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
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
I can't fit in there, I am larger than a Boeing 747!
6 BOTTLES OF OXYGEN

2.5L OF WATER

2.4KG OF FOOD

-20°C

+20°C
TIMELINE

December 2009 – The flea hop

July 2010 Solar Impulse Night Flight

2011 European Solar Flights

2012 – Crossing Frontiers

2013 – Across America

April 2014 – Unveiling Solar Impulse 2

Summer 2014 – Test Flights

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)
Latent bug or defect hunting, e.g. incorrect temperature in throttle box

No test cases or compilation needed
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
Saudi Arabia
Abu Dhabi
An idea born in Switzerland

SOLAR IMPULSE
AROUND THE WORLD IN A SOLAR AIRPLANE