The Puma AE recently had a solar panel upgrade that allowed it to fly more than 9 hours. Photo courtesy AeroVironment.

By John M. Doyle

The quest continues for ways to make unmanned systems go farther or loiter longer while weighing and costing less.

Despite decades of research, alternatives like solar power or hydrogen fuel cells are still a long way from widespread use in unmanned or autonomous vehicles. But established companies like AeroVironment, Boeing and Liquid Robotics are all moving ahead with unmanned systems driven by an alternative power source.

At the August AUVSI 2013 conference and exhibition in Washington, Titan Aerospace unveiled its plans for a high-altitude, long-endurance aircraft — called an "atmospheric satellite" rather than a high-flying unmanned aerial vehicle — powered by thousands of solar cells embedded in the composite materials of the aircraft's 50-meter (164-foot) wingspan.

The start-up company has been testing 5- and 10-meter UAS in the high desert of New Mexico, "very much under wraps," according to Maximus Yaney, Titan's chief technical officer. The planned 50-meter aircraft is still in the construction stages. Titan's young engineers and entrepreneurs say their aircraft, called the Solara, will be able to fly continuously at 65,000 feet — well above civil airspace and most weather patterns — cruising at 25 knots with a 48.5-pound payload, for up to five years. A battery-powered engine will drive the takeoff and initial ascent, but once the sun's rays hit the thousands of solar collectors on the Solara's wings, its energy will charge and power the batteries.

Company officials said the large version should be ready for Federal Aviation Administration-authorized flight by 2015.

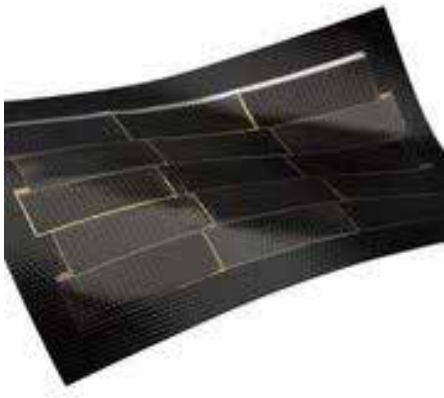
In addition to the solar cells, a key to the aircraft's ability to stay aloft for so long is its light airframe, sculpted from composite materials, including carbon fiber spar ribs, says Daniel Cornew, chief mechanical engineer.

Titan hopes to shake up both the UAS and satellite industries, because Solara will be able to circle an area much like a low-Earth orbit satellite but with a fraction of a conventional satellite's launch costs, which Yaney describes as, "somewhere in the order of one one-hundredth [the cost] of a satellite launch."

## Solar but Small

Using solar power for unmanned flight has been a dream for years, but experts believed the aircraft had to be enormous because the number of solar cells required to power the vehicle and carry an adequate payload would make it too heavy to fly.

That was the case until July, when AeroVironment successfully



Alta Devices' flexible solar cells. Photo courtesy the company.

# THE QUEST FOR (NEW) FIRE

LOOKING FOR ALTERNATIVE POWER SOURCES, SUCH AS WAVES, HYDROGEN AND THE SUN

demonstrated a solar-powered small UAS, a Puma AE. The 13-pound aircraft stayed aloft for more than nine hours. That's more than four times the standard flight time of the battery-powered Puma AE. The Puma AE had solar cells integrated into its wings, according to David Heidel, business development manager for the Monrovia, Calif., company's unmanned aircraft division.

AeroVironment collaborated on the solar-powered Puma with Alta Devices, a Sunnyvale, Calif., manufacturer of thin, flexible solar cells that are lighter, less brittle and cheaper than older solar cells, even though they are both manufactured with the semiconductor gallium arsenide. The July flight included a new AeroVironment long-endurance battery that extended the Puma's normal two-hour flight to three hours. The small UAS then flew another six hours and 11 minutes using solar power.

"We figured out a way to make solar cells that are thin, light and cheap," says Rich Kapusta, Alta Devices' marketing vice president. The company's solar panels are integrated into the top surface of Puma's wing. "The more surface area you can cover, the more power you can generate," he said.

AeroVironment is focusing on bringing the solar-powered Puma into production, says Heidel. But Kaputa says, "Why stop with airplanes? Why not put them on all vehicles?" He said Alta Devices is working with the automotive industry and on an unmanned maritime vehicle.

Kaputa said he hasn't heard of any new research into a solar-powered unmanned ground vehicle. Neither had Gill Pratt, program manager for defense sciences at DARPA. While DARPA has run solar-powered unmanned systems projects in recent years, "I don't believe we're doing one now with ground vehicles," he told *Unmanned Systems* at the August conference in Washington.

## Different Kind of Current

Another unmanned vehicle using solar power floats on the surface of the sea rather than through the air. Liquid Robotics has been building Wave Gliders for several years. Number 200 came off the factory floor recently. The surfboard-sized surface vehicle uses solar panels on its deck to power its communications, sensor and onboard computer equipment, but an array of paddle-like wings extends 13 feet beneath the surface, pulling in energy from ocean waves.

As the surface float moves up and down in the waves, the vertical motion is transferred down an umbilical cord to the glider, which turns its wings back and forth, moving the glider forward.

