Fraunhofer
EMI

Fraunhofer Institute for High-Speed Dynamics,
Ernst Mach Institute, EMI

Fraunhofer EMI

Research for a safe future

Fraunhofer Institute for High-Speed Dynamics EMI

Fraunhofer EMI was founded in 1959.
Its mission is to deliver high precision results and develop outstanding technologies.

The focus of the institute is: Making everything that happens quickly representable and measurable. Fraunhofer EMI researches collisions, impact phenomena and explosions and the associated safety concepts in the business fields of defense, security & resilience, automotive, aerospace and aviation.

Location Freiburg

Location Efringen-Kirchen

Location Kandern

Research for innovative laser applications:
Fraunhofer EMI operates laboratories that scientifically analyze the effects of intense laser radiation using the latest high-speed measurement technology. The investigations are supplemented by simulations.

Cover page: Complete range of services for innovative satellite applications – satellites are designed, built and operated at Fraunhofer EMI.

395
Employees

34.4
Million euros total budget

3
Locations

Business units

Defense

Security & Resilience

Automotive

Space

Aviation

Associations

VVS Defense, Prevention and Security

MATERIALS Materials, components

Coordinating institute of the Sustainability Center Freiburg

Alliances

Aviation & Space

Batteries

Lightweight

Simulation

Construction

Competence field Additive Manufacturing

Photos + cover picture: Fraunhofer EMI

Research for the German Federal Armed Forces: Investigation of classic protection and effect mechanisms - including new ones such as the effect of laser weapons.

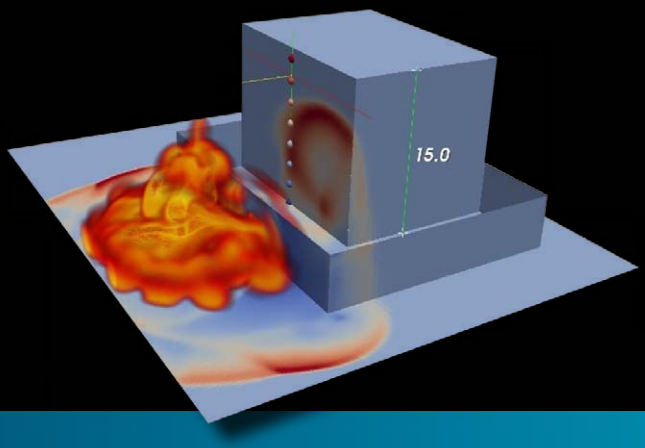
Business Unit Defense

Future-proof systems for land, air, sea and space

Fraunhofer EMI is researching scientific and technological issues in the areas of armor and anti-armor as well as safety and security of military systems.

Using measurement technology, some of which is unique in the world, it investigates issues from the fields of Impact and shock wave physics, ballistics, laser effects, blast effects and blast physics.

Investigation of classic armor and anti-armor mechanisms: extensive spectrum from small-caliber ammunition to laser weapon effect



Simulation of explosions:
Precise mapping of explosion pressure waves and their effects.

Service portfolio

Design and analysis of protection mechanisms

Numerical simulation of impact and shock wave events

Material characterization and failure analysis

Sensors and electronics for extreme conditions, high-speed measurement technology

Analyses of safety and reliability of defence systems

Strategic partner of the German Ministry of Defense: The Institute acts as a partner of the Federal Ministry of Defense (BMVg) for research and technology in the field of high-speed dynamics and extreme material stresses.

Research examples

AI-based approaches for fast and reliable damage forecasts using simulations

Safety in combat training: Dynamic definition of safety zones during combat training of soldiers using live ammunition

Structural protection in the event of explosion and shelling

Business Unit Defense
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Photos: Bundeswehr / Marco Dorow, Fraunhofer EMI (3)

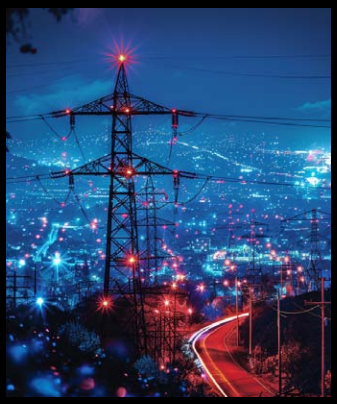
Business Unit Security & Resilience

To bend, but not to break: Technical resilience is the ability of systems to remain functional or recover quickly in the event of disruptions or unexpected events. This includes robustness, fault tolerance and flexible adaptation strategies to minimize failures and ensure operations.

