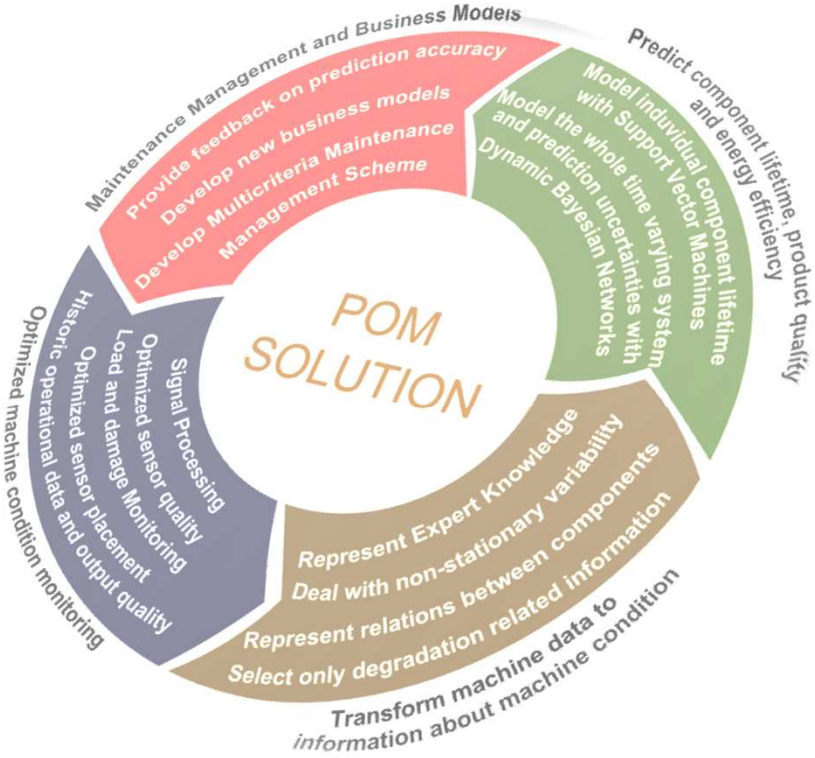


Low-cost sensors as key enabler for condition monitoring and predictive maintenance

Abdellatif Bey-Temsamani

POM2 Final Workshop

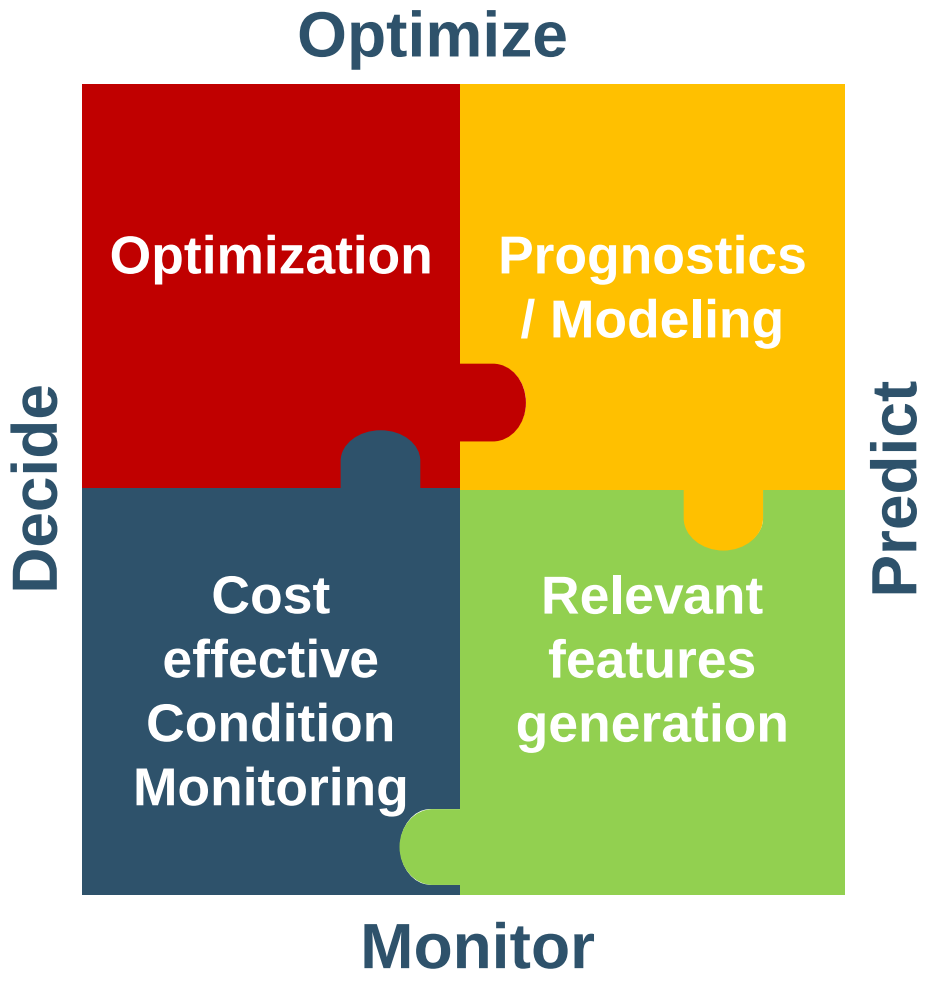
Leuven, 25/03/2014

Outlines

- **Condition Monitoring (CM) / Predictive Maintenance (PdM)**
- **Low-cost sensors as key-enablers for CM / PdM**
- **Some related results in POM project**
- **Conclusions**

Key-enablers for assets Reliability & Improved operational performance – POM project

- **Increased asset reliability / Availability ←→ Avoid / Prevent failures / faults by relevant monitoring**
- **Increased assets performance ←→ Reduce losses / increase benefits by optimizing objective functions**



Condition Monitoring (CM)

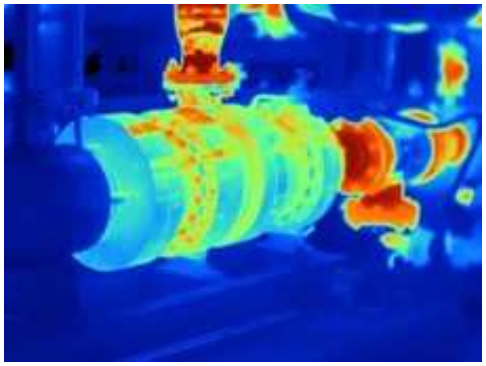
- **CM refers to a system / process to monitor the condition of an engineering asset**

