Gravity Off-load Testing of an Origami-inspired 1-meter Deployable CubeSat Reflectarray

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Introduction: Gravity Offloading

Current gravity offloading systems are limited in their number of contact points and scalability. Omni-directional robots are UT's novel solution to these problems. By freeing our system from rails, we are opening the doors to new methods of testing complex orbital deployments in the lab. This system would help to increase the reliability and decrease the cost of orbital systems. By decreasing the costs of testing orbital deployments, this system will help to accelerate the development of complex systems.

Figure 1: NASA's Active Response Gravity Offload System. *https://www.nasa.gov/centers/johnson/engineering/integrated_environments/active_response_gravity/index.html*

Objectives and Outcomes

Objectives

- ➢ Test commercial off-the-shelf mecanum robot kits to determine the feasibility of using inverted omni-directional robots for gravity offloading
- ➢ Design custom high-payload mecanum robots
- ➢ Integrate a load cell and a motion capture system to automate the system for the simulation of various environments

Outcomes

- ➢ Simplify multi-point, active gravity offloading
- ➢ Allow for the simulation of CubeSat swarm flights
- ➢ Create a scalable and reconfigurable system that can be used to test various sizes of low gravity deployments

Figure 2: The Inverted Mecanum Robot, Tested August 2017. *Testing of a prototype mecanum robot. Basic movement ability and magnetic inversion has been tested and verified.*

Current Methods and Their Restrictions

Current methods of gravity offloading are restrictive in various ways.

Water Submersion

One way gravity offloading is achieved is by submerging the test objects in water. When the objects have neutral buoyancy, they react as if they are in zero gravity. This allows for offloading with multiple degrees of freedom. Unfortunately, this system does have some disadvantages. First, all components must be made waterproof. This can become a problem in electronic devices. Next, the objects must have a neutral buoyancy. This may not fit some of the design constraints of the object. Finally, when submerged test objects experience drag which is not present in the vacuum of space.

Cable-Gantry System

A second method of gravity offloading is a cable and gantry system like the one used by NASA's Johnson Space Center. This method uses a gantry with an attached load cell and winch to simulate various environments. Using measurements from the load cell the gantry and winch respond to replicate various gravity values. Limitations with this system is its scalability and the number of contact points. This system is difficult to scale as the system becomes exponentially more expensive. The number of contact points is limited by the inability to use multiple gantries without collision.

