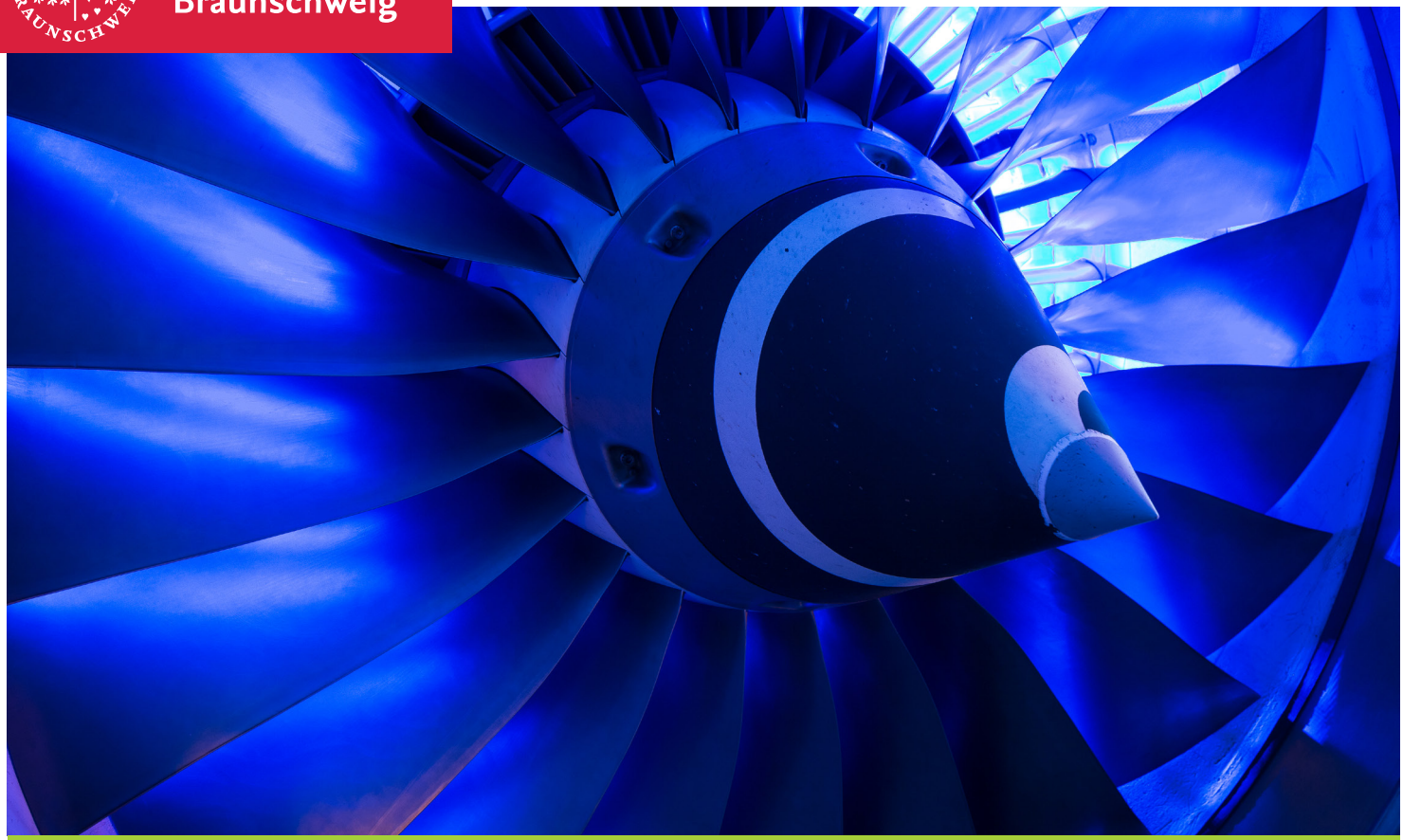
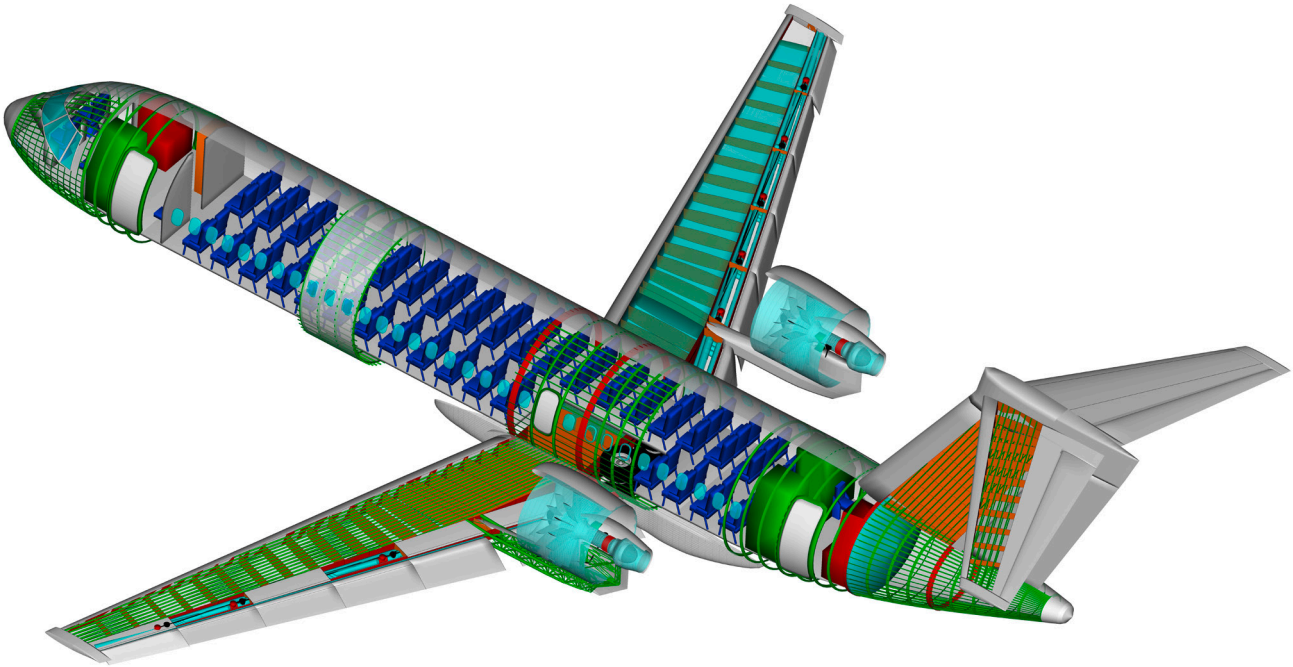
Technische Universität Braunschweig

NFL
am Campus Forschungsflughafen



Aeronautics Research Centre Niedersachsen (NFL)

Aeronautics Research Centre Niedersachsen - NFL



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Introduction to the Centre

"I am convinced that further major contributions towards solving our future mobility requirements will be conceived at the NFL."

Words of Welcome

Unique at least in Germany is the high concentration of research facilities specialising in aviation technology that you will find in and around Braunschweig. Aeronautics research and testing have a long-standing tradition here. At Braunschweig Research Airport, numerous institutes and research centres pool the aviation-specific competencies of both Technische Universität Braunschweig and the German Aerospace Centre (DLR). Developing and promoting this potential is an integral part of our research strategy.

In 2009, the Campus Research Airport was founded in cooperation with the DLR, as a TU Braunschweig research centre. Its aim has been to centralize fundamental research, applied technological developments and aviation testing at a single location, and to facilitate high-quality hands-on, research-oriented training for students in the field of aerospace technology. The Aeronautics Research Centre Niedersachsen (NFL), as the Campus Research Airport was renamed in 2013, encompasses the aviation technology institutes of the DLR and of TU Braunschweig, institutes relating to Leibniz Universität Hannover, as well as research units of the German National Metrology Institute, the Fraunhofer-Gesellschaft, and the DLR Göttingen. Through the formation of this comprehensive scientific alliance, Braunschweig and Niedersachsen have built a unique profile, both nationally and in Europe. The NFL is an institution of Technische Universität Braunschweig, within its core research area of Mobility.

The fundamental research conducted at the NFL and the orientation of the individual research projects within the Centre are guided by a common goal: to reconcile the rising mobility requirements of the future with environmental concerns, safety requirements and economic viability. Here, the integration of air traffic in metropolitan areas and its incorporation into a sustainable, closed-loop energy system represent two important fields of research. For the resulting challenges, the NFL's research projects offer innovative, efficient solutions – from reduced noise emissions and increased resource efficiency to the development of new energy and propulsion concepts for future aircraft. One of the latest outstanding achievements at the NFL has been its successful grant application to fund the SE²A (Sustainable and Energy Efficient Aviation) Cluster of Excellence. This new flagship project for fundamental aviation research will begin its first seven-year funding period in 2019.

This brochure outlines the scientific profile and competencies of each of the partners cooperating in the Aeronautics Research Centre Niedersachsen. I am convinced that further major contributions to our future mobility needs will be conceived here.

Prof. Dr.-Ing. Anke Kaysser-Pyzalla
President of Technische Universität Braunschweig

Identity and Aim of the Centre

The NFL is a research centre of Technische Universität Braunschweig in cooperation with the German Aerospace Center - DLR, Leibniz Universität Hannover, the German National Metrology Institute - PTB, and the Fraunhofer Society. The NFL focuses on coordinated fundamental research in the key areas of aeronautics guided by the needs of flight safety, environmental sustainability, and efficiency.

The purpose of the NFL is to strengthen the scientific network at the Research Airport Braunschweig. It serves this purpose through promoting coordinated and strategically significant research programmes in aerospace and involving additional partners from academia and research in Niedersachsen.
Founded in 2009, the NFL is now counting 33 personal members who are leading scientists at the five contributing institutions and represent their areas of expertise and their institutes. Their cooperation benefits from the focused competence of 24 institutes and more than 1600 researchers.
The strategic planning of long-term aeronautical research at the NFL is guided by the aims expressed by the Advisory Council for Aeronautic Research in Europe (ACARE). Thus, its coordinated research concentrates on the key aspects of aviation safety, environmental sustainability and efficiency of air transport.

One major asset of the NFL is the ability to engage in interdisciplinary research from fundamental to applied science, which means technology readiness levels (TRL) are covered from 1 to 6.
Moreover, together the members of the NFL have all skills required for creating technical innovations for future aircraft and air transportation. This broad scientific setup is supported especially by the experimental capabilities within the Centre. These capabilities have significantly been expanded in recent years through a coordinated major investment planning. Therefore, the different laboratories and test vehicles today allow for laboratory experiments to subsystem testing up to full flight tests.

NFL
am Campus Forschungsflughafen

Mission Statement

The NFL is a leading research centre for aeronautics and aerospace in Europe, providing top-level research and education. Scientific excellence and professionalism guide all its research efforts. Research conducted at the NFL helps satisfy society's need for mobility – both today and in the future.
Industry, science, and society will benefit from the research results created here. Bringing together the broad areas of expertise of all five contributing institutions gives the NFL a particular appeal, along with international visibility.
Furthermore, the NFL is building on a 90-year tradition of aeronautical research and flight testing in Braunschweig. Its infrastructure is unique internationally, with research aircraft, wind tunnels, simulators, and test facilities. Apart from that, award-winning scientists and motivated students ensure top-level research.

Research Vision

Several long-term programmes for fundamental research have successfully been established since the foundation of the Centre in the scientific domains of flight physics, aircraft design and multidisciplinary simulation of aerodynamics and structures. The NFL has developed the research vision of the 'Metropolitan Aircraft' that represents a novel segment of civil low-noise transport aircraft that enables integration of air transport into metropolitan regions.
This vision serves as a guideline for current and future collaborative programs of the NFL. It includes pursuing the aims of sustainable air traffic growth and enabling efficient point-to-point connections, short runways for take-off and landing, and drastic reductions of aircraft noise.

Education and Promotion of Young Scientists

In Braunschweig, young aerospace engineers begin their education with the bachelor studies of mechanical engineering. Already during the last two semesters, they can focus on aerospace engineering gaining basic knowledge in the field. Further specialisation is possible in the master studies of aerospace engineering - e.g. in propulsion, aircraft design or flight guidance.
With regard to apprenticeships and the promotion of young scientists, the NFL acts as a link between the aviation institutes of TU Braunschweig and those of the DLR as well as its other members. In addition, it is in close contact with further research institutes in Niedersachsen and Germany. In this way it can provide students with a basis for familiarising themselves with different fields of aerospace technology. Students can specialise according to their particular interests and gather a diverse range of practical experience which represents an outstanding prerequisite for a doctorate after their studies or the entry into working life.

A particular concern of the NFL is not only to create interdisciplinary research cooperations, but also to contribute towards a diverse and top-class training for aerospace engineers.

The research institutes participating at the NFL are mainly located at the Research Airport in Braunschweig. At this unique study location, students have have access to large-scale research facilities and laboratories on-site. This permits them to transfer theoretical study contents into practice and creates a motivating working and learning atmosphere. Both the DLR and the companies and institutions of the aviation branch located at the airport extend the range of courses, excursions, internships, theses and doctorates available. In addition, student initiatives create space for work on collaborative projects in the field of aerospace technology under students' own responsibility. Students taking part in the initiatives can forge global links to research institutions and the industry via competitions and conferences.

Supporting and motivating innovative ideas and outstanding research is an important issue at the NFL. Already young researchers have the chance of being presented with the Karl Doetsch Young Scientist Award for distinguished achievements during their studies. Excellent results achieved by researchers in their independent projects will be honoured with the Hermann Blenk Researcher's Award. For both awards, the contribution to the main aims of the research at the NFL – safe, efficient and sustainable air transport and aerospace – are crucial selection criteria. Named in honour of two pioneers of aerospace research in Braunschweig, the prizes are awarded annually by the NFL.

Master of Science

Automotive Engineering

Aerospace Engineering

Metrology and Analytics

Pharmaceutical Engineering

Sustainable Energy Engineering

Mechanical Engineering

- General Mechanical Engineering
- Energy and Process Engineering
- Automotive Engineering
- Aerospace Engineering
- Materials Science
- Mechatronics
- Production and Systems Engineering

Industrial Engineering / Mechanical Engineering

- Organization and Leadership
- Marketing
- Production and Logistics
- Decision Support
- Information Management
- Management Control
- Law
- Services Management
- Economics
- + 7 specialisation modules from Mechanical Engineering

Biochemical and Chemical Engineering

- Biological processes
- Chemical processes
- Pharmaceutical processes

Master Studies
and specialisation modules

Bachelor of Science

Mechanical Engineering

- General Mechanical Engineering
- Energy and Process Engineering
- Automotive Engineering
- Aerospace Engineering
- Materials Science
- Mechatronics
- Production and Systems Engineering

Industrial Engineering / Mechanical Engineering

- Marketing
- Production and Logistics
- Decision support
- Information Management
- Management Accounting
- Finance
- Economics
- Law
- Services Management
- + 7 specialisation modules from Mechanical Engineering

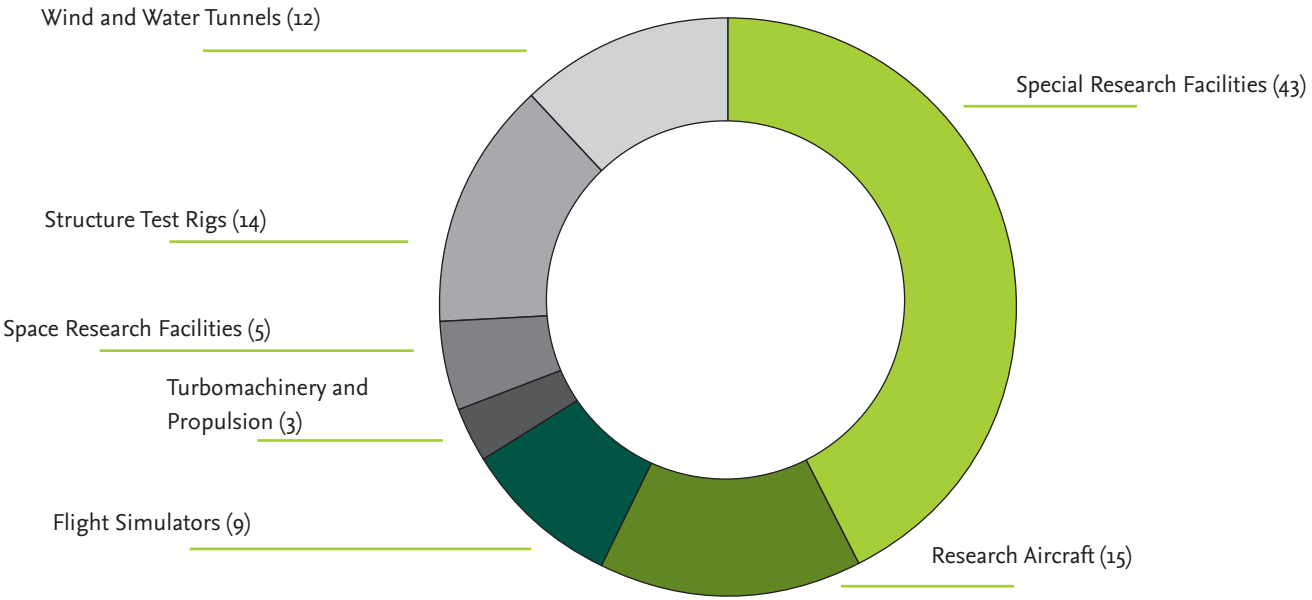
Biochemical, Chemical and Pharmaceutical Engineering

- Bioengineering
- Chemical Engineering
- Pharmaceutical Engineering

Bachelor Studies
and specialisation modules

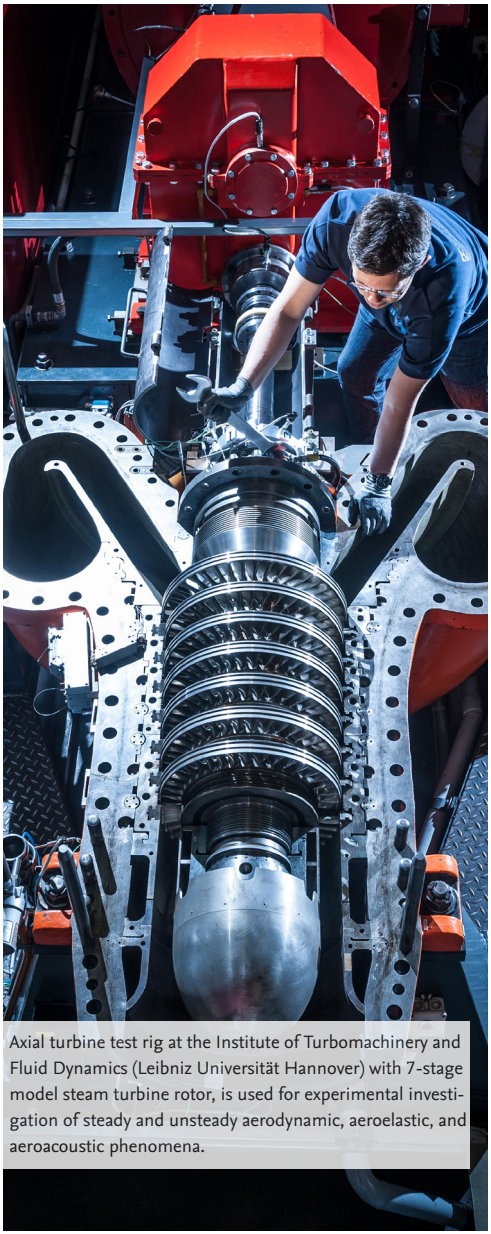
Infrastructure at the NFL

The excellent research infrastructure operated by the NFL members is a major asset of this research alliance. The unique facilities at the Research Airport – research aircraft, simulators, wind tunnels, and test beds – as well as the airport infrastructure provide the participating scientists with excellent opportunities for research and development. This high concentration and great variety of large-scale research equipment is unique in the German scientific environment. The next pages spotlight some selected facilities from the wide range of available research infrastructure and their application spectra.



Research aircraft Dornier Do 128-6 "D-IBUF" of TU Braunschweig enables a wide range of flight experiments due to its highly adaptable testing setup and flexible operational conditions.

