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FRAUNHOFER INSTITUTE FOR INTEGRATED CIRCUITS IIS

HIGHLIGHTS
2016
ANNUAL REPORT

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FRAUNHOFER IIS

The Fraunhofer Institute for Integrated Circuits IIS in Erlangen is a world-leading facility for applied research into microelectronic and IT system solutions and services. It is currently the largest institute in the Fraunhofer-Gesellschaft. Fraunhofer IIS has achieved global recognition by, among other things, playing a leading role in the development of the mp3 and MPEG AAC audio coding formats.

Cover page image

A glimpse inside the Earth with a 3D computed tomography image of a potato plant. To find out why we are using nondestructive monitoring technologies to analyze plants, read the section on recognizing and using high-yielding plants.

HIGHLIGHTS
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"INDIVIDUAL PRODUCTS ARE NO LONGER THE FOCUS."

Imagine your daily life without a smartphone. No emails, no quick online purchases. If that sounds difficult, you're not alone; most people probably feel the same. It is almost impossible to imagine our society without digitalization now, and the process is set to continue. Our editorial team spoke to the institute's directors, Professor Albert Heuberger and Dr. Bernhard Grill, to learn about the emerging digital trends and what we can contribute to them.

Professor Heuberger, before we talk about digitalization, we first want to ask you a personal question of sorts. You led the institute alone until November 2016, and you've now been joined by Dr. Bernhard Grill as a second director. Why is that?

Albert Heuberger: We had been planning to take this step for a long time. With over 900 employees, we are the largest institute in the Fraunhofer-Gesellschaft. At this size, it makes sense to share the responsibility for the institute across more than one set of shoulders. There are numerous decisions to make, and many have far-reaching consequences. I used to make the decisions in consultation with our management team, and it's good if I can do that jointly with a fellow director. In particular, an institute director has many duties that mean he or she has to be present in political circles, on the executive board, and on various committees. If we want Fraunhofer IIS to have the right kind of public image, we need more people at the top.

Our leadership tasks are clearly defined: Dr. Grill is responsible for the Audio and Media Technologies division, while I handle all the other divisions and oversee the administration. We jointly make the decisions that affect the institute as a whole.

What do you focus on when setting goals for an institute like Fraunhofer IIS?

Albert Heuberger: As a research institute, we continually have to reinvent ourselves, get to grips with fresh ideas, and tackle present and future challenges. Without question, one of the greatest changes happening in society at the moment is digitalization. We all know that digitalization is permeating every aspect of our lives. Take our private lives as an example: We listen to digital music on our smartphones; we capture memorable moments in digital snapshots; and we communicate with our colleagues, friends, and family via digital channels. Our information society is moving away from analog and toward digital.

"IF GERMAN COMPANIES MISS THE DIGITALIZATION BOAT, THEY CAN'T REMAIN COMPETITIVE."

This shift is also happening in industry – albeit at a much slower pace. In this context, we talk of "the digital transformation" or Industry 4.0. The idea is that production systems should become smart, be able to communicate with each other, thereby making manufacturing more efficient and more flexible.

Why is digitalization in industry not happening as fast as it is in our private lives?

Albert Heuberger: There are a variety of reasons for this. In most cases, the problem is that the economic benefit is not immediately obvious to the managers responsible. It is, therefore, entirely understandable that companies are initially reluctant to get on board. At the end of the day, no one wants to cut off a branch of their business that is running well or even flourishing. To put it another way, the

benefit of a new business model must first be understood and it must be shown that the numbers add up. Having said that, the clock is ticking – if German companies miss the digitalization boat, they can't remain competitive in the long term.

This is where we step in. In collaboration with our customers, we are advancing the development of the necessary basic technologies and producing new examples of applications. We cover the entire chain, from the basic technology to its application. We consider the technological questions on the one hand, and look at the economic aspects on the other. One area of our research within the Center for Applied Research on Supply Chain Services (SCS) focuses on which new business models are emerging as a result of digitalization and how businesses can make the transition successfully. The trend is moving toward system innovations – individual products are no longer the focus. So far, however, it is not yet clear which models will prevail. The interesting thing about revolutions is that they often happen in unexpected ways.

"DIGITALIZATION IN PRODUCTION TOGETHER WITH NEW SERVICES AND BUSINESS MODELS WILL CATCH ON JUST LIKE DRIVING A CAR ONCE DID."

Bernhard Grill: Digitization is still relatively new in the fields of home automation and production. I think this is similar to what happened with driving a car. In the early days, technology enthusiasts were the only ones interested in this novel mode of transport. It took some time before driving became universally accepted. Digitization is at a similarly early stage now. But I am confident that digitalization in manufacturing together with the new services and business models that go along with it will catch on in the same way that driving

a car once did. I also see a great deal of potential for digitalization in home automation – with smart homes, for instance. It just takes a bit of time before innovative ideas gain traction. Still, regardless of all the reservation there is toward the new, Germany needs to keep pace with these developments.

Dr. Grill, as one of the institute's directors, you are responsible for the Audio and Media Technologies division. Where are the main digitalization trends in this field? Where is this journey taking us?

Bernhard Grill: We laid our first digitalization milestone with the mp3 digital music format. Over time, "mp3" has become a generic term for all digital music – much like Kleenex and Band-Aid. We've now launched the fifth and sixth generations.

MPEG-H Audio brings 3D sound to television, and allows viewers to adjust their TV's audio mix. With EVS, we played a leading role in developing a new communication codec that significantly improves voice quality during cell phone conversations. Vodafone Germany is one of the operators already using EVS. Our division has always delivered the best technology in the field of audio coding – we haven't lost a technical comparison test in 25 years. That's our trademark. It has brought us to the front of the pack, and we will continue to make that grade.

Does digitalization play a role in any other areas?

Albert Heuberger: Aside from audio and media technologies, our research at Fraunhofer IIS focuses on sensors, data transfer technology, intelligent analysis of measured data, and producing conclusions in the form of business intelligence or process intelligence. In a very broad sense, you could group this work under the term "cognitive sensor technology".

Measured data are increasingly being analyzed using complex, machine-learning-based processes and then used in conclusions and findings. Over the past few years, adding cognitive abilities to our existing technology portfolio has become one of our core competencies. We currently have over 50 scientists working with these methods. We will intensify our efforts in this field even further in the future, and digitalization will play an important – or even the most important – role.

Where can these developments be usefully deployed? Which fields of application are really benefiting from them?

Albert Heuberger: Cognitive sensors are involved in many areas. For instance, they are used for checking and monitoring materials or components, for analyzing images or recognizing emotions, for evaluating measured data in manufacturing systems and in logistics, for energy networks, and for sensors in driverless cars – and much more besides. They expand the function of a conventional "smart" sensor to include a cognitive component.

Digitization allows us to tap into countless new fields and a wealth of potential. In our development work, we are doing our bit to exploit this potential for the benefit of the economy and our society.

Professor Heuberger, Dr. Grill, many thanks for talking to us.

www.iis.fraunhofer.de/digitization

CONTENT

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DETECTING HIGH-YIELD VARIETIES OF PLANTS

The consequences of climate change are extremely complex and they affect developing countries more than most. For instance, rising temperatures can make regions uninhabitable and cut people off from vital access to drinking water. Even richer countries cannot escape the impacts of climate change and are being forced to change their way of thinking – particularly when it comes to agriculture. Modern plant cultivars cannot adapt quickly enough to the effects of climate change, so farmers need to grow plants that have adapted especially well to the prevailing conditions. This is why we are focusing on nondestructive monitoring and plant analysis at the Development Center X-ray Technology EZRT.

Many plant varieties (such as potatoes, wheat, rice, and cassava) are struggling to cope with the world's shifting climatic conditions. In order to find appropriate ways of dealing with the changing circumstances, we are analyzing how different varieties of plants react to these environmental impacts. Phenotyping is one way of identifying plants that can, for instance, still produce sufficient yields at high temperatures.

Realistic environment for plant analysis

"Theoretically, you can assess plants simply visually in the field. However, this approach is subjective and therefore inaccurate. If a person gave hundreds of plants a school grade, one after the other, a trend would be visible, but the result will always vary. This is why we use nondestructive monitoring systems," says Oliver Scholz, who leads the Systems group at the

« Phenotyping
Phenotyping measures and quantifies plant properties using a variety of sensors.

AT A GLANCE

1 | Nondestructive monitoring systems allow different plants.

2 | Our systems can scan entire plants quickly and efficiently.

3 | A greenhouse and several environmental chamber help us simulate realistic environmental conditions.

1 Researchers at the Development Center X-ray Technology EZRT use a 3D CT system to analyze series of plants.

"THIS ALLOWS US TO DIRECTLY READ AND ACCURATELY ANALYZE THE LEAF'S SIZE, SURFACE AREA, INCLINE, AND CURVATURE."

2 *Environmental chamber for simulating different climatic conditions.*

Development Center X-ray Technology. To produce meaningful data, we are analyzing multiple series for dozens of plants. Our site in Fürth has a greenhouse for this purpose as well as several environmental chambers that can realistically simulate defined climatic conditions.

Identifying high-yield varieties

Plants consist of overground and underground organs. Important indicators of a plant's wellbeing and fertility are above ground. We can glean valuable information from their leaves (a plant's "solar panels") in particular. Optical monitoring technologies, such as 3D laser processes, are well suited for observing the leaves and their development.

"We are applying our 3D plant scanner essentially to take three-dimensional photographs of a plant. A laser projects a narrow line onto the surface of the leaf. As the line travels down the leaf, a camera records the displacement of the line. In just a few seconds, this produces millions of 3D coordinates that describe the surface of the leaf," says Scholz.

LASER LIGHT SHEET

A laser with a special widening lens projects a line of light onto the surface of an object. The light line follows the contours of the surface so that the shape of the curve corresponds to the profile of the surface. By analyzing the line's position as the object moves, the system can measure the entire surface and represent it as a 3D dataset. A complete 360 view can be produced by using multiple sheet-of-light sensors. Image processing algorithms can use this data as a basis for analysis of various plant features.

Since our work involves large test series of plants that we observe over a long period of time, this approach produces are large amount of 3D data. To help us compare data from the plants' individual leaves, we developed a special software program that uses a sophisticated process to calculate key parameters of a leaf and then provides us with those parameters in much smaller data packets. This enables us to directly read and accurately analyze the leaf's size, surface area, incline, and curvature. Biologists take these phenotypic data and link them with microbiological knowledge so that they can identify the biological mechanisms that allow a certain plant variety to flourish and produce sufficient yields even under extreme conditions.

Underground X-ray vision: 3D CT in minutes

The parts of a plant found underground, such as their root structures and infructescence, can also provide important information about aspects such as the plant's biomass. Optical monitoring technologies reach their limits here, which is why we are applying X-rays instead. X-ray imaging and microscopy have made enormous advances in recent decades. The technology can now easily examine even large test objects made of steel or other alloys. Tiny material defects, for instance in aluminum tire rims or cylinder head casings, show up clearly on today's systems and are easily classifiable. However, researchers who work with phenotyping face very different challenges. "Unlike with many industrial and laboratory applications, phenotyping is not first and foremost about razor-sharp image quality. Our limiting factor is the imaging time," says Dr. Stefan Gerth, head of the Innovative System Design group. "We have developed our own laboratory systems that aim to strike a balance between valid image data and much shorter measurement times," he says.

The measurement time is significant because we generally measure a whole series of plants. Longer measurement times are not economically feasible, and keeping a plant in the X-ray machine for a long time involves "ripping" it out of its familiar climatic environment, which can seriously affect the validity of the results. This is why our work at the Development Center X-ray Technology involves optimizing our X-ray systems so that they can fully scan a plant in roughly five to seven minutes. In addition to specially adapted hardware components, the software that we use also plays a key role. Due to the short imaging time, the source data contain noise and is therefore difficult to process. Intelligent algorithms largely compensate for this and can fully automatically separate the plant's organs from surrounding soil.

In the next processing step, the software automatically identifies the aspect ratio of the fruit and root structures, and the weight of the plant's organs. "To be able to make reliable statements, we observe the test series over several weeks and months. Using a diagram over time, we can work out at the end of the experiment how the plant developed in terms of underground growth," explains Joelle Claussen, who has so far measured thousands of

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plants at the Development Center X-ray Technology. "Although we achieve an exceptionally high success rate with our test series, we can never fully simulate real environmental impacts in a greenhouse environment. This is why biologists verify the research findings under real environmental conditions," says Claussen.

