EPSC Abstracts
Vol. 8, EPSC2013-464, 2013
European Planetary Science Congress 2013


# Autonomous Hopping Robotic Vehicle for Planetary Science and Exploration

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## Abstract

There is significant potential for more mobile planetary exploration vehicles. This is especially true for Mars, where the ability to cross challenging terrain, access areas of higher elevation, visit diverse geological regions and perform rapid long traverses of tens to hundreds of kilometres supports the search for past water and life. Vehicles capable of performing a ballistic ‘hop’ from location to location have been proposed in the past, but proposals using in-situ acquired propellants offer the prospect of a significant step change in planetary exploration. This paper considers a vehicle concept that tackles these challenges. An approach is described for outline missions where planetary science requirements that cannot be met by using a conventional rover. These outline missions are used to derive vehicle and technology requirements.

## 1. Introduction

The restricted range of lander and rover vehicles limits current planetary surface exploration, but a comprehensive understanding of planetary bodies requires wide-ranging investigations across different terrains and locations. This is especially true in the case of Mars and other Solar System bodies, where the ability to cross challenging terrain, access areas of high or low elevation and steep slopes (e.g. mountain summits, or the floors of canyons and deep craters) is key to meeting the goals of scientific exploration [1]. Maximising the science return from such missions (e.g. geological data as well as evidence of past or present life) will require visiting and sampling diverse widely separated regions that have been subjected to different geo/hydrological processes [1].

Accessing impact craters on Mars (characterised by steep slopes) is particularly difficult due to the physical limitations on descent and landing systems. Traversing very rough terrain is ruled out with rover technology; therefore, the current list of candidate science sites is constrained. New concepts must be explored in long-range mobility where multiple (relatively distant) regions on a planetary surface can be studied and sampled with one vehicle, over the course of a single mission. Developing some of the key enabling technologies including: landing systems, power generation, propulsion and in-situ resource utilisation for the production of propellants are advancing the development of new and challenging mission concepts and are providing cross cutting technologies that can benefit other space applications.

## 2. Hopping Around Mars

The development of a long-range “hopping” Mars exploration vehicle concept [1] is the result of the consolidation of a feasibility and design study of systems [2, 3] that will enable the future development of intelligent autonomous radioisotope-powered vehicles capable of undertaking a large number of short flights or hops on a planetary surface.

In the case of Mars this vehicle would be powered by *in-situ* resources and would use long-life radiogenic heat sources to provide both heat for propulsion and electrical power generation by using thermoelectric generator systems [1]. In the case of Mars, $CO_2$ from the atmosphere would be compressed into tanks, using electrical power, and used as the working fluid, passed over a heat source and expelled through a nozzle to produce thrust [2]. In the case of planetary bodies with atmospheres the *in-situ resource utilisation* concept applies; however, the design could be adapted to bodies with no atmospheres by carrying propellant for a limited number of controlled short hops.

The feasibility studies focused [1] on a large baseline vehicle design (450 kg), capable of carrying a useful scientific payload (~20 kg) and conservatively estimated sub-system masses over long distances. These initial studies demonstrated that such a hopping vehicle was feasible and was found to offer a range of ~1 km per controlled hop. Using a simple consideration of system reliability a cumulative range of 200 km could be achieved.

# 3. Outline Missions

An outline maximum cumulative range is sufficient to explore geologically diverse terrains, and the study outlined an illustrative traverse in Hypanis Valles/Xanthe Terra, encountering crater wall sections, periglacial terrains, aqueous sedimentary deposits and a traverse up an ancient fluvial channel.

In addition the study also identified the possibility to explore and characterise in detail an Amazonian aged (< 2.5 Ga) 50 km diameter, complex impact crater located 8.9°N, 141.3°E in the Elysium Region. Our studies using the Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) [5] on NASA's Mars Reconnaissance Orbiter Mission, have shown Fe/Mg phyllosilicates to be present in this crater, produced by either an impact-induced hydrothermal system or through exposure of underlying, ancient phyllosilicate-bearing rocks which were exposed by the impact [5] (Carter et al., 2010).

Such a diversity of sites could not be considered with a conventional rover.

# 4. Conclusions

It is clear that while this new vehicle concept presents some very significant engineering challenges, the vehicle and missions made possible, represent a valuable complement to rovers, static landers and orbital observations, significantly expanding the range of planetary regions and terrain types which could be studied.

The critical systems and technologies in the vehicle present complex, interdisciplinary challenges; the solutions to these challenges can be expected to produce new technologies, complement existing programmes, contribute widely to future projects or missions, generate opportunities and products for the commercial space sector and spinout into terrestrial applications.

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