Scalable Gravity Offloader

Student Team:
Francis Garcia – fgarcia@stevens.edu
X-Y Actuation Research and Delta Arm Design
Ammar Husain - ammarh@andrew.cmu.edu
Motion Tracking Research

Advisors:
Jason Calaiaro - jason.calaiaro@astrobotictech.com
Professor William "Red" Whittaker - red@cmu.edu

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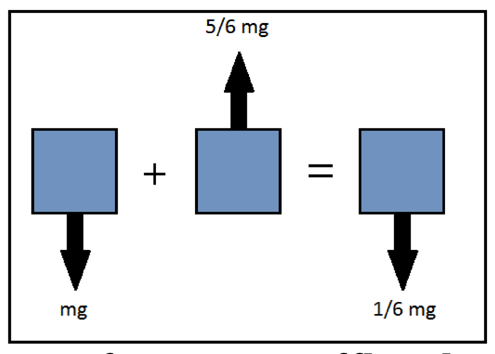
Abstract

"Gravity offloading" is a process by which one may attempt to simulate lunar gravity on Earth to test equipment such as rovers, landers, and space suits. This is performed by applying a vertical force to an object, with magnitude equal to 5/6ths of that object's weight. This makes the effective weight of the object 1/6th of its actual weight, which is what it would weigh on the Moon.



One limitation of "gravity offloading" as it exists currently is that in can only be performed on an object in one location in space. The Scalable Gravity Offloader will be a commercial device that is able to perform gravity offload on any object at any location in a workspace of any size.

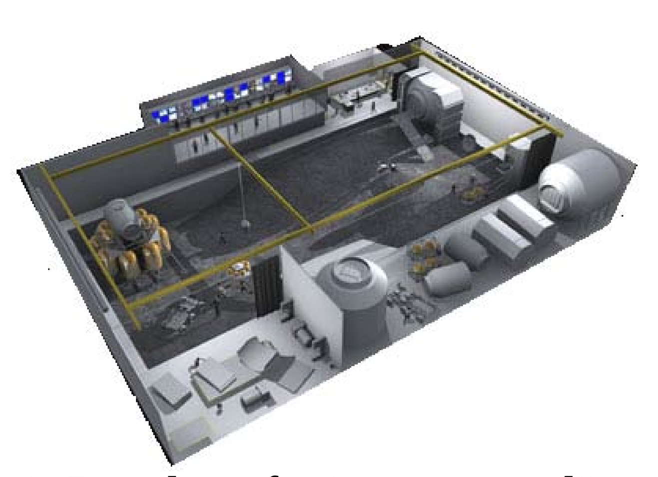


Figure 1: Render of a "moon yard" test space

Force Application

The chosen force application device is manufactured by Gorbel, which produces lifting devices that are commonly used in industrial materials handling applications. One pre-set program on the device is "float" mode, which allows the user to pre-program a specific load into the unit, whereby the Gorbel unit will then autonomously adjust the tension of in the line to maintain that load.

Figure 2: Gorbel Lifting Unit

References:

NASA Argos 3D Render

"Modeling and control of a Delta 3- Robot" by Andre Alsson, Lund University

"Descriptive Geometric Kinematic Analysis of Clavel's Delta Robot" by PJ Zsombor-Murray, McGill University

Handbook Timing Belts: Principles, Calculations, Applications

X-Y Actuation

The purpose of X-Y actuation for the Gravity Offloader is to carry the Gorbel device across the desired workspace, which consists of a 4m span and a 10m long run. The kinematic requirements for actuation are 1.5 m/s and 3 m/s^2. These values were determined by the kinematics of Polaris, which is the primary rover to be tested, as well as a survey of NASA labs and other parties interested in a Gravity Offloader for testing purposes.

Various methods of linear motion were researched and analyzed for their capability to fulfill these technical requirements. The solution chosen was belt driven actuation due to the technology's scalability and ease of installation. One potential configuration is shown below in CAD.

