Reset-able Hold Down Release Mechanism: Nitinol Actuator - Fall 2022

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Abstract

Hold-Down release mechanisms are typically single-use; preventing the user from testing it for manufacturing defects. They also are expensive in the sense that to test a satellite, a new HDRM would be needed for each test. We are proposing a fully resettable mechanism for a hold-down release mechanism, allowing the user to put a single unit through multiple actuation cycles before it needs to be replaced. A Nitinol shape memory spring (SMA) is used to achieve the ability to reset. In addition, the use of the Nitinol spring simplifies the mechanical design and eliminates the use of magnetic fields, hydraulics, pneumatics, electric motors or destructive techniques such as fuse wire/explosives, or to actuate the device. A locking mechanism combined with the Nitinol coil offers resistance against accidental actuation and a greater actuation force than the force exerted from the Nitinol coil itself. The device is designed to actuate with a force of 5lbs, when the spring is powered with 5 volts and 1.3 amps, all while taking up approximately 2.6 in^3. This project and design will ultimately lead to further iterations of a resettable HDRM, inspiring new ways to implement the technology and eventually a greater use of Nitinol based devices being used in satellites. Additionally, this project will help with increasing the scope of SMA based technology.

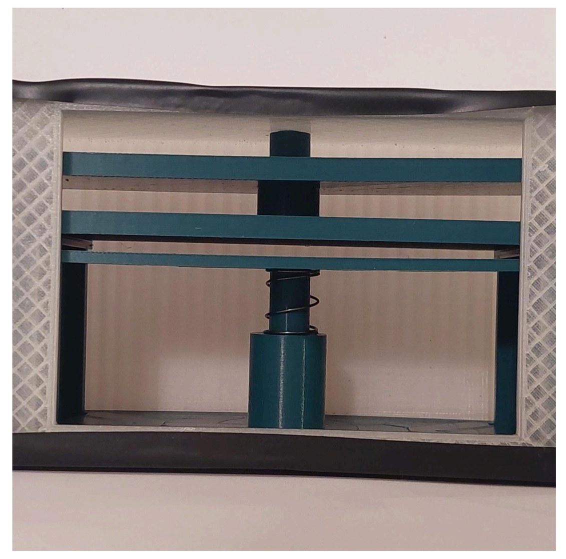
Requirements

During a meeting with General Atomics, the team Stellarhold was given a list of engineering and customer requirements that helped shaped the design. The final design was created in a way that incorporates each requirement, even if the requirement was not completely satisfied. Some of the requirements will not be met but the product is designed with consideration for future improvement. Since the representatives of our client was a group of engineers from GA, many of the customer requirements were given in the form of engineering requirements.

#	CR	ER
1	No Space Debris	No breakaway parts
2	Low Outgassing	Low outgassing materials
3	No Combustion	No combustion
4	20x30 cm Deploy Solar Panels	Minimize volume
5	Minimize Protruding Material	Minimize protruding material
6	Maximize Deployment Load/ Simultaneously	Maximize deployment force
7	Easily Resettable	No deformation
8	Retain Stowed Configuration prior to deployment	Maximize retention reliability
9	Receive Input Command	Receive input command
10	Minimize Weight	Minimize weight
11	Minimize Reset Time	Minimize actuation time

