MARS ATMOSPHERIC MEASUREMENTS PLANNED AT EXOMARS 2020 SURFACE PLATFORM

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Introduction:

The primary goal of the ExoMars 2020 mission is to deliver the ExoMars rover to the surface of Mars. The rover science (Vago et al. 2017) is focused on habitability of Mars and is concentrated around the drilling sampling device. Some occasional atmospheric observations could be performed by optical instruments on the mast of the rover: PanCam and ISEM. After the rover leaves the landing site, the immobile part of the lander, the surface (Fig. 1) starts its science mission. It is focused on climate and atmosphere of Mars, but also includes surface and geophysical experiments.

The surface platform science payload includes 12 experiments, and a common electronics box (science payload-dedicated computer). The total mass of this equipment, including cabling, etc. auxiliary elements should not exceed 45 kg.

The science payload of the surface platform is led by Roscosmos and Russian Academy of science. Two European-led instruments were selected following an ESA Announcement of opportunity in 2015. The full list of the science instruments is presented in Table 1.

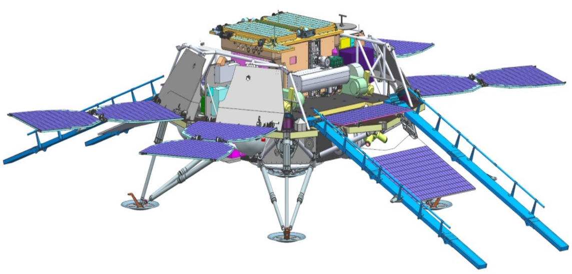

Fig. 1 The ExoMars 2020 surface platform with rover.

Science Objectives:

The science objectives of the surface platform payload may be formulated as follows:

1. Context imaging (TSPP cameras);
2. Long-term climate monitoring and atmospheric investigations (METEO, HABIT, FAST IR spectrometer, M-DLS diode laser spectrometer, PK dust suite, RAT-M radiometer);
3. Studies of subsurface water distribution at the landing site (Adron-EM neutron detector);
4. Atmosphere/surface volatile exchange (HABIT, FAST, MGAK);
5. Monitoring of the radiation environment (Adron-EM);
6. Geophysical investigations of Mars internal structure (MAIGRET magnetometer, SEM seismometer, LaRa radio science).

Entry and Descent measurements:

MTK (or METEO). The meteorological complex is based on the concept of Mars-96 small stations meteo-package (Harri et al., 1998) and Met-Net mission initiative (Harri et al., 2016). The meteorological complex includes inertial measurements unit working during the aerodynamic phase, and sensors working during the parachute phase of the descent. These measurements are enabled by the METEO electronics box, which stores the obtained data. The results ate transmitted to the ground only after the landing and critical Surface Platform/Lander operations. The inertial measurement unit includes 3-axis accelerometer and optical-fiber gyroscope. Duplicated pressure and temperature sensors work during the parachute descent.

An investigation of the EDL profile using the engineering sensors (the sensors aimed to support the landing process) of the 2020 ExoMars lander similar to ExoMars 2016 Schiaparelli AMELIA experiment (Ferri et al. 2017) is being considered.

Meteorology-dedicated investigations:

MTK is the main instrument suite dedicated to synoptic observations on the Mars surface. Once at the surface, the electronics box acquires signals from the main meteorology sensors: Three temperature (Pt-wire) sensors, a wind sensor (ion anemometer), and duplicated pressure (Barocap®) and relative humidity (Humicap®) sensors.

MTK also joins a number of optical sensors dedicated to monitoring of dust and aerosols. Sun Irradiation Sensor (SIS'20) flown at ExoMars 2016 Schiaparelli lander (Arruego et al., 2015) will measure light at two wavelengths with six differently oriented pairs of photodetectors. One pair is dedicated to ozone (centered at 255 and 295 nm), and a small diffused light spectrometer covering 340-780 nm range with ~10 nm spectral resolution. Optical Dust

Sensor (ODS, Maria et al., 2006) measures sky brightness at two wavelengths with well-determined field-of-view. Dust Sensor (DS'20) is an *in-situ* nephelometer operating at near-back-scattering mode in two IR ranges (2.5 and 4 µm). Yet another active dust sensor, called Aerosol Sensor, is essentially a Lidar pointed to near-zenith, intended to sound up to 500 m - 1 km height. A heritage sensor was flown at Mars Polar Lander mission.

Temperature, wind, and humidity sensors, and SIS are mounted at a one-meter deployable mast. After erected its full height above the surface is ~2 m; the temperature sensors are located at three different levels. The pressure sensor is inside the electronics box; dust sensors are located at the body of the lander where obscuration is minimal.

HABIT. HAbitability, Brine Irradiation and Temperature unit has REMS/Curiosity (Gómez-Elvira et al., 2012) heritage. It includes three air temperature sensors, a surface temperature, and a UV irradiation sensor. HABIT is located below the surface platform deck, and the air temperature sensors complement MTK sensors located higher. The surface temperature is measured remotely with an IR radiometer (8-14 µm).