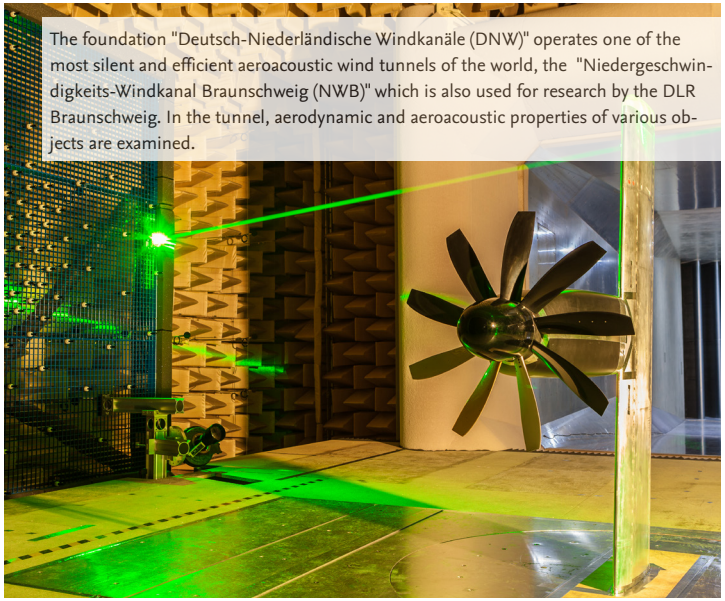
Airbus A320 ATRA of the DLR Braunschweig represents one of the most common types of commercial aircraft, thus providing research results with high relevance to the civil aviation sector.



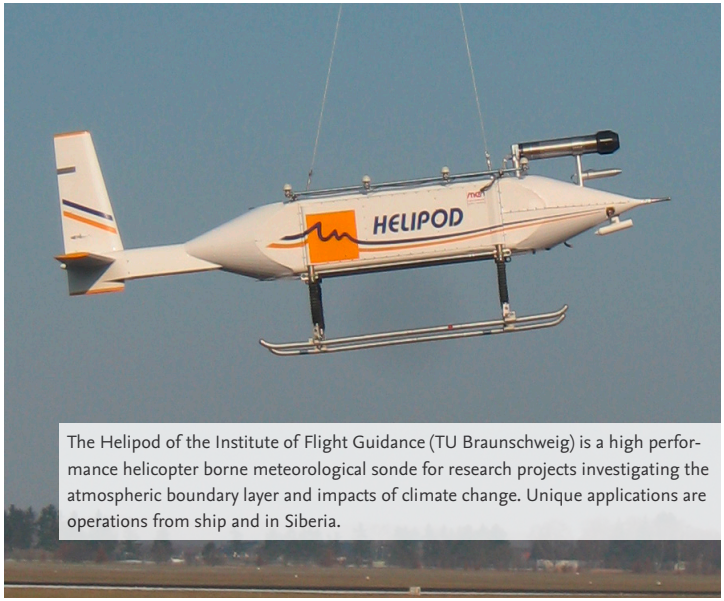
Axial turbine test rig at the Institute of Turbomachinery and Fluid Dynamics (Leibniz Universität Hannover) with 7-stage model steam turbine rotor, is used for experimental investigation of steady and unsteady aerodynamic, aeroelastic, and aeroacoustic phenomena.

Air Traffic Management and Operations Simulator (ATMOS) at the DLR Braunschweig, used for development and testing of innovative ATM concepts.

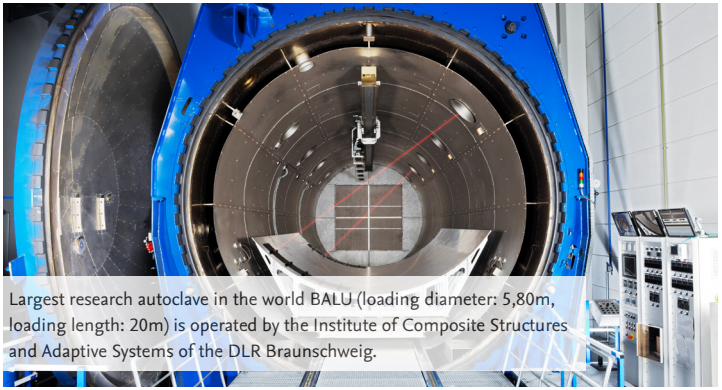
Simulator Center AVES at the DLR Braunschweig. It provides simulators of the cockpit of the Airbus A320 ATRA and the Eurocopter EC 135 FHS.



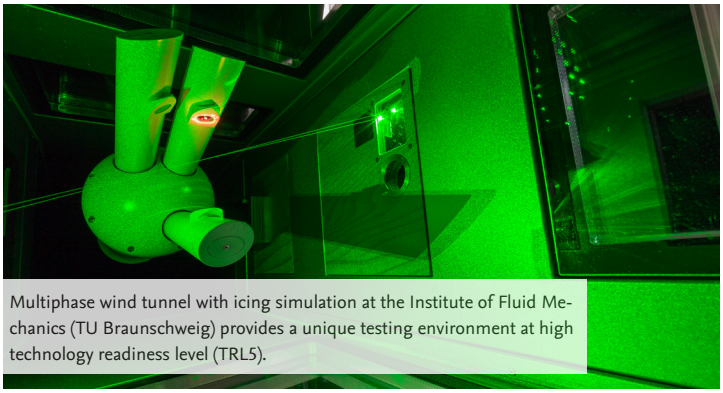
The foundation "Deutsch-Niederländische Windkanäle (DNW)" operates one of the most silent and efficient aeroacoustic wind tunnels of the world, the "Niedergeschwindigkeits-Windkanal Braunschweig (NWB)" which is also used for research by the DLR Braunschweig. In the tunnel, aerodynamic and aeroacoustic properties of various objects are examined.



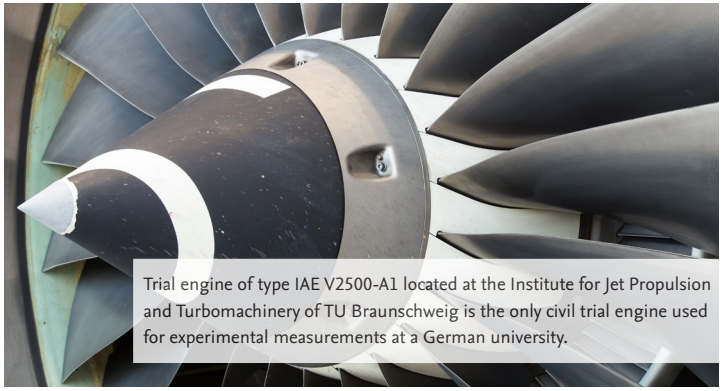
The Helipod of the Institute of Flight Guidance (TU Braunschweig) is a high performance helicopter borne meteorological sonde for research projects investigating the atmospheric boundary layer and impacts of climate change. Unique applications are operations from ship and in Siberia.



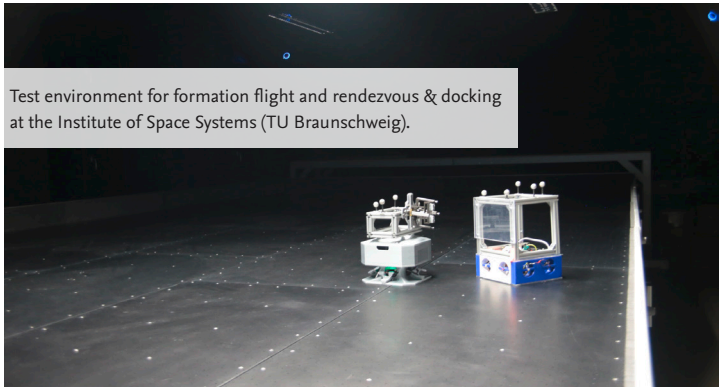
Largest research autoclave in the world BALU (loading diameter: 5,80m, loading length: 20m) is operated by the Institute of Composite Structures and Adaptive Systems of the DLR Braunschweig.



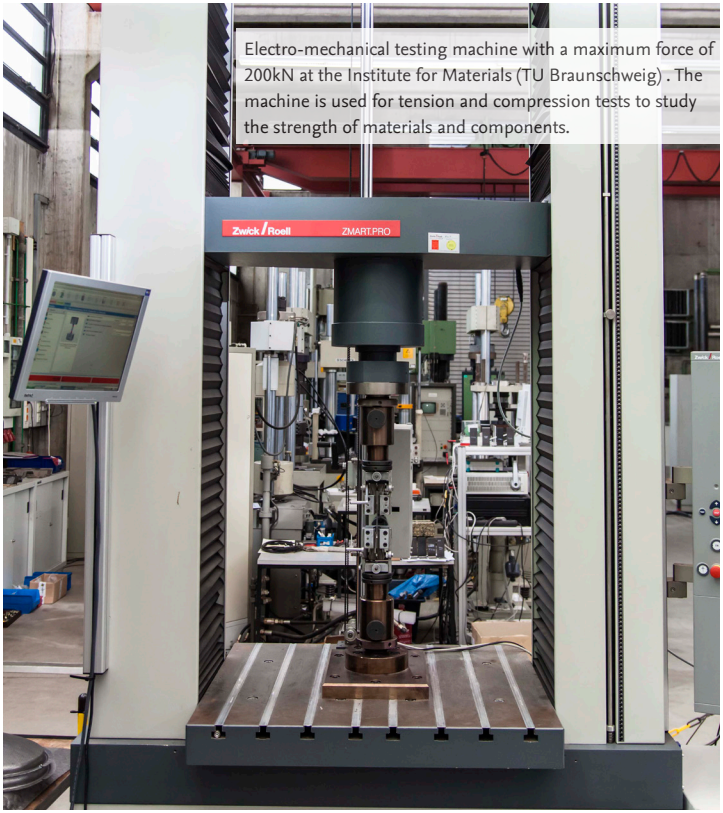
Multiphase wind tunnel with icing simulation at the Institute of Fluid Mechanics (TU Braunschweig) provides a unique testing environment at high technology readiness level (TRL5).



Trial engine of type IAE V2500-A1 located at the Institute for Jet Propulsion and Turbomachinery of TU Braunschweig is the only civil trial engine used for experimental measurements at a German university.



Test environment for formation flight and rendezvous & docking at the Institute of Space Systems (TU Braunschweig).



Electro-mechanical testing machine with a maximum force of 200kN at the Institute for Materials (TU Braunschweig) . The machine is used for tension and compression tests to study the strength of materials and components.

History of Aeronautics Research in Braunschweig

1783

The duke of Braunschweig, Karl Wilhelm Ferdinand, orders an unmanned trial balloon to be built at the "Collegium Carolinum" (first state support of research in aeronautics at a German university)

Trial balloon "Ad Astra"

1784

Two ascents of the hydrogen-inflated balloon „Ad Astra“ with landings at distances of 2 Km and 75 Km from Braunschweig

1788

First manned balloon ascent in Braunschweig by Jean-Pierre Blanchard

1922

Foundation of an aeronautical engineering group of students called "Flugwissenschaftliche Gruppe - FWG" - today "Akaflieg" - at TH Braunschweig

1931

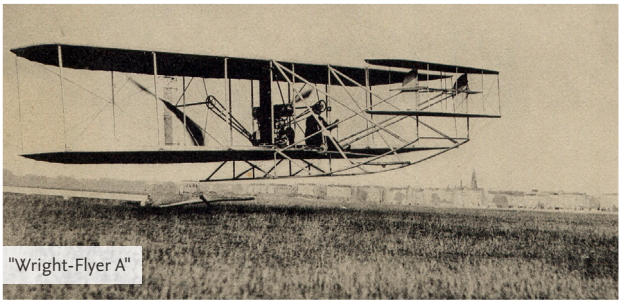
First chair at TH Braunschweig in aeronautical engineering for Prof. Dr. Heinrich Koppe on "Flugnavigation und Flugmessgerätekunde"

1936

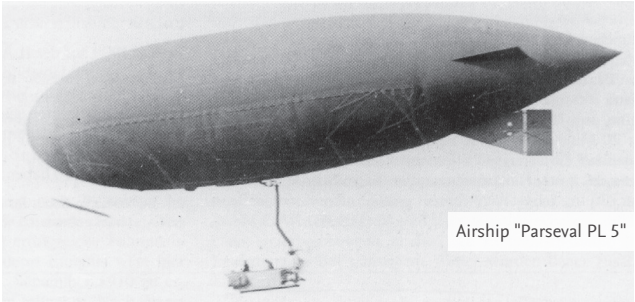
Foundation of the research establishment "Deutsche Forschungsanstalt für Luftfahrt (DFL)". It is represented at Braunschweig Völkenrode by five aeronautic institutes

1938

Inauguration of the "Luftfahrt-Lehrzentrum" of TH Braunschweig with four institutes located at the airport Braunschweig-Waggum.



"Wright-Flyer A"



Airship "Parseval PL 5"

First lecture series in aeronautics at TH Braunschweig on „Grundlagen der Luftschiffahrt" by Prof. Dr. Wilhelm Schlink

1909

First engine-powered flights in Braunschweig by Theodor Schauenburg using an airplane of type "Wright-Flyer A"

First rides of an airship "Parseval PL 5" from Braunschweig

1910

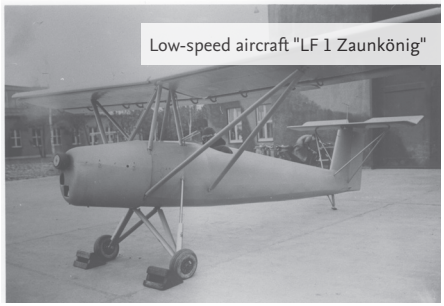
1940

First flight of the low-speed aircraft "LF 1 Zaunkönig", built at the "Luftfahrt-Lehrzentrum" of TH Braunschweig by Prof. Dr. Hermann Winter and students

First low-speed wind tunnel measurements on swept wings carried out by Prof. Dr. Hermann Schlichting at the "Luftfahrt-Lehrzentrum" of TH Braunschweig

1945

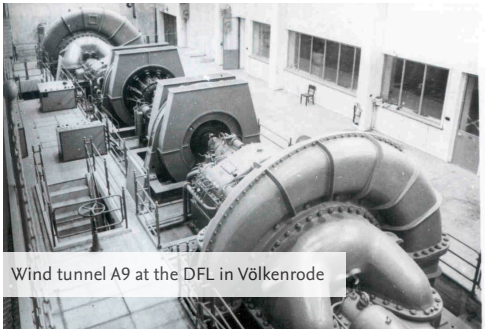
Resumption of research in aeronautical engineering at TH Braunschweig by two institutes located down-town under the leadership of Prof. Dr. Hermann Schlichting and Prof. Dr. Hermann Winter



Low-speed aircraft "LF 1 Zaunkönig"

1941-1942

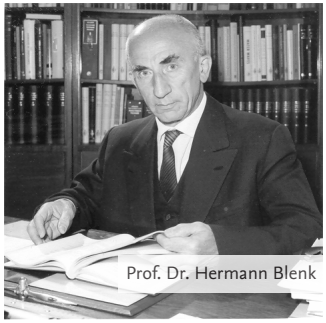
Test sections of the windtunnel A9 for transonic and supersonic flows, designed by Prof. Adolf Busemann, start operating at the DFL-institute of gas dynamics



Wind tunnel A9 at the DFL in Völkenrode

Establishment of new chairs at TH Braunschweig, contributing to research in aeronautical engineering: chair on "Maschinenelemente" for Prof. Dr. Otto Lutz who took over the subject of jet propulsion (1954), chair on "Angewandte Mechanik" taken by Prof. Dr. Hermann Blenk (1955) and chair on "Flugführung" for Prof. Dr. Karl-Heinrich Doetsch (1961)

1954 - 1961



Prof. Dr. Hermann Blenk

Resumption of research in aeronautical engineering at the DFL under the leadership of Prof. Dr. Hermann Blenk with six institutes now located at the airport Braunschweig-Waggum

1953

Experiments concerning digital flight control using sidesticks are conducted in Braunschweig for the first time

1971

Foundation of the "Zentrum für Luft- und Raumfahrt (ZLR)" by institutes of TU Braunschweig aiming at coordinated research in aeronautical engineering

1988

1989

World's first fully automated precision landing using the satellite positioning system GPS

2001

Moving of the first three ZLR member institutes of TU Braunschweig from their down-town locations to the Research Airport at Braunschweig-Waggum

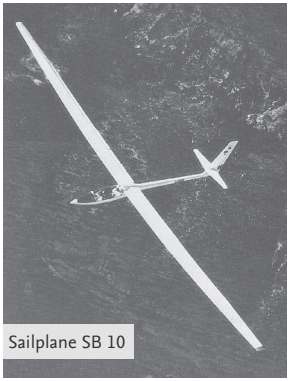
Contemporary newspaper cutting of an article on first automated precision landings in Braunschweig

1998

Foundation of the association „Forschungsflughafen Braunschweig", aiming at the expansion of Braunschweig as technology location with special focus on research in aeronautical engineering and aviation industry

1972

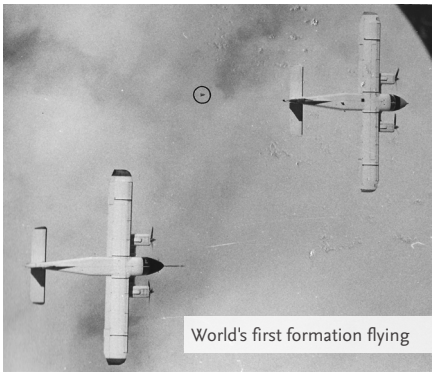
First flight of the SB 10, the largest sailplane in the world, designed by "Akaflieg Braunschweig", marks the beginning of carbon fiber construction in the main structure of gliders, which is later adopted by commercial aircraft



Sailplane SB 10

1982

Research helicopter "Bo 105" of the DFL is equipped with Fly by Wire system for flight control



World's first formation flying

1984

World's first formation flying, exploiting wake vortices is used for inflight measurement of the achievable power reduction

2007

Participation of team 'Leonie' in finals of the DARPA Urban Challenge marks the beginning of collaboration in aeronautical and automotive engineering at TU Braunschweig

Automated research vehicle "Leonie"

2009

Foundation of the "Campus Forschungsflughafen" of TU Braunschweig. Cooperation of TU Institutes in aeronautical engineering (ZLR) and mechanical engineering with the DLR (Braunschweig and Göttingen) as well as with Leibniz Universität Hannover

2012

Inauguration of the new research building at the "Campus Forschungsflughafen". Aeronautic research and education is combined at one site by moving of the two remaining aeronautic institutes of TU Braunschweig from their down-town locations to the airport at Braunschweig Waggum

2013

The "Campus Forschungsflughafen" is renamed "Niedersächsisches Forschungszentrum für Luftfahrt - NFL"

Members of the NFL

Institute for Acoustics

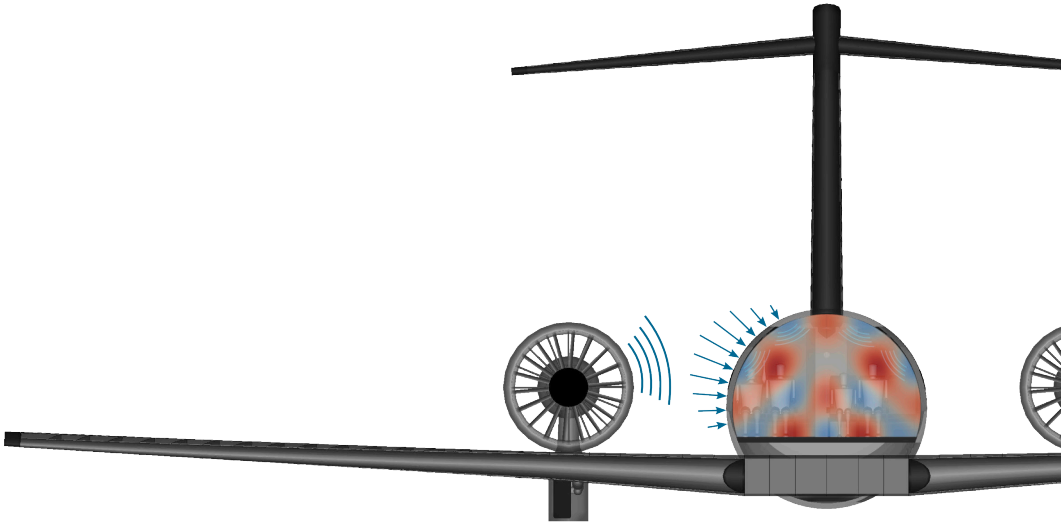
INSTITUT FÜR AKUSTIK

We devote our research to the science of sound & silence and are dedicated to acoustics for people.

Paving the way for calm, smooth and smart designs – this is the aim of our institute. Novel technologies require the development and fundamental study of acoustic effects, reliable models and innovative approaches for a quiet environment.
The Institute conducts research within three InALABs : Acoustic Engineering, Computational Acoustics and Models & Systems.

InALab Acoustic Engineering
In the InALAB Acoustic Engineering we pursue the intrinsic acoustic design in early product development phases. One of our research focuses is the integration of acoustic functions into new products and systems. The main aim is a low-noise design with noise reduction measures such as smart structural modifications and innovative passive damping measures. By means of acoustic models, efficient simulations and experiments, an optimal acoustic design can be achieved.

InALab Computational Acoustics
In the InALab Computational Acoustics we investigate wave-resolving numerical methods for vibroacoustic models and develop our in-house research code elPaSo (ELementary PArallel SOlver). Providing robust solutions of coupled air- and structure-borne sound domains is our main motivation. Key topics are the quantification of sensitivities, model order reduction techniques, hybrid methods and a sustainable code development.



