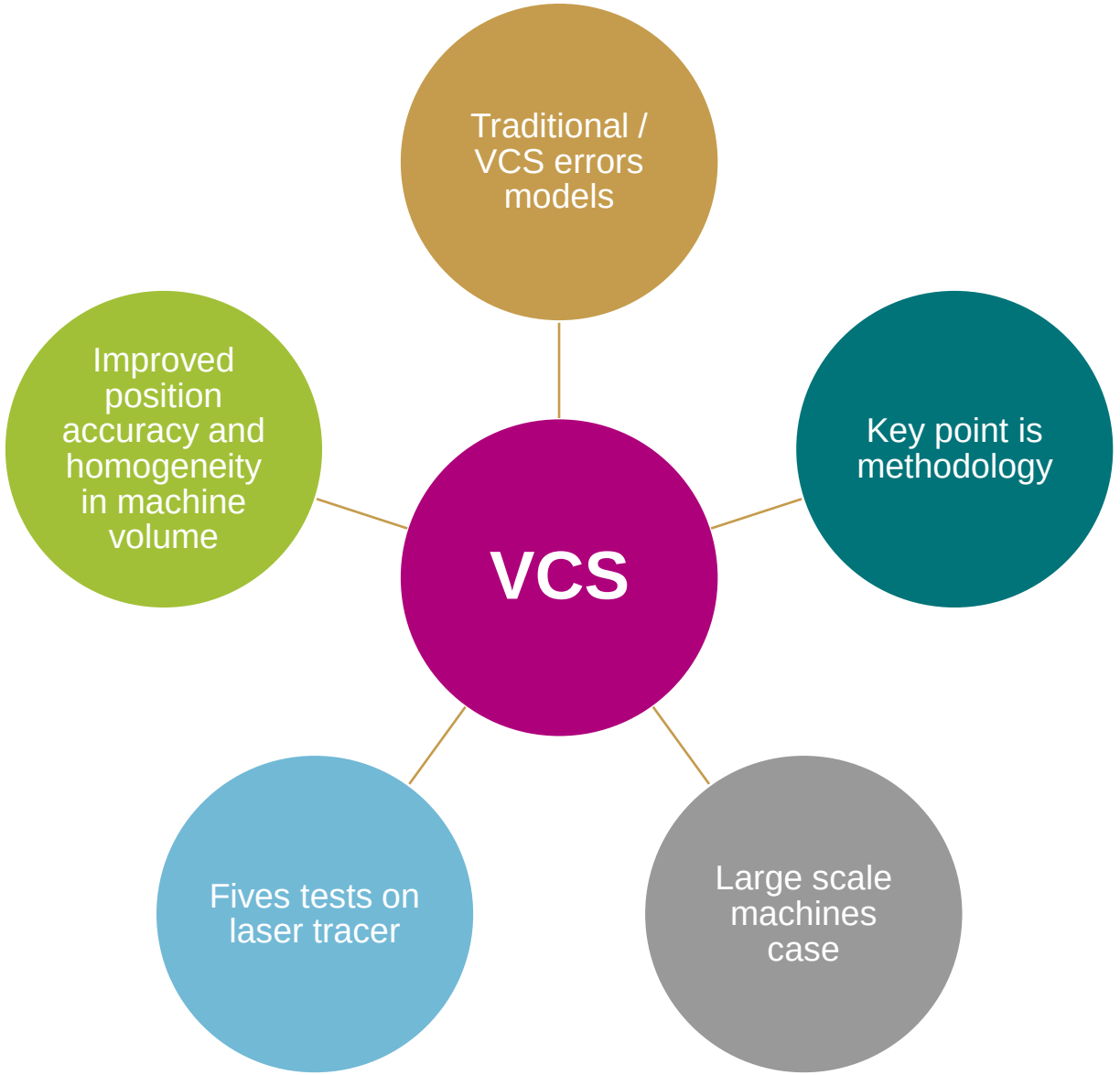






HIGH PRECISION MACHINES

VOLUMETRIC COMPENSATION
CONCLUSION



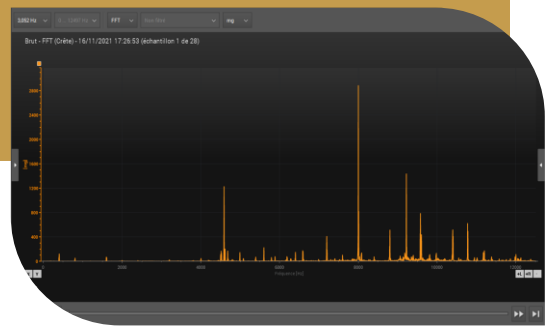
HIGH PRECISION MACHINES

SUMMARY

SENSORS & ACTUATORS

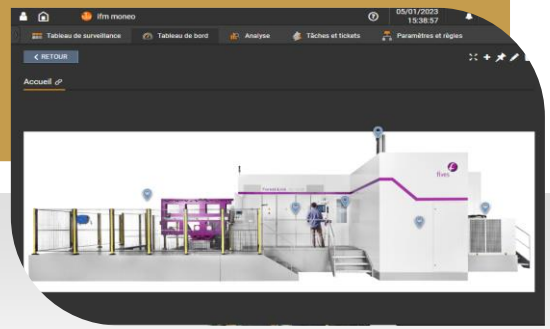
IO-Link inside

VIBRATIONS MONITORING



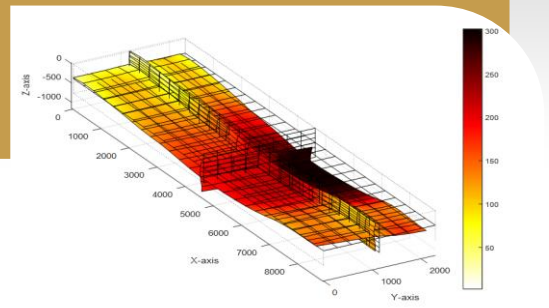
Integrated protection & maintenance

DATA COLLECTION



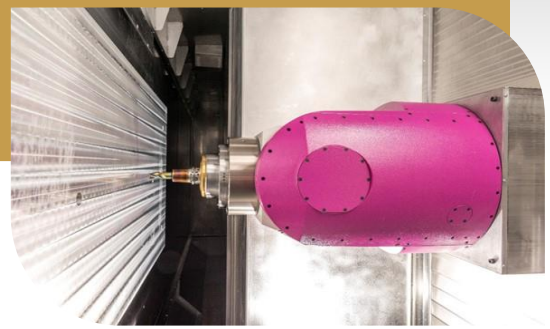
Dashboarding

PRECISION



Volumetric compensation

DILATATION



Temperature compensation

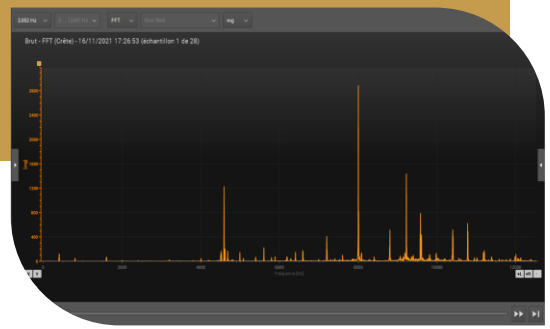
HIGH PRECISION MACHINES

SUMMARY

SENSORS & ACTUATORS

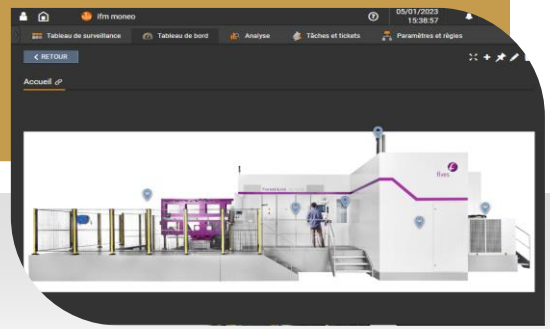
IO-Link inside

