THE MEDA THERMAL IR RADIOMETER (TIRS) FOR THE MARS2020 MISSION.

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Introduction: The Thermal Infrared Sensor (TIRS) is one of the six environmental sensors comprising the Mars Environmental Dynamics Analyzer (MEDA) [1], which in turn is one of the seven scientific instruments onboard the NASA Mars 2020 rover. MEDA is provided by the Spanish Centro de Astrobiología and has been designed to characterize the near-surface climate of Mars and prepare for human exploration by assessing the environmental conditions across the rover traverse.

Scientific Objectives: TIRS [2] will contribute to the Mars 2020 science objective "Surface weather measurements to validate global atmospheric model" by measuring the net thermal infrared and reflected solar radiation at the surface, the surface brightness temperature, and the near-surface vertical temperature profile using five different channels (Table 1).

Channel	*Purpose*	*FoV*	*Pointing angles*
IR1	Downward LW	Horizontal ±20º Vertical ±10º	Upward(+35°)
IR2	Atmos. Temp		Upward(+35°)
IR3	Upward SW		Downward(-35°)
IR4	Upward LW		Downward(-35°)
IR5	Ground Temp		Downward(-35°)

Table 1: *TIRS channels purpose, FoV and orientation.*

TIRS is the first in-situ Martian infrared (IR) radiometer including upward- and downward-looking channels, complementing and extending radiometric measurements of surface brightness temperature taken by the Rover Environmental Monitoring Station (REMS) [3] and the HP^3 [4] instruments onboard the Mars Science Laboratory (MSL) and Insight missions, respectively.

In combination with the MEDA Radiation and Dust Sensor's panchromatic channel to measure downward SW radiation, TIRS will allow the first in-situ quantification of the radiation surface energy budget, as well as the determination of key radiative, geophysical and thermal properties of the terrain such as the albedo and thermal inertia at spatial scales of a few m^2 [5].

Instrument Description: The TIRS' sensor head is located at a height of 1.5 m at the rover's sensing mast (RSM) and it has an approximate weight of 97 g and a size of 58×63×58 mm (Fig.1, left). The electronic conditioning system is located in the MEDA's Instrument Control Unit and is connected through a ~3–4 m long harness. The orientation and field of view (FoV) of the IR transducers have been selected to comply with the following criteria: (1) the FoV does not intersect with any rover's element, (2) the focused area is small enough to minimize heterogeneities in the soil composition/texture, but big enough to have a proper signal to noise ratio, and (3) the thermal influence of the Mars 2020 rover Radioisotope Thermoelectric Generator (RTG) shall be minimized. As a result of these conditions, the FoV of the downward-looking channels will cover an area of approximately 3 m^2 at a distance of 3.75 m away from RTG footprint center (Fig.1, right).

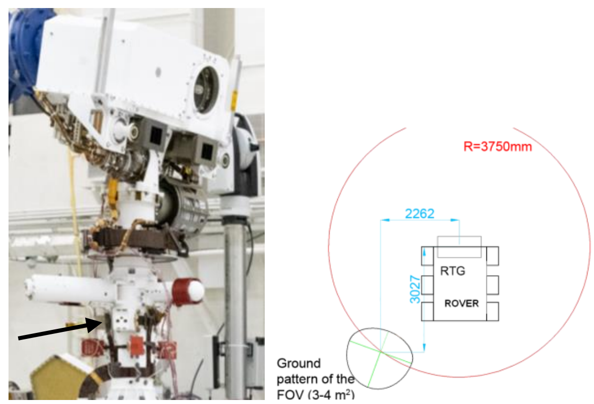

Figure 1: *TIRS mounted on Mars2020 rover RSM (left, black arrow; credit: NASA/JPL-Caltech) and downward-looking channels FoV (right).*

Five thermopile sensors model TS-100, developed at the Leibniz IPHT (Institute of Photonic Technology, Jena, Germany), have been selected as IR transducers. The thermopiles' filters and their transmission bands are shown in Table 2, and they have been selected to fulfill the science goals for each channel [2]. Silicon substrate filters become transparent at around twice the wavelength of the bandpass, while in the case of Germanium filters this occurs above 40–50 µm. In order to block the signal from these undesired windows, particularly at low nighttime temperatures for the upward-looking channels, TIRS thermopiles use IPHT interferometric absorbers (IF LW) [6]. The final spectral response of each channel is shown in Fig. 2. It has been obtained by multiplying the filter transmission characteristics by the corresponding absorber.