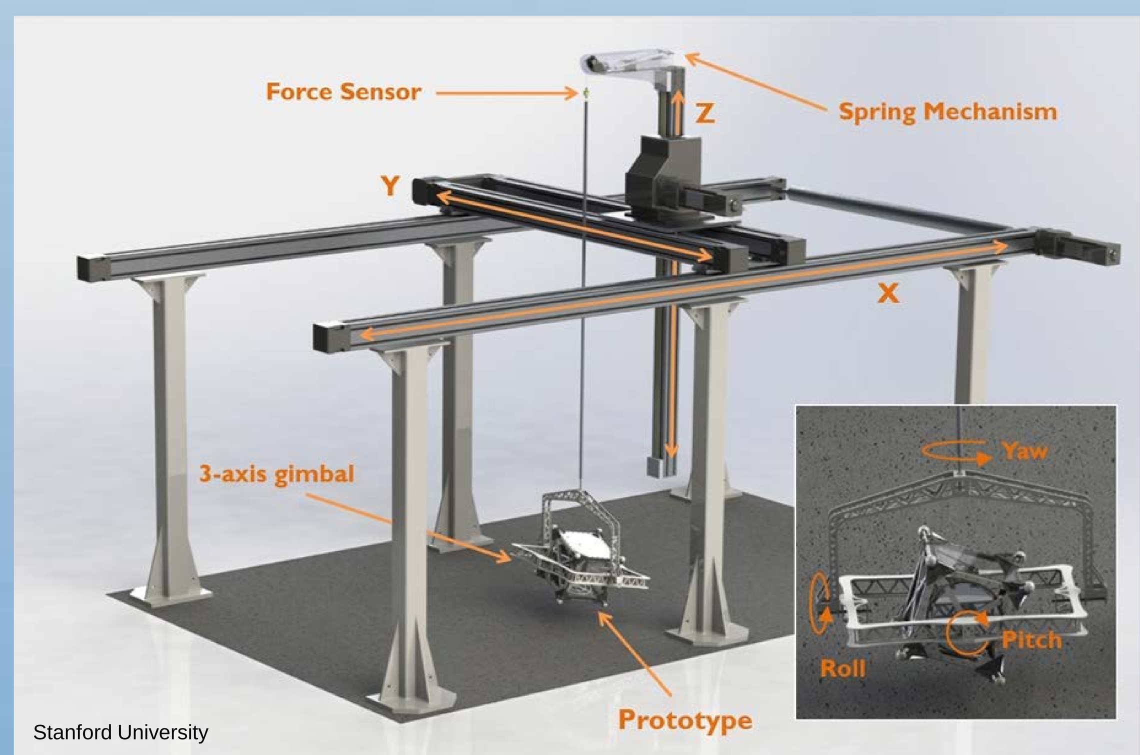


Figure 3: Prototype Gravity Offloading System for the Testing of Surface Mobility of Small Bodies. *https://asl.stanford.edu/projects/surface-mobility-on-small-bodies/*

Magnetic Mounting System

To achieve inverted motion the robot uses two Neodymium magnets.

- ➢ Each magnet has a maximum pull of 77 lbs
- ➢ By mounting the magnets with bolts to the frame we are able to adjust the standoff of the magnets and therefore change the pull force

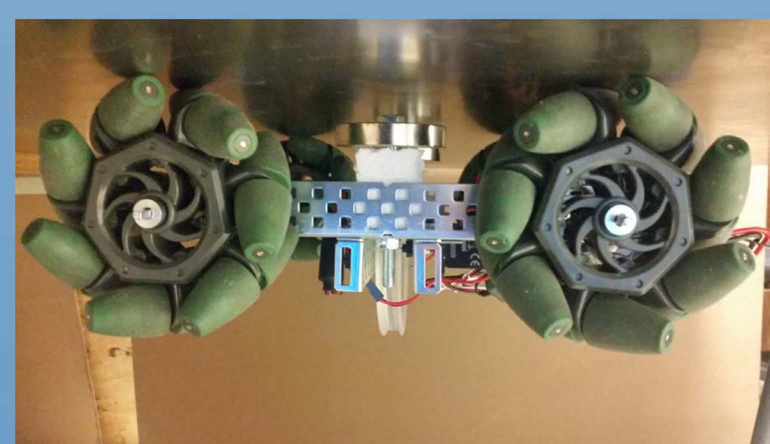


Figure 4: Close-up View of The Mounting System, August 2017. *The magnets are mounted between the wheels to create an even distribution of the pull force on the wheels.*

Preliminary Experiments: Characterizing Motion at Various Angles

Initial work included characterizing the motion of the robot at varying angles. To measure the linear velocity of the robot, a simple grid was laid out on the floor. The grid had lines 36 inches long every 10 degrees. Next, the robot was driven over the grid and recorded in high speed. Using a stopwatch in the video, we were able to determine the time it took for the robot to travel predefined distances.

Analysis of the data was performed in Microsoft Excel. The data shows that the linear speed of the robot is not the same in all directions.

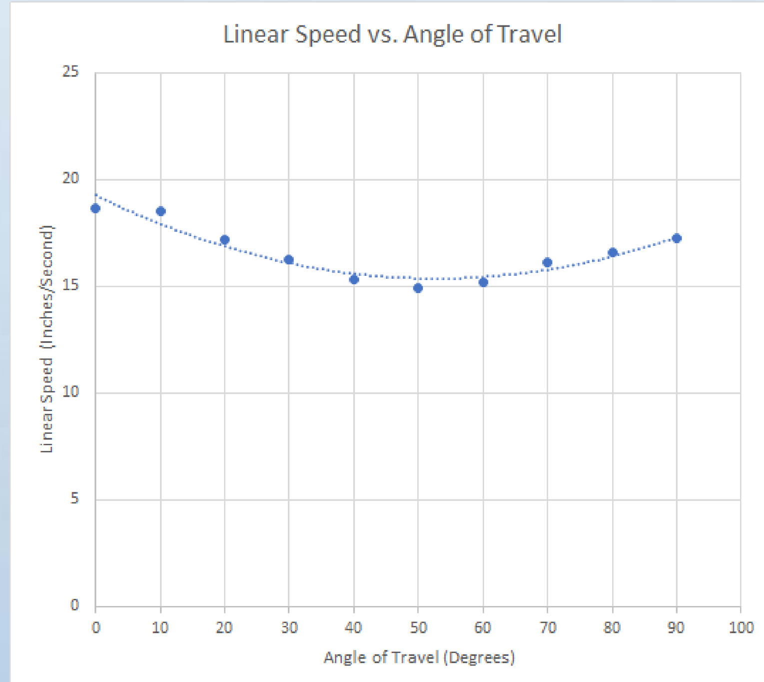


Figure 6: Data Collected to Determine the Relationship Between Angle of Travel and Linear Speed.

