Mobility: intelligent  Technology: innovative  Security: guaranteed
Welcome to the IAC 2018 in the Hanseatic city of Bremen, the city of aerospace expertise.

With 20 locations in Germany, 40 institutes and facilities, and more than 8000 employees, the German Aerospace Center (Deutsches Zentrum für Luft- und Raumfahrt; DLR) is Europe’s largest aerospace research institution. DLR’s scientific work supports many branches of industry, thereby strengthening Germany as a business location. Innovative and interdisciplinary science creates technologies that help find solutions to current global challenges. Our numerous national and international partnerships are particularly important to this. Germany plays a vital role in the global aerospace industry, which is demonstrated by its contributions to human spaceflight over the past 40 years, and even longer in the exploration of the Solar System. Germany has also helped shape and streamline the fields of Earth observation, navigation and communications.

However, while standing by its own historical achievements in space flight, DLR is committed to the use of space for peaceful purposes more than ever to echo the scientific progress of the past decades.

The 33 exhibits and topics presented by DLR at the IAC 2018 feature cutting-edge German research in the aerospace sector. DLR is also an active participant in the IAC scientific programme.

Dear IAC guests, I am very pleased to welcome you to DLR. I wish you a successful congress with many interesting discussions, and the opportunity to gain fresh ideas and establish partnerships that will lead us to embark upon new space missions together.

Prof. Pascale Ehrenfreund,
Chair of the DLR Executive Board
DLR booth
Hall 5, booth D 15

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MASCOT is a lander on board the Japanese Hayabusa2 spacecraft. The destination of the mission is the asteroid Ryugu. 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.

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.

Aims

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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

Parties involved

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

Facts and figures

Mission launch: 3 December 2014
MASCOT landing: Scheduled for 3 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
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 is observing, mapping and measuring the asteroid. 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 samples 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 attraction. MASCOT will be pushed out of its holder by a spring mechanism and fall to Ryugu from a height of approximately 60 metres. Once 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 developed by the German Aerospace Center (DLR) and built in close cooperation 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 Center 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 will be monitored and operated from DLR’s Microgravity User Support Center (MUSC) in Cologne.
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. The Eu:CROPIS satellite mission will investigate the functionality of combined biological life support systems under lunar and Martian gravity.

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.

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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

- DLR compact satellite:
  1 m in height, 1 m in diameter
- Spin-stabilised, magnetic torquer based AOCS
- Variable rotation rate to alter gravitational conditions
- Orbit: LEO, 500 – 650 km, 06:00 – 12:00
- Launch: November 2018 on board a Falcon 9
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) is to conduct tests on the long-term stability of a biological life support system for missions to the Moon or Mars. With the aid of the DLR-developed C.R.O.P.® filter system, 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 underwater. It will also serve as a new method of fertilisation or fresh water preparation.

During its mission, the Eu:CROPIS satellite will rotate at an altitude of 600 kilometres and, in its interior, generate the gravitational conditions of the Moon for six months and Martian gravity conditions 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 colony 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.

The trickle filter will be operated by the DLR Institute of Aerospace Medicine. The Friedrich-Alexander University Erlangen-Nürnberg will contribute the euglena. The DLR Institute of Aerospace Medicine will measure the radiation exposure inside and outside the satellite throughout the entire mission.
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 after decommissioning of the ISS. Interaction with the planned Free Flyer could lead to advanced research conditions and commercial applications.

Aims
The concept is a preparatory development 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 (~2028), which would be the new applications, and what is the potential for optimisation?

Applications
- Human spaceflight
- Earth observation
- Technology demonstration
- Commercial applications
- Science and research under microgravity conditions
- Preparation and training for exploratory missions
- Goods distribution in Low Earth Orbit (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’

Parties involved
DLR, Airbus DS, Bigelow Aerospace, ESA and NASA astronauts

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

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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 basic 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 from Bigelow Aerospace. It contains quarters for three crewmembers, a kitchen, working spaces, manufacturing units, laboratory cabinets and general storage facilities. It includes a small airlock so that extravehicular activities (EVA) 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 (for example 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, and would be a reliable base for long-term space exploration by astronauts beyond Low Earth Orbit.

Participants in the project are the DLR Institute of Space Systems and 10 other DLR institutes together with international partners and industry.
**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 on board the ISS by the MUSES (Multi-User System for Earth Sensing) platform developed by Teledyne Brown Engineering.

**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.

**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: 29 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

**Parties involved**

DLR, Teledyne Brown Engineering

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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. DESIS was launched to the International Space Station (ISS) on board a SpaceX rocket on 29 June 2018. 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.

Two DLR institutes are involved in the project: The DLR Institute of Optical Sensor Systems built the instrument as part of the space segment subproject, while DLR’s Earth Observation Center (EOC) in Oberpfaffenhofen is managing the ground segment subproject, which is responsible for the reception, processing and transfer of the data into applications.
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 using 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.

Applications
- Simulation of research under space conditions in the Antarctic
- Development of bioregenerative life support systems for waste management and 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)

Parties involved
International research consortium under the auspices of DLR

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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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. Moreover, a research greenhouse – the Future Exploration Greenhouse – 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 – will be used to study the mass flow relationships for the International Standard Payload Rack demonstrator and the Future Exploration Greenhouse. 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.

Numerous international partners are jointly working in a research consortium under the auspices of DLR to keep the greenhouse up and running in the Antarctic environment: Wageningen University & Research (Netherlands), Airbus Defence and Space (Germany), LIQUIFER Systems Group (Austria), National Research Council (Italy), University of Guelph (Canada), Enginsoft (Italy), Thales Alenia Space Italia (Italy), AresCosmo (Italy), Heliospectra (Sweden), Limerick Institute of Technology (Ireland), Telespazio (Italy) and the University of Florida (USA).
OSIRIS
Optical Space Infrared Downlink System

Brief description
OSIRIS is an experimental optical communications 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.

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’

Parties involved
DLR, Airbus DS, Tesat-Spacecom

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

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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 on the Bartolomeo platform being developed by Airbus in 2019. 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.
FLUMIAS
Innovative 3D fluorescence microscope for space ‘made in Germany’

**Brief description**

FLUMIAS is a compact fluorescence microscope for 3D ‘live-cell imaging’ in space, miniaturised to the size of a shoe box, capable of providing high resolution live observation of fixed and living cell cultures, human tissue, plant cells and microorganisms in microgravity.

**Aims**

The technology demonstration FLUMIAS has successfully proven the functionality of the innovative structured illumination technique in microgravity. Fixed cells were observed in the first technical experiment. In addition, the intracellular changes occurring in living human immune cells exposed to microgravity were investigated.

