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# Condition Monitoring for Predictive Maintenance and Machine Optimization

Convegno MUSP – 10/04/13

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National Instruments

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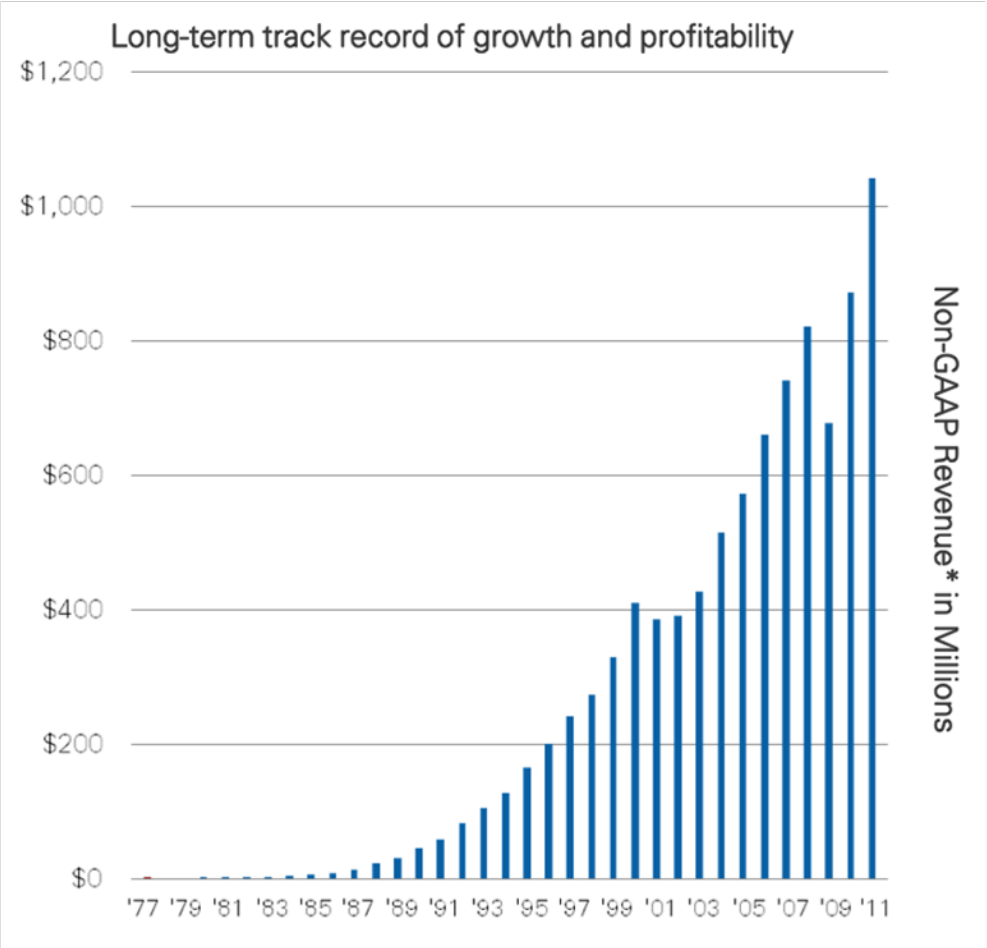
# National Instruments – who we are

We equip engineers and scientists with tools that accelerate productivity, innovation, and discovery

- Headquarter in Austin - TX
- Non-GAAP Revenue 2011: $1,1 Bn
- Global Operations: Approximately 6,500 employees; operations in more than 45 countries
- Broad customer base: More than 35,000 companies served annually
- Diversity: No industry >15% of revenue
- Culture: Ranked among top 25 companies to work for worldwide by the Great Places to Work Institute

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# Graphical System Design – what we do

- We equip engineers and scientists with tools that accelerate productivity, innovation, and discovery
- A Platform-Based Approach for Measurement and Control

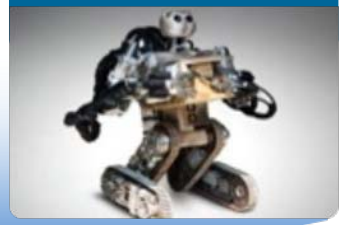
Test

Monitor

Embedded

Control

Cyber Physical

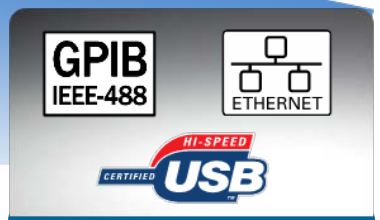


NATIONAL INSTRUMENTS LabVIEW™

Desktops and PC-Based DAQ

Real-Time Measurement&Control

RIO and Custom Designs




Open Connectivity with 3rd Party I/O

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# Smart Machine needs

| | |
|---|---|
| Autonomous Operation | • Modular manufacturing equipment with intelligent controls<br>• Awareness of environment |
| Avoid and correct processing errors | • Self-analysis and self-repairing capabilities<br>• On-the-fly modification of process plans |
| Learn and Anticipate | • Model-based control, Adaptive control<br>• Simulation |
| Interaction with other Machines and Systems | • Interconnected Systems – Smart Factory<br>• Commonly shared data structures |

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# Condition Monitoring on Machine tools two vectors:

