

BepiColombo (BELA)

BepiColombo Laser Altimeter

Brief description

BELA was launched successfully 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

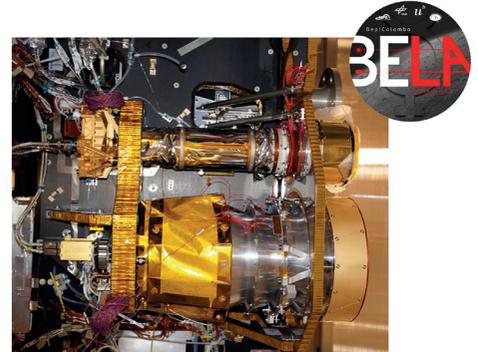
The BepiColombo mission aims to investigate the evolution of the little-explored planet Mercury. BELA will provide information about the global shape, rotation and topography of the Sun's innermost planet. In addition, tides, altitude profiles and geological features will be examined in detail. The surface 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 Andalucía

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





BepiColombo (BELA)

BepiColombo Laser Altimeter

BELA was successfully launched on board the BepiColombo mission on 20 October 2018. During the NECP (Near Earth Commissioning Phase) in November 2018, BELA was switched on for the first time in space showing excellent performance. BepiColombo will reach Mercury's orbit in 2025 after several flybys of Earth, Venus and Mercury. 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 measure the surface topography 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 obtain 3-D elevation models and determine the 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 evolution**. 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 Andalucía and industry. The DLR Institute of Planetary Research is responsible for operations and the evaluation of the scientific data.



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: 2017-2022
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





CALLISTO

Cooperative Action Leading to Launcher Innovation in Stage Toss back Operations

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.





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

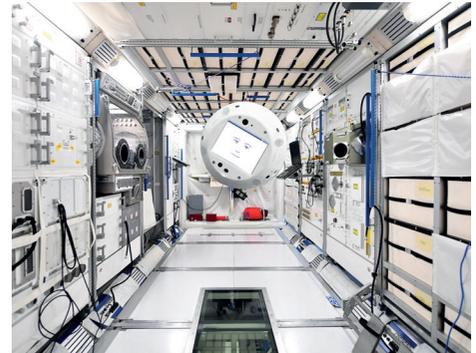
CIMON® uses the ISS as a test environment for trialling new technologies. CIMON® aims to demonstrate that human-machine interaction can support the work of astronauts and increase their efficiency. In future, the flying companion could be used, for example, to present and explain a wide range of information 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

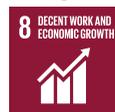


Parties involved

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

Facts and figures

Launch: SpaceX CRS-15, 29 June 2018
Commissioning: 14./15. Nov. 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 was 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**.





Dassault Falcon 20E-5 (D-CMET)

Flying for atmospheric research

Brief description

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



Aims

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

Parties involved

DLR institutes as well as universities and external clients

Applications

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

Outlook

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

Facts and figures

Length: 17.2 m
Height: 5.36 m
Wingspan: 16.3 m
Empty weight: 8.4 t
Total weight: 13.8 t
Thrust: 21 kN
Flight altitude: max. 12,800 m (42,000 ft)
Range: max. 3700 km
Maximum speed: 917 km/h (0.865 Mach)





Dassault Falcon 20E-5 (D-CMET)

Flying for atmospheric research

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

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

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



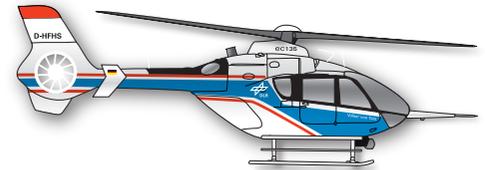
EC 135 ACT/FHS (D-HFHS)

Flying helicopter simulator



Brief description

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



Aims

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



Parties involved

DLR institutes, national and European funding bodies



Applications

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

Outlook

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



Facts and figures

Length: 12.2 m
Rotor diameter: 10.2 m
Empty weight: 1.9 t
Total weight: max. 2.9 t
Power: 2 x 415 Kilowatt
Flight altitude: max. 6096 (20,000 ft)
Flight time: max. 2.5 hours
Maximum speed: 280 km/h





EC 135 ACT/FHS (D-HFHS)

Flying helicopter simulator

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

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



Distributed Electric Propulsion

Model of a regional aircraft with distributed electric propulsion

Brief description

The model shows a regional aircraft with distributed electric propulsion, which can improve efficiency and reduce energy consumption. Synergies between the propulsion system, the aerodynamic properties and the flight controls are used to reduce weight and drag. This concept is only made possible by electric propulsion technology.

