

A wide-angle, high-altitude aerial photograph of the surface of Venus. The terrain is rugged and mountainous, with deep, winding valleys and canyons. The lighting is dramatic, with bright highlights on the peaks and deep shadows in the valleys, giving it a textured, almost wood-grain appearance. The colors are primarily shades of orange, brown, and purple, with some darker regions suggesting volcanic activity or different geological materials. In the distance, a thin, hazy atmosphere is visible against a dark sky.

Geoffrey Landis
NASA Glenn Research Center

Exploring Venus with
Robots and Airplanes

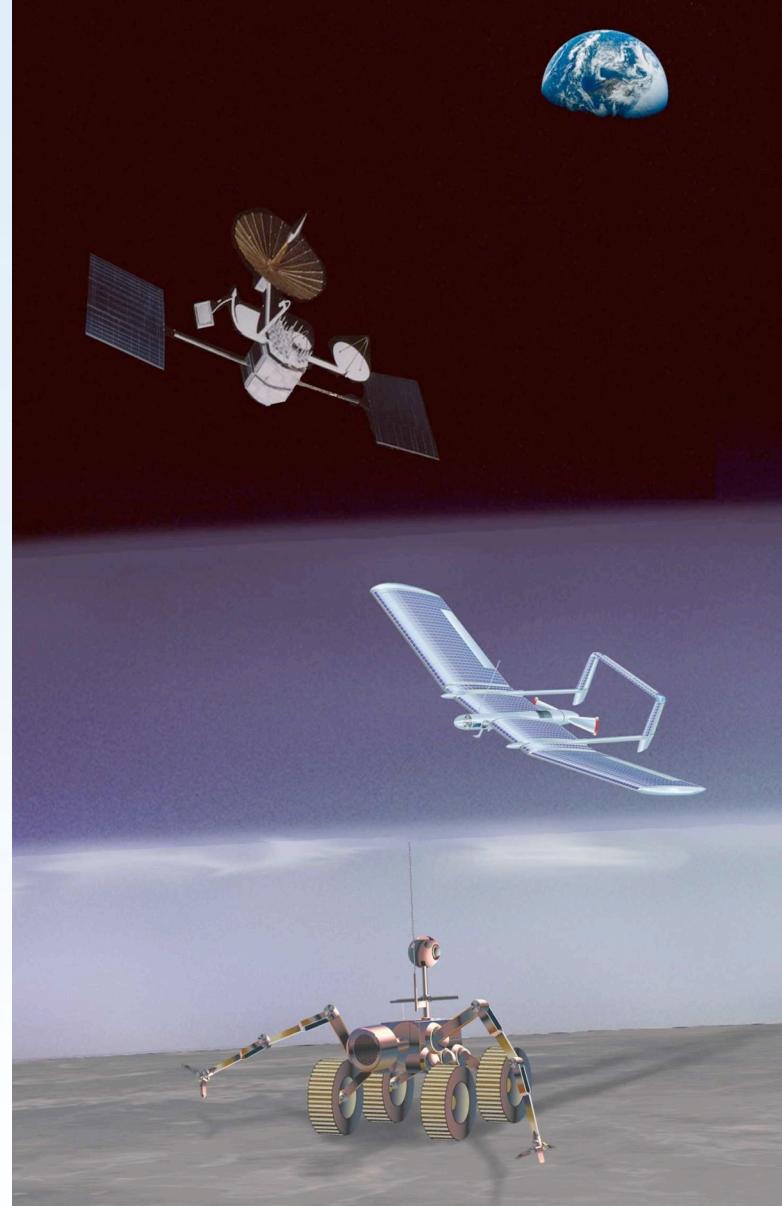
RASC study

Mission Goal:
Exploring Venus from the
