

PREFACE

This is the eighteenth and the last foreword for the ITWM Annual Report that I have written. I am now entering retirement and my successor, Anita Schöbel, has assumed the duties of an Executive Director on April 1, 2019. Anita Schöbel joins the Institute and TU Kaiserslautern as an internationally recognized scientist and an outstanding spokesperson for Kaiserslautern. Personally, I am pleased to hand over management responsibilities to her and can say with confidence that she will continue to promote applied mathematics in the department and to maintain the successful course of ITWM and, in both areas, she will set her own mark.

The year 2018 was a year of growth and future prospects are excellent. We enjoy fantastic working conditions and the accomplished and successful ITWM staff represents an outstanding team; highly motivated and highly dedicated to the institute. We are very well-connected – in the Fraunhofer-Gesellschaft, in Kaiserslautern, and in the scientific community. These networks report excellent and successful feedback. Again in 2018, all departments reported positive figures and the share of business revenue is roughly 50 percent of the operating budget. Our sister institute, Fraunhofer Chalmers Centre for Industrial Mathematics FCC in Gothenburg has grown steadily and is very well-positioned with a broad range of mathematics and engineering competence.

One of the special highlights of 2018 for ITWM was the stabilization of the High Performance Center for Simulation and Software-Based Innovation Kaiserslautern for three more years. The center focuses on research, marketing, and knowledge transfer within the general area of the digital transformation. The digital transformation is both a challenge and a great opportunity for the center. The huge potential for innovative solutions is increasingly being leveraged in areas that have not yet been penetrated by simulation and software. The performance center is ideally positioned in the area of information systems for the “Human-Machine” and “Machine-Machine” interfaces, for the implementation of AI in industrial manufacturing processes, in the design of digital infrastructure for cities, villages, factories,

schools, agriculture, etc. and also in the area of logistics and industrial data.

Again in 2018, ITWM attracted many new employees and Ph.D. candidates. The especially significant news is that almost 40 percent are women. I attribute this successful recruitment effort to intensive public relations work. In this connection, we received very positive feedback regarding a special publication. The magazine »bild der wissenschaft« was published with the supplement »Erfolgsformeln – Wie die Mathematik Technik und Wirtschaft nach vorne bringt« in July 2018. The science editors dedicated 44 pages depicting a versatile and colorful picture of our institute and our research.

ITWM underwent a restructuring in 2018 that established the division as a new organizational unit. The Optimization Division was created to house the departments of “Optimization – Technical Processes” and “Optimization – Operations Research,” both of which experienced strong growth. This growth is a reflection of the fact that industrial volume was more than 90 percent from key customers and, secondly, a funding balance in preliminary research. For example, in the Optimization – Operations Research department, a commission from Goldbeck Solar AG resulted in the development of a new tool for planning open space photo-voltaic systems. In the Optimization – Technical Processes department, industrial customers gained access to a new application-oriented methods and simulation tools in the context of the flagship project “Machine Learning for Production” and the “Fraunhofer Machine Learning Cluster.”

The Department of Mathematical Methods in Dynamics and Durability was re-organized as the Mathematics for Vehicle Engineering (MF) Division. This new division has been assigned the two departments, “Dynamics, Loads, and Environment Data (DLU)” and “Mathematics for the Digital Factory (MDF)” as well as the project group “Tire Simulation” and the Cross Section Unit “MF-Technikum,” which focuses on testing and measuring systems. The Dynamics, Loads and Environment



Data (DLU) department develops methods and tools for system simulation including environment data and variations in use. The Mathematics for the Digital Factory (MDF) department concentrates on the development of software tools for the virtual genesis and development of products.

The development of the Competence Center High Performance Computing is also accented by growth and the expansion of its portfolio of expertise and business areas, which will also undergo a re-structuring to be implemented in 2019. Last year, the EU commissioned a Europe-wide consortium to develop a European processor for a future exascale computer. The CC HPC is part of this consortium and, together with Fraunhofer IIS, is developing a special processor that will greatly accelerate a class of algorithms.

The Flow and Material Simulation department with expertise in simulation-aided characterization and virtual design of multi-functional materials enhanced its success through the further development and licensing of various simulation tools. The department works closely with the Center for Materials Characterization and Testing, which created the first ever mobile terahertz measurement system for testing plastic welds on pipelines in 2018. All focus areas of the Transport Processes department reflect positive development – in particular, the strategy of targeted software development and licensing is returning the initial successful results. Future sales of MESHFREE, our flow solver product, will be stronger as a result of increased promotion by distribution partner ScaposAG. In the Image Processing department, the research area “Industrial Image Learning” was expanded with priority on Machine Learning in image processing for manufacturing and other industries. The Financial Mathematics department succeeded in attracting well-known names in the field of data science for long term, innovative collaborative formats. In this area, anomaly detection is streamlining operative processes and optimizing accounting audits. Since April 2018, the Systems Analysis, Prognosis and Control department has been part of a consortium of eleven partners in eight countries developing an integrated simulation

framework for wind farms in the Horizon2020 Project UPWARDS.

This completes my brief summary of departmental highlights. In closing, I want to express my sincere appreciation to our employees. Today, ITWM is the largest research institute in Rhineland-Palatinate and its economic and scientific excellence is fully attributable to their know-how and experience, which together with the innovative power of mathematics is the basis of our success. Additionally, we also have our shared values and structures, i.e., sustainable employee loyalty, flat hierarchies with well-positioned autonomous departments, promising the customer only what we can deliver, and avoiding “much ado about nothing.” Ours is a corporate culture characterized by tolerance and acceptance of each other, and – last, but not least – not only working together, but also celebrating together.

I thank you all for your commitment and your enthusiasm for the institute, for the excellent cooperation, and for your untiring efforts in supporting the management of ITWM. We can be very proud of our accomplishments and I am grateful for having had the opportunity to work with you all over so many years. My thoughts and appreciation go out to all of ITWM’s project partners for the constructive and enjoyable cooperation and, finally, I hope you all enjoy reading the Annual Report 2018.

Prof. Dr. Dieter Prätzel-Wolters

Frau Schöbel, what motivated you to apply for the top position at our institute?

I have been intrigued by applied mathematics ever since my degree studies and wanted to support the transfer of research results into practice. I read the job announcement and found the position as director of a Fraunhofer Institute very appealing. My professional orientation is also an outstanding match with my colleagues at TU Kaiserslautern. By the way, I studied and earned by doctorate here. I was even a member of the ITWM staff for two years before accepting a professorship in Göttingen and moving there with my family in 2004. Meanwhile, my children are out of the house, so I have more time for new challenges. Finally, I really like Kaiserslautern and the surroundings, so I could well imagine coming back to the Palatinate.

