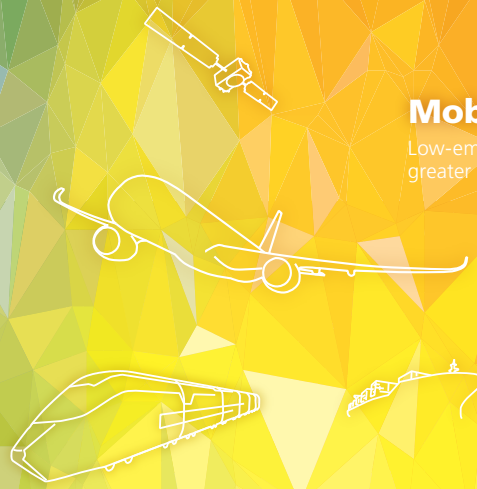
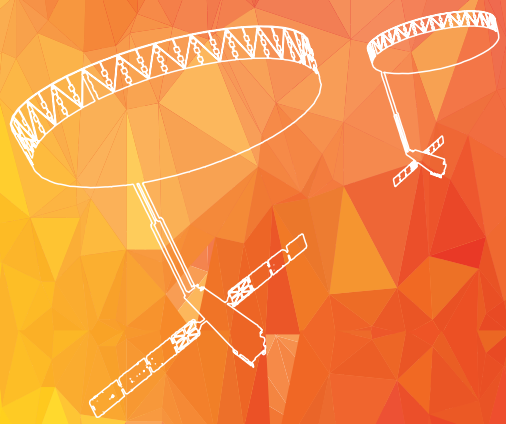
Mobility: intelligent

Low-emission, intelligently networked mobility for greater efficiency and safety





Security: guaranteed

Ensuring tomorrow's critical infrastructures with technology

Digital: forward-looking

Understanding the digital transformation and contributing with pioneering technology

DLR

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DLR at a glance

The German Aerospace Center (DLR) is the national aeronautics and space research centre of the Federal Republic of Germany. Its extensive research and development work in aeronautics, space, energy, transport, digitalisation and security is integrated into national and international cooperative ventures. In addition to its own research, as Germany's space agency, DLR has been given responsibility by the federal government for the planning and implementation of the German space programme. DLR is also the umbrella organisation for the nation's largest project management agency.

DLR has approximately 8000 employees at 20 locations in Germany: Cologne (headquarters), Augsburg, Berlin, Bonn, Braunschweig, Bremen, Bremerhaven, Dresden, Göttingen, Hamburg, Jena, Jülich, Lampoldshausen, Neustrelitz, Oberpfaffenhofen, Oldenburg, Stade, Stuttgart, Trauen and Weilheim. DLR also has offices in Brussels, Paris, Tokyo and Washington D.C.

DLR's mission comprises the exploration of Earth and the Solar System and research for protecting the environment. This includes the development of environment-friendly technologies for energy supply and future mobility, as well as for communications and security. DLR's research portfolio ranges from fundamental research to the development of products for tomorrow. In this way, DLR contributes the scientific and technical expertise that it has acquired to the enhancement of Germany as a location for industry and technology. DLR operates major research facilities for its own projects and as a service for clients and partners. It also fosters the development of the next generation of researchers, provides expert advisory services to government and is a driving force in the regions where its facilities are located.

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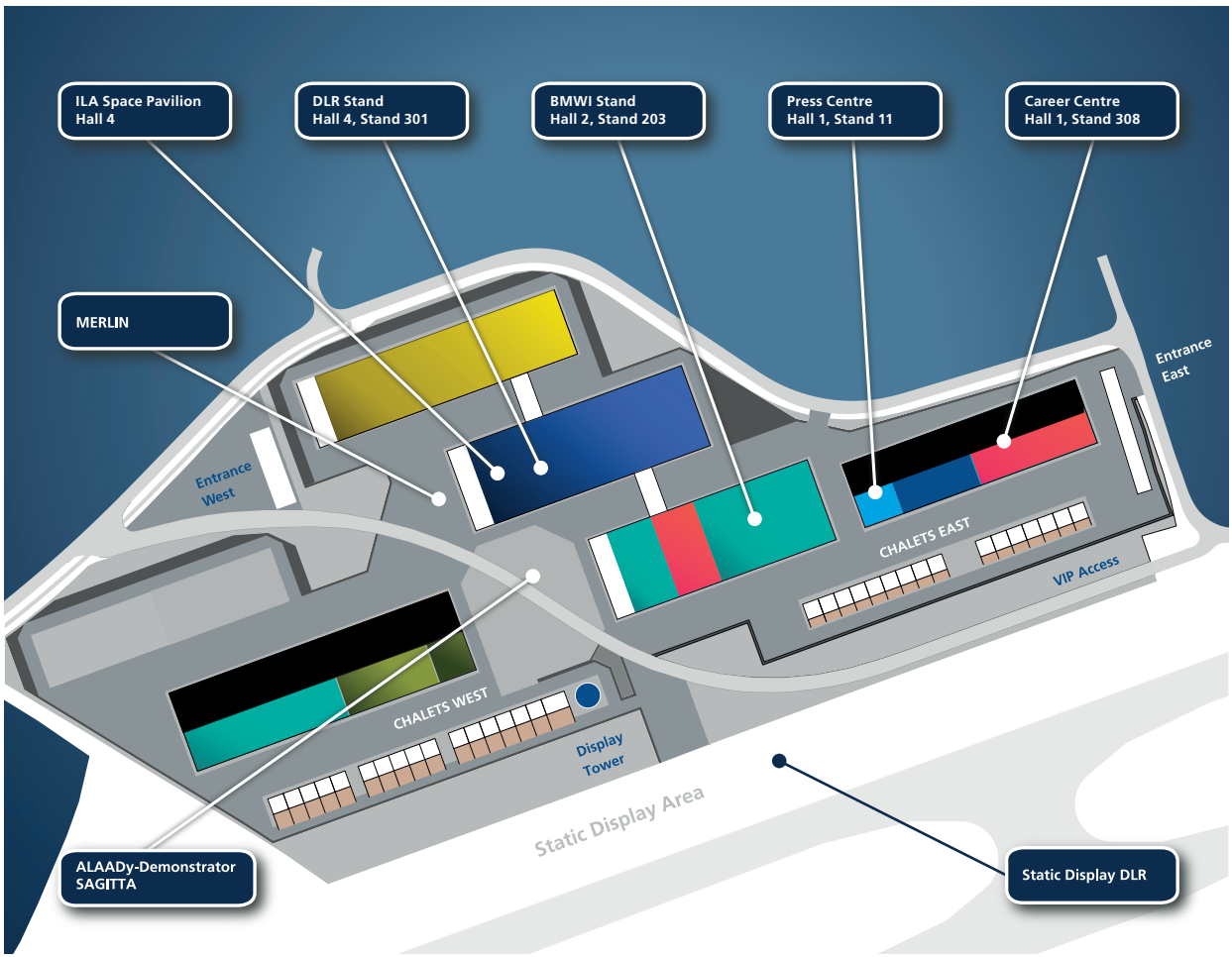
DLR at ILA



DLR

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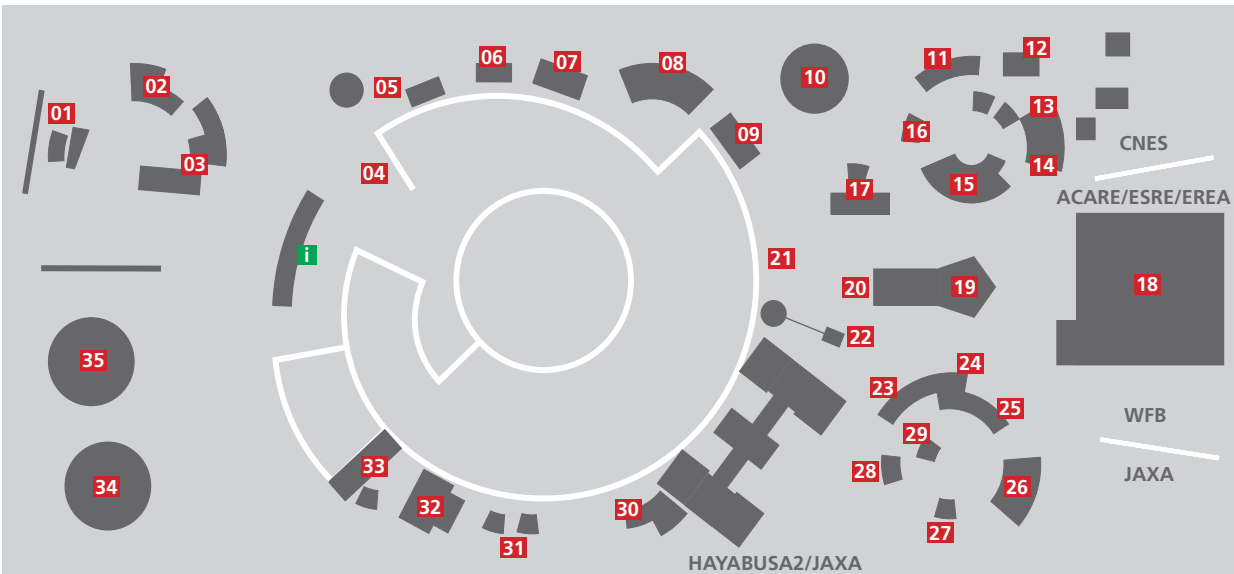
DLR stand

Hall 4, stand 301



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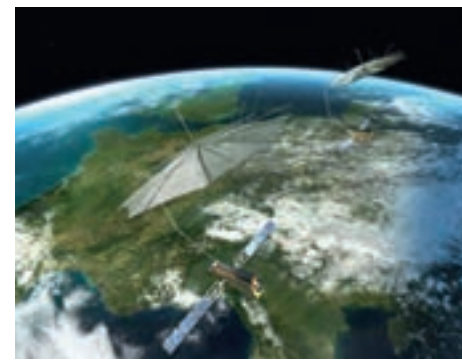
Tandem-L

Innovative SAR mission for environmental and climate research



Brief description

Tandem-L is a proposal for an innovative L-band SAR mission for the systematic observation of dynamic processes on the Earth's surface. The mission concept is based on two SAR satellites flying in close formation featuring the latest digital beamforming techniques in combination with a large deployable reflector.

Aims

Tandem-L will simultaneously measure seven essential climate variables in a single satellite mission. Primary mission objectives are the global measurement of forest biomass and its variation, the systematic monitoring of deformations of the Earth's surface, the quantification of glacier motion and melting in polar regions as well as observations of ocean surfaces.

Parties involved

DLR, UFZ, AWI, GFZ, GEOMAR, Jülich Research Center, HGF Center Munich, universities and research institutions

Applications

Novel imaging techniques and vast recording capacity for environmental and climate monitoring:

- biosphere (3D forest structure & biomass)
- geosphere (Earth surface deformation)
- cryosphere (ice melting processes)
- hydrosphere (soil moisture measurement)

Outlook

Vital contribution for a better understanding of the Earth system and its dynamics:

- ecosystem dynamics and the carbon cycle
- earthquake risk analysis for reliable forecasting
- climate change and sea level rise
- water cycle research and modelling

Facts and figures

- Two L-band SAR Satellites, ~3 tons each, flying in close formation & operating as bistatic SAR interferometer
- Advanced digital beamforming techniques in combination with a 15 m diameter deployable reflector
- Swath width: 350 km; ground resolution: 5–7 m; weekly global coverage
- Regularly updated, global higher-level information products for environmental & climate research

@DLR_en

Tandem-L

Innovative SAR mission for environmental and climate research

Tandem-L is a proposal for an **innovative L-band SAR mission** for environmental and climate research. The Earth system is permanently changing and **dynamic processes** occur in different spheres and at different time scales. Tandem-L has been designed to observe a wide range of processes at adequate time intervals and to deliver urgently required information for answering pressing scientific questions in the domain of the **bio-, geo-, cryo- and hydrosphere**. In this way, Tandem-L will contribute significantly to a better understanding of the Earth system and its dynamics. Important mission goals are the global measurement of **forest biomass** and its variation in time for a better understanding of the carbon cycle; the systematic **monitoring of deformations** of the Earth's surface on a millimetre scale for the investigation of earthquakes and risk analysis; the quantification of **glacier motion and melting processes** in the polar regions; the fine scale measurement of variations in the near-surface **soil moisture** as well as observations of the **dynamics of ocean surfaces and ice drift**. In times of intensive scientific and public debate on the scale and impact of climate change, Tandem-L delivers important, currently unavailable information for **improved scientific forecasts and socio-political recommendations** based upon these.

Tandem-L is the result of three multi-year conceptual and feasibility and mission definition studies led by DLR together with a team of more than 100 scientists in close cooperation with the German aerospace industry since 2008. The scientific data exploitation from Tandem-L is being prepared as part of the Helmholtz Alliance 'Remote Sensing and Earth System Dynamics', including more than 140 scientists from 8 Helmholtz centres, Max Planck and Leibniz Institutes and other national and international universities and research institutes.

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Eu:CROPIS

Euglena Combined Regenerative Organic Food Production in Space

Brief description

For long-duration space missions, humans require a stable life support system that provides oxygen, water and food. Such a system must also function under gravity conditions other than those prevailing on Earth. With the Eu:CROPIS satellite mission, the functionality of combined biological life support systems under lunar and Martian gravity will be investigated.

Aims

The mission is a biological experiment designed to test the stability and restartability of a closed biological life support system suitable for the Moon or Mars on a compact satellite.

Parties involved

DLR Institute of Space Systems, DLR Institute of Aerospace Medicine, Friedrich-Alexander University Erlangen-Nuremberg, Department of Cell Biology

Applications

Fresh water purification
- Production of oxygen and biomass using algae
- Zero-emission habitats (for example, in polar regions)

Outlook

- Long-duration crewed space missions
- Production of fertilisers and food
- Drinking water preparation

Facts and figures

- **DLR compact satellite:** 1 m in height, 1 m in diameter
- Spin stabilised, magnetorquer-based AOCS
- Variable rotation rate to alter the gravitational conditions
- **Orbit:** LEO, 500 – 650 km, 06:00 – 12:00
- **Launch:** summer 2018 with Falcon 9

6 CLEAN WATER AND SANITATION

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

Eu:CROPIS

Euglena Combined Regenerative Organic Food Production in Space

Astronauts in space must be supplied with oxygen, water and food. In order to produce and recycle these essential resources and thus also make them available for long-duration missions lasting several years, **closed life support systems** are required. The focus of the DLR mission Eu:CROPIS (Euglena Combined Regenerative Organic Food Production in Space) are tests on the long-term stability of a biological life support system for missions to the Moon or Mars. With the aid of the filter system developed by DLR called **C.R.O.P.®**, synthetic urine will be converted into a fertiliser solution for plants. A second system based on algae will be used to supply the entire system with oxygen and detoxify it as required.

Eu:CROPIS is intended to show that such a closed system can be operated and restarted under **different gravitational conditions** (Moon and Mars). Possible applications on Earth are zero-emission habitats in sensitive regions or closed living spaces in a hostile environment or in disaster areas, in mines or under water. It will also serve as a new method of fertilisation or fresh water preparation.

The Eu:CROPIS satellite will rotate at an altitude of 600 kilometres during its mission and in its interior space create first the gravitational conditions of the Moon for six months and then Mars gravity for a further six-month period. Tomato seeds observed by 16 cameras will germinate and produce small space tomatoes. The essential aids that make this possible will be carried on board. A collection of microorganisms in a trickle filter will ensure that fertilisers are created from synthetic urine for the tomato plants. Unicellular algae will protect the closed system against excess ammonia and supply it with oxygen. LED lights will provide a day and night rhythm for the algae and tomato seeds and a pressurised tank will simulate Earth's atmosphere.

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SpaceLiner RLV

Hypersonic transport

Brief description

The SpaceLiner is a vision for a suborbital, hypersonic winged passenger transporter. A variant consisting of a fully reusable uncrewed space transportation system (RLV) would enable low cost launching of satellites into orbit.

Aims

The SpaceLiner concept stands for the generation of a new, larger market for rocket technology with a reduction of up to 90 percent in launch costs for satellites and to reduce flight times for passengers of only 90 minutes on the Australia-Europe route and 60 minutes on the Europe-California route.

Parties involved

DLR with various European partners in projects funded by the EU; current cooperation with ONERA (F) and numerous universities

Applications

- More cost-effective, environment friendly transportation of large payloads into orbit
- Rapid intercontinental flights with space technology

Outlook

- The development of a European multi-mission launch system to perform multiple tasks and serve various markets
- Utilisation of the innovation potential of rocket technology
- Improved environment friendliness of space transport through reusability and hydrogen technology
- Dramatic reduction in intercontinental flight times and establishment of new business models

Facts and figures

Two-stage launch system
Length of orbital or passenger stage: 65.6 m
Length of booster stage: 82.3 m
Lift-off weight: up to 1832 t
Satellite payload mass to Low Earth Orbit: over 20 t
Satellite payload mass to geo-transfer orbit: over 8 t (with upper stage)
Maximum flight altitude for passenger missions: 80 km (Australia)
Maximum speed for passenger missions: 25,200 km/h
Maximum range for passenger missions: 18,000 km

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

12 RESPONSIBLE CONSUMPTION AND PRODUCTION

SpaceLiner RLV

Hypersonic transport

SpaceLiner is a vision for a suborbital, hypersonic winged **passenger transporter** that, in a variant with a payload bay, would also enable low-cost launching of satellites into orbit.

The two-stage, vertically launched configuration consisting of an uncrewed booster and a passenger stage (orbiter) is designed for 50 passengers and has a total of 11 liquid propellant rocket engines (booster nine, orbiter two), which are fuelled with cryogenic oxygen (LOX) and hydrogen (LH2). After main engine cut-off, the passenger stage glides over **large intercontinental distances in a short time**.

Depending on the passenger mission, flight altitudes of 80 kilometres and Mach numbers far exceeding 20 can be reached. With the SpaceLiner, flight times on the Australia-Europe route will be reduced to only 90 minutes, and shorter distances from Europe to California or East Asia will be around 60 minutes.

The SpaceLiner version for **transporting satellites** into orbit is almost identical in its external shape. The key difference is in the internal architecture of the upper stage, where the passenger cabin is replaced with a large, now centrally positioned payload bay. This version is envisaged as an uncrewed launch system. Due to the high degree of similarity between the two variants in terms of design and their use of identical rocket engines, considerable cost savings are possible both in development and in production. Combined with the fact that the stages are **largely reusable**, the ambitious goal of a more than 90 percent cost reduction for satellite launches relative to current levels is realistic.

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horizons – Knowledge for Tomorrow

Alexander Gerst's new ISS mission

Brief description

Alexander Gerst's launch to the International Space Station (ISS) on 6 June 2018 for his mission 'horizons – Knowledge for Tomorrow' will mark the start of his second mission to work on the largest international technology project in the history of humankind. In this scientific laboratory, the major spacefaring nations are joining forces to develop solutions to global challenges.

Aims

Germany is one of the most important ISS partners. All German contributions to the Space Station are coordinated and managed by the DLR Space Administration on behalf of the German Federal government, in coordination with the international ISS partners. In addition to science, the Space Station also provides opportunities for commercialisation. 'horizons' will turn 'science fiction' into 'science facts'.

Parties involved

DLR Space Administration, ESA, BMWi, German universities and research institutions involved in the experiments and German industry

Applications

- In addition to basic research, more than 50 German experiments provide knowledge for 'health, the environment and climate change', 'digitalisation, Industry 4.0, energy and the mobility of tomorrow
- ISS as a driver of innovation for new technologies

Outlook

- Every euro invested provides a return of one euro
- For Germany as a high-tech and science location, research on the ISS is an investment in the future and an opportunity to inspire the youth about science and industry (MINT subjects)

Facts and figures

Launch to ISS scheduled for 6 June 2018 on board a Soyuz launcher from Baikonur Cosmodrome (Kazakhstan), Docking with Soyuz MS09 on 8 June 2018.
Mission duration: expected to be 187 days
Mission operations:
German Space Operations Center in Oberpfaffenhofen, Johnson Space Center (Houston) und ZUP Moscow

horizons – Knowledge for Tomorrow

Alexander Gerst's new ISS mission

'horizons' – this is the name of German ESA astronaut Alexander Gerst's next mission to the ISS. On 6 June 2018, the 41-year-old geophysicist will embark on his **second journey** to the International Space Station (ISS) with Expedition 56/57. In August, Gerst will become the first German and second European to be **Commander** of the ISS. During an expected 187 days – until the beginning of December 2018 – Gerst will be at an altitude of approximately 400 kilometres. The name of the mission, horizons, symbolizes the **curiosity and fascination** of discovering and exploring the unknown.

Research on the ISS and the horizons mission provide important contributions and impulses for addressing **societal and global challenges**, for example with regard to increasing **digitalisation, climate change and Industry 4.0**. Germany is the most important partner for ESA ISS elements and European ISS usage. After all, the ISS is a unique and innovative laboratory and test environment for experiments that cannot be performed on Earth.

In the mission, **50 experiments** with German participation will be contributed by scientists from German universities and research institutes, German industry and DLR as a research centre. The thematic spectrum ranges from biological and medical experiments to (astro-) physical and materials science issues, through to technology demonstrations, an experiment programme for children and young people, as well as industrially or commercially motivated applications. The **Columbus space laboratory**, the scientific heart of European research on the International Space Station ISS, is also celebrating its **tenth anniversary** this year. DLR has overseen the development and production of the ISS module on behalf of the **European Space Agency** (ESA), is actively involved with experiments at the research level and manages operations from the **Columbus Control Center** in Oberpfaffenhofen.

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Terahertz laser local oscillator for SOFIA

Detecting atomic oxygen in space

Brief description

The Stratospheric Observatory for Infrared Astronomy (SOFIA) is a modified Boeing 747SP with an integrated 2.7-metre telescope. The GREAT and upGREAT spectrometers use a terahertz (THz) local oscillator. This is a world-first, highly stable frequency source that enables spectrally high-resolution astronomical observations.

Aims

The instrument makes it possible to detect atomic oxygen in the interstellar medium, in star formation regions and in planetary atmospheres. These high-resolution measurements at 4.7 THz are not feasible from ground-based observatories. They allow deeper insights into dynamic processes, such as star formation.

Parties involved

DLR Institute of Optical Sensor Systems, DLR Space Administration, Max Planck Institute for Radio Astronomy, University of Cologne, Paul Drude Institute for Solid State Electronics

Applications

- High-resolution spectroscopy
- Space exploration

Outlook

- Atmospheric research
- Environmental sensors and environmental monitoring
- Basic research

Facts and figures

- World's only laser system of its kind
- **Frequency:** 4.745 THz
- **Frequency stability:** 107
- **Power:** up to 2 mW
- **Beam profile**: M2 <1,2

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

Terahertz laser local oscillator for SOFIA

Detecting atomic oxygen in space

The Stratospheric Observatory for Infrared Astronomy (SOFIA) offers unique possibilities for **exploring the Universe.** With the 2.7-metre telescope integrated into a modified **Boeing 747SP,** astronomical observations in the infrared and terahertz wavelength ranges can largely be performed without the disturbing influence of the atmosphere.

The GREAT spectrometer and its enhanced version upGREAT (German Receiver for Astronomy at Terahertz Frequencies) form one of the monitoring instruments used on SOFIA. They are so-called **heterodyne spectrometers** that measure the sky simultaneously at two frequencies in the range of 1.25 to 5 terahertz with high resolution. With the resulting precise measurements of the line shape of atomic or molecular emission and absorption lines, researchers can determine the dynamic conditions of an astronomical object.

The local oscillator laser shown here is an integral part of the high-resolution spectrometer for measurements at 4.7 terahertz. It allowed the routine observation of the astronomically important **fine structure line of atomic oxygen** for the first time. The atomic oxygen line at a frequency of 4.7 terahertz is an important source of information for researchers to better understand the **formation of stars**. Ground-based observatories cannot detect these because of water absorption in the atmosphere. The SOFIA local oscillator laser is the first of its kind in the world. The instrument is a high-precision frequency source based on novel **terahertz quantum cascade lasers** developed by the DLR Institute of Optical Sensor Systems in collaboration with the Paul Drude Institute for Solid State Electronics. It consists of several layers of **semiconductor structures** that must be cooled down to temperatures below -220 degrees Celsius. The whole system must be sufficiently stable and powerful, while being robust enough for everyday use in the airborne observatory.

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Post ISS

Orbital Hub concept with Free Flyer

Brief description

The Orbital Hub concept is a small, modular, cost-effective human spaceflight platform that could enable astronauts to stay in low Earth orbit permanently upon decommissioning of the ISS. Interaction with the planned Free Flyer could lead to better research conditions and new applications.

Aims

Preparatory work to devise future programmes for human spaceflight and preserving long-term low Earth orbit research. The underlying questions are as follows: what could ongoing space research look like after the ISS (~2024), which would be the new applications, and what is the potential for optimisation?

Parties involved

DLR Institute of Space Systems and 10 other DLR institutes, Airbus DS, Bigelow Aerospace, ESA and NASA astronauts

Applications

- Human spaceflight
- Earth observation
- Technology demonstration
- Commercial applications
- Science and research under microgravity conditions
- Preparation and training for exploratory missions
- Goods distribution in LEO

Outlook

- Continuation of human spaceflight in low Earth orbit
- Securing European expertise and cutting-edge technology
- Openness to cooperation with international partners
- First building block of a future ‘space city’

Facts and figures

Orbital Hub: 3 modules + Free Flyer
Total mass: 84 t (20 % of the ISS) installation with four rocket launches
Wingspan: 71 m
Total length: 45 m
Total power: 30 kW basic + 20 kW Free Flyer
Crew: 3 astronauts
Free flyer as first element to be realisable in a few years; first potential Free Flyer mission using the existing ISS

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

Post ISS

Orbital Hub concept with Free Flyer

The Orbital Hub consists of two main parts: **the base** and the **free-flying module** (called the Free Flyer). The docking module on the base is the **approach point for any crew or cargo vehicles**. It contains a cupola, crew training equipment and subsystems for communications, data storage and an emergency propulsion system. The service module houses the basis functionalities (mainly power supply and thermal control), a toilet and the external reaction wheels for aligning the platform. The expandable habitat is based on the BA330 by Bigelow Aerospace. It contains three crew quarters, a kitchen, working spaces, manufacturing units, laboratory cabinets and general storage facilities. It includes a small airlock so that EVAs can be conducted in the event of an emergency.

The Free Flyer has two separate areas: a **pressurised laboratory** and a non-pressurised area with the **external platform** and **service module**. The pressurised laboratory can be entered by the crew when it is docked to the base. It has enough space to accommodate payloads (e.g. for materials science) and an airlock to equip the attached external platform. This external platform provides standardised interfaces with the **payloads** and is serviced by a robotic manipulator. The service module mainly houses the energy, thermal, data and drive systems of the Free Flyer. The Free Flyer is the active element of the Orbital Hub during the assembly phase and manoeuvring flight. An electric propulsion system also guarantees conditions that are as undisturbed as possible and **high-quality weightlessness** during the free flight phases.

The Orbital Hub would provide a cost-effective way of continuing **human spaceflight** in **Low Earth Orbit (LEO)**, and would be a reliable base for long-term **space exploration** by astronauts beyond LEO.

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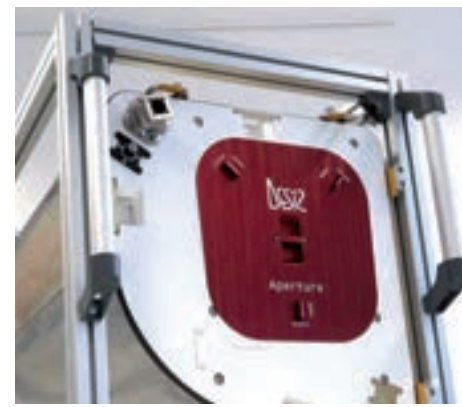
DESIS

DLR Earth Sensing Imaging Spectrometer



Brief description

DESIS is a hyperspectral camera developed and built by DLR in collaboration with Teledyne Brown Engineering (TBE). DESIS is used for Earth observation and operated by the MUSES (Multi-User System for Earth Sensing) platform developed by TBE on board the ISS.

Aims

DESIS is intended to supply hyperspectral data to support scientific, humanitarian and commercial goals. It provides information to assess the situation following environmental disasters, to help farmers manage their land in a targeted manner and to provide scientists with a basis for innovative atmospheric correction algorithms.

Parties involved

DLR Institute of Optical Sensor Systems, Teledyne Brown Engineering

Applications

- Earth observation
- Humanitarian aid
- Commercial data products from space
- Targeted agriculture

Outlook

- Global ecosystem monitoring
- Further development of hyperspectral technologies
- Improved response to humanitarian crises
- New research using hyperspectral data

Facts and figures

- **Launch:** June 2018
- **Size:** 900 x 600 x 500 mm
- **Number of spectral channels:** 235
- **Range:** 2.5 nm
- **Pixel resolution (ground sample distance):** 30 m

DESIS

DLR Earth Sensing Imaging Spectrometer

With increasing global industrialisation, the impact of humans on Earth's food supply is constantly growing. Using **hyperspectral data**, scientists can monitor and develop the dynamic relationships between geophysical parameters on an intercontinental scale. The DESIS imaging spectrometer can depict the land surface, oceans and atmosphere with great accuracy. Unlike conventional satellite-based spectrometers, DESIS has a **high number of channels** in the 400 to 1000 nanometre range. The instrument records hyperspectral data using 235 channels with a spectral range of 2.5 nanometres, covering the visible and near infrared spectrum. It has been developed to obtain a pixel resolution (ground sample distance) of 30 metres from the 400-kilometre orbit of the ISS. The spectrometer has been developed to operate on the MUSES instrument platform. In June 2018, DESIS will be launched to the International Space Station (ISS) on board a SpaceX rocket. From there, DESIS will observe Earth's surface around the clock, providing experts with information about the current state of, and any changes to the land and ocean surface. This will enable them to better understand **environmental processes** or make statements about the current state of forest and agricultural land, in order to improve global food production, for example. In addition, data from the ISS instrument will quickly be available in the event of a disaster, enabling it to assist emergency services with their deployments. The developers aim to combine the data from all MUSES instruments and thereby develop advanced **methods for remote sensing**. The remote sensing instruments can also be returned to Earth after their operational life of between three and five years, in order to more closely examine the **impact of the space environment** on them.

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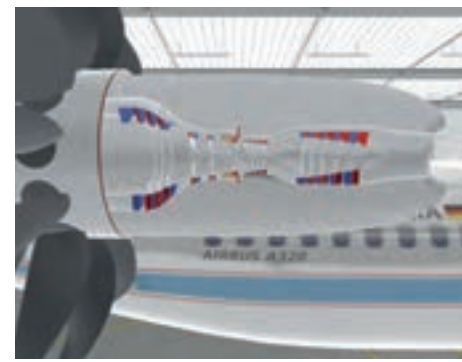
Preliminary engine design

Virtual view of future engine concepts



Brief description

Virtual reality technology gives visitors the opportunity to take a look at the inner workings of an engine and to learn more about built-in components. The exhibit shows a standard turbofan engine and a counter-rotating open rotor.

Aims

The virtual engine and gas turbine platform is used to design innovative aircraft engines that have a greater efficiency, lower environmental impact and are more cost effective. It also enables research in the area of simulation-based maintenance and certification.

