

PEZ: Expanding CubeSat Capabilities through Innovative Mechanism Design

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ABSTRACT

Since the beginning of the CubeSat program, developers have been pushing the envelope of the capabilities that can be achieved in such a small and standardized package. As CubeSat missions have become more complicated the external surface area of these cubes has become a limiting factor for the missions. In order to harvest as much power as possible, the external surfaces are usually dedicated solely to solar arrays, thus limiting the external surface area that can be used for the primary mission. The ALL-STAR mechanical team has developed an innovative and unique system that allows for both the electrical power subsystem engineer and the science instrument engineer to have full access to the exterior of the satellite without sacrificing any of the quality or capabilities of the CubeSat and its overall mission. In order to accomplish this, the ALL-STAR team has developed mechanisms that deploy both solar arrays and the payload section from the standard 3U CubeSat. The PEZ (Payload Extension Zone) effectively doubles the available area for the solar array on the CubeSat as well as allowing the payload to have access to the exterior of the satellite. These mechanisms are also innovative in that they use simple concepts and mechanisms to greatly reduce their impact on the mass and volume of the CubeSat as a whole. Through this cooperative design between maximum power collection and payload access, the ALL-STAR bus will allow for even greater CubeSat capabilities to be achieved.

1.0 INTRODUCTION

Since the introduction of the CubeSat standard by California Polytechnic State University and Stanford University¹, the CubeSat community has continually strived to expand the capability of the science missions that can be carried out on such a compact platform. CubeSat designs have been greatly limited by the fact that there is simply a fixed amount of external surface area. This limitation usually results in satellites that must carefully balance the use of all of the external surfaces for the generation of power while still allowing the science mission some limited external access. The ALL-STAR mechanical team has developed a way in which both of these objectives can be better achieved while minimizing the impact on the available volume of the satellite.

The system that the ALL-STAR team has developed to better balance the use of the external surface area is the PEZ (Payload Extension Zone). This system allows for the CubeSat to deploy its external solar array structure, exposing the internal structure and the science payload section, while still conforming to the 3U CubeSat standard during launch. The two different configurations of the system can be seen in Figure 1. In order to accomplish this, the team integrated simple mechanical elements that make up the three phases of the deployment system. These phases are restraint & activation, mechanical deployment, and locking mechanisms.

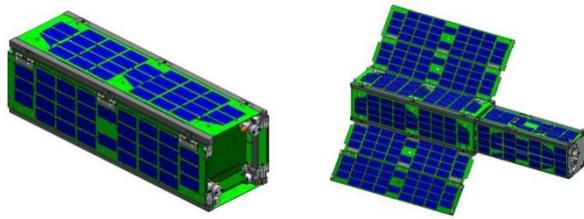


Figure 1: ALL-STAR Configurations

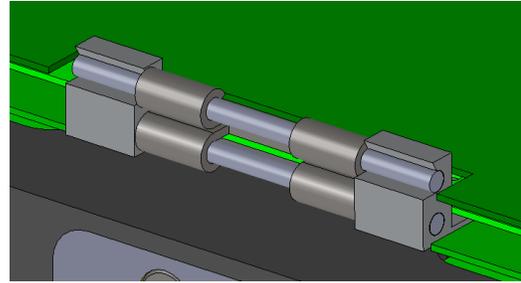


Figure 3: Center Tie-Down Hinge

2.0 RESTRAINT & ACTIVATION

During launch, the outer most deployable solar panels are restrained to the system through the use of three separate mechanisms. The first of these mechanisms consists of fixed clip & bracket sets located on the payload end of the satellite. One of these clip & bracket sets is shown in Figure 2. The clip is directly connected to the payload section of the PEZ while the bracket is attached to the solar panel. In the launch configuration, torsional springs installed in the solar panel hinges want to act to deploy the solar array. This motion is restrained by the interference between the clips and brackets.

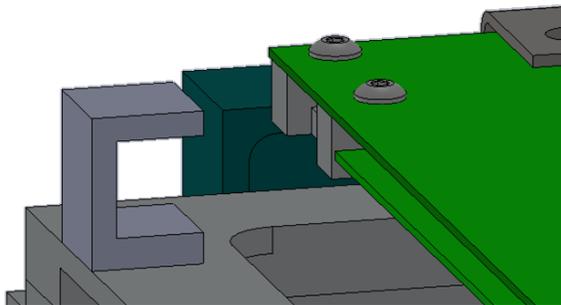


Figure 2: Fixed Solar Panel Clip & Bracket

The middle of the solar panel is restrained through the use of a modified hinge. This hinge consists of a hinge plate with an extended central pin, and a restraint bracket that will be attached to the main structure. This restraint system works by constraining the rotation of the outermost solar panels so that they will only deploy once the inner panel has begun to rotate away from the main structure. To accomplish this, the bracket attached to the main structure has an open barrel design. This restricts the rotational motion of the panel until the inner panel has begun to move. This stowed configuration can be seen in Figure 3.

