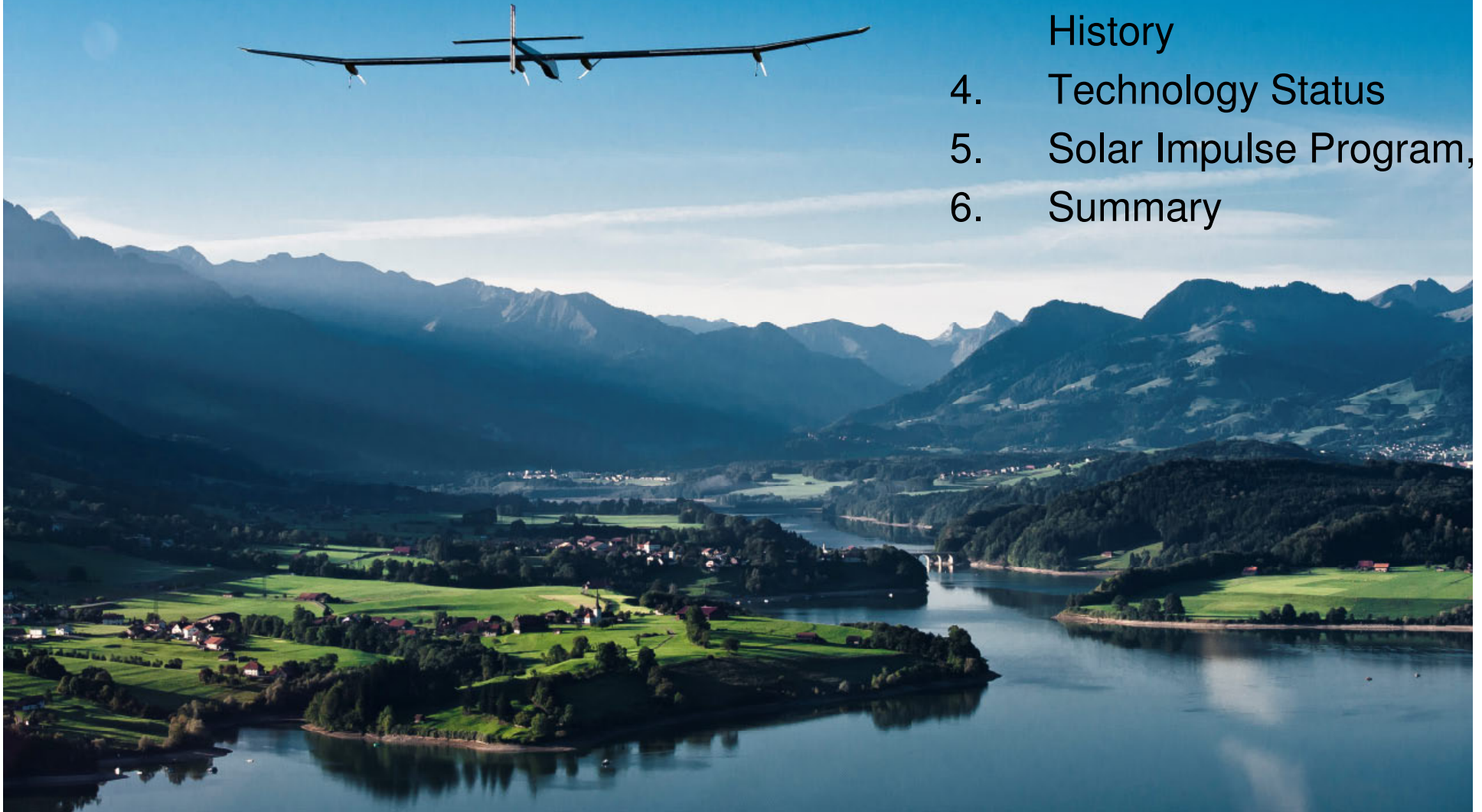


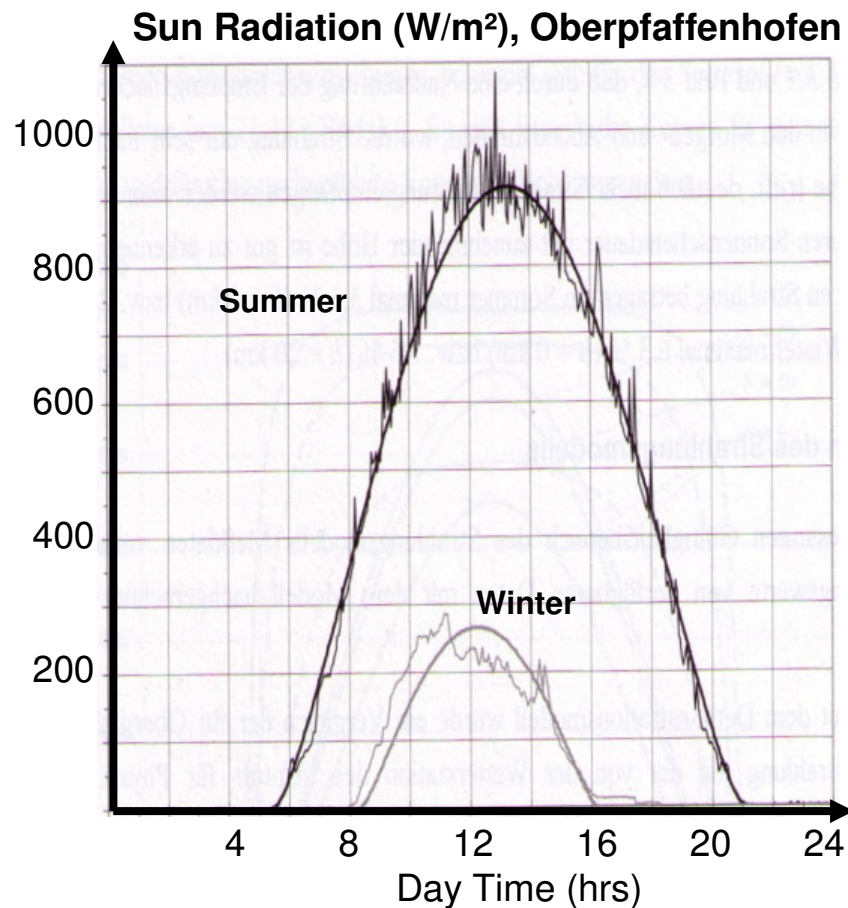
Around the World with a Solar Powered Aircraft 1.

Solar Power, Basics

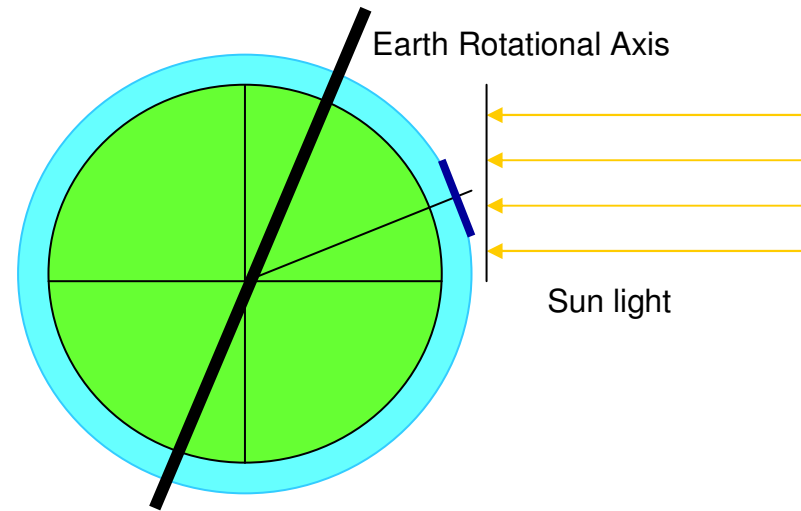
2. Flying Power, Basics
3. Solar Powered AC History
4. Technology Status
5. Solar Impulse Program,
6. Summary



Primary Energy Collection Parameters

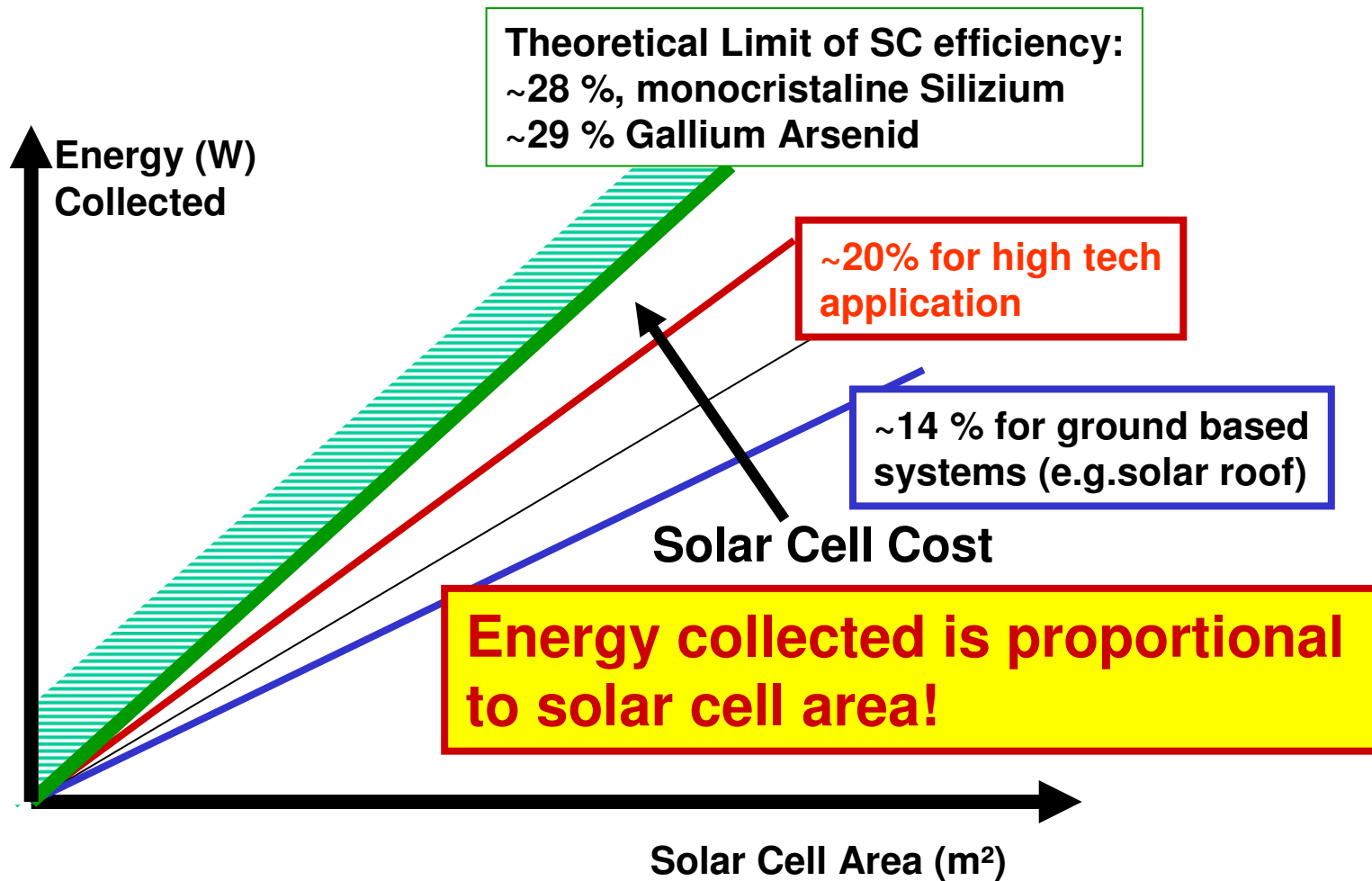


Source: B.Keidel
Dissertation



Latitude,
Time of the year,
Time of the day,
Altitude (Clouds, humidity),
Cell Temperature
Cell Orientation