VIBRATIONS MONITORING



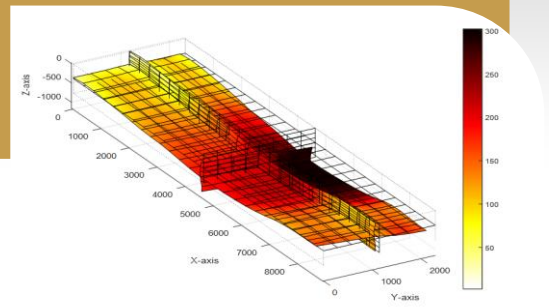
Integrated protection & maintenance

DATA COLLECTION



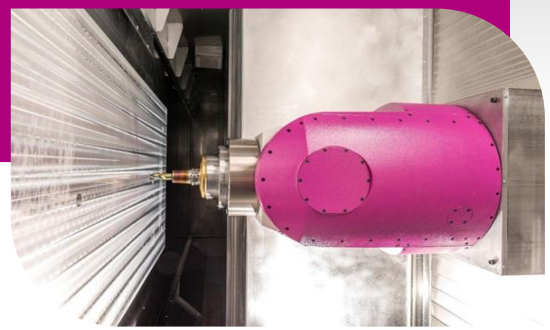
Dashboarding

PRECISION



Volumetric compensation

DILATATION



Temperature compensation

HIGH PRECISION MACHINES

DILATATION
APPLICATION ON LARGE SCALE MACHINES

Magnitudes

Aluminium : 23 µm / m /°C

Steel : 12 µm / m / °C

Glass : 6 µm / m /°C

Between Summer and Winter

(Temperature magnitude : 15°C)

Material	Dilatation on 10m
Aluminium	3,450 mm
Steel	1,800 mm
Glass	0,900 mm

Causes

- Motor heating (Joule, coolant)
- Environment temperature

Linear measurement ribbons

(Glass / Steel)

Spindle head

(Steel)