- **Such a CM system would often consists of a sensor and potentially a processor to convert the measured data to the condition parameter**

CM system = Sensors + Data2Condition

- **Applications - examples**

Vibration monitoring



Thermal monitoring

Oil monitoring

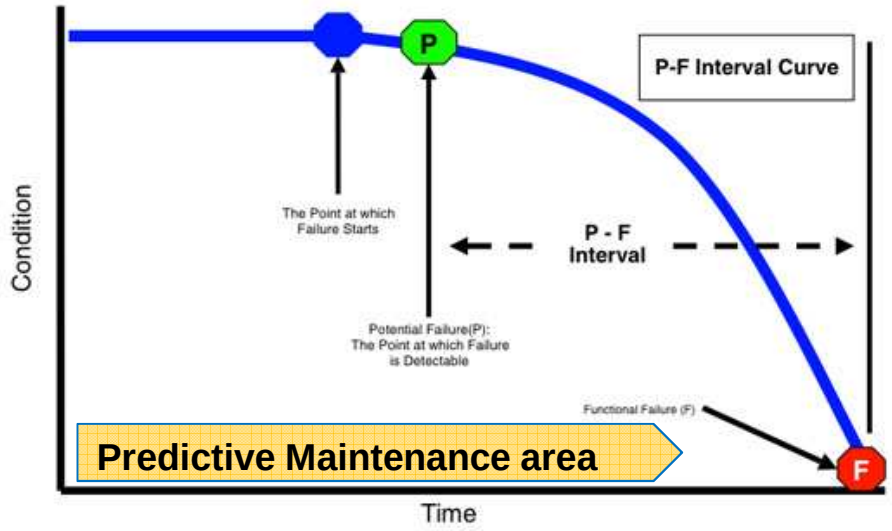
Predictive Maintenance (PdM)

- **PdM refers to a system / process to predict when a maintenance should be performed on an engineering asset based on its condition**

- **Such a PdM system would often consists of a CM system and a model to predict when maintenance is needed (prognostics)**

PdM system = CM system + Prognostics

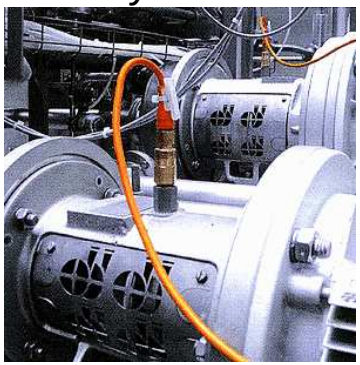
- **P-F curve**



CM / PdM types

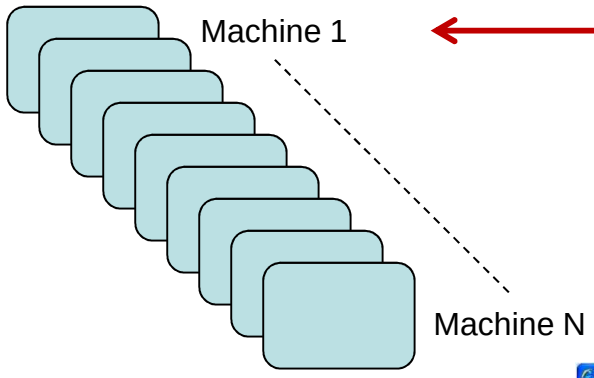
- **Periodic (off-line, intermittent)**
  - Monitor the engineering asset on periodic / intermittent basis
  - e.g. use hand-held systems to record condition of the engineering asset and trend off-line the data to predict when maintenance is needed
    - Local (advanced) processing
    - Portable

- **Permanent (on-line, continuous)**
  - CM is permanently mounted on the monitored asset to continuously record the condition
  - e.g. permanently install a sensor to monitor an asset
    - The data could be transferred automatically to the central unit for processing (wired / wireless transmission)
    - A better understandability of the asset behavior versus time as the condition is continuously tracked

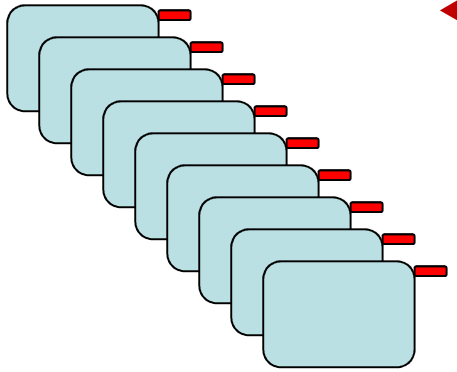


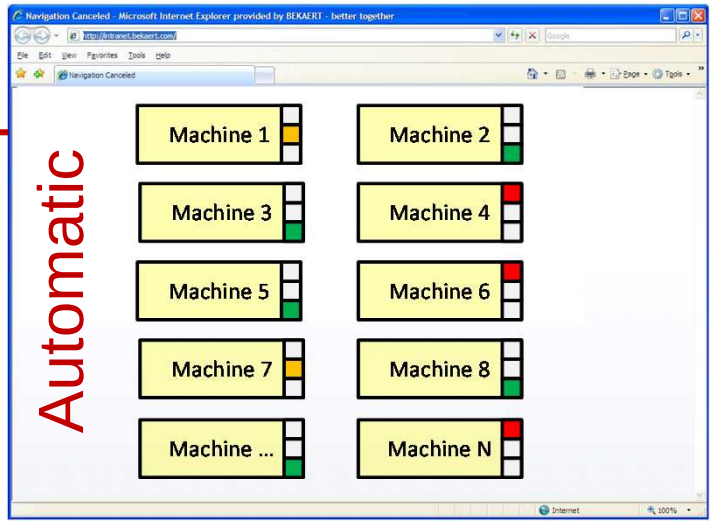
On-line – off-line systems in practice

Production plant



+ **Costs**
  - Hand-held system
  - Manual recording / analysis





+ **Costs**
  - Sensors
  - Data transmission

Outlines

- **Condition Monitoring (CM) / Predictive Maintenance (PdM)**
- **Low-cost sensors as key-enablers for CM / PdM**
- **Some related results in POM project**
- **Conclusions**

