



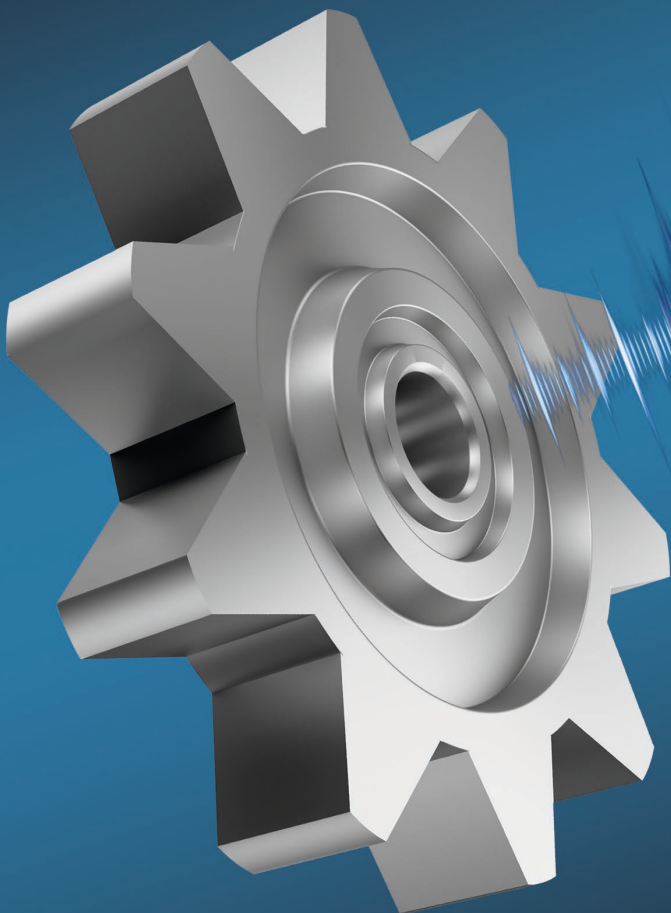
**Fraunhofer**  
IKTS

FRAUNHOFER INSTITUTE FOR CERAMIC TECHNOLOGIES AND SYSTEMS IKTS

INDUSTRIAL SOLUTIONS

# ACOUSTIC DIAGNOSTICS

DEFECT DETECTION | SIGNAL EVALUATION | QUALITY ASSURANCE



1	Overview
2	Damage detection
4	Quality assessment
6	Wear monitoring
8	Bio- and speech signals
10	Services offered
11	Cooperation models
12	Artificial intelligence
13	Glossary

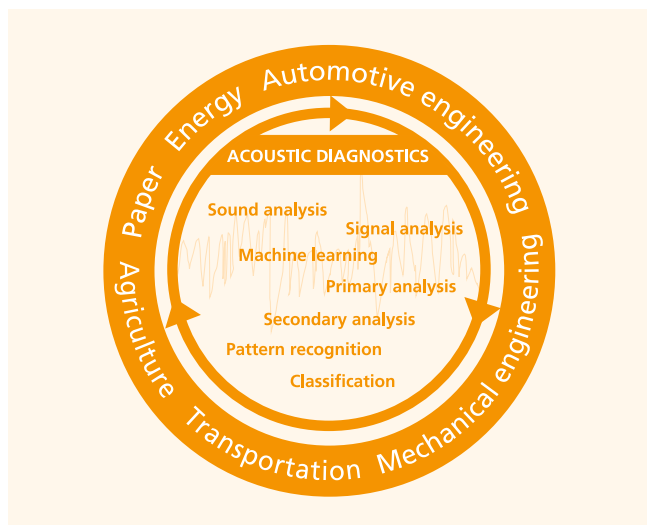


# LISTENING – ANALYZING – ASSURING QUALITY

As the complexity of products and processes in manufacturing and operations increases, so does the need for cost-effective and reliable approaches in quality assurance, repair, and maintenance. This challenge can easily be met with acoustic diagnostic methods. Defective components and critical plant and operational processes have unique noise patterns, which can be detected quickly and accurately with acoustic methods. In this brochure, Fraunhofer IKTS presents a selection of easy-to-integrate, low-cost acoustic diagnostic solutions, which can be combined with state-of-the-art artificial intelligence (AI) methods to enable optimization over the entire product life cycle.

Fraunhofer IKTS is a proven specialist for non-destructive test systems and processes and can draw on extensive experience in the area of acoustic diagnostics. Operational malfunctions and component damages can be detected using active or passive methods. Acoustic diagnostics comprises quality assessment of parts and materials, monitoring of wear parts in machines and plants, and damage detection in parts and components. Analysis and evaluation can be performed on a wide variety of materials, including iron, aluminum, glass, fiber-reinforced composites, and paper. Acoustic diagnostics can be used during and after production as well as for condition monitoring of wear and other parts in a host of industries (automotive and aerospace engineering, mechanical engineering, paper and food industry, energy sector, etc.). The technology can also be applied to non-technical sound signals, e.g., for pest detection in grain storage facilities or for realizing secure and operationally reliable voice control of industrial equipment.

