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THE SKY IS THE LIMIT

THE AIRCRAFT CABIN OF THE FUTURE IS SAFE, HYGIENIC AND COMFORTABLE

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CROSSING FRONTIERS

A solar-powered stratospheric aircraft combines the advantages of spaceflight and aeronautics

By Florian Nikodem

Satellites have become vital to Earth observation and global communications. However, they are not without their disadvantages. In addition to the costs of construction and then placing them in orbit, their remains are sometimes left behind in space, becoming space debris. In 2020, the International Space Station (ISS) had to make three collision avoidance manoeuvres. Aircraft and helicopters are far more versatile and cost-effective. They can be used for Earth observation activities in cases where the use of a satellite would be disproportionate or simply impossible. However, they have a restricted operating radius and success is often dependent on the weather. Another factor is that even the best pilots need to take a break every now and then. High-Altitude Platforms, (HAPs), offer a possible solution. These solar-powered platforms are permanently stationed in the lower stratosphere, at an altitude of approximately 20 kilometres.

An integrated approach

Given enough sunlight, HAPs can be positioned anywhere on Earth and used for a wide variety of missions. They fly far above civilian air traffic and even above the weather. The concept behind them arose from the rapid developments in solar and battery technologies in recent decades, which have paved the way for this link between aircraft and satellites. HAPs are flexible to deploy and equip with instruments and are also independent of weather conditions or time of use. As part of its cross-sectoral project HAP, DLR is conducting research into technologies and applications for a high-altitude, permanently stationed platform, and developing a research aircraft for future scientific experiments. In this process, not only the solar-powered, unmanned demonstrator is being created, but also a ground station, the operational procedures and three payloads to be carried by the platform, which offer a wide range of future applications. Seventeen DLR institutes from the fields of aeronautics, space and security are working together on this project, which is being led by the Institute of Flight Systems in Braunschweig.

From glacier observation to forest fire detection

A HAP has a wide range of possible application scenarios, ranging from the uninterrupted observation of glaciers and snow cover in polar regions to maritime surveillance, including in the Mediterranean Sea, and all the way through to monitoring herds of animals in Namibia. To that end, the DLR Institute of Optical Sensor Systems is developing a special version of its Modular Aerial Camera System (MACS), which has a very high resolution and can identify target objects independently. The DLR Microwaves and Radar Institute is building the HAPSAR radar, which can perform observations regardless of the weather conditions. A HAP equipped with this system can measure the thickness of ice in the Northwest Passage, but it can also generate maps in the event of a disaster – forest fires or flooding, for example. It is also conceivable that such technology could be used for reconnaissance in peacekeeping missions. In addition, high-altitude platforms are suitable for measuring pollutants, including over busy shipping lanes and cities. The DLR Remote Sensing Technology Institute is developing a Differential Optical Absorption Spectroscope (DOAS) for that very purpose. This instrument is designed to measure the concentration of nitrogen dioxide (NO2) in the air.

Light, robust, precise and durable

Stationing an aircraft at a particular location within the lower stratosphere is no mean feat. At an altitude of 20 kilometres, temperatures usually range from minus 60 to minus 80 degrees Celsius. High above the clouds, the platform is completely exposed to solar radiation all day long, so that areas of its outer shell may heat up to 40 degrees Celsius. Such dramatic temperature fluctuations make it difficult to rely upon thermal insulation materials. While a warm, insulating layer might prove indispensable at night, it is not at all appropriate for the intense sunlight during the day. The low air density at such altitudes means that convection cooling, whereby the inbuilt systems are cooled by air flowing around them, is almost entirely ineffective. As such, the main challenge for a HAP is proper thermal management, as different areas of the aircraft require different means of cooling or insulation.

