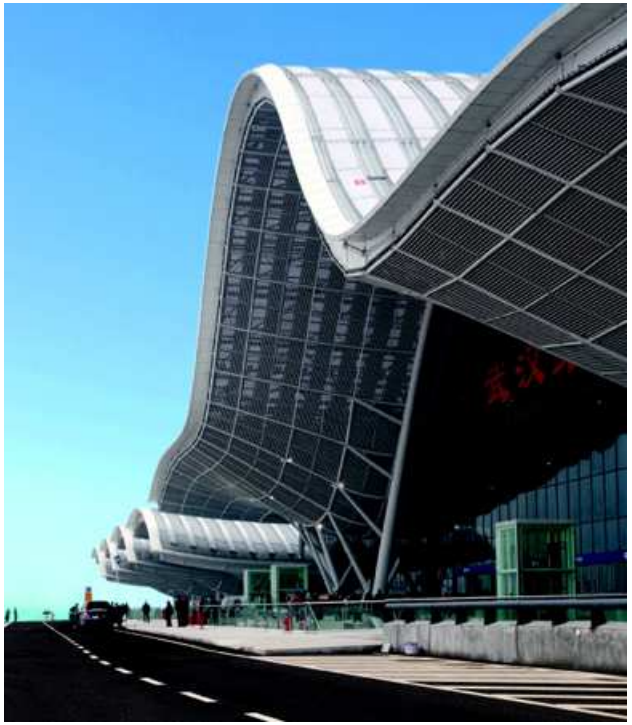




Science For A Better Life

Solar Impulse – A Challenging Development for Bayer

April 10th 2014, Malmö

Dr. Bernd Rothe

Overview

- What is Solar Impulse? Why is Bayer involved? What is Bayer?

- Timeline of the Solar Impulse Project
- What happened in 2013
- Where is Bayer present in the airplane
- Which materials are used? Why are they used?
- What did Bayer do technically?

Solar Impulse Project Scope

- Manned flight around the world by day and night with a solar-driven airplane
- Demonstrate the potential of renewable energies and new technologies
- Encourage people to develop a pioneering spirit

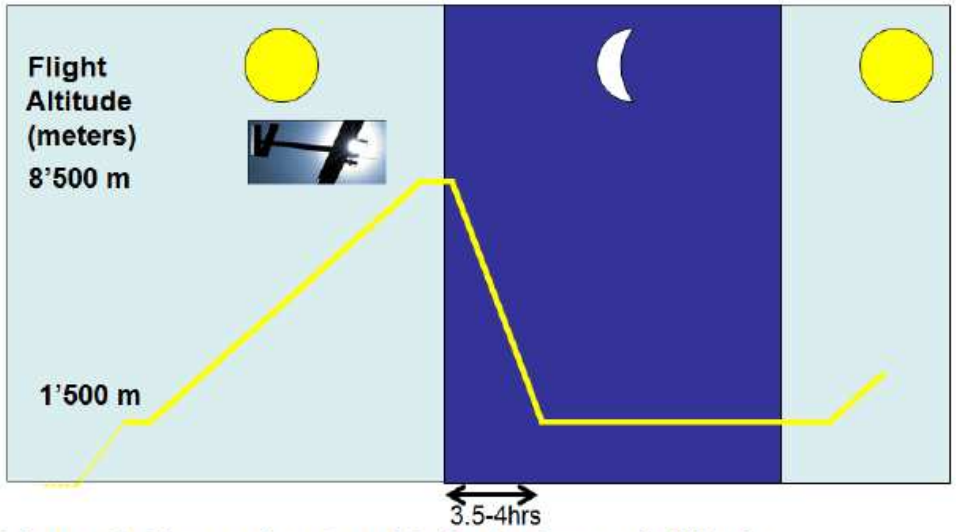


Figure 2: Energy is stored in batteries and altitude

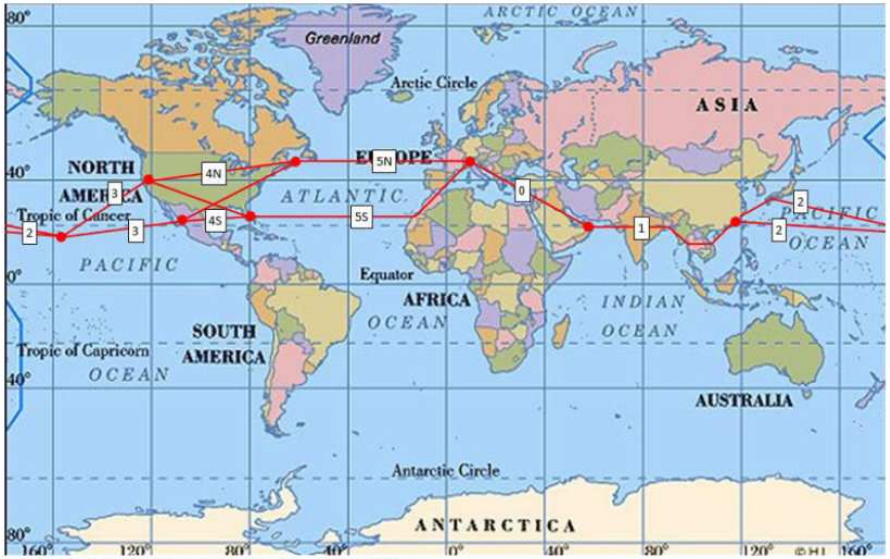


Figure 3: Round the world draft routing options

Pictures from Solar Impulse

Solar Impulse History – Already 10 years

SOLAR IMPULSE 10 YEARS OLD

Pictures from Solar Impulse

Solar Impulse is 10 years old – but since when?