At the heart of acoustic diagnostic techniques are state-of-the-art artificial intelligence methods, such as pattern recognition and machine learning, which allow for automatic and reliable analysis of even highly complex signals or signals with significant noise, in real time. Determination of damage extent or residual life is also possible.





## DEFECT DETECTION

Testing of parts and components is a critical task in transportation and environmental engineering.

In rail and air transportation, passenger safety is the top priority. Spalling and other defects in wheel treads must be identified at an early stage. This requires continuous monitoring of wheels and wheel bearings in rail vehicles. High demands are also placed on aircraft structural elements, such as the fuselage shell, because they can suffer impact or fatigue damage while in flight.

As an example in the renewable energy sector, wind turbines are exposed to extreme loads. External influences, such as mechanical abrasions, weather events, and continuously fluctuating loads exerted on the rotor blades lead to wear and aging over time. Production-related flaws can also lastingly interfere with or even prevent operation.

The sooner damage or wear effects are determined, the better the chances of repair and avoidance of consequential damage (or catastrophe) are.

### Rail transportation

Fraunhofer IKTS offers a robust, autonomous solution for monitoring wheels and wheel bearings as well as detecting blocked brakes, damaged springs, and impermissible inclinations (e.g., due to improper loading) in rail vehicles.

Monitoring is based on acceleration and temperature data as well as the structure-borne sound signals generated by contact between the train wheels and the rails. These data are recorded and evaluated with customer-specifically adapted sensor nodes consisting of modules for sensor technology as well as signal processing and radio processors. Instrumentation and support for trial runs round off the offering for this monitoring solution.

For monitoring ICE wheels, Fraunhofer IKTS offers a measurement system that is permanently installed in the hollow shaft of the wheel set. This enables processing of high-frequency structure-borne sound signals generated by the wheel-to-rail contact and monitoring of both the wheels and the track for detection of damage.

SERVICES OFFERED	
✓	DETECTION SOFTWARE
✓	HARDWARE
✓	TRAINING SOFTWARE
✓	CUSTOMER-SPECIFIC DEVELOPMENT
MEASURING PRINCIPLE	
PASSIVE	
1 TO 8 STRUCTURE-BORNE SOUND SENSORS	





### Rotor blades

An integrated system for the monitoring of rotor blades in wind power plants allows for condition-dependent component maintenance. The passive method of acoustic emission (AE) testing is used for detection of damage, such as structural damage, ice formation, and aerodynamic imbalances or lightning strikes.

This method utilizes special ultrasonic waves arising in the structure as a result of loading (acoustic emissions). Piezoelectric sensors detect these emissions. The frequency and the distribution of the acoustic emission events represent the current damage. Optical energy and data transmission are implemented to eliminate the risk of lightning strikes posed through use of metal conductors in the wind turbine rotor blades.

The IKTS system allows the evaluation of the component condition until the next inspection, thus optimizing maintenance planning.

### Aircraft structures

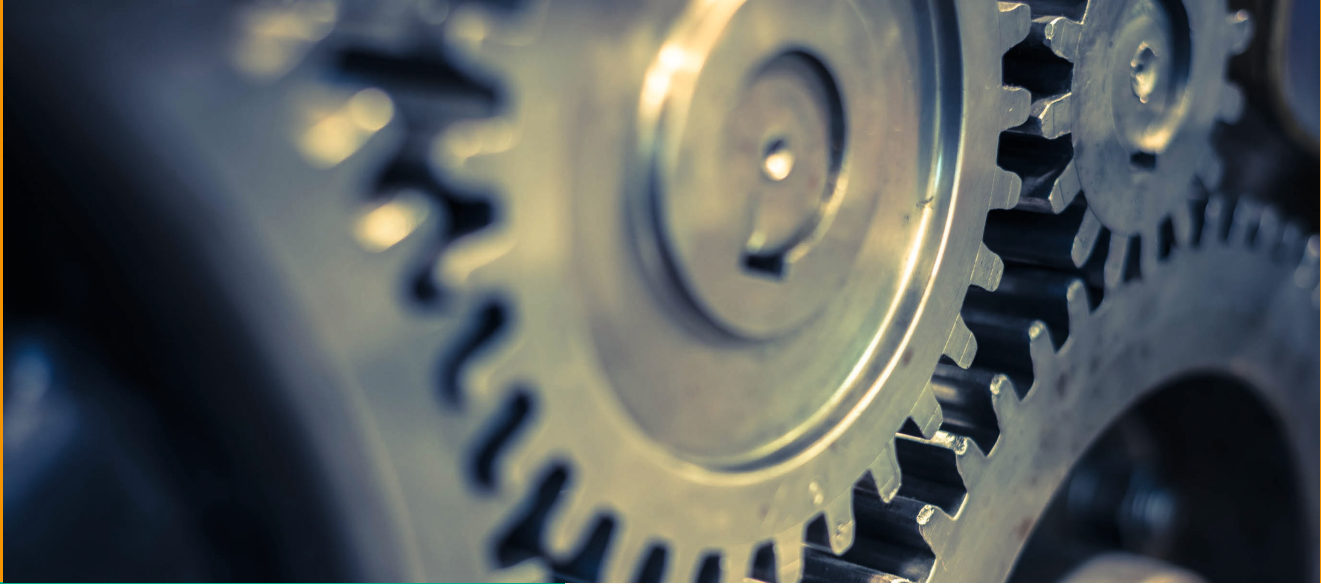
Aircraft developers rely on lightweight materials to reduce aircraft weight. However, the carbon fiber composites (CFRP) used require special processing, quality control, and inspection.