surface and the atmosphere

cool upper
atmosphere

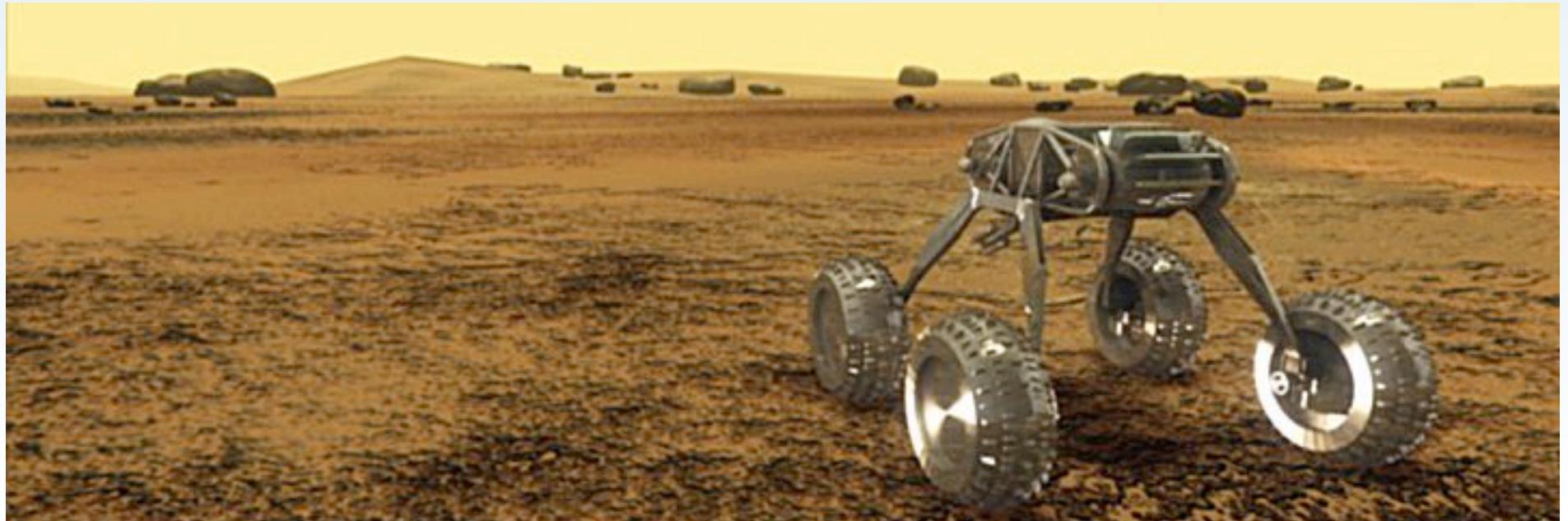
hot lower
atmosphere

very hot
surface

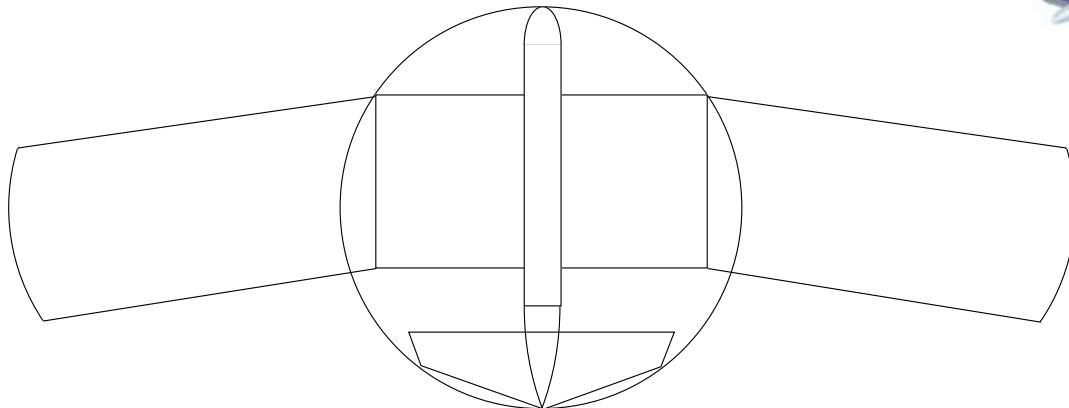
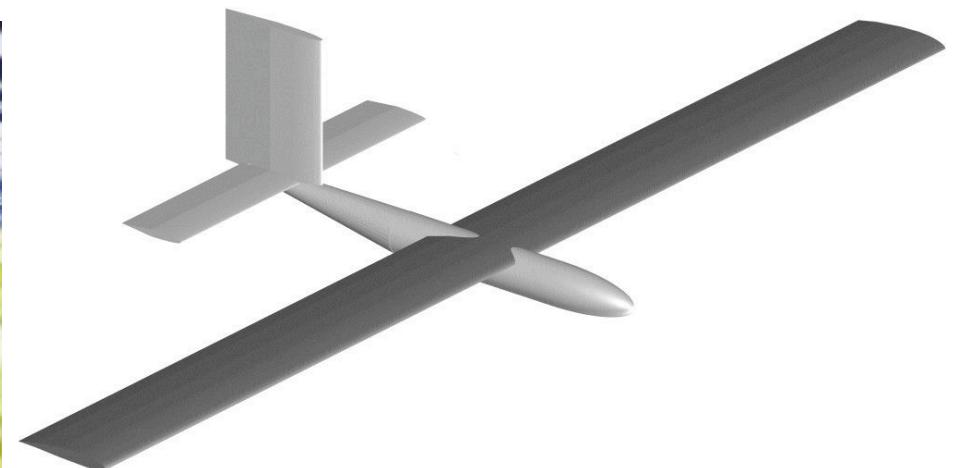
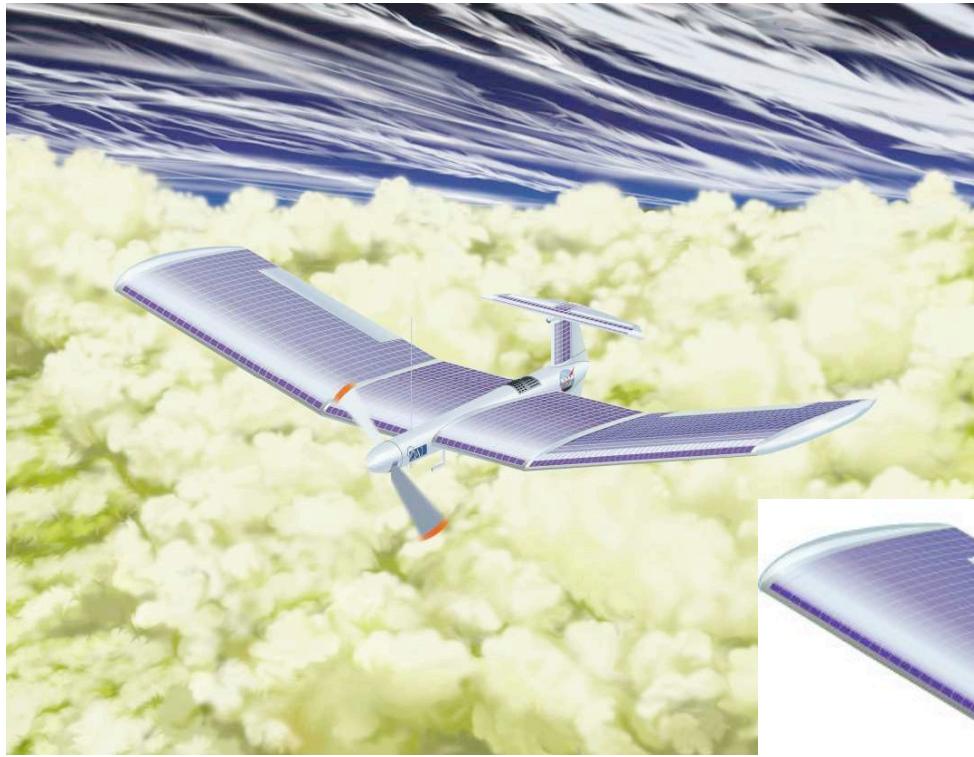


Science mission for Venus Surface Rover

- Characterize the surface at geologically diverse locations
- emplace seismometers to determine the interior structure



Venus Airplane Design Concept Evolution



Venus airplane
3 folds
Medium wing chord version

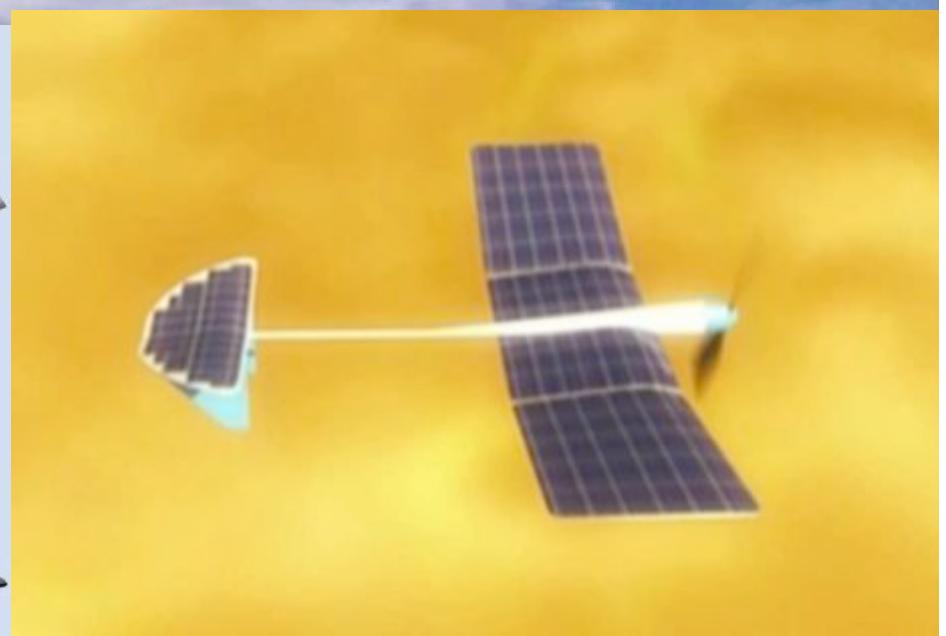
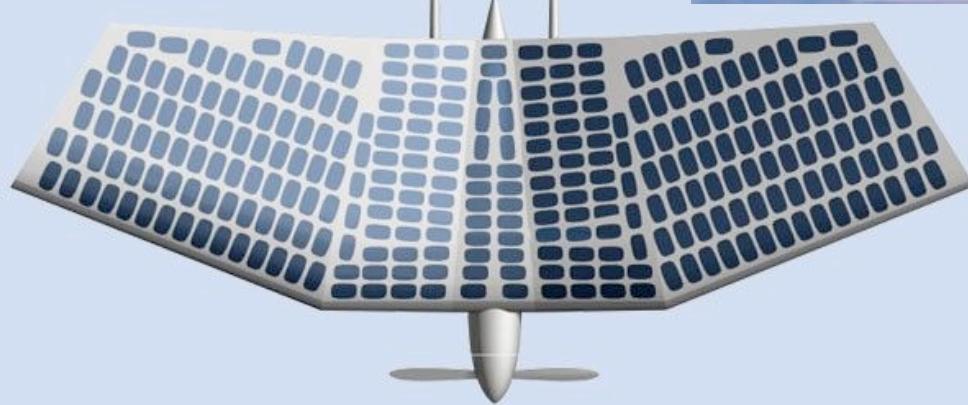
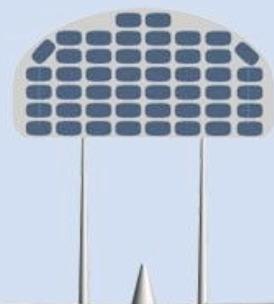
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Venus



