Solar Impulse, First Round-The-World Solar Flight

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Flight Test & Dynamics
Solar Impulse

June 21, 2016

An idea born in Switzerland

SOLARIMPULSE

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

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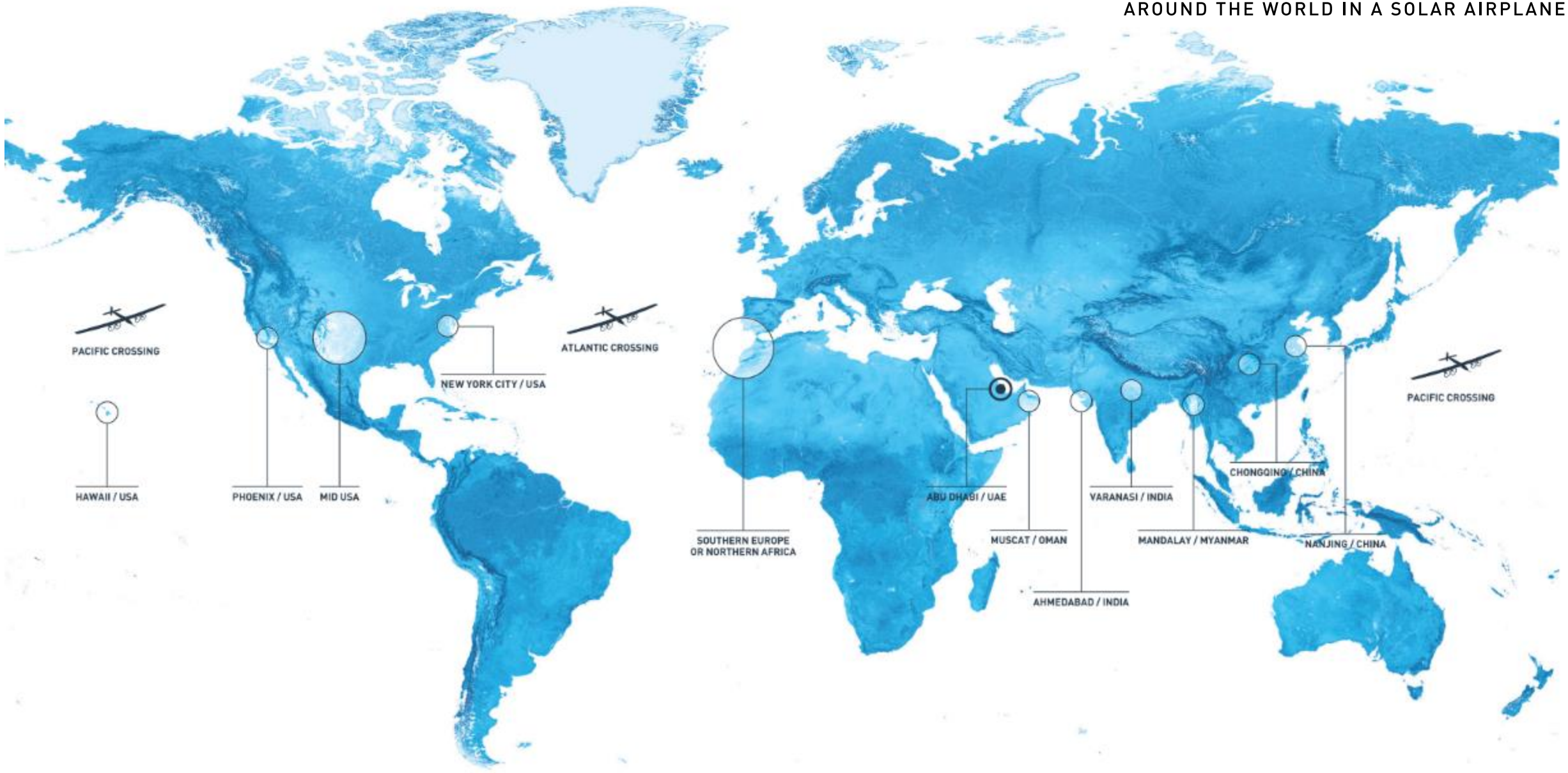
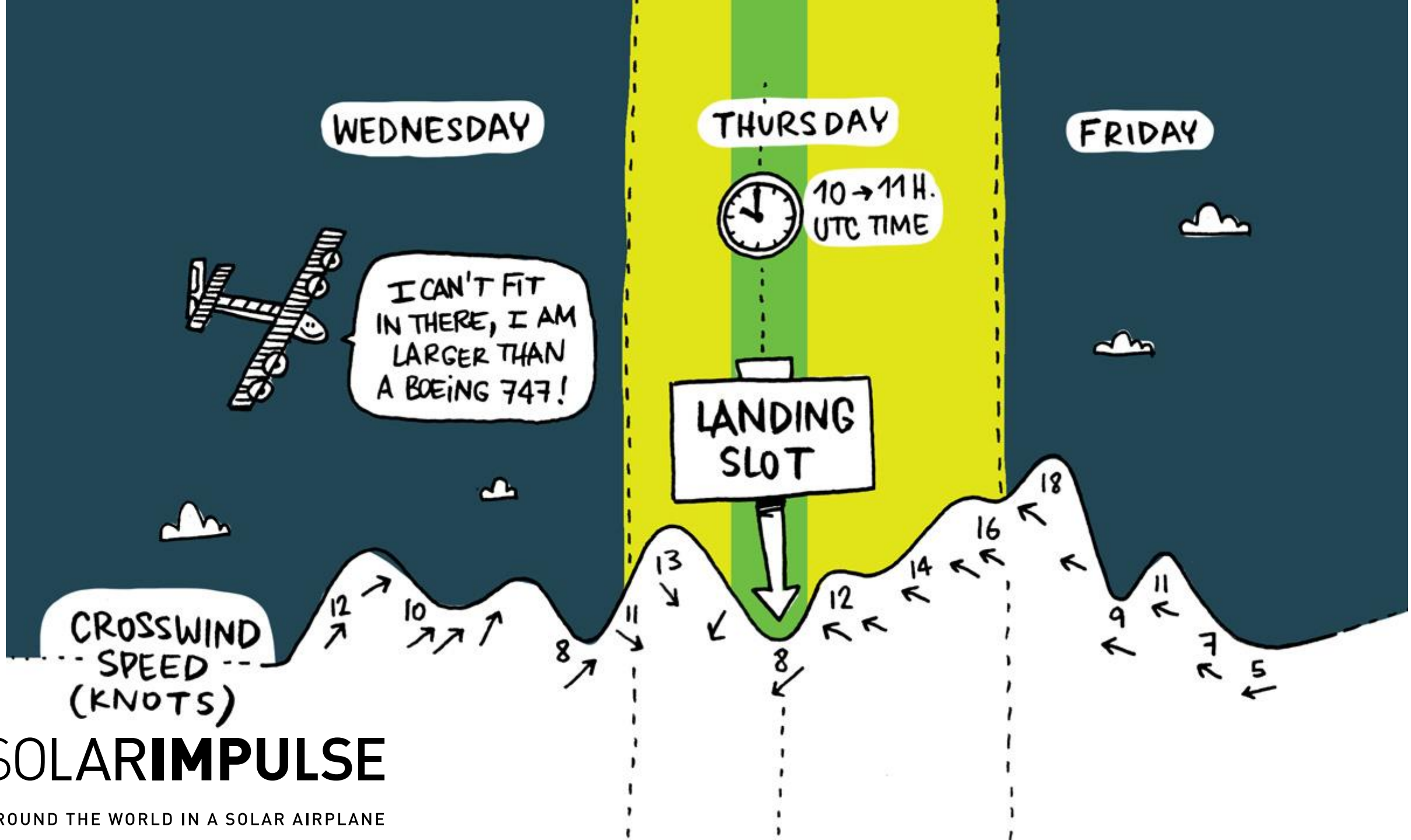
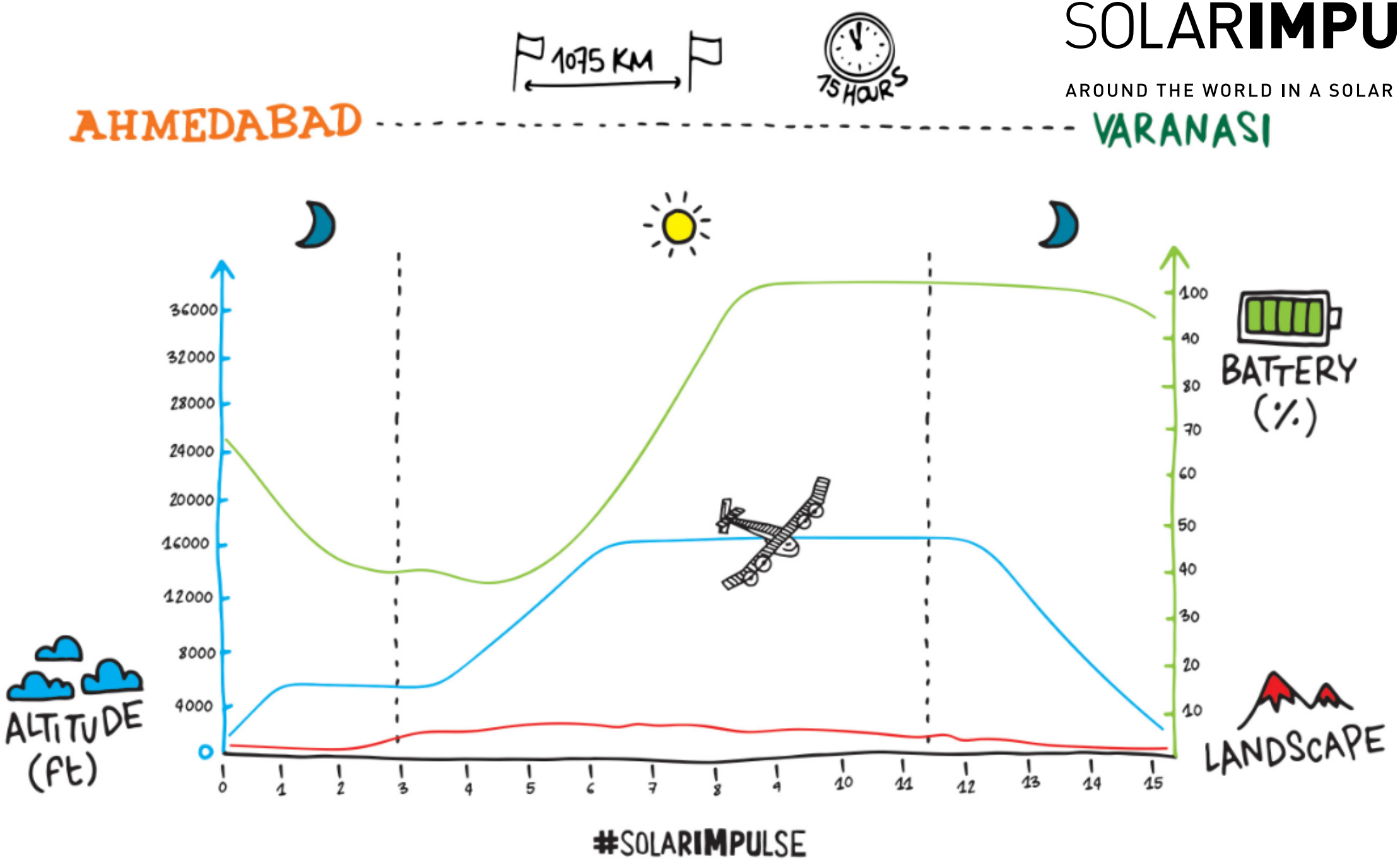
AROUND THE WORLD IN A SOLAR AIRPLANE

