Fraunhofer ESK

FRAUNHOFER INSTITUTE FOR EMBEDDED SYSTEMS AND COMMUNICATION TECHNOLOGIES ESK

ANNUAL REPORT 2016 / 2017

TABLE OF CONTENTS

Dear partners, customers, employees and interested parties,

Today, many production systems are automated, vehicles operate with driver assistance systems and road infrastructure systems communicate with traffic control centers to prevent traffic congestion.

Digitalization is of course much more encompassing and in-depth. Apart from the political and societal aspects, digitalization involves the development of completely new business models, not the expansion of existing ones. And therein lies the issue. In discussions with various companies, we know that there are still many inhibition thresholds to conquer when it comes to introducing digital processes or digital production systems. These companies are also aware that the only way to remain competitive is through digitalization. But that means more than just lending a digital design to operational flows. Instead, the entire value chain has to be digitalized, from concept and product development, to interaction with the customer. This comprehensive mindset is the only way to ensure the creation of successful digital business models.

As a research institute, we have made it our mission to provide companies clarity from a scientific standpoint. We want to offer companies a degree of security and confidence when it comes to digitalization and solving the corresponding technological challenges, so that they can successfully develop and implement their business models.

Our customers need individual solutions, either because they have to combat difficult spatial conditions, such as on farmland or in a production facility. Or because they have to manage time- and safety-critical traffic scenarios, or prevent accidents and traffic congestion.

In order to manage these requirements in a holistic fashion, we rely on connectivity and synergy effects. For example, since 2016 our institute has been collaborating with two sister institutes, Fraunhofer AISEC and Fraunhofer EMFT, within the High Performance Center for Secure Networked Systems Munich. The center serves as a platform, or sparring partner, for companies with digitalization projects in the areas of connected mobility, Industry 4.0 and smart health. Further information about the center can be found beginning on page 20.

Within the new ENARIS® innovation center (ENgineering and Architectures for Resilient Intelligent embedded Systems), we are working closely with Fraunhofer IESE, based in Kaiserslautern, Germany, to research ways to make embedded systems, which are already in a wide range of devices and applications, more dependable and intelligent. Further information about ENARIS® can be found beginning on page 18.

And we are also relying on synergies within the leadership team. Effective January 1, 2018, apl. Prof. Dr. habil. Mario Trapp moved from Fraunhofer IESE to become executive director (act.) of Fraunhofer ESK. Further information can be found on page 24.

As you can tell, a lot is happening at Fraunhofer ESK, all of which would not be possible without our customers, partners and the various organizations that help fund our activities. With this in mind, our heartfelt thanks to you, and especially to all of our employees, for the constructive and successful collaboration.

Mario Trapp

Rudi Knorr

MOBILITY OF THE FUTURE

INTERVIEW WITH KARSTEN ROSCHER

Mobility is also being impacted by the rise in digitalization. What kind of challenges will mobility face in the future?
The field of mobility will have to deal with a wide range of challenges. One of the first issues is making the roads and streets safer. In 2016, the Bavarian Police alone registered nearly 400,000 traffic accidents, including 616 fatalities. Efficiency, especially with respect to traffic flows, is another important topic. And with the diesel engine scandal coming to light, sustainability has resurfaced as a focus of public interest.

Safety, efficiency, sustainability. How can all of these goals be reached?
The automobile sector has several major fields of research, such as electric vehicles, which offer environmentally-friendly mobility. There are nevertheless issues that continue to hinder the proliferation of electric vehicles. Another area is autonomous driving, which leads to more traffic efficiency and reduces the risk of human error. Teaching a machine how to deal with complex scenarios remains a serious challenge however. Finding a solution to these problems requires an additional field of research: communication and cooperation for Intelligent Transportation Systems (ITS).

To what extent can communications and cooperation help mobility in the future?
A host of problems can be solved through vehicle-to-vehicle communications and vehicle-to-road infrastructure communications. Managing complex scenarios in the area of autonomous driving is one example. Communications can also be helpful in the area of electromobility as well. By connecting cars and charging stations for instance, drivers know where they can find an open charging station in the vicinity. Communications and cooperation help electromobility and autonomous driving exploit their full potential.

What does it take to enable cooperation among traffic participants?
One way is through mobile applications, such as the one being developed in the TIMON project, which involves analyzing and merging data from various sources like connected vehicles and road infrastructure sensors. What makes TIMON unique is that even pedestrians and cyclists, so-called vulnerable traffic participants, can be part of this cooperative ecosystem.

Karsten Roscher
is a research engineer at Fraunhofer ESK. He is active in the area of Car2X communications and conducts research into cooperative traffic systems.

From alternative drive trains and connected driver assistance systems, to autonomous vehicles, the wheels are in motion in the automobile sector. Fraunhofer ESK is involved in groundbreaking projects in the area of connected mobility. These activities are built on the foundation of two pillars:

With automobiles becoming more automated, communication among the traffic participants will be required. Dependable and predictive communication between all participants will play an especially important role, particularly at higher degrees of automation. Against this backdrop, Fraunhofer ESK is conducting research into methods that will provide the reliability and the prediction capabilities needed to implement suitable communications technologies for future cooperative driving functions and protocols.

At the same time, modern vehicles feature scores of connected, embedded systems that make them dependent on the complex interaction of their components. By utilizing fail-operational approaches, in case of an outage these systems can continue to run until the vehicle is in a safe state. Fraunhofer ESK furthermore boasts many years of experience in validating connected and safety-critical applications. This expertise is now being expanded to systems that integrate inherently unsafe artificial intelligence technologies.

OUR SOLUTIONS:

- **Safety and consistency in Car2X communications**
- **Tool environments for cooperative driver assistance systems**
- **Real-time connected driving with LTE and mobile edge computing**
- **Fail-operational vehicle systems**
- **Validating artificial intelligence systems**

SAFETY AND CONSISTENCY IN CAR2X COMMUNICATIONS

Increasing the safety, sustainability, flexibility and efficiency of road traffic systems. That's the goal of the joint project TIMON. The unique aspect of TIMON is that even so-called vulnerable traffic participants, such as pedestrians and cyclists, will be tracked within a cooperative ecosystem. Data will be collected from various sources (road infrastructure, drivers and vulnerable traffic participants), then analyzed and processed to create a cooperative, open web platform. This information can then be used to generate forecasts, such as for traffic congestion or route planning purposes. At the same time, a hybrid communications system with an adaptive cross-layer approach will be developed, which will communicate via the automobile-specific ITS-G5 WiFi standard, or LTE.