Solar Energy Collection



Contents

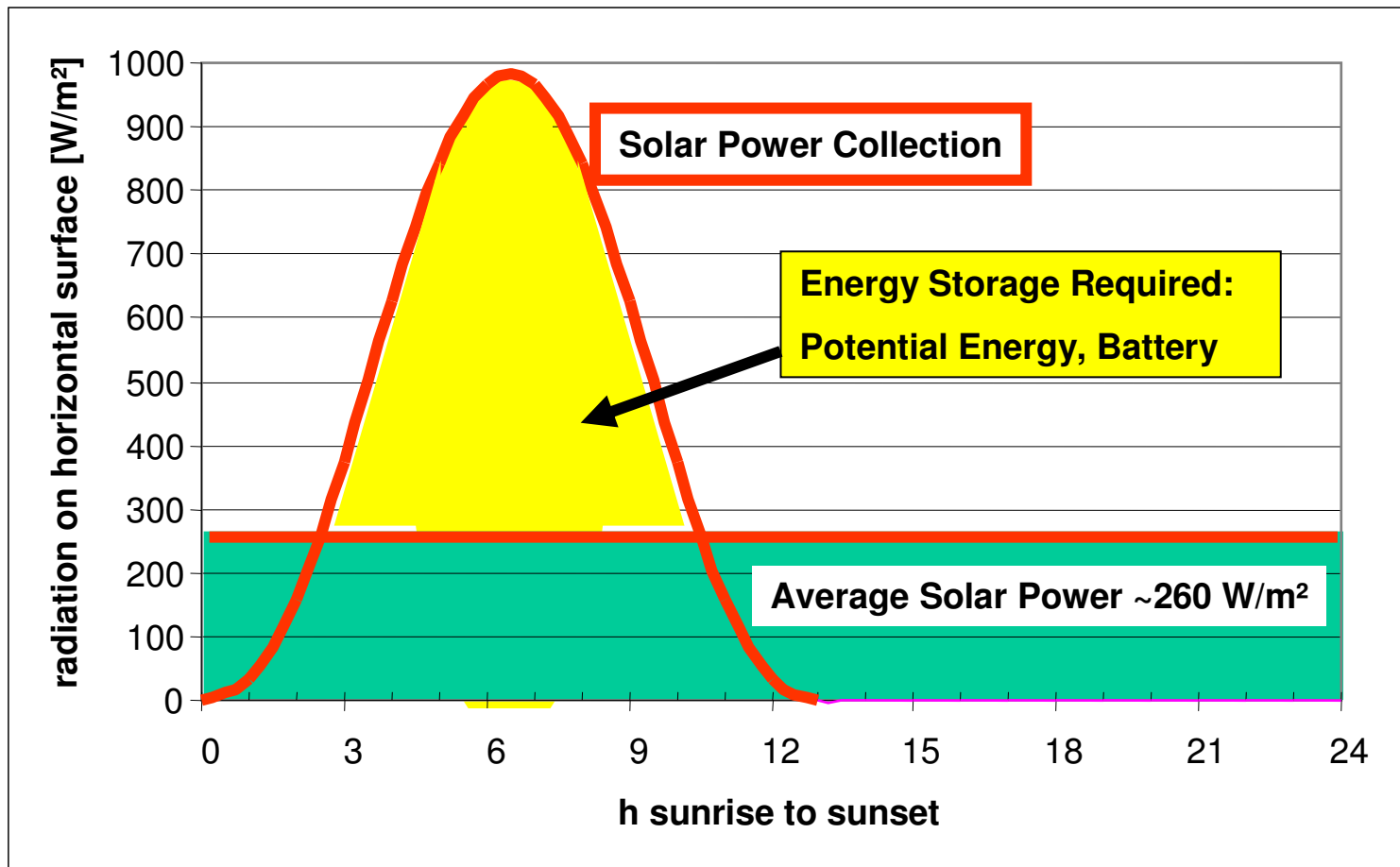


1. Solar Power, Basics
- 2. Flying Power, Basics**
3. Solar Powered AC History
4. Technology Status and Challenges
5. Manned Solar Powered AC, SI
6. Summary

Available Solar Power

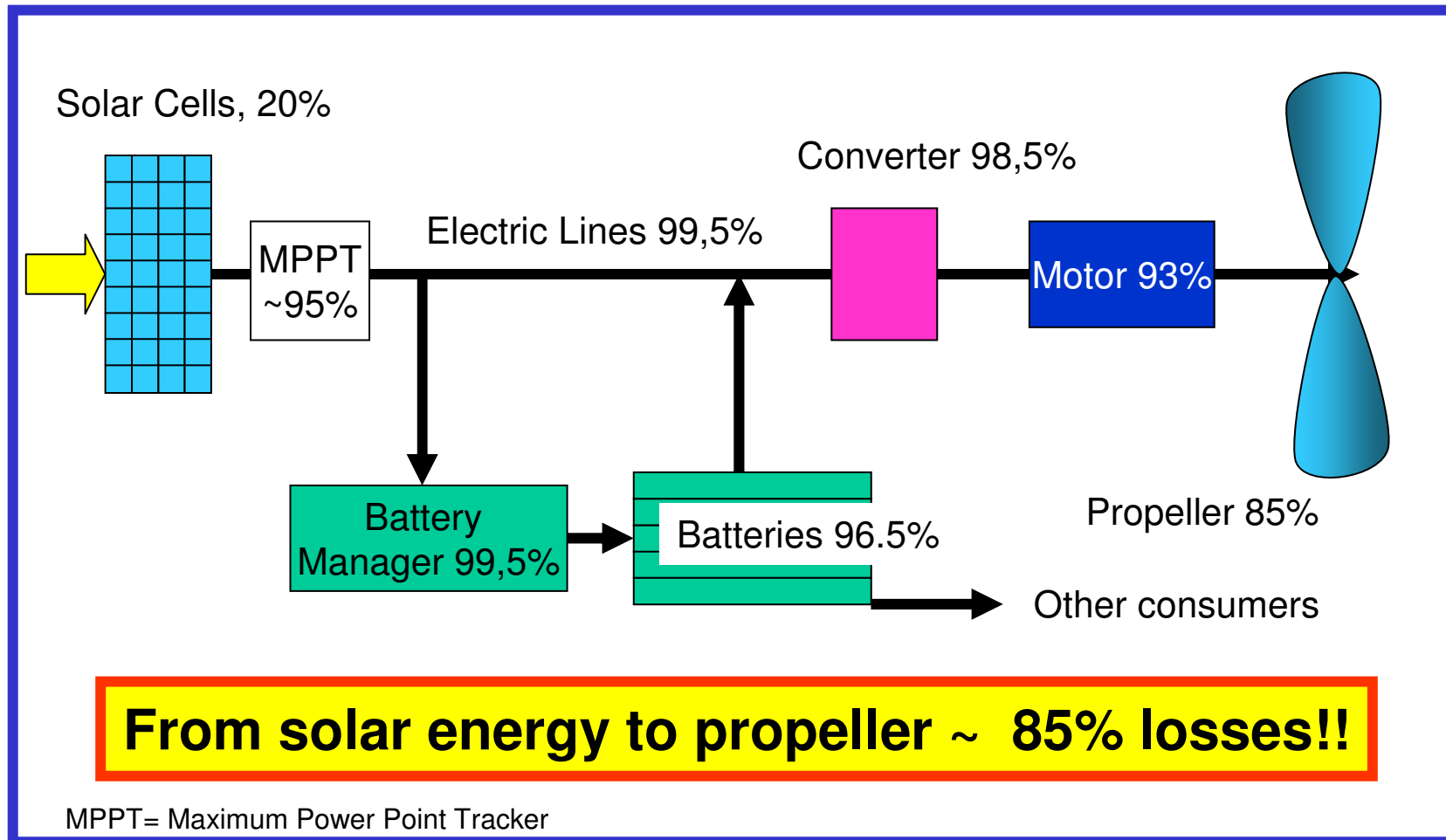


Solar constant 1300W/m^2 extraterrestrial
At flight altitudes approx. 1000W/m^2 noon peak



Power Train Schematic

And Typical Losses/Efficiencies



Wing Loading and Power Loading For Horizontal Flight



$$\text{Power} = \text{Drag} * \text{Velocity} \longrightarrow P = D * V$$

$$\text{Drag} \longrightarrow D = CD * \frac{\rho}{2} * V^2 * S$$

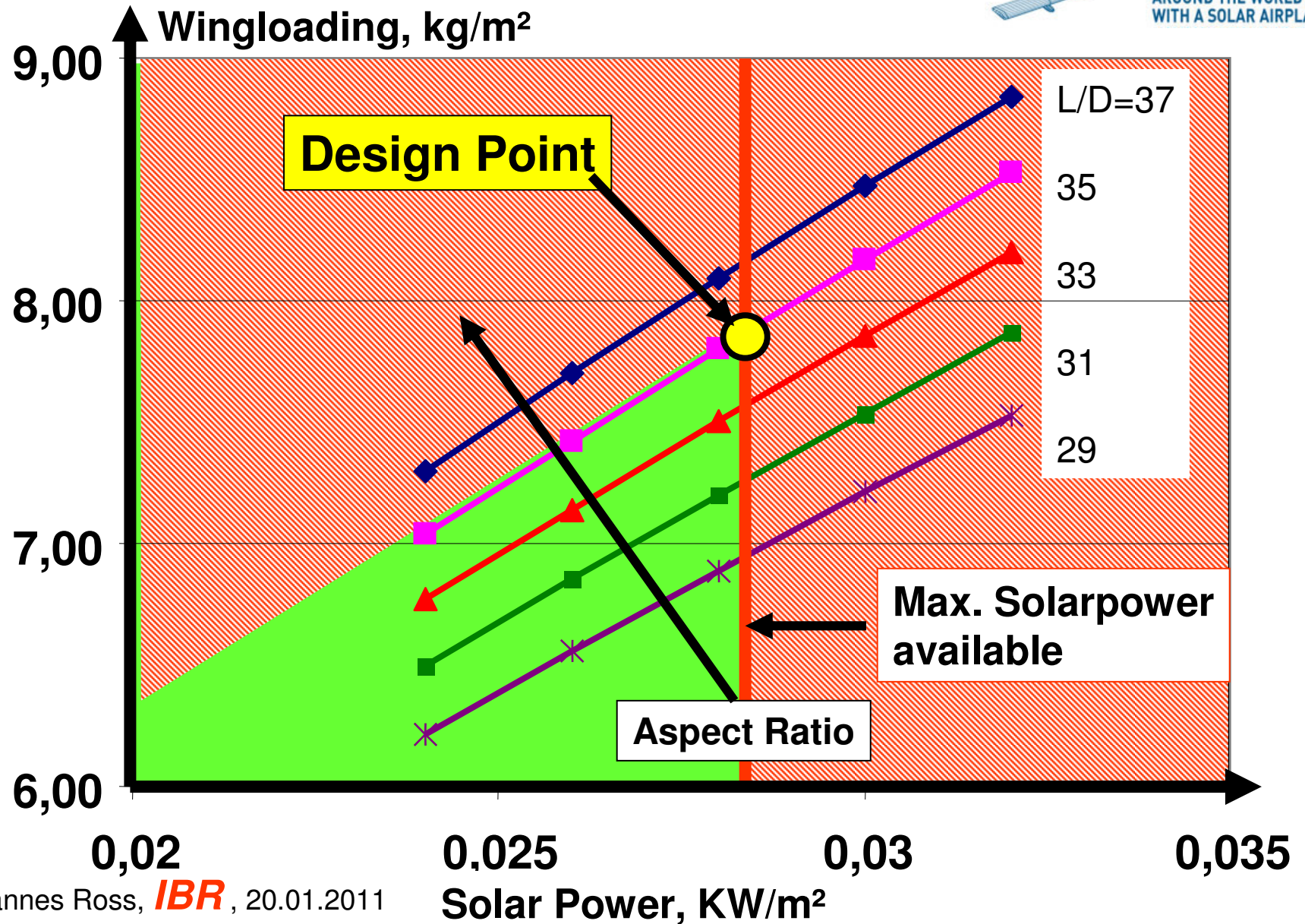
$$\text{Velocity} \longrightarrow V = \sqrt[2]{\frac{2}{\rho} * \frac{W}{S} * \frac{1}{CL}}$$