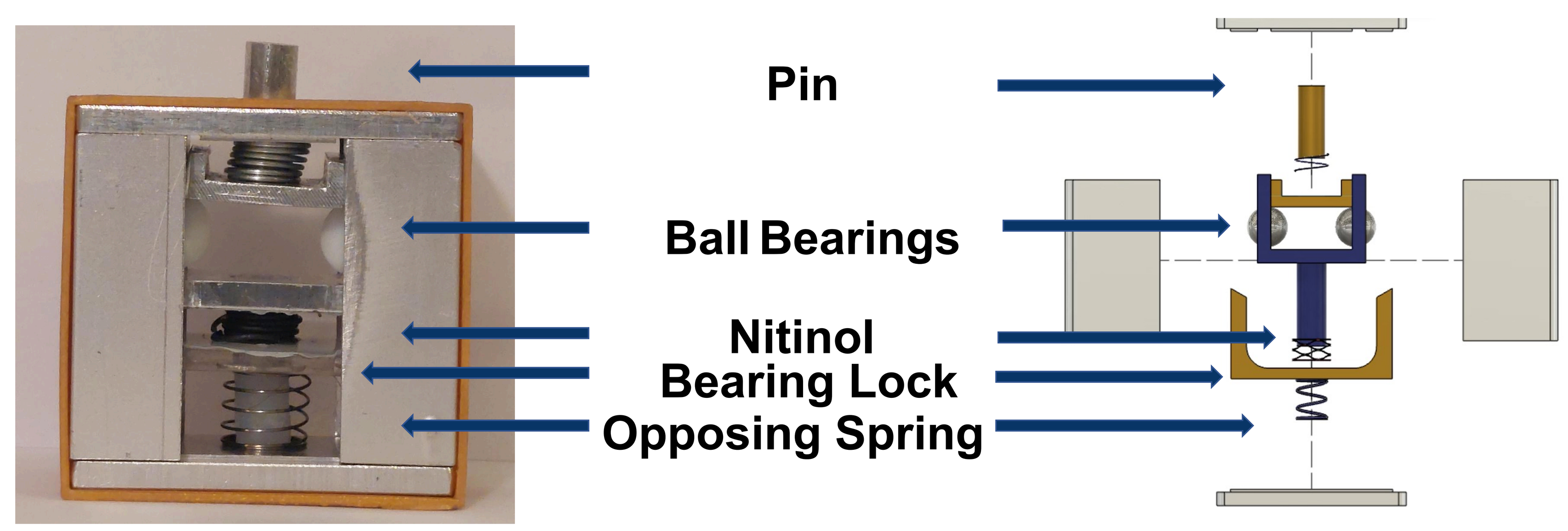
Design Efforts

Design 1: Lever Lock System



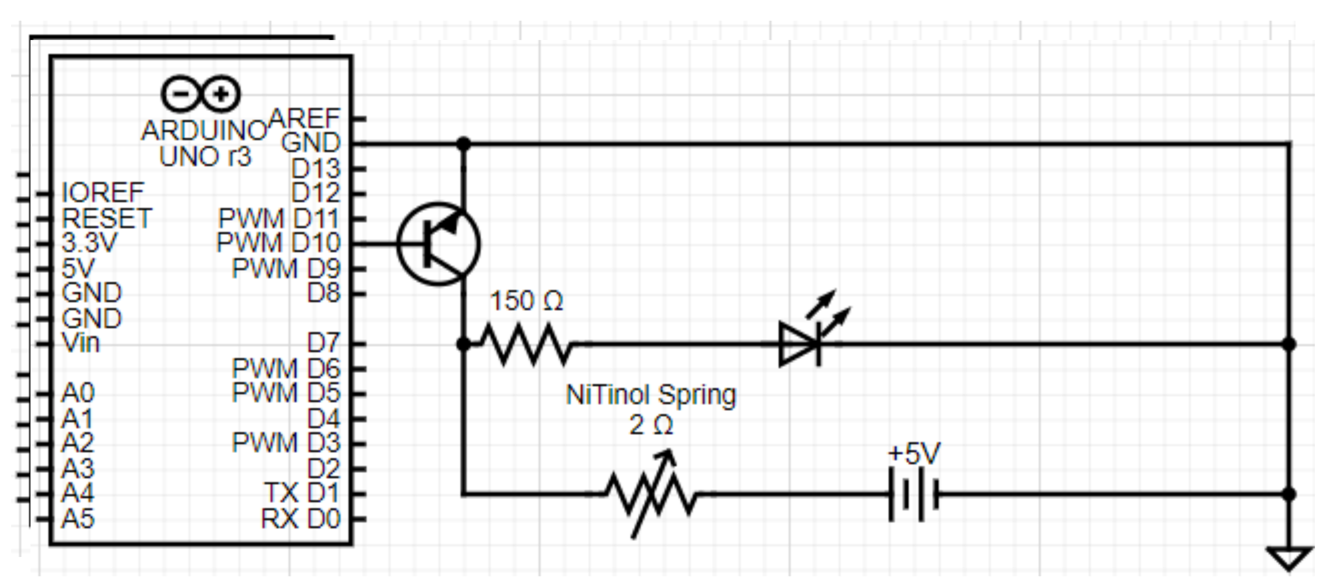
Design 2: Ball Bearing System

Design 3: Ball Plunger System



Final Design (Manufactured)

Final Design (CAD)



Nitinol Actuator Circuit

Conclusion

This project was an excellent test of adaptation and time management, as sponsor changes and manufacturing issues occurred. The manufacturing process showed the team the importance in understanding the differences between a CAD design and the actual, tolerance, fabricated product. In addition, it showed that a technically possible process may not necessarily be achievable with the resources available. Finally, this process proved a functional new design for Nitinol based HDRM's.

