Development of the NEA Mini for Low Load Applications

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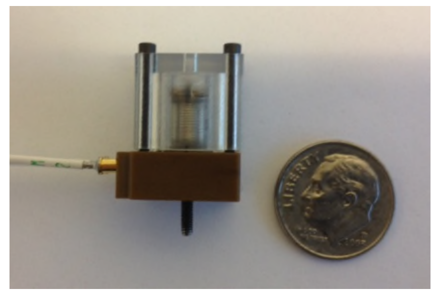
Abstract

Small satellites require simple, reliable and low-cost release devices. Nichrome burn wire solutions have been embraced by the Small Satellite community because they require low power, are inexpensive and readily available. Industry feedback gathered over the past 7 years at the Small Satellite Symposium in Logan, Utah, suggests that the failure rate of Nichrome wire is too high and a more reliable solution is needed. Based upon this industry feedback, NEA started working to see if we could adapt our GEO NEA battery bypass switch into a release mechanism for small sat applications.

Looking across our stable of qualified release products, NEA determined that the release mechanism utilized in our battery bypass switches are small, light, low power, low shock, and have high reliability. Our goal for this paper was to perform a series of load and shock output test to determine if the release mechanism in our bypass switch could be modified for used in standard release mechanism applications.



Introduction

The small satellite market has expanded quickly over the last 5 years. With affordable access to space becoming a reality, the need for a 50 - 200 lbf (89 – 890 N) class, low cost, low power, low shock, high reliability release mechanism has become a reality. Customers are now looking for ways to increase their mission success rates without breaking the bank. NEA's goal was to determine if we could leverage the volume of our battery bypass mechanism product line to offer a low cost high reliability release mechanism. The development team's charter stipulated that they had to utilize off-the-shelf common stock parts that are utilized in our bypass switch release mechanism. The stock parts could be modified for the application, but no new parts were allowed. This paper walks through the initial test data and lessons learned during the development of the NEA Mini 9300 release mechanism.

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Basic Design

The development of the NEA Mini centered on being able to utilize the common release mechanism from our battery bypass switches. The release mechanism in the bypass switch (Figure 1) is similar in operation to our standard release mechanisms and utilizes the same patented fuse wire technology.

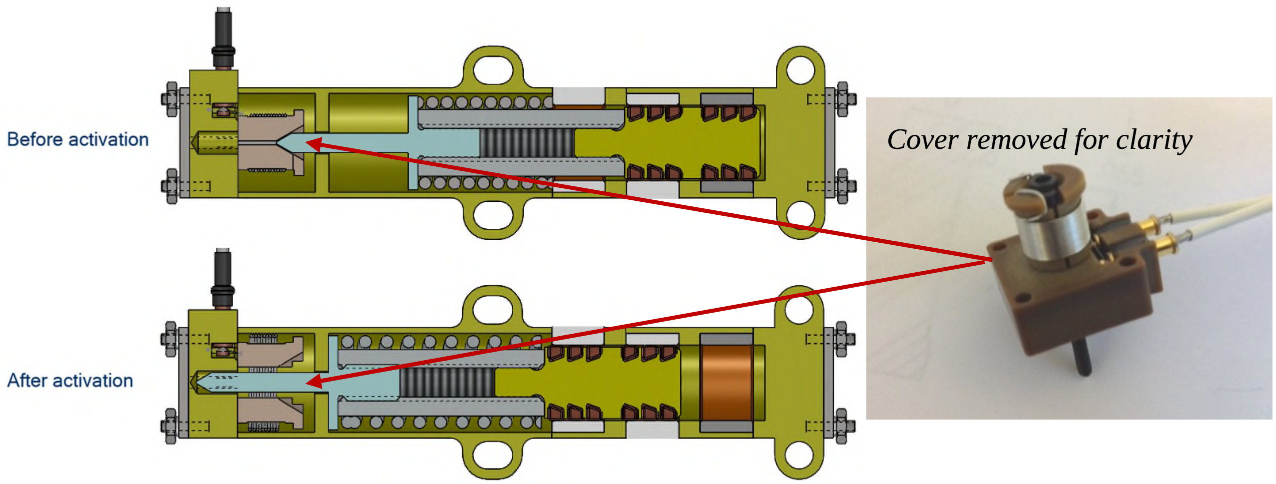

Figure 1. Battery bypass switch

For switch activation, an electrical pulse of 1.2 amps or greater is sent to the mechanism. The fuse wire breaks and releases the restraining wire that holds two spool halves together. A preloaded spring assembly pulls a plunger forward once the spools are released. The shock is minimized by releasing the stored strain energy over a longer period of time. The electrical characteristics for the fuse wire assembly are time and current dependent as shown in Figure 2:

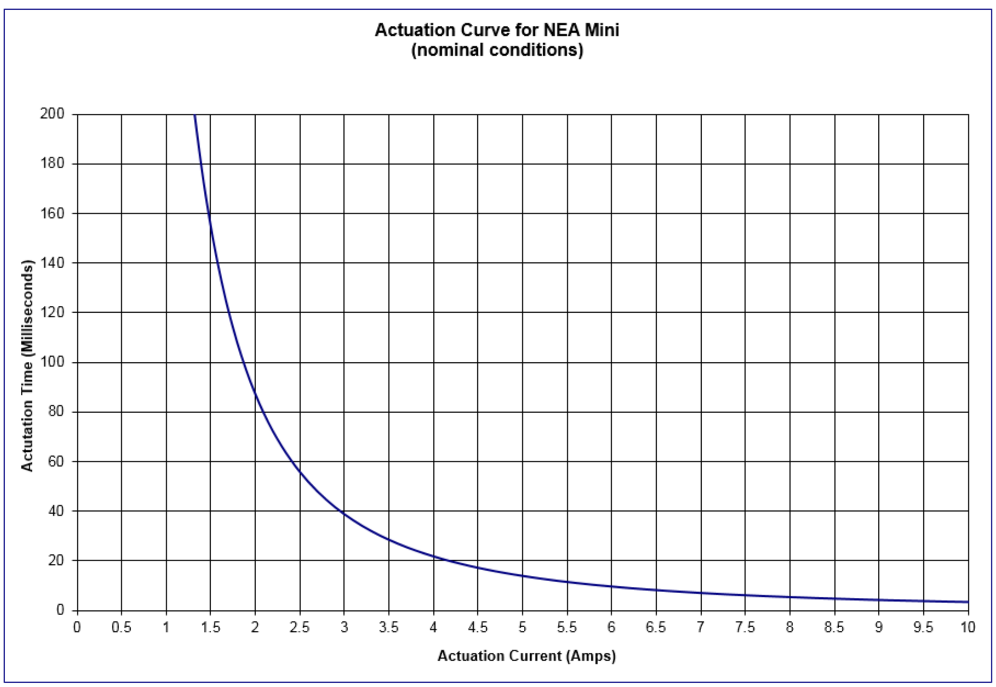

Figure 2. NEA Mechanism Actuation Curve

Based on qualification, NEA's largest bypass switch spring imparts a load of 65 lbf (289 N) on the spools of the release mechanism, so the team knew that the release part of the device could hold a least 65 lbf (289 N) of load. The next questions to be answered were, how high of a load could it handle and what were the limiting factors in the load capability of the mechanism? Was the limiting design factor the Spool Material, Restraining Wire, Fuse Wire, or Release Rod? NEA started by load testing the bypass switch release mechanism to determine its maximum load capability. The team designed tooling to push on spools until the unit failed. The load released at approximately 750 lbf (3300 N) with the restraining wire breaking first (Figure 3).