Parties involved

Multidisciplinary engine design with the participation of nine DLR institutes and facilities

Applications

- Visualisation of new engine geometries
- Virtual engine development

Outlook

- Industry 4.0
- Virtual reality engineering: covering problem areas, verifying solutions
- Implementation in development, maintenance, marketing and distribution phases

Facts and figures

- The engines of the future are increasing in size as a result of fuel-saving concepts that enhance propulsion efficiency
- GTlab simulation and preliminary design environment to design new engines virtually
- Close cooperation with industry, research and educational facilities

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

13 CLIMATE ACTION

Preliminary engine design

Virtual view of future engine concepts

In order to improve the efficiency, environmental impact and cost-effectiveness of aircraft engines, DLR is developing, analysing and comparing **new engine concepts**. A comparison between past and present engine generations clearly demonstrates the direction in which the development is heading: engines of the future **will become bigger**. This is partly due to fuel-saving concepts that are linked to an increase in propulsion efficiency. Visitors to the DLR stand are invited to don virtual reality goggles to experience the differences up close. Virtual reality technology allows the user to interact with computer graphics in an entirely new way. On display are a standard turbofan like the one installed on the DLR research aircraft ATRA, as well as an **innovative, counter-rotating open rotor (CROR)**. Visitors also have the opportunity to acquire insight into DLR's process chains of the **virtual, preliminary engine** design. A separate computer demonstrates the **simulation preliminary design environment GTlab**, which is used to create the engine models presented in the virtual reality environment.

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Airbrake

A demonstration of fibre-reinforced polymer-based designs for aviation

Brief description

DLR and its partners are exhibiting an innovative composite and adhesive-based design, as well as materials, production technology and load application components, with the new airbrake demonstrator of a Eurofighter.

Aims

The principal aim is to achieve a significant increase in cost efficiency (halving costs) over a conventional prepreg manufacturing process, while largely maintaining weight neutrality in relation to the series components. This is achieved by reducing the number of components in combination with a fibre-reinforced polymer-based, multifunctional, bionic design, as well as structural bonding and precision manufacturing using low-shrinkage materials and processes.

Parties involved

DLR-FA, Airbus Defence and Space, Airbus Central R&T, Bundeswehr Research Institute for Materials, Fuels and Lubricants

Applications

The selected demonstrator component serves to exemplify a large number of newly emerging aviation structures and parts that allow deviations from the current design patterns.

Outlook

Following on from a rapid expansion of the structural spectrum for military applications using fibre-reinforced polymer aviation components, it is expected that a more cost- and energy-efficient design will also be possible within civilian and military aviation in the long term.

Facts and figures

- The number of individual components and connecting parts was reduced by 80 percent compared with series components.
- A cost reduction of 40 percent was identified in comparison with series design.
- A previous study has determined lightweight construction potential of approximately 30 percent.
- The predecessor model to the airbrake shown here will commence flight testing in Manching, Bavaria, in 2018.

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

Airbrake

A demonstration of fibre-reinforced polymer-based designs for aviation

The demonstrator's principal structure solely consists of **two carbon-fibre reinforced polymer (CFRP) shells** that are bonded together to carry the load. **Innovative design and manufacturing methods** were applied in order to distribute the load across the geometrically complex connecting surfaces. Optical mapping of the main structure and a topological optimisation process were used to design custom-fit mounts that offset geometric deviations in the composite fibre component. The hinge fittings were manufactured in aluminium precision casting using adaptive manufacturing models, while the actuator fittings were made from stainless steel by selective laser melting.

The airbrake demonstrator was implemented together with **Airbus Defence and Space** as part of the 'Advanced Aerospace Structures' project. This is a successful and long-term cooperation that also involves Airbus Central R & T and the Bundeswehr Research Institute for Materials, Fuels and Lubricants (WIWeB). The topics and strategy within the programme are closely coordinated with the German Ministry of Defence.

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DLR LNA model

DLR Low Noise Aircraft

Brief description

DLR is concerned with future aircraft configurations. One variant is the DLR-LNA, which was developed as an innovative aircraft configuration. It is designed to significantly reduce aircraft noise. In this case, a number of constructive measures have been applied, which allow a mostly reduced sound radiation to the ground.

Aims

The comprehensive database created is used to evaluate DLR's numerical sound simulation methods. In addition, design guidelines for maximum shielding effects are to be derived. The overall objective is to further develop DLR's aircraft design capabilities with respect to sound-reducing acoustic shadowing effects.

Parties involved

BMWi, DLR, project partner Airbus, DNW-NWB (low-speed wind tunnel Braunschweig), Rolls-Royce Germany.

Applications

- Aircraft (preliminary) design
- Validation of simulation methods
- Study of low noise aircraft concepts

Outlook

- Development of non-conventional and quieter aircraft configurations

Facts and figures

- **Project:** DLR FrEACs (Completion 2017, duration 3 years)
- **Related projects:** LuFO K2020 DLR MEPHISTO, DLR DIABOLO, NATO STO, LuFo LIST, LuFo Mamut
- **Wind tunnels (including preliminary investigations and cooperations):** DLR-AWB, DNW-NWB, ONERA F2,NASA QFF

3 GOOD HEALTH AND WELL-BEING

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

DLR LNA model

DLR Low Noise Aircraft

The acoustic **assessment of future commercial aircraft** must be carried out analogously to the analysis of aerodynamic and economic efficiency through simulations in the design phase of an aircraft. Even today, the sound emission of individual components, such as engines, high-lift systems and landing gears may be evaluated for various layouts and thus the quietest variant can be determined. A further **reduction of the noise immission on the ground** can be done conceptually only by measures that prevent the sound propagation from the sound source to the observer on the ground, that is, by the shadowing of the sound source from the observer's point of view. For this reason, the Institute of Aerodynamics and Flow Technology is developing calculation methods to determine the noise immission on the ground for **non-conventional aircraft configurations**. To verify these calculation methods, **comparative wind tunnel investigations** were carried out at the DLR LNA.

As part of the DLR FrEACs (Future Enhanced Aircraft Configurations) project, DLR investigated the sound shielding properties of non-conventional aircraft configurations. The **civil aircraft concept** (DLR Low Noise Aircraft, LNA) was investigated using a model sound source in the DNW-NWB. This test sound source mimics the engine noise on a model scale. The sound source is realised by focusing a pulsed laser beam onto a point. Here, the air is heated at such high temperatures that it briefly breaks down into a plasma creating a small explosion. This bang produces sound waves with an almost equal intensity in all directions. The ratio between the reference sound pressure level and the measured sound pressure level below the aircraft is the shadowing factor, which is the measure of the achieved reduction in ground noise immission.

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GLASS

GLS approaches based on SBAS

Brief description

GLASS provides a cost-effective system that combines satellite and ground-based augmentation to enable GPS-based approaches with vertical guidance and automated landings.

Aims

As part of the GLASS project, the plan is to demonstrate 'GBAS through SBAS' technology during test flights with fixed-wing aircraft and helicopters.

Parties involved

DLR Institute of Flight Guidance and DLR Technology Marketing

Applications

- Low-cost satellite-based landing systems for airports
- Precision approach without installing a complete GBAS station
- GLS-enabled aircraft can also use the GLS option at smaller airports

Outlook

- Airports, in holiday regions for example, can be equipped with cost-effective landing aids
- Airlines that have fitted their aircraft with systems for using satellite-based approach aids at major hubs can use these without problems

Facts and figures

- There is no need for the complex installation of a GPS reference receiver and antennas, thereby making the system extremely cost-effective
- GLS approaches are possible at any airport or landing site that permits RNP approaches
- Use on oil platforms and ships
- Ambulances could request and remotely guide a rescue helicopter

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

GLASS

GLS approaches based on SBAS

Technology demonstration – satellite-based landing system

At present, **automated landings** can only be performed using precision guidance systems, such as ILS, MLS or GLS (GBAS landing system). Common to all these systems is the fact that the guidance signals are routed directly from the receiver to the autopilot. The autopilot then takes control of the aircraft for landing.
For **ground-based GLS**, a ground station transmits correction data for the individual satellite signals. The ground station also transmits approach information, such as threshold coordinates, direction and descent angle. The receiver then uses this data to calculate flight procedures and transmits these directly to the autopilot.

A **satellite-based system** (SBAS) also transmits corrections to the user. Unlike GLS, however, the data is transmitted via a geostationary satellite. The approach information data is stored in the Flight Management System (FMS) database. Flight procedures are calculated by the FMS and forwarded to the autopilot. Although automated landings can now be performed by appropriately-equipped aircraft using a precision landing system such as ILS, MLS or GLS, these systems do not permit automated landing guided by the FMS. This would require a costly certification of the autoland system.

The proposed solution is intended to combine the **benefits of both augmentation systems**. The SBAS data is converted into GLS-compatible structures and sent to the receiver with the approach data. This can now transmit flight procedures directly to the autopilot and automated landings are possible.

GLASS is a **cost-effective system** that enables even smaller airfields to provide landing systems for automated landings.

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Quiet engine

Active reduction of fan noise by injecting compressed air

Brief description

Using active noise reduction technology, disruptive fan noise is suppressed by superimposing a counter-noise field. The concept is based on the injection of compressed air through wall-flush mounted adjustable nozzles between the rotor and stator. On the rotor blades, additionally stimulated alternating forces produce the required noise cancellation.

Aims

The control system should be extended for higher frequencies. For integration into the engine, a mechanically simplified concept is being developed for the adaptation of injection nozzles. In order to reduce the technical effort, the control system will be restricted to sound-field components that emit sound in the direction of the recipient, such as residents living in the vicinity of an airport.

Parties involved

DLR Institute of Propulsion Technology, Airbus, Rolls-Royce Deutschland, MTU, the aviation research programme of the German Federal Ministry for Economic Affairs and Energy

Applications

- Reduction of blade tones from turbomachines
- Targeted minimisation of aircraft noise during take-off and landing
- Fans, compressors and turbines of conventional engines
- Fans of electric propulsion systems
- Fans, ventilators

Outlook

- Protection of residents from aircraft noise
- Greater social acceptance of air traffic
- Maximisation of the engines aerodynamic efficiency
- Embedded drives for future aircraft concepts
- Electric aviation

Facts and figures

- Up to 10 dB reduction of fan-blade tones emitted from the engine inlets -a noise reduction of 10 dB is equivalent to a 50 % diminished perceived noise level for humans
- The air mass required for the control system corresponds to 0.4 % of the total air volume throughflow of the fan

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

3 GOOD HEALTH AND WELL-BEING

Quiet engine

Active reduction of fan noise by injecting compressed air

At the DLR Institute of Propulsion Technology, an active control system is being developed to minimise engine tones. Using active noise reduction technology, the annoying tones of engine components are suppressed by targeted **superposition of an anti-sound field**. The examined concept is based on the injection of compressed air through nozzles that are integrated evenly distributed into the wall between the rotor and stator. The introduced air excites additionally alternating forces on the trailing edges of the rotor producing the required secondary noise field to actively cancel annoying tones. The functionality of the technology was demonstrated on the Institute's **UHBR (Ultra High Bypass Ratio)** compressor-testing facility under realistic operating conditions. Compressed air was injected through two nozzle rings arranged directly one after the other, allowing two degrees of freedom from the sound field to be controlled simultaneously. Researchers were able to demonstrate a 10-decibel reduction in the dominant components of the rotor-stator interaction tone emitted from the engine inlet. In terms of human perception, this is approximately equivalent to halving the volume level. An optimisation of the nozzle arrangement enabled the air mass required per nozzle to be **minimised by more than half** (compared with the first test series). The air can be extracted from the compressed air system located in the engine.

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Biofuel emissions

DLR/NASA flight tests on biofuel emissions

Brief description

An ion trap mass spectrometer was used on board the NASA DC-8 during the DLR/NASA flight measurement campaign in Germany in January 2018, in order to measure emissions of gases and chemiions during flight in the wake of the DLR A320 ATRA engine.

Aims

Alternative fuels may contribute to the environment-friendly development of aviation. During the NASA/DLR flight tests, several blends of HEFA biofuel and kerosene were used in order to examine the impact on soot formation, as well as the chemical composition and properties of ice crystals in contrails.

Parties involved

DLR Institute of Atmospheric Physics
DLR Institute of Combustion Technology
DLR Flight Experiments
NASA Langley Research Center
NASA Armstrong Flight Research Center

Applications

- Research into emissions from alternative aviation fuels
- Investigation of the relationship between the composition of emissions and the formation and properties of contrails and their environmental impact

Outlook

- Measurements are the foundation for the design of future alternative aviation fuels
- Fuel design focusing on environment-friendly emissions.

Facts and figures

Height: 130 cm
Width: 110 cm
Depth: 72 cm
Weight: 200 kg

Biofuel emissions

DLR/NASA flight tests on biofuel emissions

The **ion trap mass spectrometer** was used during a joint DLR and NASA measurement campaign in January 2018 to examine the emissions and contrails of alternative fuels. HEFA biofuel (Hydroprocessed Esters and Fatty Acids), which is derived from the oil of Camelina plants, was used as an alternative fuel. During the flight tests, which started from the air base in Ramstein/ Rhineland-Palatinate, **DLR's A320 ATRA** used various blends of **biofuel and kerosene**, and **NASA's DC-8** research aircraft measured the emissions and contrails in the wake of ATRA. The DC-8 was equipped with NASA and DLR measurement devices.

The mass spectrometer was used during the flight to **measure gas emissions**, such as sulphur dioxide, and chemiions. The instrument, developed at the DLR Institute of Atmospheric Physics, chemically ionises engine gases with the help of negatively-charged CO_3 ions that are generated in the instrument. The ion-molecule reactions with CO_3 ions generate characteristic products that are analysed using the ion trap mass spectrometer. Already charged molecules in the exhaust stream, so-called chemiions, can be directly measured using the ion trap mass spectrometer. For extremely accurate online calibration, a small amount of isotopically labelled gases are added to the air sample, which are incorporated into the mass spectra as measurement standards. The ion trap mass spectrometer therefore enables extremely accurate measurements with a time resolution of one second.

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CRISPmulti

Counter Rotating Integrated Shrouded Propfan

Brief description

A fan stage with counter-rotating rotors makes aircraft engines more efficient and environment friendly. The shape of the rotor blades increases the aerodynamic efficiency and decreases noise emissions. A reduction in the weight was achieved through the use of fibre-reinforced plastics.

Aims

The intention is to demonstrate the capabilities of the automated engine blade design tool in designing a counter-rotating fan. In addition, researchers want to test an innovative method of manufacturing fan blades from CFRP materials. Another area of focus is the possibility of performing the calculation of the flutter characteristics for a given rotor geometry at a very early stage in the design process. The numerical tools used will be validated by experimental tests.

Parties involved

DLR Institutes of Structures and Design, Propulsion Technology, and Aeroelasticity, together with DLR Systemhaus Technik

Applications

- Engine construction
- Aviation
- Lightweight construction
- Aerodynamics
- Aeroelasticity
- High-performance structures

Outlook

- Next-generation aircraft engines
- Quieter and more efficient flying: reduced noise emissions, lower fuel consumption
- Use of new materials and construction techniques

Facts and figures

- **Project duration:** 2014-2018
- **Original diameter** 1 m
- **Geometry model diameter:** 0.43 m
- **Air-mass flow at design point:** 159.0 kg/s
- **Rotor 1 rotation speed:** 5045 RPM at aerodynamic design point
- **Rotor 2 rotation speed:** 3982 RPM at aerodynamic design point

CRISPmulti

Counter Rotating Integrated Shrouded Propfan

Counter-rotating rotor blades with lightweight construction

In order to make the next generation of aircraft engines more **efficient and environmentally friendly,** the DLR institutes of Structures and Design, Propulsion Technology, and Aeroelasticity, together with DLR Systemhaus Technik, have developed and tested a **counter-rotating fan stage**. The shape of the special rotor blades, which are on display at the DLR stand with a geometry demonstrator, increases their aerodynamic efficiency while reducing noise emissions. The multidisciplinary design takes aerodynamic, aeroelastic, aeroacoustic, structural/mechanical and manufacturing aspects into account. The use of a **new construction method** based on fibre-reinforced plastics also results in a reduction in weight.

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Aerogels

Fresh impetus for lightweight design

Brief description

Aerogels are nanostructured, open porous solids. They are lightweight, have very low thermal conductivity, a large inner surface area, are sound-absorbing and can be equipped with other functions. As such, aerogels can bring fresh impetus to lightweight design. They are notable for their exceptional thermal- and sound-insulation properties.

Aims

To develop technical aerogels with customised properties for specific applications.

Parties involved

DLR Institute of Materials Research

Applications

- Lightweight construction
- Sound insulation
- Thermal insulation
- Efficient battery materials

Outlook

- Thermal insulation material for high temperatures of up to 1000 degrees Celsius
- Selective filter materials for toxic gases, humidity and oxidation-sensitive substances
- Elastic deformation and insulation at low temperatures down to the cryogenic range (20 K)

Facts and figures

- Thermal conductivity below 0.020 W/(m·K)
- Inner surfaces of up to 3000 m²/g
- Application-oriented functionalisation of surfaces
- Low densities from 5 to 150 kg/m³

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

Aerogels

Fresh impetus for lightweight design

Lightweight design with additional functions, such as super heat insulation and extreme sound absorption, is a challenge for materials in ground-based vehicles and aircraft, or in thermal insulation tasks in many industrial high-temperature processes.

Aerogels can offer fresh impetus and new solutions in these areas. They are **nanostructured, open-porous solids** produced using a sol-gel process. All types of aerogels are lightweight, have very low thermal conductivity, a large inner surface area, are sound-absorbing and can be equipped with other functions.

The Aerogels Department at the Institute of Materials Research has been synthesising organic and inorganic aerogels for over 20 years and developing processes for manufacturing them to a pilot scale. **Silica aerogels** are produced for high-temperature applications.

Hybrid and thermoset aerogels, as well as cellulose-, chitin- and chitosan-based biopolymer aerogels are being developed for applications in moderate temperature ranges.

Aerogel materials can be combined to form **new composites**, even with other aerogels.

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MACS-SaR

Modular Aerial Camera System – Search and Rescue

Brief description

MACS-SaR is an innovative camera system for fast, unmanned aerial vehicles for the creation of large-scale, high-resolution and location-specific situation images in real-time. Following natural disasters and large-scale emergencies, MACS-SaR enables the rapid creation of situation maps.

Aims

The camera supplies high-resolution situation images in near real-time, thereby enabling local experts to quickly and thoroughly assess the damage. The resulting situation image maps make orientation significantly easier in the deployment area and help emergency services to reach potential deployment sites more quickly.

Parties involved

DLR Institute of Optical Sensor Systems, DLR Programme Coordination Defence & Security Research, I·S·A·R Germany

Applications

- International disaster relief following natural disasters (e.g. earthquakes)
- National disaster relief for large-scale emergencies (e.g. flooding)
- Operational assistance with safety tasks for authorities and organisations
- Earth observation and remote sensing

Outlook

- Active deployment support from I·S·A·R Germany in the event of a disaster
- Provision of up-to-date overview maps for the United Nations and other rescue teams
- Use of situation image maps for reconstruction work
- Use of data obtained for the training and development of emergency services

Facts and figures

- MACS-SaR is optimised for operation on fast, long-range UAVs ($v > 100$ km/h)
- At an altitude of 300 m, the ground resolution is 5 cm
- An area of up to 20 km² can be mapped per flight.
- Real-time positional accuracy is approx. 2 m

MACS-SaR

Modular Aerial Camera System – Search and Rescue

MACS-SaR is a highly specialised camera system specially developed for **international disaster relief**. When saving people's lives, the first 72 hours are crucial. For the rescue services arriving at the location, an initial, rapid explanation and accurate information about the current situation are therefore essential to coordinate further action. MACS-SaR generates **high-resolution situation images in real-time**, thereby enabling local experts to quickly assess the damage and coordinate the necessary relief efforts.

The use of MACS-SaR on a fast drone makes it possible to explore large areas within minutes. This permits the needs-based creation of up-to-date situation image maps that can be immediately used by the local task forces in the disaster area. The comprehensive aerial overview allows highly affected areas and possible access routes to be identified and emergency services specifically sent to the deployment sites. This **saves valuable time** in rescuing those buried and injured.

MACS-SaR was developed in close cooperation between the Institute of Optical Sensor Systems and the non-profit relief organisation **I·S·A·R Germany** (International Search and Rescue), with which DLR signed a cooperation agreement in November 2016.

In May 2017, MACS-SaR was successfully tested during an international rescue exercise supervised by the United Nations. The first joint deployment by DLR and I·S·A·R took place following the earthquake in Mexico in September 2017. MACS-SaR is currently being adapted to the requirements for the specific application, tested and further developed during regular exercises. The aim is for the DLR technologies to actively support international relief efforts.

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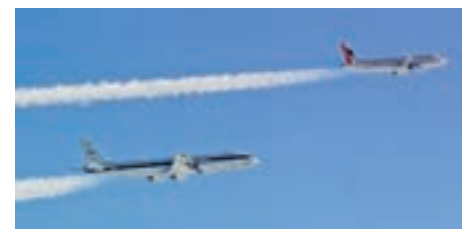
Alternative aviation fuels

Climate impact and emissions

Brief description

Two demonstration burners show the emission characteristics of different aviation fuels. With the naked eye, visitors can easily see the significantly lower soot-forming propensity of synthetic fuels compared to conventional kerosene.



Aims

In the 'ECLIF' (Emission and CLimate Impact of Alternative Fuels) project, DLR is working with NASA and other partners to investigate pollutant emissions and contrail formation at high altitudes using alternative fuels.

Parties involved

DLR Institute of Combustion Technology, DLR Institute of Atmospheric Physics, DLR Flight Experiments facility, NASA Armstrong Flight Research Center

Applications

- Aviation
- Development of designer fuels
- Investigation of particle emissions

Outlook

- Climate impact of aviation
- More sustainable and efficient fuels
- Reduction of aviation emissions
- Resource-saving mobility
- Climate research

Facts and figures

- **Duration:** ECLIF April 2015–September 2018
- **Investigation of the entire impact chain**: from fuel composition to long-lasting cirrus clouds
- **Measurement of engine emissions on the ground and in the air:** 270 tonnes of fuel, Jet A 1 as a reference, four synthetic and three plant-oil-based fuels
- **Fuel design:** ideal fuel with optimum emission properties

Alternative aviation fuels

Climate impact and emissions

Synthetic fuels produced, for example, from **natural gas** (Gas to Liquid, GtL) or **biomass** (Biomass to Liquid, BtL) have great potential for more environment-friendly aviation. Unlike conventional kerosene, the chemical composition of synthetic fuels can be controlled by appropriate manufacturing processes. Regardless of the engine design, this allows **improved combustion properties** and **reduced pollutant formation**. In the 'ECLIF' (Emission and CLimate Impact of alternative Fuels) project, DLR is working with its partners to investigate how the pollutant and contrail formation of such fuels takes place at high altitudes during test flights. At ILA, DLR is demonstrating two burners – one with conventional kerosene and one with GtL-based fuel. Visitors can instantly see the different soot-forming propensity of the two fuels. Due to the considerably reduced number of aromatic hydrocarbons, the GtL fuel produces much less soot than conventional kerosene.

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TORO

TOrque controlled humanoid RObot

Brief description

TORO is a two-legged humanoid robot with torque-controlled drives which allows it to respond to its environment with required sensitivity. It is able to use any combination of arm and leg contact to support itself and move around, even in obstructed environments.

Aims

TORO is used to study fundamental aspects of bipedal locomotion such as robust walking and balance control. Although its body parts are inherently stiff, the robot can be made artificially compliant through closed-loop torque control. This enables it to safely interact with humans and improves robustness in contact with the environment.

Parties involved

DLR Institute of Robotics and Mechatronics

Applications

- Basic research on legged locomotion
- Multi-contact locomotion in obstructed environments
- Exploration
- Transport, collection and delivery services
- Special tasks in manufacturing
- Use in environments dangerous to humans

Outlook

- Cooperative production between robots and humans in industry
- Search and rescue operations in disaster areas
- Care of highly infectious patients (e.g. Ebola)
- Assistance in disabled and elderly care
- Legged walking robot for planetary exploration
- Domestic service robotics

Facts and figures

Height: 174 cm
Weight: 76 kg
Joints: 39
Load capacity: 10 kg
Maximum speed: 0.5 m/s or 1.8 km/h
Battery operating time: 1 h

3 GOOD HEALTH AND WELL-BEING
9 INDUSTRY, INNOVATION AND INFRASTRUCTURE
10 REDUCED INEQUALITIES

TORO

TOrque controlled humanoid RObot

Legged locomotion has a number of advantages compared to wheel-based systems. For instance, a two-legged robot does not require a large footprint and is able to step over obstacles. However, the reduced footprint brings challenges such as gait stabilisation and balance control. The **two-legged humanoid robot TORO** was developed at the DLR Institute of Robotics and Mechatronics. The **torque controlled drive units** adopted from DLR's lightweight arms are among the robot's notable features. It is a key technology that enables safe interaction with humans as well as for robust contact with unknown environments. Balance control using multiple contact points on the arms and legs requires precise control of the contact forces. The methods developed for TORO are general and can also be applied to four- and six-legged robots.

TORO is used within the **EU COMANOID project** to analyse the applicability of **humanoid robots in aircraft assembly**. The project examines tasks that present physical stress for human workers due to a non-ergonomic body posture. In the presented use case, TORO autonomously finds its way through a manufacturing environment and attaches a component to an aircraft fuselage. Whenever necessary, it uses its arms to provide additional support or to reach the required mounting position. The robot's humanoid form allows it to reuse already available tools, environment features – such as stairs – and safely share the environment with humans.

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Simulated worlds

Illustrating photogrammetry for educational purposes

Brief description

A self-built labyrinth of LEGO® bricks is photographed several times from above and a digital terrain model is calculated from the images. When transferred to VR glasses, you can then walk through your very own labyrinth in a shrunken perspective. This experiment is in line with the DLR cross-sectoral topic of digitalisation.

Aims

Through authentic experiments based on actual research, DLR's 13 DLR_School_Labs hope to inspire young people to become interested in the natural sciences and engineering. This experiment has been devised by the DLR_School_Lab Berlin, to give children and young people an insight into photogrammetry – the use of photography in surveying and mapping to ascertain measurements between objects.

Parties involved

DLR Institute of Optical Sensor Systems

Applications

- To promote curiosity and interest in the natural sciences and engineering among children and young people
- Illustration of photogrammetry

Outlook

- Making a contribution to securing and further developing Germany as a research and knowledge-based society, as well as a high-technology location

Facts and figures

- This experiment is one of many in-house developed projects by the 13 DLR_School_Labs in Germany that encourage around 40,000 students every year to pursue careers in the natural sciences and engineering.

4 QUALITY EDUCATION

Simulated worlds

Illustrating photogrammetry for educational purposes

Nowadays, our measurements of the world are digital and highly accurate. High-resolution cameras and other systems supply increasingly precise data about Earth's surface from space or from the air. This involves huge amounts o**f data. One of the tasks in DLR's new cross-sectoral topic of** digitalisation is to reduce these datasets **to the essential information and to visualise them**

A good model for the **contactless measurement** of surfaces is the three-dimensional view our eyes provide of our surroundings. Each eye provides a two-dimensional image, but from a slightly different perspective. By overlapping these two images our brain transforms the information into a spatial perception. Photogrammetry works exactly according to this principle.

Cameras on satellites, aircraft or drones supply images of Earth's surface from different perspectives. If these images clearly overlap and the camera position for each individual shot is known, its location in three-dimensional space can be determined for every pixel. A cloud of points is created that lie on the surface like scattered sprinkles. In order to produce a digital terrain model from this, adjacent points located along the same plane are combined into individual network elements and given a texture from the original shots. The result is a realistic, **digital model of the surface**.

The exhibit teaches students at the **DLR_School_Lab Berlin** the step-by-step process of photogrammetric recording and evaluation. For this purpose, a labyrinth of LEGO® bricks is built and photographed along 'flight strips' from above. Using these images, a computer calculates a digital terrain model, through which the students can walk, wearing VR glasses.

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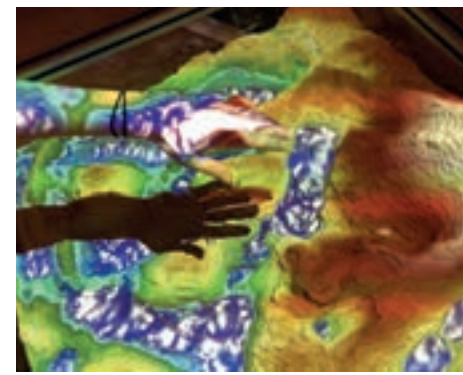
The ‘virtual sandbox’

Visualisation of methods for remote sensing



Brief description

Similar to how satellites image the elevation profile of the Earth or of other celestial bodies, this exhibit records ‘mountains’ and ‘valleys’ in a sandpit and projects the colours representing the highs and lows – as seen in topographical maps – onto the sand in real time. Visitors have the chance to shape a landscape of mountains, craters and lakes themselves.

Aims

Through authentic experiments originating from research, DLR’s 13 DLR_School_Labs are intended to inspire young people to take an interest in science and technology. This demonstration teaches children and young people about remote sensing of Earth and other celestial bodies.

Parties involved

The exhibit was developed by the W.M. Keck Center for Active Visualization in the Earth Sciences (University of California, Davis).

Applications

- Stimulating curiosity and interest in science and technology among children and young people
- Visualising methods for remote sensing
- Demonstrating various geological processes on the surfaces of celestial bodies

Outlook

- Making a contribution to securing and further developing a research and knowledge-based society and the high-tech location Germany

Facts and figures

This exhibit is one of many remarkable experiments conducted by the 13 DLR_School_Labs, which each year encourage approximately 40,000 schoolchildren to take an interest in science and technology.

4 QUALITY EDUCATION

The ‘virtual sandbox’

Visualisation of methods for remote sensing

Various methods are used to measure the surface of Earth or other celestial bodies from space using satellites – for example, in the **TanDEM-X mission**, radar signals are used to create an elevation profile of Earth’s surface. The signal transit times provide information about the topography – high and low areas, mountains and valleys. Other missions for example, use stereo cameras – as is the case of **Mars Express** – or lasers, as in the BepiColombo Mercury Planetary Orbiter. The data is utilised to generate **three-dimensional maps**, among other things.

The information obtained from other celestial bodies allows us to gain a better **understanding of the formation of the Solar System** and more precise conclusions regarding **Earth’s past and future development**. The maps also make it possible to identify scientifically interesting and low-risk landing sites for future space missions, for example to the Moon or Mars.

The benefits of Earth remote sensing are even more obvious. The topographical data can be used, for example, to record the **effects of climate change** on sea levels and to identify flood-prone areas. It can even help **save human lives**. In the event of earthquakes or other natural disasters, the **Center for Satellite Based Crisis Information (ZKI) at DLR** provides special maps for rescue workers and assistance personnel within hours. Generated from a comparison of data from before and after the disaster, they show particularly affected areas and provide rescue workers with important information, for example, about which roads are still usable by vehicles.

The exhibit teaches schoolchildren in several **DLR_School_Labs** about techniques for remote sensing and their benefits. A computer records the surface in a sandpit with a Kinect sensor in precisely the same way that satellites scan Earth’s surface, and projects the colours typical for elevation profiles onto the surface in real time. A key process for remote sensing is thus made tangible for **children and young people.**

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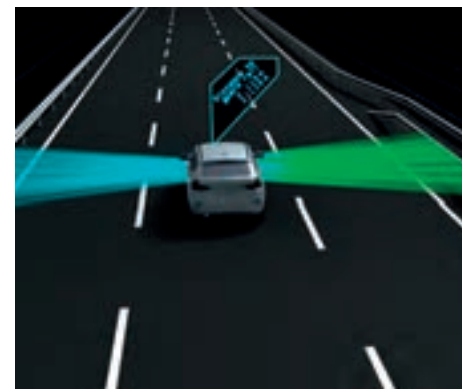
DriveMark®

Accurate road maps for vehicle positioning



Brief description

A video animation explains how novel high-precision street maps needed for driver assistance systems and autonomous vehicles are generated from radar satellite data and aerial imagery.