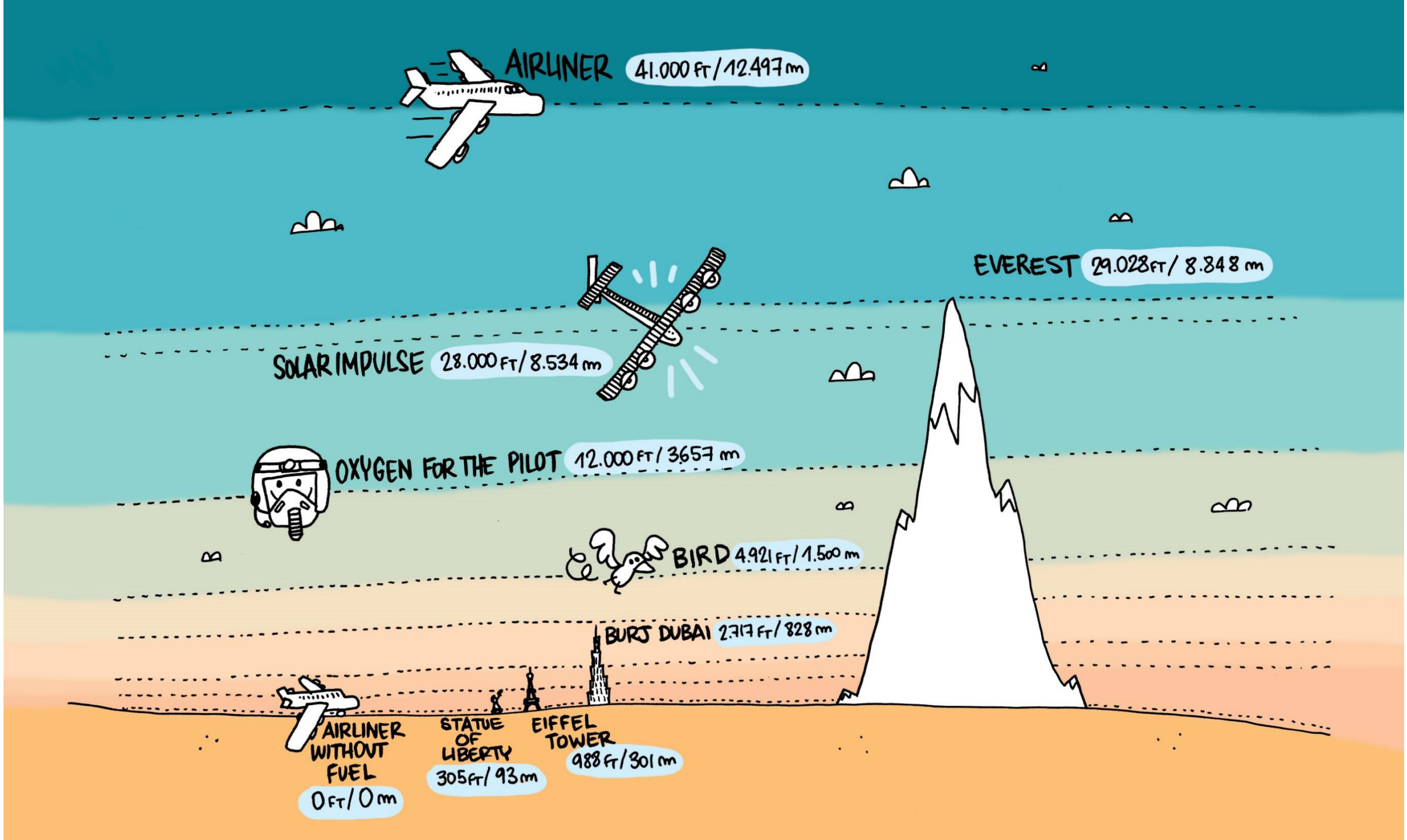




SOLAR**IMPULSE**

AROUND THE WORLD IN A SOLAR AIRPLANE


1075 KM
75 HOURS
AHMEDABAD
VARANASI
36000
32000
28000
24000
20000
16000
12000
8000
4000
0
100
40
80
70
60
50
40
30
20
10
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
BATTERY (%)
ALTITUDE (ft)
LANDSCAPE
#SOLARIMPULSE


AIRLINER
41.000 FT / 12.497 m
EVEREST
29.028 FT / 8.848 m
SOLAR IMPULSE
28.000 FT / 8.534 m
OXYGEN FOR THE PILOT
12.000 FT / 3657 m
BIRD
4.921 FT / 1.500 m
BURJ DUBAI
2.717 FT / 828 m
AIRLINER WITHOUT FUEL
0 FT / 0 m
STATUE OF LIBERTY
305 FT / 93 m
EIFFEL TOWER
988 FT / 301 m

