Environmental Monitoring Station for Mars Science Laboratory

Javier Gómez-Elvira[1] and REMS Team, [1]Centro de Astrobiología (CSIC-INTA) Carretera de Ajalvir km.4 Madrid-Spain (gomezej@inta.es)

Introduction

The Viking Landers measured pressure, wind speed and direction, and air temperature with a small boom [1]. Mars Pathfinder had the Atmospheric Structure Instrument on its lander and recorded pressure, air temperature and wind direction [2]. MSL has environment sensors within its payload as well: it is the REMS (Rover Environmental Monitoring Station) instrument, which is in charge of recording pressure, humidity, air and ground temperature, wind speed and direction and UV radiation at the rover level.

A difference with other missions is that MSL is a rover and, therefore, the instrument is part of a complex mechanical architecture that entails many design constraints that have been implemented on the REMS design.

This work describes the instrument and operation, emphasizing the problems found in the development phase and the potential impact on science.

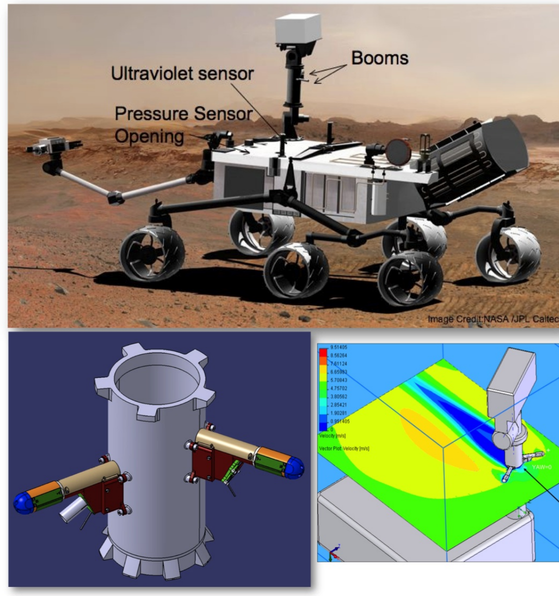

Figure 1: Rover picture shows the position of the two Booms on the RSM, as well as the UV sensor and the Pressure sensor opening. The left lower drawing depicts a more detailed view of the Booms and the RSM where is possible to seen its relative dimensions. The lower right image is the CFD output to point out the rover distortion and the influence of it on the Boom wind measurements.

Instrument

In addition to the requirements mentioned above, one of the main REMS design driver was to accommodate several sensors in a complex rover geometry trying to minimize its influence on the measurements. The architecture has evolved from a single boom that hosted all the sensor, to two small booms, the UV sensor module and the pressure sensor in the electronic box. The other main driver was the mass constraint: maximum 1.4 kg, including all the electronics.

Figure 1 shows the REMS modules distribution: two booms on the RSM, the ultraviolet sensor (UVS) on the rover deck and the pressure sensor inside de rover. RSM will be deployed after MSL landing. This feature constraints boom dimensions and position. The UVS placed on the rover deck, as far as possible to the sample inlets to avoid additional dust contamination. The pressure sensor (PS) is inside the rover and connected with the atmosphere by an opening in the rover deck and protected from dust with a small chimney.

Booms. Boom1 hosts the wind sensors (WS), ground temperature (GTS) and Boom 2 another WS and the humidity sensor (HS). The reason for having two booms is the RSM mast perturbation; with two booms, with a gap of 120 deg, it is possible to assure that in almost all wind flow directions, one of them is out the mast wake.

The proposed concept is an evolution of the Beagle one [3]. Three boards with 4 hot film anemometers [4] will provide wind speed in two perpendicular directions. By the combination of data from the three board can be drawn wind speed and direction over the cylinder. The design requirements about wind direction is 30 deg. of accuracy and for speed, 1 m/sec of accuracy and 0.5 m/sec of resolution in the range of 0 to 70 m/sec.

To mitigate as much as possible the rover handicaps, a calibration plan has been established based on: calibration test on a single boom, test with a mast section with a boom. CFD simulations on similar conditions will be performed and compared with tests. CFD simulations will allow to extrapolate full rover perturbations.