Since I first had the idea following my round-the-world balloon trip in 1999? Since I met Paul McCready, the pioneer of solar flight, for the first time ? Or since the EPFL agreed to launch a feasibility study?

Since the collaboration with André Borschberg? The signature of the first partner, which enabled us to get the company off the ground? The first flight?

It's certainly a little of all of that, but nevertheless it is the 28th of November 2003 that I would like to celebrate with you, who have followed us for so long.

That was the point of no return, the date this absolutely mad dream of going round the world in a solar aeroplane was first announced to the media. That day, André and I burned the bridges that would have still allowed us to abandon the idea, to give up. But once we had made the public announcement, we were condemned to go all the way.

Solar Impulse Project

An adventure for progress and sustainability

Today's technology, tomorrow's energy

Achieving the impossible through pioneering spirit

Push existing technologies to the limit!
Start thinking and developing completely new solutions

Picture from Solar Impulse

Solar Impulse an Airplane?

- Yes but: *"This plane was not built to carry passengers but to convey messages"*

Technical datasheet

Wingspan: 63,40 m (208 ft) Weight: 1 600 Kg (3,527 lb)

Length: 21,85 m (~71 ft) Height: 6,40 m (~20 ft)

Motors: 4 brushless, sensorless electric engines

> each developing 10hp

Monocrystalline silicon solar cells : 11 628

> 10 748 on the wing, 880 on the horizontal stabilizer

Average flying speed: 70 km/h (43 mph)

Take-off speed: 44 km/h (27 mph)

Maximum cruising altitude: 8 500 m (27 900 ft)

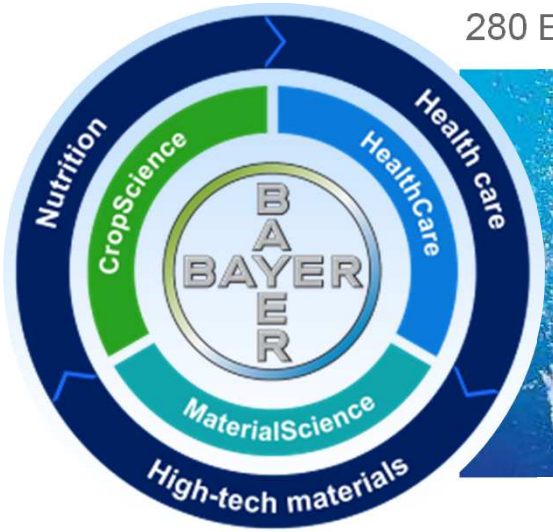
"The wingspan equal to that of an Airbus A340, and its proportionally tiny weight – that of an average car."

- The goal is not to build a new type of solar-powered electric airplane or to compete with today's fossil-fueled jet airplanes

Bayer
Science For A Better Life

110.500 Employees
280 Entities

Turnover 2012: 39.8 bn €
R&D 2012: 3.0 bn €



Subgroups:

HealthCare
- Pharma
- Consumer Care
- Medical Care
- Animal Health

MaterialScience
- Polycarbonates
- Polyurethanes
- Coatings, Adhesives and Specialties

CropScience
- Crop Protection
- EnvironmentalScience
- BioScience

Bayer MaterialScience

Full Year 2012

Employees*	**14,500**
Sales	**€11,503 million**
EBITDA before special items	**€1,251 million**
Chairman	**Patrick Thomas**

* Employees in full-time equivalents

Bayer
Science For A Better Life

PUR

Otto
Bayer

- The inventor of polyurethanes: Dr. Otto Bayer
- Elastic and rigid materials

Flexible Foams | Rigid Foams

CAS

Kuno
Wagner

- The inventor of aliphatic polyurethane coatings: Dr. Kuno Wagner
- Excellent weatherability, durability, gloss, efficiency in application

Coatings for Automotive | Coatings for Airplanes

PCS

Hermann
Schnell

- The inventor of Polycarbonates: Dr. Hermann Schnell
- Crystal clear transparency, high temperature resistance, ductility

