
# Record attempt has solar flair

Jean Revillard/Rezo.ch

An idea spawned a decade ago finally becomes a reality as Solar Impulse prepares for the first round-the-world flight by a plane producing zero emissions

**ANDY BRICE** LONDON

Soaring above an airbase in Payerne, Switzerland, one July morning in 2010, a solar powered aircraft was about to make history. Some 26 hours later, the prototype plane became the first to stay airborne both day and night using no fuel and producing no emissions.

Over 500 hours of flights – and eight FAI (Fédération aéronautique internationale) World Records – later, and the team behind Solar Impulse has since completed the construction of a second, larger plane and is counting down to its biggest challenge: circumnavigating the globe using only the power of the sun. Solar Impulse 2 was unveiled to the public on 9 April 2014 and took to the skies for its maiden flight on 2 June.

Getting such an ambitious project off the ground was certainly no easy undertaking, requiring innovative materials and the combined efforts of some of the world's leading companies. Over the past decade, Swiss explorer Bertrand Piccard and engineer André Borschberg have steered a team of 50 engineers, 80 partners and around 100 advisors and suppliers in a bid to embark on the 35,000km flight around the world.

The journey started in 2003 when Piccard was invited to speak at an internal event for Belgian-headquartered chemical group Solvay. Born to a family of pioneers and adventurers, he talked of his successful round-the-world flight by air balloon a few years earlier. The record-breaking Orbiter 3 challenge had quite literally proven that the sky was the limit for flights of fancy, and affirmed his vision that a trip around the globe might be possible without expending fossil fuels. The Solvay management team, inspired by his presentation, discussed the project's potential and the Solar Impulse dream took off.

## ACHIEVING THE IMPOSSIBLE

"If there is one word which defines this kind of project, it's 'inspiration'," says Claude Michel, head of the Solvay Solar Impulse Partnership. "Our world is moving fast and there are many crises and difficulties but Solar Impulse gives the younger generation hope and a positive view on the future. When Bertrand had his vision, he had no solution, no resources, no funding and no team; he just had the strong will of saying 'I will do it'. It proves that when you pull all your resources together you can really achieve the impossible.

"Chemistry was absolutely necessary to build this plane and this project is providing outstanding visibility – not only for Solvay, Bayer MaterialScience and all the partners but for chemistry as a whole," says Michel.

Solvay, one of four main partners supporting the project, has invested some 15m Swfr (€12.3m, $16.8m) into Solar Impulse these past ten years – and it has proven an extremely worthwhile investment, he adds.

"This is something the whole industry should be doing," says Richard Northcote, head of sustainability at German polymer producer Bayer MaterialScience, an official partner on the project. "Solar Impulse has proven that companies working closely together can come up with even better solutions. Partnerships like this are really beneficial – and the industry should start to do more of that in terms of addressing the problems that society faces. I think by putting pressure on companies to come up with even better solutions than we appreciate today is a good thing – it drives innovation.

"There is always a danger that industry will stick its head in the sand instead of

taking a more long term and therefore sustainable approach. There are alternatives to the way we look at technology today – we're proving that this can be done," he says. "We need to invest in alternative and renewable energies, look at lighter materials, and focus on sustainability."

"The project and partnership is a flagship for innovation and sustainable development," says Michel. "The values we have in our company are very similar to those carried by the Solar Impulse project: innovation, a pioneering spirit, respect for planet, and a respect for people. We are not just providing products for the project, we are providing solutions. As a technological partner we have been heavily involved in the co-development of the research; we have the technology, products and chemistry to help make the plane fly."

Central to Piccard's dream was changing people's perception towards energy savings and renewables, and to prove that our dependency on fossil fuels could be reduced – all by harnessing existing technologies.

The key objectives for the team were to make the aircraft as light as possible while ensuring optimal performance and efficiency. The materials specified for the project were therefore integral to its success and required close collaboration between the many companies involved in its construction.

## CAREFUL SELECTION PROCESS

Built from a myriad of materials common to applications in the automotive, aviation and refrigeration sectors, Solar Impulse uses of a range of specialty polymers, engineering plastics, carbon fibre composites, foam insulation, lubricants and coatings – all carefully selected because of their mechanical properties and weight.

The sun's rays will be absorbed by an array of photovoltaic panels to charge onboard batteries and allow the plane to fly both day and night. To compensate for the weight of the batteries, the team strived to make every fixture and fitting as lightweight as possible, while retaining the structural integrity needed to withstand the harsh conditions at high altitudes.