1. Remote Monitoring and Diagnostics
   - Degradation Assessment
   - Fault Classification/Localisation

2. Prognostics
   - Health Assessment
   - Performance Prediction (Remaining Useful Life)

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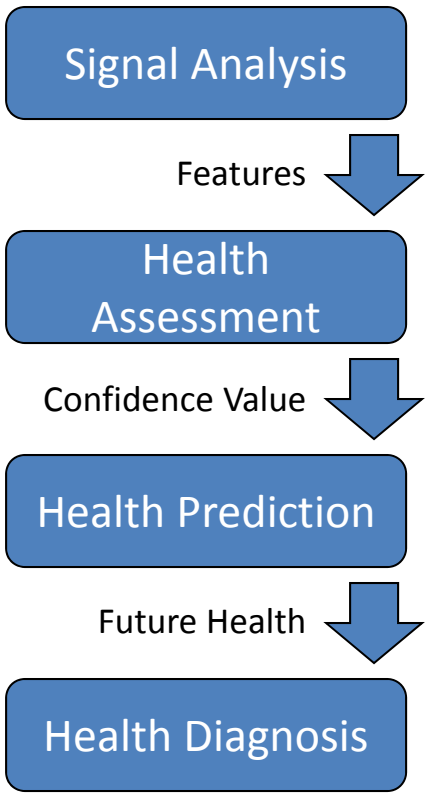
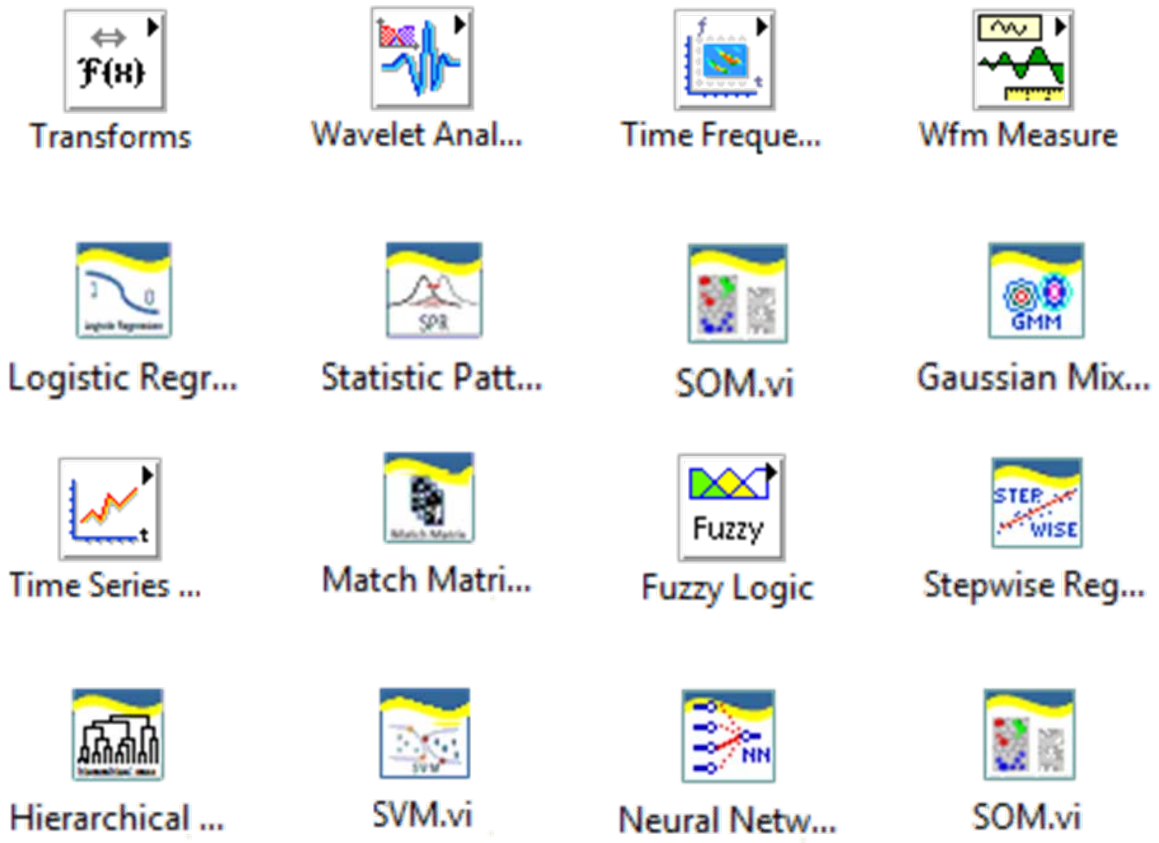
# NI LabVIEW Watchdog Agent Toolkit




