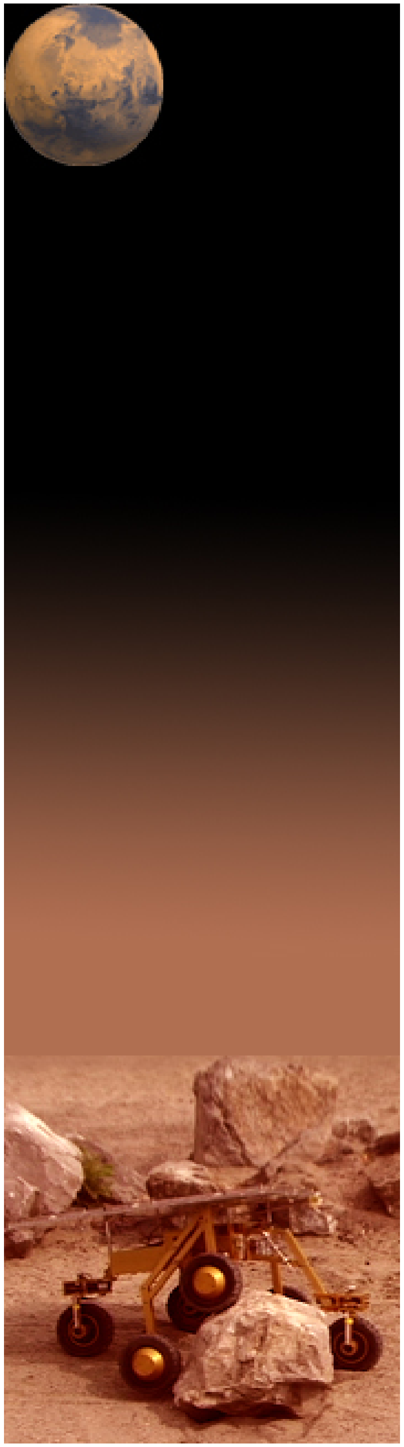
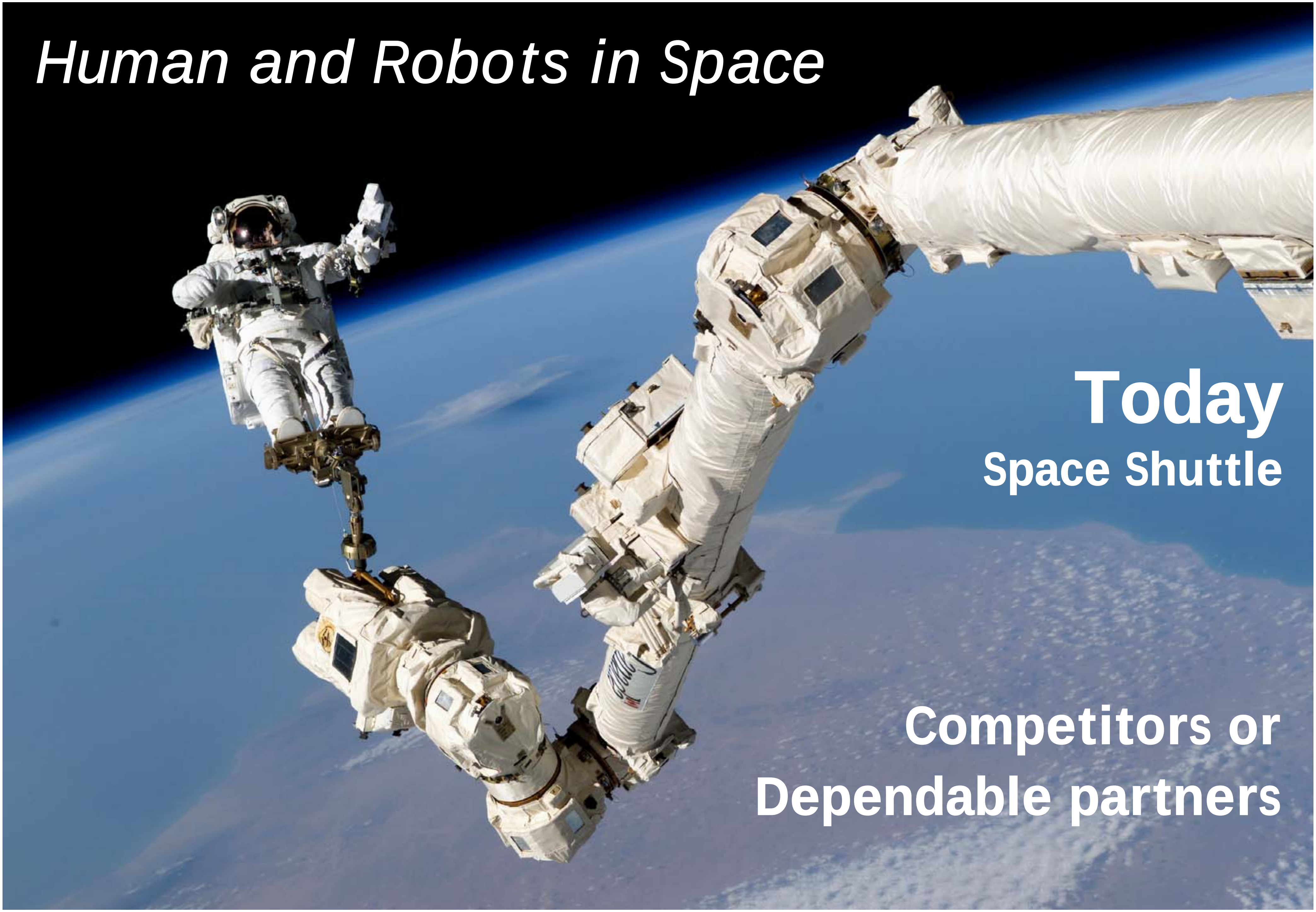
Robots for Space – Needs and Visions

Roland Siegwart
Autonomous Systems Lab
Institute of Robotics and Intelligent Systems
ETH Zurich

Autonomous Systems Lab

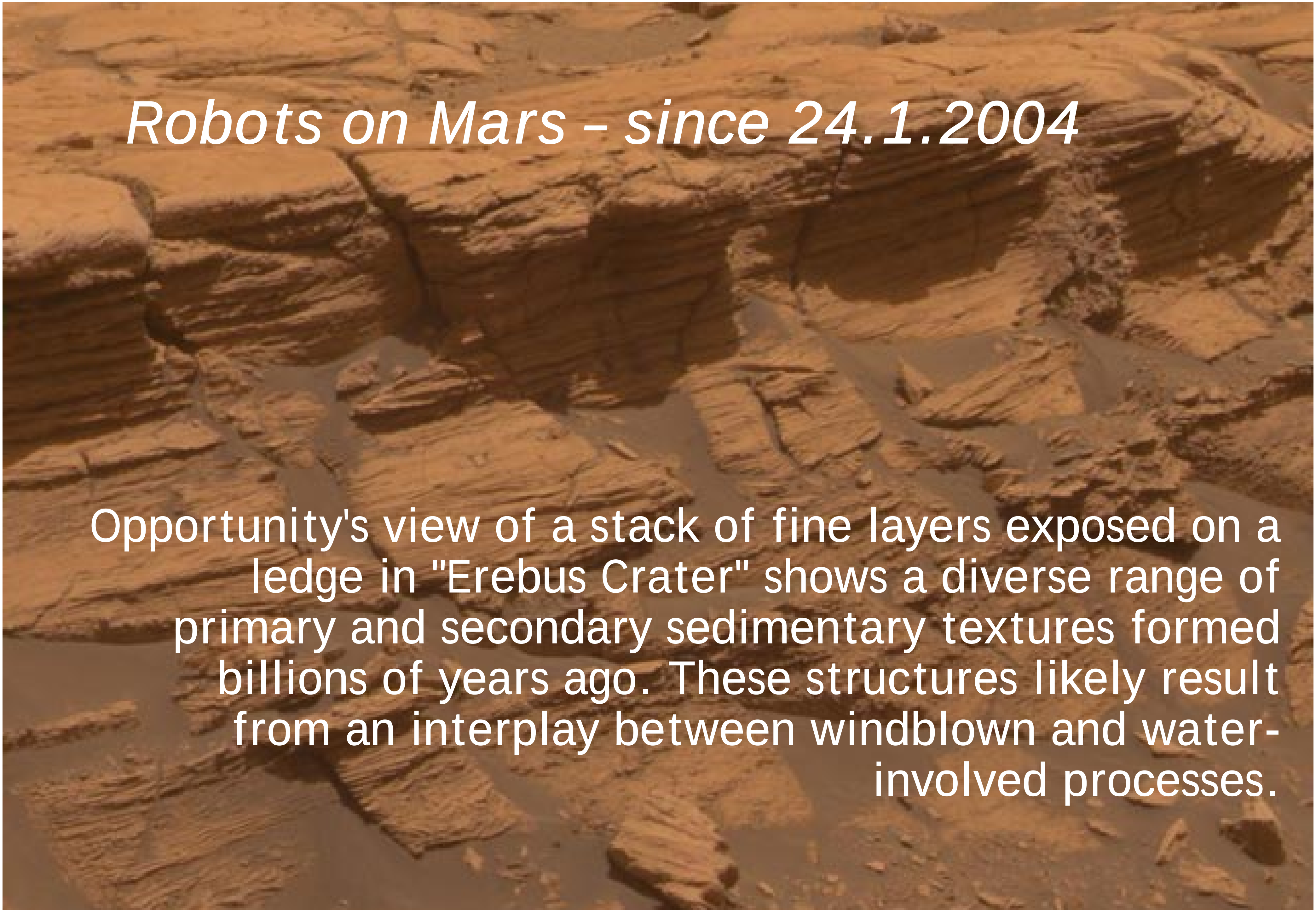
- **Robots in Space**
- **Exploration Robot Examples**