**Applications**

- Biomedical research in space
- Research in extreme and remote environments on Earth
- Applications in stem cell research, research in neurodegenerative and autoimmune diseases

**Outlook**

With the ongoing development of a next-generation FLUMIAS-ISS, the technology of ‘FLUMIAS’ will be brought to the next level. A centrifuge integrated into the microscope will enable live observation of living cells under variable gravity conditions between microgravity and 1 g.

**Parties involved**

DLR Space Administration,
University of Magdeburg, Airbus, TILL I.D.,
Space Tango Inc.

**Facts and figures**

- **Launch:** SpaceX CRS-15, 28 June 2018
- **Return:** 3 August 2018
- **Size:** 40 x 20 x 10 cm
- **Properties:** Miniaturised cutting-edge microscope technology (structured illumination microscopy) with fully automated sample analysis on the ISS
- **Scientific support:** Prof. Oliver Ullrich, University of Magdeburg

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‘Live’ examination of cells under microgravity

**FLUMIAS** is a high-resolution 3D fluorescence microscope for live-cell imaging. It provides a view inside living cell cultures, human tissue, plant cells and microorganisms with high temporal and spatial resolution. For example, changes in metabolic processes, membrane dynamics and ion flows can be viewed in real time – changes triggered by altered gravitational conditions and microgravity. Numerous cell functions are impaired under altered gravitational conditions. This is, among other things, due to structural changes in the internal supporting and organisational structures of the cells – the cytoskeletal elements. In order to better understand the dynamic sequences of these modification processes, as well as their causes and consequences for cell functions, these protein structures in human immune cells are labelled with fluorescent markers and made visible in living cells using the FLUMIAS microscope. The innovative technology of structured illumination enables fast scanning of image planes at very high resolution. Three-dimensional models and video sequences can be created by processing several image planes. The FLUMIAS technology demonstrator is a simplified variant of the planned microscope. This model will initially be used to test the space suitability of the new high-resolution microscope technology and identify critical components. Another model is prepared for use on the ISS. Mounted on a centrifuge rotor, this version will allow for the examination of numerous biomedical samples under various gravitational conditions.
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’ marked 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’.

**Applications**

- In addition to basic research, 41 German experiments provide knowledge for ‘Health, 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** on 6 June 2018 on board a Soyuz launcher from Baikonur Cosmodrome (Kazakhstan), Docking with Soyuz MS-09 on 8 June 2018.
- **Mission duration**: expected to be 187 days (until 13 December)
- **Mission operations**: German Space Operations Center in Oberpfaffenhofen, Johnson Space Center (Houston) and ZUP Moscow

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‘horizons’ – this is the name of German ESA astronaut Alexander Gerst’s current mission to the ISS. On 6 June 2018, the 42-year-old geophysicist embarked on his second journey to the International Space Station (ISS) with Expedition 56/57. On 3 October, Gerst will become the first German and second European Commander of the ISS. During his expected 187-day mission – until 13 December – Gerst will be living and working at an altitude of approximately 400 kilometres. The name of the mission – horizons – symbolises 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.

Forty-one of the 65 european experiments conducted as part of the mission have German participation, and have been 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 oversaw 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.
ICARUS
Tracking animal migration

Brief description
ICARUS is a system for the global tracking of animal migration. 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.

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

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

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)
Dimensions: 3 x 1.25 x 1.2 m (antenna), 25 x 15 x 5 mm (tag)
Properties: Simultaneous reception of a large number of miniaturised transmitters
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. The computer is located in the interior of the ISS and the antenna system on the exterior of the Russian service module Zvezda. It was installed by two cosmonauts during an extravehicular activity on 15 August 2018. 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 transmit 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 not only that the data will provide new information about animal behaviour, but they also expect to make findings about the spread of epidemics (for example bird flu, Ebola), the impact of climate change and the interplay between animal migration and food security in critical regions.
ARISE (High-flyers)

On the ISS, the formation of planets is studied through charge-induced clustering.

**Brief description**

ARISE is investigating the extent to which electrostatic forces play a role in the formation of new planets. The experiment involves shaking glass beads in a transparent container and subsequently conducting camera-supported observations of their collisions in microgravity. The experiment also aims to determine the electrical charge of the particles.

**Aims**

Present-day theories on the origin of planets describe how one-millimetre-sized particles collide with each other, thus forming larger particles. However, if these particles become too large, they bounce off each other, making it impossible for entire planets to form. The ARISE experiment examines a theory that could close this knowledge gap.

**Applications**

- Research into the principles determining the formation of planets

**Outlook**

- Fresh insights into the process of planet formation will also tell us more about our own origins

**Parties involved**

University of Duisburg-Essen, DLR Space Administration, DreamUp, NanoRacks

**Facts and figures**

- **Project term:** 15.07.2017 - 31.12.2018
- **Duration of experiment on ISS:** 30 days
- **Launch to ISS:** 29 June 2018 (SpaceX CRS-15)
- **Size:** 10 x 10 x 15 cm
- **Weight:** 2 kg
- **Financing:** 15,000 euro (DLR) + sponsors

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Present-day theories on the origin of planets describe how one-millimetre-sized particles collide with each other, thus forming larger particles. But over and above the size of a few centimetres across, these particles would inevitably bounce off each other like billiard balls when they collide. Accordingly, it would be impossible for entire planets to form. The ARISE experiment is examining a theory that could close this knowledge gap: Electrostatic interactions between particles could cause them to stick to each other and therefore continue to grow. That could clear the way for the formation of planets as we know it today. With this hypothesis in mind, the experimental assembly was used to shake a transparent container with glass beads and observe their collisions in microgravity with the help of a video camera, while determining the glass beads’ electrostatic charge. All of the data obtained is later correlated and evaluated. Extended experimental cycles in microgravity conditions without any disruption are only possible on the ISS. The basic experimental demonstration model shown here was mainly assembled from spare flight hardware parts. It is used in order to test new software versions before they leave the ground. In doing so, any problems can be dealt with before the system is deployed under ISS experimental conditions. ARISE is one of three winning experiments in DLR’s ‘High-flyers’ competition, which gave students across Germany the opportunity to have their own home-made experiments carried out on the ISS. The High-flyers initiative is organised by the DLR Space Administration and financed by the German Federal Ministry for Economic Affairs and Energy. The US companies DreamUp and NanoRacks are providing the technical know-how and supporting the students in bringing their experiments to fruition. The companies are also supervising the transportation of the experimental equipment to the ISS. Experts from the Deutsche Physikalische Gesellschaft (DPG) – a German physics association – are helping DLR in the experiment selection process.
PAPELL (High-flyers)
Pump Application using Pulsed Electromagnets for Liquid relocation

Brief description
PAPELL is trialling the concept of a pump with no mechanical moving parts. This involves moving a magnetic fluid using electromagnets by sequentially switching them on and off. A pump of this type should require less maintenance and be capable of operating more quietly than conventional pumps.

