ИССЛЕДОВАНИЕ DUST IN SPACE КОСМИЧЕСКОЙ ПЫЛИ

УЧРЕЖДЕНИЕ РОССИЙСКОЙ АКАДЕМИИ НАУК
ИНСТИТУТ КОСМИЧЕСКИХ ИССЛЕДОВАНИЙ РАН

INVESTIGATION OF MARTIAN DUST DYNAMICS WITH THE DUST COMPLEX: INSTRUMENT DEVELOPMENT AND CALIBRATION

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Background

The load of suspended dust in the Martian atmosphere varies dramatically but never drops entirely to zero.

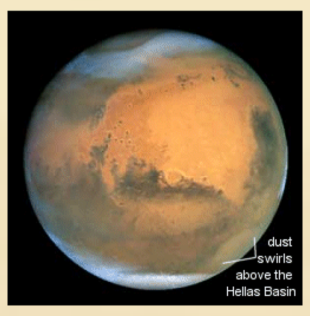
Effects of airborne dust contribute to the dynamic and thermodynamic evolution of the atmosphere and its large-scale circulation processes on diurnal, seasonal and annual timescales.

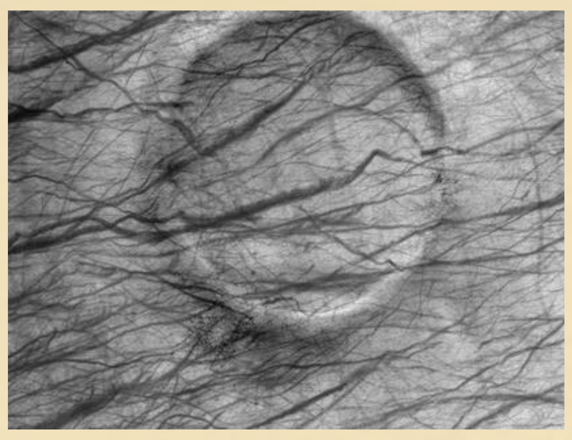
Suspended dust plays a key role in determining the present climate of Mars and probably influenced the past climatic conditions and surface evolution. Atmosphere dust and windblown dust are responsible for erosion, redistribution of dust on the surface, and surface weathering.

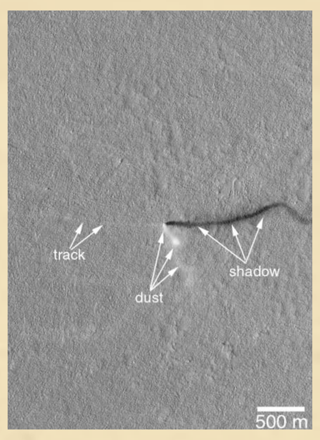
The mechanisms for dust entrainment in the atmosphere are not completely understood, as the current data available so far do not allow us to identify the efficiency of the various processes.

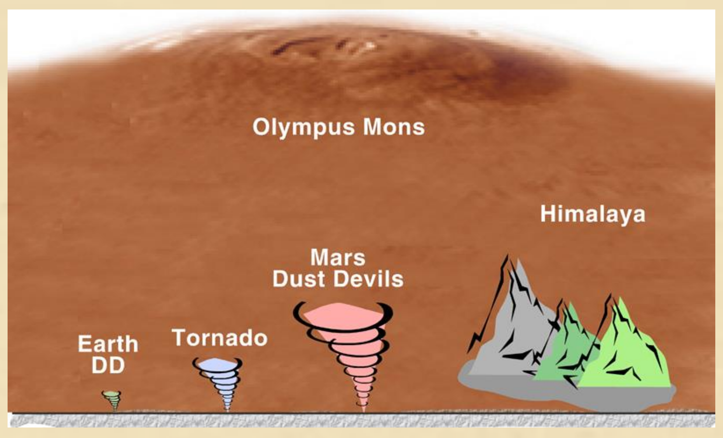
Dust-grain transport on the surface of Mars has never been directly measured despite great interest in and high scientific and technological ramifications of the associated phenomena.

Some valuable data concerning Martian dust dynamics is now planned to obtain with the Dust Complex (DC) instrument as a part of the scientific payload of the ExoMars-2020 mission's landing platform.









