A soaring vision

Propelled only by the sun's energy, the airplane Solar Impulse 2 sets out to demonstrate the promise of alternatives to fossil fuel

ERIKA VELAZQUEZ – The attempted around-the-world journey of a solar-powered plane is pushing the boundaries of energy management and conversion. To demonstrate the enormous potential of renewable energy and pioneering spirit, Swiss aviators Bertrand Piccard and André Borschberg have built the first-ever aircraft capable of using only solar energy to fly both day and night, thus able to cross continents and oceans. As a global leader for supplying technologies to enable energy efficiency, sustainable transportation and renewable energy, ABB was a natural choice to form an innovation and technology alliance with the Solar Impulse project. ABB brings its technical expertise to this attempted flight around the world, which uses only energy supplied by a plane's solar panels and onboard battery systems. ABB engineers have overseen a multitude of technical challenges that include improving control systems for ground operations, component testing, enhancing the battery systems and troubleshooting throughout the journey.

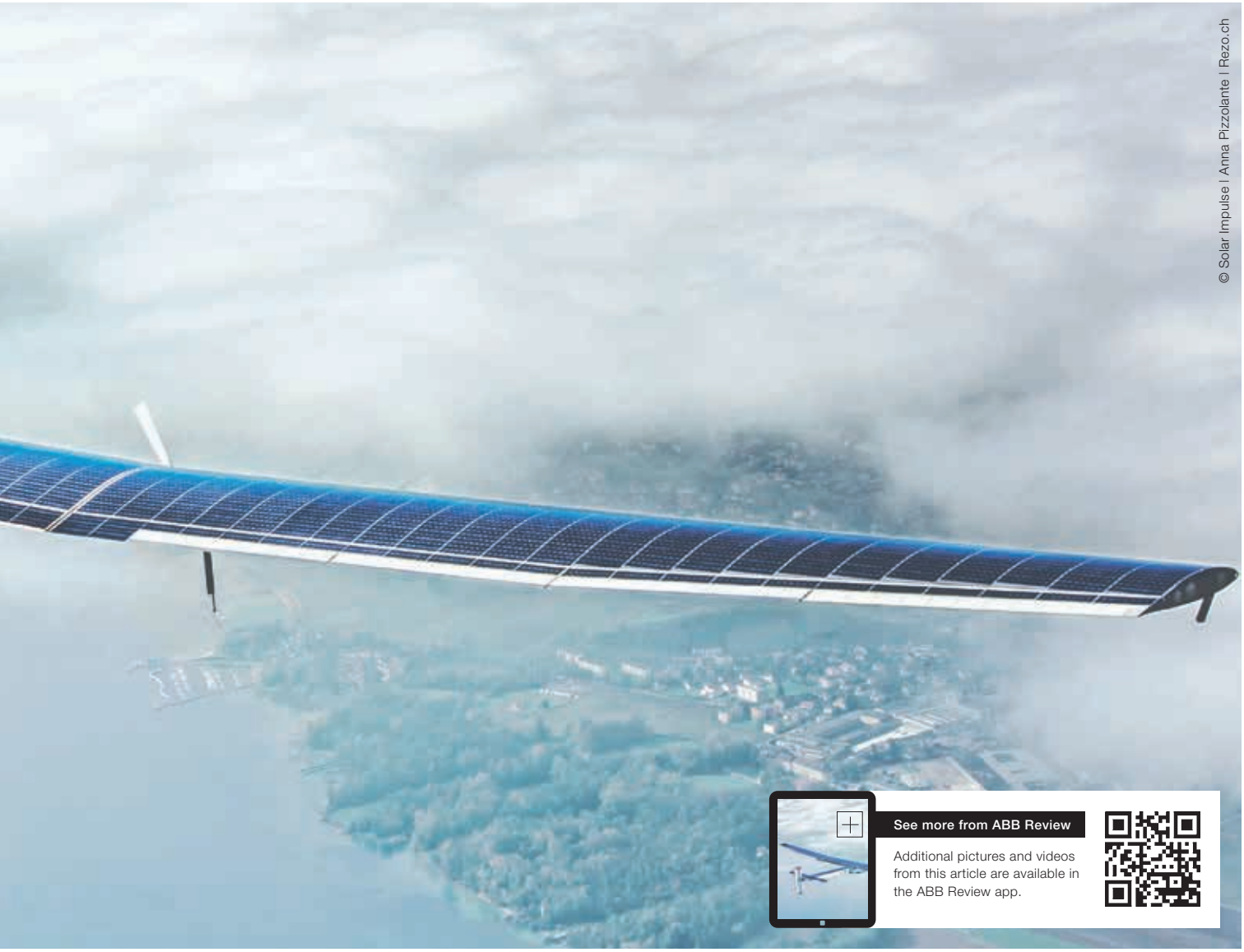

ABB and Solar Impulse formed their alliance to advance a shared vision of decoupling economic growth from environmental impact by increasing the use of renewable energy.

