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Calibration of ExoMars 2020 GTS (Ground Temperature Sensor) and its application on two-band pyrometry

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Abstract

Surface temperature is one of the critical environmental components for a long-term climate monitoring on Mars, with implications on the search for conditions to support life. The HABIT (Habitability: Brines, Irradiation, and Temperature) instrument onboard the ExoMars 2020 Surface Platform (ESA-IKI Roscosmos) will investigate the habitability of present-day Mars, monitoring: temperature, winds, dust conductivity, ultraviolet radiation and liquid water formation. In this work, we describe the calibration procedure of the 8-14 μm wavelength band sensitive infrared thermopile of the Ground Temperature Sensor (GTS) and present the preliminary test results. The calibration constants and the resultant energy balance equation obtained will be used for accurate conversion of the thermopile output voltage to the target temperature assuming the emissivity of the Martian surface from literature.

In parallel, we discuss the advantages of including a second band to perform two-band pyrometry for future Earth and Mars, low-cost, light and robust applications. Based on the calibration plan for GTS/HABIT and implementing the customized energy transfer model, we developed a prototype that uses two-band pyrometry, measuring heat fluxes from the target in different infrared spectral bands. We demonstrate the advantage of this method, by measuring both the target temperature and emissivity, allowing to detect changes of qualities of the objects under investigation, such as phase state changes or deposition of dust or snow, which may affect the emissivity. This sensor may be of interest for the future missions that will explore the Martian surface.

1. Introduction

The Martian regolith temperature with its significant diurnal variation is crucial for the interpretation of several of the associated environment phenomenon that are currently active on Mars. Hence, its accurate measurement is essential for the surface exploration missions. The GTS/HABIT is a light weight, low power, and low-cost pyrometer that will measure the soil kinematic temperature of the Martian surface during the nominal mission lifetime of one Earth year [1]. It benefits from a simple design with no moving parts and pointing to the Martian surface at an angle of 45°. The sensor acquires its heritage from the Rover Environmental Monitoring Station (REMS) Ground Temperature Sensor (GTS), an instrument aboard NASA's Mars Science Laboratory [2].

2. Materials and methods

2.1 Ground Temperature Sensor (GTS)

GTS is one of the modules of the HABIT/ExoMars 2020 Surface Platform (ESA-IKI Roscosmos). Figure 1 shows the engineering model of HABIT, including GTS as a part of the Electronics Unit (EU). The core of the GTS is an 8-14μm wavelength band sensitive infrared thermopile which depending on the total energy influx from its field of view, converts them to a corresponding voltage output.

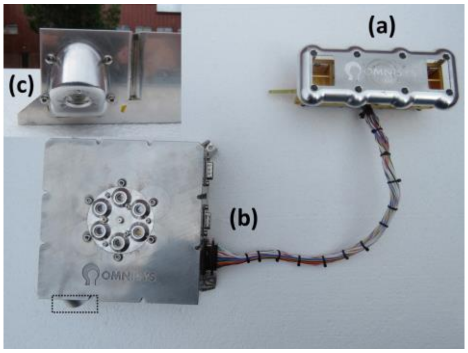

Figure 1: Image of the HABIT instrument. (a) Container Unit (CU), (b) Electronic Unit (EU) with Ground Temperature Sensor (GTS) highlighted, (c) a closer view of the GTS pointing at the surface.

2.2 Experimental setup

2.2.1 Blackbody calibration source

The calibration experiments were performed with the thermopile of the GTS/HABIT Engineering Model (EM) pointing straight at the blackbody calibration source (LumaSense Technologies M315X4-HT, 101 mm x 101 mm exit port) at ambient laboratory temperatures between 298.16 K and 373.16 K for every 10 K increments.

2.2.2 Mars environment calibration

The calibration experiments at temperatures that are representative of Mars were performed between 218.16 K and 298.16 K for every 10 K increments within a dedicated chamber. We used a custom-built Peltier controlled blackbody calibration source (100 mm x 100 mm aluminium target coated with LabIR thermographic paint, normal emissivity of 0.92 for 8-14 µm band). These experiments that were performed with the Engineering Qualification Model (EQM) used the capabilities of maintaining a 6-8 mbar of pressure with a carbon dioxide atmosphere.

2.3 Two-band pyrometer application

We developed a two-band pyrometer with an autocalibration setup based on the calibration procedures implemented on the GTS. In addition to the 8-14 µm wavelength band sensitive infrared thermopile that is used in the GTS, another thermopile measuring at a different infrared spectral band was selected. The computation of the temperature and the emissivity was performed using the algorithm developed during the REMS work [3]. We have simulated different environmental conditions with different target and sensor temperatures, ranging between 218.16 K and 298.16 K at Martian pressures. Here, we tested the change of state of different mixtures of the JSC Martian dust emulant with the deliquescent salts.

3. Preliminary results

We report a preliminary test result of the performance of the GTS based on the calibrations performed at laboratory ambient temperature. For the final presentation we will have data from the SpaceQ calibration experiments with EQM which is more representative of the Flight Model (FM).

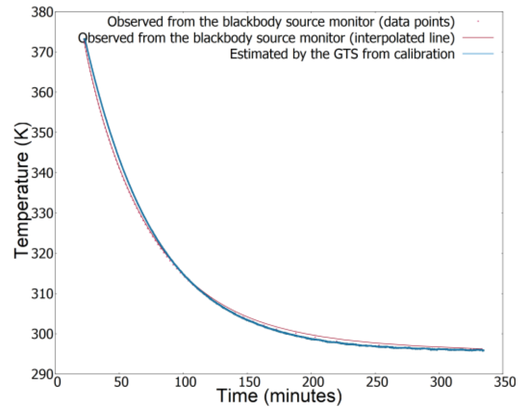

Figure 3: A comparison of the blackbody calibration source temperature as measured by the thermopile of the GTS/HABIT against its actual temperature.

4. Conclusions

A proper calibration ensures an accurate temperature retrieval. Our two-band pyrometer can detect emissivity changes that are associated with the phase state. Comparing its observations with the visible images and the environmental variables T/RH, we have studied the transition from frozen to liquid brine and to dehydrated salt. As water on the regolith is a critical resource for the future exploration of Mars, this can be applied as a real time, remote detector of sites of interest for water sampling on Mars.

Acknowledgements

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