Microgravity Test of Nanosatellite Release Mechanisms

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Abstract **-** Nanosatellites, also referred to as CubeSats, are a class of small satellite devices that exhibit the simplification of artificial satellites by condensing the volume of the payloads. To satisfy the large demand for more sophisticated payloads such as larger antennas and other deployables there are many commercial, academic and government options for release mechanisms. NASA Wallops Flight Facility has developed a release mechanism that satisfies the volume restrictions of the CubeSat platform. However, it has yet to be tested in a space-like environment. We successfully demonstrated with a success rate of 88% and a reliability rate of 100% over two flights of the new release technology in a microgravity environment. These results will be used for future work along with the release mechanism being integrated into future CubeSat designs.

Keywords: CubeSat, release mechanisms, nichrome burn wire, microgravity, nanosatellite, flight support system

1 Introduction

Small satellite (SmallSat) programs present a unique opportunity for Universities to introduce students, particularly undergraduates, to applications in engineering and space technology. As a result, through the development of CubeSat programs [1], there is a 20-year legacy with projects ranging from improvements to subsystems to design, fabrication, flight readiness testing and over 75 launches. By definition, a small satellite is a spacecraft placed into orbit with total mass under 100 kg. The most popular SmallSats, CubeSats, are in the range of nanosatellites (< 10 kg).

By streamlining the small satellite's infrastructure, researchers dramatically reduce the launch cost associated with the majority of artificial satellites. The demand for increased power, larger antennas and other deployables, such as solar panels, rises as the CubeSat technology evolves into a more capable system. The most common method to contain deployables utilizes a monofilament or fishing line. A nichrome burn wire is wrapped around the monofilament to form a release mechanism. The monofilament is melted when a voltage source is connected to the nichrome burn wire. This method is very inexpensive and proven to provide a reliable release, but it fails to provide a preloaded rigid interface. In addition, there is often a gap between the deployable and the frame where the monofilament is located. Even if a tight and preloaded interface is achieved with the monofilament cable, it could stretch over time and lose its effectiveness.

An improved version of the nichrome wire system was developed by The Naval Research Lab (NRL) [2]. In this release mechanism, the tie-down is performed by a Vectran cable instead of monofilament. A two saddle design with compression springs provides a loaded stroke forcing the nichrome wire to burn through the Vectran cable once heated. The NRL release mechanism is extremely affordable and compact, but the wire is left exposed contributing to safety concerns. Furthermore, it has yet to be fully examined in a space-like/microgravity environment. Commercial off-the-shelf (COTS) release mechanisms offer reliable and proven space solutions. However, the two main barriers for widespread use of these COTS release mechanisms within University programs are the high cost and size constraints. While the cost of nichrome wire and monofilament is almost negligible, these

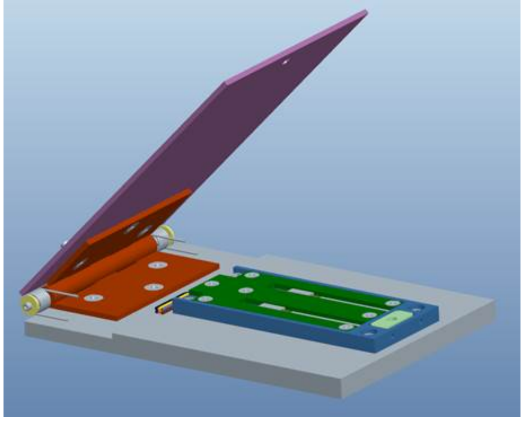


Figure 1: CAD Model of Wallops Flight Facility/Goddard Space Flight Center Release Mechanism integrated into the NASA Free Flyer complete with base plate, hinge and solar panel simulator.

mechanisms are up to $25,000. Furthermore, there is currently no COTS release mechanism that fits within the outside volume allocation for CubeSAT deployables, occupying valuable internal real estate.

