Deployable Solid Reflector Prototype

Operations Manual – April 12, 2012

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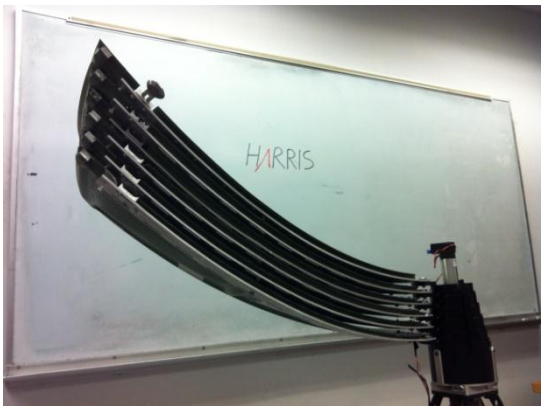

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System Description

The Tangentially Deployable Solid Reflector (TDSR) Prototype consists of two systems: the TDSR prototype panel assembly and the TDSR prototype hub assembly. The figure below shows a breakdown to the TDSR Panel Assembly.

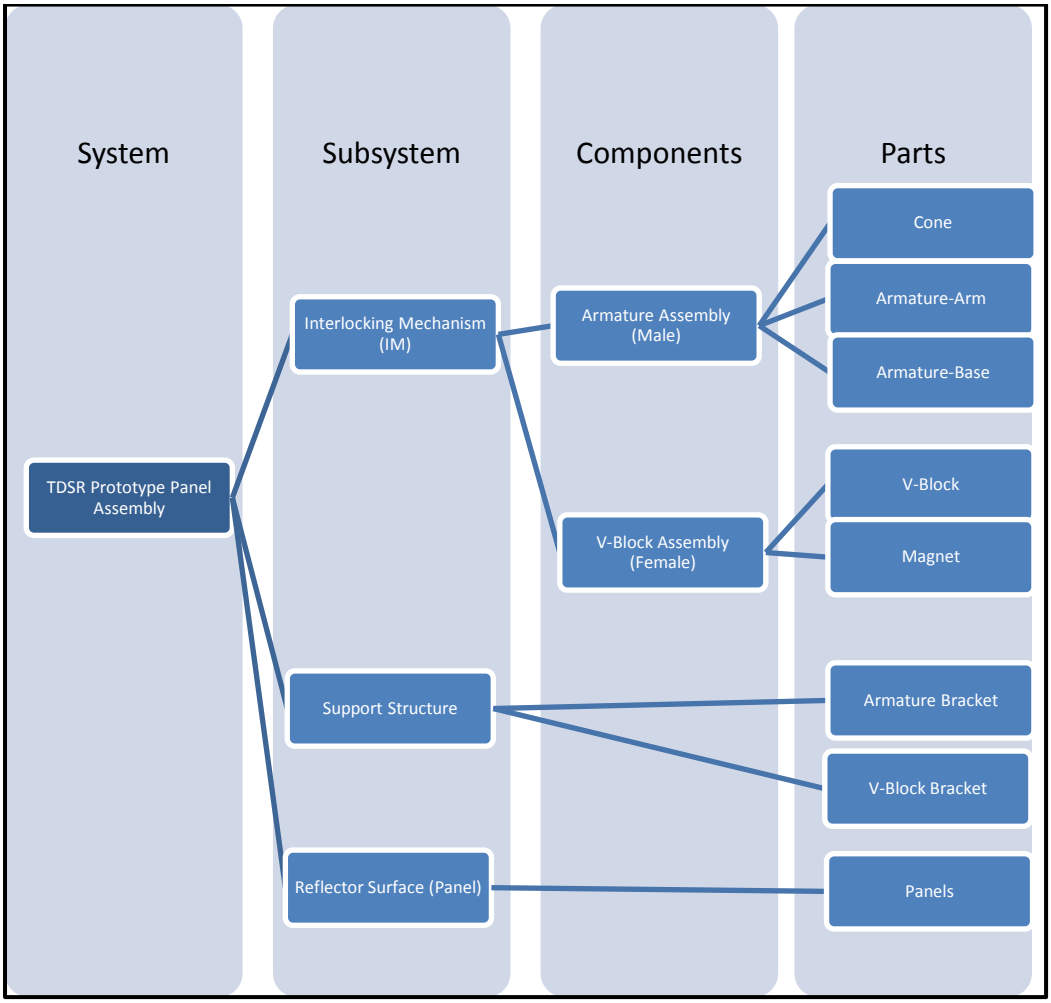


Figure 1: Shows the breakdown of the TDSR prototype panel assembly system within the entire TDSR Prototype