The TIMON project is funded through the EU's Horizon 2020 Research and Innovation program (grant number 636220).

POINT OF CONTACT:

Karsten Roscher
Tel. +49 89 547088-349
karsten.roscher@esk.fraunhofer.de

TOOL ENVIRONMENT FOR COOPERATIVE DRIVER ASSISTANCE SYSTEMS

Cooperative driving functions are highly-complex systems that can include various elements, from backend system and network infrastructure, to other vehicles. That's why the development, integration and testing of cooperative driving functions has always been associated with high costs. With this in mind, Fraunhofer ESK offers an end-to-end tool environment for developing innovative driving functions. The modeling methods developed by Fraunhofer ESK can track and validate connected vehicles and their distributed driving functions. Among other things, the broad spectrum of simulation tools can be used to set algorithm parameters. After successful simulation testing, Fraunhofer ESK creates an execution environment that can be used to test the prototype under real conditions. This results in a verified and validated model of a driving function.

POINT OF CONTACT:

Josef Jiru
Tel. +49 89 547088-379
josef.jiru@esk.fraunhofer.de

REAL-TIME CONNECTED DRIVING WITH LTE AND MOBILE EDGE COMPUTING

Message transmission latency plays a decisive role in traffic safety applications. Fraunhofer ESK is involved in a joint project to research two complementary approaches for improving connectivity in traffic management applications. One approach involves the development of a local message distribution system based on mobile edge computing (MEC), which covers the short-range areas in cellular networks in order to significantly reduce latency. This is combined with the use of heterogeneous communications technologies, thus bringing together the strengths of ad hoc and infrastructure-based communications. By using this approach, we have already managed to shorten end-to-end latency to less than 20 ms. In contrast, today's mobile phone networks and backend services typically exhibit latencies of more than 100 ms.

This project is funded by the Bavarian Ministry for Economic Affairs and Media, Energy and Technology.

POINT OF CONTACT:

Karsten Roscher
Tel. +49 89 547088-349
karsten.roscher@esk.fraunhofer.de

FAIL-OPERATIONAL VEHICLE SYSTEMS

Future vehicles will feature highly-integrated subsystems such as wheel hub motors and brake-by-wire systems. These systems need innovative software approaches to satisfy the stringent safety requirements. Fraunhofer ESK is working within a joint project to create a holistic approach for the development of adaptive systems in safety-critical environments, including tool chain support, reference architectures, system design modeling and validation and verification. This work resulted in a fail-operational approach that relies on adaption and reconfiguration to circumvent system faults and maintain control of the systems even when an outage occurs. This approach also helps to reduce the complexity and hardware costs associated with future safety-critical systems, such as those found in autonomous vehicles.

The project is funded by a grant (Nr. 608945) from the European Commission through the EU Seventh Framework Program (FP7).

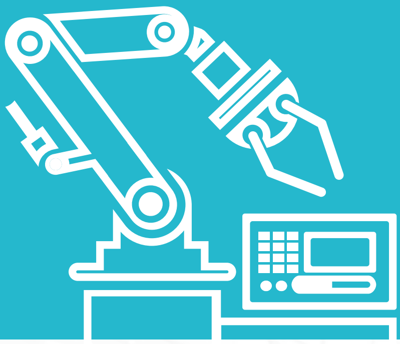
POINT OF CONTACT:
Dr. Gereon Weiss
Tel. +49 89 547088-348
gereon.weiss@esk.fraunhofer.de

VALIDATING ARTIFICAL INTELLIGENCE SYSTEMS

While artificial intelligence (AI) technologies offer enormous potential in various fields of applications, such as situation detection and trajectory planning in autonomous vehicles by means of deep learning, validating the reliability of the processes for safety-critical applications is a difficult task. With the aim of changing this situation, Fraunhofer ESK is expanding its expertise in the area of safety-critical system validation to include the dependable integration of AI processes such as convolutional neural networks. To carry out this strategy, the institute is developing concepts and methods that enable the utilization of such processes in safety-critical environments. The concepts and methods are being implemented and evaluated on a prototype basis with hardware platforms, which are also used by industry. The aim is to create a solution that will allow these promising AI approaches to be used reliably in future products such as (autonomous driving) vehicles or other safety-critical applications.

POINT OF CONTACT:
Dominique Seydel
Tel. +49 89 547088-363
dominique.seydel@esk.fraunhofer.de

INDUSTRY 4.0



INTERVIEW WITH MICHAEL STILLER

Although the term Industry 4.0 first surfaced in 2011 as part of the German government's high-tech strategy, it meanwhile represents the future of industry. What's actually behind this term?
Industry 4.0 means the end-to-end digitalization and connectivity of production and manufacturing systems. The technological leap from the third to the fourth industrial revolution is highlighted by the Internet of Things. That initially means massive utilization of the Internet, from the sensor to the cloud. And today we're seeing the integration of engineering processes and the creation of digital representations. The virtualization of the world will continue. Industry 4.0 is ultimately about new opportunities to create intelligent products and manufacturing resources.

How is an Industry 4.0 production system structured? Similar to the automated industrial systems we have seen to date?
No. To date, in many areas of production, the field, control, process control and operational levels have been rigidly separated. Industry 4.0 does away with this structure and creates a cyber-physical production system (CPPS) made up of high-grade, connected cyber-physical systems (CPS). This eliminates the issue that occurs when a specific function can be implemented and used only at a specific location.

What are the challenges facing Industry 4.0 production systems?
Industry 4.0 places high demands on industrial system communications infrastructures. In the future, every sensor or actuator will have its own IP address and no longer be connected to the machine controls via proprietary bus technologies. That means communications will run less over conventional field bus technologies and more over Ethernet and wireless technologies.

What's in store for Industry 4.0 over the next several years?
There is still much to do. Standards have to be driven forward. Research results have to be turned into practical applications. Furthermore, small-to-medium enterprises must have the opportunity to test Industry 4.0 technologies with minimal risk. This is where test beds, such as our I4.0 Comlab, can help these companies implement their digitalization projects.