With the support of national and international partners from business and research, we are confident that our nondestructive monitoring systems can help deliver appropriate responses to the consequences of climate change. ∎

THE PRINCIPLE OF 3D COMPUTED TOMOGRAPHY

3D computed tomography (CT) produces multiple X-ray images (known as projections) from various directions. Unlike with medical CT scanners, an object to be scanned by an industrial CT system is often placed on a rotary table and positioned between the X-ray tube and the detector. The projections are recorded as the object rotates around its own axis.
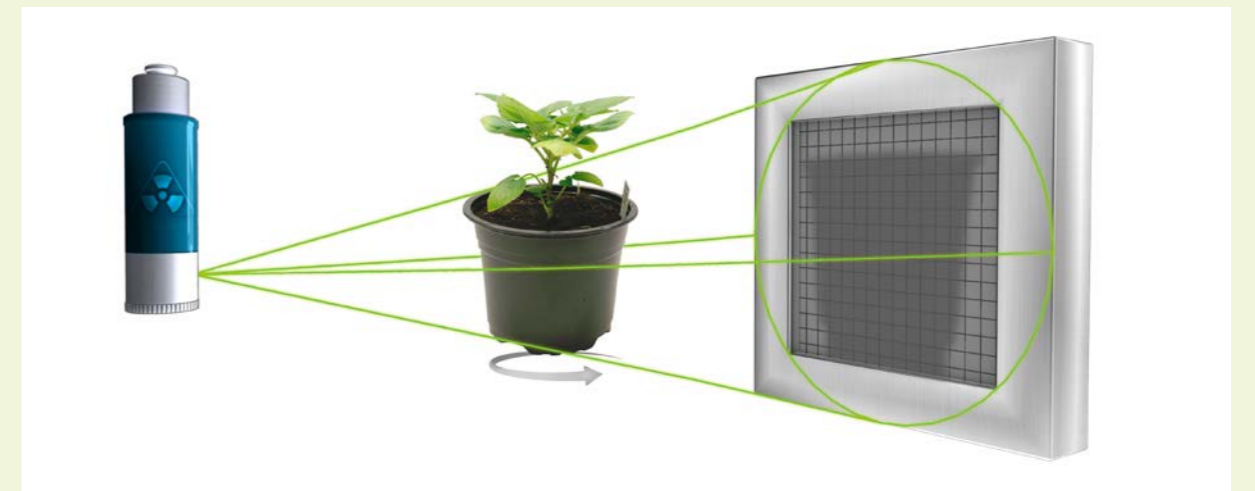
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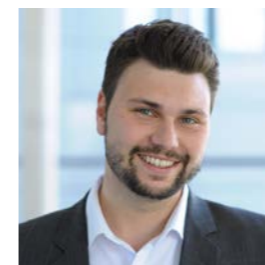
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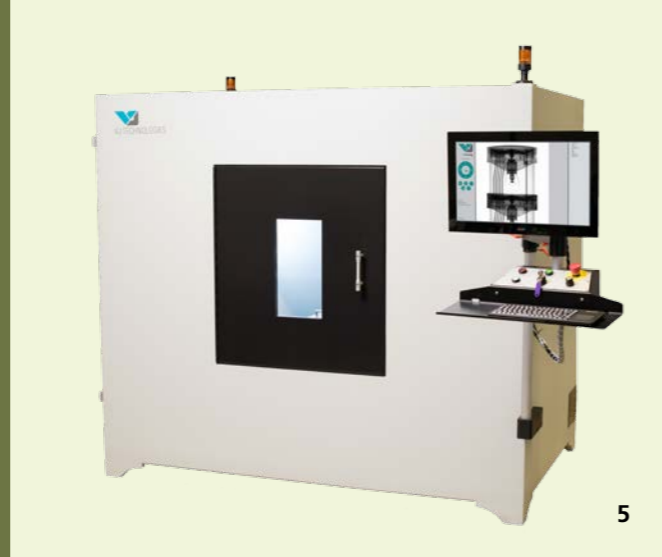
ValuCT LAUNCHED ON THE MARKET
Inexpensive X-ray system produces 2D or 3D X-ray images at the touch of a button.

In cooperation with our project partner VJ Technologies, we presented the new ValuCT X-ray system at the 2016 World Conference on Non-Destructive Testing. The inexpensive, one-click computed tomography system produces 2D or 3D X-ray images at the touch of a single button. Users can work the system without any prior knowledge, which reduces the costs of training and operations. They can adapt the system via a choice of pre-set programs without being overwhelmed by complex options. ValuCT thus produces images with parameters that are optimally tailored to the test object, and uses hundreds of individual images to reconstruct a 3D model. The system is suitable for all modern X-ray technology applications – from reverse engineering, to precise error localization, to metrology. In particular, small and medium-sized manufacturing enterprises will benefit from the new system. "We've put the system through extensive tests in our lab. We used opaque components made of carbon-fiber-reinforced polymer or aluminum as test samples – the kind of parts often found in automobile manufacturing. The test results and the data quality were of a high standard in every case," says Markus Eberhorn, head of the Advance Development group. To respond to different market needs, two versions of ValuCT are available: the basic model is primarily targeted at the Asian market, while the premium model with enhanced functionality is oriented toward the European and American markets. The company Erhardt + Abt Automatisierungstechnik is handling European sales for the premium model.
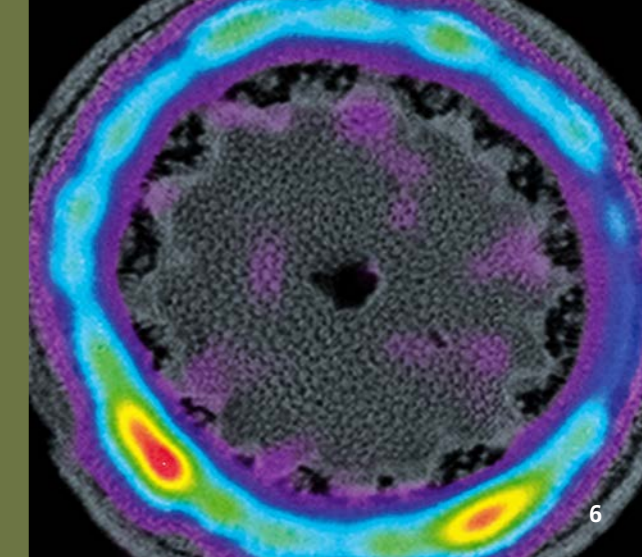
EFFICIENT RECYCLING WITH X-RAY TECHNOLOGY
New group investigates dual energy X-ray methods for sorting and recycling.

Sorting and identifying raw and other materials is becoming increasingly important. In particular, the field of recycling presents companies with problems for which the solutions are either inadequate or non-existent. At the Development Center X-ray Technology, we have therefore spent years researching processes that use X-rays to efficiently sort materials. To strengthen our research activities, the Sorting and Laboratory Systems group was set up in April 2016. In this group, which is led by Alexander Ennen, we mainly deal with dual-energy and multiple-energy X-ray imaging. These methods use different X-ray spectra and enable researchers to identify different materials in a test object without touching or destroying it. The process relies on the fact that different materials have different attenuation coefficients and thereby weaken X-rays to different degrees, depending on the energy used. This can yield significantly more knowledge for materials characterization and identification than conventional radioscopic and CT images can. Among other things, the technology has been used to make and run an industrial sorting conveyor.

MAGNETIC RESONANCE DELIVERS NEW KNOW-HOW
The Magnetic Resonance and X-ray department extends expertise at EZRT.

On January 1, 2016, the Research Center for Magnetic Resonance in Bavaria was integrated into the Fraunhofer Development Center for X-ray Technology EZRT. The ten-strong team led by head of department Dr. Karl-Heinz Hiller is now part of the Magnetic Resonance and X-ray department, which also includes the researchers from the Nano CT Systems group in Würzburg.

Having gained know-how in the field of magnetic resonance and magnetic particle imaging/spectroscopy, and through our close collaboration with the Fraunhofer Institute for Nondestructive Testing IZFP in Saarbrücken, we are now able to offer appropriate solutions to all questions regarding nondestructive monitoring – for every industry and at any stage in a product's lifecycle.

www.iis.fraunhofer.de/mrb-en

5 The system produces 2D or 3D X-ray images at the touch of a button, and users need no prior knowledge.

6 Sugar distribution in a plant as an example of spatially resolved spectroscopy.

A REVOLUTION IN TV SOUND

For the first time in decades, a revolution in TV sound is about to enter our homes. With the exception of the introduction of 5.1 surround sound, TV has previously offered little in the way of audio innovations. Now, sound on TV and the Internet is about to become individual and capable of filling whole rooms. With the new audio codec MPEG-H Audio, TV and Internet audiences will be able to adjust their own sound mix and bring 3D cinema sound to their own homes.

We've all experienced audio problems on the TV. You might be watching a whodunit, and as the detective starts questioning the suspect, suspense-filled music kicks in and muffles the dialogue. Or maybe it's a sports show and the commentator's voice drowns out the stadium atmosphere that we'd sometimes rather hear. Broadcasting companies around the world regularly have to deal with complaints about these and similar issues. Numerous specialists at the TV channels try to give audiences the most balanced sound mix possible. But audiences are so heterogeneous that a single mix cannot make everyone happy. What has been lacking up to now is a way of individually adjusting the sound.

Also lacking is the ability to bring the room-filling 3D sound of movie theaters into our homes. These days, it is very rare for a blockbuster movie to appear on the big screen without natural sound coming from every direction. To play back the immersive surround sound, movie theaters install speakers not only around the audience, but also in the ceiling so that the sound literally fills the room and emanates from all sides as it would in a natural setting. Acoustically, this puts audiences at the heart of the action and makes the movie experience

AT A GLANCE

1 | MPEG-H Audio allows TV viewers to adjust the audio mix themselves.

2 | MPEG-H Audio can efficiently deliver immersive 3D sound.

3 | MPEG-H Audio will be the first new audio system to be used in a terrestrial 4K TV system.

1 The new audio codec MPEG-H Audio will be used in TVs, smartphones, tablets, soundbars, and VR headsets.

1

"3D SOUNDSCAPES CAN ALSO UNFOLD IN YOUR OWN LIVING ROOM."

more immediate. However, this all stops when the same movies are shown on TV or the Internet, as there is still no way of efficiently bringing 3D sound to screens at home. Few of us would entertain the idea of installing a 3D speaker setup in the living room. You would need at least seven speakers for that – which puts a major obstacle in the way of mass adoption.

It is also hard to imagine the latest virtual reality worlds and devices without 3D sound. If 360° videos create the perfect alternative reality, the sound can't simply (as is currently the case) be delivered as stereo sound on the headphones. Users need 3D sound here, perfectly aligned with the wraparound video so that it makes the virtual reality seem natural and realistic. Similar to TV and streaming, one of the challenges here is to find an efficient way of delivering the immersive sound.

MPEG-H Audio: the next generation of audio coding

Audio and media technology experts have spent years developing technical solutions for these challenges. Our scientists played a major role in developing and standardizing the ISO/MPEG audio codec MPEG-H Audio. This descendant of the mp3 format was specifically developed to respond to the needs of broadcasters and streaming providers that want to offer their audience and customers a solution for the problems discussed above.

Customizable audio mix

In future, MPEG-H Audio will enable viewers to adjust the audio mix themselves. The degree to which this is possible will be decided by the TV station or the streaming provider. The possibilities are almost endless. For instance, the technology can let you turn up the dialogue so you can hear it better over the background noises and music. It can also let you choose between different commentators during sporting events, fill your living room with sound of soccer fans singing in the stadium as your favorite team plays, or listen in on the pit radio in your favorite driver's car during a race. And you will be able to do all this via your remote control.

MPEG-H Audio can also deliver 3D sound efficiently. It supports channels, objects, and ambisonics audio. Channels are the conventional method for delivering sound: two channels for stereo, six channels for surround sound, and ten channels for 3D sound. MPEG-H Audio can also transmit audio objects. Examples of objects are interactive elements or specific 3D sound components (such as a helicopter flying over the audience). Objects have advantages over channel delivery in that they can be manipulated individually and adapted to the specific playback situation. Before playing back the objects, the decoder and renderer recalculate the sound so that it fits the available speaker setup every time. This achieves a better 3D effect

than if the sound was delivered via channels alone. Lastly, MPEG-H Audio also supports ambisonics audio. Rather than delivering sound via channels or objects, this technique uses a mathematical description of the sound field recorded using a special microphone setup. Ambisonic recordings are popular among producers of virtual reality content because compact miking is enough to produce acceptable quality, and the sound can be easily played back through headphones.

3D sound at home

MPEG-H Audio thus makes it possible to deliver 3D sound flexibly and extremely efficiently, and at the kind of data rates that are largely standard for surround sound today. This means that 3D soundscapes are no longer confined to movie theaters, but can also unfold in your own living room.

Our audio team has presented a reference design for a 3D soundbar that, once placed below the television, allows users to play back room-filling sound. It removes the need to buy numerous speakers and install complex cabling – one of these soundbars is all you need to bring immersive sound into your own home.

MPEG-H Audio is not limited to use with TVs. The codec was designed so that the playback can be dynamically adjusted to the individual end device. You can play content on a smartphone, a tablet, a TV with built-in speakers, a soundbar, or a full-scale home cinema system, and MPEG-H Audio will optimize the sound quality for each playback situation.

MPEG-H Audio therefore does everything a modern audio codec should be capable of. It can be used immediately within closed systems provided by streaming services. Before it can be used with TV, however, the codec needs to be integrated into application standards such as ATSC or DVB. Our audio team was also active in this area and has ensured that MPEG-H Audio was integrated into the ATSC 3.0 standard and into the DVB standard. Now, whenever a country introduces new TV systems (e.g., for playing ultra-high-definition (UHD) 4K video), MPEG-H Audio will be available for delivering the audio.

UHDTV with MPEG-H Audio in South Korea

A current example of this is the new UHDTV system in South Korea that will use MPEG-H Audio for audio delivery. The system, which is based on the ATSC 3.0 standard, will initially be launched in Seoul and the surrounding region. The plan is to have expanded it to the sports venues in time for the Winter Olympics in 2018, and to have introduced it across South Korea by 2021. MPEG-H Audio is the first new-generation audio codec that will be

used in a terrestrial 4K system. As is so often the case, South Korea is at the forefront of this technological development.

