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Solar Impulse took the first solar-powered night flight in history in 2010. In 2015, an updated version of the plane, Solar Impulse 2, will take to the skies for a journey unlike any ever attempted.
After a successful — if sometimes harrowing — flight across the U.S. in a prototype, two intrepid pilots strive to create a solar-powered plane capable of circling the globe.

BY HELEN FIELDS

ON JULY 5, 2012, the buzz of André Borschberg’s cell phone pulled him out of a meeting at a military airfield northeast of Lausanne, Switzerland. The news wasn’t good. The former Swiss Air Force pilot rushed to his helicopter and raced the familiar 45-minute route to Dübendorf, near Zurich.

After touching down at the helipad, he sprinted to the cavernous hangar and swung open its blue door to find the splintered remains of a critical piece of his latest engineering endeavor: part of the 236-foot-long carbon fiber wing of a solar plane designed to circumnavigate the globe. A team of 40 engineers had spent nine months designing this wing, another nine months building it, and the past four weeks testing it. In a final round of tests, the team had hung an elaborate wooden framework and up to 6 tons of lead weights off the spine of the wing — known as the wing spar — to simulate the stress of the forces the plane could experience during heavy turbulence. Because of a mistake in the design, the spar had buckled.

The plane, christened Solar Impulse 2 (the first Solar Impulse was a prototype; see “On a Wing and a Photon,” page 41), has been 10 years and about $150 million in the making. Next year, Borschberg and project partner Bertrand Piccard plan to fly the plane around the world, taking turns on four- to five-day hops over the course of three or four months. But that’s assuming the plane is ready by then.
Seeing the mangled wing felt like "a big hit in the stomach," Borschberg says. But his confidence didn't waiver; he's not the kind of guy to let disappointment slow him down. And soon, he would entrust his life to this futuristic flyer. With the 2015 takeoff date looming, the Solar Impulse engineers went back to the drawing board, finally deciding on a design that added a bit of weight to get a wing that could weather the challenges in store.

Even as they worked to resolve the problem with the wing spar, the team had plenty else to do — a ton of details large and small, all of them crucial to the project's success. In the Dübendorf workshop on a chilly morning in February 2013, workers prepped the fuselage for load testing — the same kind of testing that destroyed the wing spar the summer before. "It was the final test, the most important one, and I tell you we were all sweating," Borschberg says. But the piece passed the test, bringing the pilots one step closer to their epic flight.

### Dreaming Big

Solar Impulse is the brainchild of Borschberg's project partner, Swiss psychiatrist Bertrand Piccard, a compact, 56-year-old adventurer with a history of pulling off daring long-distance journeys. In 1999, Piccard and a co-pilot completed the first-ever nonstop balloon flight around the world. They took off in the Swiss Alps with 28 full tanks of propane; when they touched down in central Egypt almost 20 days later, little more than a quarter of a tank remained.

"There was this big anxiety of being short of gas before the end of the flight," Piccard remembers. Next time, he thought, wouldn't it be nice to circle the globe without keeping an eye on the fuel gauge?

It was no idle question. Piccard was bored with depressing discussions about the state of the environment and wanted to change the perception that living sustainably means using ugly lightbulbs and cutting out pollution-producing travel. His piercing blue eyes were fixed on a high-tech future that was both efficient and exciting. That vision took the form of a plane that could fly around the world using only the power of the sun.

In 2003, Piccard sought advice from the Swiss Federal Institute of Technology in Lausanne. He needed a partner who knew the technological limits of flight — and was willing to push them. The dean of the institute's engineering school knew just the guy to spearhead Piccard's pie-in-the-sky project: André Borschberg, a mechanical engineer with a business degree and a track record of risky start-ups. "It was a little bit crazy," Borschberg says, thinking back on the initial proposal. "But I like these situations where you don't know how to get to the goal." And quite a goal it was: designing a plane light enough to run on solar energy alone, but strong enough to carry pilots, provisions and batteries storing energy to fly through the night.

Piccard is used to people calling his projects crazy, but he thinks the status quo is crazier. "What is really crazy is to continue to burn 1 million tons of [fossil] fuel every hour, and to believe that we can have a good future with that," he says. "Flying with a solar-powered airplane is much less crazy."

