NVH in production: Simcenter Anovis

Industrial quality testing solutions

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Agenda

Introduction, Portfolio
General Layout of Test System
Fault identification
Test bench integration

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Introduction

1982 MEDAV Digitale Signalverarbeitung GmbH (1 Employee) founded in Erlangen. Focused on signal processing and analysis

1994 Founding of NVH department to serve industrial and automotive customers worldwide

2012 Acquisition by Saab AB in October 2012

2015 Change of company name to Saab Medav Technologies GmbH

2019 Department NVH of Saab Medav Technologies is acquired by Siemens and integrated into Siemens Industry Software GmbH

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Global trends impacting industrial manufacturing

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Global trends impacting industrial manufacturing

Deliver excellence

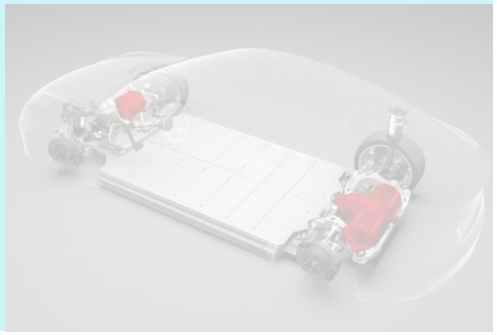
Rework, scrap, product failure and recalls can severely damage a manufacturer

Global standarization

The growth of global platforms is accelerating the trend of standardized components

Go green

Downsizing and growing prominence of hybrid and electric vehicles



Quality is built-in

Quality is crucial across organizations. The days of isolated quality control are over

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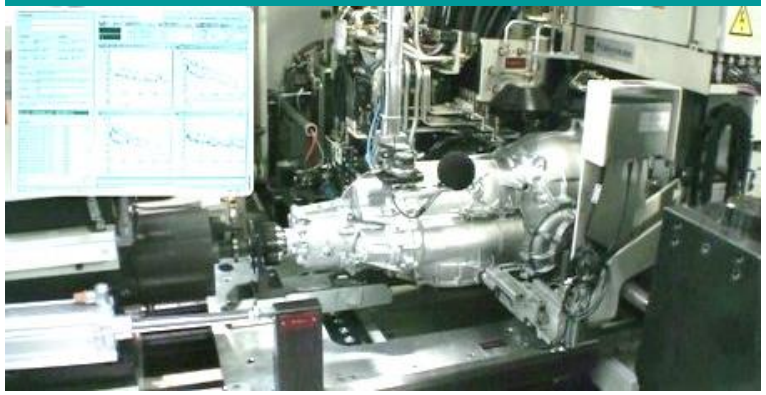
Applications - Portfolio

End Of Line Testing

Fault identification
Go/no Go decision

Examples:

- Engines, electric drive units
- Transmissions
- E-Motors and Assemblies

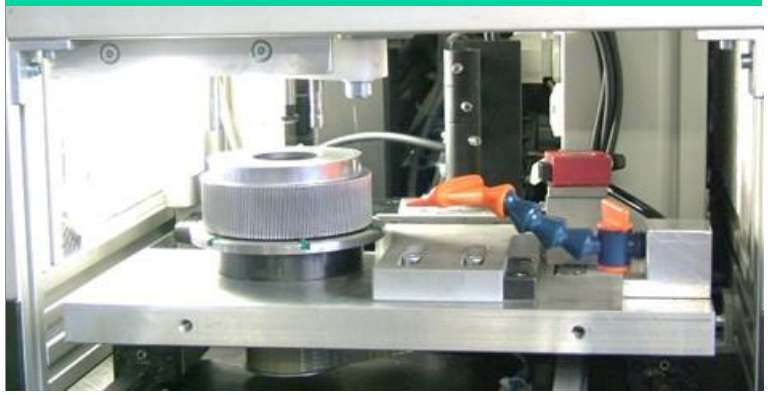


Non-destructive Testing

Resonance test
Cracks, porosity, density, ...

Examples:

- Powder metal parts
- Forging and casting parts
- Car Body parts



Process Monitoring

Breakage detection
Crack detection

Examples:

- Presses, punches
- Joining machines
- Mounting of electric plugs

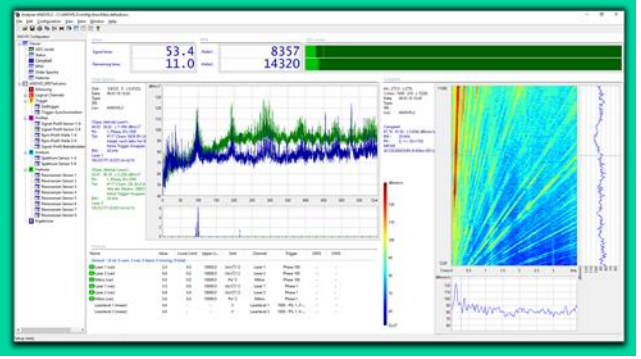
Simcenter Anovis System Overview

Hardware

- Anovis-SRD
- Impact device
- If required:
  PCs, interface cards

Software

- Anovis-professional
- Anovis-lite
- Anovis-Chameleon
- …

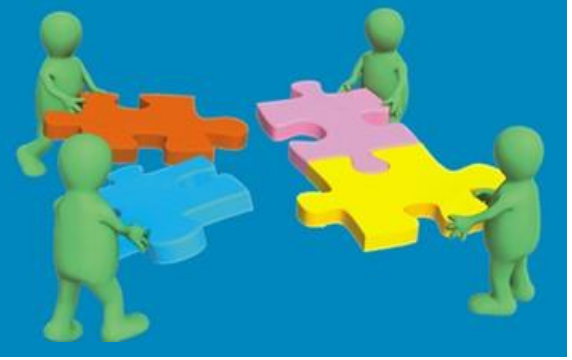


Sensors

- Microphones
- Accelerometers
- Laser vibrometers
- …

Deployment Service

- Technical consulting
- Preliminary studies
- Commissioning
- Training
- After-sales support