Aims

Electric propulsion will revolutionise air transport. Feasibility studies on electric and hybrid-electric commercial aircraft are playing an increasingly important role in working towards the vision of efficient, quiet and climate-friendly aviation for the future. The objective is to develop new transport services and individual forms of mobility while reducing costs and emissions.

Applications

- Electric and hybrid-electric feasibility studies
- Aerodynamics
- Reduced fuel consumption
- Lower noise and pollutant emissions
- New aircraft concepts for the air transport system of the future

Outlook

- Testing and demonstration of electric aircraft configurations
- Deepening of synergies (propulsion, aerodynamics, structure, flight control)



Parties involved

The DLR Institute of Aerodynamics and Flow Technology; DLR institutes AE, FT and SL as part of the 'SynergIE' project in the German national aviation research programme 'LuFo'; Clean Sky 2 project partners

Facts and figures

- A regional aircraft with a distributed propulsion system based on this feasibility study could achieve a range of 1000 kilometres while carrying 40 passengers.
- Such an aircraft could be implemented after 2050, depending on the energy storage concept.
- The exhibition model for the feasibility study has been constructed at a scale of 1:30 and measures 65 x 65 centimetres.





Distributed Electric Propulsion

Model of a regional aircraft with distributed electric propulsion

The primary objectives of European aviation research, given the growth in air traffic, are to make the air transport system pollutant-free, efficient, quiet and safe. The study of electric propulsion systems plays a decisive role in this. With the concept for a regional aircraft presented here, the arrangement of multiple propulsion units along the wing has made it possible to increase lift and improve propulsion efficiency. The increased lift can be used to reduce the wing area and thus lower the weight and drag. In addition, control of the aircraft can be partially taken over by individual control of the propulsion system motors; this means that some of the control surfaces can be smaller and thus lighter, while producing less drag.

This type of propulsion integration is made possible by electrical power distribution, since implementing the concept with conventional mechanical means is not a serious prospect. The electrical power can be provided by fuel cells or a hybrid system with a gas turbine.

Feasibility studies and performance assessments for this concept were carried out in 2015 at the DLR Institute of Aerodynamics and Flow Technology. The concept will also be studied as part of the Clean Sky 2 project ADEC. Furthermore physics-based simulations are performed in the German national project "SynergIE".



eROSITA

Hunting for Dark Energy

Brief description

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

Aims

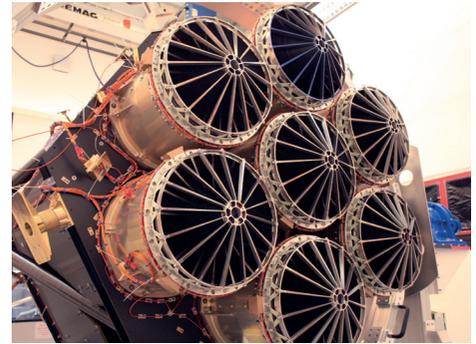
eROSITA will search for Dark Energy, which could play a major role in the expansion of the Universe since the Big Bang. The primary instrument on board the German-Russian Spectrum-Roentgen-Gamma mission, the X-ray telescope will focus on clusters of galaxies. This will make it possible to derive conclusions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

Applications

- Precise statements about the state and changes of the Universe

Outlook

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



Parties involved

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

Facts and figures

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



eROSITA

Hunting for Dark Energy

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

Dark Energy is invisible and only noticeable on vast distances. How can it be investigated with an X-ray telescope? The key to this is galactic clusters – groups of up to several thousand individual galaxies. Their gravity attracts the surrounding hydrogen gas. This process is called accretion and produces very high temperatures which cause the gas to emit X-rays. Hence the clusters of galaxies become visible to eROSITA. **eROSITA will study the distribution of approximately 100,000 galaxy clusters.** By determining the distribution of galaxy clusters in space, astronomers can estimate the structure of the Universe today and in the past. This is possible since the light which arrives from large distances has been emitted a long time ago. Therefore, by mapping the distribution of galactic clusters, eROSITA will help to determine the nature of Dark Energy. This will be achieved by scanning the entire sky multiple times, observing many other phenomena and objects, such as active galactic nuclei, supernova remnants or X-ray binaries.

