Cover Features

A place in the sun

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Within the next few weeks, a team of UK engineers hopes to launch an unmanned aircraft that could fly continuously for several months at altitudes of up to 65,000ft.

Powered by nothing more than the sun, the so-called Zephyr unmanned aerial vehicle (UAV) has been developed by engineers at Qinetiq who believe that such vehicles have huge potential across a range of scientific, military and civil applications.

The project also promises to reinvigorate the world of solar flight — an engineering dream that received what looked like a killer blow in 2003 when NASA's much-lauded Helios solar plane met a watery end in the Pacific Ocean.

Now, thanks to advances in lightweight, high-strength composite materials, new developments in batteries and solar arrays and a fundamental rethink over the likely applications of solar aircraft, renewably powered UAVs may be about to enjoy their day in the sun.

Zephyr has its origins in an ill-fated attempt to set a high-altitude ballooning record in 2002. A tear in the balloon led to it being abandoned, but not before Qinetiq had developed a small, solar-powered aircraft to fly on a tether around the balloon's gondola and film the record attempt.

Now, after five years of development, Zephyr has taken centre stage and Qinetiq's engineers are preparing to put the latest version of the technology through its stiffest test yet at the US military's White Sands research base in New Mexico.

Launched by hand, the carbon fibre aircraft has an 18m wingspan and weighs about 31kg. By day it will fly on solar power generated by the amorphous silicon arrays that cover its wings. During the night it will be powered by a rechargeable lithium-sulphur battery.

According to Paul Davey, the project's director, the solar arrays convert about 9 per cent of the solar energy they receive into electricity and are no thicker than a sheet of paper. Meanwhile the battery, which has an energy density of about 350w/h per kilo, can be recharged hundreds of times and should enable Zephyr to fly continuously for up to three months.

In previous tests the autonomously controlled UAV was flown to about 36,000ft. The challenge now, said Davey, is to establish the reliability of the on-board systems and components and send the aircraft higher for longer periods of time. Ultimately the team hopes to have it flying at between 50,000ft and 65,000 feet.

One of the biggest challenges in developing a solar-powered aircraft is keeping the weight down and this, said Davey, has influenced every aspect of the design. 'The challenges are to keep the mass down, to get very efficient elements in the power systems — the array, motors, speed controllers. You haven't got much power available. You want to be very lightweight, pretty slow and you want a clean aeroplane. We're looking to fly Zephyr on less than 200W which, for an aircraft with an 18m wingspan, is not bad.'

Though he would not be drawn on the details, Davey said the payload deployed during the trials will be used for basic surveillance applications. This 2kg load will sit in a 1m-long housing on the front of the aircraft.

Assuming the trials are successful, Qinetiq hopes to fly pre-production samples of the aircraft early next year and is now talking to potential production partners.

The system is simple to launch, light and relatively easy to produce and has a host of potential advantages over competing UAVs. With an estimated price tag of $1m (£0.5m)it is also considerably cheaper. Because it is powered, the technology also has distinct advantages over some of the high-altitude balloons that have been tested for surveillance applications.

Davey said there are a range of likely applications of the technology, including high-altitude science missions and weather forecasting. However, he suggested that military surveillance and border control applications are likely to come first.

'With something like Zephyr we would aim in a military role for persistent surveillance over a period of several months — just staring at a particular place. It's a very economical approach and prevents you having to cycle a large number of UAVs from the ground through to a particular location. It gives you a lot of the benefits of a low earth orbiting satellite, without the fact that the satellite makes a pass only once a day or so.'

In the past it was suggested that solar UAVs could ultimately replace the low earth orbiting satellites used in telecoms applications — a claim that Davey regards as over-ambitious. 'They [telecoms applications] tend to want hulking great payloads that weigh as much as a family car, that's why we've seen planes like Helios which have been designed to take a 1000lb payload are not flying — people don't think smart about the payload.'

Interestingly, Aerovironment, the US firm that developed Helios for NASA and pioneered much of the work on solar aircraft recently turned its back on the technology. Its latest UAV, the Global Observer, will instead run on liquid hydrogen. Designed primarily for military applications it will fly continuously for more than a week at altitudes up to 65,000ft. Company spokesman Steven Gitlin said solar power was ruled out because customers want technology to operate at latitudes which do not support continuous solar aircraft operation. Liquid hydrogen was chosen because of its high energy density.

While Zephyr gears up for launch, a group of engineers at ETH Zurich, Switzerland are preparing to put Sky-Sailor, a smaller, but equally ambitious solar UAV through its paces. With a 3.2m wingspan and weighing just 2.5kg, Sky Sailor is considerably smaller than Zephyr, but its designers face similar challenges with one big difference: they want to send their aircraft to Mars.

Dr André Noth, who is leading the project, said it began three years ago as an ESA-funded study into the possible use of solar-powered UAVs for Mars Exploration. Noth claimed

such a vehicle could potentially gather far more useful data than rovers or orbiters. 'An aircraft could cover large distances but at the same time be near the ground,' he said.

