ADVANCED ONLINE MONITORING AND NDE FOR NUCLEAR SYSTEMS

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OUTLINE

- FRANHOFER IZFP
- CONTEXT – WHY?
- IDEA / GOAL – WHAT? / WHERETO?
- APPROACH & CONCEPT – HOW?

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Data and Facts

- Founded: 1972
  - Research mission: NDE development for reactor safety
- Permanent staff (2019): 140
- Location: Saarbrücken
- Operating budget (2019): 17 Mio. €
- Finance
  > 75 % projects
  < 25 % basic fundings

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Competence Levels

Scientific competencies

- Data acquisition – sensor development for multiple NDT technologies
- Data assessment – 3D imaging and 3D image processing
- Knowledge about applications and materials – data analysis, Smart Materials Data
- System development – Subsystems, laboratory systems, industrial systems

Methodical competencies as cross-sectional technologies

- Acoustical procedures
- Optic procedures
- Electro-magnetic procedures
- Thermic procedures
- X-ray technologies

CONTEXT

- Materials and components easily characterized, tested and monitored by means of NDT methods.
  - Monitorability of material - design at manufacture, for the replacement of components or retrofitting.
- Ageing models, fed with data from continuous monitoring and in-service inspections, allow for predictive maintenance (as opposed to scheduled maintenance). → How to aggregate and use such data → the development of digital replica or digital twins of components.
  - Materials data generated over the entire PLC stored in a digital twin file → backtracking of material properties and their changes over the entire PLC.
  - Interrelation of data generated by different NDE methods and data fusion
- Condition-based maintenance by using continuous monitoring of the structural health of components - added value in other industries as a complement to in-service inspections at programmed intervals, and is progressively making its way into the nuclear industry.

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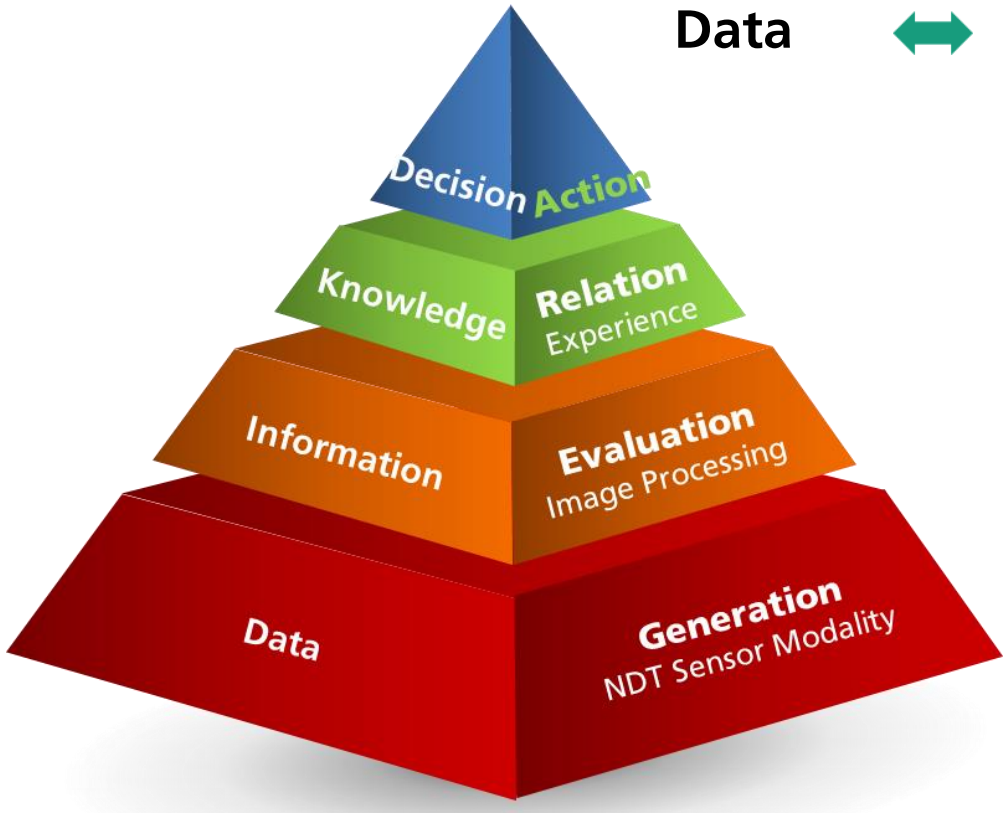
- Generate and collect data: material – component – operating structure – recycled material
- Evaluate relevant material key data by AI / ML: finger printing
- Intelligent sensors that decide on the data relevance

