

**HIGHLIGHTS**  
**2017**  
ANNUAL REPORT

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on the topic



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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 picture

*Abstract of an integrated circuit:  
Bedrock of digitalization and  
namesake of the institute.*

**HIGHLIGHTS**  
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## TECHNOLOGIES FOR TOMORROW

Dear reader,

Our research priorities span two main guiding topics, which we pursue in a systematic and strategic manner. Within these topics, “audio and media technologies” and “cognitive sensor technologies”, we work on technologies for tomorrow, helping our customers and partners prepare for the markets of the future.

2018 will be no exception: we are already hard at work on the global dissemination of our latest generation of audio codecs. These codecs enable mobile streaming of media content even over slow internet connections, three-dimensional and personalized TV sound, and vastly improved voice quality coupled with more reliable transmission in mobile telephony. In the field of cognitive sensor technology, our ongoing efforts in collaboration with partners in industry and research include our work at the Campus of the Senses, devoted to digitalizing human sensory perception and developing new technologies and services for companies and start-ups in virtually every sector.

This annual report presents some of the highlights of our activities in 2017, connected by the common thread of our two guiding topics. Read on to learn more about our work in audio and media technologies and cognitive sensor technologies, and the added value our research brings you.

Kind regards,

Professor Albert Heuberger

Dr. Bernhard Grill

Fraunhofer IIS management of the institute



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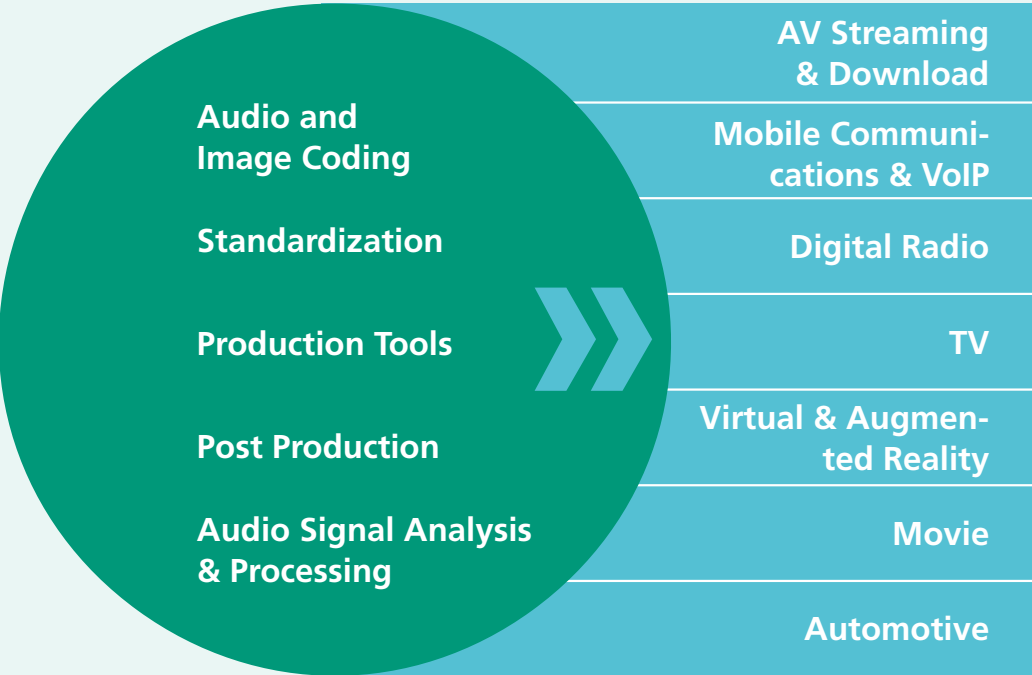
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AUDIO AND MEDIA TECHNOLOGIES

“WITHOUT OUR CODECS, SMARTPHONES WOULD LARGELY BE MUTE.”

Fraunhofer IIS has been shaping the digitalization of media for more than 30 years now. The institute was instrumental in the development of mp3 and AAC and played a significant role in the digitalization of the cinema.

Current developments in the area of „audio and media technologies“ are opening up whole new sound worlds and are being used in virtual reality, automotive sound systems, mobile telephony, streaming and broadcasting. Any mobile phone you buy today, for instance, uses audio technology developed by the institute, while Fraunhofer codecs provide the basis for sound of more than half of all TV broadcasts worldwide and almost all radio and streaming services. The institute’s professional tools for digital film and media production are also being used globally.



*Dr. Grill, in your capacity as division director and institute director you are responsible for Audio and Media Technologies. Fraunhofer IIS is the cradle of globally successful technologies such as mp3 and AAC. What developments can we expect in the future?*

**Grill:** Our first three generations of audio coding formats – mp3, AAC, and HE-AAC – are currently used in virtually all consumer electronics devices, computers, and mobile phones: mp3 and AAC remain the standard format for music distribution, while most radio systems rely on HE-AAC, and over half of the world’s population receives TV sound in AAC or HE-AAC format. Online streaming services also mostly use AAC codecs.

With our current fourth generation of codecs, we are well positioned to build on this success in the future. This generation is made up of three codecs: xHE-AAC, EVS, and MPEG-H 3D audio, each tailored to a particular application.

xHE-AAC is the first codec worldwide to successfully combine speech and audio coding, enabling it to deliver consistently high quality for all audio signal types, and constitutes the state of the art for very low bit rate transmission. This makes it attractive for applications with limited transmission bandwidth, such as digital radio or mobile streaming services. xHE-AAC is the standard codec in the Digital Radio Mondiale (DRM) system, for instance, and numerous audio and video streaming providers have shown interest in using it.

Our second fourth-generation coding format is EVS. This 3GPP communication codec, which we played a major role in developing, is optimized for VoIP over mobile networks. Compared to earlier formats, it offers notably higher quality for speech and general audio at lower bit rates, and substantially improved transmission reliability with low signal delay. EVS is already in use in Japan, South Korea, Europe,

and the US, with further countries to follow this year. Our fourth generation of audio codecs is completed by MPEG-H 3D Audio, an audio system for TV standards and streaming services which can be used to transmit 3D sound and personalized audio. Since May 2017, MPEG-H has been used in a regular commercial terrestrial 4K TV service in South Korea. We are confident that the system will soon be introduced in other countries as well. TVs with MPEG-H have been available on the market since last year, and we expect the first 3D soundbars with MPEG-H to be launched in 2018 by companies such as the German manufacturer Sennheiser.

*Let’s take an off-the-shelf smartphone as an example. Which Fraunhofer IIS technologies can be found in a device of this sort today?*

**Grill:** Without our four generations of coding formats, smartphones would largely be silent: music playback, whether from a local music library or via streaming services, relies on mp3 or AAC, while HE-AAC is the standard audio codec for video streaming. Even for telephony, our technologies play a crucial role: Apple Facetime, for instance, is based on a variant of the AAC codec optimized for telephony, which allows it to offer substantially higher audio quality than a conventional phone call. Since 2016, EVS has been implemented in most modern smartphone models, providing Hi-Fi quality in LTE mobile networks following integration with network base stations and infrastructure. With the increasing proliferation of xHE-AAC and MPEG-H, these technologies will undoubtedly also be integrated into smartphones in the future. The corresponding implementations are already available.

More information on the guiding topic “audio and media technologies” is available on the following pages and at this link:

 [www.iis.fraunhofer.de/guidingtopics](http://www.iis.fraunhofer.de/guidingtopics)



# 3D SOUND FOR EVERYONE

Until now, recording high-quality 360° sound or enjoying immersive audio in a home theater was exclusive to users willing to install and operate a multitude of microphones or loudspeakers. Such complex setups will, however, soon be a thing of the past. Thanks to the special algorithms of the Fraunhofer upHear family of technologies capturing and playback of 3D sound is now possible just with a single device.

Enthusiastic viewers use their TV and soundbar to view footage of an automobile race that they recorded with their camera from the side of the race track. The roar of the motors follows the cars on the screen, thunderously panning from left to right across the room. Above them, they hear the stadium announcer commenting on the race, while all around them the spectators cheer the drivers on. It feels as if they are back on the race track. What used to be a science fiction scenario is now reality.

Cameras able to generate 360° images and videos have been around for some time, but their audio recording capabilities have left a great deal to be desired. Compelling 360° sound, unless captured using an elaborate arrangement of microphones, has hardly been an option for everyday users. Meanwhile, soundbars have also been around for some time, but they have only been able to play back basic surround sound. Truly immersive audio as experienced in a movie theater has only been available to Hi-Fi enthusiasts willing to make the effort to equip their living room with an assortment of ear-height and ceiling loudspeakers. For most people, the obstacles of recording true 3D sound or enjoying it at home are simply too big. But even professional producers of 3D (immersive) media content welcome solutions

## AT A GLANCE

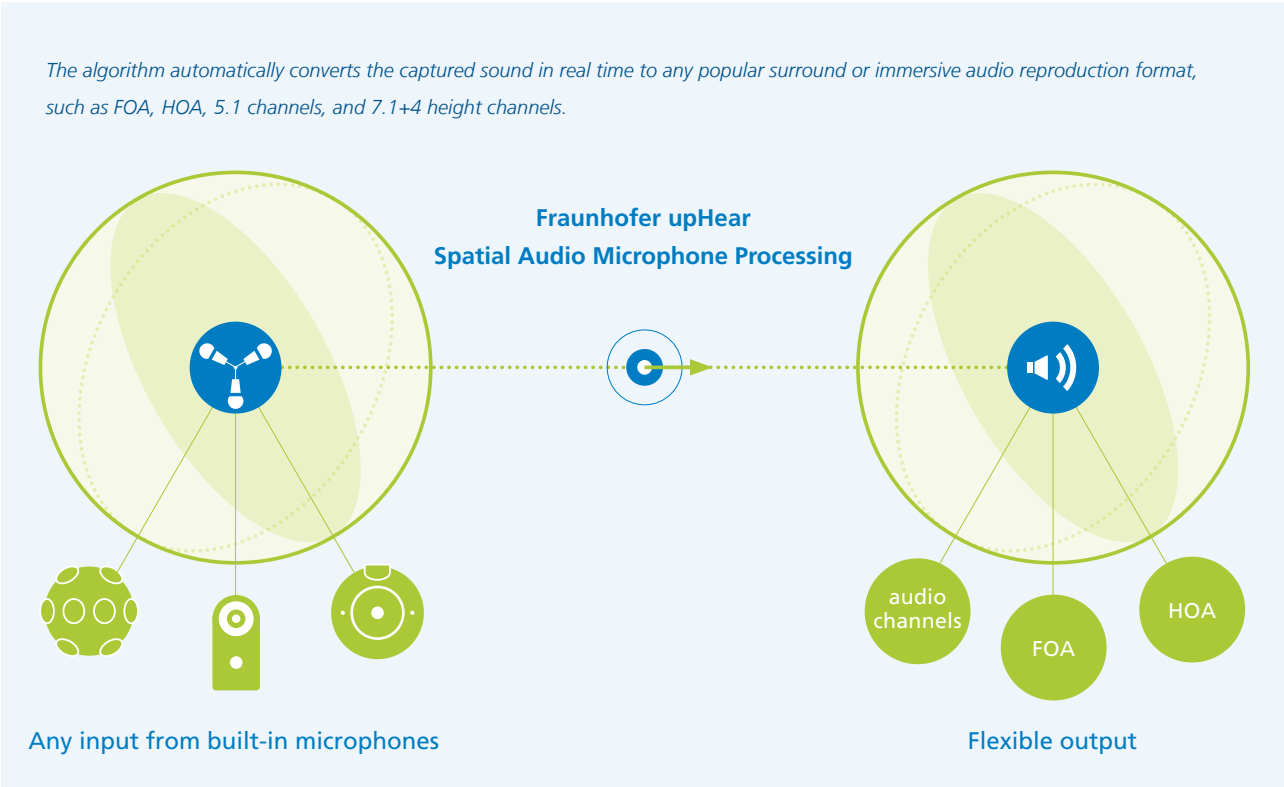
- 1 | The Fraunhofer upHear family of technologies is a range of user-friendly solutions offering a convincing 3D sound experience.
- 2 | upHear Spatial Audio Microphone Processing enables high-quality 3D sound capture at the touch of a single button.
- 3 | upHear Immersive Audio Virtualizer enables soundbars to replace a 3D home theater loudspeaker setup.

1 3D sound that transports viewers to the heart of the action.

which simplify their work. This is where the upHear technologies developed in our Audio and Media Technologies division come into play, providing user-friendly solutions for a convincing 3D sound experience. All that is needed is a single end device – a microphone or a camera on the production side, and a soundbar on the reproduction side. This way, immersive sound can be enjoyed easily.

3D sound capture made easy

Our engineers developed the Fraunhofer upHear Spatial Audio Microphone Processing technology to enable high-quality 3D sound capture using spatial audio microphones or the built-in microphones of professional and consumer-level 360° cameras and mobile devices at the push of a button. The algorithm can be implemented directly in devices, mobile applications, or post-production software, and can be flexibly adapted to meet manufacturers' requirements or the particular design of cameras and mobile devices. Integration in devices with three or more microphones in a variety of configurations, or even more demanding applications, is also possible.



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

The technology analyzes the exact position of audio signals, and automatically converts them into any popular surround or immersive playback format in real time, faithfully preserving the original sound atmosphere of the recorded scene. The information collected during this analysis allows the sound sources to be subsequently reproduced on a loudspeaker setup, thanks to the creation of audio channels. Typical formats include 5.1 surround sound or 7.1+4 for 3D sound. Additionally, an atmospheric soundscape can be created using ambisonics. For professional applications, when implemented in microphones, the technology also allows manual editing. This makes the data easier to work with and offers greater flexibility during post-production: sound designers can combine the recorded audio scenes with additional sound elements such as voice-overs or dynamic objects. This enables them to create immersive sound experiences for virtual reality applications or enhance movies with 3D sound.

The Emmy award-winning producer of virtual reality content Felix & Paul Studios uses Fraunhofer upHear Spatial Audio Microphone Processing in their 360° 3D camera system and associated production tools to faithfully and precisely capture scene-based audio. The captured sound can subsequently be combined with other sources to create a fully immersive audio experience.

Smart soundbar designs for immersive playback

Thanks to premium streaming services, TV broadcasts in UHD format or series and films on Blu-ray, it is theoretically possible to enjoy immersive theater-quality audio at home. However, conventional approaches to implementing three-dimensional sound in the living room involve multiple loudspeakers and cables and considerable technical expertise for their installation. In the future, none of this will be necessary: The Immersive Audio Virtualizer technology from the Fraunhofer upHear family will enable playback of high-quality 3D sound on soundbars or television sets.

Besides sophisticated signal analysis and perfectly matched hardware and software, the benefits of upHear for consumer electronics manufacturers also include personalized guidance on hardware specifications and individual tuning by experienced Fraunhofer Tonmeisters during product development. This allows advantageous positioning of the drivers within the device – resulting in smart, customized soundbar designs for immersive playback with no need for satellite loudspeakers. For the consumer at home, this saves time, effort, and hassle.