### IN THE GENES

Bertrand Piccard's penchant for pushing boundaries runs in the family. His grandfather, Auguste Piccard, designed a pressurized aluminum gondola that in 1931 allowed him to be the first to pilot a balloon (left) into the stratosphere. In 1960, Auguste's son (and Bertrand's father, right) Jacques Piccard steered a pressurized steel sphere called a bathyoscope to the deepest point in the world's oceans, at the bottom of the Mariana Trench.
On a Wing and a Photon

The first Solar Impulse plane (known as HB-SIA) took to the skies in 2010 in the hands of a professional test pilot. That July, Borschberg took off from a Swiss airfield on a 26-hour flight that made him the first nighttime solar pilot and also set the altitude record (more than 30,000 feet) for a solar plane. Over the next two years, he and Piccard took the plane out on a few jaunts around the neighborhood. Flying into a strong headwind on a flight to Morocco, Piccard once felt the plane moving backward: Although still heading west, he was drifting east. "It's really fun when you're facing the wind and suddenly you see the image on the GPS turning 180 degrees," he says.

For the prototype's grand finale, Borschberg and Piccard traded off legs on a five-part journey across the U.S., taking off from Moffett Field near San Jose, Calif., in May 2013. After only one close call, when a piece of the film on the underside of the wing tore, the plane landed successfully in New York in July, marking the end of its flying career. From then on, the team focused on making necessary improvements for the plane's successor, Solar Impulse 2 (aka HB-SIB), which they have been designing since the prototype was making its first tentative hops.

The new plane sports a number of changes: Solar Impulse 2’s wingspan is about 15 percent longer than its predecessor’s to support the greater weight of supplies required for several days in the air. Whereas the prototype’s fuselage was rectangular, Solar Impulse 2’s is triangular, a change that shaved off some weight. Its cockpit is also larger than the prototype’s because the pilots will spend more time there. The plane also will carry more backup systems, since technicians won’t be able to get their hands on it as often for repairs. And its electrical circuits will be waterproof, allowing the plane to fly in light rain, a feature its predecessor lacked.

Body Builders

In designing their solar plane, Piccard and Borschberg and their team faced a structural challenge. The plane’s frame needed to be strong enough to carry a human pilot, several days’ worth of resources and four heavy batteries, but light enough to fly on the solar energy absorbed by the 17,000 solar cells — each as thin as a human hair — mounted on its wing, fuselage and horizontal stabilizer.

One airplane manufacturer after another declined Borschberg’s invitation to build the plane, saying the frame he envisioned was impossible to construct; it was simply too light. Even glider-makers couldn’t pull it off. So Borschberg switched gears and contacted a friend at Decision SA, a Swiss company that makes superbright and lightweight carbon fiber sailboats, including recent winners of the America’s Cup.

Decision’s builders had “no clue” about aviation, Borschberg says, but they knew their materials. Since Solar Impulse needs to float on air instead of water, the plane’s fuselage, cockpit and wings required a composite material lighter than any Decision had ever used. The Solar Impulse team also saved weight by eliminating material wherever they could, including making much of the plane’s structure hollow, like the bones of a bird. The fuselage is a latticework of carbon composite tubes arranged like an old-fashioned railway bridge.

The plane’s three-piece wing spar and some other components were made from carbon fiber tapes that each weigh less than a tenth of an ounce per square foot — one-third the weight of a sheet of paper. (The tape is so thin that during assembly of some parts, the touch of a human hand would damage it.) To produce the tape, a robot created multiple layers of carbon fiber, precisely controlling the positioning of each microfiber so the parts could support the load and withstand aerodynamic forces. To construct the wing spar and some other parts, Decision’s builders layered sheets of carbon fiber around a honeycomb of cardboard, giving the pieces both strength and flexibility. The parts were baked to structural perfection in a tractor-trailer-size oven, then assembled.

Solar Impulse’s fuselage is made of carbon composite tubes.

Prototype vs. New Plane

<table>
<thead>
<tr>
<th>PROTOTYPE vs. NEW PLANE</th>
<th>SOLAR IMPULSE</th>
<th>SOLAR IMPULSE 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>WEIGHT</td>
<td>3,527 lbs (1,600 kg)</td>
<td>3,300 lbs (2,404 kg)</td>
</tr>
<tr>
<td>LENGTH</td>
<td>71.69 ft (21.85 m)</td>
<td>73.49 ft (22.4 m)</td>
</tr>
<tr>
<td>WINGSPAN</td>
<td>208 ft (63.4 m)</td>
<td>236 ft (72 m)</td>
</tr>
<tr>
<td>COCKPIT</td>
<td>46 ft² (1.3 m²)</td>
<td>159 ft² (4.5 m²)</td>
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LEAN, LONG ... AND SLOW. Solar Impulse 2’s wingspan is longer than a 747’s, and it weighs less than a Ford Expedition. But it’s far slower than either: With an average top speed of 40 mph in the air, the plane would lose a race against a greyhound.