NASA Wallops Flight Facility at Goddard Space Flight Center (NASA WFF) developed a miniature release mechanism (Fig. 1) to provide a rigid and preloaded interface that fits in the outside allocation of a CubeSat with a cost of less than $1,000. The mechanism was designed to solve the technological and economic constraints present within the realm of modern nichrome wire and monofilament associated mechanisms mentioned earlier. A nichrome wire was selected after researching a variety of initiators due to its optimal electrical performance on the smallest volumetric package. The mechanism holds an aluminum block in a secure and predictable manner and releases it once the current is supplied. This block is attached to the deployable by the use of a threaded interface. The total internal volume constraint was addressed by producing a mechanism with a height less than 0.200 inches.

In this paper, we present the first results of the NASA WFF release mechanism in a space-like microgravity environment aboard a Reduced Gravity flight. To achieve periods of zero gravity, the aircraft undergoes a parabolic flight pattern [3]. Over two flights, we tested the functionality of 9 different release mechanisms at zero gravity for a total of 17 deployments. Altogether the NASA WFF exhibited a success rate of 89% on the first flight and 100% on the second. This result shows that the release mechanism is not only reliable in zero gravity but the device can function in various spatial configurations such that it can deploy from any position on a nanosatellite.

2 Materials and Methods

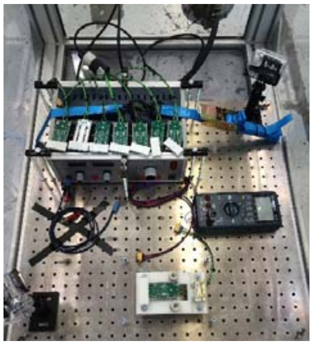
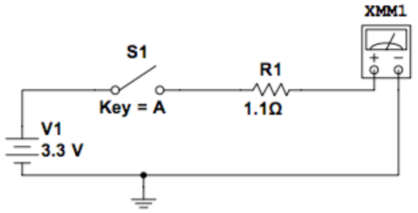


Figure 2 : Experimental setup onboard the Reduced Gravity Flight. Main components include DC power supply, multimeter, NASA Free Flyer and two Go Pro cameras

The experiment setup (Fig. 2) consists of two main components, the NASA WFF free flyer and the grounded equipment. The free flyer is an assembly that includes a plastic base plate, 4 socket head 1/4-20 x 2” screws, a 1 ½” hinge, 8 ¼” hex nuts, 4 super magnets, a NASA WFF release mechanism and a solar cell simulator. The miniature release mechanism developed by NASA’s Wallops Flight Facility has dimensions of 2.875” X 1.250” X 0.188”. It is composed of an aluminum housing, aluminum release block, aluminum harness clamp, and internal electronics. The electrical cables extending from each unit ended on a DB9 connector for ease of assembly between reduced gravity sessions. The free flyer was tethered with 4 monofilaments during the entirety of the flight, but allowed to float with no other restriction. The experimental parameters consisted of powering the NASA WFF mechanism within a reduced gravity environment to observe its functionality as success or failure. Voltage, current, actuation time, successful separation and successful feedback from switches were recorded to evaluate the performance of the release mechanisms at zero gravity.



. Figure 3 : Electrical Schematic for the NASA WFF Mechanism within the Experimental Setup. A 3.3V source is switched on and off by S1 and the NASA mechanism is represented by the resistor R1. This is then monitored for current and voltage by the multimeter, XMM1.

The NASA WFF Mechanism integrated into the experimental setup can be electrically simulated by a 1.1 ohm resistor as seen in Figure 3. When supplied by 3.3 V, a current of 3A was drawn from the system according to Ohm’s Law (V=IR). Once current was applied to the mechanism’s internal circuitry, the device released the aluminum block and subsequently deployed the solar panel simulator. After deployment, the release mechanism is replaced by other mechanism units available for the next period of microgravity. Each flight was recorded using two GoPro cameras and the data from each camera was analyzed for success or failure of the deployment along with the orientation of the with respect to the normal plane of the grounded equipment.