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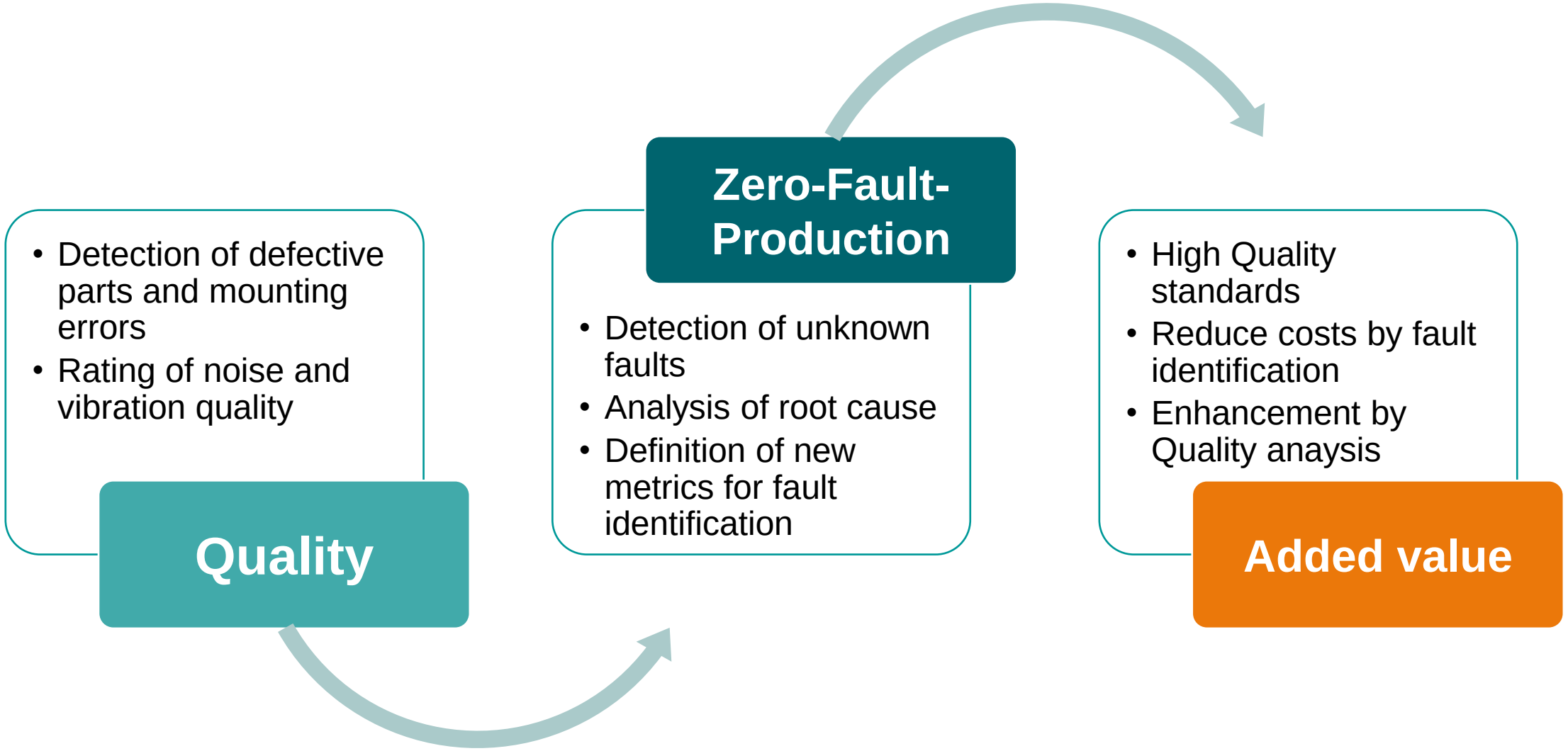
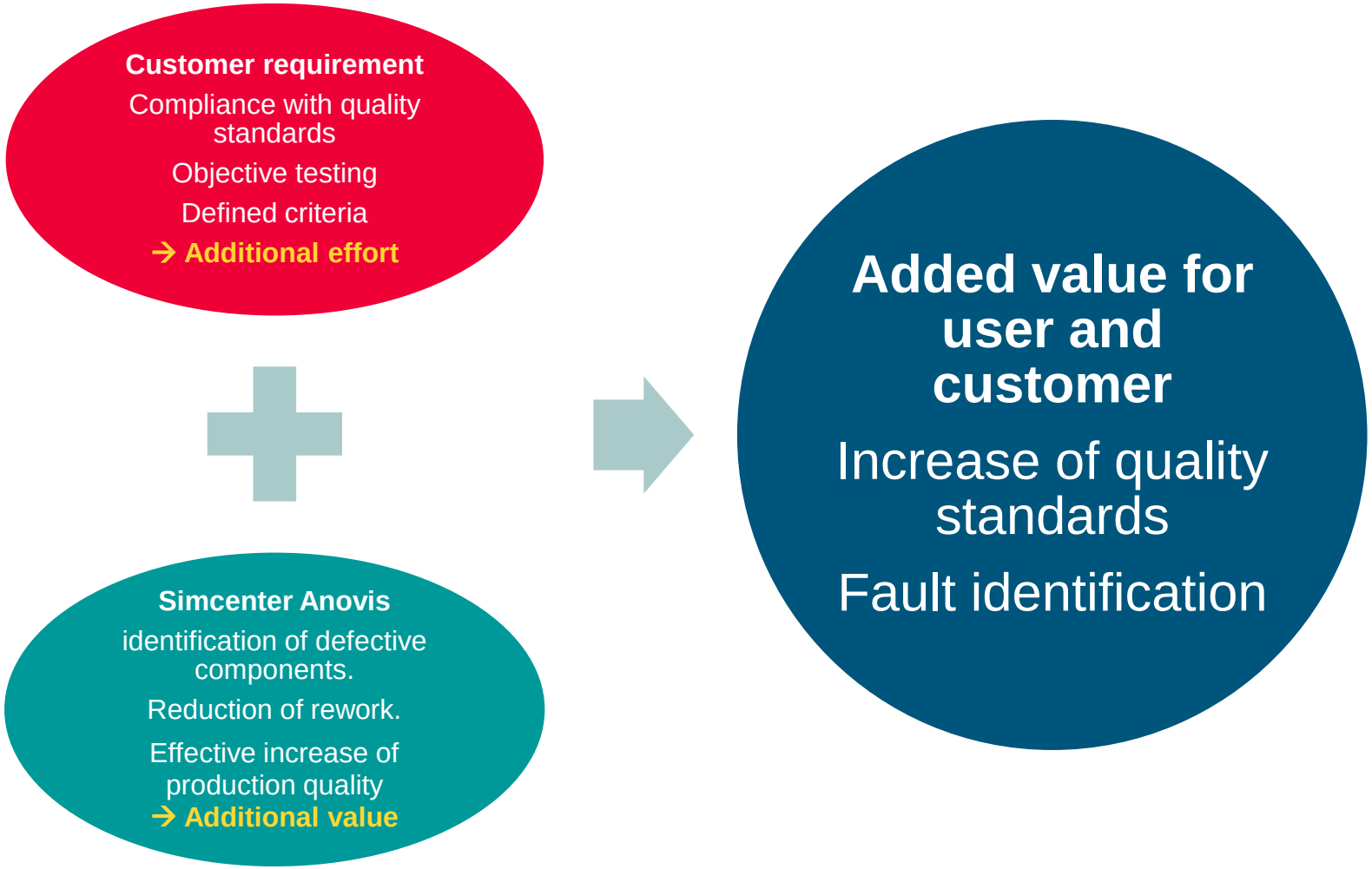
End-Of-Line-Test Objectives



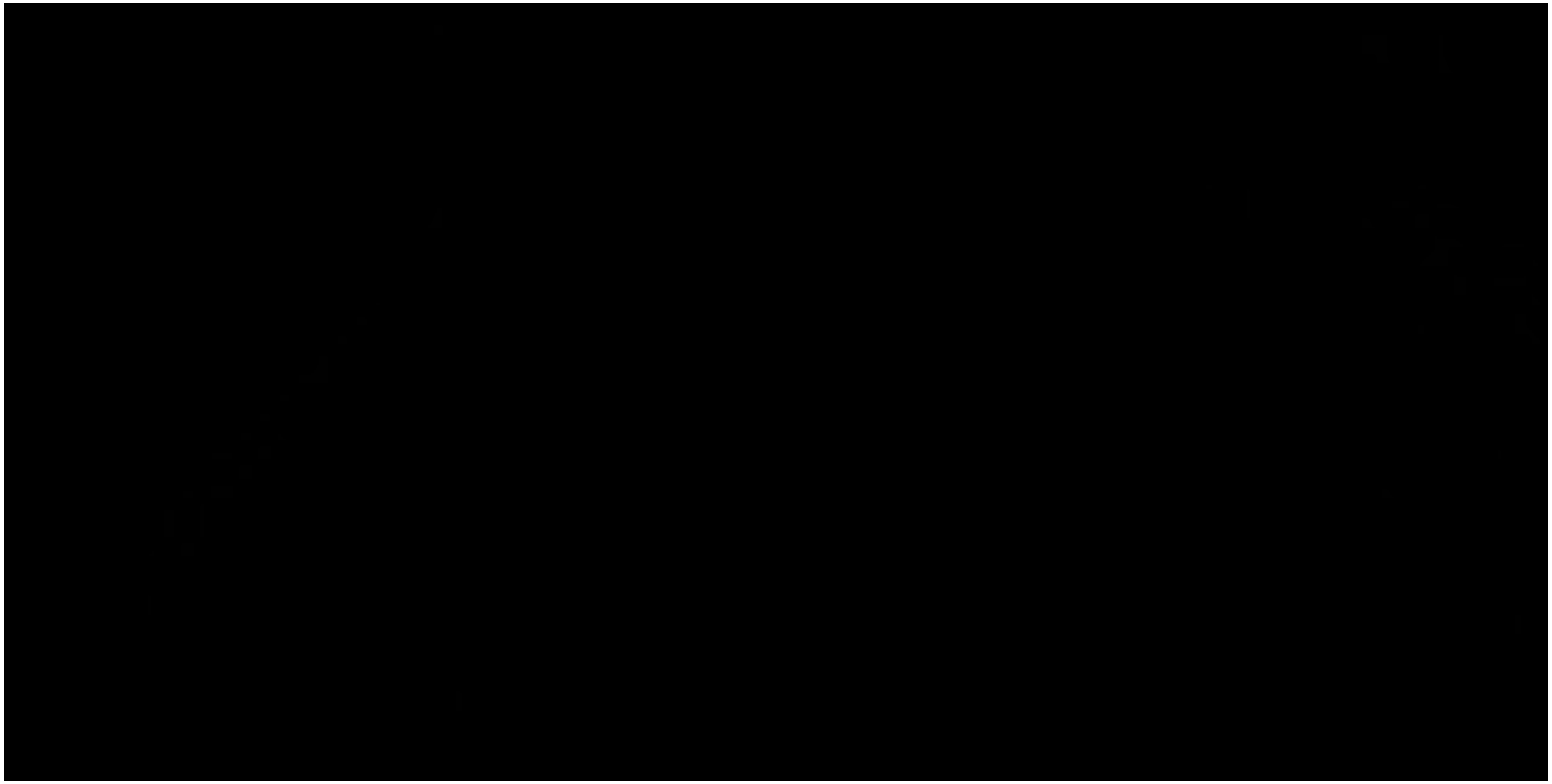
End-Of-Line-Test Objectives II

- Production line end-of-line test
- 100% test of all items regarding function, noise and vibration
- Testing is customer demand