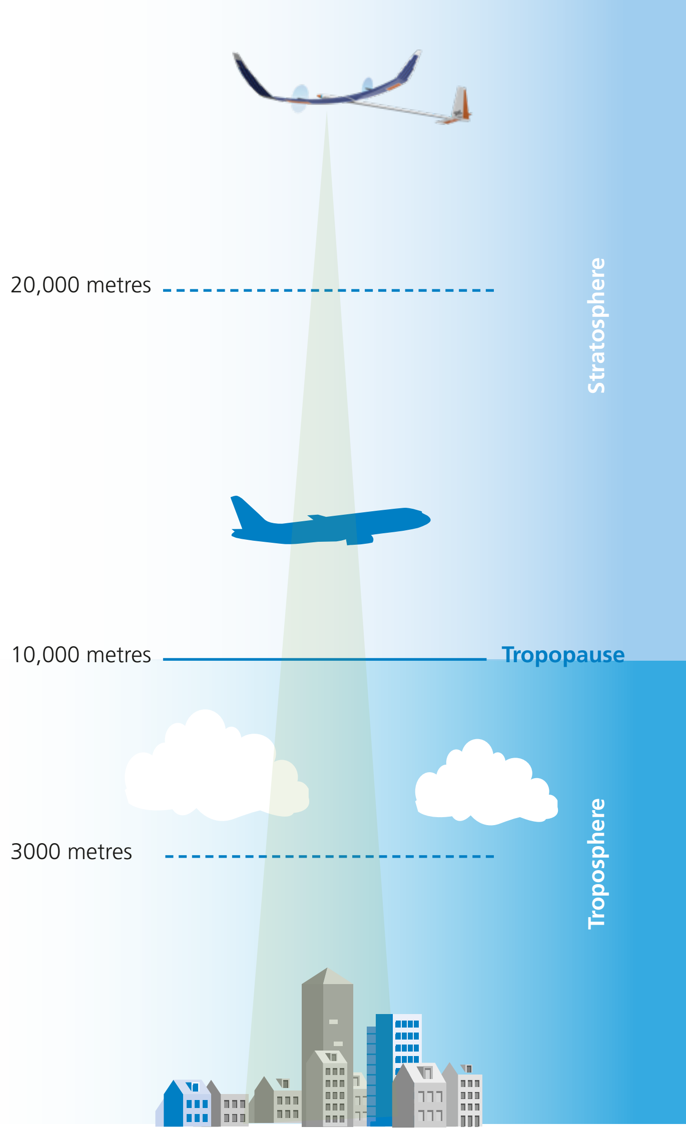
The low air density also presents another challenge; the aircraft has to be either very light or travel at an extremely high speed in order to generate sufficient lift to be able to fly continuously. But increasing the speed also means increasing the energy consumption. Throughout the day, the solar energy is converted into electrical energy via solar cells, with the excess stored in batteries for the night. HAPs that fly for long periods in the lower stratosphere must not exceed a surface area to weight ratio of four kilograms per square metre if they are to be able to generate sufficient lift. By way of comparison, Eta Aircraft's eponymous glider, one of the most powerful mass-produced gliders in the world, has a surface weight of approximately 45 kilograms per square metre, while the Eurofighter combat aircraft weighs in at 310 kilograms per square metre.

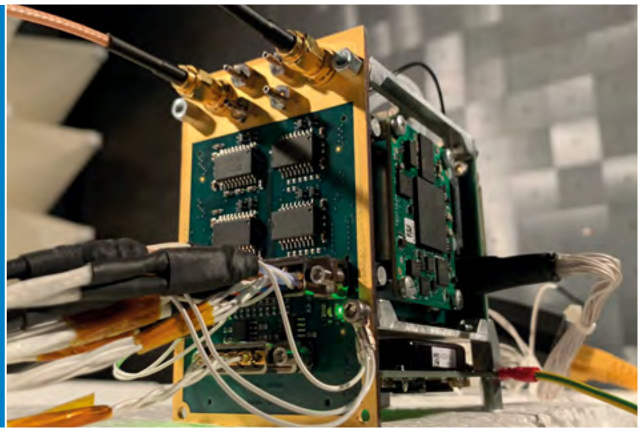
On top of that, there are operational procedures to consider, such as air traffic control for autonomous, long-term operations, or clearance for the aircraft to fly through controlled airspace until it reaches an altitude of 20 kilometres.