Center for Intelligent Maintenance Systems

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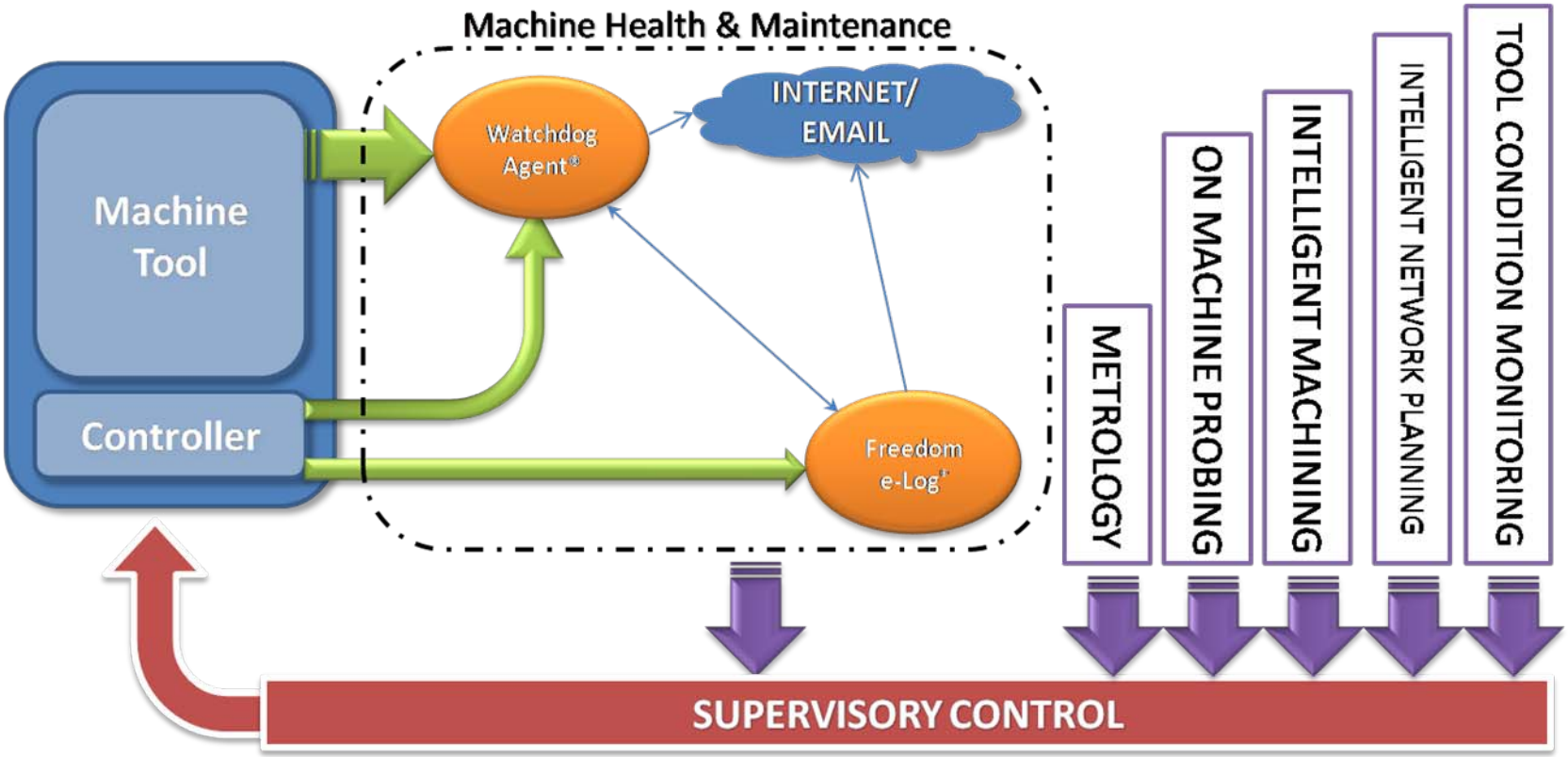
# Machine Health & Maintenance

**"It deals with the remote monitoring of machine status and assessment of the condition of the smart machine including its critical components using diagnostic and prognostic evaluation tools."**




***CAPABILITIES:***

- Remote machine performance monitoring
- Real-time machine status monitoring and alarm display
- Real-time access to machine ladder and I/O points

***BENEFITS TO INDUSTRY:***

- Reduce unscheduled maintenance
- Avoid part variability due to machine degradation
- Avoid catastrophic failures