Design evolution of Venus Aircraft

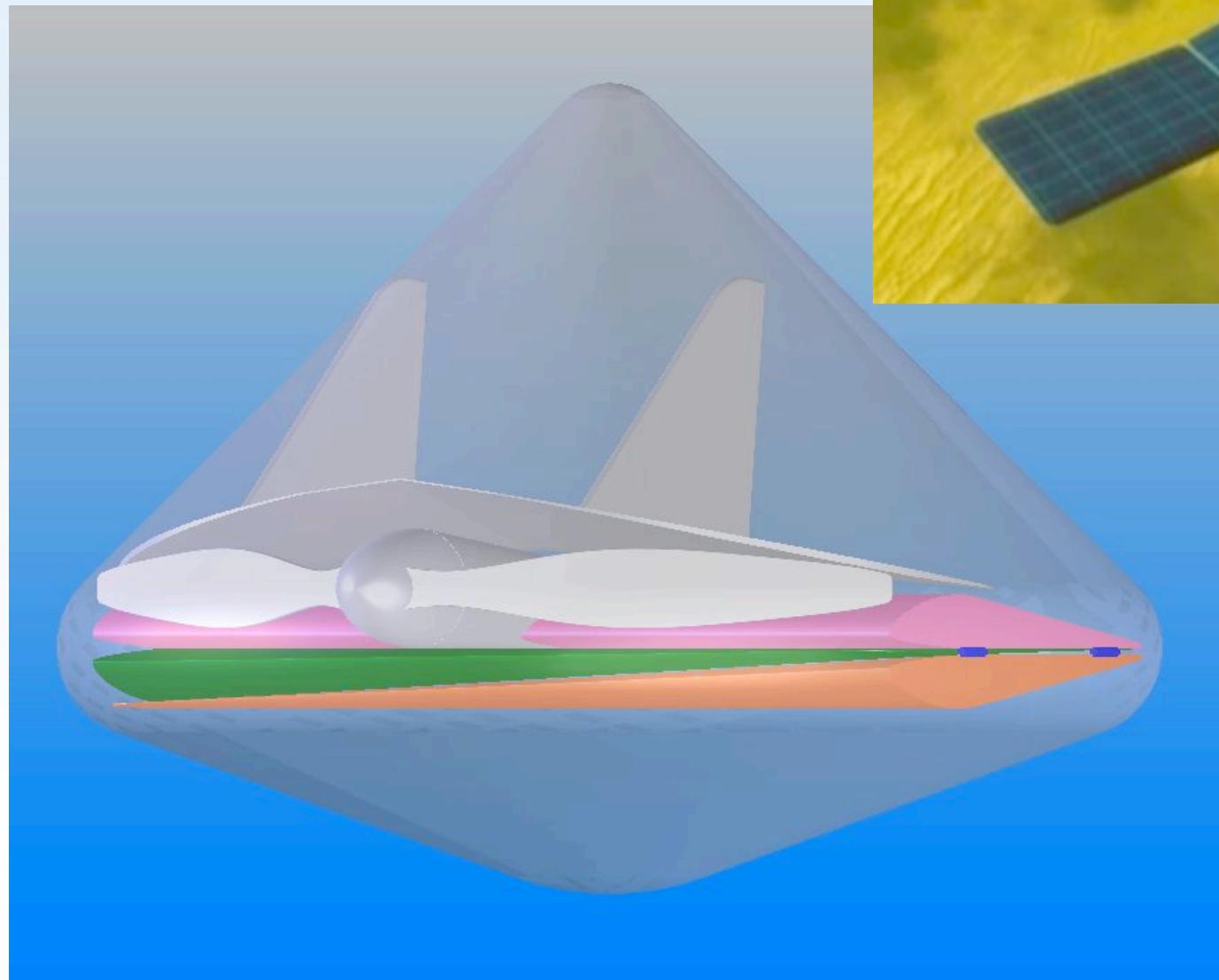
Design concept 2002



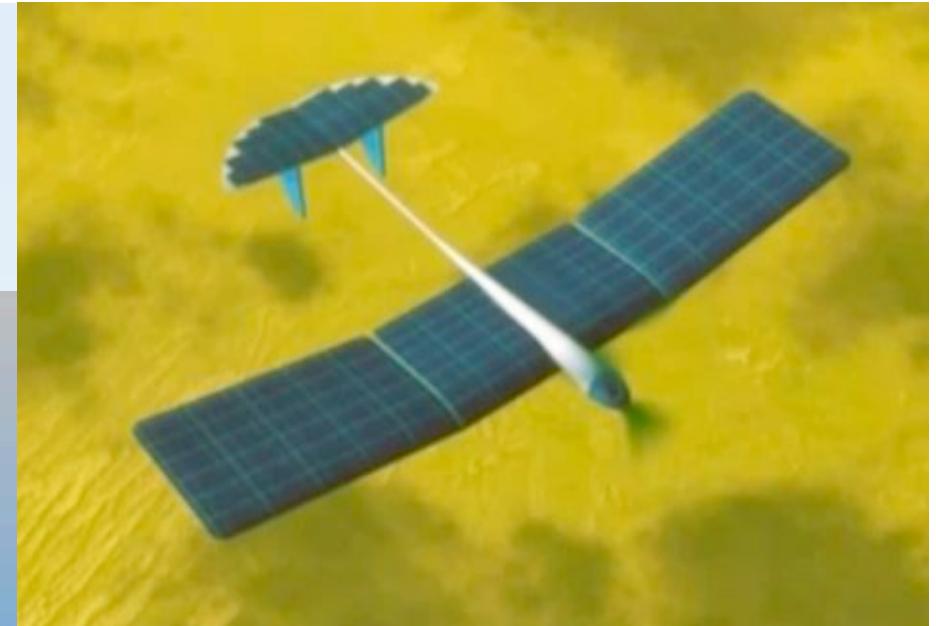
Venus



Venus airplane folded into aeroshell

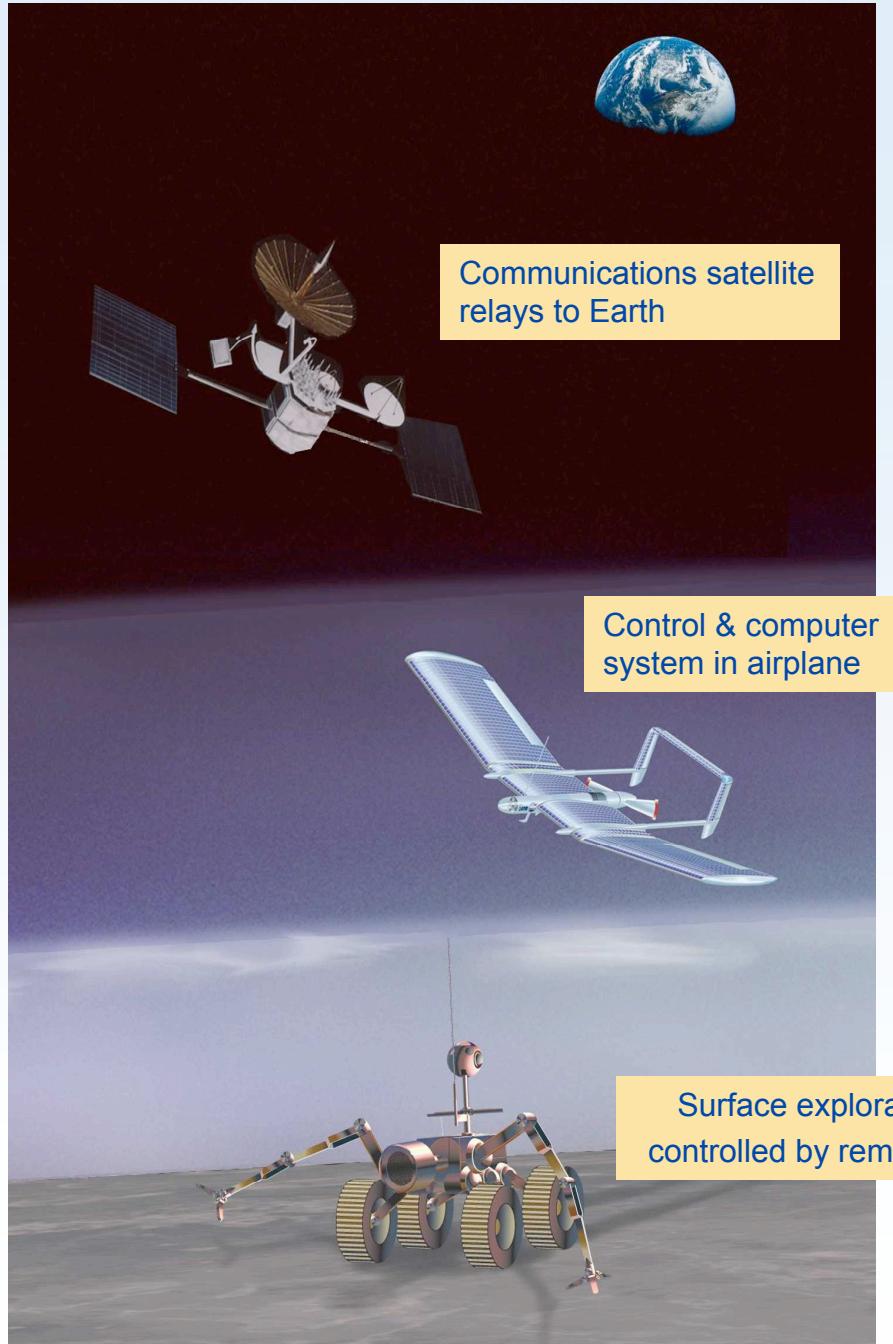


