Fig. 1 Non-stop, solar-powered ocean hop

Lausanne, Switzerland-based Solar Impulse co-founders and *Solar Impulse 2* co-pilots Bertrand Piccard and André Borschberg celebrate Borschberg's successful landing in Hawaii (inset shows the *Si2* on its approach) after his five-day flight from Nagoya, Japan.

Source | Solar Impulse

Solar Impulse 2: Pulse on the future

Not yet through their 'round the world flight, this superlight solar plane's airframe-proven materials are already destined for higher callings.

By Donna Dawson / Senior Writer Emeritus

» For anyone fascinated by aircraft, solar power and/or composites, Solar Impulse is a familiar name. It identifies the Lausanne, Switzerland-based company that, in 2010, launched the self-named *Solar Impulse 1*, the world's first piloted aircraft to fly all night on solar power alone. At this writing, its successor, *Solar Impulse 2* (*Si2*), is at the halfway point of the first attempted solar-powered *around-the-world* flight, with Solar Impulse founder and chairman Bertrand Piccard alternating at its controls with CEO André Borschberg.

On March 9, 2015, *Si2* took off from Abu Dhabi in the United Arab Emirates, and, in eight legs, flew to Muscat, Omar, thence across India — stopping at Ahmedabad and Varanassi — on to Mandalay, Myanmar, then to Chongqing and Nanjing, China, and Nagoya, Japan. From Nagoya, Andre Borschberg piloted *Si2* *nonstop* for almost five days — 117 hours and 52 minutes — on solar power alone, arriving at Honolulu, Hawaii on July 3 at 5:55 a.m. local time. (The average air speed of the *Si2* is 25 knots, or about 47 kph.)

Difficulties with the plane's batteries (not its composites) forced *Si2* to pause in Hawaii (see Learn More, p. 50). While the Solar Impulse team awaited resolution of this issue, *CW* took the opportunity to inquire into the performance and future implications of the *Si2's* ultralight composite airframe, which could not have been built for its purpose with other materials (no metal could be as light, stiff and strong as needed) and without which, the aircraft's story could not have been written at all.

Halfway around the world on thin air(frame)

For this sun-powered bird, the essential prerequisite was an *extremely light aerostructure***.** The raw material that ultimately satisfied this need proved to be very thin composite tapes. The airframe's main and rear wing spars, fuselage and empennage were constructed from thin-ply epoxy prepregs produced by North Thin Ply Technology (NTPT, Penthalaz, Switzerland). The ultra-thin composite tapes, known commercially today as thin-ply or spread-tow tapes, are made by spreading individual carbon fiber *tows*, separating the fibers and flattening them into a wider and thinner unidirectional form. For the *Si2*, NTPT spread M46J 12K ultrahigh-modulus PAN carbon tow from Toray Industries (Tokyo, Japan) to yield very thin 25-g/m^2 and 100-g/m^2 unidirectional tape. The UD tapes were resin-impregnated during the process and then converted into ±45° preforms up to 27m long by 1.2m wide, using NTPT's automated tape laying (ATL) machine (for background on spread-tow technology, see Learn More).

Fig. 2 'Round the World repair stop

Si2 rests in a hangar in Hawaii as a crewmember covers the airframe with a protective space blanket. Difficulties with the plane's batteries forced a mission hiatus for repairs. Source | Solar Impulse

Joe Summers, NTPT sales and marketing director, characterizes this project as a big success for all parties involved. "The successful flight of *Si2* validates the choice of products. Thin ply materials have created a strong, lightweight structure capable of circumnavigating the globe with only solar power," he says. He adds that the project further refined NTPT's capability to manufacture, handle and transport large preforms.

All the preforms for construction of *Si2* were shipped to composites manufacturing specialists Decision SA — a member, with Multiplast SAS (Vannes, France), of Groupe Carboman SA, in Ecublens, Switzerland.

When NTPT's prepreg preforms arrived at Decision's facility in Ecublens, they were layed up by hand into custom, precision molds designed and built by Decision for the fuselage, wing sections and tail, including tooling for the complex 27m-long wing spar box. The *total* length of the wingspan, including the spar box, is 72m. (By comparison, Boeing's 787 *Dreamliner* has a wingspan of 60m.) The preforms and ply schedule for all airframe parts were calculated to build up the necessary fiber architecture for handling anticipated loads on the strong and lightweight plane, including spar box torque resistance and bending stiffness specifications.

Decision general manager Bertrand Cardis points out that in terms of the composite airframe structure, including the wing spar box, "We have had no technical issues with the plane. After the half-around the world flight of *Si2*, including spending five days over the Pacific, the behavior of everything we built has been perfect." Cardis stresses that everything was heavily tested to the ultimate flying load on the ground before flight approval, and the flight has proceeded according to plan, verifying the approach to the composite materials and manufacturing process.

Critical cockpit construction

Covestro (formerly Bayer MaterialScience, Leverkusen, Germany) designed and calculated the fairing, or outer shell and pilot access door of the *Si2* cockpit. "The most important thing was to get as lightweight as possible," explains Bernd Rothe, Covestro's plant manager and former Solar Impulse project manager. But that critical concern had to be balanced with the need for protection against thermal dynamics and atmospheric wind currents. Ultimately, the team elected not to use a composite. The shell and door were built to Covestro's specifications by a local prototype manufacturer, using Covestro's then most recently developed low-density 27.5 kg/m^3 rigid polyurethane foam. The 30-mm thick foam has a reduced cell cross section of 180 µm, about 40% less than the standard 300-µm cell. The cockpit windshield and windows are Covestro's transparent polycarbonate — 1.2 g/cm^3 compared to glass at 2.6 g/cm^3. Covestro supplied a different, 28-kg/m^3 lightweight, rigid insulating foam to protect the pilot and instruments from external temperatures that could fall to –50°C. Borschberg reports the insulation worked very well. "We were able to keep the planned temperatures in the cockpit."

The most critical proof of part for the *Si2* cockpit was to be able to eject the door under a high wind, for pilot safety, allowing the pilot to exit and bail out if the plane was at risk. For the critical door *hinges*, then, Covestro reinforced a specially developed polyurethane resin with a standard (but unidentified) carbon fiber, and molded them by resin transfer molding (RTM). »

Fig. 3 Pilot-friendly control pod

Piccard and Covestro (Leverkusen, Germany) plant manager Bernd Rothe check out *Si2's* lightweight, thermally insulated, wind-resistant cockpit. Source | Covestro