The combination of wave- and solar-charged electrical power allows the Wave Glider to move across vast stretches of ocean at a speed of 1.8 to 2.5 knots on wave energy alone. One of Liquid Robotics' vehicles set a record for the longest journey by an autonomous surface vehicle across the planet: more than 9,400 miles, crossing the Pacific from California to Australia in just more than a year.

Liquid Robotics' Wave Glider, powered by both solar and wave energy.
Photo courtesy Liquid Robotics.

"On days when there are no waves," says Liquid Robotics CEO Bill Vass, "it's almost always a bright sunny day," allowing the surface vehicle to collect enough solar energy to power its underwater electric thruster, which can boost speed to up to 3 knots. "The two parts work together," says Vass, allowing the two versions of the Wave Glider, the 7-foot-long SV2 and the newer, larger SV3, to survive hurricanes and transmit data even in rough or becalmed sea states.

In addition to monitoring everything from weather to marine mammals and suspicious maritime vessels, the Wave Glider can tow underwater objects as long as 30 feet and sensor arrays of 100 feet, Vass says.

## Hydrogen Power

Much of the research in alternative power sources has been directed at HALE aircraft like the proposed Solara, but with liquid hydrogen as fuel.

AeroVironment has developed the Global Observer, which is powered by liquid hydrogen in a fuel tank. Liquid hydrogen has about three times the density of gasoline, and so the aircraft it powers can stay aloft longer. Hydrogen-powered engines emit only water vapor, an environmental plus. The Global Observer, with a 53-meter (175-foot) wingspan was designed to stay aloft for four to six days, carrying payloads of up to 400 pounds. The hydrogen drives an internal combustion engine that charges the batteries that power the Global Observer's four propellers.

But the big craft crashed 1 April, 2011, 15 hours into its ninth test flight at Edwards Air Force base in California. Six U.S. government agencies, including the Defense Department and NASA, have provided more than $120 million since 2007 to fund two Global Observers. But the ongoing budget squeeze has dried up development money

since the crash, and AeroVironment is looking for a new customer, Heidel says. Construction of the second Global Observer is 80 to 90 percent complete, he added.

Like Global Observer, Boeing's Phantom Eye HALE vehicle also uses liquid hydrogen to power its two turboprop engines. The demonstration vehicle Boeing has been developing since 2008 is designed to fly at a cruising speed of 150 to 200 knots for a maximum of four days. It has a wingspan of 46 meters (150 feet). The demonstrator completed its first autonomous flight in June 2012. Eventually, Boeing, which is funding the project itself, plans a larger concept model with a wingspan of 250 feet and a payload capacity of up to 5,000 pounds.

Boeing is planning a larger concept model of the Phantom Eye. Photo courtesy the Boeing Co.

Phantom Eye uses liquid hydrogen to fuel a Ford automotive engine heavily modified to allow it to operate at high altitudes. Hydrogen "gets you the most energy in the smallest package," says Bill Norby, Phantom Eye's propulsion engineer. In its most recent flight in June, Phantom Eye stayed aloft for four hours at 20,000 feet — doubling the altitude and duration of previous flights. The next test will be a four-day flight at the maximum altitude of 65,000 feet, carrying a payload for the Missile Defense Agency, says program manager Brad Shaw.

"We see a liquid hydrogen-powered vehicle as a real game changer in shaping a HALE market for very persistent" intelligence, surveillance and reconnaissance missions, says Shaw. While liquid hydrogen costs more than gasoline, cost savings come from the reduced number of aircraft and sorties required to provide persistent ISR by using a lighter, cheaper aircraft that can stay aloft longer. "It's not so much the cost to fill 'er up. It's in the cost to operate over time that you save the money," Norby says. He and Shaw noted that Phantom Eye was fueled by less than 2,000 pounds of liquid hydrogen, a light load for an aircraft with a gross weight of 10,000 pounds

The solar-powered Solara can cover areas normally viewed by low-Earth orbit satellites. Photo courtesy John Doyle.

designed to stay aloft for long periods.

Another hydrogen-fueled UAS has been developed by scientists and engineers at the Naval Research Laboratory. The Ion Tiger, a much smaller vehicle than either Global Observer or Phantom Eye, stayed aloft for 48 hours and one minute using a liquid hydrogen fuel cell technology during its last flight in May. The small battery-powered aircraft nearly doubled its previous record in 2009 of 26 hours and two minutes using gaseous hydrogen compressed to 5,000 pounds per square inch.

"We've achieved our goals," says Karen Swider-Lyons, head of the Alternative Energy Section at NRL's Chemistry Division. "Our flight data matches our calculation. So we know how to design a liquid hydrogen fuel cell airplane now."

Liquid hydrogen is three times denser than compressed gas hydrogen. A chilled cryogenic state, about 425 degrees below zero, with a lightweight storage tank allowed more hydrogen to be carried and increased flight endurance, says Joseph MacKrell, senior aerospace engineer with NRL's Tactical Electronic Warfare Division.

Without additional funding — unlikely in the current budgetary climate — the Ion Tiger project is done for now, the researchers say, although they are turning their attention to an undersea unmanned vehicle.

Swider-Lyons says alternative propulsion is the way things are trending "across the board." She points to the auto industry, where "every major company has a fuel cell program. It's going that way, [but] at what speed I don't know," she says.

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