Anniversary edition: In 1959, the Fraunhofer Institute for High-Speed Dynamics, Ernst-Mach-Institut, EMI, in Freiburg became the sixth institute in the Fraunhofer-Gesellschaft. For 60 years we have been successfully researching in order to increase security and resilience, for assertiveness and protection of systems of the Bundeswehr and in recent years, additionally, for more sustainability through less consumption of resources in our society. The cover image shows the eponym of the institute Ernst Mach in artistic editing who congratulates the institute with a wink.
Dear reader,

The internet of things, digitalization, globalization, artificial intelligence – corona – what’s next? The corona crisis is a disruption – for society, the supply chains, global trade as well as for childcare centers, retirement homes, the local café around the corner, and most families.

Disruptions are always challenging. After this crisis, many things will no longer be as they used to be. We will forever miss some things, but other, new things can emerge from it. Disruptions are not the black swan nobody could have expected. They are the standard. If we look in the history books, we quickly realize that pandemics are a recurring phenomenon. We must expect them to happen – again and again. Thus, we should gain as much knowledge as we can from the current experience – because only if we learn from experience, we can prepare better for the next disruptive event. Resilience is the key word for this crisis. Only those systems and individuals who overcome it without a lasting slump in performance can call themselves resilient. Engineers try to master the crisis and the disruption employing the five phases prepare, protect, prevent, respond, and recover.

At EMI, we also conduct research on this topic, especially in our business unit Security and Resilience. We analyze the capability of infrastructure systems to withstand disruptions and to remain available for society. Furthermore, we are looking for ways to increase their resilience. To this end, we conduct smaller and larger experiments, develop computer models and simulate the behavior of industrial facilities, supply systems, railroad connections or airports during disruptive events. In the present annual report, we present a small selection of our research conducted in the different business units. You will see that our experiments and diagnostics have become even more dynamic. Our scientists are working on future large-scale equipment of the German Federal Armed Forces as well as on safe urban environments, battery powered automobiles, and on the EMI nanosatellite ERNST. And again, the focus is put on the availability of a system even during disruptive events and beyond. This is a challenge that we have happily been willing to face for many years and continue to do so. I want to thank all partners, customers and colleagues from the scientific community, economy and politics for the trust you have continuously placed in us. Enjoy reading!

Sincerely yours,

Stefan Hiermaier

Prof. Dr.-Ing. habil. Stefan Hiermaier
Director of Fraunhofer EMI
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DESIGN OF PERSONAL ARMOR SYSTEMS USING LATEST VIRTUAL HUMAN BODY MODELS
SMALL IMPACTS WITH MAJOR IMPACT
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False color rendering of process light emission during the perforation of a plate of carbon-fiber reinforced plastic by a high-energy laser beam. (To highlight the laser beam, it was intensified in the graphics.)
The German Federal Armed Forces (Bundeswehr) need sustainable systems for land, air and sea. As a strategic partner of the German Federal Ministry of Defence (BMVg) regarding high-speed dynamics research and technology, Fraunhofer EMI explores scientific and technological issues regarding protection, armor and effect, as well as defense-related security and systems within national or European research programs.

With the support of the BMVg, Fraunhofer EMI was able to complement its high-energy laser laboratory by an extremely powerful high-energy laser system. The multi-mode industrial fiber laser system allows research on intense laser effects in the short-distance laboratory environment. From early on, long-term suitable protective concepts for soldiers and systems can now be investigated. For example, materials for military systems can be tested regarding their “laser robustness”. Further research results achieved are presented in the following.

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Fraunhofer EMI has now got significantly expanded experimental capabilities to examine the effects of high-intensity laser radiation and scaling effects at short distance in the laboratory. Basic research can now be extended up to a power of 120 kilowatts.

Dr. Jens Osterholz
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SCALING EFFECTS OF HIGH-ENERGETIC LASER RADIATION

Fraunhofer EMI has upgraded its special laboratory for investigations of the effects of intense laser radiation with an extremely powerful high-energy laser. According to the manufacturer, this laser is currently the worldwide most powerful industrial laser for continuous-wave operation on the basis of fiber laser technology. Thus, in the future, considerably extended experimental capabilities will be available to investigate the effects of high-intensity laser radiation and scaling effects at short distance in the laboratory. Basic research can now be extended up to a power of 120 kilowatts. The output power of the new laser was specified according to the assessment of experts, who expect the introduction of laser weapons with a power of well over 100 kilowatts from the middle of this decade. EMI has thus created the basis for supporting the German Armed Forces with scientific analyses of laser effects and for carrying out investigations regarding the protection of soldiers in conjunction with the application of high-energy laser weapons. Exemplarily, the new laboratory offers the capability to test the laser resistance of materials for future defense systems. The robustness against laser irradiation can now be investigated and evaluated over an extremely wide power range.

In the context of basic research, the laser will be used for the analysis of the laser-matter interaction in this new power range, where so far only few scientific studies have been carried out. The laser can now be used to achieve very high energy inputs into the material samples in time intervals which are very short compared to typical time scales of heat diffusion processes. Closely related to this topic are scientific questions on thermal effects and thermomechanical material behavior and their scaling with the laser power. With the new laboratory capability, phenomena of material failure in particular with regard to temperature dependence and heating rate dependence can now be examined over an extremely wide power range. The novel testing capabilities considerably expand the basis of experimental data, which can then be further used for modeling for the numerical simulation as well as for the development of new fields of application.
Up to now, virtual human body models have mainly been applied in applications where clothing does not play a significant role, for example, car-to-car or car-to-pedestrian simulations. The Human Body Dynamics Team of Fraunhofer EMI has developed a method to put on a soft ballistic vest to a virtual human body model in a standing posture.

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DESIGN OF PERSONAL ARMOR SYSTEMS USING LATEST VIRTUAL HUMAN BODY MODELS

Not only the dynamic response of technical materials and components can nowadays be analyzed using simulation tools, also the response of the human body can be studied by involving virtual human body models. Human body models represent actual humans in detail, including not only the outer body shape, but also bones, muscles, ligaments, tendons, and internal organs. Originated from automotive industry, human body models have started to contribute to the improvement of crash safety measures for both, occupants and pedestrians. Especially when crash scenarios strongly deviate from standard crash-test requirements, when non-standard body postures as well as body positions are of interest, or when the overall muscular stress level of the person involved needs to be taken into account, human body models are generally the only choice.

Link human body models to personal armor systems

In the field of defense, the design of personal armor systems, which is primarily driven by empirical knowledge and experimental data, can significantly benefit from the application of human body models, too. The link to involve such models to virtual body armor design was the lacking capability to transform modular-based textile components from a two-dimensional planar configuration to arbitrarily shaped and usually double-curved body contours. This until recently unsolved problem has been addressed by researchers of Fraunhofer EMI. In pre-stage forming simulations, the textile components that have been modeled in 2D get transferred to the three-dimensional body shape given by the wearer in the situation of interest. The modeling method is designed to work with human body models of different distributors and considers arbitrary postures, body sizes, statures and genders.
One base model – multiple applications
In the current case, a soft ballistic vest has been put on the torso of a 50th percentile male (GHBMCM50-P). The generated model opens a wide range of applications for simulation engineers. Using a multitude of single simulations, strengths and weaknesses of existing protective solutions can be analyzed in detail. By virtual testing, the impact of different projectile types, impact velocities, inclination angles, impact locations, the distribution of multiple hits, either regularly or statistically defined, a ballistic designed vest or any other kind of protective armor system can be tested numerically in advance. Hence, the virtual design of protective clothes is able to contribute to improved future body armor systems and last but not least, to protect the lives of men and women during their mission. When looking at new threats, the same approach will help to identify material limits that would be necessary to defeat a certain threat. Material suppliers could adjust manufacturing processes to produce materials with enhanced protection levels.

