Hedgehog - A Minimalistic Robot for In-situ Exploration of Small Bodies

Principal Investigator: Issa A.D. Nesnas (347), Marco Pavone (Stanford – former PI)
Christopher McQuin (347), Julie Castillo-Rogez (322)
Ross Allen (Stanford), Tam N. Nguyen (MIT), Jeffrey Hoffman (MIT)

Project Objective:

To **develop** a low-mass minimally-complex **robotic platform** for the *in situ* exploration of small bodies capable of:

- **Large surface coverage** (in the order of one km^2)
- **Finely-controlled regional mobility** on the order of *one meter spatial resolution*).

Benefits to NASA and JPL:

- Provides JPL/NASA with a low-mass capability for *in situ* surface investigations at both large and fine scales (from kilometers to meters)
- Enables physical and chemical characterization of surface properties relevant to both human and science exploration missions

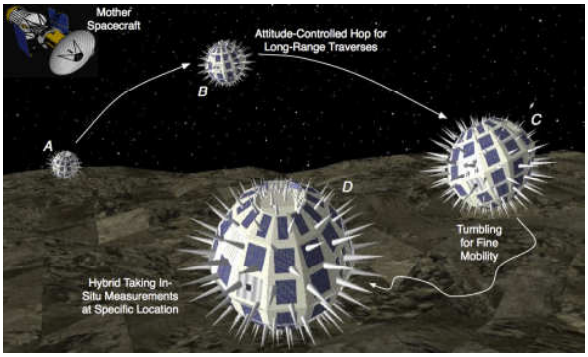
FY12 Results:

Theory, models and simulations

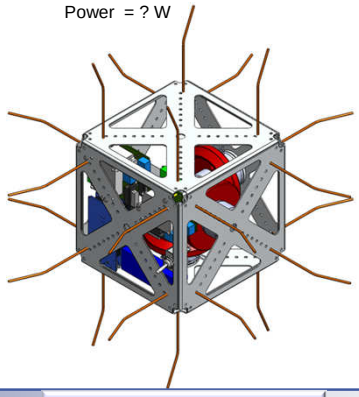
- **Developed** dynamics equations for a single flywheel platform and simulated in Matlab
- **Analyzed** torque profiles to discern ability to hop vs. tumble on flat terrain with a range of friction coefficient values. Used a spring damper model for the terrain
- Developed two independent 6 DOF simulations of the platform (Matlab (Stanford) and C++ (JPL))

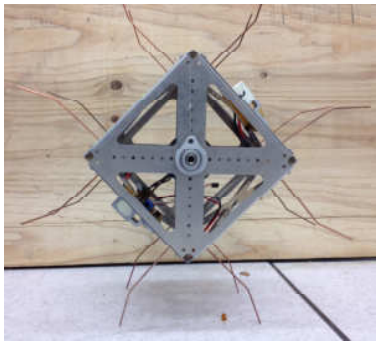
Prototype and experiments

- Designed and fabricated a single DOF prototype and a corresponding 3D microgravity test bed that uses a passive weight offloading mechanism
- Conducted tumbling and hopping experiments on flat terrain, in sand and in regolith
- Cross-validated against simulation torque magnitudes necessary for tumbling and hopping and computed hop angles
- A torque scaling correction of (ave: 6%; max: 30%) was necessary to qualitatively match mobility mode (tumble vs. hop)

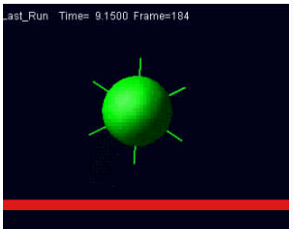


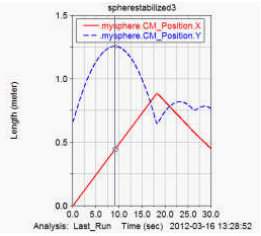
Mass = ? kg
Size =- 0.2 m x 0.2 m x 0.2 m
Power = ? W



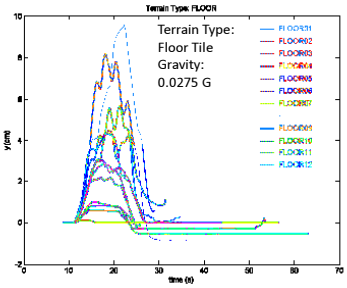


Mission Concept





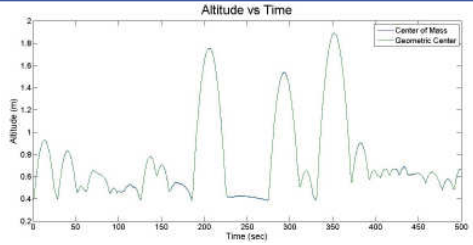
Platform Design

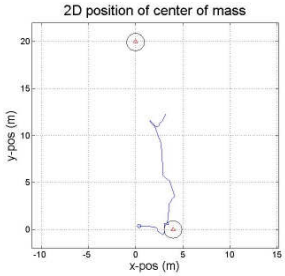


1st Prototype and Test bed

PWM	Max Speed	Torque	Max Hop	Hop Angle	File Name
	rpm	N.m	cm	degree	
110	1457.129	0.019765	0.122659	87.46376	FLOOR01
120	2754.195	0.032256	0.585816	162.9883	FLOOR02
123	3011.618	0.034127	0.821564	162.8715	FLOOR10
125	3160.779	0.040532	0.992672	161.4192	FLOOR05
128	2858.597	0.041919	2.834677	151.1832	FLOOR06
129	2879.313	0.04158	3.002413	153.7934	FLOOR11
130	3058.184	0.045661	2.185013	159.96	FLOOR03
130	3163.991	0.043521	5.677698	148.6586	FLOOR07
132	3615.04	0.046284	4.356951	155.6543	FLOOR12
135	4079.299	0.050969	4.507254	153.7454	FLOOR04
138	4119.684	0.050266	9.566877	163.5041	FLOOR08
140	4424.382	0.050505	8.190249	158.6489	FLOOR09

ADAMS Simulation (1 flywheel)





Experimental Comparison (1 flywheel)

Publications:

- M. Pavone, J.C. Castillo-Rogez, I.A. Nesnas, and J. Hoffman, "Observational Strategies for the Exploration of Small Solar System Bodies," *IEEE Aerospace Conference*, Montana, March 2012
- R. Allen, M. Pavone, C. McQuin, I.A. Nesnas, J.C. Castillo, T. Nguyen, J.A. Hoffman, "Internally-Actuated Planetary Rovers: Theory and Experimentation," submitted to Int'l Conference on Robotics and Automation, Sept 2012

Advancing state-of-the-art
Investigating multi-mode mobility (hopping, tumbling and attitude control hops (future work)) for small bodies for large coverage and precise maneuvers.

National Aeronautics and Space Administration
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

www.nasa.gov

Poster No. TO-38