- Development of Intelligent NDE technologies
  - for the characterisation of materials' and components' health
  - for condition-based maintenance
  - for monitoring, preventing and mitigating the ageing effects of structural materials and components

APPROACH

Data Value-Added Chain



Data ⟷ **Information** ⟷ **Knowledge** ⟷ **Decision**

Problem
- Definition (Engineering)
- Understanding (Process and Material Science)
- Solution (Computer Science)
- Requirement (Physics)

APPROACH

Data generation (multi-sensor data)

Collection of physically various non-standardized sensor effects (magnetic, electrical etc.) that react to material properties

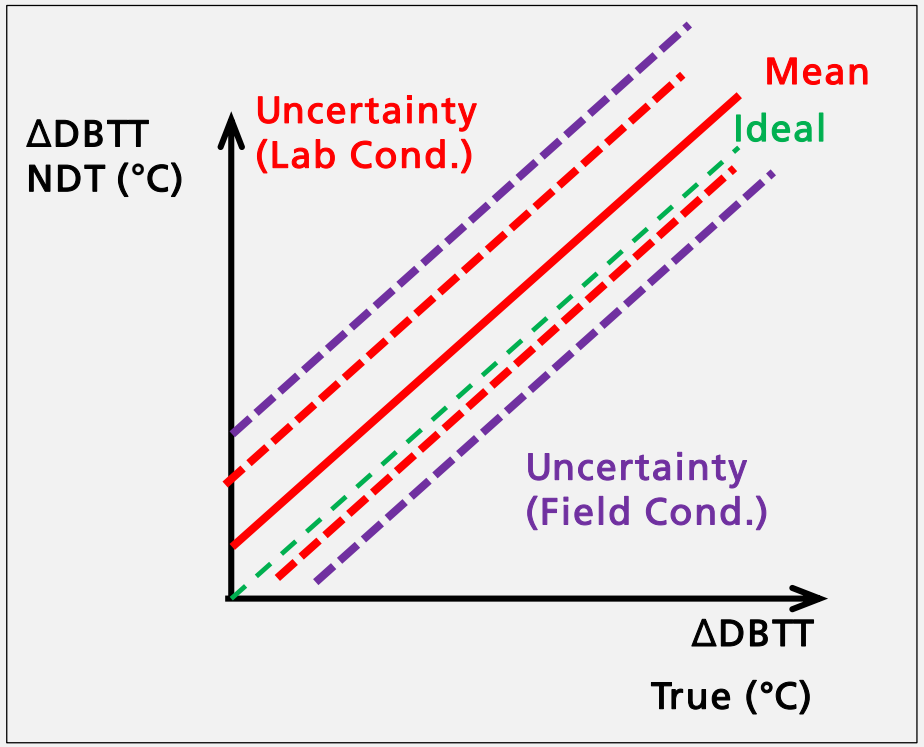
Training data & Machine learning

Polynomial and/or

Pattern recognition

$$\sqrt{|x|}\quad x^2\quad 1/x$$

Targeted material property



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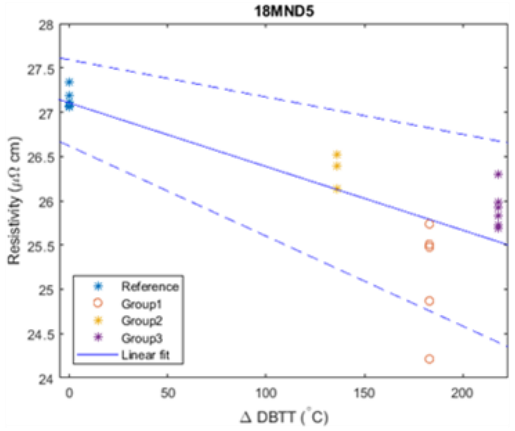
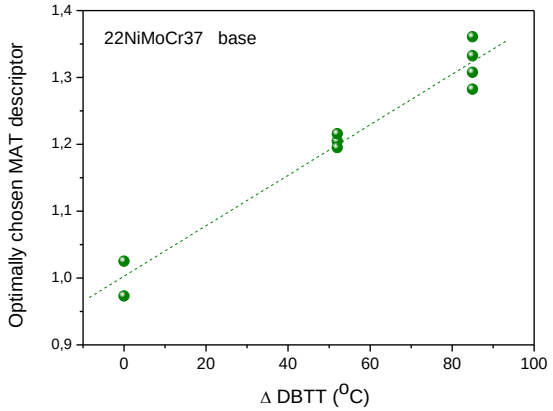
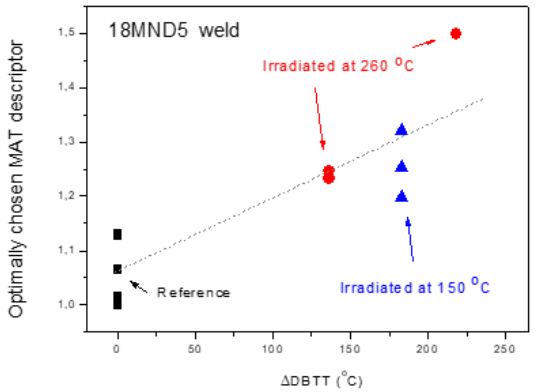
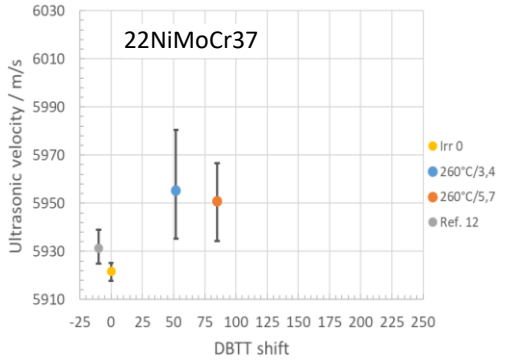
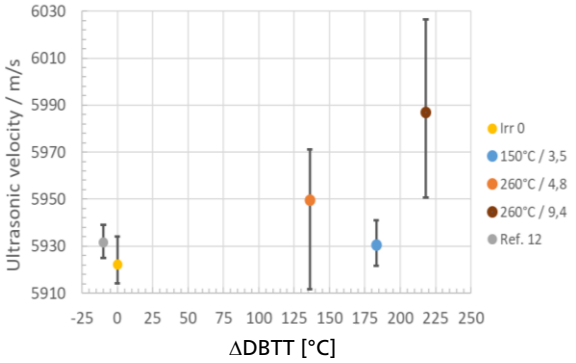
APPROACH