Experimental backup – the biofidelic dummy
For backing up numerical simulations with experimental data, it is planned to involve the so-called biofidelic dummy in near future. The distinguish-
ing mark of this dummy, originally developed for pedestrian accident reconstruction, is its wide and flexible range of application and its failure limits that have specifically been adopted to human body requirements. If an external force acting on this dummy exceeds a certain threshold, when one would expect a human to suffer from a severe injury, e.g., rupture of bones or ligaments, edema, abrasion, blunt trauma, the dummy's component will fail accordingly. A technical autopsy allows to get insight into the interior of the dummy so that a comprehensive damage report can be generated. Last but not least, the dummy can be equipped with conventional measurement devices such that experimental results can be compared to conventional dummies and lots of test data can be generated, e.g., for the evaluation of injury risk assessment.

Basic FE model of the soft ballistic part of the body armor in flat shape.
The application of hydrocodes for the simulation of initiation processes in plastic-bonded explosives (PBX) on the mesoscale is a challenging task. The thermo-mechanical behavior of the material shall be predicted, including possible initiation. For this purpose, EMI uses its own, highly specialized software SOPHIA, which is continuously further developed and improved.

Representative volume element with simulated velocity and temperature distribution.

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sized explosive crystals, is represented in high spatial resolution. The challenge here is to replicate the behavior of the material under rapid mechanical or thermal loading up to possible initiation in order to be able to predict the time when a chemical reaction starts. Here, internal processes, such as the damage that is caused by detachment of crystals from binder or by breaking of crystals, play an important role. Using this type of models, security features of PBX, for example, the insensitivity to shock loads, are being investigated and optimized by changing the composition. The new methods required for this application are implemented in EMI’s own software SOPHIA, which, in this context, is used for the mesoscale simulation of PBX for the German Federal Armed Forces.

EXCELLENCE IN THE FURTHER DEVELOPMENT OF HYDROCODES

For many years, hydrocodes, numerical simulation methods for highly dynamic processes, such as crash, impact and explosions, have been used at the Ernst-Mach-Institut. In addition to the use of software from various providers, the institute’s own hydrocodes are being continuously developed, applied in projects and also licensed for external customers.

A particularly demanding field of application is the simulation of initiation processes in plastic-bonded explosives (PBX) on the mesoscale. In this kind of numerical models, the heterogeneous structure, i.e., plastic-based binder and micrometer- to millimeter-
Meanwhile, methods are now available in SOPHIA that, in this combination, cannot be found in commercial and research codes of other institutions worldwide. This includes sophisticated algorithms for the calculation of temperatures in dynamically loaded materials, which have been combined with a special element formulation for tetrahedra. Tetrahedral elements offer maximum flexibility for the representation of geometrical structures. However, they tend to show numerical instabilities, particularly with hardly compressible materials, such as binder materials typically are. Therefore, special correction algorithms are developed and used. The figures on page 18 and 19 show an RVE in its initial state and the simulated velocity and temperature distributions. In the simulation, the right edge has been pushed to the left at a speed of 1000 meters per second. At the displayed point of time, the resulting wave has almost reached the left side.

The capability to represent material failure in three-dimensional models of PBX with fracture-mechanics-based, so-called “cohesive zone elements” is also unique. This technique is used, for example, for the separation of crystals from the surrounding binder matrix. During the calculation, cohesive elements are automatically inserted where the maximum strength is exceeded; they are used to calculate the decreasing traction during the cracking process. The picture on the right shows at the top a uniaxially compressed RVE, in the middle the corresponding crystal structure without binder and at the bottom the damage value for the cohesive zone elements.
The detonation of IEDs (improvised explosive devices) can cause high impulse transfer into vehicles in operation and thus endanger the occupants. In the department Experimental Ballistics, scientific methods are being developed to better protect land vehicles against IEDs. A scaled experimental technology was set up to analyze the effect parameters of buried charges. This results in the possibility of an efficient evaluation of improvement measures directly on the vehicle, e.g., vehicle floors with different shapes.

In addition, an arrangement was developed that allows the specific impulse to measure when a buried charge is detonated as a function of the distance in the horizontal plane. After the reaction of the load, several concentric rings are accelerated. The local specific impulse can be determined from the respective velocities. By investigating different embedding materials, important influencing factors for the impulse transfer were worked out, which are used as the basis for the validation of simulation models.

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Investigation of the structural behavior of a soil-filled protective wall in a shock-tube test (detonation event in the far field).

SOIL-FILLED PROTECTION SYSTEMS

Soil-filled gabions can provide effective protection against shock waves resulting from detonation events. Therefore, the group Security of Structures is researching the potential of these structures as protective enclosure in order to design them as a wall system safe and efficient against hazards like blast loads.

At component level, such protective walls with different types of soil are tested on EMI’s own shock-tube facility BlastStar. The soil-specific properties of the backfilled materials are determined in the laboratory.

This allows a detailed evaluation of the structural response under consideration of soil-mechanical and dynamic aspects, respectively. The results are supported by numerical analyses using hydrocode simulations. Thus, the structural behavior of these highly dynamically loaded protective walls can be recorded and evaluated effectively. In the future, research work will enable a faster and more accurate dimensioning of such structures and at the same time serve as part of basic research in the field of soil dynamics.

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FUTURE COMBAT TRAINING SYSTEM
SAFE TRAINING IN REALISTIC SCENARIOS

To enable Bundeswehr soldiers to carry out their mission successfully and safely, they must be optimally prepared. An essential element is the training of realistic operational scenarios – especially in live firing (“train as you fight”). New technical approaches allow to enhance the training area structure.

As part of a research project on range safety in handgun training, research was started on how the digitization of military training facilities can provide at least the same or increased range safety – with improved training and extended training options. One focus was on generation and processing of sensor data with integrated weapons and portable target systems. The data thus accessible are used for a security system to determine and control the internal and external range safety. In doing so, the concept of dynamic hazard areas was developed, which requires a digital training area environment.

A first field demonstration is scheduled for 2020 at a Bundeswehr military training area.

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SAFE JOINT CONNECTIONS UNDER VERY HIGH-RATE LOADING

Military aircrafts are subjected to very high-rate loading, as for example high-velocity impacts or blast loads. In order to design safely these types of structures, it is important not only to characterize the materials but also the joints connecting the different parts. However, for the relevant high loading rates, the high-rate servo-hydraulic testing machines cannot provide reliable oscillation-free load-displacement curves.

For this reason, a high-rate material testing device, the “split Hopkinson tension bar”, has been adapted at Fraunhofer EMI in order to enable the testing of aviation representative joints. For this purpose, samples made of typical aircraft material, carbon-fiber reinforced plastics (CFRP) and aluminum, have been manufactured. During the first test campaign on the adapted device, three kinds of joints have been tested successfully: bonded, mechanically fastened and hybrid bonded-mechanically fastened.

Thus, realizing tests with the split Hopkinson tension bar constitutes an adequate method for the high-rate characterization of joints. The obtained results demonstrate furthermore the potential relevance of hybrid joints to increase the safety of aircrafts: These types of joints both withstand high forces and absorb much energy until failure. Further joints will be characterized in the future using the developed setup.

