Concept Generation

EML 4551C – Senior Design – Fall 2011 Deliverable 3

Team # 6
Panel Interlocking Mechanism for Solid Reflector

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Project Overview

Two teams sponsored by Harris are working together to build a deployable solid reflector prototype for a satellite. Our task at hand is to design and build the interlocking mechanism that will keep each of the solid reflector panels flush and in contact with one another.

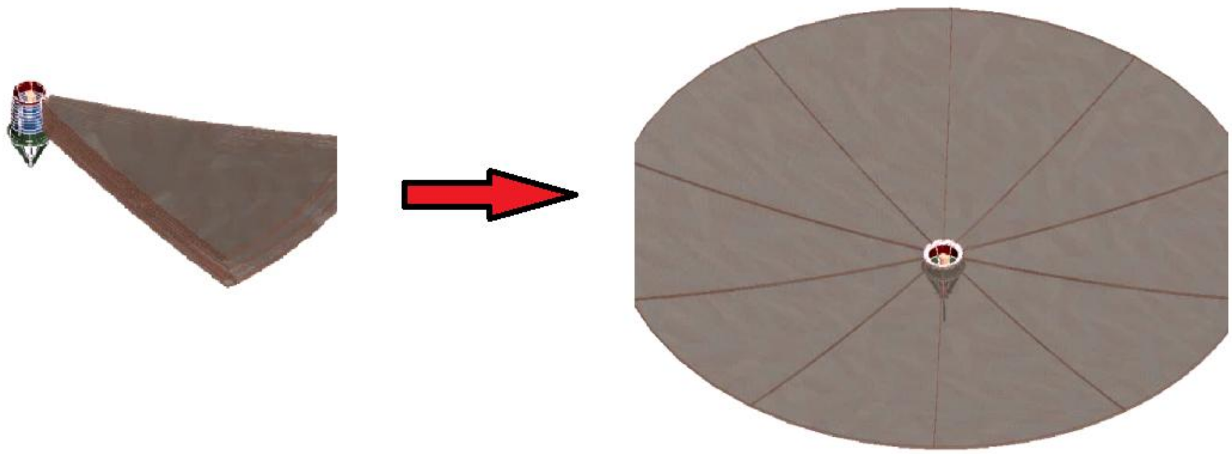

Figure 1: Shows the stacked, stowed position of the panels of the reflector (left) as well as the set up of the final, fully deployed configuration (right)

There are ten panels in total that must mesh and lock together after the satellite deploys. The hub uses rotational motion to spread the panels out, and then linear motion to collapse the panels so that they can mesh and lock together. The actual satellite is about 10 meters in diameter, but for our project we are building a scaled prototype. The satellite is designed for space and ground applications. The goal is to produce a working prototype of this system to demonstrate how it moves from its stowed position, how it would sit in a rocket on the way to space, (seen on the left in Figure 1 above) to its fully deployed configuration (seen on the right in Figure 1) as it would stand once deployed in space. Though it is being designed with space applications in mind, our team is focusing on ground applications because our prototype must work on earth to demonstrate this concept. Our group is focusing our attention on designing a means to autonomously latch and hold each panel to its two adjacent panels without failing.

Selection Criteria

- Alignment Criteria
  - **(1) Engagement Proximity**
    - This is the minimum distance the panels must travel before the interlocking mechanism can engage.
  - **(2) Engagement Force**
    - This is the force required to engage the interlocking mechanism once the panels are within the minimum *engagement proximity*. A negative force represents attraction, such as would be experienced with a magnetic based mechanism.
- Structural Criteria
  - **(3) Separation Failure**
    - This defines the force required to separate the panel-panel seams once the interlocking mechanisms have engaged.
  - **(4) Stability**
    - Resistance to flexure after deployment, such as would be caused by acceleration of the assembly. Hypothetical sources include gravity for ground applications, and post deployment repositioning of a satellite for space applications. Stability also encompasses dynamic stability and vibration dampening.
- Implementation Criteria
  - **(5) Reversibility**
    - The ability of the reflector to collapse into the stowed position after deployment. An autonomously reversible reflector would be ideal for many ground applications, but is outside of the project scope where the primary consideration is for spaced based applications. Demonstration of the prototype, however, will require assisted separation of the panels, and the final design must take this into consideration.
  - **(6) Complexity**
    - Intricate designs will incur increased costs for production, and increase potential sources of failure. The simplest possible solution that satisfies the all criteria should be favored.