Example 1: IC Engine Cold Test

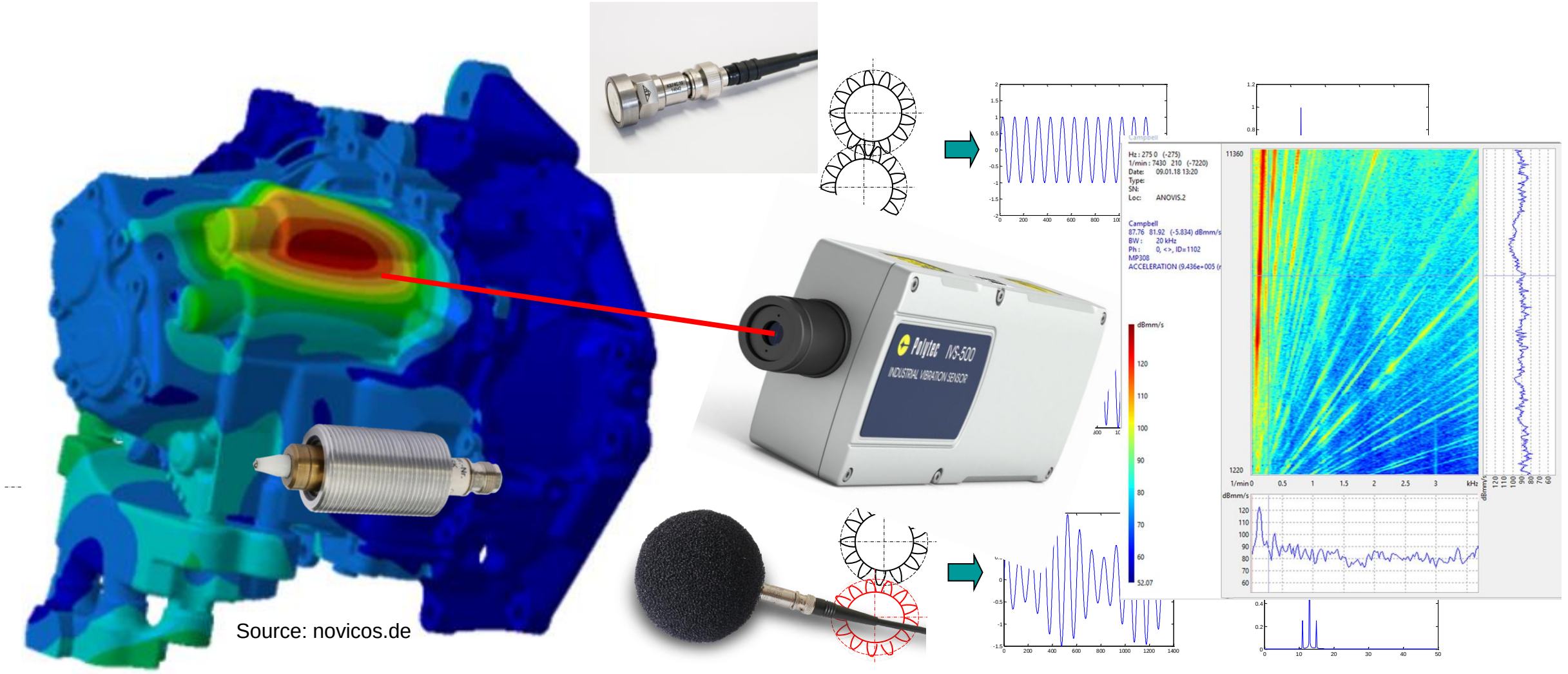
- 100% quality inspection.
- Every single part on the assembly line is inspected, and either accepted or rejected,
- known faults are identified,
- unknown faults are alarmed.



Example 2: Automatic Transmission Test

- 100% quality inspection.
- Quality control inspection based on extended and evolved testing methods
- vibration and sound measurements
- Fault identification

Fault Detection By Noise And Vibration



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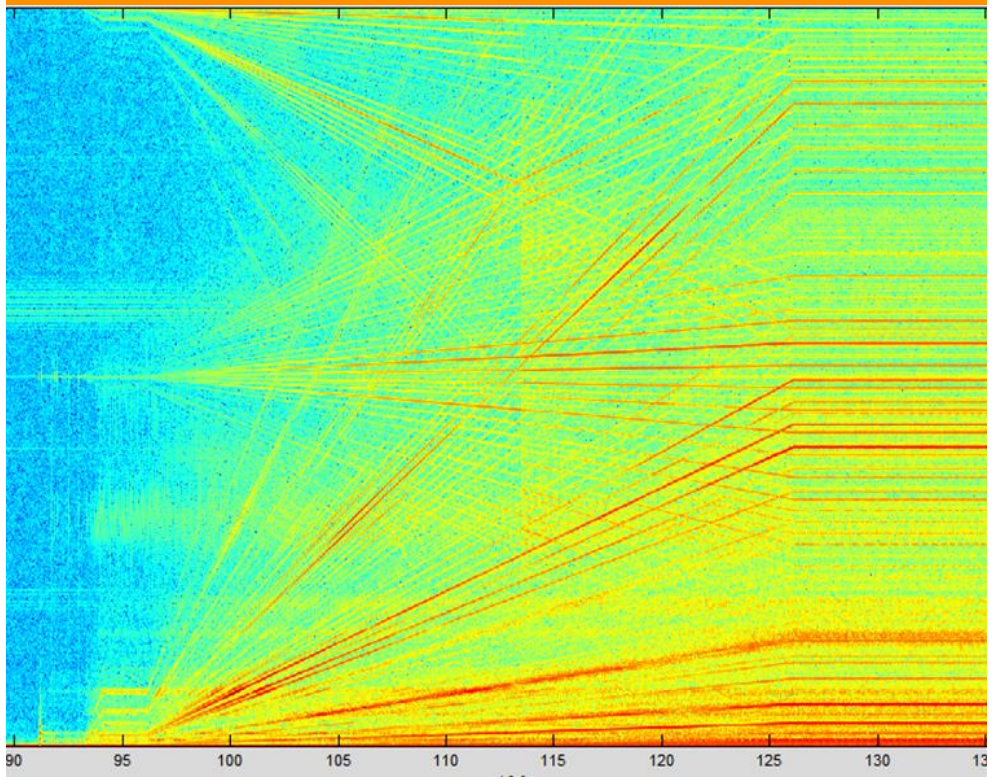
Bandwidth Requirements

Signal components e-drive and error patterns:

1. Shaft and bearing orders
   - Unbalance
   - Alignment
   - bearing damage
2. Gear orders and sidebands
   - Tooth damage
   - tooth flank shape
3. Engine orders and side bands
   - Rotor eccentricity
   - Deviations of magnetic field (magnet pairing quality)
4. Inverter frequencies
   - Component Vibrations
5. Resonances

Interesting bandwidth:
0 .. 20 kHz



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Sensors - Accelerometers

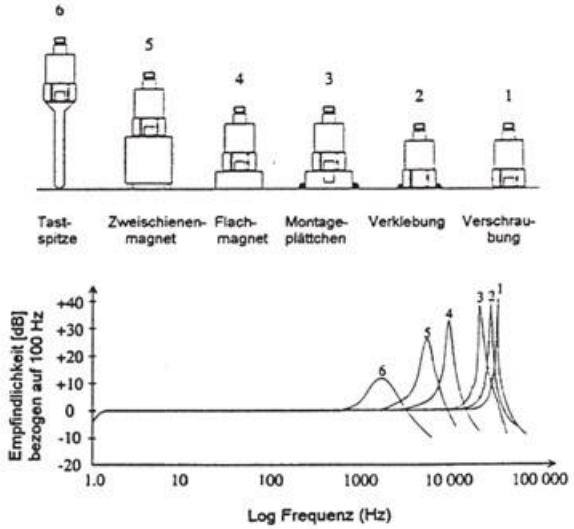
Dynamic testing with high bandwidth

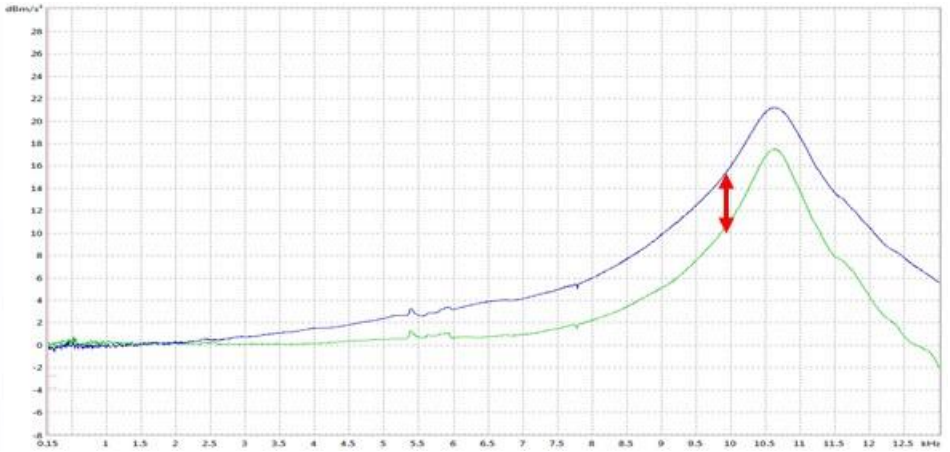
Tactile accelerometer:

- Bandwidth limited by contact resonance
- Manual adaptation at manual test benches
- Automatic adaptation of sensors at automated test benches