HIGH PRECISION MACHINES

Mitigation

- Motor cooling
- Air blowing
- Climatisation

RIBBONS DILATATION
INSTRUMENTATION

12 sensors

On our demo Aerostar

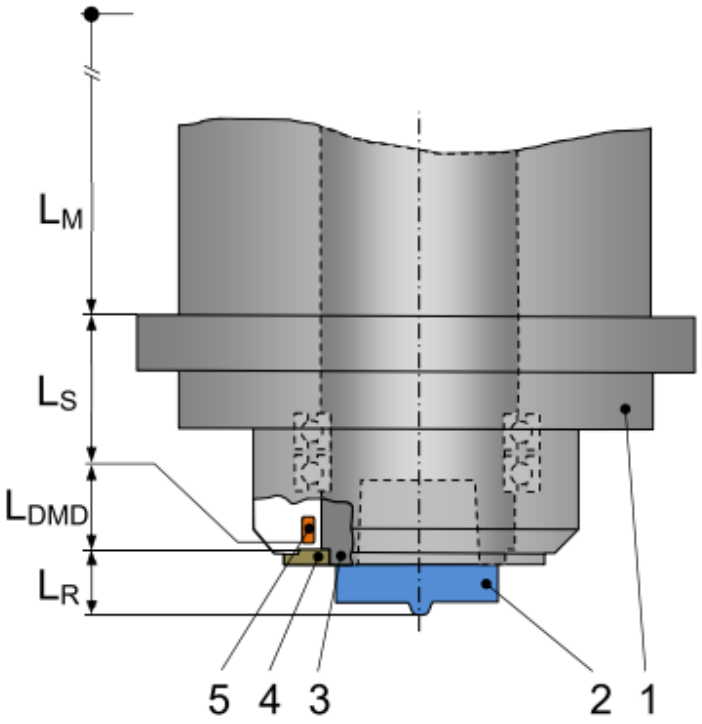
Measure temperature
on every machine part