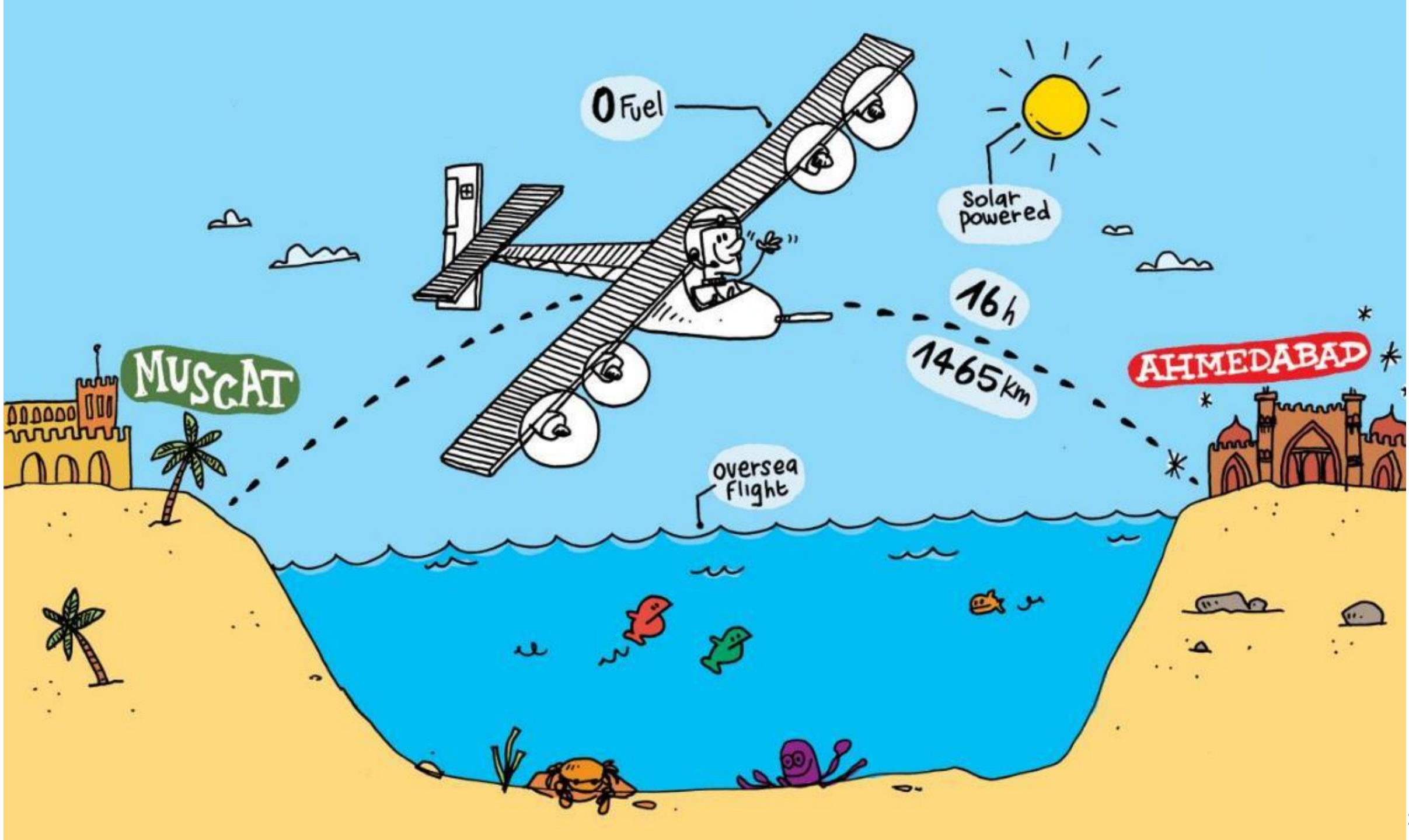
6 BOTTLES OF OXYGEN

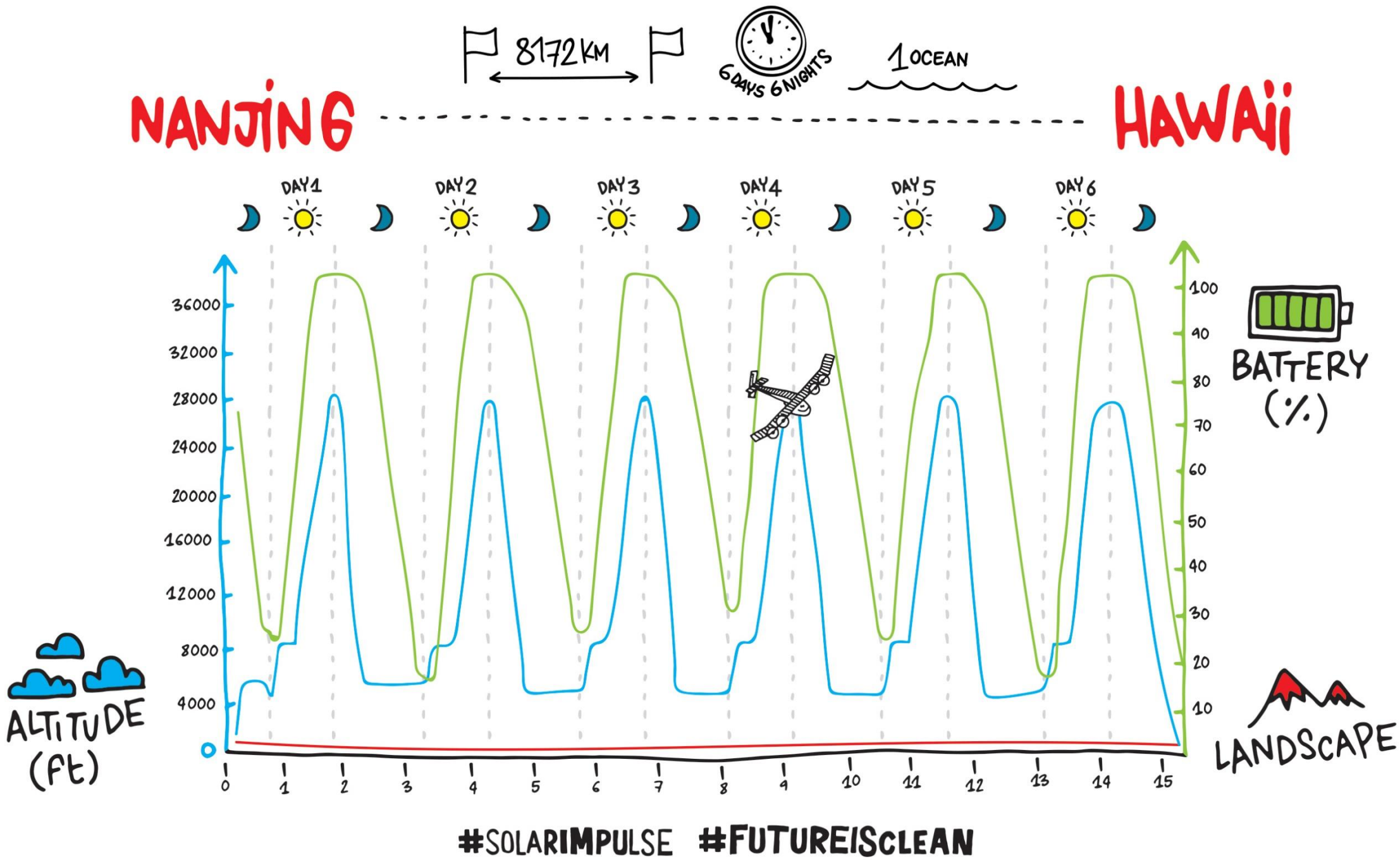
2,5 l OF WATER

2,4 KG OF FOOD

-20°C

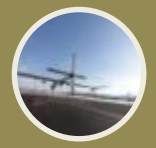
+20°C


0 Fuel
Solar powered
16h
1465km
MUSCAT
AHMEDABAD
oversea flight

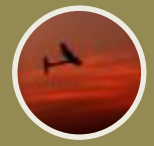

8172KM
6 DAYS 6 NIGHTS
1 OCEAN
NANJING
HAWAII
DAY 1
DAY 2
DAY 3
DAY 4
DAY 5
DAY 6
36000
32000
28000
24000
20000
16000
12000
8000
4000
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
100
90
80
70
60
50
40
30
20
10
BATTERY (%)
ALTITUDE (ft)
LANDSCAPE
#SOLARIMPULSE #FUTUREISCLEAN