Aims

Realisation of a method for precise measurement and mapping of road networks and traffic-relevant objects. DriveMark® enables its commercial users to produce digital road maps based on satellite data. These precise maps, together with vehicle on-board sensors, open up new possibilities for monitoring changes along roads by constantly receiving data from the vehicle fleet.

Parties involved

Helmholtz Validation Fund; OEMs and suppliers; Munich University of Applied Sciences, Faculty of Geoinformatics

Applications

- Mapping
- Navigation
- Autonomous driving
- Driver assistance systems

Outlook

- Creation of the next generation of street maps using remote sensing
- Mapping of entire countries across the world without requiring local data acquisition

Facts and figures

- Absolute accuracy of road maps down to 10 centimetres
- Use of appropriate on-board sensors allows the self localisation of a vehicle with a similar accuracy

DriveMark®

Accurate road maps for vehicle positioning

DriveMark® is a completely new method that uses radar satellite data to allow the x, y and z coordinates of **geodetic control points** to be determined with 10-centimetre accuracy. The unique advantages of this method – beyond the excellent precision – are reduced costs, simplified data processing, large area coverage and worldwide availability.

The highly precise image maps produced using the DriveMark® technology form the basis for novel maps created for **highly automated and autonomous driving**. The automated combination of optical imagery with geodetic measurements obtained from **radar satellite** data is particularly innovative. The project included the development of software processors along with validation of the results and geoinformation products. DLR began the DriveMark® project in 2014. It was co-financed by the Helmholtz Association and was successfully completed in September 2017.

The resulting competitive advantages are: high geometric precision; coverage of large areas; worldwide availability; fast, efficient and secure data collection; consistent and comparable data; cross-border and independent of satellite navigation; highly automated processing.

Target user groups are: remote sensing companies; surveying service providers; navigation map providers and mobility services; vehicle manufacturers and automotive suppliers; sensor manufacturers; system integrators.

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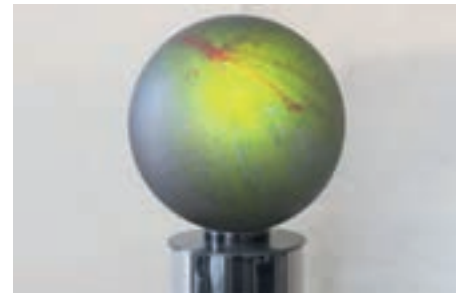
Climate-optimised flying

Visualising global flight paths on a spherical display



Brief description

Visualisation of the results from internal and external research projects. This brings up three research questions in particular: How can climate-optimised flight routes in Europe and over the north Atlantic be planned? How can formation flight in civil aviation increase efficiency worldwide? How are the pollutant emissions of aviation globally distributed?

Aims

The research carried out at DLR deals, among other things, with the development of sustainable aviation. The results shown were studied in the WeCare, REACT4C, ATM4E and FORMIC projects. These projects looked at the potential and feasibility of climate-optimised flying, the cost-benefit analysis of various concepts and technologies for reducing the environmental impact of aviation, as well as the demonstration of the atmospheric effects of air travel.

Parties involved

DLR institutes of Air Transportation Systems, Atmospheric Physics, Flight Guidance, Flight Experiments, Simulations and Software Technology, Propulsion Technology, Airbus Operations, EUROCONTROL, TU Hamburg, TU Delft, RWTH Aachen. REACT4C and ATM4E consortium partners.

Applications

- Understanding of the effects of modified operational measures on the global distribution of flight movements
- Identifying challenges for Air Traffic Management
- Determining the environmental impact of air traffic emissions
- Comparing different options for reducing the negative effects of air traffic

Outlook

- Development and evaluation of promising solutions for efficient and sustainable aviation in the future
- Quantifying technological potentials and devising decision guidelines for policy makers and operators

Facts and figures

Climate-optimised flying: A 25 percent reduction in climate impact (CO_2 and non-CO_2 effects) can be achieved with just a 0.5 percent cost increase.
Nitrogen oxide emissions (forecast): Tripling of nitrogen oxide emissions by 2050 compared to 2015 due to strong increase of air traffic, doubling of the radiative forcing.
Formation flight: Currently being investigated within the FORMIC project

12 RESPONSIBLE CONSUMPTION AND PRODUCTION

13 CLIMATE ACTION

Climate-optimised flying

Visualising global flight paths on a spherical display

The exhibit shows global flight paths and emission distributions on a spherical display. Typically, geo-reference data like this is transposed onto a two-dimensional map using cartographic projections. This is always associated with some level of distortion that makes interpreting the results more difficult. Using a **spherical projection**, information can be mapped onto a spherical surface thus allowing size ratios, distances and angles to be accurately compared.

The results from three different areas of interest are shown:

Climate-optimised flight routes: The concept of climate-optimised flying is based on the idea of flying around regions where there would be a particularly severe effect on the environment and avoiding the formation of contrails and emission of substances (ozone) that are harmful to the environment. The globe shows flight routes over the North Atlantic and in Europe that would **significantly reduce climate impact**.

Formation flight routes: Flying in formation in a similar fashion to migratory birds allows for a significant **reduction in air drag**. This in turn leads to increased fuel efficiency and reduced climate impact. A number of challenges must first be addressed for use in civil aviation. The exhibit shows the places where efficient formation flights could be operated across the globe based on real flight schedules and which airports would be particularly affected.

Distribution of global emissions: Aviation generates greenhouse gas emissions that have a particularly severe effect on the climate due to the typical altitude at which aircraft operate. In order **to quantify this effect**, atmospheric researchers use emission inventories that contain the global distribution of the individual type of emission. The globe shows, among others, surveys of nitrogen oxide emissions that also contain future projections of how the levels will change up to the year 2050.

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H²LED

HLFC HTP Leading Edge Demo

Brief description

H²LED demonstrates the cost-effective realisation of a horizontal tailplane leading edge with an integrated suction system. This ensures laminar flow and the associated drag reduction achieves a significant reduction in kerosene consumption.

Aims

Construction of a simplified but almost production-ready prototype structure. Development of a process for the bonding of the support structure (carbon fibre reinforced polymer) and the outer skin (titanium sheet). Development of cost-effective concepts for manufacturing the horizontal tailplane leading edge with an integral suction system. Development of concepts for the automation of mass production. Enabling certification by finding solutions for still open issues.

Parties involved

EU Joint Undertaking Clean Sky 2, Airbus Industries, Aernnova (Spain), DLR institutes: AE, AS, BT, FA, FT, MO

Applications

- Risk analysis for production and system integration
- Investment estimate for mass production
- 'Door opener' application with key airlines

Outlook

- Transfer of the concept of reducing kerosene consumption by ensuring laminar flow on the vertical stabiliser and wings
- Fast market introduction through constructive handling of risks and costs
- Sustainable air transport
- Establishment of adhesive technology for functional structures

Facts and figures

- The dimension of the demonstrator was chosen on the basis of the horizontal tailplane of the Airbus A350
- It is planned to develop the concept up to flight test readiness
- Each flight would save about 250 kilograms of kerosene

H²LED

HLFC HTP Leading Edge Demo

Horizontal stabiliser leading edge with integrated extraction

New commercial aircraft need to use even less kerosene. This can be achieved by low-drag laminar flow. Achieving laminar flow even at high airspeeds requires the combination of a laminar flow wing body with a leading edge that controls the flow using suction to keep the airflow laminar. This combination is called a **Hybrid Laminar Flow Control** (HLFC) wing.

Although the physics of laminar flow is well understood and predictable, its introduction into production aircraft has not occurred due to the complexity of the systems required for an HLFC wing. As part of the EU / **Horizon 2020 / CleanSky 2** initiative, a consortium of **Airbus**, the Spanish supplier **Aernnova**, and **DLR** has been formed with the aim of implementing a mass-producible HLFC horizontal tailplane.

The aim is to find a **compromise between low production costs and weight, as well as aerodynamic efficiency**, in a project supported by the EU and led by Airbus that will present a business case for the design. The **system components** (for example, **pumps and pipelines**) must also be implemented in compliance with aviation certification requirements.

Despite the high standards and tight constraints, an implementation strategy was developed that proved to be promising in all aspects. The integration of innovative pumps and the **combination of the structure** with the **necessary control systems for extraction** through the **microporous erosion protection layer** were the keys to success. With the H²LED structural and functional demonstrator, numerous uncertainties in the design could be eliminated. This has led to a horizontal tailplane leading edge that can be mounted on an Airbus A350.

The transfer of this concept to the wings within the EU / Horizon 2020 / CleanSky 2 initiative has begun, because a laminar flow wing can achieve much greater kerosene savings.

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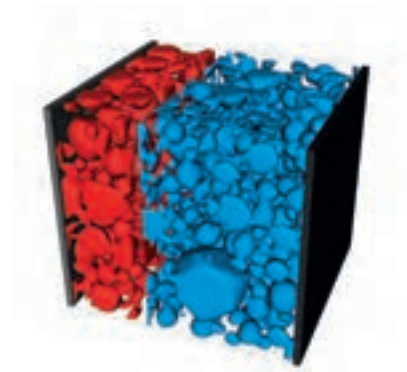
DLRbat

Reliable batteries for satellites



Brief overview

In the 'DLRbat' project, fundamental researchers and satellite developers are working closely together to get reliable satellite batteries into space more quickly and cheaply. The researchers' studies of a battery's inner functioning also provides the developers with information about how a battery module should be constructed.

Aims

The aim of this DLR project is the development of reliable batteries for satellites. On Earth, the findings will also help with the design of more efficient and higher capacity batteries for electric vehicles and electric aircraft, as well as for storage needed in connection with renewable energy sources such as photovoltaic cells and wind turbines.

Parties involved

DLR Institute of Engineering Thermodynamics, DLR Institute of Composite Structures and Adaptive Systems, DLR Institute of System Dynamics and Control, DLR Institute of Optical Sensor Systems, DLR Institute of Space Systems

Applications

- Satellite technology
- Battery systems for space
- Electric vehicles
- Electric aircraft
- Static energy storage

Outlook

- Virtual development
- Sustainable energy systems
- Electric mobility on the ground and in the air
- Next-generation batteries and the generation beyond that

Facts and figures

- 2019: planned launch on the DLR S2TEP satellite
- Cooperation of five DLR Institutes
- **Project duration**: three years

DLRbat

Reliable batteries for satellites

Studying a modern battery's internal functioning

The aim of the 'DLRbat' project is to develop reliable satellite batteries. What is unique is that fundamental researchers are working closely with satellite developers to get reliable satellite batteries into space more **quickly and cheaply**. Five DLR institutes are collaborating, each contributing their specialist expertise. The Institute of Engineering Thermodynamics is developing the **control electronics** and simulating the **battery's internal functioning**, in order to give the developers important information about its capacity. The Institute of Composite Structures and Adaptive Systems is developing an extremely lightweight yet mechanically stable **battery structure.** The Institute of System Dynamics and Control is simulating the battery's behaviour on the spacecraft, while the Institute of Optical Sensor Systems is researching how very **high power delivery** can be enabled on the satellite for short periods. The Institute of Space Systems is testing whether the battery can withstand the **intense vibrations** it will experience during launch and the conditions in the **vacuum** of space.

The battery will be carried on DLR's **Small Satellite Technology Experiment Platform (S2TEP)**, scheduled for launch in 2019, and demonstrate its performance in orbit. In future, reliable satellite batteries with the **latest battery technology** (such as lithium-sulphur) can then be used without having to undergo a number of lengthy, expensive tests. The findings will play a major role not only in space, but also on Earth. The knowledge gained will help to develop higher-capacity batteries for electric vehicles and electric aircraft, as well as for the static storage needed in connection with renewable energy sources such as photovoltaic cells and wind turbines.

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UFO

Unmanned Freight Operations

Brief description

The importance and use of unmanned freight aircraft are steadily growing. In future, freight aircraft could increasingly be controlled from the ground. DLR's Unmanned Freight Operations (UFO) project has developed solutions for integrating these aircraft into the existing air transport system, which could feasibly be implemented in the foreseeable future. An example of this is presented in this video.

Aims

The aim of the research project was to develop concrete solutions for air traffic controllers and pilots in order to integrate unmanned freighters into conventional controlled airspace.

Parties involved

DLR Institute of Flight Guidance, DLR Institute of Flight Systems, DLR Institute of Communications and Navigation, DLR Institute of Aerospace Medicine, DLR Air Transportation Systems

Applications

- Corporate transport
- Long-haul freight transport
- Aid transport

Outlook

- More flexible working hours for pilots
- More balanced distribution of pilots' workload
- Extended flight times
- Reduced kerosene consumption

Facts and figures

- DLR internal project
- **Duration**: 2014–2017
- **Funding**: institutional funding

UFO

Unmanned Freight Operations

The DLR institutes of Flight Guidance, Flight Systems, Communications and Navigation and Aerospace Medicine, along with DLR Air Transportation Systems, present the UFO (Unmanned Freight Operations) project in this video. Under the direction of the Institute of Flight Guidance, the project accepted one of the key challenges for the operation of **unmanned freight aircraft**: to integrate these into existing, **conventional air traffic**. They therefore developed specific solutions for the airspace managed by air traffic control. This resulted in **three different scenarios** for which researchers then developed and validated new support systems, processes and technologies for air traffic controllers and pilots.

These three scenarios include **freight transport** between two manufacturing sites, **long-haul freight transport**, and the **transport of aid supplies**. These three examples primarily differ in terms of the size of aircraft used and the distances covered. In addition to the technical challenges of communications, navigation and surveillance, along with the monitoring of the condition of the unmanned aircraft, the investigation also considered human-machine interaction. The researchers developed ideas to assist pilots and air traffic controllers.

The project has demonstrated that unmanned long-haul freight transport is generally possible in technical and organisational terms. Until the actual implementation of unmanned freight flights, however, many open questions remain, such as determining responsibilities for activities that pilots have thus far performed on site, or clarifying the security of the communications data link. But their use would then be feasible in the foreseeable future.

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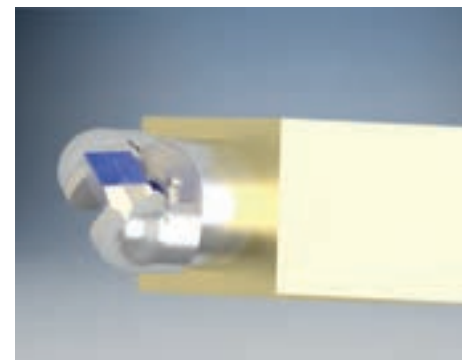
OSIRIS

Optical Space Infrared Downlink System



Brief description

OSIRIS is an experimental optical communication system that has been specially optimised for small satellites. The third generation OSIRIS achieves data rates of 10 Gbps and will be installed on the Bartolomeo platform outside the Columbus module of the International Space Station in 2019.

Aims

OSIRIS is intended to demonstrate the practical application of optical satellite downlinks. An important part of the project is the implementation of a scientific measurement campaign to characterise the transmission channel and optimise the transmission methods used.

Parties involved

DLR Institute of Communications and Navigation, Airbus DS, Tesat-Spacecom

Applications

- Earth observation
- Scientific satellite missions
- Networking of satellite constellations
- Transmitting large amounts of data from A to B – on Earth, in the air and in space

Outlook

- Near-real-time provision of Earth observation data
- Digitalisation – Internet access via satellite, based on laser technology
- Industry 4.0 – large-scale networking for the 'Internet of Things'

Facts and figures

Data rate: 10 Gbps
Power consumption: 50 W
Weight: 5 kg
Integrated storage: 1 TB

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

OSIRIS

Optical Space Infrared Downlink System

The resolution of the cameras and other sensors on Earth observation satellites is steadily increasing. This leads to ever-larger amounts of data that are currently transmitted to Earth via radio systems, which achieve data rates of up to approximately one Gbps. The data link between a satellite and Earth often represents a bottleneck when it comes to increasing the amount of data acquired by satellites.

Optical communications systems are the only way to **significantly increase data rates.** They are also smaller, lighter and require less power than comparable radio systems. The optical communications system on DLR's BIROS satellite weighs just 1.64 kilograms and already enables a data rate of one Gbps. Together with its partner, **Tesat-Spacecom**, DLR is also developing an **optical data transmission system** that, with a weight of just 300 grams, is even suitable for CubeSats.

The DLR Institute of Communications and Navigation conducts research in various areas of optical data transmission for satellite applications. The aim is to be able to use this pioneering technology in a reliable and cost-effective manner. According to the current plan, DLR will develop, certify and launch six OSIRIS models by 2019.

The third OSIRIS generation, OSIRISv3 for short, is currently under development and will be installed in 2019 on the **Bartolomeo platform** being developed by Airbus. Bartolomeo is an external payload platform that will be installed on the Columbus module of the International Space Station (ISS). OSIRISv3 will enable data rates of **10 Gbps** between the ISS and Earth and will be the basis for conducting extensive measurements to **characterise atmospheric influences** on the transmission path. The scientific measurement data will be used to optimise the transmission methods employed and ensure stable data transmission.

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Prometheus

Air-to-air refuelling/automatic catch basket

Brief description

Prometheus is an unmanned, experimental research aircraft, equipped with sensor technologies that enable automatic approach and coupling to other aircraft in flight.

Aims

Prometheus allows complex scenarios and manoeuvres to be trialled without endangering pilots. The flying apparatus enables automatic air-to-air refuelling and the automatic capture and towing of flying objects.

Parties involved

DLR Institute of Aerodynamics and Flow Technology, Institute of Composite Structures and Adaptive Systems, Institute of Flight Systems, and Institute of Space Systems

Applications

- Increasing the range and flying time of unmanned aircraft due to in-air refuelling
- Testing the principles of returning space transport systems, such as reusable rocket boosters

Outlook

- Extension to electric drives and charging processes
- Ad-hoc towing scenarios
- Ensuring that loads from space land gently

Facts and figures

- **Description:** Prometheus
- **Type:** UAS/drone
- **Take-off weight:** 30 kg
- **Flight time:** up to 1 h
- **Speed:** up to 160 km/h
- **Flying altitude:** 300 m
- **Payload:** 5 kg

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

Prometheus

Air-to-air refuelling/automatic catch basket

Unmanned research aircraft with coupling unit

Prometheus is a **research and experimental vehicle** that has already been used for five years to develop forward-looking functions for unmanned and automated flying. The focus is on manoeuvres and missions that require highly dynamic responses to unknown or highly variable environmental conditions, such as **collision avoidance** or **automated low-level flight** over unexplored terrain.

The latter category also includes the in-air coupling of two unmanned flying vehicles using an active catch basket. In this case, the receiver aircraft – the Prometheus – automatically flies in close formation with the aircraft in front. A connection then has to be established with the catch basket dragged by the Prometheus, while the relative position to the front aircraft has to be maintained exactly during the coupling process. In order to ensure that the execution of the manoeuvre depends as little as possible on the technical equipment of the preceding or receiving aircraft, DLR has developed a way of transferring part of the required technology to an **automatic coupling unit** located at the end of the tow rope. This allows the catch basket to be actively controlled and operated. The intelligent coupling unit has many attributes of a **conventional unmanned aircraft**, as an autopilot system uses visual information, for instance, to head for aerodynamically effective control surfaces in order to reduce its distance and relative speed in relation to the receiver aircraft.

The applications of this technology include air-to-air refuelling. It is conceivable that the pilot could be supported up to and including a **fully automated refuelling process**, as the hose locates the tank nozzle on the aircraft automatically.

Similarly, the technology can also be used to capture **rocket booster stages** by means of powerful unmanned towplanes, and returning them to Earth undamaged for further use.

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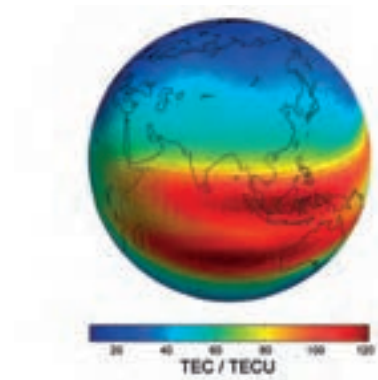
IMPC

Ionosphere Monitoring and Prediction Center



Brief description

DLR's IMPC is a space weather observation, forecasting and warning centre for industry, government, science and interested laymen. Using ground- and space-based GNSS data, it is possible to make statements about solar activity and the current state of the ionosphere.

Aims

At the IMPC, experts collect real-time information about the state of the ionosphere, in order to predict disturbances caused by space weather events, such as solar storms. Accurate forecasting provides users of navigation and communications systems with timely information. Damage caused by interference to communications and satellite navigation can be minimised.

Parties involved

DLR Institute of Communications and Navigation, DLR Technology Marketing, ESA

Applications

- Security of communications and navigation systems
- Ionospheric research
- Real-time space weather observation
- Support for GNSS services
- Contribution to ESA's Space Situational Awareness programme

Outlook

- Development of a global space weather service to support aviation
- Commercialisation of high-resolution, global ionosphere data
- Accurate forecasting of disturbances in the ionosphere
- Ionospheric modelling

Facts and figures

- **Start:** March 2015
- **Funding:** DLR
- **Area:** ionospheric monitoring and forecasting
- **Website:** impc.dlr.de
- **Ionospheric maps (database):** approx. 800 GNSS ground stations

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

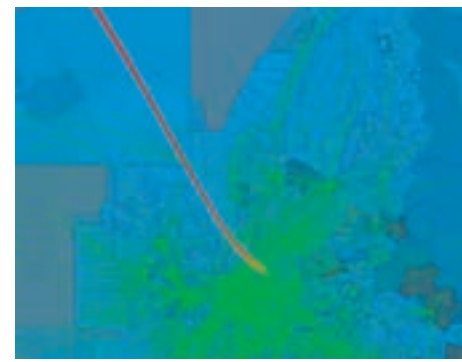
IMPC

Ionosphere Monitoring and Prediction Center

The IMPC is the permanent **ionosphere weather service** at DLR's Neustrelitz site, where experts conduct research into the causes and effects of space weather and provide specific information about the current **state of the ionosphere**. Solar storms and solar flares can lead to disturbances that damage technical systems in Earth orbit. Depending on the severity of these events they may result in the failure of global navigation and communications systems such as radio communications for civil aviation. Extremely heavy geo-magnetic storms may also cause power outages. The accurate forecasting of such eruptions is not currently possible, as the physical relationships that lead to their occurrence are still not fully understood. In order to determine whether and how strongly a solar storm will affect Earth and what can be done about this, DLR scientists use **ground- and space-based GNSS data (Global Navigation Satellite System)** from extensive geodetic reference networks such as IGS and from satellite missions such as GRACE. The IMPC publishes this real-time information, forecasts and warnings about the state of the ionosphere **on its website: impc.dlr.de**. In this way, users are able to find out to what extent ionospheric interference is currently affecting their systems. The IMPC's predecessor was the SWACI (Space Weather Application Centre Ionosphere) pilot project, a real-time data centre for ionospheric weather, funded by the Ministry of Education, Science and Culture of Mecklenburg-Western Pomerania. At the end of the project, SWACI was transferred to the IMPC with the help of DLR Technology Marketing. Europe's only receiving station of the global real-time solar wind observation network is connected to the IMPC. A **space weather centre to support aviation** as part of a European consortium is planned.

Spaceplanes

Space Traffic Management and Space Port Management in Europe



Brief description

Spaceplanes – aircraft that reach their destination on earth through space – are a conceivable addition to future aviation. They will fly through airspace and land at airports. Operational scenarios are already now being investigated and evaluated in Germany and elsewhere in Europe, including the identification of possible landing sites (spaceports).

Aims

Development of solutions and assessments for the safe integration of spaceplanes into the European air transport system, and for associated joint traffic with other aircraft, as well as for adapted landing procedures and possible spaceports.

Parties involved

DLR Institute of Flight Guidance

Applications

- Innovative concepts for airspace management
- Rapid space access for communications technology, remote sensing and microgravity experiments in the fields of biology, medicine and materials science

Outlook

- Rapid, independent access to space for Germany and the rest of Europe
- New business models in commercial space travel
- Promotion of space-based digitalisation (data networks)
- Promotion of Germany as a location for small and medium-sized enterprises (SMEs)

Facts and figures

- Development environment for spaceplane trajectories
- Evaluation in the Air Traffic Validation Center (including fast-time and real-time simulations)
- Development of a tool for access to the Single European Sky and the international exchange of flight data

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

Spaceplanes

Space Traffic Management and Space Port Management in Europe

In future, spaceplanes will join the **air transport system**, flying into space at **supersonic speeds** and returning inertly to earth for landing. Potentially, these innovative combined air- and spacecraft will soon be able to take off and land at **'spaceports'** in Germany or elsewhere in Europe. This additional mode of transport represents an opportunity for promoting Germany as an industry location, but may also affect air traffic. As such, DLR is already investigating how this aviation system of the future can be integrated effectively here. This involves the **selection and assessment** of potential spaceports and **airspace management** to ensure safe take-offs and landings that will not affect other air traffic. Likewise, systems are being developed to allow the **'Single European Sky'** to be integrated into an international framework and in the US **'NextGen'** airspace.

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LNAS

Low Noise Augmentation System

Brief description

The LNAS pilot assistance system shows the pilot the necessary setting and control requirements for a noise-optimised approach. During the approach, these are continuously adjusted to the changing boundary conditions (such as wind speeds and instructions from air traffic control) and displayed via the Electronic Flight Bag (EFB).

Aims

The aim of the LNAS is an energy-efficient descent from cruising altitude to landing. Fuel consumption should also be reduced as a result of the minimum demand for thrust during the approach. Using the LNAS, the aircraft is configured as close to the runway as possible (flaps, landing gear), in order to minimise drag for as long as possible. Noise emissions are minimised. Furthermore, the probability of a go-around can be reduced thanks to energetic anticipation.

Parties involved

DLR Institute of Flight Systems, DLR Technology Marketing in cooperation with UNH, Fraport, DFS and Lufthansa

Applications

- Pilot assistance
- Noise reduction
- Fuel saving
- Increased efficiency
- Flight management
- Improved situational awareness

Outlook

- Long-term testing of the LNAS assistance system in aircraft operated by a major German airline
- Long-term testing during regular day-to-day operations in cooperation with airport operators and authorities

Facts and figures

- 74 approaches during 25 flight hours successfully completed with the DLR research aircraft, A320 D-ATRA, at Frankfurt Airport
- Fuel saving of 10–15 % over the final 28 NM before landing
- Noise reduction potential demonstrated by moving aircraft configuration points towards the runway

3 GOOD HEALTH AND WELL-BEING

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

13 CLIMATE ACTION

LNAS

Low Noise Augmentation System

Pilot assistance system for noise-optimised, fuel-saving approaches

Landing is one of the most labour-intensive flight phases. In order to help pilots with the complex handling procedures for a low-noise approach, DLR has developed the LNAS (Low Noise Augmentation System) pilot assistance system. This system shows the pilot exactly when to perform which pilot action via an energy-based **display** in the cockpit. This display on the Electronic Flight Bag (EFB), which can be intuitively and instantly grasped, thanks to its simple representation, is used as the **long-term planning basis** for the entire approach. The optimal approach profile is divided into different phases. The optimum times for setting the flaps and extending the landing gear are each marked in the approach profile. If the pilot follows these instructions, the approach can be implemented from cruising altitude to the stabilisation height of 1000 feet above ground level with minimum thrust, and therefore the **lowest possible noise development** and **lowest possible fuel consumption**.

In 2016, the LNAS pilot assistance system successfully completed initial flight tests during everyday peak-time operation at **Frankfurt Airport.** A total of 74 approaches were implemented on board the DLR A320 ATRA (Advanced Technology Research Aircraft) in five test series. The assistance system was of great help to the pilots, especially in difficult situations, such as strong tailwinds or speed limits from air traffic control. In the next step, the assistance system will be integrated into the aircraft of a major airline at Frankfurt Airport and tested during regular day-to-day operations. The LNAS project is funded by Umwelt- und Nachbarschafthaus (UNH) in Kelsterbach and DLR Technology Marketing.

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SHM

Structural Health Monitoring

Brief description

Carbon fibre reinforced polymers (CFRPs) are increasibly being used to make aircraft lighter and to improve their comfort and efficiency. To facilitate maintenance and improve safety, a fuselage shell made of CFRP that provides information on the extent and location of damage was developed as part of the EU SARISTU project (Smart Intelligent Airframe Structures).

Aims

Structural Health Monitoring (SHM) enables the detection and localisation of damage. One of the benefits is that it will no longer be necessary to disassemble a defective part and subject it to extensive testing. Maintenance and repairs are simplified in this way, and no damage remains undetected, thus improving safety and reducing costs.

Parties involved

DLR Institute of Composite Structures and Adaptive Systems, Airbus, Invent, FACC

Applications

- Structural monitoring of safety-critical components
- Early detection and assessment of damage
- Network with structurally integrated sensors
- Maintenance on demand

Outlook

- Improvement in safety, as damage does not go undetected
- Increase in aircraft availability, as damage can be assessed directly
- Lighter structures, as excessive safety factors can be dispensed with

Facts and figures

Number of sensors: 584
Size: Full-scale (5 x 7 m)
Project runtime: 2011–2015

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

SHM

Structural Health Monitoring

Carbon fibre reinforced polymers (CFRPs) are increasingly being used in aircraft. In order to make these aircraft even safer, the DLR Institute of Composite Structures and Adaptive Systems is researching technologies that can provide information on the extent and location of damage. Structural Health Monitoring (SHM) involves equipping the CFRP component with sensors that act like a **nervous system**. Here, the sensors are not glued to the surface, but have been integrated directly into the material, thereby **reducing manufacturing costs**. If an aircraft sustains any damage due to an impact during loading, for example, in future there will be no need to call a technician to detect the damage. The structure provides information on the location of the damage and whether repairs are necessary at the push of a button. The structure surrounding the door was chosen because this is where damage is most likely to occur. DLR has developed a sensor network that is robust enough to survive the manufacturing process. Current research is now focusing on making the SHM system operationally ready for in-flight use under real conditions in order to turn the vision of a **sensory aircraft** into reality.

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VR HubSim

Virtual reality helicopter simulator with active control loading components

Brief description

VR HubSim is a simulation platform with active helicopter controls. The environment is not displayed using conventional screens or projectors – the pilot instead wears virtual reality glasses. By measuring the head position, the pilot can look around freely and have the appropriate stereo image displayed in the glasses.

Aims

The virtual reality helicopter simulator expands DLR's existing cockpit simulator portfolio (motion simulator, fixed-base simulator, etc.). Since most of the cockpit environment is virtual, the setup can be modified easily and more quickly than with conventional cockpit simulators. This flexibility makes it ideal for conducting research into novel cockpit display concepts.