Dr. Mathieu Imbert
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The accuracy of weapons is largely determined by the mechanical interaction between the barrel and the projectile during launch. Barrel vibrations and lateral oscillations of the projectile perpendicular to the barrel axis cause variations in the bullet’s motion state after muzzle exit, resulting in a dispersion of target impact locations. Centrifugal forces also play a role in the case of rifled launch tubes. Aside from the effects on dispersion, the mechanical loads during launch may cause excessive damage to the projectile, which in the worst case poses a hazard to personnel and equipment. Experimental investigations on launch dynamics by means of on-board diagnostics are difficult due to the high level of longitudinal acceleration (sometimes more than 100,000 g). As for small-caliber projectiles, they are not suited simply because of the prevalent space limitations.

Numerical simulations are therefore used at Fraunhofer EMI as a fast and cost-effective alternative. Through the coupled use of structural-dynamic finite-element codes in conjunction with a lumped-parameter interior ballistics model and 6-DOF flight calculations, it is thus possible to gain valuable insights into the influence of individual parameters on the projectile unit accuracy.

Deformation of a small-caliber projectile after firing in experiment and simulation.

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TEST METHODS FOR THE SAFETY OF BATTERIES IN USE

Lithium-ion (LI) technology is nowadays indispensable in both military and civil environments. Their use ranges from battery packs for portable electronics to vehicle batteries and large stationary storage systems. Fraunhofer EMI researches to improve the safety of these batteries and carries out experimental tests with a focus on dynamic load cases (for example, the crash behavior of batteries).

For the safe use of LI batteries in the German Armed Forces, additional military conditions – such as shelling or blast loads acting on a vehicle – must be considered and tested. The risk potential under these special load cases as well as suitable protective measures can be investigated at Fraunhofer EMI thanks to a unique portfolio of experimental technology. In recent years, experiments have been conducted with small battery packs worn on the person. An expansion of the test facilities is currently being planned to extend the experiments to larger batteries that can be used in military vehicles.

While safety tests for civil applications are already specified in a large number of standards, Fraunhofer EMI is supporting with its research that this step can also be advanced for specific military requirements.

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RISK FROM AGING AMMUNITION

Aging and spilled ammunition pose dangers. The risk analysis tools developed at EMI can be used to determine how high these risks are and whether risk reduction measures have to be taken or how these measures should be assessed. For example, Fraunhofer EMI is working with the Swiss authorities on the Mitholz case (see page 36).

View into a non-collapsed tunnel area with ammunition items thrown in by the explosion.

PRESENTATION FOR A PROMINENT AUDIENCE

During a visit of General Eberhard Zorn, Inspector General of the German Armed Forces, and Saxony’s Prime Minister Michael Kretschmer to the military training area Oberlausitz in July 2019, Sven Nothdurft, Sebastian Hess and Dr. Siegfried Nau had the opportunity to present their innovative approaches to digital support for safe training with hand-held weapons in live fire at the highest military level.

General Zorn (center) and Saxony’s Prime Minister Kretschmer (front left) on the military training area Oberlausitz. Dr. Siegfried Nau (right), Sebastian Hess (fourth from right) and Sven Nothdurft (second from right) present solutions for the digitalization of the Bundeswehr.

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BUSINESS UNIT
SECURITY
Security is a fundamental social need.
The world affairs reveal that our societies face ever-increasing challenges to ensure their security. Repeatedly, we find ourselves confronted with threats of sorts and extent society as a whole never imagined. How can we address such threats while considering a world in constant change? This is the core question concerning research of the business unit Security.

In this connection, solutions have to be developed to offer answers to complex issues. The wide range of threats is also mirrored in the range of requirements to matching solutions that aim to counter such perils in urban and rural environments in a national and trans-national setting.

The following articles cover topics such as security of cities and their citizens with respect to deliberate explosive attacks as well as analyzing the resilience of trans-European networks against man-made and natural hazards.
In the two-year German-Austrian project DURCHBLICK led by Fraunhofer EMI and the Austrian AIT, research focused on a robot-assisted, high-performance sensor system for the examination of improvised explosive devices (IEDs). By integrating new technologies, bomb squads will have a better tool to help assess situations of danger. The results were presented at several international events, including the international congress of bomb-disposal (EOD) experts of the Federal Criminal Police Office (BKA) in 2018.

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Project research included the use of imaging methods by mobile X-ray backscatter technology as well as, together with the Freiburg Materials Research Center (FMF) at Freiburg University, the gamma camera to detect radioactive materials. The goals set for the two-year project could be accomplished and it was shown that the investigated concept is viable and that the sensor technologies offer practical added value. In consultation with the end-users, several scenarios were defined for realistic tests on the sensor technology, and these experimental setups were also featured during the project closure events in Germany and Austria.

During the project period and after, the results were disseminated in several popular-scientific publications of broad impact (interviews, magazine articles), in eight publications in scientific journals and by participating in seven conferences, workshops and specialized fairs. In this context, particular emphasis can be put on the presentation of our findings at the international congress of bomb-disposal (EOD) experts of the Federal Criminal Police Office (BKA) in November 2018.

**DUCHBLICK**

**PROJECT CLOSURE**

Due to the increasing dissemination of simple instructions for preparing improvised explosive devices (IEDs), Germany and Austria face serious threats to public security. Yet, technologies available to security forces only offer limited possibilities. The objective of the bilateral German-Austrian project DUCHBLICK was to investigate a robot-assisted, high-performance multi-sensor system to be used in such difficult settings. A key element was to enable novel sensor systems for deployment, which until then had not been available for this purpose before. It was an essential issue that also objects that are accessible from only one side can be examined.

Upon successful project closure, the results of DUCHBLICK were presented to many external guests in Efringen-Kirchen.
The design and architecture of public spaces have a considerable influence on the subjective sense of security for urban dwellers and may even prevent criminality. For the assessment and improvement of this sense of security, you have to identify places that are perceived as dark, out of sight and out of hearing range. In the project Stadtsicherheit-3D (urban security 3D), this is accomplished by a software tool, which is applied to existing three-dimensional city models. Focus was on three case-study areas in Berlin.

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STADT-SICHERHEIT-3D – IMPROVING THE IMPRESSION OF SECURITY

Security as a topic not only touches on the important role of ensuring objective security, but also acknowledges the importance of the subjective sense of security. For this reason, the main focus in the project Stadtsicherheit-3D (urban security 3D) is on the assessment and improvement of the subjective sense of security among urban dwellers. Structural and spatial factors in urban environments, which foster the various perceptions of security as being present or rather absent, are identified and operationalized. Emphasis is placed on the identification of places that are perceived as dark, out of sight and out of hearing range. Based on experience from best-practice examples and on-site measurements, the identified elements are incorporated into the algorithms that serve as the core of a software-based planning tool. The software can then be applied to existing three-dimensional city models and thus allows an improved security assessment.

