# Into the *Wild* GREEN YONDER

Boeing's super-clean fuel-cell aircraft will create history this year with aviation's first zero-emissions flight.

By Tom Koehler

Later this year, a pilot will board a small one-seat propeller-driven airplane at an airport in Ocaña, Spain, taxi to the runway and take off. After climbing to an altitude of about 2,000 feet (610 meters), the pilot will level the wings, fly straight ahead for several minutes, and then return.

What will be different about the airplane and this flight?

It will be the first time in aviation history that a manned airplane will maintain straight-level flight with a zero-emissions hydrogen fuel cell as its only power source.

Developed by a team of four engineers at Madrid-based Boeing Research & Technology-Europe (BR&TE), with the help of industry partners in Austria, France, Germany, Spain, the United Kingdom and the United States, the experimental Boeing Fuel Cell Demonstrator Airplane will produce none of the products of combustion, such as carbon dioxide, found in conventional airplane engine exhaust. Water and heat will be its only exhaust.

It's an example of how Boeing is developing environmentally progressive technologies for aerospace applications, says Francisco "Paco" Escarti, BR&TE managing director.

"Given the efficiency and environmental benefits of emerging fuel cell technology, we want to learn all we can about how to apply it in our Boeing products."
– Francisco Escarti.

The BR&TE team, part of the Boeing Phantom Works advanced research-and-development unit, completed the systems integration phase of the Fuel Cell Demonstrator Airplane project earlier this year, and thorough systems integration testing has been under way to prepare for ground tests and a series of flight tests. BR&TE has been working on the project since 2003.

A modified motor glider, the demonstrator has a wing span of 16.3 meters (53.5 feet) and will be able to cruise at approximately 100 kilometers per hour (62 miles per hour). It will use

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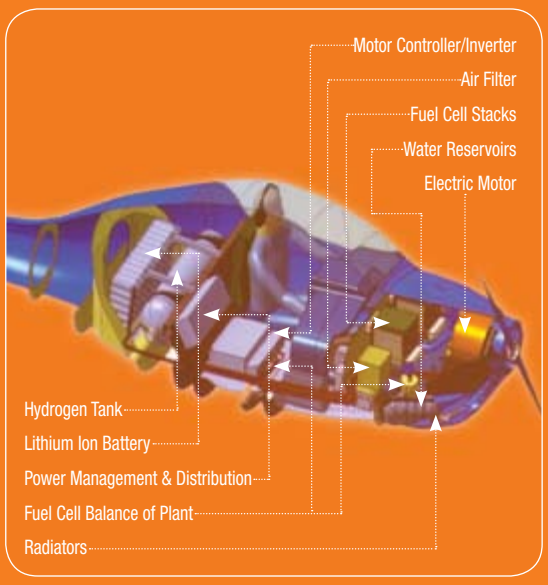
**With the Boeing fuel-cell airplane on the tarmac in Madrid, Spain, are (from left): Jonay Mosquera, aeronautical engineer; Elena Bataller, electrical engineer; Nieves Lapeña-Rey, Environmental Technologies Team technical leader; and Jose Enrique Román, Engineering Programs director Boeing Research and Technology – Europe.**

## What is a fuel cell?

A fuel cell is an electrochemical device that converts hydrogen directly into electricity and heat without combustion. Fuel cells are emission-free and quieter than hydrocarbon fuel-powered engines. They save fuel and are cleaner for the environment.

**FUEL CELL FEATURES INCLUDE:**



# Hands across the ocean:

## A cosmopolitan industry team helps Boeing develop fuel-cell-powered airplane

**Francisco Escartí, director of the Boeing Research & Technology – Europe (BR&TE)**

Boeing Research & Technology – Europe in Madrid, Spain, has worked closely with its colleagues in Boeing Commercial Airplanes, its Spanish partners, and companies in Austria, France, Germany, the United Kingdom, and the United States to design and assemble the experimental Boeing Fuel Cell Demonstrator Airplane.

The fuel-cell system used on the flight demonstrator was designed and built by the UK-based firm Intelligent Energy. The airplane itself is a Dimona motor glider, built by Diamond Aircraft Industries of Austria.

The Madrid-based avionics group Aerlyper performed airframe modifications, as well as the mounting and wiring of all components; SAFT France designed and assembled the auxiliary batteries and backup system; Air Liquide Spain performed the detailed design and assembly of the onboard fuel system and the refueling station; the Electronic Engineering Division of the Polytechnic University of Madrid (School of Industrial Engineering) collaborated in the design and construction of the power management and distribution box; post-integration bench testing is being conducted in a facility that belongs to the university; and SENASA (Spain) will provide a test pilot and facilities for flight tests.