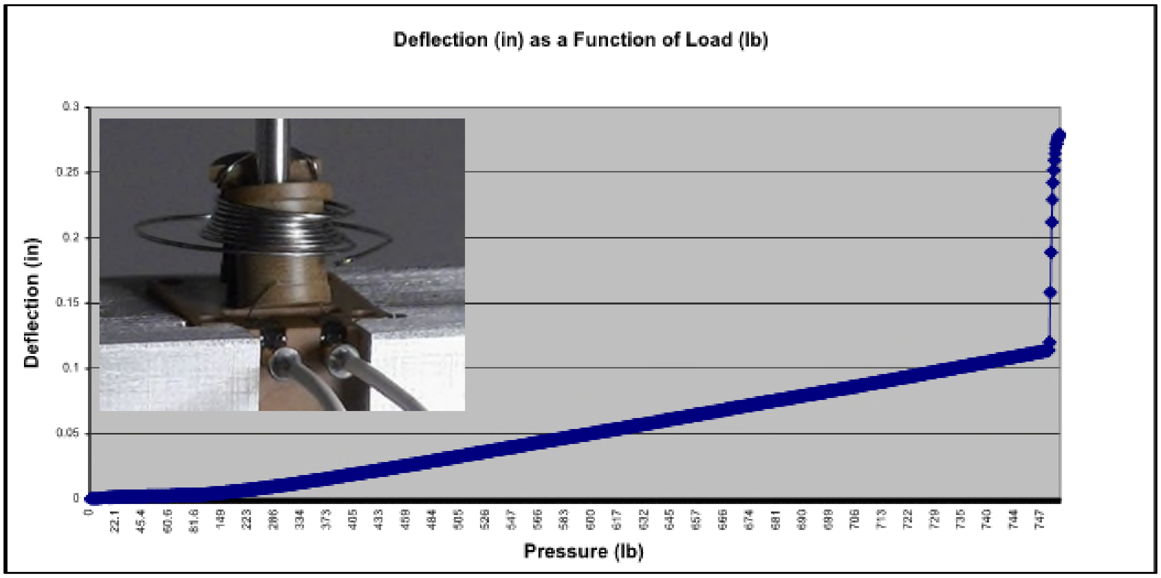

Figure 3. NEA Ultimate Load Test

Now that we knew the ultimate load of the bypass switch release mechanism, we next turned our attention to the design of the release rod. As discussed above, to hit our cost targets, the team was only allowed to alter stock bypass release mechanism parts. They reviewed the piece part detailed drawings to determine our design constrant for the size of release rod. It was determined that the size of the hole that could be drilled between the guide pins that restrain the the spools was the limiting factor. This is shown in Figure 5. Our calculations showed that we could install a hole in the assembly that would support the release of a #1 fastener (release rod) and that this rod would have the structural capability to hold 450 lbf (2000 N).

We then looked at the contact pressure at the conical interface between the release rod and the spools. As it turned out, this was the limiting factor relative to the maximum load capability of the device. The spools are machined from a high-strength engineered plastic that has a maximum compressive strength of 28,900 psi (199 MPa).

$$RRod_{Dia\_minor} := .0560 \cdot in \qquad Spool_{Contact\_Area} := .01063 \cdot in^2$$
$$RRod_{Tensile\_Area} := \frac{\pi}{4} \cdot \left(RRod_{Dia\_minor}\right)^2 = 0.0025\ in^2 \qquad Spool_{Comp\_Strength} := 28900 \cdot psi$$
$$RRod_{UTS} := 180000\ psi$$

$$RRod_{Strength} := RRod_{Tensile\_Area} \cdot RRod_{UTS} = 443.3\ lbf$$
$$Spool_{Comp\_max} := Spool_{Comp\_Strength} \cdot Spool_{Contact\_Area} = 307.2\ lbf$$

Figure 4. Release Rod Load Calculations

The design team armed with the ultimate load data and release rod load data set off to do our first prototype test. We modified a bypass release mechanism and machined the release rod in our rapid development lab. The release rod was made by modifying a commercial #1 socket head cap screw.

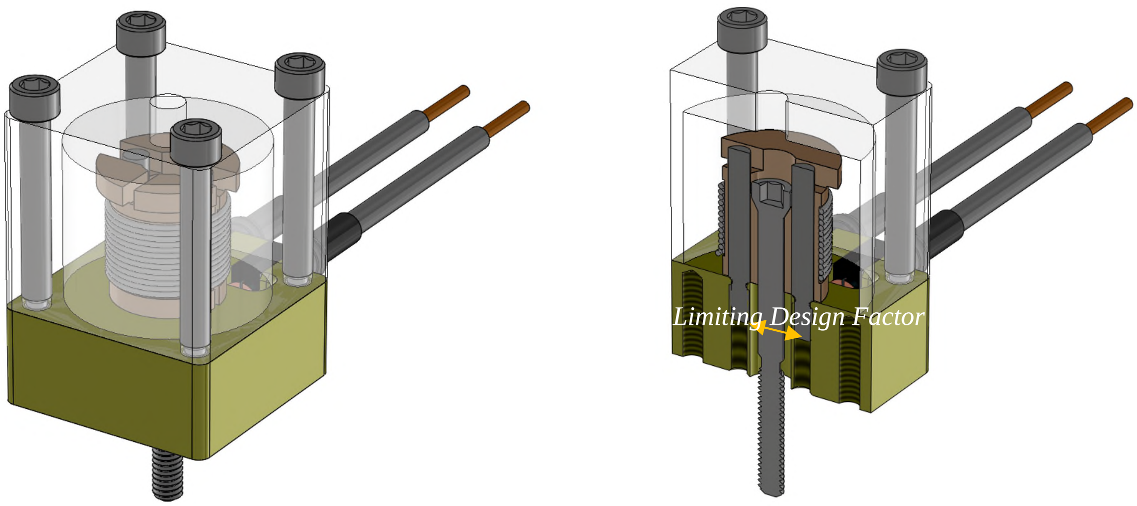

Figure 5. Release Rod and Release Mechanism Modified

At this point we had our first lessons learned. Our first experiment (Ultimate Load) along with the release rod load calculations theorized that the load capability of the mechanism should be near 450 lbf (2000 N). The first test of the mechanism produced contrary results. The initial load test done with the bypass switch mechanism was performed by pushing on the spools (using an Instron test apparatus) with a constant load rate; hence, load creep or loss was not measured. In reality, the plastic spools of the baseline mechanism deflect radially outward at applied loads greater than 150 lbf (660 N). While this test was considered acceptable because the load was within the desired 50 to 200 lbf (89 – 890 N) load range, the team felt they could improve the results.