Concepts

Concept 1: Plate Design

This concept is very simple and easy to install. A stiff plate is installed beneath each panel and the adjacent panel will rest on the plate once the panels are collapsed. The simplicity of this design is important because it can be applied with other designs if needed. The design on its own will not be secure enough.

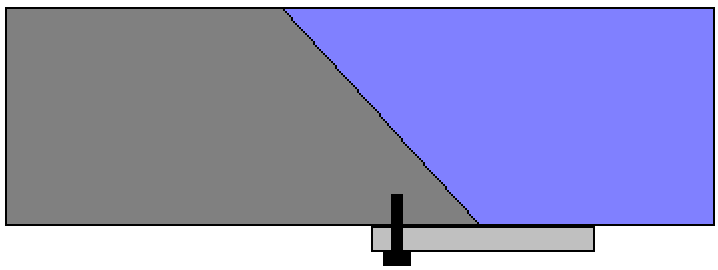

Figure 2: Cross section, side view of two panels

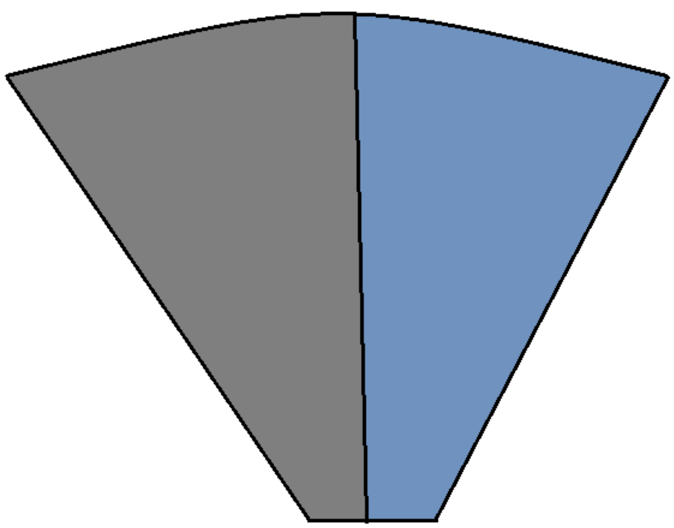

Figure 3: Top view of two panels

Concept 2: Cup and Cone Design:

This design concept is a simple cup and cone. Each panel will have a cup on one side and a cone on the other side. When the panels come together the cup and cones will mesh together just like a jigsaw puzzle. This will help lock the panels together and keep them from shifting around after the panels collapse. This design concept will be able to be utilized with other designs as well.

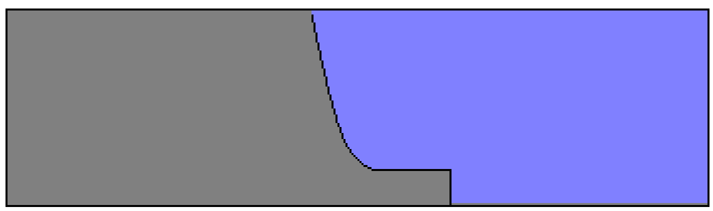

Figure 4: Cross section, side view of two panels using the cup and cone design

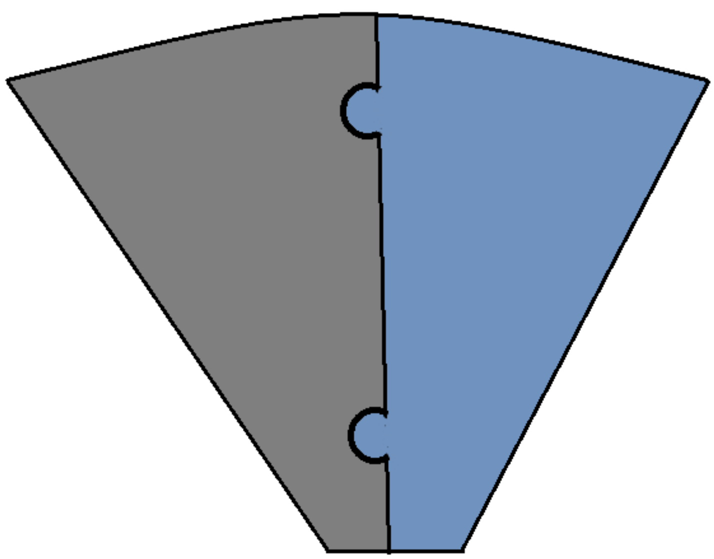

Figure 5: Top view of two panels using cup and cone design

Concept 3: Solenoid Design

This concept utilizes the common plunger solenoid. By sending an electrical current into a solenoid, the plunger deploys into the adjacent panel where a hole is located. The plunger will secure the two panels together. Using solenoids will require that the mechanism has a source of power, which can be a drawback compared to other designs that do not require power. However, the strength of the connection may be more important than the inconvenience of needing power.