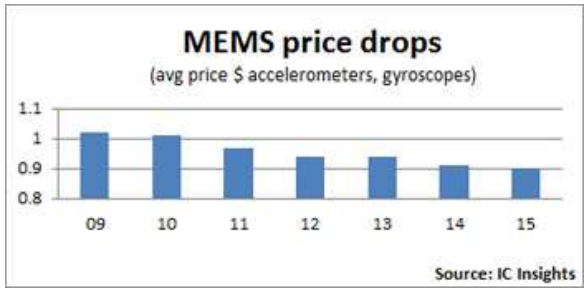
Low-cost sensors

+ General observations

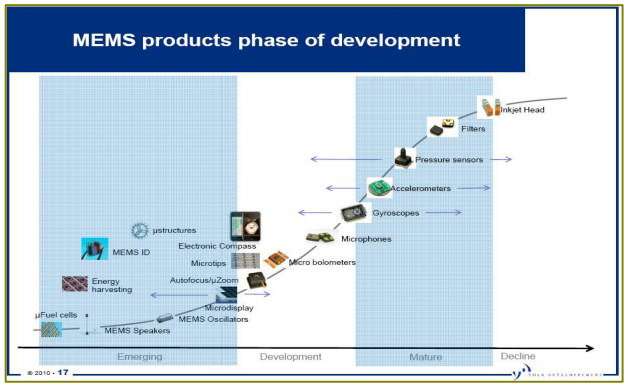
- Price of sensors in continuously decreasing → high competitiveness
- New emerging cheap sensing technologies → e.g. MEMS sensors
- Emerging / cheap wireless solutions for data transmissions
- Solutions for harsh environment / industrial applications are available

→ The low-cost ingredients for online CM / PdM are appearing …

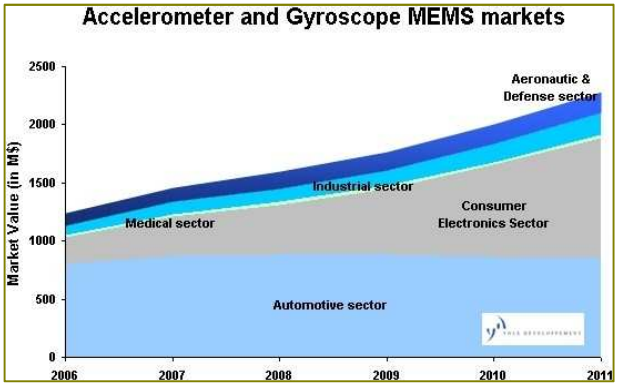
Price drop



Maturity



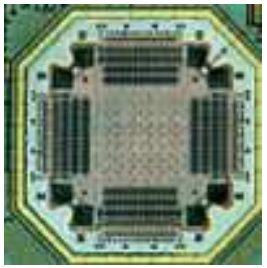
Market shares

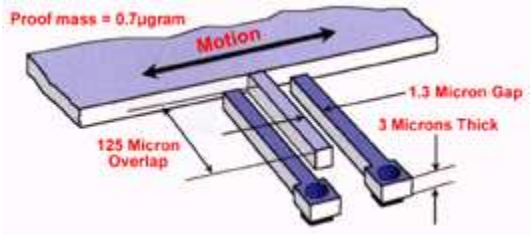


MEMS accelerometer for condition monitoring

- **Although MEMS accelerometer are more and more available in the market → they still suffering from some artifacts to make them competing with the conventional sensors***
  - Response of microscopic mechanical systems / materials
  - Response of electronics (Op-Amps / transistors non-linearity)

  → End-users should learn techniques to compensate non-ideal MEMS behaviors
- **In POM project we developed a set-up to characterize MEMS accelerometers which allows to identify non-ideal MEMS responses**