What do value most about your new place of business?

That would be the employees, who maintain an open and good working atmosphere and who facilitated my start at the institute. Of course, I also appreciate the work of many exciting projects, which explore a diverse range of subjects. And, let me also mention this classy office building.

What are your special goals for the future of ITWM?

It is important to me that we are perceived as a leading research institute in the scientific community. Furthermore, I want our work at the institute to be recognized under the motto "Mathematics for a bright future." Many of our projects already represent this description, for example, the development and characterization of new useful materials, vehicle safety, and health and energy projects are just a few of them. I also want to encourage better inter-departmental cooperation to better exploit the potential synergy effects.

What do you see as the greatest challenges facing ITWM in the coming years?

The departments have established a strong reputation in industry and business in recent years. This must definitely continue in the years ahead and we must maintain our availability as a competent project partner. The digital transformation offers many areas of opportunity for applied mathematics; it would be nice to contribute to the development of innovative ideas. Internal to the institute, there is always the challenge of maintaining a good and trusting working environment for all employees, even as ITWM continues to grow in terms of space and personnel.

How are you managing so many new tasks?

I have already seen many interesting projects, gotten to know many of the employees, and am starting to understand the Fraunhofer procedures. Additionally, I am establishing initial contact to other Fraunhofer Institutes, to the government, and naturally, to the Technical University and other local scientific institutes. Fortunately, if I have questions or do not know something, everyone has been very understanding, especially, the administrative units. Mr. Prätzel-Wolters has given me great support in the first few months, and I am very grateful for his time, explanations, and answers to my many questions. I also appreciate that he is continuing his support to our institute as a consultant and I personally look forward to working with him.

A professorship is associated with your position as director of the institute. At the Georg-August University in Göttingen you were a professor for optimization at the Institute for Numerical and Applied Mathematics: As a member of the faculty of mathematics at TU Kaiserslautern, what working group will you chair?

My professorship here is quite commonly called "Professor for Applied Mathematics," which is a reflection of the diverse functional range at ITWM. My focus continues to be in the field of optimization. I am pleased that I can already contribute to an existing working group at the department and also that



the doctoral student and two post-docs, who switched from Göttingen with me to Kaiserslautern, have found such an outstanding professional environment. I also relocated my German Research Foundation (DFG) group on “Integrated Transport Planning” to TUK.

Do you see any synergies with your work at the institute?

My expertise and research interest is a natural match with the Optimization division of ITWM. Still, discrete optimization problems also exist in other departments, for example, in MF, BV, HPC, and FM (and perhaps, I will find some more!). My application area “Mobility in the Future” also overlaps several departments and I think a joint collaboration would be valuable and maybe even result in a couple of new projects. My experience includes work with multi-criteria optimization and planning under uncertainty; which are also relevant to the practical applications pursued at ITWM.

Our neighbor, the German Research Center for Artificial Intelligence has recently appointed Prof. Jana Köhler as CEO. You are one of the first women to lead a Fraunhofer Institute – does the future belong to women?

Well, the future is certainly more female than the past – we are hopefully out of the era in which people were hired or not hired because of their gender! The goal often mentioned is to have an equal number of male and female staff in each special subject area. It makes more sense to me that people work in the area of their interests. But it is important that everyone has the same opportunities for further development. For example, it should not be the case that the ratio of women to men decreases as the hierarchical level increases – there is still room for improvement in this respect!

Scientific career

- 1979 – 1988 High school “Karolinengymnasium” in Frankenthal
- 1988 – 1994 Study of mathematics with a minor in economics at the University of Kaiserslautern
- 1994 Diploma thesis: Kombinatorische Optimierung in der Tarifplanung im ÖPNV
- 1999 Dissertation thesis: Locating Lines and Hyperplanes – Theory and Algorithms
- 2003 Habilitation thesis: Customer-oriented Optimization in Public Transportation

Professional activities

- 1994 – 1998 Research assistant at the department of mathematics, University of Kaiserslautern
- 1998 – 1999 Head of the traffic group at Fraunhofer ITWM
- 1999 – 2004 Scientific assistant (C1) at the department of mathematics of the University of Kaiserslautern
- since 04.2004 Professor (W2) at the Institute for Numerical and Applied Mathematics at the Georg-August University Göttingen (since 10.2007: W3 position)
- Summer 2007 Calls to W3 positions in Wuppertal and Trier
- since 01.2019 Professor for Applied Mathematics, University of Kaiserslautern and director of Fraunhofer ITWM

Research interests

Integer optimization, robust optimization, optimization of public transport, geometric optimization methods, location theory



INSTITUTE PROFILE

Computer simulations are an indispensable tool in the design and optimization of products and production processes, services, communication processes and work processes. Real models are replaced by virtual models. Mathematics plays a fundamental role in the creation of this virtual world. Because mathematics is the technology which generates these images and converts them efficiently into software, the raw material of the models and the core of every computer simulation.

Applied mathematics as a key technology

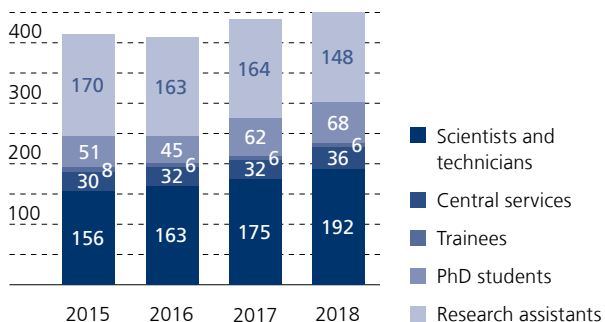
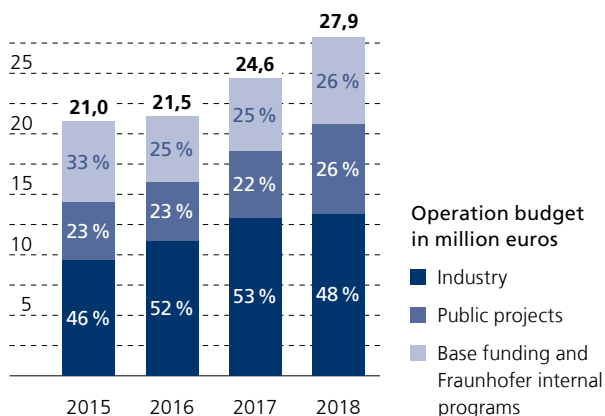
Increasingly more small and medium-sized companies utilize simulation for cost reduction. It is specifically these companies that we support with consultation and computing power. They profit in the market through the use of simulation as identification for innovation and quality assurance of their products. Of course, we also cooperate with large companies, especially in the automotive sector, mechanical engineering, the textile industry, microelectronics, the computer industry and the financial sector. Integral components of our R&D projects are consulting and implementation, support in the application of high-performance computer technology and the provision of tailor-made software solutions. We not only use simulation software, but also develop it ourselves, often in cooperation with leading software companies.