By employing intelligent spatial audio, a soundbar equipped with the upHear algorithm is able to render 3D sound in a way that would normally require seven loudspeakers, a subwoofer, and four height loudspeakers. The algorithm can process any audio format, and legacy formats such as surround or stereo can be given added spatiality by the integrated

« Ambisonics  
Mathematical representation of  
a sound field.



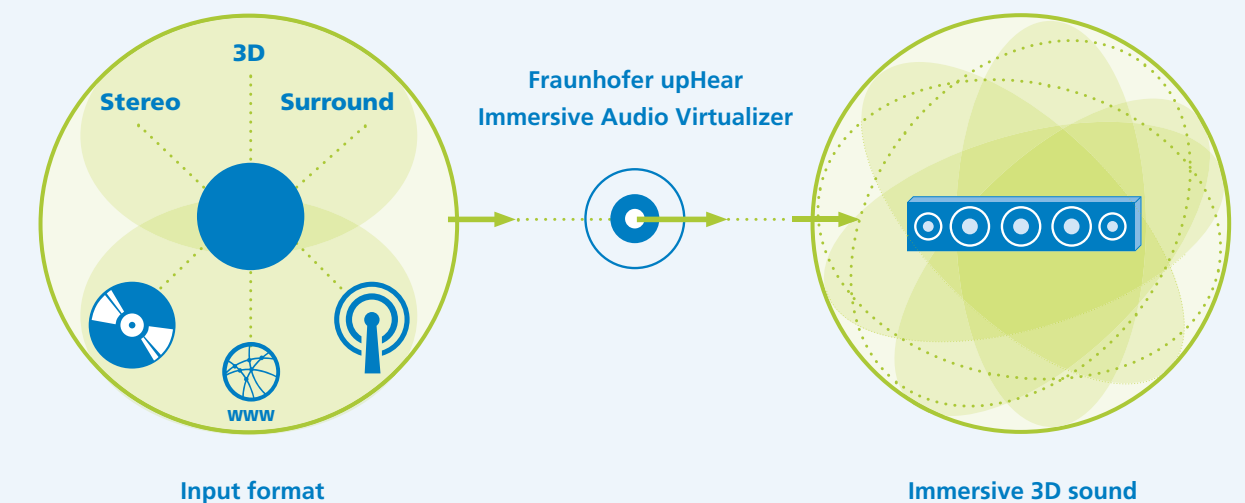
2 Capturing 3D sound with a highly compact microphone setup.

upmix functionality. The perfect partner for highly authentic 3D sound is the next-generation audio codec MPEG-H Audio. MPEG-H allows efficient transmission of immersive sound for TV or streaming at bitrates typically required to transmit 5.1 surround sound today. Furthermore, the technology offers a range of features for a new, exciting TV audio experience: in addition to the immersive sound provided by 3D audio components, the sound mix can also be adjusted to meet individual requirements – allowing users to enjoy audio tailored to the device it is being played on. In collaboration with our partners, we will soon be delivering authentic 3D audio to living rooms everywhere with the help of the Fraunhofer upHear Immersive Audio Virtualizer.

## upHear: Outstanding solutions for immersive soundscapes

Life is not two-dimensional, and 3D sound is an important gateway into new media environments, giving users the impression of being in the midst of the action. Accordingly, interdisciplinary teams in our Audio and Media Technologies division are working on the upHear family of technologies to provide just that. Our goal is to create technically and artistically outstanding solutions designed to bring authentic, immersive soundscapes to life. ■

Thanks to sophisticated signal analysis, perfectly matched hardware and software and individual tuning during product development, the Fraunhofer upHear Immersive Audio Virtualizer allows soundbars to deliver a convincing 3D sound experience, regardless of the input source used – with no need for special speaker setups.



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## PUTTING SOUND IN THE DRIVER'S SEAT

New Sonamic® technology is a major step forward for in-vehicle audio.

With Symphoria®, Fraunhofer has brought 3D sound for your car to series maturity. The new Fraunhofer Sonamic family of technologies comprises intelligent audio processing solutions that take the customer experience of in-car entertainment systems to a whole new level of comfort and quality. The new family is currently made up of three members: Sonamic Enhancement, Sonamic Loudness, and Sonamic TimeScaling.

To ensure optimum sound quality, audio codecs should be used at sufficiently high bitrates. However, in commercial practice, low or very low data rates are often chosen to reduce transmission costs, sometimes resulting in audible artifacts. Using intelligent, blind detection, Sonamic Enhancement can substantially reduce the occurrence of such artifacts. After the signal is analyzed, the necessary repairs and optimization are performed in real time. Among other operations, the semantic algorithms restore high-frequency signal components, remove scratches or roughness, and reconstruct lost spatiality.

The number of in-vehicle media sources has increased significantly in recent years. It is a simple matter to play back audio data from USB sticks, mp3 players, or smartphones in your car. Unfortunately, the volume level from the various audio sources varies considerably, requiring frequent adjustments. This is not just an inconvenience: it is also a safety risk, as the driver's attention is momentarily disrupted. Sonamic Loudness addresses this problem, ensuring consistent volume when switching between radio stations, media sources, or individual audio tracks. In spite of the automatic volume adjustment, the music's dynamic range is preserved.

With hybrid radio, listeners on the road can stay tuned in to a particular station even when leaving its broadcast area. This is achieved by switching from a broadcast signal to a web stream by the same station. However, the two sources can be separated by a time offset of up to 20 seconds. When switching from one to the other, these seconds are either lost or played twice. Sonamic TimeScaling synchronizes the two signals in the radio receiver, ensuring a precise, unnoticeable transition, allowing passengers to seamlessly continue listening to a radio broadcast wherever they are.

 [www.iis.fraunhofer.de/sonamic](http://www.iis.fraunhofer.de/sonamic)

3 No need to reach for the volume dial with Sonamic Loudness: the technology ensures a constant volume level when switching between radio stations, media sources, or individual audio tracks.



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## CRYSTAL-CLEAR PHONE CALLS

Developers of the EVS codec awarded with the Joseph von Fraunhofer Prize.

There is not much that smartphones can't do, but one aspect of their performance still leaves a great deal to be desired: voice quality in phone calls. This is set to change with the new Enhanced Voice Services (EVS) standard: instead of sounding muffled and distorted, the voice on the other end of the line will be as clear and natural as in a face-to-face conversation.

EVS is the new communication codec of the 3rd Generation Partnership Project (3GPP), an international standards body for mobile communications. Fraunhofer IIS played a major role in the development, with a research team of more than 50 experts. The Joseph von Fraunhofer Prize was received by Markus Multus, Dr. Guillaume Fuchs, and Stefan Döhla on behalf of the team.

A standard of this sort has to fulfill rigorous specifications. "First of all, the codec must be capable of transmitting high-quality speech signals at relatively low data rates, so as not to compromise cost-efficiency," says Markus Multus, who coordinated the software development for the codec at Fraunhofer IIS. Furthermore, the codec must be sufficiently robust to withstand transmission errors. Finally, it must also be able to transmit other signals, such as music, with high sound quality.

"The average human ear can hear frequencies of up to 20 kilohertz," explains Dr. Guillaume Fuchs, in charge of scientific development for the EVS standard. "The codec currently used for most telephone calls on mobile networks in Germany only transmits audio signals up to 3.4 kilohertz – the range between 3.4 and 20 kilohertz is simply cut off. This makes phone calls sound muffled. The new codec allows frequencies of up to 16 or even 20 kilohertz, depending on the bitrate." As a result, the entire audible frequency spectrum is transmitted.

Before a new codec can be implemented as a standard, it has to pass numerous listening tests involving thousands of test subjects. In these tests, listeners rated EVS as significantly better than previous formats. The new codec has since been approved as a standard by 3GPP, meaning that chip manufacturers can implement it in mobile phone application processors and device manufacturers can integrate it into new products. "EVS is already in commercial use in a number of countries including Germany, Japan, the Netherlands, Austria, Poland, South Korea, the UK, and the US," says Stefan Döhla, who represents Fraunhofer IIS at 3GPP.

 [www.iis.fraunhofer.de/evs](http://www.iis.fraunhofer.de/evs)

4 Joseph von Fraunhofer Prize recipients: (from left to right) Markus Multus, Dr. Guillaume Fuchs, and Stefan Döhla.



## LIGHT-FIELD HOLDS PROMISE FOR VIRTUAL REALITY

Additional perspectives expand possibilities in VR and video production.

One of the most promising new techniques for production of immersive media content – which gives spectators the impression of truly inhabiting a scene – such as virtual reality (VR), or composites of virtual and real images created in post-production, is light-field technology. With this method, multiple shots of a particular scene are used to create additional perspectives.

The goal is to optimize the complex and time-intensive modeling steps required for the creation of photorealistic content and subsequent rendering by using intelligent light-field algorithms. In this process, light-field technology directly captures reflections, lighting or textured surfaces. Furthermore, the different perspectives make it possible to look past objects and people and genuinely move around them in VR scenes. This is currently the most far-reaching potential application of light-field technology: creating real content for VR glasses with practically flawless perspective.

A crucial element when working with light-field technology is a scene's depth information and geometry, as with classical 3D reconstruction. This information is what makes it possible to correctly render masking or overlapping between individual objects in a scene when calculating new perspectives.

Our computational imaging experts are currently working on a suite of light-field software applications under the brand name Realception®. We also offer additional tools to process multi-camera content. Furthermore, in collaboration with the Max Planck Institute for Informatics, we offer a video light-field dataset for first-time users to hone the necessary skills and facilitate work with light-field material in post-production.

Our plans for further light-field developments envisage perfect 3D reconstruction of objects and scenes, complete with reflections, shadows, and much more for photorealistic content. This opens up new creative storytelling and design possibilities for computer and video games.



5 Light-field technology opens up new storytelling and design possibilities for computer and video games.

6 xHE-AAC is particularly attractive for use in digital radio or mobile streaming services.



## xHE-AAC INCLUDED IN AAC PATENT POOL

Patent pool administrator Via Licensing adds xHE-AAC to the AAC patent pool.

Extended High Efficiency AAC (xHE-AAC) is the first MPEG audio codec to combine elements of speech coding with audio coding. The codec offers exceptional audio quality at low bitrates, e.g., for mobile applications, while allowing seamless switching to higher bit rates for audiophile users. At lower bit rates, service providers can distribute content more efficiently, while consumers can enjoy high quality audio playback at reduced data usage and therefore less costs.

Previously, the only way for manufacturers to implement Extended High Efficiency AAC technology in their devices was to acquire an additional xHE-AAC license on top of an existing AAC license. Now, Via Licensing has granted all licensees in the AAC patent pool usage rights for xHE-AAC

at no additional cost. Furthermore, manufacturers of Digital Radio Mondiale (DRM) receivers with xHE-AAC technology can benefit from special rates for emerging markets formerly only available to AAC licensees.

The xHE-AAC codec's fields of application are digital radio broadcasting, streaming on mobile and wired networks, and terrestrial radio. It has already been incorporated into the DRM standard and is currently in worldwide use for DRM broadcasting.

## JPEG XS – VIDEO CODEC FOR TV PRODUCTION

Low-complexity codec enables real-time transmission of videos up to 8K via Ethernet.

A key trend in video production is the adoption of increasingly high-resolution formats such as 4K (UHD-1) or 8K (UHD-2), which also offer wide dynamic range. The result is a massive increase in the volume of image data for transmission. Furthermore, consumers want to use cost-effective standard Ethernet infrastructure rather than dedicated cabling such as SDI. For applications in film, TV, and video, there is a need for a new codec to enable low-latency, real-time transmission of these huge video streams, which require capacities of 3 to 40 GBit/s.

The new codec is aimed at applications in TV production environments, local video networks, KVM extenders, connections for virtual and augmented reality applications, and internal display connections. To this end, we are colla-

borating with partners on the development of a new video codec. Specifications for the codec were compiled in JPEG to safeguard resolution, bit depth, color space, platforms, and robust transmission across several generations of devices. The key focus of JPEG XS – the name chosen for the new format – is specifically on 4K and 8K productions with high data rates.

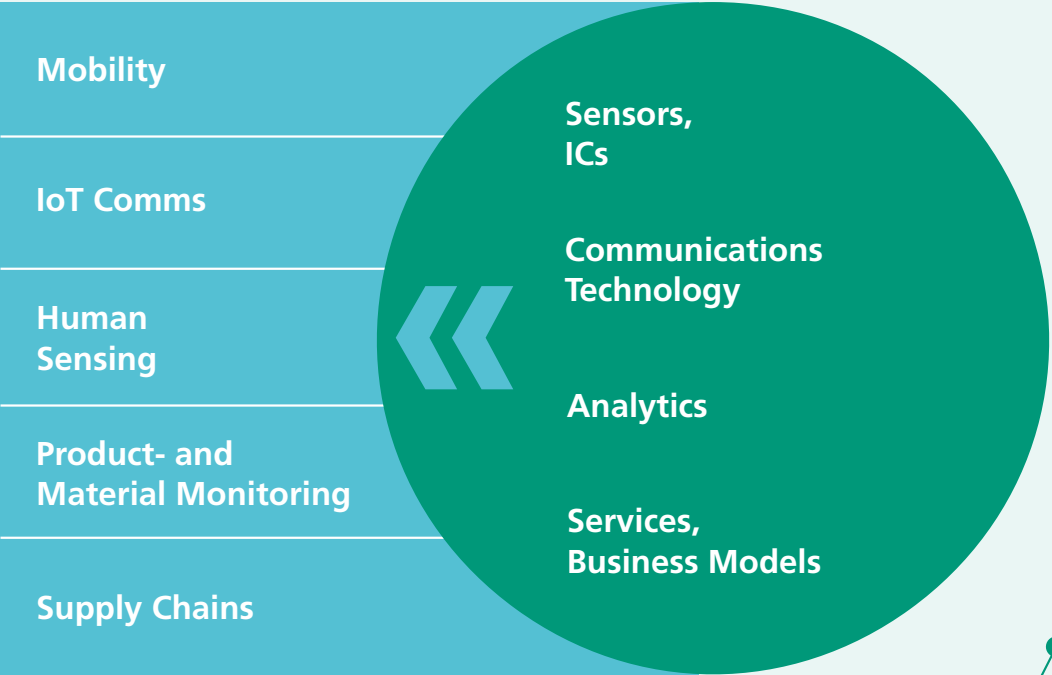
The leading candidates for the new codec were selected from proposals submitted by a wide range of technology companies. The first model implementations of JPEG XS will be released in spring of 2018.

COGNITIVE SENSOR TECHNOLOGIES

“OVERCOMING COMPLEXITY.”

