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Radiation and Dust Sensor for MARS2020: technical design and development status overview

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Abstract

MEDA (Mars Environmental Dynamics Analyzer) is a payload to be included in the rover of the MARS2020, NASA mission. The RDS (Radiation and Dust Sensor) is part of this set of instruments and consists on a suite of photodetectors with different spectral bands and a dedicated CCD pointed to the sky. The main objective of the instrument is to characterize the Mars dust opacity, size and morphology. We report on the design and development of this sensor.

1. Background

MEDA RDS incorporates two main sensing technologies: a set of discrete photodetectors and a CCD. A large heritage exists for both of them from previous missions:

On the photodetectors side, heritage comes from:

- REMS-UV instrument on MSL. REMS (Rover Environmental Monitoring Station) [5] is one of the 10 scientific instruments on board MSL's Curiosity Rover.

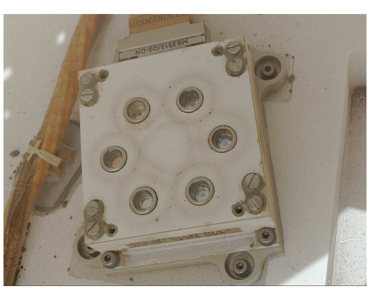

Figure 1: REMS UV Sensor.

REMS is a set of sensors aimed at the in-situ characterization of meteorological and atmospheric phenomena in the low atmosphere. It includes air and ground temperature sensors, wind sensors, humidity and pressure sensors, and also a reduced photometer focused on UV radiation. A mixed-signal ASIC designed for being able to operate in the Martian ambient temperature, outside thermally conditioned compartments, performs the main signal conditioning tasks. The UV [9] photometry is based on SiC detectors and interference filters.

- MetSIS [4] on Mars MetNet Lander [1]. The Photodetectors-based part of RDS, will mostly take advantage of the previous developments carried out in the frame of two different Mars explorations missions: Mars MetNet Lander and ExoMars 2016.

Figure 2: MetNet QM Penetrator and inflatable heat shielding.

Mars MetNet Lander is a tri-lateral mission developed by Russia, Finland and Spain, that aims to deploy a meteorological network (at a planetary scale) on Mars surface. It will be based on penetrator-type landers that make use of inflatable devices for the Entry, Descent and Landing phase. As in any other mission, resources such as mass and power are extremely scarce. A compact “Solar Irradiance Sensor” (MetSIS) has been developed by INTA to be part of the meteorology payload of the first penetrator (MetNet Precursor). This MetSIS has been fully qualified for MetNet requirements, including low-temperature operation. It is designed as a single-box unit that includes 32 detecting elements in 11 spectral bands, distributed in 5 different orientations (zenith pointing detectors, plus lateral detectors sweeping 360º in azimuth). It also contains the conditioning front-end electronics, A/D conversion, control logic, internal memory and a digital serial I/F to a main computer. It allows autonomous and configurable operation (sampling rate, channels to be sampled, etc.). The sensing elements are composed of Si photodiodes and a combination of interference and density filters, plus FoV-shaping elements built in the structure

- DREAMS-SIS on ExoMars 2016: This mission includes a technology-demonstration of an Entry and Descent Module (EDM) that contains some short-life scientific payload. The main payload package is a meteorological sensor suite, called DREAMS [3]. DREAMS-SIS [14] is the photometer developed for this package and it makes use of the same design concepts and technologies used in MetSIS, although in this case it is composed of 2 separate units: Optical Head (OH) and Processing Electronics (PE). This is due to the special accommodation requirements imposed to the sensor. The OH mass was limited to less than 26 g, also with strong envelope volume constraints. It contains 7 detectors, one of them facing zenith and the other six, in 2 different spectral bands (UVA and NIR), lying on the faces of a tetrahedron, thus providing 360º azimuth vision.

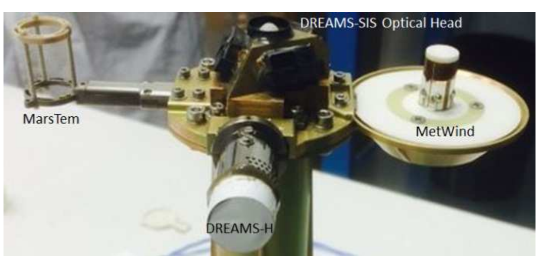

Figure 3: DREAMS Mast QM.

With regard to the CCD heritage, it consists in the reuse and accommodation of one of JPL’s engineering cameras already used in MER [6] and MSL: Hazcams.

Figure 4: HazCams on MSL.

The Camera (renamed as SkyCam), includes the focal plane module, with 1024x1024 effective sensor and the main electronics box. The optics of SkyCam will be designed ad-hoc for the present application, including a shadowing mask, at low zenith angles, and a neutral filter near to the lens center.