Other suppliers include UQM Technologies Inc. (United States), MT Propeller (Germany), Tecnicas Aeronauticas de Madrid (Spain), Ingenieria de Instrumentacion y Control (Spain), GORE (Germany), Indra (Spain) and Inventia (Spain).

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a Proton Exchange Membrane fuel cell, along with lightweight lithium-ion batteries, to power an electric motor, which is coupled to a conventional propeller.

During takeoff and climb, the flight segment that requires the most power, the system draws on the lithium-ion batteries. The fuel cell will provide all power for the cruise phase of flight. At the peak of the plane's power demand, its electric motor will operate on 45 kilowatts, half from the battery component and half from the fuel cell.

**Members of the Fuel Cell Team in a discussion. From left, Elena Bataller, Jonay Mosquera, Nieves Lapeña-Rey and Fortunato Ortí.**

"Given the efficiency and environmental benefits of emerging fuel cell technology, we want to learn all we can about how to apply it in our Boeing products," Escarti says. "While Boeing does not envision that fuel cells will provide primary power for future commercial passenger airplanes, demonstrations like this help pave the way for potentially using this technology in small manned and unmanned air vehicles in several years in areas such as fire prevention, aerial photography and weather surveillance."

Escarti says the research also gives Boeing hands-on experience to complement other fuel-cell studies being carried out throughout the company. For example, Boeing researchers believe that fuel cell technology could be mature enough in 10 to 15 years for potential use in an auxiliary power system on a large commercial airplane. ■


**Nieves Lapeña-Rey, Environmental Technologies Team technical leader: "We are pioneering something new here."**

## The team behind the technology

Motivated by the challenge of balancing environmental concerns and the search for industrially viable processes and materials, project leader Nieves Lapeña-Rey joined Boeing Research & Technology – Europe (BR&TE) in Madrid five years ago. She brought with her strong industry and academic credentials in fuel cell technology development and chemical engineering. She says she has "thoroughly enjoyed" her assignment to research, develop and better understand aviation requirements for fuel cell technology integration in areas such as power density, safety, motion and vibration resistance.

"I've been delighted by the opportunity to participate on this innovative and challenging project," she said. "We are pioneering something new here – learning how to operate an airplane flying on pressurized hydrogen." She says that she and her small team have been tested by the work of integrating the different subsystems in the demonstrator aircraft while maintaining its weight and balance. She also said managing the power contribution of two different power sources such as the batteries and the fuel cell, as well as managing the heat generated by the fuel cell, has been challenging.

"I am pleased that we have reached this stage of the project and with the knowledge we have acquired as a team," Lapeña-Rey says. "In aviation, weight is very important – so we have been very focused on reducing the overall system weight while also ensuring a safe operation with compressed hydrogen fuel and lithium-ion batteries.

"The company's willingness to promote fuel cells and fund programs like this one shows real foresight and a genuine commitment to the environment," Lapeña-Rey says. Aeronautical engineer Jonay Mosquera performed fuel cell feasibility studies and thermodynamic analysis for Boeing Commercial Airplanes at the Technical University of Munich in Germany before joining BR&TE four years ago. He has been in charge of the Fuel Cell Demonstrator Airplane project's flight performance calculations and center-of-gravity definitions. He has also been responsible for installation of the equipment, design of the propulsion thermal management system, and the "pre-design" of the instrumentation panel and fuel system. "I am especially proud of our work in mounting all of the components inside the airplane," Mosquera says. "At the beginning, it seemed as if it would be impossible to fit all of the components into such a compact space. Hard work and some imagination helped us achieve it."

Elena Bataller joined BR&TE two and a half years ago after obtaining engineering degrees in Spain and France, and industrial electronics experience at General Electric and Delphi. She has been in charge of the detailed design and test of the Fuel Cell Demonstrator Airplane's electrical system, including the airplane's wiring design, as well as the power management and distribution box.

"Work on this prototype has been extremely motivating," Bataller says "We've had to integrate so many systems into such small space. I'm especially happy with the design of the power management and distribution box – work that required system-level thinking to identify all of the interactions in the power management."
"Working with this team has been exciting," adds Fortunato Orti, senior technical advisor at BR&TE, who supervised Lapeña-Rey, Mosquera and Bataller during much of the formative stage of the project and who has been deeply involved in the design of the airplane. "We all have been very encouraged by this work and are excited about the challenge of making the airplane fly."