The ExoMars Experiment
MiniHUM

The search for water on Mars

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The water content of soil significantly influences their chemical, physical and biological properties. In respect of Mars the thin layer of the upper millimetres of the Martian surface are of particular interest since this soil interacts directly with the diurnally varying atmospheric humidity (Möhlmann (2004)), which can reach saturation during night and early morning (Fig.: 1; 2). Adsorption/desorption of water in the soil and freezing of it can be a consequence . Therefore, near-surface measurements of the atmospheric content of water vapour will allow to investigate the interaction between the atmosphere and the adsorbed water, which is deposited in the upper soillayer (Bish et al. (2003), Möhlmann (2004)). This should be an important aspect for exobiology and the futur exploration of Mars. The Institute of Planetary Research at the German Aerospace Center and the SMB Dr. Wernecke Feuchtemesstechnik GmbH are jointly developing a humidity sensor system in preparation for the ExoMars mission. Its objective is to obtain first in-situ measurements of diurnal and seasonal variations of the near surface atmospheric water vapour content. Therefore MiniHUM will be able to measure as well as traces of humidity as saturation phenomena (Fig.: 2) on Mars. The instrument consist of two different units: HUM and ASS.

Image courtesy NASA/JPL-Caltech

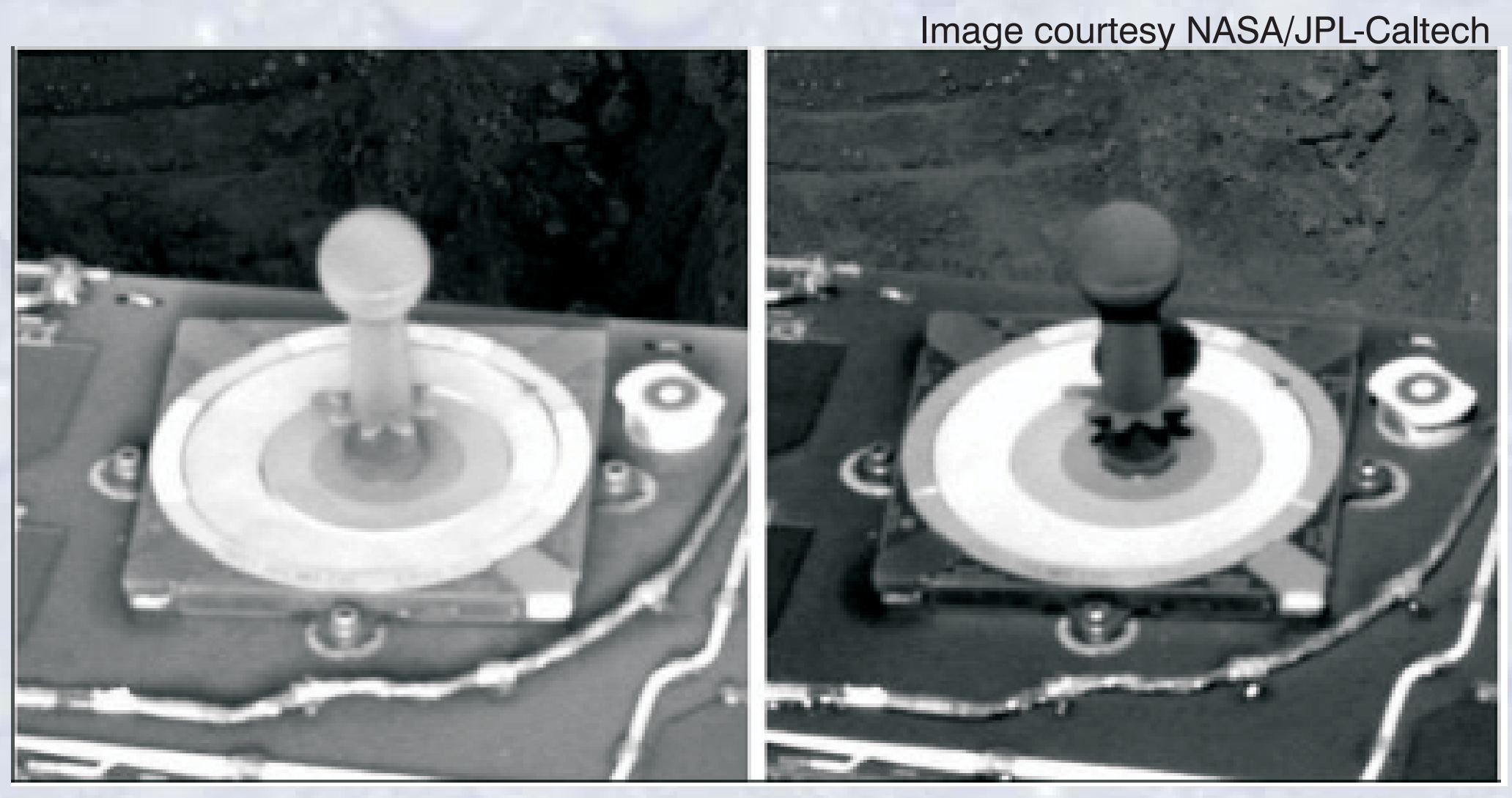

Fig. 1: Frozen water at the PanCam calibration target on Opportunity (Landis et al. (2007))