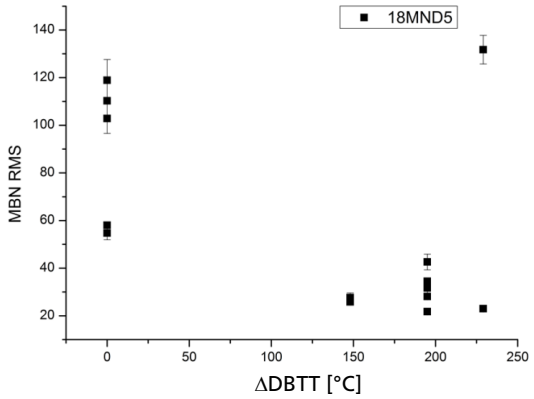


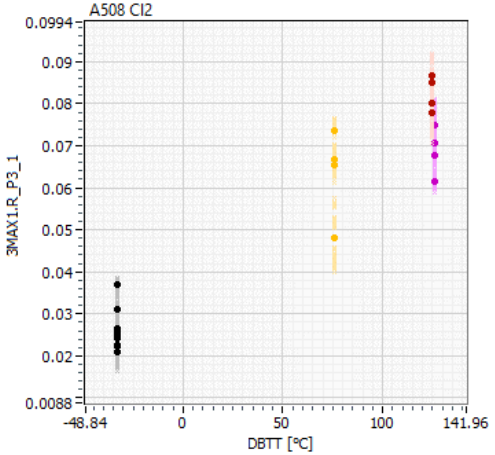


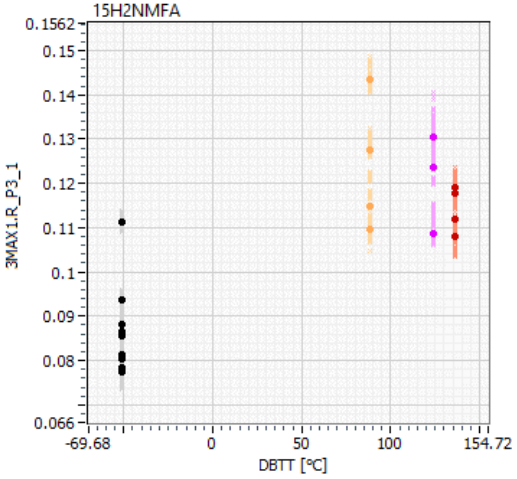