Described as a Flying Laboratory, Solar Impulse showcases innovative technologies and materials on a global stage.

Launching in March 2015, the plane will leave its base in the Arabian Gulf and head east, via India and Myanmar to China. After a five day flight across the Pacific Ocean the route will take Solar Impulse through the US and across the Atlantic and Europe before returning to the Gulf region.

Jean Revillard/Rezo.ch

**The record-breaking trip showcases the many technologies and materials**

The exact route of the plane is yet to be confirmed but the journey will be completed in stages, allowing the pilot to rest between legs and the iconic aircraft to be seen by as many people as possible on the ground. Its arrival in carefully selected locations around the globe will help spread the message of sustainability and innovation, which is so central to the project.

"The hops are very important for spreading the message – it's just as important as the actual flight round the world," adds Northcote. "When Bertrand came up with this idea, people said it couldn't be done; he wanted to prove the impossible was possible. For a plane to take off with no energy and land with a full battery, it's quite spectacular.

"The great thing is that once you get your products onto the plane and get them flying around the world, people see the value of what chemical companies can do in terms of achieving these dreams. Then they start to realise that the products that are helping to make this whole voyage successful are the same as those they can buy in everyday household items," he says.

Despite investing so much time, money and manpower in the project, neither company has been guaranteed a place for all their products on the plane. Each and every material was carefully scrutinized and individually assessed by the Solar Impulse team to ensure it met their strict requirements.

**"Solar Impulse has proven that companies working closely together can come up with even better solutions"**

**RICHARD NORTHCOTE**
Head of sustainability, Bayer MaterialScience

"The project made us look at things differently," says Northcote. "There were a number of characteristics we had to meet but the weight requirements really forced us into a new way of thinking.

"If you go back through history, if you look at the space shuttle or moon landings, for example, so much innovation came out of these incredible projects and so many inventions contributed to the success of these dreams. Now we take them for granted, of course, as they are part of our everyday life."

As an example, Northcote points to Bayer's microcellular foam used to insulate the doors to the redesigned cockpit. Solar Impulse marks its first application but he suggests it will not be too long until exactly the same foam will be taking the latest range of refrigerators to new energy saving performance levels.

"There is a growing consumer-based pull for more sustainable products and new legislation keeps pushing for lower energy consumption and lower greenhouse gas emissions," he says.

Michel says there has been a similar ripple effect throughout Solvay's business, with the techniques and research learned on the powertrain and lightweighting of the plane, in particular, being relevant to the automotive and aviation sectors.

"The mobility megatrend means that all manufacturers of planes or cars are looking to develop lightweight solutions," says Michel. "Solar Impulse's development has really been a springboard for this, whether it's in the structure of the plane or in the devices inside." ■