Better machine reaction understanding
in cutting conditions

HIGH PRECISION MACHINES

fives

SPINDLE DILATATION
MODELISATION



Up to 200 µm

Dilatation of a spindle rotating at 30 000rpm

5 temperature sensors

- 1 for each bearing
- 1 for the spindle motor

+/- 20 µm

Deviation measured on a surface milling with a model-based compensation

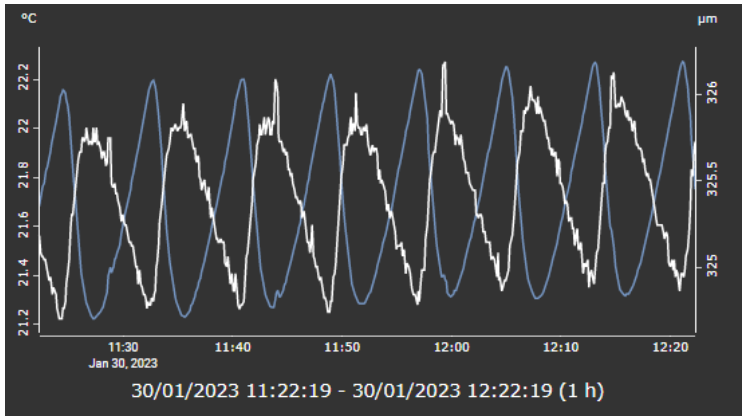
$$\delta = f(S_{rot}, T)$$

HIGH PRECISION MACHINES

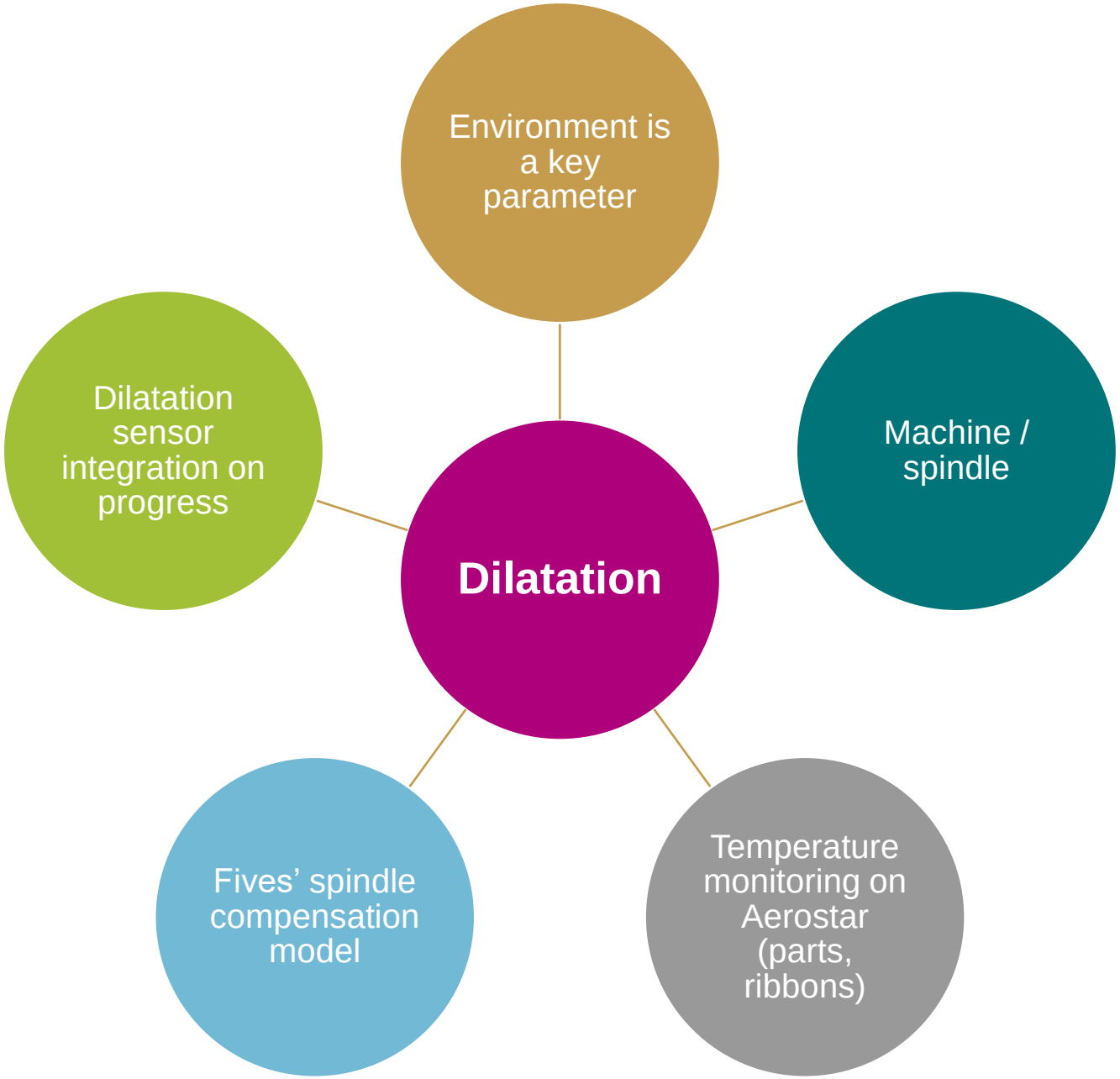
fives

Testing new sensor integration

- Mechanical dilatation
- Temperature



DILATATION
CONCLUSION



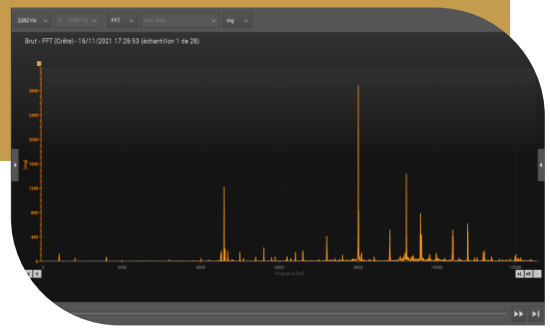
HIGH PRECISION MACHINES

SUMMARY

SENSORS & ACTUATORS

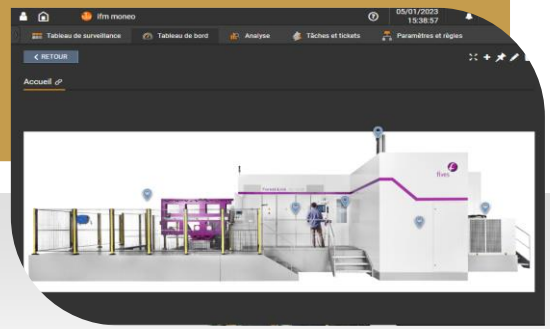
IO-Link inside

VIBRATIONS MONITORING



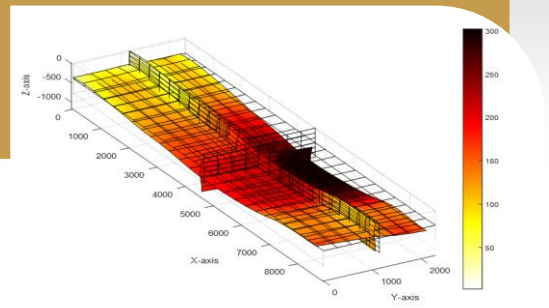
Integrated protection & maintenance

DATA COLLECTION



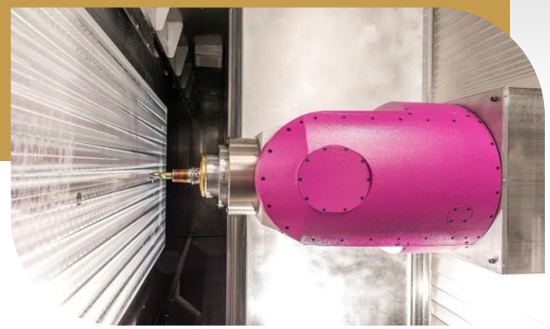
Dashboarding

PRECISION



Volumetric compensation

DILATATION



Temperature compensation

