Low-gravity penetrometry of asteroids and comets

Conference or Workshop Item

LOW-GRAVITY PENETROMETRY OF ASTEROIDS AND COMETS. A. J. Ball[1], [1]Planetary and Space Sciences Research Institute, Centre for Earth, Planetary, Space and Astronomical Research, The Open University, Walton Hall, Milton Keynes MK7 6AA, U.K. Email:A.J.Ball@open.ac.uk.

Introduction: There are a number of contexts in which space hardware may interact mechanically with the solid material present in a low-gravity environment at the surface of an asteroid or comet, possibly penetrating to some depth and yielding useful information. These contexts range from low-speed scenarios, such as passive free-fall to the surface, to hypervelocity impact. Such penetrating devices may be classed as penetrators, anchors, impactors, 'moles', etc.

Measurements performed for engineering or scientific reasons using the penetrating hardware are generally termed penetrometry, though strictly speaking the term referred originally in the terrestrial context to the measurement of geotechnical parameters, with application in fields such as foundation engineering in the construction industry.

An increasing range of sensors can now be incorporated into penetrometry devices, addressing both physical properties (mechanical, electromagnetic, acoustic, etc.) and composition (elemental, molecular, etc.). Another application that can fall under the umbrella of penetrometry is sampling, where the device is not just inserted into the sub-surface but extracts a sample of the target material for analysis elsewhere.

Penetrometry encompasses both payload hardware on a spacecraft as well as cases where the penetrometer *is* the spacecraft, i.e. a penetrator delivering its own payload to a surface.

Application to Asteroids and Comets: Having been applied in the first instance to the Moon, Venus and Mars[1], penetrometry is now reaching a broader range of extraterrestrial targets including, most recently, Titan. Penetrometry sensors are currently en route to a comet nucleus on board the *Rosetta* mission's comet lander *Philae*.

We can expect variants of the technique to feature in a number of forthcoming mission scenarios for asteroids and comets [2]. These include the following:

- Asteroid or comet sample return
- Anchoring of landers
- Impact penetration of penetrators
- Demonstrating of asteroid mitigation techniques and supporting measurements or technologies
- Emplacement of sensors for *in situ* analysis

While many aspects of penetrometry are generic, some particular constraints and issues arise for use of the technique in the low-gravity, airless environment of asteroids and comets. This talk will examine some of these issues and the challenges and opportunities that arise.

For example, a high degree of integration between the penetrometry subsystem and the instrumentation is usually required, given the tight resource envelope and operational constraints. Issues of robustness to shock, adequate pre-flight testing and simulation are also important.

References: [1] Kömle, N. I., Kargl, G., Ball, A. J. and Lorenz, R. D. (Eds) (2001) *Penetrometry in the Solar System.* Proceedings of the International Workshop, Graz, 18-20 October 1999. Austrian Academy of Sciences Press, Vienna. ISBN: 3700129688. [2] Ball, A. J., Lognonné, P., Seiferlin, K., Pätzold, M. and Spohn, T. (2004) Lander and Penetrator Science for NEO Mitigation Studies. In: Belton, M. J. S., Morgan, T. H., Samarasinha, N. and Yeomans, D. K. (Eds), *Mitigation of Hazardous Comets and Asteroids.* Proceedings of the Workshop on Scientific Requirements for Mitigation of Hazardous Comets and Asteroids, Arlington, 3-6 September 2002. Cambridge University Press, pp.266-291.