WE LIGHTEN. EVERYTHING.

INSTITUTE OF STRUCTURES AND DESIGN

DLR

INSTITUTE OF STRUCTURES AND DESIGN

PROGRESS MADE EASY.

The Institute of Structures and Design has set itself a major goal: to lighten the future. At our sites in Stuttgart and Augsburg, we develop high-performance structures for the aerospace, automotive engineering and energy technology sectors that go above and beyond the standards set by conventional developments and deliver real technological advances.

Our work is based on the interplay between high-performance, temperature-resistant materials and the very latest digital technology. This combination allows us to develop new construction methods that open up previously unimagined possibilities in lightweight construction in the areas of assembly, system integration and recycling.

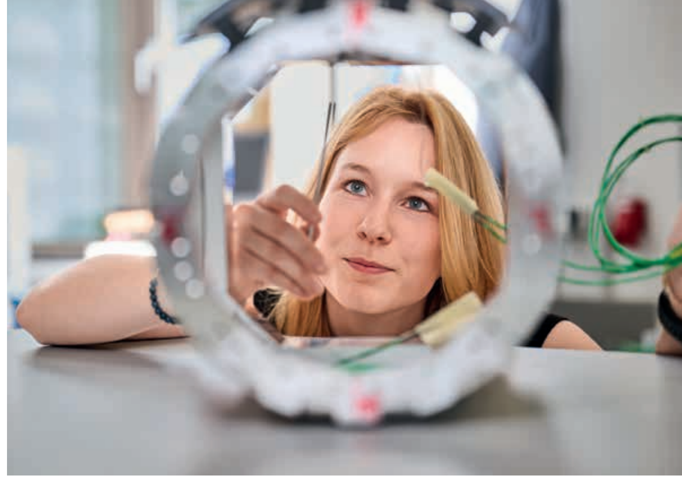
In our five departments and our close, strategic cooperation with the Institute for Frontier Materials on Earth and in Space, we push forward technical progress on a daily basis. From the materials we use through to the demonstrators we construct and the automated production processes we develop, we always rely on solutions that are climate friendly, efficient and conserve resources.

INSIGHTS INTO THE INSTITUTE

»INNOVATION IS THE INTERPLAY BETWEEN PEOPLE AND TECHNOLOGY. WE COMBINE AN INSPIRATIONAL TEAM SPIRIT WITH FORWARD-LOOKING INFRASTRUCTURE. THIS ALLOWS US TO ALWAYS STAY ONE STEP AHEAD.«

UNIV.-PROF. DR.-ING.
MICHAEL KUPKE
Director of the Institute

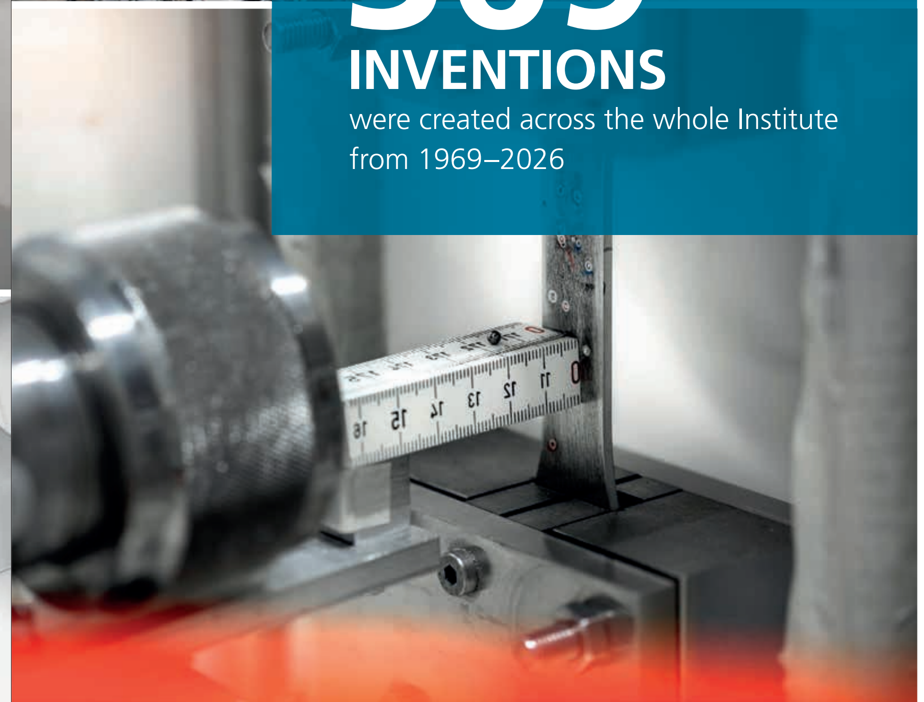
UNIV.-PROF. DR.-ING.
HEINZ VOGGENREITER
Director of the Institute



