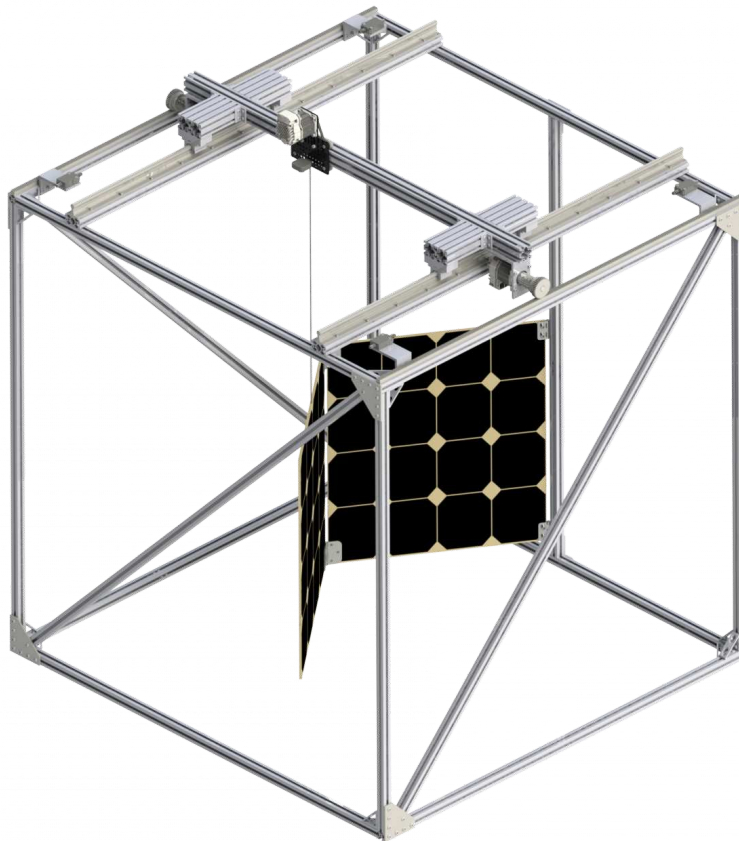# Project Marion

Autonomous Gravity Offload System for Solar Array
Deployment Testing

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Table of Contents

Executive Summary

Powering most modern satellites and spacecraft, solar arrays are designed to deploy and operate in a zero-gravity environment. In order to ensure reliability in orbit without allocating resources to a full launch, careful and precise testing is conducted on the ground. Namely, gravity offloading is essential to successful ground testing, but what defines gravity offloading? Perfect offloading counteracts the single, vertical gravitational force that anchors us to the Earth. In practice, successful offloading aims to minimize the lateral forces (non-gravitational forces) imparted on the test subject. Project Marion develops a testing apparatus for the deployment of solar panel arrays, where the objective is to allow natural movement while simulating a zero-gravity environment.

Current methods in ground testing include passive (non-motorized) and active (motorized) systems, specialized for different sizes and types of solar array deployment. However, designing a unique testing apparatus for each solar array is both inefficient and expensive. Project Marion provides an active, scalable, and reconfigurable apparatus to support ground testing for a wide range of solar array sizes and variable deployment architectures. The scaled-down, final prototype utilizes computer vision to autonomously track the path of each solar array. The active, two-axis gantry system positions itself over the attachment point suspending each solar array, minimizing lateral forces and providing successful offloading. The computer vision software and mechanical systems of this prototype will be applicable to future, full-scale projects conducted by Ball Aerospace.

Background

Gantry System

A gantry system consists of a moving bridge-like overhead structure with a moving platform attached. This bridge-like structure is referred to as the *girder* and the moving platform if referred to as the *trolley* in our system. This structure is connected to a stationary frame at each end allowing a gantry system to move freely in two axis or have two degrees of freedom. The gantry system is connected to the solar panel by a wire that is fixed to the trolley and the solar panel.

The Axes

The axes represent the 3D space our project operates in. The gantry system moves freely in the X-Y directions with no movement in the Z direction.