Within the TDSR prototype panel assembly system are three subsystems: the interlocking mechanism (IM), the support structure and the reflector surface. The chosen IM incorporates the use of a kinematic coupling component (cup and cone) along with magnets. The individual parts making up the IM can be seen in the figure above. The cup and cone design was chosen because it provides a means of helping guide the panels to their final, intended locations. Once the panels have finished their rotational course of motion they will then transition to a linear phase of motion. Even the most minimal radial misalignment before this linear phase of motion drastically increases the chance of failure of the latching mechanism to engage. By using cups and cones, the design accounts for a small range of potential

misalignment. In the case that the panels are not in their intended positions after the first phase of motion, incorporating the kinematic coupling component into the second phase of motion will then guide the panels to their precise location.

The second subsystem is the support structure. Consisting of two variations of brackets, the support structure here provides a mountable surface for the IM. The third and final subsystem to the panel assembly is the reflector surface. Here, six panels provide the visualization to the system as a reflector. Furthermore, these panels enhance the stiffness of the overall system and provide a surface to which the support structure can be mounted. These three subsystems, once assembled, form the complete system to the TDSR prototype panel assembly.

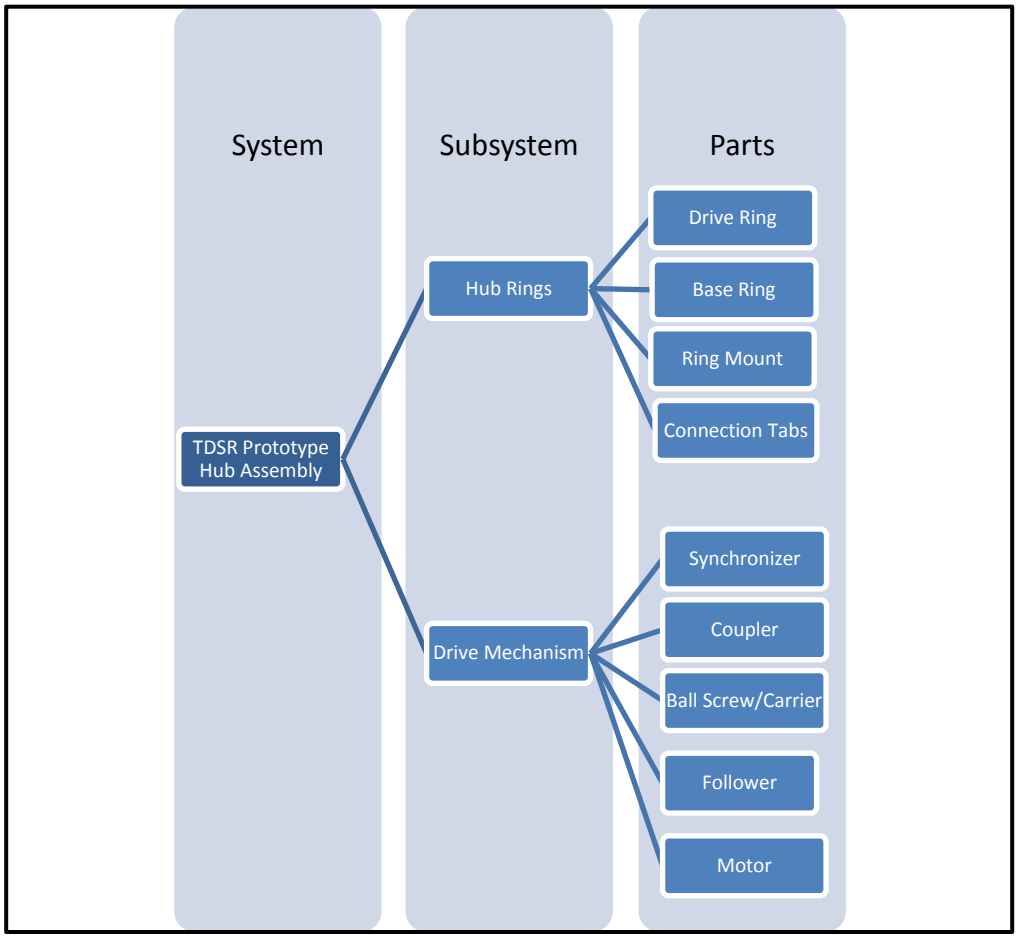


Figure 2: Shows the breakdown of the TDSR prototype hub assembly system within the entire TDSR Prototype

Within the TDSR prototype hub assembly, there are two subsystems: the hub rings and the drive mechanism. The hub rings use a series of vertical slots and pins to guide the motion of the rings as to keep the attached panels aligned properly and accurately. The series 3 pins and 3 vertical slots are located at specific points along the circumference of each rings. The diameter of the main driving rings is 2.75”

while the diameter of the base ring is 4". The ring mount, which it attached to the bottom of the base ring, allows the rings to be connected to the drive mechanism. The connection tabs provide a panel to hub interface.

