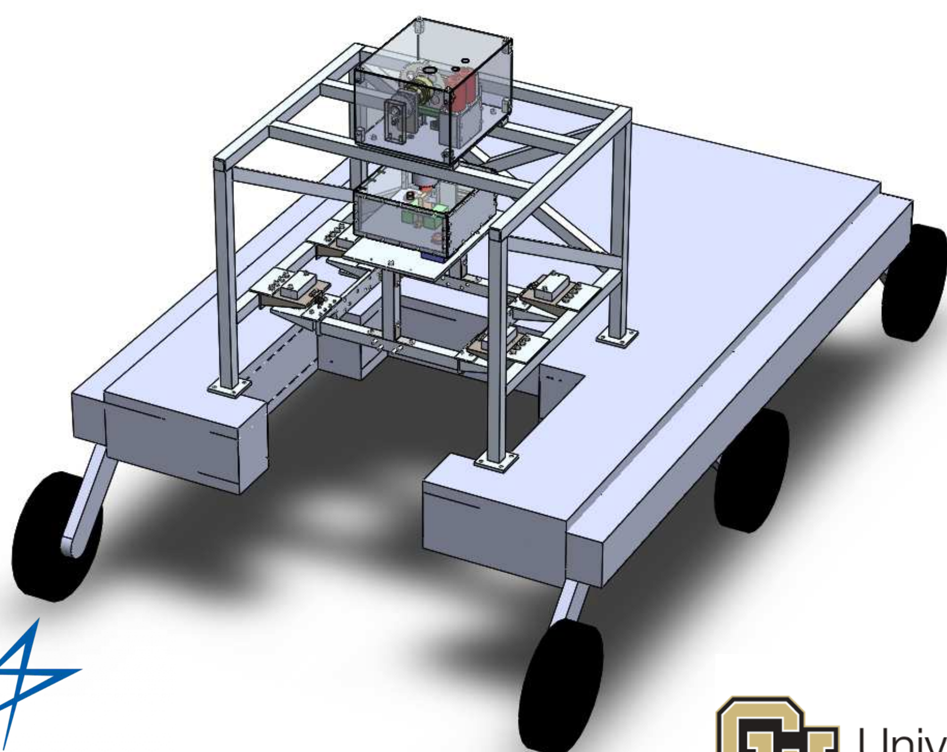
LUNAR PAYLOAD DEPLOYMENT SYSTEM

CU DESIGN TEAM 10
LOCKHEED MARTIN SPACE SYSTEMS



LOCKHEED MARTIN

University of Colorado Boulder

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Project Summary

Under Lockheed Martin's banner and part of NASA's Artemis Program, the Lunar Payload Deployment System (LPDS) is the next step in returning and maintaining a human presence on the moon. CU Design Team 10 designed the LPDS to function onboard a lunar rover to deploy and move payloads around the lunar surface. Our work is based on a full-size LPDS (which needs to be able to lift a 200-pound payload that is approximately 3.3ft x 3.3ft x 5ft), but the team designed and built a prototype with 70% reduction by mass, as well as completing CAD and analysis for full scale recommendations.

Major considerations included:

- The ability to redeploy multiple payloads
- Withstand the launch environment of an Atlas V launch vehicle
- Function under the extreme hot and cold environments on the moon, and in the abrasive dust on the lunar surface
- Operate with less than 4 Amps and 28 Volts

Figure 1: Various Pre-existing
Rover Concepts

Systems Overview

The resulting assembly consists of four main subsystems as seen in Figure 2: Payload (Purple), Chassis & Launch Securement (Red), Grappling (Green), and Vertical Actuation (Blue). In order to provide LPDS status and a level of autonomy, sensors and feedback control were integrated into each of the subsystems. To verify the design, motion study and strength analysis were performed.