Computer Vision

The computer vision system tracks the solar panel's location and sends commands to each motor moving the gantry to be directly overhead the panel. The *camera* locates the panel and logs its distance from the center of the frame as an X-Y coordinate. These coordinates are sent to each motor commanding them to move the gantry overhead the panel. To completely reduce the lateral force on the panel, the camera will need to be directly overhead during the entire deployment.
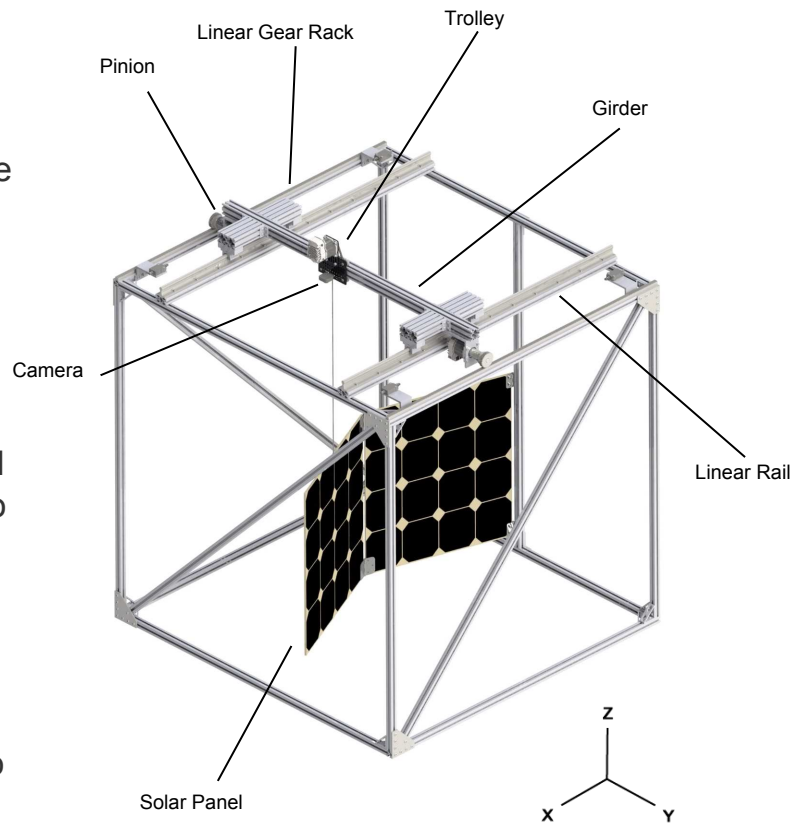
Motorized System

The gantry is powered by three motors; two motors move the *girder* in the X-direction and one motor moves the *trolley* in the Y-direction. The two motors move the girder via a pinion and linear gear rack. The *pinion* gear rolls along the *linear gear rack* on both sides of the girder. The single motor moves the trolley via a belt system where both ends of the belt are secured to the ends of the girder. This configuration allows for the addition of multiple girders to accommodate multi-panel systems.

Linear Gear Rack

Trolley

Pinion

Girder

Camera

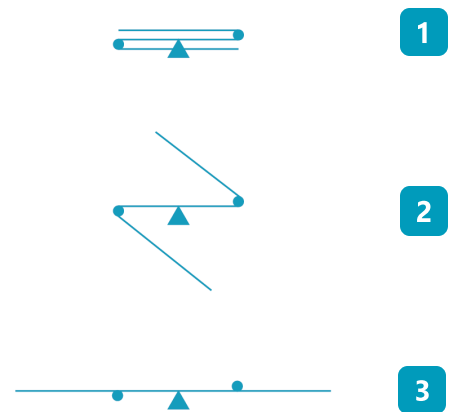Linear Rail

Solar Panel

2

Deployment Configurations

Z-Fold

The Z-Fold is the most common deployment type. Panels deploy simultaneously and at the same rate.
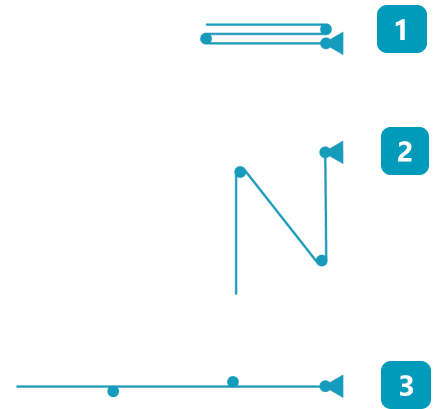
H-Fold

Instead of being mounted on the end, the H-Fold is mounted from the center panel while the other two open away from each other.