South Korean companies are also among the first providers to have started developing and selling transmitters and receivers that support MPEG-H Audio. For instance, Kai Media, DS Broadcast, and Pixtree announced and launched the first TV encoders. Broadcasters need the encoders so that they can encode their programs prior to transmission and thus prepare them for transmission. A German company has also begun offering professional equipment: the MPEG-H Audio Monitoring and Authoring Unit by Jünger Audio from Berlin makes it possible to mix immersive, interactive sound (even during live events) and prepare it for broadcast. Finally, to coincide with the introduction of MPEG-H Audio, the South Korean market will see the launch of plug-ins and software tools that will enable tonmeisters and sound designers to mix MPEG-H Audio sound in their preferred working environment. On the receiver side, leading manufacturers of consumer electronics are launching TVs equipped with MPEG-H Audio. Everything is therefore in place for the introduction of interactive 3D sound in South Korea: the codec will provide immersive sound at low data rates, TV broadcasters have access to the equipment they need, and consumers can buy TVs that can play the new programming.

Initial tests in Germany

German TV broadcasters are also interested in the new possibilities presented by interactivity, 3D sound, and MPEG-H Audio. Our tonmeisters helped public-service broadcaster ZDF to record and mix 3D sound for the Wolfskinder (Wolf Children) episode of the documentary show Terra X. This unusual production tested out new technologies for recording and broadcasting sound and images. The show was shot in 4K resolution, and 360° videos were produced to run online in parallel to the broadcast. 3D sound is particularly important for the 360° videos.

It will doubtless take a few more years before a terrestrial 4K TV system is introduced in Germany. When it does arrive, MPEG-H Audio will be ready, because it is included in the DVB specification and can thus be used in all DVB-based systems. Of course, this does not only apply to Germany: countries all over the world will introduce ultra-high-definition TV in the future, and MPEG-H Audio will always be an option for achieving the perfect sound. ∎

2 *MPEG-H Audio allows users to adjust the audio mix themselves.*

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revolutiontvsound

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SOUND FOR VIRTUAL WORLDS
New VR devices that support Cingo® and solutions for producing 3D sound.

Two major manufacturers of consumer electronics – LG and Alcatel – added virtual reality (VR) equipment to their product ranges in 2016. The LG 360 VR headset and the Alcatel Vision both use Fraunhofer IIS Cingo® technology for playing back realistic 3D sound.

Cingo® enables users of VR devices to hear immersive 3D sound through their headphones. The playback even adapts to head movements. The right sound is crucial for creating the perfect illusion of a virtual world. If you are in a rainforest, you will hear birds rustling in the treetops, small branches snapping underfoot, and a gentle breeze blowing past. A 360° video of a rainforest on a VR headset will only be convincing if the system can achieve the correct playback of this 3D soundscape through the headphones.

But how does this sound reach the user's ears? When producing 360° videos, the sound recording has to happen more or less invisibly. We have developed a very compact microphone array on which individual microphones can be arranged in almost any pattern. A special algorithm that works similarly to the human ear can use the recordings to produce a good reconstruction of the recording situation. This technology was used in the Wolfskinder (Wolf Children) episode of the documentary series Terra X, which is produced by German public-service broadcaster ZDF.

When it comes to postproducing the scenes in the sound studio, the aim is to create realistic 3D sounds and to skillfully place or move audio objects in the virtual world. We offer Cingo® Composer for this task. It is a plug-in designed for the most common digital audio workstations and allows sound designers and composers to mix convincing 3D sound for virtual worlds directly in their working environment of choice. Crucially, users can immediately check their work by watching the 360° video at the same time as playing back the 3D sound on headphones.

New solutions are also needed for delivering 3D sounds, and we played a major role in developing the open MPEG-H Audio standard. Its efficient coding and its support for audio channels, audio objects, and ambisonics make MPEG-H Audio ideal for delivering 3D sound in VR applications. Thanks to these Fraunhofer technologies, realistic 360° sound will finally be available in VR applications.

www.fraunhofer-cingo.com

3 *Fraunhofer Cingo® delivers perfect 3D sound for virtual reality headsets.*
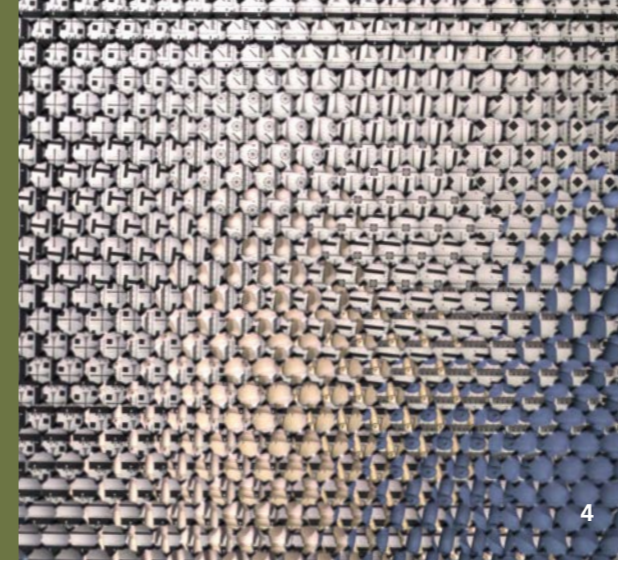
COMPOUND EYE USES LIGHT-FIELD TECHNOLOGY
With the project facetVision, Fraunhofer is developing ultra-thin cameras for industry and smartphones.

As part of facetVision, a project funded by the Fraunhofer Future Foundation, we are collaborating with the Fraunhofer Institute for Applied Optics and Precision Engineering IOF to develop a process for producing a camera just a few millimeters in height. Our inspiration for this comes from nature: much like an insect eye, the lens for the new camera consists of 135 tiny facets. The camera is just two millimeters thick and has the potential for a resolution of up to four megapixels. This is possible thanks to a combination of state-of-the-art sensor technology and algorithms from light-field technology. We use the slightly different perspectives of each individual lens facet to generate a high-resolution overall image and glean information about the depth of the scene in question. We have achieved this with an innovative algorithm that can assemble the partial images to form an overall image while compensating for parallax (optical displacement). The technology can pave the way for novel applications in the automotive industry and for medical technology. The basic principle is also suitable for making ultra-thin smartphone cameras. With multiple small lenses, the cameras will require considerably less installation space. The impractical "camera bulges" on smartphones (caused by the sensor and lens) will soon be confined to the past.

4 *Multisensor views, the basis for further processing using light-field technology.*

CHECK – AUTOMATICALLY TRANSCODE – CHECK
Quality check for IMF exchange format saves transcoding time in media production.

IMF stands for Interoperable Master Format. It is a new universal format for exchanging files in professional media production settings. Since it was released as a standard by the Society of Motion Picture and Television Engineers (SMPTE), it has become a popular exchange format in film production. It takes account of many challenges presented by today's distribution channels – such as producing different language versions. We are pooling our expertise with the Fraunhofer Institute for Digital Media Technology IDMT to develop software components that can run automatic quality checks and be optimally integrated into IMF workflows. The software checks the material for errors and artifacts that can occur during, for instance, compression or color space conversion. Given the ever-increasing volume of distribution formats, these are key developments for saving time and money in production. Our joint approach was to integrate quality assurance modules into the transcoding processes. At the IBC in 2016, we presented a version that can already check the production of IMF packages (IMPs). The function is integrated into the overall system of our easyDCP software. In future, it will be possible to run checks when producing distribution formats from IMPs, and to use advanced test settings.

www.iis.fraunhofer.de/easydcp

5 *Critical sections during the creation of an IMF package.*
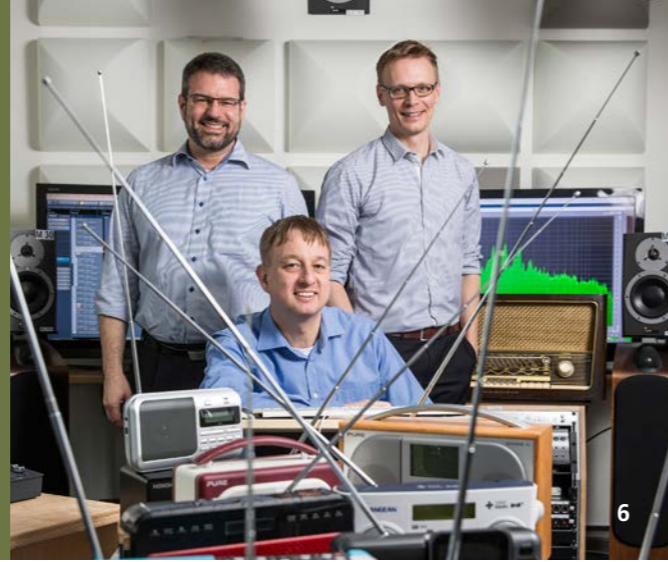
OUTSTANDING DIGITAL RADIO TECHNOLOGIES

Joseph von Fraunhofer Prize goes to Fraunhofer IIS for digital radio in Germany, Europe, and the world.

The last remaining blind spot in digital media is soon to disappear. Analog radio has held out for a long time, but thanks to better quality, more choice, and innovative extras, digital radio is on the up worldwide. In most European countries, digital radio is already part of everyday life. Many newly industrialized countries are currently planning to switch from analog short-wave and medium-wave radio to digital radio, and efforts to digitize local FM broadcasting are underway. India is one of the forerunners here and is on its way to becoming the biggest digital radio market in the world. The two open and complementary standards Digital Audio Broadcasting (DAB/DAB+) and Digital Radio Mondiale (DRM) play a key role in digitizing radio services.

In recognition of their work on developing the basic principles of digital radio and for developing them to the point of market penetration, Alexander Zink, Martin Speitel, and Max Neuendorf were awarded the 2016 Joseph von Fraunhofer Prize on behalf of the entire developer team. The jury were impressed by "the steady advancement of fundamental technology and the establishment of standards in this area."

Our technologies and developments play a significant role in the growing success of digital radio. We have designed technologies and components along the entire digital radio broadcast chain. These include new audio coding formats, server solutions for encoding and producing digital radio broadcast signals, and software components for playback devices. The audio codecs xHE-AAC and HE-AAC, both part of MPEG's standards, process data intelligently so that their amount is drastically reduced but the quality remains the same. Additional services, such as the Journaline data service, allow users to read text content such as the news, weather, and traffic information on their radio's display.

Digital radio also offers benefits for broadcasting companies. By transmitting programs more efficiently, it reduces the amount of energy and therefore money needed for broadcasting, and allows broadcasters to offer more programs.

🌐 www.iis.fraunhofer.de/digitalradio-en

6 *The 2016 Joseph von Fraunhofer Prize: (from left) Alexander Zink, Martin Speitel, and Max Neuendorf of Fraunhofer IIS.*

7 *Like talking face to face: EVS improves voice quality.*

EVS GOES GLOBAL

Full HD Voice quality available on cell phone calls in USA, Japan, South Korea, and Germany.

Once the fourth-generation mobile communications system was introduced, the technology quickly gained acceptance because it offered significantly higher transmission power, and IP-based infrastructure. While this initially only applied to data transfer, voice services are now increasingly switching over to the system – and are known as "Voice over LTE" services. The Enhanced Voice Services codec (EVS) was developed so that these services could deliver comparable voice quality to "over-the-top" services such as Skype. We played a major role in developing EVS, and the results of the work were presented as a new 3GPP standard in late 2014. The first smartphones with integrated EVS were launched in 2016, and users in USA, Japan, South Korea, and Germany have been able to enjoy the new EVS quality on selected cell phone networks since the end of 2016. As the first 3GPP voice codec, EVS can deliver the full audio spectrum (up to 20 kHz) perceptible to humans. This makes EVS the first Full-HD-Voice-capable audio codec for use in mobile telephony. Cell phone users will benefit from a unique audio and voice experience that is comparable to today's media services (e.g., streaming music and films) in terms of quality. In addition, EVS is significantly more resistant to failure, which not only ensures better sound quality, but also increases the performance of the mobile communications infrastructure.

🌐 www.full-hd-voice.com

NEW ROLE

Siegfried Foessel named SMPTE governor.

Dr. Siegfried Foessel, head of the Department of Moving Picture Technologies, has been elected to serve a two-year term as governor for the international section of the Society of Motion Picture and Television Engineers (SMPTE).

The international section includes Europe (minus the UK), Africa, and South and Central America. The SMPTE is a global network of industrial companies and individuals active in the media and entertainment sector. It provides professional development opportunities in the form of conferences, workshops, and online seminars.

One important aspect of its work involves standardizing technologies and infrastructures within the ever-changing movie, TV, and media industry. In coordination with other standardization bodies, such as the International Organization for Standardization (ISO), it focuses on specific applications in the media sector.

Each of the ten regional SMPTE governors is responsible for an area that contains at least 500 members. In addition to representing specific interests on the overarching SMPTE board, Foessel is also part of the SMPTE conference program committee, a member of the standardization group, and is involved in discussions about SMPTE's strategic direction.

8 *New SMPTE governor: Dr. Siegfried Foessel.*

SATELLITE COMMUNICATION OF THE FUTURE

Space is teeming with satellites. They allow us to receive TV shows, give us Internet access on planes and ships, and keep communications going during disasters. We are working on a range of developments that will make this kind of communication more efficient, more flexible, and more stable in the future.