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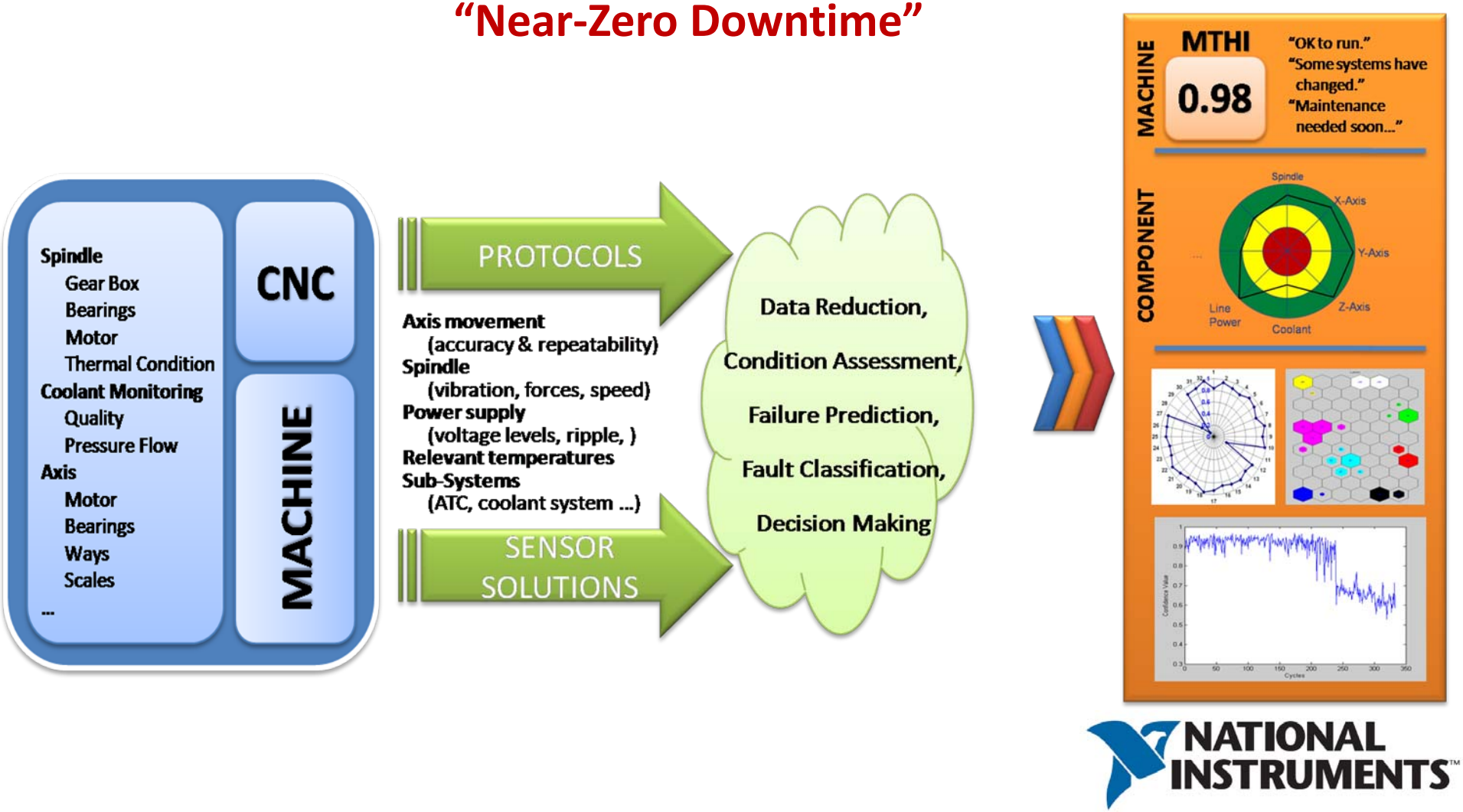
# Goal

**Develop an integrated health monitoring system capable of accurately monitoring and predicting the machine health for: "Near-Zero Downtime"**

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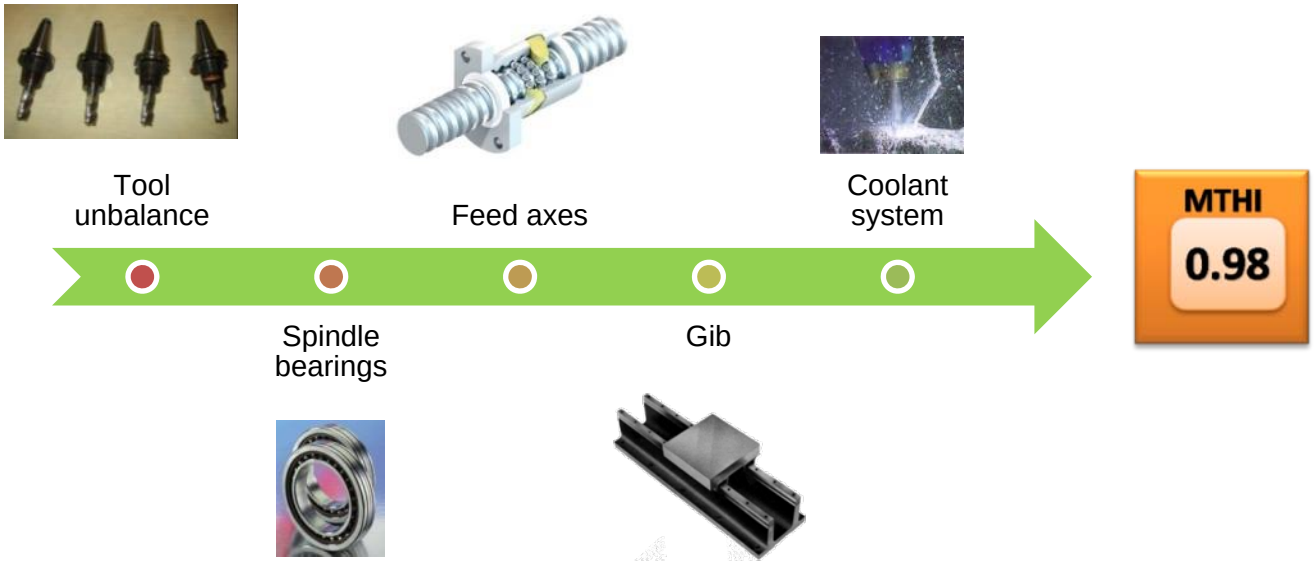
# Tasks




1. Build health assessment models (Confidence Value(CV)/ Remaining Useful Life/ Fault Detection) for smart machine components