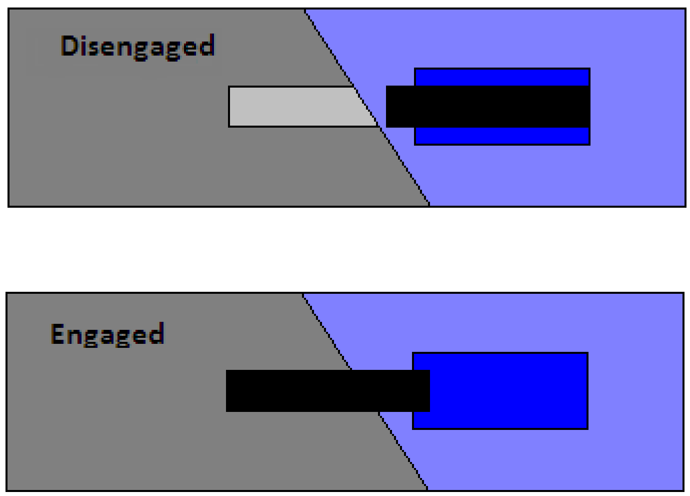

Figure 6: Cross section, side view of two panels using solenoid design

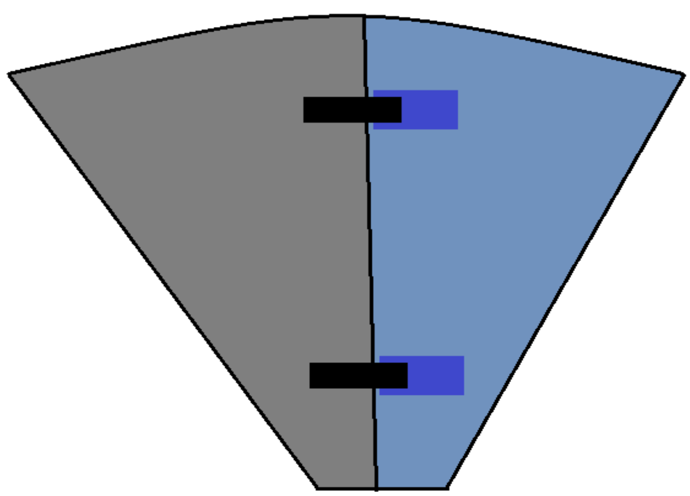

Figure 7: Top view of two panels using solenoid design

Concept 4: Magnet Design

This design uses magnets to lock the panels together. The magnets are a cheap way to unite the panels once deployed without having any worries of mechanical failure. When reversing the operation to bring the panels back to a stowed position, the force of the magnets will have to be overcome by the hub. As a result, the magnets cannot be too powerful for the reversible prototype.