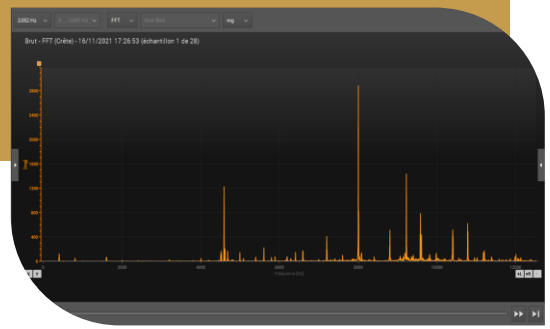
HIGH PRECISION MACHINES

SUMMARY

SENSORS & ACTUATORS

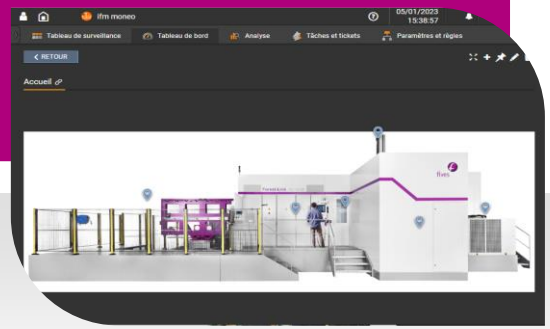
IO-Link inside

VIBRATIONS MONITORING



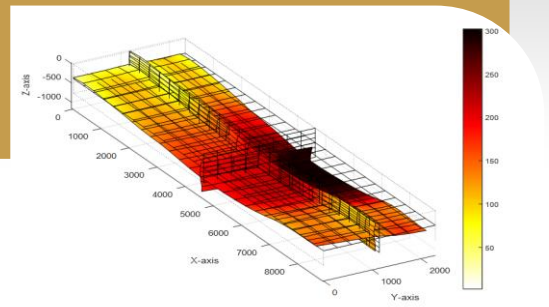
Integrated protection & maintenance

DATA COLLECTION



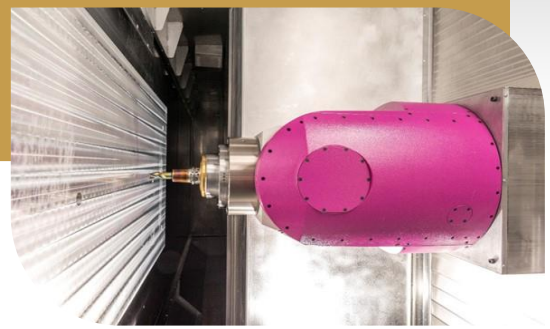
Dashboarding

PRECISION



Volumetric compensation

DILATATION



Temperature compensation

HIGH PRECISION MACHINES

DATA ACQUISITION
FIVES MACHINING'S PHILOSOPHY

Core machine systems
(sensors, CN, PLC, servo)

Monitoring, process systems
(vibrations, …)

HIGH PRECISION MACHINES

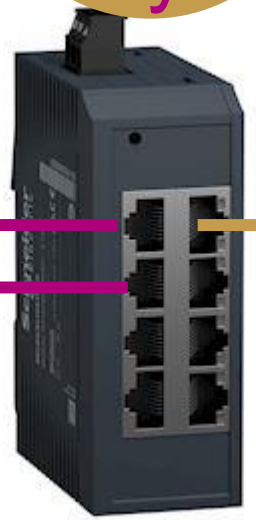
OPC UA

Diziscop

Other protocols

Machine

Machine 4.0 Ready !



Data acquisition

Deliver 4.0 machine…

Let the customer the freedom to use it !

DATA ACQUISITION
EDGE VS CLOUD

Sensors data
(IO-Link)

CN, PLC, motors data
(OPC UA, CortX)

Local PC
- Store data
- Compute data

Local network

Direct access via web browser on a local network

Vibrations
(VSE IFM, OPC UA)