Tool as planning and design aid
For the first time, a software tool based on numerical modeling is developed with which security assessments can be made systematically and empirically. Further key factors that cannot be physically depicted are inquired interactively. The tool helps city planners and security experts to create more security in urban environments and can be used in participative decision processes.

s.fhg.de/stadtsicherheit-3D-en
RISK ANALYSIS FOR FORMER AMMUNITION DEPOT MITHOLZ

In December 1947, part of the approximately 7000 tons of ammunition stored in the underground ammunition depot in Mitholz, Switzerland, exploded, killing nine people. Approximately 3500 tons of remaining ammunition containing several hundred tons of explosives are suspected in the collapsed facility and the rubble cone in front of the installation. Contrary to previous assumptions, a current risk analysis by the Swiss Department of Defence (DDPS) concludes that the risks of further possible explosions are significantly above the accepted limit values according to the Swiss Major Accident Ordinance. The Swiss Federal Office for the Environment (FOEN) as the responsible specialist agency has commissioned Fraunhofer EMI to evaluate the current risk analysis of the DDPS and its planned measures for risk mitigation. The second opinion by EMI has confirmed the assessment of the DDPS. Ongoing project work is dealing with complex questions about aging ammunition, the exact distribution of which is unknown under collapsed rock in the extensive area. Partial finds have shown that ammunition items are equipped with functioning fuses, the explosives are preserved in their original state, and explosive densities are present that make sympathetic detonation transmission possible.

More information on the pages of the DDPS.

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In an emergency in the underground tunnel system, rescue workers need reliable guidance. © Helen Schäfer

SENSOR SYSTEM FOR UNDERGROUND TUNNELS

Fortunately, fires in underground tunnels are extremely rare, but they are all the more dangerous for the emergency services. Above ground, important information, for example from residents, is available and direct access to the fire site is possible. In the event of an underground fire, it is important to decide in advance from which tunnel direction access should be made. However, the information required for this is missing. The sensor system developed in the German-Indian project SenSE4Metro, which detects fire, smoke, water ingress and explosions, provides a remedy.

Final exercise
The final exercise of the project took place on October 7, 2018, in Berlin. A fire in an underground tunnel was simulated and the benefits of the project results were examined. Over a hundred firemen and Red Cross volunteers rescued injured people, played by actors, from a train in the Jungfernheide training tunnel. The passengers had to be brought outside via an emergency staircase, and carrying seriously injured passengers required quite a bit of strength. They were then given medical care. The developed sensor system was successfully used primarily for access planning.

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The safety of technical systems is often not planned properly: On the one hand, they are extremely robust for foreseeable malfunctions, because partly redundant protection capacities are provided for each respective potential fault. This is inefficient and consumes unnecessary resources. On the other hand, there is no protection for unforeseen incidents. This leaves the system vulnerable, since the possibility of damage must be planned in advance. In contrast, biological systems are characterized by very high efficiency, resilience and sustainability. They react dynamically and adapted to their manner to different external disturbances. Decisive for the complete system are the selection and timing of the individual reaction mechanisms, which also influence each other in a complex biological network.

As part of the BioMOTS project, a project team consisting of staff from Fraunhofer EMI and Fraunhofer ITEM has now shown, using the example of battery systems for electric vehicles, that biological protection principles can be abstracted and transferred to technical systems. For this purpose, principles of wound healing and pain reflex response were systematically characterized and transferred to a simulated battery system so that its resilience was significantly increased.

**BIOMOTS**

**BIOLOGICAL MODELING OF TECHNICAL SYSTEMS**

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SUSQRA
PROTECTION AGAINST
IMPROVISED EXPLOSIVE DEVICES

For the forensic investigation of an explosive event that was foiled or that actually took place, one of the main questions in court is the evaluation of the possible extent of damage. In this context, reconstructions of the explosions are time-consuming and expensive. Moreover, risk analyses are necessary prior to major events in order to prevent threats.

The project SUSQRA is funded by the German Federal Ministry of Education and Research (BMBF) and aims at the creation of an expert system to quantitatively analyze the expected damage of improvised explosive devices without experiments. For this purpose, numerical and analytical calculation methods are developed and validated with damage data from experiments. The SUSQRA analysis tool supports experts in the risk analysis prior to an event to identify threats, to develop security concepts and to establish protective measures. The SUSQRA demonstrator assists forensic experts after an explosive event to make statements regarding the used explosive, coating materials or distances of the fragments.

A clear graphical user interface of the SUSQRA demonstrator facilitates the experts' daily work. During the whole project, the feedback of the experts is constantly incorporated to continuously improve and adapt the SUSQRA demonstrator to the needs and requirements of the end-users.

s.fhg.de/SUSQRA-en

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BUSINESS UNIT
AUTOMOTIVE
Crash using X-ray car-crash (X-CC) technology.
Digitalization and virtualization are on the rise along the entire automotive development process chain – from material modeling to structural design to production. This increases the urgent need for valid data as input for a variety of computer-assisted processes. At the same time, already in 2016, the science journal Nature pointed to a significant reproducibility crisis, especially concerning data from the fields of physics and engineering. That is why our research group Digital Engineering deals with new concepts supporting sustainable digitalization with the aim to exploit and utilize the whole life cycle of research data by the consequent implementation of the FAIR guiding principles.

EMI itself generates valuable research data, for example, originating from a novel measuring and evaluation method that employs X-ray diagnostics to observe the dynamic behavior of hidden vehicle structures during crash.

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Visualization of the dynamic X-ray analysis based on a crash simulation inspecting a Toyota Yaris with one occupant (Hybrid III dummy). Simulations were performed with LS-DYNA (Livermore Software Technology Corp.) on the 2010 Toyota Yaris Finite Element Model (CCSA).

Using X-ray technology enables the observation of the dynamic behavior of hidden vehicle structures under crash conditions. In addition to novel measurement technology, necessary algorithms for analysis and evaluation are developed within the scope of industrial and research projects.

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Within the scope of industrial and research projects, a novel measuring and evaluation method is currently developed at EMI, which enables the observation of the dynamic behavior of hidden vehicle structures during crash. This method helps to capture precious information for the validation and optimization of numerical crash simulations.

In cooperation with the Fraunhofer Development Center X-ray Technology EZRT, researchers of Fraunhofer EMI develop the hard- and software required for the application of the novel measuring and evaluation method. With regard to measurement technology, considerable progress has been made on the design of a specialized detector, which is optimized for very high energies and frame rates. For the analysis of the collected data, algorithms for the automated identification and tracking of vehicle features are devised. Computation of simulated X-ray images facilitates the optimization of the experimental test setup and allows for a comparison of the numerical crash simulation and the real-world experiment in X-ray images. Using methods from the field of data assimilation, 3D information, which is not contained in the 2D X-ray image, is augmented by incorporating information from the numerical crash simulation. This approach allows for a reconstruction of the crash behavior of the vehicle in the real-world experiment and a comparison with the corresponding crash simulation. The project is accompanied by numerous generic load cases of varying complexity. In this context, the dynamics of a pivoted leg of a typical crash-test dummy was studied as it impacts on a foamed-plastic barrier at 30 g acceleration. In this example, the application of the novel measuring and evaluation method demonstrates the possibilities of a detailed analysis of the dynamic behavior, which is unfeasible using conventional observation methods such as high-speed cameras.
The research group Digital Engineering addresses solutions for the digital management of research data and cross-domain data spaces. © FE model: NHTSA/DOT

In the light of digital transformation and increasingly data-driven research approaches, it is an essential goal to address the entire life cycle of research data and to sustainably exploit the data in versatile ways by the consistent implementation of the FAIR guiding principles (FAIR: findable, accessible, interoperable, reusable). The purposes of digital data management, which builds upon semantic technologies, include maximizing the added value from research data.