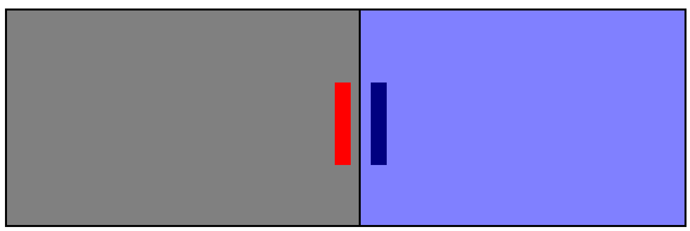

Figure 8: Cross section, side view of two panels using magnets

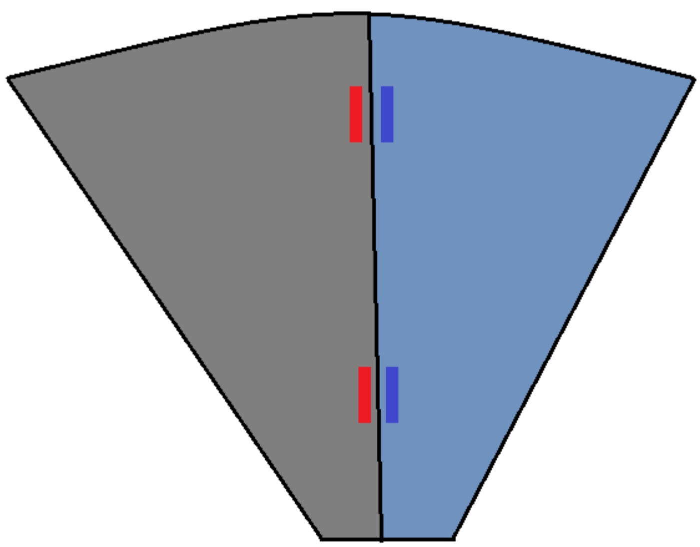

Figure 9: Top view of two panels using magnets

Concept 5: Double Spring Design

This design (shown in figure 9 to the right) implements the use of two springs as the means to the latching between panels. There is one large spring (1) contained within the cross section of each panel. This spring is connected to a piece of material (2) that is designed with a curved bottom and a flat top. Within this material is a smaller spring (3) connected to a smaller piece of material (4) that is rectangular in shape. The smaller spring (3) is initially fully compressed while the larger (1) remains uncompressed in its stowed position. Once the panels have completed their path of rotational motion, they will move downward to find a final, level position. As two panels come together at a time, one side of the lower stationary panel will essentially be pushing along the curved bottom of the piece of material (2) which is exposed on the opposing side of the moving panel. This will force the larger spring (1) to compress and the exposed material (2) to submerge within the panel's cross section. The material (2) will continue to be pushed until the larger spring (1) reaches its fully compressed state. This mechanism is designed so that once the surfaces of the two panels are flush, the large compressed