Bandwidth-optimized constructions:

- Resonance frequency around 10 kHz, usable bandwidth up to 8 kHz





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Sensors – Microphones and Laser Vibrometers

Microphones

- Suitable for frequencies up to 75 kHz
- Recording and evaluation of harmonic signals in the industrial environment possible
- Consider the acoustic behaviour of the test environment (reflections)
- Calibration

Laser vibrometer

- Suitable for frequencies up to 100 kHz
- Objective assessment of signal quality
- Consider reflection behaviour of the test object and installation

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Sensor Calibration

Calibration:

- Industrial-proof calibration equipment for microphones and accelerometers
- Calibration supported by system software (approx. 5min per sensor)

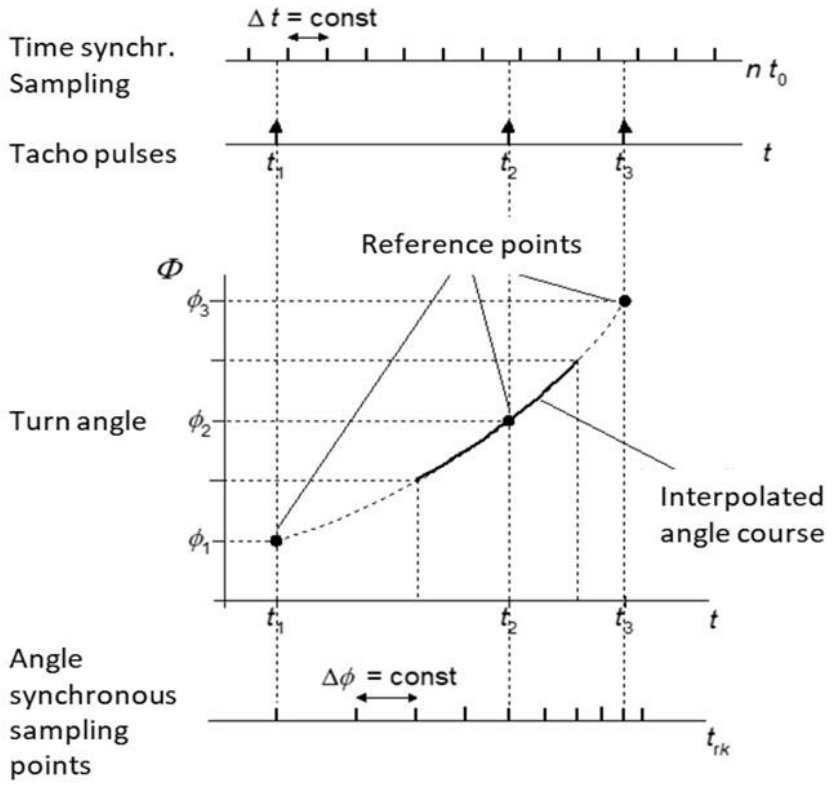
Recording The Rotation Angle

Tacho signal:

- Required for angle synchronous signal processing (i.e. order analysis)
- Accuracy determines significantly the quality of testing

Precise tacho acquisition:

- 48 MHz sample rate
- Increased accuracy requirements for angle detection
- Classic signal acquisition often insufficient



Data Acquisition – Simcenter Anovis Signal Recording Device

Different housings

DIN rail unit

19” housing

2 noise/vibration channels per module

75 kHz Bandwidth, 24-bit ADC, integrated AA-filter,

High quality analogue input signal conditioning

Supervised ICP power supply for direct sensor input

2 trigger/tacho channels per module

20 MHz bandwidth

10-bit ADC, integrated AA-filter,

High-speed tacho signal acquisition

Ethernet connection

to Host-PC

operating system independent

(Windows 7, 10, Linux)

Optional modules

Operational data

Switching unit

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Designed for integration into EoL test benches
Flexible configuration software

flowlets
Processing modules to configure a set-up interactively by mouse click

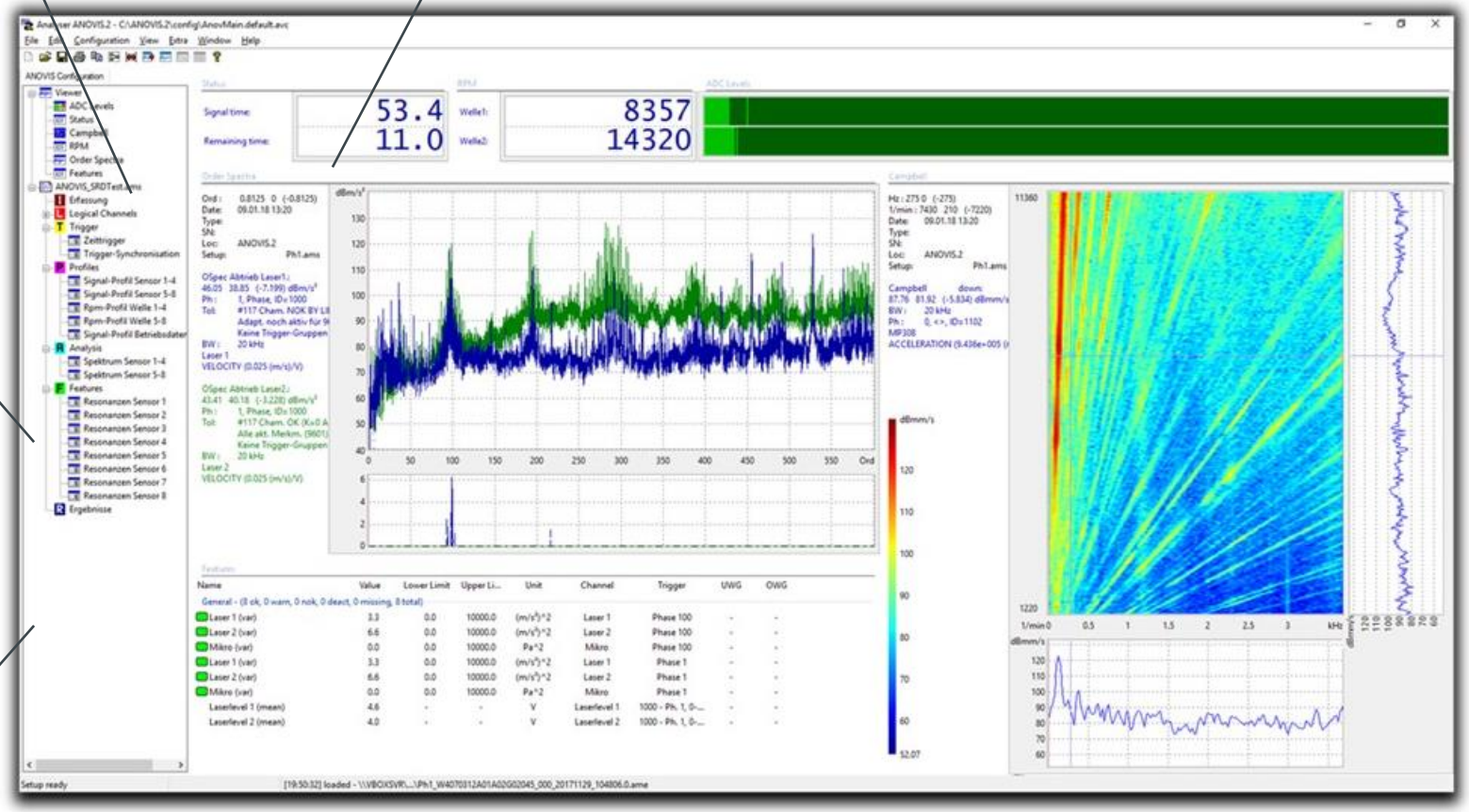
online and offline mode
Data recording using an open and documented file format

Automated playback and offline analysis

phases
Realization of complex signal processing tasks

online and offline data visualization
Viewers configurable by mouse click

Viewers for 1D, 2D and 3D data / Cursors, markers, legends, …



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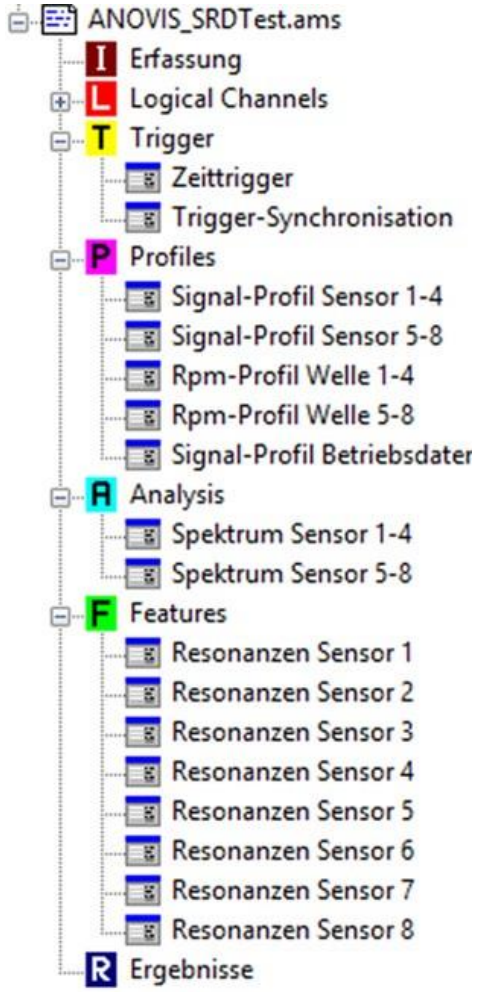
SIMCENTER ANOVIS SOFTWARE / SIGNAL PROCESSING