369

INVENTIONS

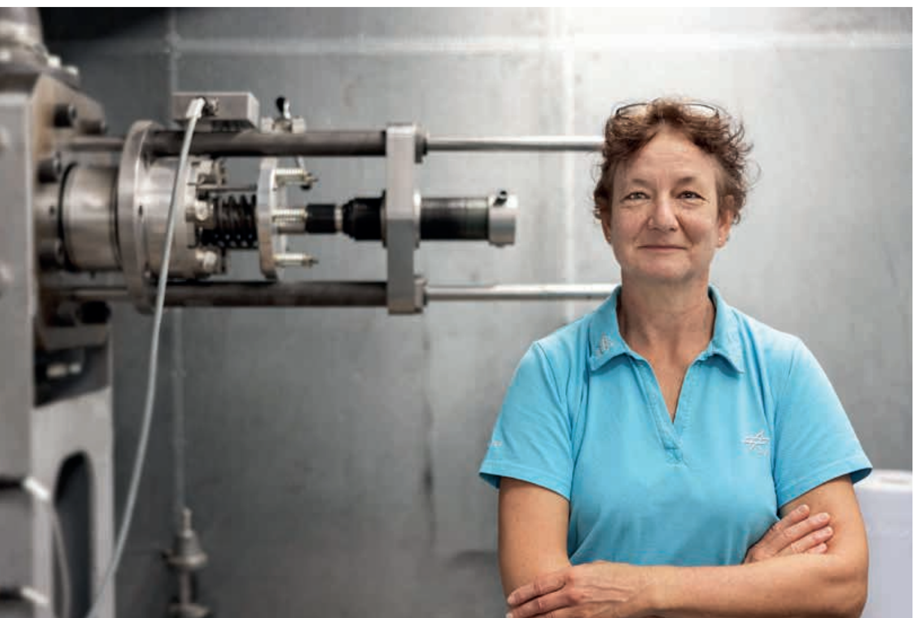
were created across the whole Institute from 1969–2026



138

EMPLOYEES

25 female, 113 male



209

PATENTS

were registered across the whole Institute from 1969–2026

OUR MISSION

Where conventional developments hinder progress in high-risk areas, we open up previously unimagined paths in lightweight construction. Thanks to our unbridled enthusiasm for research, revolutionary approaches and unconventional construction methods, we help our industrial partners to achieve technological breakthroughs. In this way, we help to increase Germany's competitiveness and make aerospace, like other areas of technology, more resource-efficient, climate-friendly, and efficient – and thus more sustainable for the future.

»WE LIGHTEN TECHNOLOGICAL ADVANCES«

OUR VISION

Revolutionary technologies for aerospace, mobility and energy technology are created because we as an organisation provide optimal conditions for them. When expanding our technical capabilities, we include the entire process chain – starting with the material, through the production of lightweight structures, to full-scale prototyping and integrated data management. We develop our own working methods and digital tools, thereby promoting an open, inspired and lively institute culture. By harmonising technology, people and our organisation, we create a place where we play a decisive role in addressing the great challenges facing the aerospace industry.

With this vision, we integrate ourselves into the programmes and strategies of the German Aerospace Center.

»WE ARE DEVELOPING TO BECOME A CENTRE OF EXPERTISE FOR DIGITALLY INTEGRATED LIGHTWEIGHT CONSTRUCTION«

TWO SITES WITH ONE AIM: CONSISTENTLY LIGHTWEIGHT CONSTRUCTION

The DLR Institute of Structures and Design has its origins at Stuttgart Airport. The German Institute for Helicopters and Vertical Flight Technology (DSH) laid the foundations for today's institute at the airport in 1958 with its four departments for flight physics, transport industries, aerodynamics and flight mechanics. In 1969, the Institute BT emerged from the Department of Applied Flight Physics. Today, the research that began more than 50 years ago is continued at two locations in accordance with the latest standards.

STUTTGART

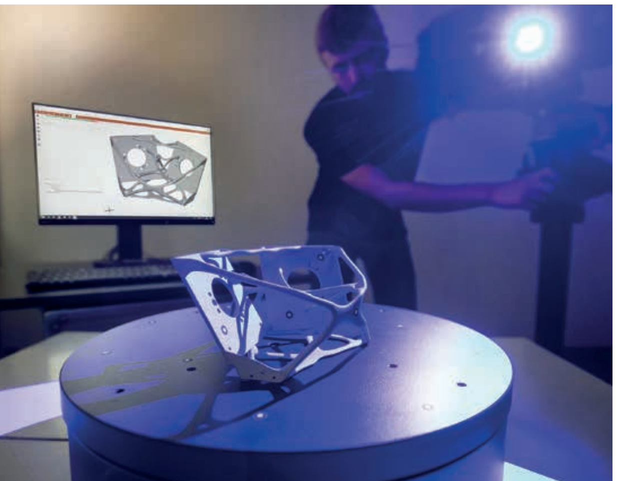
The site in Stuttgart is located on the premises of the University of Stuttgart-Vaihingen. The scientific work conducted here ranges from the development and optimisation of materials and their manufacturing and joining technologies, through to new design approaches and the construction of full-scale demonstrators. Of course, their testing and validation in specific test facilities and in flight tests is also part of the daily work. The focus is placed on fibre-reinforced ceramic, polymer and hybrid composites. Research into new multidisciplinary design tools and digital models forms the basis for the development of hardware.