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

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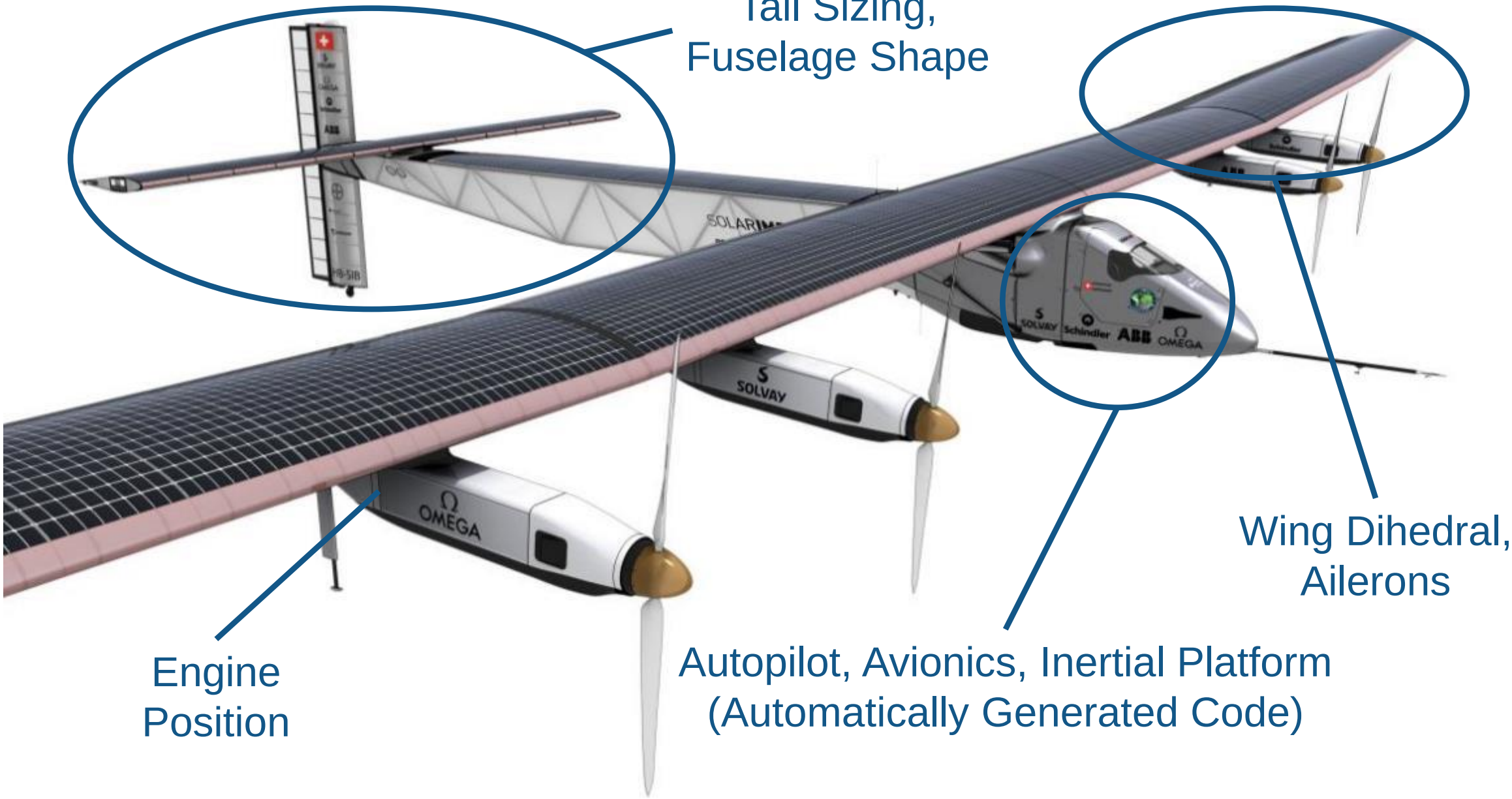
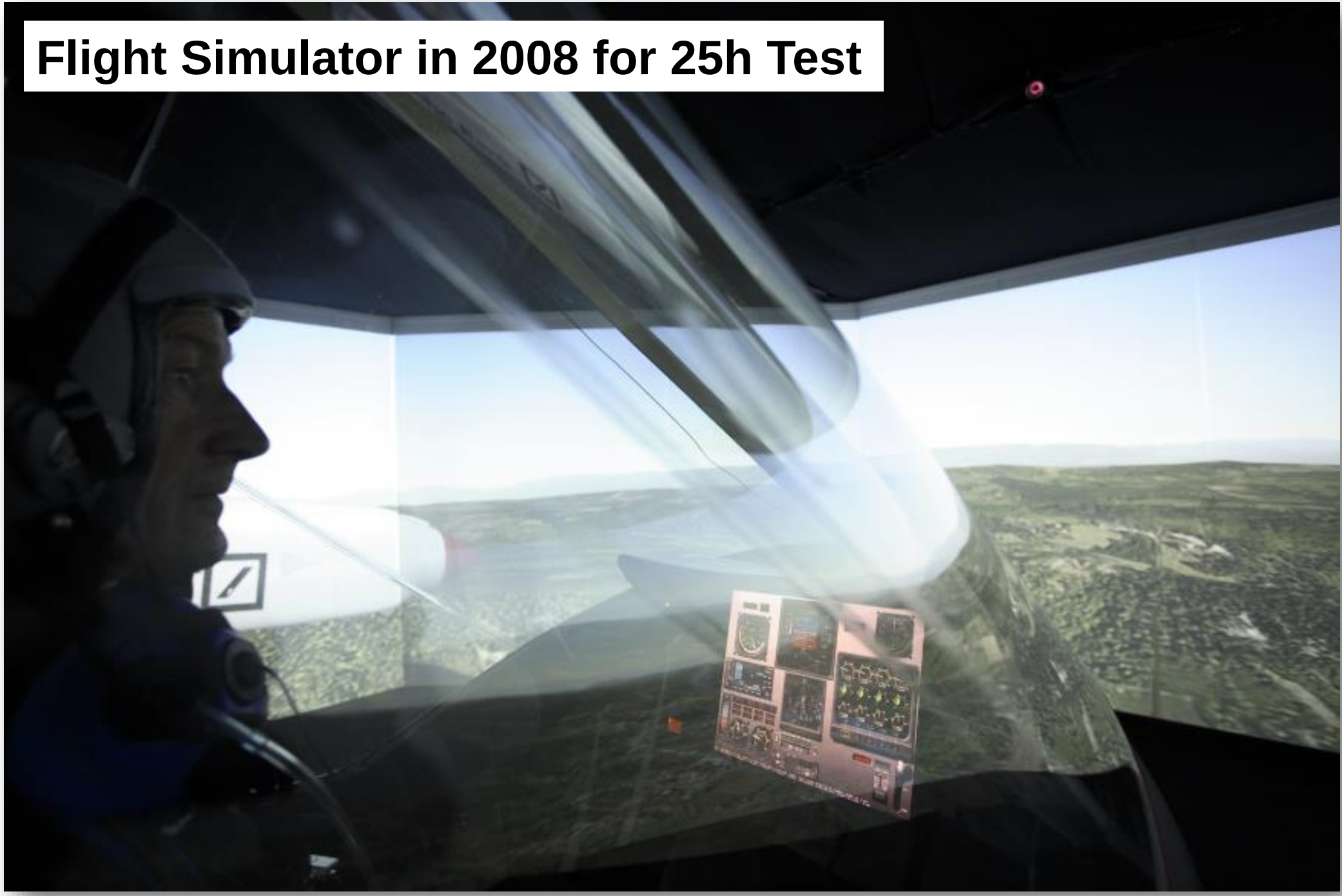
AROUND THE WORLD IN A SOLAR AIRPLANE