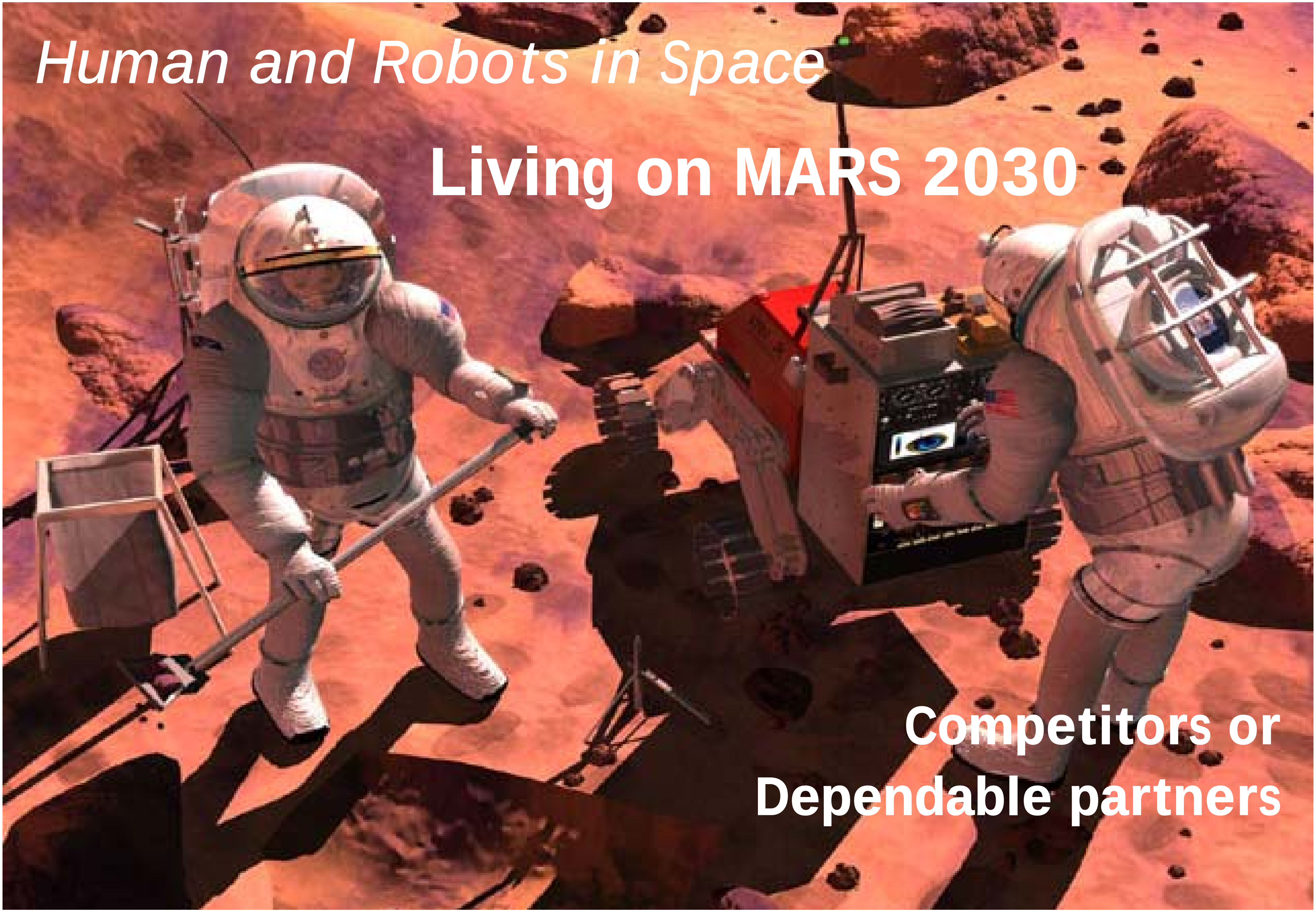



Human and Robots in Space
Today
Space Shuttle
Competitors or
Dependable partners

Spirit et Opportunity on
the surface of the Red Planet

Where no human can go yet


Robots on Mars – since 24.1.2004
Opportunity's view of a stack of fine layers exposed on a ledge in "Erebus Crater" shows a diverse range of primary and secondary sedimentary textures formed billions of years ago. These structures likely result from an interplay between windblown and water-involved processes.

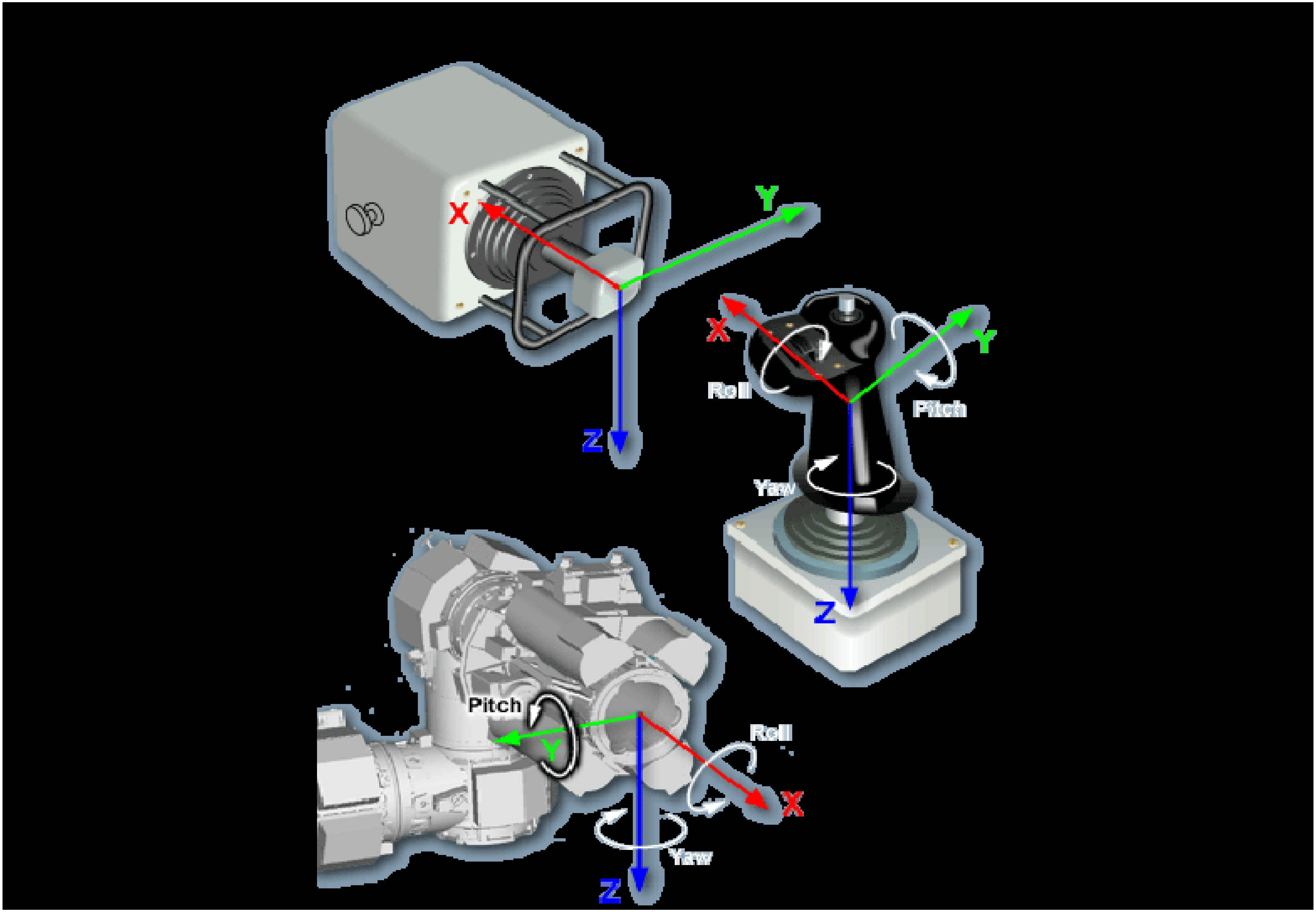

Human and Robots in Space
Living on MARS 2030
Competitors or
Dependable partners

Robots are absolutely needed in Space

- To go where no human can go yet
  - *E.g. Mars expiration rovers*
- To assist humans where they can go
  - *International Space Station*
  - *Habitats on Mars*