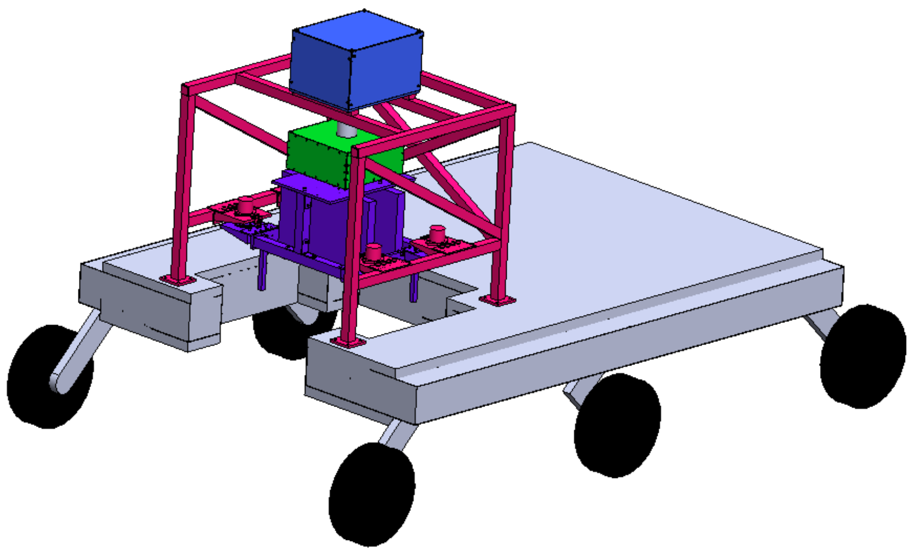

Figure 2: CAD model of LPDS mounted on rover

Figure 3: Manufactured LPDS

Payload

A payload had to be designed that could accommodate multiple configurations and necessary tests. Two different weights, 10lbm and 60lbm, simulated lunar and terrestrial gravitational environments. Additional weights could be added to shift the payload's center of mass by up to 3 inches.

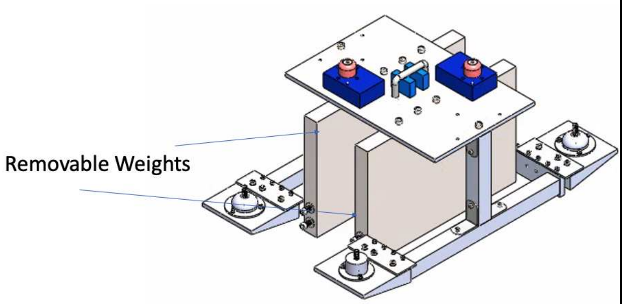

Figure 4: 60lbm Payload Configuration

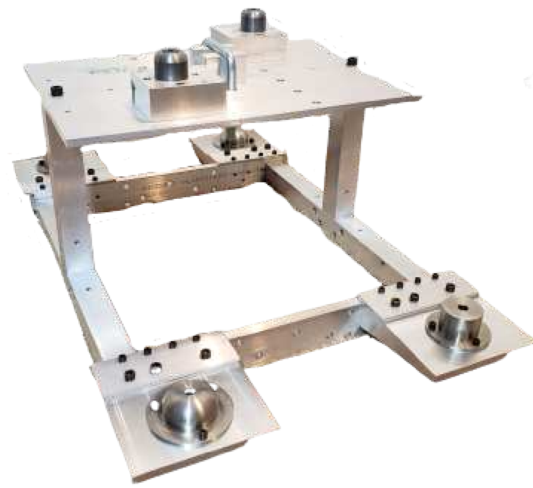

Figure 5: 10lbm Payload Configuration

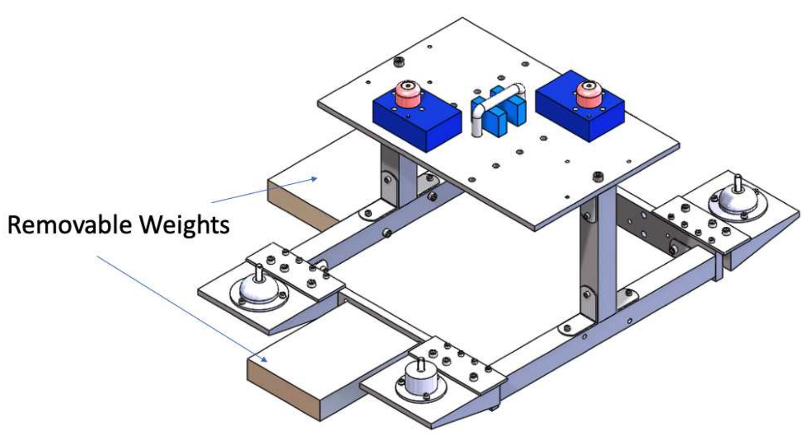

Figure 6: Adjustable Center of Mass Configuration

Chassis & Launch Securement

The payload will experience several hundred pounds of force and excessive vibration. A welded aluminum alloy chassis was designed to be lightweight and to secure the payload with four non-explosive, hold down and release mechanisms (HDRM) and kinematic constraints, which reduced vibration and forces on the HDRMs.

