Atmospheric Pressure & Humidity Instrument Technologies for Planetary Landers.

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Introduction: Finnish Meteorological Institute (FMI) has developed a line of meteorological pressure & humidity sensing instruments for several planetary landing missions. Succesful missions have been Huygens entry probe to Titan moon [1], Phoenix '07 lander to Mars [2] and Curiosity Rover to Mars [3]. Currently FMI is developing and building the next generations of these these instruments for proposed MetNet Precursor miniature lander [4] and for 2016 scheduled ESA Exomars EDM lander "Schiaparelli" to Mars [5]. FMI sensors will fly too on the recently selected P/L of the NASA 2020 Rover in the MEDA instrument package. New sensor technologies are developed for the coming next decade planetary missions. Sensor technology testing and calibrations are performed in-house in FMI's calibration facility. Instrument technologies for these wide variety of missions are presented.

Pressure Sensor technology: Sensor technology is based on the Barocap micromachined monocrystal silicon pressure sensors manufactured by Vaisala ltd. Sensor is a capacitor, the other electrode is thin film diaphragm over a vacuum chamber on the silicon. Pressure moves the diaphragm electrode and thus the capacitance changes. Sensors are available for different pressure ranges. For Mars, low pressure sensors with (accurate) pressure range 0…50 hPa are used. In Huygens entry probe to Titan, three sets of sensors for different altitudes were used to measure the whole pressure profile from the vacuum to 1.5 Bar on the surface.

Humidity Sensor technology: Humidity sensors are Vaisala ltd Humicap polymer thin film sensors. Active polymer changes it's dielectric constant as function of vater vapour density and thus the capacitance of the sensor changes.

Transducers: Sensor transducers convert sensor capacitance to a frequency signal which can be measured by a microprocessor system. This microprocessor system may be an external (lander CPU or another instrument CPU) or it maybe integrated with sensor system as stand-alone experiment which can communicate directly with digital instrument bus.

Missions: The first mission participated was Russian Mars-96 1996 (pressure & humidity sensors, lauch failed). After this, FMI has provided these sensors for five planetary lander missions, one of them to Titan moon and the rest for the Mars. Table below lists the missions:

Mission	**Devices**	**Launched**	**Status**
Mars-96	P, H	1996	Launch failed
Huygens	P	1997	Successful
Mars Polar Lander	P	1999	Landing failed
Beagle-2	P	2003	Landing failed
Phoenix '07	P	2007	Successful
Curiosity	P, H	2011	Successful

P = Pressure, H = Humidity

Coming missions: FMI will provide pressure and humidity sensors for at least three this or next decades landing missions to Mars:

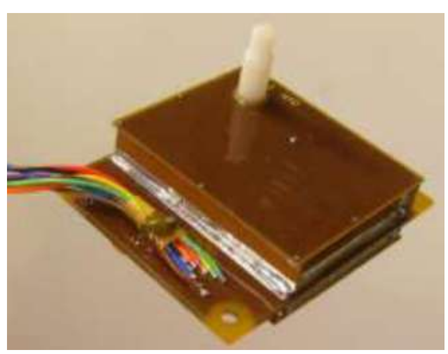
MetNet Precursor Mission: MetNet Precursor is a FMI/IKI/INTA mission concentrating to meteorology & geosciences. MetNet Precursor lander is a miniature size lander. Total entry mass is 24 kg and scientific P/L is 1.4 kg. Lander engineering model and critical subsystems have been completed and tested.

Schiaparelli: ESA Exomars EDM 2016 lander. A short lifetime lander (works on batteries for a few days). FMI has built pressure and humidity sensors and their control electronics for the "Dreams" P/L. Flight models will be delivered on autumn 2014.

2020 Rover: NASA rover. FMI will provide pressure and humidity sensors for MEDA instrument suite.

Instrument set-ups: Sensor set-ups for the most recent and coming missions are presented below:

Curiosity: FMI provided sensors and pre-state transducers. REMS experiment controller controlled the sensors.



Pressure sensor unit "REMS-P" for Curiosity rover

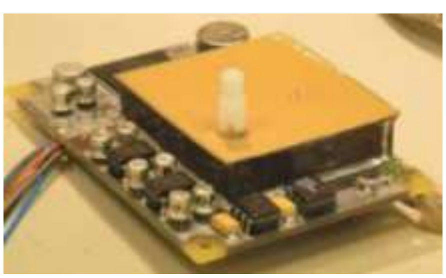
- 62 x 50 x 31 mm (P sensor only)
- Mass: ~35 g (P sensor only)
- Power:
    - 5V: ~15 mW (P sensor only)
    - High-quality 5V (+/-50mV) required
- Digital signals to FPGA
- Additional mass and power budget for
    - FPGA
    - Power converters for high-quality +5V

Curiosity pressure sensor specifications

MetNet Precursor Mission : Pressure sensor & controller is a “stand-alone” system with internal control logic (FPGA) and has digital communication with lander CPU. White “chimney” is the pressure lead-in piping connector.

- 85 x 60 x 36 mm
- Mass: ~100 g
- Power:
    - +5V: ~50 mW
    - +12V: ~80 mW/sensor
        - Each sensor takes ~3 mA
- Data exchange: RS-422
- High-quality secondary +5V for sensors provided by converters on the same PCB (12V -> 5V)

Exomars EDM Schiaparelli 2016: Pressure sensor & controller is a “stand-alone” system with internal control logic (Freescale uP) and has digital communication with lander CPU. White “chimney” is the pressure lead-in piping connector. Pressure sensor elements are inside the “box” on the circuit board.