The drive mechanism consists of parts that are broken down in the figure above. The drive mechanism, especially the synchronizer and the ball screw, creates a means for the panels to be rotationally deployed then linearly retracted into position. With the help of the follower and coupler, the timing of the system is perfected so that all motions are carried out fully. Since a substantial amount of torque is needed to deploy the panels at a low speed, a Brushless DC Motor was implemented into the system.

Functional Diagram

The figure below shows a breakdown of functionality of the TDSR system. The primary function of the prototype is to demonstrate its capability in delivering the panels from an initially stacked position to a fully deployed configuration in which the panels are securely interlocked and the entire system represents that of an actual reflector system.

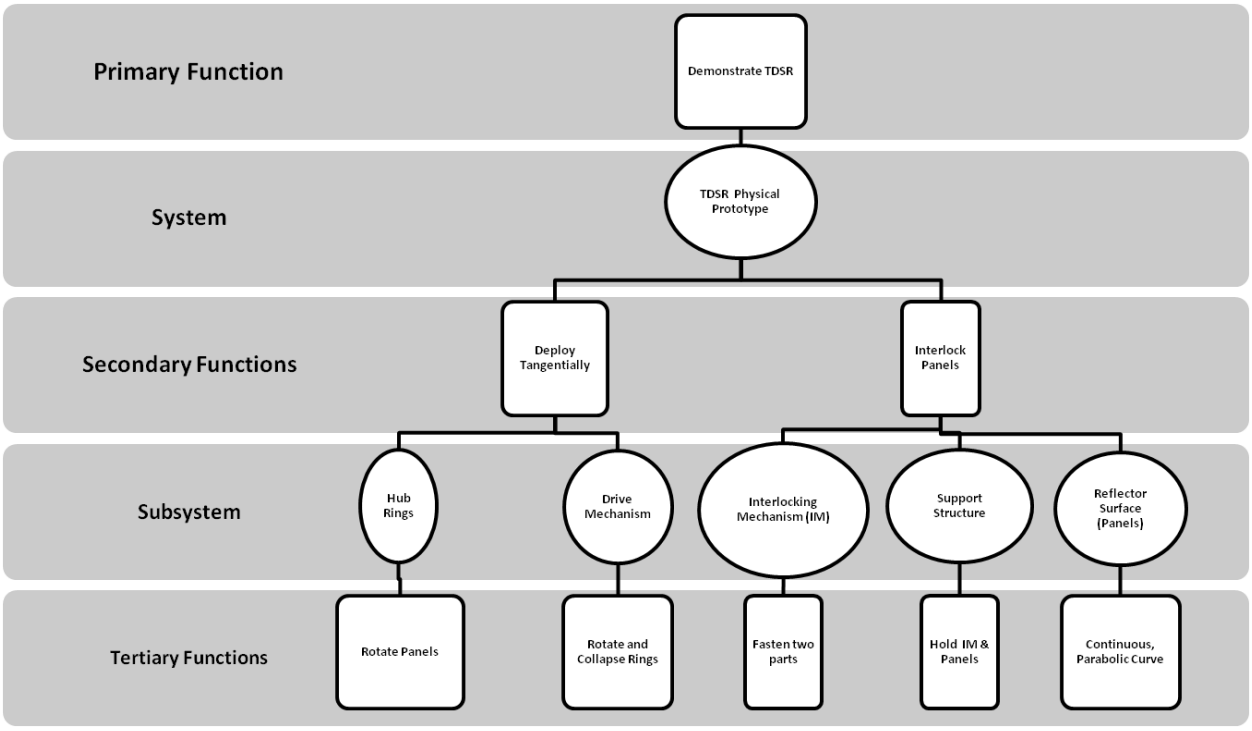


Figure 3: Functional Diagram of the TDSR Prototype System

As can be seen in the figure above, the TDSR system is capable of two secondary functions: tangentially deploying and interlocking the panels. The system must be capable of doing both of these in

order to successfully demonstrate the TDSR's capabilities. In order to accomplish each of these secondary functions, the system is comprised of a series of subsystems. These subsystems are responsible for the most basic functions within the overall system. The specific task to the system and corresponding subsystems can be seen in the figure above.

Material Specifications

The various parts, their quantities, vendor and details assessing their individual and total costs can be seen in the following two tables. The first table gives the details to all of the materials comprising the TDSR panel interlocking mechanism assembly. The second table gives the details to all of the materials comprising the TDSR hub mechanism assembly.