Image courtesy ESA/DLR/FU Berlin

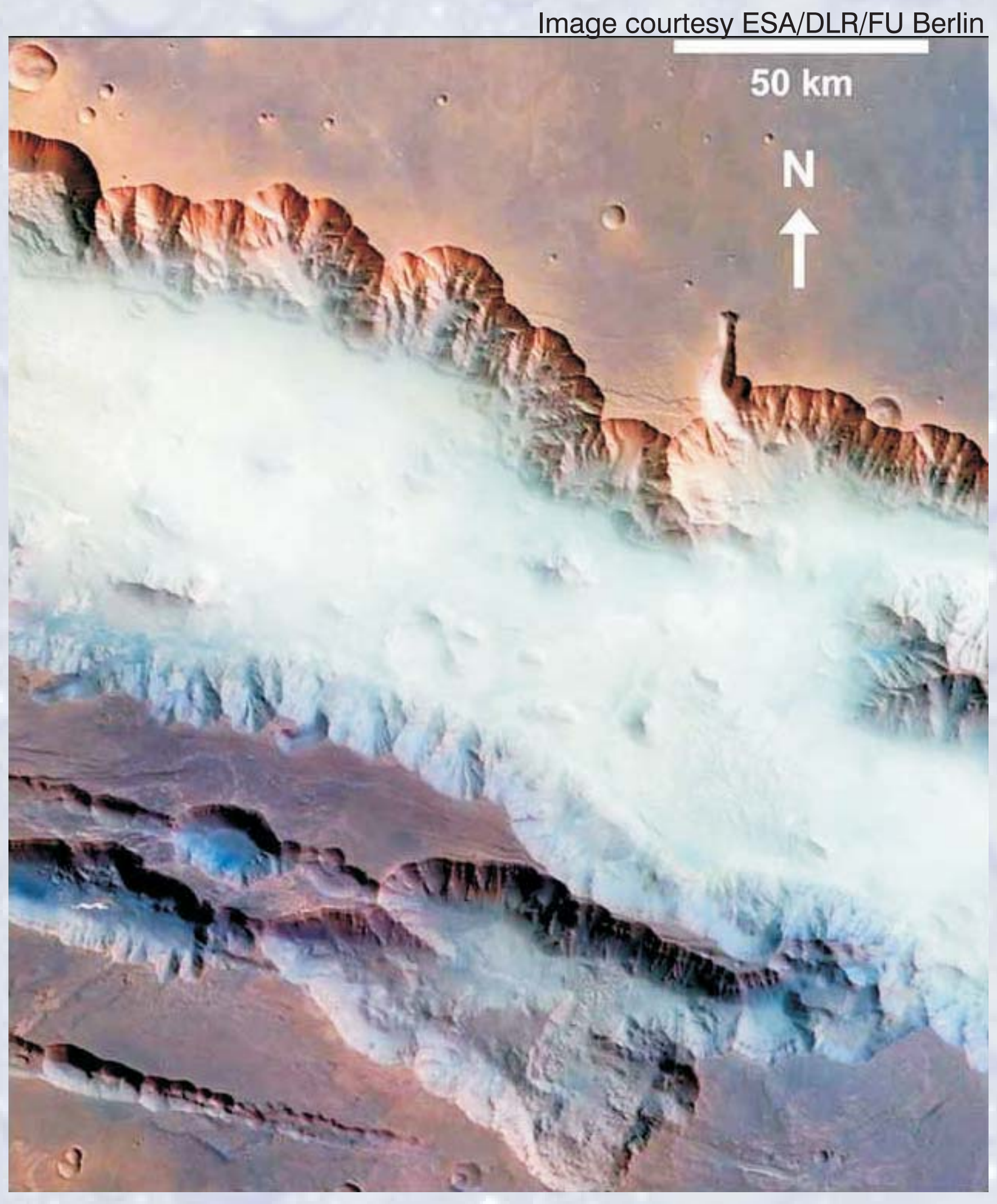

Fig. 2: Morning fog at Valles Marineris (G.Neukum: Image centre at -14,17° latitude,57,52°W longitude, May 25th 2004, local time: 9h 29min)

Faradays Law:

$$Q = I \cdot \Delta t = F \cdot z \cdot \frac{m_W}{M_W}$$

Chemical Reaction (QSE):

$$P_2O_5 + H_2O \longrightarrow 2HPO_3$$

$$2HPO_3 \longrightarrow H_2 + \frac{1}{2}O_2 + P_2O_5$$

Fig. 3: Faradays Law and chemical reactions, which take place on the coulometric sensor (QSE)