After spending hours in an airplane, things can become a little dull, especially when darkness falls and you lose interest in looking out of the window. At this stage, watching Hollywood movies and surfing the Internet can help pass the time. Satellites make this possible. A ground station sends data (e.g., a film) to a satellite, which receives the data, amplifies them, and sends them back down to Earth. The data can then be picked up by a receiver – on an airplane, aboard a cruise ship, or via a ground station.

More efficient and affordable: a new standard for satellite communication

Normally, the DVB-S2 standard is used for transmitting data – and not just for the satellite TV you watch at home, but also for the satellite Internet available in aircraft. The standard was developed in the early 2000s and is now set to move up to the next level as DVB-S2X, which will primarily bring improvements in terms of efficiency and costs. With satellite communication increasing all the time, there is a desire to transfer data faster and more efficiently. We were, and still are, heavily involved in developing this improved standard and in bringing it "to the streets."

AT A GLANCE

1 | The new DVB-S2X standard will take satellite communication to the next level, making it faster, more flexible, and more efficient.

2 | With the Fraunhofer On-Board Processor (FOBP), satellites can be reprogrammed and adapted for different types of use.

3 | New terminals enable satellite communication from moving vehicles, which is especially helpful during disasters.

1 *Recording a constellation diagram in the antenna measurement hall.*
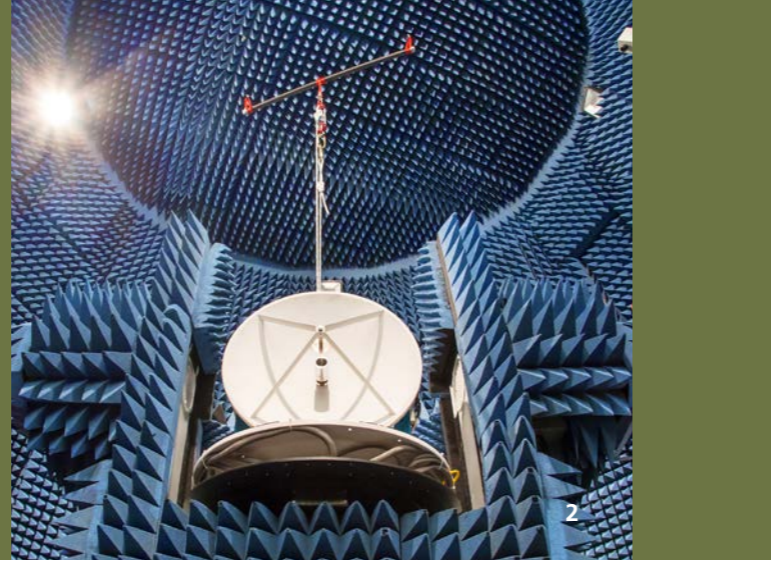
2

"WE'VE MADE SATELLITE COMMUNICATION FIT FOR MOBILE USE."

Compared to its predecessors, the DVB-S2X standard is much more powerful, and offers improved flexibility and spectral efficiency. This means that each and every bit transmitted in this way costs less than it did before. The aim is an ambitious one: the new standard is intended to be 20 to 30 percent more efficient on average than its predecessor, and this should rise to as much as 50 percent for some applications. The new standard also makes communication less prone to error, and so paves the way for new applications. "With DVB-S2X, we can improve the flexibility and utilization of the satellites. This has an impact on reception at sea and in the air, and on reception via small satellite antennas," says Rainer Wansch, head of RF and SatCom Systems department.

Numerous optimizations make this possible. One example concerns the receivers and transmitters on the ground. At the moment, they use many small transponders that can each transmit up to 36 megahertz (MHz). The problem is that not every signal uses the full 36 MHz. For example, if one user only needs 15 MHz, it will still block the entire transponder. Another user will not be able to get a signal through in case it would exceed the 36 MHz. "That's why the new standard uses a wide transponder with a bandwidth of roughly 400 to 500 megahertz. This makes it possible to divide the data streams more efficiently," says Wansch. In other words, users receive the exact amount of transmission capacity that they need in each case. As a result, the full bandwidth of a satellite channel can be used efficiently and signal distortions decrease.

The new standard offers numerous applications and configurations, and this makes it hard to implement. With that in mind, we have developed a special receiver and a testbed that allows us to simulate the complete wideband transmission chain for DVB-S2X, and to test devices thoroughly. The testbed covers every aspect – from wideband transmission, to signal modulation, to receiver signal processing. "Our testbed offers customers enormous added value. It allows us to simulate real transmission situations and conditions. That means we can test and optimize the entire transmission chain from transmitter to receiver under actual operating conditions," says Wansch.

A new processor for the satellites

Aside from the transmission standard, the satellites themselves also have room for improvement when it comes to efficiency. The current models are highly configured, which means that they can perform the tasks for which they were built – for 15 years if possible. Still, over such a long period of time, there is a good chance that something will change, or even be revolutionized.

Today's satellites, however, can only respond to changes within certain limits; they are relatively "stupid." They receive the signals, amplify them, and send them back. This is perfectly adequate for many applications, such as radio broadcasting. With other applications, satellite operators want more flexibility. After all, it is almost impossible to know today what demands a satellite will have to fulfil in 15 years' time. And with new services, we can only roughly estimate what the utilization situation will be. In short, only a few satellites continue doing the job that they were designed for. At the moment, repurposing satellites is an extremely complex task – if it is even possible at all.

We now want to make satellites significantly more flexible, and are aiming to achieve this with the Fraunhofer On-Board Processor (FOBP), which we are developing in our laboratories. "You can usually only program the satellite-integrated processors once, and then they're fixed for a single application. Our on-board processor, however, can be reprogrammed as many times as you like. It's also very straightforward – you can do it from down on the ground," says Wansch. In future, therefore, it will be easy to tailor satellites equipped with this type of flexible on-board processer (OBP) to other applications. The main achievement here lay in developing the necessary programs and the firmware and software architecture, and in making them usable in the harsh conditions encountered in space.

The signal that a satellite transmits using the OBP is much clearer than current signals. This is because conventional satellites also amplify the noise that occurs during signal transmission. The OBP, by contrast, does not simply amplify the signals it receives, but instead interprets them and then produces them again. The noise is therefore not amplified, and the satellite transmits only useful information. In Low Earth Orbit (LEO), for instance, the OBP is a key element in mega-constellations, as it can act as intermediary between the satellites. This is useful because although two-thirds of low-flying satellites are located above the sea, as the Earth is, after all, roughly two-thirds ocean. But these satellites do not have all that much to do because few signals are sent into space from the sea. Therefore, the processors in these satellites have the majority of their capacity free. Using the OBP and inter-satellite connections, the satellites could send "work" between each other and share the processing load. The users would not notice anything; there are no disadvantages to doing this. For satellite operators, however, this kind of collaboration offers enormous advantages. They would need fewer ground stations, which in turn would save them money. The FOBP is scheduled for completion at the end of 2017, when we will deliver it to the satellite manufacturer. The plan is for it to take off with the DLR Space Administration's Heinrich Hertz mission in 2021.

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Satellite communication even on a bumpy ride

Having an Internet connection on a plane or on board a ship is undoubtedly useful. A more fundamental role for satellite communication, however, concerns extreme events like tsunamis and earthquakes. Telephone lines and cellular networks are often no use to rescue teams after these kinds of natural disasters, as the lines are generally dead. Communication via satellite is therefore the only option left. However, this is also not without problems. If the links are overloaded, the connection fails – and this can happen even during a simple storm. It also takes time for the rescue teams to set up the necessary small satellite stations in among all the destruction. Another shortcoming is that the receiver must not make any fast movements. Instead, the satellite antenna has to be pointing directly at the satellite (as is the case with TVs). While the steady movement of aircraft and cruise ships means the links work well in those contexts, someone driving a car down a dirt road has almost no chance. Drivers have to stop if they need a connection.

Rescue teams should be able to communicate more easily in future thanks to the KASYMO-SA project (Ka-band systems for mobile satellite communications) in which we together with a number of other partners developed an innovative communications system. Among those involved were Technische Universität Ilmenau, Industrieanlagen-Betriebsgesellschaft mbH Ottobrunn IABG, and the German Aerospace Center (DLR). "We've basically made satellite communication fit for mobile use," says project manager Florian Raschke. "Our development eradicates the main disadvantage of satellite communication. The connection is also much more reliable: the bandwidth during transmission is so big that the connection won't even cut out if it's overloaded. We've also removed the inconvenient and time-consuming task of setting up a transmitting station."

Let's start by taking a look at the moving systems, and at how we overcame this shortcoming in satellite communication: When a car drives over potholes and around bends in the road, the antenna corrects its position in a fraction of a second. This happens with a high level of precision, as the antenna only ever moves 0.2 degrees out of the satellite's focus. To put this in perspective, the car's antenna would move more than that if a person got into the car. We achieved this using a special mechanical system and, above all, with algorithms that allow us to adjust the antenna precisely and quickly. The antenna itself is also the product of much development work. With diameters of 60 centimeters, conventional satellite dishes are too big to install on the roof of a car. This is why we use a flat satellite antenna, known as a panel antenna. Although panel antennas are already available on the market (they are installed in aircraft, for example), these models cannot withstand being driven over bumpy roads. "So our partners at Technische Universität Ilmenau developed their own flat antenna that meets the requirements very well," says Raschke.

Another improvement lies in the reliability of the connections. We have modified the data processing so that the data rate changes according to the situation. So if the line is overloaded, the conversation doesn't cut out entirely, as was previously the case. All that happens is the transmission quality decreases – in the same way as happens with Internet connections. We achieved this with a special modem developed as part of the project that transmits the data. "It enables us to reach very high data rates of several megabits per second," says Raschke. "Of course, this is nowhere near the gigabit streams of a fixed data line, but it is a major step forward for satellite communications." This means rescue teams will be able to send maps, and videos of the situation on the ground, secure in the knowledge that the connection will not cut out. They will also be able to make clear satellite calls without any interruptions and without being disconnected.

Rescue teams will also no longer have to set up transmitting stations. "With our system, every terminal – which comprises an antenna and a modem installed in the car – can transmit directly to the satellite. This means, for instance, that the systems in two separate cars can communicate directly with one another without having to first send their data to a central hub." Not only does this make it easier to communicate, but it also increases data security. Consequently, as well as being suitable for use on water and in the air, satellite communication will soon also be available while driving down bumpy roads. ∎
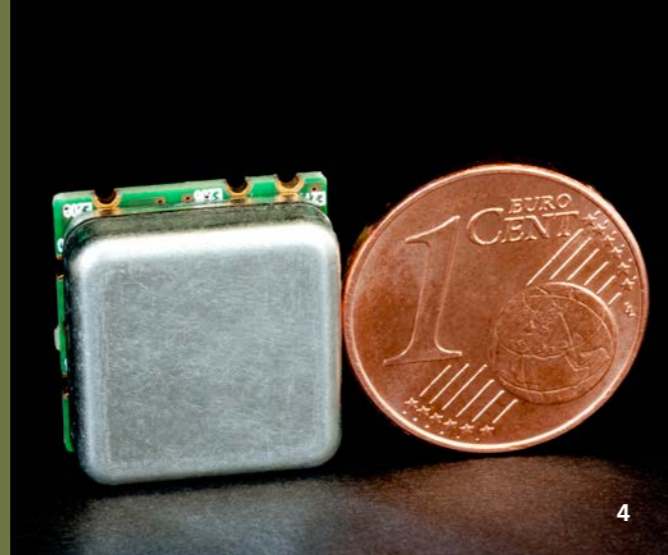
3 *A wideband satellite.*

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satellitecommunication

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READY FOR FUTURE COMMUNICATIONS STANDARDS

A digitally tunable bandpass filter makes receivers and transmitters more flexible.

The growing heavy use of the available radio spectrum presents major challenges for the communications industry. Wireless communication systems must increasingly be capable of flawlessly recognizing and separating signals. It is also important that they can be adjusted to new communications standards. Digitally tunable bandpass filters are one solution to this and ensure that devices using multiple communications standards can keep pace with the constantly evolving technologies.

With our high-frequency bandpass filter, we have developed a prototype that can meet these requirements. It is suitable for replacing conventional filter banks in high-frequency receivers. The filter module is digitally tunable, which means it is not fixed to one wireless technology. It can move through the entire frequency spectrum and thus does the work of several fixed frequency filters. This saves space and reduces costs. It can also be tuned to new wireless standards, which means it will remain usable in the future.

The filter module reliably selects the required frequency spectrum while suppressing signals outside the chosen band. It can be reconfigured while it is operating so that transmitters and receivers can be adapted to new communications standards and to country-specific or application-specific frequency bands.

This flexibility is beneficial for all systems that use multiple wireless technologies or that will undergo changes in the future. Fields of application include communication in cars, mobile communications, Industry 4.0, and the Internet of Things.

The prototype comes ready-to-solder, and is easy to integrate. We permit customers to adapt and develop the filter, and we also offer tailored licensing models.

www.iis.fraunhofer.de/bandpassfilters

GUIDED SAFELY FROM DOOR TO DOOR

Project NADINE wins CNA special prize.