$$P = CD * \frac{\rho}{2} * V^3 * S$$

$$\frac{P}{S} = \sqrt[2]{\frac{2}{\rho}} * \left(\frac{W}{S}\right)^{3/2} * \frac{CD}{CL^{3/2}}$$

$$\frac{W}{S} = \left(\frac{P}{S}\right)^{(2/3)} * \left(\frac{\rho}{2}\right)^{(1/3)} * \frac{CL}{CD^{(2/3)}}$$

Design Space



Contents



1. Solar Power, Basics
2. Flying Power, Basics
- 3. Solar Powered AC History**
4. Technology Status and Challenges
5. Manned Solar Powered AC, SI
6. Summary

Solar Powered AC

since 1974



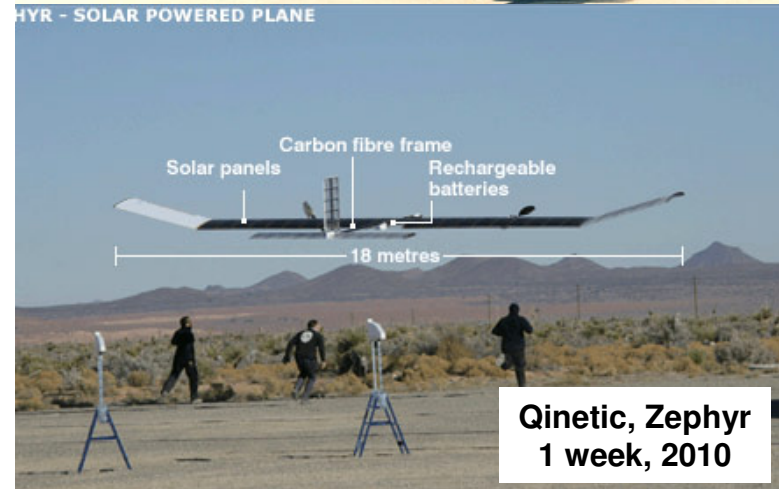
Ray Boucher's
„Sunrise1“, 1974



Gossamer Condor,
P. McReady, 1979



Alan Cocconi, 2005
48 hours



QinetiQ, Zephyr
1 week, 2010

Solar Aircraft History



Solar Challenger 1981
McReady



262 km, 5 hrs,
2.5 KW

Sunseeker 1990



E. Raymond
400 km

Unmanned Helios



2001
Aerovironment
30'000 m, 21 KW



Solair 1 1983
Günter Rochelt



> 5 hrs, 2.2 KW

Icare 2 1996



Voit-Nitschmann
350 km, 3.5 KW

Contents



1. Solar Power, Basics
2. Flying Power, Basics
3. Solar Powered AC History
- 4. Technology Status and Challenges**
5. Manned Solar Powered AC, SI
6. Summary

Technological Challenges

For manned ac with flight time >24 hr's



Propulsion

- high specific power solar array >20%
- high specific energy batteries > 200 Wh/kg
- high efficiency electric motors
- high efficiency propeller
- thermal control systems for batteries, engines