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Venus





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Robotic Exploration Concept:

"brains" of the robot stay in the cool middle atmosphere

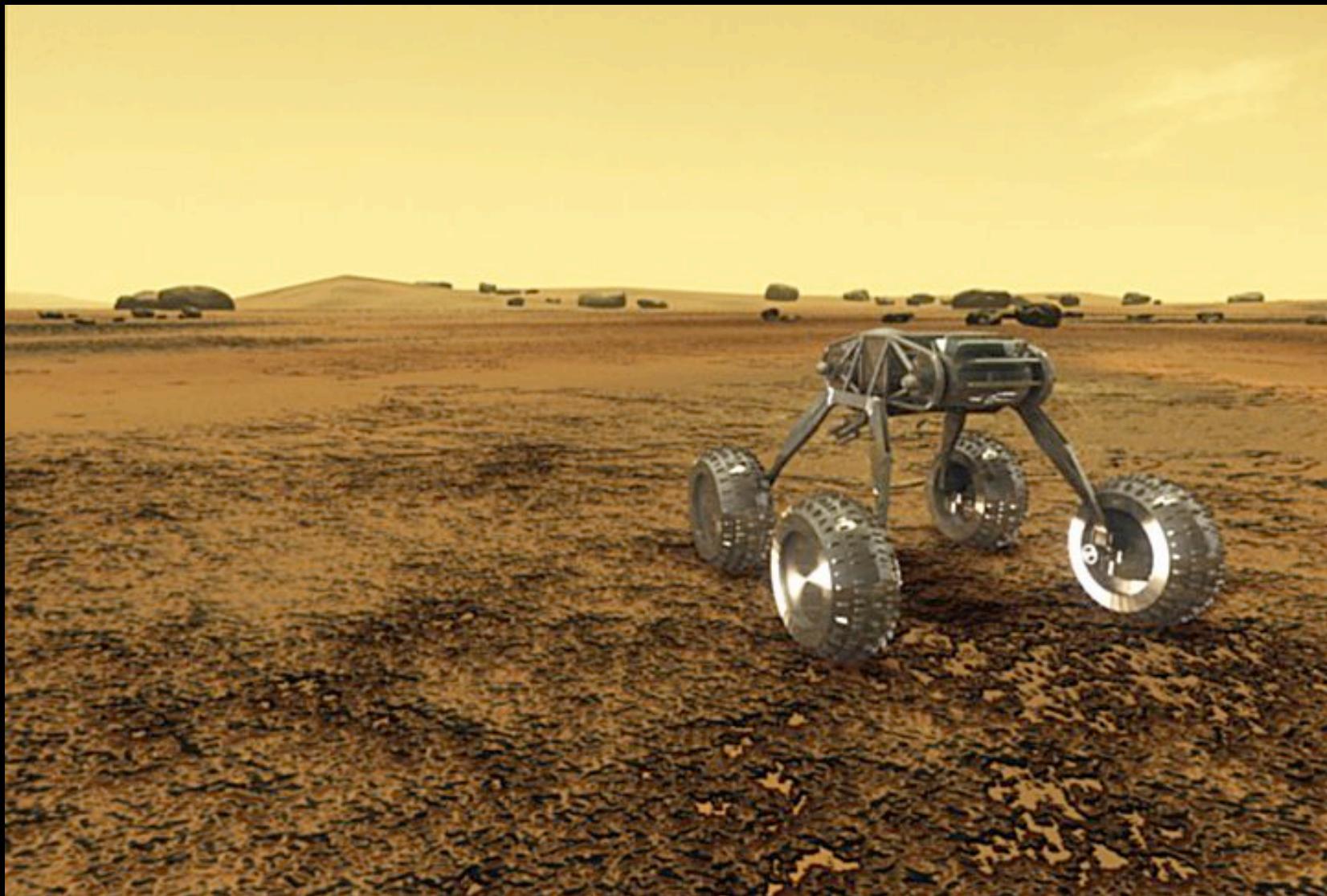
Computer stays in cooler middle atmosphere