*Source: http://www.sensorland.com/HowPage023.html

Outlines

+ **Condition Monitoring (CM) / Predictive Maintenance (PdM)**

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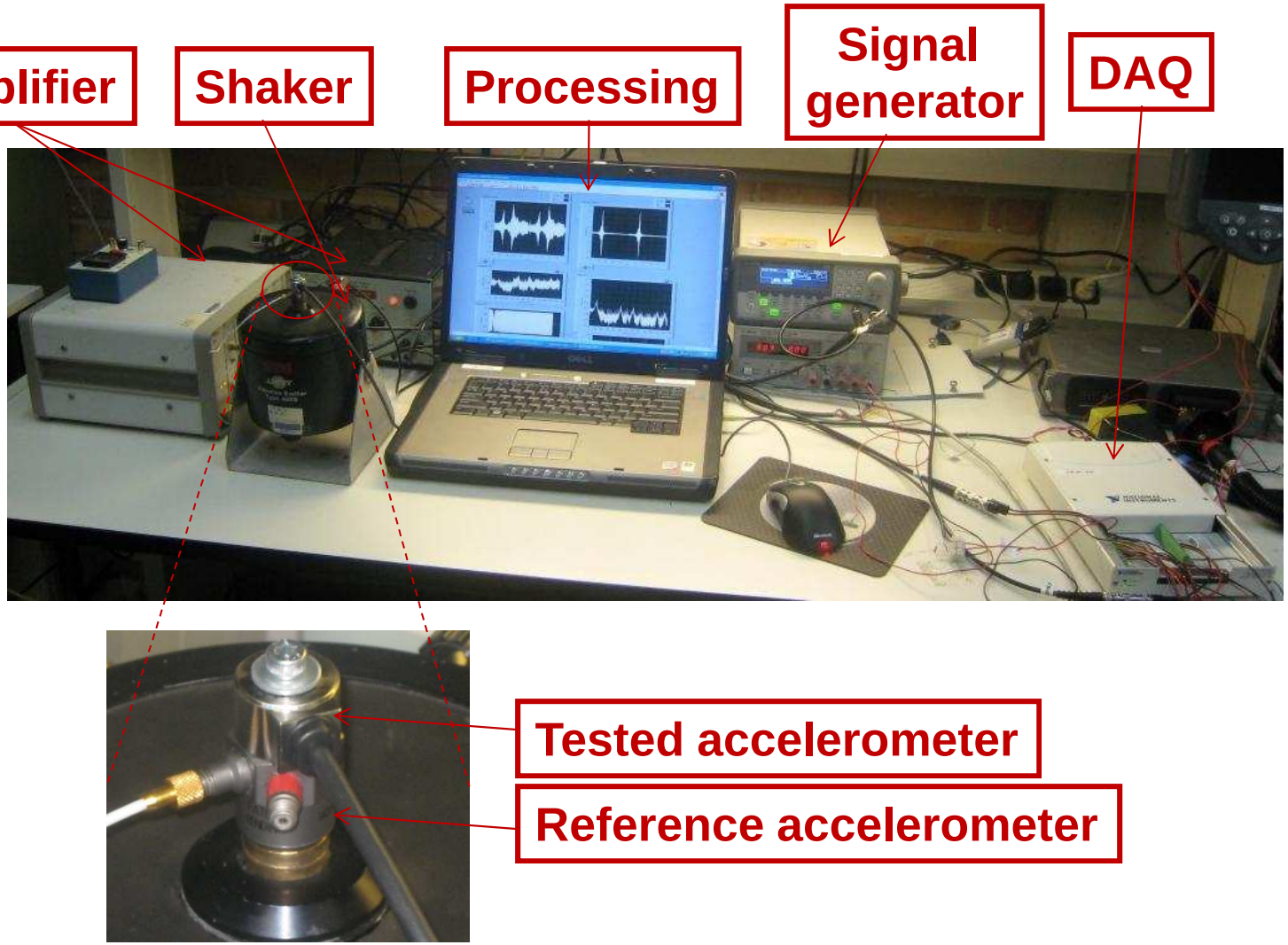
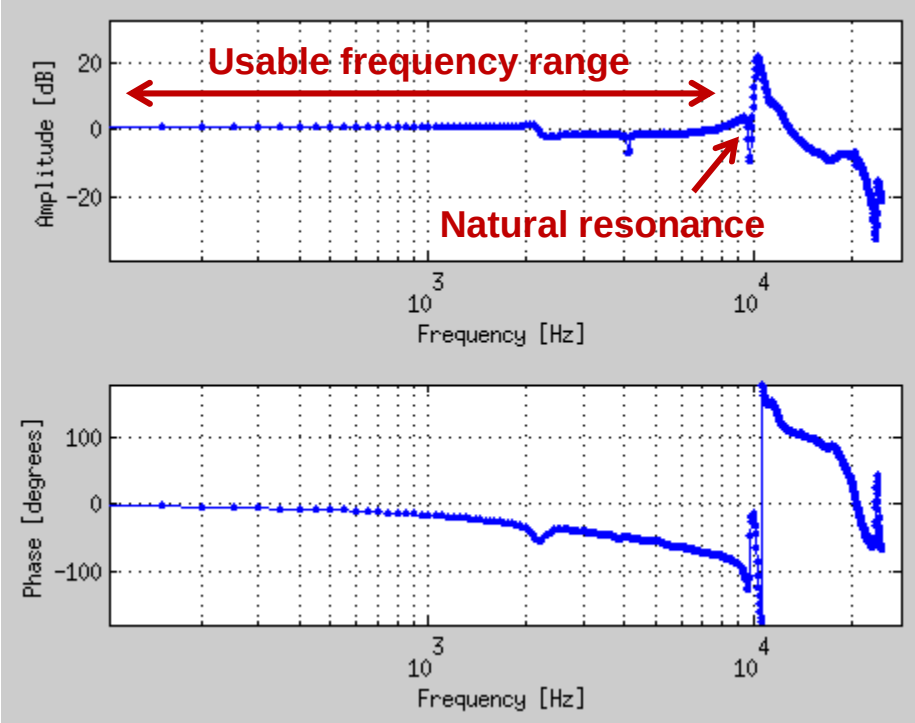
+ **Some related results in POM project**

