IN-VENTO 2026
International Conference of the Italian Association for Wind Engineering
Bari, September 13th – 16th, 2026

Creating a Martian wind tunnel

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SUMMARY:
The MWT, as part of the Plata facility, born from a collaboration between INAF-OACN and the Italian company ASSE, is one of the few facilities in the world able to reproduce the atmospheric conditions of the planet Mars, having its own unique characteristics. Its challenging design took into account the simulation of Mars's boundary layer, grains electrification, surface temperature and the integration of a wide variety of instruments. It will be used to study sand and dust motion, crucial for Mars missions.

Keywords: Aerodynamics, Wind tunnel, Dust lifting, Mars, Planetary simulation facility, EMM infrastructure

1. INTRODUCTION

1.1. A new Martian simulation facility

In the framework of the PNRR "Earth-Moon-Mars (EMM)" project, the Istituto Nazionale di Astrofisica, Capodimonte observatory (INAF - OACN) and the company ASSE have collaborated for the development of a Martian simulation facility, to be installed in INAF's laboratory. The facility was denominated PLATA (PLanetary images, LAboratory experiment, Terrestrial Analogues).

The laboratory was already equipped with a cylindrical vacuum chamber of 2.3 m length and 1.3 m diameter, able to reproduce Martian atmospheric conditions in terms of pressure (6-10 mbar) and atmospheric composition (95.3% CO_2) (Franzese et al., 2025). In order to study sand and dust mobilization and lifting phenomena taking place in the Martian atmosphere, a wind tunnel was designed to be integrated in the vacuum chamber. This machine, denominated Martian Wind Tunnel (MWT) and part of PLATA, allows the simulation of Martian atmospheric conditions in terms of wind, soil temperature, dust suspension and dust electrification.

1.2. Facility's purpose and potential

The main purpose of the MWT is to study sand and dust mobilization and lifting phenomena in Martian atmosphere. Dust storms and dust devils are widespread events on the whole planet, causing erosion on the surface. The dust cycle also influences the planetary weather and the atmospheric electric field and chemistry (Franzese et al., 2020; Balme and Greeley, 2006).

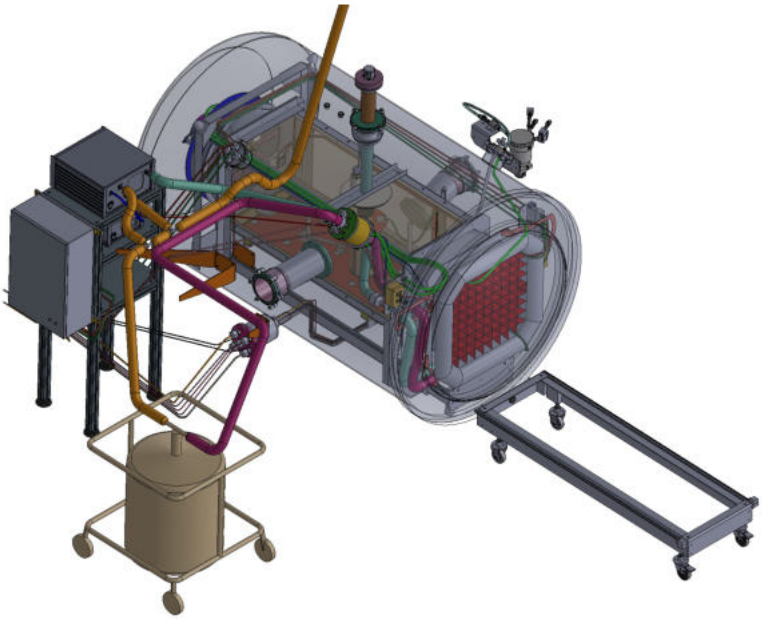

Figure 1. Model of the MWT installed in the vacuum chamber and connected to the external subsystems

The phenomena regarding sand and dust motion are complex due to the interaction between the eolic and the electric component: mobilized sand and dust grains, in fact, acquire charge during their motion and collision, leading to the generation of electric fields up to tens of kV/m. Studying these effects is crucial for Mars missions since dust events can cause damage to both instrumentation and space suits due to impact and to dust induced electric discharges (Franzese et al., 2025).