2. Build the machining quality(MQ) models (correlating CV to MQI) for smart machine components

3. Build the framework for calculating MTHI and dashboard integration

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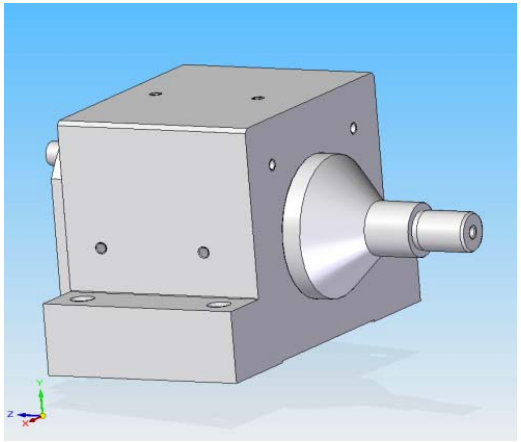
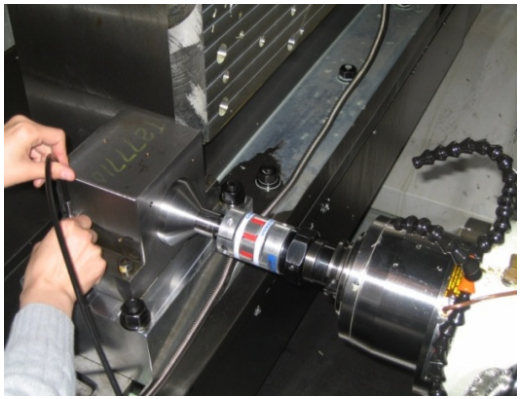
# Task 2: Overview



**Why spindle monitoring**

- a spindle failure can cause severe part damage and machine downtime, affecting overall production logistics and productivity

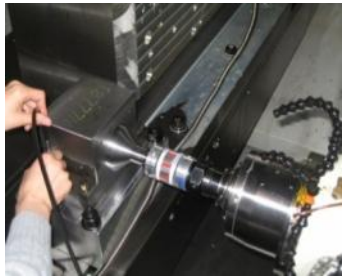


**Spindle components monitoring**

- Spindle bearing: Vibration/Temperature
- Spindle load: Current
- Tool-retention system: Vibration
- Coolant: Concentration/pH/Temperature

# Task 2: Recap

**Data Acquisition** → **Signal de-noise** → **Feature Extraction** → **Health Assessment**



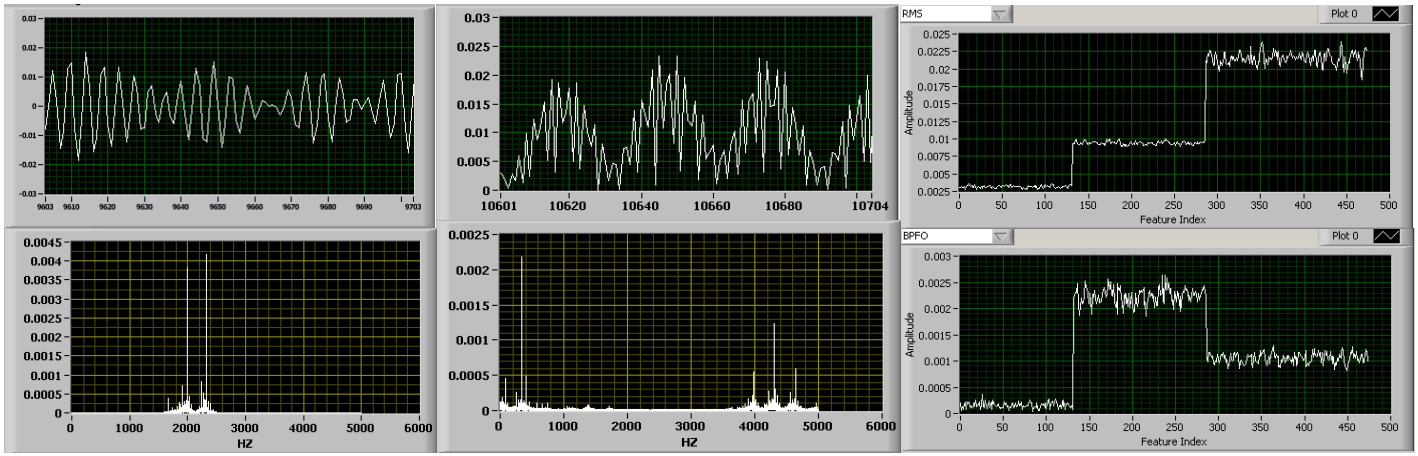
**Method:**
- Averaging
- Windows
- Overlap
- Filtering
- Demodulation

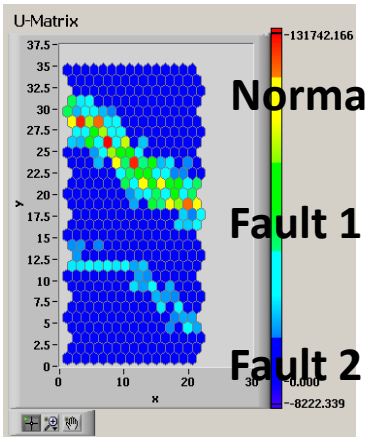
**Features:**
- RMS
- Mean
- Kurtosis
- Crest Factor
- Signature Frequency
  - BPFO, BPFI
  - BSF, FTF