Drivers often use a satnav device in the car, particularly for unfamiliar routes, so that they can quickly and easily reach their destination or find specific places such as the next gas station or the nearest restaurant without making any detours. People are also increasingly using navigation services on their smartphone to guide them to their desired destination when they are out and about on foot. Expanding these capabilities and guiding pedestrians easily through public transit networks using all forms of transportation was the aim of the NADINE project (the acronym comes from the German name, which translates as "navigation in public transit systems with modular service architecture for integration into external applications").

The Center for Transportation & Logistics Neuer Adler e.V. (CNA) awarded the NADINE project consortium its special prize for intelligence in transportation and logistics, in recognition of outstanding scientific achievements in the field of public transit. Our awiloc® technology makes positioning possible both inside and outside, and thus delivers uninterrupted navigation services. awiloc® uses existing wireless networks such as WLAN and BLE (Bluetooth® Low Energy). Instead of needing a specific signal network, it uses the characteristic signal strength distribution of the available wireless networks. A major advantage is that mobile devices can use awiloc® technology to determine their position themselves. As a result, the position is usable on the device without any connection to central computers. awiloc® optimally complements existing positioning technologies, such as GPS, for urban environments and in buildings. Mobile applications for guiding people safely from door to door, and location-based services will become quick and easy to implement, even from inside buildings.

www.iis.fraunhofer.de/nadine-en

4 *One of the advantages of the digitally tunable filter is its size. The prototype is roughly the size of a 1 cent coin.*

5 *Dorothee Bär, parliamentary state secretary at the German Federal Ministry of Transport and Digital Infrastructure, presents the CNA special prize for innovations in the field of transportation and logistics to Dr. Günter Rohmer (2nd from right) of Fraunhofer IIS, who accepted the award on behalf of the partners in the NADINE project consortium.*

1

SMART DATA: THE FUTURE OF LOGISTICS

The Internet and containers are two obvious innovations that have revolutionized logistics over the past decades. They linked up the world, created new and bigger markets, and ultimately drove enormous growth in global trade. Thanks to them, the world has become smaller. They also expanded economic opportunities – although only for businesses that recognized the potential of these innovations early on and mastered the full repertoire of possibilities presented by this new age. This is why it is so important to know today what the state of the art will be tomorrow. To do that, however, we have to know what innovations are on the horizon.

So how will logistics develop from here? What technologies in manufacturing and transport will simplify processes? And how have businesses organized themselves to respond to the needs of their customers? Anyone who wants to answer these questions must know the trends that will define the market in the future. At the Fraunhofer Center for Applied Research on Supply Chain Services (SCS), we have spent more than 20 years observing developments in logistics. We recently produced an internal study that identified eight megatrends with the potential to fundamentally change the way supply chains will work over the coming years.

The eight megatrends in logistics

One trend is 3D printing, with its individual and often even personalized products with a batch size of one, and fundamentally different supply structures. Then there is autonomous

AT A GLANCE

1 | We have identified eight megatrends that could radically change logistics. Digitization and servitization are our main focus.

2 | Increasing digitalization is creating new business models for companies.

3 | Compared to physical products and pure services, data will gain more in importance.

1 *Smart transportation processes in the L.I.N.K. Test and Application Center in Nürnberg.*

"DATA WILL GAIN IMPORTANCE IN THE FUTURE – INCLUDING IN LOGISTICS."

driving, for instance on existing test tracks such as the A9 highway between Munich and Nürnberg. Robotics promises ever-smarter helpers for areas such as warehousing and production. The information society concerns rapid growth in global knowledge and an exponential increase in global data volumes. Diversification is about workforces becoming increasingly heterogeneous. Sustainability is in growing demand, including from customers, and the trend toward digitalization and servitization impacts the entire value chain.

All of these trends can pave the way for disruptive innovations or even become one themselves. The next few years will show us when exactly this will happen and what it will mean for logistics. At the moment, we are paying special attention to two trends in particular: increasing digitalization and the growing focus on service in everyday life and business. These trends affect the entire value chain, are not limited to any specific sector, and therefore possess the necessary force for disruptive innovations.

Focus on two megatrends: digitalization and servitization

Servitization ››

Servitization refers to the strategic shift that sees a company adopt a consistently customer-focused and solution-oriented approach. Its aim is to provide the best possible support for the customer's value-creation processes. It replaces the straightforward selling of products and services with close collaboration and knowledge sharing.

The effects of digitalization and servitization on logistics and supply chain management are already visible and will only increase in the future. If new technologies, mobile computers, and the Internet of Things keep making objects smarter and more intelligent, there will be scope for developing new data-driven services around these smart objects in order to make products and processes more efficient. This transformation is also linked to fundamental changes in customer contact, in business models, and in collaborations between businesses. In addition, Germany is transforming from an industrial society into a service society. Customers no longer buy the product on its own – they also buy the associated services. These "hybrid products" allow businesses to increase their sales opportunities and boost customer loyalty.

How digitalization and servitization are changing intralogistics

In the field of intralogistics, transport processes and in particular tugger trains are playing an increasingly important role in making processes lean. A tugger train comprises a tow tractor and several trailers. It generally drives a predefined route and stops at certain points along the way. Material is offloaded at each stop, and more material is usually loaded on.

To ensure that tugger train systems continue operating efficiently once they have been introduced, and that they can adapt to what are sometimes subtle changes in their environment, operators need to record relevant key figures. With this in mind, we developed IKE, which is a system that can intelligently determine key figures and record detailed information about tugger train processes in a production or warehouse setting. A sensor box installed on the

tow tractor records positioning data, driving and stationary times, and the load situation. These basic data make it possible to analyze the routes taken and the utilization of the tugger train, which means that weak spots in the processes can be reliably identified. This knowledge can then help to make transport in production and warehouse settings faster and more efficient.

The key to digitalization: using data properly

Data use, however, is currently often limited to a very narrow field. Although most companies already have large volumes of data available, it is often contained in numerous "data silos," i.e., in insular, non-networked data spaces that are only used for a clearly defined subject and task field, such as improving transport processes in the warehouse. Other business areas and even other businesses tend to have either limited or no access to this information; shared use does not occur.

Yet this is the key to actually exploiting the continual march of digitalization in manufacturing and its associated processes sustainably. Only by using and combining all relevant and existing data across businesses and functions is it possible to generate the necessary added value that justifies what is often an extensive investment in new technological solutions.

From process to new business model

The task is therefore to collect information, connect it in different ways, and use it to create added value. For the tugger train processes described above, for instance, this means that the data and information would no longer only be used to improve the organization of internal transport processes. They would also create new business for manufacturers of industrial trucks. For instance, the information could be used to develop more appropriate billing systems. Instead of buying a whole industrial truck, customers would then lease it and pay according to operating times or the distance travelled.

This type of approach would benefit both sides. Customers could reduce the size of their fleets and with it the amount of capital they have tied up. Manufacturers could increase the utilization rate of their fleets because they could flexibly lease and bill for vehicles according to requirements.

Manufacturing companies could also make additional use of the movement profiles of their industrial trucks. One example would involve linking the profiles to other information collected by sensors on, for example material stock and consumption, and using it to calculate reorder points. The information would be forwarded to the relevant offices inside and

2

outside the company. As well as triggering repeat orders to suppliers from the company's procurement department, this would also allow logistics service providers to efficiently plan full capacity utilization of their transportation systems in advance. This would create the foundations for sustainable logistics.

The future is smart

The increasing availability of internal and external data has enormous potential for the services of the future. The data can allow businesses to predict future customer needs, for instance when patterns in a machine's usage data indicate that an outage is imminent, or when weather and traffic data suggest that a delivery might be late.

The ongoing optimization of the relevant basic technology also plays its part. In future, for instance, RFID tags will no longer only be used for simply identifying objects. Additional functions such as sensor technology and positioning systems will enter many different fields of application, including warehouse and container management. Multisensor labels will monitor aspects such as temperature, pressure, and moisture. They will reduce search times and help with inventories. This will also create new and additional potential for technology suppliers and users.

Data drive the megatrends

Data are the main drivers of all eight megatrends. The more networked, mobile, smart, automated, and therefore digital our world becomes, the more important these new raw materials will be. The term "raw materials" is fitting, as data alone are nowhere near capable of creating value for companies. It is not just a question of collecting data – they also have to be analyzed, interpreted, and potentially optimized before they can be used. Once that has happened, though, they open up entirely new worlds of application – with all the consequences for businesses, which have to learn how to handle new customer groups, payment models, technological infrastructures, cost structures, and collaborations.

Success and added value from data – including in logistics

Working with data like this is our core work at the Center for Applied Research on Supply Chain Services (SCS). We therefore know that, compared to physical products and pure services, data will gain more significance in the future – including and primarily in logistics which, as the "gateway to customers" in sales and production processes, is increasingly being confronted with the subject. On the one hand, this comes from shipping agents who expect better networking and communication, and more transparency for more agile processes. On

the other hand, it comes from the industry itself, which is virtually obliged to profit from the digital transition so that it can master the future rather than be mastered by the future.

In the near future, the logistics industry will need to deploy data in their processes, service offerings, and business models in a way that adds value. Even if we cannot tell from this distance which trends will change logistics and at what intensity, one thing is sure: digitalization and the increasing focus on service in business and everyday life are advancing. Collecting, analyzing, optimizing, and exploiting data as key economic factors will therefore become essential in the future. ■

2 *The future of logistics and supply chain management: the eight megatrends.*

www.iis.fraunhofer.de/
smartdata

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THE INTELLIGENT INTERACTIVE TOOTHBRUSH
Fraunhofer IIS and Procter & Gamble develop smart cleaning system for personalized dental care.

Proper dental care and the resulting benefits for oral hygiene do not depend on the toothbrush alone – a much more important factor for healthy teeth is "correct", uniform cleaning of all areas. In order to provide the best support possible, Procter & Gamble worked with us to develop a new generation of smart interactive toothbrushes. The ORAL-B GENIUS tracks cleaning behavior and guides users with information provided via a smartphone app. It works like this: the toothbrush connects to the app via Bluetooth. The smartphone is mounted on the mirror, and as soon as brushing begins, evaluation kicks in. The integrated Fraunhofer-SHORE™ facial recognition and analysis technology enables head movements and hand position to be detected and analyzed in real time, immediately telling users if they are spending too little or too much time on a particular spot, or if they have left anywhere out. Image-based classification accurately tracks the position of the toothbrush, even in poor lighting conditions.

To further improve robustness and precision, additional sensors are built into the handle of the smart toothbrush. Data from these sensors are fed into our smart analysis software to evaluate position and movement. By fusing data from image and inertial sensors, the system is able to more accurately determine whether each area of the mouth has been cleaned thoroughly, for long enough, or not at all, displaying the result directly on the smartphone. We were able to successfully overcome the challenge of reliably classifying each area in spite of the relatively low volume of measurement data.

The cooperation with Procter & Gamble, in place since 2013, is devoted to novel solutions for software-based assistance systems aimed at providing user-oriented added benefits in the field of dental hygiene.

www.iis.fraunhofer.de/smartbrush-en

3 *ORAL-B GENIUS with Fraunhofer Shore™ technology and positioning technology.*

4 *The digital village project aims to harness the potential of digitalization in rural areas.*

5 *The CWS Washroom Information Service enables more efficient planning of cleaning requirements and cycles.*

DIGITAL VILLAGES
"Digitales Dorf" project prepares rural areas for the future.

Increasing urbanization, in conjunction with demographic change, is taking a massive toll on rural areas. Ultimately, these developments restrict the viability of services in the public and private sector, and technological and social infrastructure, causing them to slowly die out. However, digitalization offers new ways to combat these challenges. Accordingly, the Bavarian Ministry of Economic Affairs and Media, Energy and Technology has tasked us, in conjunction with the Fraunhofer Institute for Experimental Software Engineering IESE in Kaiserslautern and the Deggendorf Institute of Technology, to harness this potential and put it to the test in two model villages in North and South Bavaria.

The project aims to network key spheres of life in rural areas and the results are expected to be applicable nationwide.

The model villages were chosen in a competition open to all Bavarian municipalities in "regions with a particular need for action". The selection was announced in December. The winner for North Bavaria is the Steinwald Alliance in the Oberpfalz district, while in South Bavaria Spiegelau-Frauenau was chosen. As project partner in North Bavaria, we will begin implementation of the project idea in the Steinwald Alliance from March 2017 along with the Fraunhofer IESE. Implementation of the project's key components is scheduled to continue until mid-2018.

www.edorf.bayern

WASHROOM HYGIENE 4.0
Wireless sensor networks to monitor the washroom of the future.

Digital technology could make empty towel and soap dispensers in the washrooms of office buildings or airports a thing of the past. In collaboration with full service provider CWS-boco, we are developing a solution to simplify washroom management and maintenance. The three-tier communication chain that underpins the solution was created by our Application Center for Wireless Sensor Systems in Coburg. Dispenser fill levels are automatically measured using special sensors developed by the Fraunhofer IIS, and the results are transmitted wirelessly to a local "Washroom Control Unit". The individual washrooms in a building are connected via a self-configuring multi-hop wireless network. The gateway at the edge of the building relays all of the data to a central server and is accessible to cleaning personnel and the washroom operating company.