The final solar panel restraint is a rotating claw mechanism that hooks into the solar panels in the same way as the fixed clips. These claws, shown in Figure 4, are attached to the main structure requiring them to be rotated out of the locked position upon deployment. In the launch configuration, the lower portion of the claw interfaces with the PEZ structure. This contact prevents the claw from rotating out of the solar panel bracket.

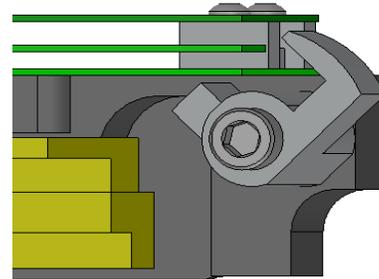


Figure 4: Rotating Claw & Bracket

The PEZ deployment is restrained during launch through the use of a mini-Frangibolt actuator. This tiny device, shown in Figure 5, uses a shape memory alloy (SMA) that is compressed prior to integration. The actuator is then installed using a modified 4-40 bolt and torqued to 2.5 in-lbs. When the deployment has been activated, the SMA is heated and expands to its uncompressed length. While this change in the length of the actuator is very small, approximately 40 mil., this expansion increases the preload on the bolt until the bolt fractures. Once fractured, the mechanical deployment systems are allowed to function. Figure 6 shows the implementation of this system. In the figure the Frangibolt and its housing are connected to the PEZ structure and the right components are connected to the main structure. This system insures that both pieces of the bolt are contained following deployment and allows for the mechanical deployment systems to be actuated.



Figure 5: Mini-Frangibolt²

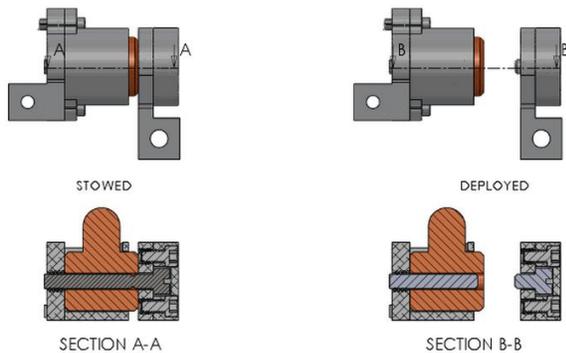


Figure 6: Frangibolt Implementation

3.0 MECHANICAL DEPLOYMENT

The main deployment of the PEZ utilizes constant force springs, shown in Figure 7, that are held in tension in the launch configuration. When the Frangibolt fractures, these constant force springs will begin to retract similarly to how a tape measure will when you release it. The main structure and the PEZ structure interface through smooth sliding surfaces that allow the springs to extend the structures to the final configuration. These sliding surfaces are much like the rail surfaces of the P-POD¹.

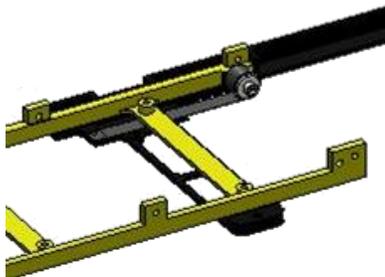


Figure 7: Constant Force Spring Implementation

During the deployment, the fixed clips move linearly with the PEZ structure and are disengaged from the brackets on the back of the solar panels. This movement of the PEZ structure also removes the contact interface with the rotating claws. The rotating claws contain an integrated torsional spring which acts against the main structure to rotate the claws out of the solar panel restraint brackets. Figure 8 shows both the stowed and deployed states of the rotating claws. In the figure the blue surfaces are where the torsional spring's legs interface with the parts. The motions of both the fixed clips and the rotating claws allow the external panels to begin to rotate.

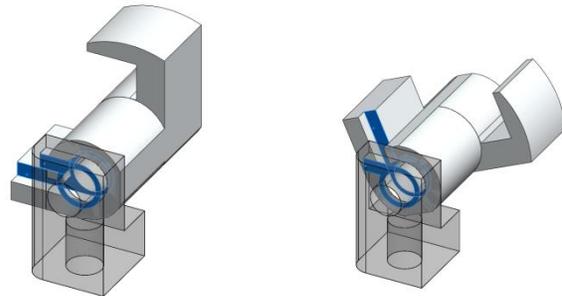


Figure 8: Stowed and Deployed Rotating Claw

The solar array hinges also contain torsional springs that rotate the panels to their deployed configuration. Once the panels have rotated through a minimum angle the center restraint will release and the outermost panels will be allowed to rotate freely as well. This release is shown in Figure 9. As the inner panel begins to rotate, the pin on the outer panel will move out of the locked position until the pin clears the restraint bracket. After the center tie-down has been cleared, all of the panels are allowed to freely rotate until they have reached their fully deployed angle as shown in Figure 10.