Where It All Started: Flight Simulation in 2007

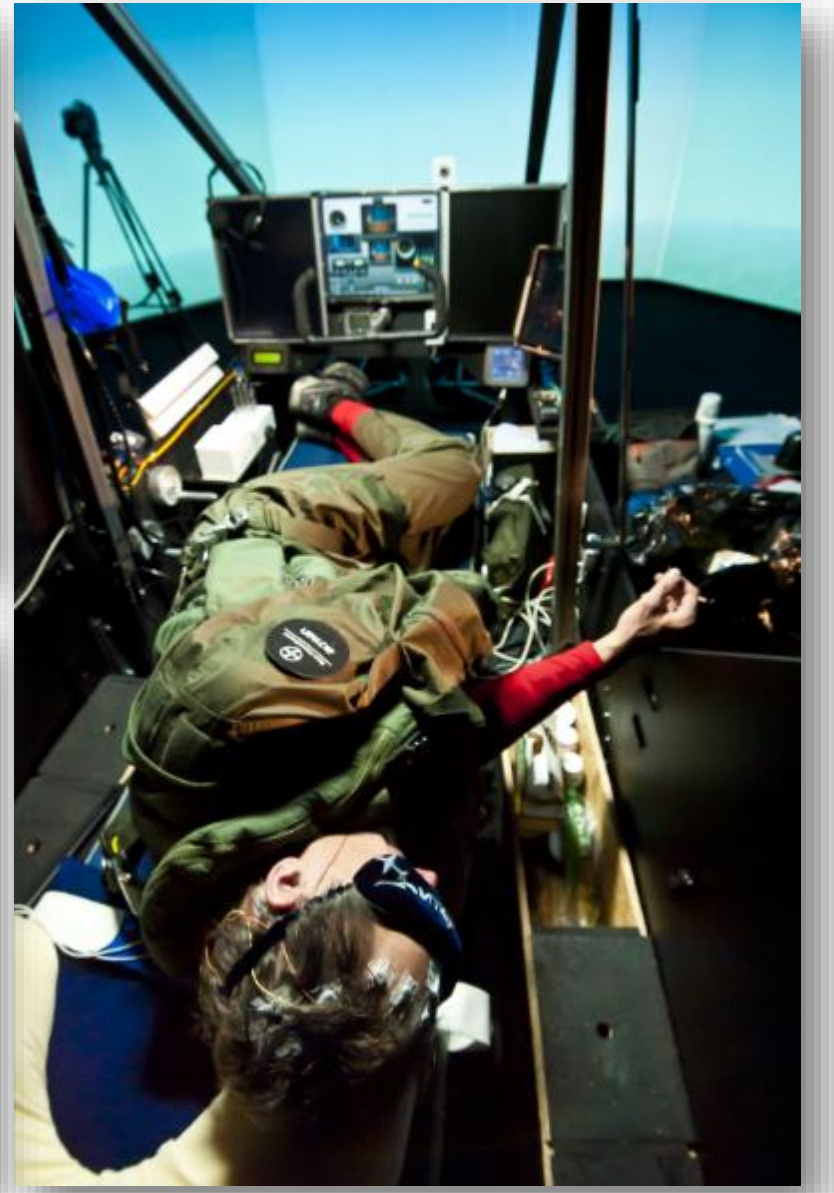
Mission Simulation in 2007

Flight Simulator in 2008 for 25h Test

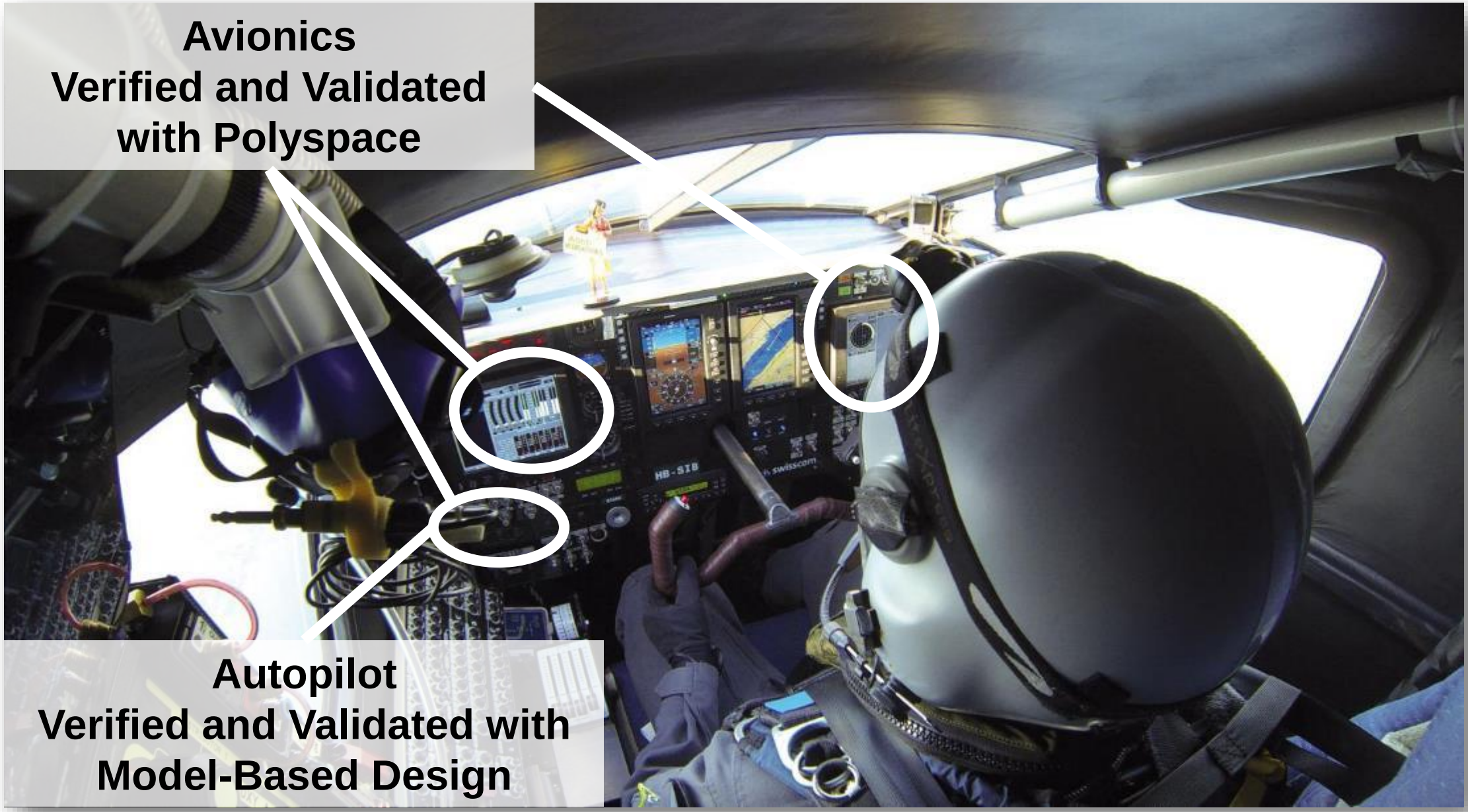


Combined 72h Mission and Flight Simulation 2012 and 2013

Combined 72h Mission and Flight Simulation 2012 and 2013



How did we Leverage MathWorks Design Flows



Autopilot (Basic Loop) in Simulink

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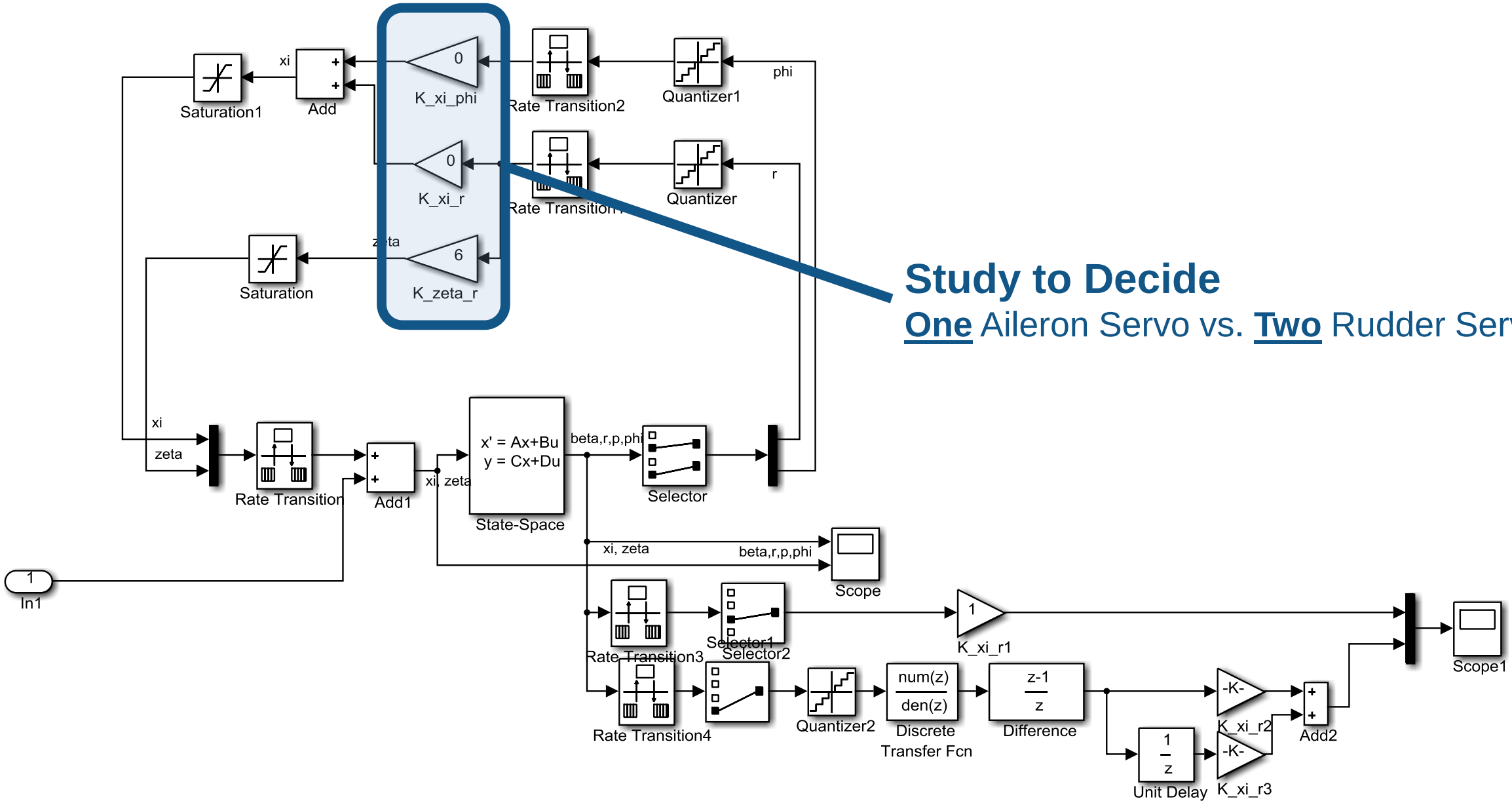

Study to Decide

One Aileron Servo vs. **Two** Rudder Servos

Formal Analysis of Avionic Software to DO-178B

applying Polyspace Bug Finder and Code Prover