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metadata. Especially in the light of increasingly data-driven research approaches, the large quantity of information contained in data assets is of crucial value to future R&D activities. The greater goal of the scheme is therefore to address the entire life cycle of research data and exploit it by the consistent implementation of the FAIR guiding principles. To this aim, metadata play a superior role as they form the base to describe and exploit the meaning of data. Semantic technologies allow for the integration of metadata as context information in order to harness the knowledge from the underlying data.

**Interoperability**
The comprehensive reuse of data is also inhibited because institutions accumulate heterogeneous data assets in so-called data silos – where they partly lie waste. This is counteracted by semantic data enrichment, which renders transdisciplinary and cross-domain interoperability possible. Due to their high expressiveness, ontologies as knowledge organization systems permit to preserve and infer domain knowledge. They formally represent the explicit description of the shared concepts within a domain, their logical relations among them as well as the governing rules and restrictions. This entails a human- and machine-interpretable specification of the underlying data structures and contents and promotes interoperability across heterogeneous data, models and systems. The outcome of this is a productivity gain potentially crucial to success as misconceptions, costly mistakes and extra work can be prevented.

**DIGITAL DATA MANAGEMENT**
Digital transformation is increasingly entering classical engineering disciplines. Especially in materials science and engineering, groundbreaking innovations due to modern methods of data processing emerge. That is why the research group Digital Engineering addresses concepts to sustainably digitalize the management of data originating from the various research areas at EMI.

**FAIR data: findable – accessible – interoperable – reusable data**
In recent years, the pace how heterogeneous and unstructured data are generated worldwide has dramatically accelerated. In addition to their inaccessibility, the bigger part of data assets is not reusable because they are poorly annotated and lack rich metadata. Especially in the light of increasingly data-driven research approaches, the large quantity of information contained in data assets is of crucial value to future R&D activities. The greater goal of the scheme is therefore to address the entire life cycle of research data and exploit it by the consistent implementation of the FAIR guiding principles. To this aim, metadata play a superior role as they form the base to describe and exploit the meaning of data. Semantic technologies allow for the integration of metadata as context information in order to harness the knowledge from the underlying data.
Research activities are not limited to the goal of maximizing the internal value creation from research data present at institutions like EMI: In cooperation with external partners, also cross-company data spaces, such as the International Data Spaces, are harnessed for materials science and engineering. This way, the reuse, the versatile exploitation and combination of data provide the conditions for inferring new conclusions and producing research results of higher value. Furthermore, modern data processing methods from materials informatics can be employed – for example, by the automated analysis of large bulks of data by means of intelligent algorithms. If nothing else, interoperable data and models create the basis for innovative digital workflows, for example, in model-based systems engineering.

**Reproducibility**
The exact knowledge on the data provenance is essential to precisely address and trace back completely the current as well as the previous processing status of resources along a process chain.

To this end, data and their evolution are described by semantically interoperable metadata, so-called RDF graphs (resource description framework). If these build on ontologies, their context becomes transparent to its full extent and is rendered interpretable. The single entities are logically linked to form a semantic network – resulting in a knowledge graph, and thus, the transition from data to information to knowledge is accomplished. Based on these principles, the entire life cycle of resources is depicted. This serves the objective of universal transparency concerning the current or past status of materials, technical systems and data accumulating from each process step and improves the overall data quality.

**Digital data management**

Digital data management sustainably exploits the entire life cycle of research data.
(Source: f1000research.com/articles/6-1618/v2)
A short-circuit caused by external forces, as they occur in crash situations, leads to an uncontrolled discharge of the battery cell. As a consequence, the battery cell heats up locally and, if it comes to the worst, this results in an explosive reaction of the cell.

Within the BATTmobil project, the deformation behavior of battery cells is investigated experimentally as well as by means of simulations. It shows that their behavior is determined essentially by their inner structure. As long as this structure remains largely intact, battery cells can withstand astonishingly large deformations. For predicting possible failure loads and to assess the criticality of the occurrence of a short-circuit, the deformation behavior is simulated. Within this context, it is decisive that the experimentally identified failure mechanisms are modeled correctly.

Thus, correspondingly validated simulation models enable a detailed insight into the cell behavior and can be applied in order to increase the crashworthiness of battery modules and vehicle structures. BATTmobil is a research project funded by the State Ministry of Baden-Württemberg for Economic Affairs, Labour and Housing Construction. Research partners within the project are Fraunhofer EMI and Fraunhofer IWM.
MORE ROAD SAFETY FOR EVERYONE – RESEARCH WITH BIOFIDELIC DUMMIES

The protection of vulnerable road users (VRU) is a critical aspect of road safety. Consumer protection organizations have already established guidelines for the sake of VRU protection, which govern the development of new vehicles and, up to now, mainly concentrate on pedestrians and cyclists.

Research at EMI wants to investigate the protection of further VRU groups in detail such as wheelchair users or electric-scooter riders, as they considerably differ from other VRU with regard to posture, size or velocity. Statistics show a higher mortality rate for wheelchair users in road accidents compared to pedestrians.

For future research on these loading cases, biofidelic dummies will be used at EMI. Based on first activities by the engineering office Priester & Weide in 2013, such pedestrian dummies were continuously advanced by the HTW Dresden and crashtest-service.com GmbH to enhance similarity to real humans with regard to injury replication, anatomy and kinematics. For example, the bone substitute of epoxy resin aluminum powder reveals similar fracture properties as the biological role model. To understand how fractures of the bone substitute occur in various loading cases, the method of time-resolved and highly dynamic X-ray technology devised at EMI will be used. The comparison with simulation data from finite-element human models is supposed to create new insights for the benefit of VRU protection.

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“GREY-BOX-PROCESSING”
DATA PROCESSING AND ANALYSIS AT THE INTERFACE BETWEEN EXPERIMENT AND SIMULATION

The continuously increasing requirements on future vehicle systems regarding safety, costs, development times and the environmental impact lead to growing challenges within the automotive development process. To overcome these challenges, the continuation of the digitalization and virtualization of the development process is of vital importance. A reliable virtual vehicle development calls for simulation methods and models, which are optimized and validated based on the results of few real-world experiments.

To allow for a reduction of the amount of time- and cost-intensive crash tests, the detection of the greatest possible amount of information about the experimental behavior as well as the optimal utilization of this information is necessary. For this reason, along with novel measurement systems, methods for data processing and analysis at the interface between experiment and simulation are developed at Fraunhofer EMI. These new methods allow for the transfer of complexly structured experimental data sets into the simulation environment in the shape of a virtual solution corridor. The resulting integration of virtual and experimental data sets allows for the identification and assessment of deviations between experiment and simulation as well as for the determination of improvement measures derived from physically based characteristic values.

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BUSINESS UNIT
SPACE
2-unit engineering model of a nanosatellite. At EMI, we develop our own nanosatellites as well as hard- and software for satellites.
A novel optical 3D measuring method developed at EMI allows measuring the dynamic evolution of a complete hypervelocity impact fragment cloud in unprecedented quality for the first time. This method has already been successfully used in the ESA project MIRAD and in other research projects.

The engineering qualification model of ERNST, our nanosatellite demonstrator, has been completely integrated in 2019 and was space qualified during several campaigns. On this occasion, we also put a new thermal vacuum chamber and a shaker table into operation.

The use of satellite data, i.e., the downstream, is increasingly attracting attention in the business unit Space. ConstellR, Fraunhofer EMI’s first spin-off, will focus on downstream applications after starting business in the course of 2020. ConstellR will offer high-precision and continuous temperature measurements of our planet employing a constellation of CubeSats.
LISA shall investigate events such as two black holes orbiting each other. © LIGO/Caitech/MIT/Sonoma State/Aurore Simonnet.