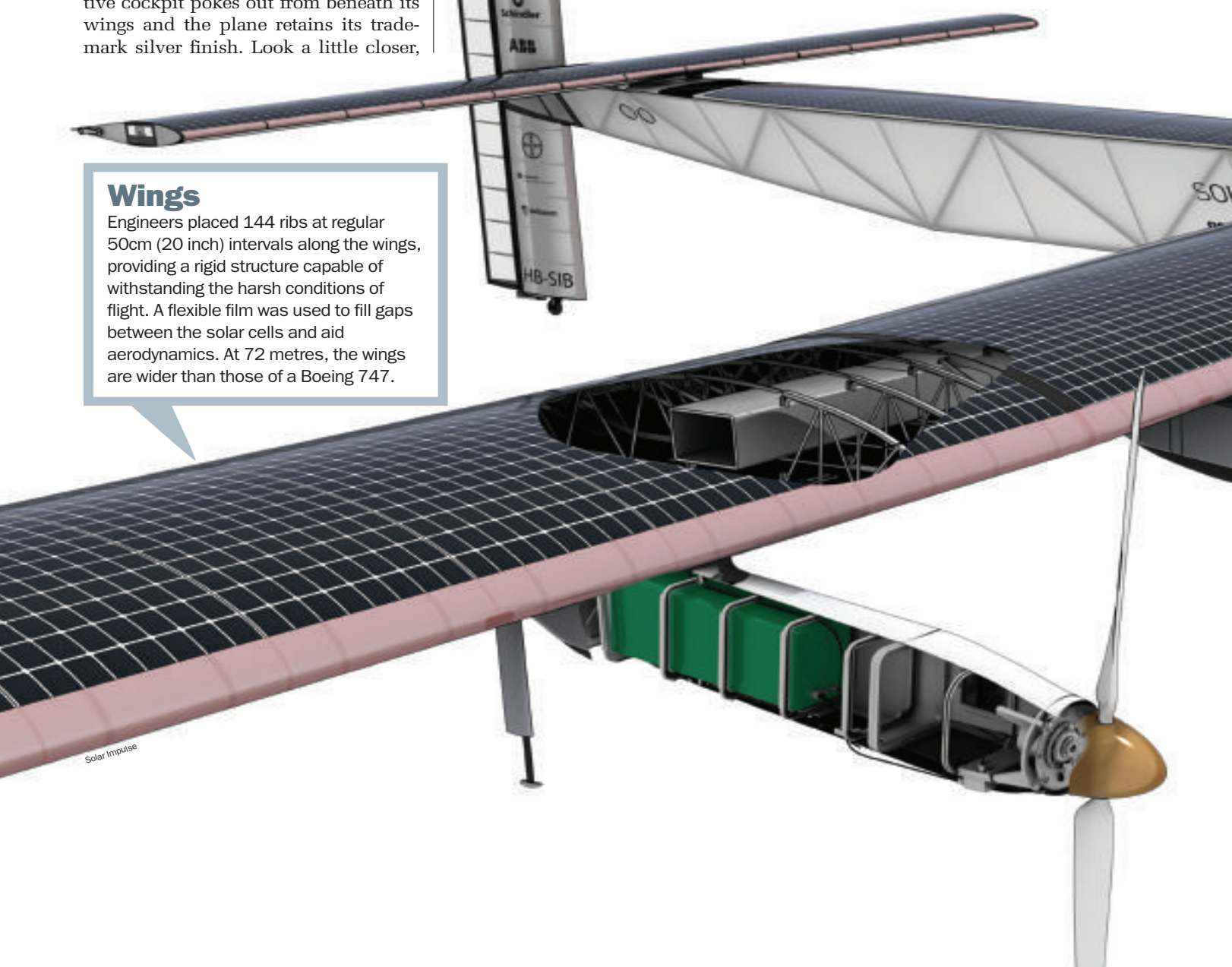
# Partners play a weighting game

Solar Impulse 2 appears similar to its predecessor but looks can be deceptive

**ANDY BRICE** LONDON

Sitting in its huge hangar in Switzerland, it may appear that the latest incarnation of the Solar Impulse plane has barely changed from its prototype form. Most of its slender frame is still covered in photovoltaic panels, the nose of the diminutive cockpit pokes out from beneath its wings and the plane retains its trademark silver finish. Look a little closer, however, and it becomes clear that there have been innumerable enhancements to assist the plane on its epic journey around the globe.

The original plane was a resounding success, proving the concept of flight powered only by the sun. However, an even more ambitious attempt to fly a solar plane around the world required the project's engineers to head back to the drawing board and design a bigger, more powerful machine not only capable of crossing continents and oceans, but of comfortably carrying a pilot for up to five days at a time. And it had to still remain as light as possible.




Solar Impulse

## Wings

Engineers placed 144 ribs at regular 50cm (20 inch) intervals along the wings, providing a rigid structure capable of withstanding the harsh conditions of flight. A flexible film was used to fill gaps between the solar cells and aid aerodynamics. At 72 metres, the wings are wider than those of a Boeing 747.

To withstand the gruelling conditions and cope with the longer flight times of a round-the-world attempt, Solar Impulse 2 (SI2) had to be larger and more robust than its predecessor. Despite its size, however, the new plane weighs only around 2,300kg – more than the prototype's 1,600kg but still little more than a standard family car. SI2 may boast a wingspan of 72 metres and be wider than a Boeing 747 commercial airliner but its engines only provide the power of a motorbike.

During the challenge SI2 will soar to 8,500m (27,000ft) during the day to absorb the sun's rays and descend to 1,500m at night to conserve energy. A 300m$^2$ surface spread over the wings, fuselage and horizontal stabilizer is home to over 17,000 monocrystalline silicon photovoltaic cells to soak up the sun – almost 50% more than were used previously. The panels are protected by Solvay's *Halar* ECTFE (ethylene chlorotrifluoroethylene), a thin fluorine copolymer film that at only 17 microns thick is far thinner than the 26 microns of the alternative film that was considered. The result is a weight saving of around 35% without compromising the electrical performance.