Water-/Food Packaging | Glazing Construction, Automotive

The Faces behind Bayer's Activities

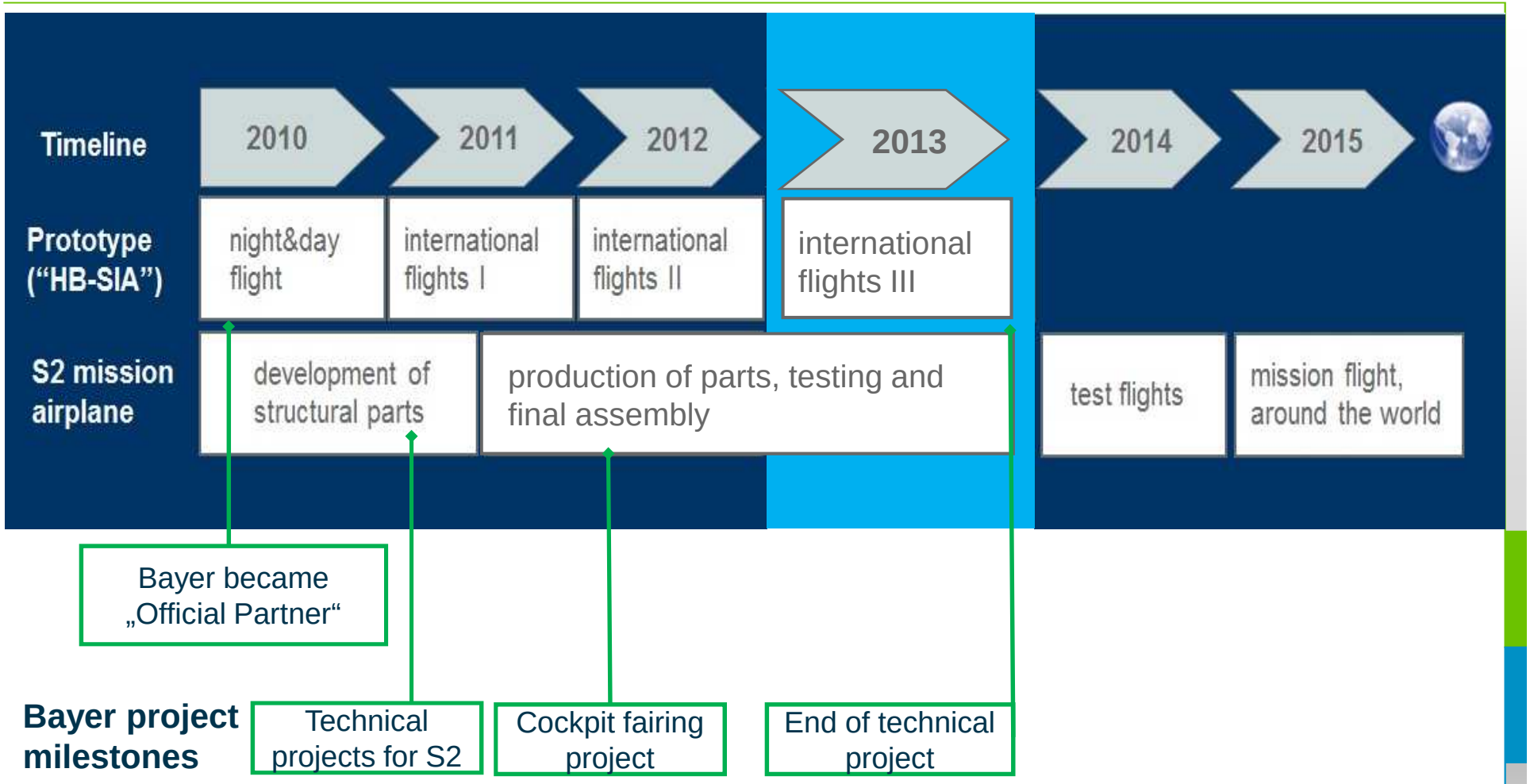
- Interdisciplinary team of 30 Bayer people working on Solar Impulse
- Scientists and laboratory technicians
- Product developers and design engineers
- Calculation, simulation and testing experts
- Prototype, process and tooling experts
- Purchasers and supply chain coordinators
- Marketing and communications experts

The History of Solar Impulse

Solar Impulse History HB-SIA

2003	Project start
2004-2006	Concept, design and calculations
2007-2009	Prototype (HB-SIA) construction and unveiling on June 26th 2009
2010	First test flights and first night flight on July 7th in the history of solar aviation, lasting in total 26 hours, 10 minutes and 19 seconds
2011	Solar Impulse HB-SIA flies to Brussels and then to Paris-Le Bourget
2012	Mission to fly across the Mediterranean see to Morocco . This journey took place in 7 legs: Payerne-Madrid-Rabat-Ouarzazate-Rabat-Madrid-Toulouse-Payerne
	Virtual 72 h flight of Andre Borschberg in February

Timeline Overview



Main Solar Impulse Events in 2013

Prototype (“HB-SIA”):

- Disassembly, shipment, reassembly
- Across America flight

1. San Francisco, Mountain View, CA;

2. Phoenix, AZ; 3. Dallas, TX; 4. St. Louis, MO;

5. Washington D.C.; 6. John F. Kennedy, New York City

Pictures from Solar Impulse

Activities for S2 (“Solar Impulse 2”) the “Mission Airplane”

- 06/2013 – Wind tunnel test
- 08/2013 – Wing spar test
- 12/2013 – Final assembly and 72 h virtual flight

Pictures from Solar Impulse

The Involvment of Bayer

-> beyond Knowledge and Material

Bayer Solutions for HB-SIA

High-performance polyurethane rigid foams used in wing tips, motor gondolas and cabin