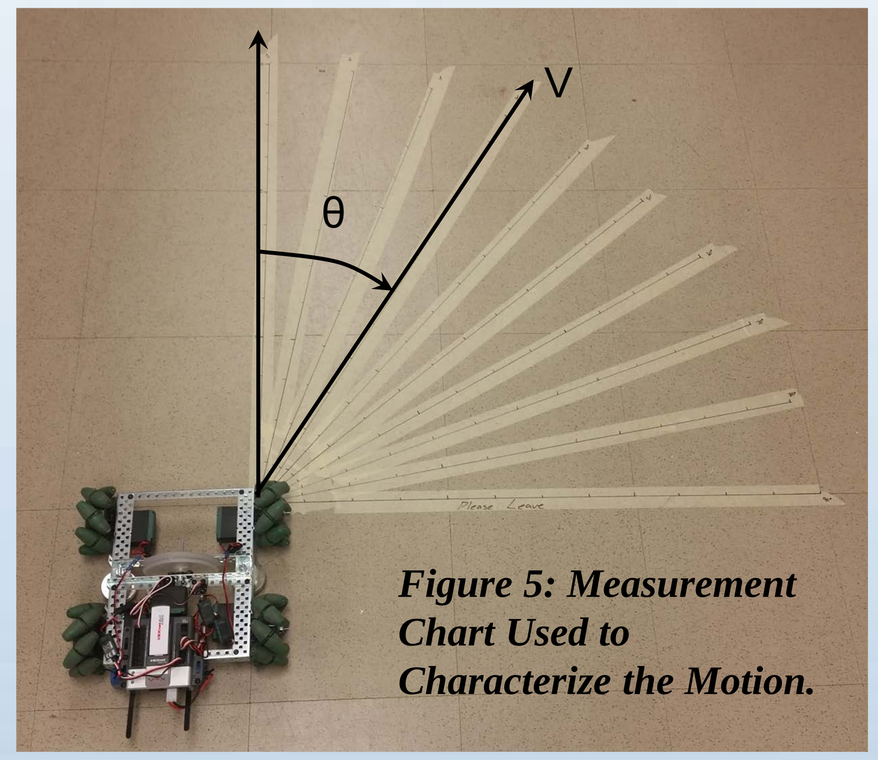
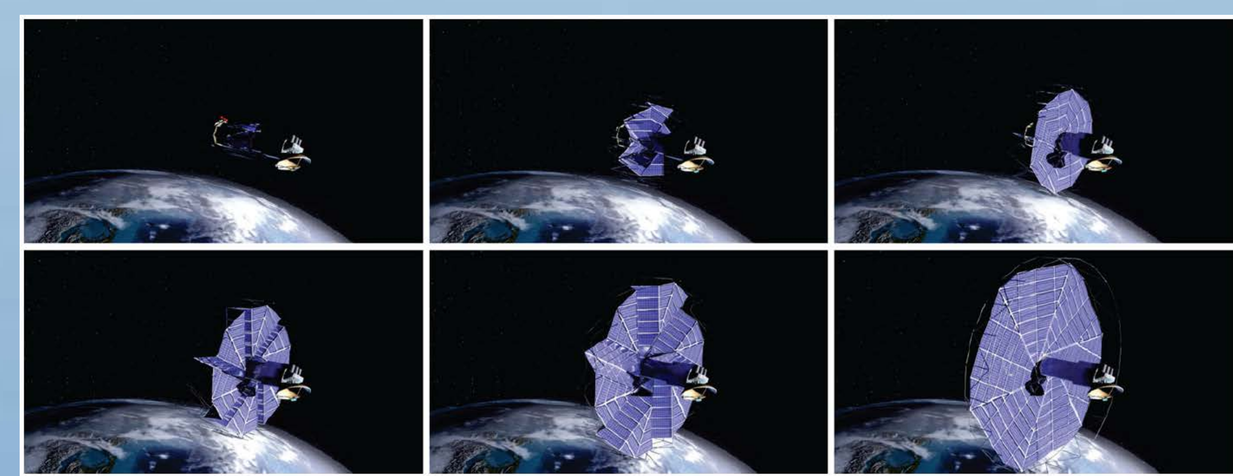
