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Autonomous Hopping Robotic Systems: Long Range Mobility and Extended Lifetime for Planetary Exploration

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Abstract

There is significant potential for more mobile planetary surface science 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 long traverses of up to 200 km supports the search for past water and life. Vehicles capable of a ballistic 'hop' 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 mission concept termed "Mars Reconnaissance Lander". An approach is described for a mission where planetary science requirements that cannot be met by a conventional rover and are used to derive vehicle and mission 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 and access areas of high or low elevation (e.g. mountain summits, or the floors of canyons and deep craters) is key to meeting the goals of scientific exploration [1]. Achieving great outcomes from such missions (such as evidence of past or present life) will rely upon visiting diverse geological features and sampling widely separated regions that have been subjected to different geo/hydrological processes [1].

Accessing high and low elevations on Mars is particularly difficult due to the physical limitations on descent systems and traversing very steep or rough terrain is ruled out by foreseeable rover technology, as a result the current list of candidate science sites is frustratingly constrained. New ideas are needed in long-range mobility where multiple (relatively distant) regions on a planetary surface can be studied and sampled with one vehicle and over the course of a single mission. Developing some of the key enabling technologies now that could advance such ideas from concept to reality in the future would not only render missions more cost effective in the longer term but will significantly advance our scientific understanding of the Solar System and enhance our capability to explore planetary bodies and surfaces with robots.

1.1 Mars Reconnaissance Lander

The development of the Mars Reconnaissance Lander (MRL) [1] concept 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 a long-life radioisotope in dual-mode operation to act as both heat and electrical power source [1]. CO_2 from the Martian atmosphere would be compressed into tanks using electrical power, and then used as the working fluid, passed over a heat source, to be expelled through a nozzle in order 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. Examples include the Moon, where there is resurgent interest in exploring some of the more inaccessible regions such as craters or regions where access to solar power is limited.

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.

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

2. 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.

References

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