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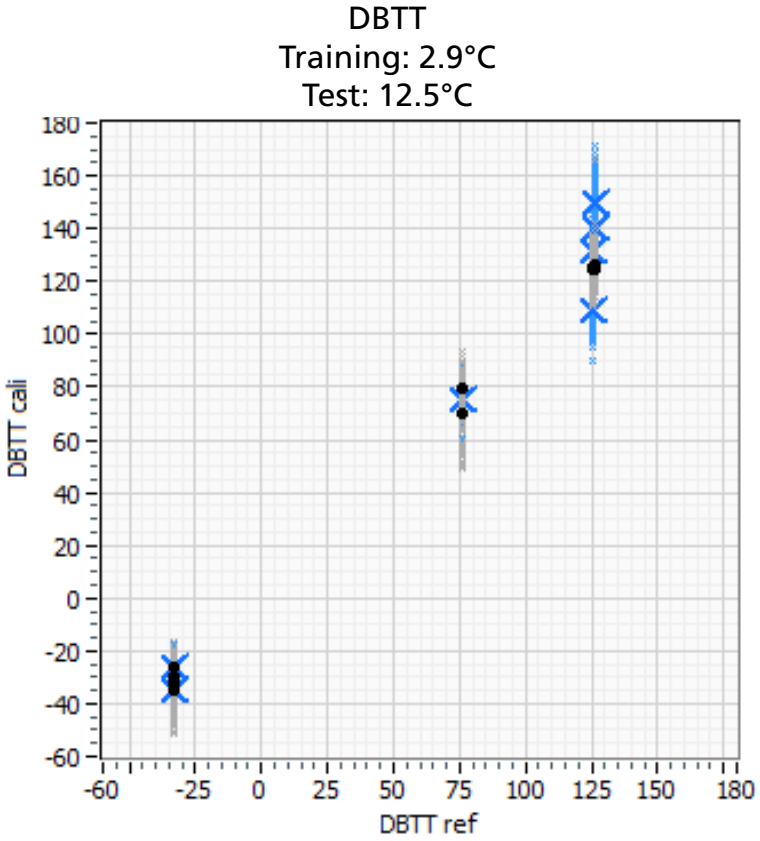
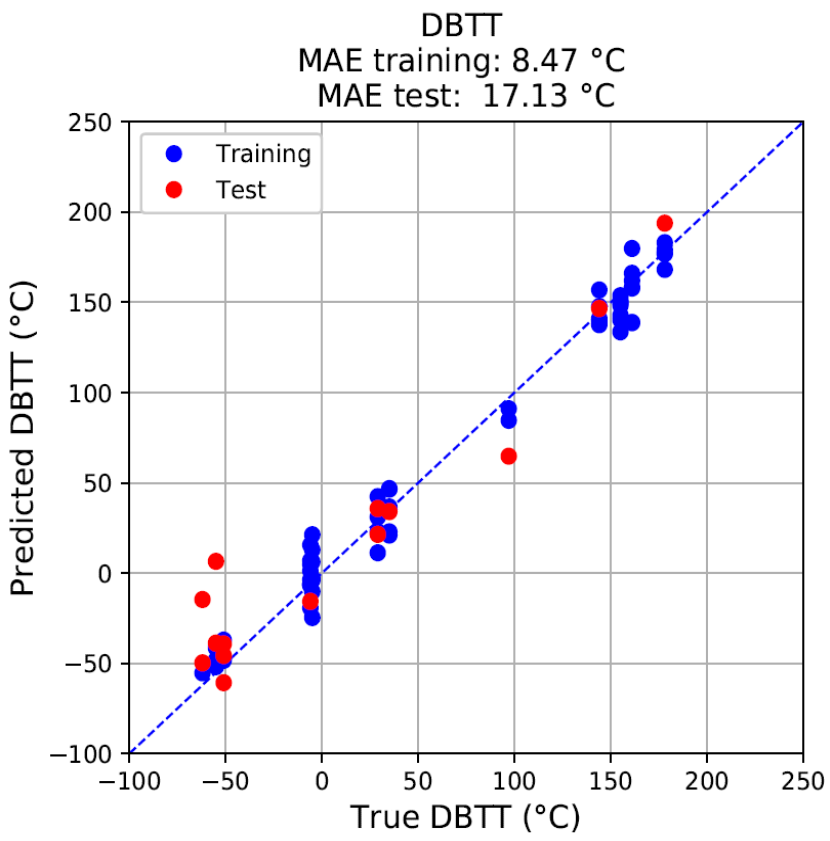
APPROACH

