POWERLIGHT TECHNOLOGIES

HAPS and Laser Power Beaming

A Marriage Made in the Stratosphere

Introduction

In recent years HAPS (High Altitude Platform Stations) have garnered increasing interest for commercial and defense applications. These platforms hold great promise for many applications, especially continuous and far-reaching communication transmission, however there is still some ways to go before HAPS will be able to accomplish the highly ambitious objectives expected of them.

Sitting down with Paul Stevens of Voltitude, we discussed the current status of HAPS, obstacles to their development, and how PowerLight Technologies' laser power beaming may prove invaluable in the next HAPS frontier.

High Altitude Platform Stations (HAPS)

HAPS are unmanned aerial systems (UAVs) that fly in the stratosphere, at altitudes from 60,000 feet (18 km) up to as high as 100,000 feet (30 km). (Although in this paper we are focused on the fixed-wing version of these systems, HAPS also include balloon-based platforms, sometimes referred to as HABS.) In the stratosphere, HAPS can act like "pseudo-satellites," providing telecommunications and observation platforms that are not constrained by orbital mechanics. Typical existing and proposed HAPS are solar-electric fixed-wing vehicles, which are powered by photovoltaic (PV) arrays that collect sunlight during the daytime hours, store energy not used immediately for flight or payload in batteries, and use the stored energy to operate through the night. Since the typical altitude for HAPS is above the troposphere, the region where most weather phenomena occur (about 6-10 km above ground level), HAPS usually do not have to contend with wind or rain once they have reached their cruising altitude.

We spoke with Paul Stevens, the president and founder of Voltitude, Ltd., a company that is developing advanced, fixed-wing HAPS aircraft. Stevens is a physicist who has been working in the aerospace industry for over 25 years; before founding Voltitude, he led the team that designed Zephyr, a fixed wing HAPS that is owned and operated by AALTO, an Airbus subsidiary. "HAPS have recently become possible because of advances in lightweight computer systems for avionics controls, ultralight high-stiffness carbon fiber composites for manufacturing aircraft bodies, lightweight battery technology for powering the system, and very lightweight high efficiency solar arrays," Stevens said. "Each of these developments includes the words 'light' or 'lightweight' for a reason: creating components that can perform at the lowest weight possible is crucial to building a system that can reach the stratosphere and cruise there indefinitely only on solar power. Building HAPS aircraft is all about managing an energy budget, which is very much like an accountant managing a financial budget: you have to make sure that the money out doesn't exceed the money in, or you go into the red. In the same way, you can't use more energy to cruise through the night than you can collect during daytime through the solar array and store in high-efficiency batteries, at least in the long term, or eventually you don't have enough energy to stay flying in the stratosphere, and the HAPS will have to descend, potentially into hazardous weather. It's a constant balancing act. Once you're in the air, the only source of 'energy in' that we have right now is solar power; that's why we're so excited about the possibility of adding laser power beaming to the system."

In a military context, HAPS are relatively difficult to detect, since they have low signatures and fly at such high altitudes. They can "station keep," maintaining a close-to-fixed position over the ground to act like a geostationary satellite (but thousands of times closer to Earth), and they can also move from place to place relatively quickly, with some being able to take up a new station 1,500 miles away in only a day. Stevens explained, "HAPS have the potential to be low-cost, highly automated pseudo-satellites that can be dynamically re-tasked, with overlapping sensor footprints and the ability to project capability from the near-space environment of the stratosphere. They combine the amazing properties of aerial platform resolution with the low cost and wide footprints of space-based observation. This sounds like a technology that has the potential to dominate communications markets. And it is, but when you design a plane to fly on such low power to cruise and also do its work, you have to make certain compromises. One of those compromises is that HAPS tend to have very large wingspans, and they tend to fly very slowly, at least compared to other aircraft. Since they fly so slowly, they are very vulnerable to the gusts and turbulence that are found in the troposphere, which they have to fly through at launch and every time they come down for maintenance or to change payloads. The dirty secret of the industry is that HAPS have a one in three chance of breaking up and falling out of the sky every time they climb to the stratosphere. Solving that unacceptable failure rate is why Voltitude exists."

He went on, "I used to be the head of design for the Zephyr [the Airbus HAPS], probably the most advanced HAPS platform which is operational today. And I felt that this Achilles heel of vulnerability to launch and recovery was going to hold the entire industry back. I started Voltitude to explore new technologies to expand the operating envelope, but without jeopardizing that ultra-efficiency in the stratosphere, and allowing that delicate energy budget to be closed positively." Voltitude has developed a new 'gust alleviation' technology, which Stevens said is the key to survivability. "This new technology ensures that the highly flexible aeroelastic HAPS structures have greater resilience to the effects of gusts and turbulence, without adding significant weight or extra drag. The Voltitude solution controls the aircraft's shape, ensuring maximum flight control authority even when transiting through turbulence. This is very similar to how large wingspan birds react to gusts and control the shape of their wings to safely maintain their flight envelopes. When applied to HAPS, gust alleviation technology expands the flight envelope to the extent that we think we can get the failure rate down from one in three, to better than one in a hundred transits to or from the relative safety of the stratosphere."