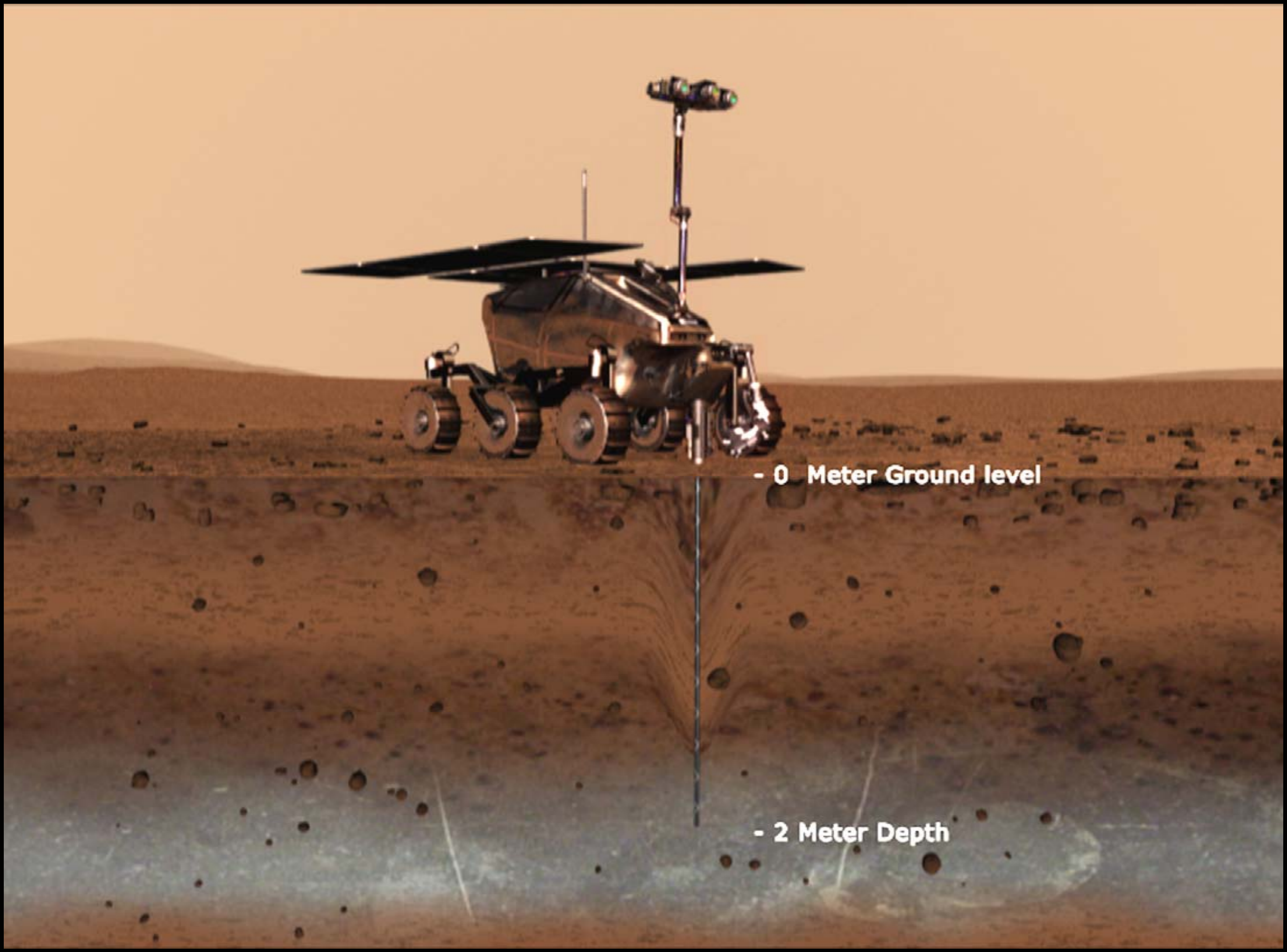

Courtesy of Claude Nicollier ESA/NASA
Robot Assistants
STS-103
December 1999


OVHD
HATCH



X
Y
Z
X
Y
Roll
Pitch
Yaw
Z
Pitch
Y
Roll
X
Yaw
Z

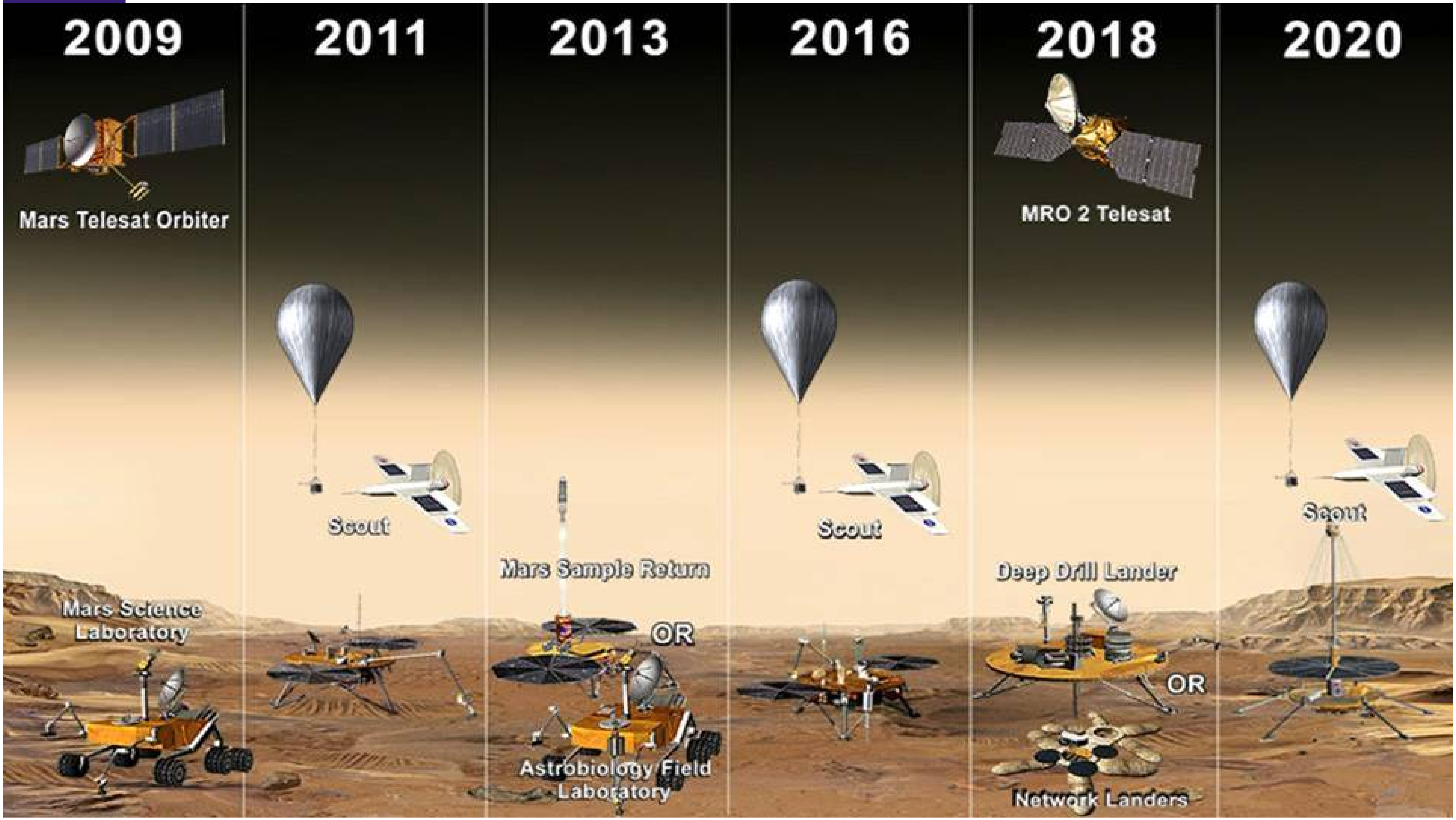
Robotic Mars Explorers



EXOMARS digging...

Source: Capability Roadmap, NASA 2005

"Search for Past Life" Pathway Example



Exploration Rovers for Mars
- Going Beyond the Limits

The Way Forward

- Optimized suspension mechanisms
- Adapted wheels
- Advanced autonomous navigation capabilities

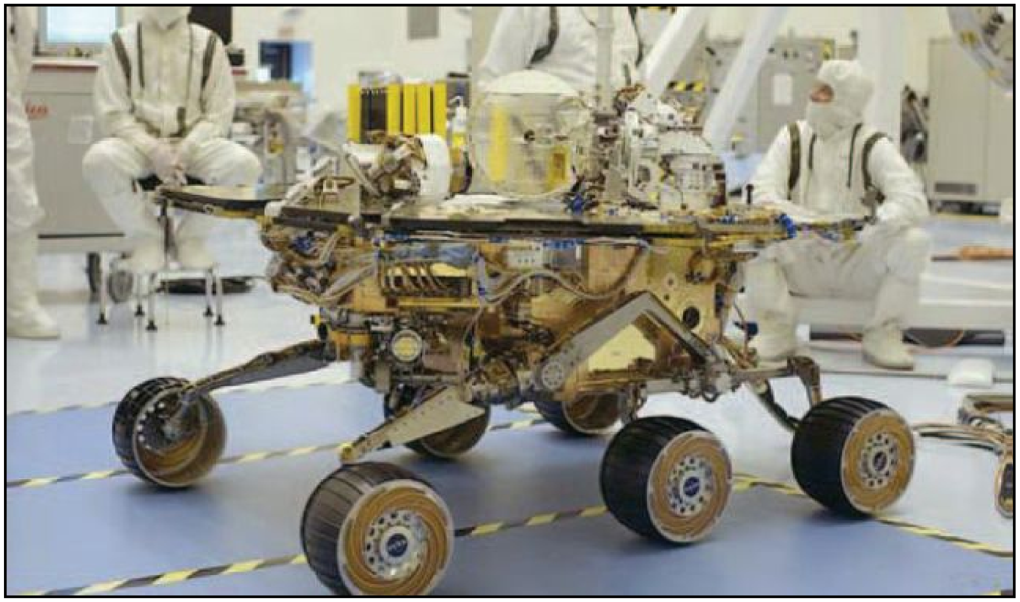
Machine Intelligence Starts with the Design

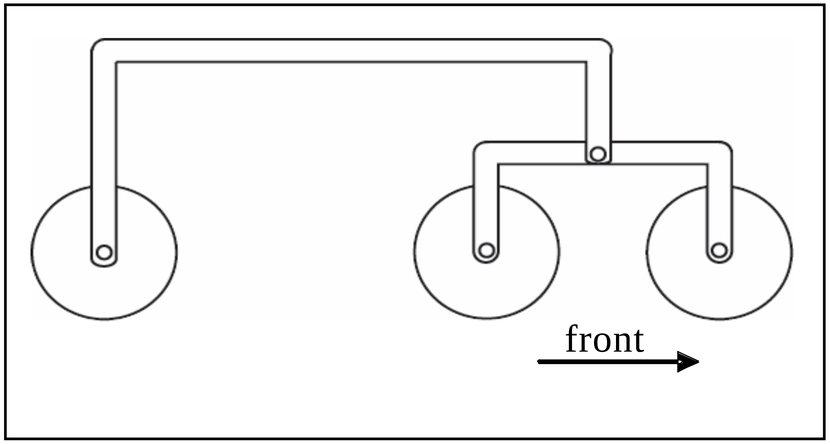
Mechanical Intelligent

- Locomotion Concepts adapted for rough terrain
- **The Shrimp**

Rover Description – MER

- Mars Exploration Rover (MER)

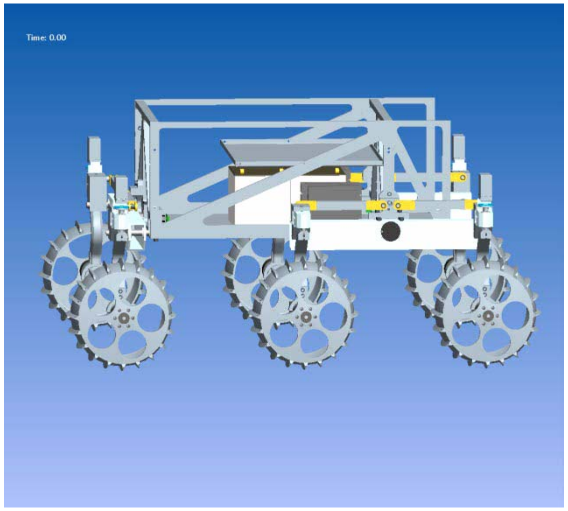


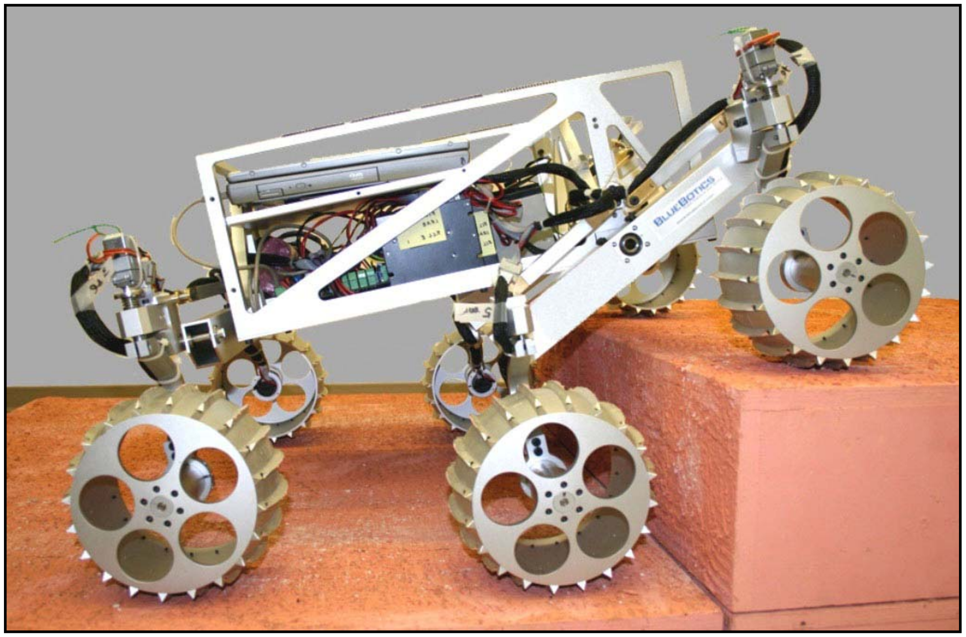


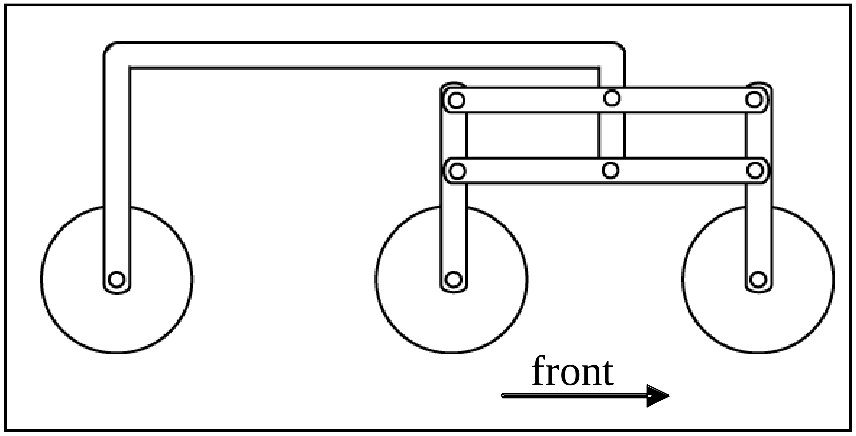
- *MER by NASA; successful mission on Mars*
- *Original rocker bogie type structure*

Rover Description – RCL-E

- Concept E (RCL-E)