InALab Models & Systems

In the InALab Models & Systems we provide robust and yet reliable system-adequate modeling techniques for challenging tasks in the field of acoustic computations. A major aim is the quantification of model and parameter uncertainties by applying intrusive and non-intrusive procedures. Having a close cooperation of experimental and computational system characterization, we provide corroboration of the provided models by applying validation techniques.

Teaching

Low-noise Design, Technical Acoustics, Vibroacoustics, Computational Acoustics, Acoustic Measurement, Lecture series 'Fascinating Acoustics', Innovation through intuition and inspiration

Infrastructure - Acoustics Laboratory

Air- and Structureborne Sound measurements

- Sound pressure
- Impedance
- Mobility
- Damping

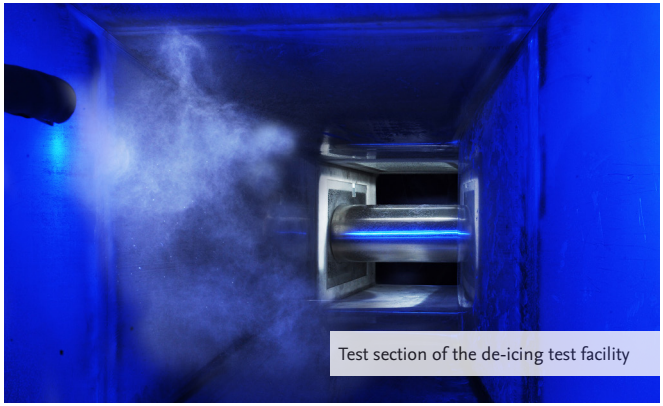
Material Characterization

- Flow resistivity
- Absorption
- Material parameters

Institute for Acoustics
Founded: 2019
Head of Institute: Prof. Dr.-Ing. Sabine Langer
Staff: 11 (2019)
https://www.tu-braunschweig.de/ina
ina@tu-braunschweig.de

Institute of Adaptronics and Function Integration

The iAF deals with the research and development of self-adapting components and structures for engineering as well as aerospace applications. The general target areas are vibration and noise reduction, shape-control, and structural health monitoring.



Test section of the de-icing test facility

Study at the Institute of Adaptronics and Function Integration

The Institute of Adaptronics and Function Integration (iAF) has conducted research in the scientific fields of adaptronics and functional lightweight structures since 2012.

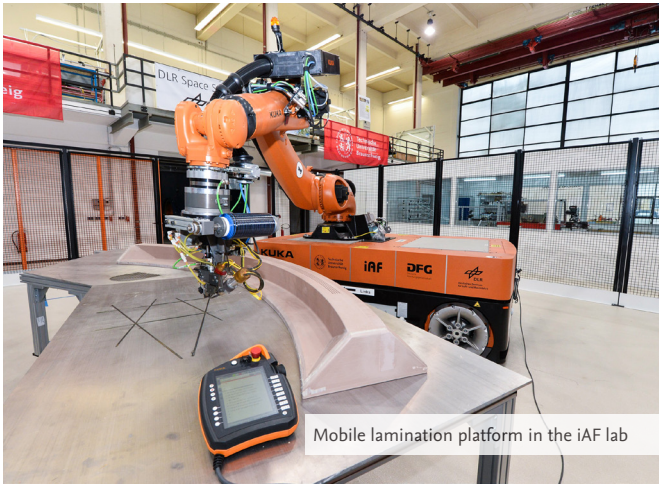
Our vision is a new school of lightweight construction through:

- Structure compliant integration of functions from material level right up to component level
- Adaptivity to environmental conditions and alternating requirements
- Self-regulating production processes
- Simultaneous assurance of robustness and fault tolerance

Possible solutions by means of adaptronics normally involve integrating additional functions into supportive structures by combining conventional engineering materials with active (smart) materials. The latter are not only capable of carrying loads, but also function as sensor or actuator, or both. In combination with fast controllers, these active materials enable components to adapt their properties to changing operating conditions effectively or in the best possible way. Amongst other things, the vibration isolation of components and assemblies as well as influences on the properties of adaptive machine parts (aerodynamic foil bearing, slider bearing) are investigated in different research projects at the iAF.

Furthermore, the research at the iAF concentrates on the development of processes for an adaptive self-controlled production of

Space structures lab



Mobile lamination platform in the iAF lab

fiber composite materials as well as on the possibilities for improving the properties of composite materials by means of nano-scaled matrix additives. Other research projects at the iAF focus on the corrosive effects of hybrid materials (consisting of composites and metallic layers), on de-icing methods for airfoils and on integrated sensor guided structural health monitoring systems. The Institute of Adaptronics and Function Integration works in close cooperation with the DLR-Institute of Composite Structures and Adaptive Systems.

Our research is focused on the following fields of adaptronics:

- Active shape control
- Active noise control
- Active vibration suppression
- Structural health monitoring
- Self-regulated composite manufacturing

We offer lectures in Adaptronics, Active Vibration Control, Active Vibroacoustics, Adaptive Lightweight Design, Vibration Measurement Technology, Experimental Modal Analysis, Composite Manufacturing, and Additive Layer Manufacturing.

Infrastructure

- Mobile Lamination Platforms
- Autoclave
- Tapelaying Machine
- De-Icing Test Facility
- Space Structures Lab
- Vibration Test Equipment, incl. Laser Doppler Vibrometer
- Composite Assembly Lab

Institute of Adaptronics and Function Integration
Founded: 2011
Head: Prof. Dr.-Ing. M. Sinapius & Prof. Dr.-Ing. C. Hühne
Staff: 30 (2018)
https://www.tu-braunschweig.de/iaf
iaf@tu-braunschweig.de

Institut für Flugzeugbau und Leichtbau
IFL

Institute of Aircraft Design and Lightweight Structures

It is the aim of the Institute to find efficient and energy-saving solutions, both in lightweight structures as well as aircraft design. This includes basic research and applied research.

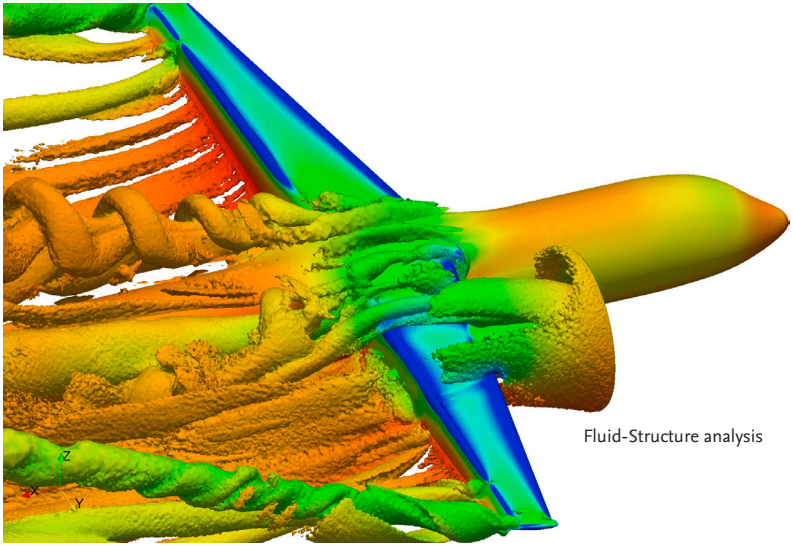
Multiaxial panel test

The Institute was founded in 1938. It targets all varieties of lightweight structure applications, including aircraft structures. In addition, it conducts research on aircraft design in the sense of a multidisciplinary task. There are five groups working in the fields, namely: conceptual design of aircraft (Dr. Heinze), simulation and multiphysics (Dr. Haupt), damage mechanics on composites, metals and hybrid materials and structures (Prof. Horst), new lightweight designs (Prof. Horst), and structural experiments (Dr. Fabel). A close connection of theory and experiment is a key characteristic of most of the projects.

Typical subjects in the field of multiphysics are fluid-structure interaction (figure right), thermomechanical and electromechanical interactions. All simulations of the individual physics rely on highly sophisticated numerical methods (e.g. commercial finite element methods, DLR-TAU etc.). An in-house coupling software named ifls is used.

The topic of damage mechanics comprises subjects from micromechanics up to full-scale tests on aircraft; special emphasis is placed on theory and experiments. Highly specialised structural optimisation strategies are used to develop new designs.

Damage mechanisms are investigated in the field of metal materials and fibre composite materials. New construction methods are developed on structural optimisation both for metal and for fibre composite structures.



Fluid-Structure analysis

Overall aircraft design is a distinctly multi-disciplinary optimisation task which can only be reliably fulfilled through complex computer codes. The PrADO program has been devised for this purpose and is constantly developed further in various projects.

Teaching comprises subjects regarding Lightweight Structures, namely: Finite Element Methods, Stability Theory, Damage Tolerance, Composites, Composite Damage Mechanics, Product Modelling and Simulation, Wind Power Rotors, Aircraft Structural Design, Aeroelastics and, in the Bachelor programme: Elements of Lightweight Design and Basic Engineering Methods in Lightweight Structures. Aircraft Design as a type of multidisciplinary subject is read in the Master programme, and Information Technology in the Bachelor for all Mechanical Engineering students.

Infrastructure

There are several test set-ups available, which are in part highly flexible. These range in sizes from tests for micromechanics to large structural items, including aircraft full-scale tests. All tests may be used for basic research as well as applied science. As an example, the figure on the left page shows the test set-up used to test large reinforced panels under multiaxial loading conditions.

Institute of Aircraft Design and Lightweight Structures
Founded: 1938
Head of Institute: Prof. Dr.-Ing P. Horst
Staff: 35 (2019)
https://www.tu-braunschweig.de/ifl
ifl@tu-braunschweig.de

Institute of Automotive Management and Industrial Production, Chair of Production and Logistics

Our focus of research is placed on the development and application of techno-economic models and quantitative methods for decision support in production, logistics, and sustainability management.

Since more than 20 years, the Chair of Production and Logistics is known for its research expertise in sustainable design, planning, and control of industrial production and logistics systems. Focusing on a technology and decision-oriented business administration, we address research questions related to the following topics.

Energy- and Resource-Efficiency: Industrial production requires the use of resources and energy for the creation of final products. We deal with the development of descriptive models of resource and energy demands as well as the efficient design, planning, and control of production systems on this basis.

Digitization in Production and Logistics: The digitization leads to new business models (e.g., predictive maintenance) and technologies (e.g., human-robot collaboration) in production and logistics systems. In this field, we concentrate on the selection, planning, and control of such new business models and technologies.

Sustainable Mobility: Emissions and resource consumption of passenger and freight transport have to be cut down significantly. To support a sustainable mobility, we address, amongst others, research questions regarding the market introduction of electric vehicles, the production and recycling of innovative powertrains, and the planning and operation of airline fleets.

Circular Economy: The closed-loop circulation of products, materials, and substances gains more and more importance. We conduct research on the economic design of closed-loop supply chains and recycling concepts, as well as recycling planning and control.

Teaching

Our teaching portfolio comprises lectures that cover methods for the design and planning of industrial production and logistics systems. In the Bachelor's program, we focus on Principles of Production and Logistics as well as Production and Logistics Management. In the Master's program, we offer advanced courses such as Supply Chain Management and Sustainability in Production and Logistics as well as tutorials on software tools. Guest lectures and field trips complete the teaching portfolio. Our philosophy is to offer students an attractive and well-founded teaching that captures current research and practice-oriented topics.

Infrastructure

- State-of-the-art optimization and simulation software
- Computer pool for research, teaching, and further education

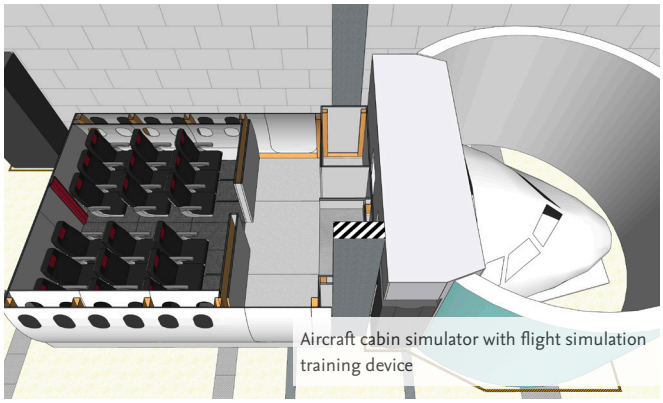
Institute of Automotive Management and Industrial Production
Founded: 1998
Head of Institute: Prof. Dr. Thomas S. Spengler
Staff: 15 (2018)
https://www.tu-braunschweig.de/aip/prodlog/index.html
aip-pl@tu-braunschweig.de

Institute of Flight Guidance

Institute of
Flight Guidance
Technische Universität Braunschweig

The research work conducted at the Institute of Flight Guidance of TU Braunschweig provides innovations for a safe, efficient and environmentally-compatible air transport system.

Research aircraft Dornier 128-6 "D-IBUF"



Aircraft cabin simulator with flight simulation training device

The Institute of Flight Guidance is based on the Professorial Chair created in the year 1931 by Technische Universität Braunschweig for "Flugnavigation und Flugmessgerätekunde". Building upon over 85 years of experience in the development of new methods in flight guidance and air traffic control, over 40 researchers from the fields of aerospace technology, electrical engineering, meteorology and IT currently collaborate in project teams. Their research covers a broad spectrum ranging from enabling technologies e.g. in navigation and measurement technologies up to functions and systems at aircraft or air transport system level. Significant contributions to the state of the art in research and innovation have been delivered in aircraft avionics and cockpit assistance systems, and weather data processing, positioning and navigation, ground systems for air traffic control, airports and airlines. In addition, measuring technologies for aviation applications and fundamental meteorological research are developed, implemented and assessed. The aim of flight guidance research is the development of means for supporting the human being in operating aircraft. The Institute of Flight Guidance approaches this aim through the development of solutions for pilots, air traffic controllers as well as airport and airline operators. In addition, technologies and operation of unmanned aircraft systems are addressed.

Helipod (helicopter-borne turbulence probe)

Diamond D-Sim-42 flight simulation training device

Main Research Fields
- Air Traffic Management (ATM)
- Navigation
- Flight guidance systems and flight mechanics
- Airborne meteorology and measuring technology

Fields of Teaching
- Flight guidance
- Flight measuring technology
- Positioning and navigation
- Simulation technology
- Meteorology

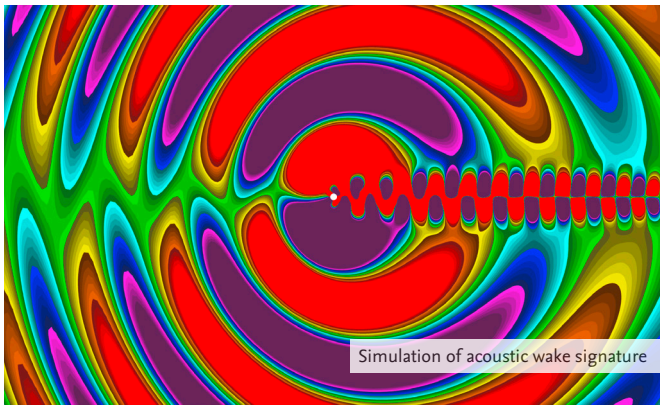
Further subjects are amongst others flight mechanics, rotor technology, aerospace medicine and certifications in air traffic.

Infrastructure
- Flight testing department with two research aircraft
  - Dornier 128-6 " D-IBUF"
  - Cessna 172 "D-EMWF"
- Flight simulators Airbus A320 and Diamond DA42, integrated air traffic simulation
- Test Vehicle Driver Assistance Systems, VW Passat
- Helipod (helicopter-borne turbulence probe)
- Lidar for wind measurements
- Galileo Testbed aviation GATE
- Precision navigation systems
- Galileo laboratory (Full Constellation Simulator)
- Multiple unmanned flight systems (UAS)

Institute of Flight Guidance
Founded: 1931
Head of Institute: Prof. Dr.-Ing. Peter Hecker
Staff: 40 (2019)
https://www.tu-braunschweig.de/iff
iff@tu-braunschweig.de

Institute of Fluid Mechanics

Our work combines fundamental research in fluid mechanics theory, experimental and numerical simulation with advanced applications in aerospace, automotive and energy technologies.



Simulation of acoustic wake signature

Flow visualisation for car model in wind tunnel

The Institute of Fluid Mechanics was founded in 1923 as the Aeronautics Institute of "Technische Hochschule Braunschweig". The Institute has developed engineering models for aerospace and automotive vehicle aerodynamics for more than 90 years. We investigate new design concepts to improve flow behaviour and vehicle performance using numerical flow simulations and experiments in wind and water tunnels.

Main Research and Teaching

Aerodynamics of Aircraft: We seek new physical models of turbulence and boundary-layer transition to enhance future flow simulations of aircraft and space vehicles. We aim at improving performance parameters of aircraft by providing new design options to enhance lift and to reduce drag.

Measurement and Manipulation of Flows: We develop and utilize new methods for active and passive flow control. The goals are to efficiently control turbulent separations for high lift or low drag, and to control laminar-turbulent transition.

Scale-Resolving Simulation of Acoustic Sources: A significant proportion of the noise emissions from aircraft and automobiles have their origin in turbulent shear flows. We develop scale-resolving simulations of aero-acoustic sources for noise prediction and for physical analysis of noise sources.

Wind tunnel testing of flow control device on winglet

Multiphase Flows and Icing: Multiphase flows and icing are relevant for aircraft, automobile and wind turbine performance. Our research group operates a unique wind tunnel facility where interactions of flow, super-cooled droplets, and ice crystals with test models are measured.
Flow Modelling and Control: Closed-loop offers great potential in providing robust and optimum flow control. Therefore we develop tools, models, and algorithms for flow analysis and closed-loop flow control applications.
The institute contributes to Bachelor and Master study programmes in engineering. We offer comprehensive courses in aerodynamic theories, numerical flow simulation and experimental methods. Further courses address aerodynamic applications for aircraft, spacecraft and motor vehicles.

Infrastructure
The institute operates excellent test facilities that are equipped with state-of-the-art measurement systems:
- Low speed wind tunnel
- Large water tunnel
- High-speed Ludwieg tube for supersonic and hypersonic flows
- Multiphase wind tunnel with icing simulation at TRL5
- Wind tunnel for micro air vehicles

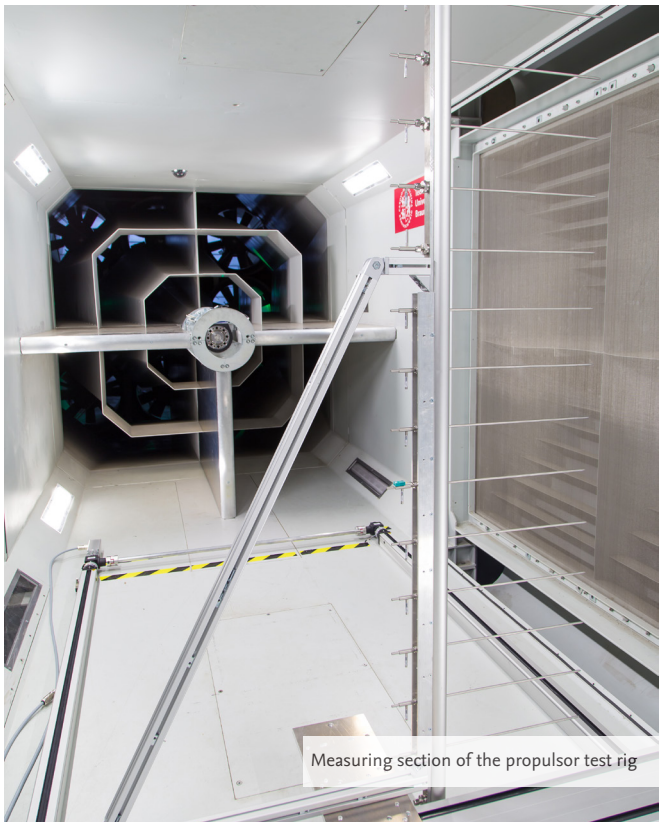
The institute has access to high-performance computational resources.

Institute of Fluid Mechanics
Founded: 1923
Head: Prof. Dr.-Ing. R. Radespiel & Prof. Dr.-Ing. R. Akkermans
Staff: 36 (2019)
https://www.tu-braunschweig.de/ism
r.radespiel@tu-braunschweig.de

Institute of Jet Propulsion and Turbomachinery

IFAS Institut für Flugantriebe und Strömungsmaschinen

The focus of research at IFAS is placed on fundamental analysis for the improvement of the economic viability and reduction of the noise emissions of aircraft engines and their maintenance technologies.