Table 1: Cost of all the materials involved in the assembly, testing and modifications to the panel assembly of the TDSR

Vendor	Item Description	Qty	Unit Price	Total Cost
McMaster Carr	Multipurpose Aluminum Alloy 6061 Rectangular Bars (1/2" x 1" x 3')	2	17.23	34.46
	Multipurpose Aluminum Alloy 6061 Rectangular Bars (1/8" x 1" x 6')	6	9.97	59.82
	Multipurpose Aluminum Alloy 6061 Rectangular Bars (1/4" x 1" x 6')	5	16.02	80.10
	Multipurpose Aluminum Alloy 6061 Rectangular Bars (1/16" x 1/2" x 6')	1	2.04	2.04
	Multipurpose Aluminum Alloy 6061 Rectangular Bars (1/4" x 8" x 1')	1	16.63	16.63
	Machine able 1117 Low-Carbon Steel Rods (1" diameter x 1')	4	10.35	41.40
	Wrap Around Safety Glasses	1	7.31	7.31
K&J Magnetics, Inc.	Grade N42-Nickel Plated Magnets (5/8" diameter x 1/10" thick)	12	1.40	16.80
	Grade N42-Nickel Plated Magnets (5/8" diameter x 1/8" thick)	12	1.64	19.68
	Grade N52-Nickel Plated Magnets (5/8" diameter x 1/8" thick)	12	2.08	24.96
			Total:	**303.20**

Table 2: Cost of all the materials involved in the assembly, testing and modifications to the hub assembly of the TDSR

Vendor	Item Description	Qty	Unit Price	Total Cost
McMaster Carr	Aluminum 6061 Tube (1ft x 4.5" diameter)	1	81.38	81.38
	Aluminum 6061 Tube (1ft x 4.0" diameter)	1	71.86	71.86
	Aluminum 6061 Tube (1ft x 3.5" diameter)	1	48.95	48.95
	Aluminum 6061 Tube (1ft x 3.0" diameter)	1	36.09	36.09
	Aluminum 6061 Rectangular Bars (1/4" x 2" x 3')	1	17.23	17.23
	Aluminum 6061 Rectangular Bars (2"x 1')	1	32.95	32.95
	Aluminum 6061 1 Rectangular Bars (1/8" x 6"x 3')	1	26.78	26.78
	Screw- 6-40 Black Oxide Alloy Steel 3/16" (100 pack)	1	11.22	11.22
	Ball Screw- 3/8" diameter, 1/8" travel dist./turn, 1 ft. long	1	30.68	30.68
	Ball Screw Nut- 3/8" diameter, 1/8" travel dist./turn, 136 lb load cap.	1	93.89	93.89
	Steel Hand Taps 3 (6-40 thread)	3	4.74	14.22
A.M. Metal Finishing	Hard anodizing with Teflon coating	on all aluminum	374.50	374.50
MicroMo	MicroMo 2657 DC motor	1	742.90	742.90
	Feedback Controller	1	491.00	491.00
			Total:	**2073.65**

The total cost of all materials used towards the fabrication, testing, modifications and assembly of the TDSR prototype, consisting of both the hub and panel assemblies, is $2376.85. It should be noted that all manual labor was provided by the FSU/FAMU College of Engineering Machine Shop. Additionally, the panels used in the prototype were provided by Harris Corporation, and all connecting hardware used in the assembly of the TDSR panel interlocking mechanism assembly was provided as well.