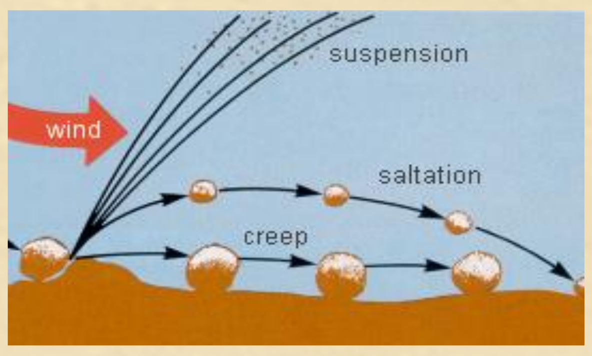
Mechanisms of Aeolian Sand Transport

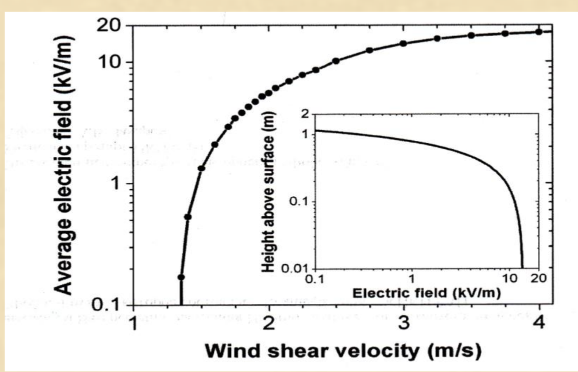
Wind mobilized particles on Mars range in size from less than 1 µm, for suspended dust, to perhaps as large as 1 cm in diameter.

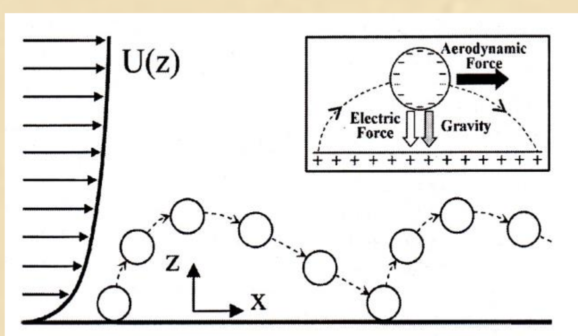
A first model for dust injection required sandblasting, where saltating sand-size particles are responsible for dust entrainment via impacts (saltation). Martian saltation process has been widely studied due to the observations of the very extended dune fields on the surface of Mars (generated as on the Earth by saltating sand grains), and is now considered an important mechanism explaining movements of Martian dunes and some other observations made by the Mars Exploration Rovers.

Dust devils and dust storms are very common events on Mars and saltation is considered to be the main mechanism responsible for rising dust during these phenomena, though other plausible dust emission mechanisms have also been suggested.

Two kinds of quantities are important to make clear the question of dust sources: surface flux and granulometry characteristics.