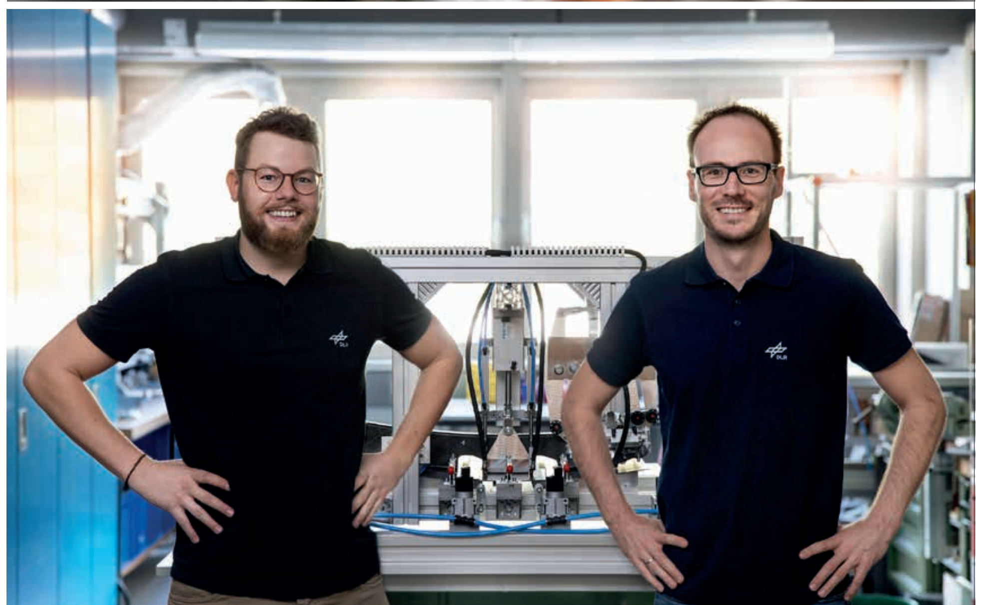
AUGSBURG

At the Augsburg site, which is located within the Innovation Park, work focuses on the development of lightweight production methods ready for industrial applications. Here, everything revolves around the robot-based production of lightweight structures and process-integrated quality assurance and its feedback with structural technology and design. The main strategic lines are research along process chains, full-scale capability and the consistent digital integration of all elements in line with Industry 4.0. The acquisition, processing and analysis of large amounts of data form the basis for the Institute's digitalisation strategy. This enables questions that arise from research and industry to be answered quickly and flexibly. Together with the site in Stade, our Department in Augsburg also forms the DLR Center for Lightweight-Production-Technology (ZLP).

In addition, we are developing valuable synergies through our interdisciplinary cooperation with internal and external partners.

Fibre-reinforced composites focussing on thermoplastic or duromer matrices.





RESEARCH FIELD

HIGH-PERFORMANCE LIGHTWEIGHT STRUCTURES:

DESIGN AND MANUFACTURING TECHNOLOGY

MATERIALS AND TECHNOLOGY IN BALANCE.

The development of lightweight structures for the aerospace industry or the transport and energy sectors always lies at the heart of the work at the Institute – in one form or another. In the field of design and manufacturing technologies, the journey from the first design idea through to the finished component is viewed as one integrated process. This research field has been using digital processes to develop optimal solutions for more than 30 years. Alongside structural aspects, the specific properties of the materials being used and appropriate production technologies are already taken into account during the design phase. The main focus of this research is fibre-reinforced composites with thermoplastic or duromer matrices.

THE FOLLOWING GOALS ARE PURSUED IN THE AREA OF COMPONENT DEVELOPMENT:

- Development and application of digital development paths for designing and optimising components
- Development of functionally integrated construction independent of the type of material
- Demonstration and validation via internal production and testing

THE FOCUS IN THE AREA OF TECHNOLOGY DEVELOPMENT IS:

- Consolidation of fibre-reinforced thermoplastics without autoclaves (vacuum and pressing process)
- Thermoplastic in-situ tape laying (AFP process)
- Welding processes for thermoplastic composites

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RESEARCH FIELD

HIGH-PERFORMANCE LIGHTWEIGHT STRUCTURES:
CRASH & IMPACT

RESEARCH WITH IMPACT.

Whether in air or ground-based transport, safety always comes first.

For 40 years the 'Structural Integrity' department has been conducting research in the fields of high-velocity impact and crash safety to make vehicle structures safe and thus protect passengers.

THE RESEARCH FIELD PURSUES THE FOLLOWING OBJECTIVES:

- Designing aeronautical structures and components able to withstand hazards such as impacts by birds, drones or hail, and thus guarantee a safe landing
- Using suitable designs and appropriate construction to protect passengers as much as possible in the event of a crash landing or an emergency landing on water
- Pushing forward the development of lightweight structures and resolutely using them to save fuel and make flying more sustainable

The key to achieving these goals is to use the very latest technology and to develop numerical methods for predicting material damage and structural failure on the micro level through to the component level.

In the field of high-speed impact research, numerical methods are developed to design and optimise novel impact-resistant structures. In the field of crash safety, the focus is placed on the development of specific design methods that support all development and evaluation work across the entire digital process, from the first design idea through to the final aircraft configuration.

The developed methods, the resulting concepts and the detailed designs are validated in extensive test campaigns. This is done down to the subcomponent level via short-time dynamic testing. This includes tests carried out with modern high-rate testing machines, gas guns and drop towers.

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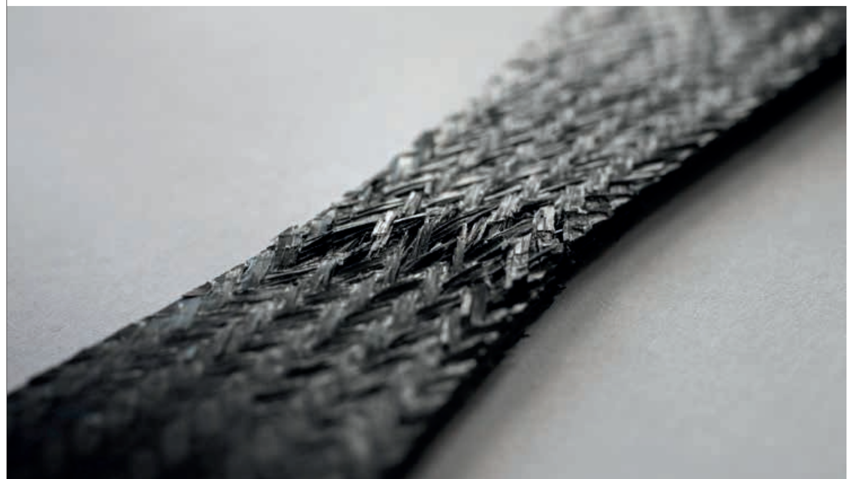
Flying high: Using validated numerical methods and lightweight structures for increased safety and sustainability.