Strengthening security with technical resilience

Terrorist attacks, natural disasters or massive accidents: Fraunhofer EMI develops technologies and solutions to make our society and its infrastructures more resilient.

In addition to topics such as technical reliability, robustness, predictable risks and resilience, research is increasingly focusing on the security of complex socio-technical systems.



Resilient electricity grids for the energy transition
The elimination of baseload power plants and the increasing demand for electricity for heat pumps and e-mobility require a new architecture for the electricity grid.

Service portfolio

Analysis of impact and explosion events

Evaluation of security concepts against explosion, flood, storm

Resilience analyses of supply networks

Simulation of security at major events

Development of robust and resilient sensors, data analysis in particularly harsh environments

Testing and certification

Development of resilience management tools for business resilience

Increasing the resilience of companies
The free online tool "Fraunhofer Resilience Evaluator FReE" helps to increase the resilience of companies and systems.
→ **www.resilience-evaluator.de**

Research examples

- Software-based calculation of extreme weather damage to buildings caused by climate change
- Shock resistance of 3D-printed constructions in safety-critical applications
- Fast and reliable localization of objects in transport containers
- Quantification of the reliability of AI in safety-critical applications
- Transfer of biological protection principles to technical systems
- Analysis and management concepts for resilient logistics and production, e.g. food supply

Business Unit Security & Resilience
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Safety for all road users

The traffic of the future presents us with major challenges: Increasing automation, an increasing proportion of battery electric vehicles and the multimodality of traffic.

Increasing complexity: Fraunhofer EMI develops solutions to make the transportation of the future safe and resource-efficient.

Business Unit Automotive

Fraunhofer EMI offers an innovative service portfolio with a special focus on battery safety, X-ray crashes and the protection of vulnerable road users.

Service portfolio

Highly instrumented and customized experiments: from material to complete vehicle

Safeguarding vehicle batteries in experiment and simulation

AI-based optimization of simulation models and structural designs

Monitoring and simulation of traffic flows

Human models for the protection of pedestrians, cyclists and passengers

Interaction between experiment and simulation: X-ray images are simulated on the basis of FE simulations. This data helps to optimize the experimental setup. The data obtained in the experiment validates the simulation models.

Grey-Box-Processing: Fraunhofer EMI has developed an AI-supported method for the integrated processing of uncertain measurement data. Grey-Box-Processing enables the precise quantification of deviations between experiment and simulation on the basis of physically interpretable metrics.

Research examples

- X-Ray Car Crash: Dynamic in-situ X-ray diagnostics in full-vehicle crash tests
- AI-based real-time prediction of pedestrian and cyclist injury severity
- Simulations and experiments on the thermal runaway of battery cells
- Design of protective structures for high-voltage storage systems
- Agent-based traffic simulations and automatic early detection of critical situations
- Simulations and experiments on airbag deployment

Business Unit Automotive
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Photos: Patrick Federi / unsplash.com, Fraunhofer EMI (3)

Business Unit Space

In summer 2024, the nanosatellite ERNST was launched into space with SpaceX: It is Fraunhofers' first research satellite developed by EMI. Its purpose is to deliver thermal infrared imaging data from the Earth. It is intended to show that it can also be used to detect rockets.

Space exploration as driver of innovation: small satellites as key technology

Space is increasingly being used commercially. This is witnessed by the rapidly increasing number of satellites in low-Earth orbits. The satellite constellations form a new infrastructure in space.

Satellite technology is enabling new applications for economic growth and governmental sovereignty. Small satellites are the key to this.