Aims
In spaceflight vehicles, pumps are a recurrent source of malfunctions. They are prone to wear and tear due to their moving parts. Furthermore, they produce a constant, disruptive level of noise during operation. In order to minimise these problems, the PAPELL experiment is investigating the concept of an innovative pump that works without any mechanical moving components.

Applications
- Pumps in spaceflight vehicles (for example for propellant, water or coolants)

Outlook
- To enable low-wear, quiet pumps

Parties involved
The University of Stuttgart, KSat e.V., DLR Space Administration, DreamUp, NanoRacks

Facts and figures
Project term: 15.07.2017 - 31.12.2018
Duration of experiment on ISS: 30 days
Launch to ISS: 29 June 2018 (SpaceX CRS-15)
Size: 10 x 10 x 15 cm
Weight: 2 kg
Financing: 15,000 euro (DLR) + sponsors

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In spaceflight vehicles, pumps are a recurrent source of malfunctions. Their moving parts result in wear and tear, which can cause failure or reduce performance. Furthermore, a constant level of noise is generated during operation, which is particularly disruptive in astronautical applications. In order to minimise these problems, the PAPELL experiment is investigating the concept of an innovative pump that works without any mechanical moving components. For this purpose, it uses a magnetic fluid – a ‘ferrofluid’ – in conjunction with electromagnets. These are switched on and off in a predetermined sequence, thus transporting the ferrofluid along the desired route. The experiment consists of two sub-sections. In the first area, the fluid is moved over a flat surface. In various cycles, different magnetic sequences enable transportation along a range of routes. In the second experimental section, the fluid is employed to transport a small floating ball made of plastic. A concept of alternative choices for different routes is to be used in this process. These routes will be filmed by cameras to analyse these experimental cycles. The experimental demonstration model shown here was assembled mainly from spare flight hardware parts. It is used for exhibitions and trade fairs. PAPELL is one of three winning experiments in DLR’s ‘High-flyers’ competition, which gave students across Germany the opportunity to have their own home-made experiments carried out on the ISS. The High-flyers initiative is organised by the DLR Space Administration and is financed by the German Federal Ministry for Economic Affairs and Energy. The US companies DreamUp and Nano-Racks are providing the technical know-how and supporting the students in bringing their experiments to fruition. The companies are also supervising the transportation of the experimental equipment to the ISS. Experts from the Deutsche Physikalische Gesellschaft (DPG) – a German physics association – are helping DLR in the experiment selection process.
CIMON®
The flying astronaut assistant – technology demonstration

Brief description
CIMON® (Crew Interactive MOBILE companion) could be described as a ‘flying brain’ – an autonomous astronaut assistant. Powered by 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. In future, the flying companion could be used, for example, to present and explain a wide range of information and instructions for scientific experiments and repairs.

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

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

Facts and figures
Launch: SpaceX CRS-15, 29 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.
CIMON®
The flying astronaut assistant – technology demonstration

Technology demonstration – astronaut assistance system

CIMON® is an innovative and globally unique astronaut assistance system developed and built in Germany. 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 of 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 taking inventory. 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 Watson AI technology from the IBM Cloud. 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.
The Heinrich Hertz mission is scheduled for 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 to be operated by Germany since 2002.

**Aims**

The objective 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.

**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

**Parties involved**

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

**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
Heinrich Hertz mission
New technologies for satellite communications

Today, we are reachable – anytime and anywhere – via the Internet, email or via text messages, which we send and receive using a smartphone, tablet PC or notebook. This results in a sheer inconceivable flow of data across the globe. The development of new technologies for communications satellites will be necessary 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 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 in Earth orbit. 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.
EurEx – Europa Explorer
Autonomous exploration of the ocean floor on Jupiter’s icy moon Europa

Brief description
This interactive virtual reality experience lets you slip into the role of a sophisticated artificial intelligence controlling a robot to explore a 100-kilometre-deep saltwater ocean on Europa. Search for extraterrestrial life and other stunning features on the ocean floor. The EurEx space mission is planned for beyond 2050.

Aims
The primary objective of the future space mission EurEx is the intense investigation of Europa’s saltwater ocean and, in particular, the search for any forms of extraterrestrial life in it. The discovery of extraterrestrial life would greatly affect science and humanity – making us rethink our place in the Universe.

Applications
- Melting probe technologies
- Autonomous underwater vehicles (AUV)
- Artificial intelligence, autonomous navigation and decision making
- Acoustic long distance homing techniques
- Maritime exploration strategies

Outlook
- Better understanding of the origin and evolution of life
- Advancement of biology and medicine
- Impact on awareness of our place in the Universe
- New technologies

Facts and figures
Ongoing development of required key technologies:
- Manoeuvrable shuttle melting probe to penetrate a 10 - 25 km thick ice sheet
- In-ice fore field sounding
- Robotic underwater vessel for high-pressure environment operations
- Energy supply implementation
- Fully autonomous mission performance
- Robust navigation and communication
Proven technology readiness expected by 2035

Parties involved
DLR Space Administration,
DFKI – German Research Center for Artificial Intelligence GmbH

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EurEx – Europa Explorer
Autonomous exploration of the ocean floor on Jupiter’s icy moon Europa

A 10-to-25-kilometre-thick ice shield makes up the surface of Jupiter’s moon Europa. Beneath it lies a salt water ocean approximately 100 kilometres deep. Europa is subjected to strong tidal forces due to the gravitational force of Jupiter and its biggest moons Io, Ganymede and Callisto. The existence of hydrothermal energy sources on the ocean floor is thus possible – maybe similar to ‘Black Smokers’, deep-sea hydrothermal vents found on Earth. Direct contact between Europa’s ocean and seabed could cause eroded minerals to dissolve in the water, thereby creating a possible source of nutrients for potential life. The combination of these features makes Europa’s ocean the most promising location in the Solar System for harbouring extraterrestrial life. But accessing and exploring this ocean is technologically demanding. One of the biggest challenges of EurEx is the need for sophisticated artificial intelligence (AI):

The propagation time of a radio signal from Earth to Jupiter varies between 33 and 53 minutes (depending on the relative distance of both planets). This means that the exploration of Europa’s ocean floor cannot be directed remotely from a ground control station on Earth; it requires a fully autonomous underwater vehicle (AUV). Continuous parameter and data analysis, decision making in real time, and full control of the vehicle by the AI shall enable it to successfully conduct the exploration part of the overall mission. Once the exploration data has been transferred to the melting probe, it will be transmitted to Europa’s ice surface, and from there to Earth.

The EurEx virtual reality demonstration model gives you the opportunity to ‘be’ the EurEx AI with full control of the AUV. Explore Europa’s ocean floor and search for life and other amazing features waiting to be discovered in this alien world. Monitor the system energy and other parameters, and ensure a safe return to the melting probe for data transfer. Make your personal EurEx mission a success!
Space and Innovation
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 IAC to present the ‘Space Moves!’ 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 Moves!’ initiative in 2017. The purpose of the initiative is to forge networks between the space, mobility and logistics industries, as well as to develop future-oriented solutions.

