Penetrometry on an asteroid

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An end-of-mission landing on a near-Earth asteroid (like the NEAR landing on Eros) offers the opportunity to make dynamic force measurements followed by extended thermal investigations of the subsurface using simple sensors housed inside or outside of a penetrometer fixed to the spacecraft body. Such measurements could provide useful information on the microstructural and thermal properties of the regolith [1,2]. The high mass (about 100 kg) and low landing speed (<2 m s^{-1}) of the spacecraft will provide enough momentum to push a penetrometer into an asteroid regolith. To simulate the impact under the low gravity of the asteroid, where the strength of the material would dominate the impact dynamics, it is desirable to remove the effect of Earth's gravity from both the target and the penetrometer/spacecraft. A low speed, high momentum, penetrometer test rig, built at The Open University [3] effectively removes the gravitational force acting on the landing penetrometer/spacecraft, but not the target. This enables tests to be conducted with regolith analogues of lower strength than would otherwise be possible if the acceleration due to gravity was acting on the landing spacecraft. The rig has been used for conducting penetrometry [4] and thermal experiments [2] in a variety of planetary regolith analogues. Here we examine the advantages and disadvantages of using a small penetrometer that can easily penetrate the surface. We also examine the advantages and disadvantages of using a large, wide penetrometer, that could possibly decelerate the spacecraft before its base impacts the surface and compacts the regolith beneath it. Laboratory tests comparing the two penetrometers are presented with some realistic calculations for simulating a spacecraft landing with a non-zero horizontal speed.

References: [1] Paton M. D. et al., 2012, Microstructral penetrometery of asteroid regolith analogues and Titan's surface, Icarus, 220, 787–807. [2] Paton M. D. et al., 2012, Investigating the thermal properties of gas-filled planetary regoliths using a thermal probe, Geoscientific Instrumentation, Methods and Data Systems, 1, 7–21. [3] Paton M. D. et al., 2004, Laboratory simulation of a spacecraft landing on a near-Earth asteroid, International Science Symposium on Sample Returns from Solar System Minor Bodies, The First HAYABUSA Symposium, ISAS/JAXA, Oct 20–22, Kanagawa, Japan. [4] Zarnecki J. C. et al., 2005, A soft solid surface on Titan as revealed by the Huygens Surface Science Package, Nature, 438, 792–795.