RAT-M is another surface/shallow subsurface temperature monitor. It will measure the temperature from the surface down to a depth of ~1m in three broad microwave ranges (8-16 GHz). The second RAT-M antenna is pointed upwards, and aimed for measuring microwave radiation from dust, in particular during periods of high dust loading and the dust storms to characterize high optical depths, immeasurable in the visible or IR ranges.

PK (Dust complex) joins sensors dedicated to contact measurements of dust properties (Zakharov et al. 2014). A set of piezoelectric sensors is sensitive to impacts of individual dust particles and allows to measure their flux and impact characterizing saltation and other dust lifting processes. A channel of PK, MicroMED is a laser nephelometer involving active pumping of the dusty air trough the sounded volume (Esposito et al., 2015). PK includes two additional channels to characterize electric phenomena related to dust: An electric field sensor, and an electromagnetic emission sensor. The electric field sensor is at a dedicated boom.

FAST. Fourier-spectrometer will operate in the spectral range of 2-17 µm, and in the "Atmosphere" mode can measure the radiation coming from near-surface layers (≤500-1000 m; Smith et al., 2006) with spectral resolution ~2 cm^{-1}. This would allow to measure the temperature structure of the boundary layer and to characterize near-surface aerosols, discriminating for dust and condensation aerosol.

Composition of the atmosphere:

FAST. To study the composition of the atmosphere FAST will be operated in "Sun" mode by pointing to the sun with 2D scanner system. The instrument targets high spectral resolution of 0.05 $cм^{-1}$, and in the spectral range from 2 µm to ~10 µm would allow measurements, sensitive detections, or significant improvement of the existing upper limits of several minor gases: Organics (CH_4, C_2H_2, C_2H_4, C_2H_6), nitrogen-bearing (NO_2, NH_3), chlorine-bearing (ex. HCl), different isotopes of CO_2 and H_2O, and other species, including CO, O_3, H_2O_2, OCS etc.

MGAK is a GCMS targeting measurements of volatile components, micro-components, noble gases. GC is based on the heritage of Phobos-Grunt, and the MS is an ion-trap mass-spectrometer similar to that used in Ptolemy/Rosetta. MGAK will also measure D/H, $^{17}O/^{16}O$, $^{18}O/^{16}O$, $^{13}C/^{12}C$, possibly $^{34}S/^{32}S$ and $^{37}Cl/^{35}Cl$, isotopes of noble gases, and will address mechanisms of volatile atmosphere/surface exchange, activity of the surface material under the UV radiation, etc. factors.

MDLS, Mars diode laser spectrometer is technically closely connected to MGAK, sharing components of the atmospheric sampling system. The instrument is an *in-situ* highly sensitive spectral analyzer employing two lasers and two multipass cells. MDLS investigation will focus on precise H_2O measurements allowing to calibrate the RH sensors, and measurements of isotopologues of water and CO_2.

Related investigations:

TSPP Cameras. Images obtained by the camera set can capture different atmospheric phenomena. With four camera heads TSPP allows for 360° RGB panorama; each camera features a FOV of 115°x115° and a CMOS sensor of 2048x2048 pixels.

ADRON-EM includes a neutron detector with activation (DAN/MSL heritage), allowing to estimate the hydrogen contents and depth within ~0.6-1.5 m below the surface. Measuring its seasonal cycle, together with RAT-M temperature sounding, surface temperature sensors, and various volatile me is important for climate studies.

Microphone (included into MTK) might provide supplementary information. Its lower frequency bound is under discussion.

Concluding remarks:

The ExoMars 2020 Surface platform provides unique opportunity for long-term climate monitoring with a powerful instrument suite on a stationary base, many years after the Viking Landers. The guaranteed lifetime is one Martian year. A global dust storm might be an obstacle for operations. But for various reasons the development of the Surface platform payload is seriously behind the development of the Rover payloads. Current schedule appears very challenging, and the instruments are very different in terms of technology readiness. A descoping of the payload might become real in the coming year. In this case the priorities will be given to the imaging and meteorological monitoring.

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Table 1. The science instruments of the ExoMars 2020 Surface platform. The instruments dedicated to meteorology and atmosphere studies are marked in blue.

Name	**Description**	**Mass**	**Lead institutions**
TSPP	Set of four cameras	2.1 kg	IKI
Adron-EM	Neutron detector for water and dosimeter	5.6 kg	IKI/Bulgarian Acad of Sci
MAIGRET	Magnetometer	1.7 kg	IKI/Inst Atmosph Phys, Prague
HABIT	Meteo/Habitability	1.0 kg	Luleå Univ of Technol
PK	Dust sensor suite	2.3 kg	IKI/Obs Capodimonte/LATMOS
RAT-M	Radiometer for soil temperature	0.6 kg	IKI
MTK	Meteo, EDL profile	4.8 kg	IKI/FMI/INTA/Univ Carlos III
FAST	IR spectrometer	3.5 kg	IKI
LaRa	Radio science experiment	1.0 kg	Royal Obs of Belgium
MGAK	GCMS (atmosphere)	7.0 kg	IKI
SEM	Seismometer	1.8 kg	IKI
M-DLS	Diode laser spectrometer	2.6 kg	IKI
BIP	Science I/F computer	3.0 kg	IKI
	Total mass with cables	**<45 kg**	