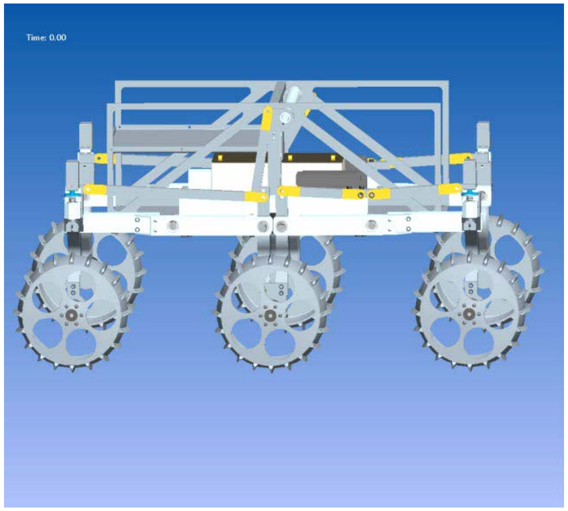


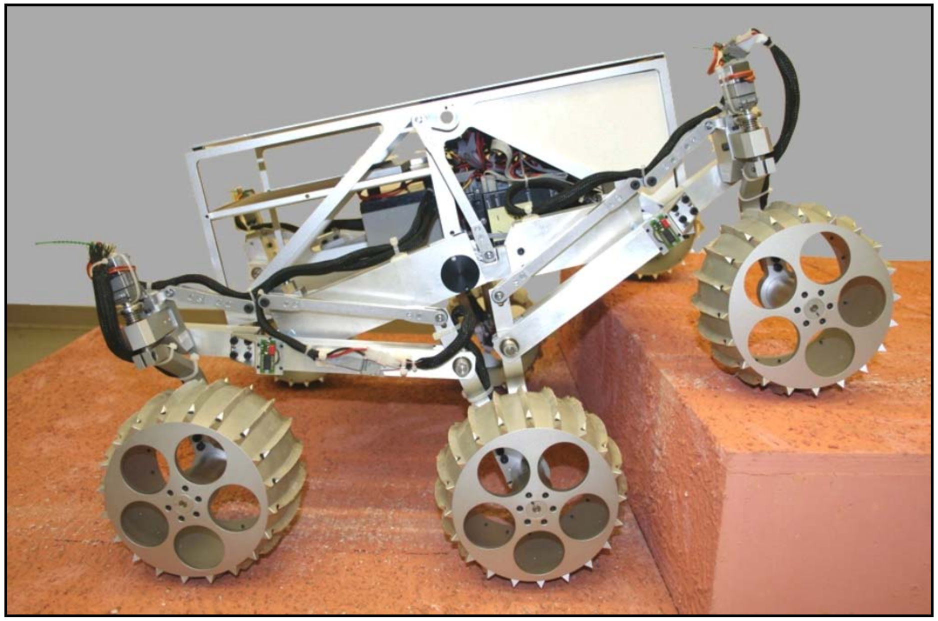
➢ *RCL and VNIITRANSMASH: ESROL-A*

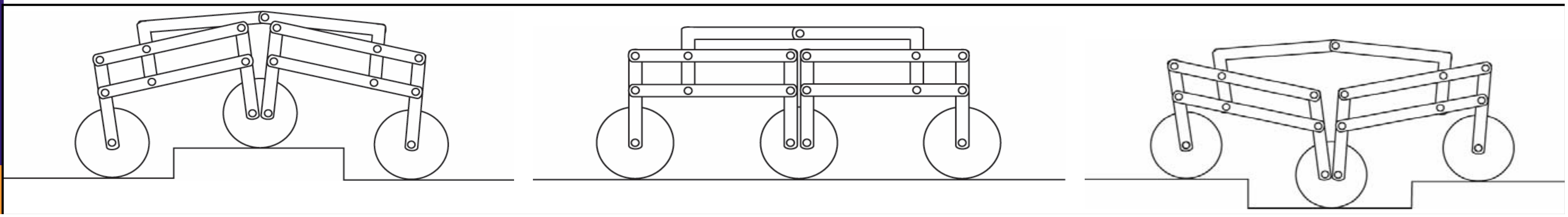
➢ *Simple structure, 3 parallel bogies, no compliance between body and back wheel*

Rover Description – CRAB

- CRAB
  - *Parallel bogies*
  - *Articulated rocker*
  - *Symmetrical structure (longitudinal)*