Measuring section of the propulsor test rig

The Institute of Jet Propulsion and Turbomachinery (IFAS) dates back to the appointment of Prof. Carl Pfleiderer, who is considered one of the founders of modern flow machine research, at TH Braunschweig in the year 1912. In the year 2011, the Institute was re-named the Institute of Jet Propulsion and Turbomachinery when Prof. Jens Friedrichs was appointed head of the Institute. One year later it moved to a new building at the "Campus Forschungsflughafen". There, scientific employees were provided with an outstanding research infrastructure consisting of a central workshop, testing laboratories, a fan test rig and a test engine. The subject area of aviation engines and flow machines concerns itself with the design and operating characteristics of overall flow machine systems and their components. The increasing scarcity of energy resources demands increasingly efficient propulsion systems. Thus, one focus of the institute is the development of design recommendations for future engines through the further development of design concepts and re-calculation processes and component research. Wear diagnosis issues and the further development of aviation engine maintenance repair processes also play a major role.

Main Research and Teaching

The research focuses of the institute are the optimisation of thrust generation, i.e. the propulsors of future aircraft engines, and the

Test engine IAE V2500-A1

Control room of the propulsor test rig

investigation and forecasting of wear effects in engine systems. In addition to the further development of design processes, comprehensive research projects are conducted on components and systems behaviour. As far as teaching is concerned, lectures are offered on the components, control, measuring technology and the operating characteristics of aviation engines. Economic aspects are covered through lectures on maintenance of aircraft propulsion and operation of airlines.

Infrastructure

The comprehensive experimental facilities at the Institute permit both examinations of the aircraft engines themselves and their components.

Important testing facilities are:

- Propulsor test rig (drive power 3,000 KW) for experimental examination of intakes and fans with headwind, and angles of attack right up to pure crosswind
- Test engine IAE V2500-A1 as test vehicle for the validation of wear models as well as regeneration technologies and measuring devices for in-situ diagnosis
- Cascade wind tunnels for the measurement and characterisation of compressor and turbine profiles
- Fan and low-speed compressor test rigs
- Multi-channel measurement data recording, telemetry systems
- Computing cluster

Institute of Jet Propulsion and Turbomachinery
Founded: 1912/2011
Head of Institute: Prof. Dr.-Ing. J. Friedrichs
Staff: 28 (2019)
http://www.ifas.tu-bs.de
info@ifas.tu-bs.de

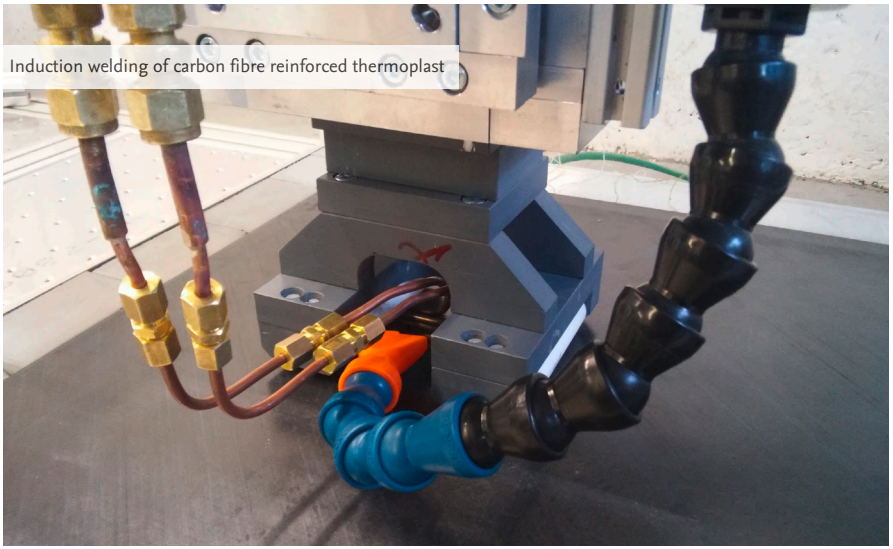
Institute of Joining and Welding

The Institute of Joining and Welding (ifs), concerns itself with joining procedures and the characteristic profile of joined components, focussing in particular on lightweight construction materials and methods.

Hydraulic press "Siempelkamp 2500t" for hybrid materials and composites

The Institute of Joining and Welding, comprising approximately 70 employees, conducts research amongst other things on the joining and production technology of lightweight constructions and of high-strength and highly heat-resistant materials. Here, generative procedures for component manufacture and component repair are also considered. In addition to state-of-the-art equipment for execution of the production procedures, comprehensive analysis systems are available which play a valuable role in the selection and assessment of production procedures and in the evaluation of damage cases. The experimental investigations are accompanied through a process and structure simulation (also coupled).
The Institute of Joining and Welding is subdivided into nine competence units which deal with joining technology (e.g. adhesive bonding and welding) and material technology (e.g. light metal die casting and composite technology). One focus is the investigation of manufacturing and joining procedures suitable for series production for lightweight construction structures within the so called "Leichtbaucampus Open Hybrid Labfactory". In addition to experimental research, the institute concerns itself with the simulation of joining processes and the effects of the joining process on the component characteristics.

Adhesively bonded CFRP repair



Induction welding of carbon fibre reinforced thermoplast

Main Research and Teaching

The institute focuses on the consistent improvement of joining techniques under particular consideration of the composites for joining tasks of all sizes.

It is possible to create optimised joined connections through the consideration of the entire process chain, from the production of the material to its further processing, right up to the end product. The orientation of the institute is also reflected in the courses held there. In addition to fundamental lectures on joining technology and material technology, specialised lectures, exercises and laboratories are offered for both subject fields.

Infrastructure

The equipment at the Institute permits the entire bandwidth of joining and a large proportion of material technologies to be covered:

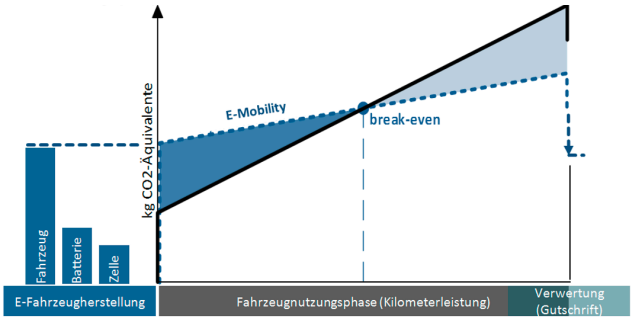
- Casting manufacturing processes (injection moulding, light metal die casting)
- Laboratories for mechanical joining, adhesive bonding and fibre composite manufacture
- Welding technology (amongst other things, a practice room)
- Laser and electron beam equipment
- Destructive and non-destructive composite testing and lab analyses
- Access to the comprehensive system technology within the "Leichtbaucampus Open Hybrid Labfactory"

Institute of Joining and Welding
Founded: 1963
Head of Institute: Prof. Dr.-Ing. K. Dilger
Staff: 72 (2019)
http://www.ifs.tu-braunschweig.de/
ifs-bs@tu-braunschweig.de

Institute of Machine Tools and Production Technology, Chair of Sustainable Manufacturing and Life Cycle Engineering

With our research we promote sustainability in manufacturing, which aims for cost-efficient products and processes with minimal environmental impacts over the entire life cycle.

Visual Analytics for Life Cycle Engineering

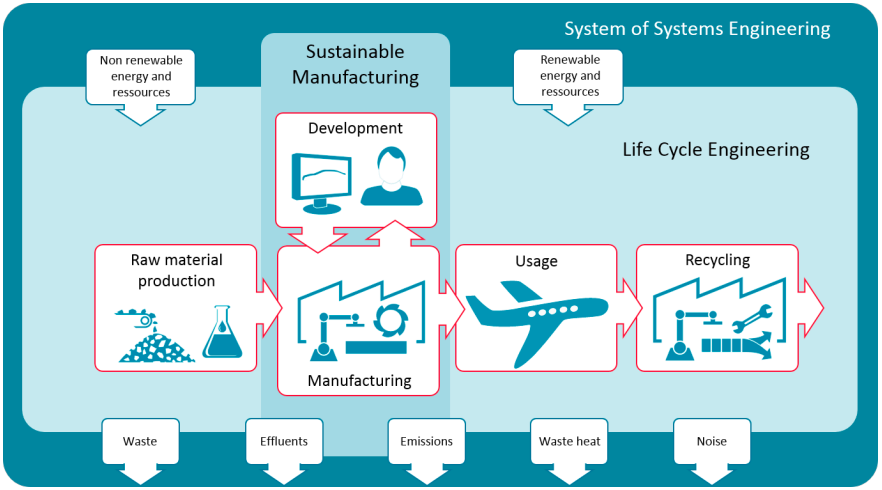


Break-Even Analysis

The chair for Sustainable Manufacturing and Life Cycle Engineering pursues a systemic approach towards the integrated design of products and processes under the requirements of sustainable development (technical, economic and ecological). The chair is structured as a "matrix organization" into the groups "Sustainable Manufacturing" and "Life Cycle Engineering" as well as "System of Systems Engineering". On the one hand, the groups are supplemented by the "Eco-Efficient Lightweight Construction" team, which focuses on the energy and resource-efficient production and life cycle engineering of hybrid components with function integration for applications in today's and future vehicle concepts within the Open Hybrid LabFactory (OHLF). On the other hand, the team "Eco-efficient battery production" is bundling our research into "green" batteries. In the Battery LabFactory Braunschweig (BLB), we are investigating approaches for the manufacturing of battery cells with minimal environmental impact and high efficiency.

Research

- Sustainable production technologies: maximizing energy and resource efficiency in factories
- Integrated Computational Production, Life Cycle and System of Systems Engineering: combining complementary modelling and simulation paradigms to assess complex dynamic systems
- Factories of the Future: developing solutions addressing the increasing convergence of industrial production with digital technologies



Framework for Sustainable Manufacturing, Life Cycle Engineering and System of Systems Engineering

- Circular Economy and Industrial Symbiosis: developing new recycling systems, substituting non-renewable resources, investigating strategies to improve eco-efficiency
- Cyber-Physical Production Systems: integrated approaches for data collection, processing and analysis under the Industry 4.0 paradigm
- "Die Lernfabrik": unique infrastructure to disseminate our findings, innovative teaching methods, supporting a deeper understanding of sustainability in engineering

Teaching

Our teaching is based on a research-oriented teaching/learning approach using the specifically designed learning infrastructure "Die Lernfabrik". Our lecture on "Total life cycle management" was rewarded with the LehrLEO award by the TU Braunschweig as the best lecture in the bachelor degree programme. Further lectures are (selected):

- Energy Efficiency in Production Engineering
- Material Resources Efficiency in Engineering
- Life Cycle Assessment for Sustainable Engineering
- Case studies on electro-mobility and manufacturing systems design

Infrastructure

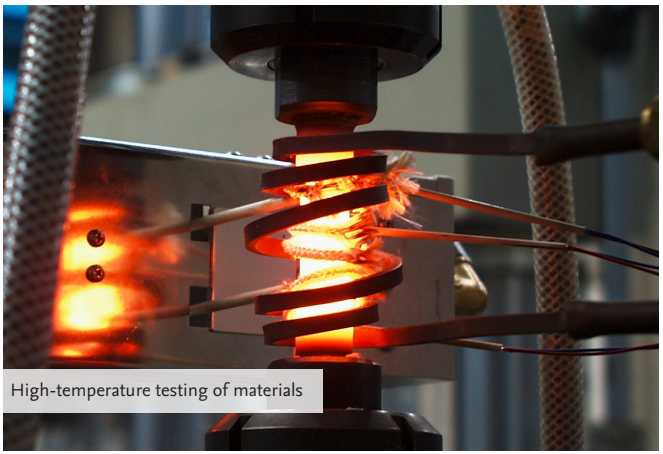
- Life Cycle Design & Engineering Lab based on Visual Analytics at Open Hybrid LabFactory, Wolfsburg
- Advanced tools for Life Cycle Assessment and simulation of complex systems

Institute of Machine Tools and Production Technology
Founded: 1932
Head of Chair: Prof. Dr.-Ing. Christoph Herrmann
Staff: 79 (2019)
https://www.tu-braunschweig.de/iwf
✉ c.herrmann@tu-braunschweig.de

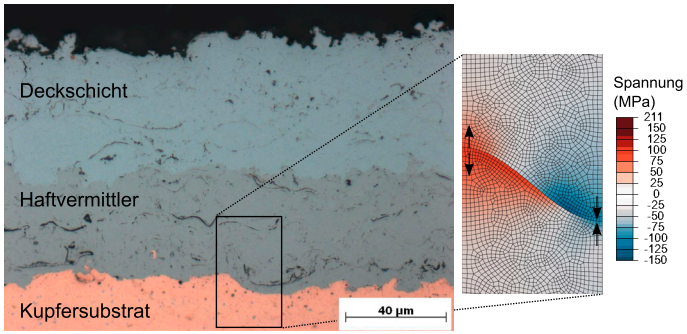
Institute for Materials

Institut für Werkstoffe

The Institute for Materials researches and develops high performance materials in order to facilitate new developments in aerospace technology and other fields.



High-temperature testing of materials



Thermal barrier coating for a rocket combustion chamber with calculated stresses at the coating interface

In modern technology, materials are frequently subjected to extreme thermal and mechanical loads. Therefore, technical innovations require the development of materials with increased performance.

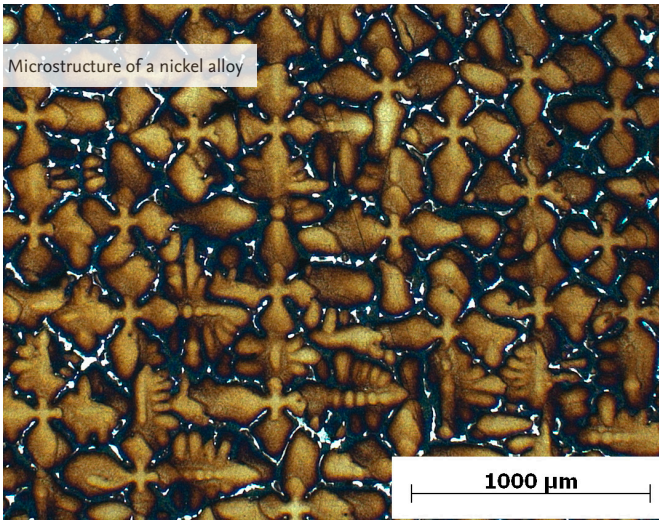
Approximately 20 employees from different areas of mechanical engineering, physics and chemistry collaborate at the Institute for Materials to optimise state-of-the-art materials and to develop completely new materials for future applications. Areas of application range from aerospace technology to energy generation to medical technology.

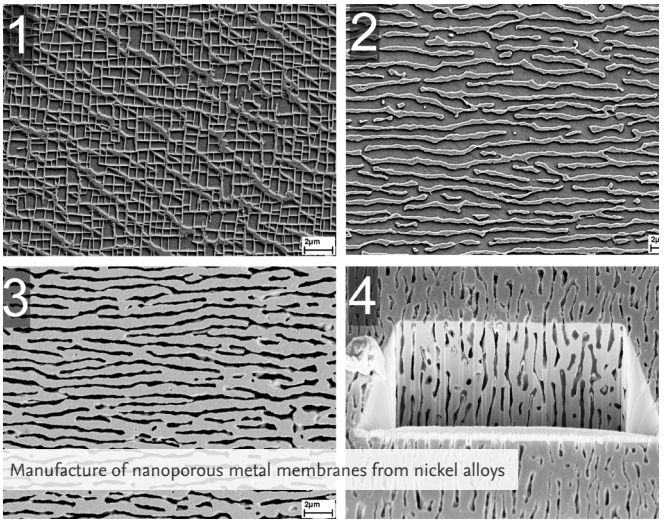
The challenge inherent in material research is to alter the structure and composition of materials in a targeted manner in order to improve their properties.

Concepts for new or optimised materials are designed at the institute, frequently with the aid of computer simulations. Materials based on these concepts are then manufactured, analysed and finally tested for their mechanical and thermal properties, and are further improved accordingly.

Main Research and Teaching

Metallic materials are the focus of the institute's research. High-temperature alloys for extreme thermal loads are developed and improved in order to increase the performance of aircraft engines.





Tailored coating systems further increase the performance of these alloys. High-strength lightweight construction materials such as titanium are optimised to open up new fields of application.
The noise emissions of aircraft are reduced through utilising porous materials.
Teaching at the institute comprises the entire material behaviour as well as analytical methods, different material classes and applications.

Infrastructure
To be able to manufacture and test new materials, the institute has a comprehensive range of experimental equipment:

- Electric arc and vacuum induction furnaces for the production of materials
- Industrial Coating Centre
- Mechanical, thermal and thermomechanical testing
- Optical microscopy
- Electron microscopy with nanomanipulators and ion beam etching
- Computer tomography
- X-ray diffractometry

Institute for Materials

Heads: Prof. Dr. J. Rösler & apl. Prof. Dr. H.-R. Sinning

Staff: 20 (2019)

https://www.tu-braunschweig.de/ifw

ifw@tu-bs.de

Institute for Particle Technology

iPAT
Institut für Partikeltechnik

We combine multidisciplinary expertise to achieve fundamental understanding as well as applied solutions in modern areas of particle technology relevant for a variety of products from battery cells to pharmaceuticals.

Battery electrode production

Particles are the base of numerous established products like cement or pharmaceuticals as well as many functional and composite components such as nanocomposites or battery cells. The complex properties of particles – on the one hand, their size and shape, on the other hand, their functional properties such as conductivity, magnetic or optical properties – result in complex product development and high challenges in particle and product design. Our goal at the Institute of Particle Technology (iPAT) is to combine the expertise of engineers and natural scientists to establish excellent research on select areas of particle technology, applied materials synthesis, and nanotechnology.

Key focus areas in our fundamental research are the mechanical stressing of particles, and the fabrication of particles tailored for specific applications, for example by functionalization of particle surfaces. This expertise is the foundation of our applied research that is focused on the areas of high-performance battery electrodes, functional coatings and nanocomposite materials, and novel pharmaceutical formulations.

Battery electrode production

X-ray computer microtomograph with integrated shear tester

Main Research and Teaching

Accordingly, our research is coordinated in five research divisions: Powder and Slurry Processes, Battery Process Engineering, as well as Bio- and Pharmatechnology (all headed by Prof. Arno Kwade), Nanomaterials (headed by Prof. Georg Garnweitner), and Particle Simulation and Functional Structures (led by Prof. Carsten Schilde). Our teaching activities involve all areas of classical mechanical process engineering as well as modern particle technology. Furthermore, we organize seminars and short courses on current topics in particle technology directed to novices and experts from industry.

Infrastructure

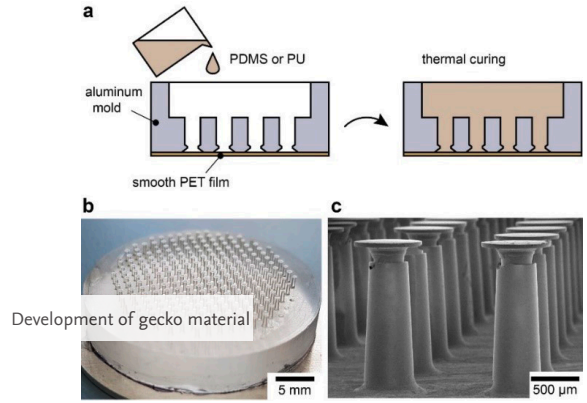
- Variety of instruments for measurement of particle and materials properties, including an X-ray microtomograph
- Battery process technology at pilot scale, including coating, drying and calendering devices

Institute for Particle Technology
Head of Institute: Prof. Dr.-Ing. Arno Kwade
Staff: 100 (2019)
https://www.ipat.tu-bs.de
ipat@tu-bs.de

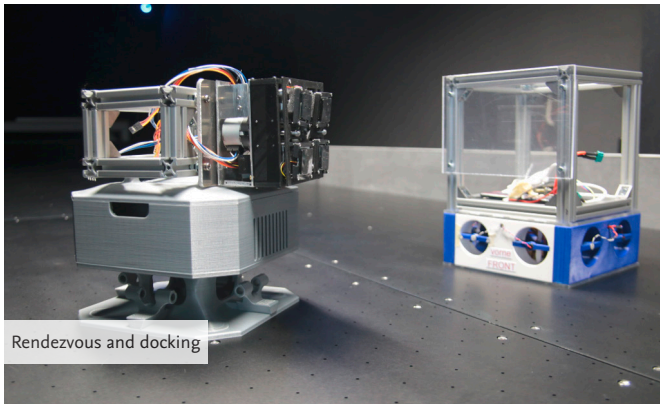
Institute of Space Systems

Institute of Space Systems

We develop methods, technology, and approaches to ensure the sustainable use and the safety of space infrastructure during design, operations, and disposal.