THE HIGH-ALTITUDE PLATFORM HAP alpha

- **Wingspan:** 27 metres
- **Launch mass:** 138 kilograms
- **Service ceiling:** Over 22 kilometres
- **Payload capacity:** Five kilograms
- **Platform budget:** 13 million euro
- **Energy generation:** Triple-junction cells based on gallium arsenide (wafer-thin triple-layered solar cells with a high efficiency of 32 percent and a power density of 1.40 g/Wp
- **Storage system:** Rechargeable lithium-ion batteries with silicon anode (energy density per cell: 350 Wh/kg)

Stratospheric aircraft fly at an altitude of 20 kilometres, higher than civilian aircraft and the influence of weather.





The brain of the high-altitude platform, the Flight Control Computer, was developed and built at the DLR Institute of Flight Systems.

The wings of the platform consist of a sandwich rib structure made of carbon fibre reinforced polymers (CFRP). A round CFRP tube forms the backbone. This makes the wing light and stable. In total, the structure of the HAP alpha weighs 36 kilograms, 75 percent of which is the main wing.

Unlike in manned aircraft, the pilot controls a HAP from the ground station. The remote pilot must rely on the aircraft's status information, course data and information from the civil airspace below.

INSTITUTES AND FACILITIES INVOLVED

- German Remote Sensing Data Center
- Institute for Software Technology
- Institute of Aerodynamics and Flow Technology
- Institute of Aeroelasticity
- Institute of Atmospheric Physics
- Institute of Communications and Navigation
- Institute of Composite Structures and Adaptive Systems
- Institute of Engineering Thermodynamics (only in 2018)
- Institute of Flight Guidance
- Institute of Flight Systems
- Institute of Networked Energy Systems
- Institute of Optical Sensor Systems
- Institute of Robotics and Mechatronics
- Institute of Structures and Design (only in 2018)
- Institute of System Dynamics and Control
- Microwaves and Radar Institute
- Remote Sensing Technology Institute
- Space Operations and Astronaut Training
- Systemhaus Technik

The missions of the stratospheric aircraft HAP alpha will be coordinated from the mobile ground station

Long-term Earth observation missions operate over periods ranging from a few weeks to several months. The platform must be able to carry out these missions without regular maintenance of the kind customary in conventional aviation.

Many companies have expressed an interest in the development of these kinds of high-altitude platforms, including Facebook, Aurora Flight Sciences, Prismatic and Ordnance Survey. Airbus has so far been the only company to put the functionality of such a platform to the test, when it assessed its Zephyr over the course of several campaigns and a 26-day endurance flight in 2018. However, even the Zephyr is not yet ready for commercial operation, as was made clear by two crashes over Australia in 2019. This shows that this HAP technology is still almost in its infancy today.

A unique aircraft

DLR scientists are currently developing a technology carrier called the HAP alpha as part of the cross-sectoral project. It Is designed to fly to an altitude of 20 kilometres carrying a five-kilogram payload. At the same time, its robust, modular design is easy to modify. With a wingspan of 27 metres, it is comparable to an aircraft capable of continuous flight, but its structure weighs only 36 kilograms, while the whole aircraft weights 138 kilograms in total. The researchers have been able to achieve this low weight using an extremely lightweight carbon-fibre-reinforced polymer (CFRP) design. The main spar, fuselage and tail spar of the structure are made of circular wound CFRP tubes. These are very light yet highly stable. The HAP alpha does not yet have solar and battery technology for flying during the night, but it is designed in such a way that this can be retrofitted when it becomes available. The project team is setting up a mobile ground station in transportable containers, with the aim of coordinating the missions and data reception. It should be able to exchange data with the HAP from a distance of over 100 kilometres.

The research team is combining traditional processes with new approaches to systems technology. At the end of each phase of the project, the HAP team conducts a thorough review, bringing in external experts for that purpose. This procedure is based on the conventional approach to systems development used worldwide, whereby the technical aspects of the project life cycle are set out and the development process divided up into easily manageable sections. In addition, scientists are also looking at newer methods of system development, such as model-based system engineering. This means that all of the essential information relating to the HAP, such as the requirements, physical architecture and mass data, is stored and characterised in a central place, and therefore, are inherently consistent.