Parties involved

DLR Institute of Flight Guidance,
DLR Institute of Flight Systems,
BRUNNER Elektronik AG

Applications

- Simulation environment for evaluating cockpit display concepts (rapid prototyping)
- Evaluation of human factors
- Procedure training
- Development of future cockpit concepts based on head-worn display systems (e.g. 'Virtual Cockpit')

Outlook

- Low-cost flight simulator
- Cockpit of the future
- Remote control station

Facts and figures

- **Demonstrated display:** Virtual cockpit instruments and synthetic 360° view from different perspectives
- **Operation:** Active helicopter control loading system (BRUNNER Elektronik AG)
- **Flight simulation:** DLR's own, highly stabilised helicopter command model
- **Display system:** Oculus Rift CV1 VR glasses

VR HubSim

Virtual reality helicopter simulator with active control loading components

The DLR Institute of Flight Guidance has developed and operates several cockpit simulators for the purposes of demonstrating and evaluating new flight control technologies. This includes, for example, a **virtual reality helicopter simulator**, a fixed-base cockpit simulator where the cockpit and surrounding environment is displayed via head-worn virtual reality glasses. This allows researchers to **simulate different existing helicopter types**, as well as display and test their own newly developed flight deck layouts.

Just like a conventional helicopter, the simulator is flown using three control elements: cyclic stick, collective and pedals. These are active control components. Integrated motors generate precise force feedback to give the pilot a **realistic impression of the controls**. The flight simulation itself is powered either by the commercial simulation software X-Plane 10 or by DLR's own helicopter flight model including novel flight control systems.

The use of virtual reality technology brings numerous advantages. On the one hand, the VR glasses provide a very wide field of view, and on the other, the tracking of head movements provides the ability to freely look around the virtual environment. This gives the test subjects a very realistic impression of their surroundings. A virtual cockpit environment gives researchers a **high amount of freedom for designing human machine interfaces**. Flexible test environments like this are particularly important during the early development phases for comparing different configurations in a shorter time and as realistically as possible.

The research primarily involves real-time simulations using human subjects for evaluating **new display and operating concepts**. In collaboration with pilots, novel operational methods and procedures that may be useful with the future use of new technologies are also being developed and investigated.

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Volcano ash test stand

Interaction with engine components

Brief description

Ash particle deposits can damage the ceramic thermal barrier coatings on turbine blades and other components due to the high operating temperatures in aircraft engines. Research is aimed at reducing this significant risk for aviation.

Aims

The objective is to gain an understanding of the damage caused by volcanic ash and how it affects the engine.

Parties involved

DLR, Laboratory for Environmental Measurement Techniques at the Düsseldorf University of Applied Sciences, Hammer Engines GmbH. The work is integrated within the VolcATS project (Volcanic Ash Impact on the Air Transport System), in which six DLR institutes are researching the issue of how volcanic ash affects aviation.

Applications

Test of coatings for turbine blades

Outlook

Improved understanding of the risks presented by dust and volcanic ash in aircraft engines

Facts and figures

Thrust: 15 kg at 120.000 rpm
Weight: 1.595 g
Diameter: 112 mm
Speed: 33.000–120.000 rpm
Exhaust gas temperature: 650 °C–750 °C
Fuel: 420 g/min Jet A1/Shell V-Power, Aral Ultimate Diesel, petroleum or kerosene
Maintenance interval: 50 h

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

Volcano ash test stand

Interaction with engine components

When the Icelandic volcano Eyjafjallajökull erupted in 2010 and its ash cloud significantly obstructed air transport in Europe, it became clear that extensive in-depth research is required to gain a precise understanding of the mechanisms at play when ash enters an aircraft engine – as realistically as possible. A test rig has been available since 2015 to conduct these types of investigations and to accurately simulate the **effects of volcanic ash on aircraft engines**. The test rig was developed and built in a collaborative research project conducted by DLR, the Laboratory for Environmental Measurement Techniques at the Düsseldorf University of Applied Sciences, and the company Hammer Engines GmbH.

To conduct the tests, the researchers mix volcanic ash with air and let this mixture be sucked into a miniature turbine. Molten volcanic particles can be identified in the exhaust stream exiting the turbine, confirming that the test rig is able to replicate the reaction between the components and volcanic ash in flight operations. This allows the DLR scientists to analyse precisely how the size, concentration and composition of volcanic ash particles affect the **adhesive mechanisms.** The experiments provide information on the interactions with the engine components and on which **chemical reactions** take place during operation. This enables the researchers to understand exactly how the damage is caused in the jet engine. They intend to use the findings to produce better assessments of the critical levels of volcanic ash concentration in the air, how much damage aircraft engines can take and how this will reduce their service life.

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ALAADy

Automated Low Altitude Air Delivery

Brief description

The concept of mission-based flight clearance for unmanned aerial vehicles aims to achieve a balance between the necessary safety and economic operation of drones. The ALAADy project evaluates concepts and builds demonstrators for low-altitude freight transport. Presented here is the small 45 kg demonstrator.

Aims

ALAADy demonstrates and evaluates unmanned aviation technologies. Operating concepts and cost models can be developed and risks identified, assessed and managed. With ALAADy, DLR supports authorities in the development of secure framework conditions.

Parties involved

Scientists from various DLR institutes and facilities (FT, FL, LK, FW, KN, TT, AE, FX)

Applications

- Air transport
- System design
- Flight route planning
- Data fusion
- Risk management and flight termination
- Flight control and flight performance
- Airborne experiments
- Artificial Intelligence

Outlook

- Safe, cost-effective, viable, compatible and integrated automated air transport in civilian airspace

Facts and figures

- **Designation**: Air Cargo Gyrocopter (ACG)
- **Type**: UAS/drone
- **Take-off weight**: up to 45 kg
- **Flight time**: up to 20 minutes
- **Speed**: up to 100 km/h
- **Altitude**: below 500 ft (planned)
- **Payload**: up to 15 kg
- **Maiden flight**: 2017

ALAADy

Automated Low Altitude Air Delivery

Technology demonstration – unmanned freight transport

The **ALAADy** and **ALAADy Demonstrator** projects launched in 2016 examine the theoretical and practical aspects of **automated and unmanned air transport**. For this purpose, the ideal aircraft configurations for automated airfreight transport were initially determined through the evaluation of fixed- and rotary-wing aircraft with regard to their flight performance and characteristics.

To **implement a 'transport drone'** as a technology demonstrator, particular attention was placed on safety aspects, operational boundary conditions, system architecture and the necessary capabilities. Gyrocopters have the particular advantage of being inherently safe, as their freely rotating rotor enables a soft landing in case of failure, just like a parachute.

To demonstrate various **aspects of automated air transport**, DLR test aircraft are equipped and/or modified and tested in flight. A scaled demonstrator called Air Cargo Gyrocopter (ACG), weighing approximately 45 kilograms, is being used to understand the flight characteristics of such configurations. The 450-kilogram Air Dolly (ADO) gyrocopter, based on AutoGyro GmbH's MTOfree, is intended to demonstrate the transport of cargo weighing up to 200 kilograms. New automated flight control functions are also being developed for all the gyrocopter's flight phases, such as take-off, cruising, landing and taxiing. Integration into a simple logistics chain, operation-centric risk assessment, the automated surveillance of the system status by a safety monitor and the safe termination of the flight in case of failure are other project objectives. The findings from the project will lay an essential foundation for the safe, affordable operation of unmanned aerial vehicles outside restricted areas.

In this context, DLR is a **neutral pioneer of civilian research** in unmanned aviation.

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A320-ATRA functional model

Airflow optimisation to reduce fuel consumption

Brief description

In order to illustrate the diverse missions of DLR's largest research aircraft, the A320-232 'D-ATRA', a highly detailed technical scale replica of the ATRA has been produced using almost 400 exchangeable individual components. The model is currently demonstrating two innovative technologies being investigated at DLR – using a vertical stabiliser with an extraction system and active flow control at the UHBR engine-wing transition.

Aims

Measurement and test fittings can be flexibly added to the model in order to demonstrate the use of the ATRA platform across various disciplines. The technologies currently shown on the vertical stabiliser and wing-engine transition serve to optimise airflow and reduce fuel consumption.

Parties involved

DLR and project partners,
RPT – Rapid Prototyping Technology GmbH Gifhorn

Applications

- Aerodynamics
- Aeroelastics
- Cabin research, acoustics, climate
- Flight systems technology
- Flight control
- Communications, navigation
- Combustion technology, atmospheric research

Outlook

- Demonstration of advanced aeronautics research topics using the ATRA functional model
- Transfer of research findings/ technologies from the various application areas to future aircraft generations

Facts and figures

- **Individual components:** 395
- **Production processes:** 9
- **Main materials:** 5
- **Scale:** 1:13,6
- **Length:** 2.77 m
- **Span:** 2.50 m
- **Height:** 0.90 m
- **Weight:** 97 kg
- **Paintwork:** same as ATRA/DLR design

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13 CLIMATE ACTION

A320-ATRA functional model

Airflow optimisation to reduce fuel consumption

Given the increasing volume of air traffic, reducing fuel consumption and pollutant emissions is a primary objective of European aeronautics research. Aerodynamics with **active flow control** technologies makes a significant contribution to these objectives. This topic is being researched and investigated using the largest aircraft in the DLR research fleet – the Advanced Technology Research Aircraft A320-ATRA. As part of DLR and EU projects, it is used as an **experimental platform** for researching the **engine-wing transition** and the **empennage**, among other things. This research work is illustrated on a highly-detailed technical model of the ATRA – a modular functional model consisting of 400 exchangeable individual components.

In its current configuration, a vertical stabiliser with a simplified extraction system provides insight into **Hybrid Laminar Flow Control (HLFC)** research on the almost three-metre-long exhibit. Using HLFC technology, part of the airflow is sucked through tiny holes in the outer skin of the aircraft, to ensure that the flow close to the surface remains laminar – that is, low-drag. The extraction system is currently undergoing test flights as part of the **EU AFLoNext project**.

Additionally, an **Ultra High Bypass Ratio (UHBR) engine** has been integrated into the model. While such an extremely efficient engine is in itself more economical and environment-friendly, due to its size it influences the airflow around the wing, thereby reducing the engine's benefits. By blowing compressed air through fine double slots on the leading edge of the wing, the flow can be positively affected, thereby reducing losses that are a result of the engine mounting. This active flow control technology was tested last year in one of the world's largest wind tunnels, the TsAGI T 101, and is being further developed for flight testing as part of the EU Clean Sky 2 project.

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ACARE – EREA – ESRE

Guest - European aeronautics and space associations

Advisory Council for Aviation Research and Innovation in Europe (ACARE)
In 2000, under the leadership of the former EU Commissioner for Research, a Group of Personalities came together as part of 'Vision 2020' to define targets for European aeronautics research up to the year 2020. To realise this vision, ACARE was founded in 2001 as a forum for all aeronautical research stakeholders (manufacturing industry, research, universities, aviation industry, member states) to prepare, update and actively support the implementation of the first European Strategic Research Agenda (SRA) for aviation research. Following the publication of the 'Flightpath 2050', ACARE has revised the Strategic Research and Innovation Agenda (SRIA). Over the years, these documents (SRA / SRIA) have become the guidelines for virtually all aeronautics research in Europe.

Association of European Research Establishments in Aeronautics (EREA)
EREA was founded in 1994 as an association of national aeronautics research institutes, tasked with improving cooperation and coordination between the facilities and representing shared interests in dealings with other aeronautical research stakeholders (industry, universities) and European institutions. The members are AIT (A), CEIIJA (PT), CIRA (I), CSEM (HE), DLR (D), FOI (S), ILOT (PL), INCAS (ROM), INTA (ES), NLR (NL), ONERA (F) and VZLU (CZ). The strategic partners within EREA are TsAGI (RU) and VKI (BE).

Association of European Space Research Establishments (ESRE)
ESRE was established in 2016 to develop a common stance for presentation to the European Commission and to develop technology roadmaps in the medium to long term – as a basis for coordinating content with ESA, the industrial sector and work programmes within the European Commission.

CNES

Guest – Centre National d'Études Spatiales (CNES)

CNES (Centre National d'Études Spatiales) plays a key role on the national, European and international space scenes as a driving force for innovation and proposals, as well as a centre for technical expertise regarding the design, development and operation of space systems. In order to implement French space policy, CNES relies on approximately 2500 staff members, spread out over four centres of excellence. They contribute to the wide range of CNES activities covering five main areas – Launchers, Sciences, Earth Observation, Telecommunications and Navigation, as well as Defence and Security. DLR is a major partner with whom CNES has been working closely for over 30 years in all areas of the space industry, notably Defence, Launchers, Climate Study (with the development of the MERLIN – MEthane Remote Sensing Lidar Mission – satellite) and Exploration, with the Japanese Space Agency, JAXA's international Hayabusa2/MASCOT mission to the asteroid 1999 JU3 (Ryugu). CNES is currently developing several other collaborative projects with DLR institutes.

JAXA

Guest – Japanese Aerospace Exploration Agency

Japan Aerospace Exploration Agency

Designated as a core agency to support Japanese government's overall aerospace development and utilisation, the Japanese Aerospace Exploration Agency (JAXA) conducts integrated operations – from basic research and development, to utilisation.

Germany and Japan have been working together in the fields of space and aeronautics for more than 30 years. To strengthen this cooperation, DLR and JAXA signed an Inter Agency Arrangement for Strategic Partnership in February 2016. This collaboration is aimed at promoting the development and utilisation of aerospace technologies to solve global societal challenges, as well as at furthering their substantial joint work in research and development projects and missions. The synergy of cooperation by the two countries is expected to yield this positive result and improve their competitiveness. In September 2017, DLR and JAXA also held an Inter Agency meeting and issued a joint statement announcing the outcome of the meeting, and the new areas in which the bilateral cooperation will be strengthened.

The Japanese Hayabusa2 spacecraft represents the existing close ties between the two aerospace agencies. It was launched towards asteroid Ryugu (previously known as 1999 JU3) in December 2014. Hayabusa2 is scheduled to reach Ryugu sometime between June and July and deploy the small lander MASCOT (Mobile Asteroid Surface Scout), developed by DLR and CNES. At ILA 2018, JAXA is displaying a 1:1 scale model of Hayabusa2 at the DLR stand.

As partnering front-runners of aerospace development, DLR and JAXA will provide more prosperous and effective values to society.

DLR

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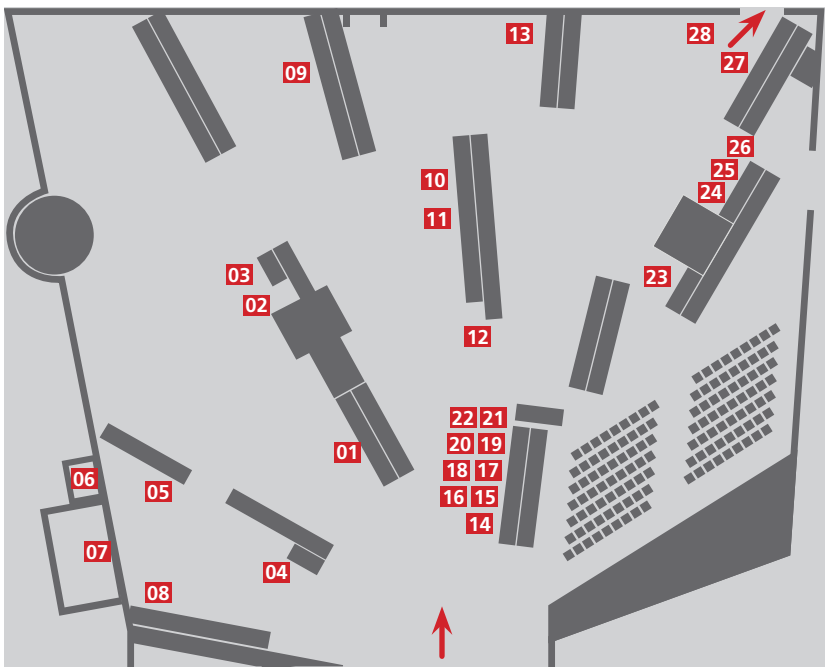
DLR at the ILA Space Pavilion

Hall 4



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24 Insight/HP^3
25 BepiColombo (BELA)
26 BepiColombo (MERTIS)
27 eROSITA
28 MASCOT

DLR Lampoldshausen

Unique testing competency for European space transport

Brief description

At Lampoldshausen, DLR engineers operate test rigs for testing rocket engines. These are a prerequisite for developing propulsion technologies to commercial maturity and ensuring their quality. The key competence is therefore the operation of altitude simulation systems that allow engines to be tested under near-real space conditions.

Aims

With decades of expertise in the field of liquid chemical rocket propulsion systems and its unique engine test rigs, DLR Lampoldshausen is indispensable in Europe for safe, flexible and competitive access to space.

Parties involved

Ariane Group, ESA, CNES,
DLR Institute of Space Propulsion,
DLR Institute of Technical Physics

Applications

- Research and development of liquid rocket engines
- Operation of test rigs for space propulsion systems, especially altitude simulation systems
- Verification of new technologies under representative conditions
- Development and design of test rig systems

Outlook

- Research into new advanced propellants
- Development of advanced technologies for space propulsion systems

Facts and figures

- Founded by Prof. Eugen Sänger in 1959
- Ten test facilities with a Technology Readiness Level of 1-9
- An average of 129 test days with more than 200 tests
- Lowest tested thrust: 0.1N
- Highest tested thrust: 1500N

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

DLR Lampoldshausen

Unique testing competency for European space transport

DLR in Lampoldshausen has **more than 50 years of experience and history**, as well as core competencies in the field of liquid chemical space propulsion. The global space market is constantly growing and changing. The cost of launchers is decreasing in line with increasing reliability and efficiency. The DLR scientists focus their research activities on the **development of sustainable propulsion technologies**. Based on decades of expertise and its unique test rigs, the DLR site at Lampoldshausen is indispensable in Europe for safe, flexible and competitive access to space. The test rigs and facilities for testing rocket propulsion systems operated by the DLR Institute of Space Propulsion cover the entire portfolio of test requirements: from component testing, through to engine tests, to testing entire rocket stages. In order for the test conditions to resemble flight as closely as possible, the test rigs simulate rockets. The engines are supplied with all fuels and fluids via appropriate interfaces. The test systems measure data and control, regulate and monitor the engines during operation. Research and development creates the foundations for advanced technologies for future space transport systems. This research work starts with experiments in laboratory combustion chambers and ultimately permits tests under real-space propulsion conditions. New technologies can therefore be verified in accordance with representative requirements.

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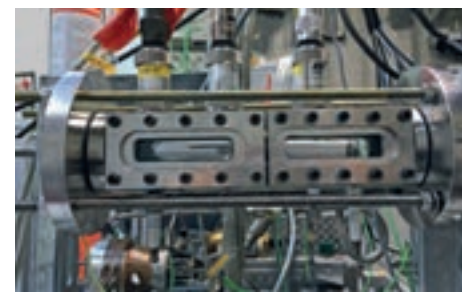
Green impulse for advanced fuels

Rocket propellant from nitrous oxide and hydrocarbons

Brief description

An experimental set-up to investigate the ignition, flame propagation and flashback of green rocket propellants. The measurement section consists of two chambers that are separated by a flame arrester. To use flame arresters efficiently and safely in a future engine, they are extensively tested within the ignition measurement section.



Aims

Examination of a green propellant composed of nitrous oxide and hydrocarbons through the testing, validation and analysis of flame arresters, the investigation of the propellant combustion behaviour, and analysis of various ignition methods.

Parties involved

DLR interdisciplinary 'Future Fuels' project: Institute of Space Propulsion, Institute of Combustion Technology, Technical University of Munich

Applications

- Development of a non-toxic propellant for satellites, probes and landers
- Hydrazine replacement
- Use of pre-mixed oxidiser/propellant blends consisting of nitrous oxide and hydrocarbons
- Reference experiment for CFD simulations
- Basic combustion investigations

Outlook

- Safe, efficient use of a green rocket propellant
- Cost reduction when fuelling and operating a satellite
- Development of lightweight, low-cost flame arresters for industrial applications (pipelines, pumps, etc.), such as for the chemical industry
- Understanding of basic combustion processes

Facts and figures

Project duration: 2014–2017, 2018–2021
Funding: institutional DLR funding
Technical data: maximum pressure with **glass windows:** 40 bar, use of pre-mixed, gaseous propellants, application of various ignition methods, high-speed camera shots with up to 120,000 images/second, 50 kHz data capture rate for pressure measurements, flame arresters with <100 µm pores

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

Green impulse for advanced fuels

Rocket propellant from nitrous oxide and hydrocarbons

Hydrazine (N_2H_4) has been used in the field of orbital propulsion (such as for satellites, probes and landers) since the 1960s. The use of hydrazine has several advantages: the propellant can be stored for **long periods of time**, is efficient and can be utilised in **simple propulsion systems** by using a catalyst. Despite all these benefits, hydrazine has a major drawback: it has adverse health effects meaning that **extensive safety measures** are required when fuelling a spacecraft, which in turn leads to increased costs.

Several so-called **'green propellants'** are therefore being investigated worldwide. DLR is examining various propellants consisting of either ammonium dinitramide (ADN), hydrogen peroxide (H_2O_2) or a mixture of nitrous oxide and hydrocarbons (HyNOx). The latter propellant – a nitrous oxide/hydrocarbon blend – comprises so-called 'pre-mixed monopropellant'. This means that the oxidiser and propellant are mixed and liquefied under pressure in a tank. However **if such a mixture unintentedly ignites**, it would be accompanied by a sudden reaction. If the mixture is burned in a rocket engine, there is a danger that a flame flashback happens in the propellant supply line and the tank via the injection system. In a spacecraft, this would have catastrophic consequences for the entire system and must therefore be prevented at all costs. In order to **use this propellant safely and reliably**, the development and use of optimised flame arresters is essential. DLR scientists are testing and analysing these flame arresters within the exhibited ignition measurement section. Using the knowledge gained, flame arresters will then be designed and used for a DLR model engine.

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LOX/Methane

New rocket propulsion for Europe

Brief description

LOX/methane propulsion has huge potential for the development of cost-effective and reusable high-thrust rocket engines. After researching this fuel combination at its Lampoldshausen site since 2006, DLR is now working to make its large test rigs fit for complete LOX/methane engines.

Aims

- Support the development of the 100 t LOX/methane Prometheus demonstrator engine with accompanying research projects
- Support European space research and industry by providing full-scale testing opportunities for complete LOX/ methane engines and their components.

Parties involved

ArianeGroup, DLR, ESA, CNES, DLR Institute of Space Propulsion

Applications

- Space transport research and development
- Reusable, cost-effective engine of the future

Outlook

- Cost-effective and reusable high-thrust rocket engines
- 3D-printing process
- Ariane Next

Facts and figures

- **2006:** Start of DLR LOX/methane research
- **2016:** Start of LUMEN (3 t demonstrator) development
- **2017:** Start of CNES Prometheus (100 t demonstrator) cooperation
- **Lab scale:** component tests, e.g. on the M3
- **Sub-scale:** engine and component tests on the P6 and P8
- **Full-scale:** component tests on the P3 (2016), engine tests on the P5 (2020)

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

LOX/Methane

New rocket propulsion for Europe

By developing liquid oxygen (LOX)/methane technology, Europe is meeting the global requirements of the launcher market, as this fuel combination has huge potential for the development of cost-effective and re-usable high-thrust rocket engines. The use of methane as rocket fuel has been investigated for decades, but LOX/methane propulsion has never been used in a launcher thus far.

As part of the **Prometheus programme**, ArianeGroup is now developing a LOX/methane **demonstrator engine with 100 t thrust**, based on a concept by the French national space agency (CNES). In order to make this new engine cost-effective, new **production processes are also being used, such as 3D printing**. Since 2016, the programme has been part of the European Space Agency's (ESA) 'Future Launchers Preparatory Programme'. The aim of the programme is to test the finished engine under representative conditions on the P5 test rig at the DLR site in Lampoldshausen from the end of 2020. Following the **successful test of a 30 t thrust chamber** on the P3 component test rig in collaboration with ArianeGroup in 2016, this will be the second full-scale test of LOX/methane hardware on a large DLR test rig. In order to guarantee the success of these tests, DLR engineers are already preparing for the necessary conversion of the P5 test rig. DLR Lampoldshausen has been conducting its own LOX/methane research since 2006. Furthermore, **DLR has been collaborating with CNES since 2017 in order to support ArianeGroup's development of the Prometheus engine with accompanying research projects**. It is also drawing on the experience gained from LUMEN, the DLR internal development project that began in 2016 with the aim of developing its own LOX/methane demonstrator in the 3 t thrust class.

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German Space Operations Center (GSOC)

Brief description

2018 marks the 50th anniversary of the German Space Operations Center (GSOC) within the DLR Space Operations and Astronaut Training division in Oberpfaffenhofen near Munich. The engineers and scientists working here have been involved in more than 70 spaceflight missions since 1 March 1968.

Aims

Whether for planetary and climate research, communications satellites or astronaut missions – one key element for all these missions was established 50 years ago: the German Space Operations Center. From here, national and international missions like the German Earth observation satellites TerraSAR-X and TanDEM-X are controlled; it also houses the 'direct line' to the ISS – the Ground Control Center for the European Columbus Laboratory on board the International Space Station.

Parties involved

DLR Space Operations and Astronaut Training including GSOC and the Mobile Rocket Base (MORABA) in Oberpfaffenhofen, Weilheim ground station, Microgravity User Support Centre (MUSC) in Cologne

Applications

- Operation and control of German satellite missions
- Research into innovative operating technologies used in aerospace missions
- Microgravity User Support Center for space experiments
- Launch services for research rockets and balloons

Outlook

- Advancement of expertise for future Earth observation missions like GRACE Follow-on (from 2018) and Tandem-L (from 2022)
- Expansion of operations for the European Data Relay System (EDRS)
- Provision of broadband, optical communication connections between spacecraft in low Earth orbit and receiver stations on the ground

Facts and figures

Establishment: 1968
Employees: 520
Location: DLR sites in Oberpfaffenhofen, Weilheim and Cologne

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE
15 LIFE ON LAND
13 CLIMATE ACTION

German Space Operations Center (GSOC)

Located in Oberpfaffenhofen near Munich, the German Space Operations Centre (GSOC) is part of DLR's space operations and astronaut training division, the key institution for implementing space missions in Germany. It has facilities in Oberpfaffenhofen, Weilheim and Cologne. Its responsibilities extend from **satellite missions for Earth observation, science and communications, through to human spaceflight and missions to explore the Solar System**. It also takes part in astronaut training, experiment preparation and develops sounding rockets for global use. In addition, DLR Space Operations and Astronaut Training works on new technologies that will facilitate even the most complex aerospace projects in future.

DLR Space Operations and Astronaut Training plays a **crucial role in European aerospace**, working in close cooperation with other DLR institutes and with public sector and industrial partners. Impressively pooling engineering, operations and applications, DLR Space Operations and Astronaut Training is a gathering point for all stakeholders within the aerospace sector and interested laypersons. It is here that visionary projects are put into practice and innovative ideas for the development of tomorrow's aerospace are developed.

INVIRTES

Integrated development of complex systems with virtual testbeds

Brief description

INVIRTES is used to research new methods for the integrated development of complex systems for all phases in the lifecycle of complex space projects. The developed methods, components and processes are based on advanced, modern e-robotics methods and in particular the virtual testbed.

Aims

Methods are developed to efficiently pool expertise in various areas of aerospace within the virtual testbed and to support the various developmental stages of a mission. This process makes implementation more cost-effective, robust and faster. The key objective is for the virtual mission to 'fly' years before the real mission.

Parties involved

RIF e. V., RWTH Aachen – MMI, CPA ReDev GmbH, Fraunhofer IEM, DLR Space Administration, BMWi

Applications

Holistic simulation of complex aerospace missions, for example exploration and in-orbit servicing
- Virtual space robotics testbed
- Virtual commissioning of industrial manufacturing and automation systems

Outlook

- Reduction in costs, even at the development stage
- Utilisation for alternative industrial applications
- Collaboration with SMEs in the aerospace sector to implement simulation technology

Facts and figures

Project runtime:
January 2014–May 2018

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

12 RESPONSIBLE CONSUMPTION AND PRODUCTION

INVIRTES

Integrated development of complex systems with virtual testbeds

The INVIRTES project aims to develop concepts for the **construction of a crystallisation point where complex systems in the area of space robotics and related fields can be developed**. This crystallisation point is intended to support development as a so-called engineering backbone and bring together the results at a central location. In order to ensure that this central point is used effectively for project planning, coordination and verification in associated projects, its mobile reference installation was developed and built as a 3D-compatible 80-inch monitor with a connected simulation computer. The installation can be used at numerous locations to suit the specific tasks. It is therefore a crucial building block in the verification and communication of findings, and contains individual reference applications.

The developments within INVIRTES and the numerous innovations on virtual testbeds that have already been conducted and are still scheduled provide a concept for a comprehensive methodical toolkit in the fields of crucial importance to German space robotics.

Possible scenarios: ISS simulation (interior/exterior), approach service module for the ISS, Mars Rover, iBOSS as a reconfigurable satellite.

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iBOSS

Intelligent building blocks for satellites … and more

Brief description

iBOSS (intelligent Building Blocks for On-Orbit Satellite Servicing and Assembly) is a research project supported by the DLR Space Administration with funds from the German Federal Ministry for Economic Affairs and Energy (BMWi). It focuses on the development and provision of a toolkit for future satellites and the application of a highly modular concept to ensure necessary standardisation.

Aims

The iBOSS building block system is based on innovative key technologies that involve the development of standardised building blocks, a multifunctional interface and a holistic concept. The modular system also enables new services, for example for in-orbit verification of aerospace concepts, for logistics in orbit or on the ground, and for assembly.

Parties involved

TU Berlin, RWTH Aachen, FZI, RIF e. V., JKIC, DLR Space Administration

Applications

- Maintenance and expansion of space systems in orbit (on-orbit servicing) to increase lifetime and operational efficiency
- Assembly of the actual space system in orbit (on-orbit assembly), for example on the ISS

Outlook

- Reconfigure the satellite platform and payload equipment as mission requirements change during operation
- Reuse / recycle modules in orbit on other systems
- Increasing the degree of automation in space
- Long term cost reduction through more efficient use of the systems

Facts and figures

Project start: 2010
- In-orbit demonstration planned for early 2020
- Two spin-offs from the project context: iBOSS GmbH, iBOSS solutions GmbH

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

12 RESPONSIBLE CONSUMPTION AND PRODUCTION

iBOSS

Intelligent building blocks for satellites … and more

The conventional design approach for space systems is based on a monolithic solution, developed for a specific application scenario. The disadvantages in this regard include high development costs or unsustainable solutions for maintenance in orbit, as well the issue of space debris. In contrast, the **individual modules of the building blocks (iBLOCKS) in the iBOSS approach can be built into almost any conceivable, functioning space system (for instance satellites), similar to the LEGO® principle**. The central component in the concept is known as the iSSI (intelligent Space System Interface), a multifunctional aerospace-capable interface. This interface can be used to make mechanical, data and energy connections between individual modules, vehicle components or payloads, hence producing the first USB standard for aerospace applications.

A **digital twin** complements the building block system. The implemented design tools permit the generation of possible system solutions for a satellite, based purely on the technical and operational requirements. This is the first time that principles otherwise applied in an IT environment and used in the AppStore®, the IKEA Kitchen Planner® or in vehicle configuration tools will be exploited for aerospace purposes.

iBOSS demonstrates how to **move away from 'expensive, inflexible, disposable satellites' and toward maintainable, modifiable and cost-efficient, recyclable systems**. What makes the building block system special is that it can be used for many different applications using the same technical basis, without having to permanently repeat expensive development and qualification steps. When the current project phase is completed at the end of 2018, these developments will have reached a level of maturity that will permit transfer of iBOSS technologies into industrial use and enable in-orbit qualification.