Schiaparelli pressure sensor & control unit “Dreams-P”

- 90 x 60 x 31 mm
- Mass: ~55 g
- Power:
    - +5V : 55-60 mW
    - +12V :70-80 mW/sensor
        - Each sensor takes ~3 mA
- Data exchange: RS-422
- High-quality secondary +5V for sensors provided by converters on the same PCB (12V -> 5V)

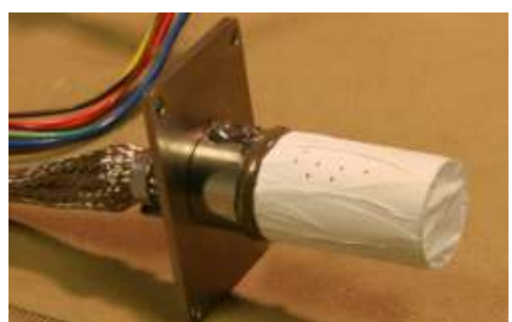
Schiaparelli Dreams-P specifications

Pressure sensor performance: Table below shows the REMS-P pressure sensor performance of the Curiosity.

Calibrated range:	0 - 12 hPa
Accuracy BOL:	± 3 Pa
Drifting:	1 Pa / year
Noise level:	0.2 Pa
Time constant:	< 1 s
Oper. temp. range	-45ºC…+55ºC
Survival. temp. range	-55 ºC … +70 ºC

For coming missions, some improvements maybe expected in the sensor performance.

Humidity sensor heads: Humidity sensors heads of the Curiosity REMS experiment (REMS-H) and Exomars EDM Schiaparelli 2016 (Dreams-H) are shown below:

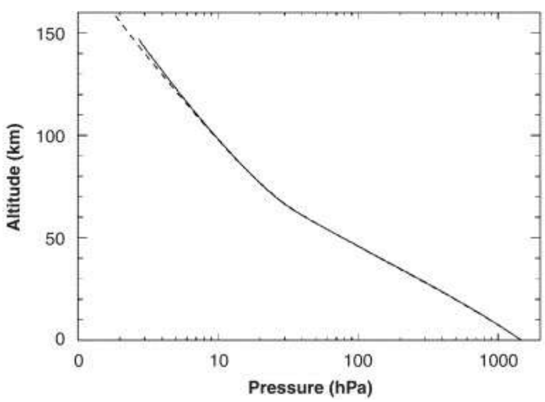


Humidity sensor performance and specifications: Performance of the MetNet Precursor, Curiosity and Schiaparelli type humidity sensors is shown in the table below:

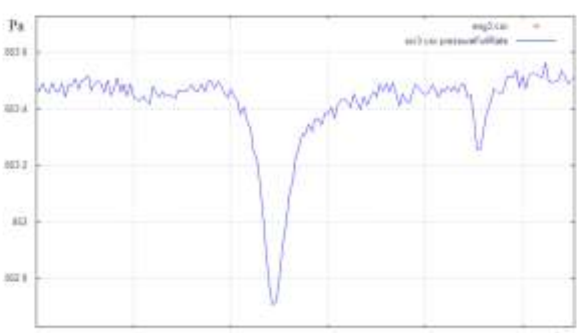
Range:	0 - 100 % RH
Accuracy:	< 10 % RH
Resolution:	< 1 % RH
Time response:	~ 1000…2000 s
Oper. temp. Range:	-90ºC…+55ºC
Survival temp. Range:	-135 ºC … +70 ºC
Mass:	< 16 g
Power:	< 20 mW.

For coming missions performance will be still improved.

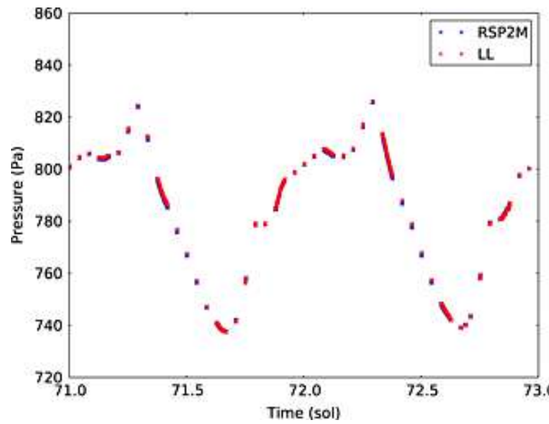
Observations: These instruments onboard Huygens, Phoenix ’07 and Curiosity have provided valuable observations, some examples are presented here:



Pressure profile of the Titan moon measured by FMI’s pressure sensor system (HASI-PPI) [1]



Detected dust devils by FMI’s pressure sensor onboard Phoenix (MET-P)



Diurnal pressure cycle measured by FMI’s REMS-P pressure sensors onboard Curiosity rover. [3]

Testing and calibration: FMI in-house calibration laboratory is used for environmental testing and calibration (temperature, pressure, humidity, vacuum). This minimizes need for transporting equipments and improves safety, reliability and cleanliness. However, if required, external calibration services may be used like MIKES (National Centre for metrology and accreditation.


Various test set-ups of pressure and humidity sensors.

References: [1] Harri A-M., Mäkinen T. et al. (2006) PSS, vol 54, 1117–1123. [2] Taylor P. A., Kahanpää H. et al. (2010) JGR Planet Vol 115. [3] Harri A-M. et al. (2014) JGR Planets, Vol 119, 82-92. [4] Harri, A.-M. et al. (2014) Eighth International Conference on Mars, LPI. [5] Esposito, F. Montmessin, F. et al, (2012) EGU General Assembly.