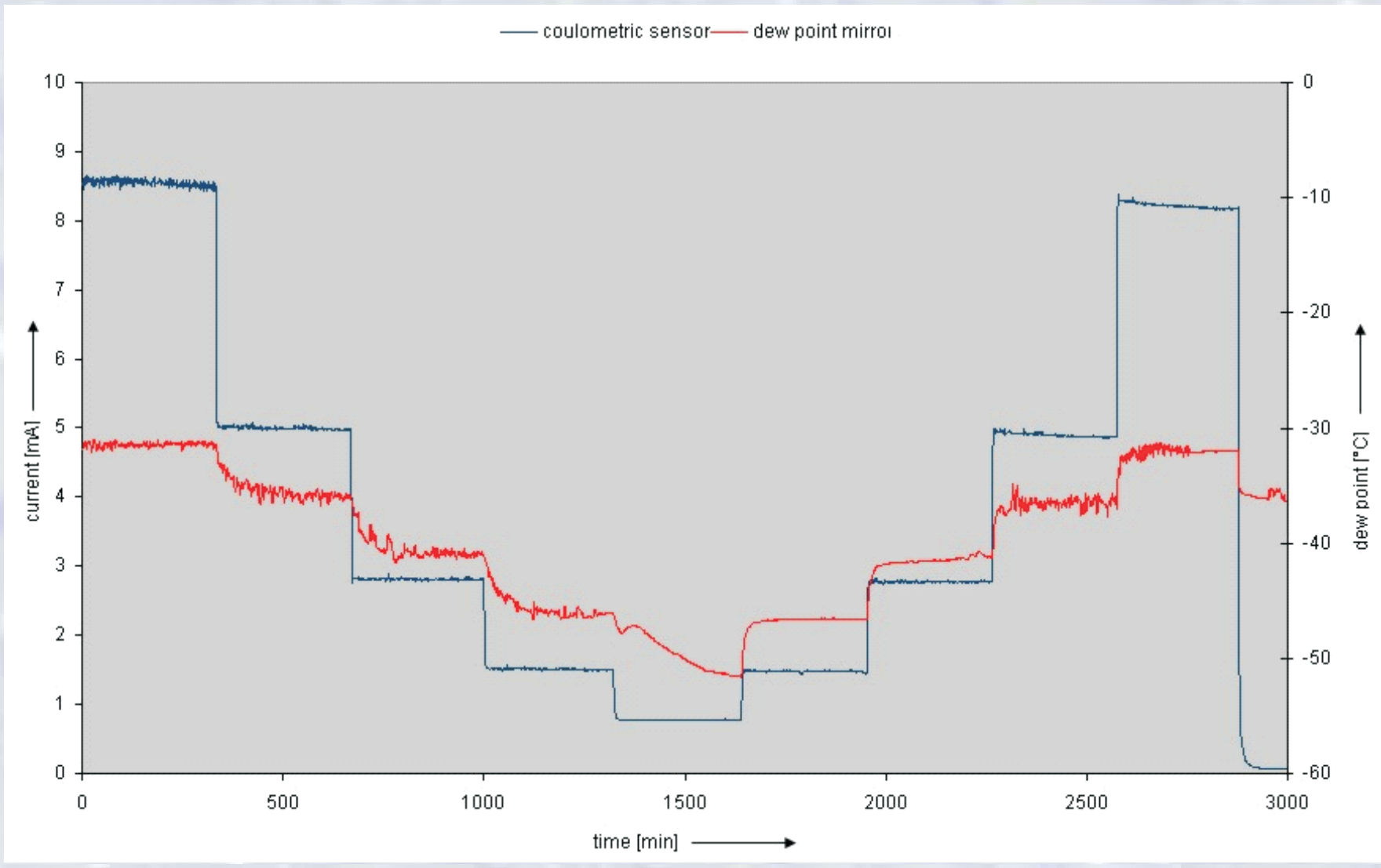

Fig. 4: Comparison of coulometric humidity measurements (red line) and those, made by the standard dew-point mirror technique (blue line).The signal from the coulometric cell quickly follows preset humidity changes more faster than the standart dew-point mirror.

The humidity sensor (HUM) is a combined unit of a coulometric sensor (QSE) and a capacitive sensor (CPS) with an integrated thermocouple. Under Martian conditions the capacitive and the coulometric principle are the most appropriate. The coulometric principle is based on the ability of Diphosphorpentoxid (P_2O_5) to adsorb environmental water vapour almost completely. In case of an applied DC voltage the resulting current is directly related to the amount of adsorbed water, as described by Faraday´s law (cf. Fig.: 3). The capacitive humidity sensor uses the humidity dependence of a polymeric dielectric to measure the relative humidity of environmental gas.