To shape the future of lightweight production, we rely on **internally developed systems and a unique infrastructure.**

RESEARCH FIELD

HIGH-PERFORMANCE LIGHTWEIGHT STRUCTURES:
MANUFACTURING & PRODUCTION

PRODUCING QUALITY, INSTEAD OF JUST TESTING IT.

If you want to shape the future of lightweight construction, you must resolutely push forward the development of new innovations. The research field 'Manufacturing and Production' does precisely this in cooperation with industry. The team uses its broad level of expertise to develop holistic solutions for this purpose, while the unique infrastructure enables the team to develop full-scale automated production processes under realistic industrial conditions.

DIGITALISATION THAT CONNECTS.

One of the most important pillars supporting the day-to-day work in this research field is the digital linking of interdisciplinary processes. This is based on data collected in every phase of the production process. An internally developed Integrated Data Management System (shepard) is used by the research group to optimally evaluate this data. This system is also used by other DLR institutes and external partners. Our innovative system even allows the group to evaluate the data collected from the different processes during ongoing production. This means that quality management starts during production, ensuring that quality can be produced instead of just being tested.

A STRONG PARTNER TODAY AND IN THE FUTURE.

To remain a strong partner for industry today and in the future, the Institute must be able to quickly respond to the constantly changing requirements in lightweight production. In this respect, the research field relies on short innovation cycles based on flexible, platform-independent technology components and competency modules that can be quickly put together for use with a variety of different materials, technologies and construction methods. This ensures that our research in this field remains agile and continues to open up new possibilities in the area of lightweight production.

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RESEARCH FIELD

CMC TECHNOLOGY AND STRUCTURES

FROM THE DEVELOPMENT OF MATERIALS THROUGH TO FULL-SCALE STRUCTURAL COMPONENTS.

In the design and construction of CMC structures (ceramic matrix composite), the Institute of Structures and Design not only sets the standard in the area of materials development but also applies this expertise to the development of components made of ceramic matrix composites. Using the Liquid Silicon Infiltration process (LSI) developed at DLR, it is possible to produce ceramic matrix composites on-site on an industrial scale quickly and economically. The Institute has become a leading player internationally in this field thanks to this process. This is reflected by the numerous components developed in cooperation with industry that have now been turned into marketable products. With this technology, the Institute is represented in all relevant space projects in Germany and across Europe, and is also involved with series-production components used in aviation and the transport sector.

CMC ENGINEERING:

The Institute's secret to success lies above all in the cooperation between the various development fields. The complete engineering chain and the associated expertise with it guarantee the successful implementation of even the most ambitious CMC components.

This development area covers:
- Materials development
- Process development
- Construction method development
- Design and dimensioning
- Production of prototype components in their original size
- Quality assurance and component qualification

Alongside the team's specialist expertise, the infrastructure available to them also makes a difference. Tailored Computer-Aided Design (CAD) and Finite Element Analysis (FEA) systems for evaluating the structures in real applications, as well as furnaces of various different sizes and temperature ranges for pyrolysis and siliconisation processes, make it possible to develop components using optimised processes. The latest quality assurance testing equipment, such as CT and air ultrasonic systems, as well as scanning electron microscopes with integrated energy dispersive X-ray spectroscopy, guarantee that the development projects are carried out in accordance with the highest technological standards.

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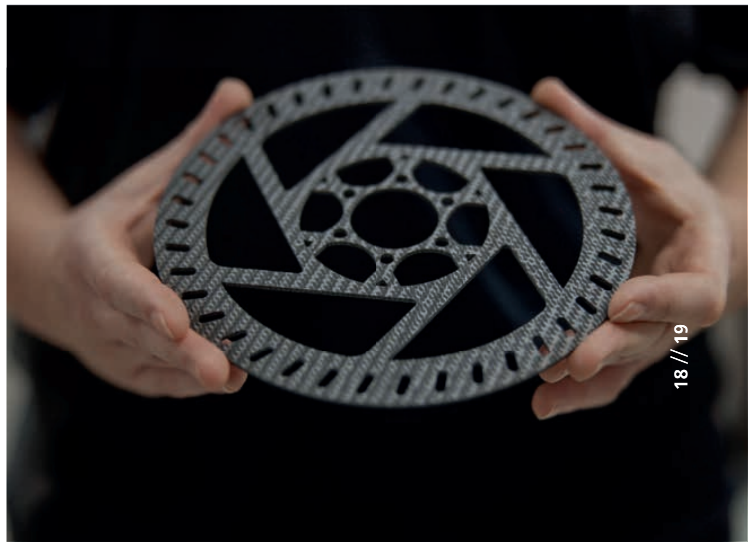
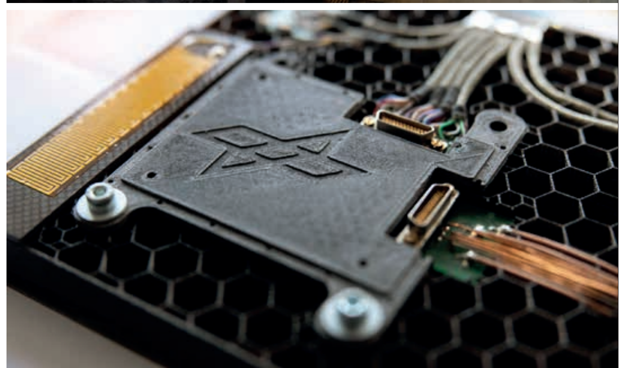
Developed at DLR and globally recognised: **The Liquid Silicon Infiltration process (LSI) is used around the world.**



If you want to drive research forward, **you must consider and understand the whole system.**



RESEARCH FIELD

LIGHTWEIGHT STRUCTURES FOR SPACE APPLICATIONS

LIGHTWEIGHT. RELIABLE. TEMPERATURE-RESISTANT.