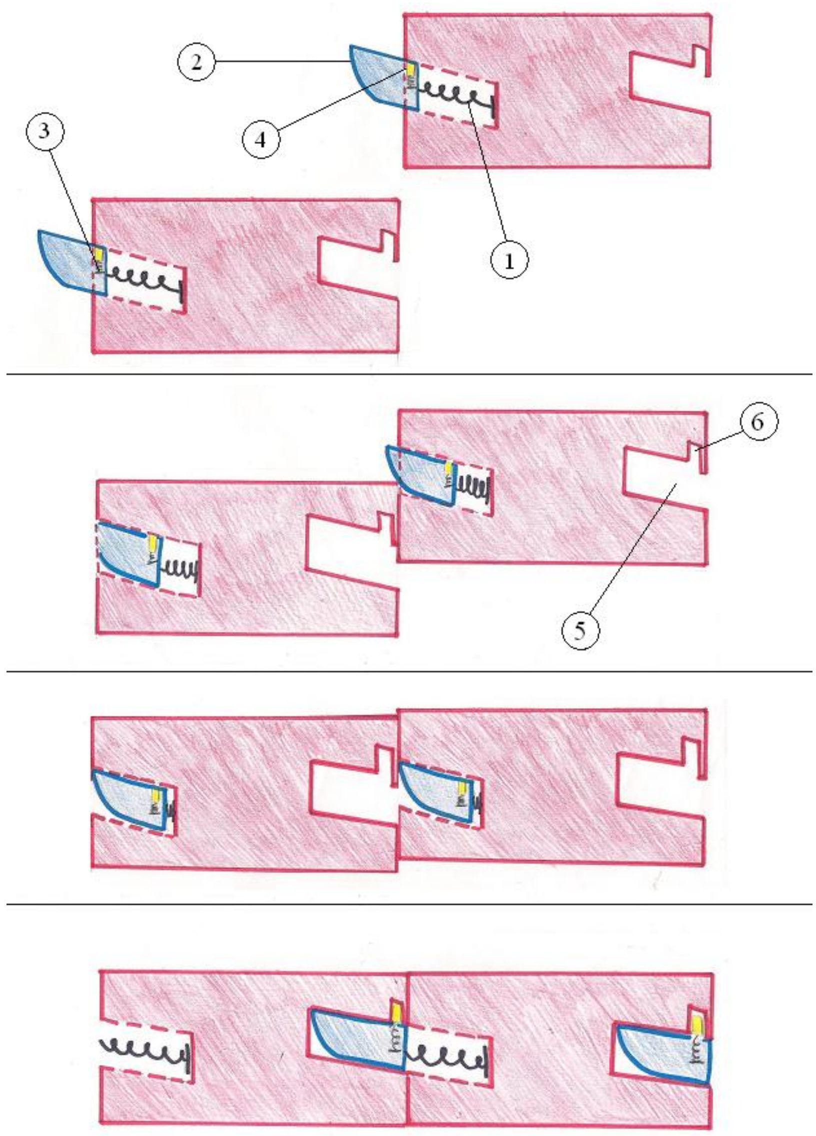

Figure 10 shows the double spring design first with no contact between panels, second at initial contact, third at maximum compression of the large spring (1) and fourth in its fully deployed configuration.

spring (1) and material (2)will meet an opening (5) and no longer have a force to maintain its compressed state. It must then be released, and the material (2) will be moved into the opening of the opposite panel beside it (5). As it is inserted, the smaller spring (3) is designed with the same intentions as the larger, only releasing in an upward direction. There is a small slot (6) within the larger opening (5) on the side of the panel that will hold the smaller piece of material (4) once the smaller spring (3) is released. The larger spring assembly is used to restrict vertical motion, while the smaller spring assembly restricts horizontal motion, thus providing a final, flush position between panels.

The benefit to this design is its security. Once the panels have reached their fully deployed positions, the interlocking provided by the spring assemblies will lock and hold them together. However, this design is non reversible. Additionally, with numerous moving parts the chances of failure are increased due to the complexity of design. The material selection would also be limited to those stiff enough to support the force of the large spring against the thin panel wall without failing.

Concept 6: Ring and Latch Design

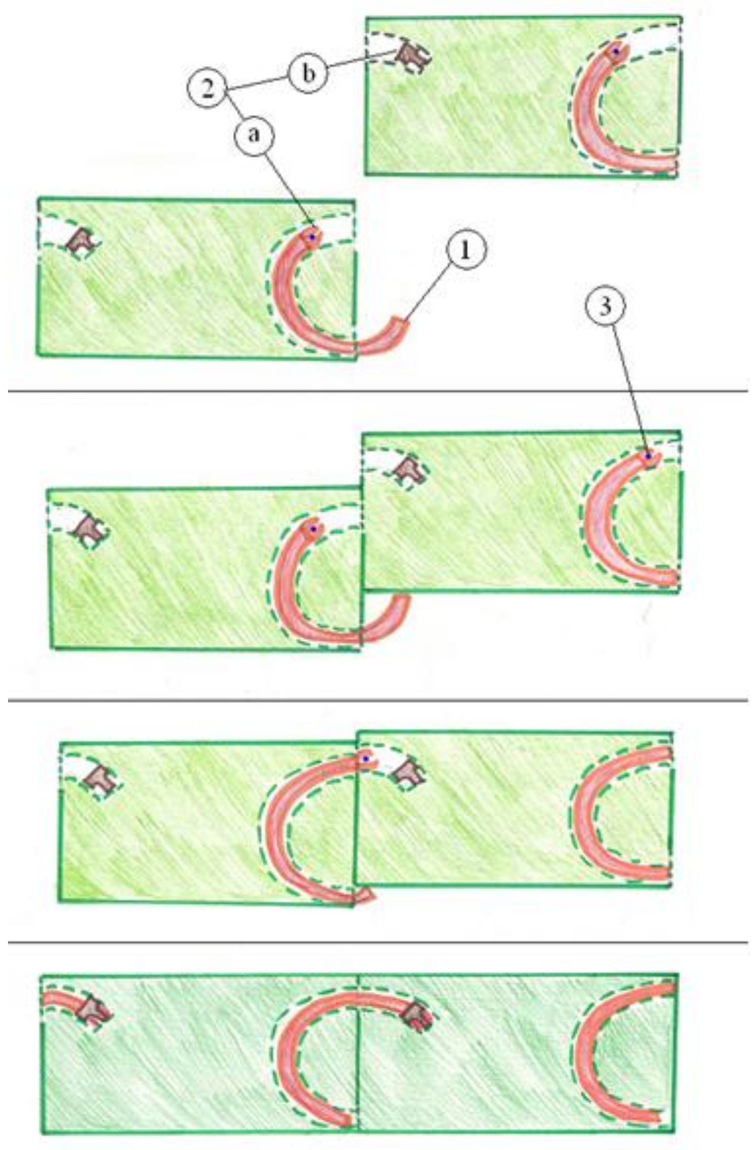

Figure 11 shows the ring and latch design first with no contact, second upon initial contact, third as the ring passes into the moving panel and fourth in its fully deployed configuration.