In the context of “cognitive sensor technologies”, the institute researches technologies for sensor technology, data transmission technology, data analysis methods and the exploitation of data as part of data-driven services and their accompanying business models. This adds a cognitive component to the function of the conventional “smart” sensor.

The results of this research have been applied in the areas of connected mobility, communication and application solutions for the Internet of Things, digitalization of human sensing, product and material monitoring, and business analytics in supply chains.



**Professor Albert Heuberger, as executive director of Fraunhofer IIS, you are at the helm of an institute researching sensor technology that is not just able to capture and transmit data, but can also use this data to form conclusions. How does that work?**

**Heuberger:** In many areas, the limits of conventional signal processing technology have been reached. Cognitive sensor technology is primarily about forming conclusions using artificial intelligence. This opens up entirely new possibilities. Sensors are equipped with additional capabilities and enhanced with empirical knowledge about their environment. They are also able to act independently. This helps us to overcome the data’s complexity. For example, besides simply measuring a temperature of 37.6 degrees, a body temperature sensor can also make deductions about the person’s well-being. Today, electronics alone are no longer enough to create a global market leader.

In the near future, we plan to collaborate with industry partners and Bavarian universities to research machine learning methods at the ADA Center. At the Campus of the Senses in Erlangen, we aim to digitalize human sensory perception, including smell, taste, and touch. This too can only be done with cognitive sensor technology.

**Fraunhofer IIS researches cognitive sensor technology in a range of areas across the entire IoT reference chain, including communication technologies and the associated business models. Can you cite any concrete examples?**

**Heuberger:** The results of our research on cognitive sensor technology are already being applied in a very wide range of sectors, in which we would like to continue to specialize in the future. A good example is undoubtedly the field of autonomous driving, where we hope to enhance safety with high-precision positioning and low-latency communication.

Until autonomous driving is adopted on a large scale, we can use Human Sensing to detect whether a driver is becoming stressed or tired. Intelligent sensors can read the driver’s emotions and react accordingly, such as by tweaking driver assistance systems or changing the music. Another area in which we are active is the Internet of Things, where we are working on improved networking, for instance with reliable wireless communication solutions in industrial warehouses; the forthcoming 5G mobile communication standard has an important role to play here. In materials monitoring we are using X-ray sensors such as those in our RoboCT technology to generate three-dimensional images of car body parts in order to form conclusions about the quality of the manufacturing process.

“INTELLIGENT SENSORS CAN READ THE DRIVER’S EMOTIONS AND RE-ACT ACCORDINGLY.”

With a data pool gathered over the course of 20 years at our Center for Applied Research on Supply Chain Services (SCS), we can help companies adapt their business models to the digital age and advise them on appropriate services.

More information on the guiding topic “cognitive sensor technology” is available on the following pages and at this link:

 [www.iis.fraunhofer.de/guidingtopics](http://www.iis.fraunhofer.de/guidingtopics)

# MODULAR SENSOR TECHNOLOGY FOR SMES

The Internet of Things (IoT) presents small and medium-sized enterprises (SMEs) with almost insurmountable hurdles – and widens the digital divide between them and large corporations. This is set to change in the future thanks to a sensor platform that will allow smaller companies to occupy market niches in the IoT sector and to hold their own against international competitors.

“Life is so unfair,” many a younger sibling must have thought watching their older brother get much more pocket money, afford much more, and generally enjoy far greater opportunities than his younger brothers and sisters. The staff of smaller manufacturing companies must feel the same from time to time: Small and medium-sized companies often struggle to compete with the big players. This is especially true when it comes to the extremely powerful, smart, and networked systems that customers increasingly demand, as such systems are usually only needed in small volumes and for highly specific applications. They typically also call for highly integrated technical solutions, in these circumstances, standard semiconductors are of little use.

## **SMEs often lack the necessary venture capital**

However, SMEs often lack the necessary funding to develop specialized technologies – that is, they have barely any venture capital. Developing a high-end product based on new technologies will quickly swallow up 20 million euros or more, and it can easily take up to four years for the finished product to reach the market. This is a long time that SMEs typically

### AT A GLANCE

- 1 | It is difficult for smaller companies to compete on the IoT market.
- 2 | In the future, SMEs will be able to order customizable sensor nodes quickly and cheaply via a Universal Sensor Platform.
- 3 | Smaller companies will receive easy and affordable access to advanced microelectronics technologies and new markets.

1 The modular system paves the way for SMEs to enter the Internet of Things.

**Tactile Internet »**  
*The next leap in innovation in terms of the interaction between humans, machines, and systems: Applications controlled via the Internet respond in real time – in other words, in under a milli-second.*

can't afford – after all, the product can only generate revenue once it goes on sale. The resources available to SMEs are on a totally different scale, averaging around half a million euros to develop a new product, with development times limited to five or six months.

Furthermore, the staff of small and medium-sized enterprises often lack the necessary microelectronics expertise to keep up with trending technologies associated with the Internet of Things and the Tactile Internet. Often SME staff also have only very limited access – if any – to expensive design software. This is illustrated, for example, by the customers of the semiconductor manufacturer GLOBALFOUNDRIES, which supplies state-of-the-art systems-on-chips (SoCs) – that is, integrated circuits on a semiconductor substrate.

The majority of the company's customers are abroad, with only a handful in Germany or Europe, and none of them are SMEs. In other words, to create intelligent products and meet the needs of the market, German and European SMEs rely above all on off-the-shelf microelectronics products. This cannot be a permanent solution if the companies hope to remain competitive on the international stage.

**Rapid change in the semiconductor industry is creating a digital divide**

SMEs are in need of urgent assistance, as the information and communication technology sector and semiconductor industry are undergoing rapid and dynamic change. One example is the Internet of Things, which seeks to network real and virtual objects so that they can work together. The Internet of Things is intended to support people imperceptibly in their everyday activities, operating in the background without attracting attention. One option here is wearables – miniaturized computers that are incorporated into clothing and use sensors to record data such as the wearer's pulse or the number of steps they have taken so far that day. The hurdles SMEs are facing threaten to create a "digital divide" in the corporate sector, as stated by the Commission of Experts for Research and Innovation (EFI) in its annual report in January 2017. On the other hand, the transformation currently taking place is an opportunity to turn value chains upside down, as the IoT market is not yet divided, unlike the smartphone market, for example.

**A modular system for sensor nodes allows SMEs to participate in the market**

How can SMEs seize their opportunity and survive this transformation? The only answer is for them to supply powerful, highly integrated, specialized solutions for next generation products. These solutions must allow a high chip packing density on the one hand and require little energy on the other. But what exactly does that mean? How can the development times for new products like these be shortened to half a year while also bringing the costs down

**“WITH OUR MODULAR SYSTEM, SMES CAN OCCUPY NICHEs AND COMPETE WITH LARGE COMPANIES.”**

to around half a million euros? In other words, how can the looming gap between SMEs and large companies be bridged?

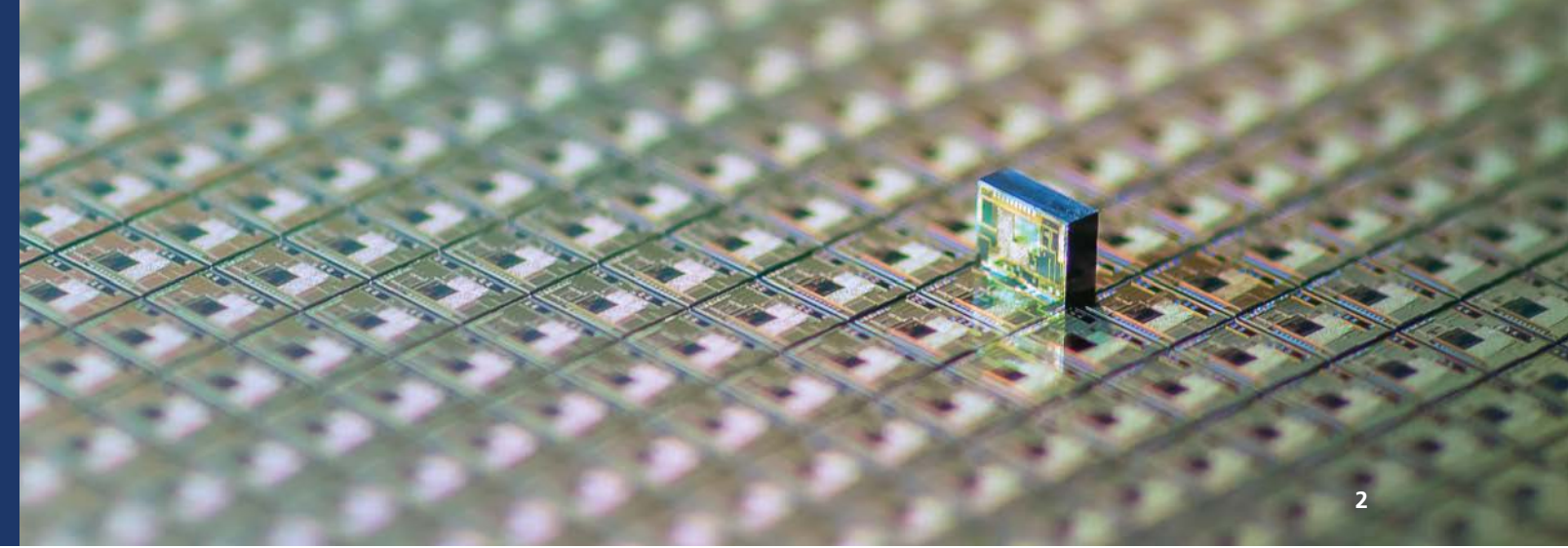
These questions are the focus of a joint initiative that we have launched with GLOBALFOUNDRIES. The initiative seeks to make it easier for SMEs to access advanced technologies and corresponding system integration technologies, enabling them to participate in the market springing up around the Internet of Things. The Universal Sensor Platform (or USEP) project's participants include not only our own Engineering of Adaptive Systems EAS division but also the Fraunhofer Institutes for Photonic Microsystems IPMS, for Electronic Nano Systems ENAS and for Reliability and Microintegration IZM, as well as the semiconductor manufacturer GLOBALFOUNDRIES. The state of Saxony and the European Union are providing around 18 million euros of support for the project under the auspices of the European Regional Development Fund (ERDF).

The project centers around modular technology that we are making available via a sensor platform. But what exactly does the term "sensor platform" mean? Broadly speaking, this is a technological platform that allows even small suppliers to meet the growing development and manufacturing requirements of next generation electronics. Just as car manufacturers provide a website – which experts call a "web front end" – where customers can tailor their vehicle to their own requirements, this modular system allows customers to assemble their own sensor nodes. The whole process is similar to ordering a car. As a result, not much engineering work is required, and there is no need for in-depth specialist knowledge on the part of SME staff.

The customers don't simply receive a system-on-chip (SoC), such as those already supplied by semiconductor manufacturers. These chips alone are not much use to smaller companies, which lack the time and specialist knowledge required to develop them into a corresponding product. Rather, we offer a sort of "all-round-satisfaction package": a completely finished – and tailor-made – sensor node made up of various elements. The first of these is the SoC, which is based on a GLOBALFOUNDRIES technology known as 22FDX, followed by a range of sensors from different manufacturers, as well as a power supply, a radio interface, and/or wired interfaces – that is, communication technology that communicates with the outside world either wirelessly or via a cable. Customers tell the system what they need from such a sensor node and receive suggestions as to how these requirements can be met.

Together with a third partner from industry, Fraunhofer and GLOBALFOUNDRIES plan to found a company that will use this information to produce an initial prototype of the sensor node and that can also supply volumes running into the millions if necessary. Moreover, all of this will be achieved at a reasonable cost and within a few months. In the interests of

**« System-on-Chip (SoC)**  
*The functions of a microelectronic system are incorporated into a semiconductor chip.*



carefully taking demand into account, we are currently looking for companies to contribute their ideas. We then aim to have the first prototype ready in 2019.

#### What are sensor nodes actually used for? A few examples ...

However, before we take a more-detailed look at the benefits this modular system offers for SMEs, let us first consider what SMEs actually use sensor nodes for. The diverse range of applications includes multisensor solutions in the areas of production and home automation, using everything from simple sensors to highly powerful image processing systems. Let us take a large office complex as an example. If corresponding sensor nodes are fitted to the building, they can record data relating to air quality, temperature, and the number of people in the rooms – and if necessary can adjust the air conditioning accordingly. They can also optimize the elevators, for example: If the sensor nodes record the number of people in each location, or the direction in which they are moving, and relay this data to the elevator control system, the elevators can be operated more efficiently.

Another example can be found in the field of robotics. Nowadays, many of the robots working alongside human employees in production facilities have a sensitive “skin”. They use this to detect when they touch a person – and stop their movement for safety reasons. Using cameras, they can also detect when a human hand moves into their field of action. However, the scope of this detection system has so far been very limited, for example, it is difficult for a robot to look around the corner as it moves through the room. Using intelligent sensor nodes that communicate with one another wirelessly, it would be possible to provide systems of this kind with more information and to design working environments better. These are just a few examples of where sensor nodes can be used.

#### Contract handling and legal requirements are also being clarified

Let us now turn our attention back to sensor nodes. The platform not only makes it easy to assemble customized nodes, but also takes over almost the entire process of contract management and negotiations with suppliers on behalf of SMEs. This is a laborious task that smaller companies would struggle to cope with: Just to obtain the components for SoCs, they would have to sign numerous contracts with different suppliers and purchase the corresponding licenses at considerable cost. Now this contractual burden is no longer something smaller companies have to deal with.

Another advantage of the sensor nodes is that they feature a high-performance miniaturized computer that performs all of the necessary calculations. There is therefore no longer a need for direct access to external clouds or fogs, as with existing sensor nodes, in order to store

and analyze the data streams. Instead, all of the necessary calculations can be carried out directly on the node. The security aspect is also extremely important to us as we develop the sensor platform. It will use state-of-the-art encryption technologies and meet the strictest security requirements. As a result, the sensor platform allows smaller companies to find their niche within the IoT sector and thereby to compete with large companies. ■

**2** Companies receive not only SoCs but also tailor-made sensor nodes.



[www.iis.fraunhofer.de/usep-en](http://www.iis.fraunhofer.de/usep-en)



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## SOUNDS DETECT MACHINE WEAR

Acoustic condition monitoring of production systems with intelligent sensors.

In today's production facilities, information from sensors is already used to monitor machines and systems. Until now, this condition monitoring has relied primarily on structure-borne noise signals, whereas measurements of airborne sound waves for this purpose are virtually unheard of. Although microphones could be used to record operating noise from systems to determine whether they are operating without irregularities, this approach is fraught with problems as a result of normal ambient noise.