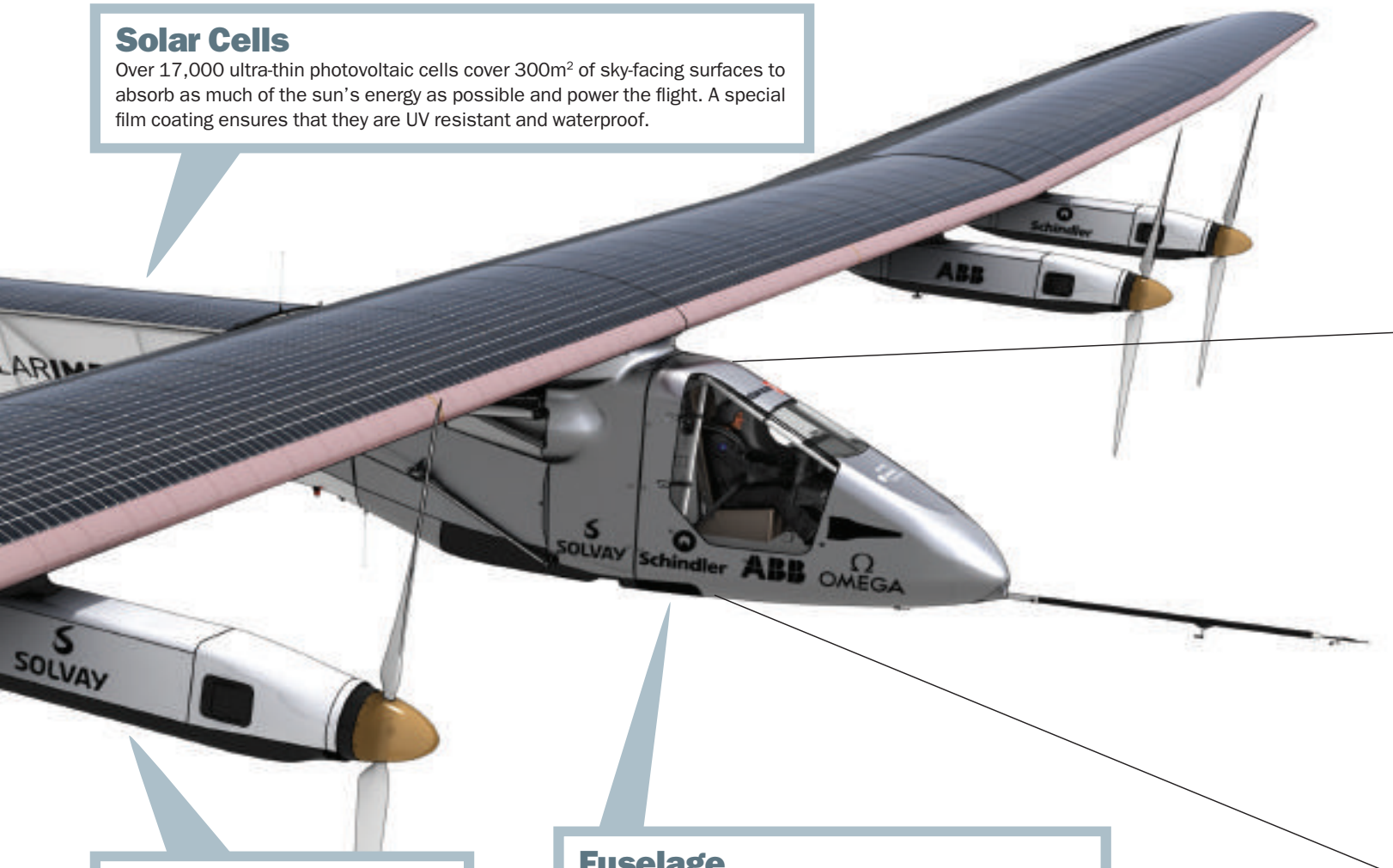
The cells themselves are among the best currently available and are only 135 microns thick, equivalent to a single human hair. They are UV resistant and waterproof, offering vital protection from the elements.

With weight such an important element of the project, the team often had to make tough decisions to reject materials that would otherwise have been suitable, says Bernd Rothe, Solar Impulse project lead, Bayer MaterialScience. "For Solar Impulse, the main priority was to be as light as possible. We developed a glue to attach a film to the top of the solar cells but the Solar Impulse team said no as our solution was 28g/m$^2$. Even though it had excellent properties and transmission, and it was a faster process, the existing solution was 25g/m$^2$. The weight is the main factor for them."