3 Results and Discussion

At *1g*, there is an acceleration due to gravity that counteracts the ability of the release mechanism to fully actuate the solar panel simulator. The result of the deployment at *1g* is seen in Figure 4A. At microgravity, there is no acceleration present therefore; we observed a full actuation of the solar panel simulator. In fact in most cases for actuation at zero gravity, the solar panel fully actuated and then oscillated back and forth between completely open and closed positions until finally resting at open (Fig. 4B). This is expected in a reduced gravity environment where the release mechanism will ultimately be exhibited. Furthermore, it was observed that after the release, there was extra momentum that changes the orientation of the free flyer. Depending on the specific CubeSat mission, orientation may or may not be important with respect to solar harvesting of energy and/or scientific result. In order to stop the oscillations and counteract mechanical energy changes to the system, there should be considerations when integrating the release mechanism into a CubeSat format for future missions.

Figure 4: Deployments at *1g* (A) and during microgravity (B). Unlike in A), the solar panel simulator is fully actuated in B).

For *1g*, to test the success rate of the mechanism in different orientations, the mechanism is placed in the desired orientation and remains in that orientation. In true deployment, this may not necessarily be the case. In addition, a mission may require that multiple devices be attached at many different orientations. In zero gravity, despite the fact that the free flyer was tethered, we discovered that there were many different spatial orientations as a result of the length of the free flyer. In other words, the NASA flyer was free to exhibit any orientation at zero gravity because there was no limitation due to contact forces with the grounded plate. This is illustrated for 4 different spatial orientations of the free flyer in Figure 5.

In all, there were 17 deployments each with its own unique spatial orientation. For the first flight, there was only one unsuccessful deployment. At this time, we are not certain the cause of the malfunction of that particular release mechanism. Before the second flight, this same release mechanism was not able to be refurbished. Thus, 8 of the mechanisms were tested during both flights with all 8 being successful during the second flight. Altogether, we can confidently yield a success rate of 89% with a reliability rating of 100%. In other words, the mechanisms that were successful on the first flight were also successful during the second flight. Furthermore, the average actuation time from the moment that power was supplied was under 2 s which is on average 2 times faster than the Vectran cable cutting time in the NRL mechanism [2]. Notably, one of the mechanisms exhibited a ~3-4 s actuation time although we are not certain the reason of delayed deployment.

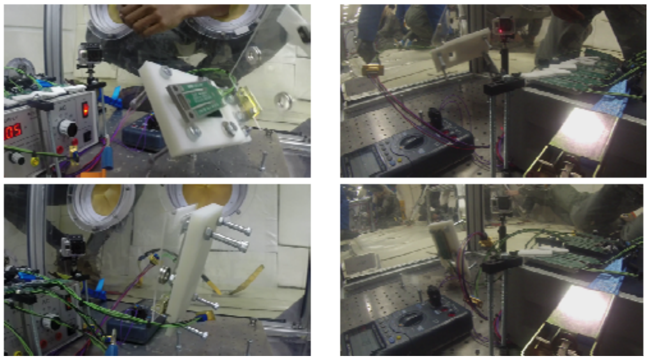


Figure 5: Four different spatial configurations of the NASA WFF Free Flyer (white) during periods reduced gravity. Note that in picture on the bottom left the mechanism has yet to be deployed.

4 Conclusion

In conclusion, we achieved 17 successful deployments employing the NASA WFF release mechanisms in a microgravity or space-like environment. This study yields valuable information on the space-readiness of the new technology and will be followed by further examination and comparison of this work for both commercial and other government release mechanisms like the NRL release mechanism. Furthermore, the NASA WFF system is expected to be featured on rocket mission in January 2014 and integrated into the CubeSat currently being developed by Morehouse College's Micro-Optics Research & Engineering Laboratory with an expected launch date of 2020.

Acknowledgment

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