At our EAS division in Dresden, we are therefore collaborating with numerous industrial partners and the Fraunhofer Institute for Digital Media Technology IDMT to develop an affordable, easy-to-operate platform with versatile applications as part of the ACME 4.0 project. The platform will pave the way for acoustic monitoring in both industrial and mobile applications and is based on our own IC solution, which is fitted to sensor systems that are then used in combination with complex signal processing algorithms. There are also plans to take advantage of both energy harvesting and totally wireless communication.

A compact construction and high energy efficiency aim to ensure that the sensor system can be integrated into production facilities and mobile applications easily. The hardware can also be quickly adapted via software in order to open it up for additional use cases. To ensure that the solution can be applied in as many areas as possible, the project's demonstrators are chosen to cover a wide range of frequencies.

Our work on the project centers around designing a dedicated hardware front end for recording microphone signals, as well as the development of signal analysis algorithms. The focus here is on designing an integrated sensor-reading circuit complete with analog-to-digital conversion. The project will also benefit from our existing experience in the implementation of condition monitoring systems for machines and other equipment, as well as the associated signal-analysis and data-processing algorithms. The aim is to explore new methods of event and condition detection and to adapt these to the project's requirements.



**3** Acoustic condition monitoring can be used to check the operability of an axial piston pump in a digger.



## WIRELESS INDUSTRIAL BUILDINGS

Delivering reliable and wireless communication in industry with a standardized test method.

Because of their mobility, it is difficult to connect driverless transport vehicles and rotating parts to a network via cables. To facilitate an efficient production process within the context of Industry 4.0, wireless communication is essential for linking up areas that previously could not be reached using wired solutions.

Industrial companies are already investing in network planning and connectivity, but there is still no standardized procedure for assessing the suitability of a wireless solution for specific application scenarios. A standardized assessment system is required so that development companies and customers can rely on a wireless communication solution to meet all their requirements even in critical use cases. In industrial buildings, for example, different wireless transmission standards or unwanted emissions from machines can cause interference, which can ultimately lead to production downtime in the worst-case scenario.

The RelCOvAir (Reliable Industrial Communication Over the Air) project aims to develop standards, methods, and test instruments that can be used to demonstrate the potential for reliable and wireless communication in an industrial environment. Industrial companies benefit from a standardized selection process for wireless technology that perfectly matches their specific use case. In turn, manufacturers of wireless solutions can design and evaluate their system better according to standardized criteria and can compare competing solutions with their own system.

The use of RelCOvAir solutions allows wireless radio systems for industrial applications to be assessed and selected according to standardized testing criteria at an early stage. This results in greater flexibility in the use of machinery while also reducing the total installation costs, as there is no need to install cables.

In this project, we are conducting research together with partners from Finland and Spain. This collaboration at the European level helps us to take account of country-specific differences in the relevant industries and allows the project to incorporate different ways of thinking. Accordingly, the overall results are less prone to error, and the project's outcomes are relevant to companies operating worldwide.



**4** RelCOvAir will enable industry to overcome uncertainties affecting the use of wireless communication in manufacturing processes.

# THE IOT ENTERS THE WORLD OF INDUSTRY

Companies look to the Internet of Things (IoT) for reliable solutions that can be retrofitted to their applications. In an interview Dr. Günter Rohmer, head of the Positioning and Networks division, explained the key objectives for the IoT in industrial environments and set out the next milestones on the path towards Industry 4.0.

The much-discussed digital transformation in industry not only results in the construction of completely new production facilities, for which fully automated digitalization scenarios are designed. Digital transformation is also currently taking hold in existing production facilities and industrial and logistics environments, where existing specialist expertise in production is being put to use in order to make it available digitally for networked processes. However, many companies still lack technologies that allow either the successive linking up of production with digital processing steps or subsequent expansion.

Above all, highly specialized small and medium-sized companies frequently complain about the lack of suitable, secure technologies and solutions that can be retrofitted. This requires solutions as quickly as possible in order to prevent the high-tech nation of Germany, and Europe as a whole, from falling behind. In the era of the IoT, we are rising to this challenge. Under the leadership of Dr. Günter Rohmer, our Nürnberg site pools various development and technology offerings for applications in the Industrial Internet of Things (IIoT). With more than 170 scientists and engineers on-site, Rohmer's teams are working on practicable, retro-fittable positioning, identification, and networking technologies for cognitive sensor systems – the key components for industrial and non-industrial IoT applications. Other key topics

## AT A GLANCE

- 1 | Over 170 people at the Nürnberg site are carrying out research into positioning, identification, and networking technologies.
- 2 | Positioning systems play a key role in the Industrial Internet of Things.
- 3 | The aim for 2018 is to drive forward positioning and networking technologies in production and logistics.

1 Dr. Günter Rohmer is head of the Positioning and Networks Division.



2 With wireless MIOTY technology, sensor data can be transmitted over distances of up to 15 kilometers.

rounding off the Nürnberg site's portfolio include networked sensors and edge computing developments that record, analyze, and supply data precisely where it is needed – instead of sending it straight to the cloud.

In the Test and Application Center L.I.N.K., we also offer customers and partners the ideal conditions for the practical development and testing of new cognitive solutions for production and logistics.

**Dr. Rohmer, what sort of development requests are you currently receiving from companies?**

**Rohmer:** Many requests from industry focus on technologies that can easily be retrofitted and integrated into existing systems. In the industrial setting, this isn't about data capture in the sense of "big data" where the objective is to generate and collect as much data as possible and then process it in the cloud. In the Industrial Internet of Things, the question for companies is how to record the right data in the right place and at the right time. For this, you already need initial decision-making and/or analysis steps at the point when data is recorded, in order to reduce latencies and keep the data within the company.

**What sort of technical expertise do IIoT applications primarily call for?**

**Rohmer:** Without precise information about the location, time, and production batch, a lot of data cannot be relied upon in communication or the networking of downstream processes. That's why positioning technologies are of vital importance. Here at the Nürnberg site, we offer positioning expertise for everything from satellite-based positioning to accurate positioning in indoor applications. This expertise allows us to provide assistance systems for automated transport systems or intelligent tool tracking by combining various technologies into sensor fusion processes, for instance. The networking, or rather the communication, operates across wireless sensor networks, for example, and adapts to existing infrastructures.

**What technological approaches are currently at the forefront of development?**

**Rohmer:** At the moment, we're seeing a lot of demand for condition monitoring in indoor and outdoor applications. With our MIOTY technology, we offer a wireless transmission system that can transmit sensor data over long distances – several kilometers, for example – in a robust and reliable manner. MIOTY can be used to network several hundred thousand sensors and to relay data for the purpose of further analysis and regulation. The MIOTY

**"IN THE INDUSTRIAL INTERNET OF THINGS, THE QUESTION FOR COMPANIES IS HOW TO RECORD THE RIGHT DATA IN THE RIGHT PLACE AND AT THE RIGHT TIME."**

protocol is currently undergoing standardization for low-power wide area networks by the European Telecommunications Standards Institute (ETSI). The decisive advantages of MIOTY technology also make it interesting for many cloud operators, as well as a wide range of other service providers. For example, it's currently part of the early adopter program for services in the Microsoft Cloud. In particular companies that deal with predictive remote maintenance and that are planning new applications in this area are taking advantage of this efficient networking technology's potential.

**Particularly in the areas of intralogistics and assembly, companies are keen to use digitally networked technologies to handle the management and provision of the correct components at the assembly stand. Have you been putting any solutions of this kind through their paces?**

**Rohmer:** In terms of networking, we also work with wireless sensor technologies. In this context, sensor tags can be fitted to a wide range of objects, such as containers. The sensors use our s-net technology to connect to one another in so-called self-organizing multi-hop meshed networks: If a transmission path or partner is unavailable or connections are too weak, the intelligent sensor tag looks for the next available partner. In line with the concept of an intelligent object, the sensor tag can also already make decisions or conduct analyses independently. A pioneering application of this kind of sensor network is in intelligent container management in intralogistics and interlogistics. One practical example that has already been implemented is mobile picking systems, here, containers can be arranged on a flexible basis. The intelligent sensor tag ensures that the overall system always guides the operator to the correct container for the relevant assembly components. If you combine this with an additional technology such as inductive near-field positioning, for example, the system can also detect the fill level and the exact nature of the contents. The container can therefore initiate the refilling process autonomously.

**Are you currently trialing your technologies in any other areas with a view to practical applications?**

**Rohmer:** Yes, as a division specializing in accurate positioning technologies, we are currently studying and developing practical solutions in order to record machine, object, and vehicle movements as accurately as the application requires and to provide this data in a suitable form for further networking and analysis processes. This includes efficient planning of the transport fleet both inside and outside the building. However, to allow the rapid and correct delivery of assembly parts or machines, we also equip industrial trucks with our positioning technologies. For example, the position of forklift trucks can be determined using the stand-alone wireless LAN positioning capabilities of the awiloc technology developed by



Fraunhofer IIS. This ensures not only the availability of suitable trucks, but also optimized and reliable routing in production and logistics. However, this is another area where alternative approaches are also possible: Ultra-wideband technology can be used to guide the forklift truck to the precise pallet position – in combination with optical methods such as infrared, video, and many others. In this regard, it's particularly important to us when implementing digital technologies to ensure precise adaptation to the application in question and to provide scope for expansion, but not to overload applications with too much technology from the outset.

### **“WE’VE CARRIED OUT LIVE TESTING OF THE POTENTIAL OF NETWORKED DIGITAL ASSISTANCE SYSTEMS DURING ASSEMBLY.”**

***You’ve already presented several scenarios from a technological perspective. Are there any specific research or pilot projects relating to these scenarios?***

**Rohmer:** This year we’ve already completed several projects with industrial partners and carried out live testing of the potential of networked digital assistance systems during assembly. In collaboration with BMW AG, our network box for intelligent tool tracking was fitted to several workstations where production staff use hand-guided screwdrivers. The technology was connected to the existing infrastructure at a pilot line at the Regensburg factory. A display on the screwdriver indicates to the production staff whether all operations have been executed. Further stages of expansion are conceivable, potentially including transparent verification for safety-relevant steps of the process.

We’re also currently working on research and development projects with Siemens with a view to integrating positioning and networking technologies into the engine assembly process. In addition, we have many industrial partners who already rely on our cognitive sensor technologies in a wide range of scenarios.

***Dr. Rohmer, if you look ahead to the future, what are the next key milestones on the successful path towards Industry 4.0 from a technological development perspective?***

**Rohmer:** From our discussions with customers and the numerous user workshops and forums, it’s clear that companies are acknowledging the need for digitalization in their

production processes. Generating widely available knowledge, establishing partly digitized processes, and having the conviction that it’s possible to achieve considerable efficiency improvements in this context are clear objectives for the next five years in the management and planning departments of companies, be they small or medium-sized enterprises or large corporations. I therefore think we’ve put the most important prerequisite in place by adopting an approach based on technologies that can be combined with one another and that mirror the human system of perception – recording and selecting important data in the right place, making it transparent, and then feeding it back into the process. This approach can then be implemented within partly or fully automated networked environments and translated into new services. Without this technological basis, it will be some time before the Internet of Things finds practical applications in the industrial setting, and there will be delays in the implementation of many ideas surrounding new services, distributed working, and business development in the industrial cloud.

***What do your teams have planned for 2018?***

**Rohmer:** In 2018, we’ll continue forging ahead with the work we’ve begun on positioning and networking technologies. With this in mind, we’ll present new examples of how cognitive systems can be used in production and logistics. In addition to our standardization activities for industrial communication systems in the context of MIOTY and our activities relating to 5G, there are also many points of contact in this area that can help us make the Industrial Internet of Things a reality in collaboration with our industrial partners. ■

**3** Test and Application Center  
L.I.N.K. at the Nürnberg site.



[www.iis.fraunhofer.de/iiot-en](http://www.iis.fraunhofer.de/iiot-en)



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## SMART MEASURING STATIONS FOR A BETTER CLIMATE

In the Ensiro project, smart sensor networks monitor and transmit various types of environmental data.

Fine particulate matter, ozone, nitrogen oxides, and other harmful substances lead to serious environmental pollution. It is therefore prudent to conduct reliable monitoring of air quality both indoors and outdoors on an ongoing basis. Our Application Center Wireless Sensor Technology in Coburg is developing a system – consisting of sensors and a digital platform – that collects the environmental data, transmits it wirelessly, and makes it available to a wide range of target groups. The application-specific sensor networks serve as a basis for the development of further analysis procedures and of heuristics to determine and improve data quality. We are also developing various demonstrators for data collection: Networked using the MIOTY wireless technology developed by Fraunhofer IIS, the stationary EnsiroAmbit for indoor and outdoor applications collects data in order to determine

air quality and calculates the pollutant concentration or residence parameters, for example. There is also a version that is suitable for use on public transport vehicles. The mobile EnsiroGo device is so compact that private individuals can attach it to a backpack, handbag, or bicycle and thereby make a valuable contribution to the comprehensive recording of environmental data, which is of great use in weather forecasting, climate research, town planning, and environmental protection.

4 Private individuals can attach EnsiroGo to a bicycle, for instance, to collect environmental data.

## SELF-SUFFICIENT TRACKING SYSTEM

Energy from the environment provides a long-lasting energy supply for sensor tags in tracking systems.

In the Daedalus project, our positioning, navigation, and energy management experts and the DFKI Robotics Innovation Center have combined satellite-based navigation (with relative positioning in wireless sensor networks) with a technique known as energy harvesting that supplies energy to tracking tags.

In April 2017, Daedalus experts gave a live presentation of the results to the project's sponsors and participants, and the tracking tag is already being optimized and tested for industrial applications and logistics scenarios. The tracking components have a modular structure and can be adapted flexibly to suit potential application scenarios. Depending on requirements, the tracking module can be equipped with a wide range of energy converters, such as solar

cells, thermoelectric generators, and vibration harvesters. Energy harvesting can be used to obtain small quantities of electrical energy from the environment. Depending on the environmental conditions, the maintenance costs for battery replacement in positioning and data transmission are very low, so that the tags can achieve unlimited operating times.

 [www.iis.fraunhofer.de/entras-en](http://www.iis.fraunhofer.de/entras-en)

5 For example, energy harvesting allows containers to be tracked without generating maintenance costs.

## INTELLIGENT TOOLS IN ASSEMBLY

A smart electric screwdriver assists production-line staff at BMW.

New cars can be purchased with any number of custom add-ons, such as entertainment equipment or heated front seats. This forces staff on the manufacturer's production line to adapt to new screwing profiles on a minute-by-minute basis.

An intelligent electric screwdriver equipped with our algorithms can help staff achieve the correct execution. A prototype of the system is currently being tested at the BMW Group's Regensburg factory, where, for each car on the production line, staff receive individual feedback on whether all screwing operations have been executed correctly. The software can analyze the direction, number, and correct movement of screws in real time.