Michael Stiller
is a research engineer at Fraunhofer ESK and is active in the field of Industry 4.0, where he focuses his research on machine-to-cloud connectivity.

Massively connected production systems, fully-connected locations and companies that communicate with one another in real-time. Industry 4.0 is having a major impact on today's production and manufacturing systems. Fraunhofer ESK is focusing its Industry 4.0 research activities on two critical aspects.

In light of the growing numbers of connected machines, robots and autonomous guided vehicles in Industry 4.0 environments, wireless transmission resources e.g. radio frequencies are being stretched to their limits. To address this issue, Fraunhofer ESK is working within the HODRIAN and CAROUSAL projects to develop adaptive wireless technologies robust enough to connect industrial production networks.

At the same time, close coupling of the production process and the control systems has become an obsolete approach. Over the past 15 years, industry has been moving to more open systems in which a software SPS assumes responsibility for control functions within a connected system. Fraunhofer ESK is already working on the next step: cloud-based control services. The cloud can furthermore be used for other applications, such as assistance systems that provide more flexibility when it comes to service and maintenance.

OUR SOLUTIONS:

- **Cognitive frequency hopping methods for industrial applications**
- **Predictive spectrum management in industrial wireless environments**
- **Adaptive architecture for the cloud-based assistance of complex agriculture machines**
- **Cloud-based production control**

COGNITIVE FREQUENCY HOPPING METHODS FOR INDUSTRIAL APPLICATIONS

In the HODRIAN project, Fraunhofer ESK researched cognitive, highly-dependable wireless technologies for industrial applications. The team developed a cognitive, seamless frequency hopping method to provide dependable, real-time and robust wireless connectivity by relying on adaptive wireless systems that monitor the environment and adapt the communications behavior accordingly. This approach was made possible through cognitive frequency hopping, a method that involves three key steps. The affected system first detects interference and uses this information to evaluate the quality of the channel. Frequency hopping is then initiated in the final step, which involves spontaneously switching to the channel that can best guarantee the required quality of service. The result is a real-time delay of just a few milliseconds. The method of cognitive frequency hopping thus guarantees dependable and real-time wireless communications in industrial environments.

The project was funded by the German Federal Ministry of Education and Research.

POINT OF CONTACT:
Ahmad Saad
Tel. +49 89 547088-392
ahmad.saad@esk.fraunhofer.de

PREDICTIVE SPECTRUM MANAGEMENT IN INDUSTRIAL WIRELESS ENVRIONMENTS

In the CAROUSAL project, researchers translated their research results in the field of cognitive radio technologies, which to date have been primarily theoretical in nature, into industrial scenarios. This work relies on predictive spectrum management to increase the efficiency and improve the coexistence of heterogeneous industrial wireless networks. The goal of the project was to develop a prototype, which among other things, is capable of transparently tunneling a wired field bus system via wireless technology. Cognitive radio boasts four characteristics that play a key role here. The technology uses predictive algorithms and artificial intelligence to detect unused spectra, selects the frequency range that best fulfills the requirements, adaptively transmits the signal and provides intelligent access to the unused frequency ranges. Cognitive radio thus satisfies the efficiency and dependability that industrial wireless networks call for.

The project is funded by the German Federal Ministry of Education and Research.

POINT OF CONTACT:
Ahmad Saad
Tel. +49 89 547088-392
ahmad.saad@esk.fraunhofer.de

ADAPTIVE ARCHITECTURE FOR THE CLOUD-BASED ASSISTANCE OF COMPLEX AGRICULTURE MACHINES

One of the challenges facing agriculture machine manufacturers is providing customer-oriented, on-site maintenance and service to global markets. In the INVIA project, seven project partners are developing a concept for an innovative, mobile cloud-based assistance system to diagnosis and service complex farm machinery. The project team is also implementing a prototype of the system. The potential fields of application include image- and video-supported error diagnosis, online diagnostic tools for local service technicians and online-supported operator training guided by the manufacturer.

INVIA relies on technologies such as cloud computing, mobile edge computing and fog computing. The adaptive architecture developed by Fraunhofer ESK allows the system to optimally respond if the connection to the mobile base station exhibits poor quality or is temporarily unavailable. That means the basic functions of the assistance system can be provided even without connectivity to the manufacturer’s service control center, thus ensuring cost-effective and fast on-site service.

POINT OF CONTACT:
Michael Stiller
Tel. +49 89 547088-346
michael.stiller@esk.fraunhofer.de

CLOUD-BASED PRODUCTION CONTROL

With support from Fraunhofer ESK, the partners in the CICS project are examining new end-to-end, web-based control systems that can be flexibly adapted to application-specific requirements with little effort. Private and public cloud infrastructures are utilized to manage and operate the systems. The control services can also be operated with a web client.

The reference architecture that evolved from the project serves as the basis for setting up the cloud solutions or for developing new products. Cloud-based control platforms satisfy the need for efficient, flexible and individual production systems. Among other things, they can be used to quickly add sensors and actuators in a plug-and-play fashion without the need to reconfigure the controls. Cloud-based control systems also lead to cost savings since production is run with a location-independent cloud-based service.

Funding for this project was made possible by the German Federal Ministry for Economic Affairs and Energy under a resolution passed by the German Parliament. The grant was issued through the German Federation of Industrial Research Associations (AiF) under the framework of the Joint Industrial Research program (IGF project 18354 N).

POINT OF CONTACT:
Michael Stiller
Tel. +49 89 547088-346
michael.stiller@esk.fraunhofer.de

ESK SOFTWARE DEVELOPMENT SOLUTIONS

Fraunhofer ESK continuously conducts research into new methods aimed at simplifying the development of applications in connected, embedded systems and implements them on a prototype basis in various software tools.