Our specific competencies are

- Processing of data acquired from experiments and observations
- Drafting of mathematical models
- Implementation of mathematical problem-solving in numerical algorithms
- Summarization of data, models and algorithms in simulation programs

- Optimization of solutions in interaction with the simulation
- Visualization of simulation runs in images and graphics

We not only want to build the bridge between the real and virtual world, but we also want to be the link between university mathematics and its practical implementation. Therefore, the close connection to the Department of Mathematics of the Technical University of Kaiserslautern plays a special role.





Industries – who do we work with?

Thanks to the comprehensive methods resident in our departments and the broad spectrum of application areas, our customer base may range across many sectors. Fraunhofer ITWM provides core competencies in the areas:

- Modeling and simulation
- Optimization and decision support
- Data analysis and visualization

and addresses companies and organizations in the sectors:

- Process/Mechanical/Systems engineering
- Automotive and suppliers
- Pharmaceuticals and medical systems
- Power industry
- Technical textiles
- Information technology
- Finance

As a result of the long term cooperation with our regular customers, a considerable domain competence has evolved in some areas of individual sectors; to name a few in particular, the automobile sector, process engineering, and the energy sector. For all sectors: Fraunhofer ITWM's modeling and simulation competence creates a real competitive advantage in the marketplace.

Advisory board Fraunhofer ITWM

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MACHINE LEARNING – A PROMISING APPROACH

The digital transformation of the economy and society is increasingly being driven by the use of Artificial Intelligence. It is now found in everyday applications like route planners and voice assistants, but also in professional applications like industrial quality control, medical diagnostics, and autonomous vehicles. This innovation is mainly driven by Machine Learning techniques; in particular, Deep Learning or neural networks are responsible for significant progress along with the enormous increases in computing power and major investments in know-how.

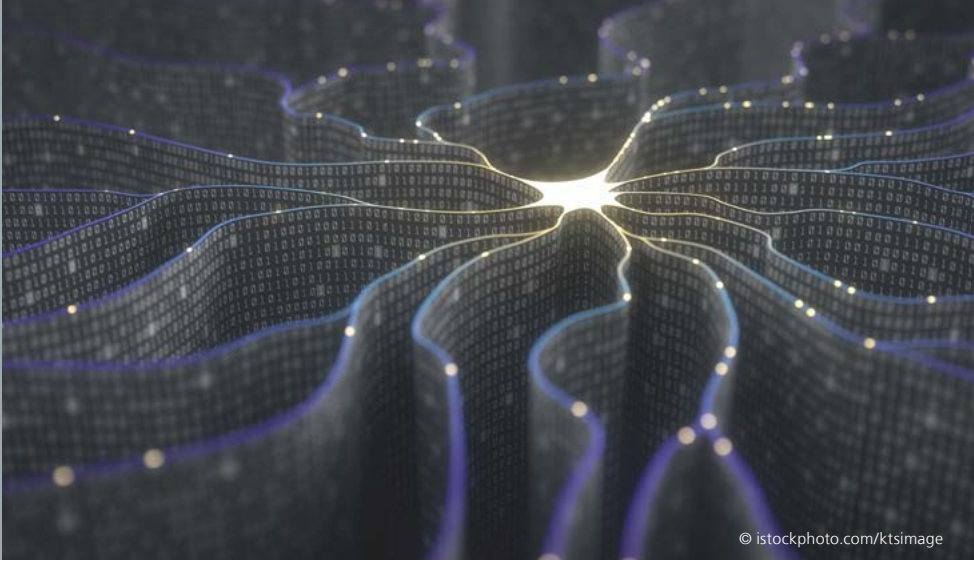
Machine Learning is now a routine technology, but every algorithm is only as good as the data used to train it. Often, large amounts of data are available in companies that want to leverage ML methods to optimize their processes and products, but rarely is this in a form easily used for Machine Learning. However, problems such as data reliability and robustness are now well understood and are being researched worldwide, including at our institute.

Hybrid approach: Expert knowledge combined with Machine Learning

We want our joint venture partners in industry and business to have the software tools they need to improve their processes. This refers to customized software that enables fast comparisons of different alternatives to assist in identifying potential improvements. The modeling of real processes has to be highly realistic and reliable: reality must be so well represented that the proposed improvements are both feasible and quantifiably reliable. Machine Learning processes combine with the existing expert and physical models to provide answers to this challenge. Various methods, like neural networks or support-vector machines are trained and integrated using existing data. This technique ensures the model is accurate enough to identify substantial process improvements.

ML methods in action institute-wide

At ITWM, nearly every department uses Machine Learning, mainly some hybrid simulation-based Machine Learning methods. For example, the System Analysis, Prognosis and Control department uses ML algorithms to create tools that analyze, interpret, and visualize biological medical data. ML methods are also used in a predictive maintenance context to predict the occurrence of unwanted operating states and events. The Transport Processes department develops a hybrid approach to design and optimize production processes in the textile industry using ML methods: the DensiSpul project focuses on the optimization of bobbin winding machines. Specifically, the research aim is to improve the dyeing of the yarn wound on the bobbins.



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ML methods have long been important in the field of image processing: just consider the major focus on the development of safe and stable algorithms for optical quality controls in production. Quality is not the main challenge here because in a well-functioning plant many images of fault-free products are available, rather the problem is insufficient data since only a few images of products with defects are available. One possible solution is data augmentation, that is, the creation of artificial error databases that are based on real error data. You can also prepare mathematical descriptions of the defects and train the image processing algorithms with the model. The department offers classic machine-learning solutions that can be used to automate the processing of vast amounts of image data that previously had to be classified manually.