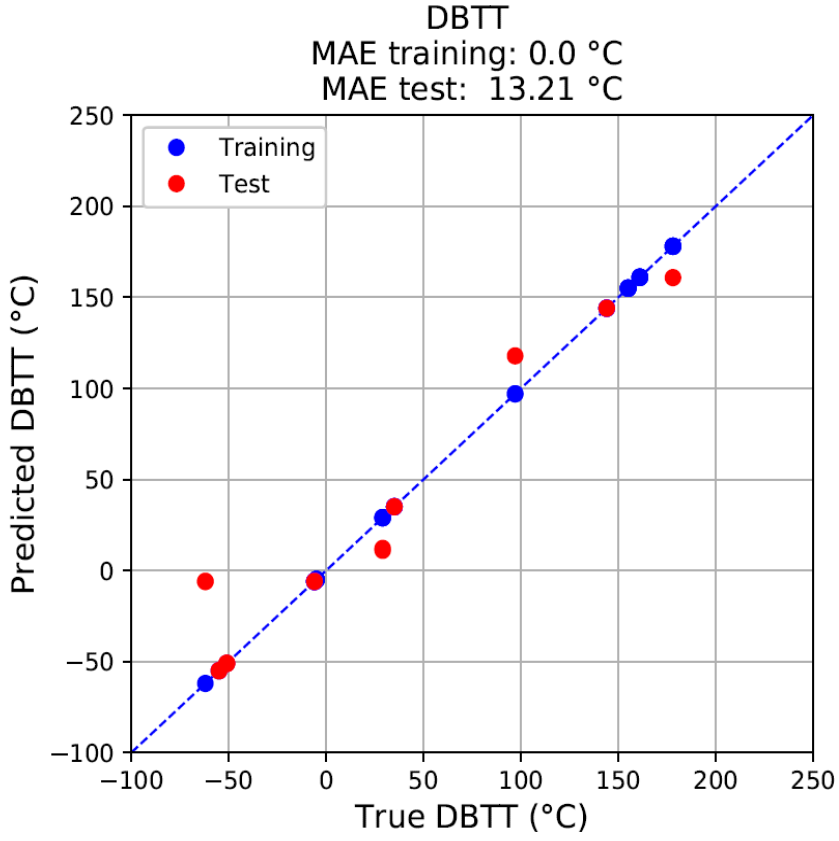
Monitoring of damage progress + Regression Analysis



NDT of individual damage conditions + Kernel Ridge Regression



NDT of individual damage conditions K Nearest Neighbours



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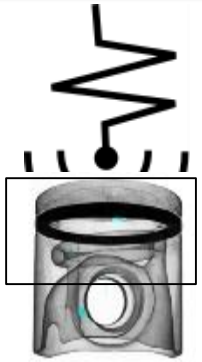
ADVANCED CONTINUOUS MONITORING VIA COMPRESSED SENSING

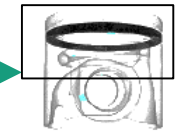
Digital Product Memory

Cognitive Sensor



Innovation

Reconstruction



What has changed?

- What is the advantage?
  - Less data to record: simpler sensors; Less power consumption; Less storage requirement
  - Less data to handle: post processing simplified; Bottleneck of transmitting/communicating the data reduced

THANK YOU FOR YOUR ATTENTION!

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