To ensure safety in consideration of the high loads experienced by aircrafts in flight, early detection of cracks and impact damages is crucial. With the help of active and passive ultrasonic diagnostics, damages can be rapidly detected and the severity assessed automatically.

Testing and monitoring of material properties, such as the structural integrity of the aircraft fuselage, are currently performed on the ground in load tests. In the future, monitoring should be able to take place in the air.

SERVICES OFFERED	
✓	DETECTION SOFTWARE
✓	HARDWARE
✓	TRAINING SOFTWARE
✓	CUSTOMER-SPECIFIC DEVELOPMENT
MEASURING PRINCIPLE	
PASSIVE	
4 TO 12 PIEZOSENSORS	

SERVICES OFFERED	
✓	DETECTION SOFTWARE
✓	HARDWARE
✓	TRAINING SOFTWARE
✓	CUSTOMER-SPECIFIC DEVELOPMENT
MEASURING PRINCIPLE	
ACTIVE	
8 TO 12 ULTRASONIC ACTUATORS/SENSORS	



## QUALITY ASSESSMENT

More than just “good” or “bad” – quality assessment of parts and products, especially during and directly after production, is a central element of quality assurance. In most cases, 100 % inspection is a prerequisite for the acceptance of the manufactured items.

The goal is to segregate all bad parts, but only a minimal number of defect-free or “still” good parts, in an automated test. It sounds easy, but it is a challenging task due to the plethora of defect types that are possible. Alone in the inspection of gears, defects can include cracks of various sizes on outer gear surfaces or supports, cracked or detached teeth, blowholes, inclusions, and flaws. A capable test system must be able to detect all of these defects.

Quality also plays a major role in many aspects of daily life: in tissue products, for instance, for which softness is the key criterion for customer acceptance. However, softness perception is subjective. Fraunhofer IKTS has developed a system for the instrument-based determination of softness.

### Gears

Reliable and reproducible automated classification is useful for quality assessment of gears and other sintered components.

Fraunhofer IKTS has developed a system for gear testing based on sound analysis. Sound analysis is a rapid, low-cost test method that can easily be applied to mass production processes.

A part is positioned in a defined manner. A suitable sensor excites the test part, causing it to vibrate. AI methods are also employed for filtering patterns out of the recorded signal. Following a training phase, signal evaluation is automated to enable differentiation between “good” and “bad” parts. The system is especially designed for use in harsh industrial environments and can be integrated into existing test stations on production lines.

SERVICES OFFERED	
✓	DETECTION SOFTWARE
	HARDWARE
✓	TRAINING SOFTWARE
✓	CUSTOMER-SPECIFIC DEVELOPMENT
MEASURING PRINCIPLE	
ACTIVE	
3 ULTRASONIC ACTUATORS/SENSORS	



### Tissue products

Tissue products encompass all products, such as paper tissues, cosmetic facial tissues, and toilet paper, for which softness is an important selling point. Previously, trained testers (panel test) were employed to categorize this subjectively perceived property.

To estimate the subjective softness, Fraunhofer IKTS has developed a new approach based on analysis of the tearing sound made by a tissue product. So, an unknown sample can be assigned to one of the known classes (soft, medium, or hard) defined in panel tests.

The result can support the tissue product manufacturer at every stage in the production process by enabling continuous quality control as well as use of chemical additives to modify the softness in a defined way.