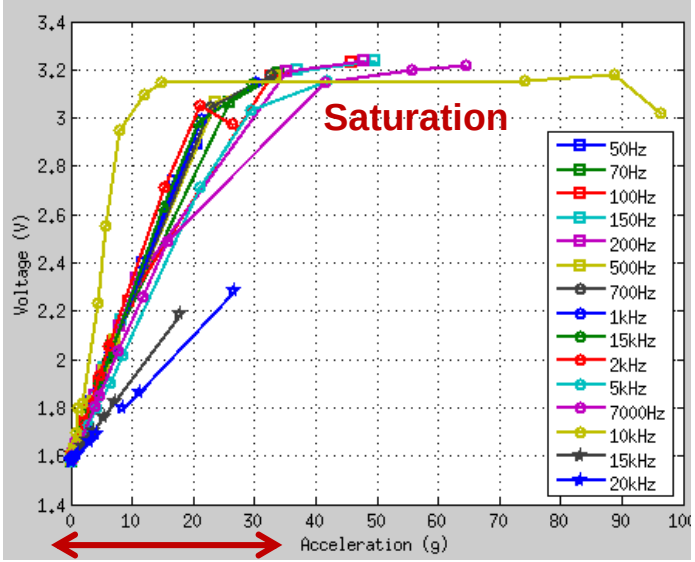
+ **Conclusions**

MEMS accelerometer characterization set-up

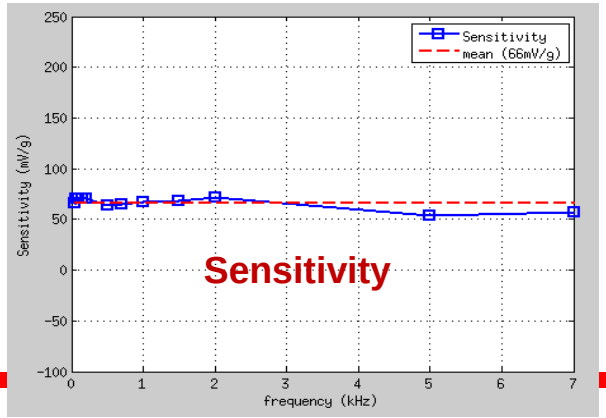


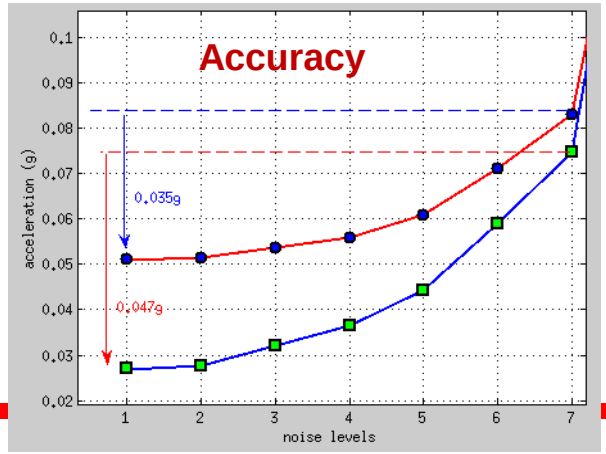
Derive MEMS Characteristics …



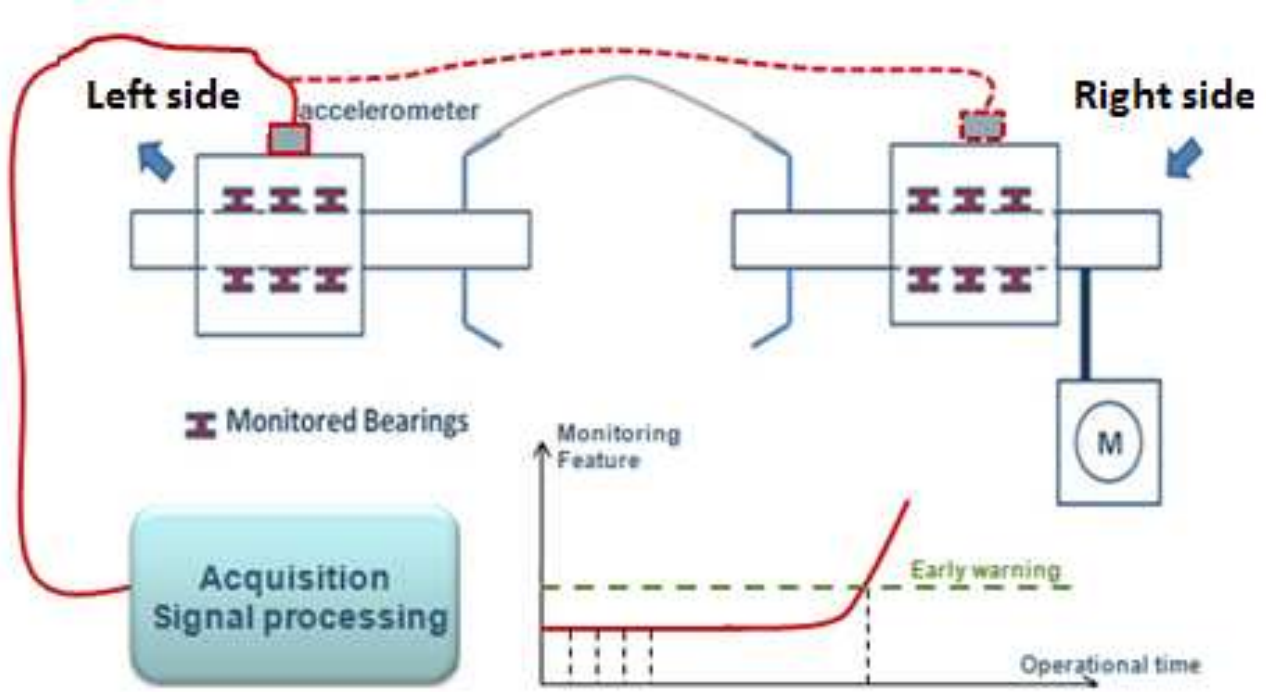


Useful acceleration range





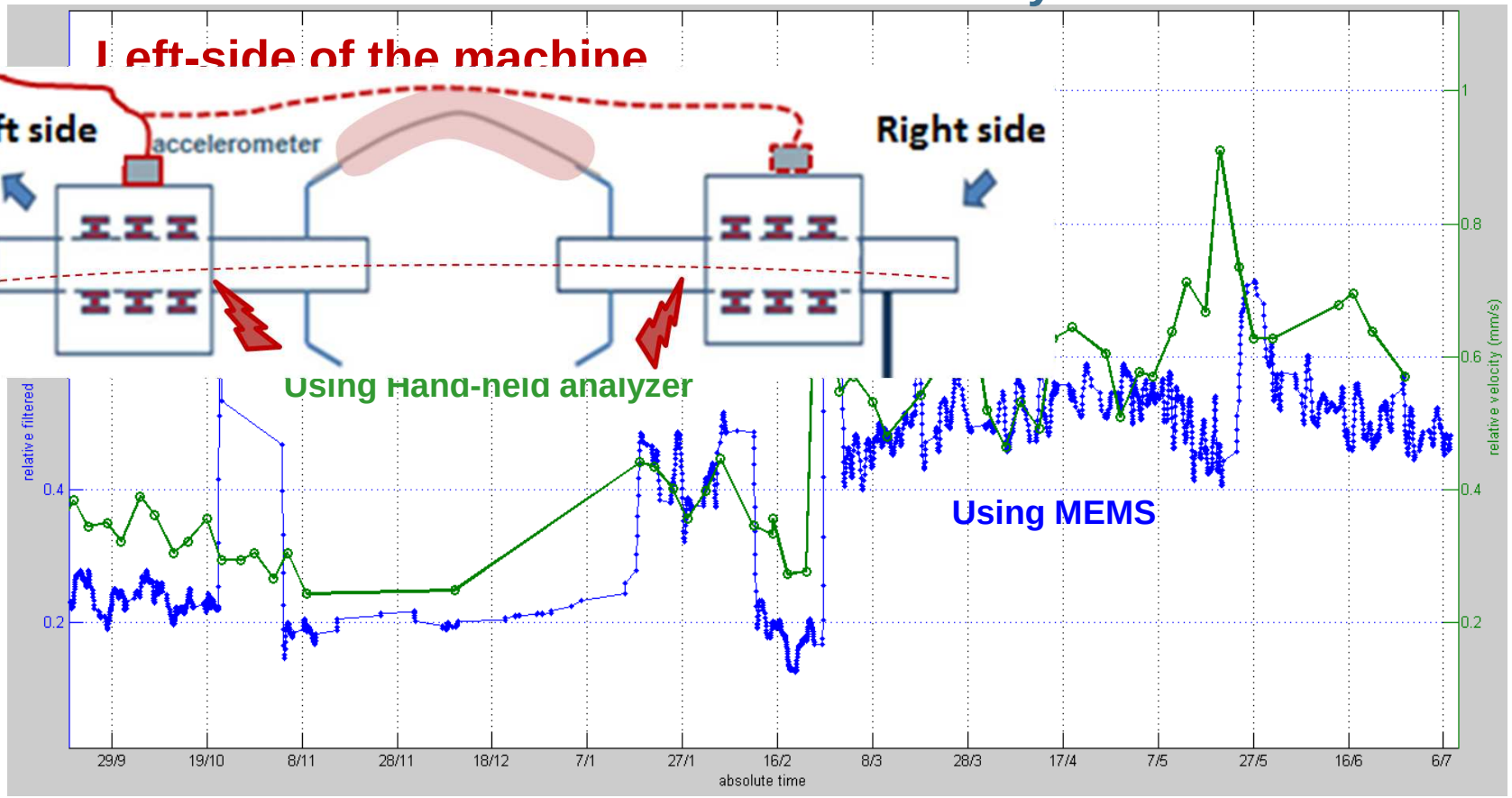
Case study – monitoring the bearings of a steel cord production machine



