Hold Down Release Mechanism
Team Stellar Hold

Analytical Analysis

Maia Warren

Spring – Fall
2022

NORTHERN ARIZONA UNIVERSITY
College of Engineering, Informatics, and Applied Sciences

Project Sponsor: General Atomics – Electromagnetic Systems
Advisor: Pam McCulley
Instructor: Carson Pete

Introduction:

Satellites are typically in a folded/stowed away state until they are in their final position, usually orbit, and then they unfold to become operational. The mechanism that allows this operation is called a hold-down release mechanism, or HDRM. These devices need to be relatively small, hold a desired load, and then release the load upon receiving a command. These must be extremely reliable and non-destructive to the satellite, as if the mechanism fails, the entire satellite is likely to be non-functional and cannot be recovered. General Atomics – Electromagnetic Systems (GA-EMS) offers small scale satellites called CubeSats, ranging in size from a loaf of bread to a refrigerator. They typically source their HDRM's from other companies that have a reliable history of manufacturing these devices. Most HDRM's are single use, which eliminates the possibility to perform multiple tests on a single device, eliminating the ability to test for manufacturer defects. GA-EMS has tasked the team at Northern Arizona University to begin a design process for their own HDRM. The goal of this project is to eventually have a device that is as advanced as current, state-of-the-art designs, that GA-EMS can manufacture themselves. Additionally, they need their HDRM to be resettable for multiple uses, to allow each individual device to be tested multiple times for reliability before attaching it to a satellite. This has many benefits for both GA-EMS and the industry.

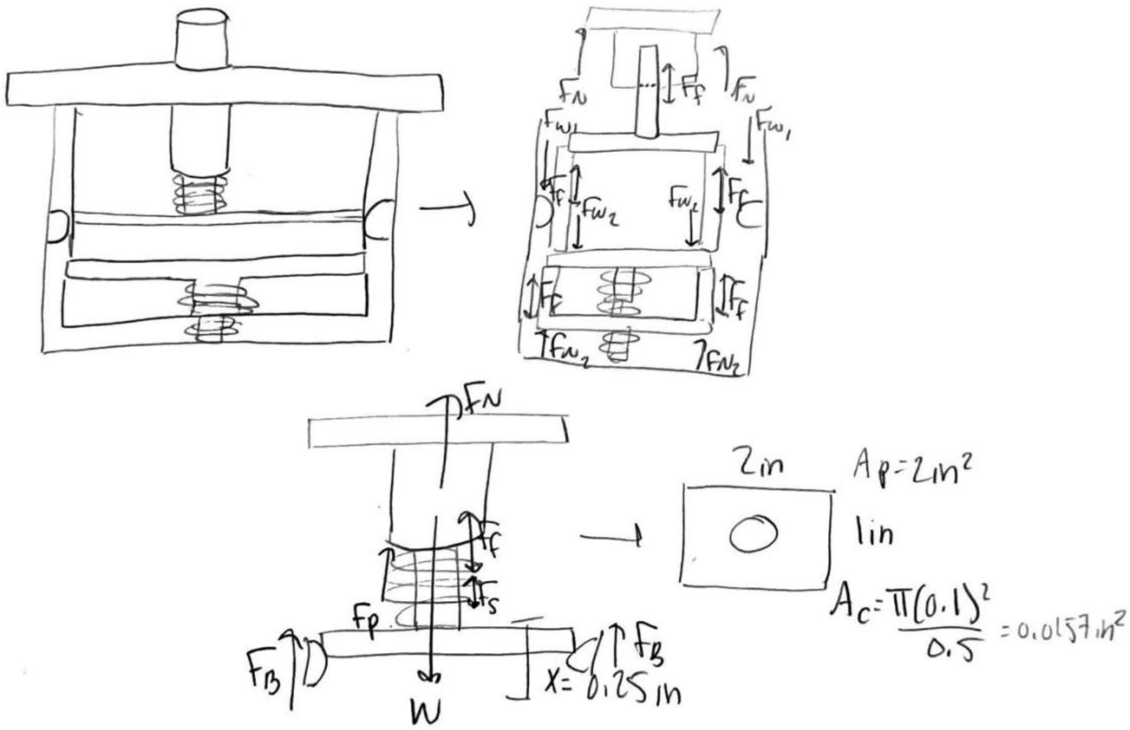
One main outcome of this project will be GA-EMS saving money on their products. By vertically integrating these satellite components, they will be able to both save money by manufacturing their own product and be allowed to modify it with greater ease to fit their purposes more adequately. Another outcome of this project is potential improvements and advancements in current HDRM technology. As the industry moves away from pyrotechnic (combustible) designs, most HDRM's are still single-use and cannot be reset. By beginning development for a completely resettable HDRM design, it may open or widen a pathway towards safer, more cost-effective resettable HDRM's or lead the industry into an innovation for these mechanisms.