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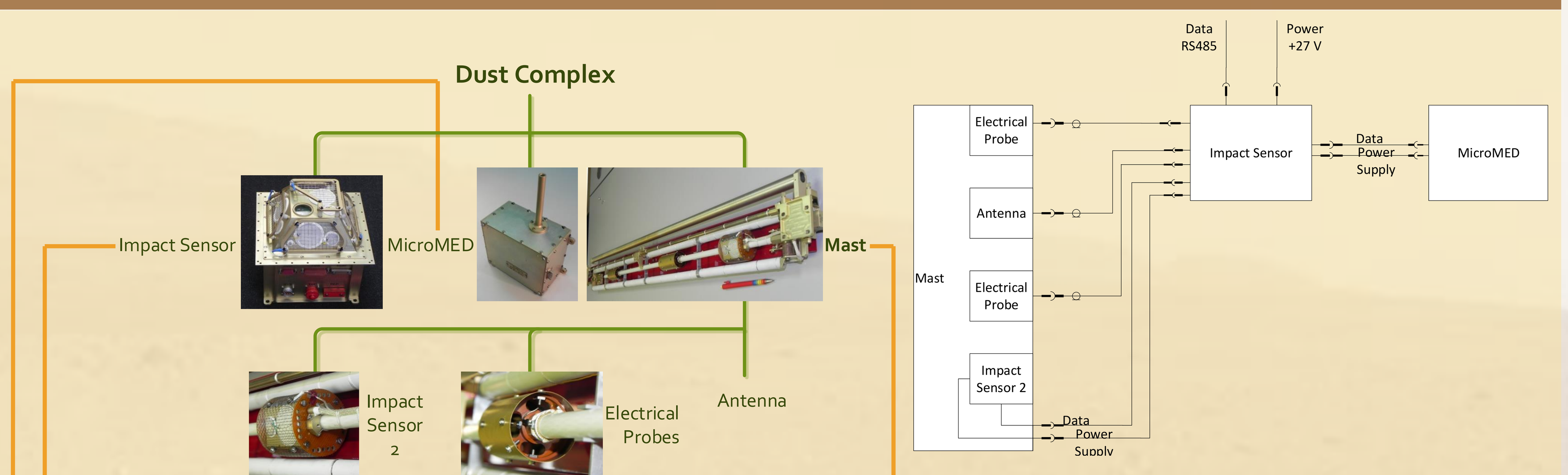
Purposes of the Dust Complex Instrument

The DC instrument primary scientific goal is to monitor dust cycles by direct measurements of dust flux at the surface of Mars. It has never been previously performed. Indeed, the dust cycle and the resulting feedback on atmospheric circulation are still poorly known for Mars. The unpredictability of the global dust storms on Mars is one of the most evident consequences of this lack of understanding.

ExoMars 2020 mission will offer a unique opportunity to study these processes by monitoring dust dynamics for one Martian year. This will allow spanning from periods of relatively clear sky to more dusty periods, where an important load of dust is expected to be injected into the atmosphere.

Scientific outcomes of the DC have future meteorological and environmental applications on Mars, including studying the dynamics of atmospheric aerosols and near-surface stratification.

Design and Characteristics



Impact Sensor	
Mass, kg	0,8
Power consumption, W	10 (for all units)
Dimensions, mm	120 ×120 ×138
PZT sensing range, N·s	10^{-12} …10^{-2}
Error	35%
Grid sensitivity, C	$1,6\cdot10^{-16}$
Data volume, Kbit/sol	1024

MicroMED	
Concentration, sm^{-3}	0 - 2000
Particle dimensions, µm	0,4…20
Mass, kg	0,5
Dimensions, mm	190x126x70
Data volume, KB/sol	300

Mast	
Mass, kg	0,3
Dimensions	765,5 × 56,3 × 53 mm
Impact Sensor 2:	
PZT sensing range, N·s	10^{-12} …10^{-2}
Error	35 %
Grid sensitivity, C	$1,6\cdot10^{-16}$
Electrical Probe:	
Sensing range, Ratm = $10^{11}\Omega$, kV	±100
Error	10 %
Antenna:	
Sensitivity, µV/m	30
Range, MHz	0,1 – 1

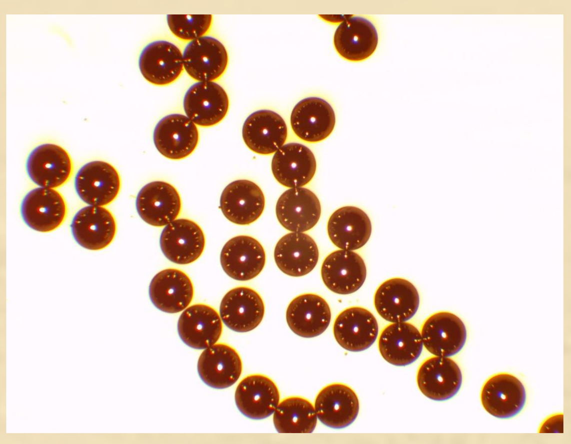
The Dust Complex is a suite of sensors for studying Aeolian processes on Mars. It includes four units: the Impact Sensor, the MicroMED , the Conductivity Sensor and the Mast.

