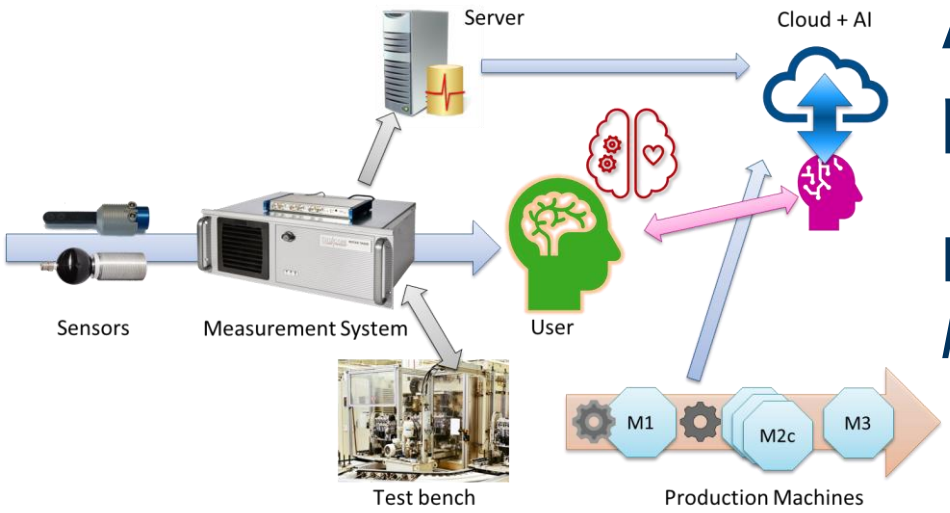
HBK Technology Days – Virtual Seminar Series

Tuesday, November 8, 2022



Acoustic quality assurance in industrial production end-of-line

Presented by Dr. Holger Behme-Jahns,
Head of Project Engineering and Acoustics, Discom

Acoustic quality assurance in industrial production end-of-line

Abstract

Acoustical quality has become an increasingly important topic over the last years. Customers expect technology to be not only reliable, but also sustainable, well-designed and quiet. Especially in the automotive industry, the change towards electric mobility shifted customer expectation from roaring engine power sound to silent gliding. This leads to ever-increasing requirements for acoustic quality testing in the production, not only in R&D.

A well-designed acoustic analysis for end-of-line testing can do much more than simply find “loud” units. By using constructive information about the device under test, irregular noises can be attributed to specific parts and root causes, enabling efficient repair. Combining results from actual drive tests in cars with limits derived from production statistics, it is possible to identify units which would lead to customer complaints and as well units which have hidden production defects. Long-term statistical analysis of production data expand the scope from the single device under test towards the whole production process with trends and hidden correlations.

This presentation will show the current state of end-of-line acoustic production testing with focus on automotive powertrain applications and on the Discom production test system.

About the presenter, Dr. Holger Behme-Jahns, Head of Project Engineering and Acoustics, HBK Discom

Dr. Behme-Jahns has a PhD in Physics, graduating from Göttingen University. He joined Discom in 1995 as first employee to founder, Dr. Thomas Lewien, and has worked as technology and software developer, consultant, sales and many other roles during the growth of Discom. He currently heads the Project Engineering team at Discom which adapts our solution to customer needs, develops new approaches and supports our customers with training and consultancy.

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Acoustic Quality Assurance in Industrial Production

End-of-Line Testing and Production Monitoring

Dr. Holger Behme-Jahns
Discom Göttingen

Abstract

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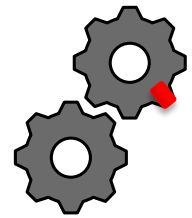
Why Acoustical Production Testing?

Customers ask for quieter cars

- While some “engine roar” might be wanted, gear whine is generally annoying.
- Electric cars are generally designed to give that luxurious quiet gliding feeling.
- “Show Room Effect”: when examining a car on display at a dealer, strange noises from anywhere make a bad impression.

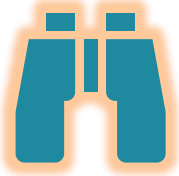
Find hidden defects

- Even if a noise goes unnoticed to the driver in the cabin, it may be an indicator of a production defect which limits the lifetime of the product.
- E-Drive torque ripples will transmit into the car body via the motor fixtures. They can be measured as torsional acceleration or even as linear vibrations.



Production overview

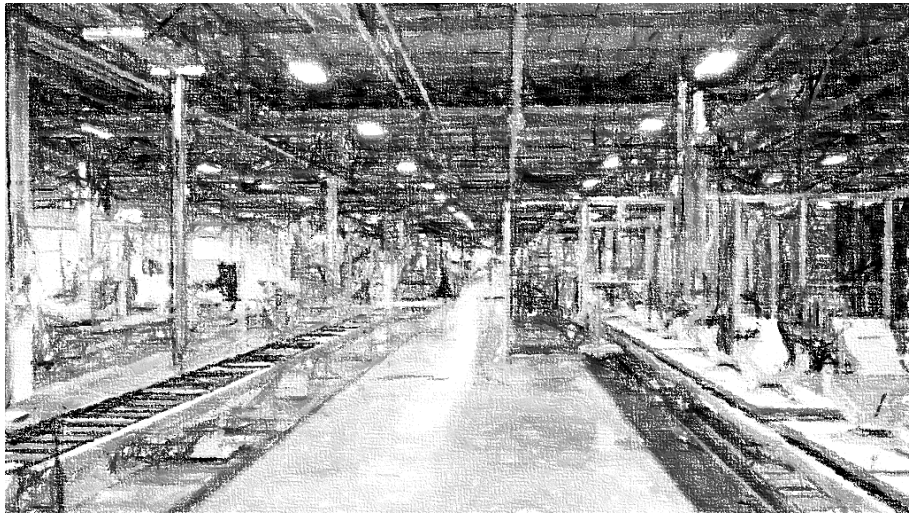
- Storing all results from a 100% production testing allows for production statistics evaluations, trend detection and top-N-defect analysis.
- Correlating the results from acoustical end-of-line test with machining parameters obtained from the production process can reveal root causes in production and give early warnings for machine maintenance.