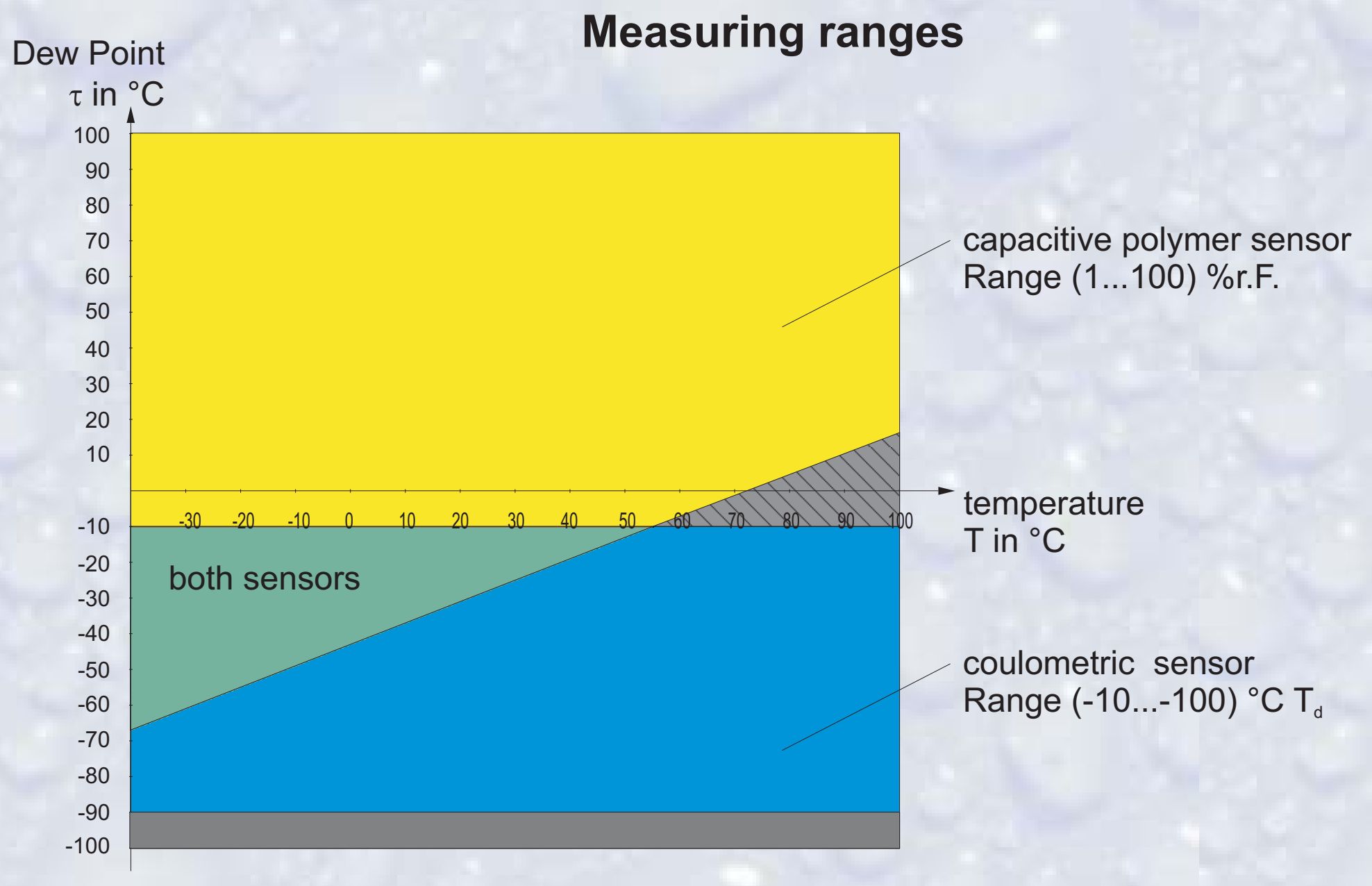

Fig. 5: Measurement range for a combined sensor: coulometric sensor cell for trace humidity, capacitive cell for middle and high humidity.