Organised since 2016, the INNOspace Masters competition rewards 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 at DLR’s booth at the IAC.

Applications
- ‘Space Moves!’ 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

Outlook
- The focus is on measures such as technology workshops, networking 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

Parties involved
DLR Space Administration, BMWi, University of Würzburg

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The 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 the German Federal Ministry for Economic Affairs and Energy (BMWi), in partnership with ESA BIC Bavaria and Darmstadt, as well as Airbus Defence and Space. It was organised by the Anwendungszen-trum 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 the overall winners of the competition and 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 with data cables. Instead of these cables, Skith uses miniaturised, high-speed, real-time radio modules with short ranges. This reduces design efforts and costs while increasing the satellite’s reliability and flexibility.
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 the necessary standardisation.

The iBOSS building block system is based on innovative key technologies that involve the development of standardised building blocks, a multi-functional 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.

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

Aims

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

Facts and figures
Project start: 2010
- In-orbit demonstration planned for 2020
- Two spin-offs from the project context: iBOSS GmbH, iBOSS solutions GmbH
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 establish 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 enable 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 towards maintainable, modifiable and cost-efficient recyclable systems.** What makes the building block system special is that it can be employed 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 make it possible to transfer iBOSS technologies to industrial use and enable in-orbit qualification.
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 presents 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.

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)

Parties involved
DLR Space Administration, BMWi, BMVI, ESA

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.
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 such as 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 the 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.
Photobioreactor PBR
Life support system in space – from carbon dioxide to oxygen

Brief description
The Photobioreactor (PBR) provides the environment for algae cultivation, enabling oxygen and biomass to be generated while carbon dioxide is consumed. Carbon dioxide is supplied to the algae by ESA’s Life Support Rack, demonstrating the hybrid setup of a combined physico-chemical and biological life support system. As a backup, a PBR carbon dioxide tank can be used.

Aims
The Photobioreactor is a technical demonstration of a hybrid life support system that will, for the first time, expand a physicochemical system using a biological complement. It will thus close the resource cycle, significantly reducing the transport of resources, which are necessary for long-duration missions. The demonstration of long-term algae cultivation is also a prerequisite for future hybrid systems.

Applications
Closed-loop hybrid systems make it possible to reduce the consumption of oxygen and fresh water during missions. The biological system is able to generate food, further closing the resource cycle.

Outlook
On Earth, microalgae biosystems/farms could be used to produce food (poor regions), energy and bio-fuels. Air treatment and CO₂ reduction in sealed environments are further applications.

Parties involved
DLR Space Administration, Airbus, University of Stuttgart, Institute IRS, ESA, NASA

Facts and figures
Launch: February 2019, SpaceX (TBD)
Properties: Producing oxygen and in general edible biomass whilst consuming CO₂
Microalga used: Chlorella vulgaris
Liquid loop/reactor: 0.65 l
Accommodation: 2MDL in US experiment rack (ER)
Experiment duration: up to 180 days
Start of development: March 2015
PI: Dr. S. Belz Co-PI: N. Henn, H. Helisch
Photobioreactor PBR
Life support system in space – from carbon dioxide to oxygen

For astronauts to survive in space, the resources necessary for life have to be provided. Conventional life support systems use physical and chemical processes for oxygen generation (electrolysis of water) and air revitalisation, but they nevertheless partly rely on regular water re-supply. However, due to the fact that astronauts and spacecraft cannot carry unlimited supplies during long-term exploration missions, the resource cycle must be closed.

In autumn 2018, ESA’s Life Support Rack LSR (also known as the ACLS, Advanced Closed-Loop System), an advanced physicochemical life support system constructed by Airbus Defence and Space, will be brought to the ISS. Due to chemical stoichiometry, the LSR will not convert all the carbon dioxide extracted from the cabin air into oxygen and water.

The Photobioreactor (PBR) experiment will be connected to the Carbon Concentrator Assembly of the Life Support Rack by a specially designed interface to a so-called hybrid system. Some of the excess carbon dioxide (waste) will be made available to microalgae in the PBR for photosynthesis, producing oxygen and biomass.

This further closes the resource cycle and increases the efficiency of the overall system (hybrid system), even more when the biomass is edible. The experiment, expected to begin in the first quarter of 2019, will be connected to the LSR (hybrid setup) after LSR commissioning, and will run for up to six months thereby also investigating the long-term stability and performance of microalgae cultivation in space. The PBR will demonstrate a hybrid life support system for the first time. This is an important milestone in closing resource cycles. This approach is beneficial to space as a step in reducing re-supply requirements, thus enabling future exploration missions.

On Earth, it will also make contributions to air treatment in sealed environments (for example, submarines), carbon dioxide reduction using microalgae, and food production in underprivileged, sunny regions.
Mynaric laser terminals for inter-satellite communication

To enable small- and large-scale satellite constellation networks

Brief description

Terminal for wireless laser communication enabling the transmission of extremely high data rates of up to 10 Gbps between satellites in Low Earth Orbit. In future, this terminal will be used to connect hundreds of satellites, thereby helping to establish global satellite-based communication networks.

Aims

Studies as part of the S2SBroad project contributed to the early product development of Mynaric’s laser terminals. The studies explicitly examined how Mynaric’s existing laser terminals could be used for stratospheric applications, and how cost-effective laser terminals for inter-satellite links operating in Low Earth Orbit could subsequently be developed.

Applications

- Satellite constellations
- Global broadband coverage
- Internet of Things
- Earth observation

Outlook

As a key component of satellite networks, the laser terminal can bring the Internet to the remaining three to five billion people currently without connectivity or with very poor access, to drive the digital revolution to places lacking Internet access.