Complete range of services for innovative satellite applications in Earth observation: Scientific cameras, powerful on-board data processing systems, new concepts for satellite structures, 3D printing, mechanisms, construction and testing as well as launch and operation of research satellites.

Service portfolio

Installed on the ISS: Data collected by the Longwave Infrared Camera (LisR) are used to optimize water use in agriculture. The development of LisR was led by EMI researchers.

Hypervelocity impact of space debris and fragmentation of spacecraft during collisions

Scientific space instruments

Small satellite technology

On-board data processing of satellite data

Artificial intelligence for earth observation

Strategic research partner of industry and government: In the field of satellite protection and small satellite technologies for defence and security.

Research examples	Satellite technology for imaging the Earth's surface.	Real-time methods in Earth observation: on-board processing and analysis for fast response.	Development and testing of protective shields for satellites and space stations
	Infrared technology: using long-wave infrared radiation to analyze the Earth's surface and atmosphere	Philos-Sophia software for numerical simulation of satellite collisions	EMI software tool PIRAT for risk analysis for spacecraft

Business Unit Space
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Photos: SpaceX, NASA, Fraunhofer EMI (3)

High-performance aviation: sustainable and reliable

Fraunhofer EMI is working to maximize the safety of aircraft and their components - and at the same time to develop solutions for sustainable and high-performance aviation.

Business Unit Aviation

Through specialized tests and precise simulations, the institute supports the industry with safety-critical issues such as bird strikes, hailstorms or collisions with drones.

Service portfolio

Analysis and optimization of aircraft structures under impact from hail, debris and bird strike

Acceleration tests for seats, cabin structures, etc.

Battery safety: for energy storage systems and cabin devices

Characterization of materials, testing of structures, components and joints

Modelling and optimization of lightweight structures

Additive manufacturing of metallic components: Fraunhofer EMI is researching innovative solutions to make this technology usable for aviation.

How dangerous are cell phones and laptops on planes? Fraunhofer EMI investigates the smoke and fire risks of lithium-ion batteries in aircraft cabins

Research examples	Crashworthiness	High-rate material characterization	Electronic devices in the cabin
	Impact safety	Safe energy storage for emission-free flying	Topology optimization and 3D printing of structural components

Business Unit Aviation
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Photos: Pascal Meier / unsplash.com, Fraunhofer IBP, Fraunhofer EMI (2)

Focus topics of the institute

Fraunhofer EMI has updated its institute strategy for the period 2023 to 2027. Six focus topics were defined in a joint strategy process. These topics are particularly promoted by the institute.

Laser-matter interaction

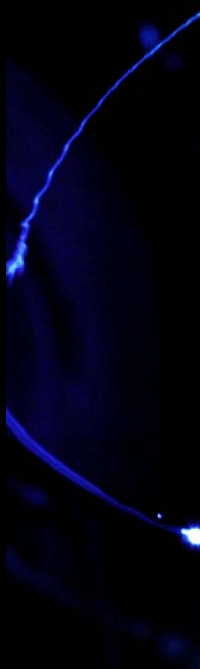
Research for innovative laser applications

The institute operates laboratories that scientifically analyze the effects of intense laser radiation using the latest high-speed measurement technology. The investigations are supplemented by simulations.

They enable physics-based calculation of the interaction processes and optimization of the process parameters. The aim is to develop new types of laser applications.

Methods and technologies:

- Artificial intelligence and machining processes
- Novel materials using additive manufacturing
- Recycling of composite materials
- Neutralizing explosive devices
- Application potential of high-power laser radiation
- Use of high-speed measurement technology



Making battery systems safe: For over ten years, Fraunhofer EMI has specialized in increasing the safety of battery systems.