### Hollow bodies

For small-, medium-, and large-scale production of hollow bodies, such as cups or tubes, Fraunhofer IKTS offers a new, automated test method based on sound analysis. This method is suitable for test specimens made from different materials, such as metals and ceramics.

In the test, the parts are suitably positioned for being automatically excited and made to vibrate in a subsequent step. Sensors or microphones adapted to the specific test task record the response to the excitation signal. A good-or-bad evaluation is automatically derived from this.

SERVICES OFFERED	
✓	DETECTION SOFTWARE
	HARDWARE
✓	TRAINING SOFTWARE
✓	CUSTOMER-SPECIFIC DEVELOPMENT
MEASURING PRINCIPLE	
ACTIVE	
1 TO 4 SENSORS/MICROPHONES	

SERVICES OFFERED	
✓	DETECTION SOFTWARE
	HARDWARE
✓	TRAINING SOFTWARE
✓	CUSTOMER-SPECIFIC DEVELOPMENT
MEASURING PRINCIPLE	
ACTIVE	
3 ULTRASONIC ACTUATORS/SENSORS OR MICROPHONES	

1 Hollow ceramic bodies for stationary batteries.





## WEAR MONITORING

Moving parts in machines and plants are subject to high loads. Failure can lead to downtime, costly repairs, and production losses.

Early detection of defects in wear parts, such as rollers, bearings, valves, and gears can be very beneficial from an economic standpoint. In safety-sensitive areas, such as chemical plants, failure of these parts can have devastating consequences. For example, valves that cannot be closed properly and hence allow liquid to continue flowing unimpededly must be replaced before failure occurs.

A mere good-or-bad distinction is not sufficient. Wear monitoring solutions developed at Fraunhofer IKTS offer a new approach: with the help of service life analysis, the residual life of a part can be determined. This provides an indication of when the part in question will need to be replaced.

### Rollers

Rollers in spinning machines, such as are used in the textile industry, undergo significant wear. Mechanical defects, such as cracks, friction-induced damage, and spalls, occur frequently.

State-of-the-art acoustic diagnostic methods help detect impending failure of rollers and other machine parts. They are based on typical signatures in the vibration spectra of the respective functional components. These patterns are generated by mechanical defects and can be determined through time-frequency analysis.

The method developed at Fraunhofer IKTS evaluates these signatures. Failure can hence be detected in advance and appropriate preventive measures introduced.

#### SERVICES OFFERED

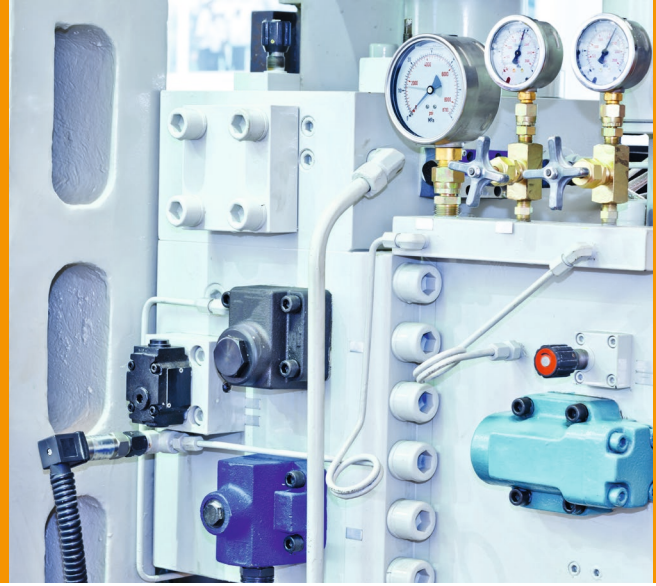
- ✓ DETECTION SOFTWARE
- ✓ HARDWARE
- ✓ TRAINING SOFTWARE
- ✓ CUSTOMER-SPECIFIC DEVELOPMENT

#### MEASURING PRINCIPLE

PASSIVE

1 TO 4 STRUCTURE-BORNE SOUND SENSORS





## Valves

Mechanical changes arising due to progressing age and wear affect the switching noise emitted by a valve. This noise has a pronounced spectral and temporal structure and forms a good basis for condition monitoring.

Pattern recognition methods are hence ideal for classifying these noises. With knowledge of the behavior over various lifetimes for known valves, the remaining lifetime can be determined for unknown valves. This allows impending failure to be identified and prevented. Conversely, unnecessary replacement of properly functioning valves can be avoided and maintenance costs thereby lowered.

## Hydraulic test stands

Until now, hydraulic test stands need to undergo maintenance at regular intervals, whether faults are present or not. Fraunhofer IKTS has developed a system for condition-dependent maintenance that obviates this costly practice.