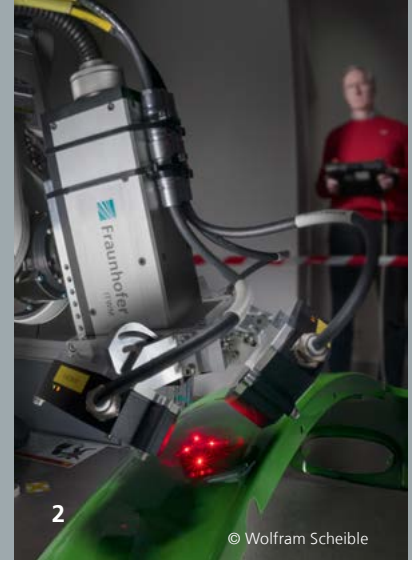
Neural networks enable significant energy savings

The Optimization Division successfully uses Machine Learning in process engineering and has created a new analytical tool to save significant amount of energy in the production of chemicals. Here, again a hybrid approach is used. Measured data such as pressure or temperature is collected with sensors in technical systems and serves as the basis of this approach. In the past, sensor data was used only for process monitoring; now it can be used for training neural networks. The development of the new tool was selected for the Fraunhofer Prize 2019.

Priority for High Performance Computing

Machine Learning and data analysis have been declared a main research focus of the Competence Center for High Performance Computing. One of the tasks is the development of new algorithms for the distributed computation for the training of neural networks and realization on specialized hardware. The main focus is on the implementation of scalable optimization algorithms for the distributed parallelization of large Machine Learning problems. In fact, the basis for this was developed at CC HPC. It is HPC components like the parallel file system BeeGFS or the programming framework GPI2.0 that make the efficient implementation of new algorithms possible.

Fraunhofer ITWM has seen increased demand in recent years not only for its outstanding research activities, but also as a service provider of seminars on Machine Learning.



“BILD DER WISSENSCHAFT” PUBLISHES FORMULA FOR SUCCESS

Two of the featured high-light projects:

1 *Radiation therapy planing*

2 *Layer thickness measurement using terahertz waves*

Our supplement was published in “bild der wissenschaft” in June – 44 pages explaining why mathematics is universally indispensable as a key technology. The successful journalistic preparation of our priorities with illustrative example projects allowed us to reach a significantly larger audience and the resulting publication can be used in the longer term for a wide variety of PR channels, target groups, and occasions. In effect, networking our multimedia content allows us to use and re-use it for a longer period of time.

The June edition of “bild der wissenschaft” marked the start of our campaign with a distribution of 90,000 copies, after which we further increased the range through targeted mailings, presentations at various events, and multiple online media publications. Another benefit from our cooperation with Konradin publishers is the access to first-class photo material: the images of the different project topics were created entirely for us and can be used in all media.



What was the outreach of our „Erfolgsformeln“?

- bild der wissenschaft: coverage approx. 505.000
- ITWM: 5.000 print copies
- Industrieanzeiger: coverage approx. 200.000
- bild der wissenschaft newsletter: approx. 19.000 subscribers
- Website wissenschaft.de: 475.000 page impressions
- Facebook: 7.100 persons reached
- Twitter: 12.000 impressions



A NIGHT OUT WITH SCIENCE: SCIENCE SLAM, MATHEMATICS WORKPLACE, AND “TRANSPARENTES GLÜCK”

ITWM participated in the local “Night out with science” again in 2018 to present our “Mathematics Workplace” to a broad public. The Science Slam kick-off event attracted many visitors to the Fraunhofer Center where they subsequently streamed into the atrium to see the ITWM exhibits that were clustered there: The Mathematics Workplace was divided into the areas “Measurement – Testing – Evaluation”, “Modeling and Optimization”, and “Technologies for e-mobility and energy management”.

The exhibition “Transparentes Glück” by photographer Thomas Brenner was on display in the foyer of the Fraunhofer Center – nine large-format collages, composed of staged and journalistic photographs, X-rays, and even text passages. The multi-faceted work forged a creative bridge between complex high-tech subjects like High Performance Computing, Big Data, and algorithms and their sensitivity in contemporary social reality.

1 *Photo art at the entrance foyer*

2 *Within reach: real and virtual worlds in the ITWM*

3 *Another eye-catcher on Tripstadter Straße: Sandstone sculpture “Virus”*

VIRUS INSTALLATION

Since autumn, a sandstone sculpture with cast iron spines stands on a platform in front of our building: The work is titled “Virus” and it was created for the Sculptor Symposium 2017 at the Picard quarry sponsored by the Skulpturen-Verein Rheinland-Pfalz. The search for a permanent home for “Virus” proved to be difficult. Because of the heavy weight of the installation, displaying it in the interior of the Fraunhofer building was ruled out of the question and the placement in a public space requires a safety audit – a lengthy procedure. Finally, at the end of October, the Kaiserslautern Fire Department managed to transport the three-ton sculpture and, with the help of a giant crane, the piece was safely lowered into its current location.

About this piece, visual artist Monika Biet says: “Natural forms of great beauty exist in the microcosmos, but they may also hide a powerful potential for destruction. Virus represents this state of ambivalence between aesthetics and aggression, creating a visual and tactile experience.”

A case can also be made for a scientific relevance: In collaboration with other Fraunhofer Institutes, mathematicians in the Optimization Division are studying the effectiveness of artificially modified Herpes viruses for use in tumor therapies in Project TheraVision.



1

KLEINE FORSCHER
Naturwissenschaften und Technik für Mädchen und Jungen



2



3

© fleXstructures

KITA KLAMMERÄFFCHEN DESIGNATED AS A »HAUS DER KLEINEN FORSCHER«

1 *Young researchers at our daycare*

2 *Thursday is Researchers' Day*

3 *f.l.t.r.: Dr. Ulrich Link, ISB Board Member, Maria Beck, Business + Innovation Center Kaiserslautern, Oliver Hermanns, CEO fleXstructures, and Dr. Klaus Dreßler, Head of Mathematics for Vehicle Engineering at the ITWM, after the award ceremony*

The "Klammeräffchen" daycare center at the Fraunhofer Center celebrated its certification as "Haus der kleinen Forscher" with a science festival. Klammeräffchen became the fourth institution in Kaiserslautern to be awarded this title. The certification is awarded by the non-profit "Haus der kleinen Forscher" Foundation to daycare centers committed to a good early education. The aim is to prepare girls and boys for a strong future with the main focus on the domains of natural sciences, engineering, computer science, and mathematics (MINT) – while also teaching them to act in the interests of sustainability.