Circuit diagram

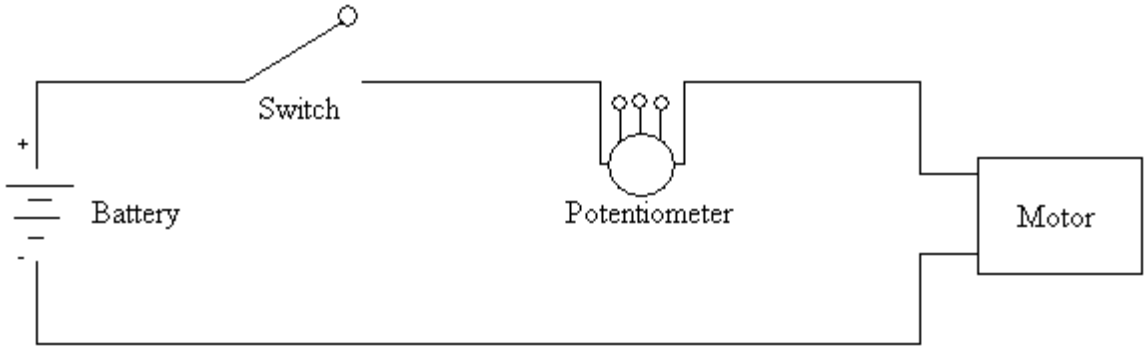


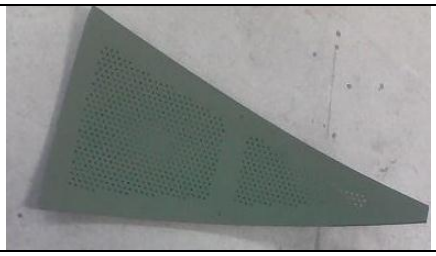
Figure 4: Shows the circuit diagram for the TDSR system

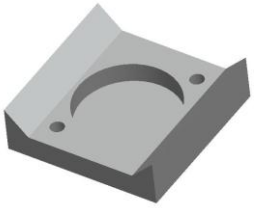
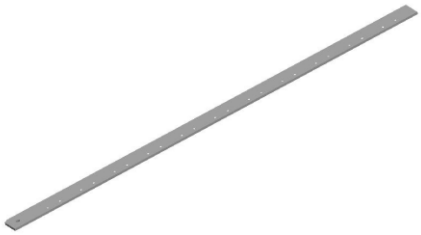
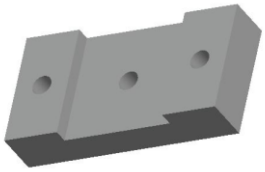
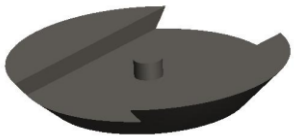
In order to more accurately and safely deploy the panels, a circuit like the figure above was created. The addition of the switch allows us to provide power to the motor more easily; this also allows us to cut the power quickly. The potentiometer acts as a variable resistor or rheostat. This allows us to increase and decrease resistivity in order to control the amount of power the motor receives.

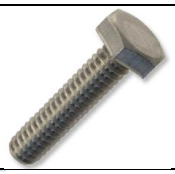
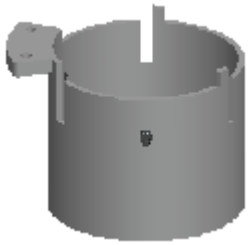
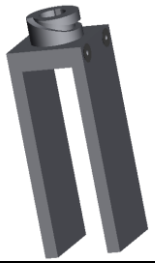
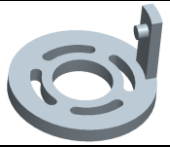
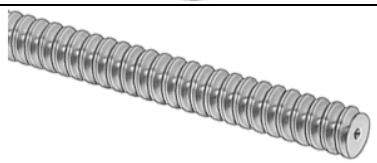
Instructions of Assembly

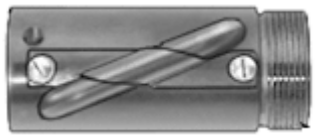
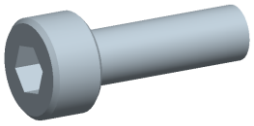
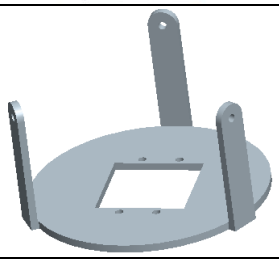
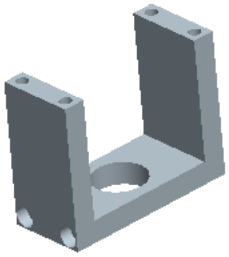
Required Materials:

Table 3: Shows the part number and quantity to the individual parts used to assemble the TDSR prototype

Part Number	Part	Quantity	Picture
1	Panel	6	
2	V-Block Bracket	6	

3	UNC 4-40 Screw	66	
4	4-40 Washer	66	
5	Set Screw	6	
6	Magnet	6	
7	V-Block	6	
8	Armature Bracket	6	
9	Armature Base	6	
10	Cone	6	

11	Armature Arm	6	
12	4-40 Plastic Screw	12	
13	¼-20 Bolt	12	
14	Hub Rings	6	
15	Synchronizer	1	
16	Coupler	1	
17	Follower	1	
18	Ball Screw	1	

19	Ball Carrier	1	
20	Key	1	
21	Hub Pins	18	
22	Motor	1	
23	Base Plate	1	
24	Ball Nut Mount	1	
25	Power Source-Battery	1	

There are six panels (1) required in the prototype assembly. The figure below is shows the orientation of the references to these panels (1) that will be mentioned hereafter.

