White Paper

High Altitude Platform Stations (HAPS)- A Future Key Element of Broadband Infrastructure

There is a great need for broadband communications infrastructure worldwide. However, the expansion of terrestrial systems with fiber-optic networks for fixed-network connections and radio towers for mobile communications is very costly. Alternative communication platform carriers include satellites in geostationary orbit (GEO) and low earth orbit (LEO), and high-flying carrier platforms in the stratosphere. Several such systems are currently under development or already undergoing testing. In Germany, an aircraft with a hydrogen fuel cell propulsion system as a high-altitude stationary platform (HAPS) has been under development since 2015 under the leadership of Leichtwerk AG from Braunschweig. Hydrogen propulsion enables flight times of several days, regardless of season and latitude. This results in applications that were previously not possible with solar propulsion or conventional fuels.

For more than two decades, great hopes have been associated with the use of satellites or HAPS for ubiquitous, worldwide availability of broadband communications. Success is decided not only by technological feasibility, but in particular by the cost-effectiveness of the various technical solutions. A key factor here is the data transmission capacity of a HAPS or satellite. The required data rate varies according to demand and the area of application. For worldwide deployment, there must be no seasonal restrictions. In addition, HAPS must meet regulatory requirements and government and other safety requirements for aircraft operations. So which technology is suitable as an alternative to terrestrial expansion?

Satellites

The use of geostationary satellites enables nationwide basic coverage, but foreseeably only with special terminal equipment and, due to the large distance, with considerable signal propagation times, i.e., latency. In LEO between 350 and 2,000 kilometers altitude, the problem of latency can be overcome, but even several tens of thousands of satellites can only provide a limited total telecommunications capacity. Connectivity to mobile smartphones is provided by terrestrial base stations with local wireless networks. Satellites in LEO have to be permanently replaced and put into orbit in large numbers due to their limited lifetime until re-entry into the atmosphere and are therefore very cost-intensive.

The Airbus „Zephyr“, Source: Airbus

HAPS enable ubiquitous broadband coverage

HAPS

As an alternative and supplement to satellites, high-flying platforms with flight altitudes around 20 kilometers can be used. In this region of the stratosphere, low wind speeds prevail for the most part, so that geostationary operation is possible. These platforms can be realized with the static lift of balloons or airships, or with the dynamic lift of airplanes, serving areas of about 100 to 200 kilometers in diameter.
Balloons and airships do not require any additional energy for lift, but because of their shape and the associated air resistance, they are difficult to position geostationarily.

Like satellites, HAPS always have a direct line of sight to the receivers, so that restrictions due to mountains or buildings are low. The achievable latency is even lower than in LEO and can be less than one millisecond, depending on the communication technology. Deutsche Telekom demonstrated the seamless and direct integration of a "flying radio tower" into the terrestrial communications network in October 2020 with a Grob G 520 operating at flight level (FL) 450 in Bavarian airspace, establishing a stable broadband connection to a commercially available smartphone. HAPSMobile demonstrated in September 2020 a video call between California and Japan, using an LTE capable antenna on their solar powered platform.

The flight duration of the HAPS and the performance of the telecommunications payload are directly related to the available energy. Fossil fuels are not an option due to the mass of fuel required to be carried..

Solar Power

Purely solar-powered aircraft, with additional energy storage as a buffer, can ideally achieve a repeatable day-night cycle, limited only by maintenance requirements or aircraft system life. The fairly low yield of available solar energy requires ultralight aircraft that can operate year-round only in the tropics near the equator. Also, only a small amount of power, 100 to 1,000 watts, is available for the payload; this limits the telecommunications capacity.

Airbus Defence and Space already has a flight-proven solar-powered platform, the Zephyr, which has a flight endurance of 100 days, proving the concept's viability.

„Helios“ in flight through turbulence (right), Source: NASA

Large wing spans with low weights can be achieved by distributing individual masses (e.g. engines) along the wing; each wing section then carries part of the total weight, as in AeroVironment's "Sunglider". The wing can be designed to be very elastic due to the low strength required, as shown in the photographs of the "Helios," a precursor from the ERAST program (Environmental Research Aircraft and Sensor Technology) of the U.S. aerospace agency NASA, when flying through turbulence.

Due to the large bending deformation, the electric propulsion motors here interact with the twisting of the wing and with the pitching motion of the aircraft. Without the influence of active control to stabilize the deformations, the extreme couplings present here can become unstable and lead to failure. So far, tests with highly flexible aircraft configurations are in the experimental stage.

Germany has been a world leader in the development and construction of the highest performance sailplanes ever since the first gliders were tested in the last century. Today, the highly optimized aircraft achieve glide ratios of up to 70 with very slim wings of up to 31 meters span. Extensive experience is available in laminar wing aerodynamics, aeroelasticity and controllability of elastic aircraft structures. This knowledge forms an excellent basis for the development of high-flying platforms.