Surface robot uses simple high-temperature electronics

Aerostat vs. airplane trade study indicates airplane is preferable

Venus

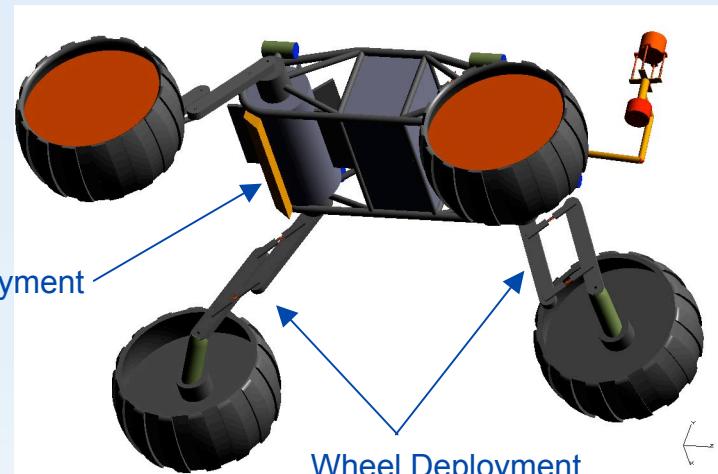
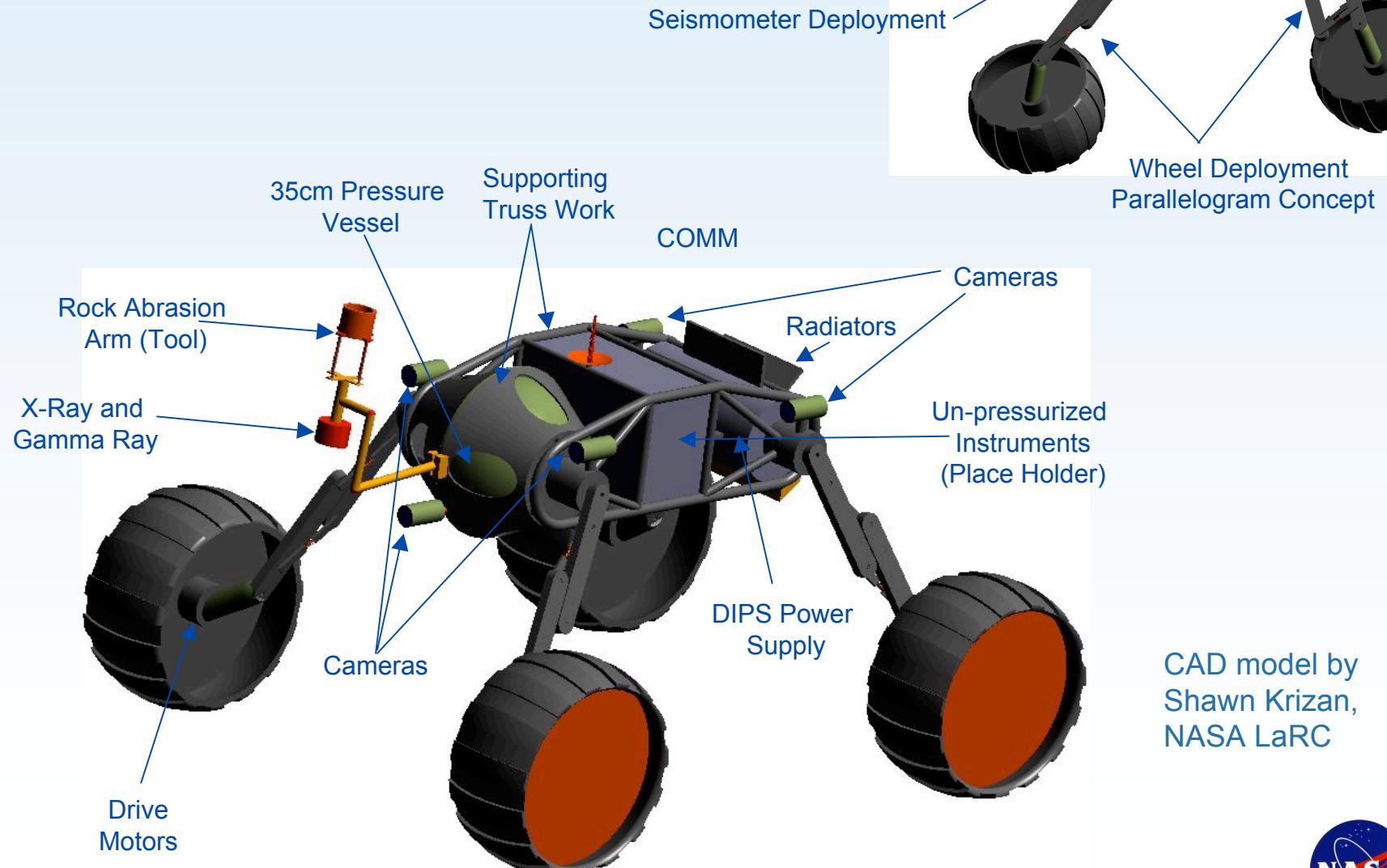




Animation is available at:

<http://www.grc.nasa.gov/WWW/5000/pep/photo-space/venus-mission-design.htm>

Surface Rover concept



CAD model by
Shawn Krizan,
NASA LaRC

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Venus



Engines with hot-end above Venus Temperature

ASC-1 and ASC-1HS

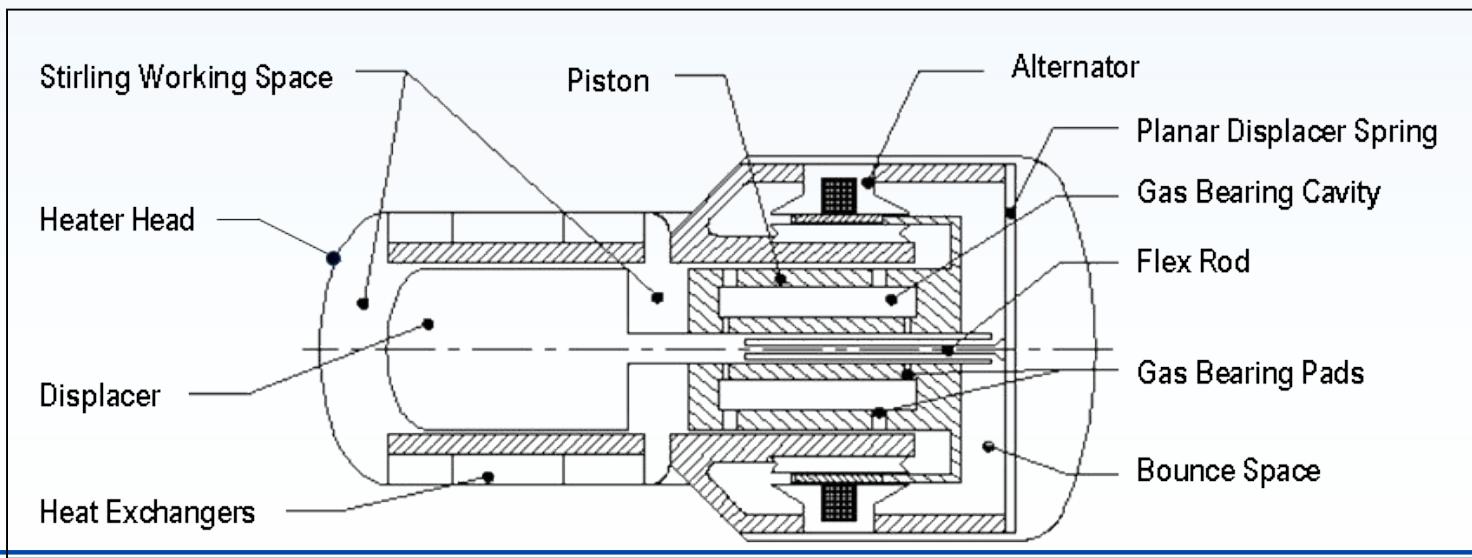
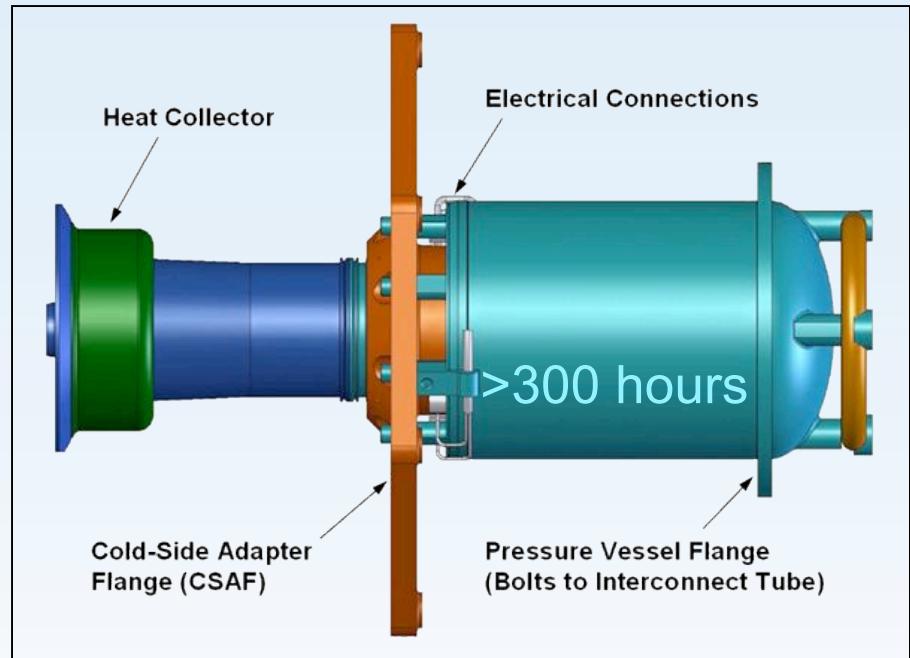
Single Convertor Operating over 300 hours