DANA – ANALYSIS PLATFORM FOR NETWORKED EMBEDDED SYSTEMS

DANA is a model-based, extendable tool platform for validating the interactive behavior of connected, embedded systems. With the help of a description of the target behavior, DANA immediately reveals deviations in the behavior of the system under test during runtime, which allows the full functionality of the system to be restored more quickly. By compiling an embedded verifier, the monitoring can be permanently integrated into the system so that it automatically reacts to anomalies. For the description of the target behavior, state machines can learn by observing the correct system operation. For this reason, DANA can also be deployed even if no machine-readable description of the interaction behavior exists.

www.dana.fraunhofer.de

POINT OF CONTACT:
Christian Drabek
Tel. +49 89 547088-357
christian.drabek@esk.fraunhofer.de

EZCAR2X® – SOFTWARE FRAMEWORK FOR DEVELOPING CAR2X APPLICATIONS

The flexible ezCar2x® software framework can be used to quickly develop applications for connecting vehicles with the surrounding environment. The framework, which boasts a high degree of flexibility, modularity and portability, can be integrated into a wide range of environments such as conventional on-board and road-side-units or directly into a simulation platform.

www.ezcar2x.fraunhofer.de

POINT OF CONTACT:
Karsten Roscher
Tel. +49 89 547088-349
karsten.roscher@esk.fraunhofer.de

ERNEST – FRAMEWORK FOR THE EARLY-STAGE VALIDATION OF NON-FUNCTIONAL REQUIREMENTS

ERNEST is an open-source platform built around a SystemC simulation framework of component-based software for networked embedded systems. Through integration into Eclipse, the target system can be modeled, the simulation analyzed and the result visualized. The focus of the ERNEST framework is the validation of non-functional requirements in the early modeling stages of the system.

https://github.com/FraunhoferESK

POINT OF CONTACT:
Christian Drabek
Tel. +49 89 547088-357
christian.drabek@esk.fraunhofer.de

AUTOPLAN – AUTOMATED PLANNING AND INTEGRATION OF AUTOSAR SYSTEMS

AUTOPLAN enables the planning and configuration of distributed AUTOSAR systems by taking into account real-time and reliability requirements. What makes AUTOPLAN unique is the capability to find a schedule that is simultaneously valid for all software components and bus signals within an electronic control unit (ECU) network. Exchange of the system models and other AUTOSAR tools is carried out with standardized ARXML formats. The integration effort is significantly reduced thanks to the central planning of the timing behavior and the downstream automated configuration of ECU modules and safety monitors. The tool also makes it possible to plan systems with multiple operation modes in order to ensure fail-operational behavior for automated driving functions with the help of reconfiguration, to cite just one example.

POINT OF CONTACT:
Philipp Schleiß
Tel. +49 89 547088-398
philipp.schleiss@esk.fraunhofer.de

LABORATORIES

To carry out their research activities, our scientists have relied on five different test laboratories, an Industry 4.0 test bed, plus a demonstrator for connected driving. These labs and technical platforms have also been used by companies and partners for their own research activities.

EMBEDDED SOFTWARE LAB

The Embedded Software Lab is used to support research projects in embedded systems and embedded software with a focus on industry partners in areas of connected mobility and industrial communications. The lab is equipped with various tools, prototyping platforms and other equipment for developing and validating software systems, including vehicle and rest bus simulation and development environments for embedded software.

Equipment

- Various software tools for the model-based development and validation of software systems
- Vehicle and rest bus simulation, electronic control unit prototyping, vehicle bus measurements (CAN, MOST, FlexRay, Ethernet)
- Hardware debugger (e.g. Lauterbach)
- Diverse hardware prototyping platforms
- Embedded software development environments

POINT OF CONTACT:
Markus Klein
Tel. +49 89 547088-375
markus.klein@esk.fraunhofer.de

WIRELESS LAB

In the Wireless Lab, researchers develop and analyze wireless systems and communication protocols for future vehicle connectivity and industrial communication systems that pose special challenges. To do that, Fraunhofer ESK offers diverse measurement and test stations for local and infrastructure-based wireless systems, which can be used to carry out interoperability tests, real-time monitoring of the radio spectrum and wireless system prototyping among other things. The Wireless Lab supports numerous wireless technologies, from software defined radio with USRP platforms, 4G/5G OpenAirInterface and LTE-V2X OpenAir Interface, to IEEE 802.11 and IEEE 802.15.4 based systems or 802.11p and ETSI ITS communication stacks.

Equipment

- Spectrum analyzers, vector network analyzers and logic analyzers
- Signal generators
- Broadband transmit and receive antenna systems
- Tool kits for developing and testing wireless sensor networks

POINT OF CONTACT:
Arnold Plankl
Tel. +49 89 547088-371
arnold.plank@esk.fraunhofer.de

COMING SOON:
Industry Labs –
Take advantage of our expert
know-how and test equipment
in the area of digital mobility
and industry!

ACCESS & INHOUSE TEST LAB

The Access & Inhouse Test Lab is used to analyze communication solutions in line with international standards and to evaluate and develop customer-specific solutions. Among other things, Fraunhofer ESK measures and tests network components, end-user devices and services to determine adherence to technical guidelines. The lab therefore has test setups for broadband powerline communication systems, twisted pair and powerline test networks as well as measurement stations for VDSL2 and ADSL2+ standard conformance tests.

Equipment

- Test setup for broadband powerline communication (PLC) systems
- Twisted pair and powerline communication networks
- Diverse measurement equipment, including Ethernet test systems, PC-based data and load generators and analyzers, vector network analyzers and bit error rate testers
- Measurement stations for VDSL2, ADSL2+ standard conformance tests

POINT OF CONTACT:
Mathias Leibiger
Tel. +49 89 547088-372
mathias.leibiger@esk.fraunhofer.de

NGN TEST LAB

In the NGN Test Lab, Fraunhofer ESK researchers develop and optimize customer-specific communication solutions under the aspect of information security. They also analyze communication systems, from the local environment up to cloud services. To do that, Fraunhofer ESK offers usability and interoperability tests, prototype implementation tests and test series for the deployment of user equipment.

Equipment

- Diverse Internet connections (ADSL, VDSL, Gbit connection to the German Research Network)
- Protocol analyzer and traffic generators
- Powerline adapter test environment
- Model institute for the Fraunhofer central private cloud voice service
- SIP test environment consisting of servers and end-user devices

POINT OF CONTACT:
Thomas Messerer
Tel. +49 89 547088-336
thomas.messerer@esk.fraunhofer.de

LABORATORIES

LIVING LAB

With the Living Lab, Fraunhofer ESK offers an environment for researching connected systems, such as those found in industrial systems or automobiles. Apart from a model factory, the Living Lab features a wide range of commonly-deployed devices and machines that can be used to research industry projects in near-real environments, in addition to equipment for developing and analyzing (industrial) wireless networks. The lab is furthermore equipped for rapidly prototyping connected applications.