Facts and figures

Laser terminal:
- Data rate: up to 10 Gbps (bidirectional)
- Link distance: up to 4500 km
- Wavelength: 1550 nm

Project:
- Name: S2SBroad
- Investment (Mynaric): 226,000 euro (total: 401,000 euro)
- Duration: July 2016 to June 2017
- Sponsor: DLR Space Administration

Parties involved

Astro- und Feinwerktechnik Adlershof, Mynaric

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Mynaric produces laser communication products, that are the equivalent of fibre optic cables, for aerospace applications. This enables secure, high-rate wireless data transmission between aircraft, drones and satellites. The global demand for a rapid and, above all, continuous network connection is growing relentlessly. Nowadays, data networks such as the Internet are largely based on infrastructure on the ground, which cannot be arbitrarily extended due to legal, economic and logistical limitations. The future therefore requires an expansion of the existing network infrastructure into the air and space. Firms such as Facebook, Google, SpaceX and OneWeb have been working on their own networks for years at great expense. The common objective is to create an ‘Internet above the clouds’, comprising hundreds, and even thousands, of airborne platforms or satellites intended to provide the most remote and inaccessible regions of our planet with cost-effective Internet access. In future, this terminal will be used to connect hundreds of satellites, thereby helping to establish these communication networks. It enables wireless laser communications offering extremely high data rates of up to 10 Gbps between satellites in Low Earth Orbit. Studies as part of the S2SBroad project contributed to the early product development stages of the laser terminal. These have explicitly examined how Mynaric’s existing laser terminals can be used for stratospheric applications to develop a cost-effective laser terminal for satellites in Low Earth Orbit. At the end of the project, the development was independently driven by Mynaric and is due to be completed in early 2019. In future, several hundred to several thousand of these terminals could be mounted on satellites orbiting the Earth to interconnect the planned global satellite networks, thereby creating large-scale optical networks in space.
Quantus II/Cold Atoms Lab
A high-tech drop capsule for cold atom research in microgravity

Brief description
The QUANTUS II drop capsule is used in the Bremen drop tower for cold atom research and technology development and testing. The duration of the microgravity experiment is approximately 4.5 seconds in the drop mode and 9 seconds in the catapult mode of the drop tower. Cutting-edge miniaturised and robust high-precision lasers, vacuum components, electronics and atom chips are essential for this research.

Aims
Ultra-cold atom clouds, consisting of several thousands of atoms and with temperatures of just above absolute zero (Bose-Einstein Condensates, BEC’s), are macroscopic quantum objects and behave like a single giant atom. They exhibit wave behaviour. The generation and precise manipulation of ultra-cold atom clouds in microgravity is a prerequisite for long-term matter wave interferometry, which will be used for ultra-precise measurements in fundamental physics, such as testing Einstein’s Theory of Relativity.

Applications
The technology can be applied to advanced satellite navigation, extreme precise measurements of the gravitational field of Earth and other celestial bodies, and cutting-edge fundamental physics experiments.

Outlook
The German QUANTUS technology, together with the experience acquired with NASA’s Cold Atom Lab, which is currently in operation on the ISS, will open a new era for cooperative cutting-edge fundamental physics experiments with a next-generation ISS facility called BECCAL.

Parties involved
DLR Space Administration, University of Hannover, ZARM Bremen, Humboldt University of Berlin, Ferdinand-Braun-Institut Berlin, University of Mainz, University of Ulm, TU Darmstadt

Facts and figures
Weight: 400 kg
Diameter: 0.6 m
Height: 1.5 m
Properties: Cold atom research, Bose-Einstein Condensates, matter wave interferometry

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German high-tech for cold atom research

The QUANTUS II drop capsule is a compact, atom chip-based facility for examining ultra-cold quantum gases, such as Bose-Einstein condensates (BEC), in the drop tower Bremen. The capsule is used for self-standing research and for technology development in this field. Its predecessor, QUANTUS I, produced the worldwide first BEC in microgravity in the drop tower in Bremen in the year 2007. QUANTUS II was used to test cold atom research hardware for the MAIUS sounding rockets, which produced the worldwide first BEC in space in 2017. Inspired by this success, NASA has built a Cold Atoms Laboratory (CAL) for the ISS. CAL represents a new era in ISS research, as for the first time, fundamental physics questions can be investigated with high precision using quantum objects at almost absolute zero (-273.15 degrees Celsius) in long-term microgravity. In this installation, clouds of rubidium and potassium atoms are generated, as well as mixtures of both atom types. The movement of the atoms is slowed down using pulses of laser light. These extremely decelerated atoms are trapped in an atom chip – a magnetic trap. When the magnetic field is reduced, only the coldest and thus slowest atoms remain in the trap. With decreasing temperature – very close to absolute zero – the atoms behave like a single ‘giant atom’ – a Bose-Einstein Condensate. This can now be examined macroscopically. In a state of microgravity on the ISS, BECs have a lifespan of up to 20 seconds. This cannot be achieved in any laboratory on Earth. The longer the BEC can be maintained, the more accurate the results provided by the macroscopic quantum sensor – here, the sensitivity of an atomic interferometer increases with the square of the lifespan of a BEC. The advanced technical developments for installations such as CAL and the German BECCAL ISS facility (under development) mean that quantum sensors can also be used outside fundamental research – for example to control the positions of satellites, to control the distances in formation flights of a satellite swarm, or to measure the gravitational field of the Earth or other celestial bodies.
CALLISTO
Cooperative Action Leading to Launcher Innovation in Stage Toss back Operations

Brief description
CALLISTO is a reusable demonstrator for a vertical take-off, vertical landing (VTVL) rocket stage. CALLISTO is being jointly developed, constructed and tested by DLR and CNES. The noteworthy features – compared with conventional expendable launch vehicles – are CALLISTO’s landing system and its aerodynamic control surfaces.

Aims
The purpose of CALLISTO is not only to improve knowledge concerning vertical take-off, vertical landing (VTVL) rocket stages, but also to demonstrate the capabilities and technologies required to develop and exploit an operational, reusable VTVL rocket stage. CALLISTO is to carry out several flights and manoeuvres under conditions relevant to an operational launcher system.

Applications
- Demonstration of manoeuvres specific to the VTVL launcher, such as boostback or precise landing
- Demonstration of vehicle preparation between flights for next operation
- Collection of data required to optimise reusable launch vehicles

Outlook
- Cost reduction for accessing space; increased competitiveness
- Enhancing mission versatility: a broad range of payloads could be launched at low costs
- Greater environmental friendliness due to the reutilisation of rocket stages

Parties involved
DLR, CNES (France)

Facts and figures
- Project term: 2017-2021
- Length: approximately 15 m
- Diameter: 1.1 m
- Take-off weight: approximately 3500 kg
- Maximum thrust: > 40 kN
- Propellant: LOx/LH2
- Planned number of flights: ≥ 5
- Maximum flight altitude: ≥ 30 km
- Launch site: Kourou, French Guiana

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CALLISTO is a reusable demonstrator for a vertical take-off and vertical landing (VTVL) rocket stage. The introduction of reusability for launcher systems could make it possible to reduce launch costs and enhance the versatility of the launcher system. The project aims at improving the knowledge of VTVL rocket stages and demonstrating the capabilities and technologies required for developing and exploiting an operational, reusable vertical take-off and vertical landing rocket stage. Test flight results will also be used to optimise the design of a future reusable operational space transportation system.

The CALLISTO vehicle itself is single stage and is operated using cryogenic oxygen (LOx) and hydrogen (LH2). The engine can be throttled so as to enable precise, soft landings. At least five different missions are to be flown using the same vehicle from Europe’s Spaceport in French Guiana.

