VENUS ROVER DESIGN STUDIES. G. A. Landis[1] and S. R. Oleson[2], [1]Photovoltaic and Electrochemical Systems Branch, NASA John Glenn Research Center, 21000 Brookpark Road, Cleveland OH 44135, geoffrey.landis@nasa.gov, [2]Mission architecture and Analysis Branch, NASA John Glenn Research Center, 21000 Brookpark Road, Cleveland OH 44135, steven.r.oleson@nasa.gov

Introduction: The planet Venus is one of the most fascinating targets in the solar system, with many unanswered questions in the fields of geology, geochemistry, surface and atmospheric interaction, and atmospheric and climate science. A goal for NASA exploration would be to put a rover on the surface of Venus with capability equivalent to the Mars rovers.

Rovers:

Rover and lander systems to operate on the surface of Venus have been analyzed by the NASA Glenn COMPASS team. The surface of Venus is a hostile environment, with a surface temperature averaging 452°C, and atmospheric pressure of 92 bars of carbon dioxide. Nevertheless, exploration of the surface of Venus is of scientific interest. Technologies currently being developed at NASA bring the operation of robots on Venus into the range of feasibility. These include high-temperature electronics; radioisotope power systems that operate at Venus temperatures; Stirling-based power and cooling systems to keep mission components within temperature constraints; high-temperature, corrosion-resistant materials; and high-temperature sensors, motors, actuators, and bearings. This paper presents the results of design studies for a Venus rover, with the goal of surface exploration capability that is comparable to that of Mars rover missions. Figure 1 shows the visualization of the rover from an early study; figure 2 shows the more capable rover from a later study [1].

The most critical portion of the design is the power and cooling system required for operation at Venus, and this analysis will comprise most of the work presented. The thermal design requires operation at an external temperature as high as 500°C. Figure 3 shows the heat flow. To minimize external heat flow into the electronics enclosure (and also to provide maximum structural strength against external pressure) the electronics enclosure is assumed to be spherical shell. A radioisotope Stirling Duplex engine provides electrical power and 2-stage cooling. In order to minimize heat leaks, the number of penetrations to the thermal enclosure was minimized. Optical instruments were assumed to operate through sapphire windows, and all the components that could be operated in the high-temperature Venus environment were located outside the enclosure. Total rover design mass (including cruise and EDL system) is 872 kg without growth, and 1059 kg with mass growth allowance included; this is easily within the launch capability of an expendable launch vehicle. There are no apparent showstoppers to the design of a rover capable of operation on the Venus surface, although some of the technologies will still need development to bring them to flight readiness.

Beyond the initial rover,we have studies advanced rover designs using the Venus atmosphere for power and propulsion, including both wind turbine and wind-sail rover designs operating at ambient Venus temperature.

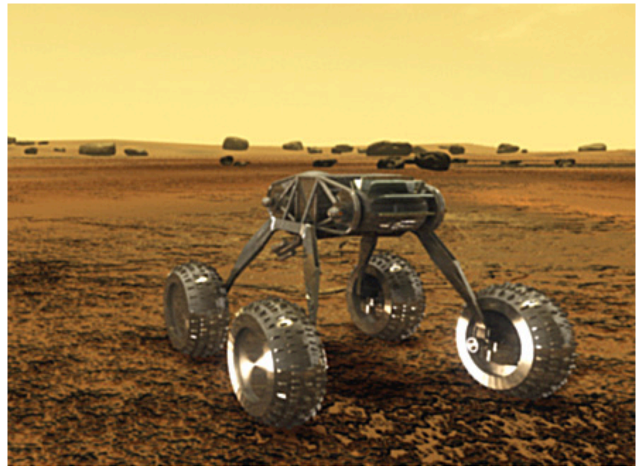

Figure 1: Proposed Venus rover from RASC study

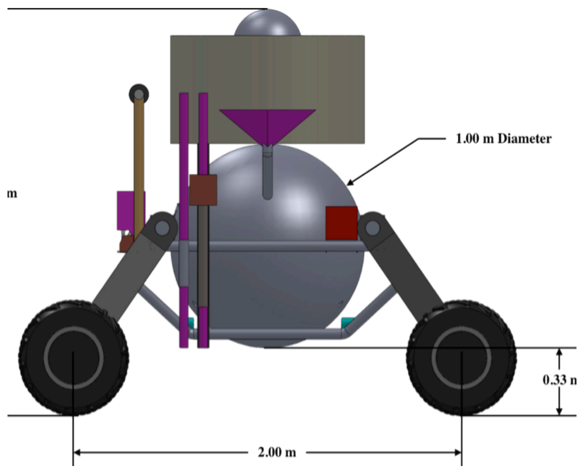

Figure 2: Proposed Venus rover from HERRO study

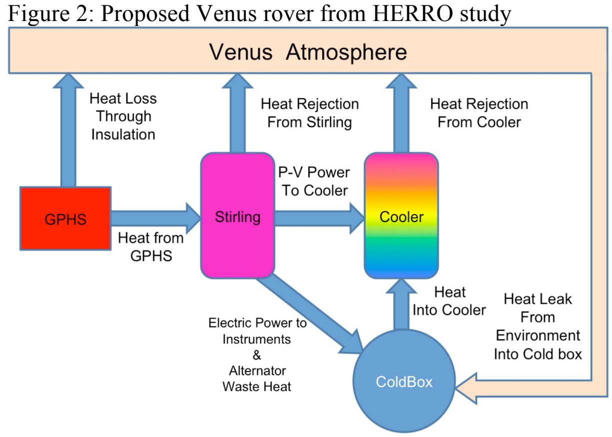

Figure 3: Energy flow block diagram

References:

[1] G. Landis, *et al*, "Venus Rover Design Study," paper AIAA 2011-7268, *AIAA Space 2011 Conf*, 2011.