A detailed finite element analysis confirmed that the spools were deflecting only in the area above the restraining wire; that is, in the area unsupported by the restraining wire. Based on this analysis, the team elected to modify the spools by lowering the conical section deeper within the spool, assuring that the radial load generated by the conical area was fully supported by the restraining wire. This deviated from the charter of the project because parts needed be altered such that stock parts could not be used. The results of the second test were much more favorable and improved the load capability of the mechanism to more than 300 lbf (1330 N).

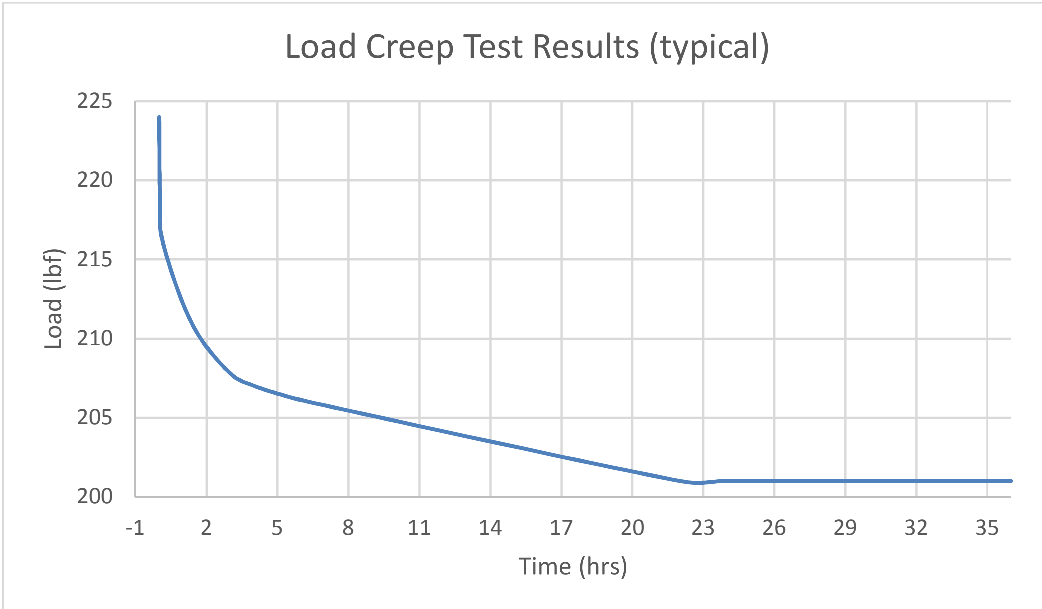

Figure 6. Load Creep Test Results

Now that load characterization was complete, the team moved on to capture shock output data. Given the small size of the device, a modest 12 inch by 12 inch (30 cm by 30 cm) aluminum plate (1/8-inch (3-mm) thick) was used for shock output testing. The test set up is shown in Figure 6.