Modular concept

- Signal conditioning: Calibration, Differentiation, Integration, Logical RPM channels, Tacho pulse conditioning
- Trigger and Profiles: Time and Signal Trigger, RPM Trigger, Trigger Combination, Signal and RPM profiles
- Analysis: Frequency analysis, order analysis, digital angle synchronous resampling, envelope analysis, cepstrum, synchronous cepstrum, octav analysis
- Features: Frequency and order spectra, order level tracks:, harmonic levels and tracks, time signal measures, (order-) spectral level values and curves, angle synchronous averaged time signal, frequency / order sonagram
- Psycho acoustics
- High sophisticated classifiers, Chameleon



Creating solutions for new tasks is done by mouse click, without programing, within some hours

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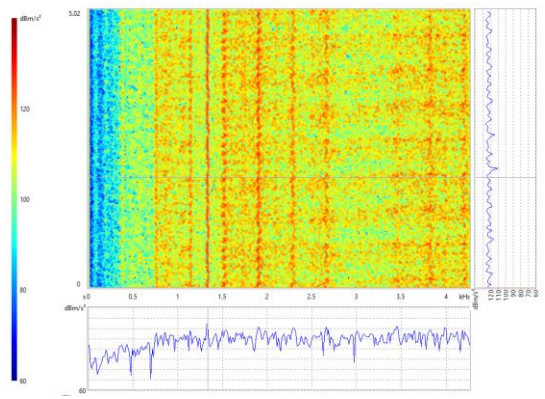
Example Signal Flow for Electric Motor Test

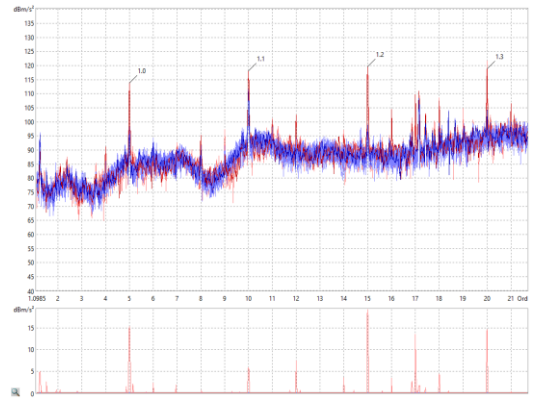
Order Analysis

- **Basic analysis parameters**
- Set up according to criterion for special signal type



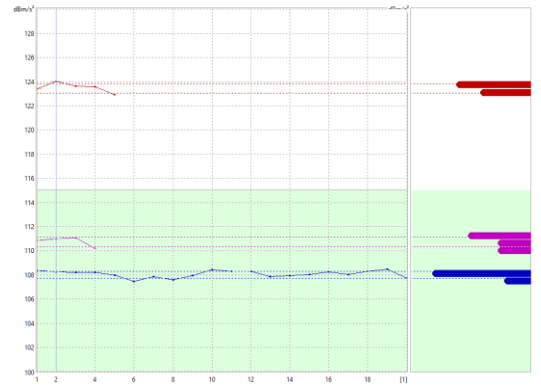
Order Spectrum

- **Measurement curve**
- Extraction of signal components from overall signal



Order Level

- **Metric**
- Rating of extracted signal components



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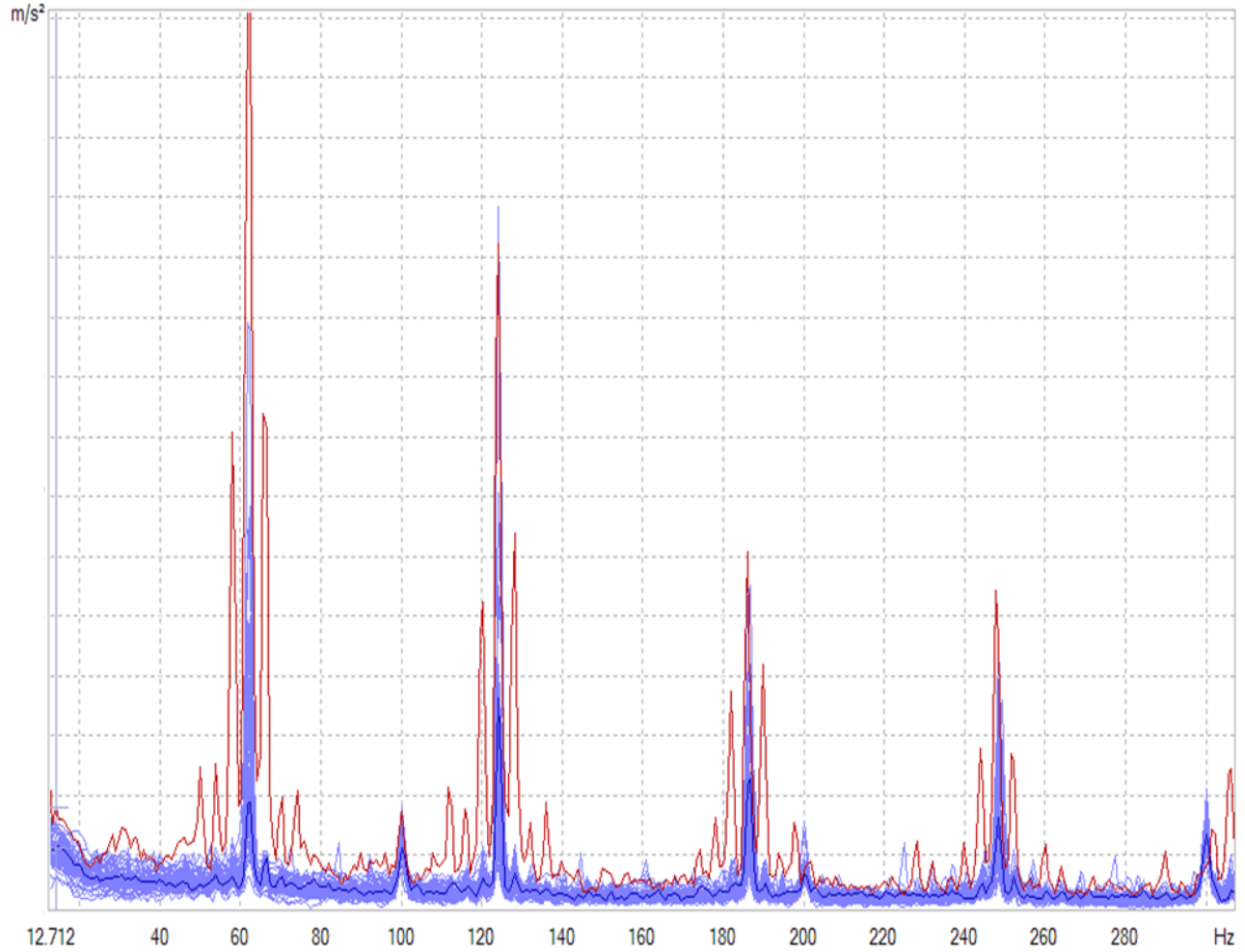
Analysis Functions
Envelope Spectrum, Modulation Spectrum

Analysis of modulation effects

- Assessment of signal characteristics (modulation)
- Description of faulty component and kind of issue
- Modulation spectrum → normalized envelope spectrum showing the degree of modulation



Analysis Functions
Angle Synchronous Envelope

Detection of tooth damage:

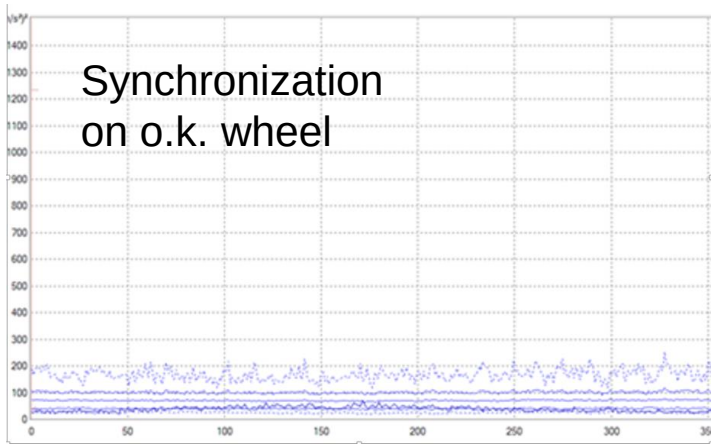
- Transient signals synchronous to the rotational frequency of the damaged gear
- Use by synchronously averaged envelope
- Asynchronous transient signals are suppressed

