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Spacecraft/Rover Hybrids for the Exploration of Small Solar System Bodies

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In this talk we describe a mission architecture that allows the systematic and affordable in-situ exploration of small Solar System bodies, such as asteroids, comets, and Martian moons. Our architecture relies on the novel concept of spacecraft/rover hybrids, which are surface mobility platforms capable of achieving large surface coverage (by attitude-controlled hops, akin to spacecraft flight), fine mobility (by tumbling), and coarse instrument pointing (by changing orientation relative to the ground) in the low-gravity environments of small bodies. The actuation of the hybrids relies on spinning three internal flywheels, which allows all subsystems to be packaged in one sealed enclosure and enables the platforms to be minimalistic, thereby reducing the cost of the mission architecture

The hybrids would be deployed from a mother spacecraft, which would then act as a communication relay to Earth and would aid the in-situ assets with tasks such as localization and navigation. Power would be provided by primary batteries, and/or secondary batteries with solar panels for recharging. The hybrid systems would leverage COTS and new subsystems developed by JPL for CubeSats. Since this mobility concept is scalable, the platform can be sized accordingly to accommodate a suite of scientific instruments such as cameras, microscopes, and XRS.

Specifically, the hybrids apply torques to internal flywheels to transfer angular momentum to the external structure. For a grounded rover, this gives rise to controllable ground reaction forces that propel the hybrid along desired trajectories. This type of hopping mobility is critically enabled by the microgravity environment of small bodies, whereby small surface contact forces can produce long-range ballistic flight. We have demonstrated this locomotive capability both in simulation and in high fidelity experiments using a six-degree-of-freedom microgravity test bed. Furthermore, two prototypes will be tested on 160 parabolas during a NASA parabolic flight campaign in June 2015.

Collectively, our study aims to demonstrate that exploration via controlled mobility in low-gravity environments is technically possible, economically feasible, and would enable a focused, yet compelling set of science objectives aligned with interests in planetary science and human exploration. After two years of maturation under the NIAC program the hybrid rovers will become available for infusion into space missions in the 2017-2018 timeframe.

This is a joint project between Stanford, the Jet Propulsion Laboratory, and the Massachusetts Institute of Technology, and is performed under the NASA Innovative Advanced Concepts program.