The research field 'Lightweight Structures for Space Applications' has a clear focus: to consider the whole system in order to find new solutions for every detail. Spaceflight places many diverse demands on structural systems; they have to be light, reliable and above all resistant to thermal loads of between -250 °C and +2000 °C.

Every day, this research group deals with the whole process chain from the materials through to airworthy prototypes. Their work mainly focuses on the use of fibre-reinforced plastics and ceramics, while integrating production methods and technologies into design and simulation processes.

Digitalisation opens up possibilities for generating an increasing number of unconventional and innovative system solutions. The latest, flexibly configurable mechanical and thermal test equipment is used for verification purposes, supplemented by access to flight tests in realistic conditions.

A special feature of this research field is the development of innovative approaches for the cost-efficient development and construction of highly integrated commercial satellite systems, creating new standards in this area in cooperation with industry and university partners time and again.

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RESEARCH FIELD

AERO ENGINE STRUCTURES

OUR ENGINES CONSERVE RESOURCES AND IMPROVE SAFETY.

Air travel still faces the following problem: How do we balance the need for cost-effective and efficient transport with growing demands for sustainability and environmental protection? An important part of the answer lies in the systematic further development of various propulsion concepts.

The research field 'Aero Engine Structures' uses its broad range of expertise to make an important contribution to research into propulsion systems at DLR – and has done so for many decades. Innovative fibre-reinforced composites for engine blades were already being developed at the end of the 1970s. Since then, the field has been developing and applying new construction techniques and methods for conventional aero engines as well as for future propulsion concepts.

THE MAIN FOCAL POINTS TODAY ARE:

- The development of numerical methods that range from the materials and component design through to consideration of the entire system.
- Multidisciplinary design and optimisation of aero engine structures.
- The development of construction methods and manufacturing technologies for highly loaded structures in all areas of aero engines, such as in compressors, combustion chambers and turbines. This includes structures made of metal, fibre-reinforced materials (plastics or ceramics) and hybrid construction methods, as well as the production of the structures themselves.

In order to validate and refine the construction techniques and applied methods developed here, the research field relies on a modern combination of simulation-based predictions and the testing of real components. The work we conduct with other participating DLR institutes focuses on developing a 'virtual engine'.

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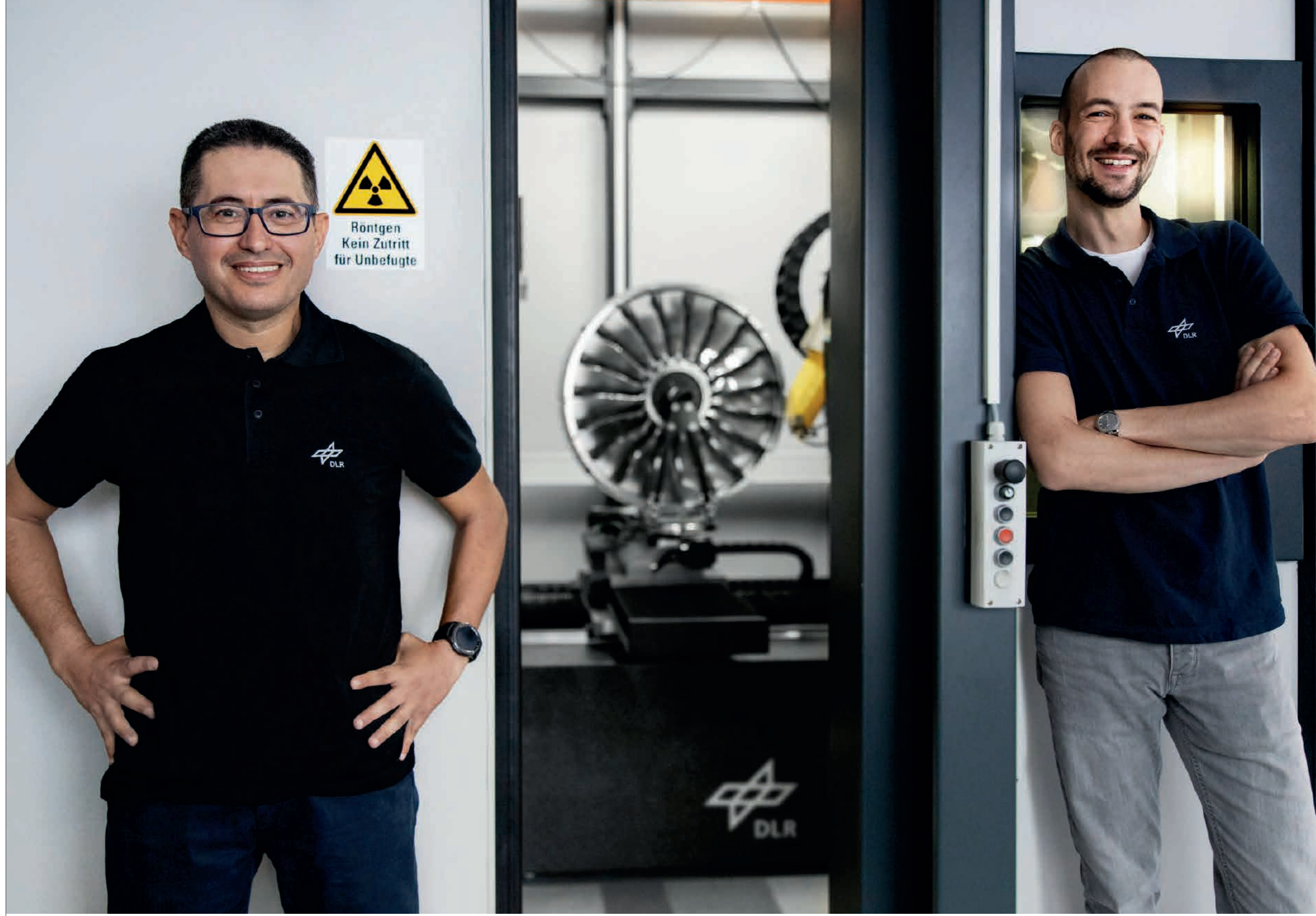
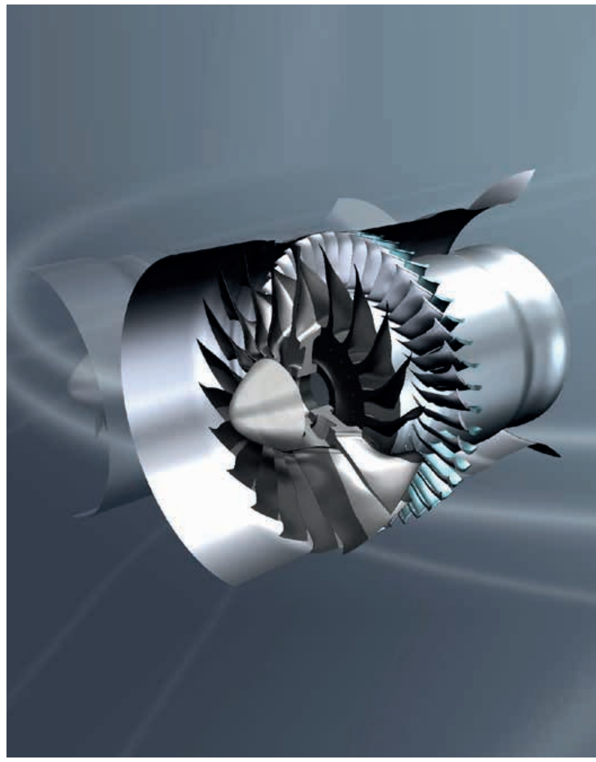