**Method:**
- Self Organize Map (SOM)

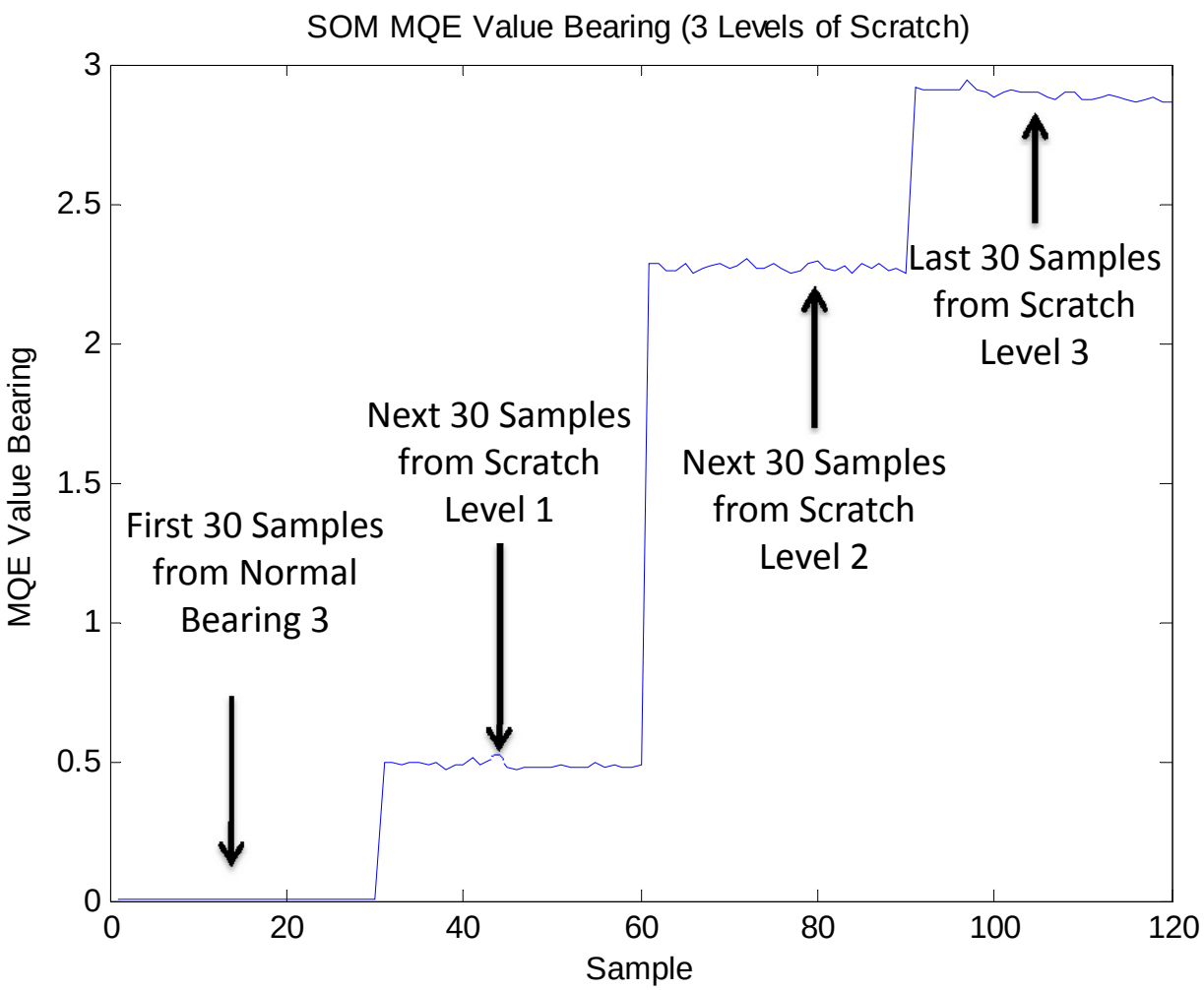
Time

Frequency



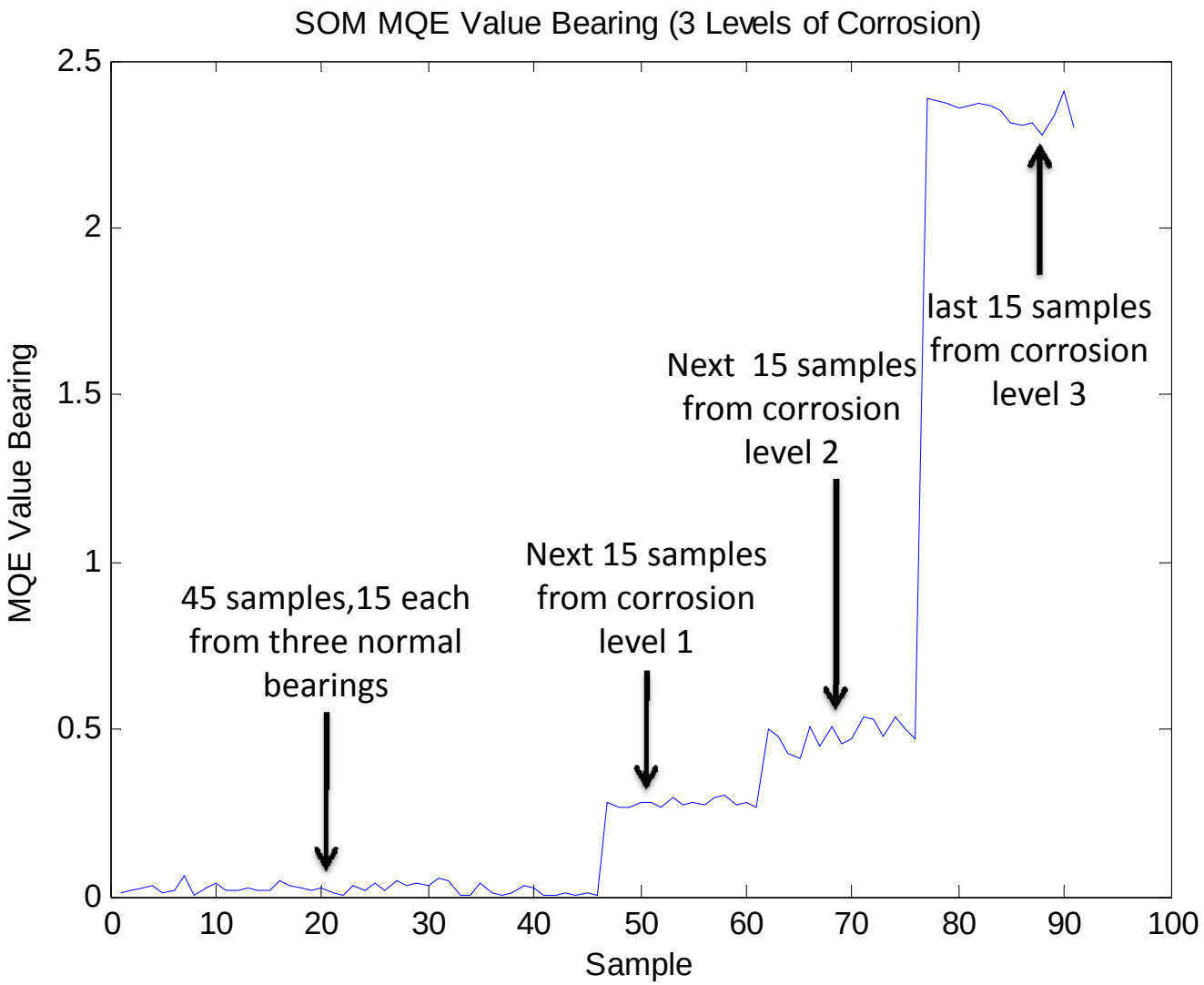



# Task 2: Health Results (Scratch)



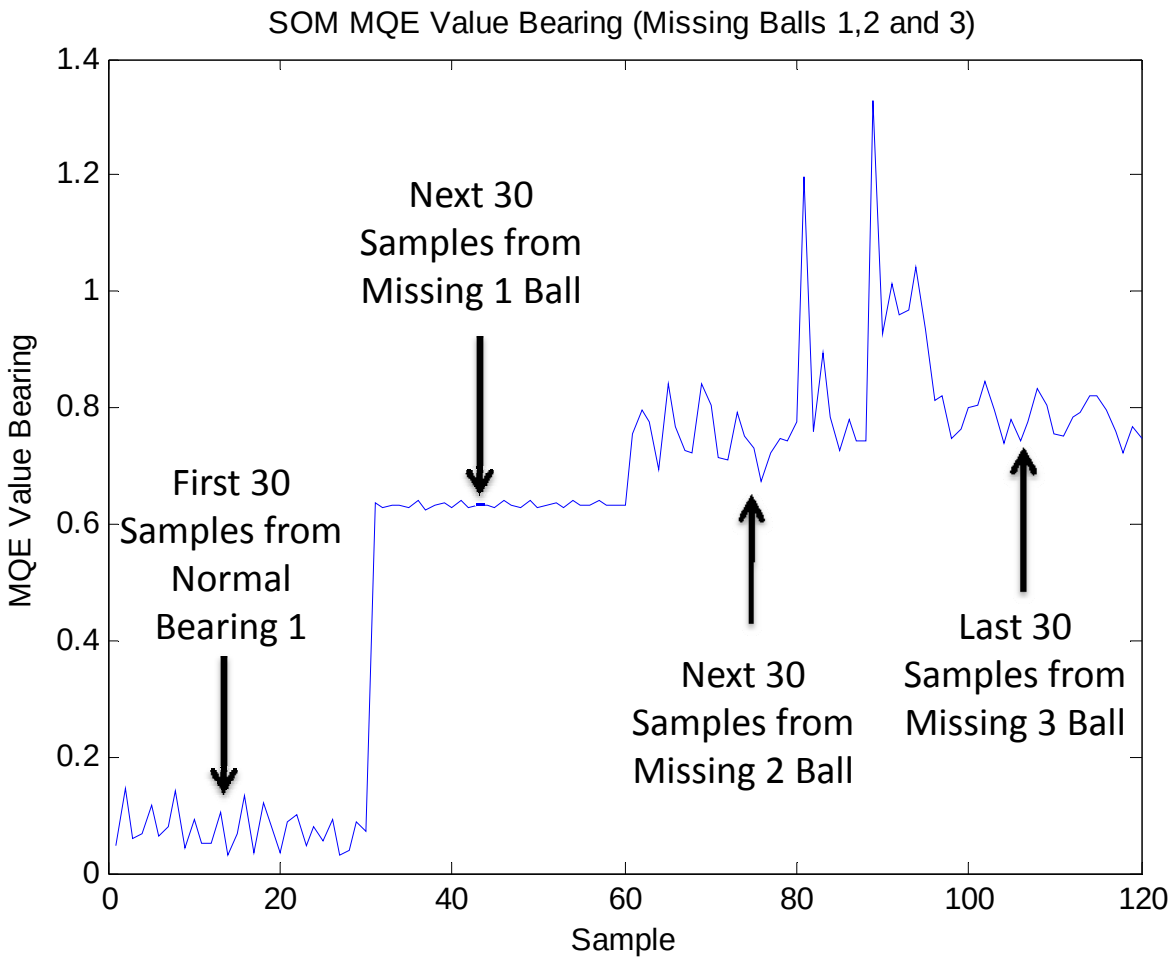

- The normal bearing health value is much smaller than any of the bearings with scratch damage.
- It is very clear to distinguish the different levels of scratch damage using only 1 feature.
- If bearing health assessment can be done with just 1 feature, this reduces the computational requirements.
- Using one feature(RMS ) at 1500 RPM

# Task 2: Health Results (Corrosion)



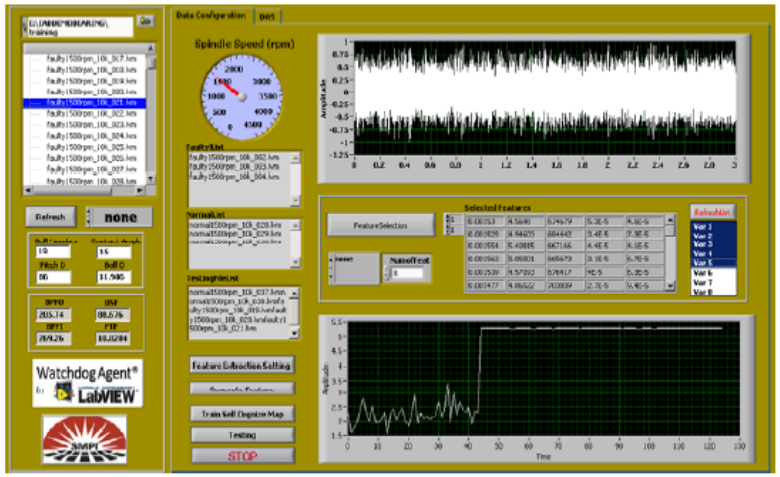