"Thursday is research day!" at our daycare center. Our educators continuously train for this. Their dedication was also rewarded by the Fraunhofer Headquarters with a second place finish in the "Creative kids" competition: The winner's certificate is accompanied by new toys, a 300 euro voucher, and DOCH gym bags.

"SUCCESS AWARD 2018" FOR ITWM SPIN-OFF FLEXSTRUCTURES

The Ministry of Economics Affairs, Transport, Agriculture and Viticulture Rhineland Palatinate and the state's Investment and Economic Development Bank (ISB) selected our spin-off "fleXstructures" for the Success Award 2018. Every year, this award is presented to a small and medium-sized company that has developed and brought future-oriented new products, production processes, and technology-oriented services successfully to the market. fleXstructures was awarded the highest endowed technology prize of 15,000 euro for its innovative measuring machine MeSOMICS, which is integrated in the proven IPS software.

In combination with the simulation software IPS Cable Simulation, it is now possible to optimally accommodate several kilometers of cables and hoses in the small installation spaces available in modern vehicles. The product was developed and patented by the department of Mathematical Methods in Dynamics and Durability and is now distributed worldwide by fleXstructures GmbH.



DOUBLE AWARD: YEAR'S BEST TRAINEE AND COMPANY

The IHK Pfalz not only honored the trainee, but the training company too in November 2018. Tobias Grau (former trainee assigned to the IT department of ITWM), as well as his training institution (= Fraunhofer ITWM) were selected as the "Year's Best" in a ceremony at the Bad Dürkheim Salier Hall. Tobias Grau completed the program with a grade of 1.7 (excellent), graduating as an IT specialist with a concentration in in system integration. During his three years at ITWM, he was exposed to many different areas: Windows and Linux administration, desktop management, conference systems, and selected parts of network administration.

1 *Year's Best IT specialist :
Tobias Grau*

2 *ITWM-Alumni at the
first part of the network-
ing meeting*

ALUMNI DAY: STRENGTHENING THE BONDS – FORGING NEW OPPORTUNITIES

The second ITWM Alumni Day looked to the future with a look back: in the afternoon, the fifty or so alumni were introduced to current and future-oriented projects at the institute in 16 "elevator pitches" given by the current staff. The pitches focused, for example, on industrial image learning, thickness transparency, MESHFREE, or district heat. Next, visits to the relevant working groups led to detailed discussions. Later that evening, current employees met with the former employees at a strategic networking event at the Fruchthalle in Kaiserslautern. A stage play conceived by employees and alumni focused on the institute's past. In a three-act play, they reviewed the last twenty years of the institute – a pleasant history lesson for many of the alumni. The catalyst was the upcoming farewell of our longtime director Dieter Prätzel-Wolters, who retired in April. During his tenure, he intensified the networking of the ITWM within Fraunhofer and with universities and non-university organizations; but also increasingly important is networking with alumni.

This commitment to our alumni is supported by the Fraunhofer Alumni Association. Among other activities, the association awards prizes for successful new member recruitment concepts. The submitted concepts are evaluated at the end of the year. The evaluation criteria includes the effectiveness of the concept in terms of increasing the membership in the Fraunhofer Alumni Association, planning alumni events, or other successful networking formats at the institute. The idea of an ITWM Alumni Day was nominated for a prize!



CAREER NIGHT AT FRAUNHOFER CENTER

1 *Tinkering together in the Escape Game: in our lecture hall, a 5×6 m cube was built and converted into the office of a Fraunhofer scientist.*

2 *Our scientists were sought-after contacts at Fraunhofer Career Night.*

Can you master team challenges while at the same time realizing your own ideas? YES you can; for example, when you play the Fraunhofer Escape Game, one of the many activities at Career Night at the Fraunhofer Center. ITWM and IESE jointly organized the event to attract interest in Fraunhofer as an employer: more than 150 MINT students and even recent graduates spent the entire evening at the Fraunhofer Center gathering first-hand information about initial entry jobs and the career outlook at Fraunhofer.

The highlight of the evening was the “Escape Game”. In a specially built room, players solved riddles together and tried to fend off a hacker attack, all to protect and save some critical data – a challenge which demanded knowledge, technical savvy, and team spirit to win. In addition to the Escape Game, participants enjoyed guided tours through the two institutes and individual sessions on selected “Research Live” projects. The event came to an end with in-depth networking in a relaxed atmosphere with the current employees of both Fraunhofer IESE and Fraunhofer ITWM.

MINT-EC MATH TALENT SCHOOL

What does the professional world of a mathematician look like and what is applied mathematics? In August, 26 school children from schools in national excellence network “MINT-EC” learned the answers at the Math-Talent-School at our institute. The school is supported by MINT-EC in cooperation with the Felix-Klein Center for Mathematics (a joint institute of Fraunhofer ITWM and the Mathematics Department at TU Kaiserslautern).

The students who come to work on various issues using mathematical modeling and computer simulations are passionate about math. The issues are broad enough to reflect the diversity of mathematics in everyday life: “Choreographies for music wells”, “Navigation in times of e-mobility”, “Produce together, consume together” and “Smart farming - the digital farm”. At the end of the Math Talent School, each group presented and discussed their solutions in a plenary session. Of course, a visit to the Department of Mathematics of the Technical University of Kaiserslautern was also on the program, which included detailed information about the mathematics program.



Front, left to right: Brigitte Williard, Sylvia Gerwalin, Dr. Markus Pfeffer, Esther Packullat, Ilka Blauth, Martin Vogt, Michaela Grimberg-Mang, Prof. Dr. Anita Schöbel, Katharina Parusel, Stephanie Beck, Manuela Hoffmann, Jana Mai, Eva Schimmele, Dieter Eubell, Prof. Dr. Dieter Prätzel-Wolters, Hülya Zimmer, Waltraud Dully, Gaby Gramsch, Steffen Grützner, Tino Labudda, Christian Fuchs, Mirko Spell, Yvonne Kusch-Engers, Brigitte Biguet, Elmar Gerwalin, Christian Peter, Dominic Schunk, Martin Braun