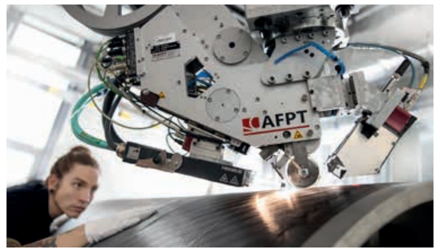
Modern research into aero engines **is now based on the interplay between simulation and reality.**



OUR

EQUIPMENT

HIGH-TEMPERATURE THERMOPLASTICS



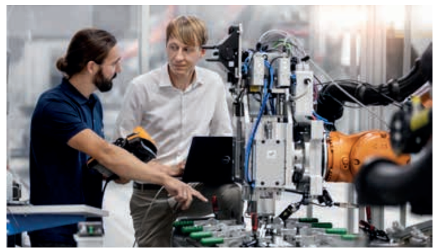
HIGH-TEMPERATURE THERMOPLASTIC TAPE LAYING

State-of-the-art tape laying machines at the sites in Stuttgart and Augsburg are used for research and development work into high-performance thermoplastic structures using Automated Fibre Placement (AFP) and the corresponding process technologies. They consist of a KUKA industrial robot with a linear axis and tilt-and-turn table for flat components and a winding axis for rotationally symmetrical components. The heat source for both machines is a 6 kW diode laser.

The machine in Stuttgart can produce flat components with a length of 3.6 m and a width of 2.0 m, while the one in Augsburg can produce components with a length of up to 6.0 m and a width of 3.0 m. This makes it possible to produce segments of the aircraft fuselage in their original size.

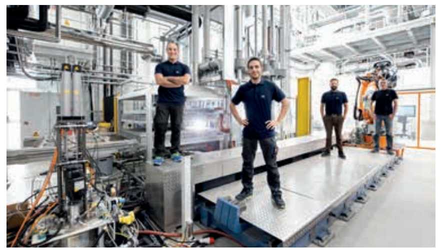
RESISTANCE WELDING

A resistance welding system can also be found at each of the two sites. The systems are used to produce welds under laboratory conditions in order to determine the key mechanical properties of the joint. They are also used in the production of demonstrators. A temperature of up to 400 °C can be reached in the joining zones of the welding systems within 30 seconds.



ULTRASONIC WELDING

Thanks to its end effector design with robot handling, this system can automatically produce welding geometries with almost any dimensions in complex processes. The system is used to join thermoplastic laminates on prototypes through to full-scale applications. The heart of the system is a 20 kHz Branson weld generator with a number of sonotrode configurations.



HOT PRESSES

The Institute has three hot presses at the sites in Stuttgart and Augsburg. They are used to investigate the production processes for structural components made of fibre-reinforced thermoplastics. The hot presses make it possible to quickly remould and consolidate complex parts.

