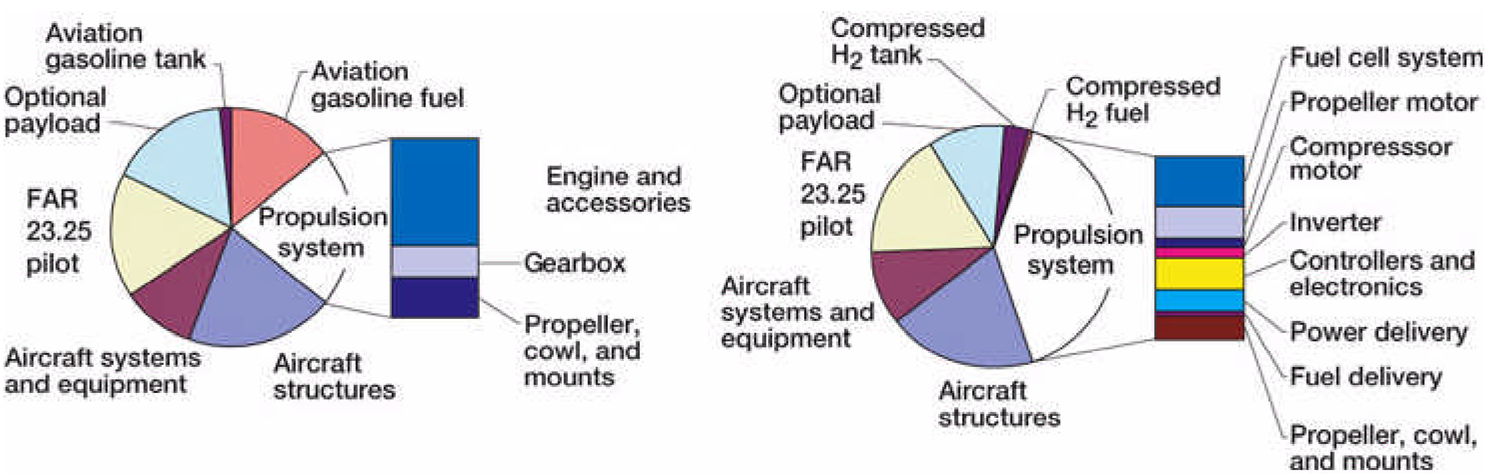
Performance of a Fuel-Cell-Powered, Small Electric Airplane Assessed

Rapidly emerging fuel-cell-power technologies may be used to launch a new revolution of electric propulsion systems for light aircraft. Future small electric airplanes using fuel cell technologies hold the promise of high reliability, low maintenance, low noise, and--with the exception of water vapor--zero emissions. An analytical feasibility and performance assessment was conducted by NASA Glenn Research Center's Airbreathing Systems Analysis Office of a fuel-cell-powered, propeller-driven, small electric airplane based on a model of the MCR-01 two-place kitplane (Dyn'Aéro, Darois, France). This assessment was conducted in parallel with an ongoing effort by the Advanced Technology Products Corporation and the Foundation for Advancing Science and Technology Education. Their project--partially funded by a NASA grant--is to design, build, and fly the first manned, continuously propelled, nongliding electric airplane.

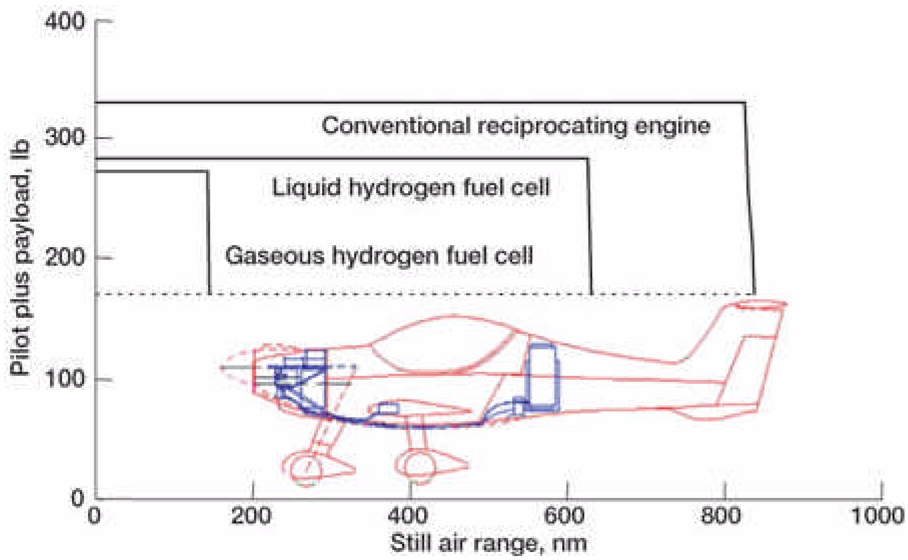
In our study, an analytical performance model of a proton exchange membrane (PEM) fuel cell propulsion system was developed and applied to a notional, two-place light airplane modeled after the MCR-01 kitplane. The PEM fuel cell stack was fed pure hydrogen fuel and humidified ambient air via a small automotive centrifugal supercharger. The fuel cell performance models were based on chemical reaction analyses calibrated with published data from the fledgling U.S. automotive fuel cell industry. Electric propeller motors, rated at two shaft power levels in separate assessments, were used to directly drive a two-bladed, variable-pitch propeller. Fuel sources considered were compressed hydrogen gas and cryogenic liquid hydrogen. Both of these fuel sources provided pure, contaminant-free hydrogen for the PEM cells.



Takeoff gross weight breakdowns. Left: Conventional reciprocating-engine-powered airplane. Right: Fuel-cell-powered airplane.
Long description.

Takeoff gross weight breakdowns are shown in the preceding pie charts for the conventional reciprocating-engine-powered MCR-01 (left), and for the fuel-cell-powered airplane (right). To reduce weight, designers sized the electric powerplant to provide much less power than for the original reciprocating engine. Such a small powerplant would result in lower airspeeds and ceilings, longer field lengths, and inferior climb rates; it is adequate only for a proof-of-concept, technology demonstration vehicle. Even so, the electric powerplant is much heavier than the reciprocating engine, in part because fuel cell technologies are not yet as mature as piston engine technologies.

The use of a payload-range diagram is one method to illustrate airplane performance as well as utility. These characteristics are shown in the following graph. The classic volume problem associated with most hydrogen vehicles applies here as well. Much more hydrogen fuel can be carried if it is stored as a liquid cryogen, resulting in greater range.



Payload-range performance diagrams for a fuel-cell-powered airplane equipped with compressed gaseous hydrogen fuel, a fuel-cell-powered airplane with cryogenic liquid hydrogen fuel, and a conventional reciprocating engine-powered airplane.

Long description.

Electric flight appears possible using off-the-shelf fuel cell and power management technology levels, albeit at reduced speed, climb rate, range, and payload-carrying capability. Aircraft performance appears sufficient to fly a technology demonstration, proof-of-concept type vehicle using today's automotive-derived fuel cell and power systems. Only light aircraft are anticipated to be feasible with near-term technology because of their relatively low, automobile-like power requirements. Advanced fuel cell and power management technologies will be needed to achieve comparable reciprocating engine aircraft performance and utility and to enable the design of larger electric aircraft.

Find out more about this research:

Propulsion and Power Base Project
http://www.grc.nasa.gov/WWW/AERO/base/psbase.htm
Fuel-celled-powered aircraft research NASA TM-2003-212393

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