Battery safety

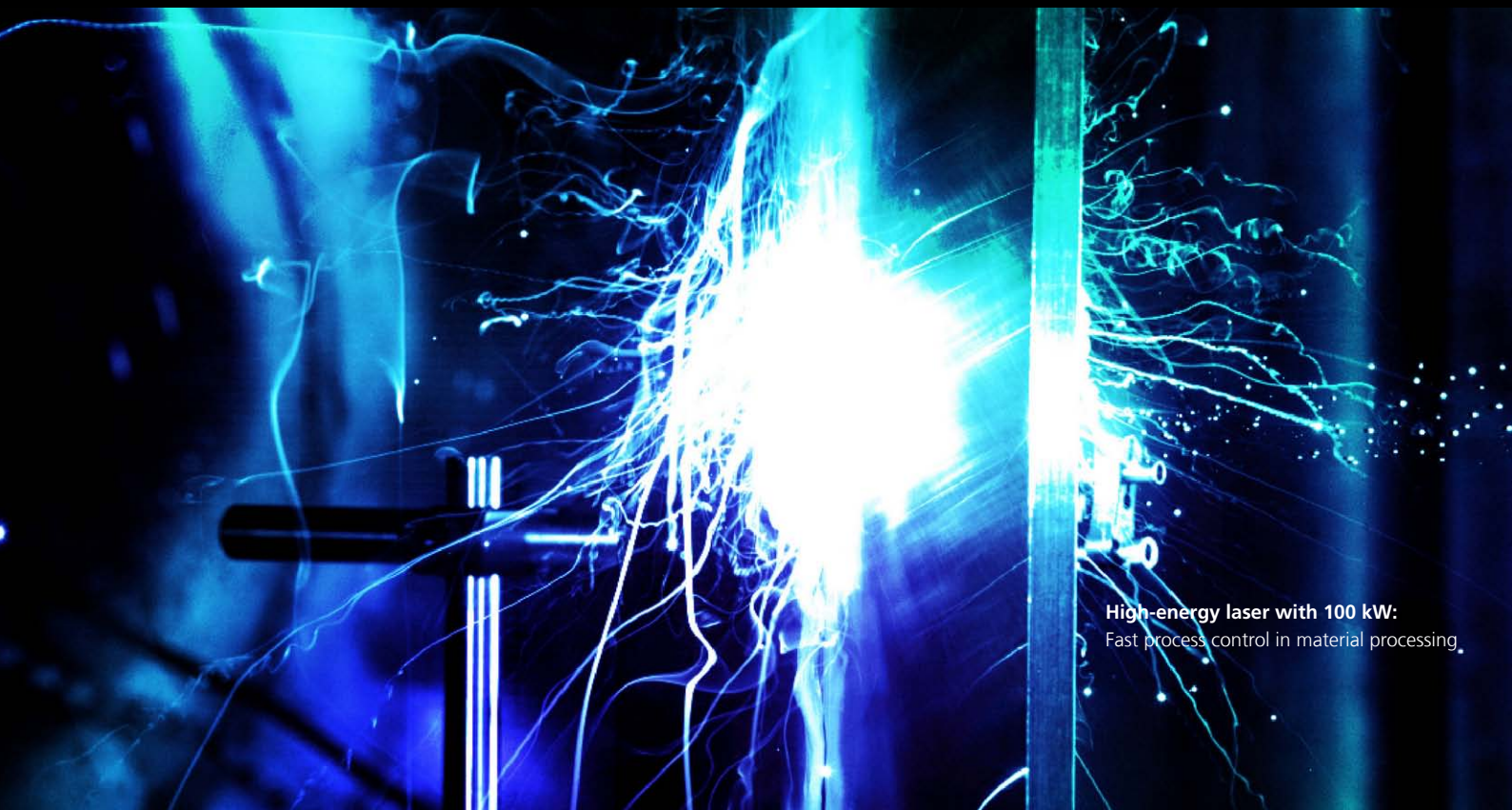
Comprehensive battery tests for detailed system understanding

Using an interplay of experiment and simulation, Fraunhofer EMI offers analysis and optimization of safety at the cell, module and overall system levels.

A special research facility has been set up for electric cars and stationary applications. This allows complete vehicle batteries to be tested under abuse conditions.