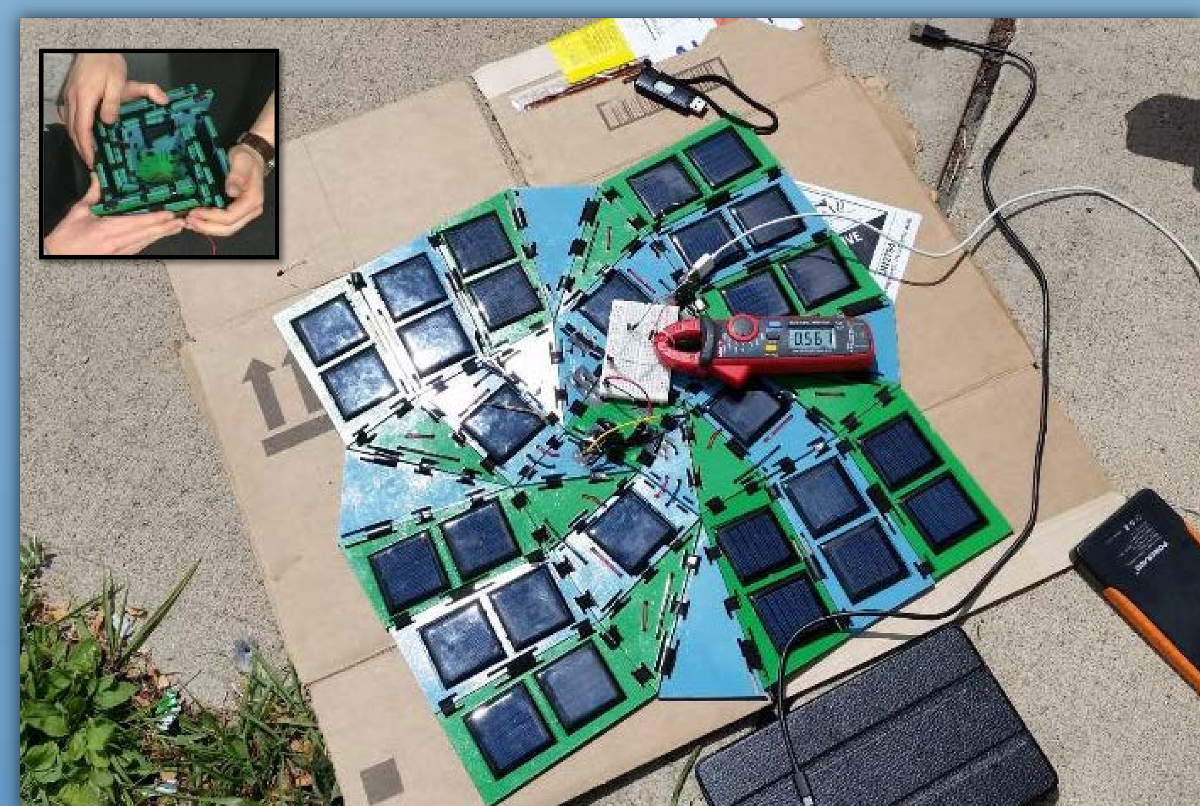