- **Use MEMS accelerometers to monitor the condition of the bearings in a steel cord production machine**
- **Use dedicated signal processing techniques to deal with MEMS limitations and extract relevant features to trend the evolution of faults**

Imbalance monitoring –

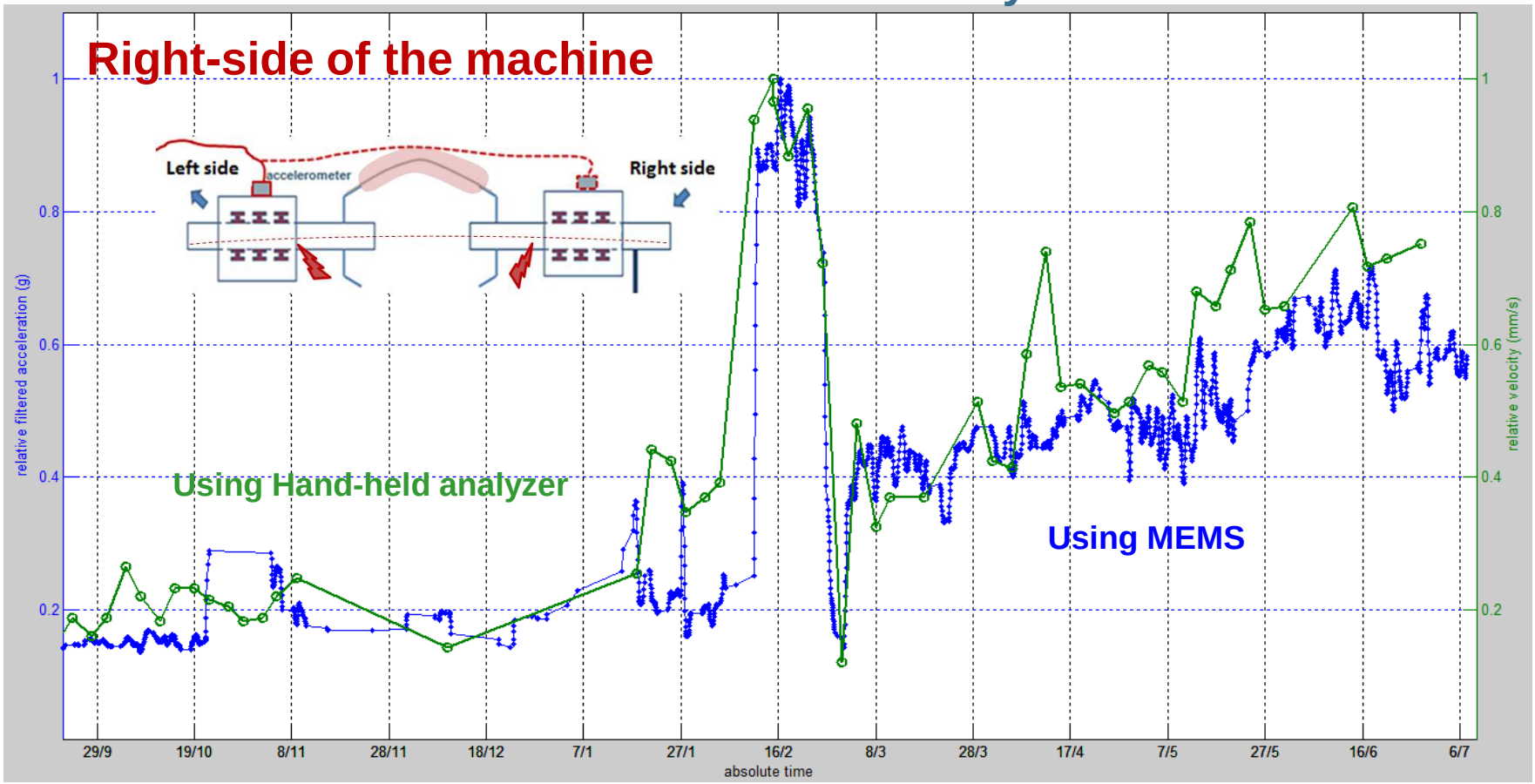
MEMS accelerometer versus Hand-held analyzer



Relative trends of imbalance fault extracted using MEMS accelerometer and using Hand Held system are comparable