Methods and technologies:

- Mechanical cell characterization
- In-situ X-ray video
- Propagation tests
- Crash tests
- Simulation and virtual prototypes



High-energy laser with 100 kW:
Fast process control in material processing

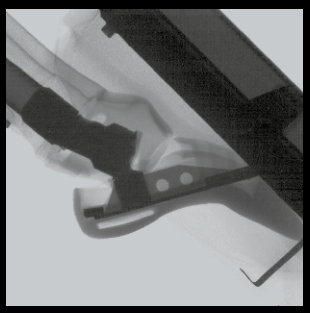
World's first X-ray crash - at 1000 images per second: Together with Mercedes-Benz, Fraunhofer EMI has carried out the world's first X-ray crash. A linear accelerator with around 8 million electron volts was used.

Highly-dynamic X-ray

See what is really happening inside

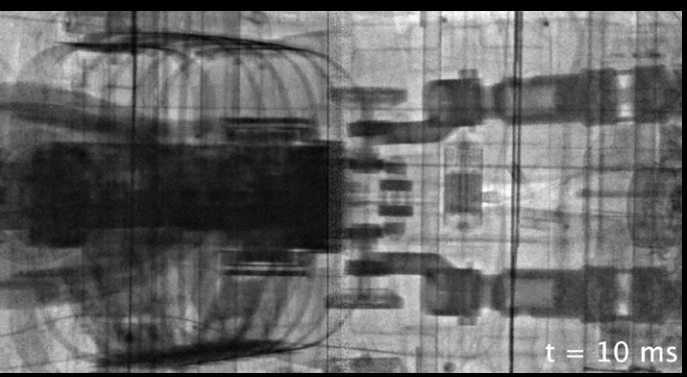
The innovative research concept of X-ray simulation, X-ray experiment and analysis provides unique data and views with up to 1000 images per second.

The technology makes it possible for the first time to experimentally validate the behavior of internal components and subsystems during the test.



Direct observation of critical processes: Until now, many processes could only be measured indirectly (e.g. using acceleration sensors) or reconstructed after the experiment. High-dynamic X-ray enables the direct observation of critical processes.

The impact of a crash lasts 0.1 seconds.
During this time, the technology developed at Fraunhofer EMI generates a video with 100 X-ray images. The images provide information about hidden processes during the crash.



Methods and technologies:

- Direct observation of critical processes
- Millisecond-precise analysis and data feedback into familiar working environment
- Linking of design, process and material

Resilience engineering

Making materials and structures more resilient: One of the world's largest shock tube systems can be used to simulate shock wave loads caused by explosives and gas explosions.

Recognizing and overcoming crises and learning from them

Fraunhofer EMI analyzes socio-technical systems using numerous modeling approaches. They are then implemented in software applications.

These include infrastructures, urban spaces, industrial processes and coupled networks.

The institute examines behavior in the event of disruptions and can thus identify weak points and develop solutions to increase resilience.

Learning resilience from nature: One example of resilience in nature is trees, which adapt to environmental influences through flexibility and strength and can withstand storms. In the picture: a beech tree on the Schauinsland near Freiburg.

Resilient logistics ensures that goods and raw materials are transported and distributed reliably even in the event of disruptive events such as natural disasters, supply bottlenecks or political crises.

Methods and technologies:

- Modeling of complex socio-technical systems
- Efficiency analyses of resilience measures
- Stochastic modeling
- Coupled network analyses
- Agent-based simulations
- Robustness analyses of structures

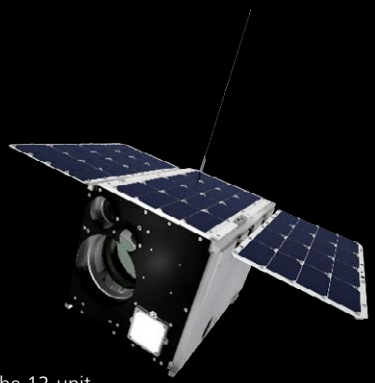
Satellite-based data analysis

Thermal infrared camera "LisR": The scientific instrument was tested on the International Space Station in 2023 and provided a large number of high-resolution bispectral thermal images of the Earth.