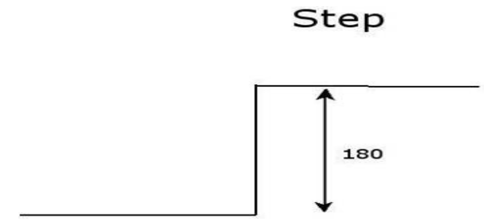


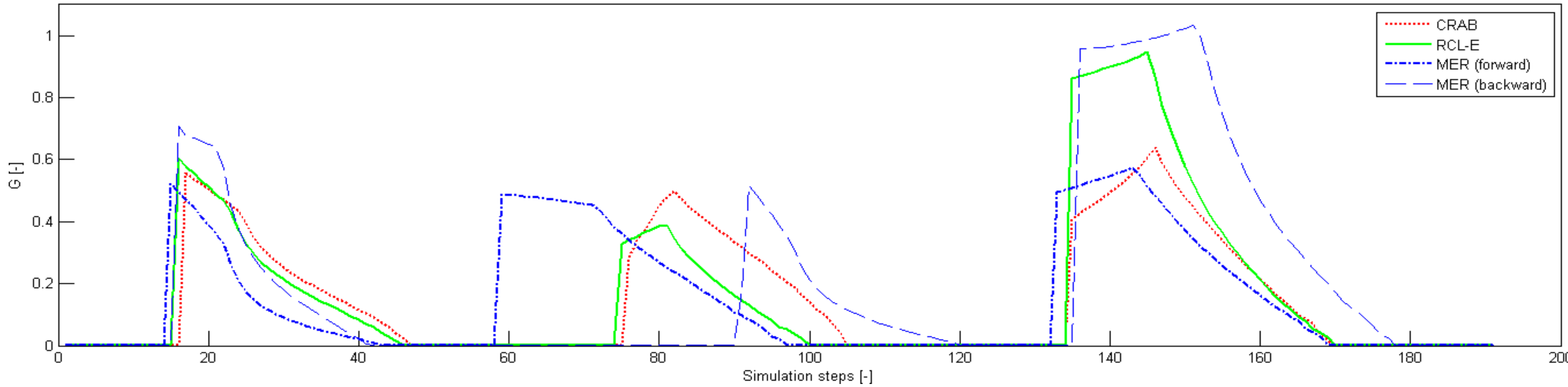


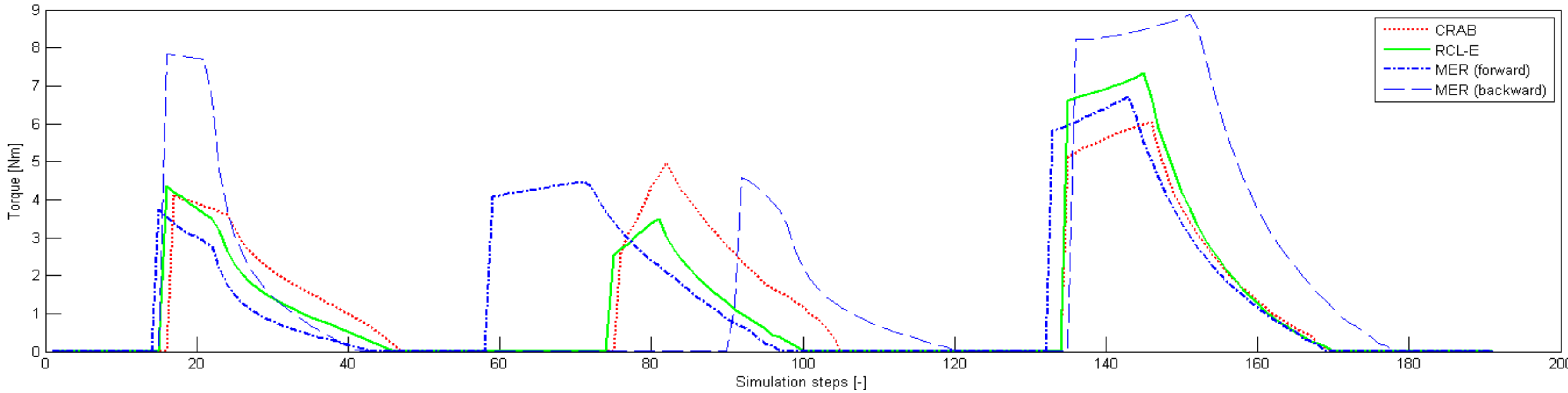


Autonomous Systems Lab

Simulation: Results

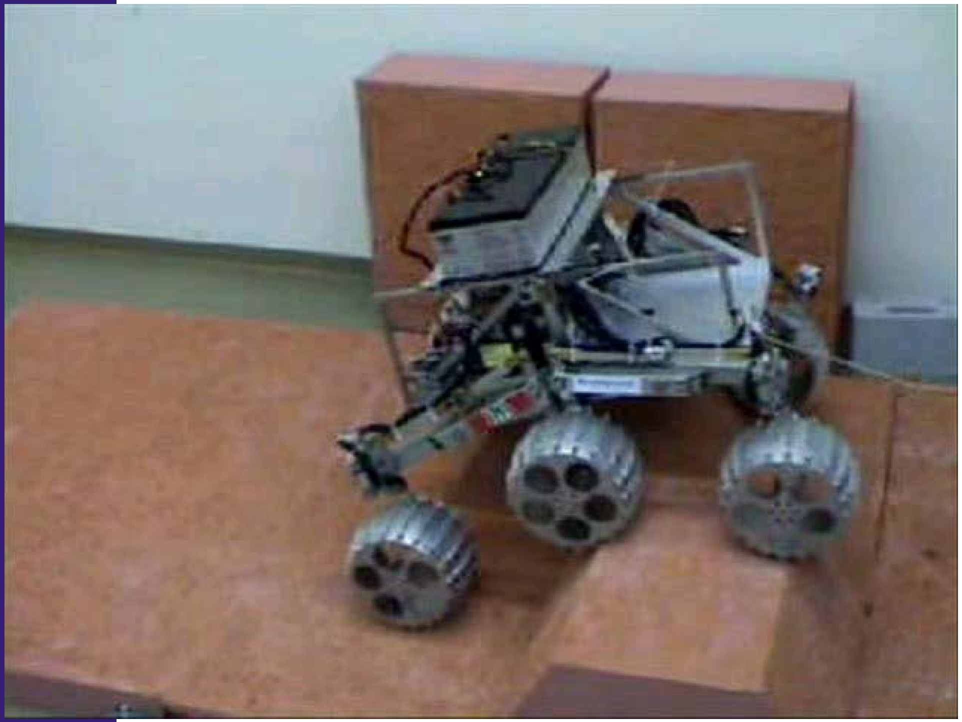






	CRAB	RCL-E	MER FWD	MER BWD
Max. G [-]	0.64	0.95	0.57	1.0
Max. T [Nm]	6.0	7.3	6.7	8.9

Space Rovers
Experimental results

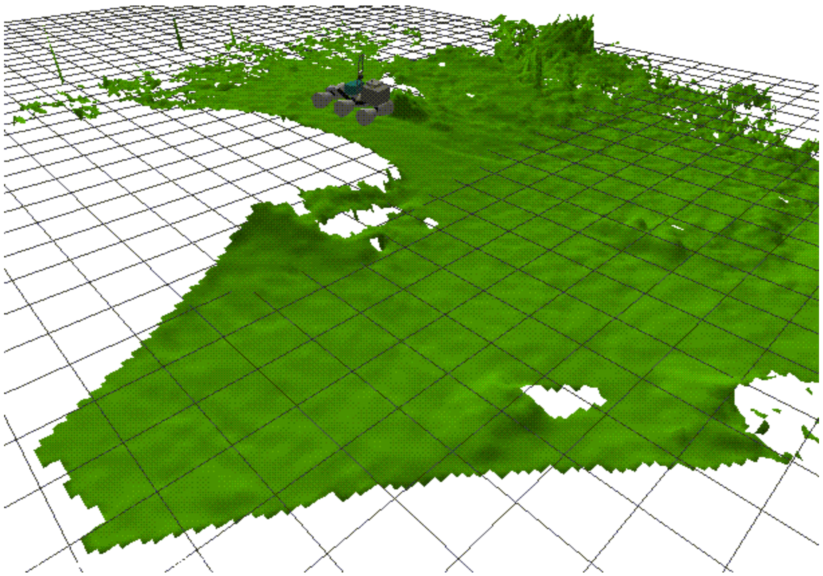


EPFL-Crab

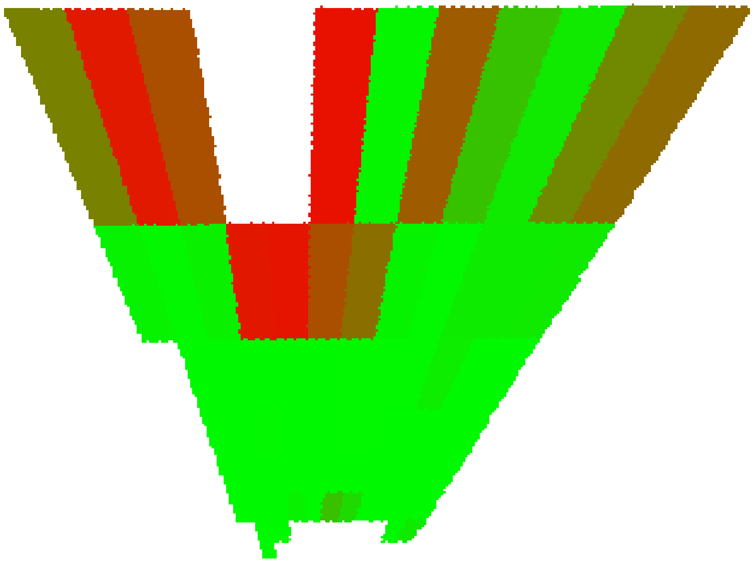
RCL-C

Motion Planning

- Onboard the rover: for navigation
  - *Motion estimation and control*
  - *Planning based on 3D maps perceived by the stereo imager*
- On earth: for science and rover operation planning



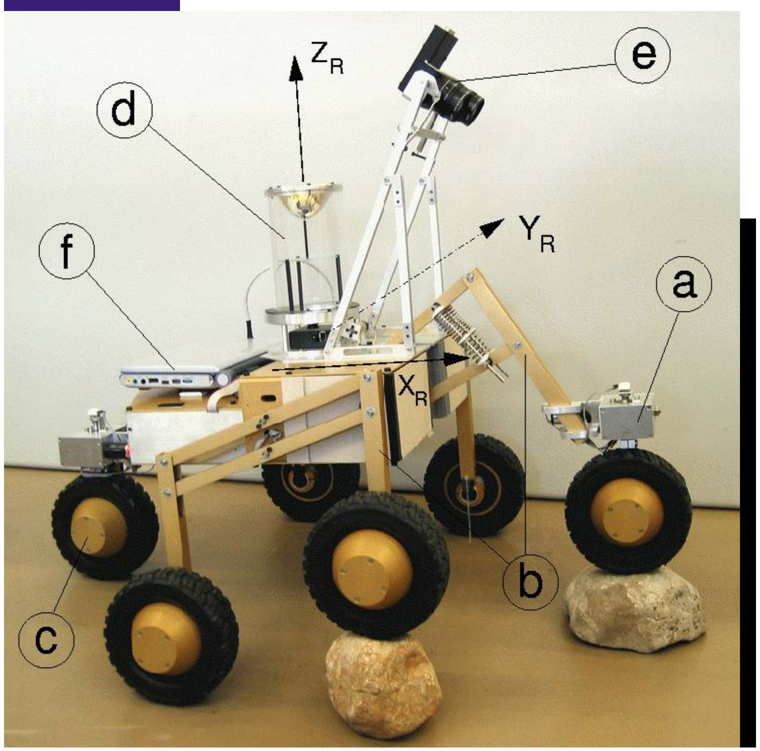
DTM

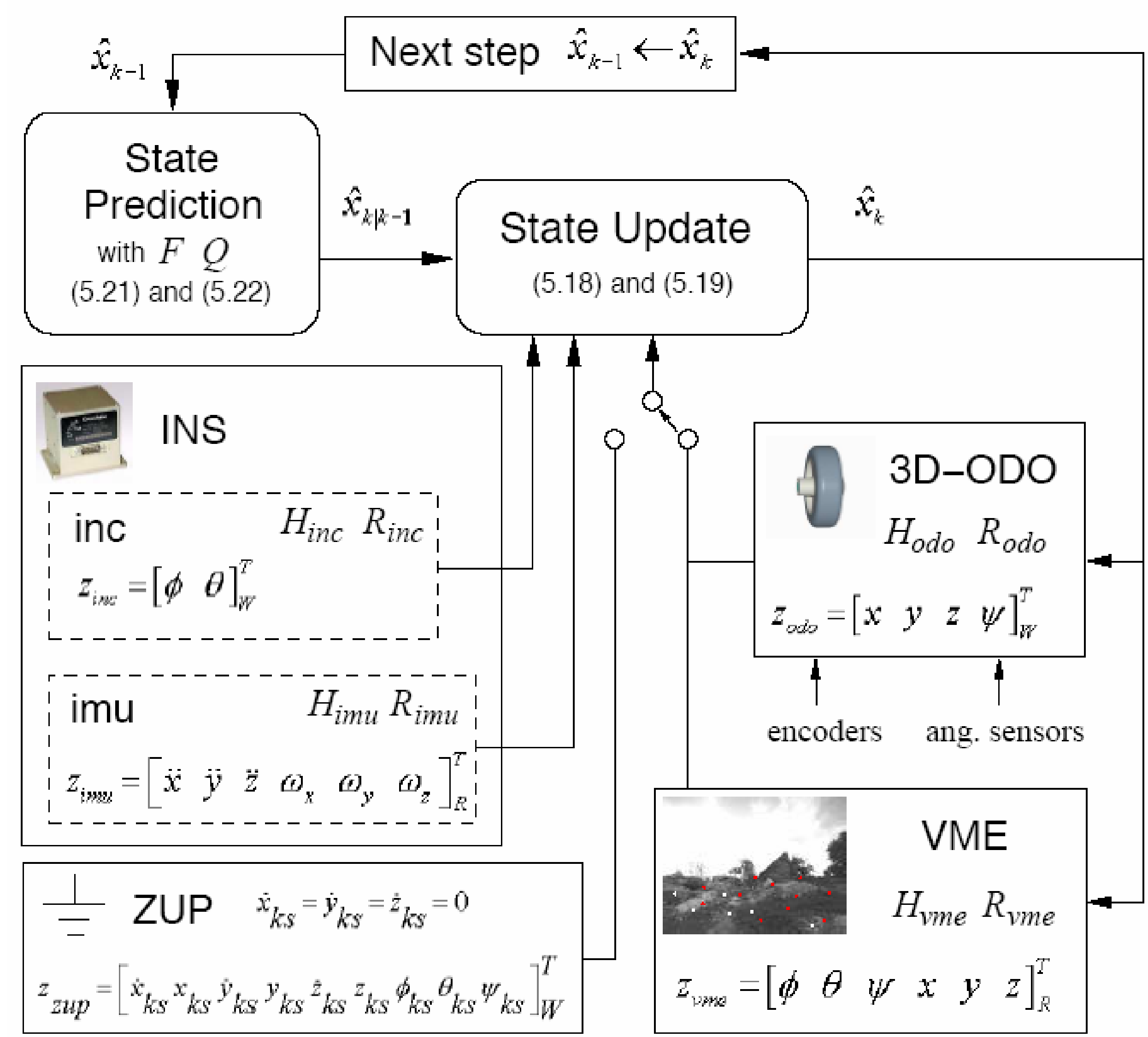


Traversability map

Navigation –

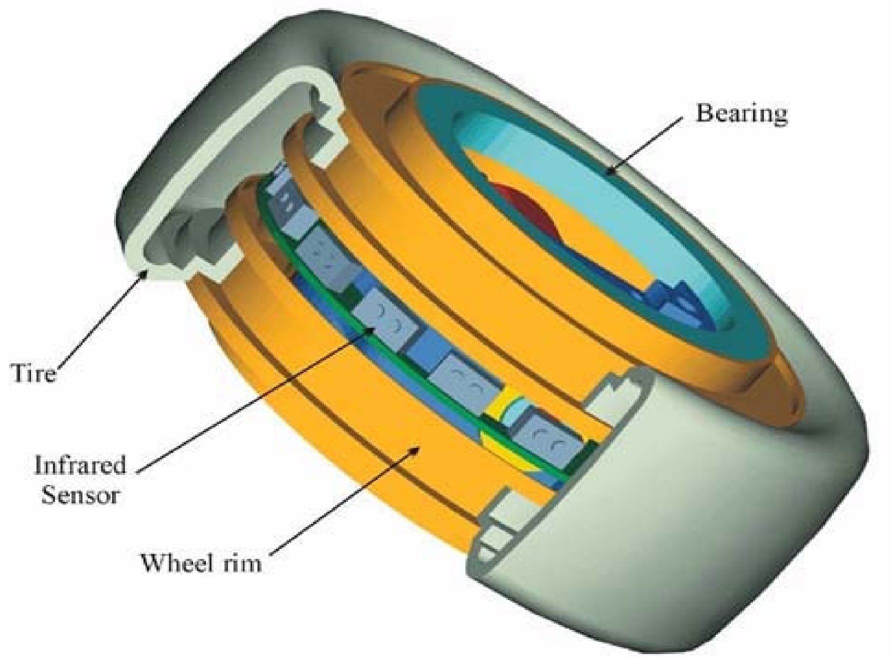
Motion Estimation and Control in Rough Terrain





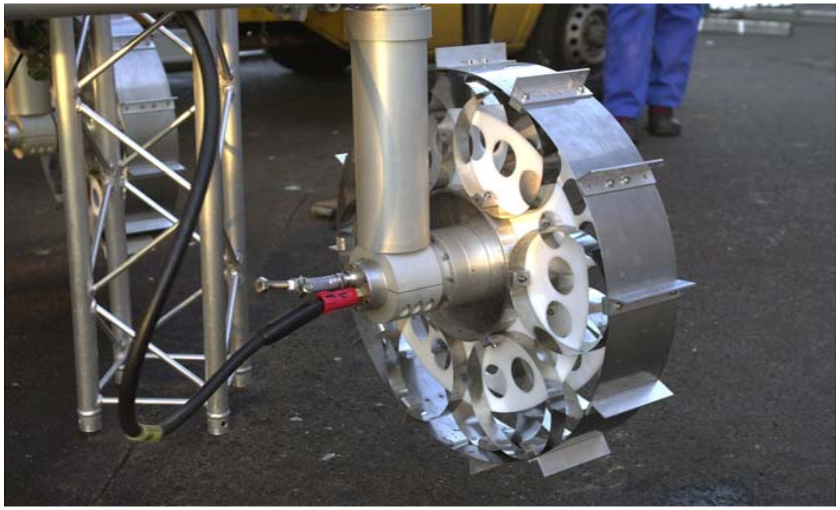
Flexible Wheel
- Feeling the Environment