2. Instrument Design

2.1 RDS-DP: Discrete Photodetectors

The sensor consists of two different cofigurations for this technology:

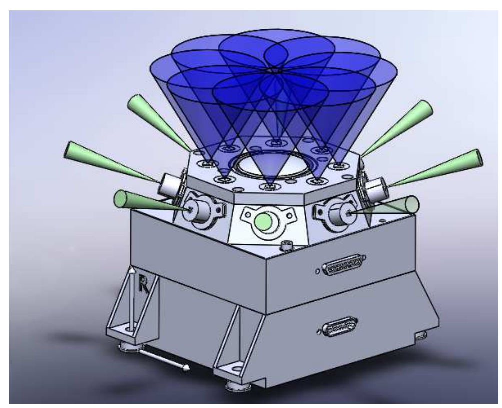

Figure 5: RDS-DP channels Field of View.

- Eight sky-view, narrow spectral channels that are pointing to the zenith. These channels will study the aerosols opacity, occasional clouds and ozone column abundance. [9][14]

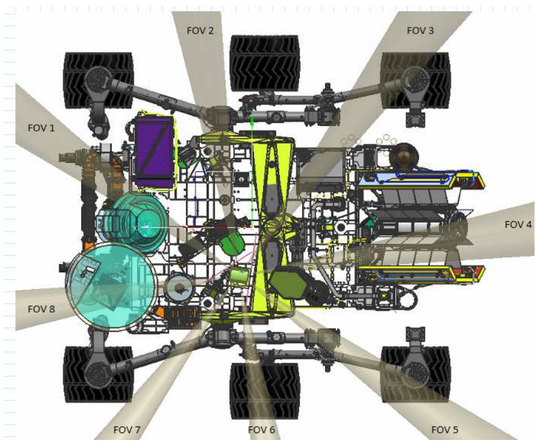

Figure 6: RDS rover accommodation.

- Eight 20º side pointing channels, separated 45º in azimuth, with the same wavelength, dedicated to measure the phase function to infer the shape and size of the dust.[2][7][12][13].

The next tables summarizes the channels for the discrete photodetectors

Table 1: RDS-DP sky-view channels

DP Nº	Description	Wavelength (nm)	FoV (º)
1	O3 Redox	255 ± 5	± 5
2	O3	295 ± 5	± 5
3	UV	250-400	± 15
4	MZCAM cross cal.	450 ± 40	± 15
5	SkyCam cal.	650 ±25	± 15
6	MZCAM cross cal.	880 ± 5	± 15
7	Dust	950 ± 50	± 15
8	Phanchromatic	190-1000	± 90

Table 2: RDS-DP 20º side pointed channels

DP Nº	Description	Wavelength (nm)	FoV (º)
1-8	Sky brightness	880 ± 5	± 5

The detection range of the photodetectors is 190-1100nm due to its Si based technology. It is being considered to substitute three of them by a thermopile, with the aim to study the IR range up to 3µm (dust + ice clouds). This consideration depends on the results of the validation tests that are being developed for these sensors.

Each channel is configured as an opto-mechanical assembly [14]. The core of this set is the Si based detector (2 of figure 7) to provide the signal. An interference filter (3) is used encapsulated with the photodetector as a whole to discriminate each band. To obtain the corresponding FoV of the channel, a FoV-shaping element is placed (4). Then, the set is finished on top by a sapphire or a density filter (6) to enhance the optical response of the detectors and to avoid the dust deposition inside the drills of the FoV-shaping part. On the bottom, the opto-mechanical set is finished with a “radiation shield” (an aluminum plate) to complete a 1 mm radiation shielding protection of the box in any direction. The last part is a cobalt-samarium magnet ring (5) that prevents the dust deposition on the sensitive zone of the assembly (REMS heritage [5][9]).

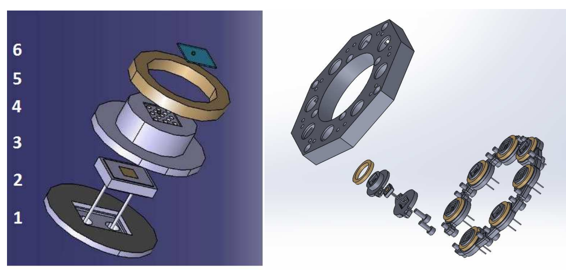

Figure 7: RDS-DP Opto-mechanical sets assembly.

RDS includes embedded electronics to perform the digital conversion of the different optical and handshaking channels. The core of the design will be and anti-fuse FPGA that be in charge of: acquire the different channels, handling/storage the digitalized data, and manage the communications with the MEDA Instrument Control Unit (ICU) by a master-slave protocol over RS422 differential interface. All this electronics will operate outside any warm box, with an operational temperature requirement going down to -130ºC.