The monitoring strategy, which is realized via structure-borne sound sensors, targets especially wear-prone hydraulic components, such as servo-driven valves. Through the oil flow, acoustic signals characterizing the hydraulic processes are generated with a very wide range of frequencies. Changes in the conditions of components through which the oil flows lead to changes in the signal characteristics. From the envelopes of the time signals and the amplitude range of the signals, features can be extracted and used for condition monitoring of the components. In this way, the necessity of maintenance measures can be assessed.

SERVICES OFFERED	
✓	DETECTION SOFTWARE
✓	HARDWARE
✓	TRAINING SOFTWARE
✓	CUSTOMER-SPECIFIC DEVELOPMENT
MEASURING PRINCIPLE	
PASSIVE	
1 TO 4 SENSORS	

SERVICES OFFERED	
✓	DETECTION SOFTWARE
✓	HARDWARE
✓	TRAINING SOFTWARE
✓	CUSTOMER-SPECIFIC DEVELOPMENT
MEASURING PRINCIPLE	
PASSIVE	
2 TO 4 STRUCTURE-BORNE SOUND SENSORS (EXTENDABLE)	



## BIOSIGNALS AND SPEECH SIGNALS

Acoustic diagnostic methods also lend themselves well to non-technical signals, such as biosignals, speech or music.

Pests, such as beetles, generate noise when eating and crawling. This allows their presence in storage sheds or grain silos to be detected. Because pests can destroy large amounts of food and grain supplies, permanent monitoring of storage facilities makes a great deal of sense.

Another useful application for acoustic pattern recognition, albeit not for diagnostic purposes, is voice control of industrial equipment. The system supports customers who cannot manually control test devices themselves, e.g., test engineers in the field. Fraunhofer IKTS offers a secure and reliable solution for this.

### Pest detection in grain silos

Safe, tradeable grain is taken for granted in these days. Wherever grain is stored and processed, pests can be present. Saw-toothed grain beetles, Indian meal moths, red flour beetles, grain weevils, lesser grain borers, and other pests destroy up to 15 % of grain harvests worldwide. The reasons for this are residual populations in silos, storage facilities that are not hermetically sealed, or introduction of pests from the field or from suppliers. Continuous monitoring of storage facilities can aid in detecting pests early on at the larval stage.

There are numerous methods (pheromone traps, temperature monitoring, etc.) for pest detection on the market, but they are often extremely inaccurate. Fraunhofer IKTS uses AI-based methods to detect pests based on the noise they emit. Solutions especially adapted to grain storage facilities and transportation systems provide information on pest infestation levels, insect species, and insect developmental stages (e.g., larval or adult beetles).

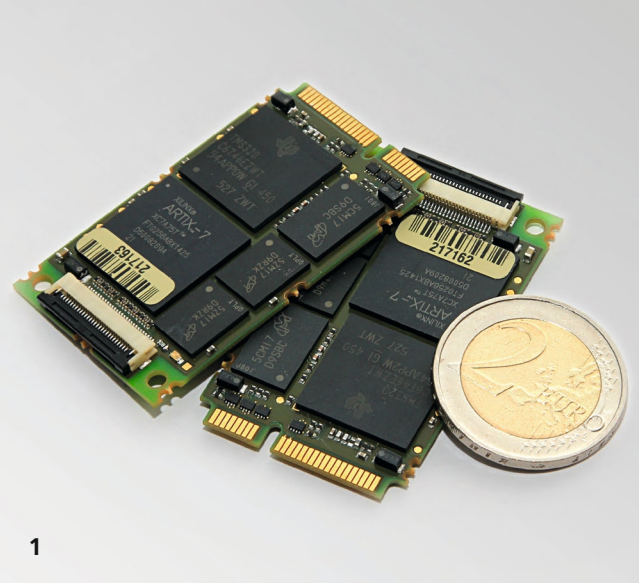
#### SERVICES OFFERED

- ✓ DETECTION SOFTWARE
- ✓ HARDWARE
- ✓ TRAINING SOFTWARE
- ✓ CUSTOMER-SPECIFIC DEVELOPMENT

#### MEASURING PRINCIPLE

PASSIVE

1 TO 20 SENSORS



### Voice control

State-of-the-art measuring and test equipment offer numerous setting and programming options. However, manual operation is often difficult (multitude of menus and submenus) or impossible (hands occupied or dirty during testing) in practice. Use of speech recognition and speech synthesis technology offers tremendous potential for improving process flow efficiency.

Speech technologies have advanced to the point that natural human-to-machine communication is now easily possible. Commercially available solutions usually transmit the user speech input to third-party servers, which can compromise data security due to the transmission of information to external parties, who can potentially save and reuse these data. In addition, the operational reliability can be disrupted due to the reliance of the solutions on wireless network connections. These solutions are hence not recommended for use in test equipment.