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ARCHES

Multi-robot cooperation

Brief description

ARCHES (Autonomous Robotic Networks to Help Modern Societies) is a new Helmholtz Association future research topic that deals with cooperating robots. In future, these should be able to overcome challenges during planetary exploration and deep-sea research in autonomous robotic networks.

Aims

The use of autonomous, cooperative robotic systems is the only way to achieve continuous, long-term and long-range data acquisition, as well as the direct manipulation and interaction with the surroundings. There is therefore an urgent need to develop key robotic technologies and methods that permit large-scale monitoring and object manipulation. Such a robotic network will act as a 'few extra pairs of eyes' and an extended human arm.

Parties involved

German Aerospace Center, Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research (AWI), GEOMAR Helmholtz Centre for Ocean Research Kiel, Karlsruhe Institute of Technology KIT

Applications

- Monitoring hard-to-reach environments using cooperating heterogeneous robots
- Exploration of Earth's marine environment
- Space exploration, installation and maintenance of permanent structures on planetary surfaces

Outlook

- Continuous, long-term and long-range monitoring of difficult-to-reach environments using cooperating heterogeneous robots
- Understanding continuous processes that take place in different ocean levels

Facts and figures

HGF future topic
Total budget: 10 million euro
Project duration: 01.01.2018-31.12.2020

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

14 LIFE BELOW WATER

ARCHES

Multi-robot cooperation

Autonomous, cooperative robotic systems are becoming increasingly important for both industry and science. The aim of the ARCHES consortium is to research cross-domain, interdisciplinary technologies that can provide the basis for solutions to the societal challenges ahead. ARCHES endeavours to combine the various, and as yet, very specific **robotic developments of three Helmholtz research areas**, thereby developing technological advances in Germany and beyond.

ARCHES will use robot hardware that can meet the characteristically stringent robustness and reliability requirements of two domains: **deep-sea and planetary exploration**. The adaptation of configurable carrier systems will pursue the aim of optimally exploiting the potential synergies of a competence network. The focus is on researching methods for the joint analysis and interpretation of data by the robots within the network. The intelligent automation and cooperation of the systems will also play a central role. Both aspects are essential, as the **independent operation of the robotic network** is a basic prerequisite for the missions under consideration. Consequently, the motivation is to research approaches to autonomous navigation in unknown areas, intelligent interaction with the surroundings, **self-sufficient energy management and the self-organisation of communication** with mission headquarters and within the network. For human interaction, an interface must be created for planning the mission and organising the robots. ARCHES also creates the basis for opening up applications in medicine and therapy, logistics and autonomous urban transport. In the long-term, for example, an **autonomous robotic transport network** can help to ensure individual independence, as well as the mobility and care of an increasingly ageing society.

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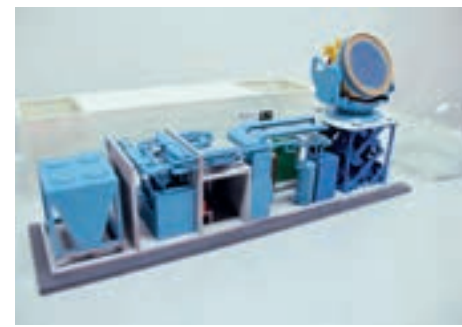
GESTRA

Experimental space monitoring radar



Brief description

GESTRA (German Experimental Space Surveillance and Tracking Radar) is an experimental space monitoring radar. The sensor is being developed and built by the Fraunhofer Institute for High Frequency Physics and Radar Techniques FHR and financed by DLR with funds from the German Federal Ministry for Economic Affairs and Energy (BMWi). The space monitoring system is scheduled to start delivering data in 2019.

Aims

For the first time, GESTRA is making it possible for Germany to independently track, identify and catalogue objects in space. The equipment is intended to record orbital data from satellites and debris in low Earth orbit at an altitude of between 300 and 3000 kilometres.

Parties involved

DLR Space Administration, FHR Wachtberg, DLR and German Air Force Space Situational Awareness Centre

Applications

- Establishment, maintenance and operation of an orbital data catalogue by the DLR and German Air Force Space Situational Awareness Centre in Uedem.
- Development of system competence and expertise in space situational awareness, as a basis for operational space surveillance

Outlook

- Sustainable and safe satellite operation for space-based services and products, from navigation systems to Earth observation and communications
- Strategies for addressing the growing amount of space residue/debris

Facts and figures

Start: planned for 2019
Size: housing container**:** 18 m x 4 m x 4 m**,** mass: approx. 90 t**,**
radiation dome: 5 m,
diameter: 5 m
Properties: transmitting frequency, 1280 – 1380 MHZ, beam angle max. 20 degrees zenith distance, no ionising radiation

8 DECENT WORK AND ECONOMIC GROWTH

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

GESTRA

Experimental space monitoring radar

GESTRA (German Experimental Space Surveillance and Tracking Radar) is an experimental space monitoring radar designed to record the **orbital data of satellites and debris in Low Earth Orbit** at an altitude of between 300 and 3000 kilometres. It is expected to conduct its first measurements from 2019. The radar is operated by the **joint DLR and German Air Force Space Situational Awareness Centre** in Uedem. GESTRA is also intended to work in conjunction with other large-scale facilities, such as the space observation radar, TIRA, or the radio telescope, Effelsberg, in order to expand expertise in so-called bi- and multi-static radar operation. This is based on the radar-supported observation of objects in space, involving several, spatially separated transmitters and receivers. Smaller objects, in particular, can therefore be more easily detected and more accurately determined. There are around 16,000 recorded and catalogued space debris objects, usually with a diameter of at least 10 centimetres. The **largest accumulation of space debris is located at an altitude of around 900 kilometres**, the site of frequently used orbits. We estimate that there are a total of 29,000 objects larger than 10 cm, 750,000 objects larger than 1 cm and 150 million objects larger than 1 mm.

The GESTRA data will be made available to research institutions in Germany, and form the basis of future developments in operational space surveillance. GESTRA is also a major step towards implementing the German government's space strategy, which places a great deal of importance on establishing its own capacity to continuously record the space situation, including in an international context. The ability to continuously monitor space objects in order to prevent the collision of satellites and other objects is therefore being systematically developed and expanded in Germany.

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Heinrich Hertz mission

New technologies for satellite communications

Brief description

The Heinrich Hertz mission is scheduled to launch in 2021. Named after the German physicist Heinrich Rudolph Hertz, the communications satellite will be used to test innovative technologies. Heinrich Hertz will be the first proprietary, geostationary communications satellite that Germany has operated since 2002.

Aims

The purpose of the Heinrich Hertz mission is to test the space capabilities of new technologies for satellite communications.The conditions in space are extreme: immense heat and cold, vacuum and microgravity. Heinrich Hertz will carry a payload of approximately 20 scientific and industrial experiments for communications, antenna and satellite technology. In this way, the project will demonstrate Germany's system capabilities in satellite communications.

Parties involved

German Federal Ministry for Economic Affairs and Energy, Federal Ministry of Defence, DLR Space Administration

Applications

- In-orbit verification to minimise failure risks in future satellite missions
- Demonstration of German system capabilities in the area of satellite communications and cutting-edge technology 'made in Germany'

Outlook

- Through its involvement in an independent satellite communications mission, Germany is strengthening its position in geostationary satellite systems and services, and is hence supporting the creation of a digital society.

Facts and figures

Launch: planned for 2021 using an Ariane 5
Orbit altitude: 36,000 km, geostationary
Satellite size: approx. 2.3 m x 1.9 m x 3.2 m (retracted solar panels and antennas), approx. 5.8 m x 21.0 m x 3.2 m when operational
Satellite mass: approx. 3.5 t
Energy consumption: approx. 6 kW
Frequency bands: Ku and Ka band for communication; S and Ku band to command the satellite

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

Heinrich Hertz mission

New technologies for satellite communications

We are reachable at anytime and anywhere by Internet, email or text message, which we send and receive by smartphone, tablet PC or notebook. This results in a sheer inconceivable flow of data around the globe. The development of new technologies for communications satellites will be necessary in order to satisfy this hunger for information. The German Heinrich Hertz satellite mission caters precisely to this need: it will be used as a **test platform for technologies that are exposed to the extreme stress of a space environment**. The satellite will need to cope with strong radiation and immense temperature fluctuations for up to 15 years. Known as in-orbit verification, this procedure minimises the risk of failure, which cannot be adequately simulated on Earth. The testing of an innovative, flexible and hybrid payload concept will also use experiments to examine the opportunities and limits of adaptability for future missions. **Heinrich Hertz** will allow the scientific and industrial communities to conduct numerous experiments to demonstrate the functionality of various technologies. For instance, innovative developments in the area of user terminals with antenna diameters of less than 80 centimetres will indicate the limits placed on mobility and reachability in congested frequency bands. In addition, the German communications satellite will serve as a **'relay station' for microsatellites orbiting Earth**. Here, Heinrich Hertz will significantly extend their contact times with ground control stations, which in turn will substantially increase data transfer. In addition to the scientific and technical mission objectives, which are funded by the German Federal Ministry for Economic Affairs and Industry (BMWi), the German Federal Ministry of Defence (BMVg) is also involved in the Heinrich Hertz mission. Among other things, this will benefit civilian and military forces in disaster and crisis regions in the event that the ground-based communications infrastructure is overloaded or destroyed. The DLR Space Administration is responsible for the planning and control of the mission.

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Assistance in the event of disasters

The DLR Center for Satellite Based Crisis Information (ZKI)

Brief description

Rapid assistance in emergencies: the Center for Satellite Based Crisis Information (ZKI) at the German Aerospace Center (DLR) assists government agencies and rescue services during natural disasters and other major emergencies by providing Earth observation data. The information can also be used for preventative purposes.

Aims

ZKI is tasked with the provision of a 24/7/365 service for the rapid acquisition, processing and analysis of satellite data in the event of natural and environmental disasters, for humanitarian aid activities and for civilian security worldwide. In this regard, ZKI operates in a national and international context and collaborates closely with a variety of government agencies, non-government organisations, satellite operators and space agencies.

Parties involved

Center for Satellite Based Crisis Information (ZKI) of the DLR German Remote Sensing Data Center (DFD)

Applications

- Satellite data for government authorities
- Collaboration in the European emergency mapping service 'Copernicus EMS'
- Satellite data for global disaster relief and technical accidents
- Fully automated fire/flooding service

Outlook

- Continuous advancement of methods, products and services
- Focus: entire disaster management cycle from acute crisis response through to reconstruction, risk analysis, prevention and early warning

Facts and figures

Establishment: 2004 (Previous service since 1999) in Oberpfaffenhofen

Since 1999, the ZKI has:

- conducted over 300 activations and trainings
- generated more than 1000 products,
- supplied the International Charter 'Space and Major Disasters' with data for more than 200 activations

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

3 GOOD HEALTH AND WELL-BEING

Assistance in the event of disasters

The DLR Center for Satellite Based Crisis Information (ZKI)

When an earthquake occurs or a tsunami strikes the mainland, we realise that Earth is at risk – continuously. Another thing is clear: the repercussions of these disasters on the population and economic assets in the affected regions have risen sharply in recent decades. Nevertheless, **satellite-based Earth observation can mitigate the consequences of these natural and environmental phenomena** by providing decisive support to ensure a rapid response to the crisis. It is even used to prevent disasters from happening.

Not only does satellite data provide a large-scale **overview of a crisis situation**, it also permits detailed analysis and assessment of damage. Moreover, Earth observation data can be used to acquire valuable information for risk assessment, allowing government agencies and emergency services to improve preparations for possible future events. This is why the **demand for satellite-based information has risen noticeably** in recent years as a means of responding to natural and environmental disasters, completing humanitarian aid actions and in civilian security matters.

DLR responded to this growing demand by establishing the Center for Satellite Based Crisis Information (ZKI) in 2004 in Oberpfaffenhofen. Users can access the ZKI services around the clock. Moreover, its services and products are improved continuously through extensive research and development to ensure their compliance with state-of-the-art research and technology. The **services cater to the following tasks**: ZKI-DE: provision and analysis of satellite data for German government authorities to ensure civilian security and for disaster management; Copernicus EMS: collaboration in the European emergency mapping service Copernicus EMS for the management of natural disasters; International Charter ‘Space and Major Disasters’: provision of satellite data for authorised users around the world to manage natural disasters and man-made accidents; provision of fully automated fire and flooding services.

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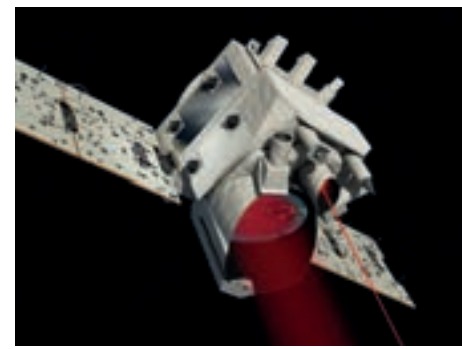
MERLIN

The Franco-German satellite mission



Brief description

From 2021, the Franco-German climate mission MERLIN (MEthane Remote sensing LIdar missioN) will trace the greenhouse gas methane using a Lidar instrument. Germany's contribution to MERLIN is managed by the DLR Space Administration with funding from the German Federal Ministry for Economic Affairs and Energy (BMWi), and the space agency CNES is responsible for the French contribution.

Aims

Methane is one of the most effective greenhouse gases at making the planet warmer and is partially responsible for climate change. This three-year mission is aimed at producing a global map of atmospheric methane concentrations. Among other things, it will provide information on the main regional sources of methane and the areas in which the greenhouse gas is removed from the atmosphere (sinks).

Parties involved

DLR Space Administration, French space agency CNES, European space industry led by Airbus in Ottobrunn

Applications

- Earth observation satellite for research into the causes of climate change
- Innovative measurement methods and thus better-quality data for documenting and creating a catalogue of global methane concentrations

Outlook

- Development of systems expertise and know-how relating to global methane observation
- Real contribution towards implementing the Paris Climate Agreement targets
- Demonstration of new, highly accurate satellite-based measurement methods to determine methane concentrations

Facts and figures

Launch: scheduled for 2023 with Soyuz or Vega/Vega-C from the European Spaceport in French Guiana
Satellite platform: Myriade Evolutions
Satellite dimensions:
approx. 1.60 x 4.50 x 1.60 m with extended solar panels
Satellite mass: approx. 430 kg
Instrument mass/power requirement:
approx. 150 kg / 150 W

MERLIN

The Franco-German satellite mission

The Franco-German climate mission **MERLIN** (Methane Remote Sensing Lidar Mission) is expected to measure **methane levels in Earth's atmosphere** from 2023 with unprecedented accuracy. Missions like MERLIN help to gain a deeper insight into the mechanisms that influence climate on Earth. Data from the mission are processed and evaluated jointly and in close collaboration with various research laboratories. MERLIN is set to orbit the Earth at an altitude of approximately 500 kilometres and will operate for at least three years.

Methane is a particularly potent greenhouse gas. The climate impact of methane is 25 times greater than that of CO_2. Although the concentration of methane is significantly lower than that of CO_2, it is responsible for approximately 20 percent of global warming.

MERLIN will be installed on the new '**Myriade Evolutions' satellite bus**, which has been developed by CNES in conjunction with the French space industry. The satellite's **payload**, an active **Lidar (Light Detection and Ranging)** instrument which can measure even at night-time and through thin clouds, is being developed and built in Germany on behalf of DLR Space Administration. The methane Lidar includes a laser that can emit light in two different wavelengths, enabling it to conduct highly precise measurements of methane concentration at all latitudes, regardless of sunlight. The wavelengths are in the infrared range and are chosen so that one is absorbed by methane, while the other is not. MERLIN sends two such pulses at the same spot on the ground in quick succession. The small satellite captures and registers the reflected pulses with a telescope. The presence of methane in the atmosphere weakens one of the pulses, but not the other. This difference allows scientists to determine the amount of methane between the satellite and Earth's surface.

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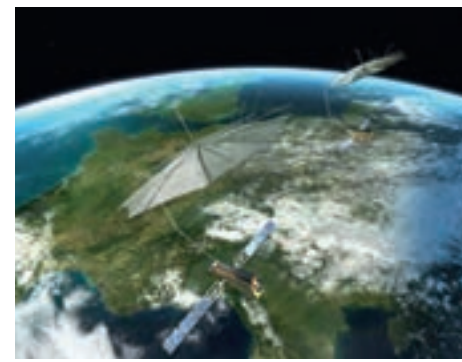
Tandem-L

Innovative SAR mission for environmental and climate research



Brief description

Tandem-L is a proposal for an innovative L-band SAR mission for the systematic observation of dynamic processes on the Earth's surface. The mission concept is based on two SAR satellites flying in close formation featuring the latest digital beamforming techniques in combination with a large deployable reflector.

Aims

Tandem-L will simultaneously measure seven essential climate variables in a single satellite mission. Primary mission objectives are the global measurement of forest biomass and its variation, the systematic monitoring of deformations of the Earth's surface, the quantification of glacier motion and melting in polar regions as well as observations of ocean surfaces.

Parties involved

DLR, UFZ, AWI, GFZ, GEOMAR, Jülich Research Center, HGF Center Munich, universities and research institutions

Applications

Novel imaging techniques and vast recording capacity for environmental and climate monitoring:

- biosphere (3D forest structure & biomass)
- geosphere (Earth surface deformation)
- cryosphere (ice melting processes)
- hydrosphere (soil moisture measurement)

Outlook

Vital contribution for a better understanding of the Earth system and its dynamics:

- ecosystem dynamics and the carbon cycle
- earthquake risk analysis for reliable forecasting
- climate change and sea level rise
- water cycle research and modelling

Facts and figures

- Two L-band SAR Satellites, ~3 tons each, flying in close formation & operating as bistatic SAR interferometer
- Advanced digital beamforming techniques in combination with a 15 m diameter deployable reflector
- Swath width: 350 km; ground resolution: 5–7 m; weekly global coverage
- Regularly updated, global higher-level information products for environmental & climate research

Tandem-L

Innovative SAR mission for environmental and climate research

Tandem-L is a proposal for an **innovative L-band SAR mission** for environmental and climate research. The Earth system is permanently changing and **dynamic processes** occur in different spheres and at different time scales. Tandem-L has been designed to observe a wide range of processes at adequate time intervals and to deliver urgently required information for answering pressing scientific questions in the domain of the **bio-, geo-, cryo- and hydrosphere**. In this way, Tandem-L will contribute significantly to a better understanding of the Earth system and its dynamics. Important mission goals are the global measurement of **forest biomass** and its variation in time for a better understanding of the carbon cycle; the systematic **monitoring of deformations** of the Earth's surface on a millimetre scale for the investigation of earthquakes and risk analysis; the quantification of **glacier motion and melting processes** in the polar regions; the fine scale measurement of variations in the near-surface **soil moisture** as well as observations of the **dynamics of ocean surfaces and ice drift**. In times of intensive scientific and public debate on the scale and impact of climate change, Tandem-L delivers important, currently unavailable information for **improved scientific forecasts and socio-political recommendations** based upon these.

Tandem-L is the result of three multi-year conceptual and feasibility and mission definition studies led by DLR together with a team of more than 100 scientists in close cooperation with the German aerospace industry since 2008. The scientific data exploitation from Tandem-L is being prepared as part of the Helmholtz Alliance 'Remote Sensing and Earth System Dynamics', including more than 140 scientists from 8 Helmholtz centres, Max Planck and Leibniz Institutes and other national and international universities and research institutes.

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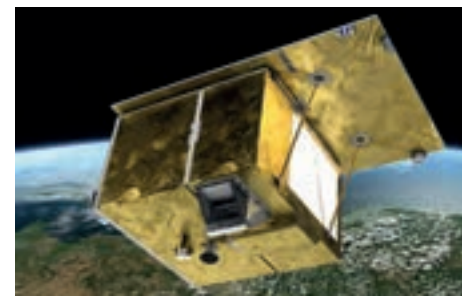
EnMAP

Germany's hyperspectral satellite



Brief description

EnMAP is Germany's hyperspectral satellite mission, and is funded by the DLR Space Administration with funds from the German Federal Ministry for Economic Affairs and Energy (BMWi). Imaging spectrometers will observe the sunlight reflected from Earth across a wide range of wavelengths from the visible to the short wave infrared. This will make it possible to acquire precise information on the condition and changes of Earth's surface.

Aims

EnMAP will provide high-quality hyperspectral data on a regular basis. It should help to find global answers to a range of questions dedicated to environmental, agricultural, land use, water management and geological issues. The mission is scheduled for launch in 2020 and is designed to operate for five years.

Parties involved

DLR Space Administration, GFZ Potsdam, OHB System AG, DLR German Space Operations Center, German Remote Sensing Data Center (DFD) and the DLR Remote Sensing Technology Institute

Applications

- Precise statements about the condition and changes of Earth's surface
- High-resolution spectral data also provides quantitative information, such as the provision of nutrients to crops, water quality of lakes or the identification of the mineralogy in rocks and soil

Outlook

- Global and long-term data acquisition to to find answers to a range of questions dedicated to the environment, agriculture, land use, water management and geology
- Development and strengthening of competencies in the area of 'System Earth'

Facts and figures

Launch: scheduled for 2020 with a PSLV rocket from Sriharikota (India)
Orbit: Sun-synchronous at a height of 653 km
Satellite dimensions: 3 x 2.1 x 1.5 m
Satellite mass: approx. 850 kg
Power consumption: 800 W
Mission operation: German Space Operations Center in Oberpfaffenhofen and Weilheim (DLR)
Data reception/-processing: DLR Ground Station Neustrelitz, DLR IMF

EnMAP

Germany's hyperspectral satellite

EnMAP (Environmental Mapping and Analysis Program) is Germany's **hyperspectral satellite mission for Earth observation**. Imaging spectrometers will measure the sunlight reflected from Earth across a wide range of wavelengths from the visible to the short wave infrared. This will make it possible to accurately study the condition of Earth's surface, and the changes affecting it. The mission is scheduled for launch in **2020** and is designed to operate for five years. EnMAP data should help to find global answers to a range of questions dedicated to environmental, agricultural, land use, water management and geological issues. Conventional multi-spectral sensors record radiation reflected from Earth in a small number of broad spectral channels. They deliver reliable data and information, for example, about **land coverage and its spatial distribution**. However, quantitative information such as the provision of nutrients to crops, water quality of lakes or the identification of the mineralogy in rocks and soil demands higher-resolution spectral data.

EnMAP will carry a 'hyperspectral instrument' – essentially a spectrometer that depicts Earth's surface by contiguous spectra assembled by about 250 narrow bands. This will provide detailed information about **vegetation, land use, surface rocks and waterways**. The data can be used to provide information about the mineralogical composition of rocks, the damage to plants caused by pollution and the degree of soil pollution, among other applications.

EnMAP will fly at a Sun-synchronous orbit at a height of 643 kilometres above the Earth, recording data with a 30 x 30 metre ground resolution. Using a tilting mode of plus minus 30 degrees perpendicular to the flight path, this allows to acquire data over any point on Earth within a four-day period. This will make it suitable for recording changes that occur over time, such as the effects of erosion or the growth seasons of vegetation, as well as providing insight into how the ecosystems in many different natural environments are distributed and how they evolve or are being created.

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horizons – Knowledge for Tomorrow

Alexander Gerst's new ISS mission

Brief description

Alexander Gerst's launch to the International Space Station (ISS) on 6 June 2018 for his mission 'horizons – Knowledge for Tomorrow' will mark the start of his second mission to work on the largest international technology project in the history of humankind. In this scientific laboratory, the major spacefaring nations are joining forces to develop solutions to global challenges.

Aims

Germany is one of the most important ISS partners. All German contributions to the Space Station are coordinated and managed by the DLR Space Administration on behalf of the German Federal government, in coordination with the international ISS partners. In addition to science, the Space Station also provides opportunities for commercialisation. 'horizons' will turn 'science fiction' into 'science facts'.

Parties involved

DLR Space Administration, ESA, BMWi, German universities and research institutions involved in the experiments and German industry

Applications

- In addition to basic research, more than 50 German experiments provide knowledge for 'health, the environment and climate change', 'digitalisation, Industry 4.0, energy and the mobility of tomorrow
- ISS as a driver of innovation for new technologies

Outlook

- Every euro invested provides a return of one euro
- For Germany as a high-tech and science location, research on the ISS is an investment in the future and an opportunity to inspire the youth about science and industry (MINT subjects)

Facts and figures

Launch to ISS scheduled for 6 June 2018 on board a Soyuz launcher from Baikonur Cosmodrome (Kazakhstan), Docking with Soyuz MS09 on 8 June 2018.
Mission duration: expected to be 187 days
Mission operations:
German Space Operations Center in Oberpfaffenhofen, Johnson Space Center (Houston) und ZUP Moscow

horizons – Knowledge for Tomorrow

Alexander Gerst's new ISS mission

'horizons' – this is the name of German ESA astronaut Alexander Gerst's next mission to the ISS. On 6 June 2018, the 41-year-old geophysicist will embark on his **second journey** to the International Space Station (ISS) with Expedition 56/57. In August, Gerst will become the first German and second European to be **Commander** of the ISS. During an expected 187 days – until the beginning of December 2018 – Gerst will be at an altitude of approximately 400 kilometres. The name of the mission, horizons, symbolizes the **curiosity and fascination** of discovering and exploring the unknown.

Research on the ISS and the horizons mission provide important contributions and impulses for addressing **societal and global challenges**, for example with regard to increasing **digitalisation, climate change and Industry 4.0**. Germany is the most important partner for ESA ISS elements and European ISS usage. After all, the ISS is a unique and innovative laboratory and test environment for experiments that cannot be performed on Earth.

In the mission, **50 experiments** with German participation will be contributed by scientists from German universities and research institutes, German industry and DLR as a research centre. The thematic spectrum ranges from biological and medical experiments to (astro-) physical and materials science issues, through to technology demonstrations, an experiment programme for children and young people, as well as industrially or commercially motivated applications. The **Columbus space laboratory**, the scientific heart of European research on the International Space Station ISS, is also celebrating its **tenth anniversary** this year. DLR has overseen the development and production of the ISS module on behalf of the **European Space Agency** (ESA), is actively involved with experiments at the research level and manages operations from the **Columbus Control Center** in Oberpfaffenhofen.

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SKIN B

Skin changes in space

Brief description

From 2013 to 2017, the human physiology experiment SKIN B investigated the extent to which skin, the largest organ in the human body, changes in microgravity conditions. Various measurements were carried out on the surface of the skin to determine its condition before a space flight, during the period spent on the ISS, and after the return flight.

Aims

While fulfilling other functions, our skin regulates the body's water and temperature balance, prevents the intrusion of pathogens, protects against UV radiation and serves as a sensory organ and communication medium. The SKIN B experiment systematically examined changes to the skin in space.

Parties involved

ESA, DLR Space Administration, Derma-Tronnier GmbH & Co. KG Institute for Experimental Dermatology, OHB System AG (Munich), Courage & Khazaka electronic GmbH (Cologne)

Applications

- Clarification and alleviation of phenomena such as delayed wound healing and increased allergies
- Findings about the changes to blood vessels lined with endothelium and the physical strain on internal and external organs

Outlook

Increasing the wellbeing of astronauts on the basis of acquired knowledge. The skin also serves as a model for other organs, as changes to the skin may provide early signs indicating the presence of systemic diseases.

Facts and figures

Start, project period: 2011–2018;
Experimental phase on the ISS: 2013–2016
Module: Columbus, ISS
Data receipt/processing: ESA/NASA

SKIN B

Skin changes in space

The SKIN B exhibit (SKIN B reference model) being showcased is identical to the model used from 2013 to 2017 on the **International Space Station (ISS)** (excluding the laptop). The SKIN B hardware consists of **three instruments used to assess the condition of the skin** (a Tewameter, a Corneometer and a camera), including a laptop. A Tewameter is a device that can determine transepidermal water loss. The Corneometer assesses the degree of skin hydration. The special Visioscan camera was used to obtain a visual representation of the skin's surface. In addition, the capillary blood flow (microcirculation), ultrastructure and elasticity (using the Cutometer) of the skin were measured before and after the flight. The Tewameter, Corneometer and Visioscan camera were connected to the laptop for the experiment and controlled by the software.

The three devices are **commercially available instruments** that have been used in the field of skin research for many years. They were purchased from the manufacturer Courage & Khazaka for use on the International Space Station. OHB System AG – on behalf of DLR Space Administration – **converted and adapted the instruments for use in space**. The European Space Agency (ESA) was responsible for transporting the SKIN B equipment to the ISS for training the astronauts as well as for conducting the operational aspects of the experiments in the Columbus module.

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Myotones

Muscle tone in space

Brief description

The Myotones experiment is the first to monitor the basic biomechanical characteristics of the skeletal muscles with a non-invasive, portable device on board the ISS, in order to investigate changes to the muscular system due to the lack of gravity.

Aims

Myotones allows ageing processes to be observed in fast motion. On Earth, these findings are used to improve rehabilitation and training programmes as countermeasures to bone and muscular atrophy, as well as assessing the success of training in fitness regimes and competitive sport.

Parties involved

DLR Space Administration, ESA, Charité Berlin, University of Southampton (UK), Myoton AS (EST)

Applications

Astronautics
- Preparation for long-term missions
- Maintaining the health of astronauts

Outlook

- Treatment to counter muscular and bone atrophy
- Monitoring success of training for competitive sports and rehabilitation

Facts and figures

Hardware: MyotonPRO (dimensions: 162 x 67 x 28 mm; 240g)
Launch hardware: SpaceX CRS-14, 02. April 2018
Location on the ISS: Columbus module
Launch of the experiment: A. Gerst mid-2018
Research area: Human physiology
Principal Investigator: Prof. Blottner

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Myotones

Muscle tone in space

Research on board the ISS is helping to improve rehabilitation for muscular and bone atrophy

The **Myotones project** aims to analyse the basic biomechanical properties of the skeletal muscles in a non-invasive way, using a small, handheld device. With **MyotonPRO changes in human resting muscle** (tone, elasticity and rigidity) caused by lack of gravity are **measured and evaluated** for astronauts on board the ISS. The technology has already been successfully applied in bed rest studies, while the device for taking measurements in microgravity conditions has already been proven to be suitable for use in space during parabolic flights. MyotonPRO measures the passive characteristics of near-surface skeletal muscle in the same way that a doctor would, by feeling for areas of tension and hardening in the muscles when relaxed. A short mechanical stimulus is placed on the surface of the skin for this purpose, and the vibration of the muscle beneath it is measured digitally. The data provide **precise information** about the **elasticity, rigidity and tone of the examined muscle at rest**. For the first time, this makes it possible to **determine the state of the muscle objectively, quickly and easily**. In addition to monitoring the physiological parameters of astronauts on the ISS, this method also allows the **success of countermeasures against muscular and bone atrophy in the form of sports programmes** to be monitored and objectively evaluated to better effect before, during and after their time on the ISS.

On Earth, the findings are used to **optimise rehabilitation and training programmes**, and for the objective **assessment of the success of training in fitness regimes and competitive sport**. According to the German Federal Institute for Occupational Safety and Health (Bundesanstalt für Arbeitsschutz und Arbeitsmedizin, BAuA), incapacity to work was responsible for production losses of approximately 64 billion euro in Germany in 2015. Around a quarter of production losses are due to muscle, bone and connective tissue diseases. Against this backdrop, optimised treatment, training programmes and objective assessment of effectiveness are vital in hospitals and surgeries.