An incremental test plan will make it possible – in the concluding flights – to achieve flight conditions that are relevant to an operational VTVL rocket stage. In particular, the engine is ignited after a large change of CALLISTO’s attitude, and the trajectory is modified in order to reach the landing site. CALLISTO is then guided using aerodynamic control surfaces during a non-powered phase featuring a transition from supersonic to subsonic flow conditions. Finally, the CALLISTO engine will re-ignite and decelerate the vehicle. The landing system will thus be able to absorb the remaining kinetic energy, enabling CALLISTO to perform a safe, stable landing. The demonstrator will then be prepared for the next flight.
From 2023, the Franco-German climate mission MERLIN (MEthane Remote sensing LIdar missioN) will detect the greenhouse gas methane using a Lidar instrument. Germany’s contribution to MERLIN is managed by the DLR Space Administration with funds from the German Federal Ministry for Economic Affairs and Energy (BMWi). The DLR Institute of Atmospheric Physics provides the German Principal Investigator.

Methane is one of the most effective greenhouse gases 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).

**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
The Franco-German climate mission **MERLIN** (Methane Remote Sensing Lidar Mission) is expected to measure **methane levels in the Earth’s atmosphere** from 2023 with unprecedented accuracy. Missions such as MERLIN help to gain a deeper insight into the mechanisms that influence Earth’s climate. 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 28 times greater on a 100-year time scale than that of carbon dioxide. Although the concentration of methane is significantly lower than that of carbon dioxide, it is responsible for approximately 20 percent of global warming.

MERLIN will be installed on the new ‘**Myriade Evolutions’ satellite bus**, developed by CNES together with the French space industry. The satellite’s **payload**, an active **Lidar (Light Detection and Ranging)** instrument that can measure even at night-time and through thin clouds, is being developed and built in Germany on behalf of the 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 concentrations at all latitudes, regardless of sunlight. The wavelengths are in the near-infrared spectral range (1.6 micrometres) and have been chosen because one is absorbed by methane, while the other is not. MERLIN sends two pulses towards the same location 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 the Earth’s surface. The science activities are led by two Co-Principal Investigators from the German DLR Institute of Atmospheric Physics and the French Laboratoire des Sciences du Climat et de l’Environement.
EnMAP is Germany’s hyperspectral satellite mission, managed by the DLR Space Administration with funds from the German Federal Ministry for Economic Affairs and Energy (BMWi). Imaging spectrometers observe the sunlight reflected from Earth across a wide range of wavelengths from the visible to the short wave infrared. This makes it possible to acquire precise information on the condition of Earth’s surface and its changes.

**Facts and figures**

- **Launch:** scheduled for 2020 on board a PSLV rocket from Sriharikota (India)
- **Orbit:** Sun-synchronous at an altitude 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

**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, the water quality of lakes, or the identification of the mineralogy in rocks and soil

**Outlook**

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

**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 (IMF)

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No. 21
EnMAP (Environmental Mapping and Analysis Program) is Germany’s hyperspectral satellite mission for Earth observation. Imaging spectrometers measure the sunlight reflected from Earth across a wide range of wavelengths from the visible to the short wave infrared. This makes 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, the 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 in a Sun-synchronous orbit at an altitude of 643 kilometres above the Earth, recording data with a 30 x 30 metre ground resolution. A tilting mode of plus / minus 30 degrees perpendicular to the flight path will make it possible to acquire data over any point on Earth within four days. 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 the distribution, evolution and formation of ecosystems in various different natural environments.
**Green impulse for advanced propellants**

Rocket propellants consisting of nitrous oxide and hydrocarbons

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**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 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.

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**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.

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**Applications**

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

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**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

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**Parties involved**

DLR, Technical University of Munich

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**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 videos up to 120,000 frames/second, 50 kHz data sample rate for pressure measurements, flame arresters with <100 μm pores

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Hydrazine (N₂H₄) 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 is highly carcinogenic and toxic. This makes extensive safety measures necessary 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 (H₂O₂) 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 fuel propellant are mixed and liquefied under pressure in a tank. However, if such a mixture unintentionally ignites, it would be accompanied by a sudden reaction. Furthermore, a flame flashback across the injection system into the feeding lines and tank structure might occur during the combustion of the propellant in a rocket engine. 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 model engine.

The DLR Institute of Space Propulsion and the DLR Institute of Combustion Technology are involved in the interdisciplinary ‘Future Fuels’ project in cooperation with the Technical University of Munich.
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.

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 to 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

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

Facts and figures
- Two L-band SAR Satellites, ~3 tons each, flying in close formation & operating as a 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 and climate research

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Tandem-L is a proposal for an innovative L-band SAR mission for environmental and climate research. The Earth system is continuously changing, and dynamic processes occur in different spheres and over different time scales. Tandem-L has been designed to observe a wide range of processes at adequate time intervals and 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 over 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; and 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 will deliver 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, feasibility and mission definition studies led by DLR with a team of more than 100 scientists in close cooperation with the German aerospace industry since 2008. The scientific data exploitation of Tandem-L is being prepared as part of the Helmholtz Alliance ‘Remote Sensing and Earth System Dynamics’, including more than 140 scientists from eight Helmholtz centres, the Max Planck and Leibniz Institutes, and other national and international universities and research institutes.
TanDEM-X – the Earth in three dimensions
TerraSAR-X add-on for Digital Elevation Measurements

Brief description
TanDEM-X (TerraSAR-X add-on for Digital Elevation Measurements) is an Earth observation radar mission that consists of a SAR interferometer built by two almost identical satellites flying in close formation at a typical distance between 120 to 500 metres. The mission has generated a global Digital Elevation Model (DEM).

Aims
The main objective of the TanDEM-X mission is to create a precise 3D map of the Earth’s land surfaces that is homogeneous in quality and unprecedented in accuracy. The data acquisition was completed in 2015 and production of the global DEM was completed in September 2016. The absolute height error is about one metre in an order of magnitude below the 10 metre requirement.

Applications
- Earth sciences (geology, glaciology, oceanography, meteorology, hydrology, etc.)
- Environmental research, land use, vegetation monitoring, urban and infrastructure planning
- Cartography, navigation, logistics, crisis management, defence and security

Outlook
The TanDEM-X DEM provides precise topographic information and sets a new standard according to its high accuracy and homogeneity. It contributes significantly to the improvement of applications such as infrastructure planning, crisis management, prevention, cartography and navigation.