This development is possible thanks to an inexpensive sensor fusion process in which the electric screwdriver's rotational speed, acceleration, and directional information are combined and characterized together in real time, and this tracking information is reconciled with existing parameters. If the values coincide, the employee can be informed directly on-site via an LED display whether all screw connections have been properly executed. "It's important to us that, wherever machines don't or can't take on high-precision tasks, we also give employees in digital production as much support as possible through digital assistance systems," explains Jonathan Röske, project manager for innovation, digitalization, and industry 4.0 at the BMW Group. "This test phase serves to precisely analyze, together with our production employees, which figures must be used for quality assurance."

In the future, it may also be possible to combine the tool with a positioning system. For instance, the specific screw hole or screw connection could be allocated on every workpiece. Furthermore, certain processes can be documented as needed and coordinated by digital assistants for timely optimizations or adjustments.

 [www.iis.fraunhofer.de/magazin/tooltracking](http://www.iis.fraunhofer.de/magazin/tooltracking)

6 Intelligent tools improve quality in assembly. An inside view of the BMW Group's factory in Regensburg.



## STEINWALD ALLIANCE – A DIGITAL VILLAGE

Local amenities, mobility, and health: exploiting the potential of digitalization in rural areas.

Digitalization affects not only businesses but also everyday life. Yet how visible is this development in rural areas, and what form does it take? Digitalization has great potential to improve access to local amenities, mobility, and healthcare in rural areas.

This also happens to be the aim of the Digital Village project, which has been funded by the Bavarian State Government since April 2017. In the Steinwald Alliance in the Oberpfalz district, our Center for Applied Research on Supply Chain Services SCS is working with the Fraunhofer Institute for Experimental Software Engineering IESE to develop a “mobile village store” that will provide access to local amenities in remote parts of the municipality. At the heart of the mobile village store is a platform that links up residents, producers, and a brick-and-mortar village store. The platform forms the basis for a series of applications, such as an online shop for ordering products, an app for managing stock, and a route-planning app.

The platform is complemented by a sales vehicle that travels to parts of the municipality lacking local amenities. The vehicle carries a basic range of everyday goods, with a particular focus on regional products, as well as goods ordered in advance. At least as important as the operational infrastructure of the mobile village store are its economic viability and acceptance by the local community. For this reason, care has been taken since the very start of the project to develop a sustainable business model. A roadshow was also held to ask residents about their needs in relation to the mobile village store, and all households have been surveyed with regard to Internet use and shopping habits.

The mobile village store will go online – and hit the road – in mid-2018. In parallel, we are already working on further applications aimed at improving everyday life in the Steinwald Alliance, such as a digital village communication system for sharing information and providing assistance, or a digital housing advice service.



7 The digital village in the Smart Services themed area at our open innovation laboratory JOSEPHS®.



## INTERFERENCE-PROOF POSITIONING OF DRONES

The Galileo PRS ensures tamper-proof tracking of drone flights on behalf of emergency services.

The police, fire, and rescue services are gradually beginning to use unmanned drones in their operations. In order to monitor critical infrastructures, mass meetings, or political events, drones can fly along predefined routes, for example, in order to supply aerial imagery and a better overview of the situation. If operations of this kind use only the conventional satellite-based GPS positioning system, the signal is vulnerable to tampering using interfering transmitters known as jammers and spoofers.

In collaboration with Airbus Defence and Space, we have developed the Spoofing Resistant Unmanned Aerial Vehicles (SORUS) concept, which allows government-authorized users of the Galileo Public Regulated Service (PRS) to equip drones with a secure, tamper-proof system. The Galileo PRS is a highly protected, encrypted service for satellite navigation applications. The Public Regulated Service offers high security standards for civilian users to ensure tamper-proof positioning.

Conventional PRS receivers, complete with a security module, are typically too large and consume too much power to be used in drones. In the SORUS concept, the security-relevant PRS processing steps are outsourced to a secure environment. Prior to the planned operation, the sequences required for PRS access are optimized, precalculated, and then uploaded to the drone. The drone therefore only receives the data it needs for its mission, so that it can use the PRS without a security module.

“The SORUS system makes it easier for public institutions to use the Galileo PRS. It can act as a door-opener for applications that would not be feasible using a conventional PRS receiver because of its weight, size, or price,” says Alexander Rügamer, group manager Specialized GNSS Receivers at Fraunhofer IIS.

In November, Alexander Rügamer and Dr. Jan Wendel were awarded the Overall Prize in the European Satellite Navigation Competition 2017. With SORUS, they also won Best Project from Bavaria in the Bavaria Challenge and the PRS Special Prize.

8 Tamper-proof positioning applications are possible using the European satellite navigation system Galileo and the Public Regulated Service.



# X-RAY TECHNOLOGY DEVELOPS INTO A COGNITIVE SENSOR

Of the systems capable of monitoring large components such as whole car bodies, none have so far been suitable for an application for series production. Now, with RoboCT, we can inspect these components quickly and accurately. At the same time, this robot-based computed tomography (CT) system also represents the first step towards cognitive sensor systems in this field. In addition to applications in the automotive and aerospace industries, the system is to be used, for example, to inspect the condition and completeness of returned goods ordered online – without having to open them.

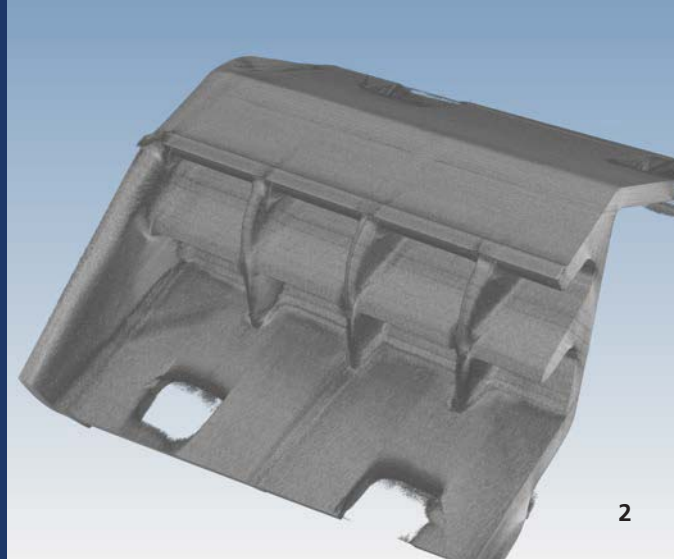
The door to the X-ray cabinet closes slowly, a quiet click signaling that the cabinet is securely locked. Wolfgang Holub, an engineer and scientist at our Development Center for X-ray Technology EZRT takes his place at the computer connected to the system and starts an X-ray measurement process with a few clicks of the mouse. As the X-ray cabinet has no windows, he keeps a watchful eye on a monitor showing a live image from inside the locked cabinet. The sizable component we see on the screen – a section of vehicle bodywork – measures around two meters wide and one and a half meters tall and deep and is securely tied to a pallet using ratchet straps. Two robotic arms, equipped with an X-ray source and detector, carefully approach the large component, one from the left and one from the right of the bodywork. After a second's pause, the robotic arms move further around the part in total synchrony and with the utmost precision. "Right now, the robots are taking 2D X-ray images," says Holub. "This already gives us a clear picture of whether there are any irregularities in the structure of the bodywork. If part of the component shows any such irre-

## AT A GLANCE

- 1 | RoboCT allows time-saving inspections of large components, such as car bodywork or aircraft wings.
- 2 | Cognitive monitoring systems provide information used to optimize production processes and to reduce the number of rejects.
- 3 | We are working on a robot-based digitalization center to improve the efficiency of returns management in online retail.

1 Robot-based CT systems are able to inspect large components quickly and accurately.

## X-RAY DEVELOPS INTO A COGNITIVE SENSOR



**2** 3D CT – a volume rendering of the nested structure in the lock area of the tailgate.

**3** A cross-sectional view of an irregular section of the tailgate with an air pocket measuring approximately 2 millimeters.

**4** A cross-sectional view of an irregular section of the tailgate with a pore measuring approximately 0.8 millimeters.

gularities, the system can automatically perform a highly specific CT scan in 3D.” Holub stops the measurement process and makes a few manual adjustments in order to demonstrate the process involved in 3D CT. Shortly afterwards, the monitor shows the robotic arms adopting a new position altogether. The robots are now revolving around the point where we suspect there to be an irregularity. During their 180° rotation, the arms pause about once a second to capture an image. “This approach allows us to create 3D CT scans that give us far more information than two-dimensional X-ray images,” Wolfgang Holub explains.

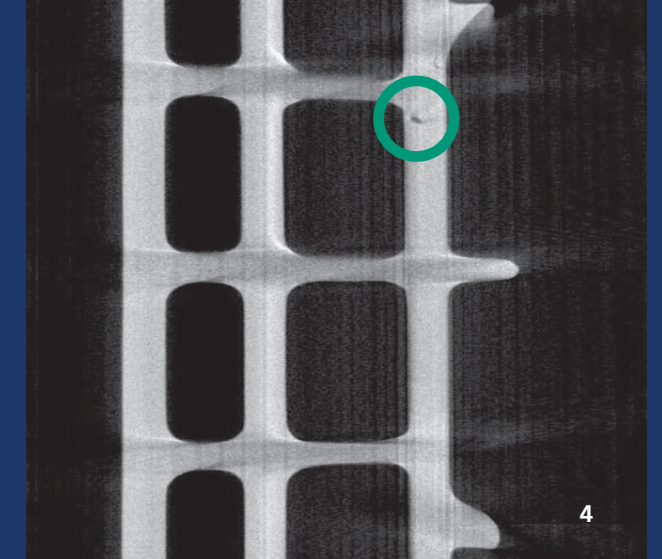
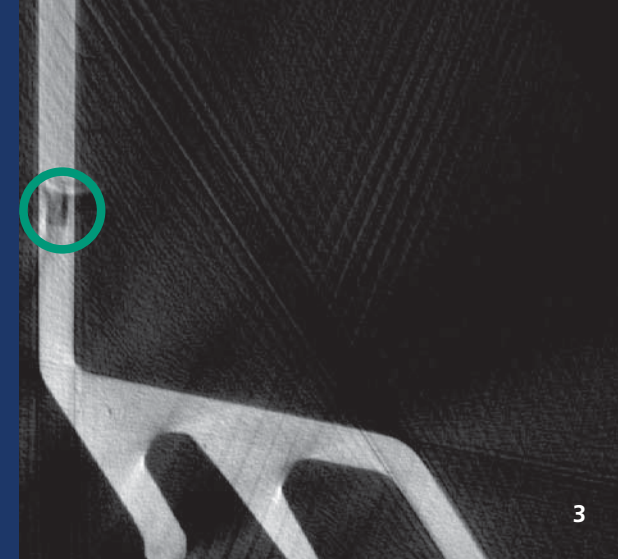
### Flexibility on a completely new level

First things first, however: What is so special or novel about this technology? After all, two-dimensional X-ray inspections have been the state-of-the-art tool of choice in industry for many years. X-ray techniques can even be applied to relatively large objects, such as alloy wheels or cylinder heads, by running through a series of inspection positions and perspectives using a device known as a manipulator.

In practice, however, inspection methods of this kind could only be applied to objects of limited size and geometric complexity. For larger components, such as the vehicle bodywork in our example, none of the existing systems are suitable for series inspection, let alone integration into the production process – and certainly not for complete 3D CT scans. The tests can only be conducted under laboratory conditions, at considerable expense, and at a small number of institutions, such as the laboratories of the Fraunhofer Development Center for X-ray Technology EZRT. It is only thanks to the capabilities of RoboCT – which uses large industrial robots to move the X-ray hardware – that it is possible to plot an automatic inspection procedure in which the component is inspected in a few seconds or minutes, depending on the inspection task, and hard-to-image sections or regions with unclear findings are analyzed in detail using computed tomography. In the example application of a cast aluminum tailgate for a car, such regions might include the area around the door lock, which has a nested structure.

### A focus on intelligent monitoring

However, the robot-based CT scanner described here is just the tip of the iceberg. Led by Professor Randolph Hanke, the team at the Fraunhofer Development Center for X-ray Technology EZRT still has a lot of work to do – and the key concept is “intelligent monitoring”. In the future, this will no longer simply be about making an OK or not OK decision. Rather, our aim is to provide customers with a monitoring system that helps them to optimize their processes.



The term “process” by no means refers exclusively to the classical production process. It also encompasses material development, design, maintenance, trading, and recycling processes. “Based on this, the focus of our research efforts is shifting. We’re now increasingly focusing on the development of cognitive and auto-adaptive sensor systems,” Professor Hanke explains. “Advances in the area of robot-based computed tomography make these aims considerably more accessible,” he adds.

### “Big data” under control

Nowadays, faced with huge volumes of available data, the aim is to use learning algorithms to extract information that can be used to achieve something – that is, to better understand, observe, or design processes. However, when we talk about big data today, we are almost always referring to factory data, logistics data, cost data, machine data, and so on. Until now, what is termed “smart materials data” has barely featured in discussions about big data. “In the future, materials and products will be monitored throughout the value chain – that is, over their entire life cycle from raw material to use and finally recycling – in order to examine the changes that take place whenever humans, machines, or the environment alter the material or product in some way. Moreover, in the future, we won’t measure material data indiscriminately or in its entirety. Instead, we’ll only record the relevant data, and it’ll be for the intelligent measurement system – the cognitive sensor system – to decide which data is relevant or smart. These are the research and development tasks for non-destructive monitoring that we’re very familiar with as experts in non-destructive testing and that we know harbor enormous potential,” Professor Randolph Hanke explains.

### The intelligent black box

In the future, we can imagine a scenario in which an intelligent monitoring system – a type of “black box” – is delivered to customers, who need not give it much thought or indeed have any knowledge of non-destructive testing whatsoever. The box might contain robots with access to different sensor systems, for example, and these robots would decide for themselves, in the broadest sense, which method to use. The robot would then select an X-ray system, an airborne ultrasound system, or even a thermal imaging system to solve a highly specific problem – instead of simply carrying out an inspection.

### Protecting the environment and saving money – robot-based monitoring in retail

At the Fraunhofer Application Center for CT in Metrology, which is part of Fraunhofer IIS, we are demonstrating that this vision is anything but far-fetched. In collaboration with

« **Cognitive sensor system**  
An intelligent system of one or more sensors that selects the right modes and measurement parameters for maximum inspection efficiency.

## X-RAY DEVELOPS INTO A COGNITIVE SENSOR



5 Percentage rates of returns in the mid-double figures are presenting e-commerce businesses with an increasingly difficult challenge.

Deggendorf Institute of Technology (DIT), we are planning, as early as 2018, to establish a robot-based digitalization center to improve the efficiency of returns management and the e-commerce sector.

The reasons for this new development are obvious: A study by the German Retail Federation shows that online sales rose by 10 percent overall to reach 48.7 billion euros in 2017, with electronic goods and clothing being particularly dominant among the most popular product groups. To be on the safe side, people often order items in two or more versions, as they can return them easily – and often without paying shipping costs – if they don't fit, if they don't like them, or if the product is damaged. This leads to percentage rates of return in the mid-double figures, presenting e-commerce businesses with an increasingly difficult challenge: At present, most of the returned packages have to be opened by hand in order to check whether they are complete, in good condition, damaged, or in working order, and then to sort them accordingly. Research into product returns shows that returning a package costs mail-order businesses an average of 15 euros due to processing costs and depreciation.