Equipment

- Rapid innovation tool kit for developing and validating innovative connected functions
- Integrated tool chain for the (model-based) design of connected applications, network and traffic simulations, analysis and validation with the ESK DANA tool, as well as diverse Car2X communications hardware (ITS-G5/802.11p, 4G/5G)
- Rental hardware (communications hardware, antennas, two demonstrator vehicles) for test bench and field testing
- Industry 4.0 test bed: model factory, mobile robots, and much more

POINT OF CONTACT:
Michael Stiller
Tel. +49 89 547088-346
michael.stiller@esk.fraunhofer.de

VICTOR – CONNECTED DRIVING DEMONSTRATOR

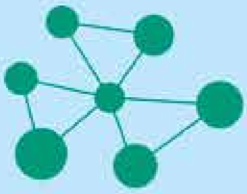
The VICTOR demonstrator, a modified, street-approved BMW 320i coupe, is the ideal platform for the rapid prototyping and testing of dependable Car2X communications concepts. The ezCar2X® software framework developed by Fraunhofer ESK can be used to evaluate various communications aspects of cooperative driver assistance systems with one or more technologies, as well as to test new communications technologies and architectures. VICTOR, which is equipped with several ITS-G5 and LTE interfaces, will be expanded with other technologies such as ITS-G63, LTE-V2X and 5G.

VICTOR also features integrated sensors, including three radar and one laser scanner, which monitor and capture information from the surrounding environment, while an inertial measurement unit provides centimeter-precise positioning. The demonstrator has two patch panels for accessing and merging the sensor data, as well as for creating cooperative environment models.

POINT OF CONTACT:
Josef Jiru
Tel. +49 89 547088-379
josef.jiru@esk.fraunhofer.de

Industry 4.0 Testbed

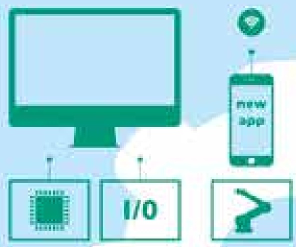
Communication (Wireless)



- Conformity
- Interoperability
- Error detection and resolution

- Wireless lab
- Powerline networks
- Model factory (demonstrator)

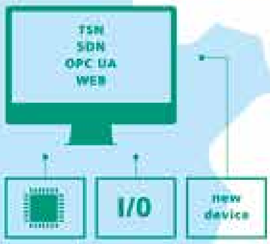
I4.0 Apps and Client-Server Applications



- Data connections
- Tests
- Code review of the data connections

- Model factory (demonstrator)
- Mobile platform (FTS)

I4.0 Devices and Systems



- Installation
- Test, integration and data connectivity
- Functional tests

- Model factory (demonstrator)
- Different communication systems

Consulting – I4.0 Software Development

- Wireless sensor networks
- Powerline
- IoT protocols

- Model-based approaches
- Operational dependability of connected systems

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ESK

INTERVIEW – THE TREND TOWARD RESILIENT INTELLIGENCE

In April 2018, visitors to the HMI in Hannover were afforded a sneak preview of the heart of ENARIS®.

START SIGNAL FOR ENARIS® – THE RESILIENT INTELLIGENCE THINK LAB

At the end of 2017, Munich-based Fraunhofer ESK and Kaiserslautern-based Fraunhofer IESE joined forces to create the ENARIS® Think Lab. Under the leadership of Prof. Dr.-Ing. Peter Liggesmeyer and apl. Prof. Dr. habil. Mario Trapp, researchers at the lab are working on solutions designed to enable resilient intelligence.
In an interview, we asked both men how the collaboration evolved, what's behind the idea of resilient intelligence and what type of added value the two institutes offer for companies.

How did the collaboration between Fraunhofer ESK and Fraunhofer IESE come about?
Peter Liggesmeyer: The idea stemmed from the new challenges created by the trend toward autonomous systems. If these systems are to gain everyday acceptance, we have to focus on more than just artificial intelligence technologies like machine learning. It has more to do with the development of intelligent systems that are also highly reliable and safe. The key lies in system architectures that guarantee reliability and safety even when problems with the artificial intelligence arise, or if these systems exhibit completely unexpected behavior. We refer to this vision as smart embedded systems.

How do the two institutes complement each other?
Peter Liggesmeyer: IESE has a long history in the field of safety engineering and the validation of innovative approaches such as artificial intelligence and highly connected systems. ESK boasts expertise in concrete system architectures that expand established platforms such as AUTOSAR

for instance, or improve dependability by means of graceful degradation. ENARIS® will allow us to offer solutions for the development of safe and reliable autonomous, highly-connected systems.

What type of added value can companies expect to receive from this collaboration?

Peter Liggesmeyer: The exciting thing is, although there is overlap in some areas, both institutes take a different approach. IESE focuses on the engineering of safety-relevant and highly-dependable embedded systems, with a special focus on safety engineering and virtual engineering. ESK's focus is on the development of components that rely on innovative mechanisms to improve the safety and dependability of system and communication architectures. In other words, depending on the requirements, we can use our know-how and project experience to create solutions for devices and technologies that to date have been considered unsafe and undependable by using existing components. We are simultaneously working on joint solutions for our customers.

Are we seeing any results from the projects?

Mario Trapp: We will be introducing the ENARIS® B Virtual Engineering Space in the fall of 2018. Using a new generation of model-based development as a foundation, we are creating a concept that offers opportunities that extend far beyond the basic idea of the digital twin. ENARIS® B will make it easier for companies to turn ideas such as the Internet of Things, cyber physical systems or smart ecosystems into reality because they have a common virtual development platform to develop new solutions and test and analyze them in a simulated Internet of Things and services environment. This virtual engineering space can even be used to validate safety functions. That saves development time and costs and accelerates time-to-market for new applications.

The overall goal of the Think Lab is to enable resilient intelligence. That sounds good, but what does it really mean and what does this type of intelligence allow me to do?