In April 2019, the team conducted a review with external experts. It has successfully shown that the established system requirements and the developed plan form of the aircraft are suitable for achieving the project goals, and that the risks relating to future changes are as low as possible. The researchers are currently preparing for the Critical Design Review in 2021. This will check whether the detailed design meets the project goals. After that, the production and assembly of the individual components will commence. These components will then undergo extensive testing before they can be integrated into the overall system.

All the way, piece by piece

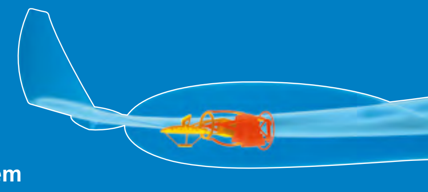
By the end of 2022, HAP alpha should be ready to take off on its first test. Initially, the aircraft will merely perform low-altitude flights over the site of the National Experimental Test Center for Unmanned Aircraft Systems in Cochstedt. The flight altitude will then be increased gradually up to 20 kilometres. For this to happen, the team is in contact with test facilities all over the world that offer a sufficiently large, restricted zone on the ground and prohibited airspace that extends up to high altitudes. One of the most promising candidates is the Esrange Space Center, near Kiruna, Sweden. Unlike the first test flights in Cochstedt, in which the actual test may only last a few hours, a high-altitude flight can take up to 24 hours due to the HAP's slow flight speed, although the platform will only be at 20 kilometres for about two hours. This means that the team not only has to coordinate the flight test itself, but also have several crews available and train their changeover in shift operation.

Payloads will also be used in future high-altitude flights. With every test, the team will gather experience and be able to modify the HAP to enable longer flights. From that point onward, the stratospheric aircraft could be used as an experimental carrier for payloads and new platform-specific technologies. One example would be using the HAP as a hub for digital communication to support the deployment of a 5G network.

Florian Nikodem is a Systems Engineer at the DLR Institute of Flight Systems in Braunschweig. He is leading DLR's HAP cross-sectoral project.

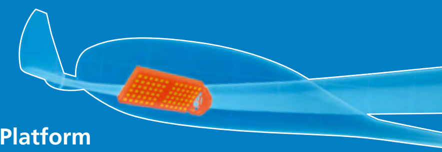
THE PAYLOADS

DLR researchers working on the HAP cross-sectoral project are developing three payloads that can be carried by the high-altitude platform. A unidirectional X-band link will be provided for exchanging payload data.



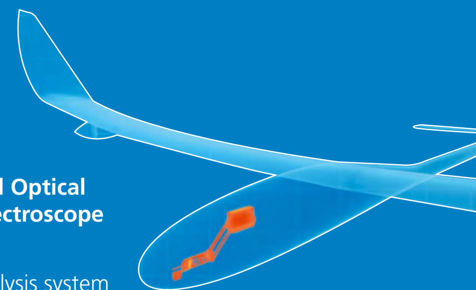
The Modular Aerial Camera System MACS-HAP:

- Self-aligning camera system with mosaic and point modes
- 150 megapixel sensor, ground resolution of 15 centimetres, scan area 400 square kilometres
- On-board image analysis for rapid identification of target objects
- Five kilogram mass



The High-Altitude Platform Synthetic Aperture Radar (HAPSAR):

- Synthetic aperture radar system (SAR)
- Stripmap SAR, Circular SAR up to 3D SAR and detection of moving targets such as ships
- Can be used day or night regardless of weather conditions
- Ground resolution of down to 60 centimetres
- Five kilogram mass



The Differential Optical Absorption Spectroscope (DOAS):

- Optical air analysis system with mosaic and point mode
- Real-time recording of the nitrogen dioxide levels in the air over the target area
- Four kilogram mass

Cover stories

A blank page can be frightening, but also inspiring. In the same way, the idea of pursuing an existing vision can be motivating. DLR researchers fill such blank pages with their ideas when they develop new concepts for the aircraft cabin and want to use the aircraft interior in a completely different way than before. The topic of digitalisation also plays an important role. DLR researchers have long been working on the question of where we still need experiments and what we can do faster and more economically on the computer. In addition, more than 25 DLR institutes and facilities are working on shaping the current image of aviation in the direction of low-emission and quiet flight. This includes research into climate-optimised flight routes, quieter engines, sustainable fuels, but also advising policy makers and local authorities.

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