Total hours on all convertors: 1257

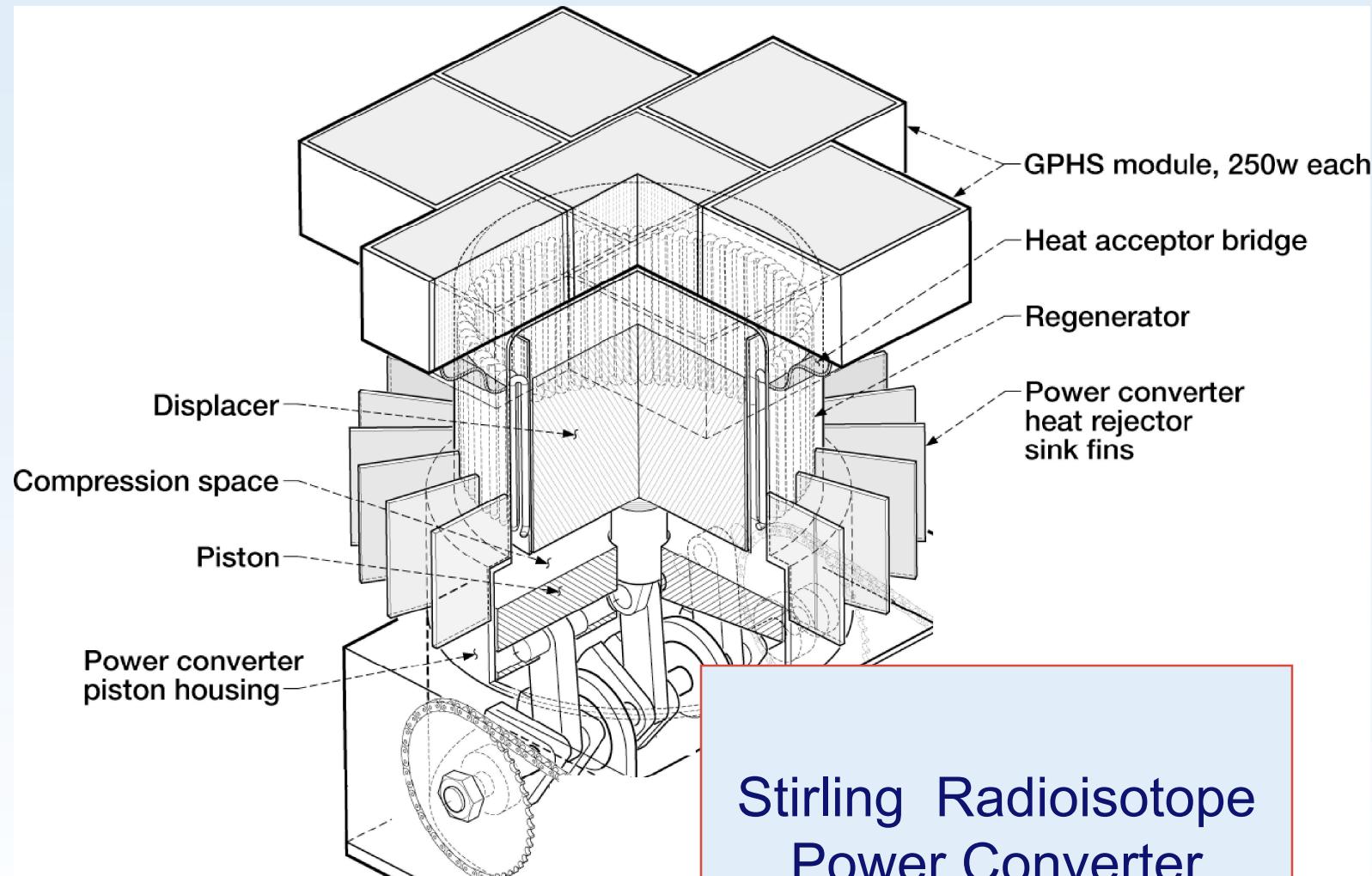
1123K (900C) hot-end

363K cold-end

38% efficient, 1.3 kg, 102 Hz, ~3.6MPa,
88 W up to 114 W, 2005



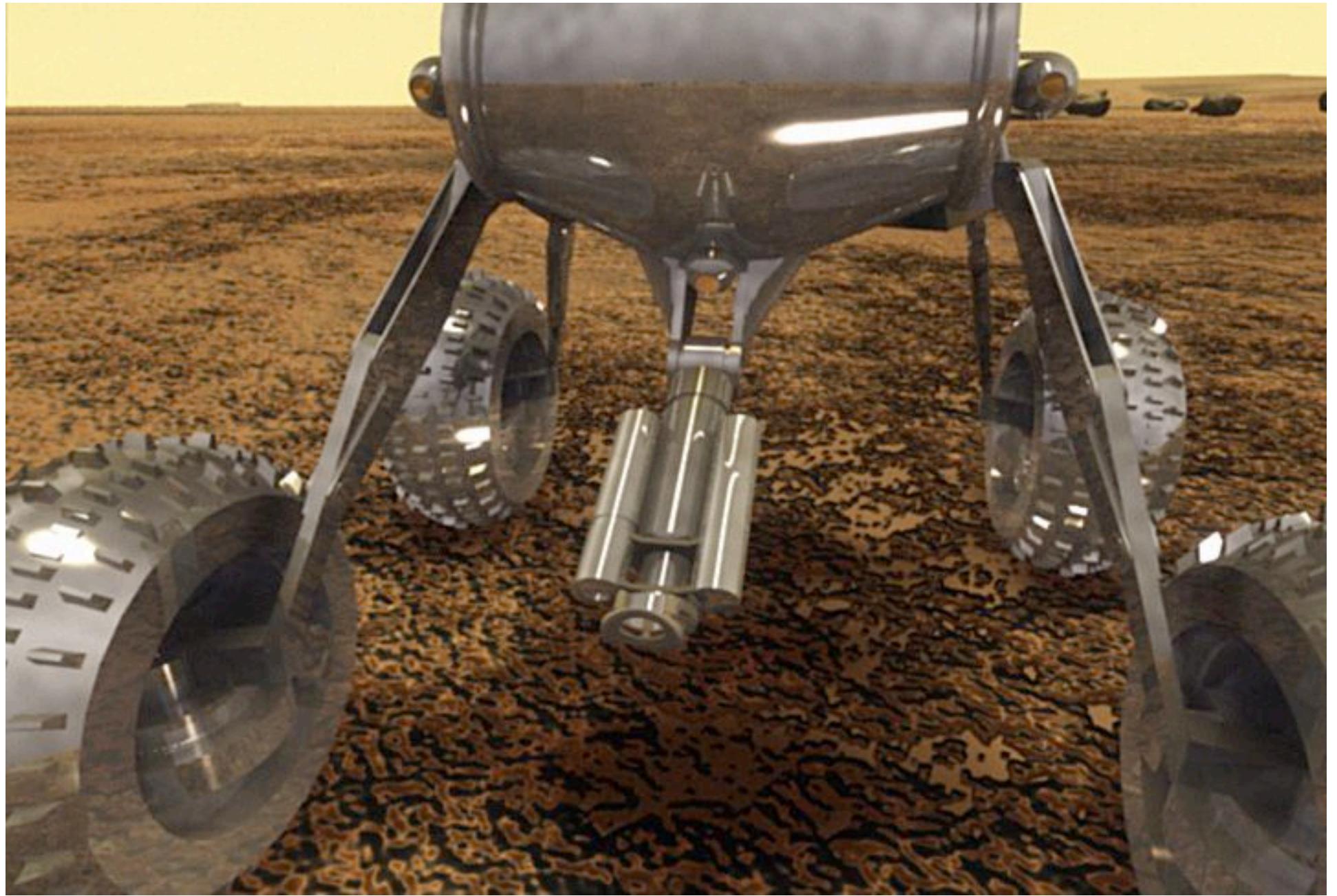
Ref. W.
Wong, GRC



Stirling Radioisotope Power Converter

Radioisotope Power: Sterling conversion

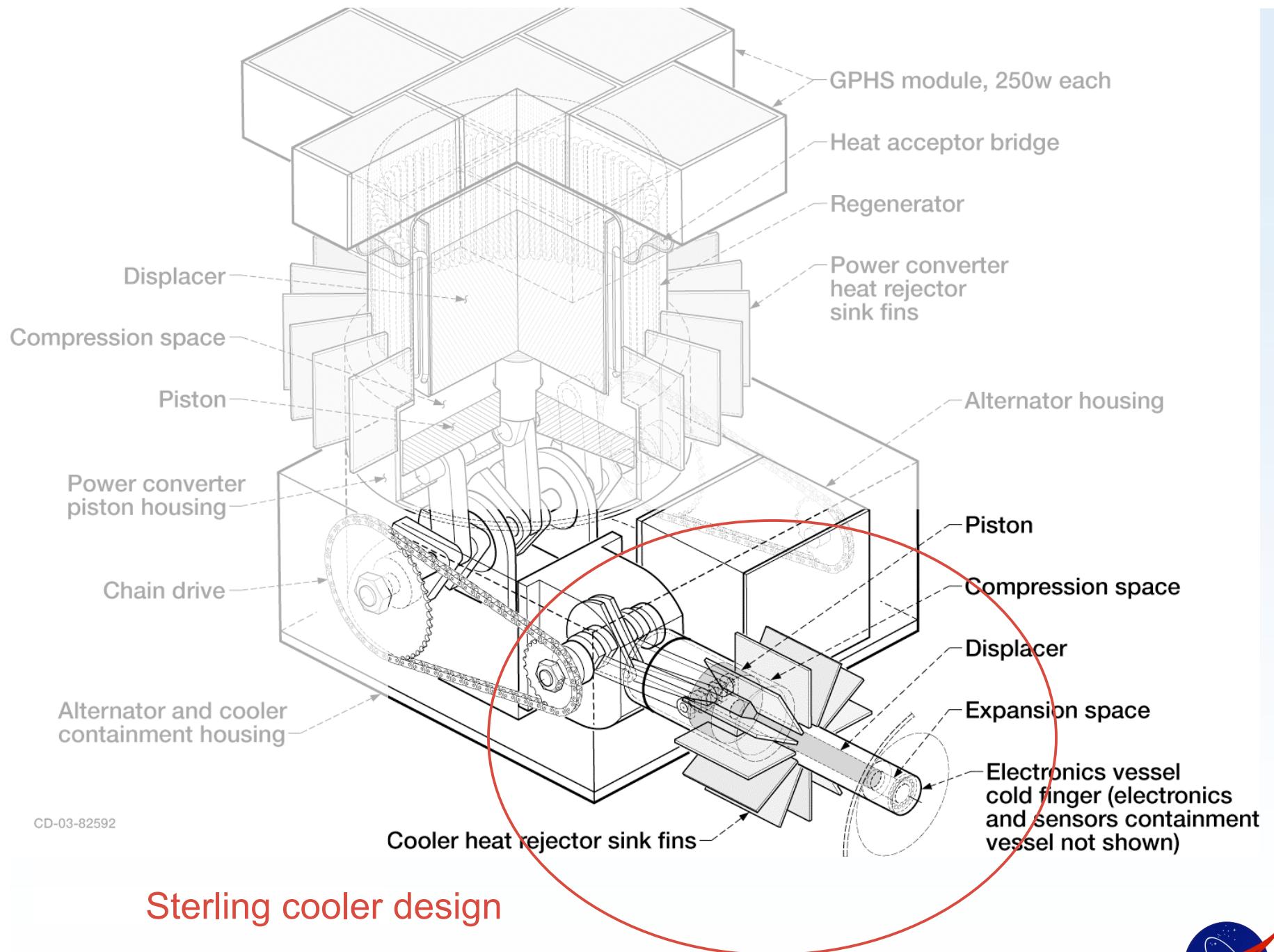
Parameter	Value
Type	Stirling cycle
Power output	478W
Source	7 250-W GPHS units
T (source)	1200 C
T (sink)	500C
Heat input	1740 W
Heat rejected	1267 W
Overall efficiency	23.4%
Mass	21.6 kg