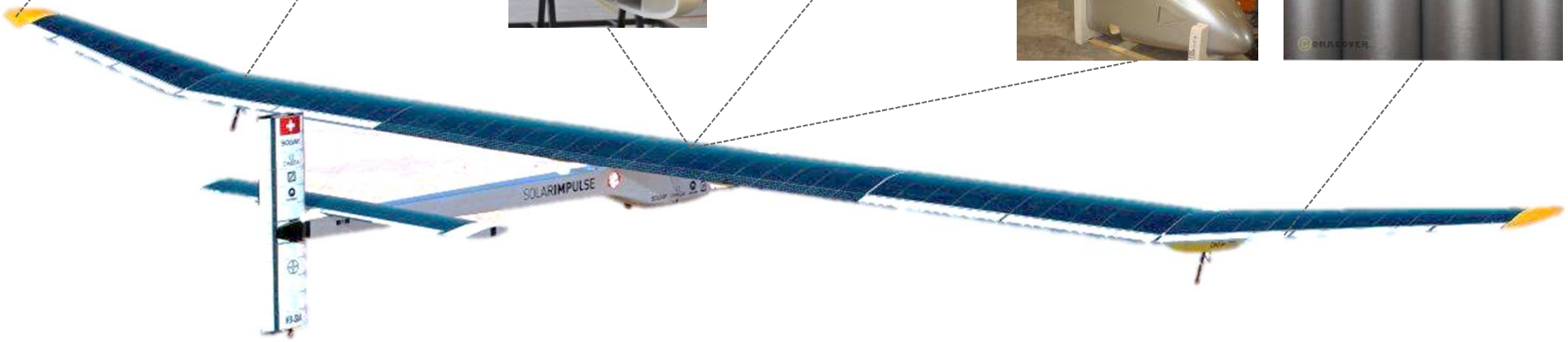
High-performance polycarbonate films used in cabin window

High-performance adhesives and coating raw materials used in cabin and structure covering films and wing covering textile









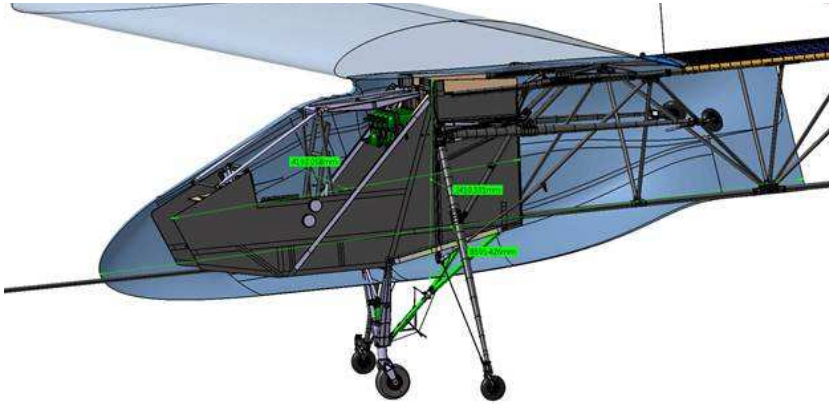
© Solar Impulse

Bayer Projects for Solar Impulse 2

- Provide materials and technologies based on Polyurethanes for a lighter airplane
  - Overall seven different polyurethane related projects
- Develop the complete cockpit fairing for Solar Impulse 2
  - Use the knowledge and materials of Bayer to create solutions for the faring
- Carbon nanotubes (CNT, Type Baytube) development and adaptation for the carbon fiber composite parts

Goal for the Cockpit Fairing Project

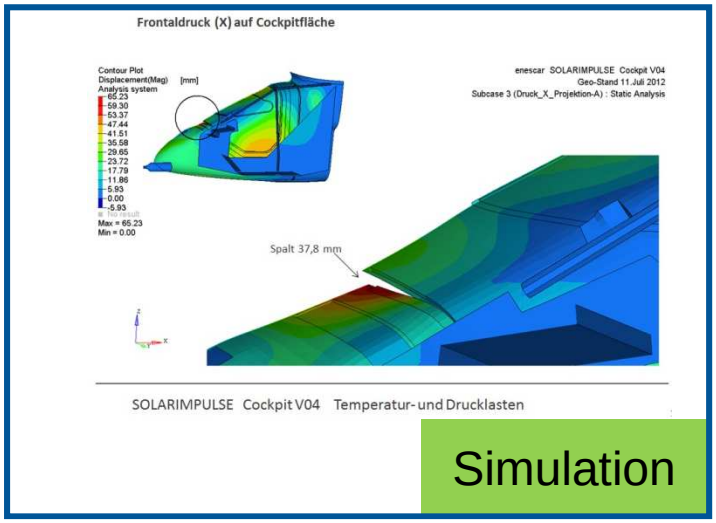
Development, design and delivery of the complete cockpit fairing for S2



Cockpit fairing is the outer shell (light blue) of the cockpit (black)

- 42 m² need to be covered and equipped with the needed functions with an overall weight of less than 35 kg
- Safe and comfortable cockpit habitat for the pilot considering outside temperatures of +40 ℃ to -50 ℃ and a minimum inside temperature of -20℃
- Aerodynamic design with an sufficient stiffness and a flutter free construction

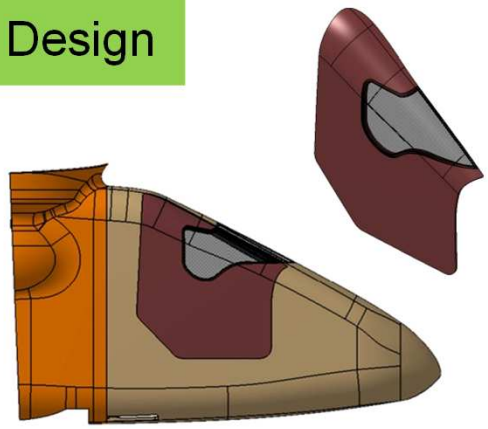
Overview for the Cockpit Fairing Project