Borschberg and Piccard have been flying increasingly ambitious solar-powered missions to draw attention to the possibilities for clean energy. In 2013, they made a record-setting journey across the United States, from California to New York, using their first ultralight aircraft Solar Impulse 1. The plane, which had a cruising speed of about 53 km/h, also completed a 26-hour overnight flight in 2010, and flew from Switzerland to Morocco in 2012.

Title picture
Solar Impulse 2 flying over Switzerland during a test flight

The pilots unveiled Solar Impulse 2 in April 2014. On its debut flight in Switzerland in June 2014, the plane reached a maximum altitude of 1,680 m and flew at an average ground speed of 55.6 km/h.

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The new carbon-fiber plane is covered in 17,248 solar cells that provide clean energy to the aircraft's four electric motors ➔ 1–2. During the day the solar cells recharge four lithium batteries, thus assuring a steady stream of power for nonstop flight day and night.

The latest journey

Solar Impulse 2 began its attempted 35,000 km journey around the world in March 2015 in Abu Dhabi. By the time the mission is set to conclude in Abu Dhabi in July 2015, the plane will have made 12 stops – in Oman, India, Myanmar, China, the United States, and either North Africa or Europe ➔ 3.

Flying at speeds between 50 and 100 km/h, the journey is anticipated to take 500 hours flight time, over the

1 Solar Impulse 2 at a glance

The plane's external dimensions feature a length of 21.85 m, a height of 6.4 m and a wingspan of 72 m. The wingspan, wider than a Boeing 747 jumbo jet, minimizes induced drag and provides a maximum surface area for solar cells.

The frame of Solar Impulse 2 is constructed with lightweight, thin materials, such as carbon fiber and honeycomb sandwich panels that reduce the weight of a carbon layer from 80 g/m² to 25 g/m², only one-third as much as a sheet of printer paper.

The plane's upper wing surface is covered with high-efficiency solar cells and the lower surface is constructed with a high-strength, flexible skin, an innovation borrowed from techniques developed by sail makers for racing boats competing for the America's Cup. The 140 carbon-fiber ribs are spaced at 50 cm intervals to give the wing its aerodynamic cross section and also maintain its rigidity. The aircraft features 17,248 monocrystalline silicon solar cells, each 135 µm thick and mounted on the wings, fuselage and horizontal tailplane, providing the best compromise between lightness, flexibility and efficiency.

Energy gained from the solar cells is stored in lithium polymer batteries optimized to have a density of 260 Wh/kg.

The batteries are insulated by high-density foam and mounted in the four engine nacelles, with a system to control charging thresholds and temperature. Their total mass amounts to 633 kg or just over one-quarter of the aircraft's all-up weight.

The aircraft is equipped with four brushless, sensorless motors, each generating 13 kW (17.4 hp), mounted below the wings and fitted with a reduction gear limiting the rotation speed of a 4 m diameter, two-bladed propeller to 525 rpm. The entire system is 94 percent efficient, setting a record for energy efficiency.

The plane climbs to 8,500 m during the day to gather as much sun energy as possible, and descends to 1,500 m at night in order to conserve energy, coasting more like a glider, and therefore using much less stored energy from the batteries than it would if it would keep a constant altitude.

The aircraft flies at an average speed of 70 km/h, with a takeoff speed of 44 km/h and has a maximum cruising altitude of 8,500 m. Minimum speed is 36 km/h at sea level and 57 km/h at maximum altitude. Maximum speed is 90 km/h at sea level and 140 km/h at maximum altitude.

course of five months, crossing four continents and two oceans.

Engineering

ABB's engineers were able to bring specific know-how to the project in areas such as testing procedures and protocols as well as specific knowledge of power electronics and cooling. Component testing was done for functionality, temperature and pressure performance.