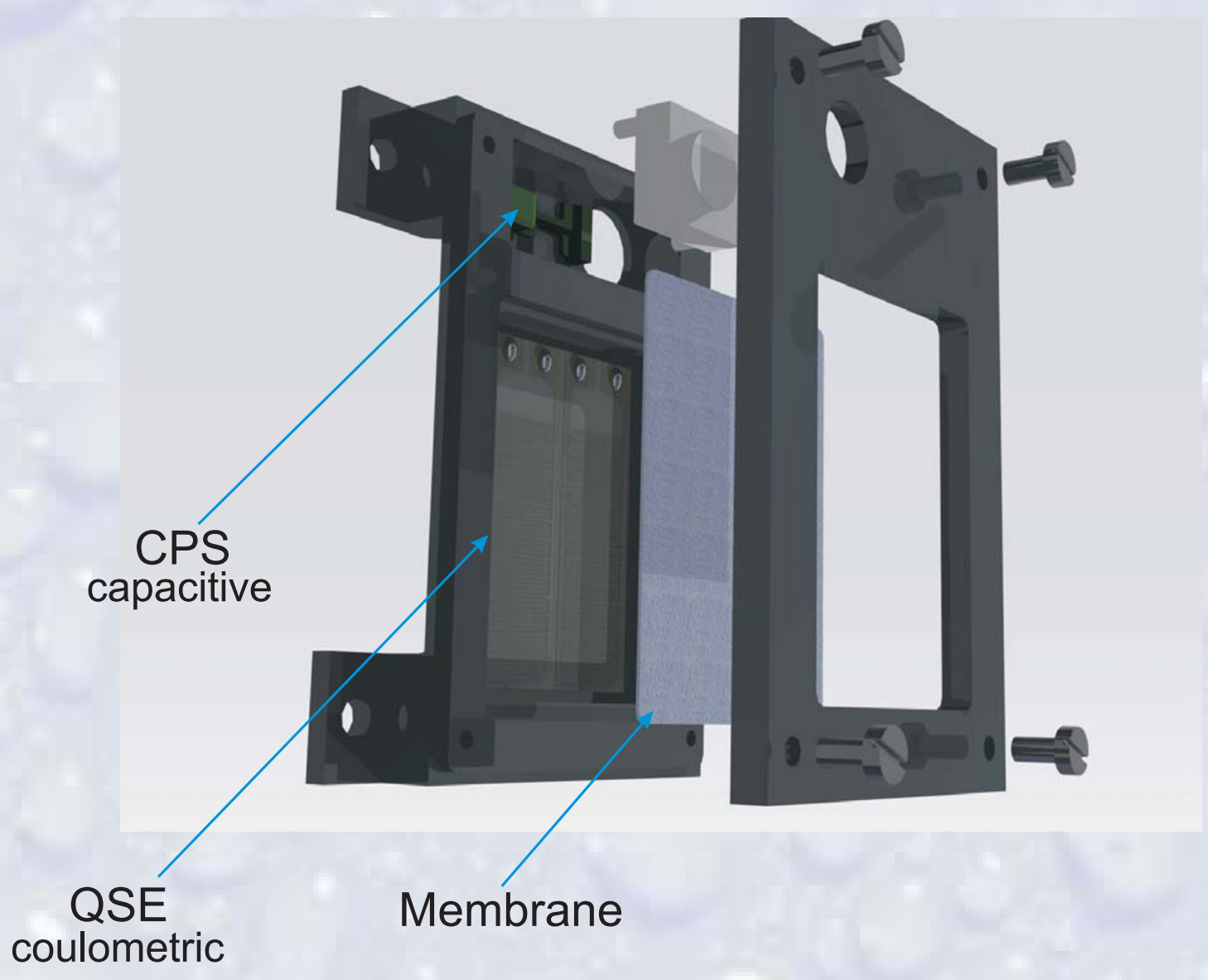

Fig. 6: Exploded view of the HUM sensor. With a mass of 27 g one of the smallest instruments of ExoMars.

Fig. 7: First Breadboardmodel of HUM. The coulometric and capacitive sensor placed inside a small sensor housing (55 x 48 x 9 mm³)

