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The Mars Hopper: an impulse driven, long-range, long-lived mobile platform utilising in-situ Martian resources

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Abstract

The ESA and NASA Mars exploration programmes are based on a joint exploration philosophy leading to a network mission and Mars sample return. The requirements and performance of planetary probes will need to meet the challenges imposed by network and sample return missions and guarantee a greater scientific return on the financial investment in new ambitious enabling technologies and each launch. As a result of increasing cost, the desire to acquire geochemical and geophysical data over large areas and samples from multiple regions, missions that can provide mobile, long range and extended lifetime platforms are becoming more attractive. If an instrumented platform could be placed on the surface of a planet that could repeatedly acquire highly detailed data from the surface and subsurface, travel large distances to multiple sites, extract and store multiple samples and deploy instrumentation, an planet could be mapped and sampled with a higher resolution than orbiting platforms. We propose to design and develop an instrumented platform that can acquire data at hundreds of locations during its lifetime - a Mars Hopper. The platform will be able to "hop" with a degree of flexibility from one location to the next, one scenario examined includes a hop every 2-3 days with a separation of 10-20 km per hop. With a lifetime goal of 10 years, the entire surface of Mars can be mapped in detail by a few dozen platforms.

1. Introduction

In-situ planetary probes that have been deployed successfully include: static landers and rovers [1, 2]. Hard landers or penetrators have been developed but not successfully deployed [3]. In 2008 a number of science reports set out a list of scientific objectives for a Mars Sample Return mission [4, 5], which included:

- Measure the composition and mineralogy of the martian crust in order to understand the processes that could support habitable environments. This includes the impact of water in the past and present on Martian rocks and minerals.
- Search for evidence of extant or extinct life on Mars by taking account of the geological context of any evidence found. Determine the potential for preserving this evidence on the martian surface and subsurface.
- Understanding the geologic modification of Mars and constraining the evolution of the martian crust mantle and core, rely on measurement techniques which include: geochronology, heat flow and seismology.
- Constrain the mechanism and timing of planetary accretion, differentiation, and the subsequent evolution of the martian crust, mantle, and core.
- Determine the process that gave rise to the spatial variations in the characteristics of the martian regolith.
- Risks to future human exploration missions and the availability of resources in-situ for the long term human exploration of Mars.
- The evolution of the martian atmosphere and the interaction with the surface.

These objectives demand sampling a broad range of lithologies (sedimentary, igneous, hydrothermal, etc...) [4], requiring robotic systems to explore and sample Mars on a global scale [4]. This is beyond the limits of robotic systems and technologies which have been successfully deployed on planetary surfaces.

The next era of Mars exploration landers should visit methane-rich localities [6], clay and carbonate in the ancient highlands [7] polar ice, young lava flows (e.g. 100 Myr old), glacial and periglacial terrains [8], deltaic and other sediments deposited from water [9]. All of these widely spaced localities are critical terrains in gaining a more accurate understanding of the history of water and testing for traces of life.

The iMars report [4] also states "There is presumably not any single landing site on Mars that could produce all of the samples necessary to support all of the objectives. How much could be achieved at a single landing site would depend on the magnitude of the rover's mobility and its ability to do scientific sample selection and context documentation."

2. The Case for the "Mars Hopper"

More ambitious technologies must be developed and methods created to increase the science return for each launch, thus increasing the scientific value for the money spent for each mission. The concept of a scientific platform that can hop large distances on the Martian surface has been proposed previously [10]. However, these systems used consumable sources of power for the propulsion, chemical or solar electric, and, thus, had limited lifetime and range.

Conceivably, if an instrumented platform could be placed on the surface of a planet that could acquire highly detailed data from the surface and subsurface, travel large distances to multiple sites, and perform this task repeatedly, then an entire planetary surface could be accurately mapped and sampled with higher resolution than orbiting platforms. In addition, network of science stations could be deployed. A platform that could access regions of Mars that could not be accessed by rovers or static landers would significantly extend our current understanding of the evolution of Mars.

We propose to design and build an instrumented platform that can acquire detailed data at hundreds of locations during its lifetime - a Mars Hopper. The basic platform can adapted for a future Titan mission.

2.1. Basic Principles

The basic concept is to utilise the decay heat from radioactive isotopes to raise a block of material to high temperatures while simultaneously diverting some of the thermal power to run a compressor. The compressed Martian atmosphere liquifies at 1.93 MPa. The liquified CO_2 is then transferred to a tank. Once full, the power converter is turned off and the core is allowed to increase in temperature. After the peak temperature is reached, the liquid CO_2 is injected into the core, heated, expanded through a nozzle and allowed to produce thrust. Part of the CO_2 propellant is consumed during the ascent phase, with the remaining propellant available for a soft landing.

Preliminary results show that a platform carrying a 200 kg payload can hop repeatedly over the Martian surface. Initial results indicate that the Hopper could cover over 10 km each time. A study led by the University of Leicester and Astrium UK is exploring the mission design and spacecraft systems. The Centre for Space Nuclear Research is working on the "Hopper" core design and prototyping activities.

6. Summary and Conclusions

A Mars Hopper that can utilise in-situ Martian resources to "hop" around the surface will enable data to be acquired at hundreds of sites over a period of years. This type of exploration vehicle will increase mobility, range and lifetime compared to current systems.

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