The system is straightforward to install, and has the capacity to react independently to circumstances in the building. In the event of failure or malfunction of the connection to a particular washroom, monitoring of the remaining dispensers is assured by our s-net© Technology, which automatically compensates for wireless connection problems and guarantees loss-free data transmission.

www.iis.fraunhofer.de/waschraum-en

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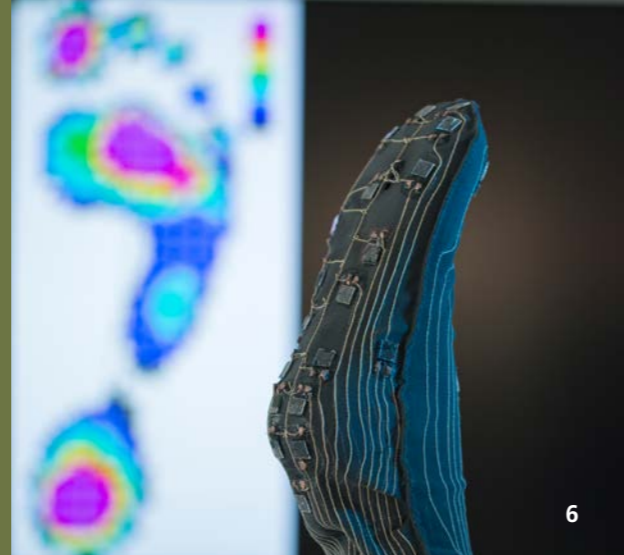
FINDING WHERE THE SHOE PINCHES
A textile-integrated sensor system measures foot pressure distribution and sends results to smartphone.

Diabetes patients often have reduced sensation in their feet, making them prone to wounds or painful pressure ulcers. A new pressure-monitoring stocking addresses this problem by monitoring foot pressure and warning the wearer of uncomfortable or harmful pressure spots. In contrast to previous systems, which only provide a short-term pressure reading from the sole of the foot, the special electronic stocking measures pressure distribution on the sole, heel, instep, and ankle in three dimensions.

Around 40 soft pressure sensors record the pressure inside the wearer's shoe during walking and standing. The sensors are made from a highly flexible soft elastomer silicone film which can be easily integrated into textiles. This film consists of conductive and insulating layers assembled in a screen printing process, and acts as a capacitive pressure sensor. Pressure or strain cause deformations in the film, measurably altering the sensor's electrical capacitance. Up to 40 of these sensors, each around 1 square centimeter in size, are attached to the stocking in line with orthopedic guidelines and connected to a flexible electronic control unit in the stocking cuff by a conductive polymer thread incorporated into the fabric.

The electronic control unit consists of an ASIC chip, a controller and a Bluetooth wireless interface. The electronics for this flexible application rely on the integration of 40 measurement channels in one ASIC. Wireless data transmission enables the measurement data to be displayed on a smartphone or tablet, alerting the patient if a change in foot posture or load distribution is needed.

The stocking has a wide range of potential applications. It is suitable for long-term monitoring of diabetes patients, gait and posture evaluation for orthopedic purposes, or even for sports and fitness activities. For instance, runners could use the stocking to monitor their running style or foot posture. The innovative measurement system was developed in cooperation with the Fraunhofer Institute for Silicate Research ISC and the University of Würzburg's Center for Telematics, with support in the form of internal funding from the Fraunhofer-Gesellschaft.

6 *A new textile-integrated elec-tronic sensor system measures foot pressure in three dimensions.*

7 *Virtual Reality Hackathon at the L.I.N.K. Test and Application Center.*

"FANCY FREE" ON THE FRAUNHOFER HOLODECK
VR Hackathon showcases the potential of RedFIR© positioning technology in apps for use on large surfaces.

Smartphone – check, VR glasses and headphones – check, and go! In our first ever Virtual Reality Hackathon, 12 teams of 3D artists and game developers created apps allowing multiple users equipped with VR glasses to freely roam the 1400 m² surface of the L.I.N.K. Test and Application Center. At the heart of this innovative application of VR is our RedFIR© positioning technology – a wireless tracking system able to accurately locate people and objects, detect their direction and speed in real time, and display them in the VR app, promptly and comprehensively reproducing their actual physical position in each VR world. The wireless technology is even able to easily track objects that would sometimes be partially or totally undetectable to purely optical tracking systems. The first prize was awarded to the HoloPac team, which developed a game where players have to collect packages within a limited time frame while being pursued by ghosts. In second place was the Eccos team, with its Social Sound Experience project, providing an innovative way to position, distribute and rearrange sounds and tracks in space. Third prize went to the Fuel team, with its Floccer Tournament Ninjago project. The winning apps were chosen by the jury primarily on the basis of the gaming experience provided and the interactivity arising from the use of the RedFIR© positioning technology.

🌐 www.iis.fraunhofer.de/holodeck-en

BOOSTING EFFICIENCY AND SAFETY IN THE WAREHOUSE
Smart tracking of industrial trucks in cooperation with Jungheinrich AG.

In search of a simple, low-cost, and easy to install method for tracking industrial trucks in warehouses, a cooperation arrangement with Jungheinrich AG has given rise to a tracking solution that can be used with all vehicle types and models. The warehouse is fitted with BLE (Bluetooth© Low Energy) beacons, and the industrial trucks (e.g., forklifts) are equipped with smartphones which independently determine their position using our awiloc© technology via BLE, suppor-ted by inertial sensors. They can then transmit their current position to the web platform, where position data can be viewed and analyzed in real time. Client applications include efficiency gains resulting from a live overview of the vehicle fleet, enabling the most suitable vehicle to be found for the task at hand, or for repairs and services. Furthermore, trans-port routes and warehouse operations can be optimized using heat maps, which retrospectively display vehicle move-ment patterns. Establishing speed zones increases safety in the warehouse, while monitoring certain warehouse areas can hinder unauthorized removal of vehicles.

🌐 www.iis.fraunhofer.de/stapler-en

8 *Tracking industrial trucks in a warehouse.*
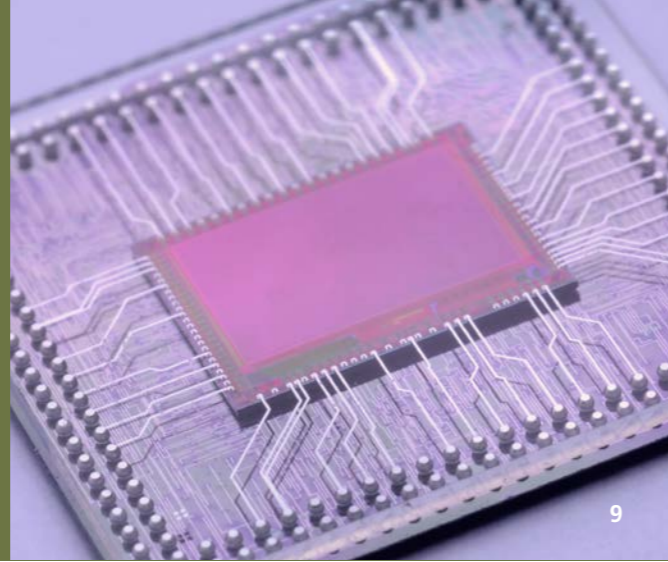
IMPROVED 3D CHIPS FOR ULTRA HD CAMERAS

Quadrupled data rate boosts transmission speed for image and audio information.

Camera resolution is constantly improving. Meanwhile, users expect hardware components to become smaller and smaller. This is particularly true of ultra HD cameras, which capture four times as many pixels as their full HD counterparts. Researchers at the Engineering of Adaptive Systems (EAS) division in Dresden have developed a compact and energy-saving solution to process the huge volumes of data this entails.

In the „Memory³" project, funded by the German Federal Ministry of Economic Affairs and Energy under the Central Innovation Program for SMEs (ZIM), researchers have developed a chip with the capacity to quadruple system performance. The new chip reduces line width by placing processor and memory in the same housing. The flow of data between the two components is ensured by a superfine substrate, known as an interposer, which allows processor and memory to be positioned so closely together that data can be exchanged at a substantially faster rate, while consuming less energy. "Whereas the distance between the chips was originally measured in millimeters, we are now working on a scale well below one millimeter," explains Andy Heinig, group manager for Advanced System Integration at the Dresden site. This 3D integrated structure significantly speeds up transmission of image and audio information, allowing a data rate of 400 GBit/s.

The Fraunhofer IIS experts spent around one and a half years on theoretical development before producing a prototype in February 2016. "We don't expect this development to be the end of the line, by any means," says Heinig, who believes that further improvements boosting performance by a factor of four or even more are entirely possible in the coming years.

The current 3D microchip structure was developed primarily with ultra HD cameras in mind. However, it could also find applications in other areas, such as graphics cards or switching nodes in fiber-optic networks.

www.eas.iis.fraunhofer.de/systemintegration-en

9 *The 3D chip enables a higher resolution from ultra HD cameras.*

10 *Polyps (green circle) are automatically detected by the "KoloPol" software.*
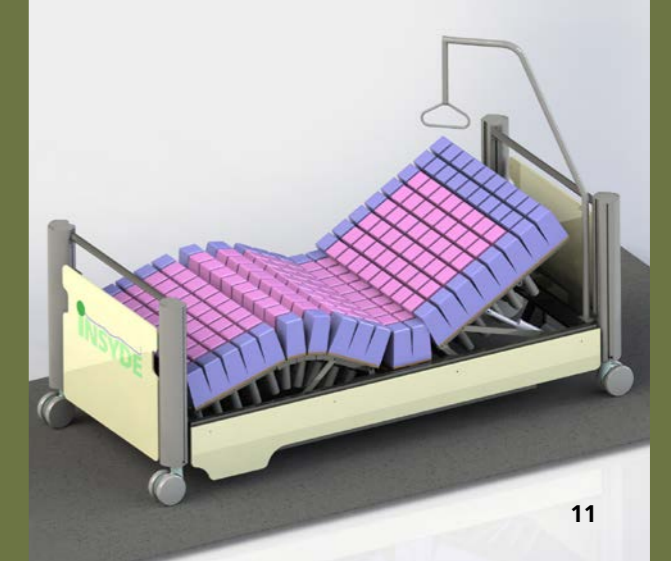
COLONOSCOPIC CANCER SCREENING

Software to automatically detect colon polyps can assist healthcare professionals.

In Germany, some 26,000 people die of bowel cancer each year. In most cases, polyps in the colon are to blame. These growths do not generally cause discomfort, and are only detected in the course of preventive cancer screening. During a colonoscopy, the colon and rectum are examined using an endoscope. The effectiveness of this procedure is heavily dependent on the experience and attentiveness of the examining physician, with 12 to 24 percent of polyps remaining undetected.

The "KoloPol" project has successfully developed a software to automatically detect polyps in the colon during colonoscopy, thus assisting physicians in their diagnosis. "Suspicious tissue areas are identified on the basis of variations in form, coloring, and texture, and automatically detected,"

explains Dr. Thomas Wittenberg, leader of the project and head of the Biomedical Research group, adding that "the software has the potential to raise the detection rate for pedunculated polyps." As well as improving detection, it could also reduce the time spent on colonoscopies by healthcare professionals. From July to October 2016, the system underwent technical validation at the Technical University of Munich's Rechts der Isar Hospital. The detection principle was tested on 58 patients, with around 75% of polyps successfully detected by the KoloPol system.

www.iis.fraunhofer.de/kolopol-en

HIGH-TECH HOSPITAL BEDS TO FIGHT BEDSORES

Adaptive mattress prevents pressure ulcers in bedridden patients.

Changing the position of bedridden patients requires a great deal of time and effort on the part of nursing staff and caregivers. In Germany alone, some 400,000 people suffer from pressure ulcers or bedsores, each year. Bedsores develop after a short period in patients with insufficient mobility. The smart hospital bed, developed in cooperation with five partners and unveiled at MEDICA 2016, detects the patient's current position and suggests a new one chosen to relieve pressure. Once the suggestion is approved by nursing staff, it can be automatically implemented by actuators built into the mattress that act as sensors to detect pressure distribution.

Information on the shift and the new pressure distribution is shown on a bedside display and can be directly added to

the patient's medical records. Evaluation of the smart bed has already begun, with initial measurements conducted by project partner DRK Soziale Dienste Baden-Baden gGmbH.

www.iis.fraunhofer.de/insyde-en

11 *A 3D model of the smart adaptive mattress.*

IN BRIEF

Research breakthroughs were not the only thing that made 2016 an eventful year for the institute. Aside from the inauguration of our new building at the Nürnberg site and the formation of a new division, notable events include the expansion of the institute's management. In the following pages, you can read a selection of the main stories from the year "in brief".

Selected stories at a glance:

Fraunhofer IIS gets a second director
Smart sensors for the world of tomorrow
More room for pioneering IoT research
Alexander Pflaum appointed director of Fraunhofer SCS
Adaptive is the new automatic
Audience award for film on JOSEPHS©
Art exhibition showcases "places of inspiration"

FRAUNHOFER IIS GETS A SECOND DIRECTOR
Professor Albert Heuberger and Dr. Bernhard Grill to share the helm.

Professor Albert Heuberger has been director of the Fraunhofer IIS since 2011. As of November 1, 2016, he will lead the Fraunhofer-Gesellschaft's largest institute side by side with his former deputy Dr. Bernhard Grill. Under the new arrangement, Heuberger is the institute's executive director, while Grill is in charge of the Audio and Media Technologies division. Director of administration Dr. Peter Dittrich takes on the role of deputy director alongside existing deputy director Professor Randolf Hanke.