HIGH PRECISION MACHINES

DATA ACQUISITION
EDGE VS CLOUD

Sensors data
(IO-Link)

CN, PLC and motors data
(OPC UA, CortX)

Gateway
- Send data to cloud service
- Protect connections (firewall)

Vibrations
(VSE IFM, OPC UA)

Cloud
- Store data
- Compute data

Internet

Access via secured Internet website

HIGH PRECISION MACHINES

DATA ACQUISITION
EDGE VS CLOUD

Solution	Pros	Cons
Edge	- Complete control on data - Local installation (limited dependancy on factory network)	- Limited data storage - Limited computing capacity - Local network management
Cloud	- Data storage redundancy - Data storage capacity - Higher computing capacity	- Data stored on a server - Need to secure an access over Internet

HIGH PRECISION MACHINES

DATA ACQUISITION
FIVES EXPERTISE ON DATA COLLECTION

Identify

- Define users
- Choose systems to monitor
- Identify relevant data to collect

Collect

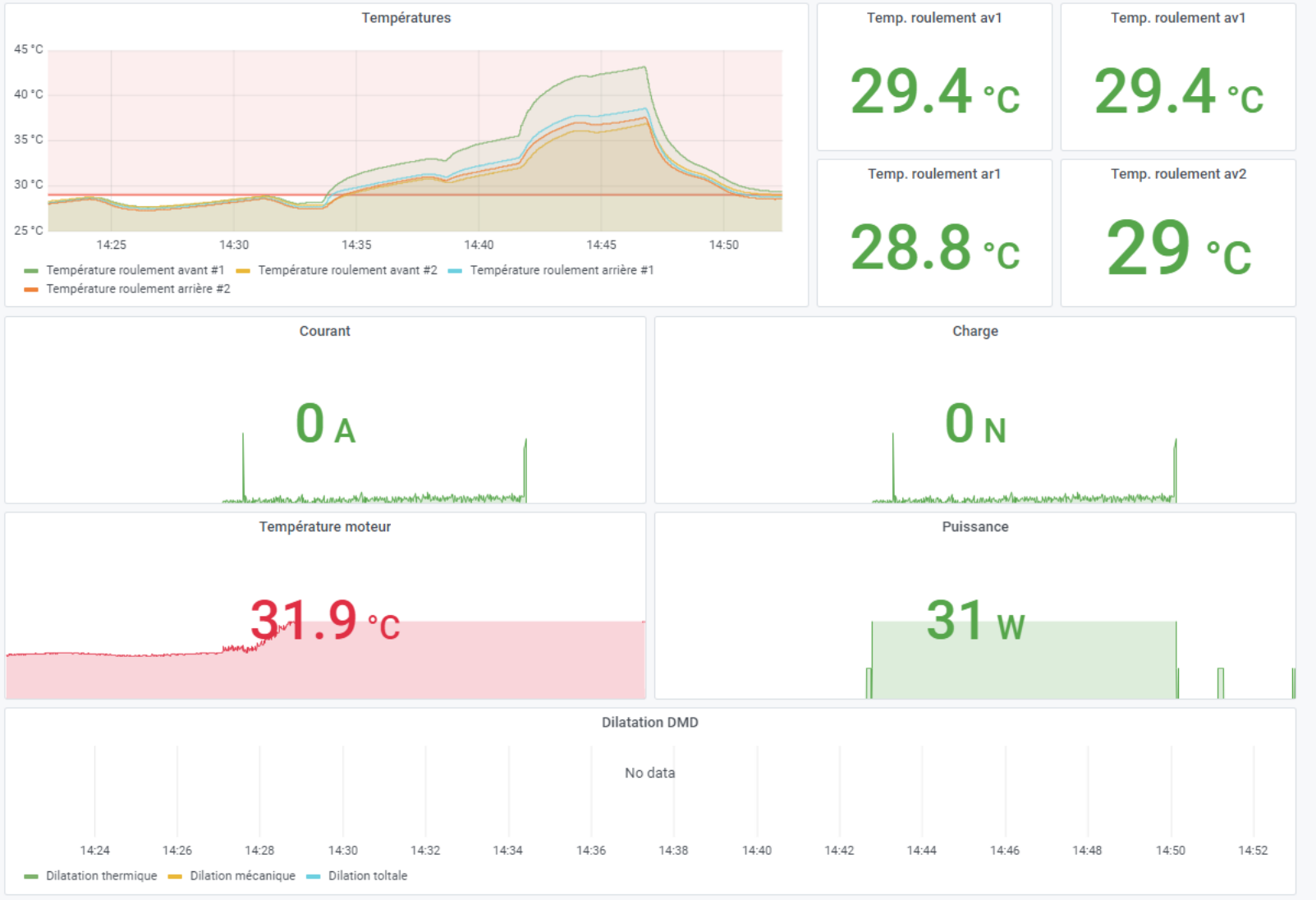
- Commission network and databases
- Define protocols and storage systems
- Collect data