What is Production Testing?

Production testing requirements are different from R&D lab testing:

- Robust, automatic and fast measurement in production environment
- Quality relevant values, pass/fail limit evaluation
- Root cause analysis for production defects
- Communication with production line control
- Handling of parameters for multiple types, test stands, test steps
- Store all results for all tests (thousands of tests per day per line)



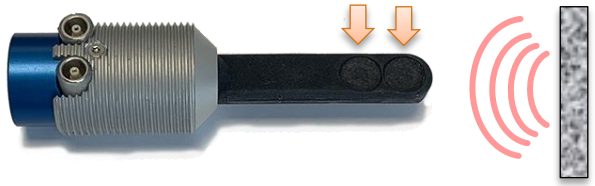
- Result data base, production statistics, production monitoring, cloud storage
- Trend analysis, problem hotspot analysis, machine correlation, and feedback to R&D
- Control the whole production, not just evaluate individual measurements

→ **Production testing goes beyond only measuring, and also beyond measuring and setting limits.**

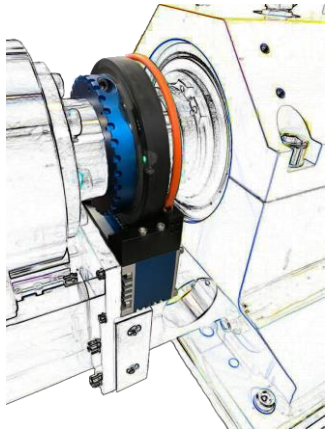
It Starts with Measurements

For robust, automatic and fast measurement in production environment, you need sensors for fast adaptation, a sturdy front end and an industrial type measurement PC.

BKS sensors are pressed onto the test object surface. The silicone elastic element ensures good contact on rough or tilted surfaces and decouples accelerometer from test stand.



NFM near-field microphone is positioned close to the surface. It uses two microphones to separate surface emitted vibrations from background noise.



TAC torsional accelerometer is mounted onto a rotating shaft. Accelerometers inside the ring measure torsional vibrations (which are linked to torque fluctuations).
Data is transmitted optically.

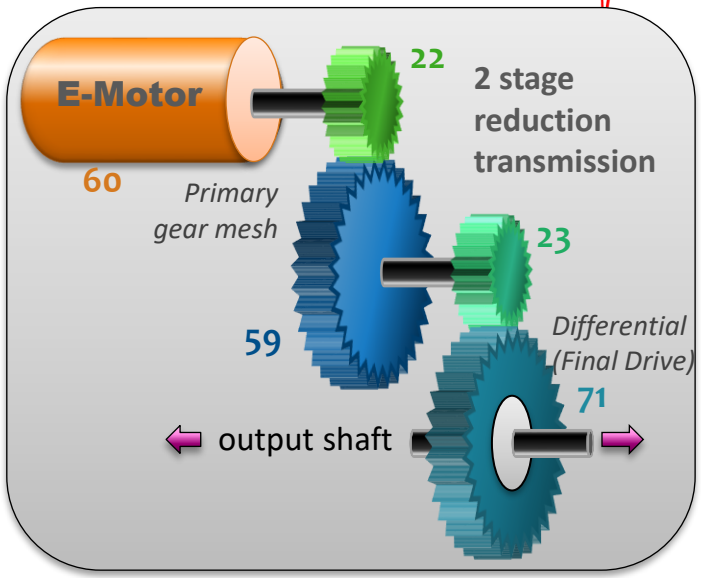
Tas Box front ends, connected via USB, are designed for low power consumption and flexible channel configuration.

Discom Measurement PCs are prepared for harsh production environments while offering high computational power and large local storage space.