This design (shown in figure 10 to the right) incorporates a ring (1) and a latch assembly (2ab) to hold the panels together. Within the cross section of each panel is a ring (1) that is partially exposed on one side. After panels are rotationally flush, they begin to move downwards. Due to their offset vertical position relative to one another, the process of aligning panels happens as the panels meet and latch together one at a time, with a brief period of time in between connections. In focusing on two panels at a time, it can be modeled as one panel moving downwards towards a lower, stationary panel. At this point the panels are rotationally flush, and as they come together the moving panel will come in contact with the semi-exposed ring (1) contained within the other panel. The downward force of the moving panel will, in turn, cause the ring (1) to rotate within the other panel. As rotation continues, the ring will circle back around to an opening in the first moving panel. The moving panel is essentially pushing the ring (1) through the other panel and back into itself. This panel must exert enough force to both move the ring (1) and then engage the latching mechanism (2ab). The latching mechanism consists of two parts. The first half (2a) is located on the upper end of the ring

(1). It consists of two pieces of material that are held together using an uncompressed spring (3). The second half of the latching mechanism (2b) rests inside the opposite end of the panel. It is designed with intentions of the first half of the mechanism (2a) to fit, but only when the spring (3) is under compression. Thus, the panels must be exerting enough force on the ring (1) to rotate it and, in turn, produce enough force so when both ends of the latching mechanism (2ab) come together, the spring (3) on the first half (2a) will compress and slide through the second half (2b). The second half (2b) is also designed so that when the first half (2a) reaches a certain point, there is no longer any compression on the spring (3) and it can return to its uncompressed state, remaining locked in place.

The benefit to this design is its security. Once the two pieces of the latching mechanism (2ab) have interlocked, there are no forces acting inside of the panels to recompress the spring (3) and release it from its fastened state. However, this design is not reversible and the dependency on the force of the panels to rotate the ring (1) increases the chance of failure. Also, the force that is being exerted on the ring (1) is dependent on the angle of contact between the panel and the ring (1). This angle is constantly changing due to the rotation of the ring and is, in turn, changing the force the panel is exerting. This fluctuation increases the chance of snag which increases the chance of failure.

Concept 7: Magnet and Pin Design

This design utilizes a pin (1) and three magnets. One magnet (2) is located within the neck of the pin (1) while two others (3) act as a latch. This magnetic latch (3) is connected onto the base of the panels by hinges (4), essentially acting as a door. For each panel, the pin (1) rests at the base of one side of the panel, while the magnetic latch (3) is located at the base on the opposite side of the adjacent panel. As one panel moves downwards, its pin (1) and the latch (3) on the stationary panel beside it are designed to come into contact with one another. The pin (1) will use the force exerted by the moving panel to overcome the restriction of the latch (3). As the panel continues to move down, the latch (3) will continue to open until it surpasses a maximum point and the latch doors (3) are no longer in contact with the pin (1). At this point, the latch (3) will return to its initial position, only now all three magnets (2 and 3) are aligned and the pin (1) of one panel is contained within the magnetic latch (3) on the opposite adjacent panel.

This design is beneficial in that it is reversible. However, the design also uses the panel's downward movement as a latching force, as opposed to solely using the motor to connect the panels. This adds extra stress to the panels and increases risk of failure.