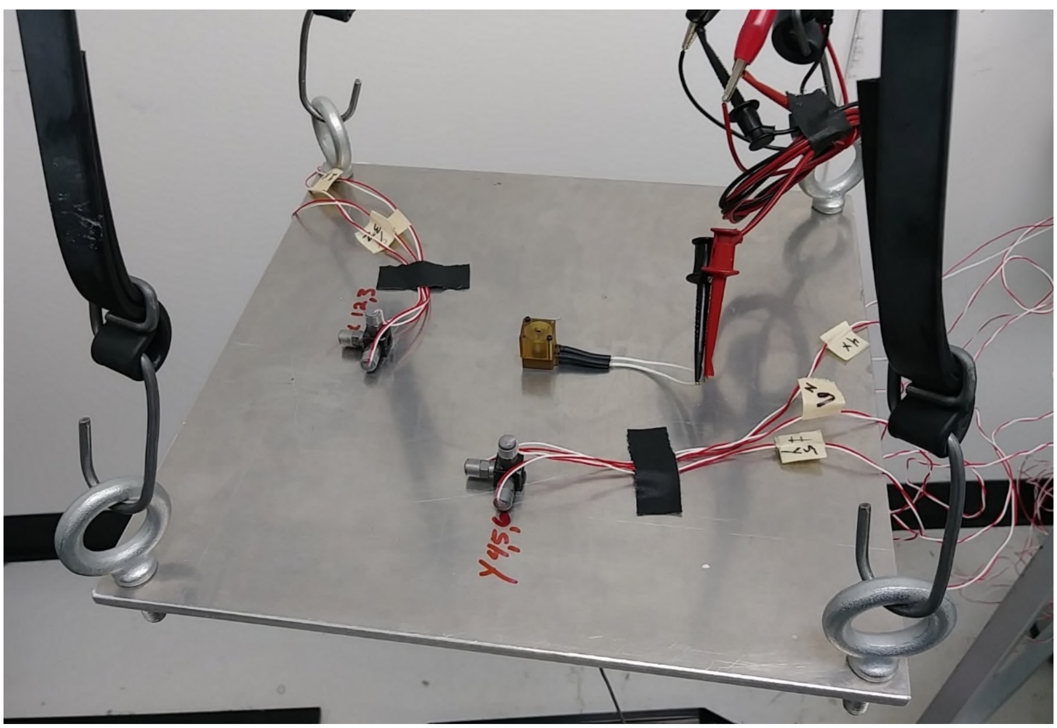

Figure 7. Shock Test Setup

NEA built and tested 5 (five) units for the shock output test. The units were loaded to 250 lbf (1100 N) and then actuated with 4.5 amps of current. The results of the output test are shown in Figure 8.

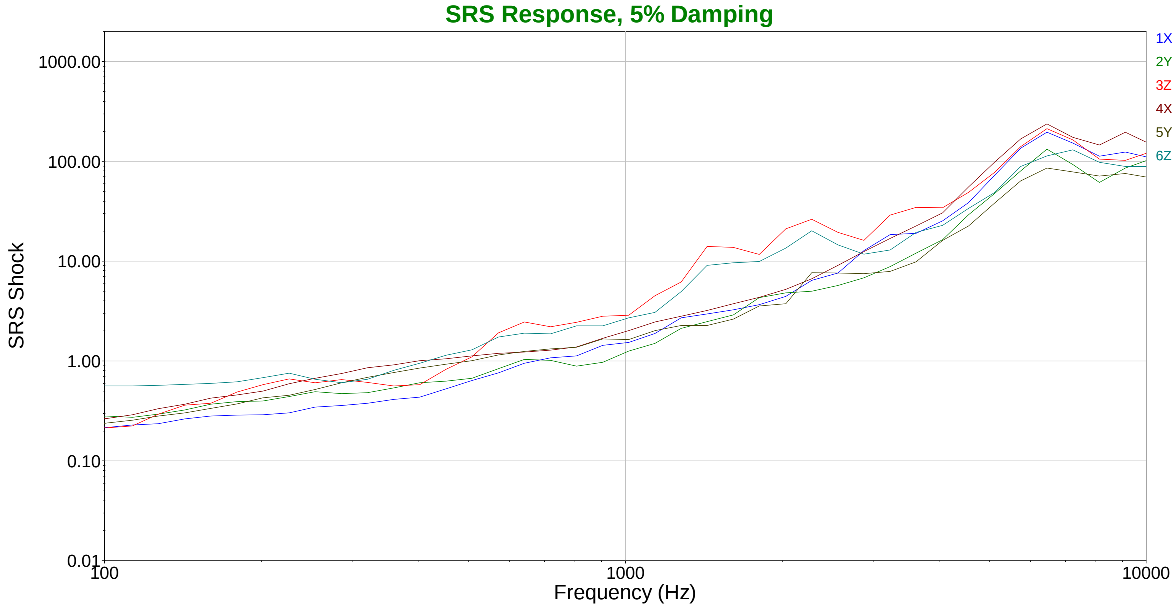

Figure 8. Shock Output Test Results

Conclusions and Lessons Learned

1. NEA produced a 100-lbf (440-N) release mechanism using common parts with our production bypass switch mechanism.
2. Much higher loads (>250 lbf (1100 N)) are achievable with slight design modifications to common parts.
3. By changing from plastic spools to metal spools, loads of 450 lbf (2000 N) can be achieved, but at a higher cost.
4. The shock output of the mechanism is well below expectations and industry standards.
5. More attention to the rod to spool interface could have saved a design iteration.