Imbalance monitoring –

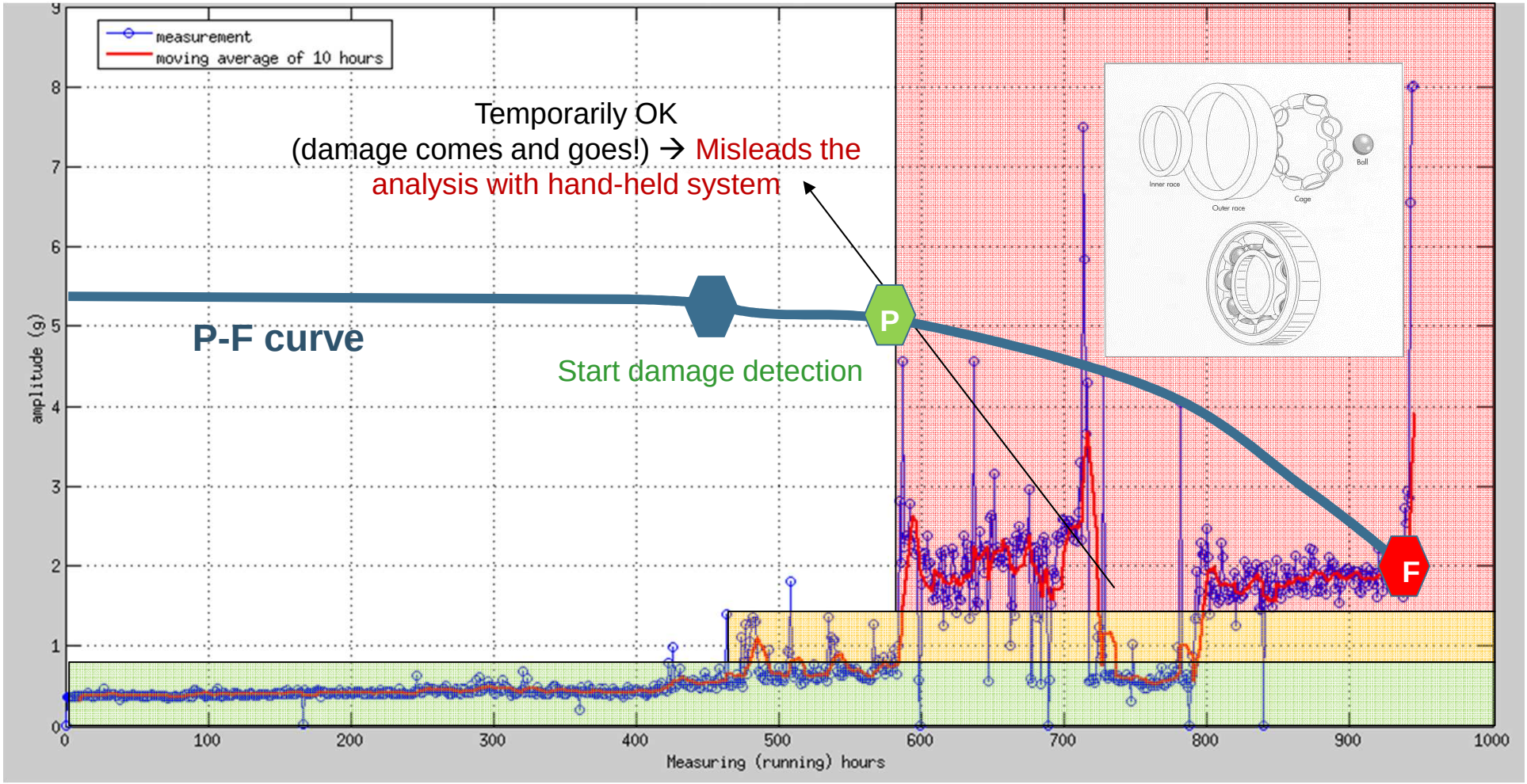
MEMS accelerometer versus Hand-held analyzer



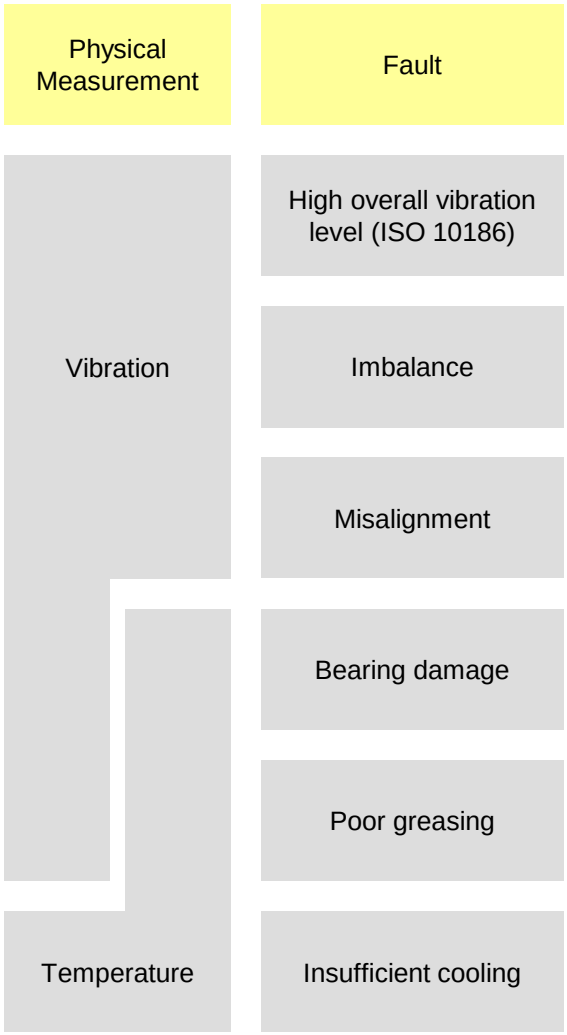
The imbalance seen at the two sides of the machine is comparable

Catastrophic failure monitoring

Accidental stop (cage broken)



