A manned Montgolfier-balloon took off in the late 18th century. Orville Wright did the same in a heavier-than-air machine in 1902. Within one hundred years after that flight, aircrafts started using solar power and batteries on experimental flights. The Solar Impulse completed an entire flight only using this solar power. It even flew using the sunlight, during night...

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In present aeronautics, one of the challenges is to let an aircraft perform as much tasks as possible without the interaction of human beings. In the solar driven aeronautics it is the other way around; the challenge is to take people onboard.

Everybody recognizes the familiar sight of the Helios unmanned aircraft, see figure 1, with 14 high-efficiency propeller-engines across its enormous wing. Reaching almost 100,000 feet, the wing would bend due to the thin air. With this aircraft, NASA set several records with its high altitude, high endurance flights. Stretched along the entire wing was an unusual sight; thousands of photovoltaic cells provide its power to this iconic solar powered aircraft. However, there was one more difference with other aircraft; it was unmanned and remotely controlled.

Several years after Helios, in 2003 a first study was performed about the possibilities of manned, solar powered flight. Considering the fact that one of the co-founders was Bertrand Piccard, who made the first non-stop round-the-world balloon flight, this is no coincidence. At the start of the project, the ultimate goal was already to reach a manned round-the-world flight, completely powered by the sun. After three years of designing and research, the construction of the first aircraft started in 2007, callsign HB-SIA, see visual and figure 2.

At the end of 2009 the team completed their first leap into the air in order to take the first leap to accomplish their dream: flying around the world using zero fuel with zero emission. Solar Impulse does not simply want to set a new record-breaking flight. They want to tickle the imagination of young, bright minds, stimulating a new way of thinking in the aerospace industry, stimulating the evolution of new (unconventional) technologies.

The first actual flight took place short after the first hop into the air on the runway at Payerne, high in the Alps. Test pilot Markus Schödler took off in utmost silence, surprisingly quick and graceful all the way. After a successful three hour flight, the HB-SIA reached an altitude of 2.5 kilometers at an airspeed of slightly above 50 kilometers per hour.

Now take some numbers of the HB-SIA’s fact sheet; the wing span of an A340, one passenger instead of several hundred; less power than a Citroen Traction Avant and the weight of a Cessna 172. Put that together in one machine and let it fly around the world using zero fuel. Anyone’s imagination will be tickled by that…

Flying with such a machine does not come easily. It is all about the energy chain during a 24-hour flight cycle. The team needs to obtain the minimal amount of energy to keep the aircraft up in the air, also during the night. Although you would like to absorb as much energy as possible during the day, efficient solar cells and many batteries cost weight. The Solar Impulse team therefore did not even choose for the most high-efficiency solar cells available; instead, they opted for a light-weight foil, see figure 3. As light as possible, these 12,000 photovoltaic cells provide enough
power to keep the aircraft flying during the day, and charge the batteries in the meantime. These batteries take up more than a quarter of the weight of the HB-SIA. Even at such a large weight, the batteries deliver the minimal amount of energy. To make it through the night, the aircraft adopts a certain flight pattern. During the day (when the sun is shining and the power is available), the aircraft flies up to an altitude of almost ten kilometers. Then, to save energy from the batteries as much as possible, the aircraft descends during the night to an altitude of just above three kilometers, at a lower engine power setting. With a glide ratio of 40:1, it will operate more like an advanced glider than it will as a solar powered aircraft. In addition, to make as much use of the available sun as possible, the aircraft will stay close to the equator to receive as much sunlight possible.

Despite seemingly smart solutions, they also pose their problems in turn. First there is the high altitude during the day. To sustain life at this height, the presence of a human requires about 300 kilograms of extra equipment to keep the pilot alive. Solar Impulse does everything to minimize this weight and came up with smart (and above all, light-weight) solutions. Andre Borschberg, CEO of Solar Impulse, mentions for instance the use of cabin insulation instead of cabin heating.

The lower altitude at the end of the night is another dangerous risk. If the aircraft has ended flying underneath the clouds in the morning, it will never receive enough sunlight to power up the aircraft again and it would have to land. This requires very accurate and daring flight scheduling in advance. Also, to receive as much sunlight at the right angle of incidence, the aircraft should fly close to the equator. However, close to the equator, tropical storms are not uncommon; the HB-SIA will behave like an expensive leaf in a stormy wind.

The flight dynamics of the aircraft also bring their own problems. A well-known problem with high lift-drag ratio aircraft, like gliders and the HB-SIA, is the adverse yaw effect. When a rolling motion is incurred, the high wing will have more lift, hence more drag, which causes the aircraft to tend to the opposite direction than the control input intended. This is one of the main reasons a rudder is necessary for control and stability, but with the low speed of the HB-SIA the (already large) rudder has less effect. Improvements on the ailerons to equal the drag are already on the drawing table. Taking one or two people around the world during several weeks also costs a lot of food and other consumables. The team will have to look to other endurance races or sports to reduce the additional weight.

Upcoming milestones for the team will be even further flights in different flight conditions. A second aircraft, HB-SIB, will be built upon the experience gathered from HB-SIA to build a second prototype to make long, non-stop flights. With this aircraft, Solar Impulse will fly around the world with several stops. Note that these stops are required due to the human aspect, not because of limitations of the aircraft. When more improvements are made on the weight and efficiency of the batteries, this aircraft can evolve in a two-seater, allowing for that ultimate goal: a non-stop circumnavigation of the entire earth.

Many challenges lay ahead of the Solar Impulse team, but with a new Solar Impulse aircraft leaping across the Atlantic soon, nothing is left up to imagination.

References
http://www.fiddlersgreen.net/models/aircraft/Solar-impulse.html

Aviation Department
The Aviation Department of the Society of Aerospace Engineering Students ‘Leonardo da Vinci’ fulfills the needs of aviation enthusiasts by organizing activities, like lectures and excursions in the Netherlands and abroad.

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