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CIMON

The flying astronaut assistant

Brief description

CIMON (Crew Interactive MObile companioN) could be described as a 'flying brain' – an autonomous astronaut assistant. Equipped with artificial intelligence, this globally unique technology demonstration will support the work of astronauts on the ISS and will bring advances to the fields of Industry 4.0, medicine and care, as well as education.

Aims

CIMON uses the ISS as a test environment for trialling new technologies. CIMON aims to demonstrate that human-machine interaction can support the work of astronauts and increase their efficiency. The flying companion can, for example, present and explain a wide range of information and instructions for scientific experiments and repairs.

Parties involved

DLR Space Administration, Airbus, IBM Watson, Reichert Design, LMU Munich, Helden und Mayglöckchen, Darmstadt University of Applied Sciences (h_da)

Applications

- Supporting the work of astronauts
- Preparation for long-term exploration missions
- Human-machine psychosocial interaction

Outlook

- Assistance systems for human-machine interaction (Industry 4.0, the internet of things …)
- Medicine and care
- Use in education

Facts and figures

Launch: SpaceX CRS-15, 28 June 2018
Scientific support:
Judith Buchheim and Alexander Choukèr
Diameter: 32 cm
Properties: Autonomous navigation using air jet propulsion, voice and object recognition, information display, video data, etc

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8 DECENT WORK AND ECONOMIC GROWTH
9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

CIMON

The flying astronaut assistant

Technology demonstration – astronaut assistance system

CIMON is an innovative and globally unique astronaut assistance system. This autonomous flying system is equipped with **Artificial Intelligence (AI)** from **IBM** and will be used for the first time by ESA astronaut Alexander Gerst during the 'horizons' mission. The DLR Space Administration awarded **Airbus** the contract to undertake the CIMON project using funds from the **German Federal Ministry for Economic Affairs and Energy (BMWi)**, and it was specially developed for use in the European Columbus module on the ISS. CIMON aims to demonstrate that **human-machine interaction** can support the work of astronauts and **increase their efficiency**. The flying companion can present and explain a wide range of information and instructions for scientific experiments and repairs. One big advantage of CIMON is that the astronaut can work freely with both hands while having voice-controlled access to documents and media. A further application of CIMON is its use as a **mobile camera** for operational and scientific purposes. **The flying companion can carry out routine tasks, such as documenting experiments, searching for objects and performing inventories.** CIMON can also see, hear, speak and understand. **Cameras** and **facial recognition software** for orientation and video documentation serve as its 'eyes'. **Ultrasound sensors** measure distances to avoid collisions. Its 'ears' are comprised of several **microphones for spatial detection** and a directional microphone for **good voice recognition**. CIMON's 'mouth' is a loudspeaker, through which it can speak and play music. The heart of the AI for understanding speech is the **IBM Watson** system. The AI for autonomous navigation comes from Airbus and is used for movement planning and object recognition. CIMON is largely produced using a **3D printing** process and, with a diameter of 32 centimetres, is slightly larger than a football. CIMON can freely move and rotate in any direction using air jets. Using these jets, it can turn to an astronaut if it is addressed, nod and shake its head, and independently follow the user on command. Terrestrial applications for the CIMON technologies are expected in **Industry 4.0** (in robotic industrial production, for example), **medicine and care**, as well as **education**.

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ICARUS

Tracking animal migration

Brief description

ICARUS is a system for the global tracking of animal migrations. Using miniaturised transmitters attached to animals, data can be gathered on their migrations and sent to the ISS. Registered in a database, this information will help to protect animals, better understand the climate and the spread of disease, and drive more sustainable agriculture.

Aims

ICARUS uses the ISS to test new technologies. Multiple overflights covering large sections of Earth's surface allow for more accurate data acquisition. German and Russian scientists expect that the data will provide new information about animal behaviour, the spread of epidemics (e.g. bird flu, Ebola), and the interplay between animal migrations and food security in critical regions.

Parties involved

DLR Space Administration, Roscosmos, Max Planck Institute of Ornithology, IG RAS, RKK Energia, STI, I-GOS

Applications

- Research into animal lifestyles

Outlook

- Conservation of biodiversity
- Evaluation of the impact of climate change
- Better understanding of the spread of epidemics (for example, bird flu)
- Securing food bases

Facts and figures

Launch: Progress 69P, 13. February 2018
Area: Technology demonstration, ornithology
Scientific support:
Prof. Wikelski, Dr Tertitski, Prof Belyaev
Mass: 111 kg (Antenna), 5 g (tag)
Measurements: 3 x 1.25 x 1.2 m (antenna), 25 x 15 x 5 mm (T.)
Properties: Simultaneous recording of a large number of miniaturised transmitters

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15 LIFE ON LAND
17 PARTNERSHIPS FOR THE GOALS

ICARUS

Tracking animal migration

Technology demonstration – research on animal migration

ICARUS is based on collaborative work between the **DLR Space Administration** and the Russian space agency **Roscosmos**. Using funds from the **German Federal Ministry for Economic Affairs and Energy (BMWi)**, the DLR Space Administration has commissioned the **Max Planck Institute of Ornithology (MPIO)** in Radolfzell to develop a new system for the **global tracking of animal migrations**. The ICARUS system consists of two main components – **small animal transmitters (tags)** and the **space hardware (antennas and on board computer)**. **With a weight of less than five grams, even small animal species, such as songbirds, can be equipped with such transmitters** without affecting their behaviour.

On 14 October 2017 and 13 February 2018, the on board computer and antenna were transported to the ISS using Russian Progress freighters. While the computer is located in the interior of the ISS, two cosmonauts will install the antenna on the exterior of the Russian service module Zvezda. On Earth, the tags collect data on animal behaviour. For example, they collect GPS data, acceleration and environmental data. To save energy and thus increase their lifetime, the tag's transmitter and receiver are in 'sleep' mode most of the time. Data relating to the current ISS orbit is stored on the tag and these functions are only awoken when the space station flies overhead. They then send their data to the antennas in orbit. The data is decoded via the ICARUS computer and forwarded to the Russian ISS ground station. From there, it is fed into a scientific database. The system, which has mainly been developed by German SMEs, is intended to provide an **unprecedented level of precision and reliability**.

German and Russian scientists are hoping that the data will not only provide new information about animal behaviour, but also expect to make **findings about the spread of epidemics (e.g. bird flu, Ebola), the impact of climate change and the interplay between animal migrations and food security in critical regions**.

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E-Nose

Electronic sniffing in microgravity

Brief description

Supported by the DLR Space Administration with funds from the German Federal Ministry for Economic Affairs and Energy (BMWi), the two E-Nose experiments conducted on the ISS are looking to detect microbiological contamination due to bacteria or fungi, as well as to analyse oxidative stress in astronauts during extravehicular activity (EVA) through breath gas measurements.

Aims

The E-Nose can identify bacteria and fungal cultures on the ISS that could be detrimental to the health of astronauts as well as the affected materials. Breath gas measurements enable astronauts' oxidative stress levels to be determined through the breathing of pure oxygen during extravehicular activity.

Parties involved

DLR, Airbus Defence and Space, Institute of Biomedical Problems (IBMP), Moscow

Applications

- Identification of bacterial and fungal infestations
- Measurements in difficult-to-reach places by using a gooseneck probe
- Prompt analysis by transmitting the measurement data to Earth via a downlink
- Detection of oxidative stress during extravehicular activity

Outlook

- Identification of bacterial and fungal infestations
- Measurements in difficult-to-reach places by using a gooseneck probe
- Prompt analysis by transmitting the measurement data to Earth via a downlink
- Detection of oxidative stress during extravehicular activity

Facts and figures

- Use of E-Nose Surface Contamination: 2012–2018
- Use of E-Nose Breath Gas: From 2019
- Sensor technology: Metal oxide sensors
- Creation of a reference database with smells from 20 organisms known to exist on the ISS
- Scientific monitoring by the Russian Institute of Biomedical Problems and the Medical Center of the Ludwig-Maximilians-University (LMU) Munich

3 GOOD HEALTH AND WELL-BEING

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E-Nose

Electronic sniffing in microgravity

The E-Nose project comprises two experiments being conducted in the Russian segment of the International Space Station (ISS), supported by the DLR Space Administration, with funds from the German Federal Ministry for Economic Affairs and Energy (BMWi).

In the first experiment, **microbiological contamination due to bacteria and fungi** was detected qualitatively and quantitatively. The astronauts were required to use the E-Nose, a gas analysis device, to carry out measurements at various places in the ISS Service Module. Importantly, the newly developed gooseneck sampler probe allowed measurements to be taken even in hard-to-access places, such as the racks. The adequate determination of the level of contamination in these spots was previously not possible. As part of the second experiment, the oxidative stress of the astronauts will be analysed before and after extravehicular activity using breath gas analysis. This involves the observation of **specific markers in respiratory gas that are indicative of oxidative stress**.

The measuring system is known as an electronic nose (E-Nose), as it uses 10 different semiconducting sensors to acquire a specific picture of the smell. This makes use of the reducing or oxidising properties of the gas molecules emitted by the biological cultures (microbial volatile organic compounds, or MVOCs). These MVOCs are formed by the metabolic process of the biological cultures and are species-specific. By examining the different levels of stimulus and types of sensors triggered among the array of sensors, it is possible to **generate an olfactory fingerprint via 'smell training'**.

Unlike the classic method of sampling (swab tests) followed by incubation, which can only be performed by experts and is particularly time-consuming while in orbit, the method presented here allows prompt analysis of the situation thanks to the data link.

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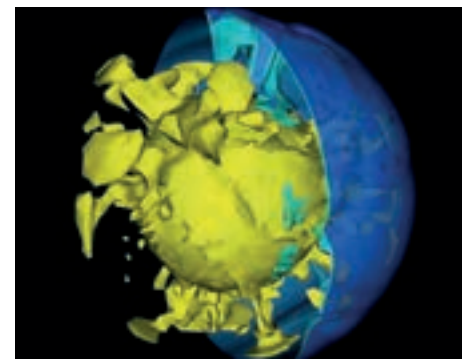
GeoFlow/AtmoFlow

Insight into the flow of matter inside Earth



Brief description

The interior of Earth resembles the layers of an onion. But what exactly occurs there? This is the question addressed by the GeoFlow (Geophysical Flow Simulation) experiment. On the ISS, where Earth's gravity and centrifugal force are in balance, it is necessary to create this force field artificially in a piece of apparatus – a 'miniature Earth' – in order to shed light on the mystery of flow and temperature conditions beneath Earth's crust.

Aims

A camera positioned above the miniature Earth records the flow patterns occurring during an experiment run. Scientists compare the striped patterns (interferograms) with model simulations and use the findings to infer the temperature distribution and flow conditions within the fluid.

Parties involved

Brandenburg Technical Univ. Cottbus, DLR Space Administration, ESA, NASA, int. Science team (Univ. of Paris, University Le-Havre, University of Leeds, DLR Institute of Planetary Research, University of Potsdam)

Applications

- Improvement in the physical understanding of flow in the liquid core of Earth and the flow of magma in the interior
- Characterisation of the flow dynamics inside Earth
- Application of electrohydro-dynamic force to control flow

Outlook

- Simulation of large and small-scale flow in planetary atmospheres
- Influence of atmospheric circulation on the climate
- Analysis of planetary waves and baroclinic instabilities
- Extreme value statistics
- Influence of global warming on atmospheric movements and the climate

Facts and figures

GeoFlow I: 7 February 2008 to January 2009
Geoflow II: 16 February 2011 to present
AtmoFlow: planned from 2022
Installation of Geoflow: I / II in the Fluid Science Laboratory (FSL) of the ISS Columbus Module
Mission operation: Columbus Control Center in Oberpfaffenhofen, MARS in Naples, E-USOC in Madrid as well as GeoFlow ground station BTU Cottbus.

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13 CLIMATE ACTION

GeoFlow/AtmoFlow

Insight into the flow of matter inside Earth

Earth's interior resembles the layers of an onion. But what exactly occurs there? Until now, theoretical physics has been unable to provide conclusive answers to this question. Anyone seeking to research this kind of flow in a terrestrial laboratory setting will encounter a problem – gravity. Gravitation acts from Earth's core on the 'real' surface, and its magnitude decreases towards Earth's crust. In this way, the radial force field ensures a characteristic distribution of temperature in Earth's mantle and outer core. In order to solve the **mystery of flow and temperature conditions inside Earth** by experimental means, this radial force field needs to be created artificially in a piece of apparatus ('miniature Earth') on the ISS, where Earth's gravity and centrifugal force are in balance.

It was precisely this idea that gave birth to the shoebox-sized apparatus called 'Geophysical Flow Simulation', or GeoFlow for short. A viscous dielectric oil layer is located between an inner, solid sphere and a hollow outer sphere. The inner sphere is heated to match the temperature conditions inside Earth, while the outer sphere is cooled. A high voltage is then applied to the gap between the spheres to create an undistorted, centrally-symmetric force field that **simulates the gravity on Earth**. A camera above the miniature Earth records the flow patterns that occur during an experiment run. Scientists compare the striped patterns (interferograms) with model simulations and use the findings to infer the temperature distribution and flow conditions within the fluid.

After GeoFlow I (2008–2009) and GeoFlow II (2011–2018), the follow-up experiment AtmoFlow, which will start in 2022, will be used to analyse complex flow patterns in Earth's atmosphere, to acquire, for example, a greater understanding of the climate impact of global warming and the resulting changes on Earth.

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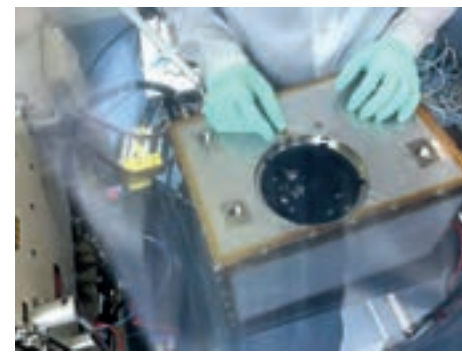
CompGran

Soft Matter Dynamics



Brief description

Granules such as sand or grain are, in addition to liquids, the most processed goods in terms of quantity. However, so far, very little is known about their behaviour in industrial processes. For the processing of these bulk materials, as well as the improvement of corresponding equipment, the behaviour of such moving granular media under microgravity is being examined within the 'Soft Matter Dynamics' experiment.

Aims

Only in microgravity is there no subsidence of particles. Their long-term behaviour without subsidence can only be monitored on the ISS. The data acquired is an important reference for modeling, and gives fundamental insights into the interaction of light with particles.

Parties involved

DLR Space Administration, Airbus, University of Cologne, University of Düsseldorf, University of Erlangen-Nuremberg

Applications

- Model development to predict granulate behaviour in general
- Development of non-contact analysis methods for the granulation industry

Outlook

- Process monitoring of industrial processes using bulk materials.
- Further development of particle analysis
- Planning of industrial plants

Facts and figures

Launch: SpaceX-CRS 15, 28 June 2018
Scientific support:
Prof. Sperl, Prof. Egelhaaf, Dr Schröter
Properties: Granular materials, dynamic light scattering, in situ process monitoring

8 DECENT WORK AND ECONOMIC GROWTH

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

CompGran

Soft Matter Dynamics

Understanding the movement of granules – improving industrial processes

Granular media are made up of small particles. The ESA **Soft Matter Dynamics experiment (SoMaDy)** will capture and describe the **dynamics** of granular material. **As a national provision, sample cells (CompGran) are being manufactured on behalf of the DLR Space Administration for the Soft Matter Dynamics installation**. In this, the dynamics of granulates of various densities are being examined. These dynamics are of great importance for **industrial operations**, such as the **processing of grain and plastic granules**. As the granules fall to the bottom of their container very quickly on Earth, their dynamics can only be investigated under microgravity conditions. The movement of the granules is examined using a technique known as **dynamic light scattering**. Here, the light scattered by individual particles is analysed to obtain information on the particle size and dynamics. Of particular interest are the transitions between different states of the granules, such as from a fluid-like behaviour to a solidified state. If a granular medium is liquid at first, the granules block one another when the packing density is slightly increased, hindering further movement. In ground reference measurements, the 'dynamic light scattering' analytical method will initially be developed and established in general for granular media. To this end, simulations and dynamic light scattering are used on reference systems, supplemented with X-ray imaging and X-ray tomography measurements. The results obtained will then be transferred to experiments on board the ISS.

In addition to liquids, granules are the most processed goods by quantity. In situ monitoring of industrial processes where granules occur is still difficult due to a lack of analytical procedures. These experiments should, on the one hand, unlock the **behaviour of granules** and facilitate theoretical descriptions of it. On the other hand, **measurement procedures will be developed for in situ analyses of granular media**, which is also of great interest for the **monitoring of industrial processes.**

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EDEN ISS

Plant cultivation with artificial light and without soil

Brief description

The EDEN ISS laboratory is a greenhouse in the Antarctic that uses a hermetic system to cultivate cucumber, radishes and other vegetables without soil and artificial light in a closed-loop system.

Aims

The consortium of the EDEN ISS project designs and tests key agricultural technologies under controlled conditions – Controlled Environment Agriculture (CEA) – for possible experiments on board the International Space Station ISS and in future habitats on the Moon and Mars.

Parties involved

International consortium

Applications

- Simulation of research under space conditions in the Antarctic
- Development of bio-regenerative life support systems for waste management, provision of water, oxygen and food within future habitats

Outlook

- Long-term stay of humans in space
- Food supply in climatically demanding regions on Earth (polar regions, deserts)
- Food production without insecticides and pesticides (closed system)

Facts and figures

Mission start: December 2017
Duration: 1 year
Cultivated plants: tomatoes, cucumbers, strawberries, lettuce, arugula, radishes, peppers, basil, chives, parsley, lemon balm and mint
Dimensions: standard 20-foot container (6 metres long)

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9 INDUSTRY, INNOVATION AND INFRASTRUCTURE
12 RESPONSIBLE CONSUMPTION AND PRODUCTION

EDEN ISS

Plant cultivation with artificial light and without soil

Sustained human presence in space requires the development of new technologies to maintain environmental control, manage waste, provide water, oxygen and food and to keep astronauts healthy and psychologically fit. **Bio-regenerative life support systems**, using higher plants, can be advantageously employed for the production of food and oxygen, the reduction of carbon dioxide, and for water recycling and waste management. In addition, freshly harvested crops in controlled environments can also have a positive impact on the psychological well-being of the crew.

The EDEN ISS consortium has designed and is testing **essential Controlled Environment Agriculture (CEA) technologies** for possible experiments on board the ISS. For this, a cultivation system is used in a research module – the International Standard Payload Rack (ISPR). Moreover, a research greenhouse – the Future Exploration Greenhouse (FEG) – is being designed to provide future bio-regenerative life-support systems in a space environment. The technologies are being tested in a laboratory setting, as well as in the highly isolated **Neumayer Station III**, which is operated by the **Alfred Wegener Institute in the Antarctic**. The mobile test system – known as the EDEN ISS Mobile Test Facility (MTF) – will be used to study the mass flow relationships for the ISPR demonstrator and FEG. In addition to technology development and validation, food safety and plant handling procedures are being developed. These are integral aspects of the interaction between the crew and plants within closed environments.

Parties involved: DLR, LIQUIFER Systems Group, Austria, National Research Council, Italy, University of Guelph, Canada, Alfred Wegener Institute for Polar and Marine Research, Germany, Enginsoft S.p.A., Italy, Airbus Defence and Space, Germany, Thales Alenia Space Italia S.p.A., Italy, Arescosmo S.p.A., Italy, Wageningen University and Research, the Netherlands, Heliospectra AB, Sweden. Limerick Institute of Technology, Ireland, Telespazio S.p.A., Italy, University of Florida, USA

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Mars Express (HRSC)

Flying over Mars

Brief description

The DLR Institute of Planetary Research specialises in the topographical mapping of Mars. The researchers used the stereo data acquired from the High Resolution Stereo Camera (HRSC) to produce a large-format and uniform, topographical map of the surface, presenting Mars in a vividness and detailed accuracy virtually unparalleled by any other experiment.

Aims

Topographical maps enable the exact depiction of geometrical relations such as elevation differences, distances and landscape characteristics. The aim is to produce a precise and global map of our planetary neighbour.

Parties involved

Institute of Planetary Research, Airbus Defence and Space, Lewicki Microelectronic GmbH and Jena-Optronik GmbH

Applications

- Exploration
- Planetary geology
- Precise representation of elevation differences
- Creation of topographic and geographic maps

Outlook

- Complete topographic mapping of Mars in high resolution and colour
- Identification of future landing sites
- Answering fundamental planetary science questions: Was there, or is there, life on Mars?

Facts and figures

- **Mission:** HRSC camera on ESA's Mars Express spacecraft
- **Achieved coverage of Mars:** 97 percent (image resolution 10-100 metres)
- **Information base of the mosaic:** 89 orbits around Mars
- **Database:** 7300 stereo image strips
- Longest and most extensive (dataset) German space experiment so far

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

Mars Express (HRSC)

Flying over Mars

Home to the sweeping highlands of Mars, pockmarked with craters, the region is 2.3 million square kilometres in size. It also includes parts of the Ares Vallis valley, the chaotic landscape of Aram Chaos, the ancient Mawrth Vallis valley and the Meridiani Planum and Chryse Planitia plains. **The film clip shows the path taken by NASA astronaut Mark Watney in the blockbuster film 'The Martian'**. In order to generate the unique mosaic, scientists from the DLR Institute of Planetary Research used data from the **HRSC camera (High Resolution Stereo Camera) on board ESA's Mars Express spacecraft**, which has been in orbit around the Red Planet since 25 December 2003. Nine sensors record the surface from a variety of angles to permit mapping of Mars in high resolution, colour and in three dimensions. In order to produce the 3-D opening credits to the successful US cinema release, the scientists processed the three-dimensional elevation models and perspective images, combining the 50 to 100 kilometre-wide image strips to produce a large-format and uniform map. Due to the detailed terrain data and the immense expansion of the region shown here, **almost five months of pure computing time was necessary to produce this film clip**.

To this day, the HRSC camera has already scanned approximately 70 percent of the Martian surface with image resolutions of 10 to 20 metres, which are used to create highly precise 3-D maps. **Coverage with image resolutions of up to 100 metres is already at 97 percent**. The film obtained from this mosaic impressively shows the elevation differences between the various Martian regions (with approximately double super-elevation). In addition, these maps will be used as a basis to select landing sites before future missions touch down on the Red Planet. The HRSC was developed at DLR and built in cooperation with industrial partners. The DLR Institute of Planetary Research in Berlin-Adlershof is responsible for operations and scientific management.

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InSight/HP^3

Interior Exploration using Seismic Investigations, Geodesy and Heat Transport

Brief description

In May 2018, the NASA InSight space probe will embark on its journey to Mars, with the goal of investigating its geophysical properties. On board the lander are the French space agency's (CNES) SEIS seismometer, the HP^3 sensor package developed by DLR and JPL's RISE experiment.

Aims

The InSight mission is intended to comprehensively examine the interior structure of our planetary neighbour. After the landing, SEIS will measure the waves from 'Marsquakes' that travel through the planet's interior. HP^3 will determine the heat flow and some of the physical properties of the Martian soil; RISE will measure the precession and nutation of the spin axis.

Parties involved

DLR, Lockheed Martin, JPL (NASA), Institut de Physique du Globe de Paris

Applications

- Exploration
- Basic research
- Planetary physics
- Comparative planetology

Outlook

- Geophysical exploration of the Moon, Mars and Mercury
- In-situ exploration of the subsurface
- Sampling

Facts and figures

- **Launch:** May 2018
- **Arrival:** 26 November 2018
- **Mission duration:** 2 Earth years
  Second heat flow measurement on a celestial body since Apollo 17 (1972)

InSight/HP^3

Interior Exploration using Seismic Investigations, Geodesy and Heat Transport

Just six months after its launch in May 2018, the InSight lander will touch down on the surface of Mars. The mission is part of **NASA's successful Discovery programme** and for the first time will intensively examine the **interior of our planetary neighbour** – its crust, mantle and core. While Earth has experienced many changes as a result of plate tectonics, Mars has undergone less of a radical change since its formation four and a half billion years ago. Scientists are hoping that InSight will provide answers to questions regarding the earliest **developments of Mars** and enable them to draw conclusions about the evolutionary history of the Red Planet and Earth. The landing site in Elysium Planum is located in the northern lowlands, approximately 1500 kilometres south of the Elysium Mons volcano. After landing, the **Seismic Experiment for Interior Structures (SEIS)** will start to record the seismic waves from 'Marsquakes' and providing data to understand the planet's history. The **Rotation and Interior Structure Experiment (RISE)** will register minimal changes in the planet's axis alignment and also allow conclusions to be drawn about its interior structure. DLR is sending a heat flow probe to the Red Planet, namely the **Heat Flow and Physical Properties Package (HP^3)**. A so-called 'mole' will penetrate to a depth of five metres using an **internal hammering mechanism** that will drive heat sensors into the ground. These will supply readings fully automatically and from various depths during an entire Martian year – the equivalent of two Earth years. An infrared radiometer will also measure the temperature profile on the surface. The combination of both data sets makes it possible to deduce the **heat flow in the planet's interior**. The instrument was primarily developed at the DLR Institute of Planetary Research and tested at the DLR Institute of Space Systems. After InSight has landed, DLR's Microgravity User Support Center in Cologne will take over HP^3 operations.

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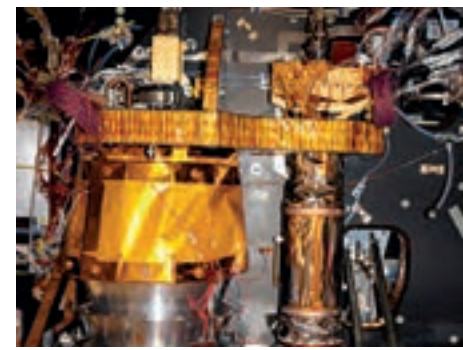
BepiColombo (BELA)

BepiColombo Laser Altimeter



Brief description

The laser altimeter BELA will be launched in October 2018 on board the joint ESA/JAXA BepiColombo mission to Mercury. BELA will measure the planet's topography using laser pulse distance measurements. Due to Mercury's proximity to the Sun, BELA will have to deal with intense heat and sunlight. As such, it has been equipped with a particularly elaborate thermal protection system.

Aims

The mission BepiColombo aims to investigate the development of the little-explored planet Mercury. BELA will provide information about the global shape, rotation and topography of the Sun's innermost planet. In addition, tides, altitude profiles and geological formations will also be examined. From the shape of the received pulses, the surface roughness can be determined.

Parties involved

DLR Institute of Planetary Research, University of Bern, MPI for Solar System Research, Instituto de Astrofísica de Andalucia

Applications

- Exploration of the Solar System
- Planetary geodesy
- Planetary physics
- Planetary geology
- Basic research

Outlook

- Unique, new data for Mercury
- First interplanetary laser altimeter on a European mission
- Expanding system leadership for interplanetary laser altimeters (Europe)
- Further development of laser altimeters: GALA (ESA JUICE mission)

Facts ad figures

- **Mission launch:** October 2018
- **Arrival at Mercury:** 2025
- **Measuring principle:** distance-time-law (speed of light)
- **Receiver:** APD (Avalanche Photo Diode)
- **Pulse frequency:** 10 Hz
- **Accuracy height measurement (vertical):** ~1 m
- **Mass:** 15 kg

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

BepiColombo (BELA)

BepiColombo Laser Altimeter

The BELA laser altimeter will be launched in October 2018 on board the European-Japanese BepiColombo mission to Mercury. BepiColombo will reach Mercury's orbit in 2025 after **several flybys of Earth, Venus and Mars**. The mission is a joint project between ESA and JAXA and consists of a **propulsion module and two orbiters**: the Mercury Planetary Orbiter (MPO) and the Mercury Magnetospheric Orbiter (MMO). The mission carries a total of 16 experiments. Upon arrival of the MPO, BELA will use a laser to measure the surface of Mercury from altitudes up to 1000 kilometres. Ten laser pulses with 50 millijoule energy and a wavelength of 1064 nanometres are emitted per second in the direction of Mercury and detected a few milliseconds later by the instrument's receiver. From the travel-time duration of the laser pulses, the scientists are able to obtain accurate information about the **shape and surface of Mercury**. Based on this data, the researchers determine the elevation model and topography of the planet. BELA also provides information on rotation, tides and roughness of the surface. These parameters are important in order to calculate an exact surface model. In addition, from the determination of the state of rotation and the tides, conclusions can be drawn on the planet's internal structure and development. **Mercury is the innermost planet** – accordingly, the MPO will be exposed to temperatures of up to 350 degrees Celsius during the scheduled one-year mission. In addition to comprehensive thermal and light protection on the instrument, eye-catching protection devices (baffles) prevent sunlight or scattered light from reaching the detector and affecting measurements. BELA was developed and built by DLR in collaboration with the University of Bern, the Max Planck Institute for Solar System Research, the Instituto de Astrofísica de Andalucia and industry. The DLR Institute of Planetary Research is responsible for operations and the evaluation of the scientific data.

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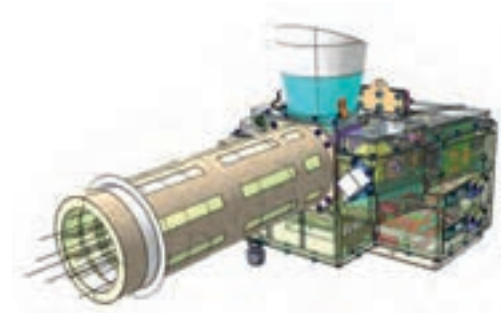
BepiColombo (MERTIS)

MErcury Radiometer and Thermal Infrared Imaging Spectrometer



Brief description

MERTIS is a spectrometer combined with a radiometer on board the ESA/JAXA BepiColombo mission, which is scheduled for launch to Mercury in autumn 2018. MERTIS is characterised by its compact design and low power consumption.

Aims

This near- and mid-infrared spectrometer will investigate the mineralogical composition of Mercury's surface and identify rock-forming minerals. The integrated micro-radiometer allows comprehensive measurements of the temperature and thermal conductivity of Mercury. From the data, the scientists hope to learn more about the formation and evolution of the planet.

Parties involved

DLR Institute of Planetary Research, University of Münster, DLR Institute of Optical Sensor Systems, OHB System AG

Applications

- Exploration and basic research
- Planetary geology and evolution
- Mineralogy and petrology
- Temperature map

Outlook

- Sensors under extreme environmental conditions
- Highly integrated and miniaturised sensor concepts
- Improved energy technology

Facts and figures

- **Mission launch:** October 2018
- **Arrival at Mercury:** 2025
- **Mass:** 3 kg
- **Power:** 19 watts
- **Spectral range:** 7–14 micrometres (Spectrometer)/7–40 micrometres (Radiometer)
- **Dimensions:** 18 x 18 x 13 cm (excl. baffles), 38 x 18 x 25 cm with baffles
- **Sensors:** microbolometer, thermal imaging sensor, fully reflective optics

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

BepiColombo (MERTIS)

MErcury Radiometer and Thermal Infrared Imaging Spectrometer

In October 2018, the thermal infrared imaging spectrometer MERTIS will be launched on board the European-Japanese mission BepiColombo to Mercury – the least explored planet in the inner Solar System thus far. BepiColombo will arrive at its destination in 2025. The mission comprises a **propulsion system and two orbiters**: the Mercury Planetary Orbiter (MPO) and the Mercury Magnetospheric Orbiter (MMO). BepiColombo is a **joint mission** between ESA and JAXA. Once in Mercury's orbit, MERTIS on board the MPO, will closely examine the surface and, indirectly, the innermost planet's interior. Using a **mid-infrared spectrometer**, MERTIS will record the planet globally with a spatial resolution of 500 metres and identify **rock-forming minerals** on the surface. MERTIS uses the first space-qualified microbolometer produced in Europe. The resolution of the instrument can be flexibly adapted to the observation conditions. It can thus also be used to study the polar regions. These have not been investigated in detail so far and which show a reflection of radar signals in deep craters into which a ray of sunlight never penetrates. Scientists suspect that water ice could be present, due to the extremely low temperatures prevailing there. Knowledge of the mineralogical composition is crucial for researchers to understand the **evolution of the Sun's innermost planet**. The MERTIS radiometer is designed to measure the surface temperature variations of the planet over the entire temperature range of 80 to 700 Kelvin (about -190 to 430 degrees Celsius) and its thermal inertia. With the innovative instrument concept developed by DLR, it has been possible to reduce the weight of the instrument to three kilograms and the power consumption to 19 watts. The MERTIS team is headed by the University of Münster and the DLR Institute of Planetary Research. The project is managed by the DLR Institute of Optical Sensor Systems.