Acknowledgements

We would like to acknowledge General Atomics for creating the project and for the guidance throughout the first semester. Their provided lists of Engineering and Customer Requirements created the basis of the design and lead us towards completing our goals. We would also like to acknowledge Professor Carson Pete for leading us through the first semester and staff meetings, Professor David Willy for being our closest form of contact throughout the second semester and for taking over as our client. Additionally, we would like to thank Perry Wood and the entire staff of the machine shop for the continued help and advice through the manufacturing process.

Future Work

- **Scale Down the Device:** Commercially available HDRM's are approximately 1 cu. in [1]. Our manufactured device is approximately 3 cu. in.
- **100% Space Grade Material:** The product has not been manufactured using space-grade materials. Some materials that may be used in a consumer-ready model include titanium, PEEK, Ultem, Nylon. Given more resources, the product could be manufactured to tighter tolerances and with more advanced methods to allow more advanced materials.
- **Optimized Nitinol Actuator:** As Nitinol coil springs are not a product commonly available, the team was unable to source a custom spring optimized for our design and were forced to use an off-the-shelf spring with undesirable parameters. The COTS spring used will not allow the required actuation force to be met, derived using the Nitinol force equations [2]. With the improved Nitinol spring and the pulse width modulated (PWM) circuit, the actuator will reach its fullest potential [3].

Testing

The test below determines the max load that can be applied to the pin in order to retract.

Axial Pin Force Testing

One Reading (g)	Average Reading (g)	Force (N)
1514.9	1504.27	14.74
1459.4	1434.86	14.06
1454.7	1471.81	14.42
1470.7	1440.58	14.12
1505.2	1498.91	14.69
1502.7	1508.05	14.78
1514.9	1505.55	14.75
1500.8	1501.92	14.72
1495.1	1489.09	14.59
1479.7	1465.97	14.37
1495.3	1507.67	14.78
1482.3	1479.71	14.50
Average:	1484.0325	14.54

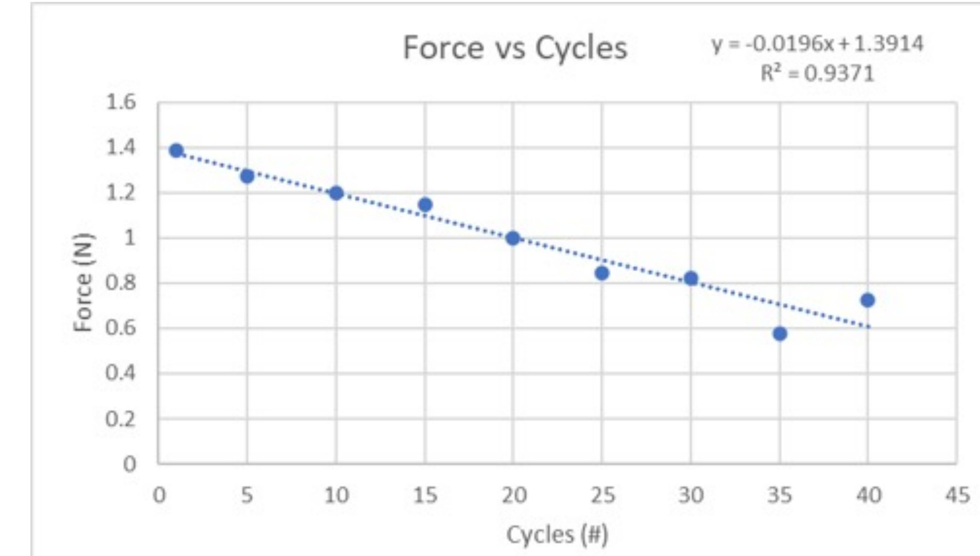
Result

Axial Force:	14.54	±	0.218	N
	3.27	±	0.049	Lbs.

The test below determines the force output of the Nitinol actuator over the course of 40 cycles. This will help determine how many cycles until it can no longer output the necessary force to actuate.

Nitinol Spring Force vs Cycles

Cycles	Output (g)	Force (N)
1	141.5	1.388115
5	130	1.2753
10	121.96	1.1964276
15	117	1.14777
20	102	1.00062
25	86	0.84366
30	83.8	0.822078
35	58.6	0.574866
40	73.9	0.724959



References

[1] Ben, "Tini™ Pin puller," Ensign-Bickford Aerospace & Defense, 05-Jul-2022. [Online]. Available: https://www.ebad.com/tini-pin-puller/. [Accessed: 28-Nov-2022].

[2] Jianzuo Ma, Haolei Huang, and Jin Huang, "Characteristics Analysis and Testing of SMA Spring Actuator." Hindawi, Sep. 08, 2013.

[3] "Activating Nitinol with Electric Current." https://www.imagesco.com/articles/nitinol/07.html [Accessed Sep. 16, 2022].