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





MERLIN

The Franco-German satellite mission

Brief description

From 2024, the Franco-German climate mission MERLIN (MEthane Remote sensing Lidar missioN) will use Lidar technology to detect the greenhouse gas Methane. Germany contributes the payload, managed by DLR Space Administration. France contributes the platform, managed by CNES. Two Co-Principal Investigators from Germany (DLR-IPA) and France (LSCE) lead the scientific activities.

Aims

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).

Applications

- Earth observation satellite for research into the causes of climate change
- Innovative measurement methods and thus better quality data for documenting and creating a catalogue of global methane concentrations and the natural and anthropogenic emissions on Earth's surface

Outlook

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

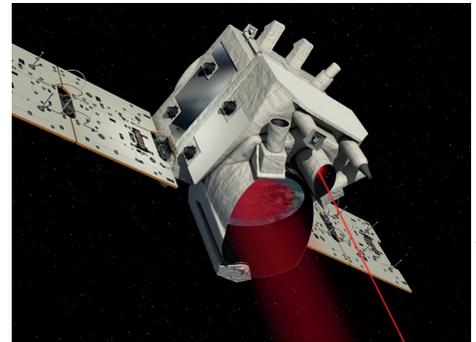


Image: David Ducros, CNES

Parties involved

DLR, CNES, European space industry led by Airbus in Ottobrunn and Toulouse

Facts and figures

Launch: scheduled for 2024 with Vega-C or Ariane 62 from the European Spaceport in French Guyana
Satellite platform: Myriade Evolutions
Satellite dimensions: approx. 1.60 x 4.50 x 1.60 m with extended solar panels
Satellite mass: approx. 430 kg
Instrument mass/power requirement: approx. 150 kg / 150 W





MERLIN

The Franco-German satellite mission

The Franco-German climate mission **MERLIN** (MErlin Remote sensing LIdar missioN) is expected to measure **methane levels in the Earth's atmosphere** from 2024 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. This instrument is being developed and built in Germany by Airbus Ottobrunn on behalf of the DLR Space Administration with funds from the German Federal Ministry for Economic Affairs and Energy (BMWi). 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 involve an international team led by two Co-Principal Investigators from the German DLR Institute of Atmospheric Physics (DLR-IPA) and the French Laboratory of Climate and Environmental Sciences (LSCE).



BepiColombo (MERTIS)

Mercury Radiometer and Thermal Infrared Imaging Spectrometer

Brief description

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

Aims

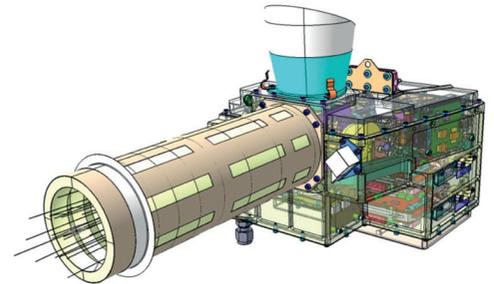
This near- and mid-infrared spectrometer will investigate the mineralogical composition of Mercury's surface and identify rock-forming minerals. The integrated micro-radiometer allows comprehensive measurements of the temperature and thermal conductivity of Mercury. From the data, the scientists hope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





BepiColombo (MERTIS)

MErcury Radiometer and Thermal Infrared Imaging Spectrometer

In October 2018, the thermal infrared imaging spectrometer MERTIS was 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.