Focusing on the planet – for a sustainable and secure future

Earth observation provides significant contributions to solving global problems in the areas of security, environmental protection, climate change impacts, as well as new approaches for agriculture, urban development, disaster management, logistics and defense.

Fraunhofer EMI focuses on research and technology development for the acquisition and real-time processing of Earth observation data on satellites.



ERNST small satellite: The 12-unit nanosatellite was launched into a polar orbit in August 2024 with a highly sensitive multispectral thermal imaging camera in the mid-wave infrared range on board.

Methods and technologies:

- Scientific camera payloads for thermal infrared images
- Data processing systems based on commercial FPGAs
- AI methods for onboard data analysis and automated anomaly detection
- Superresolution for thermal infrared images
- Implementation of Earth observation missions with small satellites

ERNST in the Fraunhofer EMI clean room: The research satellite was developed, integrated and qualified for space at Fraunhofer EMI.

Realistic traffic predictions

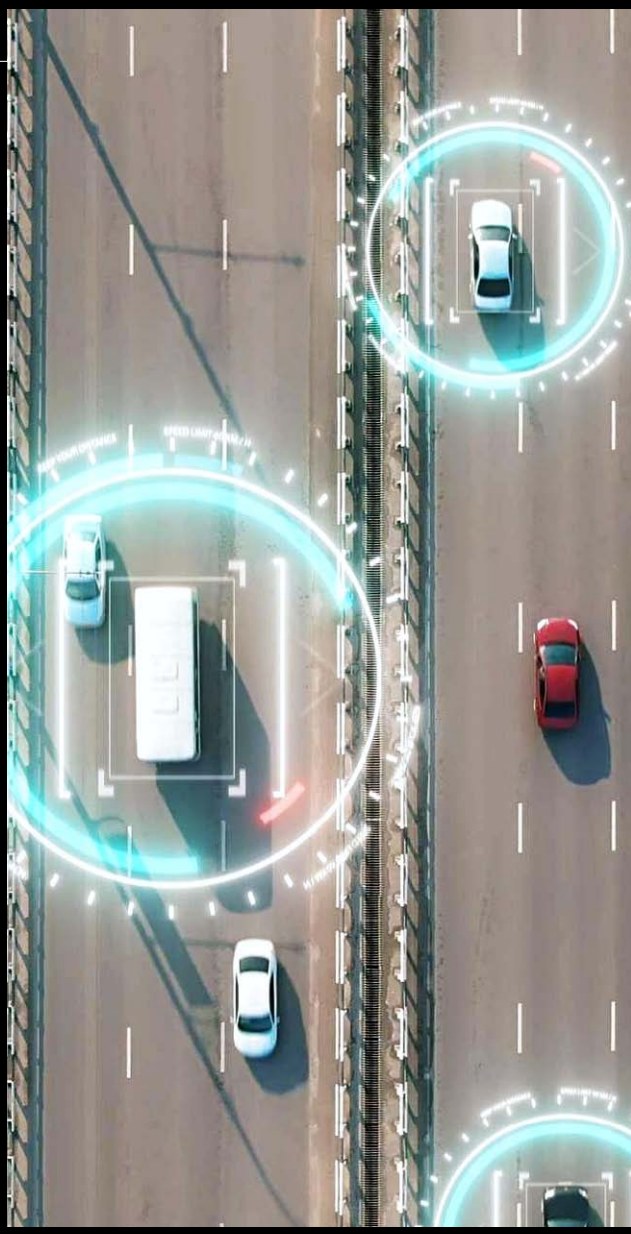
Understanding and predicting traffic

Automation and multimodal concepts are revolutionizing road traffic. This makes the safeguarding of new functions increasingly challenging.

Fraunhofer EMI therefore relies on agent-based simulations that reproduce realistic traffic situations. The focus is on the detailed simulation of critical traffic scenarios.

Methods and technologies:

- Data-based optimization of behavioral models
- Identification of critical traffic situations
- Integration of models for pedestrians and cyclists
- Simulative testing of structural and logistical improvements



Learning from data:
The increasing automation of road traffic requires new concepts for safety.

