A HEAT FLUX INSTRUMENT FOR MEASURING VENUS SURFACE HEAT FLOW Michael Pauken[1] and Suzanne Smrekar[1], [1]Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Blvd, M/S 125-123, Pasadena, CA 91109, mpauken@jpl.nasa.gov or ssmrekar@jpl.nasa.gov.

Introduction: We are developing an instrument that will help illuminate the evolutionary path that has brought Venus to its unique state today by measuring the heat loss from its surface. Knowledge of the present day heat flow would allow us to provide an estimate of the lithospheric thickness, the current level of geologic activity, and distinguish between various hypotheses of planetary evolution. Numerous models of Venus' thermal evolution exist. A very low heat flow (<20 mW/m^2) would indicate that either a recent stagnant lid or a very late stage of episodic global overturn is operating [1]. An intermediate value of heat flow (20-40 mW/m^2) would be consistent with a stagnant lid modulated by convective heat flux [2]. High values (> 40 mW/m^2) would indicate a thinner lithosphere and possibly a long period of mantle heating due to the effect of an insulating stagnant lid [3]. The predicted heat flow today is a function of the assumed concentration of radiogenic material, heat of accretion, and most importantly, the style of geologic activity.

Heat flow measurements for Earth, the Moon, and those scheduled for Mars (InSight mission) are based on subsurface temperature measurements below their diurnal and annual variations. On Venus, access to the subsurface is not necessary because there are essentially no diurnal or annual temperature variations due to the thermal stability of its dense lower atmosphere. The surface flux measurement approach described here is possible on Venus because the surface diurnal or annual temperature changes are small ~1 K; [4] and occur at much longer time scales than the time required to measure the surface flux.

Objectives: Our objective is to develop robust a instrument for rapidly measuring heat flow at the Venus surface over the range of 10 to 100+ mW/m^2 with an accuracy of ±5 mW/m^2. This level of accuracy is sufficient to determine whether the interior Venus heat flux is low, intermediate or high.

Requirements: Designing a heat flux sensor for Venus requires achieving good contact with the surface, operation at high temperatures and acquiring accurate and precise measurements in a short duration.

Analysis: Several analytical models of the heat flux sensor were developed to understand the performance and capability of the heat flux sensor and to guide the development of a prototype sensor. The analysis was performed using finite element modeling with COMSOL Multiphysics. Parametric studies of device geometry, effects of conjugate heat transfer, and assumed heat flux from the surface were carried out. The thermoelectric device-based sensor design constitutes a geometry that analytically satisfies the requirements for measuring the surface heat flux in the range of 10 to 100+ mW/m^2 with a resolution of 5mW/m^2.

Configuration: The heat flux sensor would be externally deployed from a lander vehicle. The sensor would be located on the end of a boom that places it on the surface. During operation the sensor generates a voltage proportional to the heat flux flowing through it. The electronics located within the lander vehicle measure the generated voltage signal.

Prototype: We developed a prototype heat flux sensor that used the thermoelectric effect of specific semiconductor materials to measure heat flow. Thermoelectric material pairs produce a voltage when they are subjected to temperature gradients. This principle is used by thermocouples to measure temperature.

The prototype sensor had a copper disk base. On top of the copper disk were two thermoelectric element (TE) legs. One leg was an n-type semiconductor and the other leg was a p-type. The top of each TE element was bonded to a steel disk that rejected heat by convection and radiation in an ambient environment. Aerogel insulation filled the space above the copper disk blocking heat flow from the top surface of the copper disk. Nearly all heat entering the copper disk flowed through the thermoelectric legs. The heat flow through the legs created an axial temperature gradient. The temperature gradient generated a voltage across the TE legs similar to that produced by a thermocouple junction.

Results: We used a single pair of thermoelectric elements to measure a heat flux range of 200 to 1300 mW/m^2. We plan to improve the sensitivity of the sensor by using an array of 80 thermoelectric element pairs connected in series (which will amplify the voltage signal) to measure the required heat flux range. For the selected n- and p-type semiconductors the Seebeck coefficient is 400 μVolts/K at 750K, Venus' surface temperature. This produces a voltage of 0.2 μVolts per element pair and for an array of 80 elements, the total voltage generated is 16 μVolts for the 5 mW/m^2 heat flux resolution.

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