Green Hydrogen

The propulsion of high-flying platforms with hydrogen and fuel cells opens up a special opportunity. The gravimetric energy density is higher by a factor of seven compared to fossil fuels. Carrying the hydrogen in liquid form does not result in an infinite flight duration, but it does provide the opportunity to realize a platform for effective communication service with a high bandwidth and comprehensive proof of airworthiness based on many years of experience in aircraft design.

“eta” before touchdown

The StratoStreamer

Based on concrete specifications from the telecommunications industry, Leichtwerk AG has been developing an unmanned, high-flying platform with a hydrogen fuel cell propulsion and a flight duration of several days for operation in civil airspace, at the Braunschweig research airport since 2015, the StratoStreamer. Certification and flight safety authorities were involved in the project from the very beginning.

The payload uses special beamforming techniques in the ''sub 6GHz'' range for mobile communications and in the millimeter-wave range for ground station connectivity and household coverage as an alternative to the fixed network. The antenna in the StratoStreamer consists of many individual elements and thus generates local radio cells that can be positioned on the ground. Up to 100,000 households can be supplied with gigabit speeds per HAPS and ubiquitous mobile communications can be offered in an area with a diameter of 140 kilometers.

Key features of the aircraft design are:

- Wing span: 65 m
- Wing area: 197 m²
- Payload: 120 kg, up to 7 m x 3.6 m
- Certification: EASA Type Certificate
- Operation: Integration into civil airspace
- Propulsion and power supply: fuel-cells, liquid hydrogen

In the overall result, a conventional configuration has prevailed. The payload is integrated into the wing in the area of the wing root. Propulsion and fuel tanks are positioned in pods on the wing and contribute to the payload but have little effect on flight characteristics. A cooling inlet is integrated into the fuselage tip, with a fuel cell behind it. The wing planform provides optimized circulation distribution; the low sweepback utilizes passive load reduction from the resulting bending-torsional coupling.

The wide speed range allows good controllability even in gusty conditions. The flight characteristics have been derived from experience with the high-performance "eta" sailplane. Leichtwerk AG operates the prototype of the "eta" as an instrumented research aircraft and was thus able to validate the coupled aerodynamic and structural design procedures for determining and optimizing the flight mechanical characteristics of the moderately elastic aircraft. The flight dynamic model of the altitude platform and the flight control system are created on this basis.

The ”StratoStreamer”

The aircraft structure is made entirely of fiber-reinforced plastics. High modulus carbon fibers are used in a special prepreg material. These are textile fiber matrix semi-finished products pre-impregnated with reactive resins and cured under temperature and pressure to produce the airframe components. Fibers are placed locally tailored in terms of quantity and direction throughout the structure. The material used allows automated manufacturing with robots currently used in the large aircraft industry.

While for the airframe structure large sections of the wing are already being manufactured and tested, the flight control system is being integrated into a "Wooden Bird" and is also undergoing rigorous testing.

For the hydrogen propulsion system, a CFRP tank is being developed for the laminar flow wing pods to store the liquid hydrogen. The tank must hold the volatile hydrogen at cryogenic temperatures with a low leakage rate and provide vacuum insulation. The first tank bodies are already being manufactured and tested.

The fuel cell system poses a particular challenge. It must operate with a high degree of efficiency under the ambient conditions of the stratosphere. This requires the development of particularly efficient compressor systems.

Manufacture of a liquid hydrogen tank demonstrator

The work on realizing a demonstrator aircraft system creates a need for further research. This is being implemented in an extensive network of universities, research institutions and industrial partners, also with the help of the German national aeronautics research program (LuFo). Together with Leichtwerk Research GmbH, topics are being worked on for weather-based flight guidance, icing conditions, the hydrogen tank, load collectives for operation in the stratosphere and for procedures to efficiently demonstrate the safety of complex aircraft systems.

The consistent substantiation of the development work through procedures and tests as part of the certification requirements generates a reliable design basis and reduces the risk on the way to the demonstrator with which the integration of HAPS as a new component in the overall digital infrastructure of a model region can be shown.

About Leichtwerk AG

Leichtwerk AG is a highly specialized aircraft design organization with specific knowledge for high performance, moderate elastic aircraft.

Back in 1996 the company was started by Dr. Reiner Kickert with the design of the world's biggest sailplane, the 'eta', with a wing span of 30.1 m and a very slender wing with a width of just 60 cm. The aircraft had its maiden flight in July 2000 and is still today the biggest sailplane with the highest performance ever built.

Read more on www.leichtwerk.de, www.leichtwerk-research.de and https://haps-broadband.org

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