Ground temperature measurement is computed based on the reading of three thermopiles. The bandwidth of

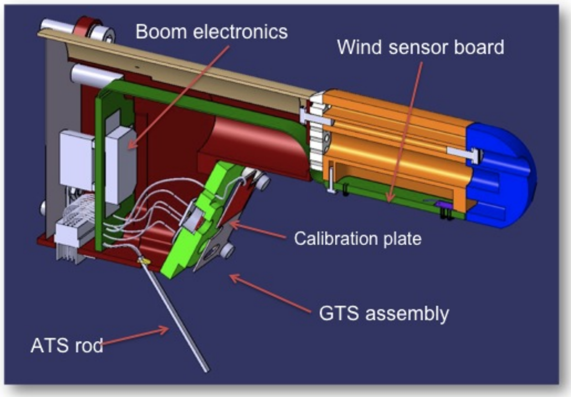

Figure 2: Cutaway of the Boom1. Boom tip has three board spaced 120 deg each one, equipped with four hot film sensor is capable to identify speed in two perpendicular direction. GTs sensor assembly, with three thermopiles and the calibration plate. ATS, the small rod in the lower part and all the conditioning electronics in its back.

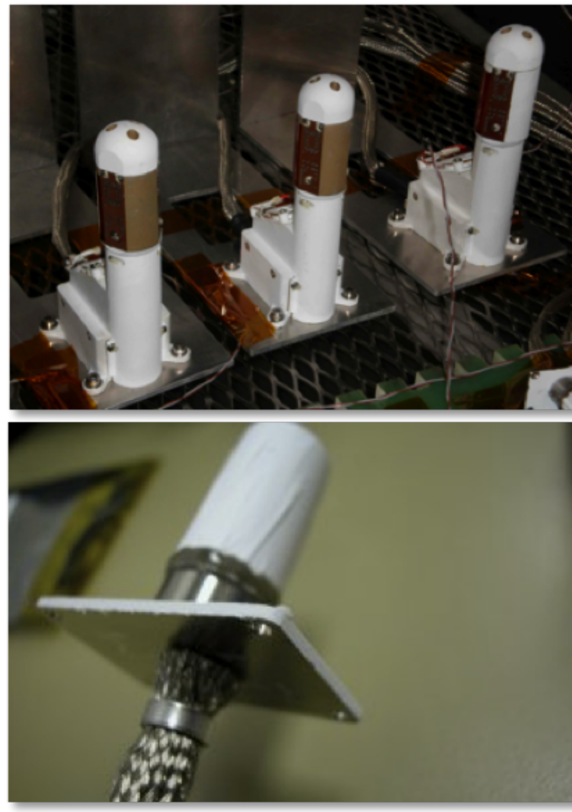

Figure 3: Upper photo shows four boom validation models during thermal cycling. The brown band close to the boom tip is the flexible PCB board where the hot film anemometers are wired. In the lower one is shown the Humidity Sensor with its Teflon protection (white cap) for preventing dust contamination.

each thermopiles is: 8-14, 14.5-15.5 and 16-20 microns. These bands were selected to avoid as much as possible the CO_2 absorption and to maintain performance in the temperature range 150 to 373 K with a resolution of 2 K and an accuracy of 5 K. The GTS assembly (see Figures 2 and 3) has in front of it a plate for in operation calibration.

Air temperature will be recorded in both booms with a PT1000-type sensor placed in a small rod with enough length to be outside the mast and boom thermal boundary layers. Its measurement range goes from 150 to 300 K with an accuracy of 5 K and a resolution of 0.1 K. Rod length has been selected to assure that the thermistor is outside the mast and boom thermal boundary layer.

HS is place in the same position that the GTS in Boom 1. That sensor has been developed by FMI and based on a Vaisala transducer, and will measure with an accuracy of 10 % in the 200 323 K range. The sensor has a Teflon protection to avoid contamination by dust. Given that the Teflon permeability is quite low, a number of small orifices have been drilled on it to guarantee same atmospheric conditions inside and outside the cap.

Ultraviolet Sensor. The UV sensor will be located on the rover deck and is composed of six photodiodes in the following ranges: 335-395 nm (UVA), 280-325 nm (UVB), 220-275 nm (UVC), 210-380 nm (total dose), 245-290 nm and 310-335 nm (these two bands have been selected to ease comparison with MRO data and correspond to ozone absorption bands [5]), with an accuracy better than 5 % of the full range. The sensor will be place on the rover deck without any dust protection. To mitigate dust degradation, a magnet has been placed around each photodiode with the aim of increasing as much as possible their operation time. Dust deposition will be evaluated based on images provide by NavCam. Comparison of these images with laboratory measurement will permit evaluation of the level of dust absorption.