- The normal bearing health value is much smaller than any of the bearings with corrosion damage.
- Very easy to see a clear trend that the health value increases with corrosion damage.
- The one with the largest corrosion clearly has the highest health value.
- All 3 normal bearings have a very low health value.
- Using two Features (RMS and BPFO) at 1500 RPM

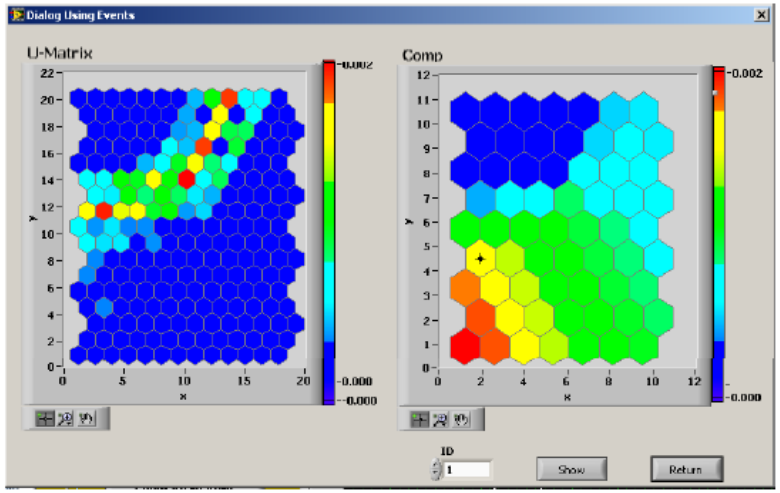
# Task 2: Health Results (Missing Ball)




- The results show that there is a clear difference in the health value for normal bearing and one with a missing ball.
- The bearing with 2 missing balls and 3 missing balls, had the missing balls removed not adjacent but spread apart from each other.
- Although it is hard to differentiate between the bearing with 2 and 3 missing balls, both are showing much more degradation than the normal bearing.
- Using two Features (RMS and BPFO) at 1500 RPM .

# Screenshots




Signal Processing/Feature extraction

- Signal de-nosing filter design
- Envelop detector for frequency domain characteristics
- Time domain analysis

Performance assessment

- Defect classification
- Operation state trajectory
- Quantitative degradation assessment using MQE for calculating CV.

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# THANK YOU!

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