Development of gecko material



Rendezvous and docking

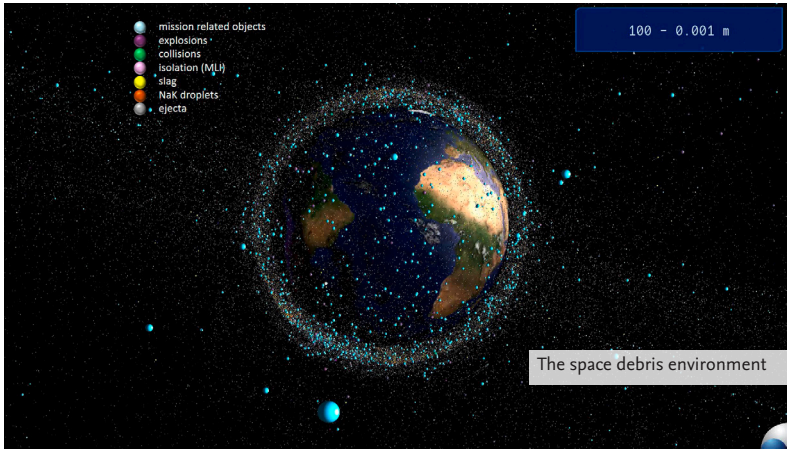
The Institute of Space Systems (IRAS) develops and maintains the European reference model (MASTER) for the estimation of risks by high-velocity impacts from space-flight residua (so-called space debris) on satellites. The research supports the entire satellite life cycle by developing methods that:

- Support the mission design process with the selection of the orbit,
- Support the satellite design process with knowledge of the direction of the space debris flux,
- Support satellite operations by providing methods for the calculation of collision probabilities and the optimization of avoidance manoeuvres, and
- Consider the re-entry of the satellite and the probabilities of trajectories that intersect populated land mass.

Main Research and Teaching

The Satellite Technology workgroup at IRAS focusses on technology for the next generation of CubeSat to enable cost effective ADR missions in the future. Biologically inspired docking mechanisms ("gecko material") are developed that enable material independent and repeatable docking to non-cooperative targets. Algorithms and approaches for docking to non-cooperative targets are developed and tested. Further, mission reliability aspects are considered in order to decrease the probability of satellite component failures.

Regolith-printing rover MIRA3D



The space debris environment

The workgroup Exploration and Propulsion Systems studies the exploration of space beyond Low Earth Orbit. Current focus is on the development of key technologies to support the construction of a future lunar base using in-situ resources and additive layer manufacturing. Furthermore, innovative propulsion concepts for cost-effective and flexible CubeSat missions are investigated. Teaching comprises but is not limited to satellite technology and operations, attitude and orbit control, spacecraft propulsion, space debris, manned systems, orbital mechanics, and the fundamentals of spaceflight.

Infrastructure

Currently, the following infrastructure is being developed at IRAS:

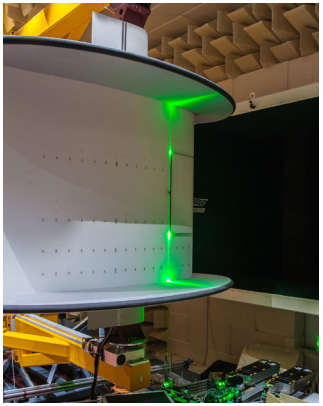
- ground station for satellite communication,
- telescope for space debris observation,
- lunar exploration lab, including a regolith-printing rover,
- clean room for satellite integration,
- air table based satellite rendezvous and docking environment.

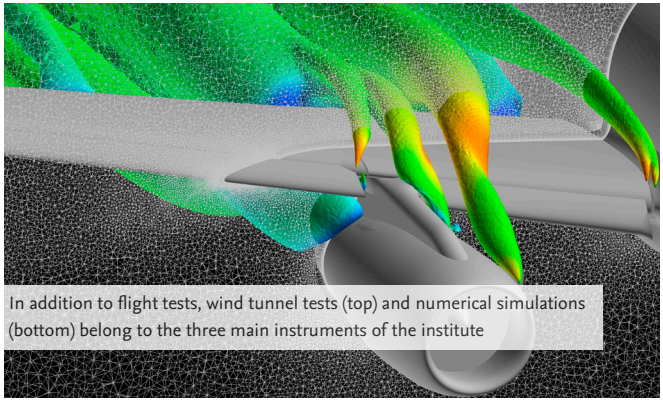
Institute of Space Systems
Founded: 2014
Head of Institute: Prof. Dr.-Ing. E. Stoll
Staff: 28 (2018)
https://www.space-systems.eu
e.stoll@tu-braunschweig.de

Institute of Aerodynamics and Flow Technology

Deutsches Zentrum für Luft- und Raumfahrt
German Aerospace Center

To make the air traffic of the future more efficient, more ecological, more convenient, more economic and safer, the institute's researchers work on improving the aerodynamic properties of aircraft and spacecraft.





In addition to flight tests, wind tunnel tests (top) and numerical simulations (bottom) belong to the three main instruments of the institute

The Institute of Aerodynamics and Flow Technology can look back on a long history: After the first “Modellversuchsanstalt für Aerodynamik“ was founded in Göttingen in 1907, the Institute for Aerodynamics and the Institute for Gas Dynamics of the "Luftfahrtforschungsanstalt Braunschweig (LFA)" were succeeded by today's DLR Institute of Aerodynamics and Flow Technology. The institute is housed in two locations - Braunschweig and Göttingen - and also maintains a department in Köln. Today, 110 scientists work in Braunschweig alone to optimise aircraft and spacecraft - from passenger aircraft to helicopters right up to hypersonic aircraft - in terms of aerodynamic and flow properties.

Focus of Work

The scientists at the institute do not only concern themselves with sophisticated numerical investigations, but also experiment with highly complex technology: for example, in unique large plants such as the low-speed wind tunnel (DNW-NWB) or the acoustic wind tunnel (AWB). At the interface between fundamental research and industrial implementation, they also conduct flight tests with the DLR research aircraft as for example the A320 ATRA.

Research and Teaching

Environmental politics fringe conditions are playing an increasigly major role in air traffic. The DLR Institute of Aerodynamics and

A combination of CFD flow simulations and real images: The DLR research aircraft A320 ATRA in flight.

Flow Technology therefore researches how future aircraft and space transportation systems can be designed and operated so that they are more efficient in their use of fuel, save costs and are more environmentally friendly. A further core competence is the development of software products for aerodynamic and aeroacoustic simulations. For example, the Computational Fluid Dynamics (CFD) solver TAU developed at the Institute is used by the European Aviation Industry for Aircraft Design.

Infrastructure

The institute coordinates its work with the international aerospace industry and a row of universities. As a leading research institute in the fields of aerodynamics, aeroacoustics and aerothermodynamics, it is subdivided into five departments in Braunschweig alone.

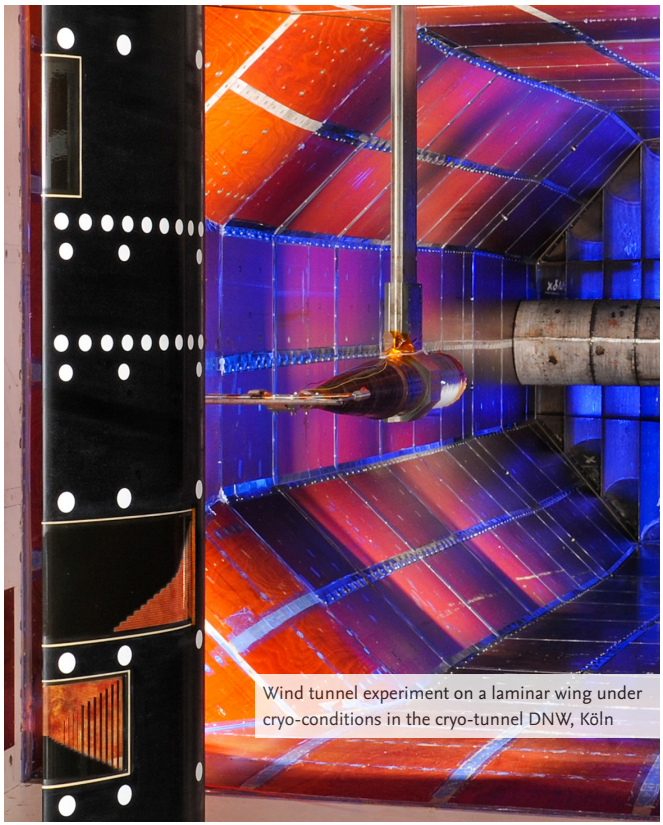
- $C^2A^2S^2E$ (Centre for Computer Applications in AeroSpace Science and Engineering)
- Transport Aircraft
- Helicopters
- Technical Acoustics
- Spacecraft

Institute of Aerodynamics and Flow Technology
Founded: 1936
Head of Institute: Prof. Dr.-Ing. C.-C. Rossow
Staff: 160 (2019)
https://www.dlr.de/as/en
h.mueller@dlr.de

Institute of Aeroelasticity

Deutsches Zentrum für Luft- und Raumfahrt
German Aerospace Center

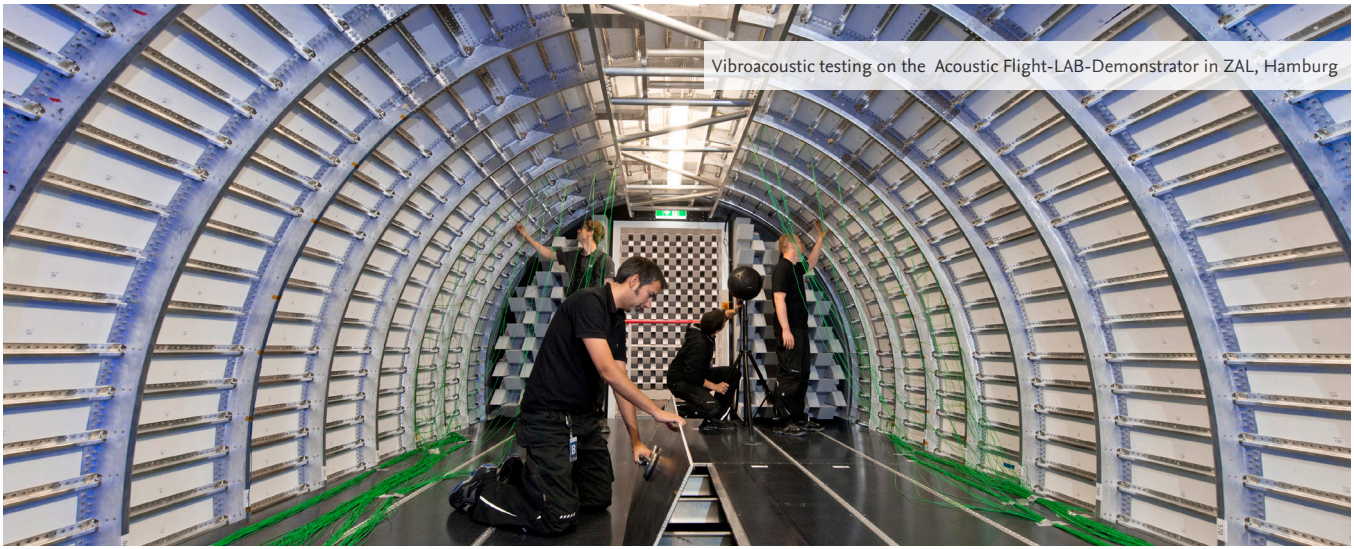
The research and exact description of aeroelastic interactions for the optimization of aerospace systems and energy technologies.



Wind tunnel experiment on a laminar wing under cryo-conditions in the cryo-tunnel DNW, Köln

The DLR Institute of Aeroelasticity in Göttingen dates back to the former Institute of Unsteady Phenomena of the "Aerodynamische Versuchsanstalt (AVA) Göttingen", which was founded by Hans-Georg Küssner in 1939.
The Institute of Aeroelasticity is the only one of its kind world-wide and here work is conducted in the field of fundamental and applied research in the area of aeroelasticity. The institute deals with research and development tasks of industrial relevance in the field of flow-structure coupling. The interaction of aerodynamic, elastomechanical and inertia forces on structures subjected to flow is investigated with numerical and experimental methods of structural dynamics and transient aerodynamics. From this interaction, relevant issues result for practical applications regarding aeroelastic stability, in particular flutter stability and - under the effect of external forces - the dynamic loads on a system.

Experimental and numerical methods are developed and applied at the institute in order to clarify these issues with high accuracy and to provide official verifications. One main task is the provision of verifications for the certification of aviation systems through flutter calculations, ground resonance tests and flight tests. Further research areas are aeroelastic effects on rotating systems, in particular on rotary wing aircraft and turbo engines and the prediction of dynamic loads in the aircraft design process.



Vibroacoustic testing on the Acoustic Flight-LAB-Demonstrator in ZAL, Hamburg

For wind power plants, the institute makes important contributions towards the accurate determination of the aeroelastic deformation of rotor blades, the flutter limit (individual blade flutter, whirl flutter) in complex flows and the dynamic loads on rotor blades and the entire system.

Teaching

Lectures: Basic Principles of Aeroelasticity I and II Prof. Dr. Lorenz Tichy

Infrastructure

- Mobile ground and flight vibration test facility (SSVA)
- Multi-axis vibration simulator (MAVIS)
- System to measure unsteady signals (AMIS III)
- Test set-ups for aeroelastic experiments in wind tunnels (in co-operation with DNW)
- Annular Cascade Test Facility Göttingen (RPG)
- Computer cluster for aeroelastic simulations

Institute of Aeroelasticity
Founded: 1939
Head of Institute: Prof. Dr.-Ing. L. Tichy
Staff: 80 (2018)
https://www.dlr.de/ae
lorenz.tichy@dlr.de

Institute of Composite Structures and Adaptive Systems

Deutsches Zentrum für Luft- und Raumfahrt
German Aerospace Center

High-performance structures adaptable – efficient – tolerant

DLR Wissenswelt Leichtbau®

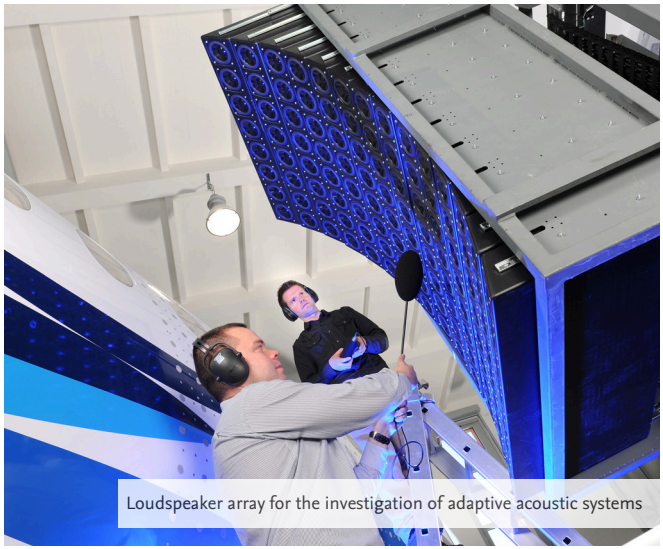
Since 2018 the DLR Wissenswelt Leichtbau® is located in the Lilienthalhaus at Braunschweig Airport. With the Wissenswelt as a transfer platform, the institute turns to business and industry partners to deal intensively with their lightweight construction challenges and issues. The Wissenswelt offers sufficient space for workshops with up to 20 participants. The use of agile innovation methods and creativity technologies contributes to the generation of new ideas.

As a leading facility in the field of lightweight composite design, the DLR-Institute of Composite Structures and Adaptive Systems has, for many years now, engaged in research into more efficient manufacturing methods for CFRP structures, and improved analysis and design methods. The Institute's additional focus on adaptive systems enables technical and economical upgrading of the components through the integration of additional capabilities in the composite. Therefore, structures that use materials and technologies developed as adaptive systems are able to change their shape, actively reduce vibrations or dampen their noise emission. The institute bridges the gap between fundamental research and industrial application.
The expertise of the institute is orientated along the entire process chain. Moreover, the institute has created the "Zentrum für Leichtbauproduktionstechnologie (ZLP)" and the "Technologie Transfer Zentrum" in Bremen to maintain close ties with clients from industry within its application-based research.

Teaching

Seeking to promote fundamental research within higher education, the institute maintains a strategic partnership and cooperation with the TU Braunschweig, Otto von Guericke University Magdeburg, the TU Clausthal and other academic institutions.

Lay-up of a large CFRP-shell with coordinated robots



Loudspeaker array for the investigation of adaptive acoustic systems

The courses are targeted at students completing Bachelor and Master degree courses, specialising in:

- Aerospace engineering
- Adaptronics
- Mechanical engineering
- Production and systems engineering
- Materials sciences

Infrastructure

In order to develop new manufacturing technologies and to investigate strength, stability and thermo-mechanical properties the institute operates experimental facilities like:

- Research autoclaves
- Filament winding machines
- Airbus certified test lab
- Buckling facilities with the special feature of dynamic loading
- Transmission loss facility
- Thermomechanical test facilities

To perform research on an industrial scale the ZLP site at Stade is equipped with unique and innovative facilities:

- A fully automated RTM process chain EVo
- Research autoclave BALU®
- CNC-based multi lay-up facility for automated fibre placement (AFP) and automated tape laying (ATL) GroFi ®

Institute of Composite Structures and Adaptive Systems
Founded: 1953
Head of Institute: Prof. Dr.-Ing. M. Wiedemann
Staff: 180 (2018)
http://www.dlr.de/fa
martin.wiedemann@dlr.de

Flight Experiments

Deutsches Zentrum für Luft- und Raumfahrt
German Aerospace Center

The DLR Flight Experiments Facility supports internal and external users in the planning and execution of their flight research and airborne science missions.

Research flight with the ATRA and Falcon in the ECLIF project

The research fleet Oberpfaffenhofen

The Flight Experiments facility (FX) acts as a service provider within the DLR for national and international research facilities, for universities, for civilian and military authorities, for the aviation industry and for test pilot schools. It operates the largest fleet of civilian research aircraft in Europe from its facilities in Braunschweig and Oberpfaffenhofen. In order to design and to certify required aircraft modifications and to enable worldwide operation, Flight Experiments consists of two flight operations and two engineering departments with integral certification and verification sections. These departments are evenly distributed between both locations. As a nationally and EASA approved design, maintenance, flight operations and continuing airworthiness management organisation, the Flight Experiments facility is subject to stringent monitoring by the "Luftfahrtbundesamt (LBA)", EASA and DLR Quality Management. This guarantees a high standard of safety, reliability and efficiency. In order to execute operations with the largest and most diverse research fleet in Europe, the Flight Experiments facility staff needs to be highly specialised, qualified and experienced. Aviation mechanics, avionics specialists, inspectors, development engineers, certification and verification engineers, logistics specialists, test pilots, flight testing engineers and scientists support the research teams with the preparation and execution of flight campaigns.

The research fleet Braunschweig

Main Research and Teaching

The Research Flight Departments in Braunschweig and Oberpfaffenhofen have nearly identical tasks. However, the missions of the utilised aircraft depend on the research areas of the DLR institutes based in Braunschweig and Oberpfaffenhofen. The focus in Braunschweig lies in the fields of Aerodynamics, Flight Mechanics and Flight Control, in-flight simulation, the improvement of aircraft systems and the development and testing of navigation and air traffic management systems. The emphasis in Oberpfaffenhofen lies in the fields of atmospheric research, earth observation and remote sensing.

Infrastructure

The Oberpfaffenhofen flight operations department provides the highly-modified research aircraft Cessna 208B, Dornier 228-212, Dassault Falcon 20 and Gulfstream G550 HALO (High Altitude Long range) for aircraft research. The Braunschweig flight operations department operates the aircraft Airbus A320 ATRA (Advanced Technology Research Aircraft), Dornier 228-101, Airbus Helicopter EC135 ACT/FHS, BO105 and other small aircraft, gyrocopters and gliders.

Flight Experiments
Head of Flight Operations: Oliver Brieger
Staff: 131 (2019)
http://www.dlr.de/fb/
oliver.brieger@dlr.de

Institute of Flight Guidance

Deutsches Zentrum für Luft- und Raumfahrt
German Aerospace Center

The DLR Institute of Flight Guidance develops innovative air traffic concepts for an air transport system that is safe, efficient, environmentally friendly and reliable.

Tower simulator ATS

Cockpit simulator GECO

Air traffic plays a crucial role in ensuring the mobility of people and goods around the globe. Environmental impact and resistance to disruptions must be balanced with sufficient capacity in the air and on the ground. Decisive steps towards achieving this are a more efficient air traffic management and the optimisation of airport processes.

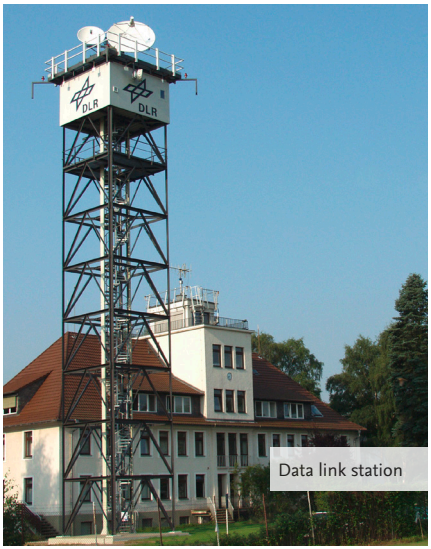
The Institute of Flight Guidance is working on the development and application of future processes and technologies for the integrated air and ground based guidance of aircraft. This means using airspace more flexibly and efficiently and enabling airports to optimise throughput, while minimising fuel consumption and environmental impact. To this end, the Institute examines all technical and operational processes on board aircraft and on the ground (air navigation services and airports). Special attention is paid to the changing role of the human operator.