Hypervelocity impacts on spacecraft surfaces cause fragments to be ejected. The fragment tracking method developed at Fraunhofer EMI allows detailed measurements of the properties of these fragments for the first time. The model developed shall be used to predict the influence of the space particle environment on the orbit and attitude of satellites.

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Hypervelocity impacts do not only create craters: The excavated matter is ejected from the crater as fragments (ejecta) at high velocities. During geological impact events, some of the ejecta escapes into space, while other parts accumulate around the crater. When particles (space debris or micrometeoroids) impact spacecraft, the same processes take place: The momentum the fragments carry away causes an additional disturbance of the satellite’s attitude; the deflection is stronger than as if the impactor had merely been “swallowed”. Until now, only little has been known about the properties of these fragments, specifically, their velocities.

ESA’s LISA mission (Laser Interferometer Space Antenna), which is planned for 2034, shall measure gravitational waves that, e.g., result from the collision of black holes. The three satellites are planned to permanently maintain laser connections over a distance of several million kilometers. A particle impact deflecting one of the satellites can interrupt the laser connection. Such interruptions pose a risk to the mission.

During the MIRAD study (Micro-particle Impact Related Attitude Disturbances), impact tests were carried out on spacecraft representative CFRP samples. With the fragment tracking method developed at EMI within the past years, the properties of the ejected fragments can be measured in detail for the first time. Specifically, the combined measurement of mass, velocity and trajectory of single fragments is unique and has never been conducted with such precision before.
The model developed at Fraunhofer EMI from this data can predict the measured properties of the fragments and the ejected material. Using this model, the influence of the space particle environment on orbit and attitude of spacecraft can be predicted, which is especially important for spacecraft with highly sensitive payloads. Currently, it is being evaluated whether the model can be transferred to geological materials, and, consequently, also to the description of planetary impact events.
FLEXIBLY RECONFIGURABLE IMAGE PROCESSING ONBOARD SATELLITES

In space-based Earth observation, high-resolution sensors generate immense amounts of data. Onboard data processing enables providing this information to the user with shorter latency periods, even up to real-time capable systems. The EMI data processing unit (DPU) features the latest generation of FPGA-based processors and allows high-performance image processing onboard small satellites. The DPU software was developed aiming at the highest possible flexibility. It can be configured in a graphical user interface. The customized configuration can be tested in a simulation environment and subsequently be transferred to orbit for execution. This flexibility allows shorter development times for future Earth observation satellites. With the EMI DPU, new applications can now even be realized after the launch of a satellite. This approach fits neatly with the New Space business models. Besides different microsatellite missions of our customers, the EMI DPU will also be employed in EMI’s ERNST nanosatellite. The launch of ERNST is scheduled for 2022.

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The Columbus module of the International Space Station (ISS) has been orbiting Earth since 2008. Natural micrometeoroids and anthropogenic space debris are impacting the module ever since. Columbus is well protected against this threat, because the meteoroid and debris protection system (MPDS) has been developed and tested at EMI. Due to its large surface area and its long stay in orbit, many small impact craters accumulated – which is a treasure for science! The models to predict such impacts rely on data: in-situ impact sensor measurements or material brought back to Earth. The most recent large data set of this kind was obtained from the Hubble space telescope solar arrays, which were replaced in 2002 for the second time and subsequently analyzed on ground.

In September 2018, a team of DLR (German Aerospace Center), Universität Oldenburg, TU Braunschweig and Fraunhofer EMI could convince NASA and ESA to conduct a video survey of the outer surface of the Columbus module with the ISS robotic arm. Using these data, several thousands of craters were identified and analyzed using an automated process developed at EMI. The smallest visible craters have a diameter of less than half a millimeter, the largest ones are about eight millimeters in size. The newly obtained data allow to better prepare future missions against such impacts.

s.fhg.de/columbus-module

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In the space sector, Fraunhofer EMI stands for comprehensive and high-quality experimental and numerical simulations of hypervelocity impact processes such as the ones occurring during collisions of space debris with spacecraft or of asteroids and planetary surfaces. As part of our activities regarding small satellites, we have expanded our test spectrum for space qualification for components and CubeSats.

We simulate the structural dynamic loads of a rocket launch with an electrodynamic shaker for payloads of up to 25 kilograms. Shock loads, which, for instance, result from the pyrotechnical separation of rocket stages, are simulated using a pneumatic actuated resonance plate. A thermal vacuum chamber is used for simulating the thermal radiation environment in orbit. The vacuum chamber will be expanded by a sun simulation, which has been put to use outside the chamber for testing of the ERNST solar generator. Furthermore, we are installing a cleanroom area in the test lab.

Our new competences in space qualification are available to external customers as testing services.

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Fraunhofer EMI is currently developing the first Fraunhofer satellite ERNST. ERNST is a 12U nanosatellite that will demonstrate the potential and agility of this satellite class for the German Federal Armed Forces with a kryo-cooled infrared payload. In 2019, we completed the integration of the ERNST engineering qualification model (EQM). The EQM comprises all components and functionalities of the future spacecraft model. However, the expensive, high-quality space components are not employed for all subsystems. We are running the ERNST EQM in simulated non-stop operation for the verification of the system’s functionality, with the satellite bus and the payloads performing test procedures. The satellite is powered by a solar generator simulator, which provides the typical power output of solar cells depending on the simulated orbit position. We test the robustness of the satellite against the special environmental loads of a space mission with vibrational and thermal vacuum tests. In 2020, additional tests are planned at Fraunhofer INT for measuring the antennas’ transmission capacity and the electromagnetic compatibility on the system level.

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In the Micro Satellite Military Utility Project Agreement (MSMU PA) project, which is performed under the umbrella of the Responsive Space Capability Memorandum of Understanding (RSC MoU), Fraunhofer EMI investigates the military utility of small satellites for the German Federal Armed Forces in cooperation with nine partner countries. The benefit of satellites is demonstrated by means of the data that the group obtains as an independent observer during military exercises, e.g., the RIMPAC (Rim of the Pacific) 2018. A large number of small satellites from the partners are used for collecting the data. In a so-called “hybrid space architecture”, military and commercial satellite capacities are combined, allowing for a better spatial coverage, a higher persistence, a larger number of experimental sensor types, and a smaller latency of the information products generated with the satellite capacities.

One of EMI’s contributions is the experimental Rapid Sensor Analysis Tool (RASCAT), which is used for the analysis of sensor availability at a particular location on Earth. This tool can also be used for overflight warnings. In 2020 and 2021, further exercises are planned.
BUSINESS UNIT
AVIATION
The increasing number of aerial drones in airspace poses a threat to aviation. Fraunhofer EMI explores methods for the evaluation of collision scenarios as a basis for adequate safety measures. © Adobe Stock
Ensuring a maximum of safety is the basis for the certification of a new airplane type. In addition to the proper functioning of the used components during operation, it has to be ensured that external influences do not lead to the crash of the aircraft. Besides the widely known bird impact, other external hazards exist, such as lightning strike or a possible collision with drones. These topics are investigated at EMI and are briefly outlined in the following articles.

In addition to safety, efficiency (fuel consumption per passenger kilometer) is decisive for the success of a new aircraft type. Additive manufacturing of metals opens up new possibilities to the industry regarding the design of load-bearing structures, allowing weight reduction and increased efficiency. At EMI, this freedom of design is explored and demonstrated by the example of a highly loaded cargo door fitting.