- Better grip on loose ground
- Measure the contact force and points



Flexible Wheels

- Better tractive performance
- Lower total motion resistance

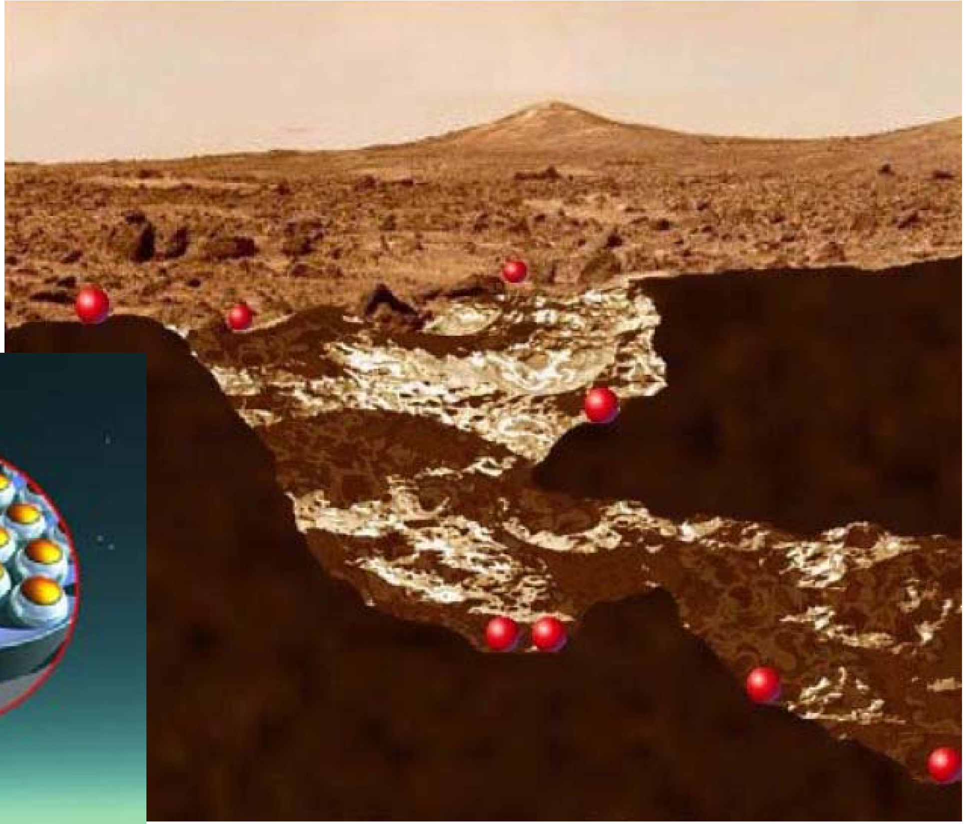


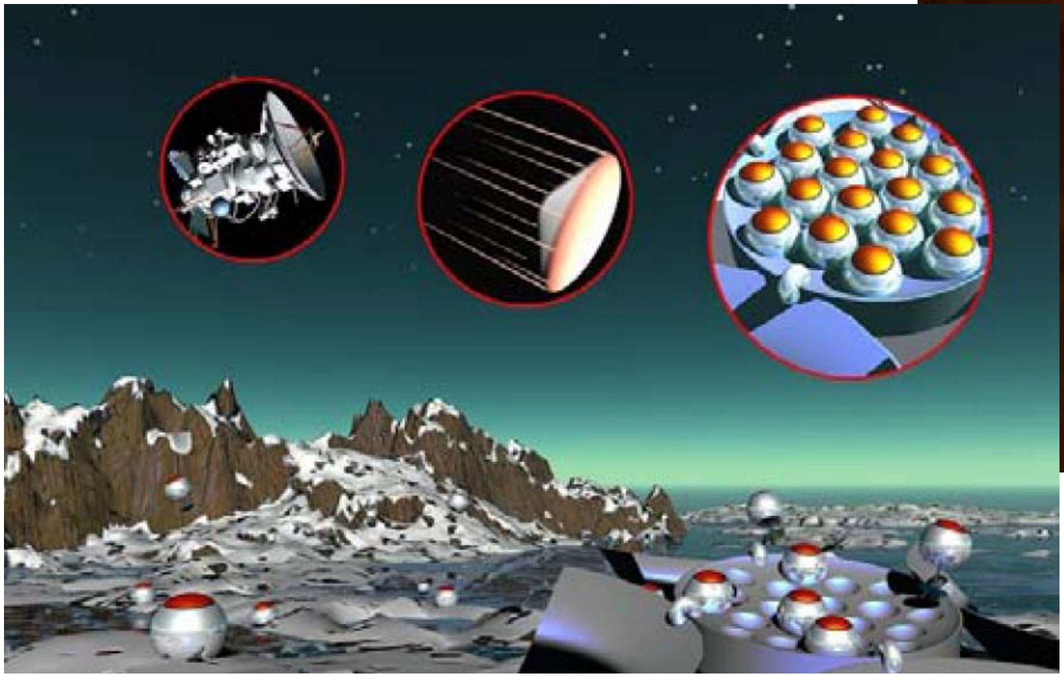
	Total sinkage [mm]	Wheel deflection [mm]	Max. soil slope [°]	Required wheel output torque [Nm]	Combined output power (6 wheels) [W]	Required input power [W]
Rigid wheel D=35 cm, b=15 cm, grouser height=3.4 cm, i=10 %	**45.8**	**-**	**13.9**	**13.87**	**10.6**	**25.2**
Flexible wheel D=35 cm, b=15 cm, grouser height=0.1 cm, pressure on rigid ground=5 kPa, i=10 %	**12.9**	**12.8**	**13.9**	**6.17**	**4.7**	**11.2**

Courtesy of Steven Dubowsky, MIT

Robot Agents

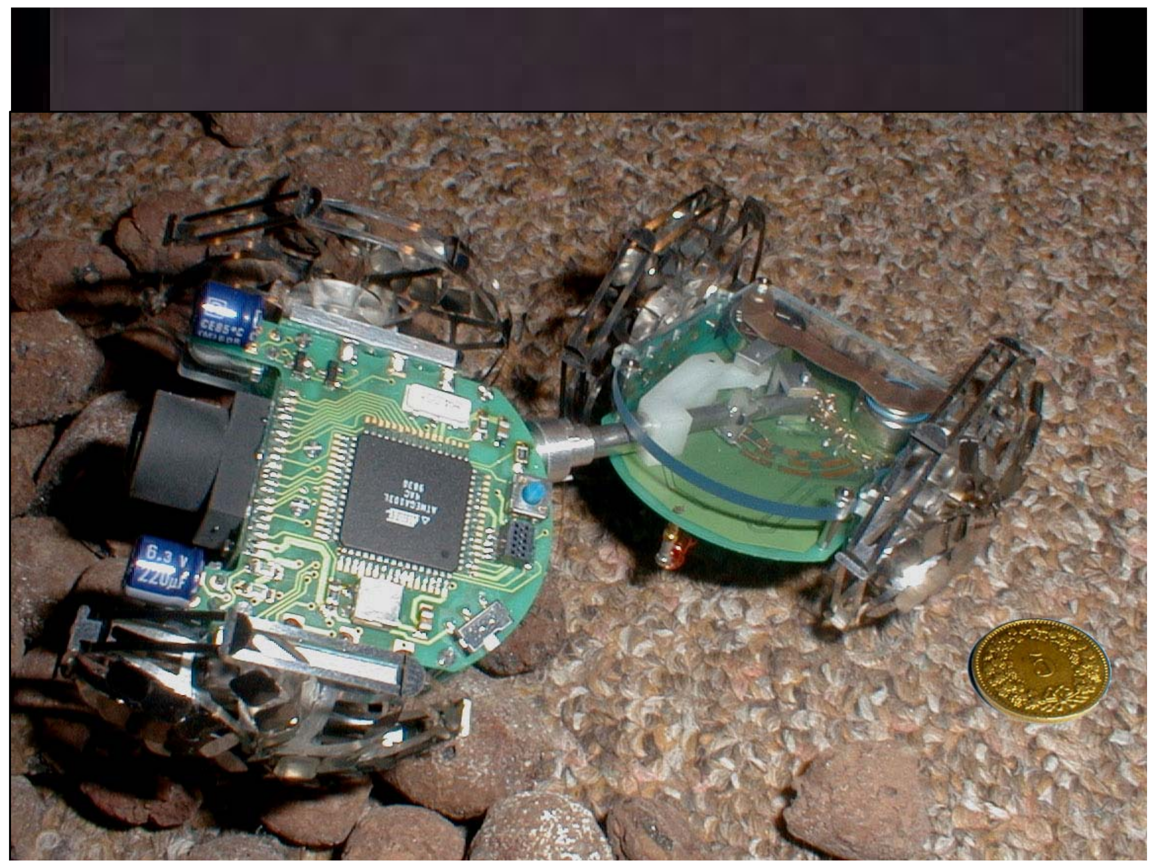
- Microbot Team System for Extraterrestrial Cave Exploration
  - ➢ *Hopping / rolling*
  - ➢ *10 cm diameter, 100 g*





LamAlice II: Pico-Rover for Planetary Exploration

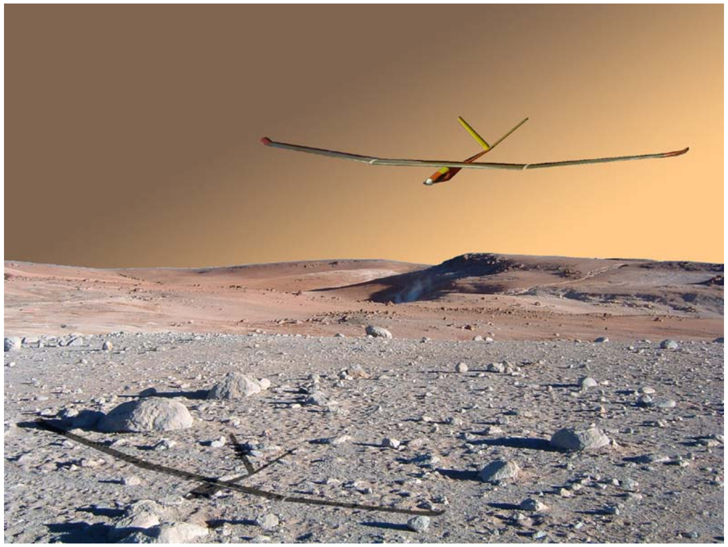
- Size: 11 x 6 x 4 cm
- Weight: 40 g
- Sensors: CMOS Camera (256x256), IR
- Motors: Watch (Lavet)
- Micro-Controller: Atmel ATmega103L
- Power: 50 mW
- Autonomy: 50 h