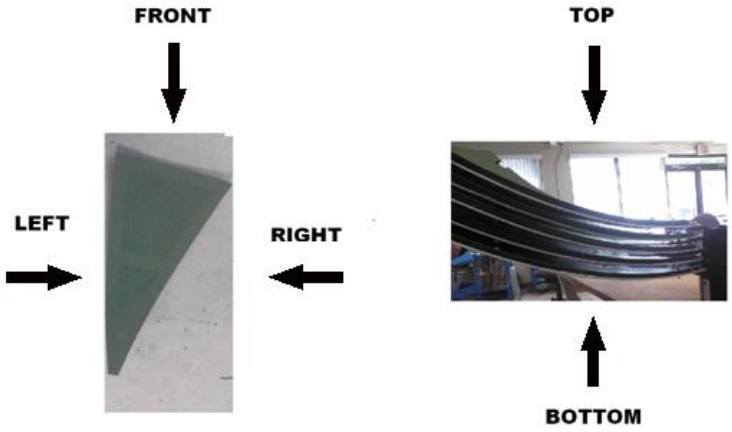


Figure 5: Shows the orientation to the references made in the following assembly description of the panels of the TDSR prototype.

The following figures are provided for the ease of assembly of the panel interlocking mechanism and support structure and will be referred to throughout the assembly procedure following them.

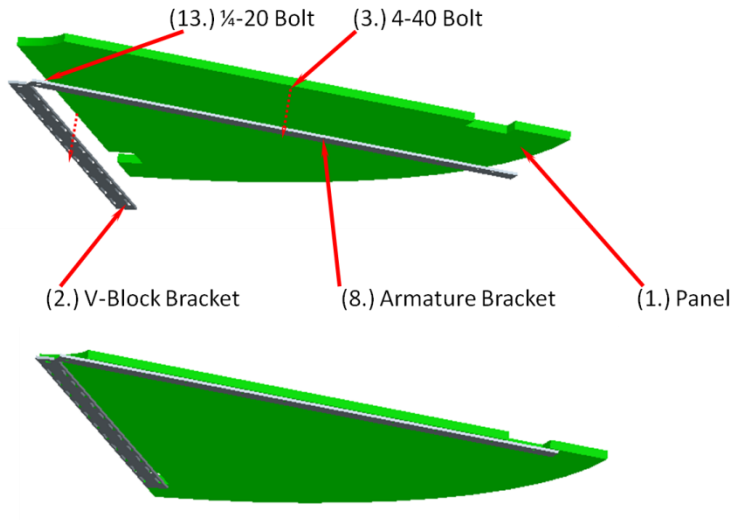


Figure 6: Shows (top) the exploded view for the components making up the support structure and reflector surface as numbered in Table 3 previously introduced and (bottom) the assembled view of the same components.

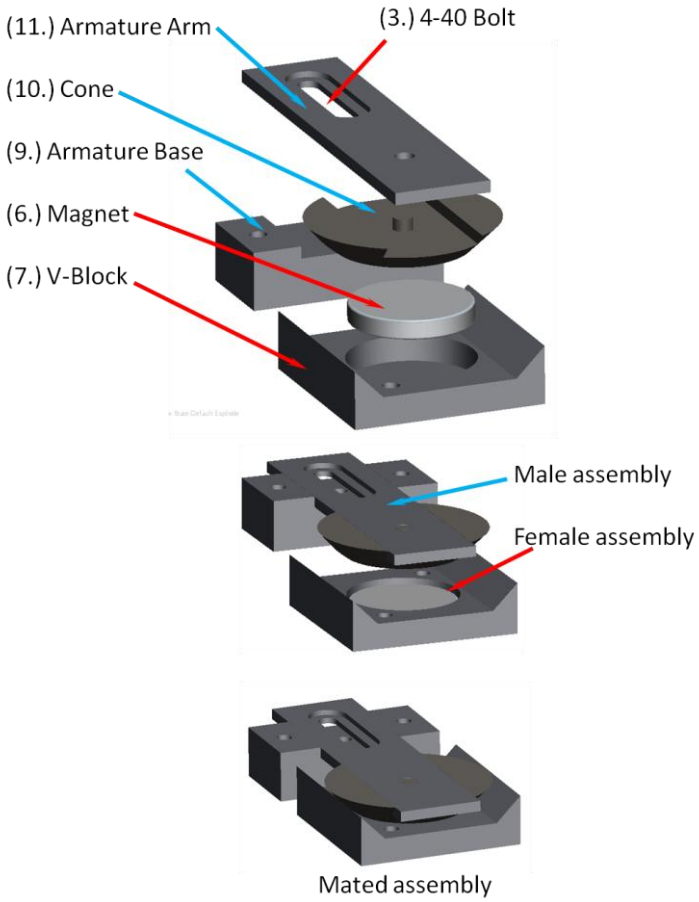


Figure 7: Shows (top) the exploded view of the interlocking mechanism, (middle) the separate male and female assemblies to the interlocking mechanism and (bottom) the mated assembly of the two

Assembly of the Panels:

To the six panels (1) there are three variations: the first panel, panels two through five, and the last panel.

