Title:

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

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Abstract:

The future in-situ exploration of small Solar System bodies requires robotic platforms capable of controlled surface mobility. In the microgravity environment of small bodies such as asteroids, comets or small icy moons, conventional wheeled rovers are quite ineffective due to the low frictional forces on the ground. Through a joint collaboration between Stanford University, JPL, and MIT under the NIAC program, we have been investigating microgravity mobility using hopping/tumbling platforms. We present a minimalistic, internally-actuated spacecraft/rover hybrid that is capable of controlled hopping for large surface coverage and tumbling for fine mobility and instrument pointing. 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. Such a mobility approach is critically enabled by the microgravity environment of small bodies, whereby small surface contact forces can produce long-range ballistic flight. We have demonstrated controlled mobility in simulation, in a high fidelity microgravity test bed, and onboard NASA parabolic flights.

This concept has the potential to lead to small, quasi-expendable, and maneuverable rovers that enable a focused, yet compelling set of science objectives aligned with interests in planetary science and human exploration. Moreover, this new paradigm of mobility for “nanorovers” is highly scalable within typical CubeSat sizes from 1U to 27U, allowing many of the subsystems to be leveraged from interplanetary CubeSats being developed at JPL (e.g., C&DH/avionics boards from NEA Scout, UHF telecom system from INSPIRE, and electrical power system from MarCO). We present a notional mission architecture to Phobos that addresses both high-priority science identified for Mars' moons and strategic knowledge gaps for the future Human exploration in the Martian system.

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Keywords:

Microgravity / Rover / Small Bodies / In-situ Science / Phobos