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eROSITA

Hunting for Dark Energy

Brief description

It is a search for clues with 'cosmic inventory': Far from Earth, the eROSITA X-ray telescope will, from 2019 systematically scan the sky for X-ray sources and detect unknown neutron stars, quasars and galaxy clusters. The eROSITA all-sky survey will be about 25 times more sensitive than the pioneering ROSAT mission of the 1990s.

Aims

eROSITA will search for Dark Energy, which could play a major role in the expansion of the Universe since the Big Bang. The primary instrument on board the German-Russian Spectrum-Roentgen-Gamma mission, the X-ray telescope will focus on clusters of galaxies. This will make it possible to derive conclusions about the effect of the hitherto mysterious dark energy.

Parties involved

Max Planck Institute for Extraterrestrial Physics, University of Tübingen, University of Erlangen-Nuremberg, Leibniz Institute for Astrophysics Potsdam, University of Hamburg, DLR Space Administration

Applications

- Precise statements about the state and changes of the Universe

Outlook

- Better understanding of the origin of the Universe
- Insights into the role / effect of dark energy

Facts and figures

- **Launch:** scheduled for 2019
- **Orbit:** around the second Lagrange point of the Sun-Earth system, L2 (1.5 million km from Earth)
- **Telescope dimensions:** approx. 3 m long (open 4.5 m)
- **Optics:** 7 mirror modules, each with a diameter of 36 cm with 54 mirror shells, focal length: 1.6 m
- **Detector:** CCD camera, The centrepiece is a silicon-frame store pnCCD. The image area of approx. 3 x 3 cm is subdivided into 384 x 384 pixels with a size of 75 x 75 microns

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

eROSITA

Hunting for Dark Energy

Since the Big Bang, the Universe has been expanding. This expansion should actually be slowed down by the gravity of matter. But driven by Dark Energy, the expansion is accelerating. The physical phenomenon 'Dark Energy' is largely unexplained. The German X-ray telescope **eROSITA (extended Roentgen Survey with an Imaging Telescope Array)**, which is being built under the auspices of the Max Planck Institute for Extra-terrestrial Physics in Garching, will shed light into the darkness. The project is supported by the DLR Space Administration with funds from the German Federal Ministry for Economic Affairs and Energy (BMWi).

How can **Dark Energy**, which is invisible and only noticeable on vast distances, be investigated with an X-ray telescope? The key to this is galactic clusters – groups of up to several thousand individual galaxies. They attract the surrounding hydrogen gas, which, when it flows in, becomes so hot that it emits X-rays, and thus becomes visible to eROSITA. **eROSITA will study the distribution of approximately 100,000 galaxy clusters.** By determining the distribution of galaxy clusters in space, astronomers can not only determine the structure of the Universe today, but also in the past – because of the gigantic distances involved. This distribution was shaped by the nature of Dark Energy, whose properties can be deduced from the observations. To discover galactic clusters, eROSITA will scan the entire sky multiple times, observing many other phenomena and objects, such as active galactic nuclei, supernova remnants or X-ray binaries.

Far away from Earth, the seven-eyed telescope is the **primary instrument of the German-Russian satellite mission 'Spectrum-Roenten-Gamma'**, which from 2019 will systematically scan the sky for X-ray sources. With special X-ray CCDs made of high-purity silicon cooled to minus 90 degrees Celsius and a mirror system composed of 378 galvanically replicated, thin-walled, gold-coated X-ray mirror shells, eROSITA optimally exploits the sparse incident X-ray light from the Universe and also permits detailed spectral analyses.

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MASCOT

Mobile Asteroid Surface Scout

Brief description

MASCOT is a lander on board the Japanese Hayabusa2 spacecraft. The destination of the mission is the asteroid Ryugu. Upon arrival, MASCOT will touch down on the surface, 'hop' from location to location, and carry out measurements at various points on an asteroid for the first time in history.

Aims

After a successful landing, MASCOT will conduct an extensive examination of the asteroid using its four instruments: a radiometer to determine the surface temperature, a camera to provide high-resolution images of the surface, a spectrometer to determine the mineralogical composition, and a magnetometer to identify the asteroid's magnetic field.

Parties involved

DLR, JAXA, CNES, TU Braunschweig, Institut d'Astrophysique Spatiale (Paris)

Applications

- Exploration
- Research under space conditions
- Insights into the formation and development of asteroids
- Technology testing: mobility under microgravity conditions

Outlook

- Insights into the origins of the Solar System
- Asteroid defence
- New developments in lightweight construction
- Landing and mobility under microgravity conditions

Facts and figures

Mission launch: 3 December 2014
MASCOT landing:
Between 1 and 4 October 2018
MASCOT dimensions:
295 mm x 275 mm x 195 mm
Weight: 9.6 kg
Four scientific experiments: Camera, radiometer, hyperspectral microscope and magnetometer

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

MASCOT

Mobile Asteroid Surface Scout

The Japanese **Hayabusa2 spacecraft** embarked on a unique mission on 3 December 2014. Its destination is the **C-type asteroid 162173 Ryugu** (1999 JU3), which belongs to the most common variety of near-Earth asteroids. Hayabusa2 will observe, map and measure it. In addition, the MASCOT lander will touch down on the asteroid, 'hop' around on the surface and take **measurements in several places**. Hayabusa2 will **return to Earth** with the probes taken from the immediate vicinity of the asteroid two years later. The aim of the Hayabusa2 mission is to learn more about the **origin and evolution of the Solar System**. Like comets, asteroids are some of the most primordial celestial bodies. Ryugu has a diameter of only one kilometre and has a correspondingly low gravitational pull. MASCOT will be pushed out of its holder by a spring mechanism and fall to Ryugu from a height of approximately 60 metres. Once it is there, it will record data for up to 16 hours, sending the information to its mothercraft. It will use its swing arm to **'hop'** across the surface. This has been programmed in such a way that the lander does not reach escape velocity when moving, which would cause it to fly back into space.

MASCOT was built by **DLR** together with the French space agency **CNES** and the Japanese space agency **JAXA**. The DLR Institute of Space Systems designed, manufactured and tested the lander. The Institute of Composite Structures and Adaptive Systems was responsible for the lander's stable structure. The DLR Robotics and Mechatronics Centre developed the swing arm, while the DLR Institute of Planetary Research contributed towards the camera and radiometer. CNES was involved in the development of MASCOT's power subsystem, part of the telecommunications system including the antenna, descent and landing emission analysis and the MicrOmega instrument (optical microscope and NIR hyperspectral camera), which was developed at the Institut d'Astrophysique Spatiale in Orsay. JAXA provided the transceiver for the telecommunications system. The MASCOT asteroid lander is monitored and operated from DLR's Microgravity User Support Centre in Cologne.

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DLR

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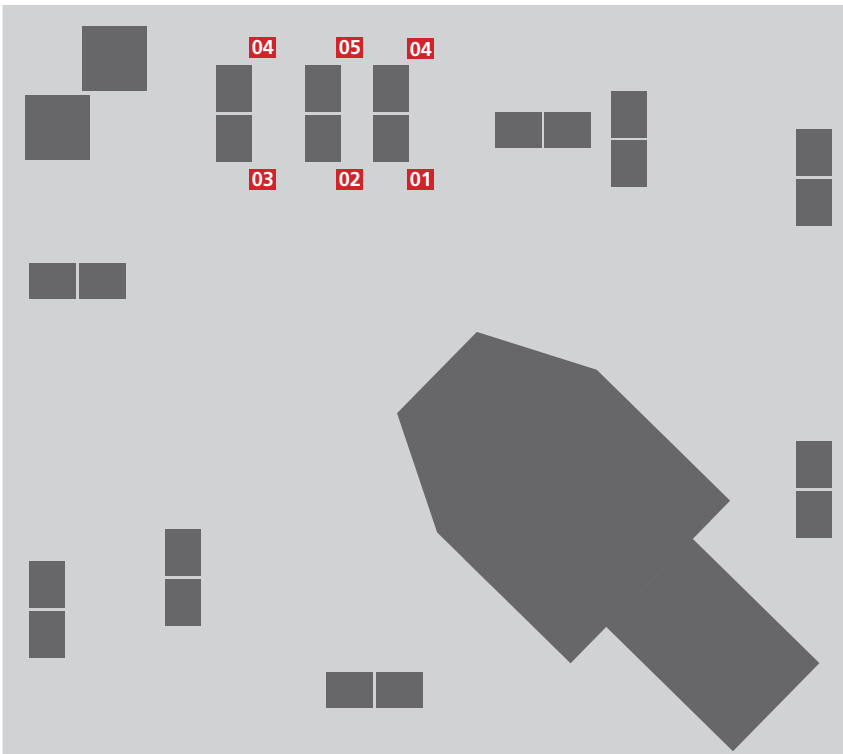
DLR exhibits at the stand of the German Federal Ministry for Economic Affairs and Energy (BMWi)

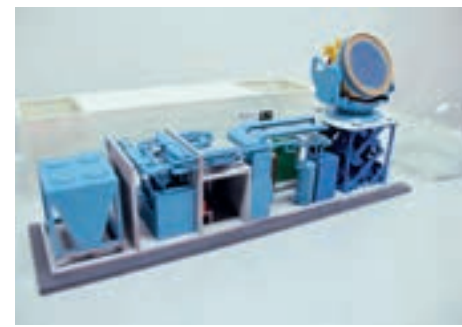
Hall 2, stand 203



01 GESTRA
02 MERLIN
03 TransFIT
04 Space makes a difference!
05 Earth observation

GESTRA

Experimental space monitoring radar



Brief description

GESTRA (German Experimental Space Surveillance and Tracking Radar) is an experimental space monitoring radar. The sensor is being developed and built by the Fraunhofer Institute for High Frequency Physics and Radar Techniques FHR and financed by DLR with funds from the German Federal Ministry for Economic Affairs and Energy (BMWi). The space monitoring system is scheduled to start delivering data in 2019.

Aims

For the first time, GESTRA is making it possible for Germany to independently track, identify and catalogue objects in space. The equipment is intended to record orbital data from satellites and debris in low Earth orbit at an altitude of between 300 and 3000 kilometres.

Parties involved

DLR Space Administration, FHR Wachtberg, DLR and German Air Force Space Situational Awareness Centre

Applications

- Establishment, maintenance and operation of an orbital data catalogue by the DLR and German Air Force Space Situational Awareness Centre in Uedem.
- Development of system competence and expertise in space situational awareness, as a basis for operational space surveillance

Outlook

- Sustainable and safe satellite operation for space-based services and products, from navigation systems to Earth observation and communications
- Strategies for addressing the growing amount of space residue/debris

Facts and figures

Start: planned for 2019
Size: housing container**:** 18 m x 4 m x 4 m**,** mass: approx. 90 t**,**
radiation dome: 5 m,
diameter: 5 m
Properties: transmitting frequency, 1280 – 1380 MHZ, beam angle max. 20 degrees zenith distance, no ionising radiation

GESTRA

Experimental space monitoring radar

GESTRA (German Experimental Space Surveillance and Tracking Radar) is an experimental space monitoring radar designed to record the **orbital data of satellites and debris in Low Earth Orbit** at an altitude of between 300 and 3000 kilometres. It is expected to conduct its first measurements from 2019. The radar is operated by the **joint DLR and German Air Force Space Situational Awareness Centre** in Uedem. GESTRA is also intended to work in conjunction with other large-scale facilities, such as the space observation radar, TIRA, or the radio telescope, Effelsberg, in order to expand expertise in so-called bi- and multi-static radar operation. This is based on the radar-supported observation of objects in space, involving several, spatially separated transmitters and receivers. Smaller objects, in particular, can therefore be more easily detected and more accurately determined. There are around 16,000 recorded and catalogued space debris objects, usually with a diameter of at least 10 centimetres. The **largest accumulation of space debris is located at an altitude of around 900 kilometres**, the site of frequently used orbits. We estimate that there are a total of 29,000 objects larger than 10 cm, 750,000 objects larger than 1 cm and 150 million objects larger than 1 mm.

The GESTRA data will be made available to research institutions in Germany, and form the basis of future developments in operational space surveillance. GESTRA is also a major step towards implementing the German government's space strategy, which places a great deal of importance on establishing its own capacity to continuously record the space situation, including in an international context. The ability to continuously monitor space objects in order to prevent the collision of satellites and other objects is therefore being systematically developed and expanded in Germany.

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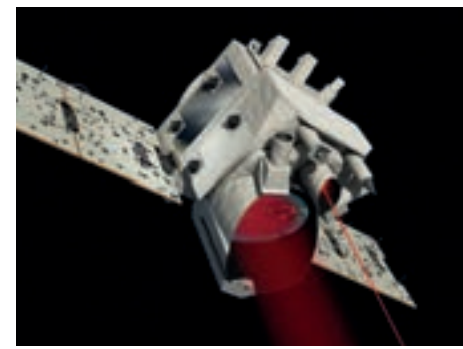
MERLIN

The Franco-German satellite mission



Brief description

From 2021, the Franco-German climate mission MERLIN (MEthane Remote sensing LIdar missioN) will trace the greenhouse gas methane using a Lidar instrument. Germany's contribution to MERLIN is managed by the DLR Space Administration with funding from the German Federal Ministry for Economic Affairs and Energy (BMWi), and the space agency CNES is responsible for the French contribution.

Aims

Methane is one of the most effective greenhouse gases at making the planet warmer and is partially responsible for climate change. This three-year mission is aimed at producing a global map of atmospheric methane concentrations. Among other things, it will provide information on the main regional sources of methane and the areas in which the greenhouse gas is removed from the atmosphere (sinks).

Parties involved

DLR Space Administration, French space agency CNES, European space industry led by Airbus in Ottobrunn

Applications

- Earth observation satellite for research into the causes of climate change
- Innovative measurement methods and thus better-quality data for documenting and creating a catalogue of global methane concentrations

Outlook

- Development of systems expertise and know-how relating to global methane observation
- Real contribution towards implementing the Paris Climate Agreement targets
- Demonstration of new, highly accurate satellite-based measurement methods to determine methane concentrations

Facts and figures

Launch: scheduled for 2023 with Soyuz or Vega/Vega-C from the European Spaceport in French Guiana
Satellite platform: Myriade Evolutions
Satellite dimensions:
approx. 1.60 x 4.50 x 1.60 m with extended solar panels
Satellite mass: approx. 430 kg
Instrument mass/power requirement:
approx. 150 kg / 150 W

13 CLIMATE ACTION

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

MERLIN

The Franco-German satellite mission

The Franco-German climate mission **MERLIN** (Methane Remote Sensing Lidar Mission) is expected to measure **methane levels in Earth's atmosphere** from 2023 with unprecedented accuracy. Missions like MERLIN help to gain a deeper insight into the mechanisms that influence climate on Earth. Data from the mission are processed and evaluated jointly and in close collaboration with various research laboratories. MERLIN is set to orbit the Earth at an altitude of approximately 500 kilometres and will operate for at least three years.

Methane is a particularly potent greenhouse gas. The climate impact of methane is 25 times greater than that of CO_2. Although the concentration of methane is significantly lower than that of CO_2, it is responsible for approximately 20 percent of global warming.

MERLIN will be installed on the new '**Myriade Evolutions' satellite bus**, which has been developed by CNES in conjunction with the French space industry. The satellite's **payload**, an active **Lidar (Light Detection and Ranging)** instrument which can measure even at night-time and through thin clouds, is being developed and built in Germany on behalf of DLR Space Administration. The methane Lidar includes a laser that can emit light in two different wavelengths, enabling it to conduct highly precise measurements of methane concentration at all latitudes, regardless of sunlight. The wavelengths are in the infrared range and are chosen so that one is absorbed by methane, while the other is not. MERLIN sends two such pulses at the same spot on the ground in quick succession. The small satellite captures and registers the reflected pulses with a telescope. The presence of methane in the atmosphere weakens one of the pulses, but not the other. This difference allows scientists to determine the amount of methane between the satellite and Earth's surface.

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TransFIT

How intelligent do space robots need to be?

Brief description

The TransFIT project being carried out by the Robotics Innovation Center at the German Research Center for Artificial Intelligence (DFKI) in Bremen focuses on the construction and assembly of infrastructure elements in space. Space missions require autonomous robots that cooperate safely with humans as well as other systems.

Aims

In this context, robots and astronauts interact to varying degrees, ranging from pure teleoperation via teleoperation with partially autonomous functions, to autonomy with an operator in the loop, through to complete autonomy. Division of tasks is not the only purpose of this interaction. The idea is also that robots should learn from assisting humans in order to operate with increasing autonomy.

Parties involved

DFKI GmbH – Robotics Innovation Center, University of Bremen, Siemens AG, DLR Space Administration, BMWi

Applications

- Development of hardware and software solutions for high-precision manipulation and safe human-machine interaction
- Development of basic technologies in robot control and environment perception for autonomous infrastructure in space missions

Outlook

- Approaches for intuitive human-robot interaction, as well as astronaut assistance with automated feedback and the use of psychophysiological data
- Transfer of solutions to Industry 4.0 for use in flexible assembly cells

Facts and figures

Project start: 1 July 2017
Project end: 30 June 2021

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

8 DECENT WORK AND ECONOMIC GROWTH

TransFIT

How intelligent do space robots need to be?

The Coyote III walking robot is a demonstrator that was developed in the TransTerra project. The TransFIT project builds on some of the results of TransTerra

Coyote III is a micro-rover that offers significant mobility in unstructured terrain. With its internal power supply, on-board sensors and computer, Coyote III is able to complete autonomous exploration tasks. The rover uses its communications equipment to cooperate with other systems. Coyote III is equipped with two standardised electromechanical interfaces that permit the docking of additional payload elements, for instance a manipulator or standardised payload container. Coyote III is light and robust in construction and can carry **several kilograms of payload**. The rover's modular design allows structural adaptations to suit specific payloads.

Coyote III is being developed as part of the TransTerra project, which aims to create a logistical chain, based on a heterogeneous team of mobile and stationary robots. Coyote III will assume the **role of shuttle rover** to operate within this chain and transport payload modules between the exploration rover and a number of stationary points. Coyote III is a direct evolution of the Coyote II rover, which has already successfully completed testing and use as a micro scout rover.

In addition to its primary deployment scenario – the exploration of extraterrestrial bodies – Coyote III can also be used for earthbound applications – for example in the area of civil security. In this regard, the system is characterised by its **compact structure and high mobility**. Furthermore, the modular design and the available electromechanical interfaces enable retrofitting or upgrading of the rover to suit different mission scenarios.

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Space makes a difference!

Cross-sectoral and innovative

Brief description

A cross-sectoral view beyond the horizon, as well as commercialisation and innovation, are crucial to the future of space. The DLR Space Administration is therefore using the Berlin Air Show to present the 'Space makes a difference!' initiative, the INNOspace Masters competition and the first wireless satellite, 'Skith', on behalf of the German Federal Ministry for Economic Affairs and Energy (BMWi).

Aims

BMWi and the DLR Space Administration launched the cross-sectoral 'Space makes a difference!' initiative in 2017 with the motto 'Mobility and space – opportunities for the future'. The purpose of the initiative is to forge networks between the space, mobility and logistics industries. Organised since 2016, the INNOspace Masters competition has rewarded companies and research institutions for innovative space ideas and business models. The overall winner of the first INNOspace Masters – the developers of Skith, the world's first wireless satellite – will present their work on the BMWi stand.

Applications

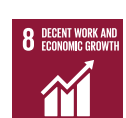
- 'Space makes a difference!' seeks to open up new markets, improve competitiveness, and create sustainable employment and high-quality added-value chains.
- The cross-sectoral network will be strengthened and expanded through new synergies between the space and mobility sectors.

Parties involved

DLR Space Administration, BMWi, University of Würzburg

Outlook

- The focus is on measures such as technology workshops, network building and group meetings
- The INNOspace Masters competition is part of the INNOspace initiative to promote innovation and new markets. It aims to foster cross-sectoral exchanges of ideas and technologies between the space industry and non-space-related industrial sectors



Space makes a difference!

Cross-sectoral and innovative

The mobility of the future will be digital, networked and partially autonomous. For this to happen, it will be necessary to move large volumes of data quickly, securely and regardless of location. The services, technology developments and infrastructure components – such as global Earth observation, communications and navigation satellite constellations – offered by the space sector provide a basis for strategic networking with the mobility and logistics industries. The **'Space makes a difference!'** initiative from the German Federal Ministry for Economic Affairs and Energy (BMWi) and the DLR Space Administration was launched in 2017 in order to promote and structure this collaboration.

The inaugural **INNOspace Masters** competition for companies/SMEs, universities, non-university research institutions and startups was held in 2016 with the motto 'Satellite 4.0'. The DLR Space Administration hosted the event on behalf of BMWi, in partnership with ESA BIC Bavaria and Darmstadt, as well as Airbus Defence and Space. It was organised by the Anwendungszentrum GmbH Oberpfaffenhofen (AZO). The purpose of the competition was to identify ideas for generative manufacturing technologies, new value chains, intelligent components and the standardisation of processes and interfaces in the context of the New Space Economy and Industry 4.0. The competition included three categories: the pre-competition phase, the start-up phase and the deployment/integration phase. Sergio Montenegro and Tobias Mikschl from the Computer Science Department at Julius Maximilian University of Würzburg were overall winners of the competition and they also won first prize in the category 'DLR Space Administration Challenge'. With their **Skith** project, they developed the **world's first wireless satellite**. Until now, all the individual components of a spacecraft had to be connected to one another via cables. Instead of these cables, Skith uses miniaturised, high-speed, real-time radio modules with short ranges. This reduces design effort and costs while increasing the satellite's reliability and flexibility

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Earth observation

Satellite data for everyday use

Brief description

Observing Earth from space is one of the key tasks of space travel. Satellites can be used to detect changes in land surfaces, oceans and the atmosphere and to develop protective strategies. The Touch Table tool is able to present these applications in a comprehensible way.

Outlook

Earth observation satellites monitor the climate and the environment. They help predict the weather and permit precise mapping of Earth's surface. When natural disasters strike, they also deliver information for emergency and rescue services. In addition, satellite data enables global predictions, for instance for crop yields or accurate irrigation and fertilisation.

Parties involved

DLR Space Administration, BMWi, BMVI, ESA

Applications

- Atmosphere & climate change
- Agriculture and nutrition
- Woodlands and forestry
- Nature and environmental monitoring
- Economy and resource management
- Crisis & disaster management
- Method development and validation
- Scientific data portals and education

Outlook

Expansion in Earth observation applications for the public sector thanks to free data

- New Earth observation systems enable increasingly precise, data-based forecasts and findings (missions: EnMAP, HRWS, MERLIN)

Facts and figures

Germany is a leader in Earth observation, both nationally and internationally:
National: TerraSAR-X and TanDEM-X missions (outstanding role in radar remote sensing); RapidEye (high resolution optical system, high temporal resolution). Copernicus: DLR designs and coordinates the national Copernicus programme on behalf of the Federal Government.
ESA: Together with Great Britain, Germany is the largest contributor to the Earth observation programme

Earth observation

Satellite data for everyday use

Space-based observation of the Earth and its ecosystems enables the detection of **changes in land surfaces, oceans and the atmosphere**, as well as the development of measures for environmental and climate protection.

Earth observation satellites quickly provide a clear view in cases of acute disasters like earthquakes, flooding or oil spillage. Their images show the extent of the catastrophe and its hotspots, and hence support rescue personnel on the ground. Satellite remote sensing allows the creation of **digital maps of Earth's surface and daily weather forecasts** that improve safety in air and maritime transport, among other things.

In addition, satellite-based Earth observation delivers **important information used in the decision-making process for international treaties**, for instance to protect the ozone layer or to tackle global warming. The European **Earth observation programme Copernicus**, with its freely available Sentinel data and services, has significantly expanded the provision of information for government agencies. The data helps with biotope mapping, in the optimisation of agricultural subsidies and in the planning of mobile communications systems. The **Touch Table** showcases a number of examples of the applications of Earth observation.

The expertise and systems used in Germany and Europe are outstanding from a scientific and technical perspective. Germany contributes to this by supporting applications and technological development, as well as with its own Earth observation satellites.

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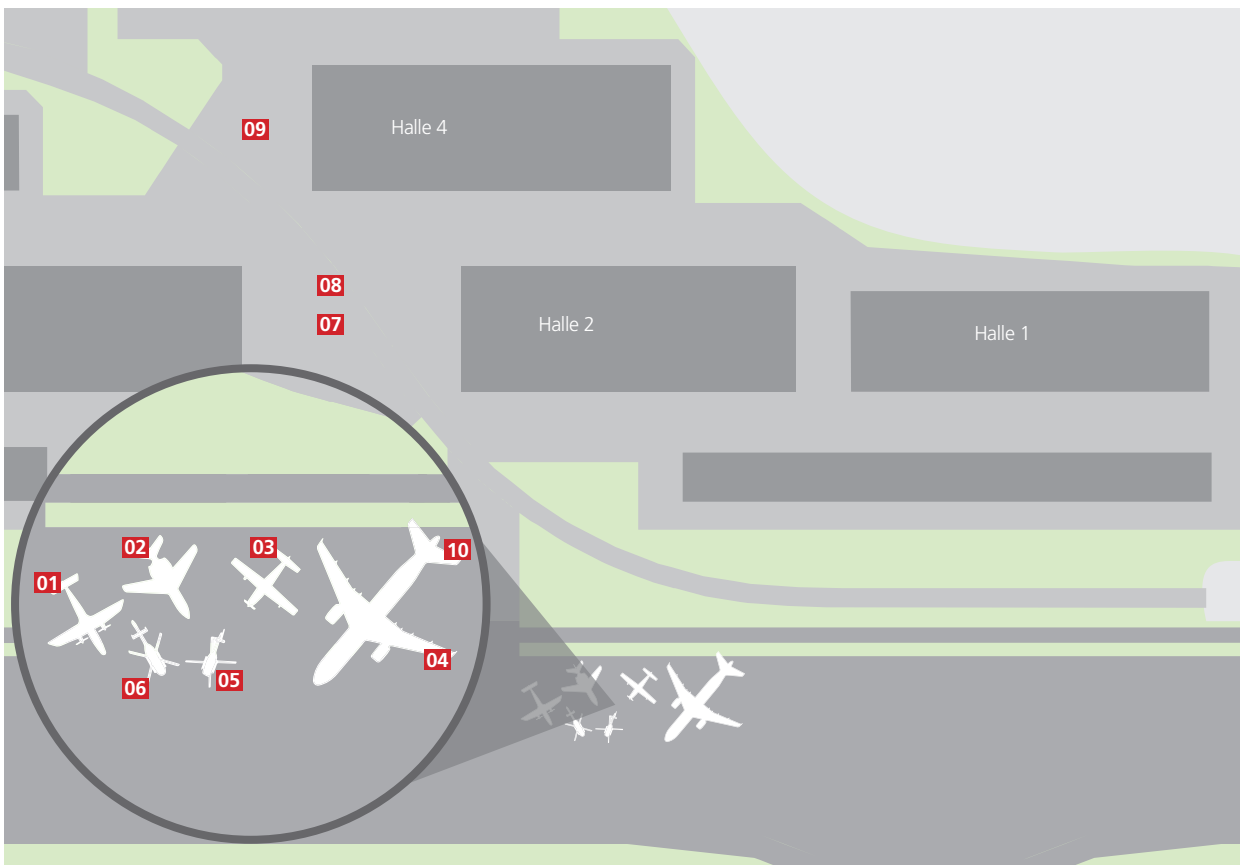
The DLR Static Display



01 Dornier DO 228-212 (D-CFFU)
02 Dassault Falcon 20E-5 (D-CMET)
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Dornier DO 228-212 (D-CFFU)

Airborne earth observation

Brief description

The twin-engine turboprop Dornier Do 228-212 aircraft, registered as D-CFFU, is mainly used for remote sensing missions by the DLR Flight Experiments facility in Oberpfaffenhofen. With its large, box-shaped cabin and the large openings in the cabin floor, it is particularly well suited for installing special Earth observation systems.

Aims

Testbed for new radar systems and hyperspectral sensors.

Parties involved

DLR institutes

Applications

- Radar measurements in the XCLS-band
- Measurements with hyperspectral sensors
- Aerial photography with the 3K camera

Outlook

- State-of-the-art radar satellite technology for climate monitoring after flight tests
- Better understanding of the Earth system

Facts and figures

Length: 16.6 m
Height: 4.9 m
Wingspan: 17.0 m
Seats: seven (three seats for crew members and up to four for scientists)
Empty weight: 4.0 t
Total weight: max. 6.6 t
Propulsion: two Garrett turboprop TPE 331-10 engines with 776 shaft HP each
Flight altitude: max. 7,600 m (25,000 ft)
Range: max. 2,360 km
Maximum speed: 378 km/h (200 kt)

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE
13 CLIMATE ACTION
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Dornier DO 228-212 (D-CFFU)

Airborne earth observation

DLR's Dornier Do 228-212 flies on **remote sensing and Earth observation** research projects. The focus is as much on testing new technologies for subsequent use in space as on investigation missions using various sensors. Digital sensors using different wavelengths may be installed as required. They provide high-resolution data in optical remote sensing, as well as in the infrared range and radar.

The **following modifications differentiate the Dornier Do 228-212 from the standard Do 228**: four openings in the roof, cabin floor and cabin sides; four hardpoints under the wings for loads of up to 250 kilograms (e.g. particular measuring probes and cameras, allowing a vertical view down); two special viewing windows along the side of the cabin; hardpoints underneath the fuselage for loads of up to 200 kilograms; two large openings in the cabin floor; attachment points on the side of the fuselage for loads of up to 50 kilograms; and a precision navigation system. An additional power system has also been installed to power the experiments (DC 28 Volt/225 Ampere, AC 220 Volt/50 Hertz).

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Dassault Falcon 20E-5 (D-CMET)

Flying for atmospheric research

Brief description

The Dassault Falcon 20E-5, registered as D-CMET, has been an indispensable part of the DLR research fleet since 1976. This twin-jet aircraft, which is based at the DLR site in Oberpfaffenhofen, has undergone thorough conversion to make it suitable for atmospheric research, including the installation of additional air inlets and measuring probes.

Aims

Aircraft-based atmospheric and climate research. One area of focus is investigating the effects of aircraft emissions on atmospheric composition.