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The growing number of drones increases the risk of collisions in airspace. How high is the risk of such a collision? At Fraunhofer EMI, we investigate this question. A software tool will evaluate the effects of different collision scenarios.
which we can assess the criticality of collision scenarios in order to provide the basis for the definition of adequate safety measures.

We have already conducted initial experiments on our test stands regarding the hazardous potential of drone collisions: First, the drone components with the highest damage potential were identified — due to their mass and compact design, mostly motors and batteries. These components were then characterized in both quasi-static tests as well as in impact experiments on deformable targets made from aviation-typical materials at different velocities.

In particular, helicopters are more likely to collide with a drone due to their lower flight altitude and because they often operate in urban airspace. For this reason, Fraunhofer EMI and other partners are planning a joint research project with the goal of developing models that allow analyzing the effects of collisions between drones and helicopters comprehensively.

The approach taken in the project combines experimental, numerical and analytical methods. The aim is to provide a software tool at the end of the project that allows an efficient analysis of a multitude of different collision scenarios. On the experimental side, a new test stand is planned to be developed that allows accelerating entire drones weighing several kilograms to velocities of up to 150 meters per second.
Every airplane is struck by lightning several times during its lifetime. Modern commercial aircraft such as the A350 or the B787 feature a high proportion of carbon-fiber reinforced composites. In contrast to the traditionally used aluminum alloys, composites are poor electrical conductors. In order to prevent lightning strike from causing local damage of composite structures, metallic meshes or foils are integrated into the structure.

Within the framework of the European research project Clean Sky 2, lightning strike experiments on composites with a copper mesh for lightning protection have been conducted at Fraunhofer EMI. The analyzed structure is impacted with an amperage current of 200 kiloamperes for a short period of time. We have observed that the copper grid was heavily damaged in the lightning strike zone. Consequently, a novel simulation approach was developed in order to be able to model the influence of the copper grid during impact loading caused by lightning. This new modeling approach contributes significantly to the understanding of the complex multi-physical issues concerning lightning strike in aviation.

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ADDITIVELY MANUFACTURED AIRCRAFT COMPONENT
ADDED VALUE THROUGH LIGHTWEIGHT DESIGN

The goal of reducing greenhouse gas emissions boosts aviation research. The newly gained freedom of design in additive manufacturing and the potentially careful use of resources by direct generation of the structural material render this new technology particularly interesting for sustainable and lightweight aircraft components. However, the safety and reliability of all components and systems are an absolute priority in aviation. For this reason, the hurdle for the implementation of new technologies in safety-relevant, highly loaded components is high.

At EMI, we thus investigate the additive manufacturing of a high-performance aluminum material and the targeted use of new construction and optimization methods for a highly loaded fitting within the framework of the European research program Clean Sky 2 Joint Undertaking. Our objective – besides lightweight design – is to generate a particularly reliable fail-safe design. As a direct reference, we use a conventional, milled component. Additive manufacturing will only be put to use if an added value is clearly evident in comparison with established technologies.

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The lightweight component manufactured using laser sintering.

s.fhg.de/additive-manufacturing-aircraft-components

This project has received funding from the Clean Sky 2 Joint Undertaking under the European Union’s Horizon 2020 research and innovation programme under grant agreement No. CS2-AIR-GAM-2019.
ADMINISTRATION
FIGURES & FACTS
The current transformation in the context of new work forms is also reflected in the processes at Fraunhofer EMI. Thanks to the digital transformation, we are able to collaborate over broad distances and time zones. To make this sort of work style possible at Fraunhofer EMI, we have successfully established flexible working hours and mobile working in 2019. This supports our employees in maintaining a harmonious work-life balance. We promote a culture of trust and cooperation, and we have made a big step towards being a more attractive employer.

Alongside this transformation, the implementation of SAP is in progress at Fraunhofer. As a test institute, we have started to run several business processes with SAP in May 2020. We greatly benefit from the fact that we are already well positioned in regard to the modernization and automation of many processes.

In research, we need creative and original ideas. Therefore, we create agile structures and cooperative forms of organization under the slogan “New Work@Fraunhofer”. The question of how we want to work in the future will continue to accompany us, and we will find new answers.

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At the end of 2019, 359 people were employed at Fraunhofer EMI: 271 employees as permanent staff, 32 as apprentices and dual students, and 56 as research assistants and interns. 183 members of the permanent staff were directly involved in research and 88 worked in the fields of management and infrastructure. The proportion of female employees of the permanent staff increased to 27 percent.

20 of the 32 apprentices worked in the fields of precision mechanics, electronics, media design and administration. The remaining 12 worked at Fraunhofer EMI within the scope of their vocational training or university studies at the Baden-Württemberg Cooperative State University (DHBW).
FINANCES

In comparison to last year, the overall budget of Fraunhofer EMI has increased by 27.5 percent to 34.07 million euros. 25.84 million euros are allotted to the operating budget (staff costs and material costs) and 8.2 million euros to the investment budget. At this point, the project on high-energy laser effects should be particularly mentioned as it comprises an investment volume of 5.28 million euros. Fraunhofer EMI is financed by external revenues from the industry and the public sector as well as by the institutional base funding of the German Federal Ministry of Defence (BMVg) and the Federal Ministry of Education and Research (BMBF). In 2019, the biggest share of the operating and investment budget, namely 70 percent, were financed by the German Federal Ministry of Defence. The amount of industrial revenues amounted to an excellent result of altogether 41.2 percent.
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The EMI advisory board at its meeting on July 19, 2019, in Freiburg.
ADVISORY BOARD

The advisory boards of the various Fraunhofer Institutes advise the directors of the institutes and the executive board of the Fraunhofer-Gesellschaft. The advisory board also enhances the institute’s contacts to other organizations and to the industry.

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The headquarters of the Fraunhofer-Gesellschaft in Munich.
The Fraunhofer-Gesellschaft is the world’s leading applied research organization. With its focus on developing key technologies that are vital for the future and enabling the commercial exploitation of this work by business and industry, Fraunhofer plays a central role in the innovation process. Based in Germany, Fraunhofer is an innovator and catalyst for groundbreaking developments and a model of scientific excellence. By generating inspirational ideas and spearheading sustainable scientific and technological solutions, Fraunhofer provides science and industry with a vital base and helps shape society now and in the future.

At the Fraunhofer-Gesellschaft, interdisciplinary research teams work together with partners from industry and government in order to transform novel ideas into innovative technologies, to coordinate and realize key research projects with a systematic relevance, and to strengthen the German and the European economy with a commitment to creating value that is based on human values. International collaboration with outstanding research partners and companies from around the world brings Fraunhofer into direct contact with the key regions that drive scientific progress and economic development.

Founded in 1949, the Fraunhofer-Gesellschaft currently operates 74 institutes and research institutions. The majority of our 28,000 staff are qualified scientists and engineers, who work with an annual research budget of 2.8 billion euros. Of this sum, 2.3 billion euros is generated through contract research. Around 70 percent of Fraunhofer’s contract research revenue is derived from contracts with industry and publicly funded research projects. The remaining 30 percent comes from the German federal and state governments in the form of base funding.

This enables the institutes to work on solutions to problems that are likely to become crucial for industry and society within the not-too-distant future.