208’ (63.4 m) 71.69’ (21.85 m)
236’ (72 m) 73.49’ (22.4 m)

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236’ (72 m) 73.49’ (22.4 m)

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On the Fly

The plane Borschberg and Piccard will take around the world, Solar Impulse 2, looks like a pearly dragonfly, its narrow, wedge-shaped fuselage balancing a single, improbably long wing. The plane will operate like a glorified glider. During the day, it will climb to 27,000 feet, drawing energy from the sun and storing some of it in ultra-efficient, purpose-built lithium-ion batteries. At night, it will glide slowly downward to as low as 3,000 feet, drawing as little power as possible from the battery reserves.

See more photos of the plane's construction and testing at DiscoverMagazine.com/Solar

Staying Alive

The engineering challenges of circumnavigating the globe in Solar Impulse 2 go beyond the plane itself. Each pilot will spend days on end alone in the plane — which means his brain and body must be prepared, too.

In December 2013, Piccard spent 72 hours in a specially designed flight simulator.

A compact parachute backpack (right) leaves room for stretching exercises (above).

Everything is close at hand in the tiny cockpit.

DRESSING SMART.

To manage temperature extremes, the pilots' clothing is made of "intelligent" nylon fibers that direct infrared heat back to the surface of cold skin and keep the pilot cool when direct sunlight turns the cockpit into an oven. The sleeves of Borschberg's and Piccard's flight suits are embedded with instruments specially designed for the solar flight. If the plane starts to bank too far to the left, for example, the pilot's left sleeve will vibrate to alert him.

WORK THAT BODY.

Even an eight-hour flight can cause life-threatening blood clots; five days of sitting motionless could be a killer. Solar Impulse's engineers revamped the typical backpack-style parachute to be less obtrusive, allowing the pilots to maintain circulation by doing modified versions of yoga and Pilates. And exercise is not the only critical function Solar Impulse engineers have taken into account. Another convenience: The toilet is built into the pilot's seat.

PERCHANCE TO DREAM.

When the sailing is smooth, the plane's autopilot will keep the plane going, allowing the pilot to take 20-minute power naps (Piccard via self-hypnosis and Borschberg via meditation and breathing techniques).
POWER HUNGRY. After Solar Impulse 2’s energy source sinks below the horizon every evening, the plane will rely on four batteries to fly through the night. When Piccard and Borschberg began work on Solar Impulse in 2004, the best batteries available were lithium-ion batteries with an efficiency of about 180 watt-hours per kilogram — not enough to fly on ‘til morning. The Belgian chemical company Solvay jumped aboard to engineer a better battery.

In a lithium-ion battery, positively charged lithium ions move toward a battery’s negative electrode to create an electrical current. A chemical binder holds the chemical elements of the electrode together. Among other improvements, Solvay chemists were able to turn one of their polymers into a more efficient binder, which meant less of it was needed. This measure saved weight and opened up space inside the electrodes for generating more electricity. The chemists also added a solvent to extend each battery’s life and allow it to recharge more times. The team eventually achieved an efficiency of 260 watt-hours per kilogram — enough to sustain overnight flight.

JUST WARMING UP. Solar Impulse 2’s batteries will charge continuously during the day, keeping them warm. But at night, the batteries’ energy is needed to keep the plane aloft. Thousands of feet off the ground, when the sun is facing the other side of the Earth, the air whipping past the plane could get down to minus 58 degrees Fahrenheit. Such frigid temperatures will halt the chemical reactions in any battery unless it’s surrounded by some stellar insulation.

To meet that extraordinary need, researchers at Bayer MaterialScience, headquartered in Leverkusen, Germany, upped the insulating power of the company’s polyurethane foam insulation. The material rolled off Bayer’s production lines in lightweight, butter-colored blocks, some the size of sofas. After cooling, the foam was cut and shaped to fit around the battery packs and cockpit. Decreasing the cell size in the foam by 40 percent gave the new foam 20 percent better insulation efficiency than conventional insulation, meaning the temperature in the cockpit shouldn’t go much below zero — plenty cozy for a lithium-ion battery, and just barely tolerable for a hardy pilot. (See “Staying Alive,” page 42.)

Invisible Influence

Solar Impulse’s technological achievements are exciting, but the limitations of its speed and carrying capacity, as well as its sensitivity to wind and weather conditions, mean we won’t be seeing solar-powered passenger airplanes anytime soon, if ever.

That’s not the goal of the project, though. The goal, Borschberg and Piccard say, is to show how exciting sustainability can be — and how it can fit seamlessly into our daily lives. In fact, some of the technologies developed for Solar Impulse have already made their way to consumer markets. Refrigerator-makers jumped on the project’s improved insulation, for example, and electronics manufacturers around the world have adopted the chemical innovations in Solar Impulse’s lithium-ion batteries. And if you own a smartphone, tablet or electric car, there’s a good chance some of the chemicals used in its batteries are a result of the Solar Impulse project.

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