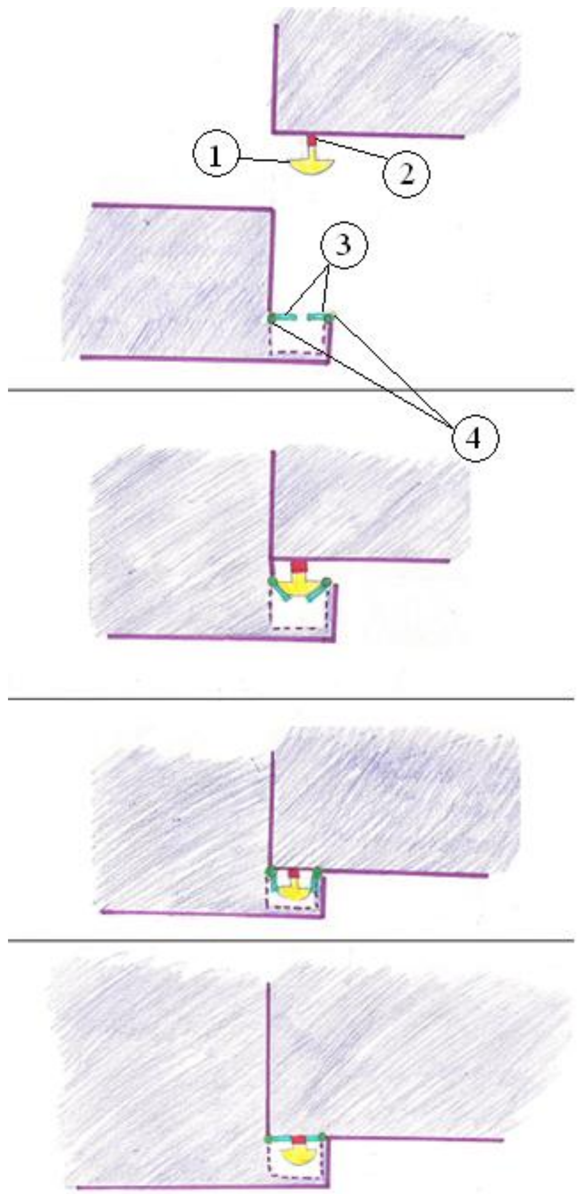

Figure 12 shows the magnet and pin design first with no contact, second at initial contact, third when the latches (4) are at their maximum opened position and fourth in the fully deployed configuration.

This particular design can be altered in both the contour of the panels as well as the latching mechanism. For example, instead of using magnets a non magnetic mini touch latch (seen in figure 12 on the right) could be used to replace the pin (1) and magnets (2 and 3).

Figure 13: the alternative design of a non magnetic mini touch latch

Cable Concepts

Cable Concept 1: Guyline

Tensioned guy lines are used to restrict movement of a structure beyond a certain point. They are commonly employed to increase the effective base of a collapsible or portable structure while only nominally increasing the stowed footprint.

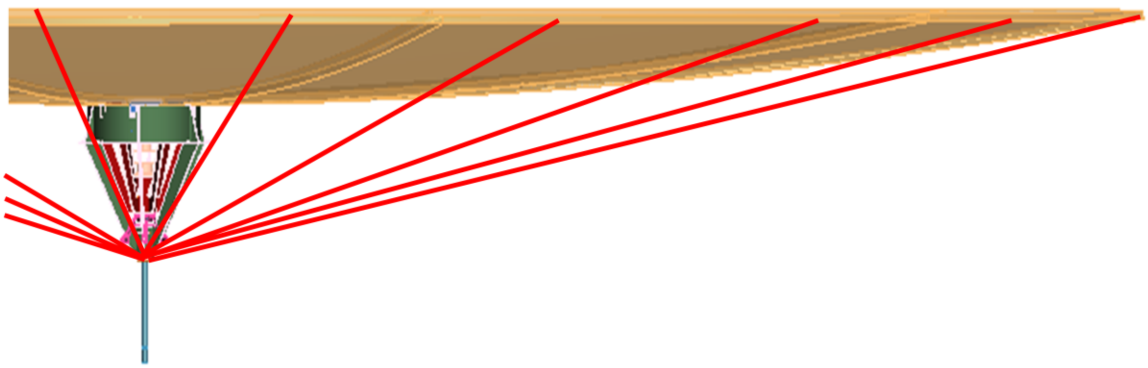

Figure 14 – Fully deployed panels using Guylines.

The figure illustrates a side view of a potential guyline implementation. The guyline cables (red) run between the hub assembly and the outer edges of each panel. This concept will require slack cable to accommodate the stowed position of the reflector, necessitating some means of tensioning the cables either during or after deployment. A tensioner of some kind will be necessary for all cable implementations. The tensioner may feasibly be incorporated into the hub assembly, which would increase the functionality of the hub motor.

Compared to alternate cable implementations, this guyline concept requires less cable, meaning less potential for cable snag. Guylines may be particularly well suited for applications where the reflector is expected to experience high forces, such as would result from a wind gust.