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- > 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

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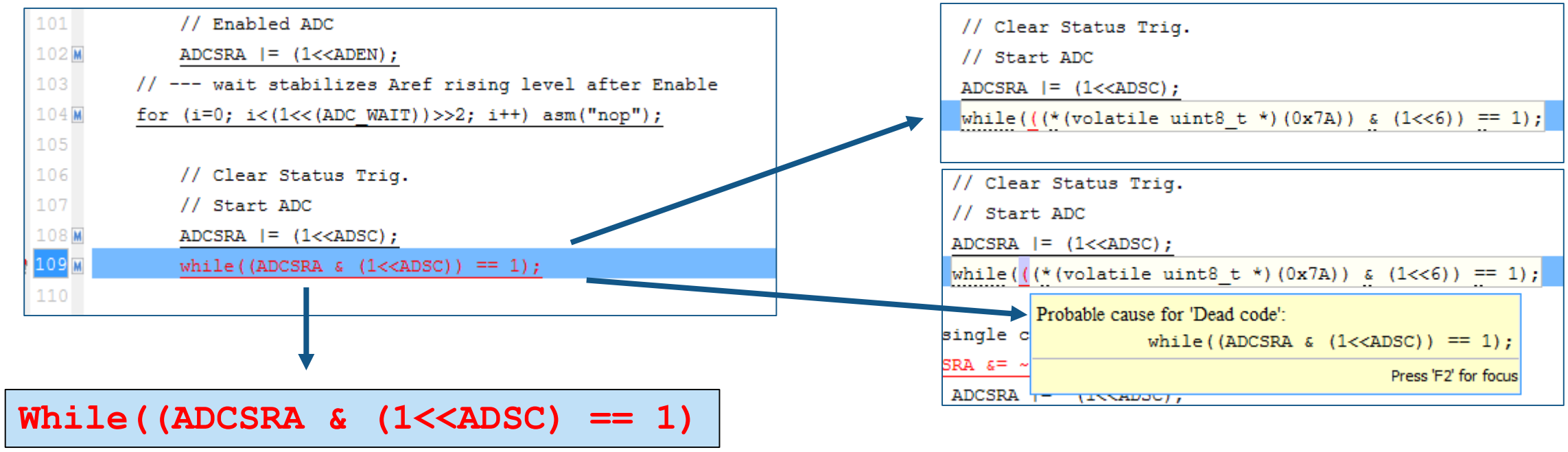
- Latent bug or defect hunting, e.g. incorrect temperature in throttle box
- No test cases or compilation needed



Formal Analysis of Avionic Software to DO-178B

applying Polyspace Bug Finder and Code Prover

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- 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

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AROUND THE WORLD IN A SOLAR AIRPLANE