Figure 7: LPDS Chassis

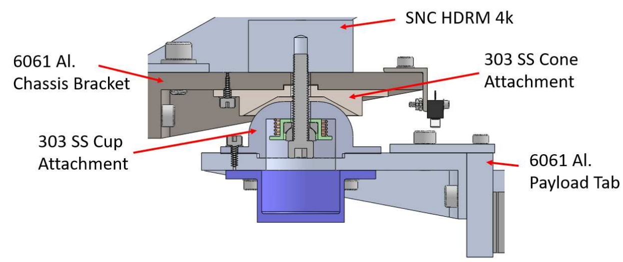

Figure 8: Chassis and Payload Interface

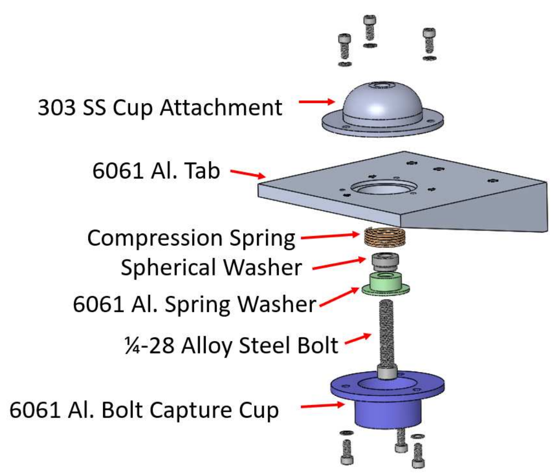

Figure 9: Payload Tab Exploded View

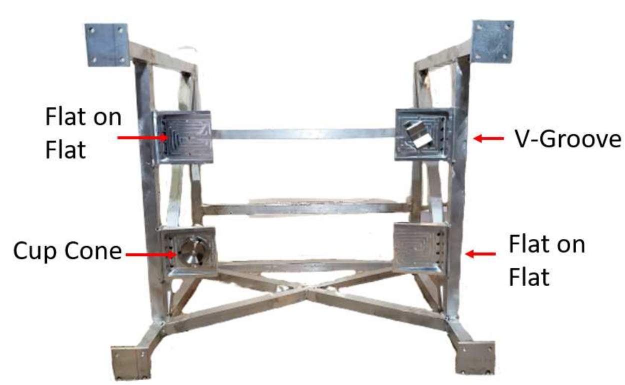

Figure 10: The Four Kinematic Constraints

Grappling

The grappling system was designed to allow the LPDS to attach and release from the payload, as well as provide the lifting point to pull the payload into the structure. To do this, a hook driven by a stepper motor allows the system to latch onto a U-bolt on the top of the payload. To make sure that the attachment is secure, there is a spring that holds the hook in a latched position, even during rocket launch, as well as two alignment features that allow the grappling head to locate itself to the right position.