2.2 RDS-SkyCam: CCD detector

A dedicated CCD element will be used to measure the dust opacity cycle and it size distribution. This sensor is intended to measure the intensity decay of the solar aureole [12] [13]

The SkyCam sensing element has a narrow spectral filter (880nm) and its optics has a neutral coating covering, near the noon solar angle (±15º from the lens center). This spectral band selection will allow to compare the intensity decay between the SkyCam signal and the 880 nm sky photodiode, when the sun reaches those high elevations.

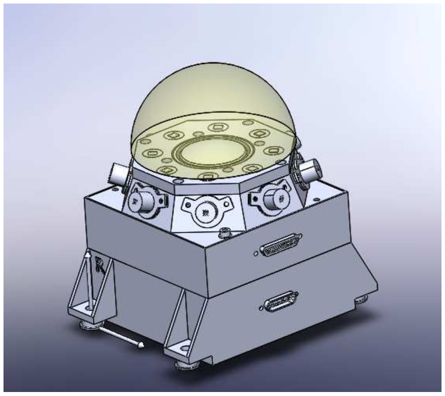

Figure 8: RDS-SkyCam.

3. Technology Validation Plan

One of the most demanding requirements in the design of instrumentation for Mars, is to survive to the extreme thermal cycling that the system will suffer during the mission. To prove that the technology used to manufacture the sensor is valid for the Mars surface, a particular test (PQV, Package Qualification and Verification) has been planned according to JPL/NASA requirements.

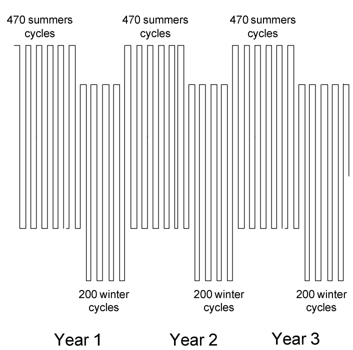

Figure 9: PQV Thermal Cycling Profile

This test tries to minimize the likelihood of packaging related failures (bonding, solder, etc.) at component level. At sub-assembly and unit level, it tests the mounting processes of all the used parts and materials. Figure 8, shows the thermal cycling profile of the test. It will simulate x3 mission time, with 1410 summer cycles from 40 to -105ºC at a maximum rate of 5º/min and 600 winter cycles from 15 to -130ºC at the same maximum rate.

The Validation Plan designed by INTA has been divided in two separate tests:

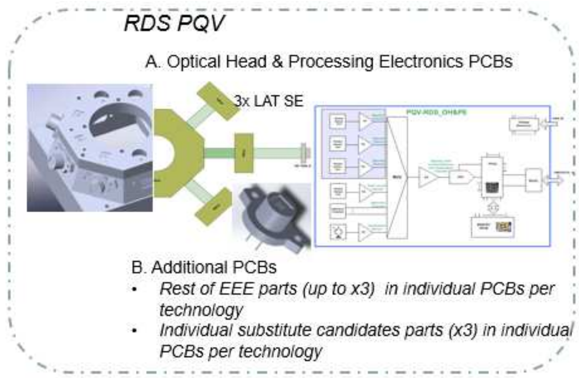

Figure 10: Technology Validation Plan for RDS.

A. Reduced version of RDS sensor: based on internal electronics used in previous Mars designs [4] [14], that have been thermally tested but with less than 2000 cycles. The design consists of two PCBs with all the necessary electronics to acquire 3 optical channels.

B. Additional PCBs: the rationale of this electronics boards is to test the same EEE Parts used in the previous option, in order to complete the quantity of 3 parts per part number tested. This approach will facilitate single tests to be performed on the components: visual inspections, X-ray, optical properties, etc. Identified parts substitutes, in case of components failure, have been incorporated also to this test PCBs.

Regarding the SkyCam, it has been tested according to MSL [11] requirements. Therefore, it can be used “as it is” for the RDS and does not need to be included in the validation plan.

4. Future Work

A dedicated PQV test is planned for thermopiles by the MEDA TIRS sensor team. Depending on the behavior of this technology, it will be considered to be included on the RDS, substituting some sky-pointing Si-based photodetectors.

From that point and fordward, the design of the sensor will follow the usual path of any space payload: detailed design through CDR, qualification, calibration, etc., applying a model philosophy that will include engineering, qualification, flight and spare units.

4. Summary and Conclusions

The RDS sensor of MEDA package has been presented. This sensor will be the first one at Mars surface fully devoted to characterize the sun brightness and to provide a dedicated camera and low elevation, 360º azimuth coverage detectors, to study the dust conditions of the atmosphere. Its measurements will have a synergy on its investigations with previous mission sensors: REMS UV[9] and DREAMS SIS [14] and with sensors presents on the same rover: MastCAM-Z [10] and Sherloc [8].

In summary, MEDA RDS will be a very powerful tool to improve the knowledge of the Mars atmosphere and to enhance the radiative and atmospheric models of the red planet.

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