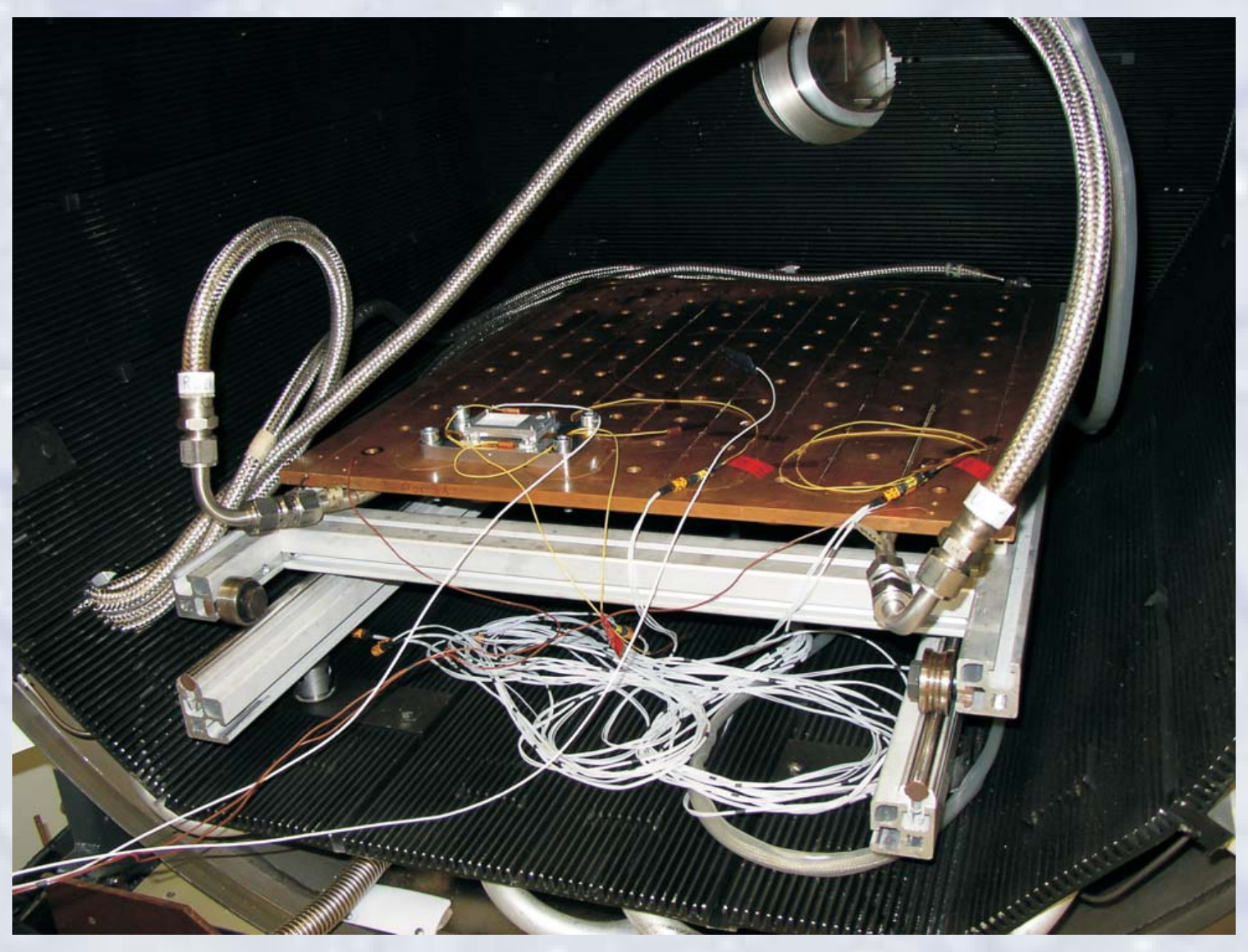

Fig. 8: Thermal cycling test at DLR in Berlin. MiniHUM succeeds 8 cycles at $5 \cdot 10^{-5}$ Torr between 153 K and 263 K, and demonstrates to function well under Martian conditions.

The atmospheric saturation sensor (ASS) consists of a highly sensitive resistant thermometer for independent determination of the frost point temperature. That will give an independent way to determine the absolute humidity specifically at that point of phase transition (cf. Ryan and Sharman (1981)). This information can also be used for calibration purposes of the humidity sensors.