More time in the air requires more energy storage and the prototype's larger sib-

## Solar Cells

Over 17,000 ultra-thin photovoltaic cells cover 300m$^2$ of sky-facing surfaces to absorb as much of the sun's energy as possible and power the flight. A special film coating ensures that they are UV resistant and waterproof.




## Gondolas

The four carbon fibre gondolas beneath the wings incorporate a 17.5hp motor, lithium polymer battery and propeller. Specially-formulated insulation foam protects the batteries from the fluctuating temperatures (-40°C to +40°C) in flight. The motors are up to 94% efficient.

## Fuselage

Larger than the prototype, 83% of the new plane is made from light carbon fibre honeycomb structure, which strengthens the structure while significantly lowering the weight. This technique is already used in competitive yacht racing. The body's silvery appearance uses the same coating that is used on the FIFA World Cup football.

ling now plays host to 630kg of lithium polymer batteries – up from 400kg in its predecessor. The batteries are hidden beneath the wings within four gondolas that also house 17.5hp engines. The team was able to wring out as much power as possible thanks to a fluorinated polymer from Solvay. As a result, the energy density is optimized to 260 watt hours/kg (Wh/kg) – far higher than the 180Wh/kg targeted for the original plane. *Solef* PVDF (polyvinylidene fluoride) is used as a binder for both electrodes and reduces the weight of the batteries, while a monofluoro-ethylene carbonate solvent helps to improve the ion flow and helps the batteries to carry more current.

"The main bottleneck was not really the energy capture," says Claude Michel, head of the Solvay Solar Impulse Partnership, "the big challenge was the intermediate energy storage. You need to capture renewable energies and transform them into electricity but most of the time it's produced when you don't need it. We had to find the right solution. We contributed to their improvement through our electrolytes, additives, binders and separators and I'm convinced that the progress we've made with Solar impulse will help us make advances with electric cars."

**"Not only have the materials been improved for the second plane but the techniques have evolved"**

**CLAUDE MICHEL**
Head of the Solvay Solar Impulse Partnership

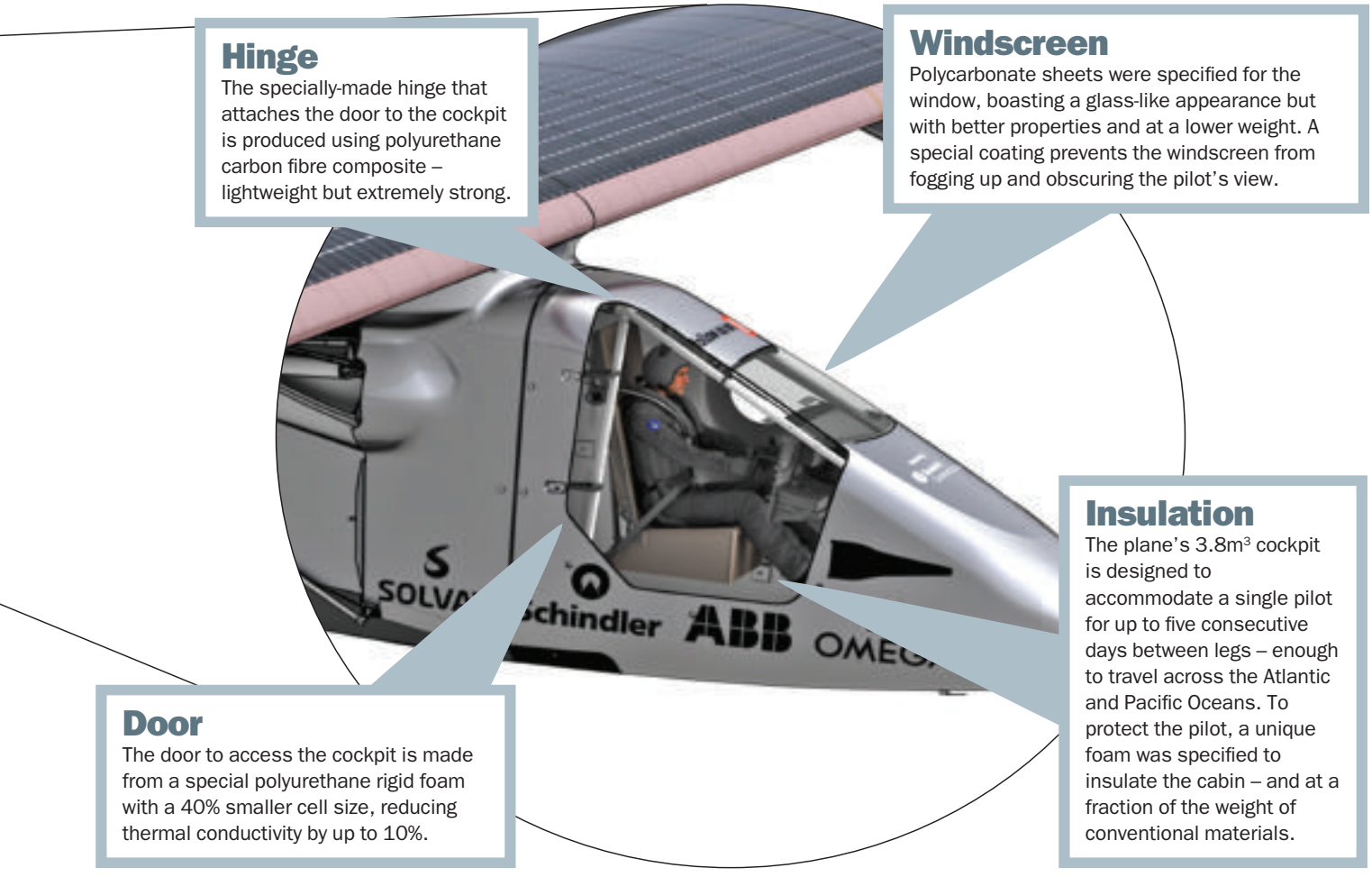
Bayer MaterialScience provided the insulation – a lightweight yet strong foam that ensures the batteries are protected from the extreme -40°C to +40°C temperatures experienced mid-flight. The polyurethane (PU) used for the insulation saves 70 times more energy than is used to make it.