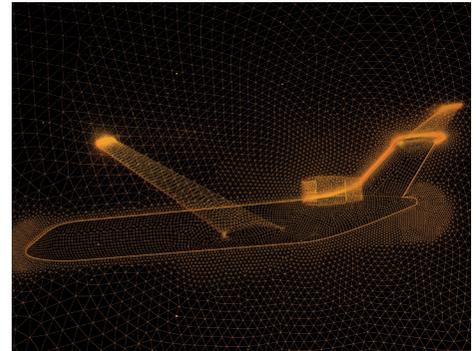


Numerical simulation

The route to a virtual aircraft involves millions and millions of computer calculations

Brief description

Wind tunnel tests and flight tests are still indispensable in the development of new aircraft concepts. But thanks to increasingly powerful supercomputers, a third tool has been playing a crucial role in aeronautics research for some time now – numerical simulation. The film explains how important this is for the digitalisation of aeronautics.



Aims

Numerical simulation aims to depict reality on the computer as accurately as possible. What the researchers envision is a digital maiden flight. As computing power continues to increase, this technology will make it possible to design an aircraft digitally, at lower cost and with fewer risks, to test it and eventually to certify large parts of it and have it perform its first flight 'in' the computer.

Parties involved

DLR Institute of Aerodynamics and Flow Technology
Earth Observation Center
(film production)

Applications

- Aircraft design
- Multidisciplinary simulation (aerodynamics, structure, flight mechanics, flight control)
- Virtual flight testing
- Noise reduction
- Increase in efficiency

Outlook

- Further development and optimisation of numerical simulation methods, prediction tools and computer software for aeronautics
- Supplementation of wind tunnel and flight tests with reliable simulation methods
- Digital design, testing and certification

Facts and figures

- Numerical simulation methods have been used in research since the 1990s
- The first high-performance computing cluster was established at DLR in 2007. From mid-2019, DLR will have a new cluster capable of performing 1.798 petaFLOPS per second





Numerical simulation

The route to a virtual aircraft involves millions and millions of computer calculations

Aeronautics researchers have been addressing the challenges of digitalisation for many years. Their vision is for the entire lifecycle of an aircraft – from the initial design all the way through development, certification, maintenance and finally decommissioning – to be depicted digitally by computer systems. Such a ‘virtual product’ would greatly reduce costs and levels of risk.

However, an aircraft and its aerodynamic properties are complex. To get closer to reality by digital means, researchers divide the space around an aircraft into a network of many cells. Physical quantities such as pressure, density and flow velocity can be calculated in each cell. The smaller the cell size, the more accurate the simulation. This produces an enormous system of mathematical equations for the flow quantities that need to be calculated. High-performance computers make it possible to carry out millions and millions of compute operations per second and to fill such a network of cells with consistent values.

One such supercomputer was installed at DLR in 2007. It was intended to serve as a basis and tool for accelerating the introduction of innovative technologies for more efficient, cleaner and safer flying and to better manage the technological risks. In 2019, the cluster will be replaced by a new high-performance computer that, with 2280 compute nodes and 145,920 compute cores, will be able to handle 1.798 petaFLOPS per second, that is 1.798×10^{15} arithmetic operations per second.

Solving complex numerical problems and simulating the behaviour of aircraft using a computer are key steps when aeronautics research seeks to reduce fuel consumption, pollutant emissions and noise, and make the aircraft of the future safer and more environment friendly, as well as increasing their cost efficiency.



superARTIS

DLR's unmanned research helicopter



Brief description

Under the name superARTIS (Autonomous Rotorcraft Testbed for Intelligent Systems), DLR operates SDO 50 V2 helicopters, which have a maximum take-off weight of over 80 kilograms. With the help of these systems – supported by a complex simulation environment – sophisticated autonomous flight missions are being developed and tested.



Aims

The research focuses on autonomous detection of the aircraft's surroundings, flightpath planning, flight control during agile manoeuvres, and navigation methods that take into account the possibility of satellite navigation system failure. With its high payload capacity, range and flight speed, superARTIS is capable of research missions close to customer scenarios missions.