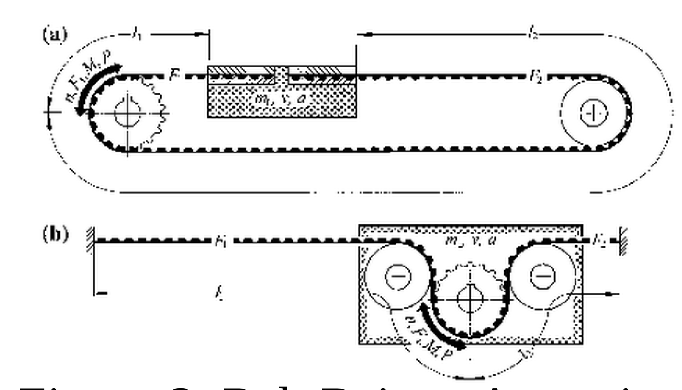


Figure 3: Belt Driven Actuation

a) Linear Slide b) Linear Traveler

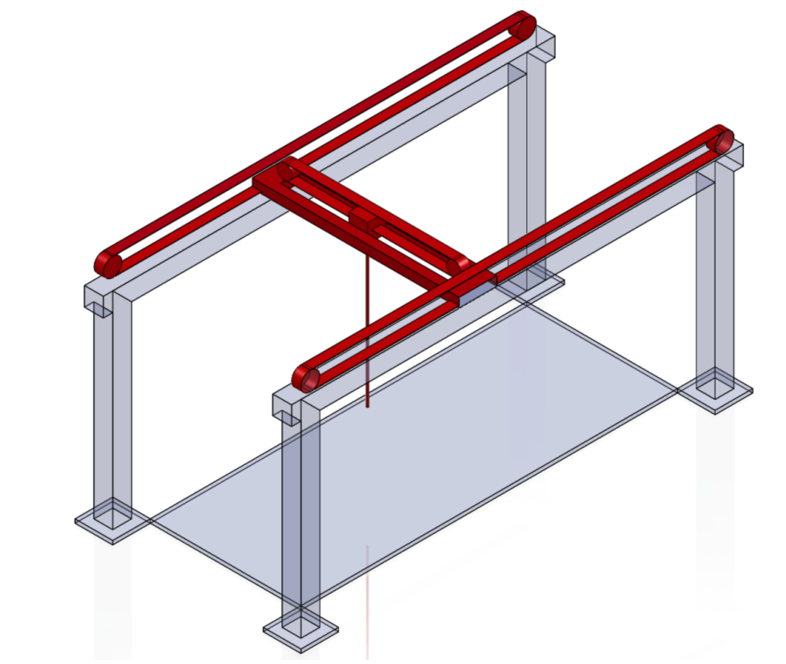


Figure 4: CAD Model of Belt Driven Actuation

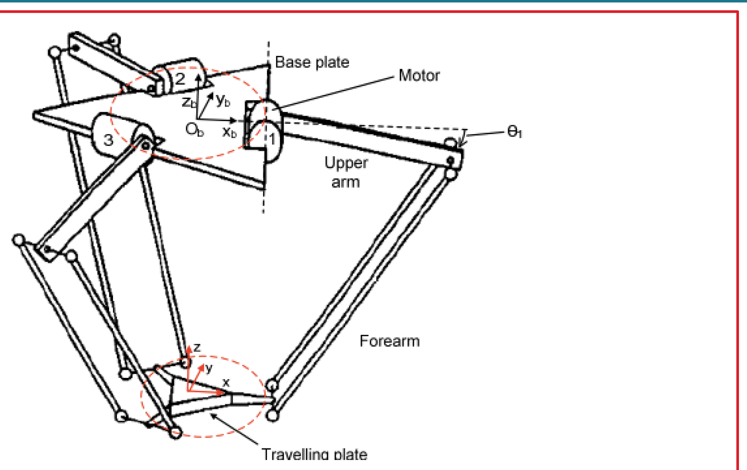
Technology	Roller Screw	Linear Motor	Rigid Chain	Roller Pinion	Timing Belt
Pros	-Long life	Faster than ball screw	Scalable stroke length	Less maintenance	Faster than screws
	-Commonly used in industry	Speed, acceleration and power advantage	High loads	Low backlash	High life span
	-Scalable stroke length		High acceleration	Positive drive	No maintenance
	-Precise and accurate	Long stroke	Accurate, consistent position		Scalable in size and price
	-High efficiency at high speeds and loads	High precision			Simple design
		High accuracy			Drive large loads
	-Less vibration				
Cons	-Can be clogged with debris	Magnetic fields generated to actuate	Not scalable to structure	Price	Requires braking
	-Critical speed is significantly smaller than desired speed		Price is not significantly scalable	Complicated installation	Supporting structure for belts
		Made in one part	Cartridge takes up bulk of space		
	-More expensive than lead or ballscrews	Low loads	Low speeds under loading		
			Complicated installation		

Figure 5: Table of technologies, pros, and cons

Motion Tracking

Combined with X-Y actuation, motion tracking will allow the Gravity Offloader is to maintain the Gorbel device over the center of gravity of the object to be tested. This will ensure that the force applied is as close to vertical as possible. Otherwise, if an angular displacement were introduced, the resulting component forces will create overall testing errors.

One method by which motion tracking will be performed is by using a delta arm, commonly used in pick-and-place operations, in a passive configuration with rotary encoders. By measuring the angles of the arm with the encoders and using forward kinematic equations, the X, Y, and Z coordinates of the lifting cord can be calculated, which will allow vertical angular displacement and heading to be determined



$$\begin{cases} (x-[\cos(\alpha_1)(l_A\cos(\theta_1)+R)])^2+(y-[-(R+l_A\cos(\theta_1))\sin(\alpha_1)])^2+(z-[-l_A\sin(\theta_1)])^2=l_B{}^2 \\ (x-[\cos(\alpha_2)(l_A\cos(\theta_2)+R)])^2+(y-[-(R+l_A\cos(\theta_2))\sin(\alpha_2)])^2+(z-[-l_A\sin(\theta_2)])^2=l_B{}^2 \\ (x-[\cos(\alpha_2)(l_A\cos(\theta_3)+R)])^2+(y-[-(R+l_A\cos(\theta_3))\sin(\alpha_2)])^2+(z-[-l_A\sin(\theta_3)])^2=l_B{}^2 \end{cases}$$