Dual Stage

In the initial position, the end of the Dual Stage array is folded within itself. This adds significant complexity to the suspension mechanics required in an offloading system. The mechanics of Project Marion are not compatible with Dual Stage deployment. However, the computer vision system can be implemented with all deployment types.

3

Iterative Solutions

Initial Concept

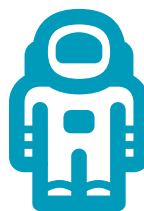Revision 1

Final Concept

Revision 2

4
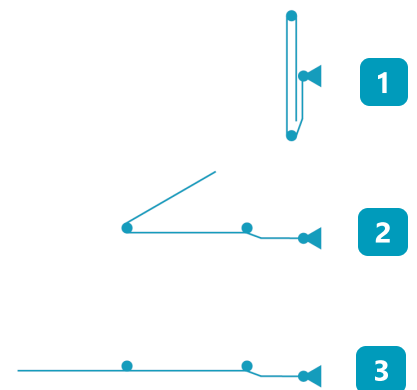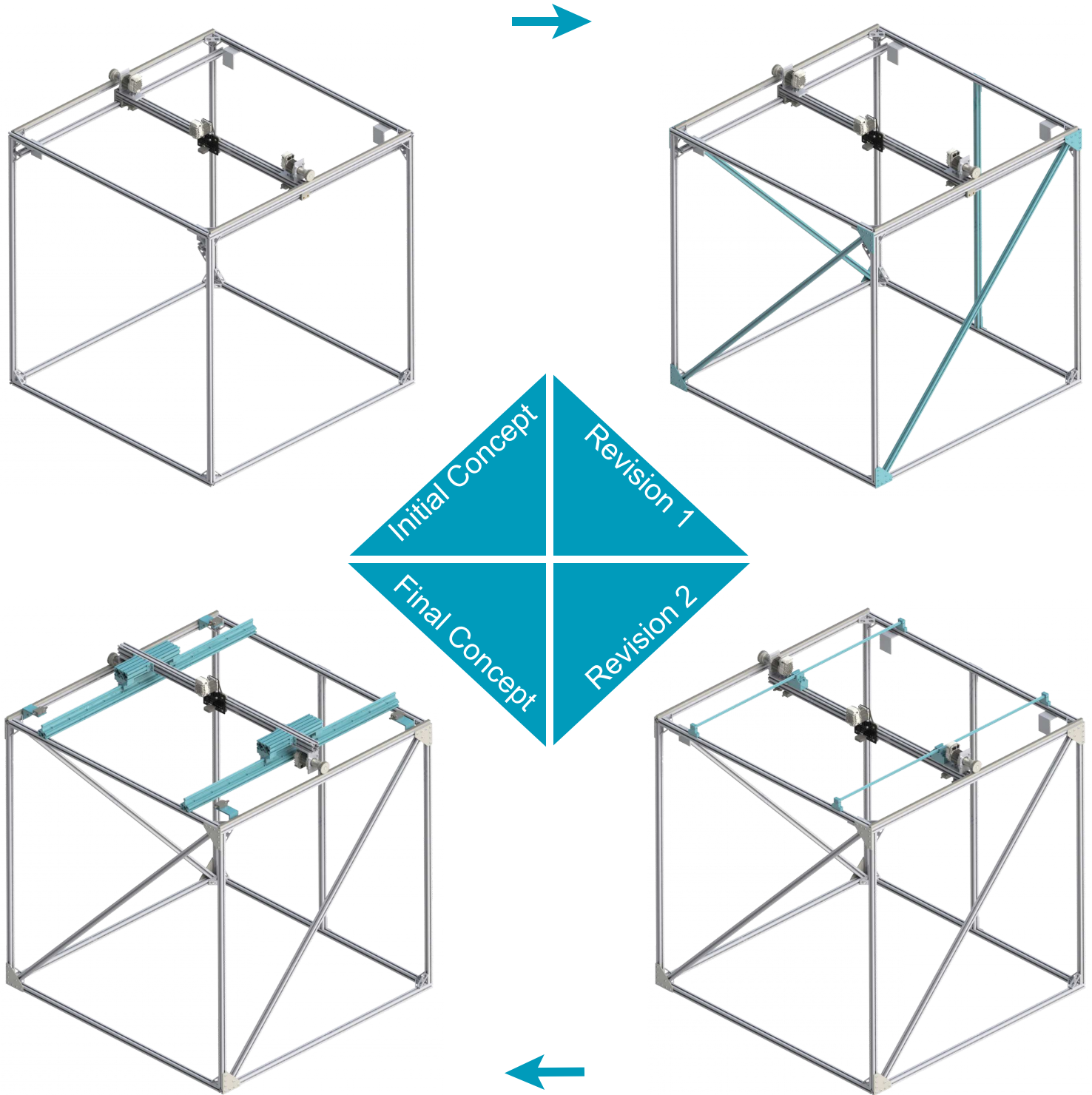
The Final Design
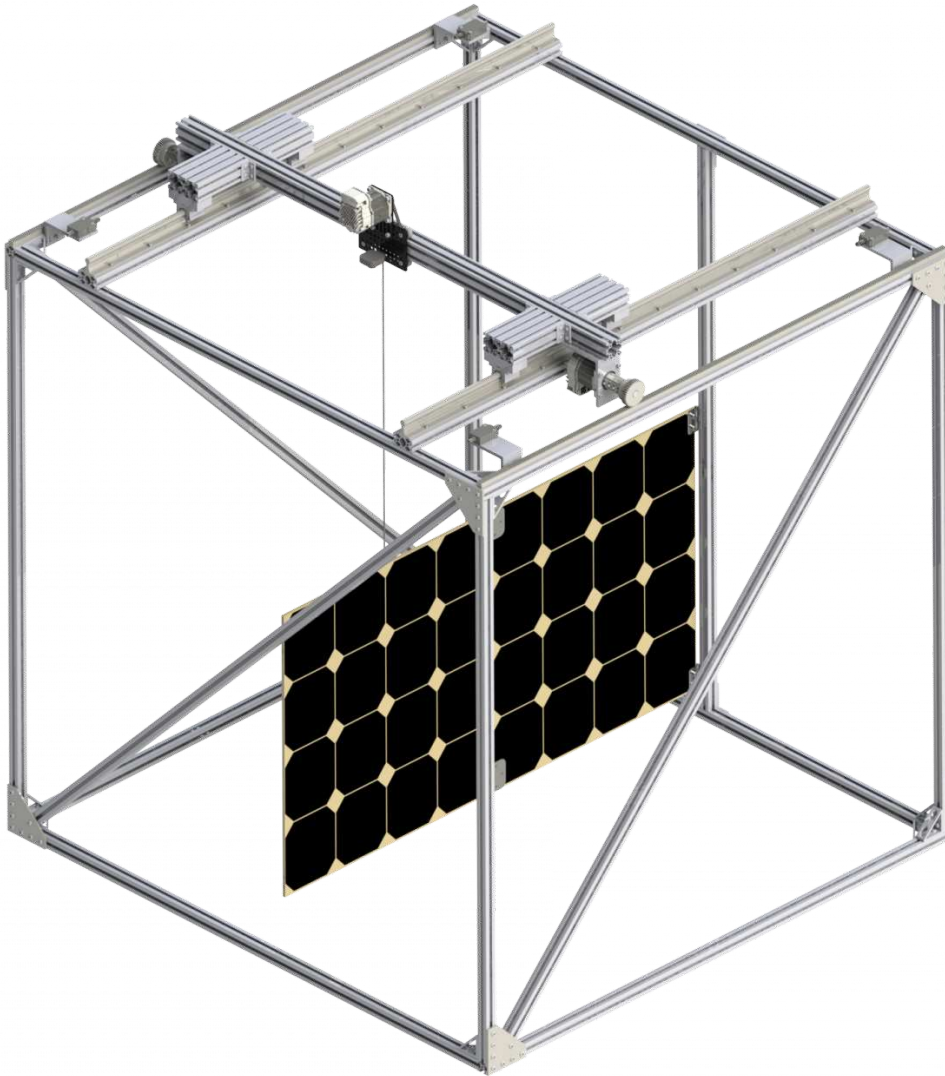
Computer Vision
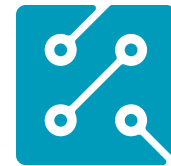
System Integration