Parties involved

DLR institutes as well as universities and external clients

Applications

- Flying laboratory for environmental and climate research
- Platform for remote sensing and in-situ measuring devices
- Comparative measurements; validation measurements in relation to ground stations, satellites and climate models

Outlook

- A better understanding of the causes and progress of climate change
- State-of-the-art satellite measuring instruments for atmospheric and climate research after testing in flight

Facts and figures

Length: 17.2 m
Height: 5.4 m
Wingspan: 16.3 m
Empty weight: 8.4 t
Total weight: 13.8 t
Thrust: 21 kN
Flight altitude: max. 12,800 m (42,000 ft)
Range: max. 3,700 km
Maximum speed: 917 km/h (0.9 Mach)

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

13 CLIMATE ACTION

Dassault Falcon 20E-5 (D-CMET)

Flying for atmospheric research

When the Icelandic volcano Eyjafiallajökull erupted in April 2010, the Falcon 20E-5 had its most spectacular deployment to date – flying into the ash cloud over Germany, the UK and Iceland as a 'volcano ash hunter'. There, it investigated the composition and concentration of the volcanic particles that had brought scheduled air traffic to a standstill. Scientists still use the Falcon to **investigate an array of queries relating to the atmosphere and climate research**. On board, they directly measure trace gases and aerosols, and collect air samples for subsequent laboratory analysis.

In recent years, the Falcon has become one of DLR's most important elements of large-scale research equipment to **research the effects of aircraft emissions on the composition of the atmosphere.** The Falcon's unique modifications and instruments make it a useful multi-purpose platform for research applications that can be adapted to specific requirements.

The following **modifications and additions** have been made to the structure of the Dassault Falcon 20E D-CMET aircraft: nose boom with integrated flow probe for measuring air inflow velocity and direction; a total of three special windows in the fuselage roof and floor, used, amongst other applications, for LIDAR atmospheric measuring instruments (the lower special windows can be protected against stone chippings during take-off and landing by covering them with a sliding screen); new engines with additional electrical generators to facilitate experiments (two at 300 A and 28 V); four small openings (8 cm diameter) on the top side of the fuselage; four attachment points under the wings for attaching particle measurement systems (PMSs); a central attachment point on the underside of the fuselage for mounting different measuring devices; side window for infrared and radar antennas (so-called microwave-measuring devices) as well as attachment points on the lower rear fuselage for radiometers.

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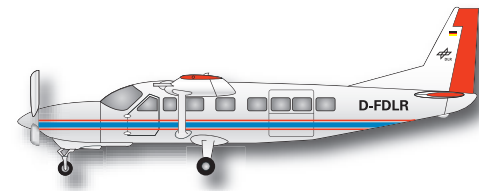
Cessna 208 B Grand Caravan (D-FDLR)

The 'Flying Auditorium'

Brief description

The single-engine turboprop aircraft with the identification D-FDLR is ideal for a broad variety of research missions that feature small instrument packages, thanks to its light but robust construction. The Cessna 208 B Grand Caravan which has been stationed at Oberpfaffenhofen since 1998, is used as a measurement platform in remote sensing and atmospheric research.



Aims

The aircraft is used for remote sensing and atmospheric research, as well as a 'flying auditorium' – a unique system to provide aerospace engineers, meteorologists and aviation personnel with advanced training.

Parties involved

DLR institutes and various universities

Applications

- Flying auditorium/summer school for meteorology and aerospace students
- Air quality measurements in the atmospheric boundary layer and troposphere
- Aerial photographs for purposes including disaster control and traffic management

Outlook

- Practical training with flight experiment experience for students
- Effective airborne remote sensing for civil protection

Facts and figures

Length: 12.7 m
Height: 4.2 m
Wingspan: 15.9 m
Empty weight: 2.3 t
Total weight: max. 4.0 t
Power: 496 kW; 675 PS
Flight altitude: max. 7620 m (25,000 ft)
Range: max. 1,690 km
Maximum speed: 313 km/h

Cessna 208 B Grand Caravan (D-FDLR)

The ‘Flying Auditorium’

The DLR research aircraft Cessna 208 B Grand Caravan is used for **remote sensing and atmospheric research, and is particularly suitable for camera flights**. **During camera flights using the 3K camera system**, for instance, high-resolution aerial images for a range of traffic management or disaster control applications can be taken. Using the laser measuring system (LIDAR), researchers on board the research aircraft can take wide-scale measurements of the concentration of trace gases, such as ozone.

In 2006, the aircraft was converted into a **‘flying auditorium’**. Seven separate measuring stations for young scientists were installed on board for that purpose. The same project allows students to follow their experiments directly on board the aircraft.

DLR’s ‘Flying Auditorium’ is a unique system for providing advanced training to aerospace engineers, meteorologists and aircraft personnel. For that purpose it provides flight projects customised for optimal learning content, seven work stations, each with a monitor and intercom, Quicklook for real-time visualisation of measured and calculated parameters, force sensors on the yoke, rudder position sensor and a full HD front-mounted camera.

In the **flight training period** for aerospace students, the performance data of the aircraft is established over several test units together with a flight test engineer during flight, including climbing performance, gliding flight performance, manoeuvring stability (manoeuvre point), longitudinal static stability (neutral point), phugoid oscillation (self-oscillation), Dutch roll and stalling characteristics.

In addition, meteorology students can measure small-scale meteorological phenomena on board the Cessna 208 B Grand Caravan during flight training, which can also be experienced on the Quicklook display: composition of the atmospheric boundary layer, turbulence, föhn wind, valley wind.

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A320 ATRA (D-ATRA)

Advanced Technology Research Aircraft

Brief description

The Airbus A320-232 'D-ATRA' is the largest member of the DLR research fleet. The aircraft has been used by DLR since 2008 and is based at the site in Braunschweig. This research aircraft stands out for both its size and versatility.

Aims

DLR uses the ATRA primarily for research. The objective is to gain insights that will feed into future generations of aircraft. Numerous research projects are taking place in close collaboration with the European aviation industry.

Parties involved

DLR institutes, national and European funding bodies, aviation industry

Applications

- Research and development activities in cooperation with the European aviation industry
- Cabin comfort and safety concepts
- Testing of new communication technologies for future air transport
- Aerodynamic measurements
- Engine research, including noise reduction
- Avionics research and development

Outlook

- Quieter, more efficient aircraft with lower fuel consumption and reduced CO_2 emissions
- Increased comfort and safety on board

Facts and figures

Length: 37.6 m
Height: 11.8 m
Wingspan: 34.1 m
Cabin (L x W x H): 29.1 x 3.7 x 2.4 m
Seats: max. 179
Empty weight: 42.3 t
Total weight: max. 75.5 t
Thrust: 111 kN
Flight altitude: max. 11,800 m (39,000 ft)
Range: max. 5,700 km
Maximum speed: 840 km/h

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

13 CLIMATE ACTION

A320 ATRA (D-ATRA)

Advanced Technology Research Aircraft

The Airbus A320-232, with the designation D-ATRA, is the **largest member of the DLR research aircraft fleet**. It has been used by DLR since 2008 and is based at the site in Braunschweig. This research aircraft is notable for its size and versatility. The DLR ATRA is used in numerous ways – from basic research, to research and development projects together with the European aviation industry. Among other things, scientists use the A320 to investigate new cabin comfort and safety concepts. They are also testing new communication technologies for future aviation – both in flight and on the ground. ATRA is unique in Europe as a modern platform for research into aerodynamics, avionics and engines. **DLR's A320 ATRA is used for numerous activities**, including the testing of aeroelastic measurement methods, investigations into interior acoustics, flow noise measurements, aerodynamic wing and tail plane measurements aimed at saving fuel, testing of the latest measuring techniques, such as the image pattern correlation technique (IPCT, an optical method for measuring the bending of wings), detection of wake turbulence and examination of alternative algorithms, engine measurements, testing state-of-the-art communications and navigation technologies, as well as low-noise approach and take-off procedures.

In future, the ATRA will have several cockpit interfaces at its disposal. This includes the implementation of an experimental cockpit display system, additional data links and a head-up display. This opens up the possibility of investigating the following research topics: flight control commands for flying through wake turbulence and load reduction, autonomous flight, ground traffic control, pilot assistance and display technology, and assigning and splitting pilot workloads.

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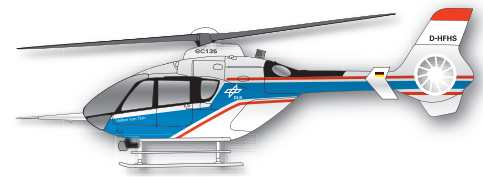
EC 135 ACT/FHS (D-HFHS)

Flying helicopter simulator

Brief description

The ACT/FHS 'Flying Helicopter Simulator' is based on a EC 135 series helicopter that has been substantially modified for use as a research and experimental aircraft. In addition to its experimental measuring equipment, the helicopter is primarily notable for its unique fly-by-wire-/fly-by-light (FBW/FBL) control system.



Aims

Testing of new open- and closed-loop control systems up to the simulation of the flight behaviour of other helicopters under real environmental conditions.

Parties involved

DLR institutes, national and European funding bodies

Applications

- Implementing and testing active control mechanisms (sidesticks)
- Testing pilot assistance systems
- Integrating and testing sensors and vision systems
- Measuring flight characteristics
- Training of test pilots and flight test engineers
- Simulating flight behaviour of other helicopters under real environmental conditions
- Sensor platform for high-resolution optical camera system

Outlook

- Innovative flight control systems for helicopters and air taxis of the future
- Rescue missions with extensive pilot assistance in bad weather conditions

Facts and figures

Length: 12.2 m
Rotor diameter: 10.2 m
Empty weight: 1.9 t
Total weight: max. 2.9 t
Power: 2 x 415 kW
Flight altitude: max. 6,096 m (20,000 ft)
Flight time: max. 2.5 h
Maximum speed: 280 km/h

3 GOOD HEALTH AND WELL-BEING
9 INDUSTRY, INNOVATION AND INFRASTRUCTURE
11 SUSTAINABLE CITIES AND COMMUNITIES

EC 135 ACT/FHS (D-HFHS)

Flying helicopter simulator

The ACT/FHS 'Flying Helicopter Simulator' is the **world's first helicopter to have a fly-by-light control system**. The scale of applications of the FHS includes training of test pilots and trials of new open and closed-loop control systems up to simulation of the flight characteristics of other helicopters under real environmental conditions. The FHS is equipped with two engines, a bearingless main rotor and a Fenestron tail rotor as standard. Fly-by-light control is a system in which, as opposed to a fly-by-wire system, the control signals between the operating devices, the flight guidance controller and the actuators for rotor blade control are transferred optically via fibre optic cables instead of electrically. In addition, there is also a mechanical emergency control system. The advantages compared with electrical data transfer are the high transmission bandwidth, high reliability, as well as low weight. The **fly-by-light flight control system** consists of a quadruple-redundant computer system and is designed such that the stringent safety criteria of the European aviation authorities are fully met.

The cockpit layout provides seats for a safety pilot, the test pilot and the flight test engineer. A comprehensive equipment line-up with sensors and systems for on-board data recording and processing is used to record the data from the flight tests. The **FHS differs from the standard Eurocopter EC 135 helicopter due to the following modifications**: optical and electronic FBW/FBL flight control system; on-board computer system that enables simulation of the flight characteristics of other – actual existing or virtual – aircraft; and a modular experimental system that consists of flight-control computers, data measurement and pre-processing systems, displays and additional equipment and controls in the cockpit. In future, the FHS will be fitted with instrumented rotor blades with a rotor measuring system.

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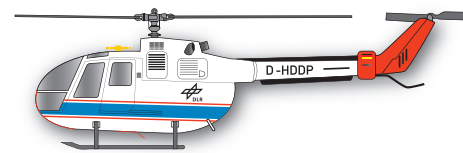
BO 105 (D-HDDP)

Versatile research helicopter

Brief description

The BO 105 is a five-seat research helicopter with a rigid, four blade main rotor and a semi-rigid two blade tail rotor. All of the rotor blades are made of glass fibre-reinforced polymers. The helicopter is powered by two Allison 250-C20 engines. This versatile helicopter has been part of the DLR research fleet since 1978 and is based at DLR's site in Braunschweig.



Aims

Diverse research applications in flight characteristics investigations, thermal imaging, carrying special sensor technology, investigating low-noise approach flight profiles, development of pilot assistance systems and flights with external loads.

Parties involved

DLR institutes, as well as national and European funding bodies

Applications

- Traffic monitoring and disaster management
- Investigation of low-noise approaches
- Testing pilot assistance systems
- Test flights with external loads
- Investigation of flight characteristics and air flow patterns at the rotor

Outlook

- Quiet, versatile and efficient helicopters of the future
- Effective airborne remote sensing for civil protection

Facts and figures

Length: 11.9 m
Rotor diameter: 9.8 m
Empty weight: 1.8 t
Total weight: max. 2.4 t
Power: 2 x 313 kW
Flight altitude: max. 5,182 m (17,000 ft)
Flight time: max. 2.5 h
Maximum speed: 270 km/h

2 ZERO HUNGER
9 INDUSTRY, INNOVATION AND INFRASTRUCTURE
13 CLIMATE ACTION

BO 105 (D-HDDP)

Versatile research helicopter

The BO 105 is a five-seater research helicopter with a rigid, four-bladed main rotor and a semi-rigid two-bladed tail rotor. All of the rotor blades are made of glass fibre-reinforced plastic. The helicopter is powered by two Allison 250-C20 engines. This **versatile helicopter is used for numerous activities**, which include investigating flight characteristics, thermal imaging, special sensor technology, low-noise approach flight profiles, pilot assistance systems and research into flying with external loads, among other applications. If required, **the BO 105 can be fitted with special equipment**. These include main and tail rotor blades enhanced with pressure sensors and strain gauges to measure the forces and pressure conditions at the rotor blades.

The DLR BO 105 research helicopter **differs from the standard BO 105 due to the following modifications**: on-board computer to record flight parameters; nose boom for precise measurement of wind velocity and direction; instruments on the main and tail rotors to measure the forces and pressure conditions at the rotor blades; attachment points outside the cabin for payloads such as infrared cameras; IFR cockpit provision (Instrument Flight Rules – for flying in difficult weather conditions, otherwise known as instrument meteorological conditions, or IMC, which require flying with instruments); the LASSIE system (Low Air Speed Sensing and Indicating Equipment – a system for accurately measuring the flying speed in the lower speed range). In future, the BO 105 will be equipped with a comprehensive measuring system for recording flight-relevant parameters.

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SAGITTA

Open innovation

Brief description

In its SAGITTA project, DLR contributed to the further development of the technology for unmanned aerial vehicles, together with universities and the aircraft manufacturer, Airbus Defence and Space. The innovative flying wing was successfully tested during its inaugural flight in 2017 in Overberg, South Africa.

Aims

SAGITTA has developed advanced technologies for unmanned flight. The flying wing configuration was demonstrated during a test flight. With SAGITTA, it has been possible to gain new insight into new technologies for systems and structures, as well as for avionics and autonomy.

Parties involved

DLR (FT, FA, SR Institutes), TU Munich, Technische Hochschule Ingolstadt, Chemnitz University of Technology, Airbus Defence and Space

Applications

- The demonstrator is used to demonstrate and test new technologies in flight tests
- The tested technologies have a variety of both civilian and military applications

Outlook

- The experience gained and the know-how gained strengthens DLR in its role as a leading research institution in the field of unmanned aerial vehicles
- Further demonstrators will follow

Facts and figures

- **Designation:** SAGITTA
- **Type:** UAS (Unmanned Aerial System)
- **Scale:** 1:4
- **Take-off weight:** max. 150 kg
- **Wingspan:** 3 m
- **Propulsion:** two 300 N turbines
- **Speed:** 300 km/h
- **Flight altitude:** 2000 m

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

SAGITTA

Open innovation

Technology demonstrator for unmanned flight

Together with universities and under the direction of Airbus Defence and Space, DLR has developed an innovative flying device for testing technologies for **future unmanned aerial systems** (UAS – Unmanned Aerial Systems) and successfully tested this during an inaugural flight in 2017. The unmanned, jet-powered technology demonstrator with the project name SAGITTA flew **fully autonomously** on a pre-programmed course at the test site in Overberg, South Africa. The innovative flying-wing construction demonstrated excellent flight characteristics during the test.

Design criteria were a high degree of autonomy, variable mission design and low in-flight visibility. The airframe is made entirely of **carbon fibre reinforced polymers (CFRP)**. The SAGITTA demonstrator is an 'electronic flying device' that is controlled by electromechanical actuators instead of hydraulic components. The aerial vehicle's unconventional configuration requires support from a **flight control system** in order to achieve good flight characteristics. The necessary control surface actuators must meet extraordinary requirements, as they must withstand high trim loads with minimum weight. Other special requirements for the flying device were a retractable landing gear and a fuel system that reliably supplies the flying device without any bubbles in all flight conditions, for example, even when it is flying upside down. The restricted space of the compact diamond wing shape in combination with high descent speeds posed major technical challenges for the design of the landing gear. To address this, a landing gear test rig was specially developed and tailored to the **requirements of the flight demonstrator**.

PhD students from various research establishments worked on relevant issues within the SAGITTA project. The TU Munich, Universität der Bundeswehr München, Technische Hochschule Ingolstadt, Chemnitz University of Technology, Airbus Group Innovations and DLR are all involved in the project.

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ALAADy

Automated Low Altitude Air Delivery

Brief description

The concept of mission-based flight clearance for unmanned aerial vehicles aims to achieve a balance between the necessary safety and economic operation of drones. The ALAADy project evaluates concepts and builds demonstrators for low-altitude freight transport. Presented here is the large 450 kg demonstrator.

Aims

ALAADy demonstrates and evaluates unmanned aviation technologies. Operating concepts and cost models can be developed and risks identified, assessed and managed. With ALAADy, DLR supports authorities in the development of secure framework conditions.

Parties involved

Scientists from various DLR institutes and facilities (FT, FL, LK, FW, KN, TT, AE, FX)

Applications

- Air transport
- System design
- Flight path planning
- Data fusion
- Risk management and flight cancellation
- Flight control and flight performance
- Airborne experiments
- Artificial intelligence

Outlook

- Safe, cost-effective, viable, compatible and integrated automated air transport in civilian airspace

Facts and figures

Designation: Air Dolly (ADO)
Type: UAS/Drone
Take-off weight: up to 500 kg
Flight time: up to 4 h
Speed: up to 160 km/h
Altitude: below 500 ft (planned)
Payload: up to 200 kg
Inaugural flight: 2018 (planned)

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

ALAADy

Automated Low Altitude Air Delivery

Technology demonstration – unmanned freight transport

The **ALAADy** and **ALAADy Demonstrator** projects launched in 2016 examine the theoretical and practical aspects of **automated and unmanned air transport**. For this purpose, the ideal aircraft configurations for automated airfreight transport were initially determined through the evaluation of fixed and rotary-wing aircraft with regard to their flight performance and characteristics.

To **implement a 'transport drone'** as a technology demonstrator, particular attention was placed on safety aspects, operational boundary conditions, system architecture and the necessary capabilities. Gyrocopters have the particular advantage of being inherently safe, as their freely rotating rotor enables a soft landing in the event of a fault, just like a parachute.

To demonstrate various aspects of automated air transport, DLR test aircraft are equipped and/or modified and tested in flight. A scaled demonstrator called Air Cargo Gyrocopter (ACG), weighing around 45 kilograms, is being used to understand the flight characteristics of such configurations. The 450-kilogram Air Dolly (ADO) gyrocopter, based on AutoGyro GmbH's MTOfree, is intended to demonstrate the transport of cargo weighing up to 200 kilograms. New automated flight control functions are also being developed for all the gyrocopter's flight phases, such as take-off, cruising, landing and taxiing. Integration into a simple logistics chain, operation-centric risk assessment, the automated surveillance of the system status by a safety monitor and the safe termination of the flight in the event of a fault are other project objectives. The findings from the project will lay the foundation for the safe, affordable operation of unmanned aerial vehicles outside restricted areas.

In this context, DLR is a **neutral pioneer of civilian research** in unmanned air transport.

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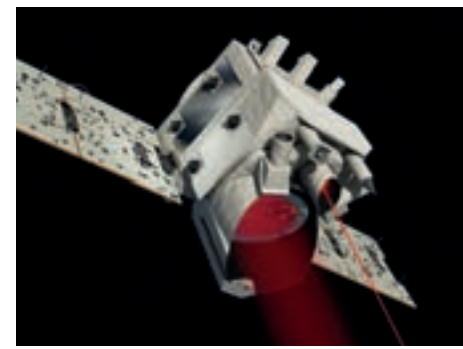
MERLIN

The Franco-German satellite mission



Brief description

From 2021, the Franco-German climate mission MERLIN (MEthane Remote sensing LIdar missioN) will trace the greenhouse gas methane using a Lidar instrument. Germany's contribution to MERLIN is managed by the DLR Space Administration with funding from the German Federal Ministry for Economic Affairs and Energy (BMWi), and the space agency CNES is responsible for the French contribution.

Aims

Methane is one of the most effective greenhouse gases at making the planet warmer and is partially responsible for climate change. This three-year mission is aimed at producing a global map of atmospheric methane concentrations. Among other things, it will provide information on the main regional sources of methane and the areas in which the greenhouse gas is removed from the atmosphere (sinks).

Parties involved

DLR Space Administration, French space agency CNES, European space industry led by Airbus in Ottobrunn

Applications

- Earth observation satellite for research into the causes of climate change
- Innovative measurement methods and thus better-quality data for documenting and creating a catalogue of global methane concentrations

Outlook

- Development of systems expertise and know-how relating to global methane observation
- Real contribution towards implementing the Paris Climate Agreement targets
- Demonstration of new, highly accurate satellite-based measurement methods to determine methane concentrations

Facts and figures

Launch: scheduled for 2023 with Soyuz or Vega/Vega-C from the European Spaceport in French Guiana
Satellite platform: Myriade Evolutions
Satellite dimensions:
approx. 1.60 x 4.50 x 1.60 m with extended solar panels
Satellite mass: approx. 430 kg
Instrument mass/power requirement:
approx. 150 kg / 150 W

13 CLIMATE ACTION

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

MERLIN

The Franco-German satellite mission

The Franco-German climate mission **MERLIN** (Methane Remote Sensing Lidar Mission) is expected to measure **methane levels in Earth's atmosphere** from 2023 with unprecedented accuracy. Missions like MERLIN help to gain a deeper insight into the mechanisms that influence climate on Earth. Data from the mission are processed and evaluated jointly and in close collaboration with various research laboratories. MERLIN is set to orbit the Earth at an altitude of approximately 500 kilometres and will operate for at least three years.

Methane is a particularly potent greenhouse gas. The climate impact of methane is 25 times greater than that of CO_2. Although the concentration of methane is significantly lower than that of CO_2, it is responsible for approximately 20 percent of global warming.

MERLIN will be installed on the new '**Myriade Evolutions' satellite bus**, which has been developed by CNES in conjunction with the French space industry. The satellite's **payload**, an active **Lidar (Light Detection and Ranging)** instrument which can measure even at night-time and through thin clouds, is being developed and built in Germany on behalf of DLR Space Administration. The methane Lidar includes a laser that can emit light in two different wavelengths, enabling it to conduct highly precise measurements of methane concentration at all latitudes, regardless of sunlight. The wavelengths are in the infrared range and are chosen so that one is absorbed by methane, while the other is not. MERLIN sends two such pulses at the same spot on the ground in quick succession. The small satellite captures and registers the reflected pulses with a telescope. The presence of methane in the atmosphere weakens one of the pulses, but not the other. This difference allows scientists to determine the amount of methane between the satellite and Earth's surface.

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AFLoNext

DLR A320 Advanced Technology Research Aircraft prepared for AFLoNext flight test campaign

Brief description

The DLR Advanced Technology Research Aircraft ATRA is showcased in the flight test configuration defined by the European project AFLoNext. Within this project, a simplified Hybrid Laminar Flow Control (HLFC) system has been installed in the vertical tailplane of the aircraft. Highly instrumented vertical and horizontal stabilisers allow detailed measurements of all relevant parameters to verify and validate the functionality of the simplified Hybrid Laminar Control System.

Aims

The EU project AFLoNext will deliver highly matured technologies in the area of flow, loads and noise abatement for advanced aircraft design and novel configurations. The simplified suction system will be flight tested for the first time in Europe to demonstrate system functionality, gain first operational experiences and to validate and verify the applied design tools and processes. The test flights will make it possible to achieve Technology Readiness Level 4 for this technology.

Parties involved

EU research project under the Clean Sky with 40 partners from 15 different countries, including Airbus, DLR, Sonaca, TAI, ACQ Inducom, Fraunhofer, Dassault, FOI, IBK, ONERACIRA. In the field of hybrid laminarisation.

Applications

- Hybrid Laminar Flow Control system can be applied on aircraft tail (fin and horizontal tailplane)
- Key application is the wing of an aircraft
- Technology can also be applied to the fuselage

Outlook

Hybrid Laminar Flow Control is a key technology for the development of more economical aircraft with a substantial reduction of fuel burn and emissions.

Facts and figures

Project duration: 5 years

- Flow optimisation using the controlled suction of low mass flows through a micro-perforated surface
- This project was supported by the European Commission's Seventh Framework Programme FP7/2007-2013, under grant agreement n°604013.

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

13 CLIMATE ACTION

AFLoNext

DLR A320 Advanced Technology Research Aircraft prepared for AFLoNext flight test campaign

Hybrid Laminar Flow Control (HLFC) is one of the key technologies for significantly **reducing fuel burn (up to nine percent fuel savings for long-range aircraft) and emissions**. The basic idea behind HLFC is the application of a **very small amount of boundary layer suction** through a micro-perforated skin to stabilise the laminar boundary layer. The surface region with applied suction is followed by a region that further stabilises the boundary layer by means of a tailored surface shape. These combined measures extend the laminar boundary layer – and hence the region of low friction drag – significantly downstream until the transition from a laminar into a turbulent boundary layer that generates higher skin friction drag occurs. Within the European project AFLoNext (Active Flow Loads and Noise control on next generation wing), an innovative HLFC system has been designed, manufactured and qualified for flight testing. The system has been **installed on the DLR A320 Advanced Technology Research Aircraft (ATRA) on the middle segment of the vertical stabiliser** (fin). Suction is generated by either a passive or an active system, consisting of an actuator adjusted flap or a four-stage compressor respectively. Infrared cameras installed in the tailplane (horizontal stabiliser) allow the detection of transition locations; pressure distributions are recorded at two cross sections of the fin, hot-film arrays are used to monitor the boundary layer status of the attachment line, and the highly instrumented HLFC leading edge allows a clear verification of the functionality. Advanced in-flight data processing technologies enable highly efficient flight testing.

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German Space Situational Awareness Centre

Sustainability in space (German Air Force, Hall 3/Stand 302)

Brief description

The German Space Situational Awareness Centre (Weltraumlagezentrum, WRLageZ) in Uedem is a civil-military facility jointly operated by the DLR Space Administration and the German Air Force since 2011. Its employees develop a comprehensive space situational overview and exchange this information with international partners on an ongoing basis.

Aims

The German Space Situational Awareness Centre monitors and assesses the behaviour of objects in near-Earth space. It supports political processes and develops products in the fields of space surveillance, reconnaissance and space weather in order to protect Earth's population and German territory, troop contingents indirectly, as well as space systems.

Parties involved

The DLR Space Administration (on behalf of the German Federal Ministry for Economic Affairs and Energy (BMWi)) and the German Air Force (on behalf of the German Federal Ministry of Defence (BMVg))

Applications

- Approach warnings, overflight alerts, re-entry warnings
- Warning about the effects of space weather
- Availability of communications devices
- Precise GPS information
- Status and functional overview of German and foreign satellites

Outlook

- Another milestone will be reached when the GESTRA space monitoring sensor is connected in 2018/19.
- In the development phase, the German Space Situational Awareness Centre is already a sought-after partner at international level.

Facts and figures

2009: Orientation phase
From 2011: Jointly established remit (BMWi and BMVg)
2011–2014: Temporary pilot phase
From 2015: Cooperation extended indefinitely
From July 2016: 24/7 service

8 DECENT WORK AND ECONOMIC GROWTH

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

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German Space Situational Awareness Centre

Sustainability in space (German Air Force, Hall 3/Stand 302)

The **German Space Situational Awareness Centre** in Uedem, which is jointly operated by the **DLR Space Administration** and the **German Air Force**, provides a comprehensive overview of the space situation and exchanges this information with international partners on an ongoing basis in order to align assessment of the situation.

For example, users and operators of satellite systems receive **warnings** of potential **collisions** with space debris and, when appropriate, recommendations for evasive action. The authorities are informed of the imminent re-entry of burnt-out rocket stages into Earth's atmosphere, if visible from Germany.

As part of its **European activities** in the field of space surveillance and tracking, Germany has made the German Space Situational Awareness Centre one of the centres creating products for collision avoidance, together with analysis and warning of re-entry material and fragmentation.

The **space surveillance radar system 'GESTRA'** is to be connected to the German Space Situational Awareness Centre in 2018/19, which will allow the monitoring of objects with low orbits. The goal is to be **fully operational** by 2020, so that routinely provided services and products will be created, among other things, through the use of dedicated sensors.

The Space Situational Awareness Centre is featured at the German Air Force stand with displays on the following:
- Simulated effects of **space debris impacts**. These kinds of simulations are carried out by the Fraunhofer Institute for High-Speed Dynamics in Germany.
- The mechanical **Tracking and Imaging Radar (TIRA)** model; the sensor is operated by the Fraunhofer Institute for High-Frequency Physics and Radar Techniques and can be used to measure orbits and to provide imaging of objects, for example for damage analysis.
- Prototype of the **GESTRA radar system**. This is intended to detect objects in near-Earth space and to track overflights. The system is highly versatile and provides different operating modes.

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Explanations

United Nations Sustainable Development Goals

Goal 1: End poverty in all its forms everywhere

Goal 2: End hunger, achieve food security and improved nutrition and promote sustainable agriculture

Goal 3: Ensure healthy lives and promote well-being for all at all ages

Goal 4: Ensure inclusive and quality education for all and promote lifelong learning

Goal 5: Achieve gender equality and empower all women and girls

Goal 6: Ensure access to water and sanitation for all

Goal 7: Ensure access to affordable, reliable, sustainable and modern energy for all

Goal 8: Promote inclusive and sustainable economic growth, employment and decent work for all

Goal 9: Build resilient infrastructure, promote inclusive and sustainable industrialisation and foster innovation

Goal 10: Reduce inequality within and among countries

Goal 11: Make cities and human settlements inclusive, safe, resilient and sustainable

Goal 12: Ensure sustainable consumption and production patterns

Goal 13: Take urgent action to combat climate change and its impacts

Goal 14: Conserve and sustainably use the oceans, seas and marine resources

Goal 15: Sustainably manage forests, combat desertification, halt and reverse land degradation, halt biodiversity loss

Goal 16: Promote just, peaceful and inclusive societies

Goal 17: Revitalise the global partnership for sustainable development

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Imprint

Publisher:
DLR German Aerospace Center
(Deutsches Zentrum für Luft- und Raumfahrt)

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Translation: EJR-Quartz, Leiden/NL

Layout: CD Werbeagentur GmbH, Troisdorf

Idea layout: Christian Karrasch

Printing: M & E Druckhaus, Belm

Place/date of release: Cologne, April 2018

Supported by:

Federal Ministry
for Economic Affairs
and Energy

on the basis of a decision
by the German Bundestag


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A technological boost for our economy and society
Sustainability: decisive
A sustainable future through research and development
Climate protection: effective
Understanding climate change and contributing to climate-friendly technology through research
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