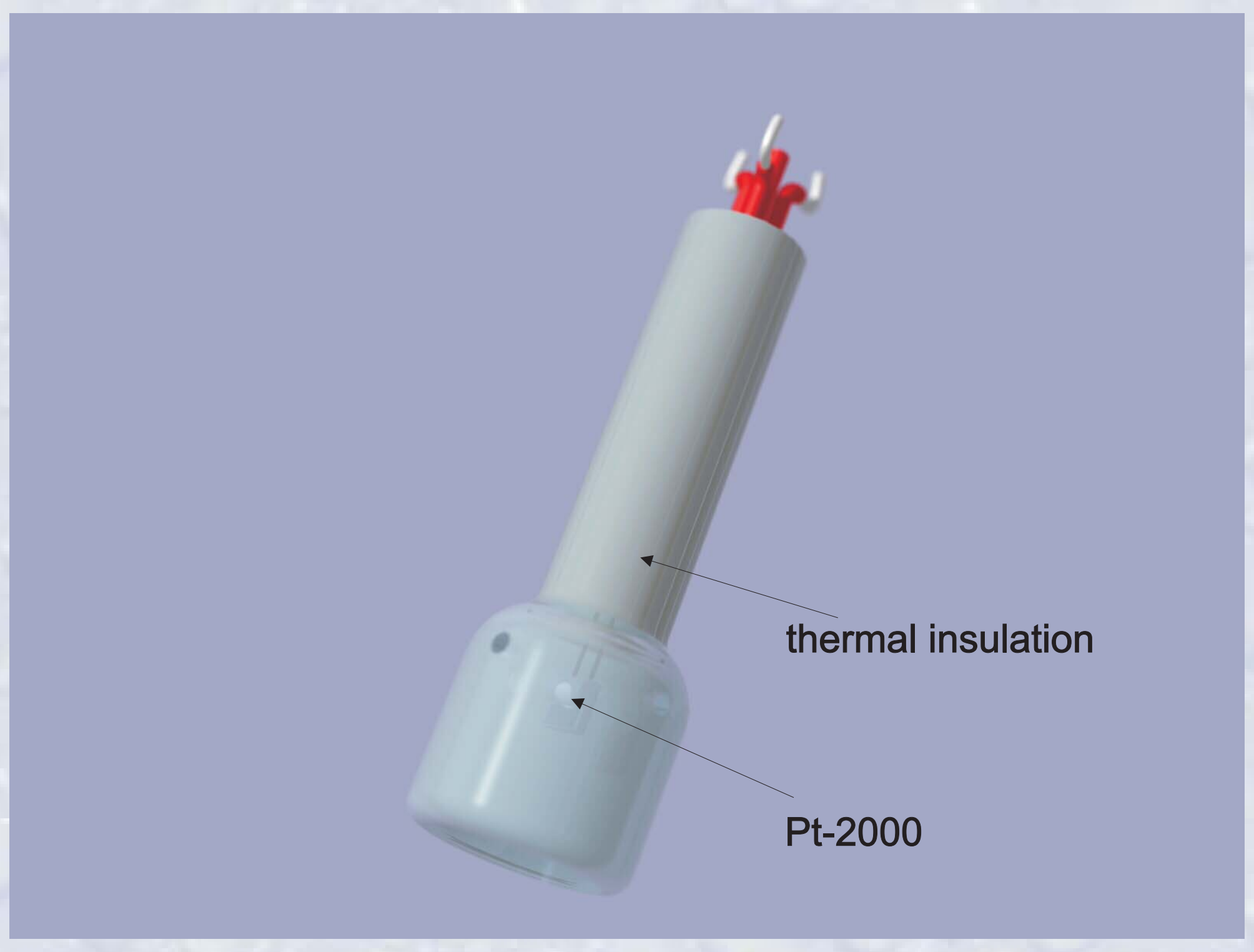

Fig. 9: Design study of the athmospheric saturation sensor ASS (Ø10 x 30 mm³, approx. 4 g)

<u>QSE</u>

meas. principle:	coulometric cell
Measures:	absolute humidity
Working range:	-90°C to -40°C Tp
Sensor mass:	2 g

<u>CPS</u>

Meas. principle:	capacitive cell
Measures:	relative humidity
Working range:	5% to 95 % r.h.
Sensor mass:	0,2 g

<u>ASS</u>

Meas. principle:	resistance thermometer
Measures:	temperature
Working range:	150 K to 300 K
Resolution:	0,1 K
Accuracy:	0,4 K
Sensor mass:	0,2 g

Möhlmann (2004): Möhlmann, D. T. F.: Water in the upper martian surface at mid- and low-latitudes: presence, state, and consequences. In: Icarus 168 (2004), April, S. 318–323. http://dx.doi.org/10.1016/j.icarus.2003.11.008. – DOI 10.1016/j.icarus.2003.11.008.
Bish et al. (2003): David L. Bish, J. William Carey, David T. Vaniman and Steve J. Chipera, Stability of hydrous minerals on the martian surface, IcarusVolume 164, Issue 1, , July 2003, Pages 96-103. http://www.sciencedirect.com/science/article/B6WGF-48TM6F8-5/2/ee954fe4e4a1cc4cf93015dde286a5b7).
Landis et al. (2007): Landis ,G.A. et al., 2007, "Observation of Frost at the Equator of Mars by the MER Rovers," in preparation.
Ryan and Sharman (1981): Ryan, J.A.; Sharman, R.D. (1981), H2O frost point detection on Mars, Journal of Geophysical Research 86 (1981), S. 503-511.