EQUIPMENT TO CONSOLIDATE AND CURE FIBRE-REINFORCED STRUCTURES

FURNACES

The Institute has four furnaces in Stuttgart and Augsburg for the production of fibre-reinforced components and assemblies – from small laboratory furnaces for preliminary testing through to large furnaces for the production of full-scale demonstrators. Some of the furnaces can reach a maximum temperature of 450 °C. The furnaces have already been used, for example, to manufacture pressure bulkheads (4.5 m in diameter) and boosters (up to 6.0 m in length) in cooperation with partners from the aerospace industry. The site in Stuttgart also has a heating table with a maximum temperature of 400 °C and a Heraeus furnace with a maximum temperature of 350 °C.

INFUSION TECHNOLOGY

Resin can be processed at the Institute in one of two infusion systems. While the smaller system is used to process single component, hot curing resin systems for quantities of less than 100 kg, the larger system can handle more than 100 kg of resin for multi-component systems.

AUTOCLAVE

The Institute has a hot-air autoclave facility for producing complex, near-net-shape C/C preforms at the site in Stuttgart. It is mainly used for applications using pre-preg technology. The high pressure inside the facility is used to compress the individual laminate layers with the help of a vacuum film bag in which the preform is located.

EQUIPMENT TO PRODUCE CERAMIC MATRIX COMPOSITES

FURNACES

The DLR Institute of Structures and Design in Stuttgart has modern equipment for the production of preforms and several furnaces for high-temperature processes that enables the development of components made of ceramic matrix composites (CMC).

WINDING MACHINE

A 5-axis winding machine is also used at the Institute for the development of novel CMC structures. An increasing amount of development work is currently being carried out into space structure systems, such as cone nozzle extensions for sounding rockets and ideal bell nozzle extensions as demonstrators for future upper stage propulsion systems.

OUR

EQUIPMENT

TESTING EQUIPMENT

MECHANICAL TESTING

GAS GUN FACILITY WITH 3 GAS GUNS

The Institute has gas guns with various calibres from 12 to 200 mm for carrying out high-velocity impact tests. A gas gun can accelerate impactors with a mass of 1 g up to 7 kg to a speed of about 50 to 500 m/s. The gas guns can thus be used to recreate all impact scenarios experienced by both aircraft and high-speed trains in a laboratory environment.

LAUNCHER (NO IMAGE)

The test equipment is able to accelerate larger impactors such as drones up to 4 kg (category 2) at speeds of up to 120 m/s.

HIGH-SPEED TESTING MACHINE

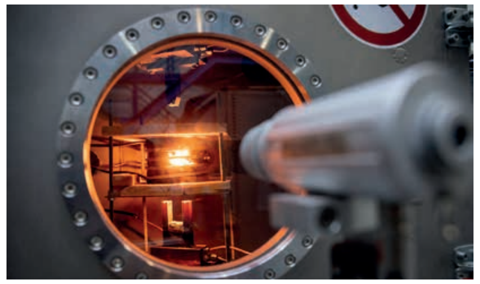
Two machines are available for the dynamic characterisation of materials and dynamic testing of components. They make it possible to conduct mechanical tests under a dynamic load of up to 100 kN and at a test speed of up to 20 m/s. High-speed video cameras with a frame rate of up to 200,000 images per second are used to record the tests. Several cameras can also be used for the contactless analysis of three-dimensional deformations.

SHAKER (NO IMAGE)

High cycle fatigue (HCF) tests are used to examine the fatigue strength of materials, components and even entire assemblies. These tests thus make an important contribution to safety in FEM analyses. They are carried out at the Institute using a shaker and small hammers.

+ THE EQUIPMENT AT THE INSTITUTE ALSO INCLUDES A RANGE OF DIFFERENT UNIVERSAL TESTING MACHINES.

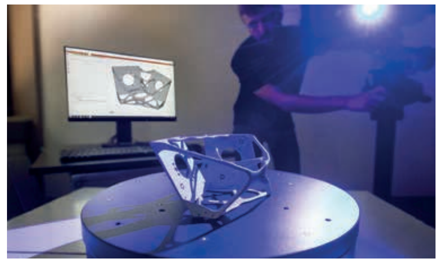
THERMOMECHANICAL TESTING

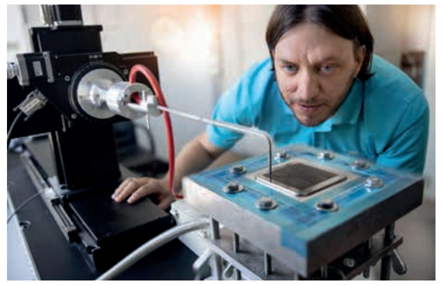


INDUTHERM

The INDUTHERM test stand is designed for the thermal and mechanical testing of structural components, for example, during the introduction of loads. Complex structural components and functional elements can be tested using inductive heating with appropriately designed coils.

NON-DESTRUCTIVE TESTING METHODS





COMPUTER TOMOGRAPHY (CT)

A large CT system and a high-resolution CT system are used at the Institute for the detailed, non-destructive, three-dimensional testing of complex components and structural assemblies.

3D COORDINATES MEASUREMENT MACHINE

In order to be able to quickly and precisely measure complex components, the Institute relies on the GOM ATOS 5. This highly precise 3D-coordinate-measurement machine can be used for the contactless measurement and digitalisation of almost any surface. By comparing the results with CAD data, it is possible, for example, to digitally record deformations from the production process.

AORTA

The AORTA system can be used to measure the permeability and also the outflow behaviour of porous materials, such as those used for transpiration cooling. In this cooling method, cooling fluid flows through the material being cooled, ideally at the same intensity everywhere. However, this is only rarely the case in real components and materials due to the microporosity of the materials. Some areas can also become 'clogged' or especially permeable due to the nature of the production processes. The AORTA system can identify these areas by taking precise measurements.