Facts and figures
- Two X-band SAR satellites, built by Airbus DS; 1.3 tons each; size: 5 m × 2.4 m, flying in close formation
- Active phased array antenna, size: 4.8 m × 70 cm, electronic beam steering capability, radar frequency: 9.65 GHz, H and V polarisation
- Satellite control, data management, reception, processing and calibration by DLR

Parties involved
DLR, Airbus Defence and Space GmbH, Deutsches GeoForschungsZentrum (GFZ)
TanDEM-X – the Earth in three dimensions
TerraSAR-X add-on for Digital Elevation Measurements

The TanDEM-X mission (TerraSAR-X add-on for Digital Elevation Measurement) opened up a new era of spaceborne radar remote sensing. It is the world’s first bistatic SAR mission with two almost identical satellites flying in a closely controlled formation with typical distances between 250 and 500 metres. The main objective of the mission is to generate a consistent global digital elevation model with unprecedented accuracy. TanDEM-X also offers a highly reconfigurable platform for demonstrating new SAR techniques and applications.

The TanDEM-X mission has acquired Earth’s entire land surface – 150 million square kilometers – several times. In addition to the high horizontal resolution according to a horizontal sampling of 12 metres and the high vertical accuracy, the elevation model created with the TanDEM-X and TerraSAR-X satellites has another outstanding advantage – it is consistently homogeneous and thus forms the basis for global uniform maps.

From now on, a ‘light’ version of the TanDEM-X DEM with a horizontal sampling of 90 metres is freely available for scientific purposes and can be downloaded from the following address: https://tandemx-90m.dlr.de

The scientific use of the data covers three areas: (1) new quality Digital Elevation Models for Earth sciences concerning the biosphere (3D forest structure and biomass), geosphere (Earth surface deformation, volcanology), cryosphere (ice melting processes) and hydrosphere (oceanology, water supply, soil moisture measurement); (2) along-track interferometry (measurement of ocean currents, traffic monitoring); and (3) new bi-static applications (polarimetric SAR interferometry).

The Earth’s surface is a very dynamic system when analysed at this level of accuracy. Height changes in glaciers, permafrost regions and forests, as well as agricultural activities and changes in infrastructure leave clear marks in the DEM. For this reason, an additional complete acquisition of the Earth’s landmass began in September 2017, and will be carried out until the end of 2019 to provide an independent unique DEM data set. The resulting product, called ‘Change DEM’ will make it possible to monitor topographic changes on a global scale.
**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 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. In addition, the flight times for passengers on the Australia-Europe route will be reduced to just 90 minutes, and to 60 minutes for passengers on the Europe-California route.

**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 environmental friendliness of space transport through reusability and hydrogen technology
- Dramatic reduction in intercontinental flight times and establishment of new business models

**Facts and figures**

- **Length of 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 geotransfer orbit:** over 8 t (with upper stage)
- **Max. flight altitude for passenger missions:** 80 km (Australia)
- **Max. speed for passenger missions:** 25,200 km/h
- **Max. range for passenger missions:** 18,000 km

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**Parties involved**

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

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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 and hydrogen. 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 lies 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. Considerable cost savings are possible both in development and in production due to the high degree of similarity between the two variants in terms of design and their use of identical rocket engines. Combined with the fact that the stages are **largely reusable**, the ambitious goal of achieving a more than 90 percent cost reduction for satellite launches relative to current levels is realistic.
Spaceplanes

Space traffic management and spaceport 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 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.

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)

Parties involved

DLR

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

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In future, spaceplanes will join the air transport system, flying into space at supersonic speeds and returning inertly to Earth for landing. These innovative combined aircraft and spacecraft might 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 industrial hub, but may also affect air traffic.

As such, the DLR Institute of Flight Guidance is investigating how this aviation system of the future can be effectively integrated. 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.
Brief description

ESA’s space science mission PLATO will search for exoplanets down to the size of the Earth up to the habitable zone of Sun-like stars, and characterise their physical parameters. Using 26 cameras mounted on a common platform, PLATO will investigate up to one million stars looking for transiting planets.

Aims

The goal of the mission is to considerably expand our knowledge about the origin and the evolution of planetary systems and answer questions such as: How do planets and planetary systems form and evolve? Is the Solar System special or are there other systems like ours? Are there potentially habitable planets?

Applications

- Exploration
- Basic research
- Comparative planetology
- Insights into formation and development of planetary bodies
- Search for Earth-like extrasolar planets and habitable worlds

Outlook

- Understand planet formation
- Detect habitable planets
- Follow-up measurements to determine the atmosphere of planets orbiting around bright stars

Facts and figures

Launch: 2026
Mission operations: 4 years
Orbit: Halo orbit at Lagrangian point L2
Payload: 26 dioptric cameras with 12 cm aperture each; 24 ‘normal’ cameras operated in white light; 2 ‘fast cameras’ for fine guidance
Total field-of-view: ~ 49°x49°
Payload mass: ~ 533 kilograms (without optical bench)

Parties involved

ESA; International Consortium lead by DLR; OHB System AG

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PLATO is Europe’s third medium ‘M-class’ space mission. Its primary goal is to search for Earth-like planets around Sun-like stars that have the potential to support life as we know it. PLATO will deliver accurate parameters for their radii, masses, mean densities and ages. In the end, a catalogue of thousands of extrasolar planetary systems of all kinds will be available that will include well-defined properties of the planets as well as their host stars. PLATO will observe the sky for at least four years (up to eight years) from the second Lagrangian point of the Earth-Sun system.

The mission will search for extrasolar planets with what is known as the ‘transit method’. This indirect method is used to discover distant planets circling their host stars – any planet passing between the star and the observer, as it travels on its orbit, will briefly reduce the apparent brightness of the star during this ‘transit’. PLATO will focus on planets orbiting bright stars and determine their mass, radius and age with unprecedented accuracy. PLATO will focus on small planets orbiting in the habitable zone of Sun-like stars. With this data planetary scientists will be able to study our Solar System within a general context and find out whether Earth is unique.

The PLATO payload consists of 26 individual dioptric telescopes, on-board computers and the related power support units. Launch is scheduled for the end of 2026. The space telescope is a mission of the European Space Agency (ESA). DLR’s Institute of Planetary Research in Berlin leads the international payload consortium and, with the DLR Institute of Optical Sensor Systems in Berlin, takes joint responsibility for the readout electronics of the fast telescopes and their data processing unit. The PLATO scientific data centre is under responsibility of the Max Planck Institute for Solar System Research in Göttingen, Germany. Among others, the international consortium includes more than 100 research institutions and commercial companies from, among other countries, Germany, Italy, the United Kingdom, France and Spain.
**MERTIS**

**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 October 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.

**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

**Parties involved**

DLR, University of Münster, OHB System AG

**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
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 the European Space Agency (ESA) and the Japanese space agency (JAXA).

Once in Mercury’s orbit, MERTIS 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 show a reflection of radar signals in deep craters into which 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.
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. The surface roughness will be determined from the shape of the received pulses.

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)

Parties involved
DLR, University of Bern, Max Planck Institute for Solar System Research, Instituto de Astrofísica de Andalucia

Facts and 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

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The BELA laser altimeter will be launched on board the European-Japanese BepiColombo mission to Mercury in October 2018. 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 Mercury Planetary Orbiter, 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 will be 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 can determine the elevation model and topography of the planet.

