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Scientific exploration of low-gravity planetary bodies using the Highland Terrain Hopper

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Abstract

Field geoscientists need to collect three-dimensional data in order characterise the lithologic succession and structure of terrains, recontruct their evolution, and eventually reveal the history of a portion of the planet. This is achieved by walking up and down mountains and valleys, interpreting geological and geophysical traverses, and reading measures made at station located at key sites on mountain peaks or rocky promontories. These activities have been denied to conventional planetary exploration rovers because engineering constraints for landing are strong, especially in terms of allowed terrain roughness and slopes. The Highland Terrain Hopper, a new, light and robust locomotion system, addresses the challenge of accessing most areas on low-gravity planetary body for performing scientific observations and measurements, alone or as part of a hopper commando. Examples of geological applications on Mars and the Moon are given.

1. The Highland Terrain Hopper

There are few limitations in the type of scientific payload conventional exploration rovers can carry, from geology and geophysics to geochemistry and exobiology. They lack two skills, however: the ability of working on uneven or unstable terrain, like in canyons and mountains, and on solid bodies having gravity too low for the friction between the wheels and the ground to generate robot displacement. ASTRONIKA Ltd. and the Polish Space Research Centre are designing the Highland Terrain Hopper (Figure 1), a small (Ø ~ 40 cm), light (≤ 2 kg), and low-cost jumping robot that may survey any type of landscape. It may assist other types of robots, or humans, in accessing difficult terrain, or even replace them for specific measurements or campaigning (Figure 2).

Figure 1. The Highland Terrain Hopper is a light and symmetric jumping robot developed by Astronika Ltd. and the Polish Space Research Centre (here jumping within a Valles Marineris-type landscape).

Maximum jumping height and length is 1.5 m on Earth, corresponding to 4 m on Mars, 9 m on the Moon, and much more on Phobos and asteroids.

2. On Mars

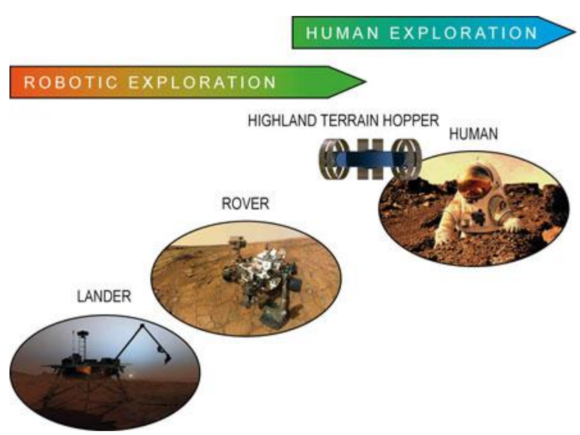

Figure 2. The Highland Terrain Hopper philosophy within the framework of conventional *in situ* planetary exploration modes

The full stratigraphy of Mars, from the pre-Noachian [1] to some of the most recent deposits, may be obtained using a small swarm of hoppers dropped along a traverse going through one of the main Valles Marineris chasmata (Figure 3) equipped with a payload including a visible-NIR multispectral camera and a clinometer. At the same time, data regarding rock fracturing, hydrogeologic and paleohydrologic conditions, paleogeography, paleoenvironments, soils and paleosoils, would be collected.

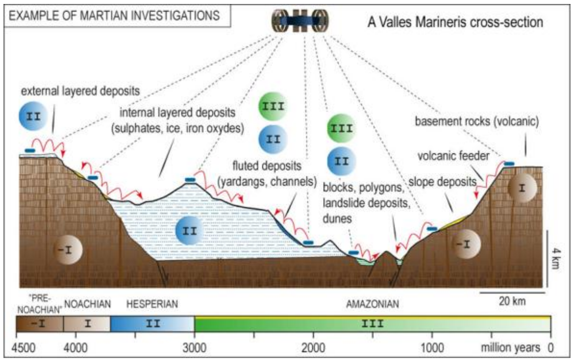

Figure 3. Hopper swarm deployment in a Valles Marineris canyon and investigated rock types.

Such measurements would provide helpful information as to early volatile delivery [2] and the very early climate, as well as assessment of past habitability. Hoppers carrying a ground-penetrating radar could probe the subsurface and look for buried ice; with geophones the present geologic activity and surface dynamics (slope processes, ice movement in rock- or dust-covered glaciers [3] etc.) could be monitored and identified [4]; a magnetometer would provide the first *in situ* measurements of Martian rock magnetization induced by the early dynamo [5].

3. On the Moon

Figure 4 gives two potential applications of Highland Terrain Hopper on the Moon: retrieving the structure and crustal rock succession from climbing lunar central peaks, and measuring the pristine orientation of lunar magnetic field in order to test for the first time if and when a dipolar lunar core dynamo was operating on the Moon [6].

4. Conclusion

Alone or as part of a swarm, the Highland Terrain Hopper can survey any type of landscape on low-gravity planetary objects, giving access to datasets that conventional planetary locomotion systems cannot obtain. Further objects of interest include Phobos with its grooves, pit craters, and Stickney; the asteroid belt, NEOs, KBOs etc.

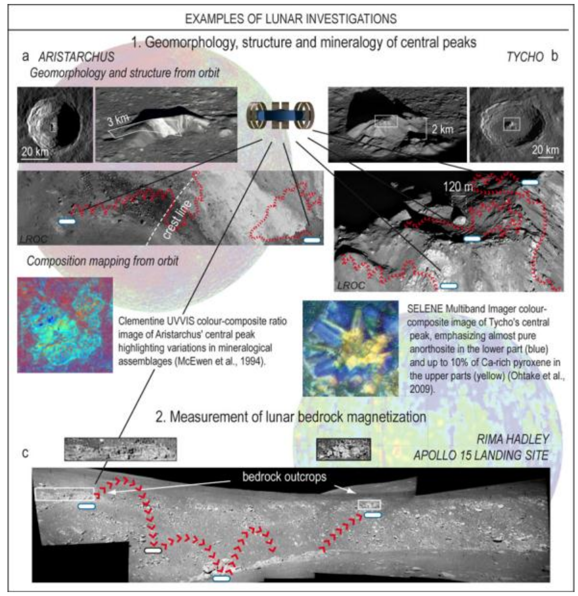

Figure 4: Examples of hopper usage on the Moon.

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