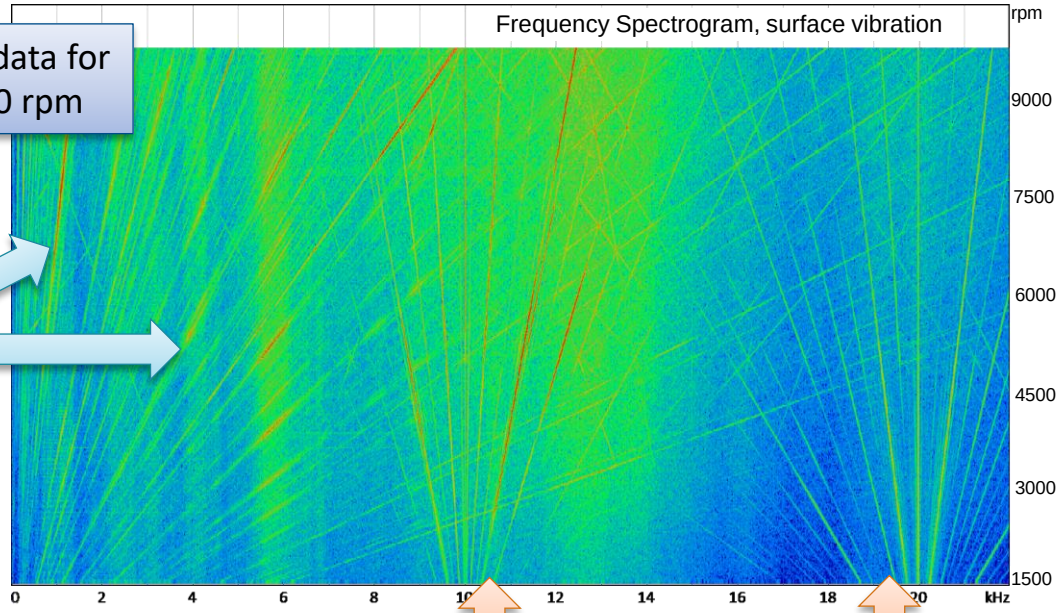
Root Cause Analysis

In production testing, the analysis system must be able to identify the source of abnormal noise components and pinpoint the root cause.

This requires that the system knows the internal structure (kinematics) of the device under test and derives the expected frequencies automatically from the construction data. By using rotor synchronous analysis, it is possible to separate the shaft noise sources.



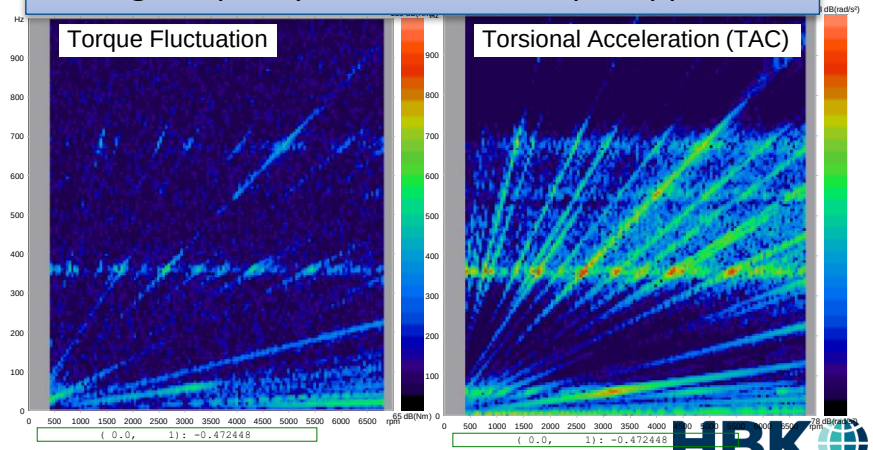
Typical E-Drive vibration data for a speed ramp up to 10000 rpm



Order components:
Motor slot orders
Primary gear mesh
Final drive gear mesh
Bearings
Imbalance

Inverter frequency components:
Base frequency 10kHz, 2nd harmonic at 20 kHz, modulation side bands

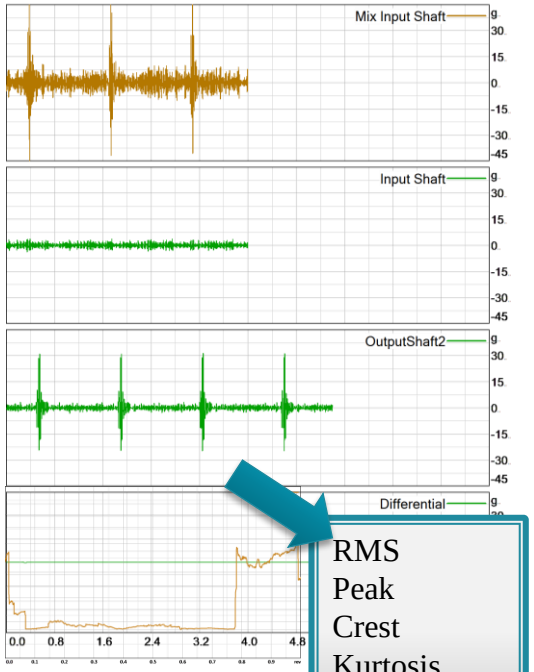
Measuring at the output shaft emphasizes final drive gear quality and E-motor torque ripples.