BELA also provides **information on the 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 orbiter 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 the DLR Institute of Planetary Research, 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.
InSight/HP³
Interior Exploration using Seismic Investigations, Geodesy and Heat Transport

Brief description

On 5 May 2018, the NASA InSight space probe embarked 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 HP³ 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. HP³ 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.

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: 5 May 2018
Arrival: 26 November 2018
Mission duration: 2 Earth years

Second heat flow measurement on a celestial body since Apollo 17 (1972)

Parties involved

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

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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 will, for the first time, 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 Structure (SEIS) will start to record the seismic waves from ‘Marsquakes’ and to provide data to understand the planet’s history. The Rotation and Interior Structure Experiment (RISE) will register very small changes in the planet’s axis alignment and 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 (HP³). 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 HP³ operations.
DLR robotics and exploration & international partners
Hall 5, booth D 50

01  Swarm navigation and exploration
02  ARCHES
03  MOREX
Swarm navigation and exploration

Brief description
Large networks of robots, called swarms, pave the way for future planetary exploration: agents in a swarm span ad-hoc communication networks, localise themselves based on radio signals, share resources, process data and make inference over the network in a decentralised fashion.

Aims
We investigate new ideas and solutions for navigation and exploration in difficult environments for robotic swarm missions on the planets and moons of the Solar System. We aim to demonstrate a distributed joint wireless communication, navigation and timing system for a swarm of robots, as well as distributed methods for information-driven exploration schemes.

Parties involved
DLR, Partners of explorer initiatives funded by the German space administration, Partners of the ARCHES Helmholtz Association future research topic

Applications
- Robust radio-navigation system demonstrated in relevant environments
- Understanding continuous processes on planetary surfaces for exploration
- Development of a joint swarm navigation and swarm exploration system
- Radio-localisation and distributed time synchronisation for robots and sensors
- Meshed communication among robots and sensors
- Localisation in environments with no – or limited – GNSS reception
- Space exploration, particularly planetary surface exploration
- Disaster management and relief

Outlook

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Swarm navigation and exploration

Today, satellite navigation is generally accurate enough for terrestrial outdoor environments. But for certain applications, such as the navigation of robots on other planets, alternative technologies have to be chosen. The approach of the DLR Institute of Communications and Navigation and its partners is to use a variety of sensors and signals of opportunity. The aim is to investigate new ideas and solutions for navigation and exploration in difficult environments, as well as for swarm missions on the planets and moons of the Solar System. Our work encompasses theoretical research, as well as simulations and demonstrations.

In a swarm of robots, each robot element is equipped with sensors and computing functionalities to cooperatively process sensor data. Swarms are based on three key technologies: (i) robotic platforms with sensing equipment, (ii) data networks that act as the swarm communication backbone and, finally, (iii) distributed computational intelligence. The main focus of our swarm exploration activities is on distributed computational intelligence – algorithms that exploit networks for efficient processing of data in a decentralised fashion while enabling full system autonomy through intelligent data analysis and decision making.

Since there is no satellite navigation system for Mars, navigating a swarm of robots requires an alternative approach: we develop navigation technologies for swarms and demonstrate them on Earth. Navigation of the individual swarm elements and communication amongst them is essential for autonomous swarm exploration. Navigation on Mars is a challenging task, as there is no Martian satellite-based navigation system. Moreover, a swarm will also explore caves and deep canyons, places in which signals from space do not usually penetrate. We are developing a wireless radio system jointly enabling meshed communication, distance estimation among robots, and timing. This wireless radio system enables the distributed self-localisation of robots. Taking the control of robots into account, the swarm spans optimal sensor apertures for navigation and scientific tasks.
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, networked robotic systems is the only way to achieve continuous, long-term and long-range data acquisition, as well as the direct manipulation of 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.

**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**

Helmholtz Association future topic

**Total budget:** 10 million euro

**Project duration:**


**Parties involved**

DLR, Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research (AWI), GEOMAR Helmholtz Centre for Ocean Research Kiel, Karlsruhe Institute of Technology (KIT)
Autonomous, networked 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 that lie 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 (Autonomous Robotic Networks to Help Modern Societies) 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 lies in researching 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.
In the DLR project MOREX ‘MOdular Robotic Exploration System’, a modular robotic exploration system will be developed to fulfil the needs of future planetary missions. The modularisation concept allows the flexible implementation of components in small scout systems as well as mid-sized modular rovers. The MOREX project will look into their qualification.

The qualification of modular key components is one key focus of the MOREX project. In addition, it will also look into the development of highly agile payloads carrying modular rover systems exceeding the LRU (Light Weight Rover) scout capabilities to deploy, install and maintain infrastructure on planetary surfaces.

- Preparation for future planetary exploration missions
- Development of modular rovers and mobility components (scout rover and modular payload carrier)
- Modularisation and standardisation of robotics interfaces

- Increase the Technology Readiness Level of key robotic components
- Development and standardisation of interfaces for robotic tools and instruments
- Development and further qualification of scout rovers
- Development of mid-sized hybrid walking robot

The planetary researchers’ increased demands for the number, spacing and nature of the ‘sites’ to be investigated on planetary surfaces require innovative rover systems. Without prioritising a detailed mission analysis, some key points of the rover system can be decided in advance: The rover should be able to **move quickly in easy terrain**, yet be able to **overcome large obstacles** in very rough terrain. In order for the scientists to be able to make use of them, the rover systems should not be monolithic but rather have the capacity to record and store standardised payload modules and loading boxes with defined, uniform interfaces. The interfaces must allow for a mechanical, electrical and also a signal-technical coupling with the rover.

A further focus is the development of **concepts for sample recording** with as many different instruments as possible in order to develop the most generic modular system possible, as well as to be able to undertake a variety of missions. The communications components are co-developed with the robotic components to develop a prototypical rover system that can navigate and manipulate autonomously in such a way that it covers the widest possible range of scientific missions.

In order to support various mission opportunities, the MOREX project combines activities carried out at the DLR Institute of Robotics and Mechatronics, the DLR Institute of Optical Sensor Systems, the DLR Institute of System Dynamics and Control and the DLR Institute of Communications and Navigation to further steer, qualify and standardise modular robotic developments.
Designated as a core agency to support the Japanese government’s overall aerospace development and utilisation, the Japanese Aerospace Exploration Agency (JAXA) conducts integrated operations – from basic research and development through 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 use 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 increase 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 arrived at Ryugu in June 2018. In October 2018, it will deploy the small lander MASCOT (Mobile Asteroid Surface Scout), developed by DLR and CNES. At IAC 2018 in Bremen, 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.
Explanation
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
Imprint

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