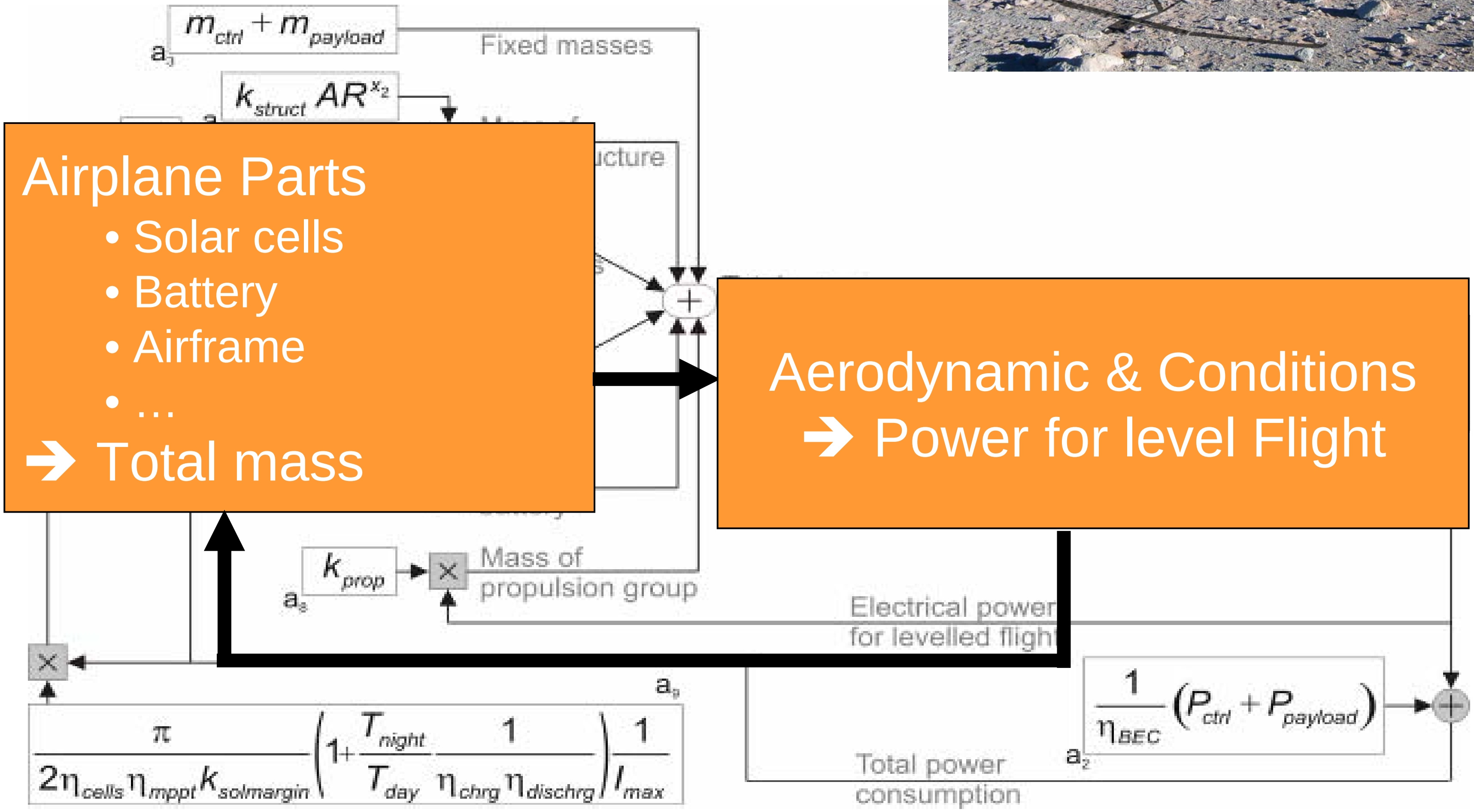
Flying on Mars – Sky-Sailor

- Develop & realize an autonomous, solar powered micro-glider
  - *Power autonomy for staying in air for days*
  - *Navigational autonomy*
  - *Fly on Earth in Martian condition (high altitude)*
- Atmospheric Density
  - *~1/80 compared with earth*
- Gravity
  - *~1/3 compared with earth*
- Solar Energy
  - *~1/2 compared with earth*
- Targeted Payload
  - *0.5 Kg*
  - *Lightweight sensors and scientific instruments*
  - *Atmosphere, magnetic field study*

Design Methodology



- Based on Mass & Power Balance
  - ➢ *Need of precise scaling laws (mass models)*



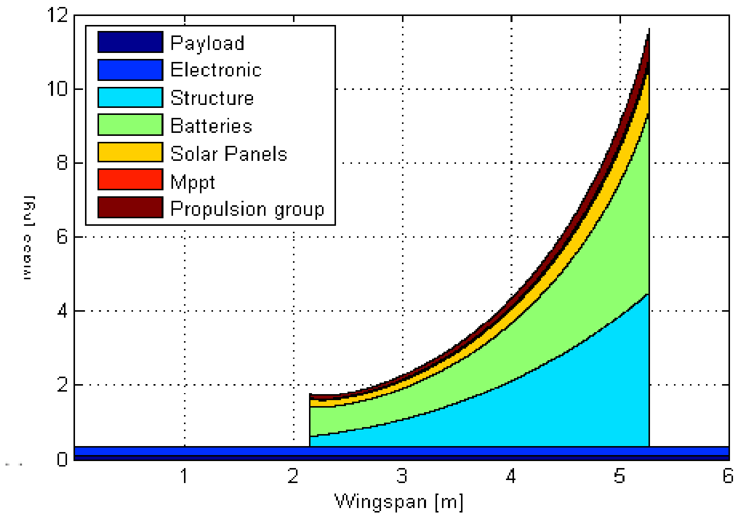
Airplane Parts
- Solar cells
- Battery
- Airframe
- …