Fraunhofer IKTS offers a secure and operationally reliable hardware-based speech dialog system with continuous speech input and output capabilities for interactions between users and test equipment. The dialog system can be integrated into existing test equipment or connected via a USB interface and supports wired or Bluetooth headsets. This enables the user to communicate with the test equipment in a “hands and eyes free” way.

Alert tones (“earcons”) serve as notification of events. By moving the computationally intensive algorithms to hardware, it is possible to miniaturize the system. For PC-based measuring and test equipment with sufficient computing power reserves, a pure software solution is also available.

During development, special emphasis was placed on security. Thus, no data are transmitted to external servers. Neither a permanent cellular or Wi-Fi network nor an internet connection is required. There is no possibility of sensitive or personal data being transmitted. In contrast to speech recognition, the system enables devices to be controlled from cell phones. Additional speech synthesis enables feedback and confirmation for complete communication between users and systems.

SERVICES OFFERED	
✓	DETECTION SOFTWARE
✓	HARDWARE
✓	TRAINING SOFTWARE
✓	CUSTOMER-SPECIFIC DEVELOPMENT
MEASURING PRINCIPLE	
NOT APPLICABLE	
1 MICROPHONE/HEADSET	

1 Miniaturized speech dialog system modules from IKTS.





## SERVICES OFFERED

Fraunhofer IKTS has accumulated know-how in the field of acoustic diagnostics over many years. With new approaches based on state-of-the-art AI methods, analysis and evaluation of technical and non-technical signals are possible. Individual service offers provide every interested party with the option of selecting a suitable offer for effective quality control or condition monitoring.

### Detection software

The detection software used for pattern recognition runs on Windows and Linux. It automatically assigns recorded signals emitted by test objects to classes (e.g., good/bad or new/worn/defective) and can estimate parameters, such as remaining lifetime or material properties. In addition, it allows evaluation to be performed on successive signal events (e.g., switching noise or speech).

### Hardware modules

Hardware modules enable variable, mobile measurements and are ideal for non-stationary test activities. They offer the same performance as the detection software does and are suitable for portable data acquisition.

### Training software

With the training software, the customer can independently create new models (other series with other properties for the same part or new part types) and adapt the detection software to them.

### Customer-specific development

Fraunhofer IKTS offers complete customized system solutions. Based on customer requirements, a concept for a system (consisting of sensors, electronics, hardware, and software) is created and realized at IKTS. The systems can be installed in test stations on production lines and used as in-line test systems.

### Other offers

- Feasibility studies
- Scientific consulting
- Data analysis and evaluation
- Development of customized software
- Development of embedded pattern recognition systems and systems for smart signal processing
- Development of complete systems (from sensor to classification)
- R&D projects conducted in cooperation with companies and research institutions





## COOPERATION MODELS

Innovation and development are the cornerstones of a promising corporate future. In order to create a competitive edge, Fraunhofer offers tailored options for cooperation, so that small and medium-sized companies can work together in the best possible way. This also allows to utilize development skills at short notice and as needed.

### One-off contracts

The classic cooperation model is the one-off contract. A company perceives a need for research or development. A discussion with Fraunhofer IKTS identifies possible solutions and clarifies the form the partnership could take and the estimated cost.

### Large-scale projects

Some challenges are so complex that they require multiple partners to develop a solution. Clients in this situation have access to the full range of Fraunhofer Institutes. It is possible to incorporate external partners and additional companies.

### Strategic partnerships and innovation clusters

Pre-competitive research which starts off without any ties to specific development contracts often results in long-term partnerships with companies on a regional and international level.

### Spin-offs

Fraunhofer researchers often take the step towards independence by founding their own company. Fraunhofer itself only participates in these kinds of start-ups up to a certain extent. Sometimes the customer who commissioned the new development is interested in taking a stake in the spin-off company.

### Licensing models

Licenses grant third parties the right to use industrial property rights under defined conditions. They provide an option for making use of an innovation in cases where in-house development is prohibitively expensive, capacities are not sufficient for market introduction, or the innovation does not fit into the company's existing range. Fraunhofer IKTS offers flexible licensing models for companywide use, supplementation of the range of offers, or marketing to end customers.