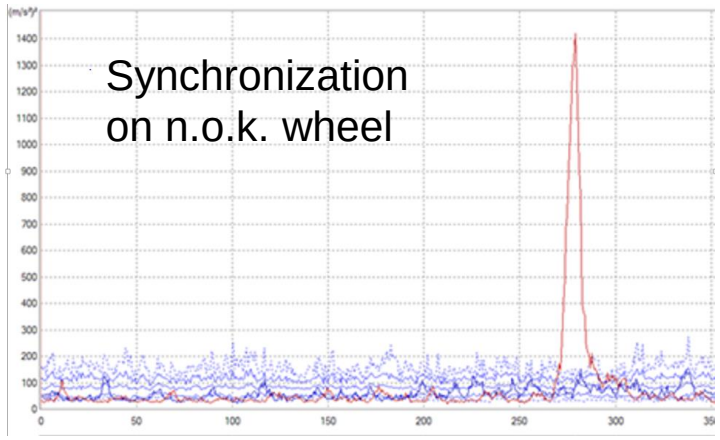
Advantage:

- Illustrative, direct recognition of the damaged component

Disadvantage:

- High number of curves required for complex gears (i.e. planetary gear sets)

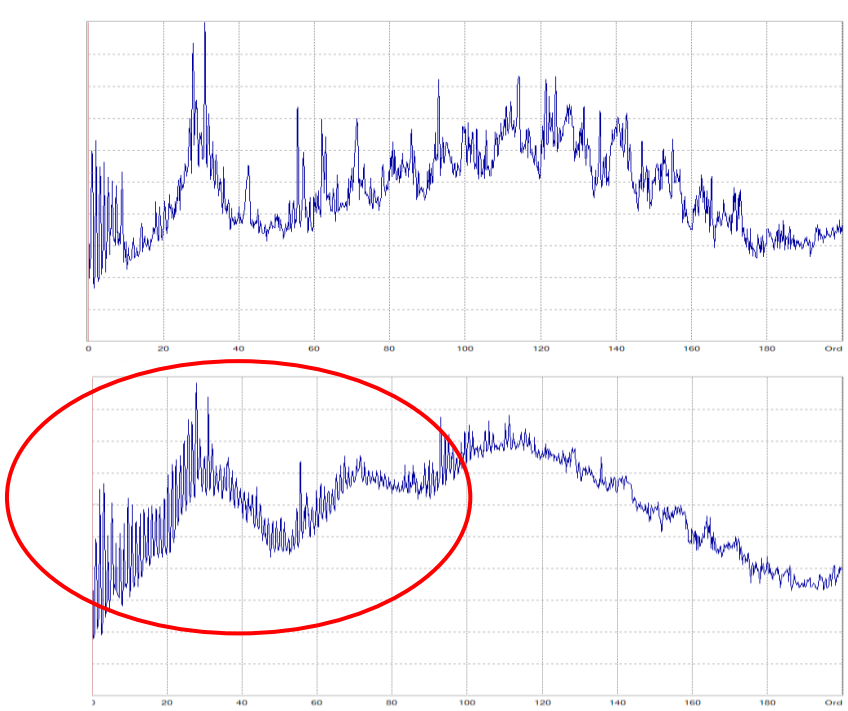




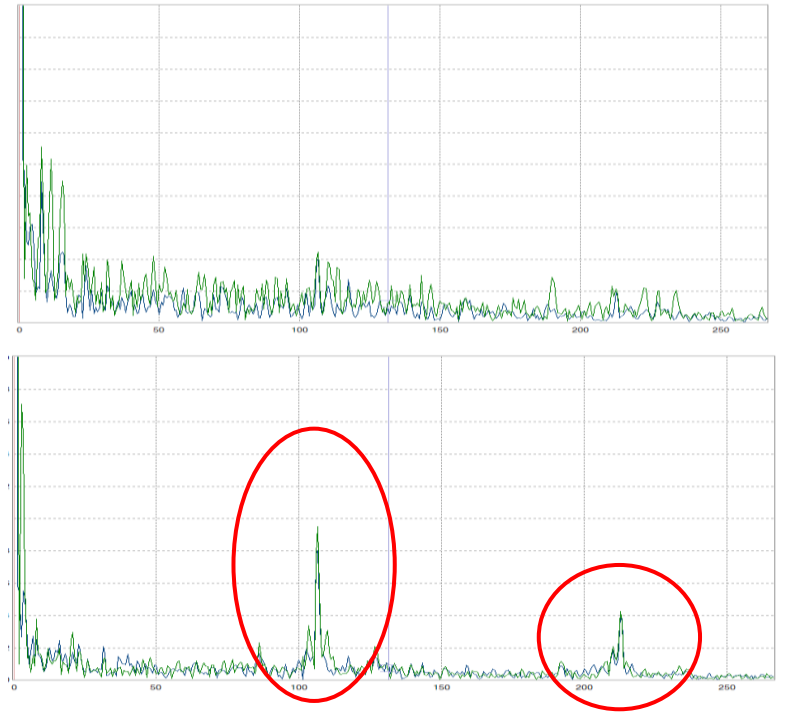
Analysis Functions
Angle Synchronous Cepstrum

Damage detection at bearings and tooth gears

- Advantages, if defect frequency is unknown or if test item contains many shafts
- Fault identification and simplified limit definition
- Application at variable or unknown synchronization ratios



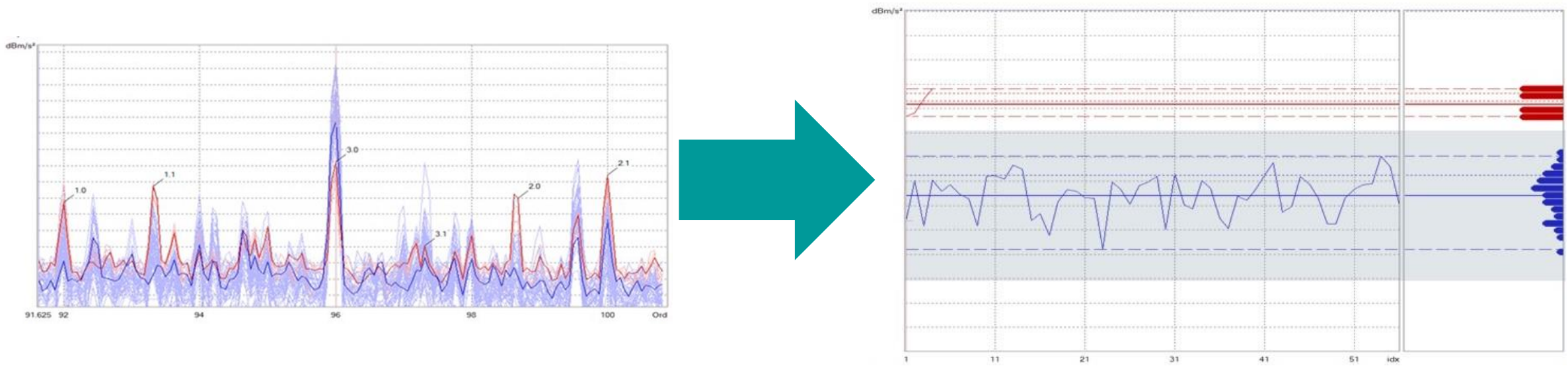
Cepstrum
(FFT from FFT)



Definition of Metrics

Metrics for known issues

- Assessment of the influence of a defect tooth gear
- Derivation of a single value metric (ideally)
- Definition of limit values based on specifications or statistics
- Valuation of the characteristic



Test Equipment Capability - Methods

Practical method:

- Derived from process capability index, takes production variance into account

$$C_{pk} = \frac{\min(\mu - USG; OSG - \mu)}{3\sigma}$$

- Statistics to be evaluated at production start (short time) and at running production (long time)

Example Audi Győr:
8.800 engines per day →
20 weeks of production

Situation	Recommended minimum process capability for two-sided specifications	Recommended minimum process capability for one-sided specification
Existing process	1,33	1,25
New process	1,50	1,45
Safety or critical parameter for existing process	1,50	1,45
Safety or critical parameter for new process	1,67	1,60
Six Sigma quality process	2,00	2,00

C_p	Sigma level (σ)	Area under the probability density function	Process yield	False rejects per 1 Mio parts
0,33	1	0,682689492	68,27%	317311
0,67	2	0,954499736	95,45%	45500
1,00	3	0,997300204	99,73%	2700
1,33	4	0,999936658	99,99%	63
1,67	5	0,999999427	100,00%	1
2,00	6	0,999999998	100,00%	0,002

Detection of New Issues

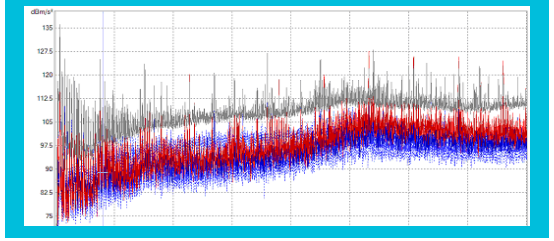
Simcenter Anovis Chameleon
Continuous process