Photos: Fraunhofer EMI (3), flashmovie / stock.adobe.com

For over 60 years: research for a safe future

1959
Foundation of the institute

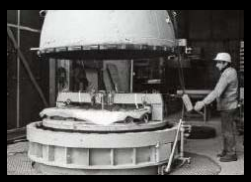
Fraunhofer EMI emerges from the Institute for Applied Physics at the University of Freiburg, founded in 1956.

It was incorporated into the Fraunhofer-Gesellschaft as the 6th institute.

Cold War:
Research for the Bundeswehr and its allies

In the first decades, the focus is on ballistic and fluid mechanics research.

To this end, the institute develops world-leading research approaches.

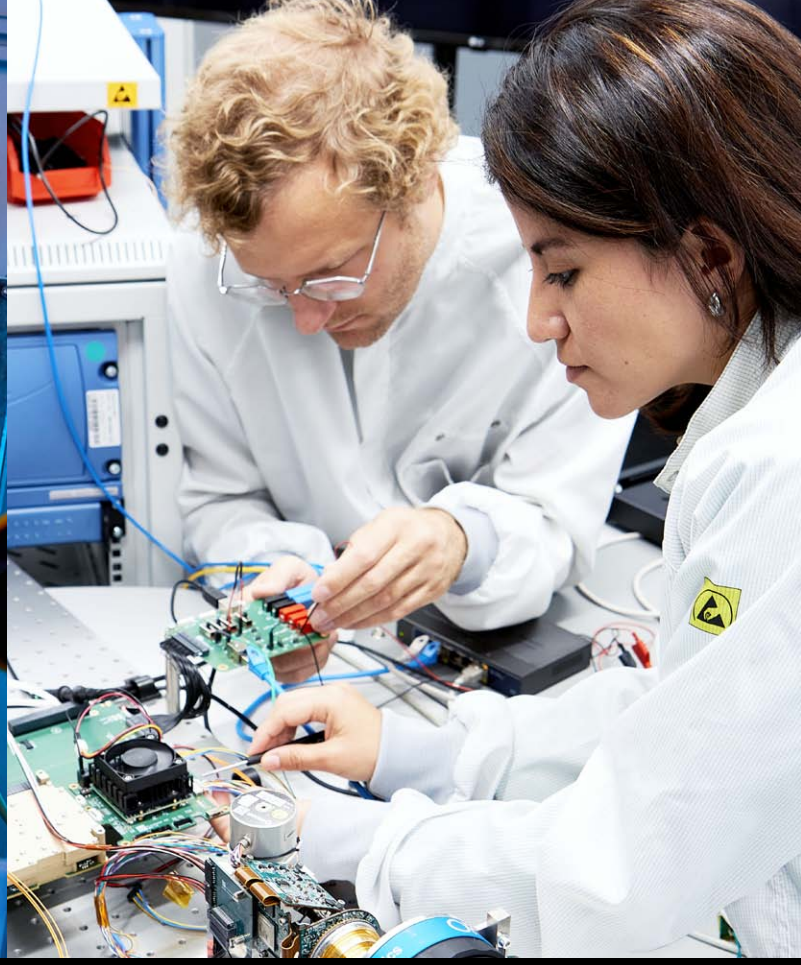


Further locations in Efringen-Kirchen and Kandern

The original quarries in Wintersweiler and Holzen are transformed into independent sites with research infrastructure.

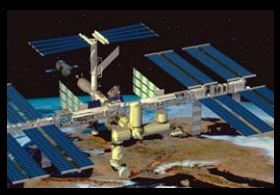
Globally unique infrastructure in the field of high-speed dynamics

Fraunhofer EMI quickly establishes its reputation as one of the world's leading institutes in the field of high-speed dynamics. Over the years, expertise and technology are continuously developed.



1990s
Opening up to civilian research

After the end of the Cold War, the institute realigns itself. It opens up civilian topics such as security, automotive and structural protection:
In 1993, EMI is commissioned to reconstruct the first bomb attack on the World Trade Center.