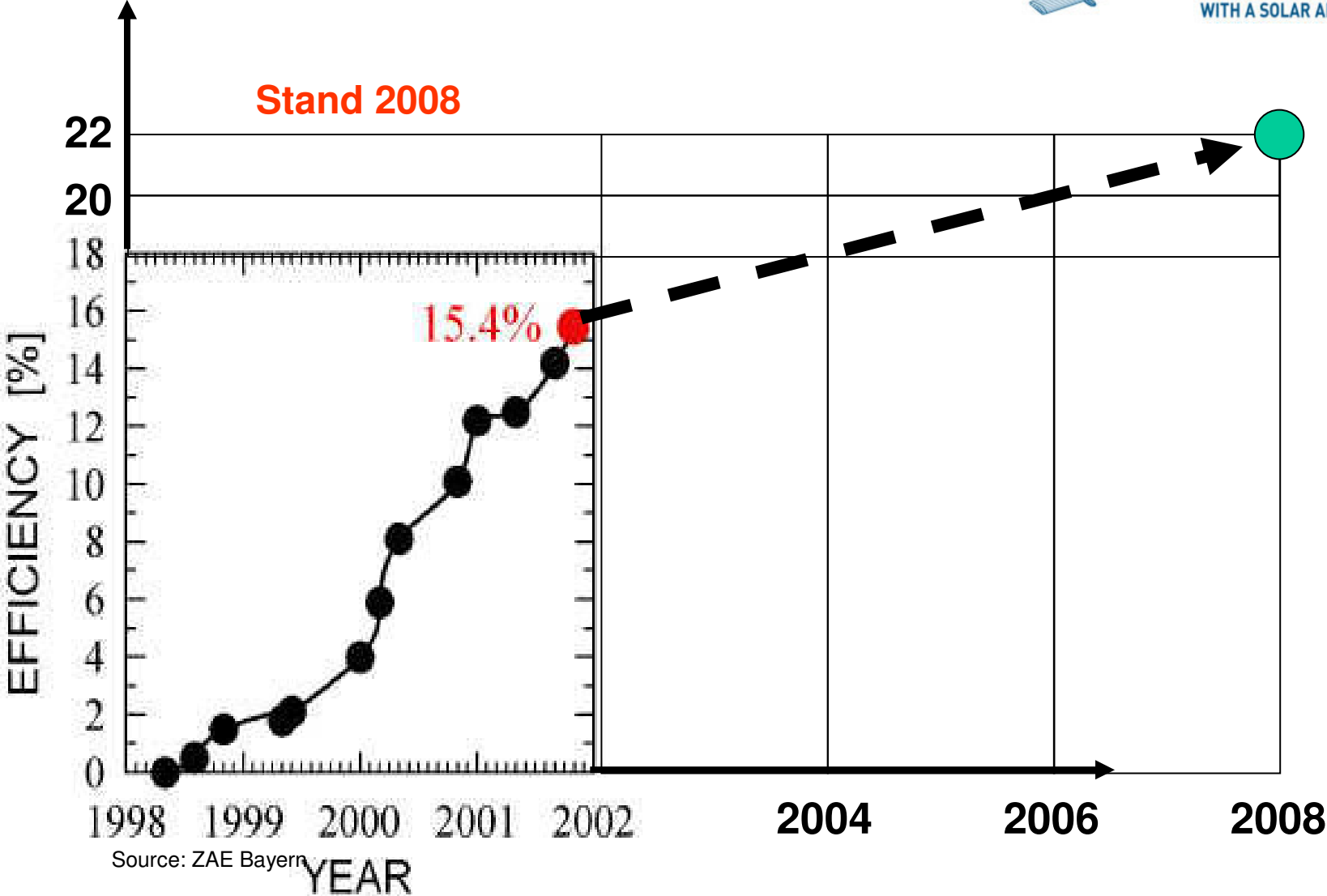
Structures

- lightweight composite structures
- acceptable aero-elastic characteristics

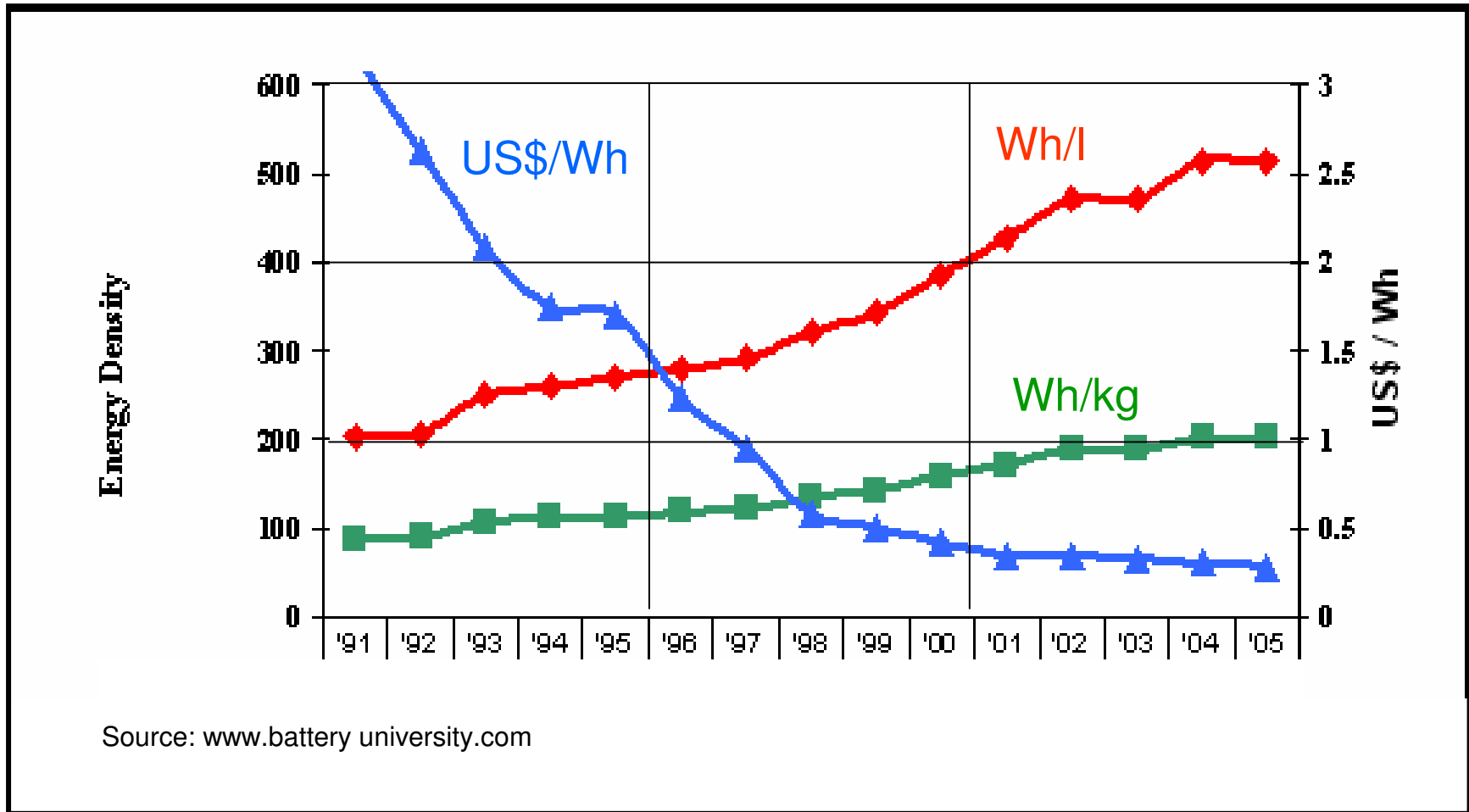
Systems with Low Power Consumption

- FCS, ECS, Communication, Navigation,

Solar Cell Efficiency



Lithium-Ion Battery Development



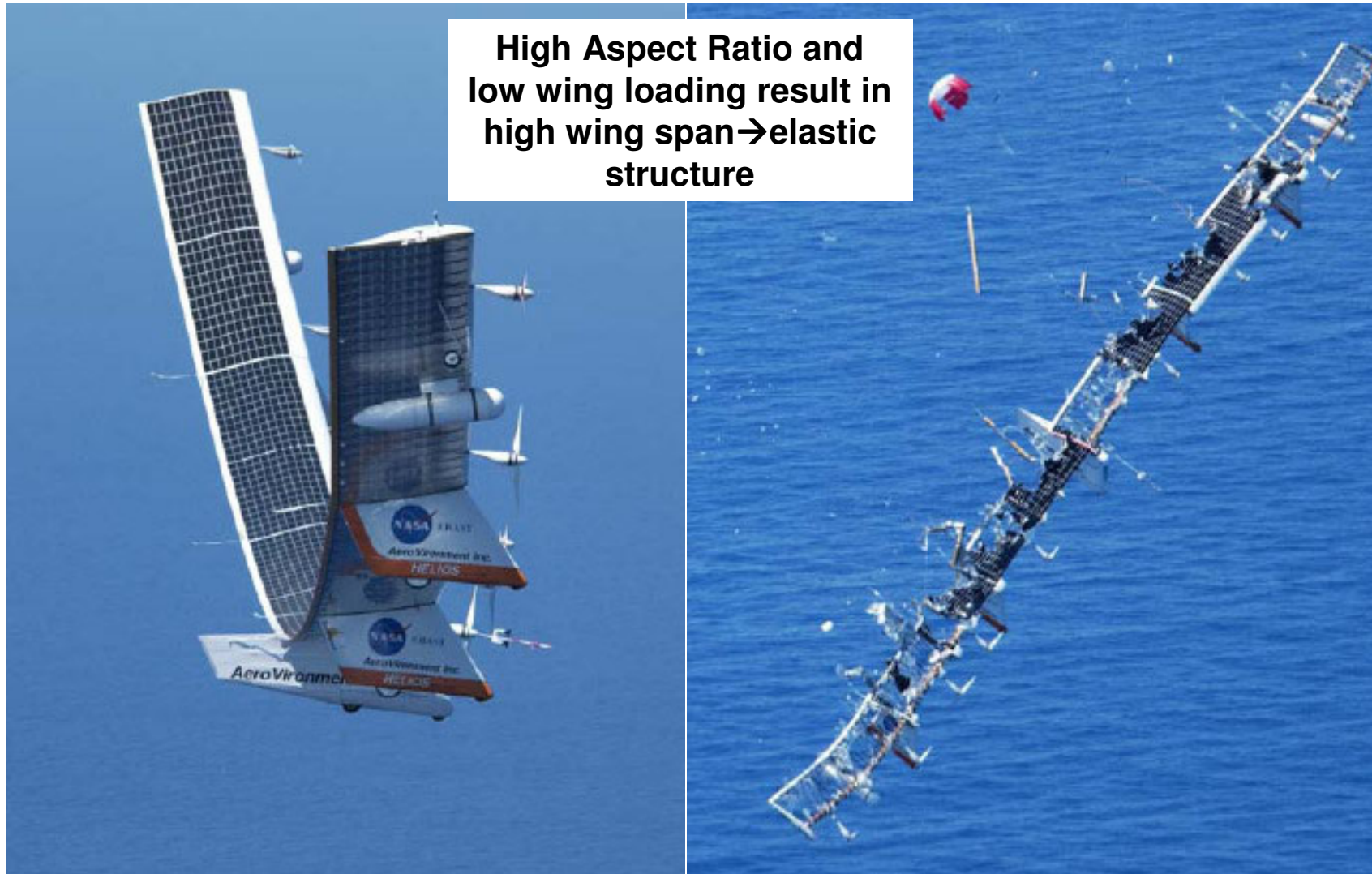
Helios, normal wing bending at 1g



Hannes Ross, **IBR**, 20.01.2011
DGLR, RAeS, VDI, @HAW Hamburg

www.solarimpulse.com

Helios Accident



High Aspect Ratio and low wing loading result in high wing span \rightarrow elastic structure

Contents



1. Solar Power, Basics
2. Flying Power, Basics
3. Solar Powered AC History
4. Technology Status and Challenges
- 5. Manned Solar Powered AC:
The Solar Impulse Project**
6. Summary

FIRST NON-STOP FLIGHT AROUND THE WORLD

March 1999

The BREITLING ORBITER 3 balloon crewed by Bertrand Piccard and Brian Jones took off from Château-d'Œx on March 1st, 1999 for its historical flight around the world. It landed in Egyptian desert on March 21st, 1999 after a flight of 19 days, 21 hours, 47 minutes.

For more information:
Office de Tourisme
1107 Château-d'Œx
Tel: +41-26 904 2109
info@batons-dorn.ch
www.batons-dorn.ch



BERTRAND PICCARD

BRIAN JONES

Le ballon Breitling Orbiter 3, piloté par Bertrand Piccard et Brian Jones, décolle de Château-d'Œx le 1^{er} mars 1999 pour son vol historique autour du monde. Il atterrit dans le désert égyptien le 21 mars 1999 après un vol de 19 jours 21 heures et 47 minutes.

Pour plus d'informations:
Office de Tourisme
1107 Château-d'Œx
Tel: +41-26 904 2109
info@batons-dorn.ch
www.batons-dorn.ch



Bertrand Piccard decided to launch into a new futuristic enterprise: to fly round the world in a solar-powered aeroplane

Solar Impulse Program



**Initiated 2001 by
Bertrand Piccard and
André Borschberg**

Objective:

**Develop a manned solar powered
aircraft
which can fly around the world
with solarpower only**

Feasibility Study 2002-2003

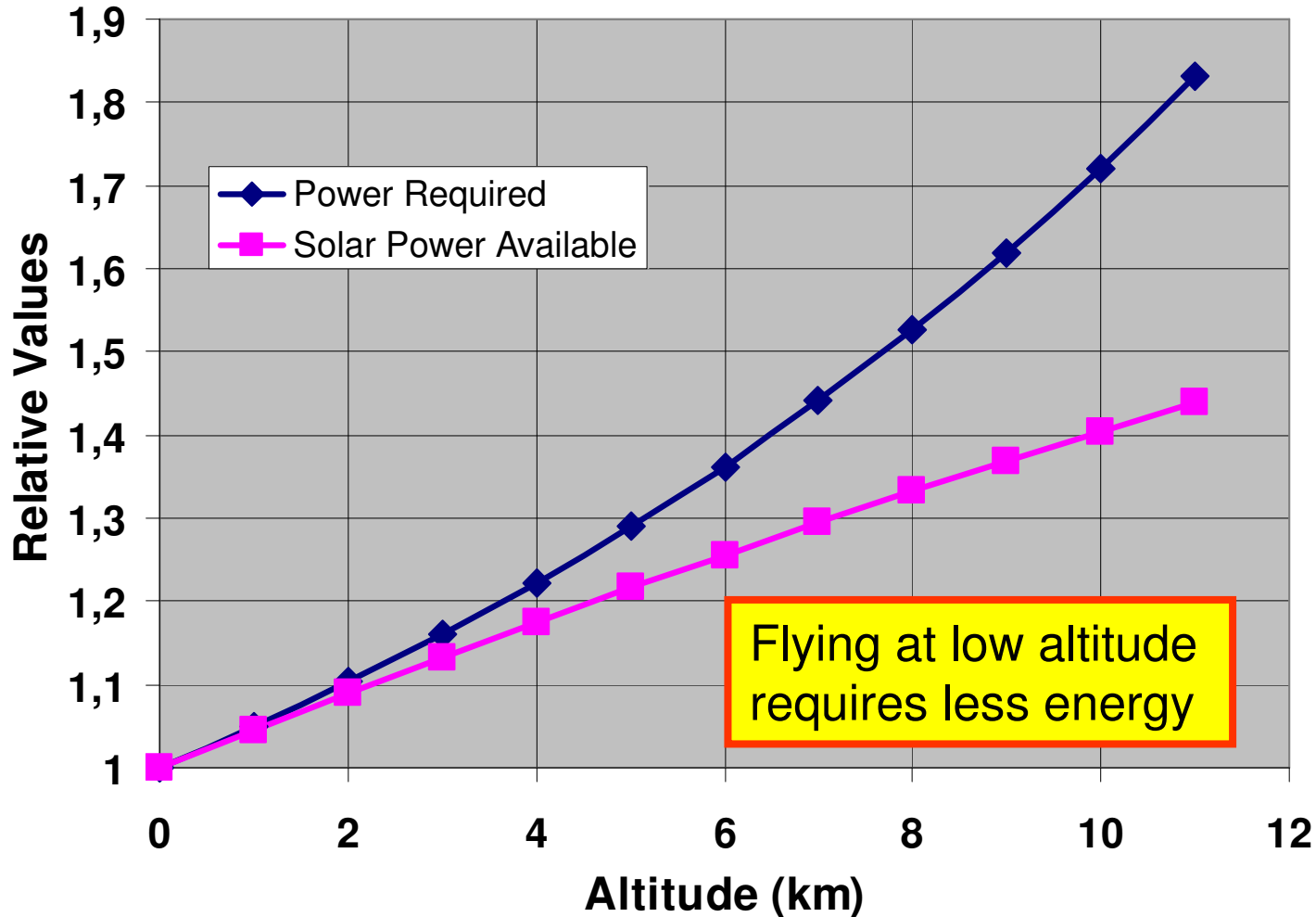
Approach:

**Develop a „Demonstrator“ aircraft
to show a 24hr energy neutral day
and night Cycle → HB-SIA**

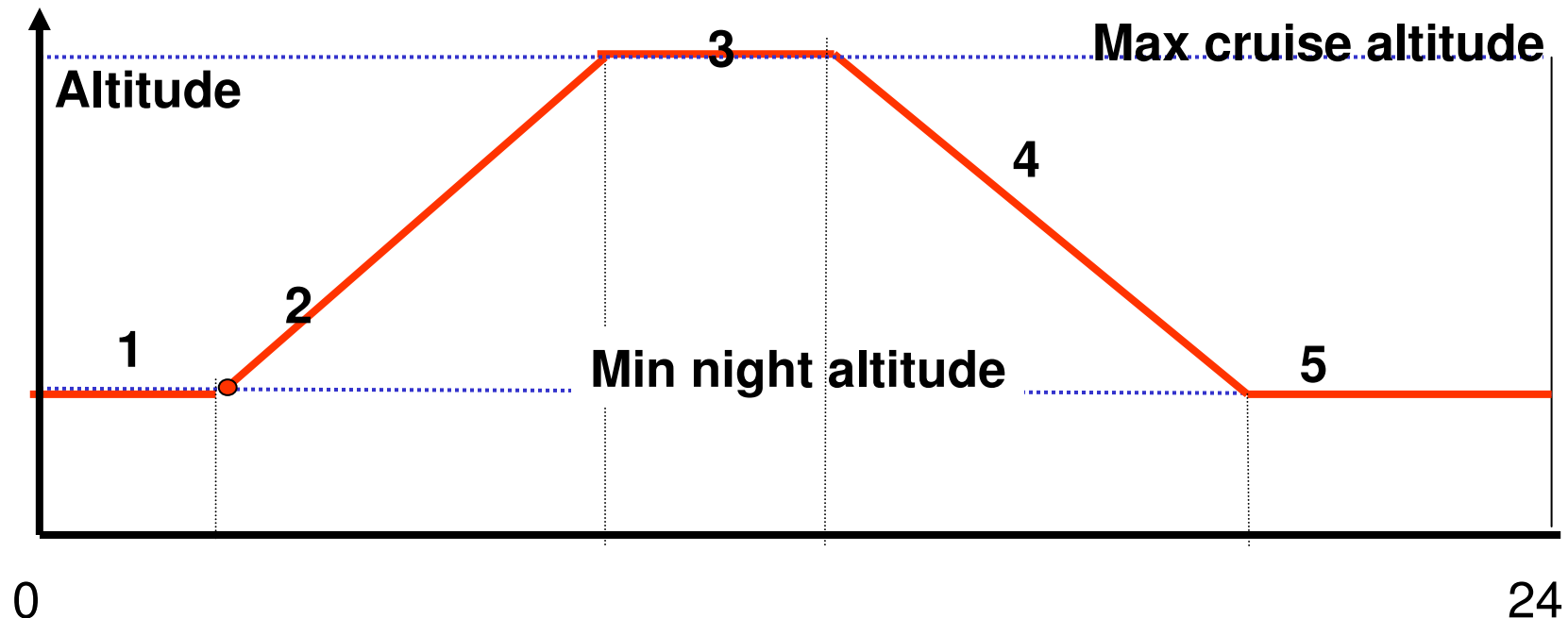
**Develop the „Record“ aircraft,
capable of crossing Atlantic,
Pacific in 4 to 5 day`s and
fly around the world in 5 to 6 legs**



Relative Flight Power Required and Solarpower generated=f(Altitude)

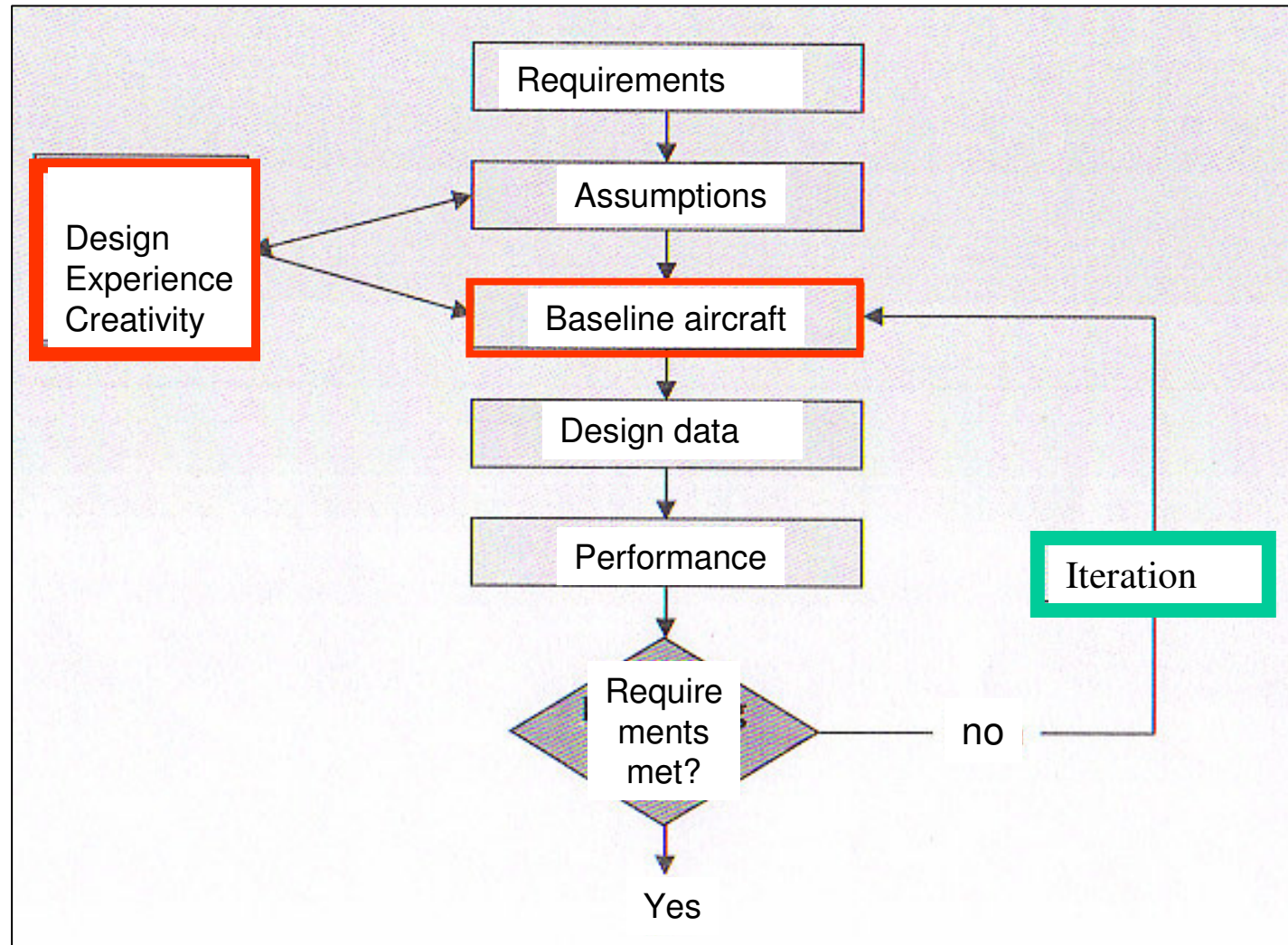


Mission Profile

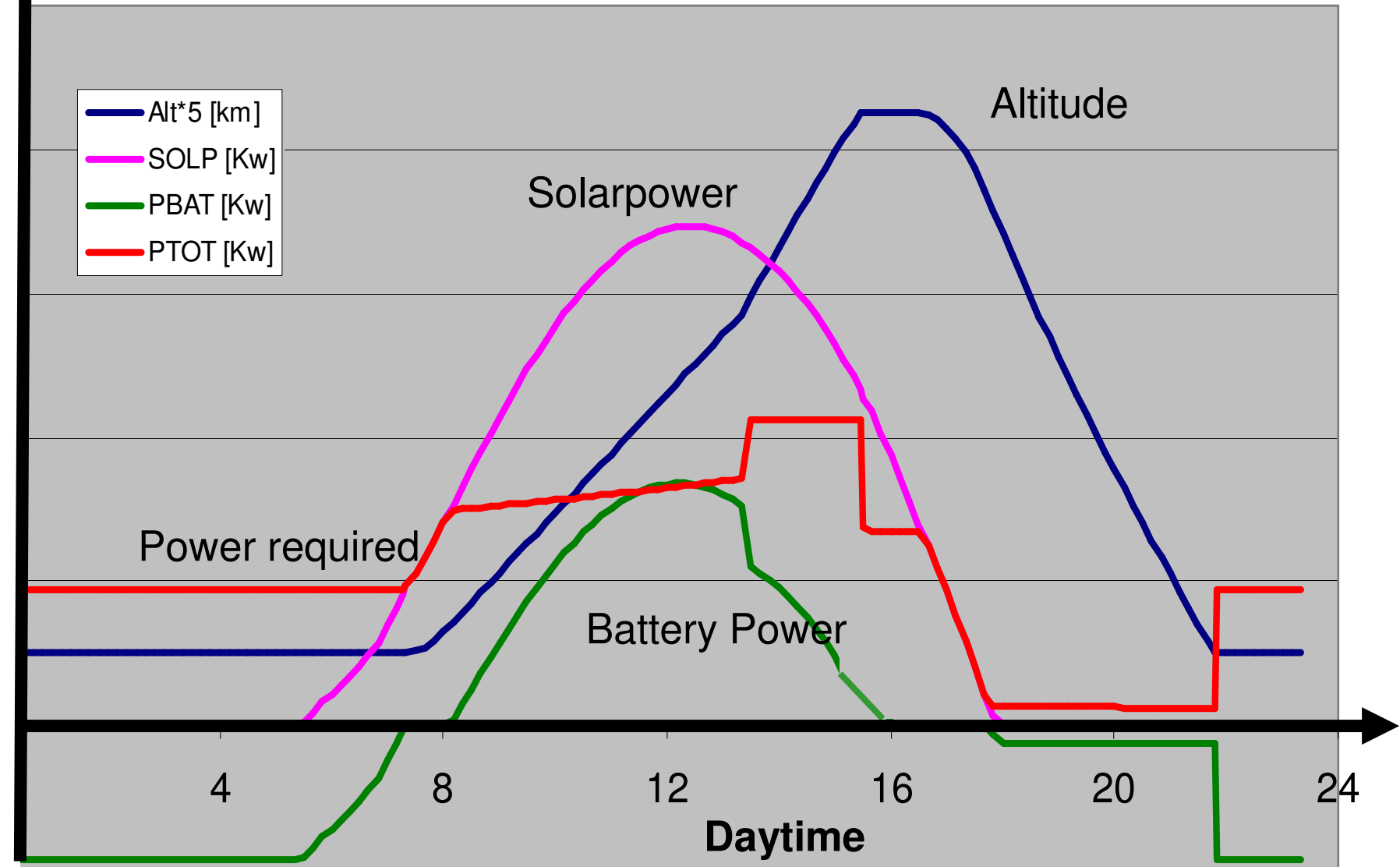


1. Fly at minimum night altitude
2. Climb
3. Cruise at at max altitude,if power is available
4. Descent at idle power
5. Fly at minimum night altitude