Bernhard Grill studied electrical engineering at the Friedrich-Alexander University Erlangen-Nürnberg, and played a key role in the development of mp3 and AAC technology in the years following 1988. In 2000, Grill and his colleagues Karlheinz Brandenburg and Harald Popp were awarded the German Future Prize by the President of Germany, on behalf of their team at the Fraunhofer IIS, for the invention of the mp3 format. Other distinctions awarded to Grill include the Joseph von Fraunhofer Prize and the Eduard Rhein Prize. Since 2000, Bernhard Grill has led the Audio department. In 2011, he was appointed director of the Audio and Media Technologies division, which by then had grown to an institution with over 200 employees. Today it is hailed as a scientific and technological trailblazer in many fields of audio signal processing.

1 *Institute directors Professor Albert Heuberger (right) and Dr. Bernhard Grill.*

SMART SENSORS FOR THE WORLD OF TOMORROW
New "Smart Sensing and Electronics" division.

A Smart Sensing and Electronics division has been created under the leadership of Josef Sauerer, bringing together the four departments Image Processing and Medical Engineering, Integrated Sensor Systems, Integrated Circuits and Systems, and Electronic Imaging. The new division develops smart sensors, software and microelectronics for applications in research, media, industry, automotive technology, and medicine.

Solutions developed in this division include the HallinOne© 3D magnetic field sensor, the POLKA Polarization Camera for quality control in production, the FitnessSHIRT for performance tracking in sports, SCube© for digitalization and analysis of biological samples, high-speed ICs for rapid transfer of large data volumes, and the SHORE™ real-time image analysis software for the detection of emotions – to name but a few. "Smart, energy-saving and miniaturized sensors with the ability to capture information about our surroundings are crucial to developments relating to the Internet of Things or mobility. The Smart Sensing and Electronics division completes the Fraunhofer IIS technology portfolio in these areas," explains division director Josef Sauerer.

MORE ROOM FOR PIONEERING IoT RESEARCH
New building inaugurated in Nürnberg.

On May 30, Ilse Aigner, Bavaria's minister of economic affairs and media, energy and technology, inaugurated our new building in Nürnberg alongside state secretary in the Federal Ministry of Education and Research (BMBF) Stefan Müller, Mayor of Nürnberg Dr. Ulrich Maly, president of the Fraunhofer-Gesellschaft Professor Reimund Neugebauer, and our own Professor Albert Heuberger. The new facility in Nordostpark in Nürnberg, led by Dr. Günter Rohmer, will house 180 experts conducting research and development in future technologies and applications for the digital transformation and the Internet of Things.

The 5,900 square meters of office and laboratory space, which include the state-of-the-art L.I.N.K Test and Application Center, will be a hothouse for technologies and cyber-physical systems which form the basis for internet-based, networked applications in Industry 4.0 – but also in smart homes, smart cities, networked mobility, autonomous driving, and security, sports and fitness. The three business areas "Localization", "Networking and Identification", and "Energy Management" are devoted to the pursuit of technologies and solutions which showcase Nürnberg's excellence as a business center and ensure its expansion and consolidation in the digital transformation.

These IT-based technologies will deliver added value for users in production, logistics or infrastructure. For example, the development of telematics modules to increase the security of air cargo containers, or positioning technology for location-based navigation and information services in buildings or urban areas – verified for compliance with data protection legislation – give rise to new offerings and services. Networked sensor and wireless systems designed to ensure reliable and energy-efficient transmission of information over long distances for automatic remote retrieval are currently in the process of standardization and industrial testing.

2 *Professor Reimund Neugebauer, state secretary Stefan Müller, and minister Ilse Aigner inaugurate the new building of the Fraunhofer Institute for Integrated Circuits IIS in Nürnberg together with Professor Albert Heuberger, Dr. Günter Rohmer, and Mayor Ulrich Maly. The building is devoted to the development of new technologies and applications for digitalized production, the Internet of Things and networked mobility.*

2

ALEXANDER PFLAUM APPOINTED DIRECTOR OF FRAUNHOFER SCS

Bamberg professor to lead Center for Applied Research on Supply Chain Services.

Professor Alexander Pflaum has been with the Fraunhofer-Gesellschaft for over 20 years. Since 2011, he has been professor of business administration, with a focus on supply chain management, at the University of Bamberg. On May 1, 2016, he was appointed director of the Center for Applied Research on Supply Chain Services, with sites in Nürnberg and Bamberg.

An expert on the application of information and communication technologies in value chains, Pflaum will collaborate with the members of the center, conducting research at the crossover between technology and business management, and generate new momentum in the group. His primary focus will be on the digital transformation of companies, business models, and supply chains, employing our technological developments among others. "We see data as the raw material of the coming decades. We mine this raw material for our clients with a view to creating crucial value for their companies," he explains.

Dr. Roland Fischer, managing director of Fraunhofer SCS, will remain in his post, sharing the group's management with Pflaum.

🌐 www.scs.fraunhofer.de/en

3 *Professor Alexander Pflaum is director of the Center for Applied Research on Supply Chain Services.*

ADAPTIVE IS THE NEW AUTOMATIC

New name and extended research focus for Fraunhofer IIS/EAS.

The capability of technical systems to adapt to changes in their environment or their own behavior will be a crucial aspect of the interaction between humans and technology in the future. At the same time, this adaptability is a key foundation of the connected world of tomorrow. Self-monitoring and failure prediction are just as important as high reliability and low energy consumption. To meet these challenges, the Dresden branch of the institute has scrutinized its research portfolio and steadily expanded its traditional focus in the field of design automation in recent years. In order to convey this development to the outside world, in May 2016 the branch was renamed the "Fraunhofer IIS Division Engineering of Adaptive Systems EAS". Research in the division will span the business areas "Design Methodology", "Efficient Electronics" and "Distributed Data Processing & Control". In addition to methods for functionally secure and reliable system design and development of application-specific circuits, the division's key areas of activity include novel approaches to sensor technologies, analysis of large volumes of data, and control of automation processes.

🌐 www.eas.iis.fraunhofer.de/en

AUDIENCE AWARD FOR FILM ON JOSEPHS©

Vision of the future painted in "JOCO 2034" wins over audience at science film festival.

The film "JOCO 2034", set in the year 2034, features "historical footage" of the real JOSEPHS© from 2014, and fictional statements by employees and companies to mark the 20th anniversary of its foundation. In 2034, JOSEPHS© institutions have become commonplace. Looking back 20 years, the characters in the film recall how clients barely had a say in how things were done, and companies developed products and services with no consumer involvement, with a mixture of amusement and astonishment.

The real JOSEPHS© - The Service Manufactory is a business in the center of Nürnberg run by the Fraunhofer Center for Applied Research on Supply Chain Services SCS in co-operation with the Friedrich Alexander University Erlangen-Nürnberg. Since 2014, it has offered visitors the opportunity to be actively involved in the development, implementation, and marketing of concepts over the course of three-month test cycles. "JOCO 2034" was nominated for the Foresight Film Festival in Halle (Saale), and went on to win the audience award in the category "The Future is Open Space" on June 30, 2016. The Foresight Film Festival is a science vision festival funded by the German Federal Ministry of Education and Research with the aim of uncovering trends and social challenges, and is a pool of ideas for future projects and research.

▶ www.josephs-service-manufaktur.de/en/visitors/media-center/

4 *A scene from "JOCO 2034".*

ART EXHIBITION SHOWCASES "PLACES OF INSPIRATION"

Images by communication designer Christina Oppitz explore the secrets of researchers' special places.

The exhibition "Art & Technology" explores the issue of where the employees of the Fraunhofer IIS find inspiration for their work. The patterns on display invite viewers to discover these "places of inspiration" for themselves. For the project, our employees were asked to photograph the places where they seek ideas for their work. The photos were then digitally altered by communication designer Christina Oppitz, who transformed the spatial atmospheres depicted in the photographs into kaleidoscopic motifs.

The resulting images, which Oppitz calls "impression patterns", bring out the fantastical and imaginative essence of the physical locations, encouraging the viewer to experience the dynamic interplay between the details and the image as a whole. The exhibition catalogue contains both the images on display and the original photos taken by our employees, alongside their ideas and commentary.

The "Places of inspiration" project is part of the Art & Technology exhibition series exploring the interdependencies between art and technology. The exhibition can be viewed in the public area of our premises until September 2017. Opening hours: Monday – Thursday 8 am – 5 pm, Friday 8 am – 3 pm.

5 *Artist Christina Oppitz (left), institute director Professor Albert Heuberger and curator Anne Krefting at the vernissage on October 27 at the Fraunhofer IIS in Erlangen.*

FRAUNHOFER IIS IN NUMBERS

Number of permanent employees continues to rise

As in previous years, we enjoyed moderate growth in the 2016 business year. The number of employees rose from 907 last year to 919. This figure refers to employees listed in the staffing plan. Those in marginal employment arrangements are not included in the chart. We employ 410 student assistants and 16 apprentices.

- permanent employees
- apprentices
- student assistants
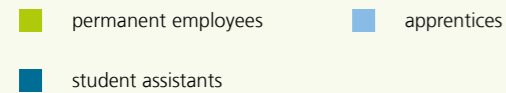
919
employees

Majority of researchers aged below 40

Many of our employees come to Fraunhofer straight from university. 17 percent of research staff are under the age of 30. Almost half are between 30 and 39 years old. Around a fifth are aged 40 to 49. Almost 16 percent are over 50. Student employees are not taken into account in the statistics.

- ≤ 29 years
- 30–39 years
- 40–49 years
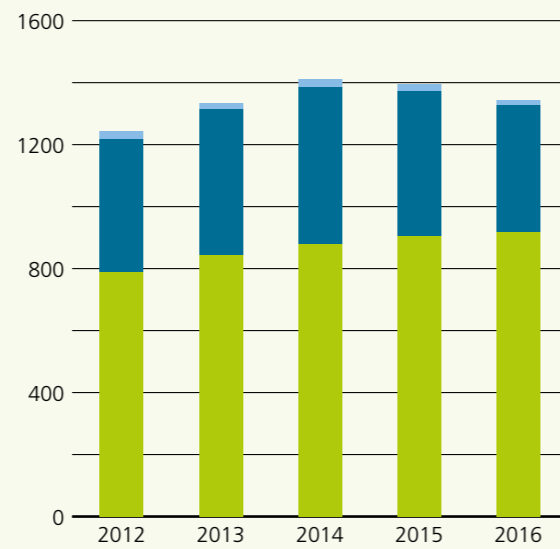- 50–59 years
- ≥ 60 years
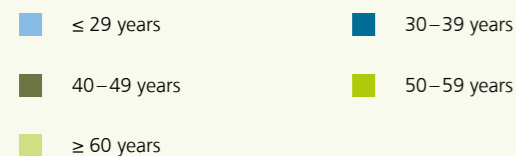
38,5
average age of research staff
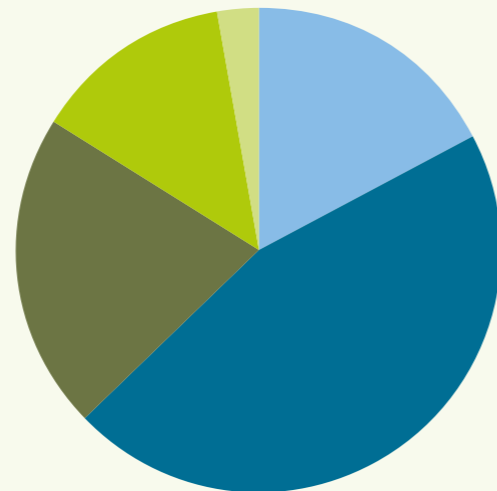
Books remain balanced

In 2016, the Fraunhofer IIS obtained 56 percent of its income from industry and business, 24 percent from base funding via the Fraunhofer Gesellschaft, and 20 percent from public and other revenue.

After high one-off license payments in 2014, income stabilized once again in 2015 and 2016.

- Base funding
- Public-sector revenue
- Industrial revenue
- Other revenue
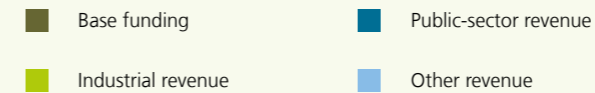
€152M
in funding
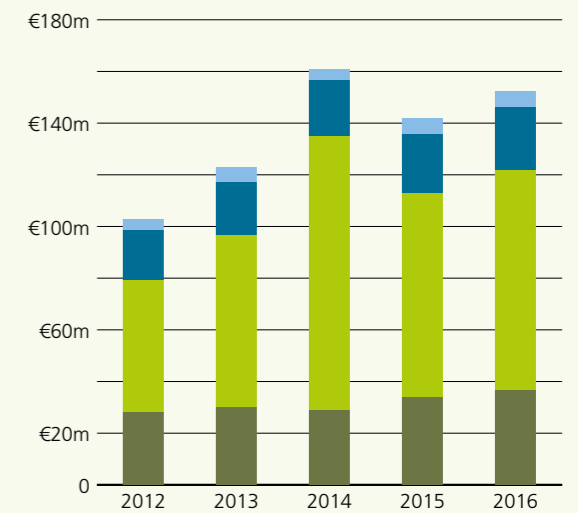
Record number of invention disclosures

Invention disclosures at the Fraunhofer IIS have remained at a healthy level in recent years, never falling below 60.