The MWT was designed to simulate the aforementioned phenomena regarding dust and sand motion. The project was developed to allow high flexibility and the use of a wide variety of instruments, allowing other possible future applications of the facility.

2. THE MWT'S CHARACTERISTICS

There are only a few facilities in the world that simulate Mars's atmospheric conditions, each one with its unique characteristics, such as NASA Ames in the USA and Aarhus University's laboratory in Denmark (NASA, n.d.; Merrison et al., 2008).

The MWT has the structure of an open loop wind tunnel, but it is installed inside a closed chamber, which serves as its return branch.

A set of CFD simulations has been performed on the CO_2 circulation inside the MWT to choose the structure's dimensions, the shape of the inlet and outlet and the fan's characteristics. Particular attention has been paid to the space between the inlet and the test section (in correspondence with the window in Fig. 2) in order to allow planetary boundary layer development (Petrosyan et al., 2011).

To recreate the planet's surface temperature, a thermal plate has been placed under the wind tunnel's floor, connected to a liquid nitrogen circuit controlled with a temperature feedback.

The MWT has the capacity to create a vertical variable electric field in the test section. This

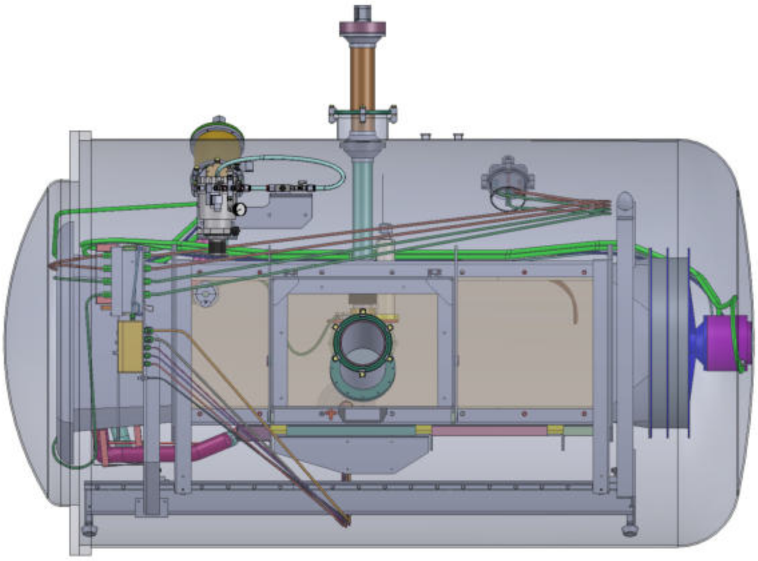

Figure 2. Side view of the MWT inside the vacuum chamber. The volume between the wind tunnel's walls and the vacuum chamber's serves as return branch for the CO_2 flow.

has been implemented with 2 electrodes connected to an 8 kV circuit. The higher electrode can be moved vertically, while the lower one corresponds to the wind tunnel's floor, electrically insulated with respect to the thermal plate underneath. Electrical insulation creates thermal resistance between the plate and the electrode, which had to be considered during the thermal circuit design.

UV sources can be placed in the test chamber to simulate UV radiation on Mars.

2.1. Instrumentation

The MWT can host a wide variety of instruments including:

- an imaging system consisting of illumination and high speed/resolution cameras, to study grain motion
- a Faraday cup, to check the amount of charge per grain
- a Langmuir probe, to characterize the induced plasma
- a field mill to measure the induced vertical E-field

3. CONCLUSIONS

The MWT has been installed in INAF-OACN's laboratories to be used for sand and dust motion experiments. Its flexible design will allow for future upgrades or additions, giving the facility the chance to expand to new applications in the next years.

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