Mario Trapp: As Prof. Liggesmeyer already mentioned, researchers are feverishly conducting research into autonomous systems. These activities are too often boiled down to a question of artificial intelligence (AI). Developing autonomous systems is a systematic challenge however. In many cases, AI behavior can become unpredictable, very quickly. Simply implementing it in a vehicle would be much too dangerous. For this reason, today's safety standards expressly prohibit the use of AI in safety-critical applications. That's why it's important to utilize architectures that ensure safety at the system level. Furthermore, autonomous systems will require intelligence at different levels. And they will be subjected to a wide range of unforeseen situations in the various operating environments. They will connect seamlessly and cooperate with systems that are completely unknown at the time of development. Autonomous systems require high-performance hardware that cannot satisfy today's safety requirements however. For that reason, they have to be developed with a high degree of hardware error tolerance. And autonomous systems have to continuously grow and develop. Despite all of the unanticipated changes that an intelligent system and its environment are subjected to, safety and reliability must still be guaranteed at all times. This combination of intelligence, safety and reliability is what we call resilient intelligence. With our research activities in the area of resilient intelligence in the ENARIS® Think Lab, we are developing methods, plus tangible software modules, that help our customers efficiently develop intelligent systems with guaranteed safety and reliability, all within the cost restraints that companies typically face.

WOULD YOU LIKE TO LEARN MORE ABOUT ENARIS®?

Visit our website at
www.enaris.fraunhofer.de
or contact
Nadine Stumpf
Tel. +49 89 547088-321
nadine.stumpf@esk.fraunhofer.de

FRAUNHOFER HIGH PERFORMANCE CENTER FOR SECURE NETWORKED SYSTEMS MUNICH

At the Fraunhofer High Performance Center for Secure Networked Systems in Munich, Fraunhofer AISEC, Fraunhofer EMFT and Fraunhofer ESK have joined forces with the Technical University of Munich, the Universität der Bundeswehr and industry partners to create a unique research transfer platform in the area of digitalization, with a focus on connected mobility, Industry 4.0 and smart health.

The center is an interdisciplinary transfer infrastructure for industry- and topic-wide systematic research and collaboration in the fields of intelligent sensors, dependable and robust connectivity, data analysis and processing, as well as integrated security and safety.

The center features a test and innovation lab for Car2X pilot projects in which the partners can conduct joint research into new connected applications for future mobility scenarios. In this area Fraunhofer ESK brings its extensive experience and developments from the field of connected mobility.

Following is a selection of ESK publications related to connected mobility and Industry 4.0:

Franze, J.; Seydel, D.; Weiß, G.; Haspel, U.:
Evaluation of Traffic Control Systems as ITS Infrastructure for Automated Driving.
In: Proceedings of the Intelligent Transport Systems (INTSYS 2017), Helsinki, Finland, 2017

Petreska, N.:
End-to-End Performance Analysis for Industrial IEEE 802.15.4e-based Networks.
In: Proceedings of the 16th GI/ITG KuVS Fachgespräch Sensornetze der GI/ITG Fachgruppe Kommunikation und Verteilte Systeme, Hamburg, 2017

BRINGING CONNECTED MOBILITY TO LIFE

Our **Car2X pilot** project is used to test the interaction of various connected systems and components within vehicle traffic networks, from test vehicles, on-board units, communication networks and road infrastructures, to mobile end user devices.

Optimize your systems

- Integration into development and simulation environments
- Hardware-in-the-loop & vehicle-in-the-loop tests
- Verification and configuration
- Timing, performance and QoS analyses

Benefit from knowledge transfer

- Workshops
- In-lab hands-on training
- Technical articles
- Training and education
- Scientific publications

Collaborate with other companies and research institutes

- Test and innovation lab
- Standards-compliant ITS communications stack and middleware
- Development, testing and validation of innovative connected functions
- System concept, proof-of-concept & prototyping

Among other things, Fraunhofer ESK brings its know-how from various committees such as the CAR 2 CAR Communication Consortium (C2C CC) and AUTOSAR.

With its **Industry 4.0 pilot project**, Fraunhofer ESK researches and develops cloud-based data and control systems, by developing the Industry 4.0 administration shell concepts and designs, evaluating new communication architectures.

Petreska, N.:
Network-Calculus-Based Approach for Optimal Transmit Power Allocation in Wireless Industrial Multi-Hop Networks.
Presentation at the Meeting of the VDE/ITG Section 5.2.4 »IP and Mobility«, Munich, 2017

Saad, A.; Staehle, B.; Knorr, R.:
Predictive Medium Access Control for Industrial Cognitive Radio.
In: Proceedings of the 15th IEEE Annual Consumer Communications & Networking Conference (CCNC 2018), Las Vegas, USA, 2018

Seydel, D.; Pöhn, D.; Weiß, G.; Wessel, S.; Wenninger, F.:
Safety & Security Testing of Cooperative Automotive Systems.
Presentation at the Embedded World Conference, Nuremberg, 2018

NETWORKS AND COOPERATION

Operating under the roof of the Fraunhofer-Gesellschaft, 72 institutes conduct research into leading-edge topics that cover a wide range of disciplines. Fraunhofer Groups thus offer an ideal network for conducting joint research activities into new technologies with experts at other Fraunhofer institutes. With this in mind, Fraunhofer ESK is closely integrated into the Fraunhofer Information and Communication Technology (ICT) Group, as well as the Fraunhofer Group for Microelectronics.

Apart from belonging to the Fraunhofer network, Fraunhofer ESK also participates in various technology and industry committees, groups, alliances and working groups. In standards committees such as the 5G Automotive Association, AUTOSAR and CAR 2 CAR Communication Consortium, the institute plays a key role in driving forward necessary standards. Our involvement in industry associations such as the Mechatronics & Automation cluster furthermore helps to identify the industry demand and develop corresponding solutions.