Channel	*Band(μm)*	*Filter Substrate*	*Absorber*	*Fillgass*
IR1	6.5–30	Si	IF LW	
IR2	14.5–15.5	Ge	IF LW	
IR3	0.3–3	Quartz	BS	Krypton
IR4	6.5–30	Si	IF LW	
IR5	8–14	Si	IF LW	

Table 2: *Thermopiles bandpass, filter substrate, absorber treatment (Interferometric longwave and black silver) and fillgass.*

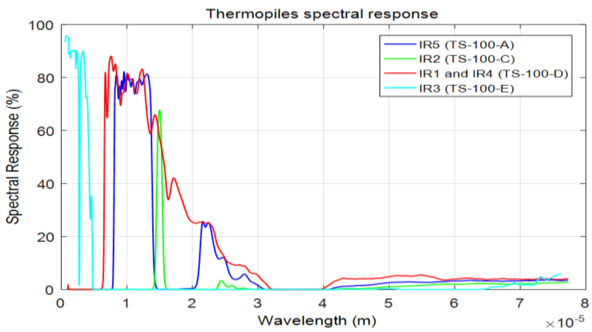

Figure 2: *Calibrated spectral responsivity of TIRS channels.*

From a mechanical point of view, the TIRS sensor head is composed of three main elements, Fig. 3: (1) the housing and covers, which provide a mechanical chassis that attaches to the rover RSM and thermally isolates and protects IR detectors from the Martian environment, (2) the support plate sub-assembly, which is essentially a thermal stabilization system for minimizing the appearance of thermopiles' package thermal gradients, and (3) the calibration plate subassembly, which has small holes partially obstructing the thermopiles' FoV to conform the target FoV, protects the thermopiles optics from dust deposition, and allows inflight recalibrations of the responsivity of each channel. For this last purpose, the support and calibration plates include contact temperature sensors and heaters that are activated during the process.

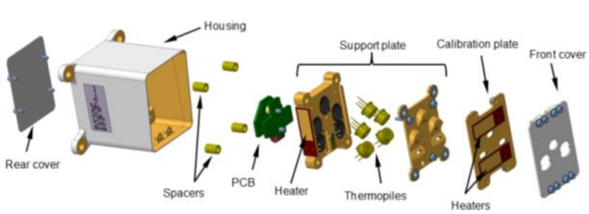

Figure 3: *TIRS exploded 3D drawing.*

Expected performance: A detailed analysis of the accuracy and resolution of the various TIRS channels is described in [2], where different sources of uncertainty such as calibration set-up errors, detectors degradation or ageing, electronic measurement errors, inflight calibration algorithm performance and thermal gradients in thermopiles packages were considered. Here, we show in Table 3 updated values of the accuracy and resolution of the various channels obtained by using results from the latest calibration of the TIRS flight model, and uncertainties from the final calibration test set-up.

Channel	*Dynamic range*	*Accuracy[1]*	*Resolution*
IR1 [W/m^2]	3.5-180	±1.7 to 6.2	±0.18
IR2[K]	173-293	±3.7	±0.45
IR3[W/m^2]	0-230	±3.7 to 9.5	±0.1
IR4[W/m^2]	50-420	±1.2 to 3	±0.1
IR5[K]	173-293	±0.7	±0.08

[1]*Variation depends on thermal scenario (diurnal and seasonal variation).*

Table 3: *Current best estimate of the TIRS channels performance (1σ error).*

The non-hemispherical FoV of channel IR3 requires extrapolation of its readings to allow comparisons with standard albedometers, which typically have hemispherical FoVs (π srad). Based on field testing, specular reflection of the solar radiation within the FoV of the TIRS IR3 is expected to cause spurious overestimations in measured reflected solar fluxes. Therefore, factors such as the position and relative orientation between the TIRS and the Sun, as well as the optical properties of the terrain will have to be taken into account for a correct interpretation of the data.

Similarly, the direct incidence of the Sun on the detectors optics of the upward looking channels IR1 and IR2 imposes limitations in their performance. Specifically, heating of frontal elements of the detectors may result in measurement errors that need to be properly assessed.

Finally, channel IR5 has been calibrated assuming a broadband LW surface emissivity of 1. For emissivities of ~0.96 [7], the uncertainty would be < 3 K at typical maximum ground temperatures of 273 K.

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