Applied research also has a knock-on effect that is felt way beyond the direct benefits experienced by the customer: Our institutes boost industry’s performance and efficiency, promote the acceptance of new technologies within society, and help train the future generation of scientists and engineers the economy so urgently requires. Our highly motivated staff, working at the cutting edge of research, are the key factor in our success as a scientific organization. Fraunhofer offers researchers the opportunity for independent, creative and, at the same time, targeted work. We therefore provide our employees with the chance to develop the professional and personal skills that will enable them to take up positions of responsibility at Fraunhofer, at universities, in industry and within society. Students who work on projects at Fraunhofer Institutes have excellent career prospects in industry by virtue of the practical training they enjoy and the early experience they acquire of dealing with contract partners.

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.

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With a big party for the public, the five Fraunhofer Institutes in Freiburg celebrated the 70-year anniversary of the Fraunhofer-Gesellschaft on Saturday, September 28, 2019. More than 5000 people came to celebrate and learn more about research at the Freiburg Institutes. Oral presentations, interactive experiments, live music, a laser show and an escape game combined into a diverse program.

More than 5000 guests were attracted by hands-on and interactive Fraunhofer research
Exhibits on the topics of “sensors and data”, “materials and functions”, “light and space”, “mobility and sustainability” were on display. Crowd-puller was the model of the crash-test facility of Fraunhofer EMI. The stand staff explained the processes during a car crash on the original scale and showed how X-ray imaging comes into play. There was also entertainment for the junior researchers. In the “kids and science” tent, children could do water experiments, make solar cells or get their faces painted.

Escape game as recruiting tool
The escape game was fully booked. Eight groups tried to crack the code and to untangle the mystery. Next to it, a recruiting stand invited interested students to learn about career possibilities at Fraunhofer.

Stage show with research and music
The center of attention was the big stage featuring presentations on Fraunhofer research. Along with the five directors of the Fraunhofer Institutes, the mayor of Freiburg Martin Horn opened the event. He congratulated on the anniversary, “It is great that the Fraunhofer Institutes celebrate their event on university premises. University and Fraunhofer are crucial for the implementation of the ambitious sustainability goals in Freiburg. As one of the biggest employers in our city, the Fraunhofer-Gesellschaft brings world-class research to Freiburg.” The Fraunhofer-Gesellschaft has about 2500 employees in Freiburg.
Top: Professor Stefan Hiermaier welcomes the guests and thanks the citizens of Freiburg for their huge interest in Fraunhofer research in their city.

Middle: The directors of the five Fraunhofer Institutes in Freiburg together with mayor Martin Horn (fourth from right), Professor Gunther Neuhaus from the University of Freiburg (second from left), Joseph von Fraunhofer (sixth from right) and ARTE-presenter Anja Waltereit (center).

Bottom: Professor Frank Schäfer during his presentation on New Space.
The motto 006 – LICENCE TO RESEARCH and a glamorous secret-agent style set the scene for EMI’s anniversary celebration on November 28, 2019, on behalf of 60 years of research on Our Applied Science’s Service. More than 300 guests had accepted the invitation by EMI director Professor Stefan Hiermaier to the Europa-Park Rust conference center including notables from the Fraunhofer Executive Board, from the Fraunhofer Groups as well as from politics economy and industry.

The evening program met the dashing Bond style. The EMI Bond Stars set the pace with their Bond medley as musical opening and demonstrated what 30 EMI employees can accomplish on stage apart beyond everyday work. In a smooth transition, the eagerly anticipated premiere of the Fraunhofer EMI corporate video called the audience’s attention and concluded the opening round with impressive images.

In his welcoming speech, Hiermaier looked back upon 60 years of research at EMI with evident pride and showed himself optimistic for the future. The scientific agenda featured speakers such as the recent Fraunhofer Executive Vice President Technology Marketing and Business Models Professor Ralf. B. Wehrspohn. He appeared impressed by the commitment of all employees for the anniversary celebration and by the institute’s success in scientific realms.

In tightly packed three-minute pitches, competition was on for six interdisciplinary scientific teams applying for the in-house fast-track program “EMIdea”. The audience was convinced by the project ideas “Shock the cell” (how shock waves can be used against tumor cells) and “GUARDIAN – saving lives purposefully!” (how private cell phones can support rescue forces in locating buried people). They will each receive prize money of 40,000 euros.

Later on, the evening blended into a party with great atmosphere and music.
PUBLICATIONS

Publications in books, specialist journals and proceedings with peer review


Publications in books, specialist journals and proceedings without peer review


Lectures at congresses, symposia, colloquia, external seminars and important working conferences


Seminar lectures at EMI


Courses of the Carl-Cranz-Gesellschaft


Lectures


Visiting Scientists at EMI


PhD


Bachelor, Master and Diploma theses


SCIENTIFIC EXCHANGE,
LECTURES

Publication series of Fraunhofer EMI


Workshops and events

60 Jahre EMI, Jubiläumsfeier, 28.11.2019.
Gedenkkolloquium Professor Klaus Thoma, 18.7.2019.

Participation in professional boards, associations and program committees

Aurich, H.: Task Force »Sandy Gravel« (Bodenproblematik).
Balle, F.: Aktives Mitglied im DGM-Fachausschuss »Hybride Werkstoffe und Strukturen« (Gründungsmitglied).
Balle, F.: Aktives Mitglied im DVM-Arbeitskreis »in-situ-Prüfung im Elektronenmikroskop« (Gründungsmitglied).
Balle, F.: Gutachter für die Deutsche Forschungsgesellschaft (DFG).
Balle, F.: Gutachter für die Netherlands Organisation for Scientific Research (NWO).
Balle, F.: Mitglied im Gemeinschaftsausschuss (GA) der DGM, DGG, DGO, DVS, VDI und DKG.
Balle, F.: Mitglied im Programmbeirat der DGM-Tagung »Ressourceneffizienz und Additive Fertigung«.
Balle, F.: Mitglied im Programmbeirat der DGM-Tagung »Verbundwerkstoffe und Werkstoffverbunde«.
Heine, A.: Member of the Scientific Committee, Lightweight Armour Group, LWAG 2019.
Hiermaier, S.: Fachbeirat der BaSt.
Lesimann, T.: Mitglied im wissenschaftlichen Programmausschuss »Forschung für die zivile Sicherheit«.
Putzar, R.: Chairman der Aeroballistic Range Association (ARA).
Ramin, M. von: Mitarbeit in der Klotz Group.

Ramin, M. von: Mitarbeit in der NATO PFP(AC/326-5G/C) AASTP-4 Custodian Working Group.

Ramin, M. von: Mitglied beim American Concrete Institute (ACI).


Schimmerohn, M.: External DLR Delegate, Deputy Chairmen of Working Group 3 at the 37th Inter-Agency Space Debris Coordination Committee (IADC) Meeting, 7.–10.5.2019, Rome, Italy.

Schopferer, S.: EDA CnGE (CapTech non-Governmental Expert) for CapTech Components.

Stolz, A.: International member ABR10 Committee on Critical Infrastructure Protection im Transport Research Board TRB.

Stolz, A.: Koordinator »Resistance of structures to explosion effects« im Rahmen des the ERNCIP (European Reference network for Critical Infrastructure protection) framework.

Scientific prizes and awards


Evaluated excellent research – projects funded by the German Research Foundation (DFG), the German Federal Ministry of Education and Research (BMBF) or the European Research Council EXERTER (Security of Explosives pan-European Specialists Network), www.exerter-h2020.eu.