Chameleon detects suspect item: **Fault detection**

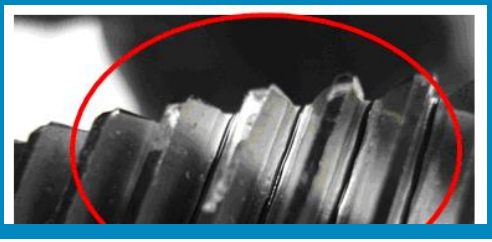
Results

Name	ID	Ist
Allgemein		
Ospec oben (maxdelta 226....	0	3.6
Ospec oben (mindelta)	0	0.0

Data analysis: **Root cause analysis**



Diagnosis: **Confirmation of root cause**



New metric for **Fault identification**

Results

Name	ID	Ist
Allgemein		
Ospec oben (maxdelta 226....	0	3.6
Ospec oben (mindelta)	0	0.0
NW-Rad	0	117.5

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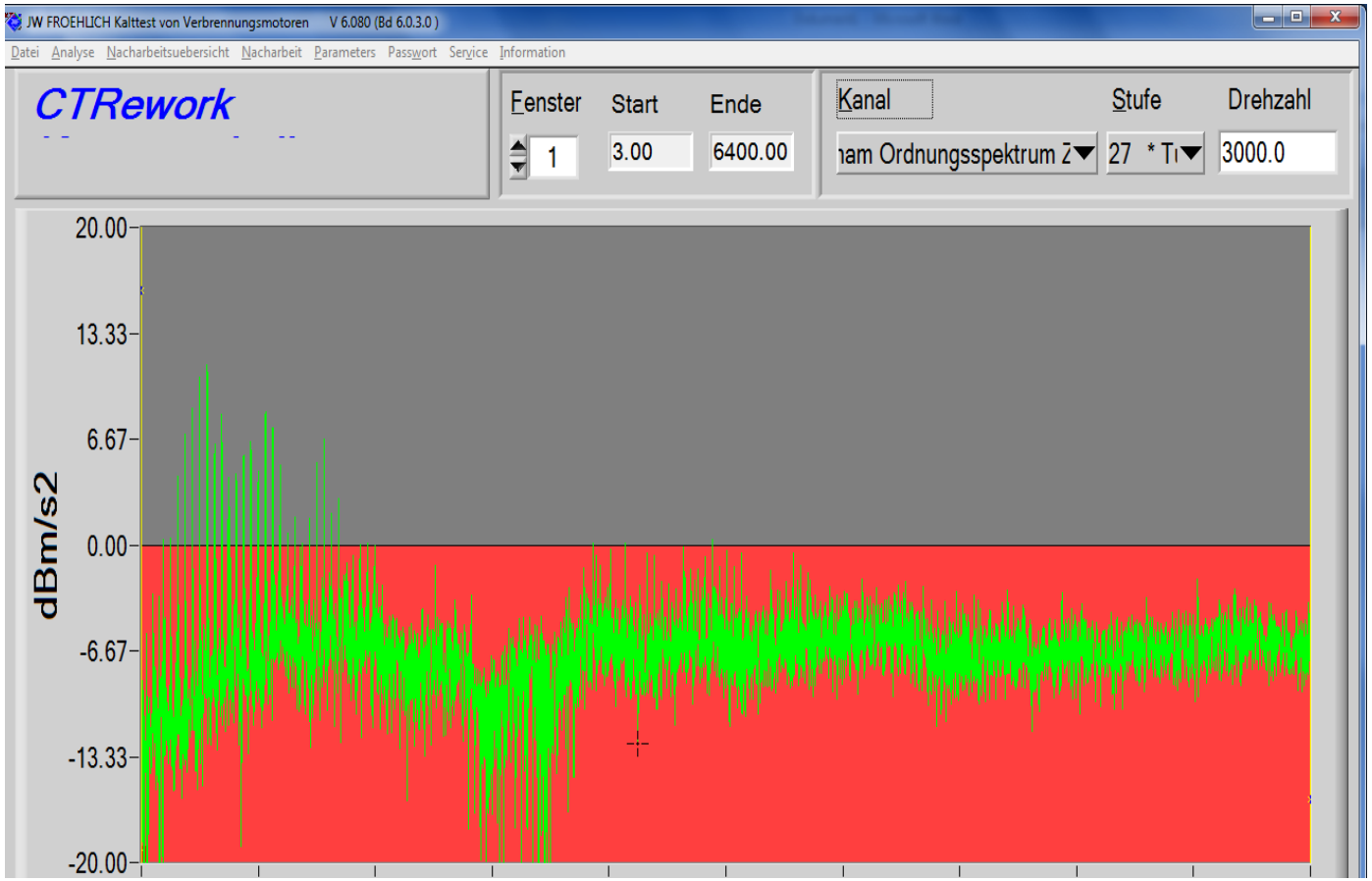
Chameleon: Example

IC engine shows suspect signal components

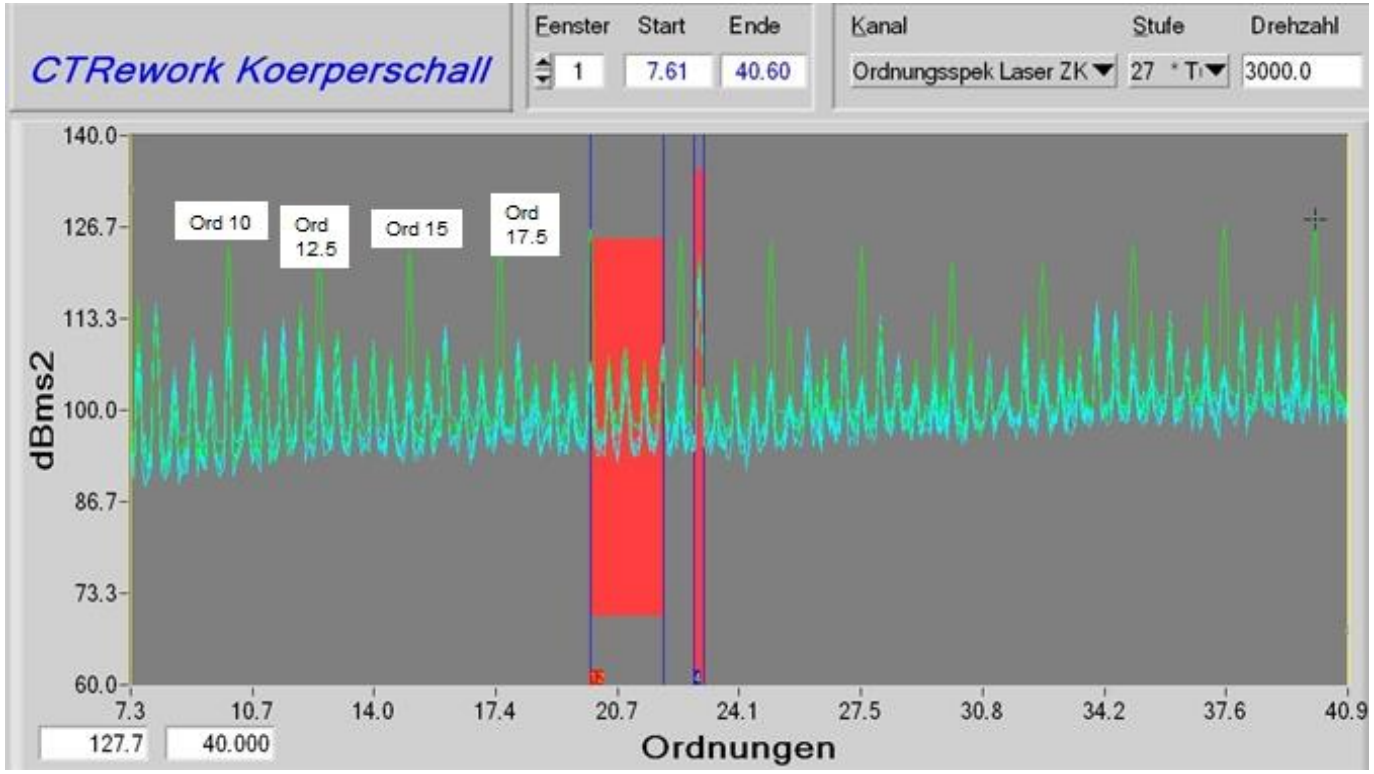
- Chameleon order spectrum cylinder head
- High order levels at certain positions