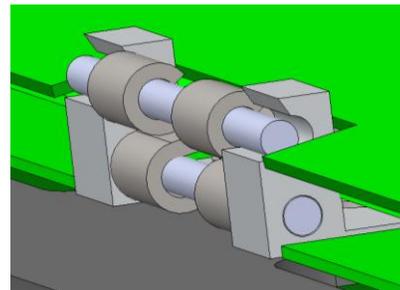


Figure 9: Center Tie-Down

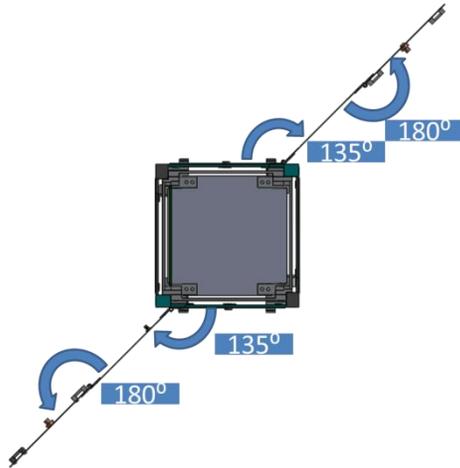


Figure 10: Final Deployed Solar Array Angles

4.0 LOCKING MECHANISMS

Once the ALL-STAR structure has fully deployed, it is important that the satellite remains as rigid as possible and that the mechanisms for the deployment do not re-collapse. In order to prevent such events, the mechanical team has also incorporated several locking mechanisms. The first mechanism is an integrated spring plunger and hard stop interface between the main and PEZ structures, as seen in Figure 11. The hard stop, seen as the two ramped surfaces, insures that the constant force springs cannot over deploy the structure to a point in which the structures would separate from one another. Once the structures have been fully deployed, the integrated spring plunger falls into a locking hole that insures that the structures do not re-collapse.

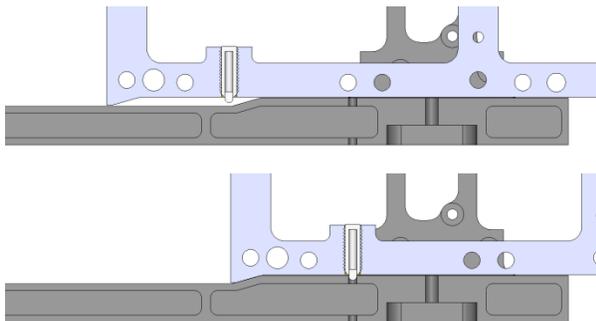


Figure 11: Locking Spring Plunger and Hard Stop

The solar panels are also held into their final configuration by hard stop mechanisms that have been designed into the hinges. As can be seen in Figure 12,

the hinges have been modified to include a feature that interferes with the opposite component of the hinge. The interference surfaces have been designed to stop the hinges at the deployed angles of 135° and 180°. The panels will also be held against this hard stop by the torsional springs that will be providing a residual holding torque on the hinges.

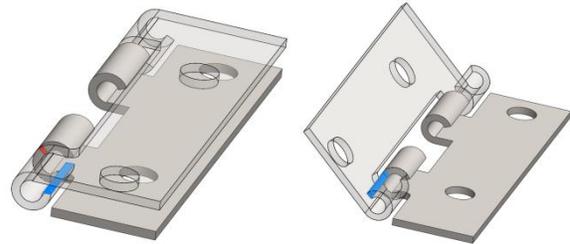


Figure 12: Hinge Plate with Hard Stop, 135° Configuration

5.0 DESIGN ADVANTAGES

All of the mechanisms for the ALL-STAR system have gone through preliminary testing and the team is currently in the process of integrating the components into the complete system. This system will also be tested in the zero-g environment through the Microgravity University, “Grant Us Space” flight week, July 7th - 16th 2011. Through these tests, the team will gain greater understanding of the dynamics of the system as well as its reliability in a zero-g environment.

The mechanisms that have been designed by the ALL-STAR team provide distinct advantages to the CubeSat designer. Through the implementation of this system, the external solar array area has been increased from approximately 159 in² to 318 in². The system doubles the dedicated area to the solar arrays while still allowing for 75 in² to be specifically dedicated for the use of the scientific payload. These benefits should allow for even greater innovations in CubeSat mission capabilities.

6.0 REFERENCES

- 1 CubeSat, California Polytechnic State University, Last Accessed 6/7/11. <http://cubesat.calpoly.edu/>
- 2 TiNi Aerospace, Mini-Frangibolt Video, Last Accessed 6/7/11. <http://www.tiniaerospace.com/fbt/minifrangiboltvideo.html>