Simulation

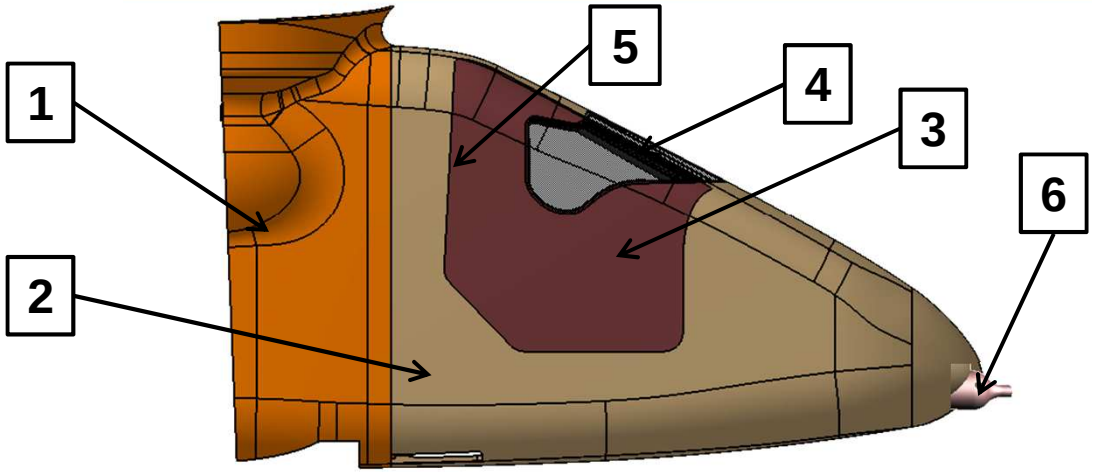
Construction

Design

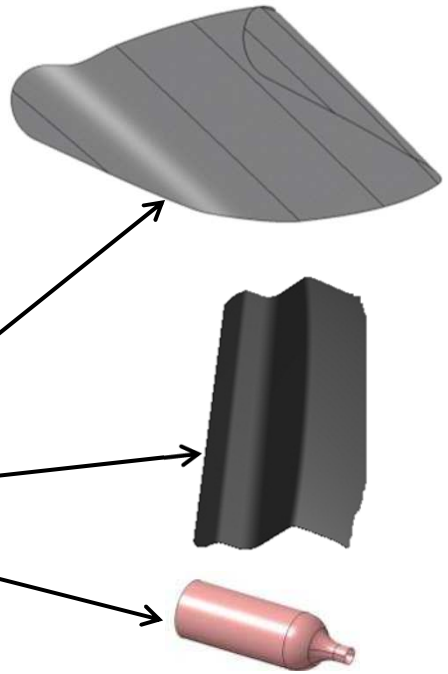


Testing

Which Materials are used for the Fairing of Solar Impulse 2?

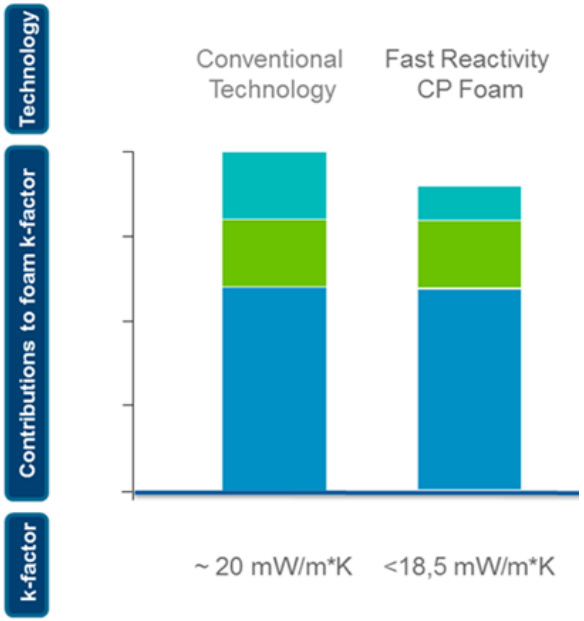


Part	Material
1,2	Polyurethane rigid foam
3	Microcell foam
4	Transparent Polycarbonate sheets
5	Carbon fiber PUR composite (RTM)
6	Carbon fiber PUR composite (filament winding)
Suppl.	Impranil and others