UNDERWATER ULTRASONIC TESTING DEVICE

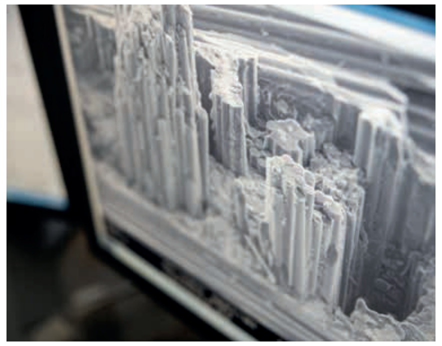
This device enables the non-destructive testing of materials. Ultrasonic waves are introduced into the test specimens and are reflected by defects in the material. This makes it possible to determine the position, type and size of the defect without damaging the material.

+ IN ADDITION, THE INSTITUTE HAS MANY OTHER ROBOT-BASED TECHNOLOGIES SUCH AS THERMOGRAPHY (LOCK-IN, PULSED, ULTRASOUND), AIR ULTRASOUND, CONTACTLESS 3D MEASUREMENT METHODS AND VARIOUS OPTICAL TECHNOLOGIES.

OUR

EQUIPMENT

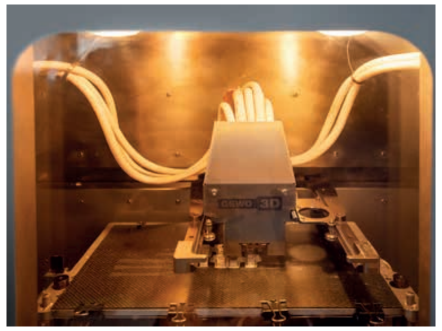
MATERIAL ANALYSIS



SCANNING ELECTRON MICROSCOPE

The Institute has a state-of-the-art scanning electron microscope – a Gemini Ultra Plus from the manufacturer Zeiss – with a magnification range of between 50 and 100,000 times. An integrated EDX detector can be used to analyse the elements in materials at a microscopic level (energy dispersive X-ray spectroscopy), whilst a field emission cathode delivers the highest resolutions and very good analysis capabilities.

+ OTHER EQUIPMENT IS AVAILABLE FOR ANALYSING MATERIALS. THESE INCLUDE DSC, TGA, DILATOMETER, RHEOMETER



3D PRINTING

Several 3D printers are used at the Institute for the additive production of thermoplastics, both in fused filament fabrication (FFF) and fused granular fabrication (FGF).

3D printers are useful, for example, for examining the processing of high-temperature thermoplastics (PAEK, PPS, PEI) that are suitable for primary structures in the aerospace sector. The aim here is to increase the level of complexity and integration of continuous fibre-reinforced lightweight structures using 3D printing.

Pellet 3D printing technology with specially developed and produced materials is also used. This technology is used to print green bodies with contours close to the final shape that are then converted into silicon carbide using the Liquid Silicon Infiltration process.

EQUIPMENT FOR FULL-SCALE AUTOMATED PRODUCTION

The following state-of-the-art equipment is available at the Institute for integrating manufacturing, installation and joining technologies and their relevant quality assurance measures into industrial, full-scale automated production.

MULTIFUNCTIONAL ROBOT CELL (MFC)

The MFC is a robot-based research platform that can be used to investigate the potential of different manufacturing processes for large components in the aerospace industry for the purposes of automated production. It is the key piece of equipment for research into production processes for lightweight structures. A total of six ceiling-mounted industrial robots can work here either together or independently.

THERMOPLAST CELL (TPC)

The site in Augsburg also has a TPC for investigating the production of fibre-reinforced thermoplastic structures. A diverse range of processes – from preforming to joining – can be investigated along the process chain using a temperature-resistant robot on a five-metre-long linear axis.

INLINE QUALITY ASSURANCE CELL (IQC)

More and more focus is being placed on inline quality assurance processes in the production of high-performance lightweight structures. The IQC enables process development, adaptation and testing to be carried out directly on an industrial robot at the Institute. Thanks to the high precision of the measuring robots used, it is also possible to conduct measurements requiring an increased level of precision.

TECHNOLOGY EVALUATION CELL (TEC)

Consisting of two robots mounted on a common 8-metre linear axis, the TEC is ideal for applications where cooperating robots are required, such as the transport of large textile blanks. There is also sufficient space around this equipment to enable experiments with large tool moulds.

FIBRE PLACEMENT CELL (FPC)

Comprising an industrial robot on a linear axis and a rotary drive for tool moulds, the FPC is used to research tape laying and fibre placement processes such as automated fibre placement. The cell can also be used to produce large components with a length of up to 6 m and a height of 3 m.

+ ROBOT TECHNOLOGY IS OMNIPRESENT AT THE INSTITUTE. ALONGSIDE THE EQUIPMENT DESCRIBED HERE, NUMEROUS SMALL ROBOTS ARE ALSO AVAILABLE FOR HUMAN-ROBOT COLLABORATION.

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About DLR

DLR is the Federal Republic of Germany's research centre for aeronautics and space. We conduct research and development activities in the fields of aeronautics, space, energy, transport, security and digitalisation. The German Space Agency at DLR plans and implements the national space programme on behalf of the federal government. Two DLR project management agencies oversee funding programmes and support knowledge transfer.

Climate, mobility and technology are changing globally. DLR uses the expertise of its 55 research institutes and facilities to develop solutions to these challenges. Our 10,000 employees share a mission – to explore Earth and space and develop technologies for a sustainable future. In doing so, DLR contributes to strengthening Germany's position as a prime location for research and industry.

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