EPSC Abstracts
Vol. 6, EPSC-DPS2011-1693-1, 2011
EPSC-DPS Joint Meeting 2011

Surface Dynamics of Phobos and Deimos

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Abstract

As robotic and human missions to Phobos and Deimos are planned, surface mechanical and dynamical properties have become increasingly important to understand. Their low-gravity environments make surface interactions and proximity operations planning similar to the situation of NEA robotic missions, although there are fundamental differences due to interactions with Mars itself. New surface dynamics tools and simulation results are presented, compared to the recent MRO HiRISE images and surface features observed.

1. Introduction

There is an interest in exploring the Moons of Mars from a scientific and a human exploration perspective. Objectives of sending robotic missions to these bodies are to understand better their origin and evolution, while the objectives of sending astronauts are to prepare for landing on Mars surface. Robotic missions have provided details on surface features, composition, shape, rotation, and axis orientation, although all returned data have been obtained through remote sensing instruments. We now design mission for surface and sub-surface exploration at high resolution. As human exploration missions seek to characterize hazards, mechanical properties, topography, composition, and internal features, surface dynamical properties are important to take into account in the design of the next lander mission.

2. Surface Dynamics

To investigate and simulate the surface dynamics of Phobos and Deimos, the moons are initially modeled as ellipsoids [3, 2]. Because of their small size, low mean densities, tidal effects of Mars, and from solar radiation pressure, particle dynamics in the vicinity of these bodies can be complex and non-intuitive. The equations of motion for surface particles take into account gravitational interactions with Mars, Phobos's rotation, and the variable solar radiation pressure [1, 4]. The dynamics at the surface also integrate surface parameters such as coefficient of restitution and friction [2].

Regions of surface equilibrium and gravitational lows are found, and inform studies of the motion of surface point masses. Figure 1 shows a simulation of particle bounces with a general gravity field and surface coefficient of restitution. To first order, some regions are found to be more easily reached: simulations indicate that particles "fall" toward the poles faster compared to equatorial regions. High-resolution color images of Phobos show evidence for surface particle transport in directions dictated by local topography's relation to the global pattern of gravity and tides. Terrain roughness, particle friction, and electrostatic forces likely complicate the picture [5] (Fig. 2).

Lander missions to Phobos or Deimos may elect to take advantage, or not, of the "natural dynamics" modeled here (such as very low escape and landing speeds at the ends), but they will have to take them into account. The natural dynamics of loose particles suggest general trends in particle transport and resulting regolith distribution, which can help select interesting touchdown sites, surface investigations, and tool designs.

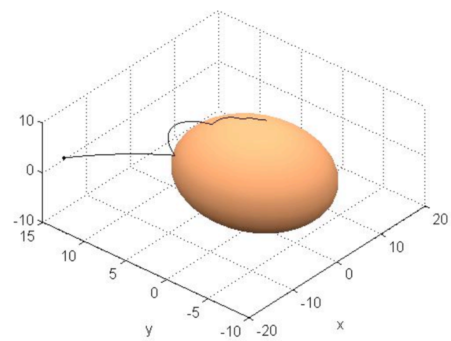

Figure 1: Particle dynamics on Phobos' surface modeled in this study. Units are km. (NASA/CMU/J. Bellerose).

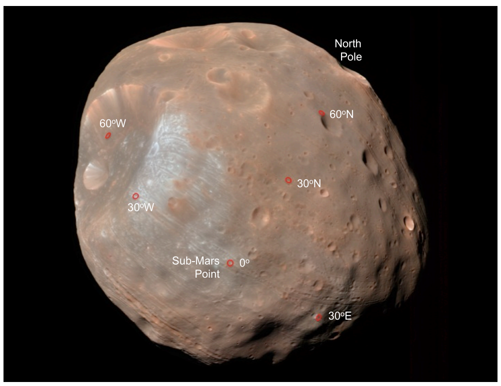

Figure 2: This MRO HiRISE color image of Phobos, with central meridian and equatorial grid points, shows regolith motion on steeper local slopes (NASA MRO/HiRISE).

3. Summary and Conclusions

Investigations of surface dynamics on Phobos and Deimos are helping understand differences in the nature and evolution of their surfaces, and are helping plan future surface experiments and activities. Further characterization of their surface properties will be key to planning future robotic and human missions.

Acknowledgements

The authors wish to thank the NASA Ames Mission Design Center for support and feedback throughout this study.

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