Additional beneficiaries of this project include the clients of GA-EMS satellites. If GA-EMS can provide a mechanism that guarantees greater success of their products, they would receive more business. This would also potentially drive down the costs of the product due to the increase in reliability and decrease in component costs.

This memo holds the analytical analysis for the pin that runs along the center of the design. The analysis will consist of the yield strength of the aluminum pin, the free body diagram and analysis of forces pertaining to the pin, fracture mechanics, and the friction factor for the aluminum against aluminum.

Below, the analysis and free body diagram can be seen. The free body diagram shows where each force occurs on the device before and during actuation and then demonstrates only the forces being analyzed on the pin itself. The forces on the device were calculated in order to be able to further determine the rest of the analysis. First, forces like the normal force, weight, spring force, and force on the ball locks were calculated. Then, the friction factor analysis was done in order to understand what force the spring would have to be pushing against in order to slide the pin out and to help determine how much wear the pin and cylinder will undergo during testing. After calculating friction of aluminum rubbing against itself, its yield strength was found. This was done by defining the stress factor and the safety factor. The last calculation found the point at which the aluminum plate would fracture after being pushed into the second position by the spring after actuation. The was also an important calculation to help determine if the pin's base would be strong enough to withstand numerous tests.

Free Body Diagram:



Variables and Equations:

Friction Factor of Aluminum against Aluminum

$$w\ sq\ in = weight\ per\ square\ inch\ =\ 0.06\ lbs$$

$$A_c = area\ of\ cylinder = \pi\ x\ (0.1\ in^2)^2\ x\ 0.5\ in =\ 0.0157\ in^2$$

$$A_p = area\ of\ plate = 1\ in\ x\ 2\ in = 2\ in^2$$

$$\mu =\ coefficient\ of\ friction = 0.3$$

$$x = spring\ compression\ distance = 0.25\ in$$

$$F_s = force\ of\ spring = -k(x) = (-0.2)(0.25\ in) =\ -0.05\ N$$

$$F_b = force\ of\ ball\ locks = \frac{F_s + w}{2} = \frac{-0.05 +\ 0.121}{2} = 0.0355\ N$$

$$w = weight = (A_c +\ A_p)(w\ sq\ in) = (0.0157 + 2)(0.06) = 0.121\ lb$$

$$F_N = normal\ force =\ w +\ F_s -\ F_b = (0.121) + (-0.05) -\ (0.0355) =\ 0.0355\ N$$

$$F_f = friction\ force =\ \mu\ Fn = (0.3)(0.0355) = 0.01065\ N$$

Aluminum Yield Strength

$$f_s =\ safety\ factor = 85\ MPa$$

$$\sigma = design\ stress =\ 103\ MPa$$

$$Y_s = yield\ strength =\ (f_s)(\sigma) =\ 8.755\ GPa$$

Fracture Mechanics

$$K = Y\sigma\sqrt{\pi a} = (0.38)(103)\sqrt{\pi(2)} = 98.08\ N$$

$$\sigma = 103\ MPa$$

$$A_p = area\ of\ plate = 1\ in\ x\ 2\ in = 2\ in^2$$

$$Y = geometric\ factor =\ 0.38$$

Conclusion:

From the analysis done, it was determined that the aluminum pin will hold a friction factor of 0.01065 N when it rubs against the stationary cylinder after actuation and the force of the loaded spring around the pin will need to be strong enough to account for this force. The aluminum used will have a yield strength of 8.755 GPa leads us to believe that aluminum will be a good material to use for the prototype because it can withstand wear form several tests. This is an important factor in choosing the material used because we will need to perform between 50-100 tests on the prototype to ensure consistency and this material was deemed durable enough to use and is a low cost. The material also has a fracture point of 98.08 N. This result proved that the aluminum was a trustworthy choice because even after 50-100 tests under a spring force of 0.05 N, we believe that the aluminum plate along the bottom of the pin will not fracture.

References:

[1] “General Environmental Verification Standard for GSFC Flight Programs and Projects,” Goddard Space Flight Center, Goddard Space Flight Standard GSFC-STD-7000A, Apr. 2019.

[2] “Load Analysis of Spacecraft and Payloads,” Office of the NASA Chief Engineer, NASA Technical Standard NASA-STD-5002A, Sep. 2019.

[3] “Design and Development Requirements for Mechanisms,” Office of the NASA Chief Engineer, NASA Technical Standard NASA-STD-5017A, Jul. 2015.

[4] “Requirements for Threaded Fastening Systems in Spaceflight Hardware,” Office of the NASA Chief Engineer, NASA Technical Standard NASA-STD-5020B, Aug. 2021.

[5] “Guidelines for the Specification and Certification of Titanium Alloys for NASA Flight Applications,” Office of the NASA Chief Engineer, NASA Technical Standard NASA-HDBK-6025, Apr. 2017.