But the challenges are huge. The extremely low air density on Mars, coupled with a solar resource that is half that found on earth, would make flight extremely difficult. The low air density would call for the development of special aerofoils, and the extreme storms that rack the Martian atmosphere would make flight difficult for an aircraft travelling at speeds as low as 14m/s. Noth admitted significant improvements in batteries and solar cell technology are required to make it viable.

The other issue is how the aircraft would be deployed. With no-one on the surface to launch it, Noth said the likely solution would be a spring-loaded folded plane emerge from a parachute-laden shell as it approached the Martian surface.

Clearly, such applications are an extremely long way off. Indeed, ESA recently withdrew funding for Noth's project. But undeterred, he and his team are now focused on the potential of the technology closer to home.

Noth is particularly enthusiastic about the possibility of using Sky Sailors to detect and monitor forest fires. 'You could launch 10 or 20 aircraft in a risk area that would patrol continuously and monitor the ground with infrared cameras — they could then alert fire services if they spotted anything. This would dramatically reduce the time between a fire starting and it being reported.'

The group is now preparing for a 24-hour long flight in Switzerland later this month. As with Zephyr's next trial, the purpose of this flight will be to evaluate the reliability of many of the components. The aircraft's actuators, for example, have been sourced from model aircraft companies and the team does not yet know whether they will last for 24 hours. Throughout the flight a specially developed Autopilot system will monitor the voltage of the solar panels, the battery, the motor and send these values to the ground.

Noth's goal is to build an aircraft that will go higher and carry a bigger payload but, like Qinetiq's Davey, he believes there are realistic limits to the size of solar-powered aircraft. More weight means you need more energy to keep the craft in the air. This requires more solar cells and the craft has to to bigger.

But beyond a certain size, the importance of making the aircraft as light as possible means the structure is not rigid enough to survive the rigours of flight. 'It's far more difficult to build a bigger aircraft because the wing has to be so lightweight that it becomes very fragile', said Noth. 'High winds and high turbulences would cause it to break very rapidly. Helios was very ambitious — the target was to embed a lot of payloads and fly at high altitudes. They did some great work but the structure wasn't strong enough.'

According to Noth's calculations a payload of just 100kg, around what would be required for a telecomms application, would need a wingspan of at least 80m, the same as an A380, and with current technology that is not feasible.

Unless, that is, your name happens to be André Borschberg. Borschberg, the Swiss chief executive of the Solar-Impulse project, is working with his team of engineers on the development of a huge solar-powered aircraft that will carry the most precious payload of all: a human being. And its wingspan, bearing out Noth's calculations, is 80m.

With technical and financial backing from watch giant Omega, international chemical group Solvay and Deutsche Bank, Borschberg's team hopes to be the first to fly a manned solar-powered aircraft around the world.

The team is building a prototype aircraft — also manned — which it hopes to fly next September. Borschberg claimed this should demonstrate the feasibility of night-flight and enable the teams to test and optimise all of the onboard systems. After that, he hopes to start construction of the larger record aircraft in 2009, with 2011 pencilled in as the year of the record attempt.

The payload will be huge, consisting not just of the pilot, but of all of the onboard systems that he needs. Also, because a human is involved, safety is more important than with a UAV.

The aircraft is made from carbon sandwiched materials and harnesses the sun's energy with monocrystalline solar cells that are almost 20 per cent efficient, Borschberg, who hopes to pilot the aircraft during the attempt, is confident that after careful study of the behaviour of these materials the design is free of the aeroelastic problems that have dogged other large solar planes.

One particularly interesting aspect of the development process is the team's use of a piece of proprietary software that is able to simulate, very precisely, the performance of the aircraft in a variety of conditions.

'We can calculate how much energy it can collect by taking into account its position, the time of the year, the heading of the airplane in relation to the position of the sun, the shape of the wings,' explained Borschberg.

'We can also integrate meteorological data such as pressure, wind horizontal vertical temperatures and clouds so that we can simulate the real conditions that the aircraft will encounter.'

While this software is proving to be an indispensable design tool, Borschberg explained that it will also be used immediately before and during the record-breaking flights to virtually test flight paths alongside weather forecasts: 'We will program in data from 48-hour weather forecasts and see how the virtual model bears up — this simulation will then be used to determine the optimum flight path for the real flight.'

The record attempt will be carried out in five legs, each one lasting between three and five days. Just like Zephryr and Sky Sailor, the aircraft will fly on solar power during the day and a rechargeable battery at night. During the day it will climb to 39,370ft and will fly down to low altitude at sunset to capture the last rays of solar energy before switching over to batteries for the rest of the night. The average speed is expected to be around 25 knots, although the aircraft could reach 50 knots depending on its altitude.

The objectives of Solar-Impulse are different to other projects. Borschberg does not expect to kick-start a new era of solar-powered passenger flight, nor does he have any big commercial applications in mind. Instead, he views it as a symbolic attempt that will demonstrate, in the most eye-catching way possible, what can be achieved with renewable energy.

Whatever Borschberg's aims, his attempts to succeed where NASA failed will be watched with interest by solar flight developers from every field of aviation.