Fraunhofer's Package Return Station is intended to put an end to this situation. This self-learning, robot-based cognitive sensor system consists of a combination of various non-destructive measurement systems, such as X-ray CT, ultrasonic sensors, or thermal imaging sensors, and allows returned packages to be imaged in three dimensions along with their contents. The special thing about this system is that the package need not be opened during this procedure. The volume data is reconstructed, visualized, and analyzed by intelligent software systems and image-processing algorithms – including techniques based on modern artificial intelligence (AI). This fully automatic process identifies wear and imperfections in the goods based on the digital image. In addition, the recorded information is compared with geometric target models, parts lists, and other important product-specific information so that further steps in the returns process, such as automated removal and sorting of the goods, can be initiated in the shortest possible time independently of the operator. This will speed up the entire returns process in the future, allowing e-commerce businesses not only to make considerable savings but also to respond faster to individual customers' requests.

The Package Return Station is not the first project in which we have successfully worked on the digitalization of consumer goods for the e-commerce sector. In collaboration with Mifitto GmbH, a start-up from the Ruhr region, we have also developed the fastest commercially available 3D scanner for shoes, which provides customers with a unique, personal foot ID in a few simple steps. This personal 3D scan can then be compared with previously digitalized shoe models from an existing – and constantly growing – database to find a shoe that is a perfect fit for the foot. In this way, the number of shoe models ordered can be minimized in advance. In addition to the economic consequences, the environmental impact of returns

**“WE WON'T MEASURE MATERIAL DATA INDISCRIMINATELY OR IN ITS ENTIRETY. INSTEAD, WE'LL ONLY RECORD THE RELEVANT DATA.”**

is considerable. With CO<sub>2</sub> emissions of 500 grams per package, transporting Germany's 300 million annual returns produces 150,000 tons of CO<sub>2</sub> emissions – not to mention the congestion on the roads.

In collaboration with Fraunhofer IIS, the Research Center for Modern Mobility at Deggendorf Institute of Technology (DIT) will construct the Package Return Station, put it into operation, and expand it with additional sensors to create a universal digitalization street based on cognitive sensor networks. This will allow the development of novel applications in the areas of mobility, trade, transport, and recycling. ■



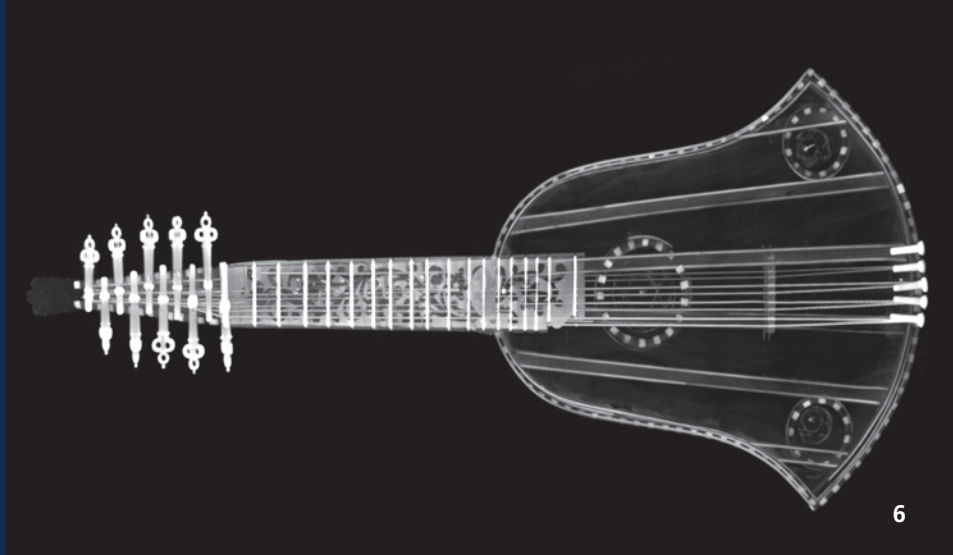
[www.iis.fraunhofer.de/  
roboct-en](http://www.iis.fraunhofer.de/roboct-en)



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## HOW MUSIC HISTORY WAS PRESERVED

3D computed tomography used to digitalize over 100 historically significant musical instruments.

In the last three years, the Fraunhofer Development Center X-ray Technology EZRT has helped to preserve music history. In collaboration with the Germanisches Nationalmuseum (GNM) in Nürnberg and the Chair of X-ray Microscopy (LRM) at Julius-Maximilians-Universität Würzburg, we have digitalized over 100 historically significant musical instruments as part of the MUSICES research project.

The 3D X-ray images not only contain information about manufacturing techniques, hidden structures in the sounding bodies, or the materials used, but also reveal unknown damage such as cracks, delamination, and woodworm. This is invaluable information for professional restorers, musicians, museum educators, and instrument makers. However, we still lack measurement standards that

define the best way of using three-dimensional CT to scan old musical instruments. We have therefore developed guidelines to enable museums around the world to digitalize different types of instruments in the future. A large part of the collections of musical instruments held by museums is kept in underground storage facilities, as there is simply not enough exhibition space to showcase all of them. The CT digitalization project will enable us to make these instruments accessible to everyone.



[www.iis.fraunhofer.de/en/magazin/2017/musices](http://www.iis.fraunhofer.de/en/magazin/2017/musices)

6 X-ray image of a "Hamburger Cithrinchen".

## NO NEED FOR X-RAYS IN FUTURE?

Study confirms the suitability of magnetic resonance imaging (MRI) for diagnosis in orthodontics.

X-ray examinations are a common technique for diagnosing numerous diseases, including in the field of orthodontics. As part of a study using pigs' heads, conducted in collaboration with University Hospital Erlangen, we have shown that MRI can be used just as effectively in many areas of orthodontics as existing standard processes involving ionizing radiation.

MRI procedures are valued for their excellent contrast ratio and complete absence of ionizing radiation. In the study, dentists assessed images from the MRI scanner and compared them with multiple corresponding cross-sectional images (or slices) and 3D reconstructions of pigs' heads produced using the techniques of computed tomography (CT) or cone beam computed tomography (CBCT). Overall, the results showed that the MRI scanner did not

differ significantly from other methods in the majority of parameters. In fact, it scored even better when it came to judging the position of tooth germs. The main clientele in orthodontics are children and adolescents. For this group of individuals, the use of ionizing radiation carries a greater risk of damaging after-effects than for adults.

At the annual conference of the German Orthodontic Society (DGKFO) in October 2017, the team of researchers was awarded the annual prize for their 2016 publication about the study in the Journal of Orofacial Orthopedics.



## TIME IS MONEY!

Upgrade kit allows threefold time saving in industrial computed tomography (CT).

Demand for CT analyses is increasing, and measurements of this kind can take several hours depending on the specific testing application. At the Fraunhofer Development Center X-ray Technology EZRT, we have therefore been working with xray-lab to develop the PolyCT upgrade kit, which can reduce measuring times by up to a factor of three.

Compatible with all standard industrial CT systems, the kit can be put into operation quickly and easily in just a few steps. This allows users to retain flexibility in the CT scanner and to use the upgrade kit on various systems. Despite the kit's simplicity, it provides enormous potential for savings: Measurement series can be performed up to three times faster with PolyCT – even when it comes to challenging tasks such as analyzing objects with poor transparency.

The special thing about this idea is that the upgrade kit integrates into the CT measurement process by purely mechanical means, removing the need for elaborate interventions into the system controller and making it accessible to a wide group of users. The CT scan proceeds as normal, with the difference being that the three samples to be measured each rotate about their own axis. To create a volume data set out of the resulting projection data, we developed the PolyReko software, which automatically ensures optimum image quality at the same time. This produces results in a third of the time that are no different from those of an individual scan.

"The PolyCT kit is clamped into the CT chuck instead of the sample or directly mounted on top of the rotary table using a centering adapter," explains Michael Salamon, project manager at Fraunhofer EZRT. PolyCT is adjusted using a built-in laser liner module, which allows easy alignment of the three rotating centers at right angles to the CT system's central beam.

"The development of PolyCT draws on experience and expertise gained in over a decade of providing industrial X-ray services," says Alexander Brock, Sales and Marketing Manager at xray-lab GmbH & Co. KG. "The PolyCT kit has a wide range of possible applications." Where the system's accuracy permits, the instrument upgrade will also be suitable for metrological tasks and is therefore not restricted solely to non-destructive testing.

7 PolyCT: an upgrade kit for industrial CT scanners.



8

## THE RIGHT NOSE

Human sensory perception goes digital at the Campus of the Senses in Erlangen.

Over five percent of Germans suffer from impaired senses of smell or taste. These disorders are caused by infectious diseases, among other things, and leave them unable to tell, for example, whether milk that initially looks drinkable has gone sour or bad. An auxiliary device, like a “pair of glasses” for the olfactory organ or tongue, would remedy this situation.

In cooperation with the Fraunhofer Institute for Process Engineering and Packaging IVV and Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), we plan to digitally recreate human senses such as sight and hearing, and especially the senses of taste and smell. With the support of machines, it might therefore be possible to enhance people’s conscious awareness of potential risks and dangers in their environment and enable them to respond more appropriately.

As yet, we do not have an adequate understanding of the human senses, especially in terms of how senses such as smell and hearing interact with one another. Do people react differently to images and videos if they are simultaneously exposed to a specific smell? And what happens if the smell changes? The work carried out at the Campus of the Senses in Erlangen aims to answer questions of this kind.

For companies and start-ups in almost every sector, the campus provides an opportunity to develop new technologies and services. In cooperation with Fraunhofer IIS, companies can generate methods and technologies for collecting and interpreting empirical data on the human senses or responses to sensory stimuli.

In the next five years, there are plans to set up three laboratories, each focusing on a different area of research, along with a coordinating office. Thanks to the broad portfolios of the participating research partners, we can conduct joint interdisciplinary research projects in a wide range of subject areas such as engineering, medicine, chemistry, and neuroscience in order to convert human senses into digital form. The aim is to work with industry to develop interdisciplinary expertise, build knowledge, and promote technology transfer in the field of sensory research and development.

 [www.iis.fraunhofer.de/campusofthesenses](http://www.iis.fraunhofer.de/campusofthesenses)

8 At the Campus of the Senses in Erlangen, human sensory experiences are being studied and converted into digital form in partnership with private companies.



9

## ROOM-SPECIFIC INDOOR POSITIONING OF MOBILE OBJECTS

With RFicient®, the position of valuable items can be determined without elaborate infrastructure.

Based on the RFicient power-saving wireless receiver technology, we have developed an efficient positioning system for moving objects in indoor environments that allows the position of valuable items to be determined at the push of a button. The system is made up of a small number of radio beacons, which emit radio signals containing position information, in combination with power-saving wireless receivers that are attached to the objects. This system allows the objects to detect their current location independently and store it locally. Geofencing applications, e.g., when objects leave or enter secure areas without authorization, can now be implemented without elaborate infrastructure and with very low latency. The positioning system can be expanded to any number of objects and radio beacons and is therefore also suitable for the energy-efficient positioning

of objects in warehouse buildings. The extremely low-power RFicient wireless receiver can receive radiotelegrams on three license-free frequency bands at the same time and independently of one another. At just 3.3 µA, the current consumption is three orders of magnitude lower than in conventional wireless receivers. As a result, even worldwide mobile applications, such as container tracking, can be achieved without manual frequency switching. Years of maintenance-free operation are possible with very small batteries, as well as solar cells or energy harvesting.

 [www.rficient.com](http://www.rficient.com)

9 RFicient ultra-low power wireless receiver for locating objects in warehouse buildings.

## A MICROSCOPE WITH A PANORAMIC VIEW

The iStix® software combines individual microscopic images into one large panorama.

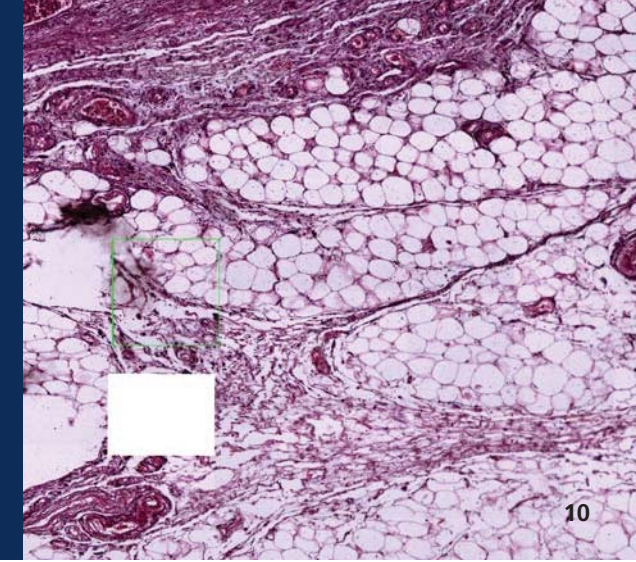
High-resolution microscopic images can often only be digitalized using expensive slide scanners. In medicine, for example, pathological findings can only be documented and archived at great expense. As an alternative, we have developed the iStix software, which can be used in conjunction with a camera and a conventional microscope to generate large-area scans. In a process known as “stitching”, the images are placed in the correct positions in the x and y directions in order to create a panoramic image. The integrated zoom and storage functions for the original images, as well as the stitched panoramic image, allow data to be exchanged easily.

iStix can also be used during training in the fields of medicine and biology. Moreover, high-resolution microscopic

images are also required in other areas, such as material science, quality assurance, and material testing, where cases of damage or new material developments must be considered within the context of the sample. There is scope to work with partners from industry to create other customer-specific functions and adaptations.

 [www.iis.fraunhofer.de/istix](http://www.iis.fraunhofer.de/istix)

10 Virtual slide including loop closure generated with a manual microscope and the iStix software from Fraunhofer IIS.



10

# IN BRIEF

In 2017, our open innovation lab JOSEPHS® was awarded the title “Place of Excellence in the Land of Ideas”. Another milestone in 2017 was the opening of our 14th location in Passau in December. The section below contains a small selection of last year’s news items.

### List of selected institute news

- Innovation lab named “Place of Excellence”
- Heiko Wrobel appointed to chair
- More cooperation on electronic systems
- New Fraunhofer IIS location in Passau
- Opening of cybersecurity training lab
- Acatech appointment
- Platform for microelectronics



## INNOVATION LAB NAMED “PLACE OF EXCELLENCE”


JOSEPHS wins 2017 “Places of Excellence in the Land of Ideas” competition.