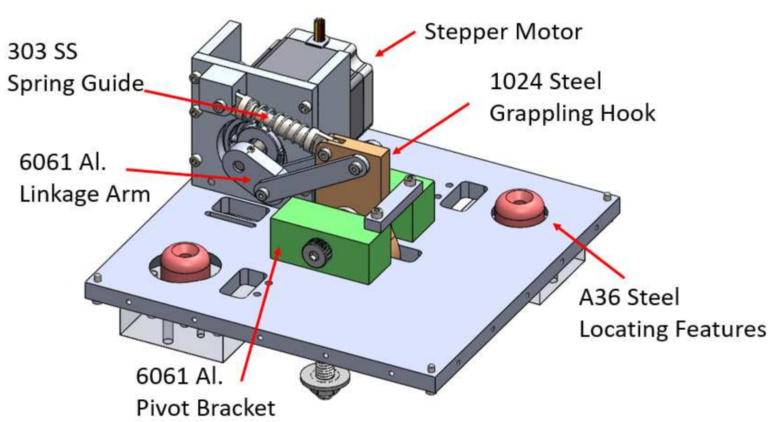

Figure 11: Grappling Assembly

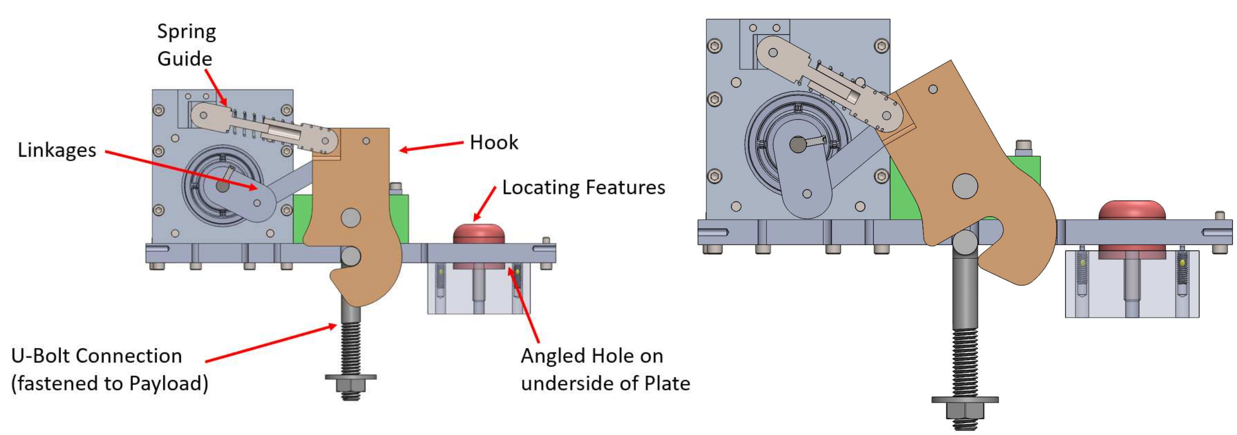

Figure 12: Hook in engaged and disengaged states

Vertical Actuation

In order to raise and lower the grappling head, a vertical actuation winch system was mounted to the top of the LPDS frame. A stepper motor was added to drive a set of gears that could unwind a spool of Vectran rope. To prevent the spool from being back-driven, a pawl-and-ratchet lock was implemented.

Figure 13: Vertical Actuation Assembly

Figure 14: Assembly mounted on chassis

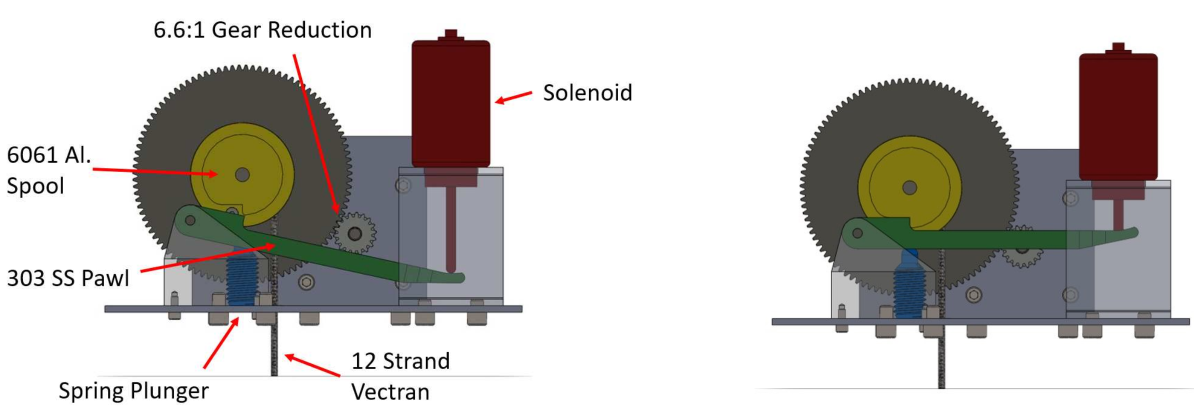

Figure 15: Pawl in Disengaged and Engaged state

Electronics

Due to the need to operate remotely, the LPDS required a controller to instruct it when to actuate its various subsystems to pick up and release payloads. It also needed various sensors to inform the controller when it was in the correct configuration to perform a function. We utilized an Arduino Mega 2560 microcontroller on the prototype to simulate the rover controller and the hardware shown in Figure 16 for actuation and feedback.