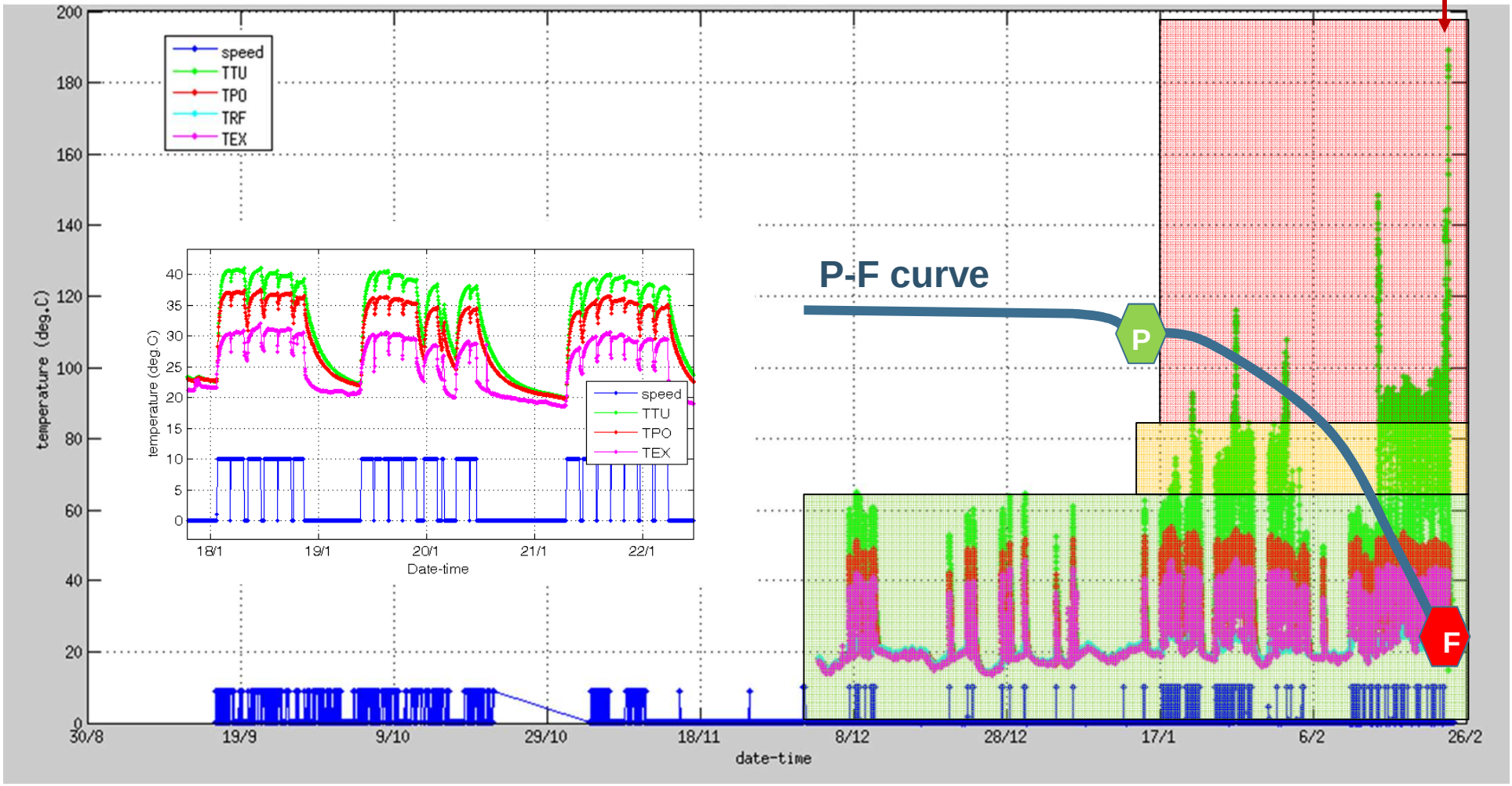
Temperature sensors for bearings condition monitoring



- **For bearing condition monitoring, temperature sensors could also be used to monitor some of these failures**
- **The advantage compared to MEMS is the price ratio (~1/100)**

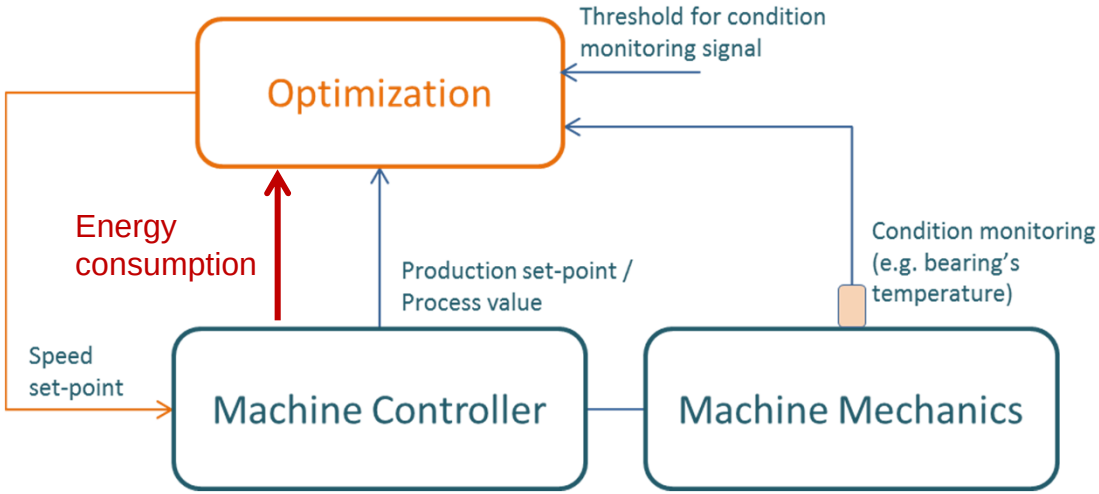
Catastrophic failure monitoring – same example slide 16

Accidental stop (cage broken, 200° C!)



Performance optimization using temperature monitoring

- + **A possible way to extend lifetime of bearings would be to control the operational temperature area**
- → **A thermal protection at 70°C was implemented in machine's controller to shut-down the machine if such a level is exceeded**
- → **We propose in the project to implement optimization of machine's settings taking into account condition monitoring and that**
  - using single-objective (e.g. maximize production capacity)
  - using multi-objective (e.g. maximize production capacity and minimize power consumption)



Outlines

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Summary

- **Monitoring the condition of the assets is needed to increase the availability and to improve the performance of the system / process**
- **Low-cost sensors might be a good investment to strengthen this monitoring (in a continuous way) and increase the Return On Investment (ROI)**
- **MEMS trends (price decline , increased maturity) are indicators of this potential ROI increases**
- **Examples using main condition monitoring (vibration) in rotary machines successfully showed the potential of MEMS accelerometer to correctly predict different types of bearings related faults / failures**
- **Thanks to the very low price, temperature sensors represent also cheap solutions for condition monitoring is some cases**
- **Example of catastrophic bearing's failures prediction was shown based on temperature monitoring**
- **Condition monitoring could be used not only to monitor the condition of the asset by also to optimize its performance**

Questions?

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