“Fresh thinking to allow new ideas to flow” — this is the motto behind the 2017 “Places of Excellence in the Land of Ideas” competition. And it was under this motto that the open innovation lab JOSEPHS was named one of the top one hundred projects of some 1,000 applicants. In downtown Nürnberg, walk-in customers can get actively involved in the development and advancement of ongoing innovation concepts such as new services, products, and business models created by established enterprises and start-up companies. To quote the jury, by utilizing the potential of this open setting, JOSEPHS is making “an outstanding contribution towards Germany’s innovative strength and future viability.” The task of selecting the winners was done by an independent jury comprising researchers, business managers, journalists, and politicians that was headed by



Professor Michael Hüther, Director and Member of the Presidium at the German Economic Institute in Cologne.

Open Innovation Lab JOSEPHS is free of charge and open Monday through Saturday. Since its launch in 2014, more than 37,000 co-creators have been actively involved in innovation projects. JOSEPHS holds more than 250 events a year.

 [www.josephs-innovation.de/en](http://www.josephs-innovation.de/en)

1 Project manager Dr. Frank Danzinger at the award ceremony for the “Places of Excellence in the Land of Ideas” competition.

## HEIKO WROBEL APPOINTED TO CHAIR

New Chair at Nürnberg Tech “Logistics, Wholesale, and General Business Administration”.

Since the start of the winter semester 2017/18, Dr. Heiko Wrobel has held the position of Professor at the Chair of Logistics, Wholesale, and General Business Administration at Nürnberg Tech. Besides a wealth of supply chain expertise acquired over many years in his role as Head of Group Processes at the Fraunhofer Center for Applied Research on Supply Chain Services (SCS), Dr. Wrobel, Doctor of Business Administration and qualified wholesale expert, also boasts more than twenty years of experience in his field.

Generating revenue of more than 1.2 trillion euros and encompassing more than 150,000 companies, wholesale trade is very important for the German economy. Despite this, to date, this area has barely been touched on in research and teaching. The new chair at Nürnberg Tech,

however, is set to close this gap in research. At the same time, the close collaboration with Fraunhofer SCS, where Dr. Wrobel will continue in his existing role, will boost both institutions’ capacity for pushing the area of digital services in the wholesale industry.

 [www.scs.fraunhofer.de/en](http://www.scs.fraunhofer.de/en)

2 Heiko Wrobel takes on professorship at Nürnberg Tech.

## MORE COOPERATION ON ELECTRONIC SYSTEMS

Establishment of the registered association Verein Leistungszentrum Elektroniksysteme (LZE e.V.).

Today, complex electronic systems are at the heart of every modern industrial and consumer application. In an attempt to promote and advance science, research, and education in this field in this future, the association Verein Leistungszentrum Elektroniksysteme (LZE e.V.) was established in cooperation with the Fraunhofer Institute for Integrated Systems and Device Technology IISB and Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU).

The establishment of the LZE Association redefines research cooperation on electronic systems in the Nürnberg metropolitan region and is instrumental in the continued development of the LZE High-Performance Center for Electronic Systems, providing additional technology utilization options and tools.

With the LZE as a joint platform, the partners in the pilot phase, which has been underway since 2015, have recourse to various different forms of cooperation for technology exchange.

Industrial enterprises can generate a competitive advantage with the help of science roadmaps or develop market-relevant information in joint labs, delivering the highest level of scientific and technical excellence. To introduce market-oriented technology transfer for cutting-edge technology onto the market, trademarked start-up companies, in particular, are promoted. For joint developments between the partners, the ENET (Erlangen-Nürnberg Excellence Track) program of LZE, a career development program spanning various organizations, was set up.

From a strategic point of view, the foundation of the LZE Association is of great value for the partners involved. The LZE Association members include Fraunhofer Executive Vice President Professor Georg Rosenfeld, President of the FAU Professor Joachim Hornegger, and Professor Siegfried Russwurm, member of the Senate of the Fraunhofer Association.



**3** One of the LZE's pilot projects is low-power electronics for sports and fitness applications. In combination with a textile integrated solution such as the FitnessSHIRT, for example, the ELECSA® sweat sensor can deliver information on your fitness level.





## NEW FRAUNHOFER IIS LOCATION IN PASSAU

New research group for knowledge-based image processing at the University of Passau.

Our development center in Fürth and the Institute of Software Systems in Technical Applications of Computer Science of the University of Passau (FORWISS) have formed professional and personal ties to conduct research in the area of knowledge-based image processing. Head of the new research group is the Chair of Digital Image Processing of the Faculty of Computer Science and Mathematics and head of FORWISS, Professor Tomas Sauer. The main research aim is to employ various non-destructive sensor-based testing methods to extract any digital information that allows for process monitoring and control. The outcome is increasingly complex quantities of data that often can no longer be processed using standard digital image processing methods. Consequently, one of the primary aims here is to develop image processing strategies and operators with new,

intelligent approaches along the lines of machine learning or deep learning. The partnership includes cooperation on individual teaching and research tasks, the implementation of joint projects and events, and the shared use of equipment and infrastructure. The new research group in Passau is Fraunhofer IIS' 14th location in Germany.

4 The man to whom the Fraunhofer Society owes its name, Bavaria-born Joseph von Fraunhofer (right) was also there at the opening.

## OPENING OF CYBERSECURITY TRAINING LAB

Development of solutions to beat cyber-attacks in the Internet of Things.

January 13, 2017 saw the launch of the first of six Fraunhofer cybersecurity training labs centering on Embedded Systems, Mobile Security, and the Internet of Things. The increasing digitalization in business and industry exposes us to the risk of cyberattacks. The resultant security risks for business enterprises need to be reduced.

In the research collaboration between the Technical University of Applied Sciences (OTH Amberg-Weiden), Aalen University, Fraunhofer AISEC, and Fraunhofer IIS, the chief focus is the development of reliable security software, security solutions with dedicated hardware support, and cryptography for the Internet of Things.

Our aim is to increase security awareness among administrators, operators, and users, especially with regard to specific context and application-related security measures. Within the context of the Fraunhofer cybersecurity training lab, we show participants where potential risks can be found, what measures can help protect them from such threats, and how to achieve a sensible benefit-to-cost ratio when it comes to cybersecurity measures.

 [www.iis.fraunhofer.de/security](http://www.iis.fraunhofer.de/security)



## ACATECH APPOINTMENT

Professor Albert Heuberger now a member of the National Academy of Science and Engineering.

In January 2017, Professor Albert Heuberger, executive director of Fraunhofer Institute for Integrated Circuits IIS, was appointed a member of the National Academy of Science and Engineering (acatech) alongside 34 other researchers and scientists. Acatech, the leading academy of science and engineering in Germany, plays an instrumental role in advising government and the public on matters pertaining to science and technology.

“On behalf of the institute and myself, I am honored to accept this appointment and welcome this wonderful new opportunity to take our institute and our ideas out into the wider community,” explained Professor Heuberger. “This takes us a step closer to fulfilling our mission and realizing our vision, which is to deliver cutting-edge research

that provides direct benefits for the economy and society.”

5 Executive Director Professor Albert Heuberger receiving letter of appointment to acatech.

## PLATFORM FOR MICROELECTRONICS

“Forschungsfabrik Mikroelektronik Deutschland” becomes a one-stop shop for micro and nanoelectronics.

For the semiconductor and electronics industry in Europe, surviving in an increasingly competitive global market marked by ever faster innovations and a digital revolution is not an easy task. To help industry, we have joined forces with ten other institutes from the Fraunhofer Group for Microelectronics as well as two institutes from the Leibniz Association in what is the first ever cross-site research and development initiative to pool research expertise in the field of micro and nanoelectronics.

The aim is to deliver a one-stop shop for the entire micro and nanoelectronics supply chain for major industrial enterprises, small and medium-sized enterprises, and universities. State-of-the-art lab lines and other key equipment is complemented by the excellent level of expertise that these

institutes boast. The research platform, officially launched in April 2017, is expected to be fully up and running by the end of 2020, by which time centrally coordinated, comprehensive equipment pools and labs will be in place, as will be a range of cross-technology, cross-site services for industry. The German Federal Ministry for Education and Research is providing some 350 million euros in funding for the necessary investments.

 [www.forschungsfabrik-mikroelektronik.de/en](http://www.forschungsfabrik-mikroelektronik.de/en)

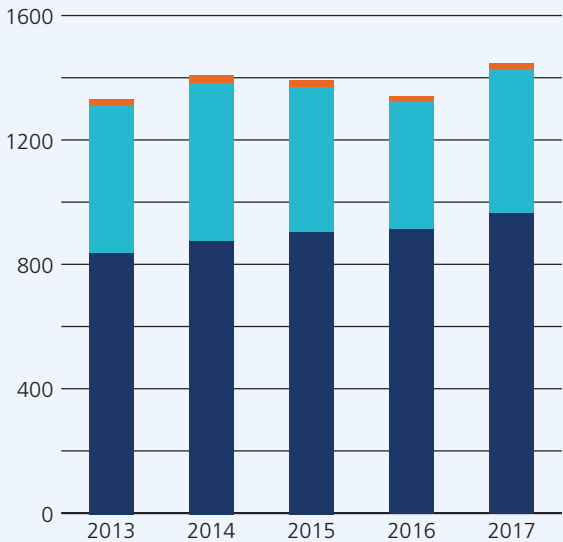
FRAUNHOFER IIS IN NUMBERS

Renewed rise in employee numbers

In 2017, the number of employees rose to 970 from 919 in the previous year. These figures refer to employees listed in the staffing plan. Those in marginal employment arrangements are not included. The number of student assistants also increased to 463 (2016: 410), and the number of apprentices rose to 17 (2016: 16).

- permanent and temporary employees
- student assistants
- apprentices

970 employees



Over 50 countries represented at the institute

Fraunhofer IIS employs people from 51 countries. Most employees are from Germany, with India, Spain, Egypt, and Turkey making up the remainder of the top five by total number of employees.

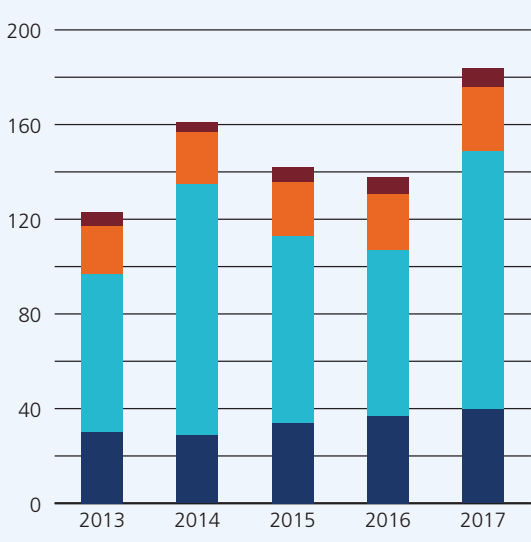


59 percent of income from industry

As in previous years, Fraunhofer IIS maintained a balanced budget and a positive carry-over in 2017. Of the institute's total income, 59 percent came from industry and business. Base funding via the Fraunhofer Gesellschaft accounted for 22 percent, and 15 percent of the budget came from public-sector revenue.

- Base funding
- Industrial revenue
- Public-sector revenue
- Other revenue

184 million euros in funding

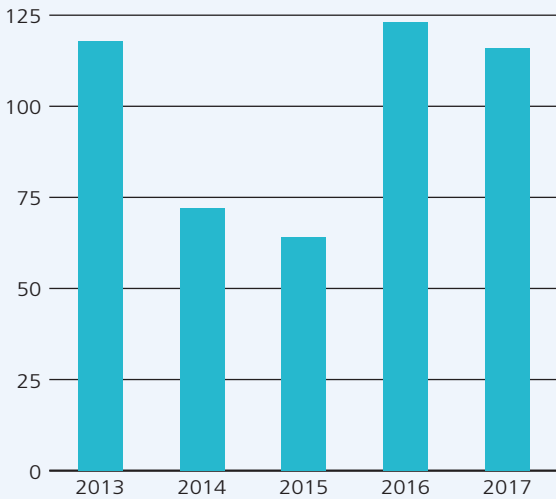


Numerous invention disclosures once again in 2017

116 inventions were disclosed in 2017. After 123 disclosures in 2016, the number of invention disclosures remains at a very high level.

As in 2016, it was above all the research areas Communication Systems and Audio and Media Technologies that were responsible for most of the inventions.

116 invention disclosures





6

## “USING SYNERGIES IS WHAT IS IMPORTANT.”

In the automotive industry, autonomous driving is more than just a trend. In collaboration with Bertrandt AG, we develop vehicle connectivity technologies that boost the level of comfort and safety for drivers. We met with Klaus Härtl, head of the Electronics Competence Centre at Bertrandt AG, to discuss the partnership.

**Mr. Härtl, for some years now, Bertrandt AG, a long-term supporter of the automotive industry, has been working on the field of autonomous driving. How did the partnership with the Fraunhofer Institute for Integrated Circuits IIS come to be?**

**Härtl:** We are very aware of the expertise that Fraunhofer IIS has in the field of localization and connectivity. In 2015, for example, we came across Fraunhofer IIS at the international VDI congress ELIV (ELectronics In Vehicles) when we were looking for major partners for our autonomous driving portfolio. Following initial meetings, it quickly became clear that both sides would be able to bring their own individual expertise to the table. In the field of autonomous driving, using synergies is of the essence, as is bringing together professionals and forming strategic partnerships. Our contribution is experience in vehicle-related areas such as software development, testing, and a holistic view of vehicles and systems, while Fraunhofer IIS brings valuable knowledge in the area of applied research in localization technologies to the table. Combined with other vehicle technologies and systems, this takes us one important step further on the road to highly automated driving.

### What does the partnership involve specifically?

**Härtl:** The key components of our cooperation are coordinated roadmaps and specific common goals. In July 2017 we unveiled our joint value proposition to selected customers and partners at a dedicated event in Regensburg.

Our showcase piece was a demo of a car stopping automatically at a stop line and was done in our very own experimental vehicle. This live demo served to demonstrate the improvement in vehicle localization by means of function/software expansion achieved by fusing two coexisting communication technologies. To be precise, GPS data is combined with DAB (digital audio broadcasting, which also facilitates data transmission to the car), which can then be used for GPS correction. Precise localization results in a clear improvement in positioning accuracy (to within just a few centimeters) and is a major step forward in autonomous vehicle safety using redundant systems. Building on this showcase, we are now engaged in talks with potential customers who might be looking to use this technology in the context of autonomous driving in the future.

We look forward to future inquiries and to working with new partners on prospective jobs.

**Mr. Härtl, thank you for talking to us today.**

Other examples of our cooperation projects can be found in the Fraunhofer IIS Magazine at:

 [www.iis.fraunhofer.de/magazine](http://www.iis.fraunhofer.de/magazine)

## FRAUNHOFER IIS AS A 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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## 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 is the largest of all Fraunhofer Institutes.