Monitor

- Define relevant KPIs
- Create dashboards
- Create monitoring routines

HIGH PRECISION MACHINES

DATA ACQUISITION
USECASE ON AEROSTAR



Operator dashboard

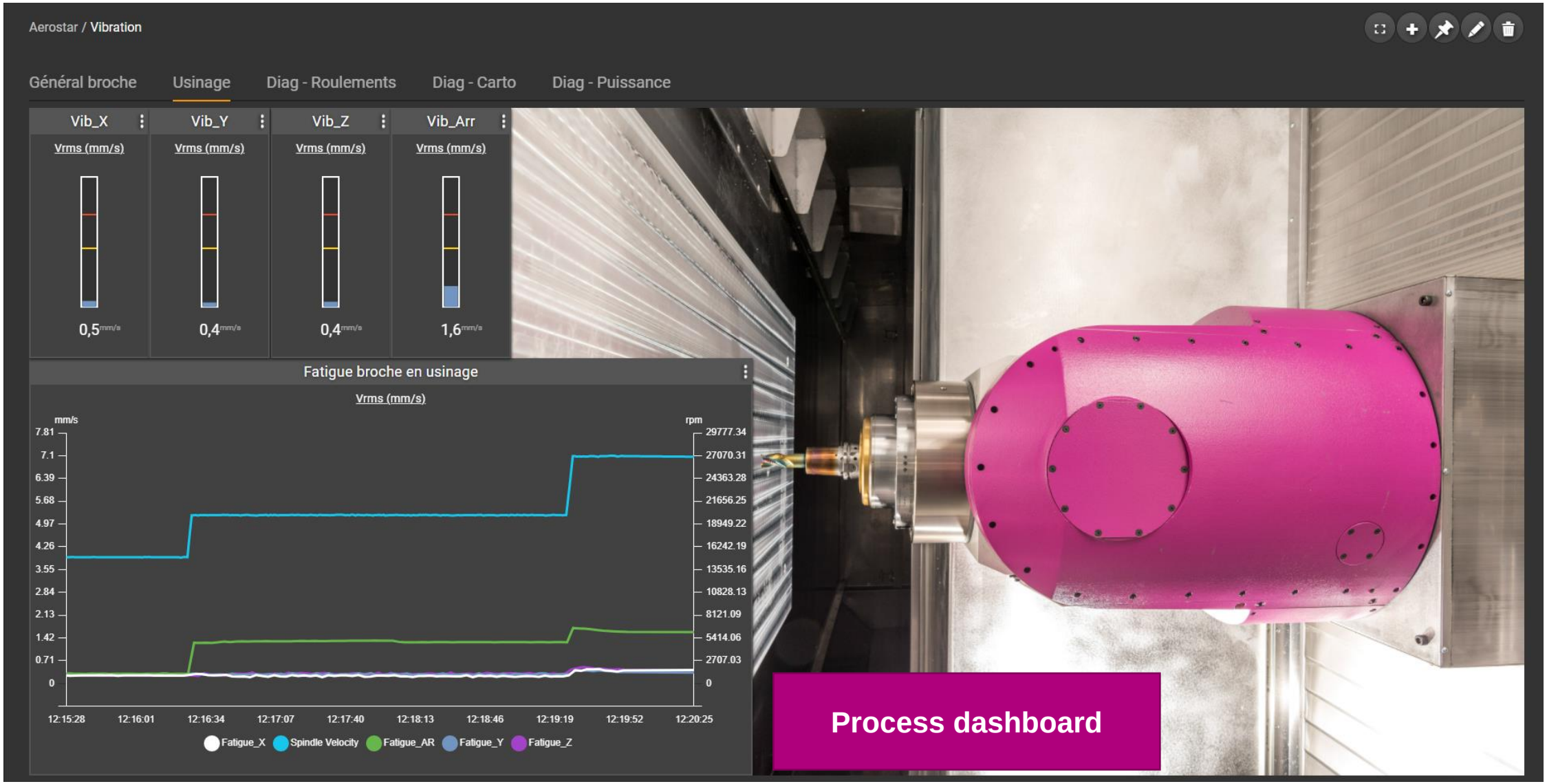
HIGH PRECISION MACHINES

DATA ACQUISITION
USECASE ON AEROSTAR

Maintenance dashboard

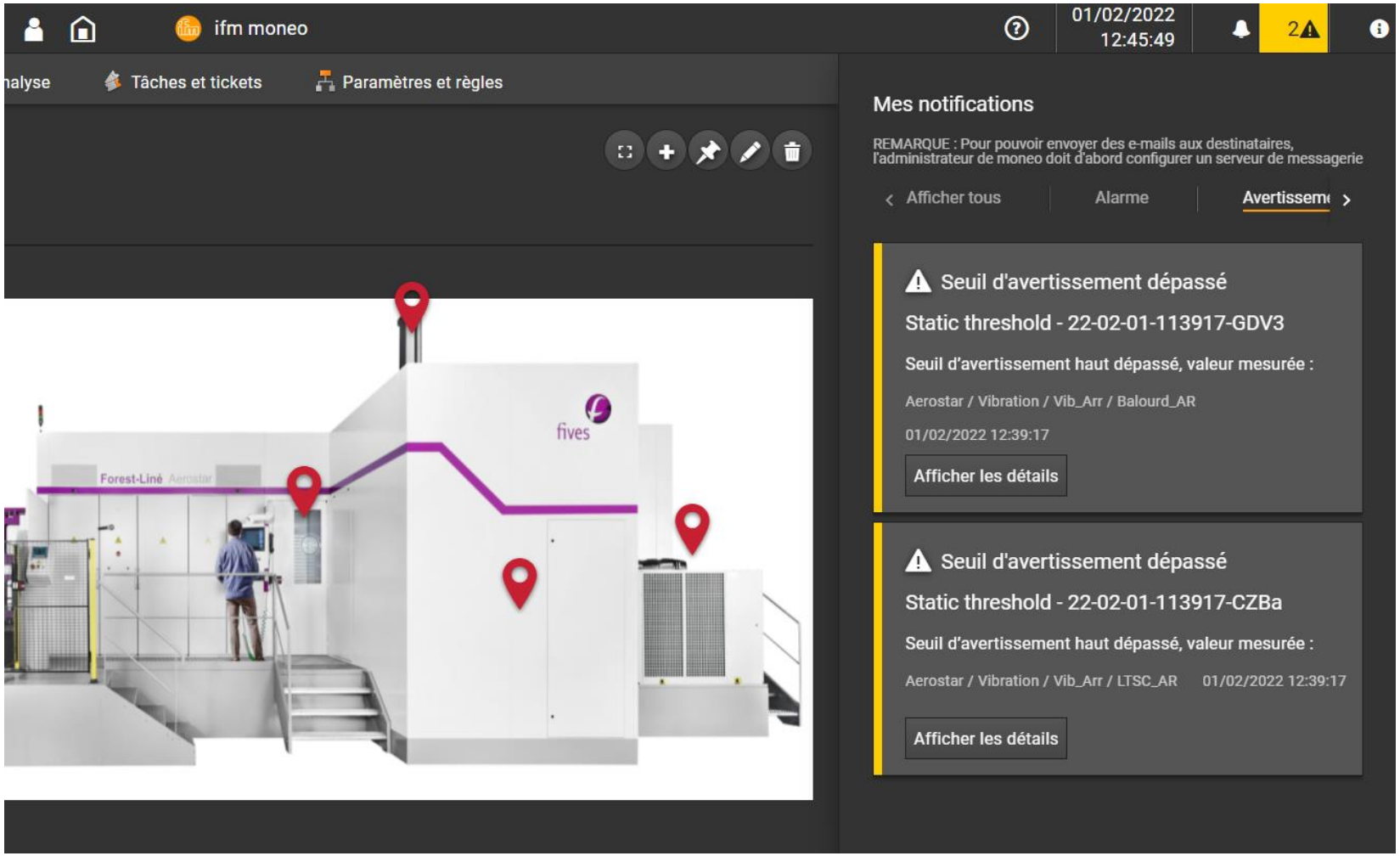
HIGH PRECISION MACHINES

DATA ACQUISITION
USECASE ON AEROSTAR



HIGH PRECISION MACHINES

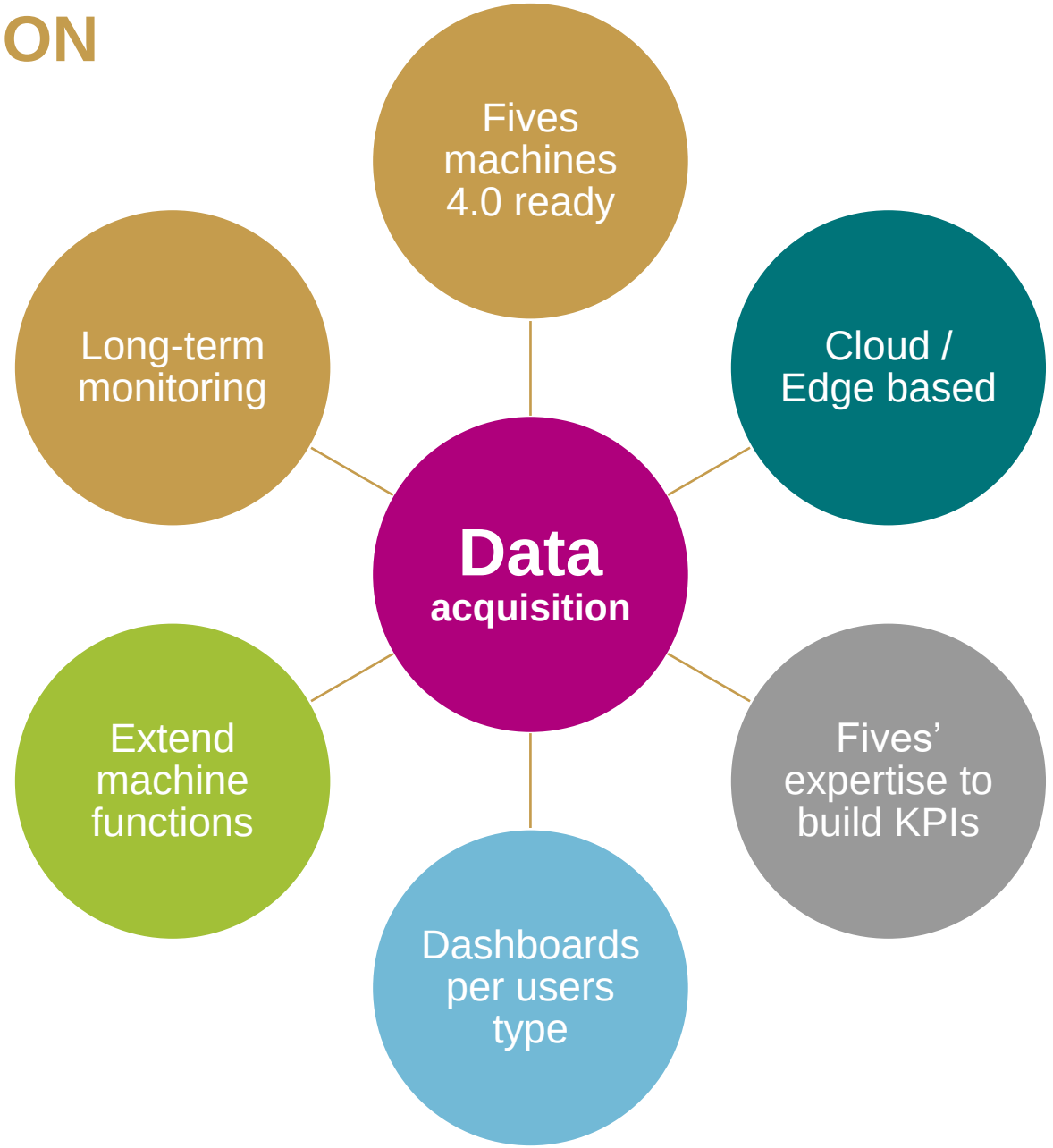
DATA ACQUISITION
USECASE ON AEROSTAR



Maintenance : enregistrement des alertes pour re-contextualisation