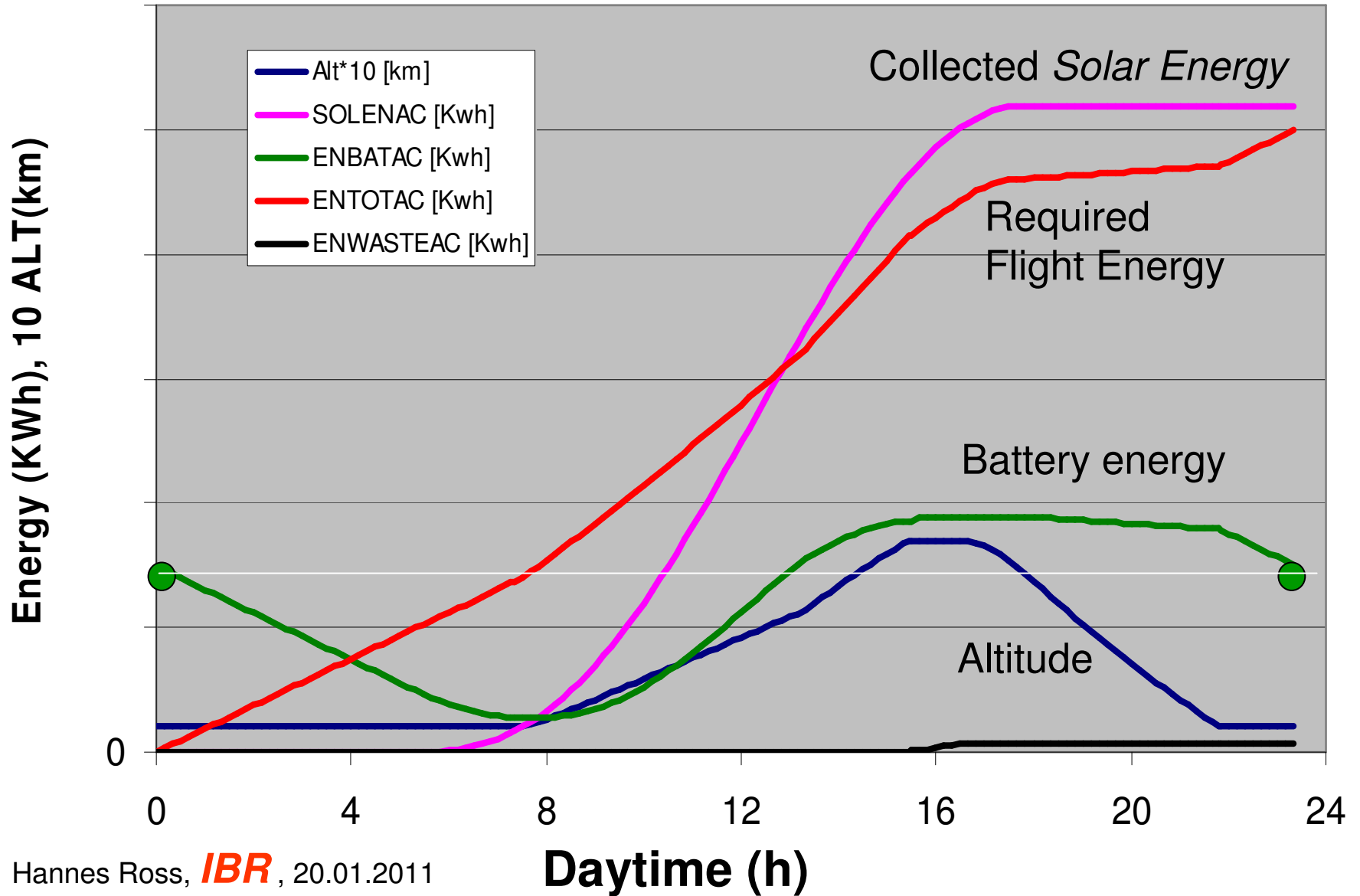
Design/Scaling Program



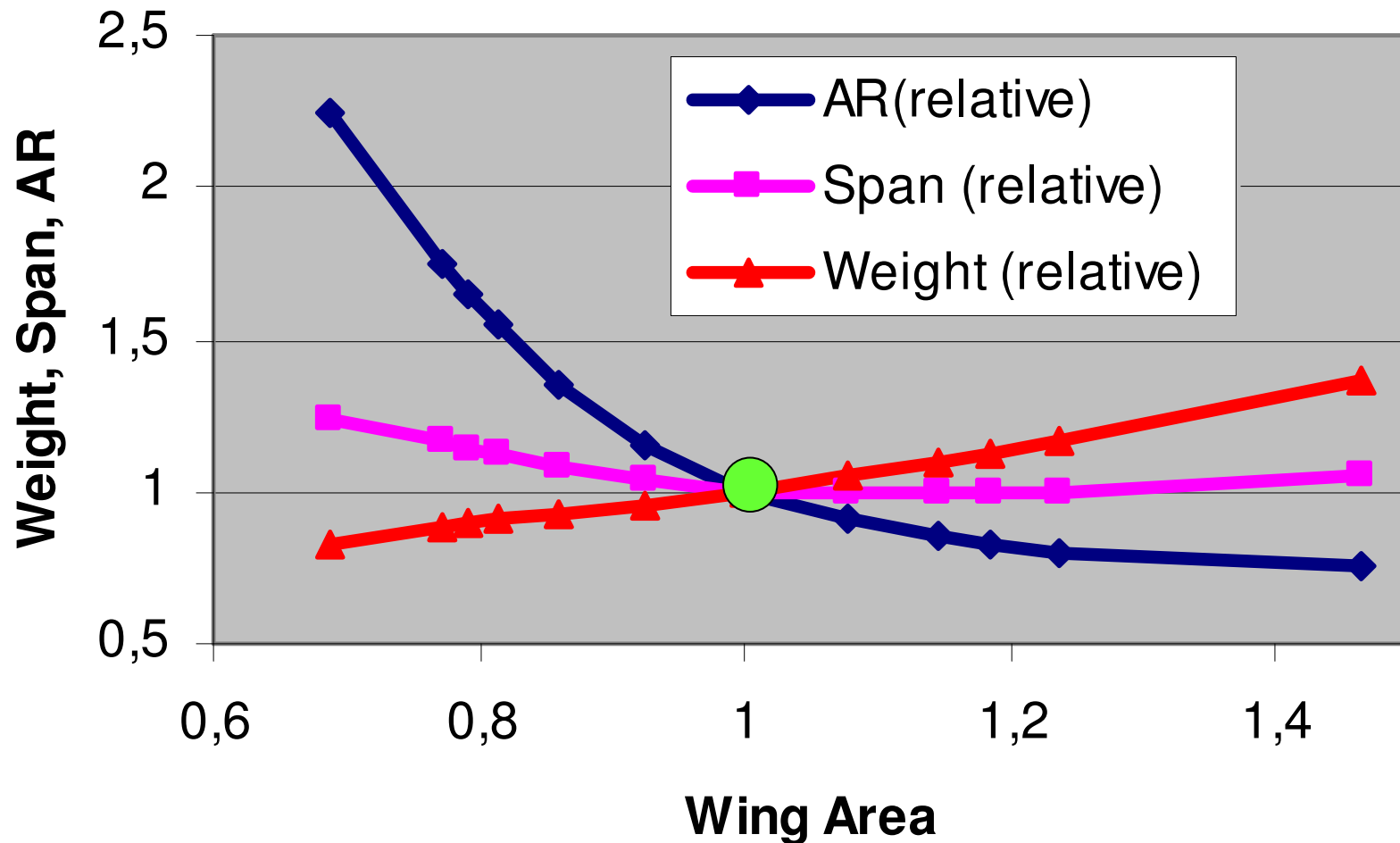
Mission Parameter (1)



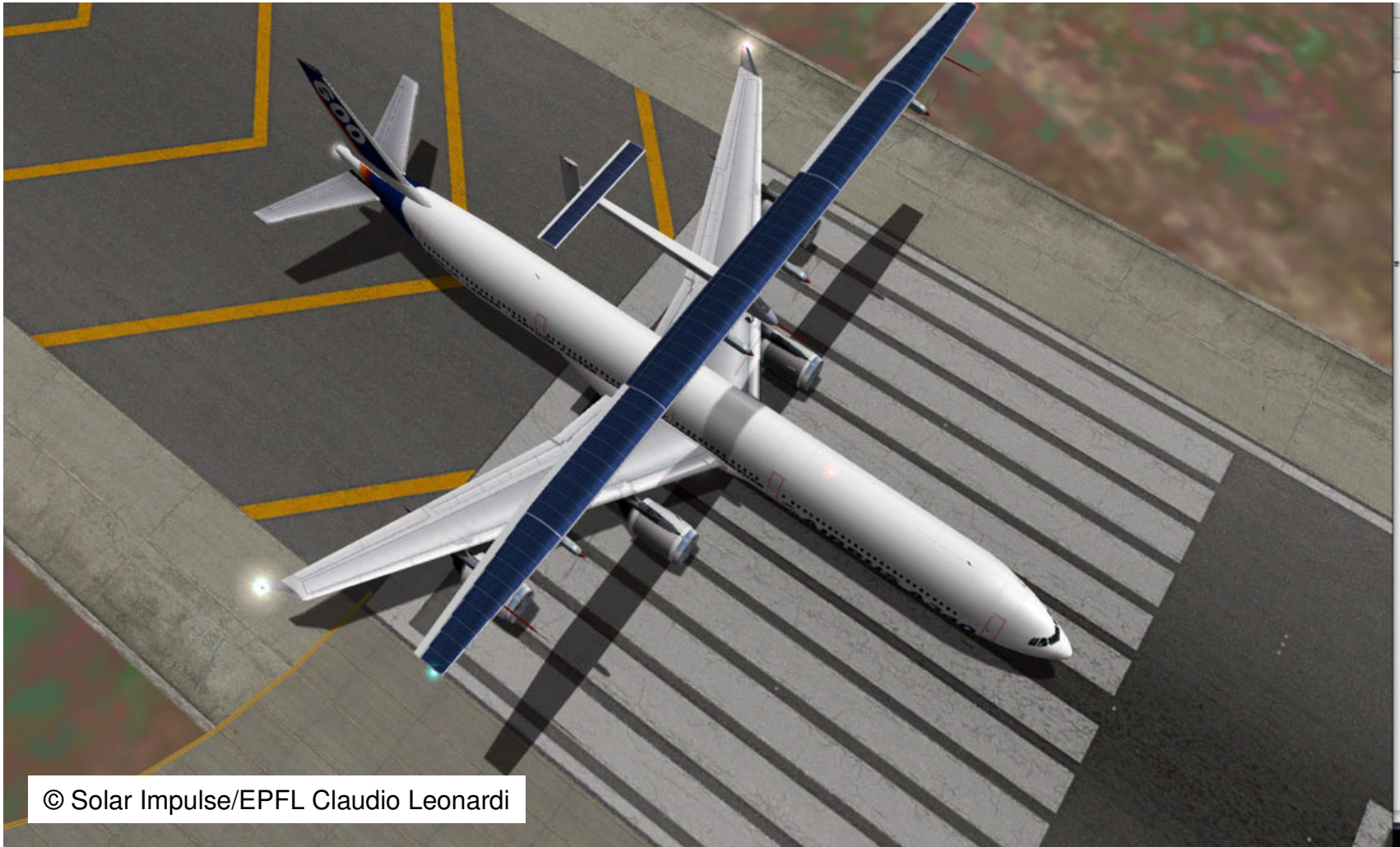
Mission Parameter (2)