Over 80% of the plane's body is made from ultralight composite materials, providing an incredibly strong frame at a fraction of the weight a conventional fuselage. Rather than conventional epoxy-enhanced solid carbon, a lighter carbon sandwich structure was specified at only 25g/m$^2$.

Its distinguishing trademark silver finish is thanks to the *Impranil* coating from Bayer Materialscience – the same coating that has been used on the Adidas *Brazuca*, the official match ball of the 2014 FIFA World Cup. The company also provided the adhesives that hold the textile fabric in place underneath the wings.

Even the landing gear has undergone an overhaul, helping to shave a few pounds off the plane's load, says Michel. The metals used in the pneumatic cylinders that raise and lower doors have been replaced by a polymer, *Ixef* PARA (polyarylamide) – marking the first time a pneumatic cylinder or actuator has ever been entirely made of plastics. This innovation proved 20% lighter than the original version.

"Not only have the materials been improved for the second plane but the techniques have evolved too," says Michel. "For example, the fasteners, bolts and screws – all made from high performance plastics – were machined in the first plane but there was some brittleness because of this process. For the second plane we used a moulding process, which means better quality and a more consistent performance. Solvay also developed a new lubricant, which will reduce the amount of maintenance needed – very important for long duration flights." ■



# Visionary design

For a little over a month – except for a few brief stopovers – Bertand Piccard or fellow pilot André Borschberg, will be confined to a cockpit measuring only 3.8m³. From here they hope to steer the plane into the history books and become the first to fly around the globe using only solar energy.

The new cockpit is significantly larger than that used in the original plane, redesigned to resist the rigours of flight at altitudes of 8,500m, as well as extreme temperatures, for up to five consecutive days at a time.

Such a test of endurance has been made a little easier thanks to the materials and technologies that have been carefully selected and refined over the past few years.

Bayer MaterialScience – an official partner of Solar Impulse since 2010 – designed the entire cockpit shell, at times dedicating a 30-strong team to its construction from May through December 2012. Although most of the materials had been successfully trialled on the prototype, every element was optimised and enhanced, says Bernd Rothe, Solar Impulse project lead, Bayer MaterialScience.