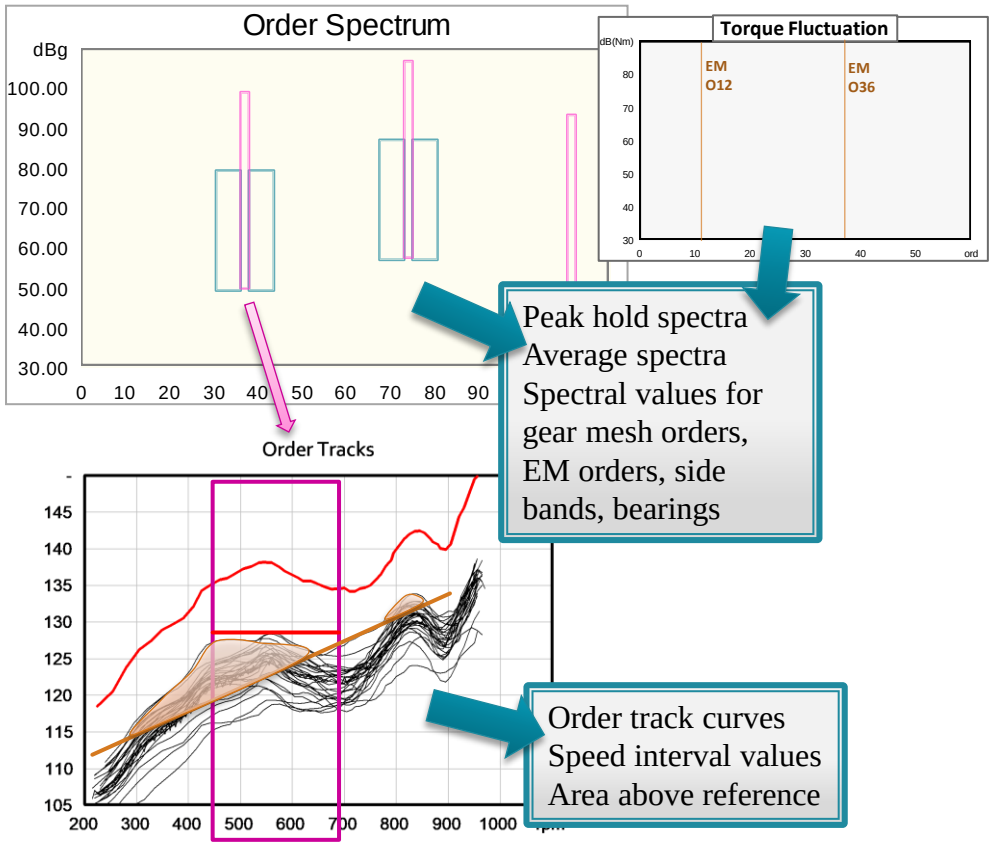
Multitude of Values

Identifying the root cause requires a broad set of acoustical tools and metrics.
Some of the most frequently used are:

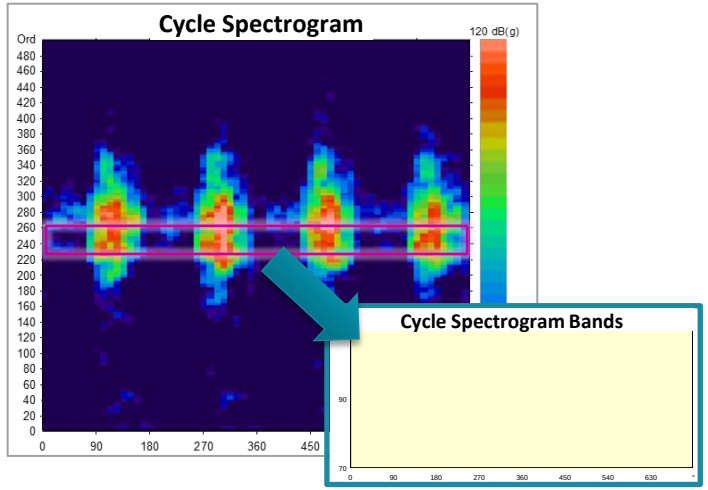
Rotationally synchronous analysis can identify the shaft which generates ticking noises or spectral components.



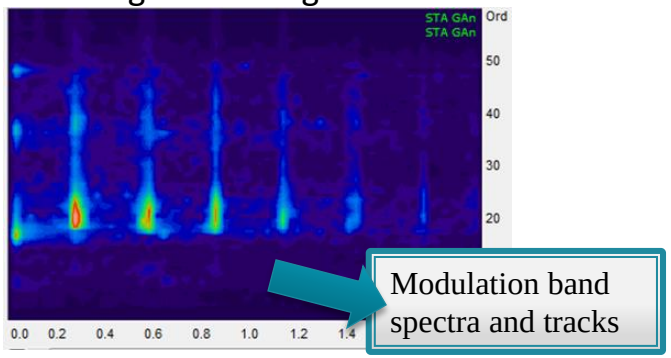
Spectra, order spectra (including torque fluctuation) and order tracks are key elements in every analysis.



Cycle spectrogram and Band Extraction are used for non-stationary noise like combustion engines



Modulation analysis for rumbling and ticking noises



Evaluation Limits Double Feature

In EOL testing, there are two major objectives:

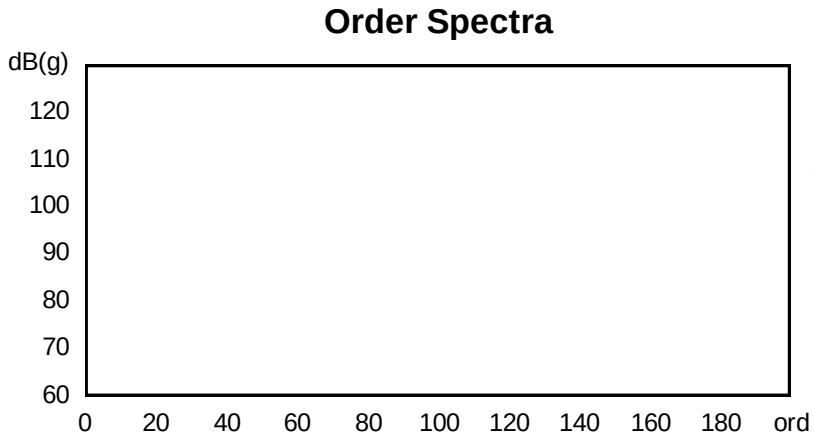
- Find parts which will be audible inside the car
- Find defects in parts that limit the lifetime

This requires two limit strategies:

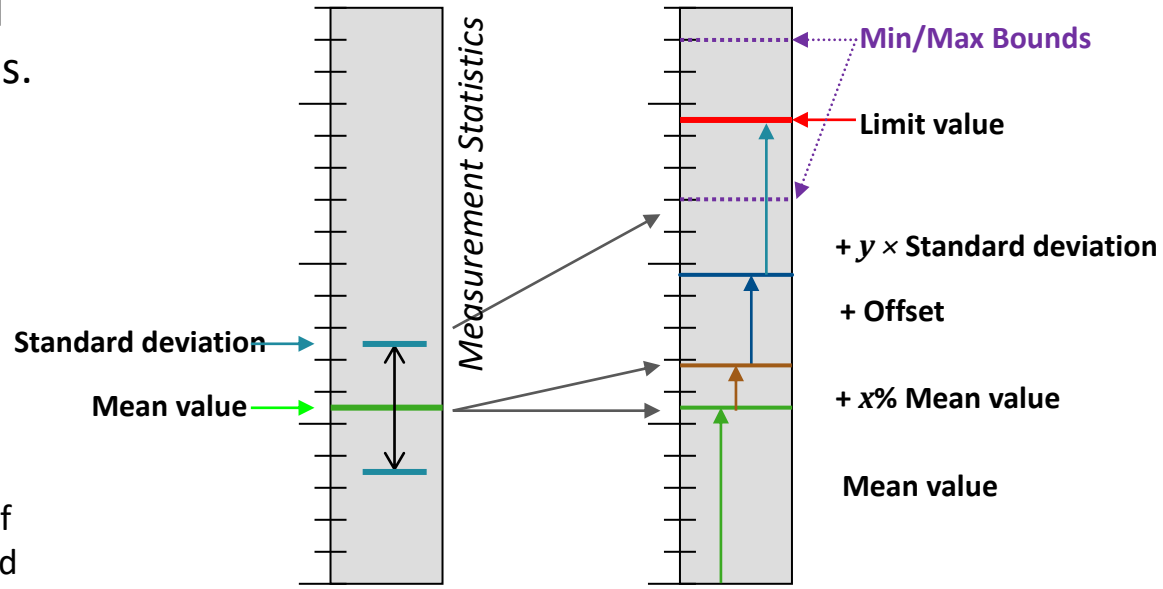
- Fixed limits confirmed by drive tests in car
- Automatically learned limits, based on statistics

The Discom system uses a combination of learned and fixed limits which provide a high flexibility for all kind of situations.

The limit parameters are controlled in the parameter database, allowing easy management even for many different types and test steps.



The combination of automatic and fixed limits also applies to limit curves



Calculation of the limit value:

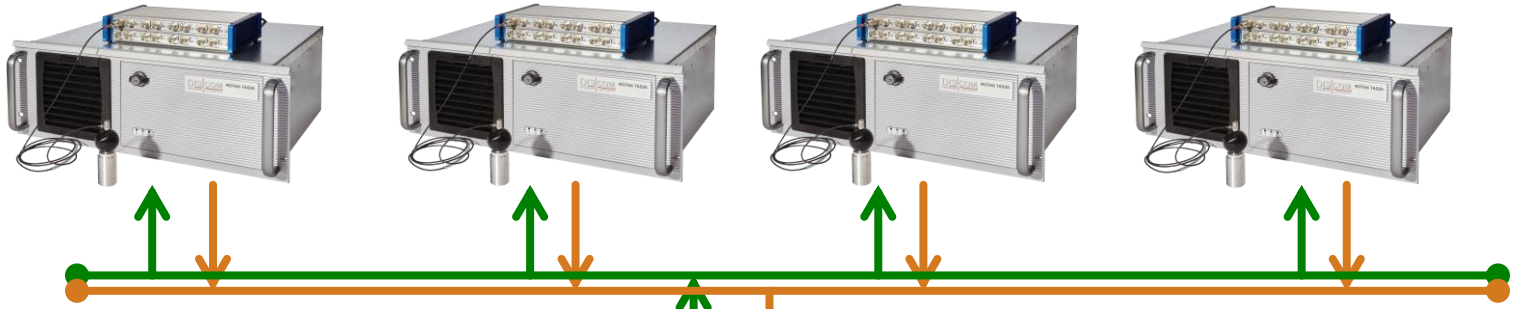
(1) Limit = Mean + x % Mean + Offset + y × Std.Dev.

(2) apply bounds: *Min* ≤ Limit ≤ Max

Keep Systems at Bay, Collect All Results

Discom's system is designed to be working on multiple test stands in parallel.

All test stands use the same parameter and result data base and are managed from the central server.
Parameter setting and result evaluation is done remotely from the user's desktop.



Distribution of parameter data base

Acquisition of measurement results and data

Office workstation (engineer)

Access for evaluation and parametrization

Cloud Server for parameter data base and result data base

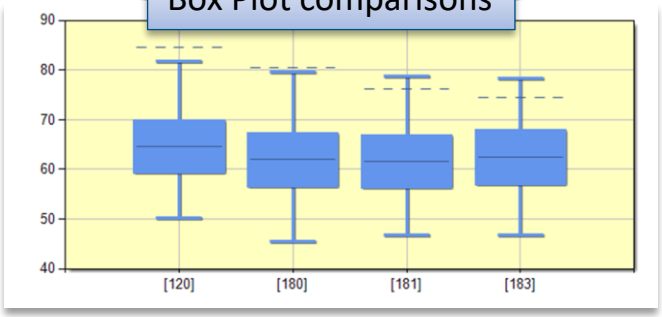
Production Statistics Dashboard
Cloud Data Interface
Remote Assistance

Which Trouble Will Hit Me Today?