Research and Education

Key research areas of the Institute of Flight Guidance:

- Airport and Ground Traffic Management
- Air Traffic Management
- Unmanned Aircraft Systems
- Human-centered Automation
- Validation Methodology and Tools.

Remote Tower Center



Data link station

The Institute uses interdisciplinary research teams and an integrated test infrastructure to conduct basic and applied research starting with the idea up to application. The staff in six departments regularly cooperates with partners from universities, other research institutions and industry on German and international research projects. Moreover, the Institute supports young scientists by holding lectures at different universities and mentoring PhD researchers and students at the Institute.

Infrastructure

For several decades, the Institute has been developing facilities for the validation of concepts, technologies and procedures in air traffic management. Together, these facilities form the Air Traffic Validation Center and are unique in Europe. The Validation Center gives scientists the right tools to test and evaluate new ideas and technologies for all areas of air traffic management. At the same time, it also allows each development step to be continuously reviewed – from the initial idea up to the testing of prototypes and their implementation under realistic conditions.

The Air Traffic Validation Center includes interconnected:

- Fast-time simulators
- Apron and tower simulators
- Airport and control center simulators
- Cockpit simulators
- UAS ground control stations
- Flight testing equipment
- Satellite-based precision landing systems
- Wide Area Multilateration System

Institute of Flight Guidance
Director: Prof. Dr.-Ing. D. Kügler
Staff: 135 (2018)
http://www.dlr.de/fl
flugfuehrung@dlr.de

Institute of Flight Systems

Deutsches Zentrum für Luft- und Raumfahrt
German Aerospace Center

The Institute of Flight Systems researches, models and develops interdisciplinary solutions in the field of flight mechanics, flight control and system technology.

Research aircraft ATRA

Research helicopter ACT/FHS

The research work by the institute is based on the interaction of the following three research fields:

1) Assessments of configurations and flying platforms
2) Improvements in the operational efficacy of flying devices through advanced functions and systems
3) The safety-critical system chain with its elements and production processes

Research in the fields named above calls for close collaboration between various disciplines. The ability to evaluate technologies and all research areas of system technology within the context of the overall system, requires a comprehensive range of equipment with testing technology right up to flight tests.

The application-orientated research concentrates on the systemic consideration of aircraft and its systems regarding flight dynamics, flight performance and flying qualities. For this purpose, approximately 180 employees at the institute have several large facilities in operation. The institute uses a very wide range of tools for the testing, assessment and demonstration of innovative technologies. This ranges from modelling to simulation on the ground, right up to flight tests and assessment of data gathered from these tests.

AVES - Air Vehicle Simulator

Installation of simulator superARTIS

Main Research and Teaching

Areas of research are flight mechanics, fllying qualities, sensors, system technology and the systemic consideration of the aircraft and its systems. Cooperations exist with various universities and other research institutes worldwide. In addition to the support of student work and dissertations, employees from the institute regularly offer courses at different universities in the areas of flight guidance, flight mechanics, flight dynamics, flight control, numerical analysis, software ergonomics and development and project management.

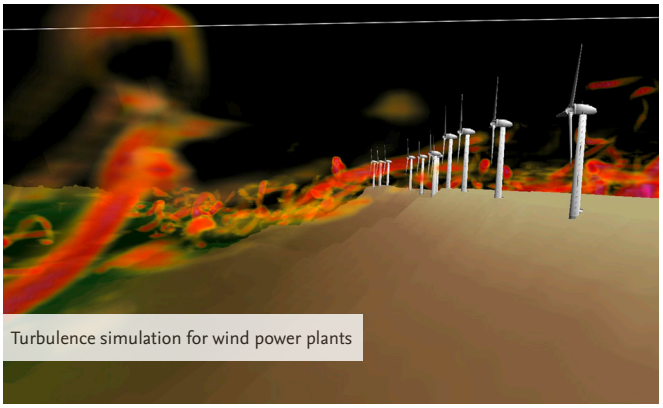
Infrastructure

The institute operates testing facilities such as the simulator centre AVES (Air Vehicle Simulator), the rotor test bench and various unmanned aircraft systems ranging from 0.2 kg up to 400 kg MTOW (maximum take off weight). For research tasks, the following flight testbeds of DLR are used: the Airbus A320 ATRA (Advanced Technology Research Aircraft), the research helicopter ACT/FHS (Active Control Technology/Flying Helicopter Simulator) and other platforms like BO 105, Do 228, etc.

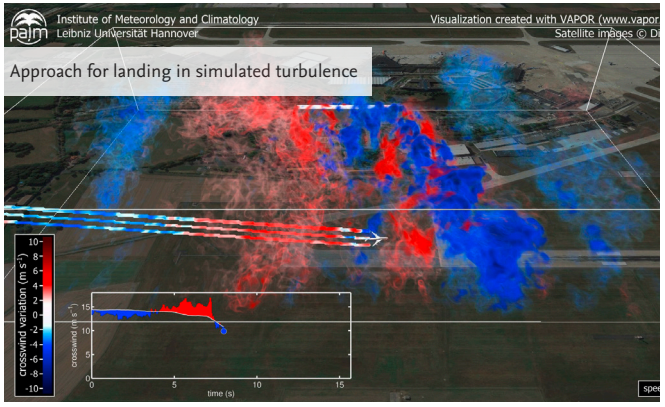
Institute of Flight Systems
Founded: 1953
Head of Institute: Prof. Dr.-Ing. S. Levedag
Staff: 180 (2018)
https://www.dlr.de/ft
✉ stefan.levedag@dlr.de

Institute of Meteorology and Climatology

This institute represents meteorology in research and teaching. In addition to fundamental research, one particular focus lies in the field of environmentally-relevant issues.



Turbulence simulation for wind power plants

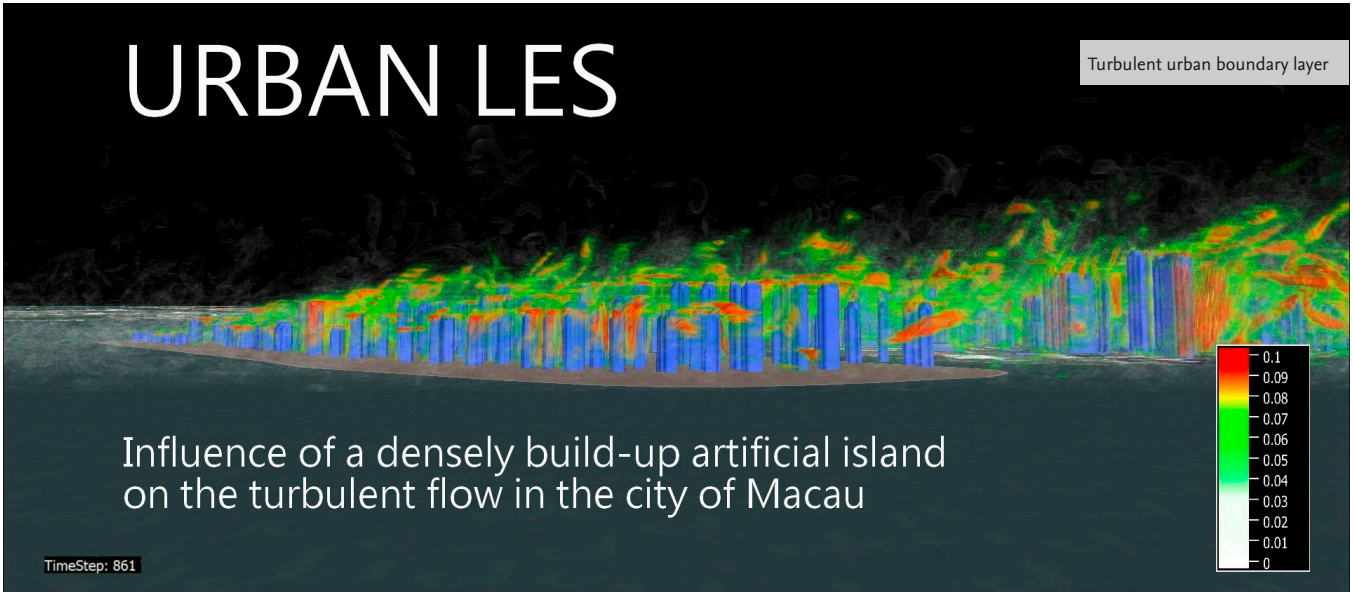


Approach for landing in simulated turbulence

The Institute of Meteorology and Climatology (IMuK) at Leibniz Universität in Hanover was founded in 1949 and has been part of the newly-founded Faculty of Mathematics and Physics since April 2005. It is the only institute in Lower Saxony at which a consecutive Bachelor-Master study course in Meteorology is possible. The research topics processed at the IMuK are guided by the major challenges of our time in the context of global issues such as climate change, water scarcity and the usage of alternative energy sources such as the sun, rain and wind.
Three meteorological specialist fields are established at the IMuK. The "Applied Meteorology" working group processes subjects from the areas of regional climate change, wind energy, distribution of pollutants, odours and noise. In the "Radiation and Remote Sensing" working group, the focus is placed on the development and use of innovative measuring devices for recording of solar energy. The main activity of the "Turbulence Simulations" working group is the development and operation of appropriate simulation models.

Main Research and Teaching

One major research topic relevant to aviation is the investigation of atmospheric boundary layer flows with the aid of turbulence-resolving simulation models (large-eddy simulation, LES). The PALM model developed at IMuK is considered one of the leading



meteorological LES models worldwide. PALM is amongst other aims used to predict critical weather conditions such as fog and gusts of wind occurring close to the airport more accurately, or to generate highly-resolved wind fields in spatial and temporal terms for flight simulators and near-field simulators.

Infrastructure

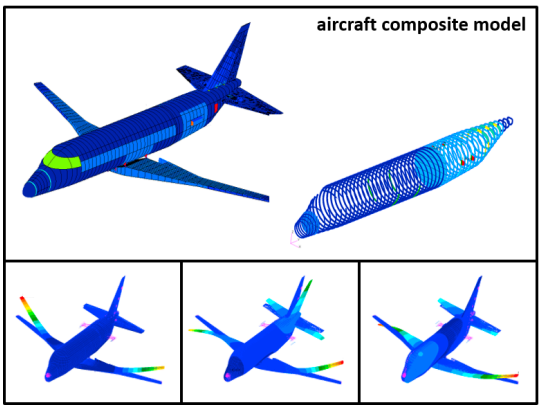
The extremely complex turbulence simulations require the use of massively parallel computers. The IMuK itself possesses a workstation cluster for program testing and development work; the actual simulations are however conducted on more than 10,000 processor cores at the " Norddeutscher Verbund für Hoch –und Höchstleistungsrechnen (HLRN)" (http://www.hlrn.de).

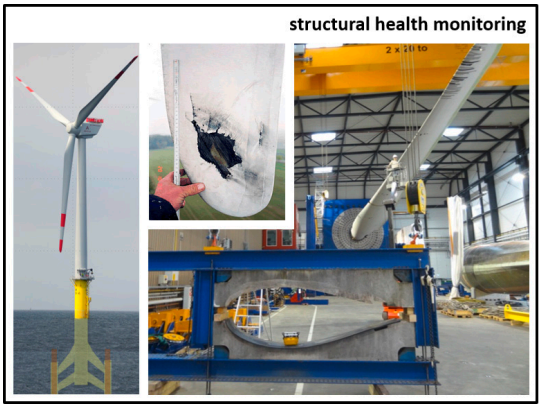
Institute of Meteorology and Climatology
Founded: 1949
Head of Turbulence Simulation Group: apl. Prof. Dr. S. Raasch
Staff: 23 (2019)
https://www.muk.uni-hannover.de
sekretariat@muk.uni-hannover.de

Institute of Structural Analysis

ISD INSTITUT FÜR STATIK UND DYNAMIK

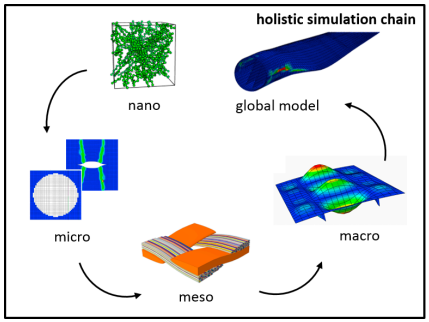
ISD focuses on modelling, simulation and structural health monitoring (SHM) of multi-functional, lightweight and durable materials and structures in aerospace, wind energy, automotive and civil engineering.

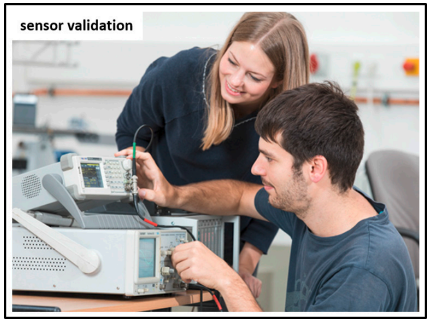




With 43 current employees, the institute is divided into the research units “vibrations”, consisting of three groups focusing their research on vibrating constructions, and “composites”, comprising of four groups working on static and dynamic analysis of fibre composites. Experienced postdoctoral researchers lead these groups. To advance the state of the art in these fields, ISD participates in a collaborative research centre, a research unit, two priority programmes, an international research training group and further projects (all funded by DFG), an innovative training network (EU, Marie Curie) and many other projects funded by, inter alia, BMWi and BMBF.

The cornerstone of ISD’s research is the material and structural behaviour of load carrying structures. In particular, this comprises the following fields: simulation and constitutive modelling of composite materials at different length scales, stability and non-linear dynamics of thin-walled composite structures, SHM, dynamics of coupled finite element and multi-body systems with fluid structure interaction and acoustics. To ensure the transfer of theoretical advances to industrial application, ISD positions itself at the interface between fundamental and applied research.





Main Research and Teaching

In the field of aerospace, the research at ISD covers the whole simulation chain, starting from nano-scaled matrix additives for composite structures, the development of powerful material models on a mesoscale for describing anisotropic composites and their progressive failure, to new, physically based fatigue damage models for CFRP, GFRP and hybrid composites, as well as innovative design approaches for thin-walled structures. Moreover, ISD intends to transfer its knowledge in the fields of artificial intelligence and model updating for SHM from wind energy to aerospace.

Infrastructure

ISD maintains a 300 square meter testing hall including stationary and mobile exciter facilities, static, dynamic and acoustic measuring equipment and two servo-hydraulic test rigs. Moreover, the Test Center Support Structures (TTH) of Leibniz University Hannover offers a unique infrastructure for testing fatigue and extreme load behaviour of large-scale components and features a fully fitted fibre composite lab including an autoclave.

Institute of Structural Analysis
Founded: 2005
Head of Institute: Prof. Dr.-Ing. habil. R. Rolfes
Staff: 43 (2018)
https://www.isd.uni-hannover.de/
sekretariat@isd.uni-hannover.de

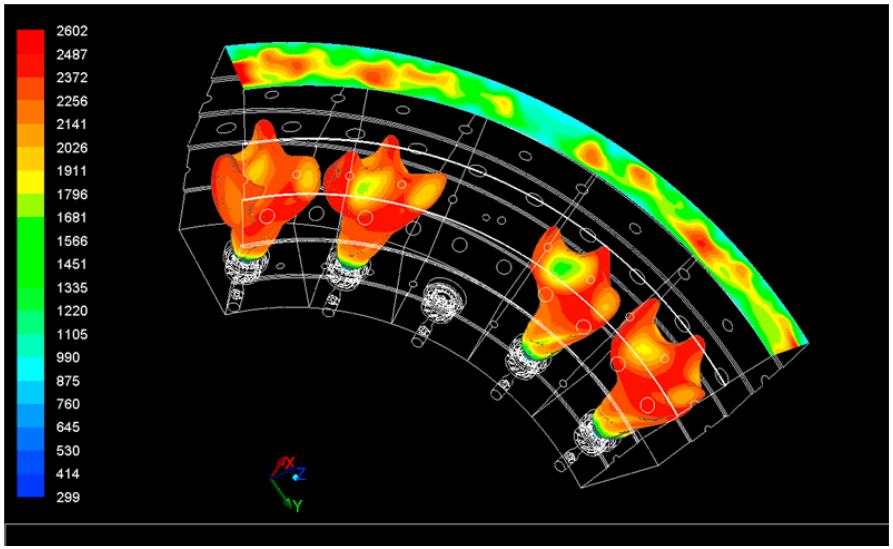
Institute for Technical Combustion

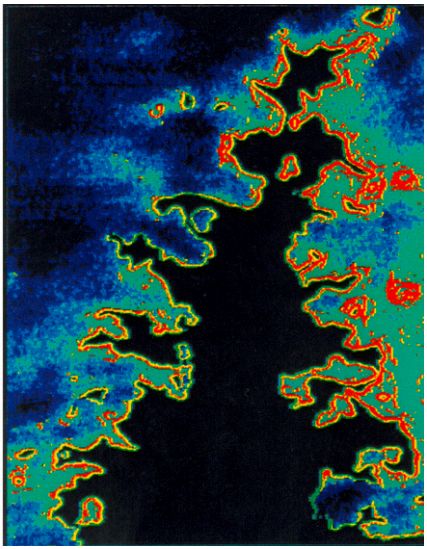
Institut für Technische Verbrennung

At the Institute for Technical Combustion, combustion processes and sustainable fuels are investigated in fundamental principles and applications.

The Institute for Technical Combustion (ITV) of Leibniz Universität Hannover conducts research and teaching in the field of combustion processes for engine applications, gas turbines and combustion chambers. The research work comprises the entire bandwidth from physical/chemical model formation right up to engineering applications. One modern approach in the field of fundamental principles is the combination of laser measuring technology and numerical model formation. Test rigs with adapted measuring technology are available for development issues and application optimisation. The calculation and simulation of the combustion processes is also becoming increasingly important. The institute features competences in the various fields of combustion technology. The following list provides example of topics or projects:

- Defect detection of combustion chamber damages (experimental and numerical, Collaborative Research Centre SFB 871)
- Turbulent premixed flame processes (measurement of the flame structure, the influence of high pressure on turbulent premixed flames, the development of models, DFG projects and AG FORTVER, completed)
- Stabilisation of flames (E-field stabilisation, completed project KW21)
- Fuels of the future - Tailor-made fuels for aviation gas turbines - stabilisation (Lower Saxony Excellence Promotion, NFF and NFL, commissioned)
- Friction minimisation in engines (DFG, industry, BMWi)





- High pressure injection processes for engines (DFG, FVV, AIF)
- Combustion processes for engines (FVV, FNR, EU, industry)
- Gas engines, calculation of pollutants (FVV, FNR, industry)
- Low-pollutant, efficient ship's engines

Research Focuses and Teaching

- Combustion engineering
- Thermo-fluid dynamics
- Internal Combustion engines I and II
- Measuring methods of combustion technology
- Combustion modelling
- Short Training Course "Modern Combustion Technology" (biennial)

Infrastructure

- Research Center for sustainable fuel combustion
- Combustion test rig for turbulent combustion and thermoacoustics (up to 450 kW, together with TFD)
- Turbulent combustion test rig (up to 200 kW)
- High pressure hot gas flue for exhaust gas cleaning process technology e.g. of ship's engines
- 4 engine test rigs for commercial vehicle combustion processes and engine friction
- 2 engine test rigs for car diesel engine research
- High pressure injection chambers with optical accessibility for detailed spray injection and ignition experiments
- Comprehensive laser diagnostic and optical measuring procedures

Institute for Technical Combustion
Founded: 1928
Head of Institute: Prof. Dr. F. Dinkelacker
Staff: 25 (2018)
https://www.itv.uni-hannover.de/
dinkelacker@itv.uni-hannover.de

Institute of Turbomachinery and Fluid Dynamics

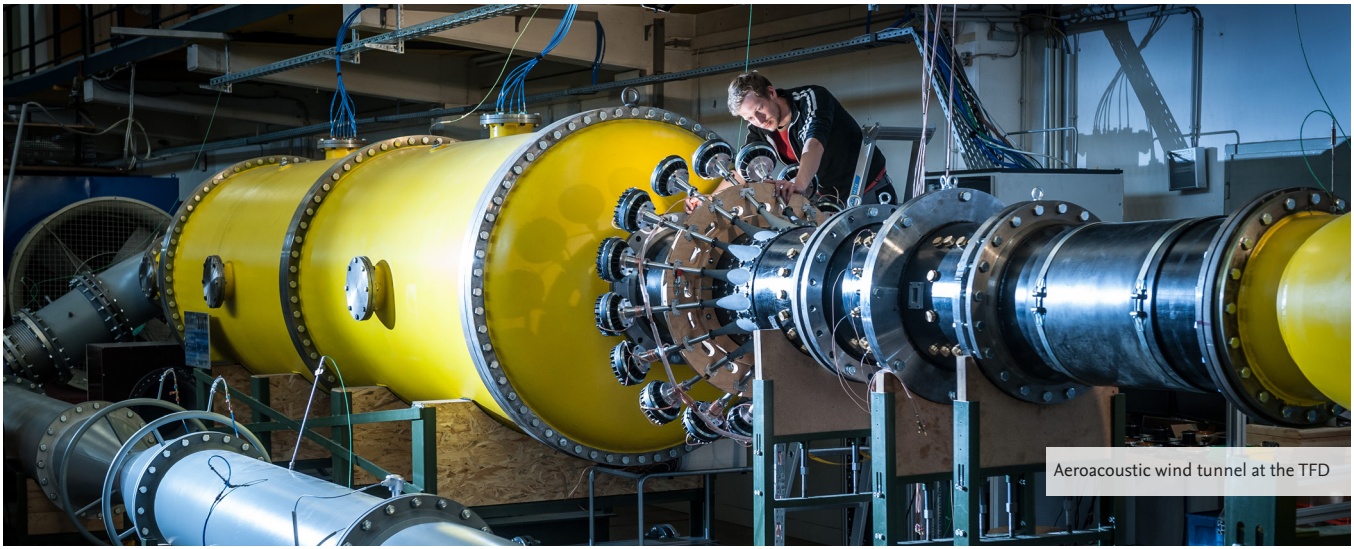
Institute of Turbomachinery and Fluid Dynamics

The TFD aims to better understand and model physical phenomena in thermal turbomachinery by performing experimental and numerical research, in order to design robust and low-emissive machines.