The Impact Sensor contains the main electronics of the DC and two different elements: a piezoelectric sensing elements for measuring fluxes and impulses of saltating sand grains, and the Charge-Sensitive Grid for measuring charges of grains.

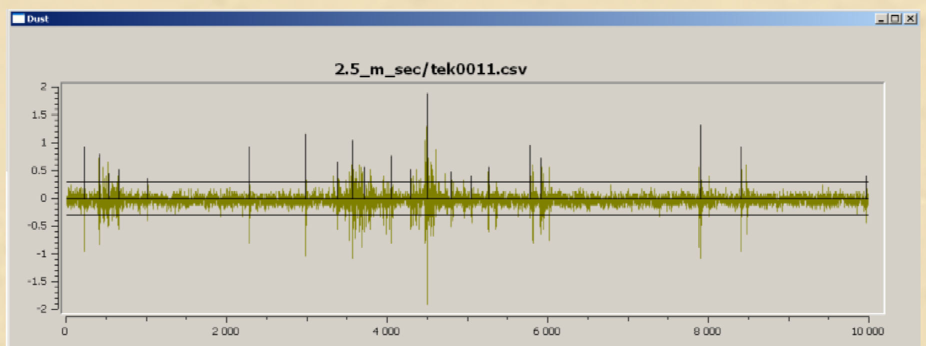
The MicroMED is an optical particle counter for measuring airborne dust size distribution and number density.

The Mast accommodates the following sensors: 1) the second Impact Sensor with the same sensing elements as at the first one, 2) two Electric Probes for measuring atmospheric electric field, 3) the Conductivity Sensor for measuring electric conductivity of the Martian atmosphere and 4) the EM Sensor (antenna), which scans the atmosphere at frequencies up to 1 MHz to monitor electric discharges in the atmosphere.

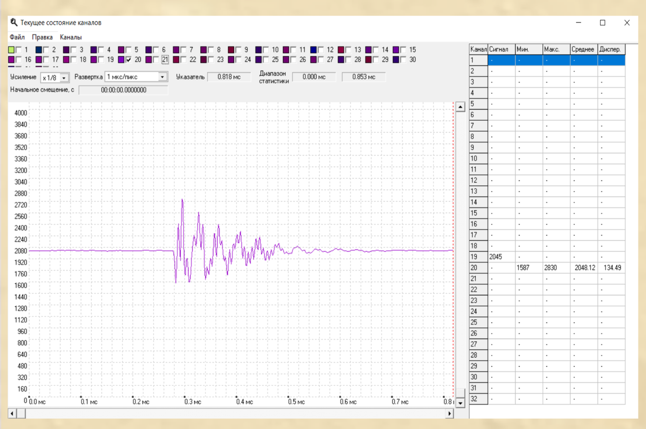
Laboratory Modelling and Calibration



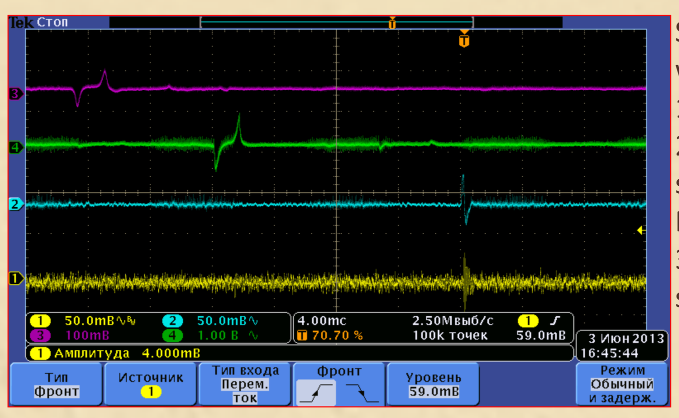
200 µm SnPb spherical particles



IS experimental data for ~40 µm particles
(glass spheres in a 0.5 -1 m/s air flow)



PZT signal for a ~200 µm particle with ~1 m/s speed.



Signals from vacuum chamber with dust injection system.
1 - signal from PZT-sensor,
2 – signal from charge-sensitive grid (5 mm above PZT),
3 and 4 – from inductive sensors