Figure 6: Delta Arm Kinematics

Primary Components:

Arduino Uno R3

3 x 2500 Count Rotary Encoder

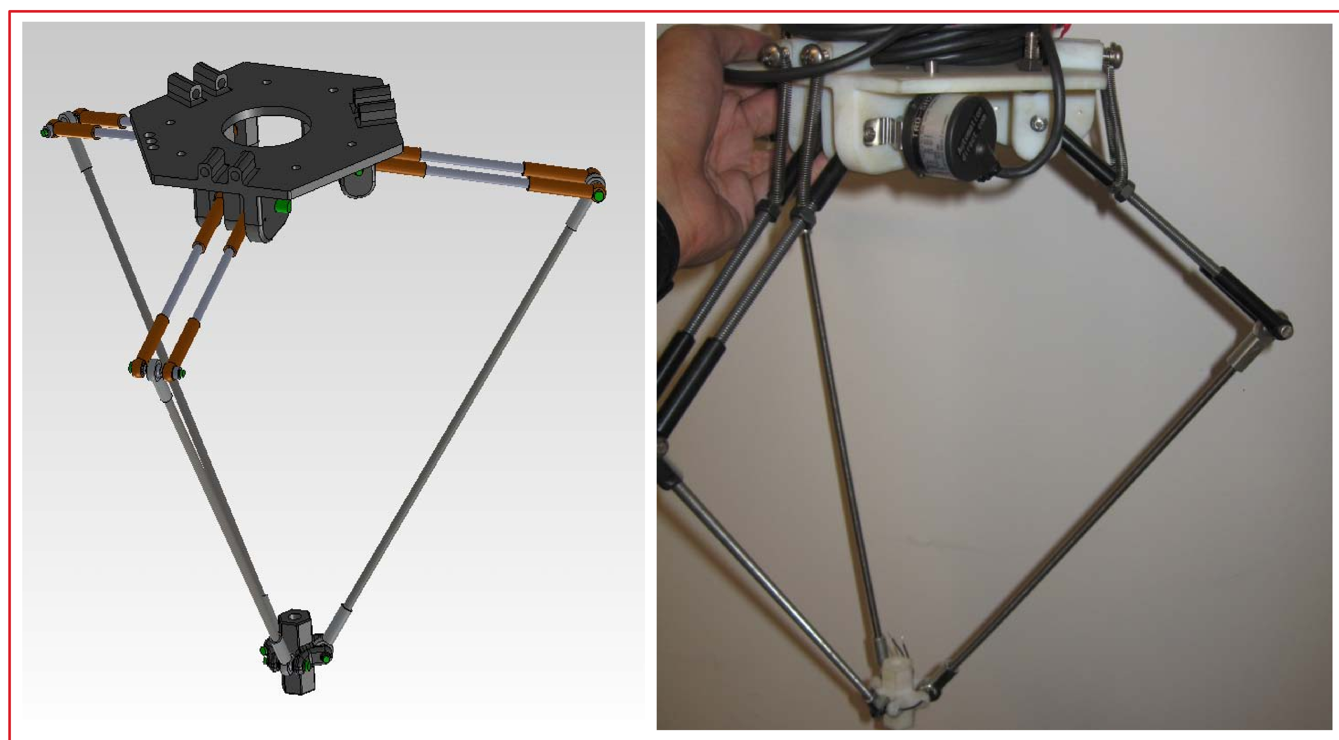


Figure 7: Delta Arm CAD (Left) and Prototype (Right)

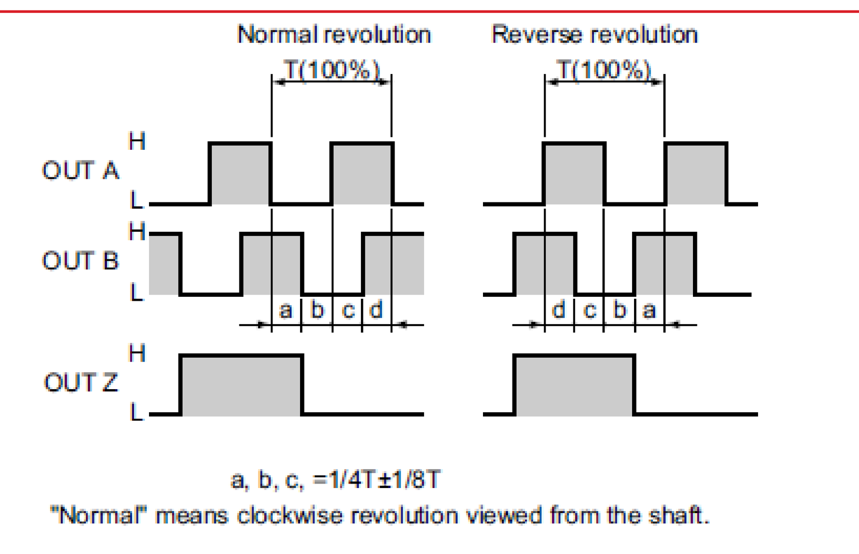


Figure 8: Encoder Timing

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