Cable Concept 2: Shoelace

The shoelace concept consists of slots along the edges of each panel (dark red). A cable (red) passes through a slot on one panel and then through a corresponding slot on the mating edge of the adjacent panel. The cable continues in this fashion, passing back and forth from panel to panel through mating slots along the length of a panel-panel seam. The concept could be implemented with a single cable that skips to the next seam after running the length of the panels, or multiple cables could be employed, one per seam.

The image shows two stages of deployment with a shoelace interlocking cable. The right-most panel-panel seam is in the deployed configuration, while the zigzag of cable to the left illustrates the path of the cable during deployment.

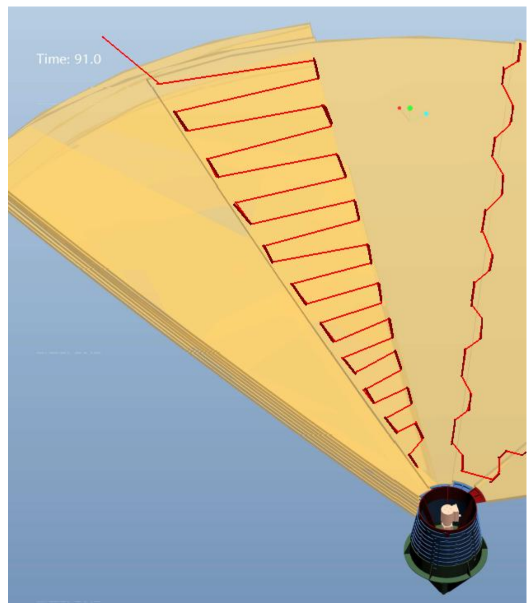

Figure 15 – Shoelace design during the deployment phase. Slack is pulled from an external means and panels come together.

The unique quality of such an interlocking mechanism is that in addition to securing the panels in their deployed configuration, the shoelace cable can be tensioned during deployment to assist with deployment and ensure appropriate positioning. As the cable is tensioned, the mating slots on adjacent panels will be pulled together. This differs from a buckle mechanism for instance, where the hub assembly alone must bring the panels into alignment such that the mating features of the buckle meet precisely. The buckle clasp were to miss, they mechanism would not engage and the reflector would not be considered to have successfully deployed. Such a cable implementation could be advantageous for implementations where alignment is complicated by the panels sagging out of place as by gravity.

Cable Concept 3: Ring Tensioner

The final cable concept is an adaptation of the shoelace. Here, a cable makes a single pass around the deployed reflector. Much of the benefits of the shoelace are achieved while drastically reducing the total length of cable required to achieve a stowed position.

The top right of the image shows a 90% deployed panel-panel seam. Mating rings from adjacent panels are nearly aligned, awaiting only the horizontal hub motion that will bring the panels into a single contiguous plane. Along the left edge of the image are the radial edges of two panels with the ring tensioner cable in the "zigzagged" or stowed position; notice that the cable must run approximately 2x the length of the radial edge to correctly pass through the rings.

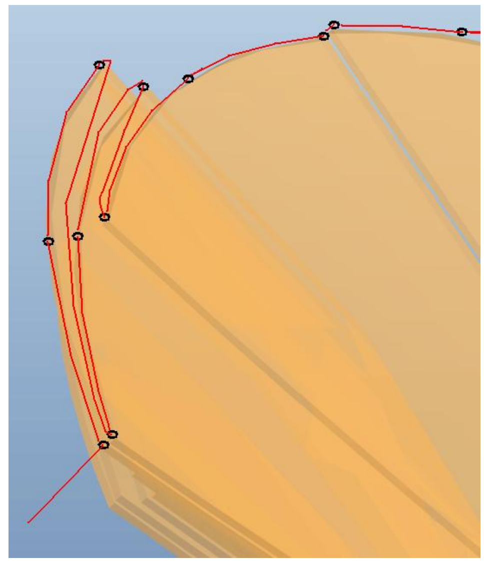

Figure 16 – Cable runs along the outside of the panels and slack is tightened from an external means to deploy the panels.

A variation of this concept would be to mount the rings along the back surface of the panels. Doing so could mitigate risk of the cable catching on the corners of the panels, as well as reducing the total length of required cable.

Decision Matrix

Specifications	Weight Factor	Concept	
		Rating	Score
Engagement Proximity	0.3		
Engagement Force	0.05		
Separation Failure	0.15		
Stability	0.05		
Reversibility	0.2		
Complexity	0.15		
Price	0.1		
		Total	