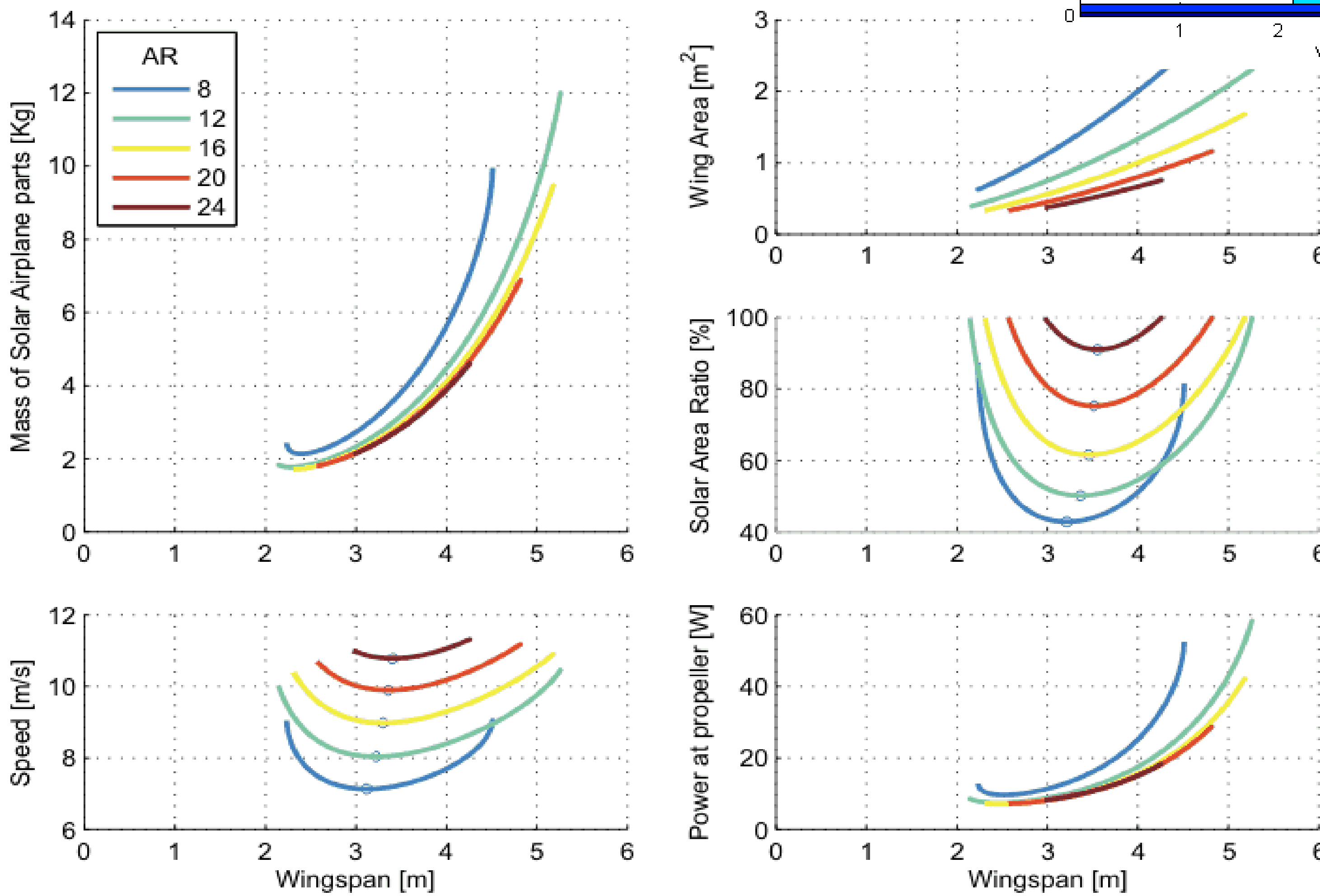
➔ Total mass

Aerodynamic & Conditions
➔ Power for level Flight

Design Methodology

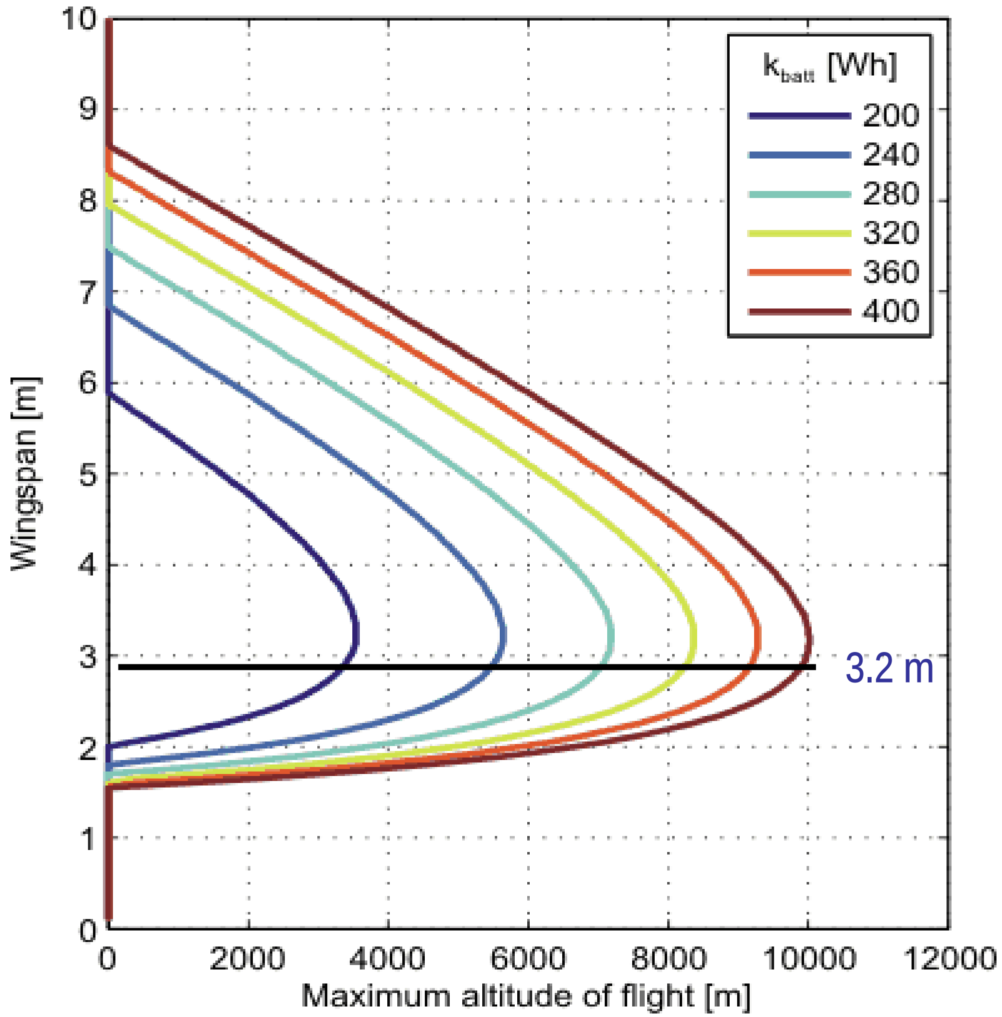
- Results: for 0.5 Kg payload on Earth





Design Methodology

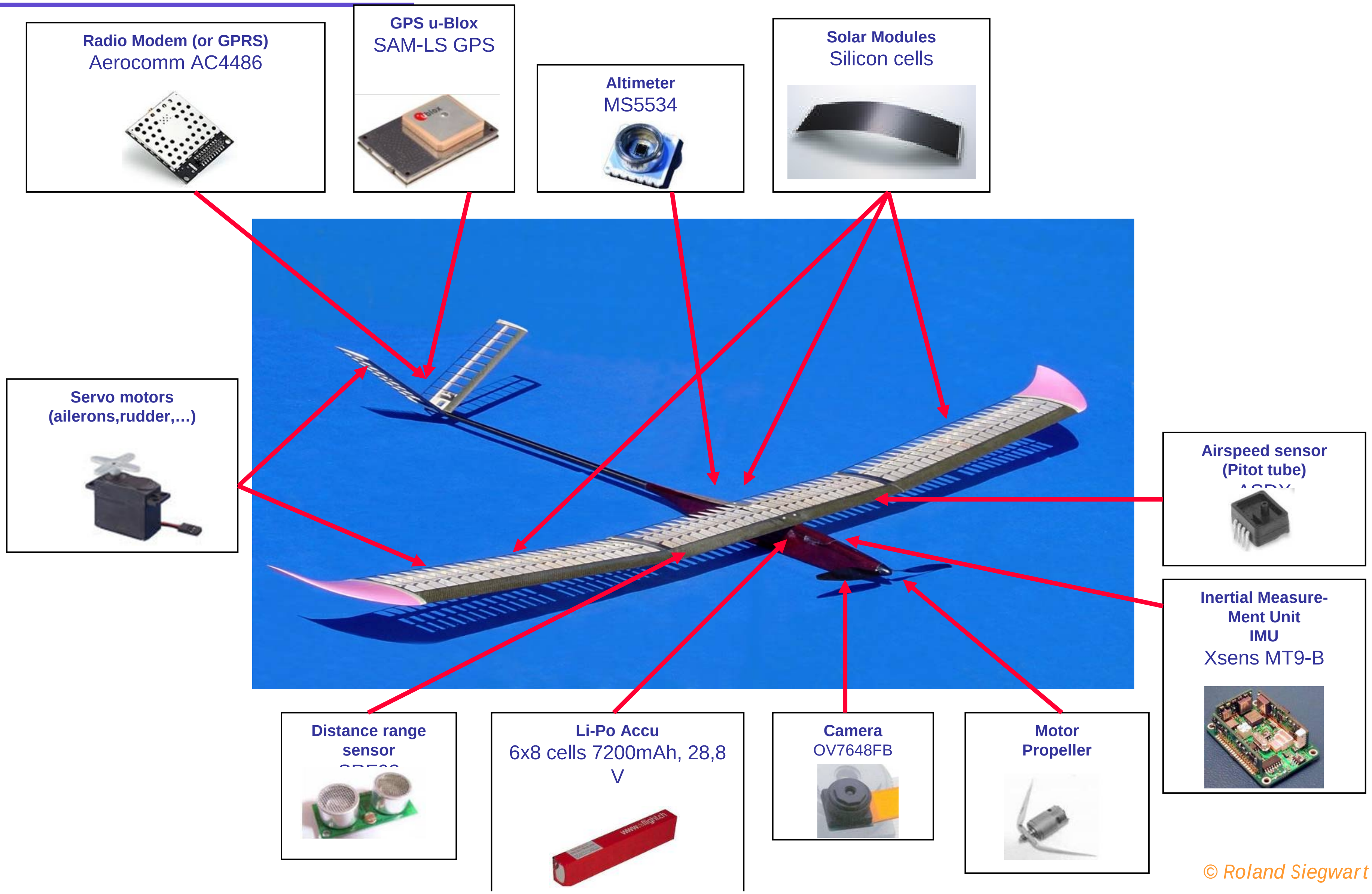
- Influence of battery technology on flight altitude on Earth



1st Prototype

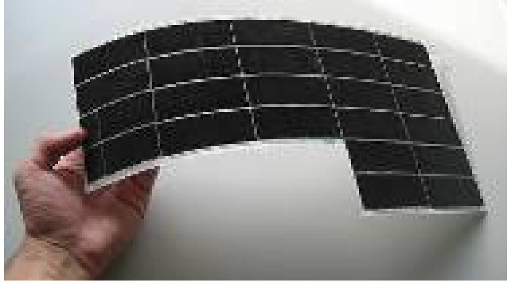
- Motorized model airplane
- Wingspan 3.2 m
- Empty weight 800 g
- Total weight 2.4 kg
- DC motor, 60 cm propeller
  → optimized efficiency for level flight

Skysailor: Systems Integration



Solar Generator

- 216 RWE solar cells
  - *17% efficiency ➔ ~90 W max*
  - *encapsulated into 3 solar panels*
  - *non reflective encapsulation*

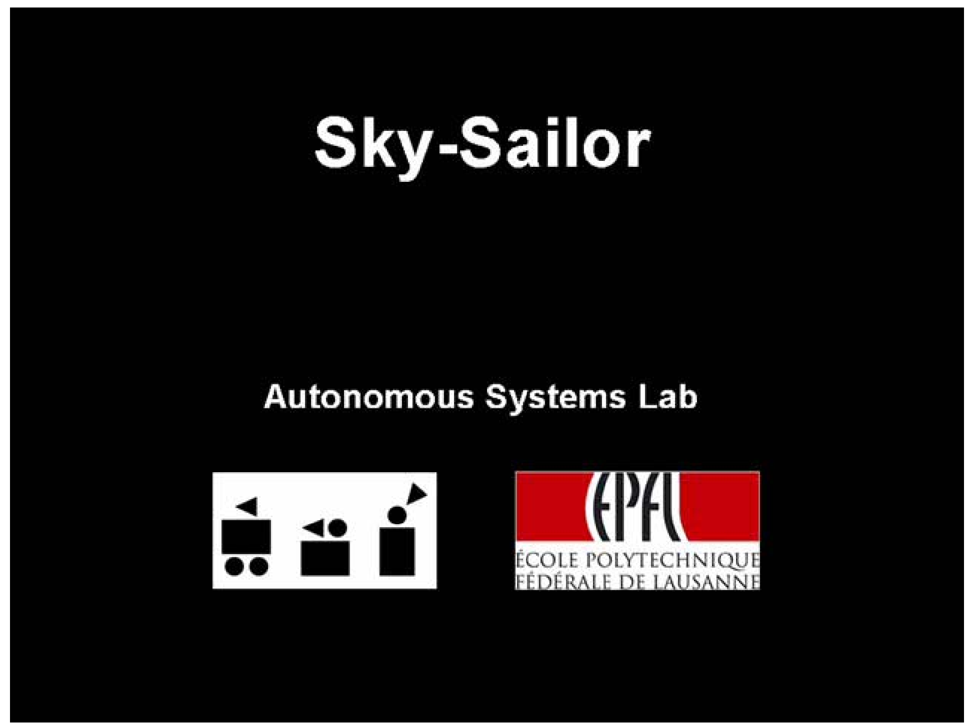


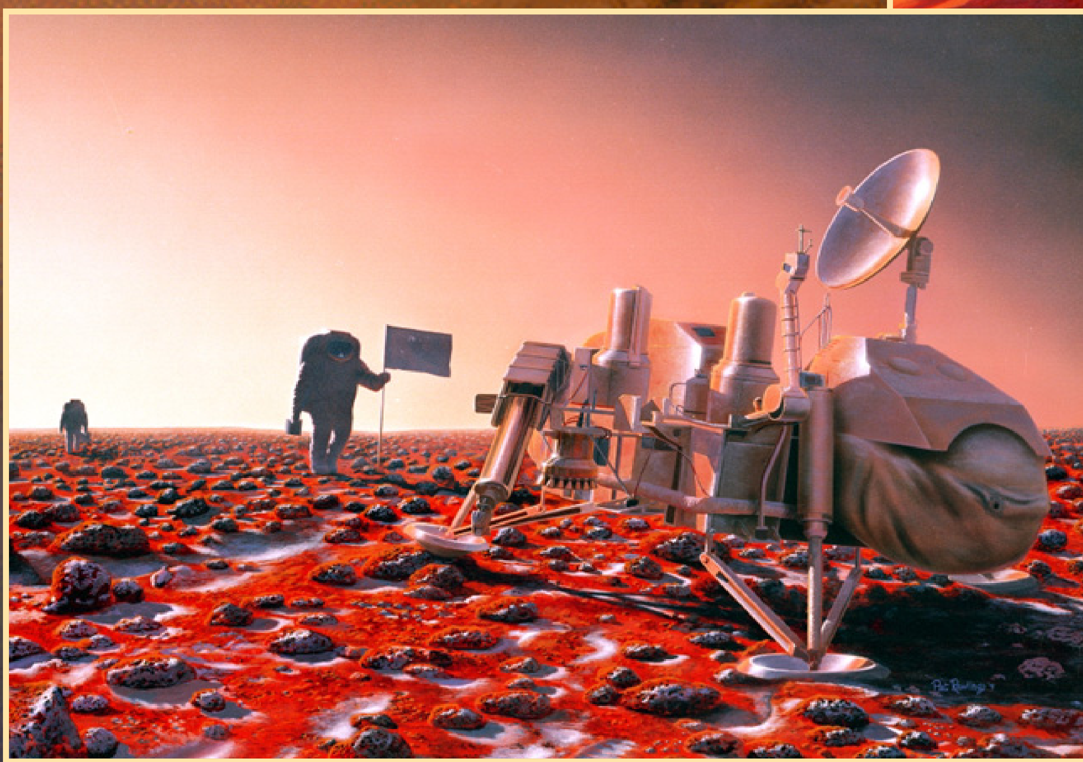
- High efficiency Maximum Power Point Tracker
  - *97 % efficiency for 25 g and 90 W*

- Lithium Polymer Battery
  - *240 Wh, 1.2 kg*

Tests

- Autonomous flight
  - *5 hours flight completed*
- Continuous flight
  - *Feasibility validated*





Mars 2030

Let’s take the challenge