"Now, if you were a passenger on an airplane, you probably wouldn't get on to an aircraft that had even a one in a hundred chance of crashing, let alone one in three. But for an unmanned vehicle that can fly months-long missions, it turns out that that failure rate is economically viable. We think that our technology will make it practical to deliver affordable services from the stratosphere. But there's still at least one more problem to solve," Stevens added.

The Zephyr 8/S, a successor to the HAPS aircraft that Stevens helped develop, has a wingspan of about 80 feet and weighs about 130 pounds, which allows it to support a ten-pound payload. It can support high burst rates of power to the payload for a short time, but averaged over the day in a typical location, it can only provide about 50-100 watts of payload power (beyond what the aircraft needs to stay in the stratosphere). Stevens explained, "This level of power cannot support enough power to a commercial radio frequency payload, like a video call on a mobile phone routing through the HAPS. There might be enough power to conduct five or even ten simultaneous video calls, but you would need ten times or a hundred times as much power to make it economically viable to use HAPS to support a 5G phone network. That's why we're hoping that laser power beaming could close that gap."

Laser Power Beaming (LPB)

Laser power beaming (LPB) is an approach to transmitting power wirelessly, through the air, over long distances. (LPB can also include transmitting power through optical fibers, but this is not a practical approach for HAPS.) With LPB, source power at the point of origin is used to energize a laser beam, and this beam is sent through the air to a receiver, where specialized photovoltaic (PV) cells transform it back into electrical power. The PV cells used for LPB are different from the solar cells that HAPS use for turning sunlight into power, because they are tuned to work best with only a single frequency (color) of light – the light from the laser transmitter – instead of transforming the whole spectrum of light from the sun into power. "Over the last 30 years, lasers have become more powerful, more efficient, and at steadily declining prices," says Tom Nugent, chief technology officer and co-founder of PowerLight Technologies, a company which has been working to commercialize LPB since 2009.

The increased power and efficiency of lasers makes them practical tools for beaming power to precise locations, like flying HAPS. While power beaming may be less efficient than transmitting energy through wires, it has the potential to reach flying aircraft and other types of receivers that are not practical to attach to a wire, and that are too far away for other forms of wireless power transfer such as inductive chargers (for example, the Qi® system). It is also possible to beam power over long distances with microwaves, but the receiver aperture required is too large to be practical for HAPS.

In 2010, PowerLight set a record for drone flight by flying a quadcopter for 12.5 hours by beaming power to it wirelessly, and they further demonstrated beaming to a Lockheed-Martin Stalker drone in 2012. In 2019, the company went on to demonstrate transmission of 400W of power safely over more than 1,000 feet through the air (to a ground-based system), using a patented "enhanced light curtain" system that protects people and objects from the laser beam by surrounding it with a guard beam system that powers down the laser if an object approaches the power beam. Next, PowerLight is developing a safe power beaming system to work over longer distances, to receivers lightweight enough to fly.

One commonly cited obstacle to LPB systems is that they may be affected by weather. While it is true that rain and clouds may interfere with efficiency, PowerLight has demonstrated power beaming systems that are able to work in the rain. "Rain decreases efficiency and effectively reduces maximum distance that we can beam power to during the rain, but it doesn't prevent beaming unless it's raining really hard," explained Nugent. "But over distances of a few kilometers on the Earth, there is almost never that much rain everywhere at once, and even when it rains heavily enough that beaming through it isn't a good idea, it usually doesn't rain that hard for very long. So finding stretches of an hour or so where we have a clear beam path usually isn't a problem."

Combining HAPS and LPB

Could LPB be the answer to the power problems of HAPS systems? Paul Stevens of Voltitude says that their models show that "we could quadruple the payload power available to a HAPS platform with just 30 minutes to 60 minutes of illumination per night from a power beaming system at current power levels." Even when local weather makes power beaming to aircraft challenging, both Voltitude and PowerLight believe that it will be reasonable to expect to find "windows" to beam power for these kinds of time frames, especially with HAPS systems that can travel to areas where a transmitter is available and weather is cooperative.

Energizing HAPS so they can reliably carry meaningful payload is a big deal. At Mobile World Conference 2023, the largest connectivity event in the world, representatives from Deutsche Telekom AG, GSMA, Intelsat, and TMG discussed the potential of HAPS solutions to open up more revenue-generating use cases and tackle the growth already on the horizon.

Without an alternative, mobile network operators will need to multiply their number of towers by 10 times as they move from LTE to 5G, and then another 10 times in the next decade as they migrate from 5G to 6G. In addition, they will incur the additional capital costs associated with truck rolls, road work, and the need to connect the network by bringing in miles of fiber cable. Right now, one HAPS, with the right payload operating in the stratosphere, could replace around 250-450 terrestrial towers, depending on the size of tower and radios.

Combining the capability of HAPS and power beaming, we can envision a system that is robust enough to operate in the stratosphere and never need to land, providing an entirely new potential for defense and research, and to cost-effectively connect the 2.9 billion unconnected people — almost half of humanity — around the globe.

Conclusion

HAPS have a promising future throughout our world – one that can completely change the course of humanity and its connectivity with each other – but as the technology currently stands, that future may prove impossible to achieve. With technology like LPB, these goals aren’t so far-fetched and technology like this can rapidly take on, and spread, a new and exciting way of life.

To learn more about HAPS and LPB, check out PowerLight’s website at www.powerlighttech.com.