Chapter 24 Do Aviators Dream of Electric Airplanes?

Run Silent

The phone rang again, and I got launched into another unexpected corner of the aircraft design universe. Electric airplanes. Early 1992. I'd just set up my company, and got a call from the head of a small company in Nevada. He was getting a contract from NASA-Glenn to study the use of fuel cell electric motors in general aviation airplanes. He had another subcontractor who would define the power plant. Could I do the aircraft design portion?

Great! I sent him a proposal, he sent me a contract, and we got started. The study objective was, and I quote, "Configuration design, analysis, and optimization of an electric-powered general aviation aircraft demonstrating use of fuel cell technology for primary aircraft propulsive power."

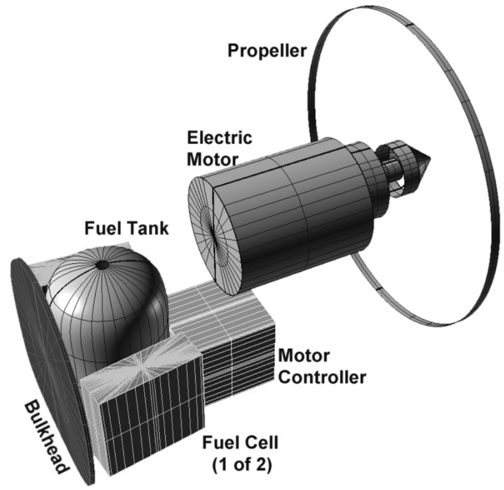
Don't we engineers talk funny?

The real purpose of the study, and therefore my design, was just to demonstrate that fuel cells were becoming a practical electrical power source for the motors of small planes. As opposed to big batteries, or solar cells, or whatever. And, of course, compared to good old internal combustion engines.

So, what kind of airplane? Trainer? Executive transport?

We settled on the classic four-place general aviation market which for over 40 years has been dominated by the Cessna 172. We used it as a benchmark. However, recent four-place designs with newer technologies such as laminar-flow aerodynamics and composite structures have a lot more performance. The four-place Lancair IV was selected as a second benchmark, and design-to requirements were defined from these. Payload of 720 lb. Range of 1250 nmi. Max speed of 275 kts. Plus rates of climb, takeoff and landing distances, and more.

Who Puts A Fuel Tank In An Electric Airplane?



The entire propulsion system was designed and defined by someone else. It was an "in the future" approach based on coming technologies. He gave it to me in rather disjointed form, dimensions and weights for a variety of components. I loaded the information into a spreadsheet for discussion purposes, and then put together a layout on my RDS CAD system.

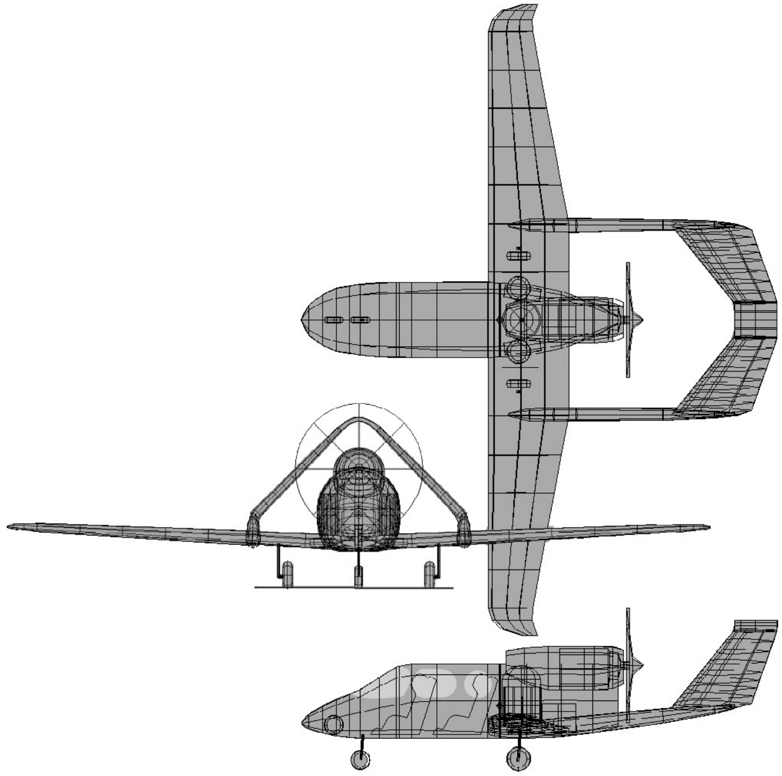
Two surprises. First - a pretty big tank. A fuel tank. Fuel for the fuel cell. The tank holds hydrogen under extreme pressure, so it needs to be a ball or a short capped cylinder. It also needs to be near the fuel cells themselves, flat battery-shaped boxes. The fuel cells should be fairly close to the motor and the almost-as-big motor controller. And the whole system together weighs over a thousand pounds. I decided to put it all together near the aircraft center of gravity, and close to the wing to make the structure lighter.

The second surprise - the fuel cells throw out heat, as do the motor and controller. So the thing needs a lot of cooling air, as much as a conventional aircraft piston engine. Silly me - I thought the electric engine would save on cooling drag. I needed a big intake duct, flow passages around the components, and an exit duct.

Then I turned on RDS and made this design. It uses a pusher configuration to allow the entire propulsion system to be co-located right behind the wing, attached to the back spar and back of the fuselage. The engine is rather high, directly behind the cooling air intake on top of the fuselage. This also lets me use a pretty big propeller for efficiency without worrying about it hitting the ground.

The tails are of inverted "V" arrangement, on tail booms. This gives a good structural arrangement, but a trade study needed to be done. Maybe the tails should be in an inverted "U" with twin verticals topped by a connected horizontal tail.

From the engine power estimated for the fuel cell system, I calculated the thrust. Fuel flow is a meaningless concept for a fuel cell - there are less than 35 pounds of fuel. It doesn't flow, it dribbles. So instead of estimating range using the classic range equation, you just calculate how long the engine will run and how far you go in that amount of time.



Since this was a small contract I did the analysis myself using RDS - aerodynamics, longitudinal stability, weights, and performance. It all checked out fine and the design requirements were met. Range and performance would be competitive with gasoline-powered propulsion systems, with only the current cost and availability of the "fuel" reducing the potential attractiveness of aircraft use for hydrogen fuel cells. Assuming, of course, that the fuel cell system numbers I was given were credible.

Better All The Time

We bid on a follow-on contract. We lost. The customer said they liked the aircraft design work. But we lost.

In 2008, Boeing Research & Technology Europe flew the first fuel cell powered manned airplane, a modified motor-glider. It needed a booster battery for takeoff, and only cruised for about 20 minutes. But the technology keeps getting better. Some time in the future, it will get as good as the numbers used for my design study. General aviation airplanes will routinely fly on fuel cells. And I'll say, "Oh yeah - I remember these."