A) Assembly of the first panel (1):

1. Using a UNC 4-40 screw (3) and washer (4), attach a v-block bracket (2) to the bottom of the panel on its left edge, ensuring that the mounting hole of the v-block bracket (2) is located away from the front edge. Visual representation is provided in figure 6.
2. Place a magnet (6) inside the hole of the v-block (7) as seen in figure 7. Mount it using a set screw (5).
3. With the magnet (6) inside, place the v-block (7) on the v-block bracket (2) where the material to the panel (1) is removed. Align the holes to the v-block (7) with the slots on the v-block bracket (2) and connect them using two screws (3).
4. Repeat steps 1-3 on the right edge of the bottom of the panel (1).

5. Using two provided holes on the front edge of the panel (1), attach two plastic screws (14) through the bottom surface.

B) Assembly of the second, third, fourth and fifth panels (1):

6. Repeat steps 1-3 on the left edge of the bottom of the second, third, fourth and fifth panels (1).
7. Using a UNC 4-40 screw (3) and washer (4), attach an armature bracket (8) to the bottom of the panel on its right edge. Ensure that the mounting hole of the v-block bracket (2) is located away from the front edge. Visual representation is provided in figure 6.
8. Press fit the cone (10) into the armature arm (11) as seen in figure 7.
9. Place a screw (3) through the slot of the armature arm (11) and connect it to center hole in the armature base (9) as seen in figure 7.
10. Using the two outside holes of the armature base (9), connect it to the provided holes in the armature bracket (8), ensuring that the cone (10) is hanging off of the edge of the panel (1).
11. Using two provided holes on the front edge of the panel (1), attach two plastic screws (14) through the bottom surface.

C) Assembly of the last panel (1):

12. Repeat steps 6-10 on both the right and left edge of the bottom of the panel (1).
13. Using two provided holes on the front edge of the panel (1), attach two plastic screws (14) through the bottom surface.

The following figures are provided for the ease of assembly of the two-step hub mechanism and will be referred to throughout the assembly procedure following them.

