Hydrogen fuel cells power UAV

Researchers at Georgia Institute of Technology have conducted successful test flights of a hydrogen-powered unmanned aircraft believed to be the largest to fly on a proton exchange membrane fuel cell using compressed hydrogen.

The fuel cell system that powers the 22-ft-wingspan aircraft generates only 500 W. "That raises a lot of eyebrows," says Adam Broughton, a research engineer working on the project in Georgia Tech's Aerospace Systems Design Laboratory (ASDL). "Five hundred watts is plenty of power for a light bulb, but not for the propulsion system of an aircraft this size." In fact, 500 W represents about 1/100th of the power generated by a hybrid automobile such as a Toyota Prius.

A collaboration between ASDL and Georgia Tech Research Institute (GTRI), the project is spearheaded by David Parekh, deputy director of GTRI and founder of Georgia Tech's Center for Innovative Fuel Cell and Battery Technologies.

Advances and advantages

Parekh wanted to develop a vehicle that would both advance fuel cell technology and galvanize industry interest. While the automotive field has made strides with fuel cells, the aerospace industry, apart from spacecraft applications, has done little to leverage fuel cell technology for aerospace uses, he notes.

"A fuel cell aircraft is more compelling than just a lab demonstration or even a fuel cell system powering a house," Parekh explains. "It is also more demanding. With an airplane, you really push the limits for durability, robustness, power density, and efficiency."

Fuel cells, which create an electrical current when they convert hydrogen and oxygen into water, are attractive as energy sources because their high energy density translates into longer endurance.

Though they do not produce enough power for the propulsion systems of commercial passenger aircraft, fuel cells could power smaller, slower vehicles such as UAVs and provide a low-cost alternative to satellites. These unmanned aircraft could also track hurricanes, patrol borders, and conduct general reconnaissance.

Tom Bradley, who developed the fuel cell propulsion system, is a doctoral student in Georgia Tech's School of Mechanical Engineering. He says that fuel-cell-powered UAVs have several advantages over conventional types. For starters, fuel cells emit no pollution and, unlike conventional UAVs, do not require separate generators to produce electricity for operating electronic components. Another plus is that fuel cells operate at near-ambient temperatures, emitting less of a heat signature. UAVs powered by such cells would thus be stealthier than conventionally powered craft, he says.

Georgia Tech's fuel cell aircraft flies above the track at Atlanta Dragway. The unmanned vehicle flew for up to a minute at a time during the test flights.

Spreading the word

A few other research groups have also demonstrated hydrogen-powered UAVs, but these aircraft were either very small or used liquid hydrogen. "Compressed hydrogen, which is what the automotive industry is using, is cheaper and easier to work with," says Bradley, "so our research will be easier to commercialize."

Unlike the smaller UAVs, which had no landing gear and had to be launched by hand, Georgia Tech's demonstrator vehicle operates like a full-sized aircraft, requiring no auxiliary batteries or boosters for takeoff.

Little information has been released about other hydrogen-powered UAVs. By contrast, outreach is an important part of Georgia Tech's project. "We are laying the groundwork in design development that others can use to develop hydrogen-powered aircraft," explains Dimitri Mavris, ASDL director and Boeing professor in advanced aerospace systems analysis in Georgia Tech's School of Aerospace Engi-

Thomas Bradley and Reid Thomas go through the procedure of starting up the Georgia Tech fuel cell aircraft during a test flight at the Atlanta Dragway. All photos by Gary Meek.

neering. "By documenting the technical challenges we have encountered—as well as our solutions—we provide a baseline for others to follow," he points out.

The researchers hope to see many other aircraft take to the skies on power from fuel cells.

"As significant as it is, we are not merely developing a one-of-a-kind airplane," adds Parekh. "We are working to define a systems engineering approach for fuel-cell-powered flight. We are seeking to blaze a trail that others can follow."

The researchers presented papers about the fuel cell project earlier this year at meetings held by the American Society of Mechanical Engineers and the AIAA. The project is supported with internal funding from GTRI along with grants from NASA and the National Science Foundation.

Design challenges

"Hydrogen power requires a drastically different approach to aircraft design compared to conventional planes powered by fossil fuels," notes Blake Moffitt, who designed much of the aircraft. Moffitt is a doctoral student in Georgia Tech's School of Aerospace Engineering.

To construct the fuel cell power plant, researchers bought a commercial fuel cell stack and modified it extensively, adding systems for hydrogen delivery and refueling, thermal management, and air management. They also built control systems that handle data acquisition and allow information to be transmitted during flight.

The work involved a number of aircraft design challenges. These included:

•Slim performance margins. Researchers developed innovative computer tools to analyze performance. These tools enabled them to optimize the propulsion system and aircraft design.

•Weight management. Creative ways of trimming pounds were found, including use of carbon foam for the power plant's radiator.

•Reducing drag. The research team achieved drag reduction by using long, slender wings (spanning 22 ft), a streamlined fuselage, a rear-mounted propeller, and an inverted-V-shaped tail.

•Miniaturization. The fuselage measured 45 in. long with a maximum width of 9.75 in. and maximum height of 7.25 in. Finding components small enough to fit in this space required some ingenuity. The team used a pump from a liquid-cooled computer and a hydrogen tank designed for a paintball gun.

Test flights

In June, researchers tested the vehicle at the Atlanta Dragway in Commerce, Ga. Hot, humid, windy weather made testing conditions less than ideal and reduced thrust. Nevertheless, the team was able to conduct four flights, with the aircraft traveling between 2.5 and 3.7 m above the ground for up to a minute at a time.

"Especially important, the data generated during these flights validated our design methodologies," says Moffitt. "The data also indicated the aircraft is capable of longer, higher performance flights."

The research team plans to continue testing and refining the aircraft, making it more reliable and robust. Ultimately they plan to design and build a UAV capable of a transatlantic flight—something Parekh believes will be possible within the next five years.

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Thomas Bradley, David Parekh, Parker Parrish, and Adam Broughton remove the hydrogen tank from the fuel cell aircraft to refill it for flight.