Optimum Design Solutions

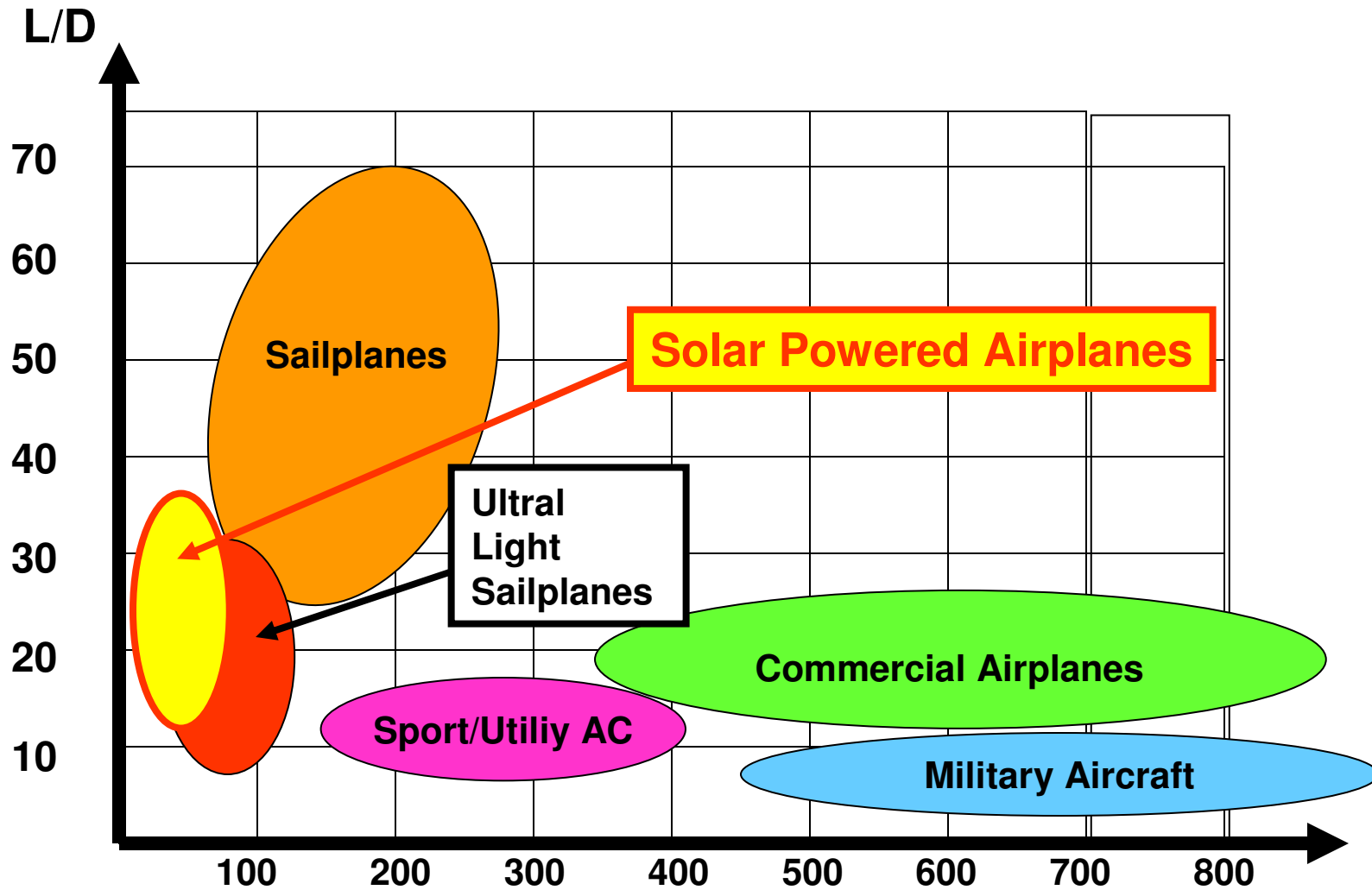


Size Comparison

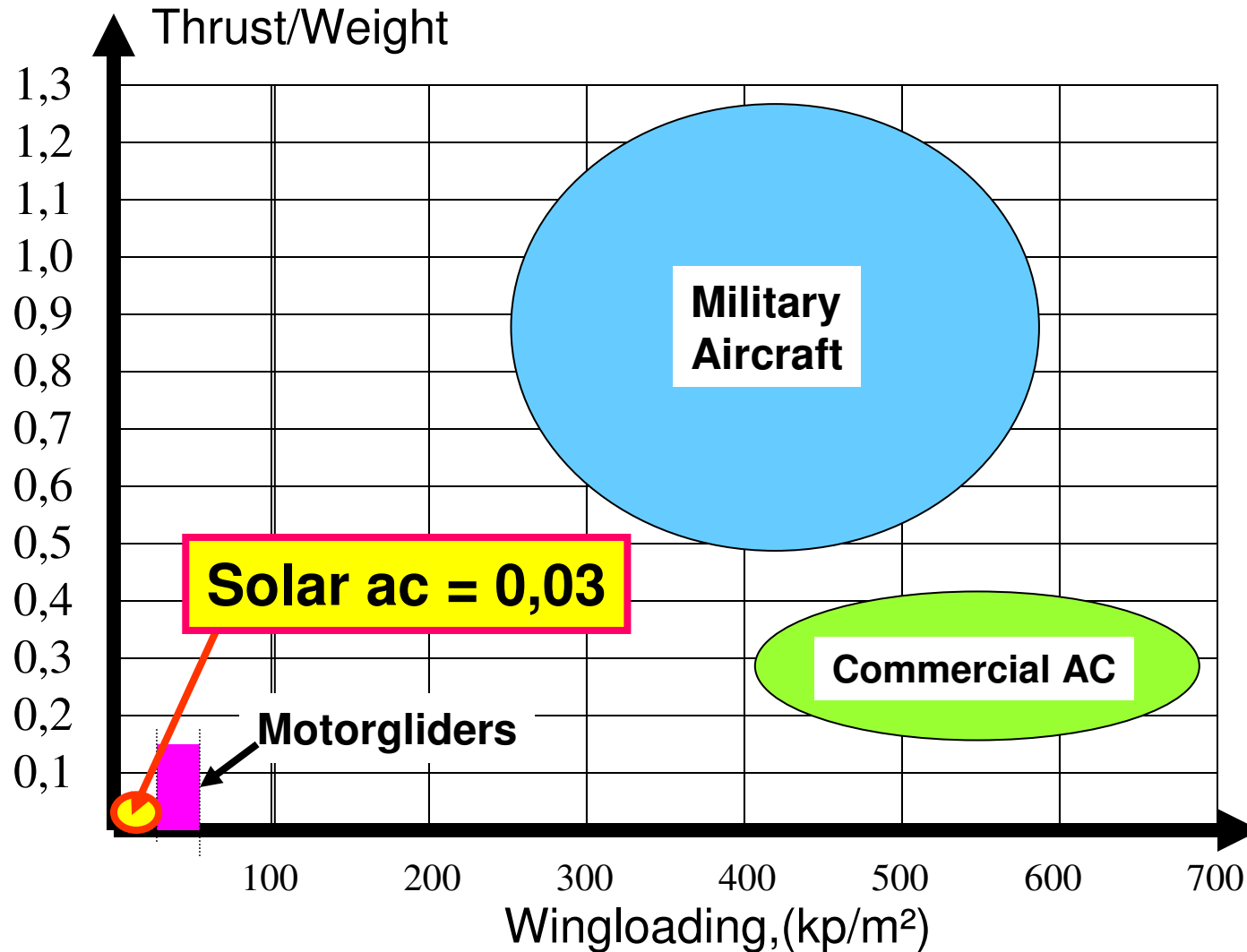


Hannes Ross, **IBR**, 20.01.2011
DGLR, RAeS, VDI, @HAW Hamburg

Operational Performance



Design Characteristics



Load Limit Tests



Hannes Ross, **IBR**, 20.01.2011
DGLR, RAeS, VDI, @HAW Hamburg

www.solarimpulse.com

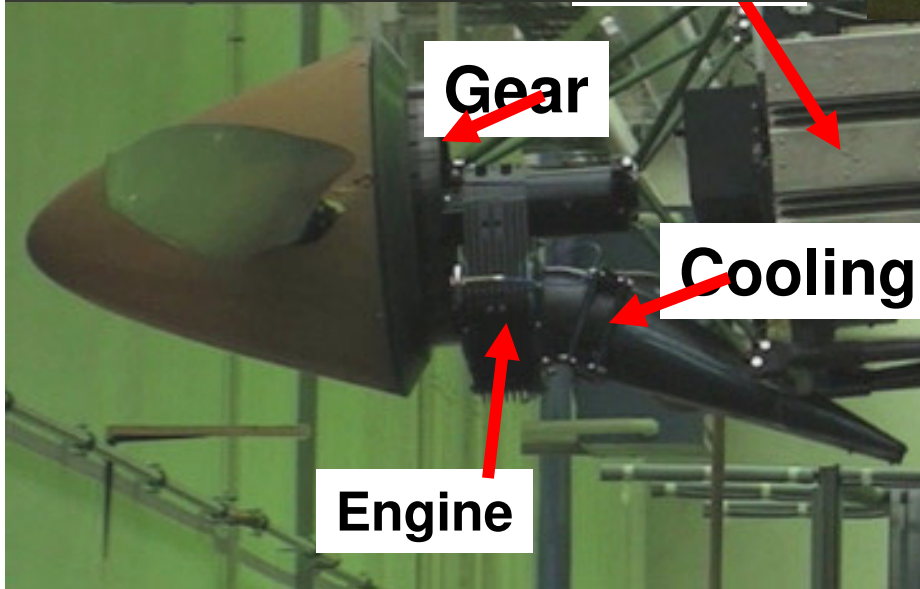
Cockpit Structure: CFC sandwich and foam shell