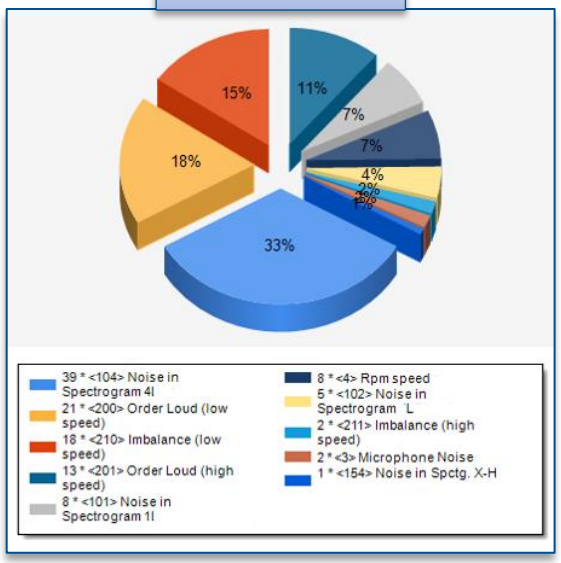
Having all results collected in a central database opens insights into production statistics.

Which defects are occurring most frequently? Where are my current problems?
How do test stands compare, or models, or sensors?
Do I have trends in my production?

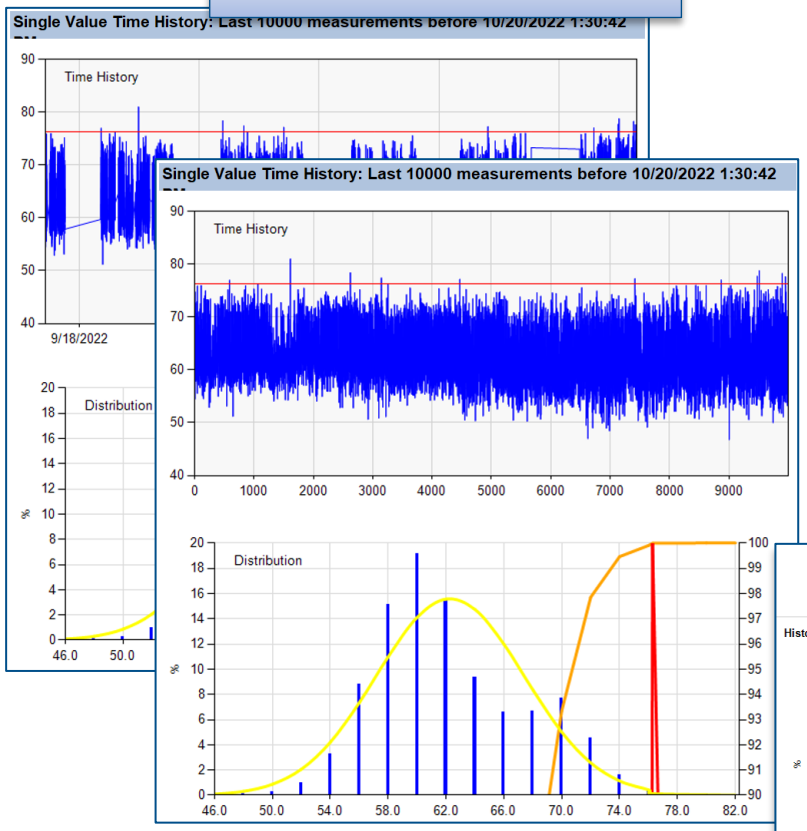
Box Plot comparisons



Top N Defects

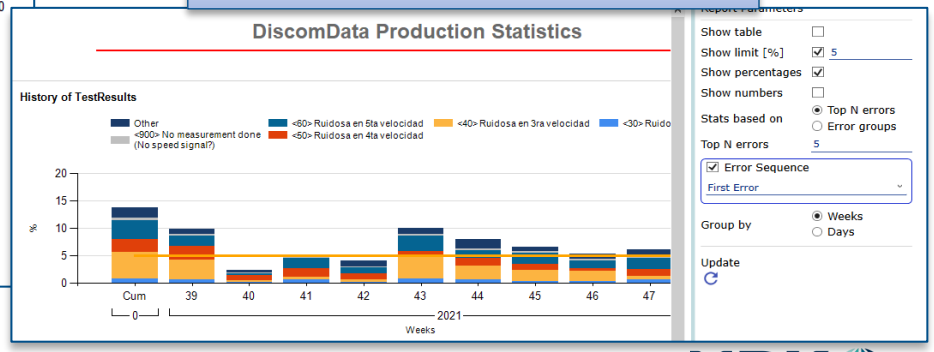


Time Series and Distribution



Smartphone Dashboard

NOK rate and root cause per week



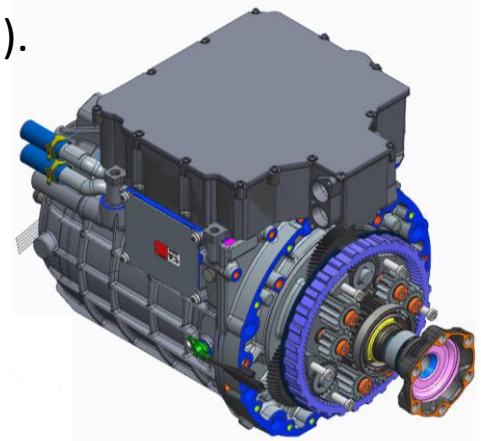
Productions statistics with many different angles of view enables setting proper limits, detecting trends and identify actions to take.