Autonomous Tracking

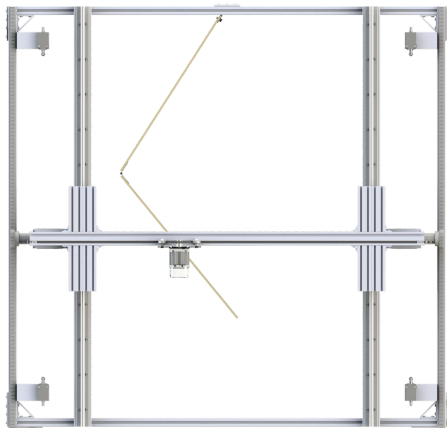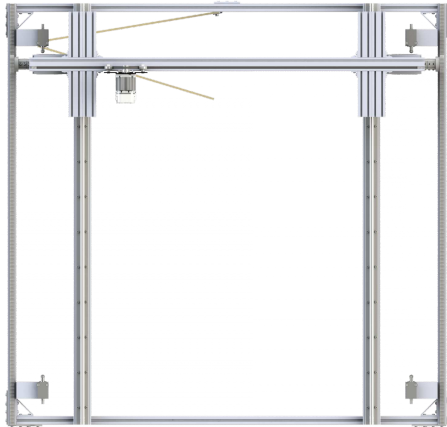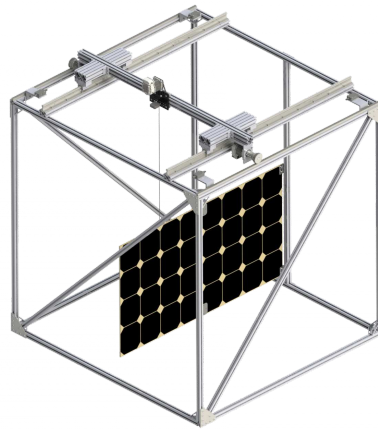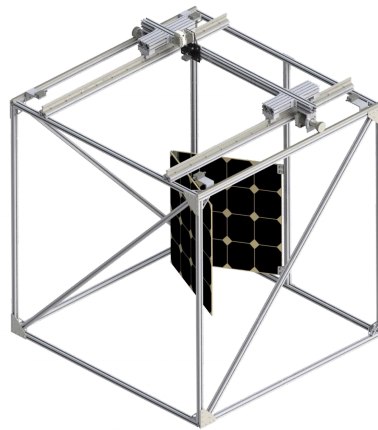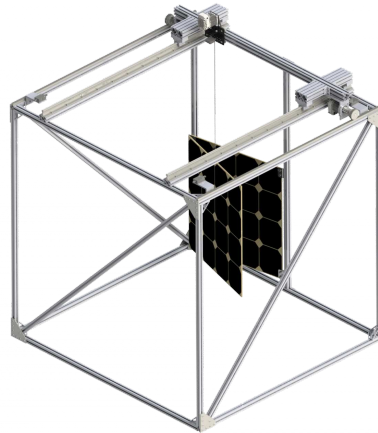Motorized Movement

Gravity Offloading

Deployment Process

Top View
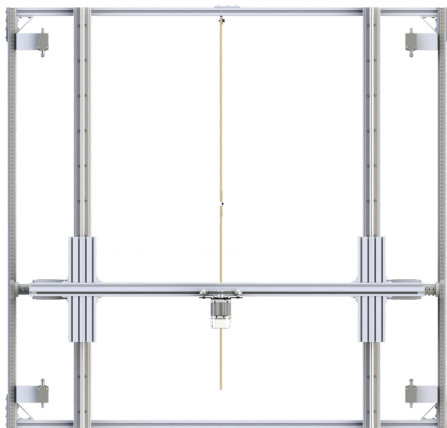
Isometric View

Plan for Future Implementation

Proof of Concept Prototype vs. Full Scale System

The goal of designing a proof-of-concept prototype is to explore solutions that can be translated to full scale systems. The differences and similarities between the final prototype of Project Marion and future projects designed by Ball Aerospace are described below and shown in the figure.