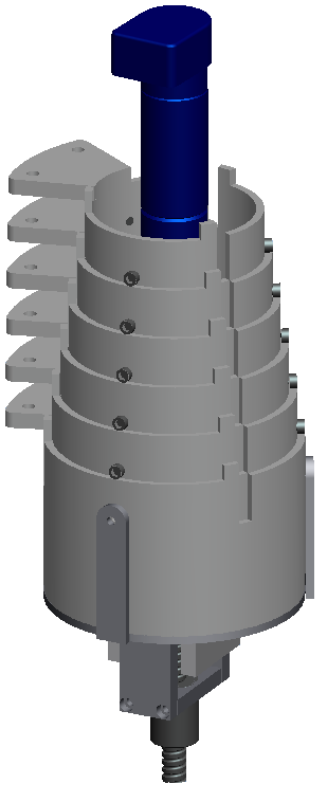


Figure 8 shows the stowed view of the two step hub mechanism

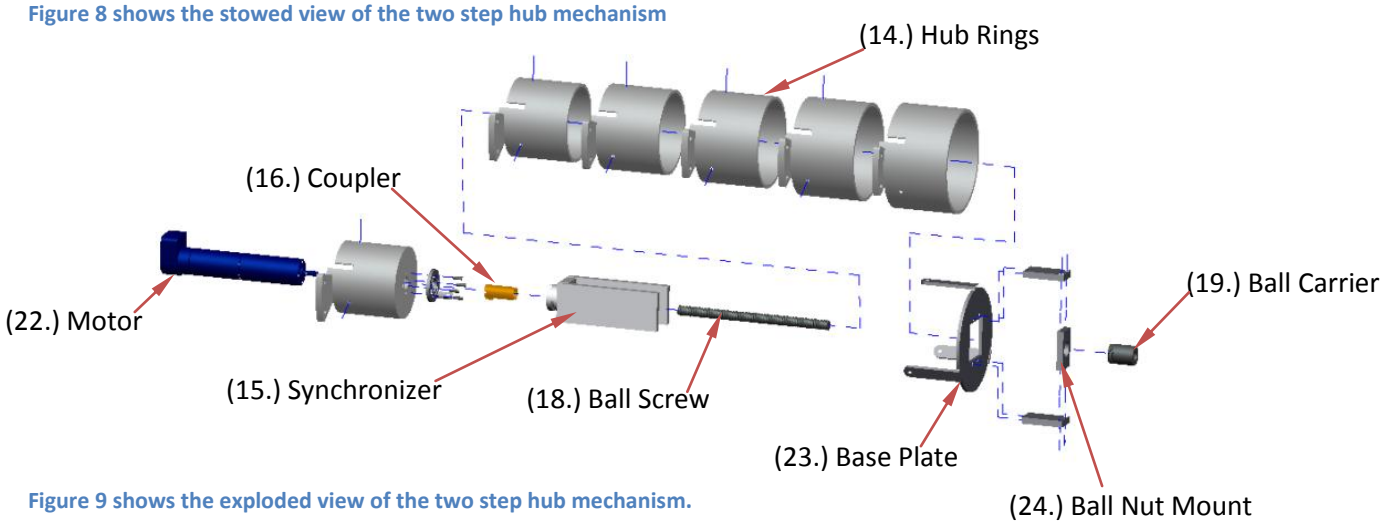


Figure 9 shows the exploded view of the two step hub mechanism.

Assembly of the Two-Step Hub Mechanism:

D) Hub Rings (14) and Base Plate (23)

14. Attach Nut Mount (24) to the Baseplate (23) with 4x UNC 6-32 screws.
15. Insert largest Hub Ring (14) into the Hub Base and secure with 3 UNC 6-40 screws.
16. Insert next largest Hub Ring into the largest Hub Ring.
17. Stack all remaining Hub Rings, except for the smallest, in a similar fashion.

18. Insert Ball screw(18) & Ball carrier(19) assembly into hole on Nut Mount(24) and secure with setscrew.

E) Driver Mechanism

19. Assemble Smallest Hub Ring(14), Motor(22), and Follower(17) together with 4x M3 screws.
20. Attach coupler(16) to Motor(22), secure with setscrew.
21. Slide Synchronizer(15) over ball screw(18) and let rest on Nut Mount(24).
22. Feed the ball screw (18) up through the bottom of the hub rings (14) so that the ball screw (18) sticks up at least 6 inches from the top of the smallest hub ring (14).
23. Attach the coupler (16) to the top of the ball screw (18) so that the flat section of the ball screw (18) is in line with the set screw (5) in the coupler (16).
24. Rotate ball screw with motor to lower Hub ring of driver mechanism into place at the top of the stack of rings

F) Assembly of the panels (1) to the hub rings (14):

25. Stack the hub rings (14) so that the each hub pin (22) is in its appropriate hub slot (23). This is the deployed and retracted position.
26. Use 2 ¼-20 bolts (13) to attach the panels (1) to the connection tabs located on the hub rings (14).
27. Tighten each ¼-20 bolt.
28. Ensure that each cone (10) is correctly aligned within its respective v-block (7). Adjust accordingly.

Operating Procedure:

Before operation can begin, the hub must be set up. In order to do this, the motor must be reversed to raise the center ring only. Once the center ring is high enough to see the coupler, the user can raise the synchronizer by hand. In order to connect the synchronizer, the follower and the coupler key must be aligned. This is done by holding the center ring in position, which in turn holds the follower in position with the opening to the path of the synchronizer. While keeping the follower in position use the motor to rotate the coupler until the coupler key lines up with the keyway on the synchronizer. When both the coupler key and follower are lined up with the synchronizer, rotate the center ring by hand until the follower is turned as far as possible in the path on the synchronizer. The synchronizer is now set up. The next step is to unlatch the magnets holding the panels together and one by one pull them up by hand and turn them into position. Once all the panels are aligned and in their stowed position the deployment can begin.

To deploy the hub mechanism, first turn the motor speed to as low as possible by turning the resistance on the power switch up. Once this is done, turn the power on. Reduce the resistance as needed until the panels are rotating at a slow, controlled speed. Once the panels are all rotated into position and the synchronizer is disengaged, turn the resistance all the way down so as to increase the speed of the motor. This will retract the rings of the hub, causing the panels to be retracted into the same surface plane. The magnets on the panels will catch and a solid reflector will be deployed.

Safety Information

During the operation of the TDSR prototype, there are several precautions that must take place:

- While the system is in use, all objects and users should remain at least six feet from the outermost edge of any panel.
- It is important with the use of magnets to keep fingers and other body parts away from the connection of these magnets to other surfaces, as they possess the risk of pinching.
- Risk of electric shock when hooking up the battery. Please assemble with care.
- Several of the components are very small and should be kept out of reach of children.