PEZ: Expanding CubeSat Capabilities through Innovative Mechanism Design

Tyler Murphy
Colorado Space Grant Consortium
Adviser: Chris Koehler
Tyler.Murphy@colorado.edu
March 22, 2011

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. Introduction
Since the introduction of the CubeSat standard by California Polytechnic State University and Stanford University [1], 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 with very little impact on the available volume of the satellite.

The system that the ALL-STAR team has developed 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 as 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

2. Restraint & Activation
The deployable solar panels are constrained during launch by three mechanisms. The first of these mechanisms is the simplest in design consisting of simply a fixed clip that is attached to the internal structure that hooks into a bracket on the back of the outermost solar panel, seen in Figure 2. The middle of the solar panels are restrained through the use of a modified hinge that restrains the outer most panel from rotating away from other panel until both panels have rotated through a minimum angle. The final restraint is a rotating claw mechanism that hooks into the solar panels in the same way as the fixed clips but in distinctly different. These claws, shown in Figure 3, are attached to the main solar array structure requiring them to be rotated out of the
locked position upon deployment. While in the launch configuration, the back of the clip interfaces with the internal structure. This restrains the claw so that it is not able to rotate.

![Figure 2. Fixed Solar Panel Clip](image)

**Figure 2. Fixed Solar Panel Clip**

While in the launch configuration, the back of the clip interfaces with the internal structure. This restrains the claw so that it is not able to rotate.

![Figure 3. Rotating Claw Solar Panel Clip](image)

**Figure 3. Rotating Claw Solar Panel Clip**

The PEZ deployment is restrained during launch through the use of a mini-Frangibolt actuator. This tiny device, shown in Figure 4, uses a shape memory alloy (SMA) that is compressed prior to integration. The actuator is then installed using a modified 4-40 bolt to a specified torque. As can be seen in Figure 5, when the Frangibolt is activated, the SMA is heated and expands to its uncompressed length. While this change in the length of the actuator is very small, it increased the preload on the bolt until the bolt fractures. Once fractured, the mechanical deployment systems are allowed to function.

![Figure 4. Mini-Frangibolt [2]](image)

**Figure 4. Mini-Frangibolt [2]**

3. Mechanical Deployment

The main deployment of the PEZ utilizes two constant force springs, shown in Figure 6, that are held in tension in the launch configuration. When the Frangibolt fractures, these constant force springs will begin to retract. The two structures interface through smooth sliding surfaces that allow the springs to extend the structures to the final configuration.

![Figure 5. Frangibolt Implementation](image)

**Figure 5. Frangibolt Implementation**

![Figure 6. Constant Force Spring Implementation](image)

**Figure 6. Constant Force Spring Implementation**

During the deployment, the fixed clips move linearly with the internal structure and are disengaged from the bracket on the back of the solar panels. This movement of the internal structure also allows the rotating claws to rotate out of their brackets. The rotating claws have an integrated torsional spring that produces this torque. These two motions allow the external panels to begin to rotate due to torsional springs that are installed in the panel’s hinges. 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.
4. Locking Mechanisms

Once the ALL-STAR structure has fully deployed, it is important that the satellite remains as ridged as possible and that the mechanisms for the deployment don’t 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 on the external structure, as seen in Figure 7. The hard stop insures that the constant force springs can’t over deploy the structure to a point in which the structures would separate. Also the integrated spring plunger falls into a locking hole that insures that the structures don’t re-collapse.

![Figure 7. Locking Spring Plunger and Hard Stop](image)

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 8, the hinges have been modified to include a feature that interferes with the opposite component of the hinge. These two surfaces have been designed to stop the hinges at the deployed angles. The panels will also be held against this hard stop by the torsional springs that will be providing a holding torque.

![Figure 8. Hinge Plate with Hard Stop](image)

5. Design Advantages

The mechanisms that have been designed by the ALL-STAR mechanisms 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. References

[1] CubeSat, California Polytechnic State University
http://cubesat.calpoly.edu/

http://www.tiniaerospace.com/fbt/minifrangiboltvideo.htm1