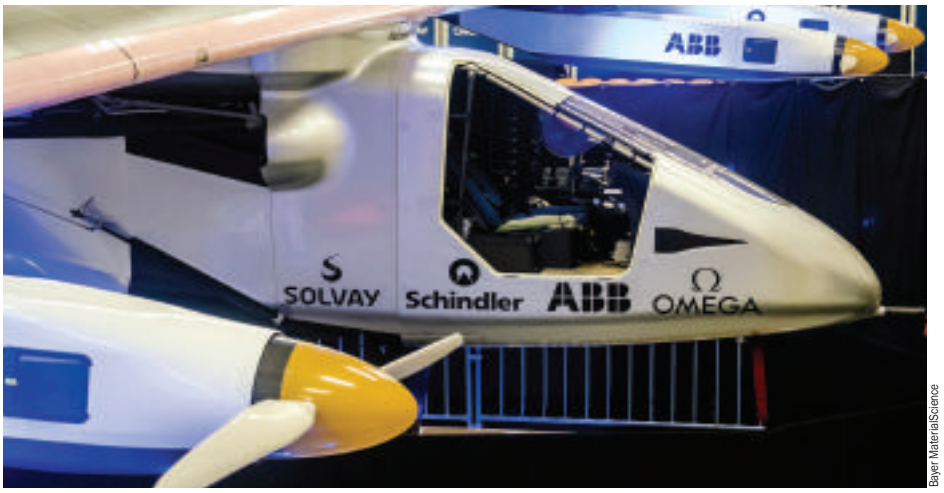
Although the volume of the cabin increased by a factor of three to 25kg, only 2kg was added to the overall weight.

The Solar Impulse team had initially stipulated the entire cockpit fairing be restricted to only 20kg, he adds – but this proved a little too ambitious: "We made our calculations and told them that wasn't possible using current materials. It was a pragmatic approach and needed a lot of discussions and adjustments; this project certainly had a lot of optimisation loops. It may be heavier but given the extra surface area and the increased functionality, on a percentage scale it's a good result."

Beneath the special silvery finish that coats the cockpit lies the inner workings of the Solar Impulse control hub. From here, Piccard will be at the controls and despite the limited cabin space can recline the chair fully to sleep.

With external temperatures falling as low as -40°C when airborne, ultra-low density polyurethane rigid foam provides insulation and protects the pilot.

"We've used Solar Impulse as an internal catalyst for our business and a lot of other projects were started because of it," says Rothe. "Making a lightweight foam with high mechanical properties led us to other projects. The team working on SI2 had the chance to have a different attack angle – normally we work in specific areas and adhere to certain restrictions. For SI2 where the main thing was lightweighting, we had to have a new way of thinking – it wasn't about processes, it was about making the material as light as possible. We learned a lot. Before long, fridges will be using these microcellular foams."



Bayer MaterialScience

**The cockpit has been given a thorough overhaul for the new record attempt**

## STRICT REQUIREMENTS

Although some materials did not make it through the selection process, Rothe insists their development is being pursued within the company. One such example were inflammable rigid foams but Solar Impulse discounted them because their density was above targeted levels. Nevertheless, says Rothe, Bayer MaterialScience continues to work on them. Similarly, the team gained indepth knowledge of carbon fibre composites and is now working closely with other companies that are focused on composite production and is planning a series of projects.

"This was a real gain from the SI project because we could test these products in a short amount of time," he says. "That's the thing with a flying laboratory – you can put new materials inside and carry out some fast-lane tests. Not all of them will be positive but you learn just as much about the things that didn't work."

Another innovation is the door to the cabin, made entirely from *Baytherm* Microcell foam. The improved lightweight polyurethane (PU) foam boasts high insulation and mechanical properties, with low heat transfer and minimal thickness. Bayer researchers succeeded in shrinking the pores in the foam by an additional 40%, making its insulating capacity 10% better than the current standard. As a result, its density was only 27.5kg/m³, far below the requirements in most other end-use sectors.

Although a comparatively small component, the hinge attaching the door had great significance for Bayer MaterialScience too. Made from carbon fibre composite and reinforced by PU resin, its design broke new ground for the company, says Rothe. "The hinge may be a small part fixed to the door but we learned so much from Solar Impulse about on lightweight composites and that's been really helpful for us to make further developments in this area."

The automotive industry is increasingly turning to polycarbonate (PC) as a replacement for glass, the lightweight alternative reducing fuel consumption and $CO_2$ emissions. This technology proved ideal for Solar Impulse. PC has a glass-like appearance and is scratch resistant with the same transmission rate and comparable mechanical properties. However, it is also far lighter: glass has a density of 2.6 g/cm³ and PC, around 1.2 g/cm³.