Chameleon: Example

Suspect order lines

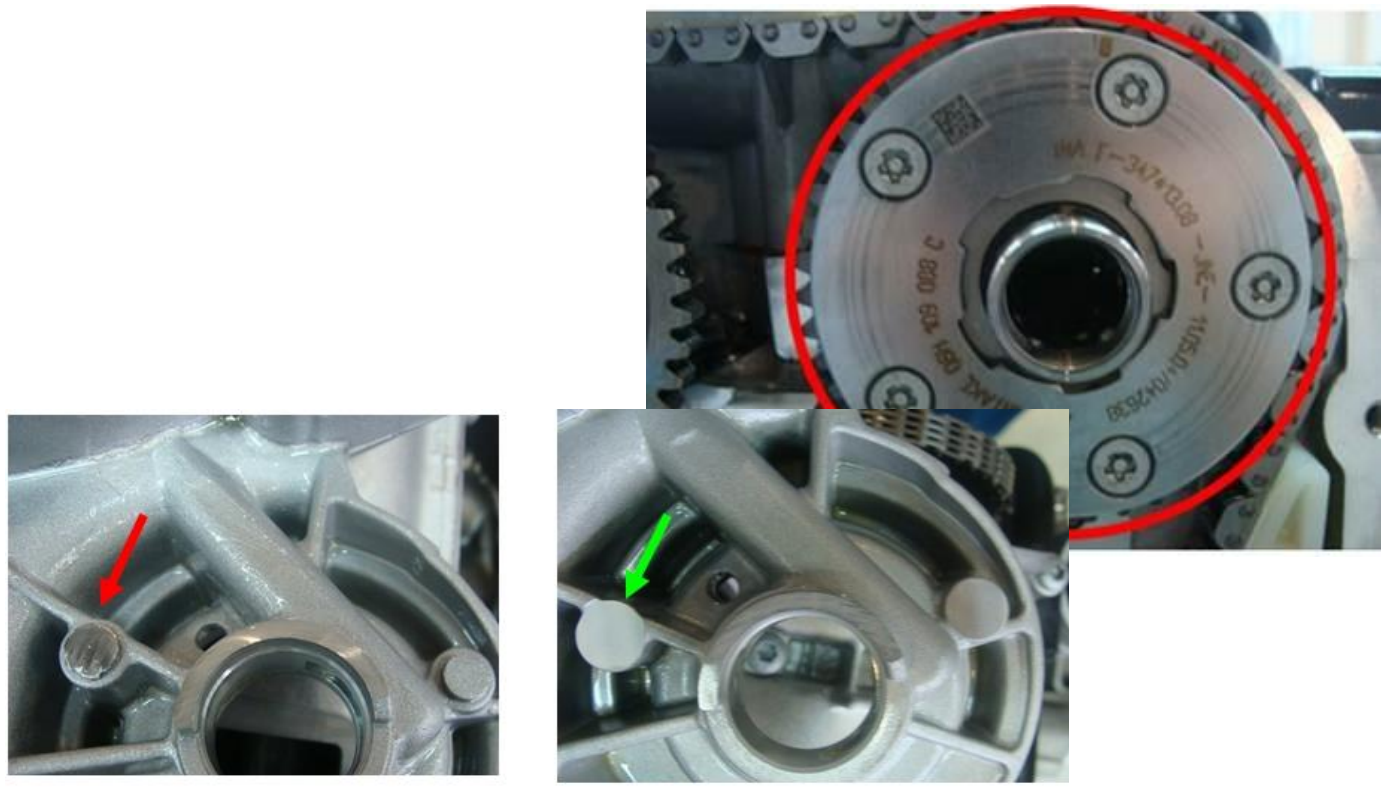
- High levels at lines with 2.5 orders distance
- Periodic transients with 5 peaks per revolution camshaft



Chameleon: Example

Root cause

- Casting residue not removed
- Faulty production
- Nose touches the screws of the NW regulator
- → **Serial error did not come to delivery**



Designed for integration into EoL test benches

- Easy integration of Simcenter Anovis into EoL test bench
- Restricted parameterization at test bench possible
- Quality assessment by test bench
- Control by test bench, integrated data handling

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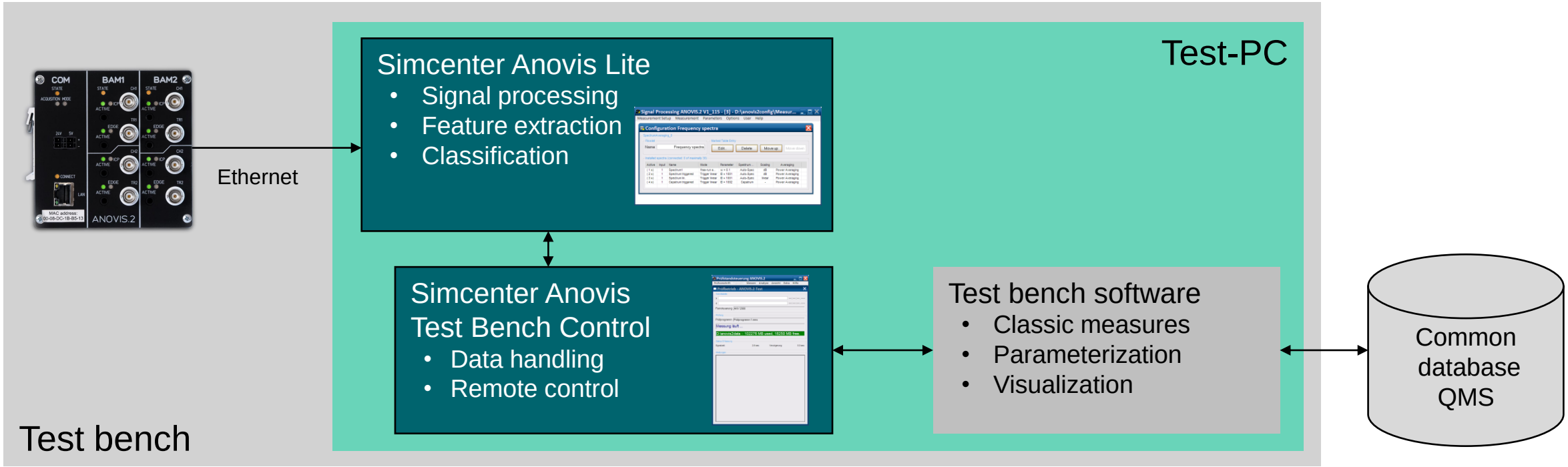
Test Bench Interface

- Communication media:
  - Field busses
    - Profinet, Profibus, Ethercat, Digital IO, …
    - Memory mapped protocol
  - IT-based
    - TCP/IP, UDP, RS232
    - Text-based protocol
  - Direct software integration
    - DLL
    - Python scripting
- Implementation of user specific requirements possible

Test Bench With Simcenter Anovis Lite

Fully integrated test system

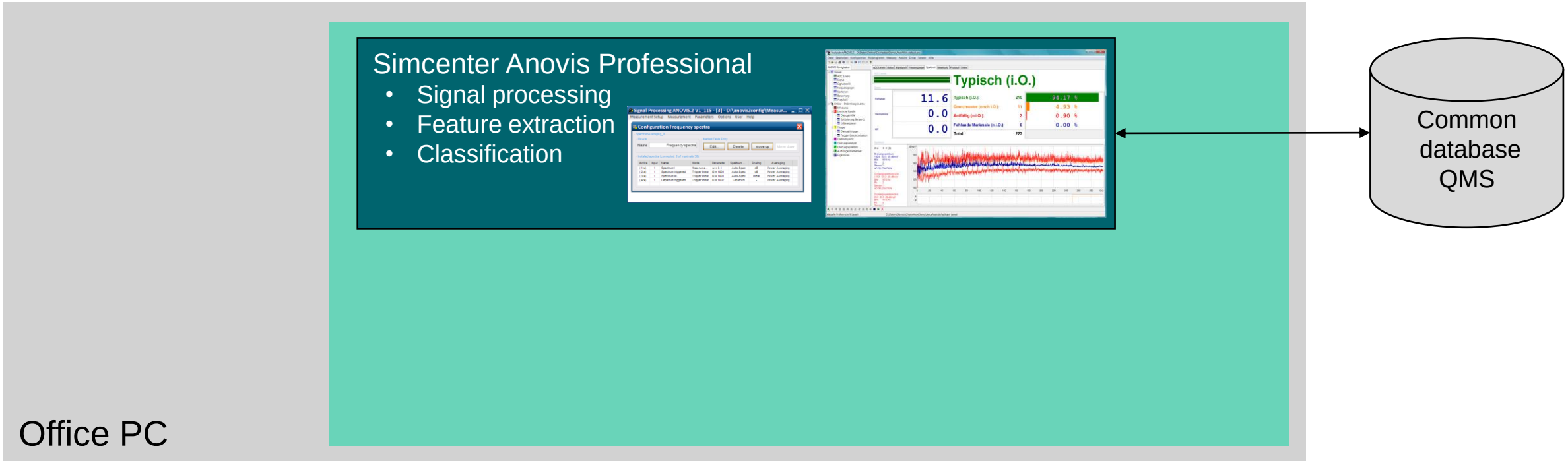
- Limited parameterization at test bench possible
- Quality judgment by test bench
- Control by test bench, integrated data handling



Simcenter Anovis Lab System

Supplementary interactive system

- Result analysis and statistics
- Off-line data analysis
- Parameterization and visualization



Summary

- Important technology for current production lines
- Comprehensive solutions for EOL test, NDT and process monitoring
- Specification of measurement chain requires special expertise and experience

https://youtu.be/EOb0pYjEWK8

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