HIGH PRECISION MACHINES

DATA ACQUISITION
CONCLUSION



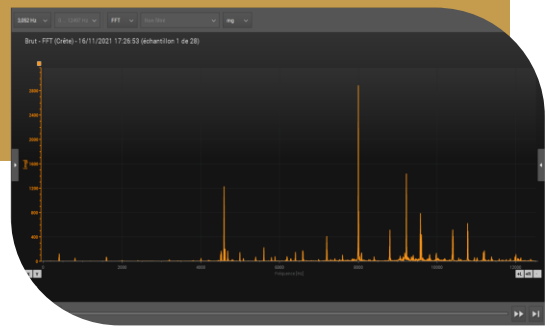
HIGH PRECISION MACHINES

CONCLUSION

SENSORS & ACTUATORS

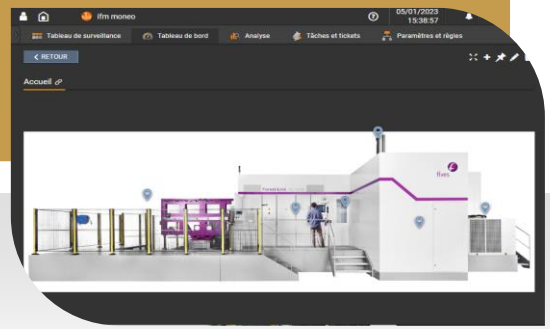
IO-Link inside

VIBRATIONS MONITORING



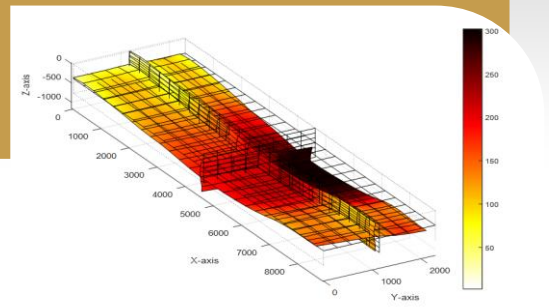
Integrated protection & maintenance

DATA COLLECTION



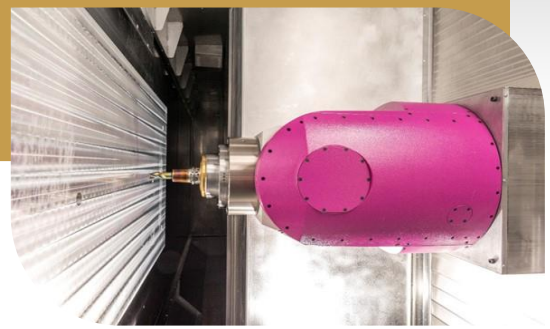
Dashboarding

PRECISION



Volumetric compensation

DILATATION



Temperature compensation

HIGH PRECISION MACHINES

fives

Industry can do it

www.fivesgroup.com