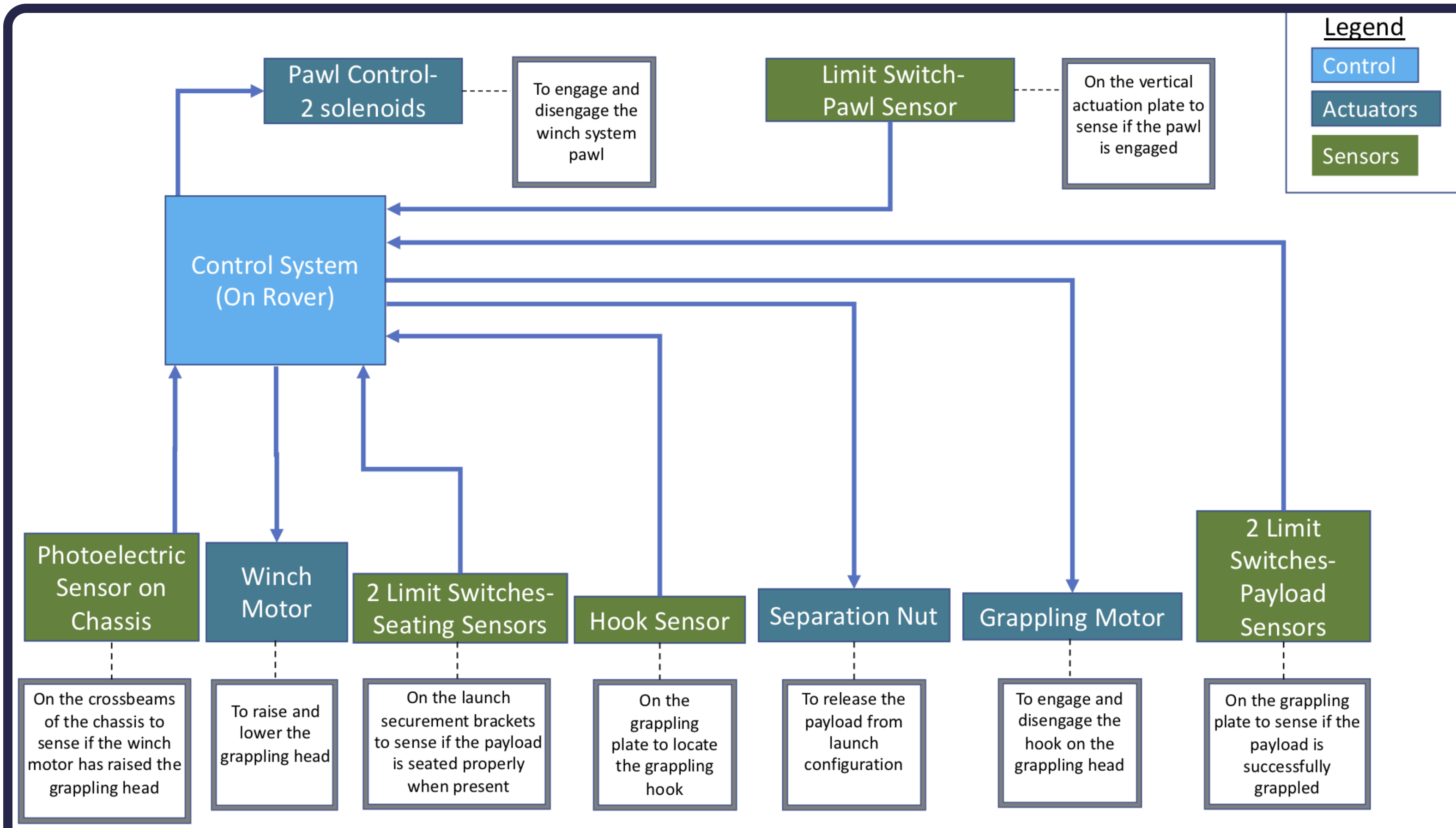

Figure 16: Electronics Systems Diagram

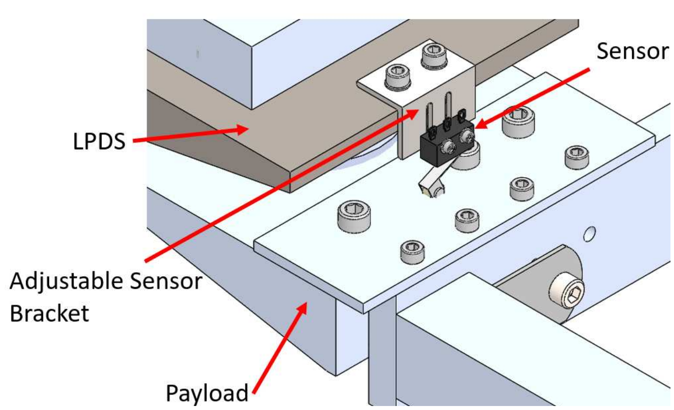

Figure 17: Payload Limit Sensors

Full Scale Design

Due to the COVID-19 pandemic and resulting shutdown of all campus activities, the team's original goals of finishing the LPDS' manufacturing, assembly, and operational testing for a functional prototype was shifted to the design and analysis of the full-scale model. This opportunity allowed the team to address any issues we found in the design from the prototype and include them as design recommendations for the full scale version. The bulk of this