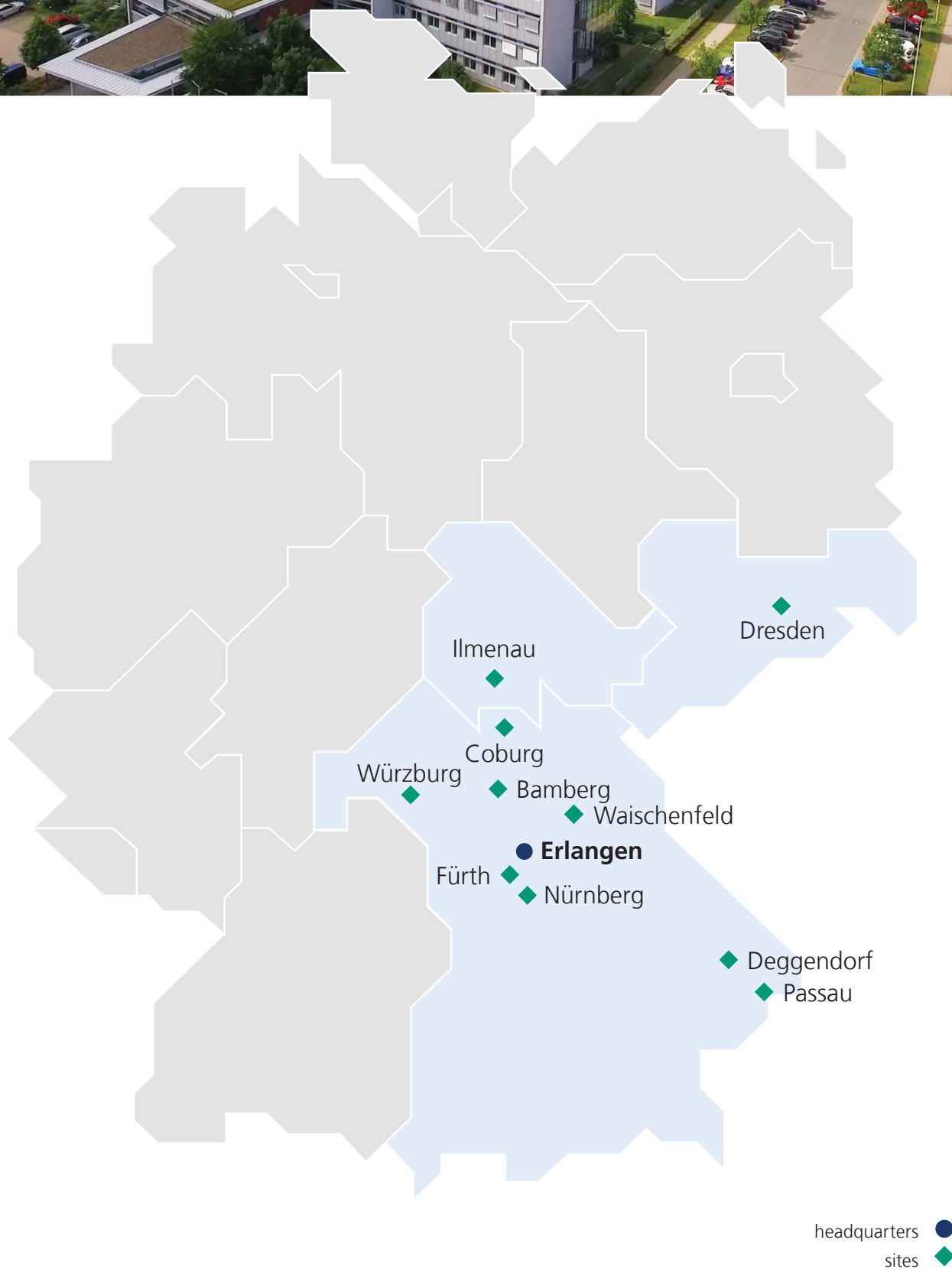
### Research at Fraunhofer IIS revolves around two guiding topics

In the area of "Audio and Media Technologies", the institute has been shaping the digitalization of media for more than 30 years now. Fraunhofer IIS was instrumental in the development of mp3 and AAC and played a significant role in the digitalization of the cinema. Current developments are opening up whole new sound worlds and are being used in virtual reality, automotive sound systems, mobile telephony, streaming and broadcasting. Any mobile phone you buy today, for instance, uses audio technology developed by the institute, while Fraunhofer codecs provide the basis for sound of more than half of all TV broadcasts worldwide and almost all radio and streaming services. The institute's professional tools for digital film and media production are also being used globally.

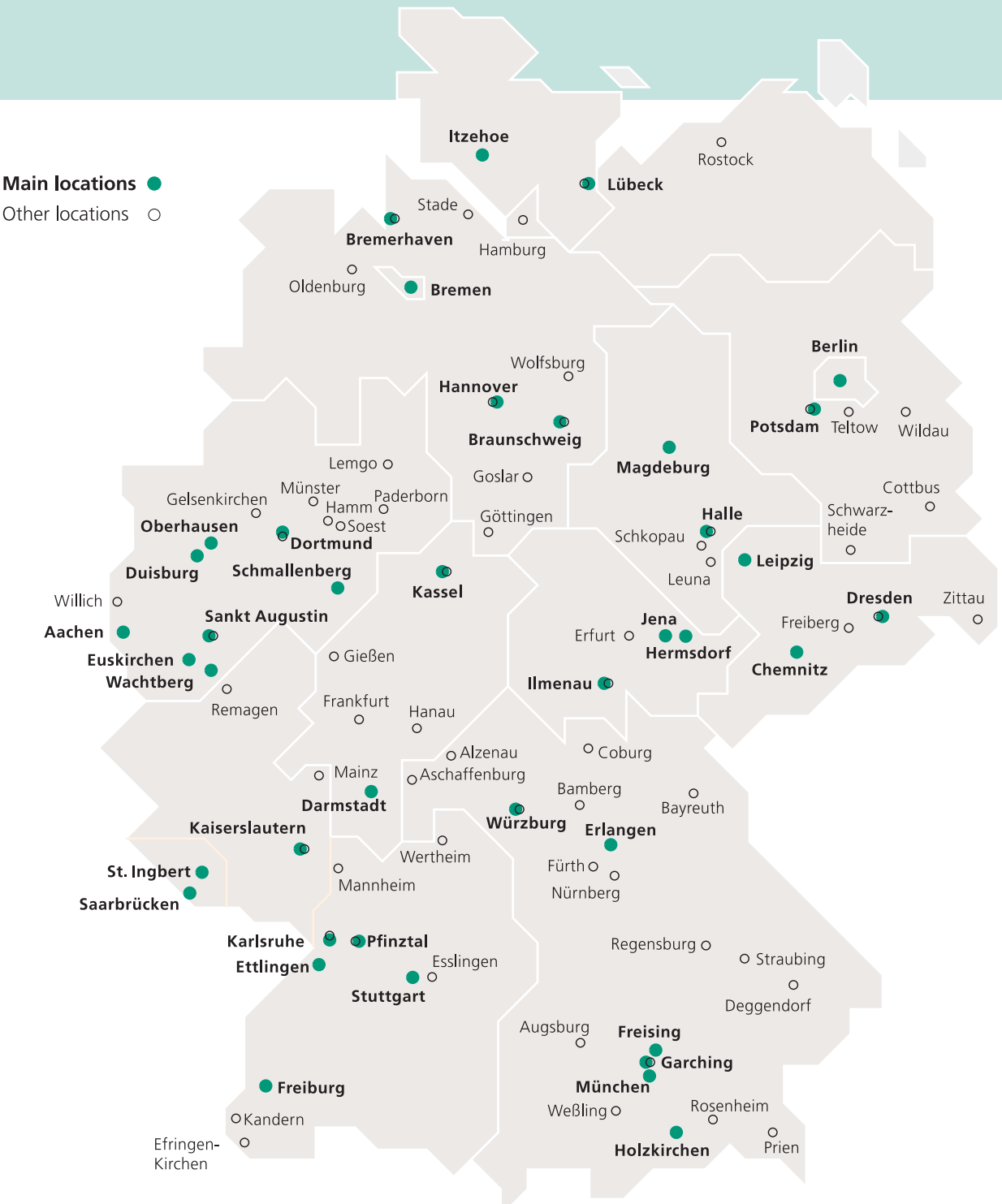
In the context of "cognitive sensor technologies", the institute researches technologies for sensor technology, data transmission technology, data analysis methods and the exploitation of data as part of data-driven services and their accompanying business models. This adds a cognitive component to the function of the conventional "smart" sensor. The results of this research have been applied in the areas of connected mobility, communication and application solutions for the Internet of Things, digitalization of human sensing, product and material monitoring, and business analytics in supply chains.

970 employees conduct contract research for industry, the service sector and public authorities. Founded in 1985 in Erlangen, Fraunhofer IIS now has 14 locations in 11 cities: Erlangen (headquarters), Nürnberg, Fürth and Dresden, as well as Bamberg, Waischenfeld, Coburg, Würzburg, Ilmenau, Deggendorf and Passau. The budget of 184 million euros a year is mainly financed by contract research projects. 22 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 pages 64 and 65.*



# FRAUNHOFER-GESELLSCHAFT IN GERMANY



The Fraunhofer-Gesellschaft currently operates 72 institutes and research institutions in Germany.

Research of practical utility lies at the heart of all activities pursued by the Fraunhofer-Gesellschaft. 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 72 institutes and research units. The majority of the more than 25 000 staff are qualified scientists and engineers, who work with an annual research budget of 2.3 billion euros. Of this sum, almost 2 billion euros is generated through contract research. Around 70 percent of the Fraunhofer-Gesellschaft's contract research revenue is derived from contracts with industry and from publicly financed research projects. Around 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.

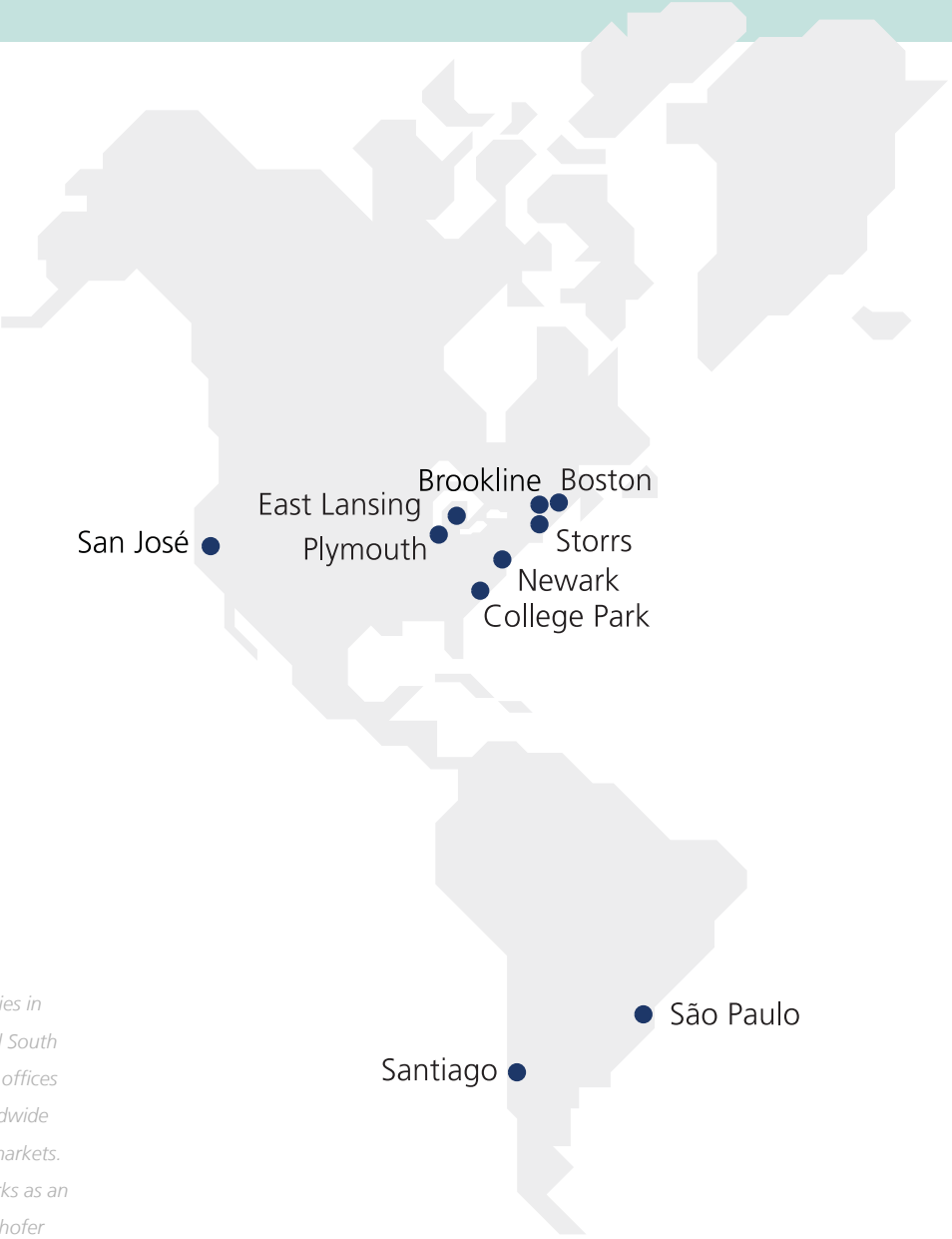
International collaborations with excellent research partners and innovative companies around the world ensure direct access to regions of the greatest importance to present and future scientific progress and economic development.

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.

# 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.*



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



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# AWARDS AND PRIZES

- Joseph von Fraunhofer Prize**  
Markus Multrus, Dr. Guillaume Fuchs, and Stefan Döhla for the development of the EVS codec
- EDA Medal 2017**  
Dr. Manfred Dietrich for 40 years of successful work in research, development, and application in the field of electronic design automation (EDA)
- Dr.-Ing. Siegfried Werth Foundation Prize**  
Anton Sigl for his bachelor’s thesis “Bau und Konstruktion eines modularen CT-Systems für Mikro- und Submikro-Anwendungen” (Design and construction of a modular CT system for micro and sub-micro applications)
- Annual prize for the publication in the Journal of Orofacial Orthopedics**  
For the study “MRI vs. CT for orthodontic applications: comparison of two MRI protocols and three CT (multislice, cone-beam, industrial) technologies”
- “Place of Excellence in the Land of Ideas”**  
The open innovation lab JOSEPHS
- ESNC Triple Prize**  
Alexander Rügamer and Dr. Jan Wendel (Airbus) for the Sorus project
- Student Design Competition of EuMW 2017**  
1st prize, Christoph Wagner, Eric Schäfer, Diego Dupleich, Tim Erich Wegner, Julia Bauer for “On-site design and production of transceivers”

## PUBLISHING NOTES

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