1

Two linear rails are used in the final prototype, while four linear rails will be required to support the full scale system.
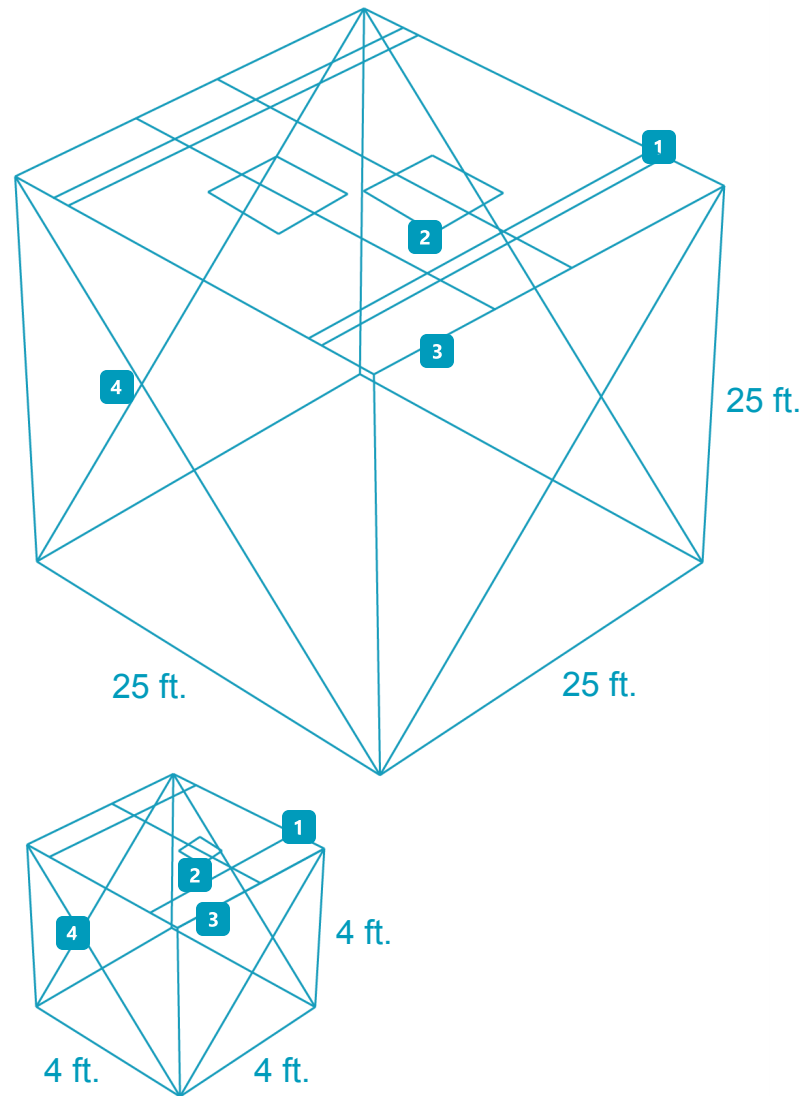
2

There will be at least two girders in the full scale system that will be used to suspend each solar array.

3

A gear rack is used in both systems to provide active offloading.

4

Both systems utilize diagonal members in the support frame. The prototype is made of extruded aluminum while the full scale system will be made out of steel.

Conclusion

As mentioned previously, solar panel arrays designed to operate on a satellite or spacecraft will be deployed in a zero-gravity environment. Project Marion is a solution to the difficulties with testing solar panel arrays on the ground. Current methods in ground testing include passive systems that introduce friction into the hinges of the arrays. These external forces can result in inaccurate behaviors throughout deployment. Other, more complicated systems exist, but are either too costly or designed for specific systems.

Project Marion operates as a powered gantry to offload each panel of the array. In a multi-panel array, multiple girders will work to suspend each panel. Once deployment of the array has begun, the mounted camera tracks the panel's displacement and commands the motors to follow the gantry to be directly overhead the panel. The gantry will follow the panel through its deployment while keeping it suspended. The computer vision's reaction time is critical as a slow reaction will result in a large lateral force. These forces can either assist or hinder deployment of the panel. Project Marion will improve results compared to current systems as lateral forces are reduced through the computer vision controlled gantry. Test data from Project Marion will assist engineers in the future for developing test structures for spacecraft.

Acknowledgements