Hannes Ross, **IBR**, 20.01.2011
DGLR, RAeS, VDI, @HAW Hamburg

www.solarimpulse.com

Low Cost „Windtunnel“ Testing



Hannes Ross, **IBR**, 20.01.2011
DGLR, RAeS, VDI, @HAW Hamburg

www.solarimpulse.com

Initial Ground Vibration Test, 3



Hannes Ross, **IBR**, 20.01.2011
DGLR, RAeS, VDI, @HAW Hamburg

www.solarimpulse.com

Wing Assembly 3



Hannes Ross, **IBR**, 20.01.2011
DGLR, RAeS, VDI, @HAW Hamburg

www.solarimpulse.com

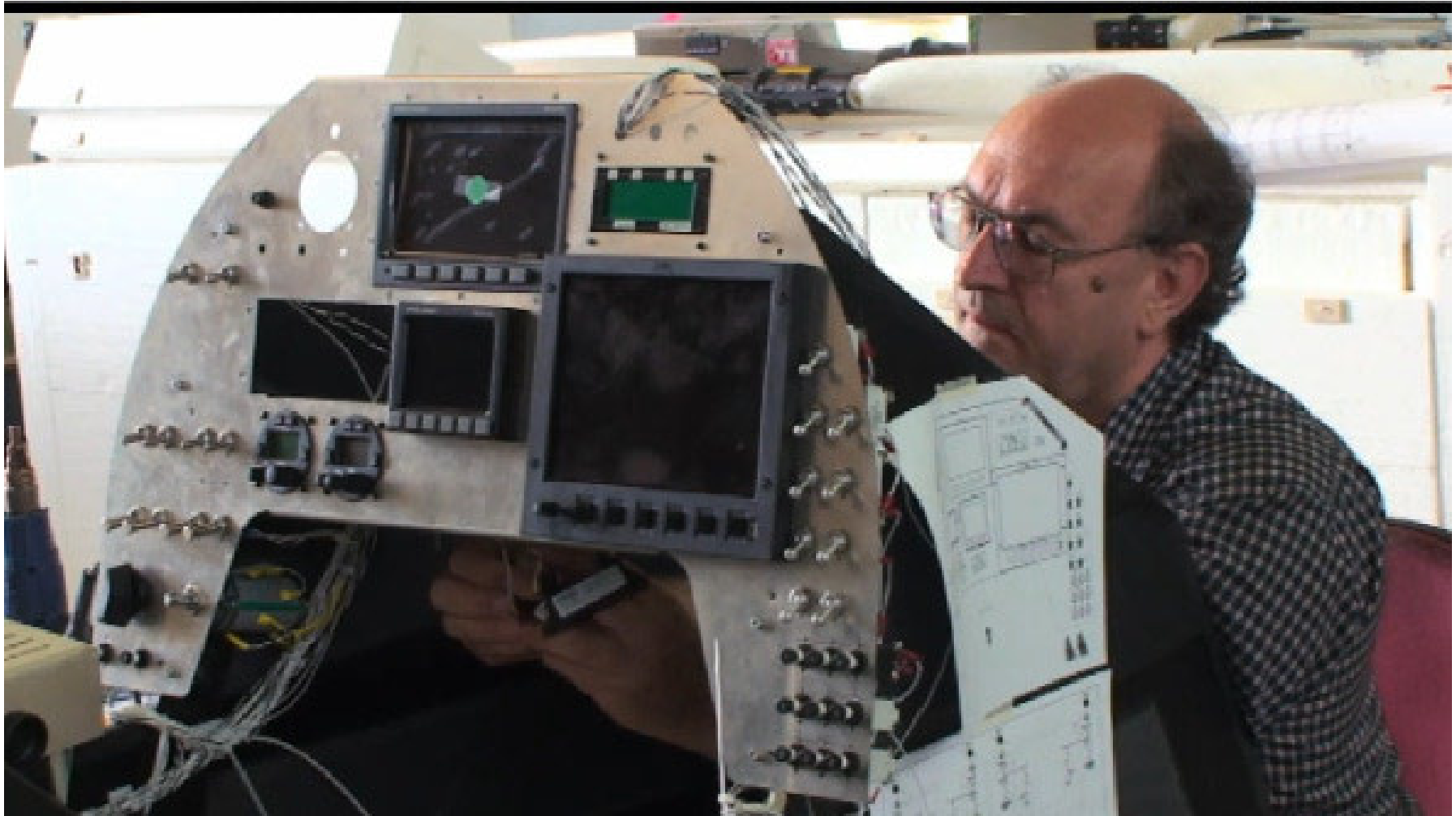
Solar Cell Attachment



Hannes Ross, **IBR**, 20.01.2011
DGLR, RAeS, VDI, @HAW Hamburg

www.solarimpulse.com

Instrument Panel



Hannes Ross, **IBR**, 20.01.2011
DGLR, RAeS, VDI, @HAW Hamburg

www.solarimpulse.com

Finally: Lift-off, 7. April 2010



Hannes Ross, **IBR**, 20.01.2011
DGLR, RAeS, VDI, @HAW Hamburg

www.solarimpulse.com

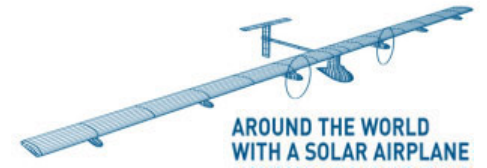
In The Air



Hannes Ross, **IBR**, 20.01.2011
DGLR, RAeS, VDI, @HAW Hamburg

www.solarimpulse.com

First Landing



Hannes Ross, **IBR**, 20.01.2011
DGLR, RAeS, VDI, @HAW Hamburg

www.solarimpulse.com

Demonstration of a 24 Hour Neutral Energy Cycle



Hannes Ross, **IBR**, 20.01.2011
DGLR, RAeS, VDI, @HAW Hamburg

www.solarimpulse.com

Swiss Flights to Genf, Zürich



Hannes Ross, www.solarimpulse.com, 20.01.2011
DGLR, RAeS, VDI, @HAW Hamburg

Program Schedule



It is a long term project:

2003	Feasibility study at the EPFL de Lausanne
2003	Announcement of challenge on 28 November
2004-2006	Concept the final Development
2007-2009	Design and Manufacturing of the prototype A/C, test of the airplane,
2009 June	Unveiling of Prototype, initial test flights
2010 April	First flight in Payerne
2010 7/8 July	26 hour record flight, from Payerne
2011	----- time now
2011-2012	Design, construction, start ground tests
2013	Flight test, Missions of several days
2014	Crossing continents, Atlantic and tour of the world five/six legs, each about 5 days long

Because of the Sponsors: A low cost program!



Main Partners



Official Partners

ALTRAN

Official Supporters

semper

Official Suppliers



Scientific and aeronautical partnerships



Hannes Ross, **IBR**, 20.01.2011
DGLR, RAeS, VDI, @HAW Hamburg

www.solarimpulse.com

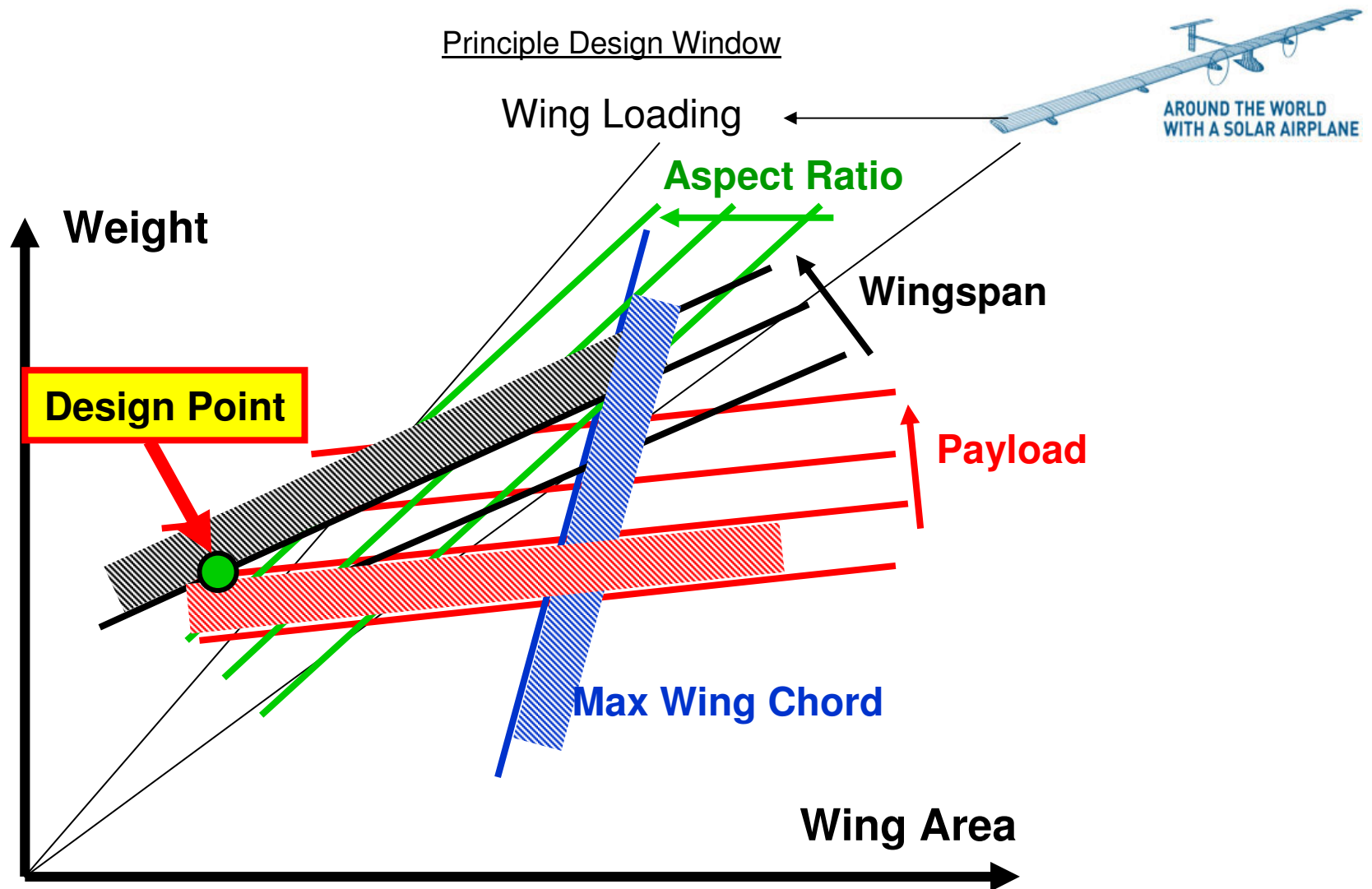


Design of the Record Aircraft To fly around The World



Hannes Ross, **IBR**, 20.01.2011
DGLR, RAeS, VDI, @HAW Hamburg

www.solarimpulse.com



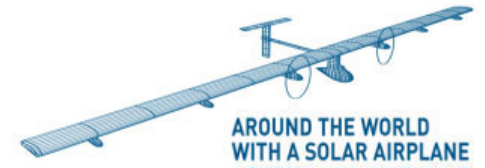
- For a given payload the minimum weight is achieved with the highest AR Limited by the maximum tolerable wingspan!!
- The more stringent the design mission is, the more will the design window Shift towards higher weight and larger wing area!!

Solarimpulse: ONE TEAM



Hannes Ross, **IBR**, 20.01.2011
DGLR, RAeS, VDI, @HAW Hamburg

www.solarimpulse.com



END

Hannes Ross, **IBR**, 20.01.2011
DGLR, RAeS, VDI, @HAW Hamburg

www.solarimpulse.com