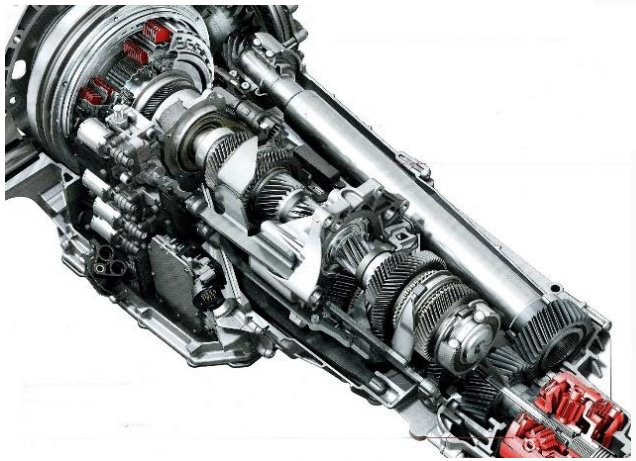
Broad Field of Applications

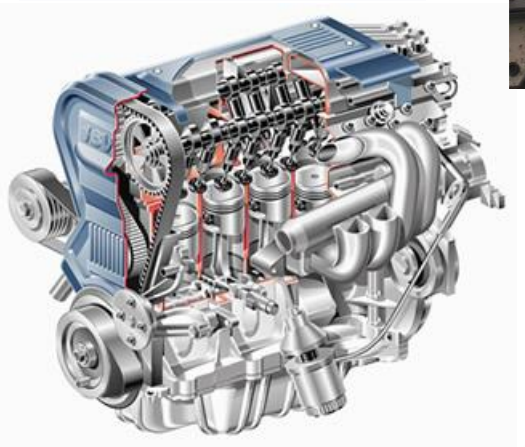
Production testing is not limited to E-motors and E-Drive units (EDU).

Discom End-of-Line test systems are used worldwide for

- Transmissions and gearboxes of all kind
- E-Drives and E-Motors
- Combustion Engines
- Actuators and small devices
- Turbochargers
- Gear testing
- Oil pumps and other pumps
- Bearings





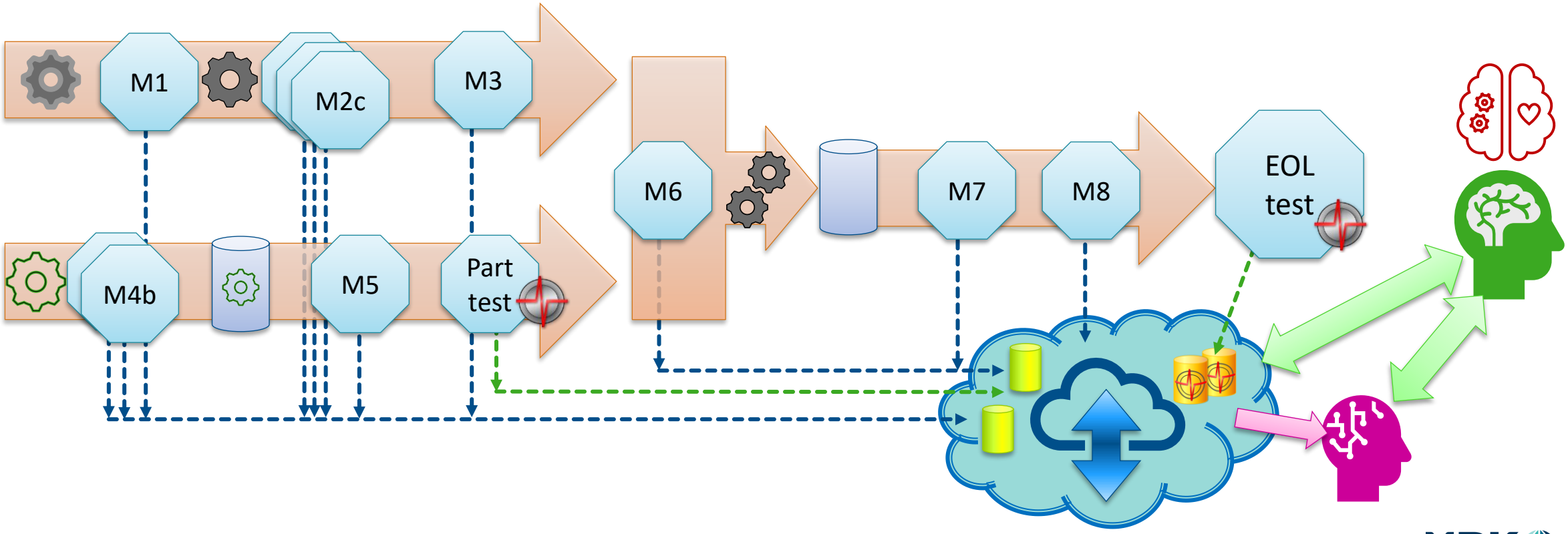


When there are test results available from different steps of the production process (e.g., E-Motor and EDU test, or gear test and whole assembly test), the results can be correlated in the result database, providing additional insights into production.