Axial turbine test rig at the TFD

The TFD is part of the Mechanical Engineering Faculty at Leibniz Universität Hannover. Prof. Dr.-Ing. Joerg R. Seume has been its director since 2000. Currently, 35 research assistants are employed there, who conduct research at the forefront of turbomachinery developments. Research projects are publicly funded as well as collaboration projects with national and international industry partners. The research assistants are supported by 22 employees in workshops and administration.
In addition to research, the TFD places equal emphasis on teaching. Pairing the fundamentals of fluid mechanics with our latest advancements in research, we want to spark the interest of our students, the engineers of tomorrow.

Focus of Work
The research agenda of the TFD aims at improving thermal turbomachinery, developing concepts for renewable energy and enhancing the understanding of fluid mechanic phenomena. To achieve these goals, the TFD is organised into five research groups: "Aeroacoustics and Aeroelasticity", "Axial Turbines" (including Wind Energy), "Axial Compressors", "Numerical Methods", and "Turbochargers and Centrifugal Compressors". In addition, the TFD is scientific coordinator of the Collaborative Research Centre 871: "Regeneration of Complex Capital Goods".



Aeroacoustic wind tunnel at the TFD

Main Research and Teaching

The focus of the TFD research agenda is placed on unsteady flow phenomena in turbomachinery. Understanding these complex interactions is fundamental for optimising complex systems such as gas turbines. Examples are: acoustic transmission in low pressure turbines, flutter in compressor blades or surface structures on blades.

Furthermore, the TFD offers a range of lectures. Based on fundamental lectures on fluid mechanics, the TFD offers advanced lectures, e.g. aeroacoustics, as well as application oriented lectures, e.g. aircraft engines. These are held either by Prof. Seume or external experts.

Infrastructure

The TFD operates a variety of test rigs. These range from simple cascades to investigate isolated flow, to high speed multistage turbomachinery to study complex flow interactions. Amongst these are an axial turbine, a high speed compressor, an acoustic wind tunnel, and a fluid tunnel. Additionally, the TFD operates its own computing cluster with 1,000 cores for performing CFD using various commercial and open source solvers.

Institute of Turbomachinery and Fluid Dynamics
Founded: 1926
Head of Institute: Prof. Dr.-Ing. J. Seume
Staff: 65 (2019)
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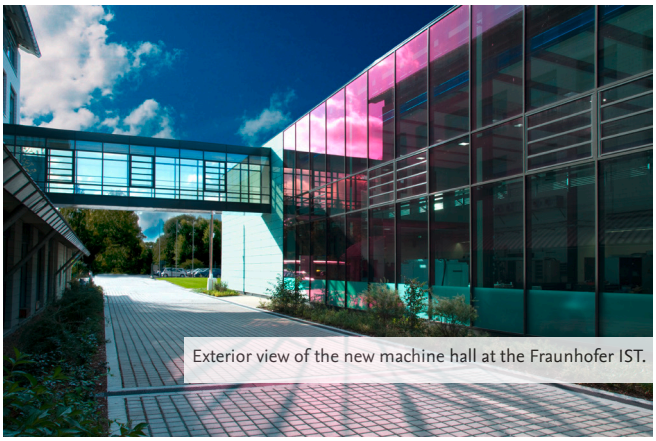
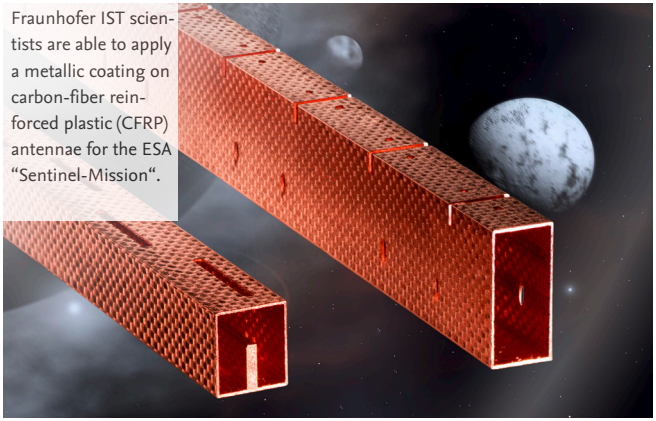
Fraunhofer Institute for Surface Engineering and Thin Films (IST)

With innovative coatings and surfaces to future product and production systems.



Exterior view of the new machine hall at the Fraunhofer IST.

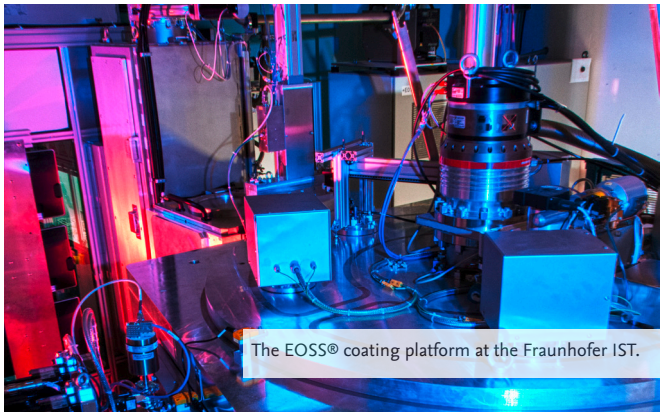


Fraunhofer IST scientists are able to apply a metallic coating on carbon-fiber reinforced plastic (CFRP) antennae for the ESA "Sentinel-Mission".

The Fraunhofer Institute for Surface Engineering and Thin Films IST in Braunschweig is an innovative partner for research and development in surface technology, with expertise in the associated product and production systems.

About 120 employees work together with customers from industry and research to develop customized and sustainable solutions: from prototypes, through economic production scenarios, to upscaling to industrial magnitudes – and all this whilst maintaining closed material and substance cycles. In addition to application-oriented research and development, scientific principles are also researched within various collaborations with universities and research institutions.

Coating and surface technology is the key to innovative products and systems: Through modification, patterning and coating of the surface, a wide range of functions and functionalities can be realized. One of the institute's particularly strong points is its ability to create the optimum process chain for the respective task on the basis of a broad spectrum of processes and coating materials. The Fraunhofer IST not only has excellent capabilities in surface analysis using the very latest equipment but has also accumulated extensive experience in the modeling and simulation of both product properties and the associated processes and production systems.



The EOSS® coating platform at the Fraunhofer IST.

Facility for electroplating of waveguides at the Fraunhofer IST.

Two examples of central research facilities at the Fraunhofer IST:

Sputtering system EOSS® for optical precision coatings with highest requirements for space applications

At the Fraunhofer IST the new coating platform EOSS® (Enhanced Optical Sputtering System) was developed and set up. In addition to extremely low-defect coatings, the EOSS® sputtering system can also be used to realize highly complex layer designs with several 100 layers at extreme precision and uniformity of the coating on an industrial scale with a high process reliability.

Plant for the metallisation of CFRP components by electrodeposition

The system was conceived for the galvanic metallisation of CFRP components for space applications. The overall process is a complex procedure which consists of many, finely adjusted individual steps. The system is primarily used for the metallisation of waveguides for the Sentinel 1 mission.

Fraunhofer Institute for Surface Engineering and Thin Films (IST)
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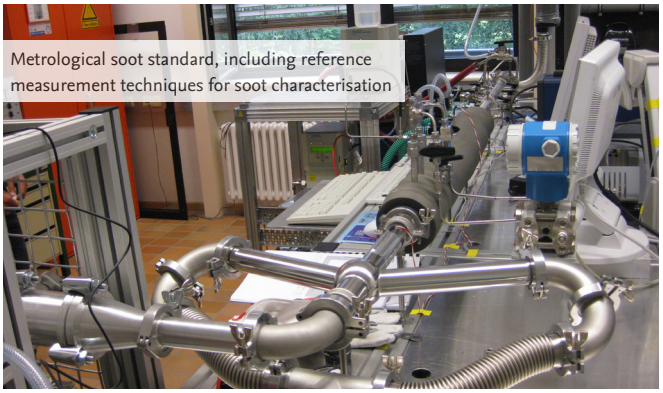
PTB Department 3.2: Analytics and Thermodynamic State Behaviour of Gases

Physikalisch-Technische Bundesanstalt
Braunschweig und Berlin

As the national metrology institute in Germany, the PTB is the highest authority regarding all questions of correct measurement.

Multiphase-TDL-Hygrometer HAI on HALO



Metrological soot standard, including reference measurement techniques for soot characterisation

The "Physikalisch Technische Bundesanstalt (PTB)" is one of the leading institutes in Metrology along with the NIST in the USA and the NPL in Great Britain. (Metrology: The science of accurate measurement.)
Topics dealt within the PTB department 3.2 are fundamental metrological research concerning chemical gas analysis and field applications for environmental protection, energy conversion and mobility.
Department 3.2 (FB32) at the PTB has been fundamentally restructured and expanded since 2009, the main science field being chemical gas analysis, with the three subtopics: aerosols, molecular spectroscopy of gases and gas humidity. These fields are covered by approximately 25 scientists, engineers and technicians. The main target areas are fundamental science, metrology and field science for climate change and environmental protection, as well as efficient energy conversion and mobility.
Department 3.2 currently encompasses three working groups: AG321 operates and optimises the national gas humidity standards (mixture fraction 10 ppb to 50 vol.%), which are used for the dissemination of the legal units to industry, science and government authorities. Based on molecular spectroscopy, AG322 develops gas analytical, optical primary and transfer standards for environmental monitoring, remote sensing and airborne monitoring of the atmosphere, as well as industrial process monitoring. Finally, the

Highest resolution fourier-transform-spectrometer

national standards for (soot) aerosol parameters (such as opacity, particle number density and size) are being developed and maintained by AG323 and used for tracing back the legal limits of mobility emissions.

Aviation-relevant research topics in department 3.2 are: the development and metrological validation of airborne, optical measurement techniques for simultaneous detection of gas phase and condensed phase water with maximum spatio-temporal resolution, optical pressure measurement, the spectroscopic detection of atmospheric pollutants using FT-remote sensing or the deployment of airborne/balloon-borne sensors, as well as traceable temperature and pressure dependent quantification of molecular spectral parameters for atmospheric remote sensing. Increasing future relevance will be given to traceable aerosol detection of aviation induced particle emissions.

Infrastructure

The department 3.2 owns, amongst other infrastructure:
in AG321, the primary gas humidity standards in the mixture fraction range from 10 ppb to 50 Vol%; in AG322, two highest resolution Fourier transform spectrometers (Bruker IFS 125 HR) covering the IR/NIR and the UV/VIS spectral range, and numerous laser spectrometers, in particular a unique airborne autonomous TDL-spectrometer named HAI for the high speed multi-phase water detection on the HALO research aircraft;
AG323 owns the national standards for soot particle number density, soot opacity as well as soot mass fraction.

PTB Department 3.2
PTB founded in Braunschweig: 1950
Head of Institute: Prof. (apl) Dr. V. Ebert
Staff: 31 (2019)
www.ptb.de/cms/en/ptb/fachabteilungen/abt3/fb-32.html
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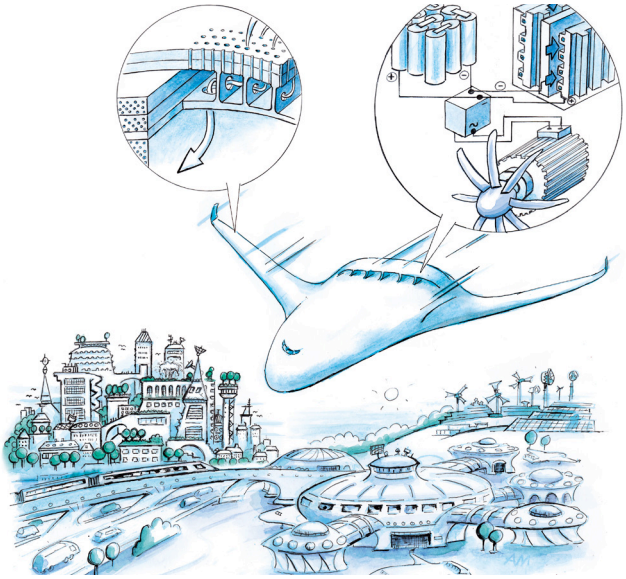
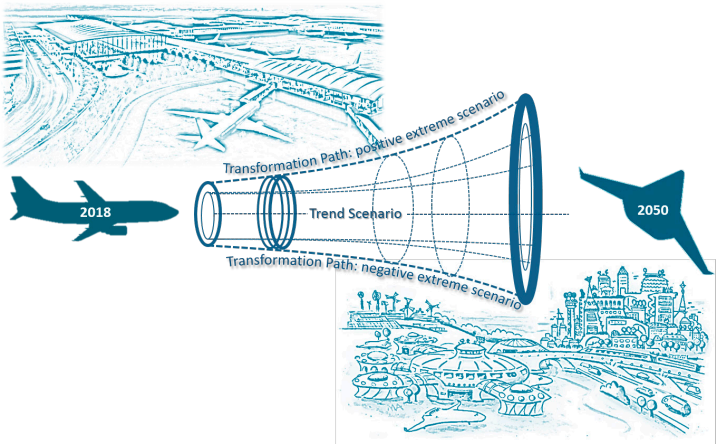
Coordinated Research Programmes

Cluster of Excellence SE²A
Sustainable and Energy Efficient Aviation





The Cluster of Excellence SE²A is an interdisciplinary research centre investigating technologies for a sustainable and eco-friendly air transport system. Technische Universität Braunschweig, the German Aerospace Center (DLR), Leibniz University Hannover (LUH), the Braunschweig University of Art (HBK) and the National Metrology Institute of Germany (PTB) have jointly accepted the challenge of making future air traffic efficient while meeting the competing demands for continuous growth and environmental sustainability at the same time. Funding is provided by the German Research Foundation, DFG, for 7 years, starting January 2019. A second 7-year funding period is possible, depending on a positive review by the DFG. Additional funding is provided by the Helmholtz Association via the DLR.
The SE²A-Cluster is subdivided into three Integrated Cluster Areas (ICA), each one focusing on one aspect of the air transport system.

ICA A: Assesment of the Air Transport System

The goal of this cluster area is the development of comprehensive criteria and metrics for sustainable air transport that can serve as a basis for decision-making and future scenarios. Life cycle assessment will capture the entire environmental impact of aviation, including not only emissions during operation, but also from manufacturing and disposal of airframes. New methods for simulation and evaluation will be developed to asses the impact of novel technologies on perceived noise pollution on the ground. Air traffic management in the air and on the ground is investigated to identify new technologies as well as operating procedures that contribute to reduction of energy usage and noise emissions.

ICA B: Flight Physics and Vehicle Systems

This cluster area takes an in-depth look at technologies that have the potential to significantly reduce the power required from the propulsion system. Aerodynamic drag can be reduced up to 50 % by full airframe laminar flow control. The research cluster strives to provide the necessary breakthroughs in the design of shell structures and boundary layer suction systems to make LFC a mature technology ready for implementation. New structural concepts, in combination with active and passive load alleviation strategies, will also help to reduce structural weight, while new concepts for engine integration will exploit the synergies of laminar flow control and boundary layer ingestion. The benefit of these technologies will be evaluated on aircraft level by a newly developed overall aircraft design module.

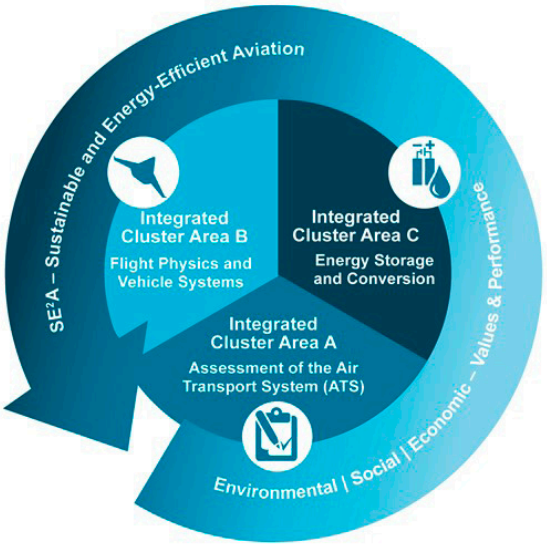
ICA C: Energy Storage and Conversion

Even with major advances in aircraft drag and propulsion efficiency, carbon emissions can only be reduced, while carbon-free aviation requires new concepts for the energy supply. Batteries can store electricity from renewable sources. However, to achieve a meaningful operating range an increase in energy density by more than one magnitude is required. The cluster looks at advanced lithium-sulfur chemistry for solid-state batteries as well as load bearing batteries that can form an integral part of the airframe structure. An alternative to batteries offering better range potential are fuel cells, converting hydrogen directly to electricity . Hydrogen has the best energy-to-weight ratio of all fuels, and fuel cells combined with electric motors for propulsion offer better conversion efficiency than the most advanced gas turbines. The challenges are the design of low-weight high-power fuel cells and finding low-volume and low-weight solutions for hydrogen storage. Finally, synthetic liquid fuels created from renewable energy sources could be burnt in optimized gas turbines with adaptive compressors, offering better efficiency over the entire operating range. The optimum solution, depending on the aircraft mission, might even be the integration of different technologies into a hybrid energy supply and propulsion system.

Program support: DFG

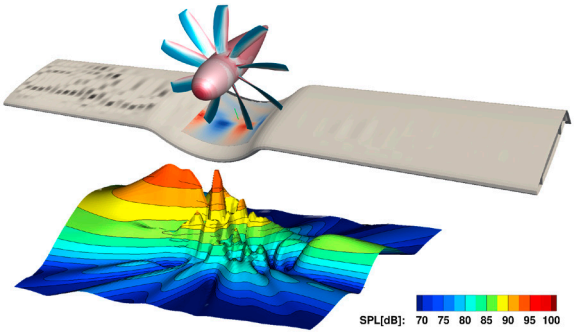
Cooperation with other Institutions:

German Aerospace Center (DLR), Leibniz University Hannover (LUH), Braunschweig University of Art (HBK), National Metrology Institute of Germany (PTB)

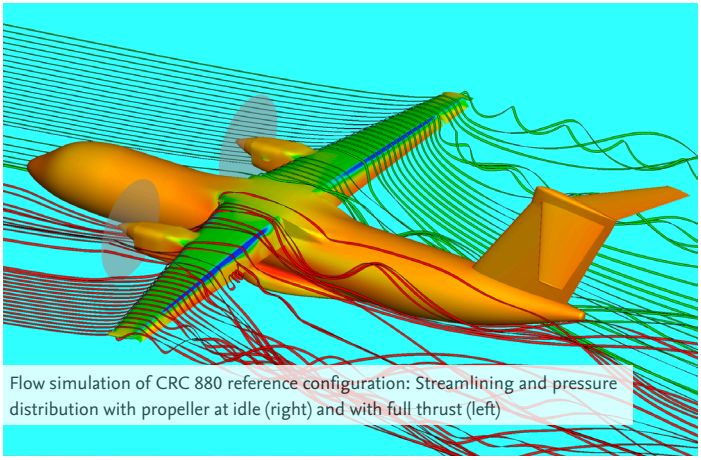


DFG Deutsche Forschungsgemeinschaft

Collaborative Research Centre SFB 880
Fundamentals of High Lift in Future Commercial Aircraft



The Collaborative Research Centre 880 develops the fundamentals of active high lift for environmentally friendly future transport aircraft. The research is motivated by growing demands for air travel in highly-populated economic zones like Europe. All forecasts indicate a sustainable growth in the aviation industry, with the air traffic volume expected to double by 2020 compared to 2000. However, such growth is associated with an increased demand on natural resources and with a considerable environmental impact by pollutants and noise. Sustainable growth can only be achieved by developing new, ground-breaking air transport technologies, which enable efficient point-to-point connections, short runways for take-off and landing, drastic reductions of aircraft noise, and low fuel consumption. This requires fundamental research on aeroacoustics, in methodology for efficient active high lift, and in flight dynamics.