In 2016, an all-time high of 123 inventions were disclosed at the Fraunhofer IIS. The rise in disclosures compared to recent years was most notable in the research areas communication systems and audio and media technologies.

123
invention disclosures
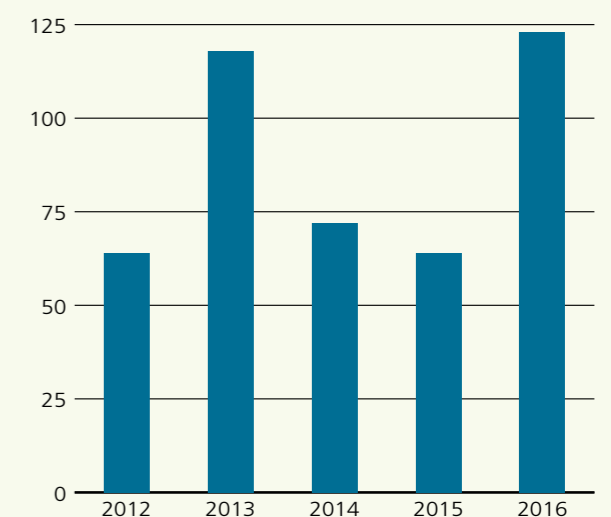
PETER BLUM
AUDI AG

"To be able to keep our promise 'Vorsprung durch Technik' at Audi AG, we need partners who quickly translate research results into **innovative technologies**. A good example is the development of a 3D car audio system in partnership with Fraunhofer IIS. The cooperation enabled us to offer realistic **3D sound** inside the car taking the listening experience to a new, highly compelling level. Key success factors of this collaboration were the **application-focused research** and **high audio expertise** of Fraunhofer IIS."

"We developed an Industry 4.0 roadmap for Maschinenfabrik Reinhausen in collaboration with the Fraunhofer Center for Applied Research on Supply Chain Services SCS. I particularly appreciated the **methodical support** and the **holistic approach** to the potential of digitalization for our value creation processes. The results inform our project roadmap, and help me with the prioritization of issues for the coming years."

DR. BERND KEMPA
MASCHINENFABRIK REINHAUSEN GMBH

BERND WACKER
SIEMENS AG

The dynamics of digital technologies – from sensors to networking of processes – is the **enabler for innovation to fully digitalized factories**. Accordingly, in collaboration with the Fraunhofer IIS, Siemens is working on research and development of **new solutions for industry 4.0 applications**."

THE FRAUNHOFER IIS – YOUR PARTNER

Outstanding ideas. Application-oriented research. Cooperation you can rely on.

The Fraunhofer IIS is a partner for clients in industry and the public sector. We develop, implement and optimize processes, products and equipment all the way to operational and market maturity. By flexibly networking skills and capacities within the Institute, we are able to satisfy even the most elaborate project requirements and deliver complex system solutions.

Market studies – knowledge for innovation
We advise you prior to a research collaboration with tailored studies, market observations, trend analyses, and feasibility studies.

Consulting and project support
You can engage us for consulting on technological issues, to refine individual work processes or to develop a product from square one. We offer guidance for your investment decisions. Furthermore, we support you in the implementation of new technologies and help you to successfully execute your applications.

Research to order
Industrial and service companies of all sizes can benefit from contract research; we are happy to share our know-how. We develop and optimize technologies, processes, and products all the way to the production of prototypes for our industry clients.

Licensing of technologies and systems
We make the results of our research available to industry in the form of patents and licenses.

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Business development and innovation

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FRAUNHOFER IIS IN PROFILE

The Fraunhofer Institute for Integrated Circuits IIS is one of the world's leading application-oriented research institutions for microelectronic and IT system solutions and services. It ranks first among all Fraunhofer Institutes in size. With the creation of mp3 and the co-development of AAC, Fraunhofer IIS has reached worldwide recognition.

In close cooperation with partners and clients the Institute provides research and development services in the following areas:

– Audio and Media Technologies
– Imaging Systems
– Energy Management
– IC Design and Design Automation
– Communications
– Positioning
– Medical Technology
– Sensor Systems
– Safety and Security Technology
– Supply Chain Management
– Non-destructive Testing

More than 900 employees conduct contract research for industry, the service sector and public authorities. Founded in 1985 in Erlangen, Fraunhofer IIS has now 13 locations in 10 cities: in Erlangen (headquarters), Nürnberg, Fürth, Dresden, further in Bamberg, Waischenfeld, Coburg, Würzburg, Ilmenau and Deggendorf. The budget of 150 million euros is mainly financed by projects. 24 percent of the budget is subsidized by federal and state funds.

The organizational units for the individual sites are shown in the organizational chart on the following pages.

Dresden
Ilmenau
Coburg
Würzburg
Bamberg
Waischenfeld
● **Erlangen**
Fürth
Nürnberg
Deggendorf
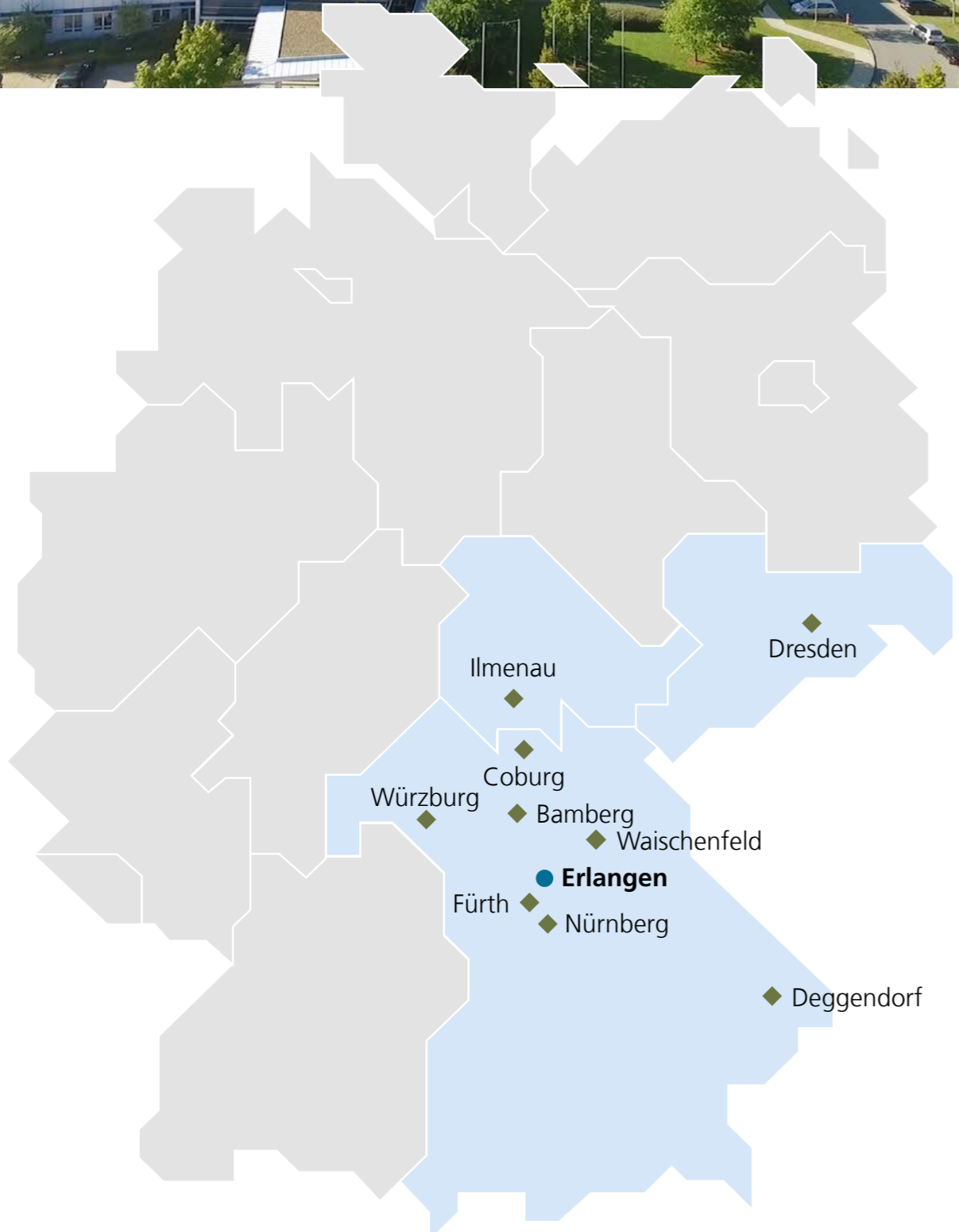
Headquarters ●
Sites ◆

FRAUNHOFER-GESELLSCHAFT IN GERMANY

Main locations ●
Other locations ○

Itzehoe
Rostock
Lübeck
Stade
Bremerhaven
Hamburg
Oldenburg
Bremen
Berlin
Wolfsburg
Hannover
Braunschweig
Potsdam Teltow
Wildau
Lemgo
Goslar
Magdeburg
Gelsenkirchen
Münster
Paderborn
Cottbus
Hamm
Göttingen
Halle
Schwarz-
heide
Oberhausen
Soest
Dortmund
Schkopau
Duisburg
Schmallenberg
Leipzig
Leuna
Willich
Kassel
Dresden
Zittau
Köln
Sankt Augustin
Jena
Freiberg
Aachen
Erfurt
Hermsdorf
Chemnitz
Euskirchen
Gießen
Wachtberg
Ilmenau
Remagen
Frankfurt
Hanau
Coburg
Alzenau
Mainz
Aschaffenburg
Bamberg
Darmstadt
Würzburg
Erlangen
Bayreuth
Kaiserslautern
Wertheim
Fürth
Mannheim
Nürnberg
St. Ingbert
Regensburg
Straubing
Saarbrücken
Karlsruhe
Pfinztal
Esslingen
Deggendorf
Ettlingen
Stuttgart
Augsburg
Freising
Garching
Freiburg
München
Kandern
Weßling
Rosenheim
Holzkirchen
Prien
Efringen-
Kirchen

Research of practical utility lies at the heart of all activities pursued by the Fraunhofer-Gesell-schaft. Founded in 1949, the research organization undertakes applied research that drives economic development and serves the wider benefit of society. Its services are solicited by customers and contractual partners in industry, the service sector and public administration.

At present, the Fraunhofer-Gesellschaft maintains 69 institutes and research units. The majority of the 24,500 staff are qualified scientists and engineers, who work with an annual research budget of 2.1 billion euros. Of this sum, 1.9 billion euros is generated through contract research. More than 70 percent of the Fraunhofer-Gesellschaft's contract research revenue is derived from contracts with industry and from publicly financed research projects. Almost 30 percent is contributed by the German federal and state governments in the form of base funding, enabling the institutes to work ahead on solutions to problems that will not become acutely relevant to industry and society until five or ten years from now.

International collaborations with excellent research partners and innovative companies around the world ensure direct access to regions of the greatest importance to present and future scientific progress and economic development. With its clearly defined mission of application-oriented research and its focus on key technologies of relevance to the future, the Fraunhofer-Gesellschaft plays a prominent role in the German and European innovation process. Applied research has a knock-on effect that extends beyond the direct benefits perceived by the customer: Through their research and development work, the Fraunhofer Institutes help to reinforce the competitive strength of the economy in their local region, and throughout Germany and Europe. They do so by promoting innovation, strengthening the technological base, improving the acceptance of new technologies, and helping to train the urgently needed future generation of scientists and engineers.

As an employer, the Fraunhofer-Gesellschaft offers its staff the opportunity to develop the professional and personal skills that will allow them to take up positions of responsibility within their institute, at universities, in industry and in society. Students who choose to work on projects at the Fraunhofer Institutes have excellent prospects of starting and developing a career in industry by virtue of the practical training and experience they have acquired.

The Fraunhofer-Gesellschaft is a recognized non-profit organization that takes its name from Joseph von Fraunhofer (1787–1826), the illustrious Munich researcher, inventor and entrepreneur.

The Fraunhofer-Gesellschaft cur-rently operates 69 institutes and research institutions in Germany.

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FRAUNHOFER-GESELLSCHAFT WORLDWIDE

Fraunhofer has subsidiaries in Europe and in North and South America. Representative offices and senior advisors worldwide act as a bridge to local markets. An office in Brussels works as an interface between Fraunhofer and EU institutions. Numerous strategic collaborations with excellent international partners round off the portfolio.

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Dr. Bernhard Grill

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Joseph von Fraunhofer Prize
Alexander Zink, Martin Speitel, and Max Neuendorf for the development of digital radio technologies

Hugo Geiger Prize
Dr. Gerd Kilian for his doctoral thesis on telemetry system optimization

PCB Design Award
2nd place, Alfred Holzberger for his circuit board design in the category "3D / Build space"

Ernst Blickle Graduate Award
Dominik Soller for his master's thesis on SDR framework with detached monitoring functionality

Dr.-Ing. Siegfried Werth Foundation Prize
Thomas Fischer for his bachelor thesis on examining the influence of scan times on the measurement accuracy of industrial computed tomography

CNA Special Award "Intelligence for Transportation and Logistics"
"NADINE" project consortium for innovations in the field of transportation and logistics

Foresight Film Festival, audience award
Patricia Petsch and Christina Müller for the film "JOCO 2034"

Medal of Honor of the Administrative Region of Oberfranken
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