www.fraunhofer.de
www.iuk.fraunhofer.de
www.mikroelektronik.fraunhofer.de

Groups, committees, alliances, working groups

- 5G Automotive Association
- aitiRaum Augsburg
- ASQF e.V.
- AUTOSAR
- BICCNet
- BITKOM e.V.
- Bluetooth Special Interest Group
- BroadBand Forum
- CAR 2 CAR Communication Consortium
- CAST e.V. – Competence Center for Applied Security Technology
- Cluster Mechatronics & Automation
- EAST-ADL Association
- Eclipse Foundation
- ETSI – European Telecommunications Standards Institute
- Fraunhofer ICT Group
- Fraunhofer Group for Microelectronics
- German Informatics Society (GI)
- IEEE – Institute of Electrical and Electronics Engineers
- IEEE 802.1 Drafts
- ITG Fachgruppe 5.2.5 Access- und Homenetworks
- ITS Bavaria
- ITS mobility e.V.
- Open AirInterface Software Alliance
- Open Alliance Special Interest Group
- Round Table: »Automated Driving« of the Federal Ministry of Transport and Digital Infrastructure (BMVI)
- Universal Plug- and Play-Forum
- VDE – Association for Electrical, Electronic & Information Technologies
- VDI – The Association of German Engineers
- ZD.B – Zentrum Digitalisierung Bayern

FRAUNHOFER ESK PROFILE

FRAUNHOFER INSTITUTE FOR EMBEDDED SYSTEMS AND COMMUNICATION TECHNOLOGIES ESK

Over the past several years, Fraunhofer ESK has concentrated on applied research activities in the area of information and communication technologies, with a focus on dependable communication systems in two specific fields:

1. Communication technologies and architectures
2. Application architecture development and validation

Communication technologies and architectures

- Design of dependable, real-time communication systems
- Hybrid and heterogeneous network selection
- Coexistence management: wireless spectrum analysis and prediction
- Network protocols for multihop networks with low latency

Application architecture design and validation

- Architecture and distributed services validation
- Architecture design and analysis
- Methods-based design, test and validation
- Web and domain-specific application protocols
- Protocol and trace analyses

Dependable communication systems

In this area, our scientists conducted research into dependable, real-time vehicle communication systems, Industry 4.0 and wireless spectrum coexistence, among other projects.
The institute worked together with customers and partners in the area of connected mobility, industrial communication, smart grid communication and telecommunications.

Realignment and new leadership since January 2018

Under the new leadership of apl. Prof. Dr. habil. Mario Trapp, Fraunhofer ESK is realigning its research activities to focus on the digital challenges of autonomous systems and connectivity.

BOARD OF TRUSTEES

FRAUNHOFER ESK FACTS & FIGURES

BUDGET

The Fraunhofer ESK research budget totaled €5.47 million in 2017 (2016: €5.69 million). Of this total, €3.8 million was allocated to personnel expenses (2016: €4.0 million) and €1.6 million to material expenses (2016: €1.7 million).

Research revenue from industry contracts totaled €1.1 million in 2017 (2016: €716,000), a level on par with 2015. For 2017 this equates to 20.1 percent of the total budget.

PERSONNEL

As of December 31, 2017, the Fraunhofer Institute for Embedded Systems and Communication Technologies ESK had a total of 50 employees, of which 80 percent were active in the research and technical area (2016: 47). The researchers were supported by 30 research assistants over the course of the year (2016: 27). During the year, 41 interns and university students worked at the institute acquiring know-how and transferring their knowledge into scientific activities.

PUBLICATIONS

In 2016 and 2017, the institute's researchers released a total of 68 scientific publications, supervised 13 bachelor's and master's theses and filed three patents.

PATENTS

Patent publications:

- Bittl, S.: Absicherung von Datenaustausch (Data Exchange Validation)

Approved patents:

- Chen, Y.; Husmann, C.: Verfahren, Vorrichtung und Computerprogramm zum Bestimmen eines Modulationsverfahrens, mit dem eine Mehrzahl von empfangenen Symbolen moduliert wurde (System and computer program for specifying a modulation method used to modulate multiple receive symbols)
- Chen, Y.: Vorrichtung und Verfahren zum Identifizieren eines für ein über einen ausgewählten Subträger übertragenes Symbol verwendeten Modulationsverfahrens (System and process for the identification of a modulation method for transmitting a symbol transmitted via a select subcarrier)
- Eilers, D.; Weiß, G.: Vorrichtung zum Erzeugen eines markierten Referenzdatenstroms (System for creating a marked reference data stream)
- Hildebrandt, G.; Saad, A.: Vorrichtung und Verfahren zur Detektion von Signalinterferenzen (System and method for the detection of signal interference)

UNIVERSITY CHAIR

CHAIR FOR COMMUNICATION TECHNOLOGY

Fraunhofer ESK is headed by Prof. Dr.-Ing. Rudi Knorr, who also holds the Chair for Communication Technology at the University Of Augsburg Department Of Computer Science. This chair is devoted to basic research in the field of self-organizing communication systems in conjunction with next generation networks such as cyber-physical systems or the Internet of Things.

The research and teaching activities are focused on the new demands being placed on information and communication technologies and embedded communication systems. These days, applications, systems and equipment, machines, vehicles, IT networks and embedded systems must operate together in order to provide functions and services that are far beyond the capabilities of the individual components. The challenge here involves ensuring reliability, which means the ability to dynamically react in real-time to changes in the environment, the availability of the devices, services, resources and the degree of robustness in the communication system.

The department's research activities include not only basic technologies for dependable connectivity and data transmission, but also the interoperability and uniformity of various systems and components required for end-to-end communication, particularly with an eye on the future Internet, or the Internet of Things. In other words, a scenario in which Internet technologies pervade all technical systems, leading to the creation of a global and application-wide integration platform.

Other activities include research into adaptive methods for the dynamic and more efficient utilization of wireless and wired channels, as well as the design of new algorithms and protocols for self-organizing networked systems.

Current research projects include the design of dependable IP-based communication processes for internal vehicle systems and wireless Car2X communication, as well as transmission technologies and methods for integrating vehicles into mobility concepts, sensor networks and protocols for use in smart grids and smart production systems.