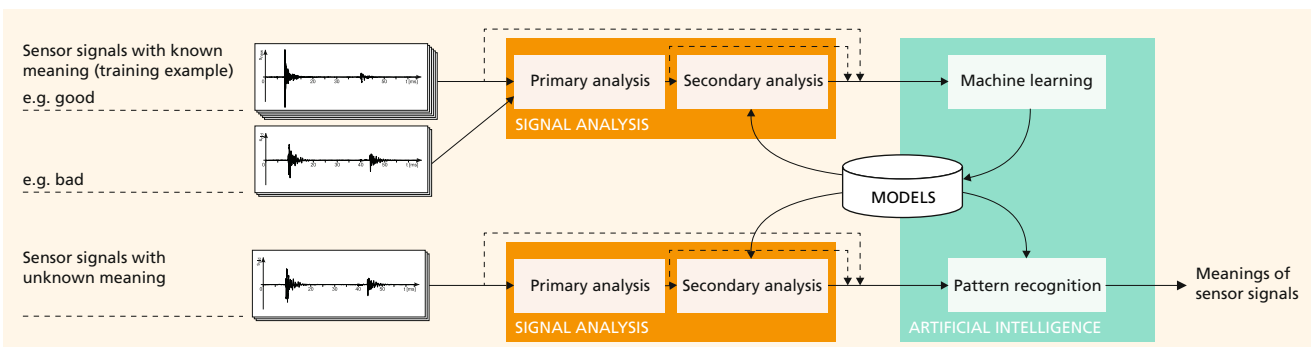
## ARTIFICIAL INTELLIGENCE

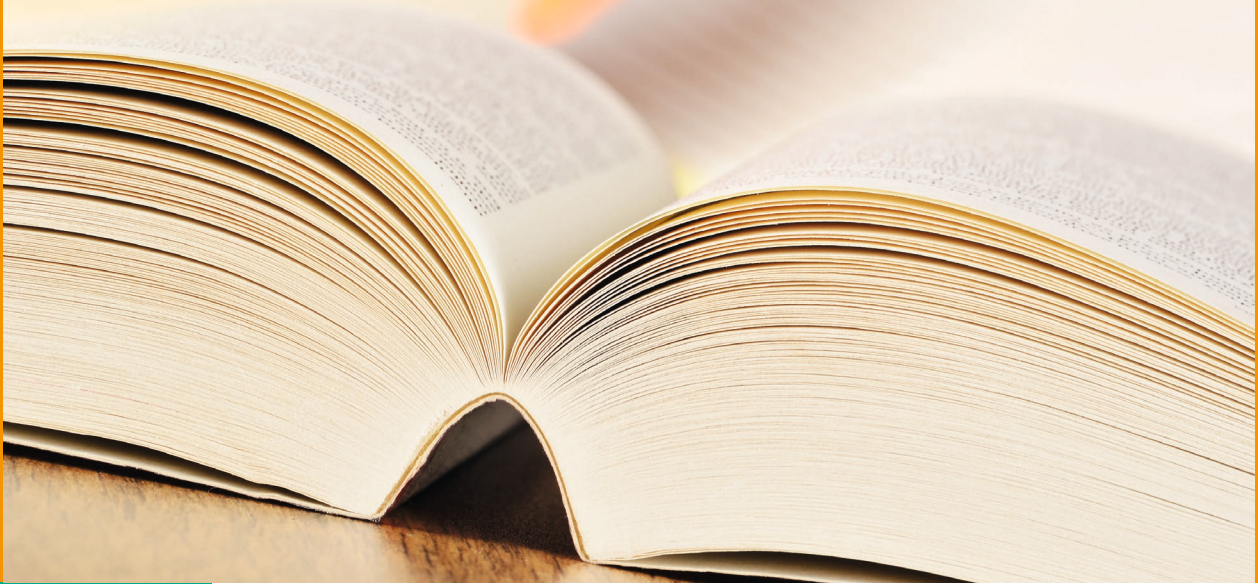
Measuring and test devices have always had the purpose not only of displaying data and values but also of providing an interpretation and a meaning for the information displayed. Industry 4.0 is experiencing the emergence of test tasks of wider scope and greater complexity. The huge volumes of data generated by new measurement methods and different sensors often make interpretation difficult. Artificial intelligence (AI) is capable of assigning meanings to complex measurement data and assessing overall situations.

Fraunhofer IKTS offers a comprehensive range of state-of-the-art AI methods for automated evaluation of technical and non-technical processes. With the help of signal analysis, pattern recognition, and machine learning processes, sensor signals can be automatically interpreted and assigned meanings, e.g., "Test specimen good" or "Component remaining lifetime at 20 %". In the industry 4.0 era, humans no longer perform the task of interpreting data displayed by measuring instruments. Instead, they interact with and monitor AI systems. AI-based measuring and test systems learn the fundamental relationships between sensor signals and their meanings for their specific test tasks by means of examples prior to being used. Later on, they can be "supervised" and corrected by humans in such a way that they can subsequently adjust and improve themselves in operation. This technology is much more flexible

and powerful than traditional test methods are. Apart from the actual AI components, Fraunhofer IKTS uses established signal analysis technology. Primary analysis is essentially based on signal processing methods, including time-frequency transformations (STFT, WT, etc.), digital filters and filter banks, signal modeling (e.g., with optimal filters), and AI-based signal analysis (e.g., CNNs). Secondary analysis is performed to extract relevant information for pattern recognition from the primary features, e.g., by principal component analysis (PCA) or linear discriminant analysis (LDA).