The position of the sensor on the deck has been selected to assure that mast shadow will cover the UV sensor during few minutes during the day. The UV diffuse radiation levels will be estimated by comparing measurements with and without sun.

Pressure Sensor. The Pressure sensor is developed by FMI and based on a Vaisala transducer. This sensor will be located inside the rover body and connected with the atmosphere by a small opening with a protection to avoid dust deposition. Its measurement range goes from 1 to 1150 Pa with and accuracy (end-of-life) of 20 Pa. As this component will be in contact with the atmosphere and in order to avoid any contamination of the Mars environment a HEPA filter will be placed on the opening.

To assure the impact of the chimney on the measurement a dynamic response tests has been carried out with and without it, obtaining similar PS response values.

Operation

Regularity is the main driver for REMS operation. Each hour, every day during the MSL life, REMS will record 5 minutes of data at 1 data/sec rate for all sensors. This strategy will be implemented based on a high degree of autonomy in the REMS operation, which means that the instrument will wake up itself each hour and, after recording and storing data, it will go to sleep independently of the rover operation. REMS will record data during both rover operation and non-operation period, during day and night. REMS operation is designed assuming three hours of operation each day, based on data volumes. In addition to the regular recording periods, it is possible to increase some of the regular periods or to define new ones, in order to capture specific times with special scientific interest.

Another option that has been studied is to implement in the REMS software an algorithm to lengthen some of the regular observations when a special and unexpected atmospheric event is detected. The decision of the prolongation of the observation period will be made on the instrument itself, based on the *in-situ* and *in real time* analysis of the recorded data.

References. [1] Hess, S. L., et al. (1997) J. Geophys. Res.,82, 4559-4574. [2] Schofield J.T. et al, Science (1997) Vol. 278. no. 5344, pp. 1752 1758, [3] Planetary and Space Science 52 (2004) pp. 1141-1156 [4] Planetary and Space Science 56 (2008) pp. 1169-1179 [5] Clancy R.T. (2007) 7th Int. Conf. On Mars Abstract 3082

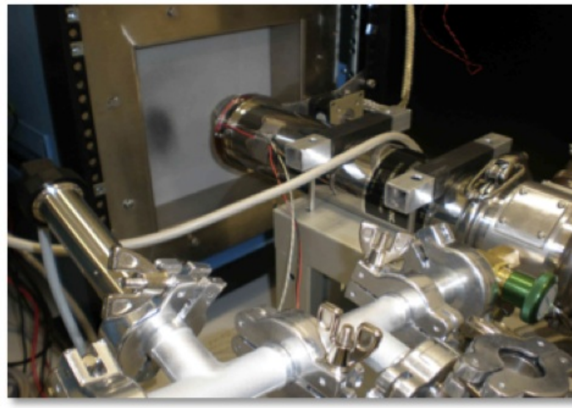

Figure 4: Upper photo shows the set up for Ground Temperature Sensor calibration; a wide area black body and a cryostat have been used to get the temperature gradients expected on Mars as well as the atmosphere condition around the sensor. Lower photo shows the Ultraviolet sensor; around each photodiode, there is a ring magnet to mitigate dust deposition. In the middle of six photodiode there is another ring magnet and evaluating (by an image) the amount of dust inside it, is possible to extrapolate the photodiode responsivity degradation.

REMS team. B. Haberlee[1] (Co-I), A. Harri[2] (Co-I), J. Martinez-Frias[3] (Co-I), N. Renno[4] (Co-I), M. Richardson[5] (Co-I), J. Alves[3] , L. Castañer[8], F. Gómez[3] , V. Jimenez[8] ,G. Muñoz[3], C. Left[3], M. Genzer[2], A. Lepinette[3], J. Martin[3], S. Navarro[3], J.Moreno[7] ,A. Peña[7], M. Ramos[6], J. Polko[2], J.A Rodrguez-Manfredi[3] , E. Sebastian[3] , J. Serrano[7] , J. Torres[3] , M.P.Zorzano[3] ,1 NASA Ames Research Center, 2 Finnish Meteorological Insitute, 3 Centro de Astrobiologa (CSIC-INTA), 4 Michigan University, 5 California Insitute of Technology, 6 Universidad de Alcala de Henares, 7 EADS-CASA, 8 Universidad Politcnica de Cataluña.

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