effort consisted of analysis to determine correct strengths for the enlarged pieces, but also included such changes as moving to a worm gear drive for the vertical actuation.

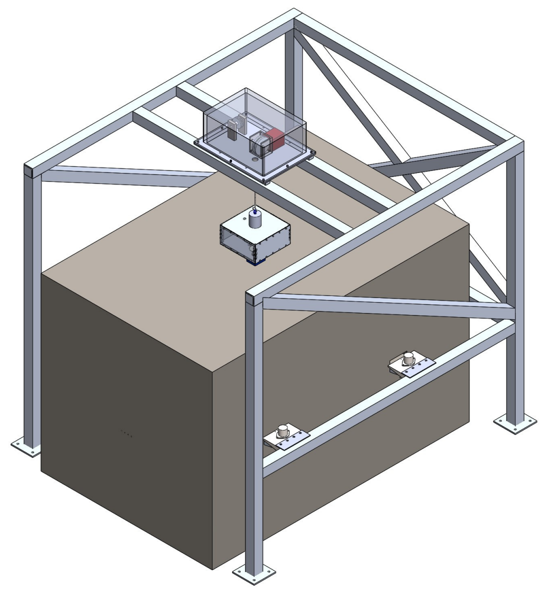

Figure 18: Full-Scale Chassis

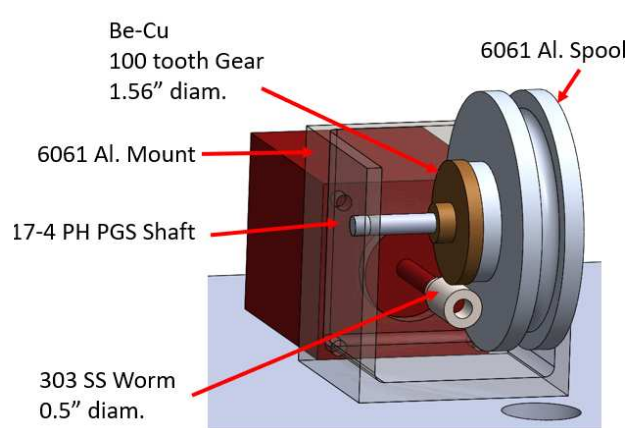

Figure 19: Worm Gear Drive

Structural/Thermal Analysis

Structural FEA

Modal and static FEA (Finite Element Analysis) was performed on the prototype and full scale LPDS models. The objective was to determine the survivability of the LPDS during launch conditions, as that is where the LPDS would experience the greatest accelerations.