Production Process Insights

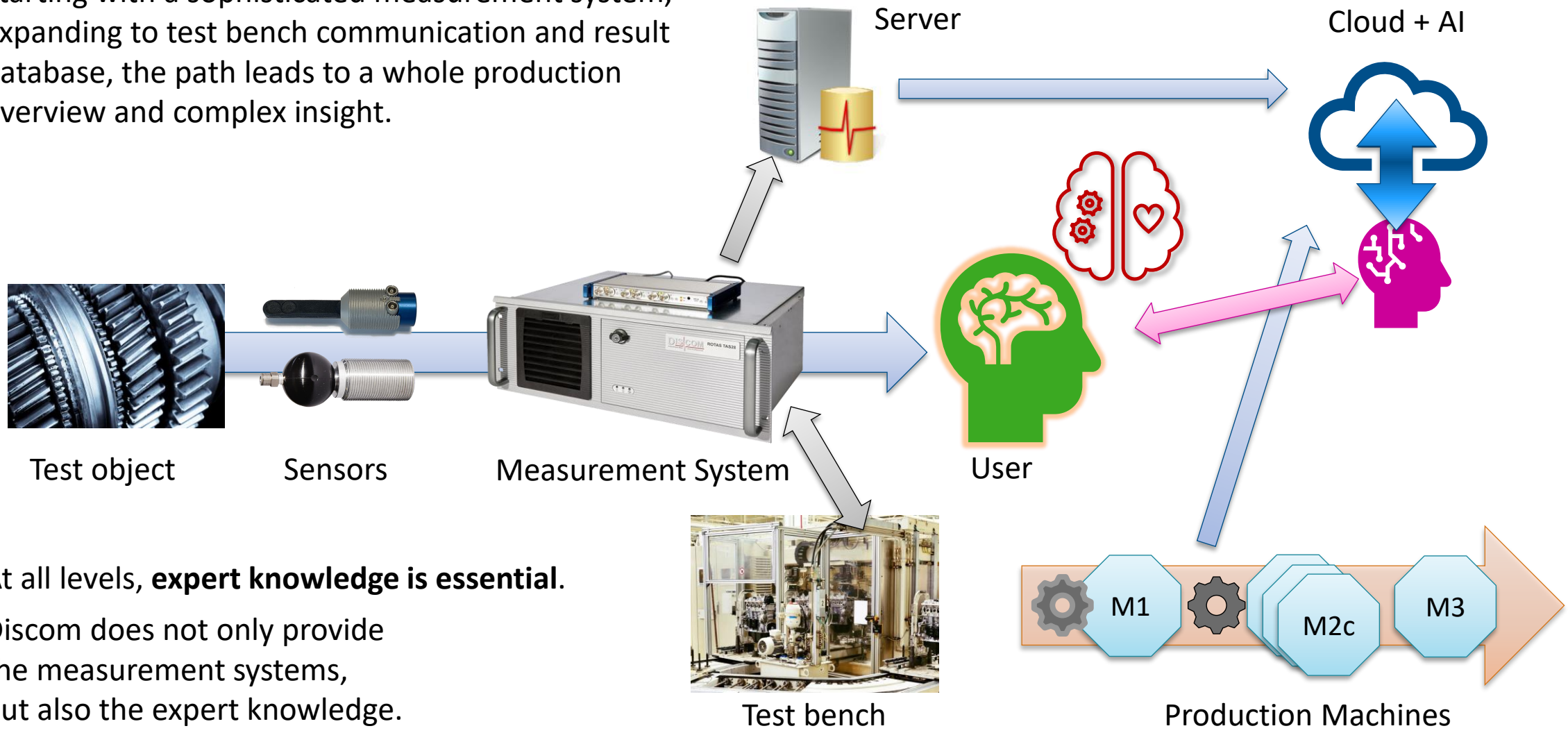
To get even more insight into the many influences on production processes, you want to correlate data (times, pressures, temperatures, …) from other production machines (welding, honing, cutting, …) with the end-of-line results.

Artificial Intelligence (AI) can help to uncover hidden connections, but not without Human Intelligence (HI) preparing the analysis parameters and interpreting the results with Common Sense (CS) and knowledge.



The Big Picture

Starting with a sophisticated measurement system, expanding to test bench communication and result database, the path leads to a whole production overview and complex insight.



At all levels, **expert knowledge is essential**.

Discom does not only provide
the measurement systems,
but also the expert knowledge.

Thank you — Dankeschön

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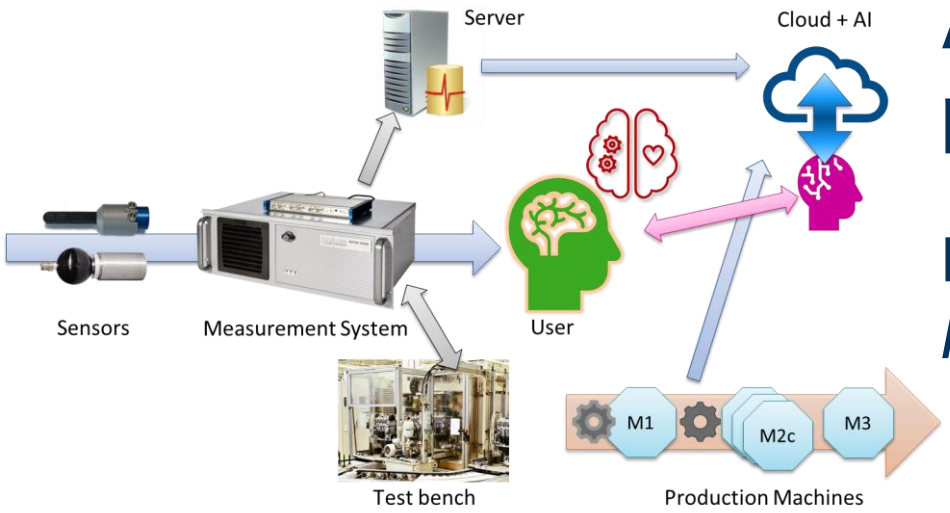

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