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The miniRAD Radiometer For The IDEFIX Rover on Martian Moons eXploration

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Introduction:

The Martian moons exploration, MMX, is JAXA's sample return mission targeting the two Martian moons Phobos and Deimos and is scheduled to launch in 2026 to return samples from Phobos to Earth in 2031 [1]. The main scientific goal of the mission is to determine the origin of Phobos and Deimos and to investigate the evolution of the Martian moons. MMX will study the Martian system for 3 years and perform close-up observations of Phobos, while carrying out multiple flyby's of Deimos. Finally, the mission will collect samples from Phobos before returning to Earth.

The MMX Rover IDEFIX [2] is one of the MMX payloads and will investigate Phobos in-situ using a suite of scientific instruments comprised of a pair of stereo navigation cameras, another two cameras mounted underneath the rover to study the wheel-regolith interaction, a Raman spectrometer to study the mineralogical composition of Phobos' surface material, and the miniRAD radiometer to study the material's thermophysical and mineralogical properties.

The miniRAD Instrument:

The miniRAD Radiometer's purpose is to measure the surface brightness temperature on the surface of Phobos in six infrared wavelength channels between 4.5 μm and 60 μm.

It houses six thermopile sensors, equipped with individual IR-filters to fulfill specific scientific measurement goals. These are:

- Determination of surface brightness temperature over a full day-night cycle on several spots on the Phobos' surface.

- Determination of surface thermal inertia of Phobos' regolith and boulders

- Estimation of the central wavelength of a suspected Christiansen feature

- Determination of the mm to cm-scale surface roughness.

Figure 1: minRAD sensor head and PEEK mounting bracket attached to a heat sink in preparation for TVAC test

The thermopile sensors are situated inside the sensor head having a radiation shield, reflective coating and heaters for temperature control. To decouple the sensor head thermally from the rest of the hopper, the head is attached to the rover using PEEK brackets. (Fig. 1)

A low-thermal conductivity flex harness connects the sensor head to the avionics box located inside the Structural and Electrical Model of IDEFIX.

Calibration: We describe the relation between target temperature T and the signal voltage U by a form of the Sakuma-Hattori interpolation equation

$$U = R * \exp(- c_2/(A*T+B)) - R * \exp(- c_2/(A*T_S+B)) + S_H*P_H + U_{off}$$

where c_2 is the second radiation constant while R, A, B, S_H and U_{off} are adjustable parameters. P_H is the heating power used to stabilize the sensor head at the chosen setpoint, and the factor S_H corrects for the instrument background radiation slightly varying with P_H.

minRAD underwent radiometric calibration in a vacuum chamber equipped with an LN_2-cooled large aperture cavity blackbody. The sensor head was placed inside a temperature-controlled aluminum box representing the thermal environment while viewing the blackbody.

By varying the blackbody temperature from 100-330 K and the box temperature between 200 K and 280 K the five calibration coefficients could be fitted for each thermopile channel. The estimated uncertainty of the brightness temperature measurement (using the broadband filters), including systematic disturbances, is 5 K for a target temperature of 100 K and the uncertainty of the narrowband channels is < 1 K for dayside temperature > 250 K.

Figure 2: Brightness temperatures inverted during calibration and deviation from blackbody temperature.