A sandwich of 1mm thermoformed polycarbonate (PC) sheets is used for the cockpit window, with a 5mm gap between the plates offering additional insulation. A special coating limits fogging during flight and ensures optimal visibility. ■

# Plane talking

In 2003, adventurer Bertrand Piccard took his dream of building a unique aircraft to André Borschberg, an engineer and pilot, and the Solar Impulse project was born. ICIS asked them about their dream, the hurdles they overcame and what the future holds

**What was behind your vision for building a solar aircraft?**

**Bertrand Piccard (BP):** Our message highlights the importance of a pioneering and innovative spirit, especially in the domain of clean technologies. Nowadays, the technological solutions that allow Solar Impulse to fly both day and night are accessible to all and are replicable in everyday life. These are not secret, futuristic technologies. If they were used routinely in our society, we would be able to save 50% of our consumption of fossil energies and to produce half of the rest with renewable energies. Solar Impulse wants to emphasize the energy solutions as well as the environmental and political solutions from a decidedly constructive angle in order to engender enthusiasm and the necessary motivation to leave behind this pervading fatalism. Aviation makes you dream, feeds your passions. A plane that flies without fuel and achieves something everyone imagined impossible will fire our imaginations and encourage many people to invest in the practical solutions that our society needs.

**How has support from the chemical industry made this challenge possible?**

**André Borschberg (AB):** The interesting thing with Solar Impulse is that most of the partners don't come from the aviation industry. In fact only a few of the 80 partners are active in this field. All the innovative solutions come from other industries, especially the chemical one. They push the boundaries out of their comfort zone and came up with solutions to meet the very specific requirements of Solar Impulse: build an airplane with the wingspan of a jumbo jet and the weight of a car capable of flying day and night on solar energy only.

**What were the most significant contributions from both Solvay and Bayer MaterialScience and how has their experience helped?**

**AB:** The solutions developed by Solvay and Bayer MaterialScience for the airplane are key in multiple areas such as ultralight materials and energy savings, efficiency of components, and solar cells and in the energy storage through increase of energy density of the batteries. Solvay has 13 products on Solar Impulse 2 which enhanced its performance while keeping its weight to a minimum. These products have accessed a host of promising new markets, including solar panel protection, computer and mobile phone batteries, baggage compartments on planes and sustainable solutions in mobility. Bayer MaterialScience developed among other products the insulation foam. This new foam has very thin pores, high rigidity and structural strength while remaining very light. It allows us to do without a cooling or heating system for the batteries and in the cockpit. It is also used in the best refrigerators and in the construction sector.


Solar Impulse | Righetti | Rezo.ch

**André Borschberg (left) and Bertrand Piccard are ready to make history**

**What were the greatest technical challenges you faced during the project – and how were they overcome?**

**AB:** On 5 July 2012, we were on the verge of rejoicing for an accomplished mission until, unexpectedly, Solar Impulse 2's wing spar cracked and the final structural test failed. Pushing the limits is no easy task and the failing of the spar led to a partial rebuilding of it, consequently causing a construction delay. It was the first time a final structural test had failed in the history of the project and even though it was hard to accept, it's an extremely valuable learning experience. What has emerged from this situation is that the flight around the world, scheduled for 2014, was an extremely ambitious deadline and that 2015 was more realistic. Moreover, it has made room for some stimulating brainstorming sessions within the team not only on how to use the time gained to improve the reliability of the aircraft but also to further emphasize the project's message and value.

**After next year's flight around the world, what next for the Solar Impulse project?**

**BP:** For the time being our focus is to complete the first round-the-world solar flight in stages. As long as we have not succeeded it will be considered as impossible. Let's start here and afterwards think of the next step. To bring such an endeavour to success you have to keep full focus on it. ■


Bayer MaterialScience


"We are delighted to be an official partner in this exciting project; through our involvement we will have the unique opportunity to contribute our know-how and innovative new materials. This support underlines Bayer MaterialScience's commitment and responsibility to a sustainable environment as well as contributing to the success of Solar Impulse's great technological challenge."
**Patrick Thomas**
*CEO of Bayer MaterialScience*

**Bayer MaterialScience AG**
BMS-COM-D
Leverkusen, K12
Germany
**www.bayermaterialscience.com**

"The partnership between our Group and Solar Impulse translates the confidence we place in personal commitment, in the spirit of enterprise and in technological innovation as responses to the challenge of sustainable development. In joining the project we also accept another challenge that will take us to the furthermost frontiers of technology by confronting us with the best experts on the planet in each discipline. This partnership assumes a definite economic dimension as an excellent springboard for promoting and developing the products, services and solutions that the Group will be in a position to bring to it."
**Jacques van Rijckevorsel**
*Member of Solvay's executive committee.*

**Solvay**
Solvay Campus
Rue de Ransbeek, 310
B-1120 Brussels
Belgium
**www.solvay.com**