Solar Impulse, First Round-The-World Solar Flight

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Flight Test & Dynamics
Solar Impulse
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An idea born in Switzerland

SOLAR IMPULSE
AROUND THE WORLD IN A SOLAR AIRPLANE
BERTRAND PICCARD
PSYCHIATRIST-EXPLORER
HANG-GLIDING CHAMPION
GOODWILL AMBASSADOR
1ST ROUND WORLD BALLOON FLIGHT
ANDRÉ BORSCHBERG
ENGINEER-ENTREPRENEUR
GRADUATE OF MIT
SWISS AIRFORCE PILOT
WORLD’S LONGEST SOLO FLIGHT
Flight Testing
Ground Tests and Flight Missions
Civil Aviation Certification
Challenges and Achievements
SOLAR IMPULSE
AROUND THE WORLD IN A SOLAR AIRPLANE

WEDNESDAY

I CAN'T FIT IN THERE, I AM LARGER THAN A BOEING 747!

THURSDAY

10-11 H. UTC TIME

FRIDAY

LANDING SLOT

CROSSWIND SPEED (KNOTS)
AHMEDABAD 1095 KM VARANASI

SOLAR IMPULSE AROUND THE WORLD IN A SOLAR AIRPLANE

ALITUDE (ft)

LANDSCAPE

BATTERY (%)

#SOLARIMPULSE
6 BOTTLES OF OXYGEN

2.5L OF WATER

2.4KG OF FOOD
TIMELINE

December 2009 – The flea hop

2011 European Solar Flights

2013 – Across America

Summer 2014 – Test Flights

July 2010 Solar Impulse Night Flight

2012 – Crossing Frontiers

April 2014 – Unveiling Solar Impulse 2

2015 The Round-The-World Solar Flight
AS WITH ALL MAJOR FIRSTS, THERE ARE NO PAST REFERENCES TO GUIDE US
Model-Based Design of the Aircraft

- Tail Sizing, Fuselage Shape
- Wing Dihedral, Ailerons
- Engine Position
- Autopilot, Avionics, Inertial Platform (Automatically Generated Code)
Where It All Started: Flight Simulation in 2007
Mission Simulation in 2007
Flight Simulator in 2008 for 25h Test
Combined 72h Mission and Flight Simulation 2012 and 2013
Combined 72h Mission and Flight Simulation 2012 and 2013
How did we Leverage MathWorks Design Flows

Avionics Verified and Validated with Polyspace

Autopilot Verified and Validated with Model-Based Design
Study to Decide
One Aileron Servo vs. Two Rudder Servos
Formal Analysis of Avionic Software to DO-178B applying Polyspace Bug Finder and Code Prover

- > 290k Lines of Code

- Power Management / Mission Information Computer
  → QNX on COTS Board (x86, 32 Bit, 500 MHz, UNIX RTOS)

- Throttle Box, Air Data Computer, Independent Display
  → ATMEL on SI Boards (ATCAN90, 8 Bit, 8 MHz, No OS)

- Monitoring and Alert System
  → ARM on ALTRAN Board (Cortex-M4F, 32 Bit, 168 MHz, No OS)
Formal Analysis of Avionic Software to DO-178B
applying Polyspace Bug Finder and Code Prover

- Latent bug or defect hunting, e.g. incorrect temperature in throttle box
- No test cases or compilation needed

```c
// Enabled ADC
ADCSRA |= (1<<ADEN);

// Clear Status Trig.
// Start ADC
ADCSRA |= (1<<ADSC);

while((ADCSRA & (1<<ADSC)) == 1);
```

```c
// Clear Status Trig.
// Start ADC
ADCSRA |= (1<<ADSC);

while((*(volatile uint8_t *)0x7A) & (1<<6)) == 1);
```

```c
Probable cause for 'Dead code':
while((ADCSRA & (1<<ADSC)) == 1);
```
Formal Analysis of Avionic Software to DO-178B applying Polyspace Bug Finder and Code Prover

- Independent, systematic code reviews, compliance to MISRA-C
- Complexity results to support DO-178B “simple system” argument for case where we had to “re-engineer” design assurance level equivalence
- Bug Finder and Code Prover provided 1-2 Man-Year savings and automated capability in parallel to development which were not available otherwise
Concluding Remarks

Model-Based Design with MATLAB and Simulink helps us
- Reuse, build, test and fly whilst exploring new ideas and concepts
- Make key design decisions early, saving time and avoiding manually coded errors
- Focus on design and development instead of low-level coding
- Understand the system and its interdependencies
- Validate and verify the final performance including pilot training
- Adapt to new situations in pre- and during-flight

Using Polyspace code verifiers
- Identified and fixed potential run-time errors and unsafe code
- Reliably analyzed C codebase early, without test cases and compilation!
we made it!
WHAT WAS ACHIEVED IN 2015

- 8 FAI WORLD RECORDS
- 225 FLIGHT HOURS
- 19,957 KILOMETERS
- 7 COUNTRIES
- 8 FLIGHTS
- 5,644 kWh of solar energy produced
WHAT IS PLANNED FOR 2016

APRIL 20TH 2016

Vancouver
San Francisco
Los Angeles
Phoenix
New York

SUMMER 2016

UK
France
Spain
Greece
Morocco
Egypt
Abu Dhabi
Saudi Arabia
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