Pattern recognition is based on, e.g., deep neural networks (DNNs), Gaussian mixture models (GMMs), hidden Markov models (HMMs), or support vector machines (SVMs) and includes interpretation of results. The class models required for this are built through special machine learning processes, such as deep learning (DNN), EM algorithms (GMM, HMM), and convex optimization (SVM). In a training phase, the system is supplied with training examples, or sensor signals with known meanings (e.g., "good test specimen" or "bad test specimen"). Models can then be taught further (adapted) during operation for improving the AI system or adapting it to changed tasks. In certain DNN configurations, the pattern recognizer assumes the task of secondary analysis, as well as primary analysis in part.





## GLOSSARY

### **Classification method**

See ► pattern recognition

### **Deep learning**

► Machine learning method for deep neural networks

### **Deep neural network (DNN)**

Artificial neural network with numerous hidden layers,  
► pattern recognizer for ► (sequences of) feature vectors

### **EM algorithm**

► Machine learning method for ► Gaussian mixture models  
and ► hidden Markov models

### **Feature analysis**

Method for calculation of ► (sequences of) feature vectors  
from measured signals

### **Feature vector (sequence)**

Set of ► classification-relevant numerical parameters, possibly  
as a temporal sequence

### **Gaussian mixture model (GMM)**

Statistical ► model for ► pattern recognition in ► feature  
vectors based on Gaussian mixture distribution densities

### **Hidden Markov model (HMM)**

Statistical ► model for ► pattern recognition in ► feature  
vector sequences based on a Markov process, e.g., GMM-  
HMM, DNN-HMM

### **Machine learning**

Automated method for building of ► models for  
► pattern recognition and decision-making processes

### **Model**

Here: computational representation of knowledge

### **Pattern recognition**

Method for differentiation into predefined classes, e.g., based  
on ► DNN, ► GMM, ► HMM, or ► SVM

### **Primary analysis**

First step in ► feature analysis (signal processing, e.g., filter  
banks, FFT, STFT, DWT, Cepstrum, LPC, Wigner-ville distribu-  
tion, etc.)

### **Secondary analysis**

Second step in ► feature analysis (statistics, data compression,  
e.g., quantiles, moments, differences, filtering, PCA, LDA, ICA,  
JFA, etc.)

### **Semantic processing**

Computational processing of meanings (e.g., of measured  
signals)

### **Sequence classifier**

► Pattern recognizer for a sequence of ► feature vectors

### **Signal analysis**

See ► primary analysis

### **Support vector machine (SVM)**

► Pattern recognizer for ► feature vectors

### **Training method**

See ► machine learning

### **Vector classifier**

► Pattern recognizer for a ► feature vector

# FRAUNHOFER IKTS IN PROFILE

The Fraunhofer Institute for Ceramic Technologies and Systems IKTS conducts applied research on high-performance ceramics. The institute's three sites in Dresden and Hermsdorf (Thuringia) represent Europe's largest R&D institution dedicated to ceramics.

As a research and technology service provider, Fraunhofer IKTS develops modern ceramic high-performance materials, customized industrial manufacturing processes and creates prototype components and systems in complete production lines from laboratory to pilot-plant scale. Furthermore, the institute has expertise in diagnostics and testing of materials and processes. Test procedures in the fields of acoustics, electromagnetics, optics and microscopy contribute substantially to the quality assurance of products and plants.

The institute operates in eight market-oriented business divisions to demonstrate and qualify ceramic technologies and components as well as non-destructive test methods for new industries, product concepts and markets beyond the established fields of application. Industries addressed include ceramic materials and processes, mechanical and automotive engineering, electronics and microsystems, energy, environmental and process engineering, bio- and medical technology, optics as well as materials and process analysis.



[www.ikts.fraunhofer.de](http://www.ikts.fraunhofer.de)

## CONTACT

Industrial solutions  
**Acoustic Diagnostics**

Dr.-Ing. Dipl.-Inf.  
Constanze Tschöpe  
**Fraunhofer Institute for  
Ceramic Technologies and  
Systems IKTS**

Maria-Reiche-Strasse 2  
01109 Dresden, Germany  
Phone +49 351 88815-522  
[constanze.tschoepe@  
ikts.fraunhofer.de](mailto:constanze.tschoepe@ikts.fraunhofer.de)