OUR NETWORK

CUSTOMERS AND COOPERATION PARTNERS SELECTON 2018

- AAC Technologies, Turku (FIN), Nanjing(RC) Shenzhen (RC)
- AbbVie Deutschland GmbH & Co. KG, Ludwigshafen
- AL-KO GmbH, Kötz
- Altair Engineering, Troy (USA)
- AUDI AG, Ingolstadt
- BASF SE, Ludwigshafen
- BioNTech AG, Mainz
- BMW, München
- BPW Bergische Achsen Kommanditgesellschaft, Wiehl
- Brückner Group GmbH, Siegsdorf
- BSN Medical, Emmerich
- ContiTech Transportbandsysteme GmbH, Northeim
- Corning GmbH, Kaiserslautern
- Daimler AG, Stuttgart
- das-Nano S.L., Tajonar, Navarra (E)
- delta h Ingenieurgesellschaft mbH, Witten
- Deutsche Institute für Textil- und Faserforschung Denkendorf
- Dilo Machines GmbH, Eberbach
- Dres. Englmaier Beratungs GmbH, Waldkraiburg
- ebm papst, Mulfingen
- Equinor ASA, Stavanger (N), Trondheim (N), Oslo (N)
- ESI Group, Paris (F)
- Evonik Technology & Infrastructure GmbH, Hanau
- EWR AG, Worms
- FLSmidth A/S, Kopenhagen (DK)
- Freudenberg Filtration Technologies, Kaiserslautern
- GEF Ingenieur AG, Leimen
- GKV Spitzenverband, Berlin
- Goldbeck Solar GmbH, Hirschberg
- Goodyear S.A., Colmar-Berg, Luxembourg
- Grimme Landmaschinenfabrik GmbH & Co. KG, Damme
- Groz-Beckert KG, Albstadt
- GRS mbH, Köln
- Haas Schleifmaschinen GmbH, Trossingen
- Helmholtz-Institut für elektrochem. Energiespeicherung, Ulm
- Universities of Applied Sciences: Berlin, Birkenfeld (Trier), Darmstadt, Kaiserslautern, Lübeck, Mainz
- Hubert Stüken GmbH & Co. KG, Rinteln
- Hübner GmbH&Co. KG, Kassel
- IAV Group, Berlin
- IBS FILTRAN GMBH, Morsbach-Lichtenberg
- Imilia Interactive Mobile Applications GmbH, Berlin
- Institut für Textiltechnik (ITA), Aachen
- IPConcept (Luxemburg) S.A., Luxemburg (L)
- John Deere GmbH & Co.KG, Mannheim, Kaiserslautern
- Johns Manville Europe GmbH, Bobingen
- Karl Mayer, Chemnitz
- Kelheim Fibres GmbH, Kelheim
- Kreisverwaltung Mainz-Bingen
- KSB Aktiengesellschaft, Frankenthal
- Liebherr, Kirchdorf / Colmar
- Lonza AG, Basel
- MAGMA Gießereitechnologie GmbH, Aachen
- Mahle GmbH, Stuttgart

- Maja Möbelwerk GmbH, Wittichenau
- MAN Truck & Bus Deutschland GmbH, München
- Maserati S.p.A./Alfa Romeo, Modena (I)
- Meggitt Polymers & Composites, Stevenage (GB)
- Merck KGaA, Darmstadt
- mfd Diagnostics, Wendelsheim
- Netze BW GmbH, Stuttgart
- Nissan, Kanagawa (J)
- Odenwald Faserplattenwerk GmbH, Amorbach
- Panasonic R&D Center Germany GmbH, Langen
- Paul Wild GmbH, Kirschweiler
- Plastic Omnium, Brüssel (B)
- Porsche AG, Stuttgart, Weissach
- proALPHA Business Solutions GmbH, Weilerbach
- Procter & Gamble, Cincinnati (USA), Schwalbach, Kronberg
- Progress Rail Inspection & Information Systems, Bad Dürkheim
- PSA Peugeot Citroen, Velizy-Villacoublay Cedex (F)
- PSI Software AG, Aschaffenburg, Dortmund
- R+V Versicherung, Wiesbaden
- Repsol, Houston (USA)
- Rittal, Herborn
- RJL Micro & Analytic GmbH, Karlsdorf-Neuthard
- Robert Bosch GmbH, Stuttgart
- Rolls-Royce, Berlin
- RWE Generation SE, Essen
- Santander Consumer Bank AG, Mönchengladbach
- SAP AG, Walldorf
- Scania CV AB, Södertälje (S)
- Schaeffler Automotive Aftermarket GmbH & Co. KG, Langen
- Schleifring und Apparatebau GmbH, Fürstenfeldbruck
- Schmitz Cargobull AG, Altenberge
- Seismic Imaging Processing SIP, Aberdeen (GB)
- SIEDA GmbH, Kaiserslautern
- Spin-offs of ITWM: fleXstructures, Math2Market, Produktinformationsstelle Altersvorsorge, Sharp Reflections, Think-ParQ (alle Kaiserslautern)
- Stadtentwässerung Kaiserslautern AöR, Kaiserslautern
- Stryker GmbH & Co. KG, Freiburg
- Technische Werke Ludwigshafen
- TGS Nopec, Houston (USA)
- Toyota Motor Europe NV/SA, Brüssel (B)
- Umicore, Hanau
- Union Investment Privatfonds GmbH, Frankfurt/Main
- uniper Anlagenservice, Gelsenkirchen
- Universities: Aachen, Berlin, Bordeaux (F), Bremen, Dortmund, Dresden, Erlangen, Frankfurt/Main, Freiberg, Freiburg, Heidelberg, Kaiserslautern, Karlsruhe, Kassel, Mainz, München, Münster, Nancy(F), Saarbrücken, Trier, Ulm
- VAN DE WIELE, Kortrijk (B)
- Varian Medical Systems International AG, Cham
- Voith GmbH & Co. KGaA, Heidenheim
- Volkswagen AG, Wolfsburg
- Volvo, Eskilstuna (S)
- ZF, Friedrichshafen

OUTSTANDING NETWORKS IN KAISERSLAUTERN

The High Performance Center for Simulation and Software-based Innovation was established three years ago. In April 2018, it entered the second funding period after a successful evaluation. This ensures the continuation of the success story in the area of application-oriented simulation and software technologies resulting from the cooperation of two Fraunhofer institutes IESE and ITWM with the Technical University, the University of Applied Sciences, other research institutions such as the German Research Center for Artificial Intelligence and the Institute for Composite Materials and several companies.

The center provides a cross-sector, application-oriented, interdisciplinary framework for pre-competitive research and cooperation. Sectors include chemical and process engineering, the vehicle industry (especially, commercial vehicle engineering) as well as the information and energy sectors. The research institutions involved cover the entire spectrum of expertise in the modeling of technical processes and products, simulation and software methods, optimization, and decision support.