2000s
Aerospace as new business fields

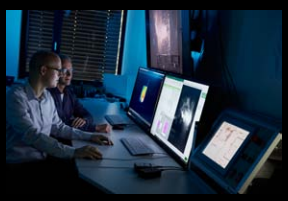
EMI transfers expertise in high-speed dynamics to the fields of aerospace.

For example, EMI conducts an investigation into the impact of meteoroids and space debris on the Columbus module of the ISS space station.

Development of crash tests with X-ray technology

For years, Fraunhofer EMI has been pursuing the goal of X-raying cars during crash tests.

Initially, only 8 X-ray images could be produced. Today, the EMI system produces 1000 X-ray images per second.

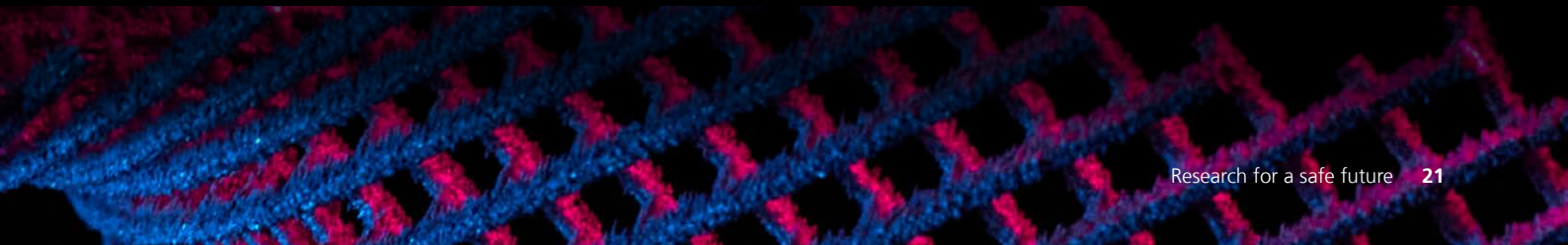


Research for a safe future

With its business units of defense, security, automotive, space and aviation, the institute has consistently focused on increasing security in the civil and military sectors.

Fotos: Fraunhofer EMI (9), US Department of Justice, ESA

↓ **Metallic 3D printing** Metamaterial manufactured at Fraunhofer EMI using the laser melting process



This is how you can cooperate with us:

Research and development mandate

The classic cooperation: e.g. contracts for material characterization, FE modelling, endevelopment and adaptation of simulation models for specific applications and load cases.

Strategic partnerships

Long-term cooperation for the development of new technologies, e.g. the development of testing procedures and simulation methods as well as support for the integration of new types of materials.

Joint publicly funded projects

For a joint project idea, we will apply for public research funding with you. The projects are usually designed to last three years.

Promotions

A doctoral student conducts research at Fraunhofer EMI on a topic related to your company.

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The Fraunhofer-Gesellschaft

With over 30 000 employees in 76 institutes, Fraunhofer is the world's leading organization for applied research.

Prioritizing key future-relevant technologies and commercializing its findings in business and industry, the Fraunhofer-Gesellschaft plays a major role in the innovation process. A trailblazer and trendsetter in innovative developments and research excellence, Fraunhofer supports science and industry with inspiring ideas and sustainable scientific and technological solutions and is helping shape our society and our future.

Founded in 1949, the Fraunhofer-Gesellschaft now operates 76 institutes and research units throughout Germany. Currently around 30,800 employees, predominantly scientists and engineers, work with an annual research budget of about 3.0 billion euros, 2.6 billion euros of which are designated as contract research. Around two thirds of Fraunhofer contract research revenue is generated from industry contracts and publicly funded research projects.

"Approximavit sidera" ("He brought the stars closer to us") was the epitaph of Joseph Fraunhofer (1787-1826). He was equally successful as a researcher, inventor and entrepreneur. The quality of his optical lenses was unrivaled for decades. Fraunhofer combined the most precise scientific work with practical application and thus created new innovative products. Today, he is considered a pioneer of modern space exploration.

In the painting: Fraunhofer demonstrates his spectrometer (standing, with black coat).

Photo: Fraunhofer-Gesellschaft

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