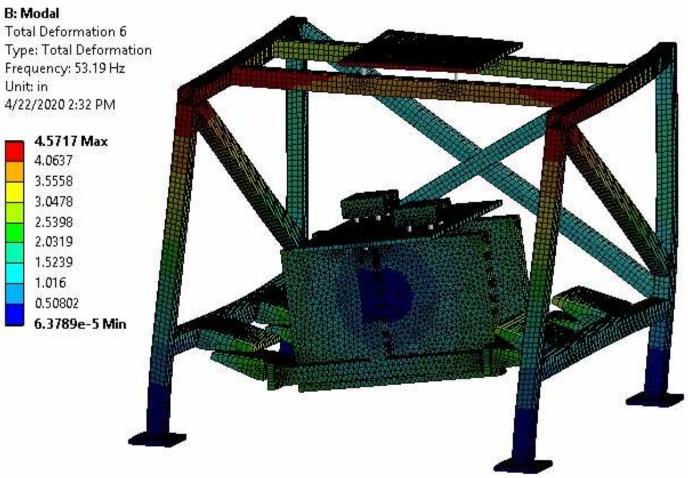

Figure 20: Modal Analysis for Prototype LPDS

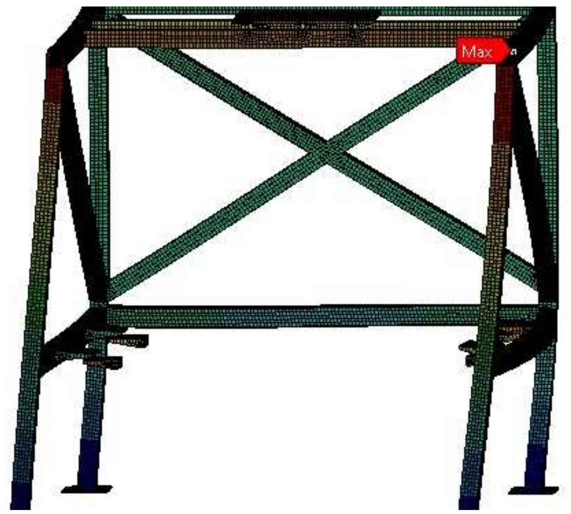

Figure 21: Modal Analysis for Full-Scale LPDS

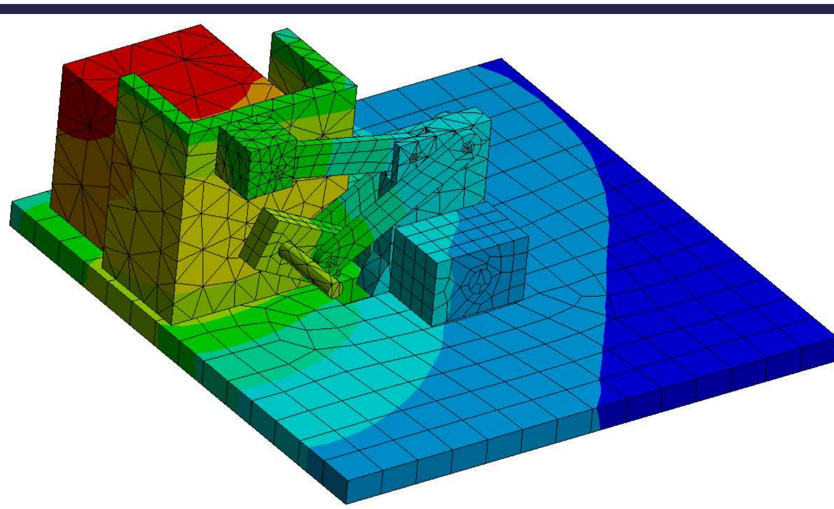

Figure 22: Thermal FEA

Thermal FEA

Steady-state thermal analysis was carried out using Ansys for the revised full-scale LPDS model. This analysis was used to verify operating temperatures for both the winch and grappling subsystems, under worst-case hot and cold conditions. Recommendations for heater sizing and placement, and relative importance of heat flow in each system were also important outcomes.

Conclusion

Though this project did not conclude as we expected in terms of hardware and electronics testing, assembly, integration, and the CEAS Expo, it did result in an LPDS prototype and initial designs for a full scale version. That provided insight into the mechanisms used on the lunar surface and the applications for which they can be useful. Through many design iterations and long days in the machine shop, we created a project that provides a prototype of which we are proud to have.

Acknowledgements:

We know our achievements are not just a result of our own efforts. This entire process would not have been possible without the aid and work of the many people who supported us along the way. Many thanks to the following:

From Lockheed Martin: Lance Lininger, Mike Pollard, Adam Wigdalski, Chris May, and all the rest of the Lockheed team who provided input and assistance
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Our welder: Paul Johnson
Our Director: Chip Bollendonk
Our fellow teammates

We are grateful to have had the opportunity to work on this project and look forward to seeing humankind back on the moon!