Research labs and transfer centers

The center's organization remains centered on R&D labs and transfer centers. The research and development labs are oriented mainly on methods; they develop the concepts and algorithms that are then made available to the transfer centers as basic technologies.

The topics in "MSO-Based Process Engineering" are centered on modeling, simulation, and optimization (MSO) in process engineering. The "Digital Commercial Vehicle Technology" transfer center focuses on commercial vehicle systems, while "Smart Ecosystems" investigates Smart Energy, Smart Health, and Green by IT in addition to adaptive and open systems.

Research subjects

- System modeling and software solutions, e.g., for e-mobility
- Lightweight construction, digitalization, and software-ecosystems
- Decision support for industrial process optimization
- Human-Machine-Environment Interaction
- Digital twins for production and autonomous systems
- Safety concepts for open and adaptive systems
- Machine Learning, in particular, Deep Learning algorithms

The High Performance Center is known nationally and internationally through its individual research partners. Overall, it has a strong regional orientation, partly due to strong regional industrial partners such as BASF, Daimler Trucks and John Deere. To increase national and international visibility, the center is increasingly cooperating with other centers of excellence.

Transfer path

To achieve our major goal – the sustainable transfer of the results to business and science – various transfer paths are considered from the center to the economy and to society along with their concomitant impact on research. Currently the following paths are taken:

Contract research

- Industrial contracts: Key customers and new acquisitions
- Industry seminars and conferences
- Demonstrators and real labs

Licensing (proprietary rights)

- IP exploitation of software and simulation products
- Licensing business with spin-offs and software companies

Spin-offs

- Incubator for simulation and software technologies
- Closing the technology gaps at external start-ups and SMEs

Continuing education (for business)

- Software engineering, digital commercial vehicle technology, deep learning
- Planned: Industry 4.0, Process simulation

Clever minds and cool careers

- Youth development at TU Kaiserslautern(workshops, lectures, graduate studies)
- Scholarship programs for bachelor, master, and Ph.D. degrees at the Felix Klein Academy for Mathematics

Community involvement

- Events sponsored by the Science and Innovation Alliance, such as "A Night out with Science"
- Participation in long term regional projects: OD Pfalz, "Digitale Dörfer", EnStadt: Pfaff

The High Performance Center relies on cooperation with established local partners specializing in spin-offs (Gründungsbüro KL, IHK Pfalz), continuing education (DISC for post-grad distance learning programs), and civic organizations (Science and Innovation Alliance, ZukunftsRegion Westpfalz) for the implementation of this last transfer path.

NETWORKING AND COOPERATION WITHIN THE FRAUNHOFER-GESELLSCHAFT

A large network and innovative partners are crucial for the success of projects. That is why we are part of a network of national and international cooperations and a member of several associations within the Fraunhofer-Gesellschaft:

- Fraunhofer Groups
 - Fraunhofer ICT Group
 - Fraunhofer Group for Materials and Components – MATERIALS (as associated institute)

- Fraunhofer Alliances
 - Automobile Production
 - Battery
 - Big Data
 - Cloud Computing
 - Lightweight Design
 - Simulation
 - Textile
 - Traffic and Transportation
 - Vision

Within Fraunhofer, we are a sought-after research partner because we are involved in various internal research projects, such as MAVO/WISA projects, five SME/MEF projects and a Discover project. Fraunhofer research clusters promote the cooperative development and handling of system-relevant topics through a cross-institutional research structure. In organizational terms, these research clusters correspond to a “virtual institute” that is spread over several locations. We are involved in these clusters:

- Programmable Materials
- Advanced Photon Sources
- CIT – Cognitive Internet Technologies

Lighthouse Projects: Preliminary research alliance

The lighthouse projects represent a special feature of Fraunhofer research. Their topics are determined on the basis of current industry demands and rely on the expertise of various institutes to provide efficient preliminary research. The aim is to secure the technological leadership of Fraunhofer – in addition to high standards of scientific excellence. The program aims to exploit the synergistic potential of the Fraunhofer Gesellschaft by bringing together the competencies of several Fraunhofer institutes to provide solutions to the challenges facing German industry. The central hub is always a specific project. Fraunhofer funded research in 14 lighthouse projects in 2018; we participate in four of these.

ML4P – Machine Learning for Production



This lighthouse project bundles the extensive expertise of seven Fraunhofer institutes in the field of Machine Learning in production processes. The need is great as both the process and the piece goods sector have processes that are interconnected and machines, interfaces, and components that communicate with each other.

The goal is to model an entire plant and, based on this overall model, use mathematical optimization methods to propose improvements in system design or operating modes. To achieve this goal we use our knowledge of physical modelling and Machine Learning methods. These learning methods are based on complex simulation data as well as on measured operating data from the production units. The operating data is obtained from sensor monitoring or from the documentation of operating conditions. The priorities are to use ML methods in statistical analysis of time series and to achieve the automated analysis of image data.

QUILT – Quantum Methods for Advanced Imaging Solutions



The QUILT network is currently very well-positioned in the field of quantum imaging thanks to technology platforms, groundbreaking experiments, and a worldwide collaborative research alliance. This position is to be further strengthened in the future as a lighthouse project, in which we perform a key role in the modeling, simulation, and optimization of quantum-based, non-contact methods. Our goal is to design more reliable, faster, and cost effective imaging processes for material surfaces. The focus is on the development of a digital twin to enable quantitative predictions of quantum-optical experiments as well as a terahertz structural analysis system to improve detection efficiency.

COGNAC – COGNitive AgriCulture




The Fraunhofer lighthouse project “Cognitive Agriculture” aims to automatically record and process the complex relationships found in crop production and optimize crop-specific operations that result in increased productivity at no consequential ecological risk. Our contribution is in the innovative area of new sensor technologies and is dedicated to the modeling, simulation, and optimization of agronomic processes (for example, the growth and yield of wheat crops). An important objective is to identify correlations and influencing factors for the purpose of deriving recommendations for action, for example, for robust crop campaign planning. We continuously monitor weather updates and harvesting data to enable us to plan personnel and equipment requirements in advance. Robust models and algorithms help us to reduce the costs of drying and fuel, while simultaneously increasing food quality and customer satisfaction.

eOPT – Electricity as a resource



The project develops electro-chemical processes for fluctuating power and resource systems; the result provides the opportunity to use low-cost electricity as the energy source – even for power intensive sectors like chemical production. Specifically, the project focuses on the electrochemical conversion processes used for the production of hydrogen peroxide as a green bleaching agent and for the conversion of CO₂ into valuable basic chemicals.