Flow simulation of CRC 880 reference configuration: Streamlining and pressure distribution with propeller at idle (right) and with full thrust (left)

Low Noise Take-off and Landing

This area of research investigates noise-reduction technologies compatible with the considered high lift systems. This addresses all relevant acoustical sources: the broadband noise generated by the interaction of the high-energy turbulent flow with the airframe edges, and noise from the propulsion system. Several possible noise reduction methodologies are investigated: a) increased maximum lift coefficient for lower take-off and landing speed, b) aeroacoustically tailored porous materials, and c) combined acoustic and aerodynamic propulsion integration approaches.

Efficient High Lift

New flexible and scalable high-lift devices that yield significantly higher lift coefficients are critical enablers for future new segments of STOL (Short Take-Off and Landing) aircraft. The Collaborative Research Centre 880 aims for a paradigm shift in the operation of active high-lift systems for commercial aircraft, namely to find the most efficient way to operate circulation control wings. To achieve this ambitious objective, several research hypotheses are pursued: a) aerodynamic and structural development of a shape-adaptive leading edge to reduce boundary layer losses, b) synergetic effect of combined suction and blowing, c) aerodynamic and mechanical development of a piezo-actuated lip for unsteady actuation, and d) closed-loop flow control.

Flight Dynamics

The proposed high lift concepts for future commercial aircraft result in drastic changes to the airplane configuration and low-speed performance. The effects of these changes on the dynamic behavior of aircraft must be researched, and safe flight control concepts must be investigated. As such, this research area examines the major interactions between the high lift system, the propeller slip stream and the aircraft rear end. New concepts for aircraft control that satisfy the short take-off and landing are also developed. New structural designs to accommodate the new high-lift system and their aeroelastic behavior are investigated. Dynamical analysis is also performed for alternate aero engines such as UHBR-engines. Finally, uncertainty margins for designing a robust controllable aircraft are determined.

Aircraft Design and Technology Assessment

This research area analyses the impact of the different research approaches on the overall aircraft design and identifies optimal solutions. More specifically, the area is defining the design space of the other research projects. It also assesses the technology advancements from these projects by using a fully integrated aircraft design. This integrated design methodology relies on multidisciplinary analyses and optimisation to yield the proper aircraft design that satisfies the set constraints.

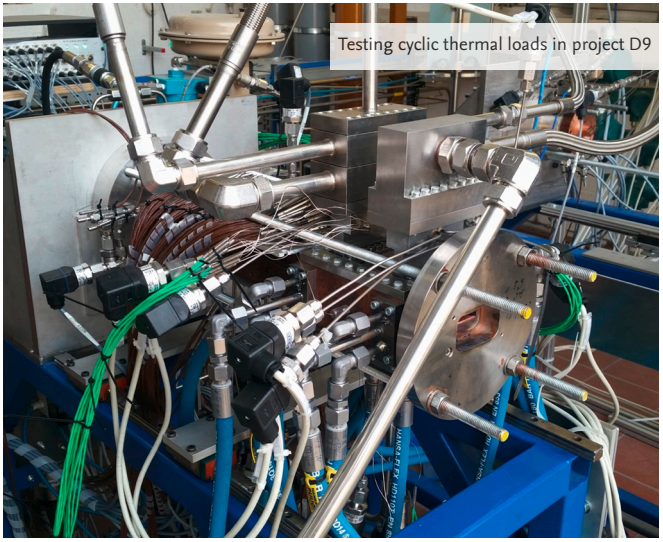
Program support: DFG

Cooperations with other Institutions:

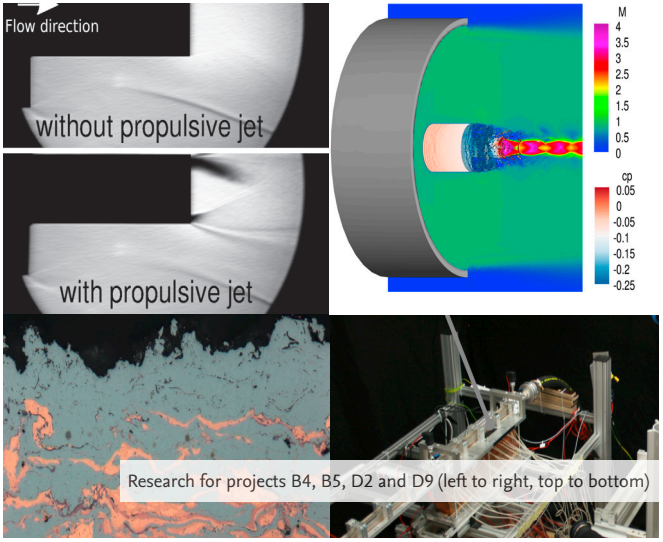
- DLR
- Leibniz Universität Hannover

DFG Deutsche Forschungsgemeinschaft

Collaborative Research Centre SFB TR40
Reusable Rocket Propulsion Technologies



Testing cyclic thermal loads in project D9



Research for projects B4, B5, D2 and D9 (left to right, top to bottom)

The scientific objective of the "SFB TR40" is to perform fundamental research for scientific progress in the efficiency, reliability and cost reduction of future rocket engines for space transportation systems. Future generations of space-launchers will rely on chemical propulsion systems as primary engines, as this type of propulsion offers the best compromise between cost and efficiency in the foreseeable future. To remain competitive with launcher manufacturers from the U.S.A., Russia and Asia, European launchers need enhanced knowledge and advanced methods in all technology areas. The particularly high complexity and extreme thermal and mechanical loads of chemical rocket engines call for intense fundamental research as prerequisites for drastic improvements and innovative technical solutions.

Program support: DFG

Cooperation with other Institutions:
Technische Universität München, RWTH Aachen, Universität der Bundeswehr München, Universität Stuttgart, DLR institutes at Braunschweig, Göttingen, Köln, Lampoldshausen and Stuttgart

Research Area A: Structure Cooling

Space transportation systems operate under extreme conditions leading to exceptionally high heat loads on the components of the thrust chamber. Extreme heat loads are generated in the combustion chamber and near the throat area of the nozzle. Without active cooling, no material can withstand these high thermal loads. The focus of this research area is on fundamentals and methods for thrust chamber cooling. Several cooling methods are investigated using numerical simulation and experiments. These are film cooling, transpiration cooling, regenerative cooling and combinations of these.

Research Area B: Aft-body Flows

Turbulent aft-body flows on modern rockets exhibit complex aerodynamic interactions during their ascent trajectory, and strong flow fluctuations often occur. This can lead to undesirable structure oscillations as well as thermal loads through radiation and turbulent heat transport in a complex flow field. The design of future rocket transport vehicles therefore calls for a thorough understanding of fundamental flow phenomena regarding the aft-body flow. This research area develops numerical and experimental simulation methodologies to resolve the relevant flow phenomena. The origins of unsteady aerodynamic loads are analysed with these methodologies, and a range of passive and active flow control approaches are scrutinised.

Research Area C: Combustion Chamber

The current technical development of rocket combustors is characterised by extremely expensive, predominantly experimental methodologies. Although numerical calculation methods play an important supporting role in the present analysis of individual effects, they are generally far away from the required level of prediction quality and robustness. This division focuses on the development and integration of tools for the reliable prediction of thermofluid-dynamic processes in rocket thrust chambers. Research concentrates predominantly on compressible stationary reactive flows and the calculation of dynamic combustion stability.

Research Area D: Nozzle

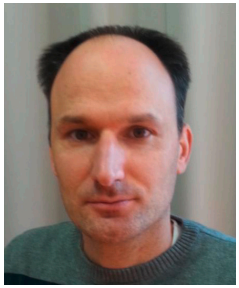
The nozzle is a highly loaded propulsion component. Its lightweight structure is designed for enormous thrust forces in axial direction; it also has to withstand spatially and temporally fluctuating side loads, and the thermal loads are generally high. The flow field inside the nozzle varies along the ascent trajectory, and it is influenced by the unsteady outer flow. The internal nozzle flow can experience transient flow separations, depending on the design concept, which result in asymmetric radial pressure loads. In research area D, advanced methodologies for fluid-structure interaction and new layout of materials and structures are investigated.

Research Area K: Thrust Chamber

The performance of the overall thrust chamber is governed by the combined effects of propellant injection, ignition, controlled heat release, cooling, and flow expansion in the thrust nozzle. The research deals with technology demonstrations in the future thrust chambers of rockets, i.e. combustion and combustion stability, heat transfer and cooling, new nozzle concepts and related technologies. Another objective is to analyse the potentials of using dual-bell nozzles for larger thrust and to evaluate the potentials of new high-temperature-resistant ceramic matrix composites (CMC).

DFG Deutsche Forschungsgemeinschaft

Register of Members



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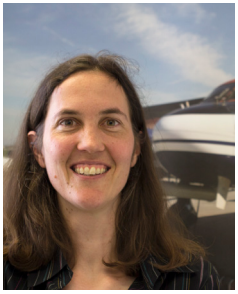

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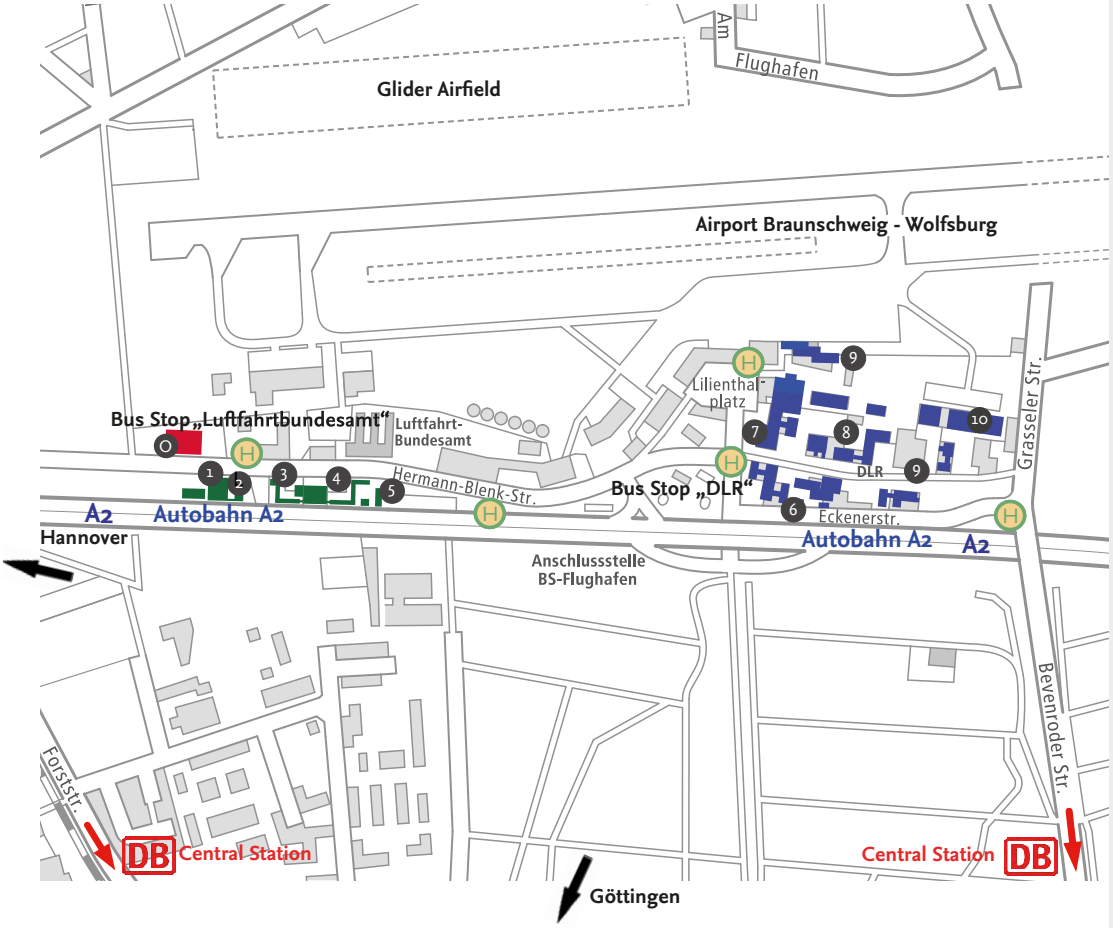
Location Plan



Aeronautics Research Centre Niedersachsen (NFL)

Technische Universität Braunschweig
Hermann-Blenk-Straße 23-42

O Main Office of the NFL
1 Institute of Jet Propulsion and Turbomachinery
2 Institute of Fluid Mechanics
3 Institute of Aircraft Design and Lightweight Structures
4 Institute of Flight Guidance
5 Institute of Space Systems

Deutsches Zentrum für Luft- und Raumfahrt (DLR)
German Aerospace Center
Lilienthalplatz 7

6 Institute of Flight Systems
7 Institute of Composite Structures and Adaptive Systems
8 Institute of Flight Guidance
9 Institute of Aerodynamics and Flow Technology
10 Flight Experiments

Further NFL-Members (not shown on the map)

- Institute of Adaptronics and Function Integration, TU Braunschweig, Langer Kamp 8
- Institute of Automotive Management and Industrial Production, TU Braunschweig Mühlenpfordtstraße 23
- Institute for Acoustics, TU Braunschweig, Langer Kamp 8
- Institute of Joining and Welding, TU Braunschweig, Langer Kamp 8
- Institute of Machine Tools and Production Technology, TU Braunschweig, Langer Kamp 19 B
- Institute for Materials, TU Braunschweig, Langer Kamp 8
- Institute for Particle Technology, TU Braunschweig, Volkmaroder Straße 5
- Institute of Meteorology and Climatology, Leibniz Universität Hannover
- Institute of Structural Analysis, Leibniz Universität Hannover
- Institute of Technical Combustion, Leibniz Universität Hannover
- Institute of Turbomachinery and Fluid Dynamics, Leibniz Universität Hannover
- Institute of Aeroelasticity, DLR Göttingen
- Analytics and Thermodynamic State Behaviour of Gases, Department 3.2 of the National Metrology Institute of Germany (PTB), Braunschweig
- Fraunhofer Institute for Surface Engineering and Thin Films

Glossary

A

Aerodynamische Versuchsanstalt Göttingen (AVA)
Akaflieg Braunschweig (Akademische Fliegergruppe)
Akustischer Windkanal Braunschweig (AWB)

Aerodynamic Research Institute Göttingen
Aeronautical Engineering Group of Students Braunschweig
Acoustic Wind Tunnel Braunschweig (AWB)

B

Battery LabFactory Braunschweig (BLB)
Bundesministerium für Bildung und Forschung (BMBF)
Bundesministerium für Wirtschaft und Energie (BMWi)

Battery LabFactory Braunschweig (BLB)
Federal Ministry for Education and Research (BMBF)
Federal Ministry for Economic Affairs and Energy (BMWi)

C

Campus Forschungsflughafen (gegründet 2009), frühere Bezeichnung des NFL bis 2013
Collegium Carolinum: Erster Vorgänger der heutigen TU Braunschweig. Gegründet 1745 durch Herzog Karl I. von Braunschweig, existierte in dieser Form bis 1862.

Campus Research Airport (founded 2009), former name of today's NFL until 2013
Collegium Carolinum: first predecessor of today's TU Braunschweig. Founded by Duke Karl Ferdinand of Braunschweig, existed in this form from 1745 until 1862.

D

Deutsche Forschungsanstalt für Luftfahrt (DFL) (gegründet 1936)
Deutsche Forschungsgemeinschaft DFG (gegründet 1920)
Deutsches Zentrum für Luft- und Raumfahrt (DLR)
Deutsch-Niederländische Windkanäle (DNW)

Aeronautical Research Institute (founded 1936)
German Research Foundation (founded 1920)
German Aerospace Research Centre (DLR)
German Dutch Wind Tunnel Foundation

E

Europäische Agentur für Flugsicherheit (EASA)
Europäische Weltraumorganisation (ESA)

European Aviation Safety Agency (EASA)
European Space Agency (ESA)

F

Faszination Akustik (Vorlesungsreihe)
Flugwissenschaftliche Gruppe (FWG) (gegründet 1922) heute Akaflieg
Forschungsflughafen Braunschweig (gegründet 1995)
Fraunhofer Gesellschaft (gegründet 1949)

Fascinating Acoustics (lecture series)
Aeronautical Research Group of Students (FWG) founded 1922, today called Akaflieg Braunschweig
Research Airport at Braunschweig-Waggum (founded 1995)
Fraunhofer Society (founded 1949)

G

Grundlagen der Luftschifffahrt (Vorlesungsreihe) 1909

Basics of Aeronautical Engineering (lecture series held in 1909)

H

Helmholtz Gemeinschaft (HGF) (gegründet 1995)
Hochschule für Bildende Künste Braunschweig (HBK)

Helmholtz Association (founded 1995)
Braunschweig University of Art (HBK)

L

Lehrstuhl für Angewandte Mechanik (Flugmechanik) (1955)
Lehrstuhl für Flugführung (1961)
Lehrstuhl für Flugnavigation und Flugmessgerätekunde (1931)

Lehrstuhl für Maschinenelemente (1954)

Chair on Applied Mechanics (Flight Mechanics) (founded 1955)
Chair on Flight Guidance (founded 1961)
Chair on Flight Navigation and Flight Measurement Instrument Research (founded 1931)
Chair on Mechanical Engineering (founded 1954)

Leichtbaucampus Open Hybrid Lab Factory (OHLF)	Lightweight Construction Campus Open Hybrid Lab Factory
Luftfahrtbundesamt (LBA)	Federal Aviation Office, German Civil Aviation Authority
Luftfahrt-Forschungsanstalt Braunschweig (LFA)	Aeronautical Research Institute Braunschweig (name of the DFL from 1938-1945)
Luftfahrt-Lehrzentrum der TH Braunschweig (gegründet 1938)	Aeronautics Teaching Centre of TH Braunschweig (founded 1938)

M

Modellversuchsanstalt für Aerodynamik (MVA)	Model Testing Institute for Aerodynamics
Nieders. Ministerium für Wissenschaft und Kultur (MWK)	Ministry for Science and Culture of Lower Saxony

N

Nationales Institut für Standards und Technologie (NIST), US Bundesbehörde	National Institute of Standards and Technology (NIST), Federal Agency of the US
Nationales Physikalisches Laboratorium (NPL), Britisches Metrologie Institut	National Physical Laboratory (NPL), National Measurement Standards Laboratory for the UK
Norddeutscher Verbund für fur Hoch- und Höchstleistungsrechnen	Northern German Computing Alliance
Niedersächsisches Forschungszentrum Fahrzeugtechnik (NFF)	Automotive Research Centre Niedersachsen (NFF)

P

Physikalisch Technische Bundesanstalt (PTB)	German National Metrology Institute (PTB)
Polytechnische Schule: Vorgänger der TH und späteren TU (existierte von 1862 bis 1878)	Polytechnical School (Predecessor of today's TU Braunschweig from 1862 to 1878)

R

Rheinisch-Westfälische Technische Hochschule Aachen (RWTH)	Rhine-Westphalia Technical University Aachen

T

Technische Hochschule (TH) Braunschweig: Vorgänger der TU von 1878 bis zur Umbenennung 1968	Technical University of Braunschweig (TH) (predecessor of TU Braunschweig from 1878 to 1968)
Technische Universität (TU) Braunschweig: seit 1968	Braunschweig Institute of Technology (TU) (since 1968)
Technische Universität (TU) Clausthal	Clausthal University of Technology
Technologie-Transfer-Zentrum des DLR	Technology Transfer Centre of the DLR

U

Universität Carolo Wilhelmina zu Braunschweig	Carolo Wilhelmina of Braunschweig (official name of today's Institute of Technology Braunschweig and its predecessors)

Z

Zentrum für Leichtbauproduktionstechnologie (ZLP)	Centre for Lightweight-Production Technology
Zentrum für Luft- und Raumfahrt (ZLR) (gegründet 1988), Vorgänger des NFL	Centre for Aerospace Research (ZLR) (founded 1988; predecessor of todays Aeronautics Research Centre NFL)

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