Model-Based Design with MATLAB and Simulink helps us

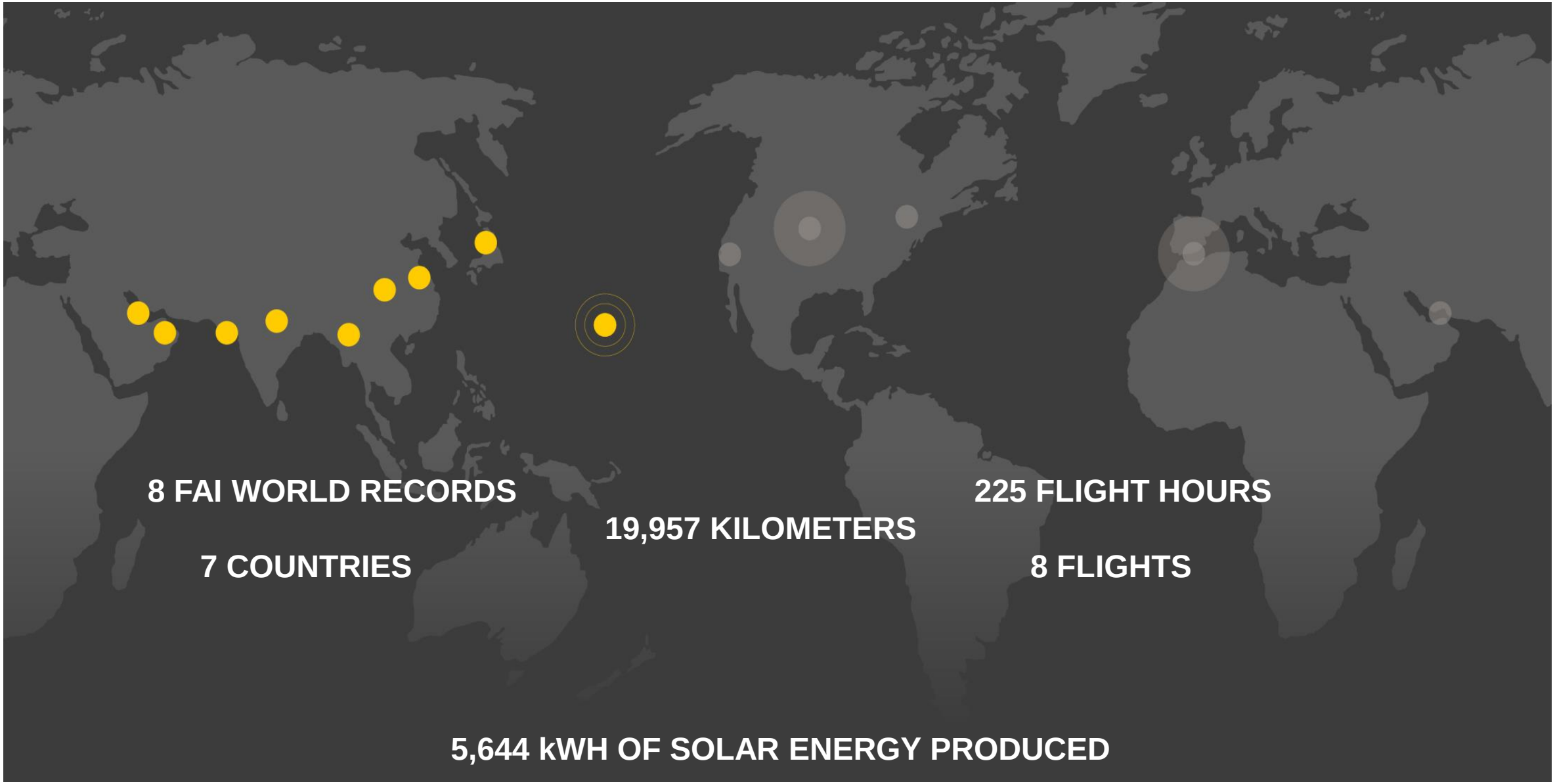
- Reuse, build, test and fly whilst exploring new ideas and concepts
- Make key design decisions early, saving time and avoiding manually coded errors
- Focus on design and development instead of low-level coding
- Understand the system and its interdependencies
- Validate and verify the final performance 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 ACHEIVED IN 2015



WHAT IS PLANNED FOR 2016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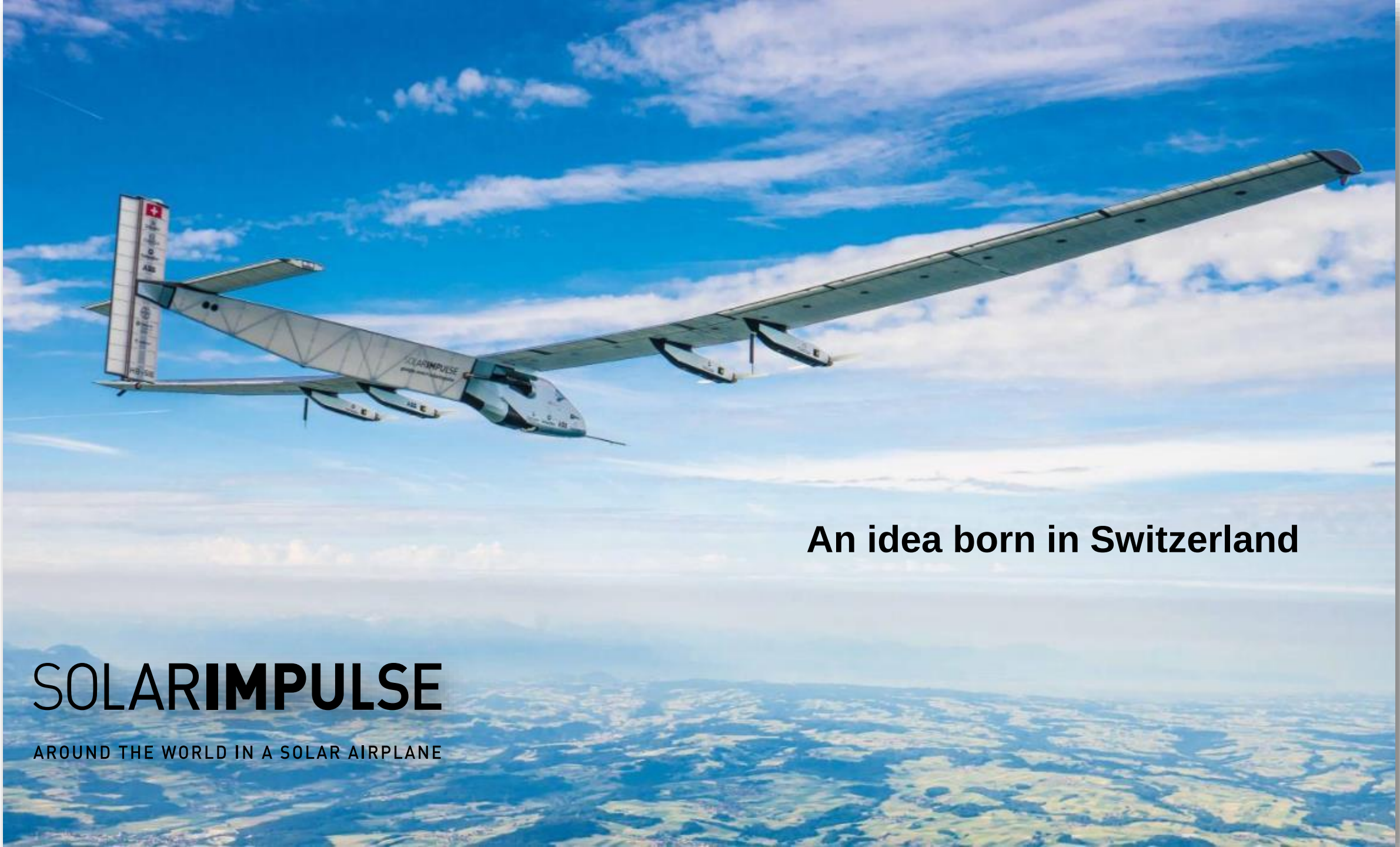
SOLARIMPULSE.COM



An idea born in Switzerland