We prepare estimates of kinetic constants by adjusting the variables in RRDE experiments and modeling the electrochemical cells, including transport phenomena. We implement the cell models for a commercial flowchart simulator and integrate them in an overall flowchart. Our expertise in multi-criteria optimization facilitates identifying the best possible operating strategy for the process, while accounting for fluctuation in the price of electricity.



SPIN - OFFS

Math2Market

Math2Market, our first and largest spin-off, was responsible in the early years for the marketing of the GeoDict software developed by the Flow and Material Simulation department. This software has meanwhile grown into the Digital Material Lab GeoDict®, which Math2Market continues to develop by integrating tools generated at ITWM. Math2Market supports companies with an integrated package for the efficient development of better materials and processes. Customers are located worldwide and represent a range of sectors including filtration, composites, and electrochemistry. However, manufacturers of batteries and fuel cells make up the majority.

fleXstructures

fleXstructures is a spin-off company of the department Mathematical Methods in Dynamics and Durability. It distributes the IPS software jointly developed with Fraunhofer-Chalmers Research Centre for Industrial Mathematics in Göteborg, Sweden. The IPS Cable Simulation is a major tool in this product group; it is used in the automotive and commercial vehicle industries, but also in aerospace and mechanical engineering to ensure the efficient laying of cables and hoses, for example in the vehicle engine compartments.

Sharp Reflections

The Competence Center for High Performance Computing jointly develops the Pre-Stack Pro software with the Norwegian oil and gas company Statoil, for the analysis of seismic reflection data. Sharp Reflections is responsible for the distribution and continuing development. Pre-Stack Pro applies parallel computer technology to derive reliable information about the properties of oil and gas deposits from large data sets. In Norway, Sharp Reflections supports the local customers and manages the worldwide distribution of the products.

ThinkParQ

ThinkParQ, another spin-off from the Competence Center for High Performance Computing, is the company behind the parallel cluster-file system BeeGFS. Large volumes of data are managed in a user-friendly way, both locally and in the cloud using this highly scalable storage product.

Product information office for retirement planning PIA

Since January 2017, on behalf of the Federal Ministry of Finance, this independent office performs the classification of the opportunity and risk profiles of funded pension plan products. It is a wholly owned Fraunhofer subsidiary and works closely with our Financial Mathematics department.

FURTHER COOPERATIONS

- **Center for Mathematical and Computational Modeling (CM)²** co-located in the Mathematics department of TU Kaiserslautern, is focused on mathematical applications in the engineering sciences.
- **Felix-Klein Center for Mathematics FKZM**
The FKZM is an institutional pooling of resources from the Mathematics department at TU Kaiserslautern and Fraunhofer ITWM, with a focus on the promotion of young researchers, to include modeling weeks for schools, scholarships, and a mentor program for students of mathematics.
- **Science and Innovation Alliance Kaiserslautern SIAK**
SIAK is a network for digital transformation, innovation and interdisciplinary research. It is regionally anchored through its members from science – universities and research institutes – and industry – especially from small and medium-sized enterprises.
- **Software-Cluster**
The software cluster is a network of companies, educational and research institutions in the field of software development around the cities of Darmstadt, Kaiserslautern, Karlsruhe, Saarbrücken and Walldorf.
- **MINT-EC**
The national Excellence School Network MINT-EC has set itself the goal of inspiring students for MINT subjects (mathematics, computer science, natural sciences and technology). In cooperation with MINT-EC, regular events such as the Math Talent School take place.
- **ZukunftsRegion Westpfalz e.V.**
The association ZukunftsRegion Westpfalz wants to bring together people, companies and organisations from the region in order to work together for strengthening the Westpfalz and the future viability of this region.
- **KOMMS**
The Competence Center for Mathematical Modelling in STEM projects was established to connect school projects, teacher trainings, education of teacher students and research.
- **EMVA**
EMVA (European Machine Vision Association) is a non-profit organization with the purpose to represent the machine vision industry in Europe. Since January 2018, the Image Processing and Materials Characterization and Testing departments have been involved as members.
- **Kompetenznetz Verfahrenstechnik Pro3**
Kompetenznetz Verfahrenstechnik Pro3 stands for the networking of industrial partners with research and teaching in process engineering, bioengineering and chemical engineering. The aim is to strengthen process engineering in Germany.



FRAUNHOFER-CHALMERS RESEARCH CENTRE FOR INDUSTRIAL MATHEMATICS FCC

One of the most important international partners of Fraunhofer ITWM is Fraunhofer-Chalmers Research Center for Industrial Mathematics (FCC), founded by the Fraunhofer-Gesellschaft and Chalmers University in Göteborg in 2001. Its mission is very similar to that of Fraunhofer ITWM and the center works most closely with our Mathematical Methods in Dynamics and Durability department as well as the Optimization and System Analysis, Prognosis and Control department. In 2015, an international committee evaluated the scientific and business development as well as the future strategy of FCC. The successful rating confirms the Institute is an outstanding research facility that has become a center for industrial mathematics in Sweden. Its portfolio covers contract research, service, algorithms and software, all based on modern mathematical methods in the area of modeling, simulation, and optimization (MSO) that flow into industrial innovations for products and production systems. Areas of application include mechanical engineering, life sciences, paper and packing industry, electronics, and information and communication technologies (ICT).

The Fraunhofer-Chalmers Research Center for Industrial Mathematics is structured in three departments:

- “Geometry and Movement Planning” works in close cooperation with Chalmers Wingquist Laboratory to develop simulations for automated path planning, sealants, flexible materials (e. g., cables and hoses) and human movement models. This last area is important for the ergonomic design of assembly processes.
- “Computational Engineering and Design” works on innovative numerical methods, fast algorithms, and engineering support tools for virtual product and process development. Applications include fluid dynamics, structural dynamics, and electromagnetism.
- “System and Data Analysis” supplies expertise in dynamic systems, forecasting and controls, image and video analysis, statistics, and quality engineering, in addition to technical, biological and biomedical applications.

The FCC currently has a staff of 55 employees and a budget of six million euros in 2018.

THE FRAUNHOFER-GESELLSCHAFT AT A GLANCE

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 26,600 staff are qualified scientists and engineers, who work with an annual research budget of 2.6 billion euros. Of this sum, 2.2 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.