One responsibility of the ABB engineers on the project was to improve the control system for Solar Impulse's balloon-like mobile hangar, which is used to house the plane during unscheduled landings or if a local airport cannot host the plane. The mobile hangar is an inflatable structure made specifically for the plane, consisting of several modules that are then connected together and dragged over the plane → 4. Each module has a double layer of fabric with ABB fans in between that inflate the hangar.

Increased reliability was achieved by incorporating ABB relays and circuit breakers into the existing system. The system was made redundant with a switchover unit that is connected to an alternative power supply. An upgrade was made in current measuring relays that activate an alarm in the event of a failure of any of the fans.

The ABB engineers also developed the cockpit battery charger that is used to charge an additional small lithium battery located behind the pilot. The cockpit battery is used as an emergency power supply for the plane's avionics and powers the essential electronic devices (navigation, communication, etc.) in case of electric power loss in the plane. This important battery is also charged exclusively with sun power as well, before and during the flight, and kept at a 100 percent charge over the long flight segments. If the plane is ever left without solar power for the motors, the cockpit battery enables communication and navigation, and all the electronics that help fly the plane, as the plane can glide for a long time after the engines are disabled.

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ABB engineers were also involved in testing the plane's electrical system, including certain aspects of the plane's battery management system and maximum power point tracking (MPPT) devices that reap as much power as possible regardless of atmospheric conditions from the collection of solar cells forming a solar skin over the plane's wings.

The plane's eight MPPT devices are critical, since failure of just one during certain legs of the flight – for example, the five-day, nonstop flight between China and Hawaii – would make it impossible to charge batteries enough during daylight while running the motors sufficiently to reach maximum altitude.

Functional component testing to ensure that all devices are fully operational before installation was a crucial aspect of the ABB engineers' involvement. For example, the plane's warning panel, which monitors all devices for faults and triggers the annunciator panel and enables the alarms to warn the pilot when there is an issue with an onboard device, is made up of over 1,000 components.

Initial testing showed that the board was too sensitive to the relays' mechanical bounces. Follow-up debugging of the circuit required four days of work on the annunciator panel (from the entire electrical and propulsion team). Only after a stable solution was designed, manufactured, and retested was the device mounted on the plane. A working alarm system is absolutely critical because it needs to alert the pilot, who then might have only 10 seconds to react to save either his life or the mission. Testing was also conducted on the pilot monitoring devices that measure pulse and oxygen level.

The last project undertaken was designing a media system that enhanced the direct recording from the onboard cam-

2 Solar Impulse 2 is equipped with four brushless, sensorless motors mounted below the wings.

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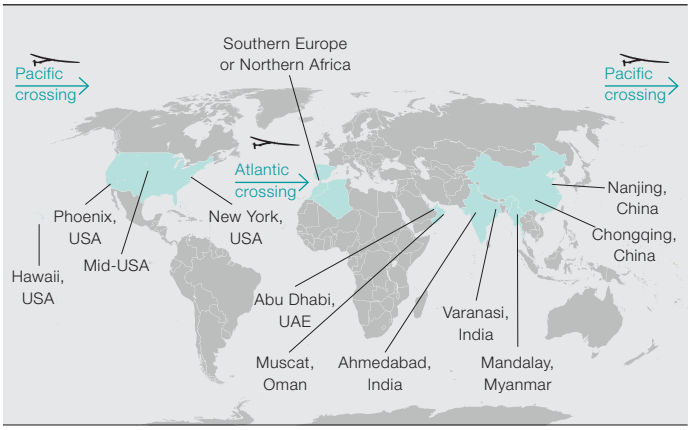
3 Flight plan of Solar Impulse 2's intended around-the-world journey



4 Solar Impulse 2's mobile hangar can be used to house the plane during unscheduled landings.

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era to high-quality 1080p. This project required the integration and interfacing of a number of components as well as cooling the media system adequately.

A true partnership

The cooperation and exchange of expertise and experience between ABB's engineers and the Solar Impulse team has enabled a unique opportunity to showcase renewable energy.

"The flight will test technology and human ingenuity to the limit, and that's another important reason why ABB is part of this adventure – because we are constantly pushing the boundaries of technology and ingenuity to serve our customers while minimizing environmental impact," says Ulrich Spiesshofer, ABB's CEO. "While our groundbreaking innovations and technologies tend to be hidden behind walls, buried underground, or located deep under the sea, Solar Impulse is literally a flying ambassador for technological innovation and its potential to improve the world."

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