PUBLICATIONS

The following pages contain a list of publications released by Fraunhofer ESK in 2016 and 2017. Publications marked with an asterisk are available for download via Fraunhofer-Publica: publica.fraunhofer.de

Aktas, Ismet; Bentkus, Alexander; Bonanati, Florian; Dekorsy, Armin; Dombrowski, Christian; Doubrava, Michael; Golestani, Ali; Hofmann, Frank; Heidrich, Mike; Hiensch, Stefan; Kays, Rüdiger; Meyer, Michael; Müller, Andreas; Brink, Stephan ten; Petreska, Neda; Popovic, Milan; Ruchhaupt, Lutz; Saad, Ahmad; Schotten, Hans; Wöste, Christoph; Wolff, Ingo:
Funktechnologien für Industrie 4.0. (*)
Frankfurt/Main: VDE, 2017

Alishov, Ramazan; Spähn, Michael; Witzmann, Rolf:
Co-Simulation Architecture for Centralised Direct Load Control in Smart Grid.
In: Proceedings of the International Conference on Electricity Distribution (CIRED Workshop 2016), Helsinki, Finland, 2016

Bittl, Sebastian; Roscher, Karsten:
Feasibility of Verify-on-Demand in VANETs. (*)
In: Proceedings of the Inter-Vehicle Communication (inter-veh-comm-2016), Berlin, 2016, pp. 10-13

Bittl, Sebastian; Roscher, Karsten:
Efficient Authorization Authority Certificate Distribution in VANETs. (*)
In: Proceedings of the 2nd International Conference on Information Systems Security and Privacy (ICISSP 2016), Rome, Italy, 2016, pp. 85-96

Bittl, Sebastian; Roscher, Karsten:
Efficient Distribution of Certificate Chains in VANETs.
In: Revised Selected Papers of the 2nd International Conference (ICISSP 2016), Rome, Italy, 2017, pp. 86-107

Bittl, Sebastian; Roscher, Karsten:
Mutual Influence of Certificate Distribution and Pseudonym Change Strategies in Vehicular Ad-Hoc Networks.
In: International Journal of Vehicle Information and Communication Systems IJVICS 3 (2017), No. 2, pp. 158-172

Bittl, Sebastian; Roscher, Karsten:
Protocol Modeling Accuracy in VANET Simulators. (*)
In: Proceedings of the 5th GI/ITG KuVS Fachgespräch Inter-Vehicle Communication (FG-IVC 2017), Erlangen, 2017, pp. 13-16

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DANA – Description and Analysis of Networked Applications. (*)
In: Proceedings of the International Workshop on Competitions, Usability, Benchmarks, Evaluation, and Standardisation for Runtime Verification Tools (RV-CuBES 2017), Seattle, USA, 2017, pp.71-80

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Method for Automatic Resumption of Runtime Verification Monitors. (*)
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Resiliente Netze mit Funkzugang. (*)
Frankfurt/Main: VDE, 2017

Franze, Juliane; Seydel, Dominique; Weiß, Gereon; Haspel, Ulrich:
Evaluation of Traffic Control Systems as ITS Infrastructure for Automated Driving. (*)
In: Proceedings of the Intelligent Transport Systems (INTSYS 2017), Helsinki, Finland, 2017

Heidrich, Mike:
The Concept of Industry 4.0. (*)
Presentation held at Industrie Paris, l'usine du futur, Paris, 2016

Heidrich, Mike:
Fehlende Standards bremsen das Internet der Dinge noch.
In: Elektronikpraxis (2016), Embedded Software Engineering,

Heidrich, Mike:
Fehlende Standards bremsen das Internet der Dinge noch.
In: Mechatronik News (2016), No. 2, pp. 3-4

Heidrich, Mike; Luo, Jesse Jijun:
Industrial Internet of Things: Referenzarchitektur für die Kommunikation. (*)
Whitepaper, Munich: Fraunhofer ESK, 2016

Heidrich, Mike; Oswald, Erik:
Kommunikationstechnik für intelligente Messsysteme. (*)
Presentation held at the 20th VDE-Arbeitskreissymposium »Netzleittechnik«, Dresden, 2017

Heidrich, Mike:
Referenzarchitektur für die Kommunikation im IIoT. (*)
Presentation held at the Internet of Things (IoT) Kongress, Munich, 2016

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Technische Umsetzung von Smart Metern. (*)
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Heinrich, Patrick; Oswald, Erik; Knorr, Rudi:
Energy Saving Potential of Adaptive, Networked, Embedded Systems: A Case Study. (*)
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Knorr, Rudi:
Wie die SPS in die Wolke wandert: Web-basierte Steuerungssysteme im Maschinen- und Anlagenbau.
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Langmann, Reinhard; Stiller, Michael:
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Konzept und Implementierung einer I40-Komponente für Steuerungen aus der Cloud. (*)
In: Proceedings of the 4th Markt & Technik Industrie 4.0 & Industrial Internet Summit 2016, Munich, 2016

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In: Atp-Edition (2017), No. 4, pp. 24-37

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Enhancing the Performance of WiNPLC Smart Grid Communication with MIMO NB-PLC.
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Presentation held at the ETP Fachforum Innovative Netzplanung und -steuerung, Berlin, 2016

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End-to-End Performance Analysis for Industrial IEEE 802.15.4e-based Networks. (*)
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Network-Calculus-Based Approach for Optimal Transmit Power Allocation in Wireless Industrial Multi-Hop Networks. (*)
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Petreska, Neda; Al-Zubaidy, Hussein; Staehle, Barbara; Knorr, Rudi; Gross, James:
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Heterogeneous Networking for Cooperative Applications. (*)
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Know Thy Neighbor. A Data-Driven Approach to Neighborhood Estimation in VANETs. (*)
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On the Feasibility of Multi-Hop Communication in a Realistic City Scenario. (*)
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Reliable Message Forwarding in VANETs for Delay-Sensitive Applications. (*)
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Fail-Operational In-Vehicle E/E-Architectures – Dependable Basis for Automated Driving.
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Neue Konzepte für zukünftige E/E-Architekturen.
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In: Internationales Verkehrswesen (2017), No. 4, pp. 49-51

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EDITORIAL NOTES

Publisher
Fraunhofer Institute for Embedded Systems
and Communication Technologies ESK
Hansastraße 32
80686 Munich, Germany

Tel. +49 89 547088-0
info@esk.fraunhofer.de
www.esk.fraunhofer.de

Editorial and production team
Nadine Stumpf
Tel. +49 89 547088-321
nadine.stumpf@esk.fraunhofer.de

Melanie Haas
Tel. +49 89 547088-397
melanie.haas@esk.fraunhofer.de

Title page
The title page shows the installation *Moving Lines* (2008) from freelance artist Reinhold Föst and OSRAM Light Consulting

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Design and layout
www.brandneu-design.com

English edition
Daniel Hawpe English Language Services
Olching, Germany (dhawpe@web.de)

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