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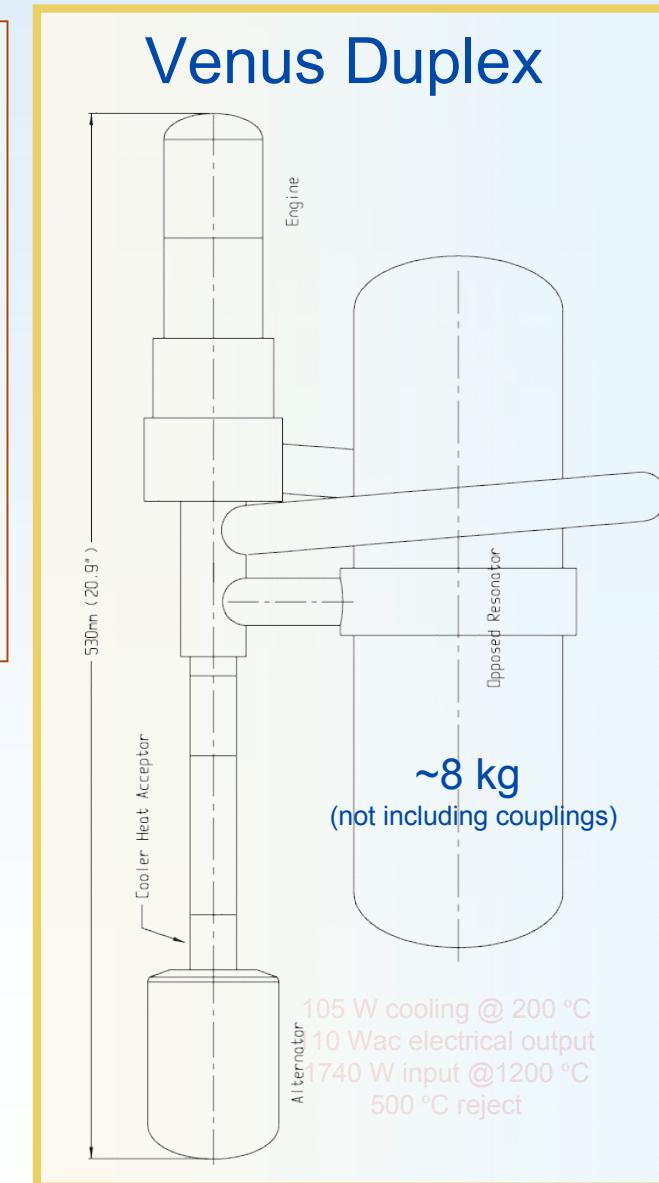


Technology Development: Stirling cooler integrated with power system

Sunpower design is coaxial with heat exchangers surrounding the Thermal Buffer Tube
Sunpower convertor performance is presently equal to Northrop Grumman
Predicting 65 Wac,
8 months development remaining in SBIR
Design and evaluation for higher power is part of the current SBIR



50 Wac



Comparison of Northrop Grumman & Sunpower Technology



Northrop Grumman



Sunpower

	Sunpower	Northrop Grumman
Pressure	3.65 MPa (530 psia)	5.28 MPa (765 psia)
Frequency	100 Hz.	125 Hz.

Venus



Venus Surface cooling system

Parameter	Value
Type	Stirling cycle
Stages	1
Heat sink temperature	500 C
Cold temperature	200C
Heat transferred	105.7 W
Heat rejected	344.6 W
Overall coefficient of performance	37.6%
Mass	1.6 kg

Venus Surface Robot Technologies: motors and actuators

High temperature motors/actuators

Motor or actuator	Max operating temperature (C)	status
Baker Hughes GeoThermal	160	commercial
Swagelock pneumatic	200	commercial
Rockwell Scientific SiC	200	development project
NASA Glenn R&T high-temperature actuator	400	prototype goal research target
	600	
NASA Glenn switched-reluctance motor	540	demonstrated; 8000 RPM, 27 hours
U. Sheffield Linear actuator	800	technology demonstrator: 1 mm throw, 500N force



Switched-reluctance motor capable of operation at 540 C

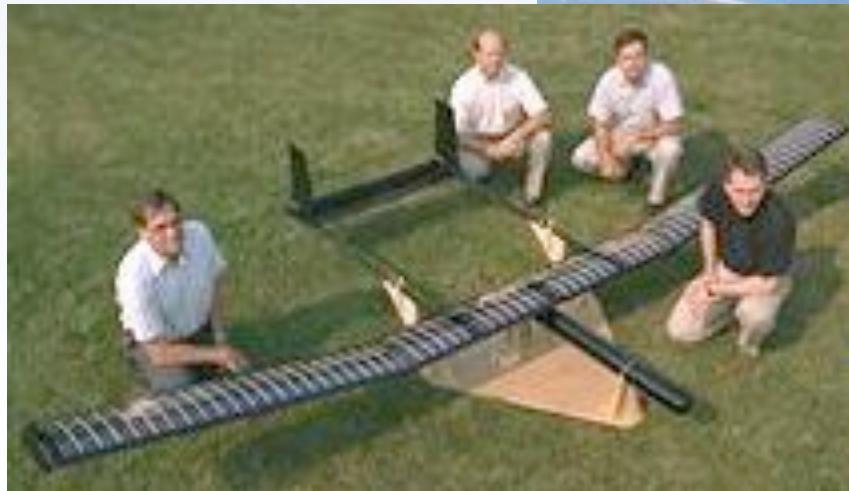


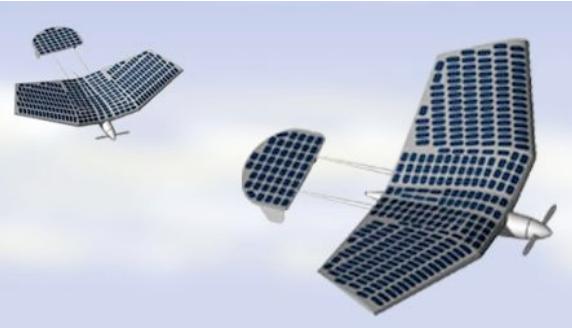
- Small version of this motor has now been demonstrated at Honeybee robotics

Solar airplanes on Earth

Right: Aerovironment
“Pathfinder”

Below: NASA Glenn
solar airplane team





For More Details:



- Animation is available at:
 - <http://www.grc.nasa.gov/WWW/5000/pep/photo-space/venus-mission-design.htm>
- Mission Design:
 - G. Landis, "Robotic Exploration of the Surface and Atmosphere of Venus," *Acta Astronautica*, Vol. 59, 7, 517-580 (October 2006). Paper IAC-04-Q.2.A.08
- Venus Airplane:
 - G. Landis, C. Lamarre, and A. Colozza, "Venus Atmospheric Exploration by Solar Aircraft," *Acta Astronautica*, Vol. 56, No. 8, 750-755 (April 2005). Paper IAC-02-Q.4.2.03
 - G. Landis, C. LaMarre and A. Colozza, "Atmospheric Flight on Venus: A Conceptual Design," *Journal of Spacecraft and Rockets*, Vol 40, No. 5, 672-677 (Sept-Oct. 2003).
- Power and cooling systems:
 - G. Landis and K. Mellott, "Venus Surface Power and Cooling System Design," *Acta Astronautica*, Vol 61, No. 11-12, 995-1001 (Dec. 2007). Paper IAC-04-R.2.06
- High-temperature electronics:
 - P. Neudeck, NASA Glenn *Research & Technology 2005*, NASA/TM-2006-214096