Parties involved

DLR Institute of Flight Systems



Applications

- Testing of mission scenarios and procedures for unmanned aerial vehicles
- Realtime 3D sensor data processing for flight control applications
- Evaluation and extension of flight performance for various helicopter configurations

Outlook

- Transport and delivery of relief supplies beyond line of sight
- Cooperative use of airspace by unmanned and crewed helicopters
- Demonstration of image-based navigation for autonomous Moon landings



Facts and figures

- Maximum take-off weight:** 85 kg
- Rotor diameter:** 2x 2.8 m
- Payload weight:** up to 30 kg
- Maximum endurance:** 2 h
- Payload power supply via generator
- Fully autonomous flight including take-off and landing
- Experimental flight control with full control authority



superARTIS

DLR's unmanned research helicopter

The DLR Institute of Flight Systems has been operating unmanned helicopters with a maximum take-off weight of over 80 kilograms under the name superARTIS since 2012. In 2015, two new SDO 50V2 helicopters, developed by SwissDrones Operating AG, became operational. Demanding automated flight missions are developed and tested using these systems, and supported by a sophisticated simulation environment. The research focuses on autonomous environment perception, flight path planning, flight control for agile manoeuvres and navigation methods considering satellite navigation interferences. Thanks to its high payload capacity, range and air speed, superARTIS is able to fly on demanding research missions over the sea, together with other aircraft, or as a platform for multi-sensor systems.

Project highlights:

- **Innovation in humanitarian aid with the World Food Programme and Wings for Aid**
Objective: To test an airdrop concept for the delivery of relief supplies beyond line of sight, dropping them in a realistic operational area.
- **Manned-unmanned teaming**
To safely operate manned and unmanned helicopters as a team in shared airspace.
- **Flight campaign in Vidsel (northern Sweden)**
Objective: Operation of an unmanned helicopter beyond line of sight, under demanding environmental conditions and together with other aircraft.
- **ATON (Autonomous Terrain-based Optical Navigation)**
Objective: To use an unmanned helicopter as a demonstrator for navigation procedures to be used during autonomous Moon landings (crater navigation and landing site reconnaissance).
- **Fast rotorcraft**
Objective: Flight operations at the edge of the flight envelope, expansion of high-speed flight capabilities, flight test methods for uncrewed aerial vehicles.



Multimodal Cockpit Simulator (MMCS)

Virtual reality helicopter simulator with 3D-audio and active control loading components



Brief description

MMCS is a simulation platform with active helicopter controls. The environment is not displayed using conventional screens or projectors – the pilot wears virtual reality glasses instead. Further, the spatial sound environment is calculated by virtual-audio software. Fast and precise head-tracking allows the pilot to look around freely while seeing the appropriate stereo image and hearing the corresponding spatial audio.



Aims

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



Applications

- Simulation environment for evaluating cockpit display concepts
- Virtual-audio evaluation environment
- Evaluation of human factors
- Procedure training
- Development of future multimodal cockpit concepts

Outlook

- Low-cost flight simulator
- Cockpit of the future
- Remote ground control station
- Rapid prototyping environment



Parties involved

DLR Institute of Flight Guidance
DLR Institute of Flight Systems
Brunner Elektronik AG
New Audio Technology GmbH



Facts and figures

- **Virtual cockpit:** instruments and synthetic 360° view from different perspectives (DLR)
- **Audio:** virtual-audio system SPAACE (DLR and New Audio Technology GmbH)
- **Operation:** active helicopter control loading system (BRUNNER Elektronik AG)
- **Flight simulation:** highly stabilised helicopter command model (DLR)
- **Display system:** Oculus Rift CV1 VR Glasses



Multimodal Cockpit Simulator (MMCS)

Virtual reality helicopter simulator with 3D-audio and active control loading components

The DLR Institute of Flight Guidance has developed and operates several cockpit simulators for the purposes of demonstrating and evaluating new flight control technologies. This includes the **Multimodal Cockpit Simulator (MMCS)**, a fixed-base cockpit simulator in which the cockpit and surrounding environment are displayed via head-worn virtual reality glasses. This allows researchers to **simulate different existing helicopter types** as well as display and test their own newly developed flight deck layouts. The simulator is equipped with a **3D virtual audio system** to create a realistic acoustic environment for higher immersion and to test future audio pilot assistance systems.

Just like a conventional helicopter, the simulator is flown using three control elements: cyclic stick, collective and pedals. These are active control components. Integrated motors generate precise force feedback to give the pilot a **realistic impression of the controls**. The flight simulation itself is powered either by the commercial simulation software X-Plane 11 or by DLR's own helicopter flight model, including novel flight-control systems.

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

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