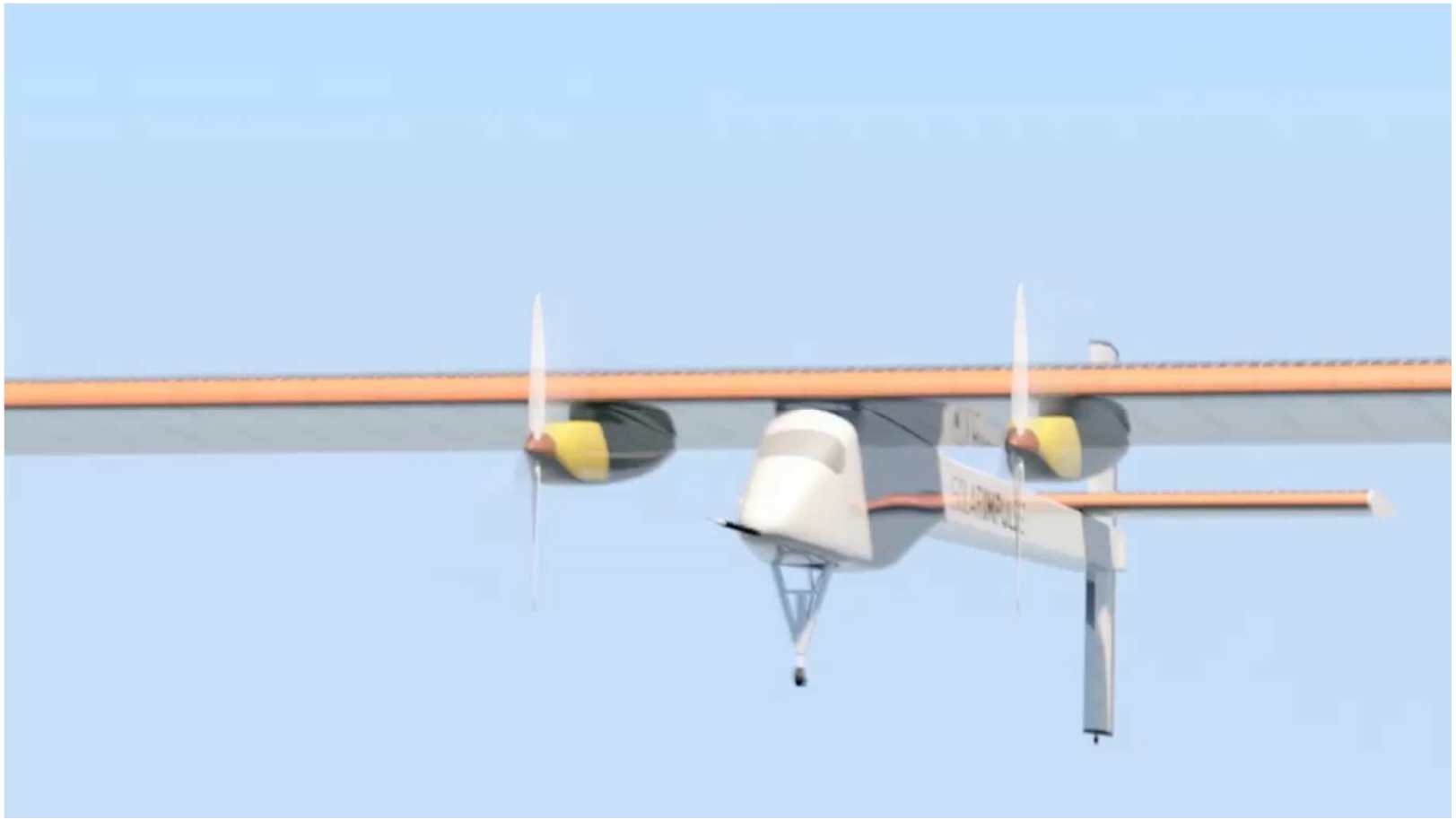


Further Development of Polyurethane Rigid Foam

- By chemical modification and process adaption the cell size of the polyurethane rigid foam was minimized by 40 % allowing for a lower lambda value at equivalent other properties
- The product also exhibits excellent flow behavior and when molded enables for a quick remove from the mold



Temperature Inside the Cockpit



Thickness needed for an Optimum Cockpit Insulation

Calculations performed for the cockpit inside temperature for a night flight with

- Heat sources inside the cockpit (pilot and instruments) Q = 430 W
- Surface of the Polyurethane insulation (s = 12,84 m²) with a lambda value of 0,023 W/Km
- Surface of the canopy made of a polycarbonate sandwich (c = 1,51 m²) with a lambda value of 0,2 W/Km

- Resulting thickness

  t = 28 mm for a minimum inside temperature of - 18 ℃ (target was – 20 ℃)

Composite Parts Made by Resin Transfer Moulding (RTM)

Production of the door hinge made of a carbon fiber composite with a polyurethane matrix

Door with the hinge made of a PU-carbon fibre composite

Resin Transfer Molding (RTM)

Production Sequence for the hinge made of a carbon fiber composite with a Polyurethane matrix

