EQUIPMENTS RELIABILITY UNDER THE MOON'S DUSTY ENVIRONMENT

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Moon 2020-2030
A new era of human and robotic exploration

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ONERA

THE FRENCH AEROSPACE LAB

return on innovation

Contamination by Dust

- Severe issue during the Apollo missions and other exploration missions

- From regolith to contamination
  - Sub micron to millimeter size dusts
  - Far from smooth shapes
  - Submitted to lander and rover activity
  - Submitted to environment constraints (micrometeroid impacts, charging by photon and plasma…)
  - Dust ejection from the surface → Generation of dusty plasma

- Rover and lander subsystems possibly affected
  - Mechanical components (ball bearings, gearings, …)
  - Optical surfaces (lenses, sensors, mirrors, …)
  - Thermal control coatings (radiators, …)
  - Seals (insulation sheets, suits zip…)

ONERA Space Environment Department

- From Space Environment Specification to Effects on Spacecraft
  - Modelling the radiation belts, Flight data analysis, Instrument modelling
  - High energetic particles effects (ionizing and non ionizing dose, single event effects, ageing, …)
  - Low energy particles effects (surface charging, erosion, contamination…)
  - Facilities: SEMIRAMIS, SIRENE, JONAS, …
  - Simulation codes: Salamboo, SPIS, MUSCA, …

- Involvement on Dust Contamination Assessment since 2012
  - ESA TRP on Near-surface dusty plasma specification, TO F. Cipriani, finished
    - ONERA, Stuttgart Univ, Leuven Univ, Lancaster Univ
  - ESA TRP on SPIS-DUST for dust contamination computations, TO F. Cipriani, delivered nov 2015
    - ONERA, ARTENUM, Lancaster Univ
    - Final Presentation Days Dec 15-16 2015
  - ESA TRP on Dust characterization, TO R. Lindner, finished
    - SITAEL, ONERA, AVS, Polito de Torino
  - PhD student Amandine Champlain on Experimental Investigation of Dust Electrostatic Dynamics
    - Started 2013

Modelling Dusty Plasma

+ Ice sublimation
+ Impacts
+ Human/Robot activity

SPIS-DUST

- Spacecraft Plasma Interaction Software (SPIS, initiated in the 2000's by ESA and CNES)
- Dust Module implemented in partnership with ARTENUM for the User Interface (see below) and validated by Lancaster University

From Digital Terrain Model (DTM) to Lander Contamination by Dust
Hess et al., 2015a

SPIS-DUST trip to the Moon

- Lunar crater and lander reproduced « by hand »
- 50 m x 20 m x 80 m

Solar wind: T~ 10eV, v~400km/s, n~8 cm-3
Solar Zenith Angle 45°

Hess et al., 2015a

SPIS-DUST trip to Churyumov-Gerasimenko

Philae on Churyumov-Gerasimenko

DTM exists at CNES

Reproduced “by hand” for this simulation

50 m x 50 m x 130 m

Hess et al., 2015b

SPIS-DUST trip to Churyumov-Gerasimenko

Sublimation of the volatile material (water and carbon oxides ices) + Electrostatic charging and deflection

Hess et al., 2015b

DROP Test Chamber

- Developed by A. Champlain PhD student and used for ESA TRP on Dust characterization

50 × 50 × 60 cm
10^{-7} mbar
Reproduce lunar environment
Dust charging by plasma
Vibrations included
Contamination assessment

Objective: assess dust contamination process & provide inputs to SPIS

DROP Test Chamber

- Contamination of Aluminium, Graphite, Multi-Layer Insulator and mirror samples
- Cross check with SPIS simulation
- Use of piezzo electric actuator to mimick seismic activity, microemetroid impact and human activity.

Champlain et al., 2015

Summary

- SPIS-DUST is open source www.spis.org
- It allows to simulate the dust dynamics and charging in space environments as well as the dust deposition on exploration units
- Models need experimental validation/constraints such as performed in DROP chamber
- First simulations show
  - at Moon, only nanometer dusts can reach high altitudes (consistent with LADEE first findings). Density simulated at least one order of magnitude too low to explain horizon glow
  - for Philae, spacecraft charging play an important role for contamination even if ejection of neutral dust is caused by the sublimation of volatile material in the soil. Deposition depends on local time
  - for DROP, good agreement with experiments. Have permitted to consolidate the charging and ejection models of SPIS

Next challenges related to dust contamination

- Dust still a threat to proper in-situ operations
- Estimation of material degradation in case of quiet activity over long periods of time (cumulative effects) or strong activity (transient but very dense dusty cloud)
- Especially how to protect sensitive elements ?
  - In-situ dust instruments
  - Measurements of dust electrical and mechanical properties
  - Mitigation techniques : electrostatics shields , plasma activation, CO2 shower …

References

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Thank you !