Figure 5: Measurement Chart Used to Characterize the Motion.

Predecessor Work in Origami-inspired Deployables



Computer-generated model of an in-space deployable solar array for solar electric power. (Zirbel, Lang, Trease, et al, JMD 2013)



Functional Prototype of Origami-flasher Deployable Solar Array for consumers. UT Senior Design Project 2016. This proof-of-concept demonstrates a precedent for current reflectarray work.

Future Experimentation

Future testing will work towards the overall goal of a complete gravity offloading system.

1. Develop a large test area to allow for larger motions to be carried out
2. Add an inline load cell between the winch and the body of the robot to detect forces on the test object
3. Create single point simulations to test and evaluate the current system with a single robot
4. Use multiple robots together to begin the evaluation of multipoint gravity offloading
5. Take all of the collected data and improve the system while scaling it up to accommodate larger tests

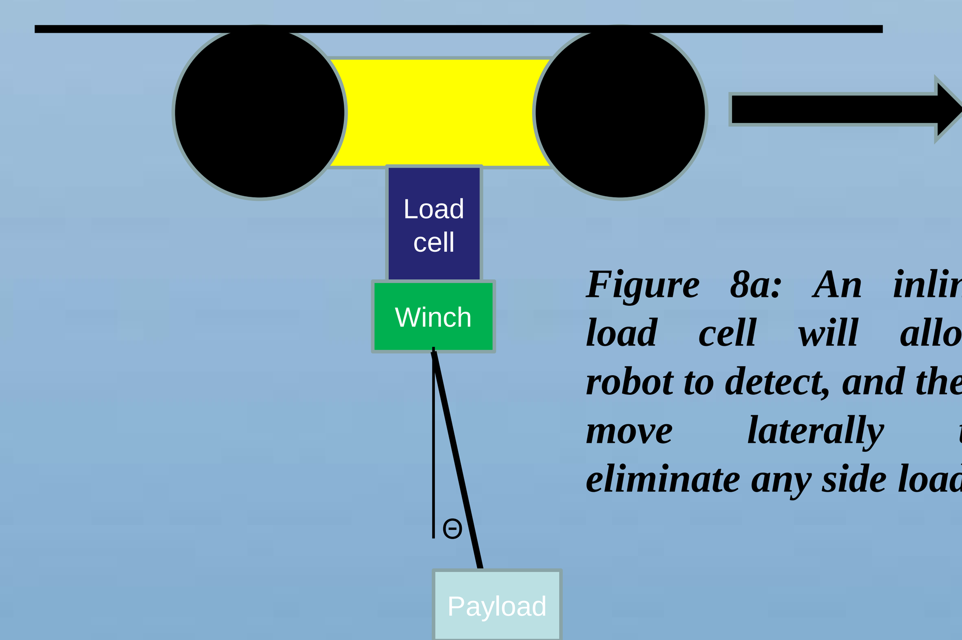


Figure 8a: An inline load cell will allow robot to detect, and then move laterally to eliminate any side loads

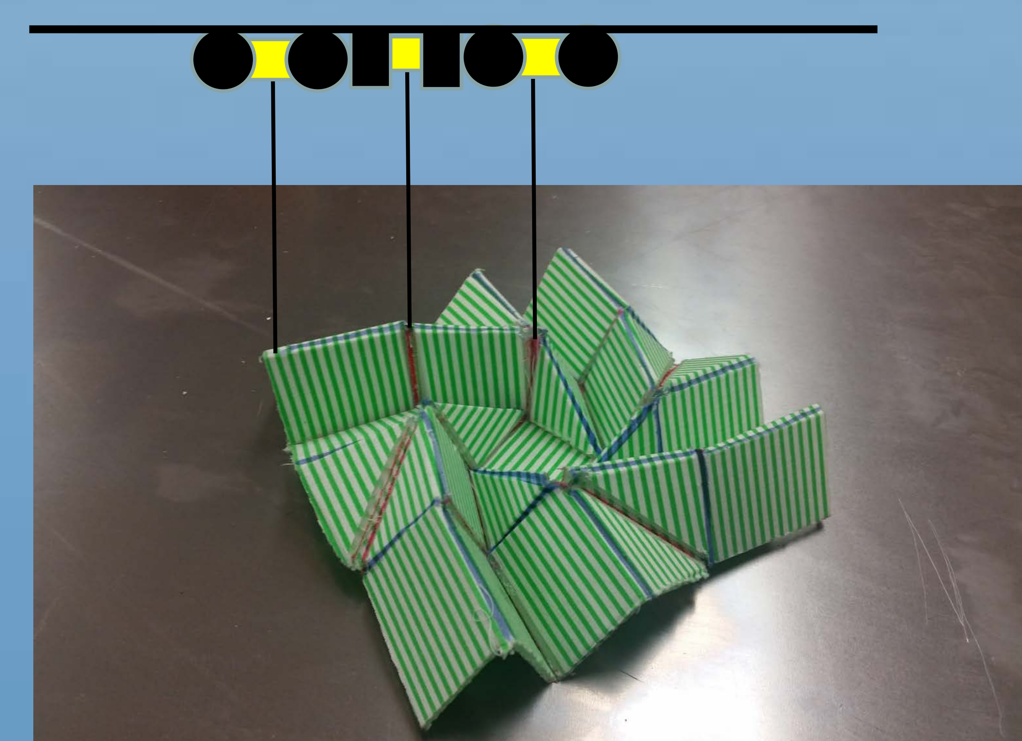


Figure 8b: Origami Flasher that Requires Multipoint (using multiple robots) Gravity Offloading.