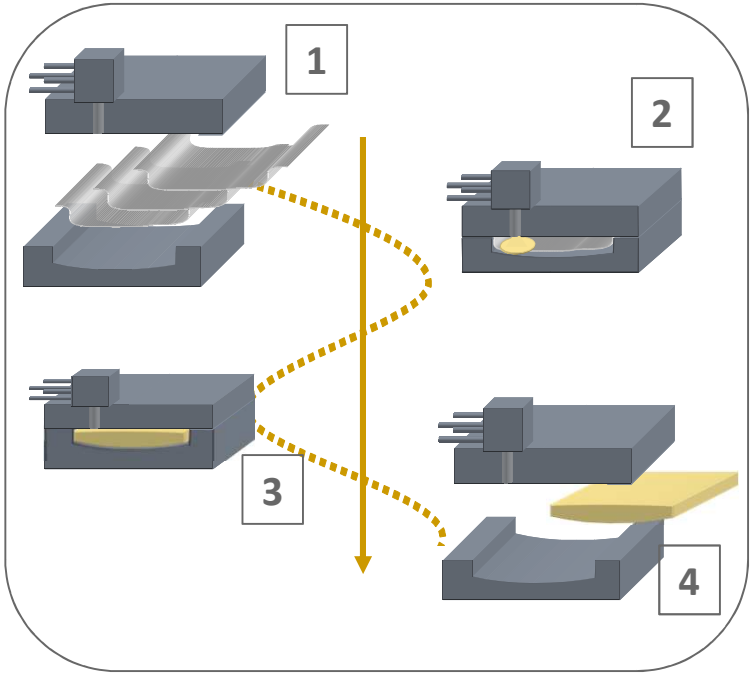

Source: BMS

1 prepare mold, lay-up fibers

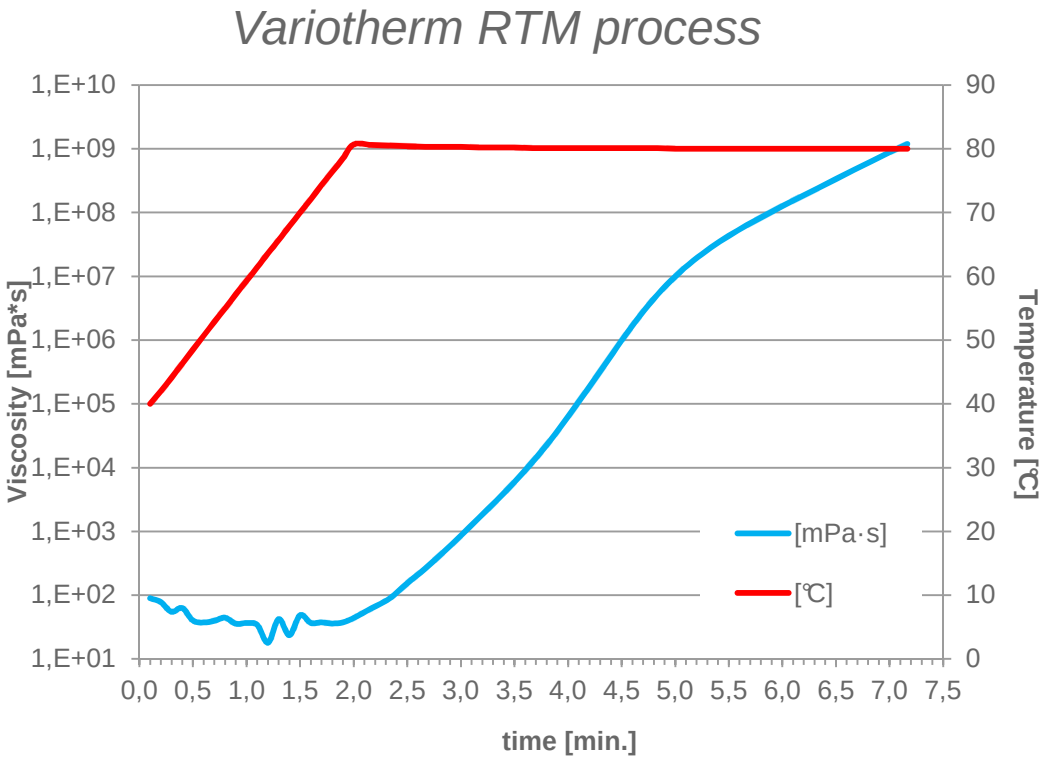
2 close mold, inject PUR resin

3 reaction of PUR resin

4 demoulding of final RTM part



Chemical Development needed for an optimum PUR Resin



Processing requirements:

1. Low viscosity during injection
2. Latent catalysis of reaction mixture
3. Good wetting behavior of fibers

Material requirements:

4. Good dimensional stability
5. Sufficient flexural modulus
6. High glass transition temperature

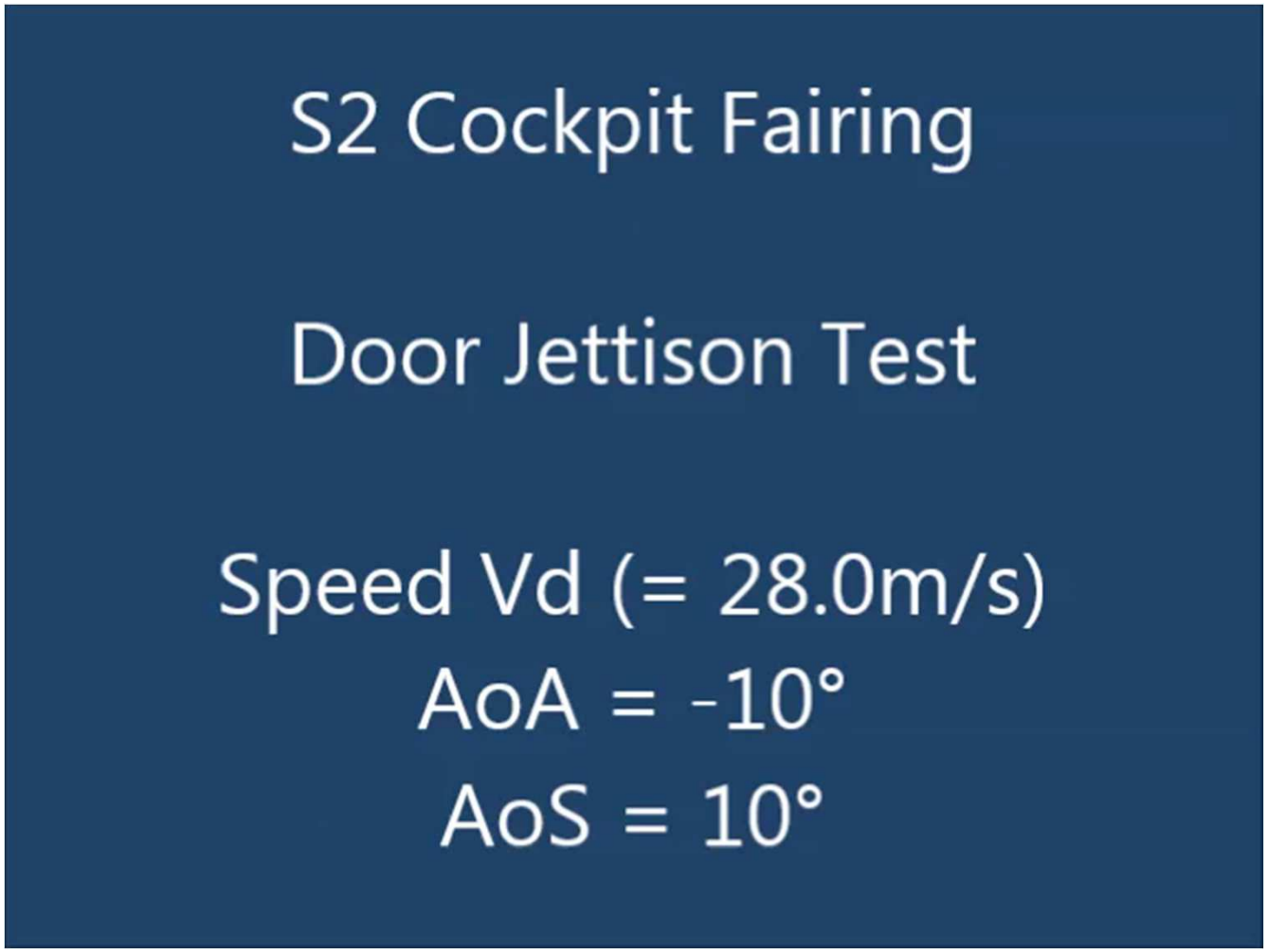
Testing of the Final Part

- Mechanical (static and dynamic) tests of all the produced parts
  - Wing spar was tested under different load conditions

  - Dynamic test of the complete fairing in a wind tunnel in Luzern

Pictures from Solar Impulse

Testing of the Fairing in the Windtunnel



Vd= Design dive speed 100 km/h
AoA = Angle of attack
AoS = Angle of sideslip

Cockpit Fairing Test of S2

- New cockpit design was fully tested and finally approved by Solar Impulse
- Mounting and optimization/finishing was done by Solar Impulse

- S2 has 20 % more wingspan and 35 % more solar cells

Bayer´s Solutions were chosen due to a high Level of Performance

Fairing shell made of ultra-low-density polyurethane rigid foams, providing

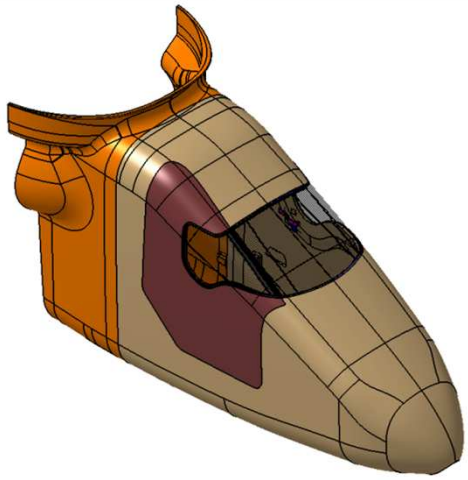
- Outstanding insulation and mechanical properties
- Optimal protection of pilot and cockpit equipment
- Easy processing, maintenance and repair

Canopy made of special thermoformed multi-layer polycarbonate sheet providing

- Better-than-glass mechanical properties at glass-like appearance
- Safety functions such as anti-fogging

Fairing cover made of specially coated film providing

- Excellent weather resistance and mechanical properties
- Optimized aerodynamics and enhanced look-and-feel



Canopy opening system made of polyurethane carbon-fiber composite, produced in resin-transfer-molding process (RTM), providing

- High mechanical strength needed in case of bail-out

… all at being ultra lightweight! → approx. 24 kg for the complete fairing

Summary

- Within the Solar Impulse project new materials were developed
- Knowledge of new technologies for these materials was developed
- Some solutions are now development projects, i.e.
  - flame resistant foams
  - highly insulating rigid foams
  - Polyurethane matrices for different composite processes (RTM)

- Bayer provided innovative materials solutions

„Ohne Bayer würde die Solar Impulse nicht fliegen“, sagt Piccard.

Die Welt, 19.07.2013

Thanks to the Team:

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BACKUP

Bertrand Piccard from Solar Impulse live at the K-Fair in Düsseldorf

During a talk Bertrand Piccard showed the involvement of BMS within Solar Impulse and answered questions with Patrick Thomas during the VIP-Talk