Solar Tracking Structure Design

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Team 18

Concept Generation and Selection

Document

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Contents

Introduction

The Solar Tracking Structure Team generated five preliminary concepts that address the needs of the customer while adhering to the project constraints. The customer requires a reliable, efficient, and inexpensive tracking system capable of moving a number of solar panels. Using weighted design criteria and a decision matrix, each design was scored based on its performance in the specified areas. As a result of the evaluation the team has decided to utilize a Nickel-Titanium wire based, single axis tracker. The design eliminates the need for motorized tracking through the creative use of a shape memory alloy. The team has also been informed that a separate Electrical Engineering team is responsible for any programming tasks. The team schedule has been updated in order to reflect this change in engineering requirements, and this new schedule is provided at the end of the report.

Design 1 - Nitinol

This design focuses on maximizing the efficiency of the East and West movement. The panel's North and South axis is set to the maximum efficiency angle, while nitinol is used to track the daily movement of the sun. A half ellipse shape, shown in Figure 1 is fixed to the axis of the structure.

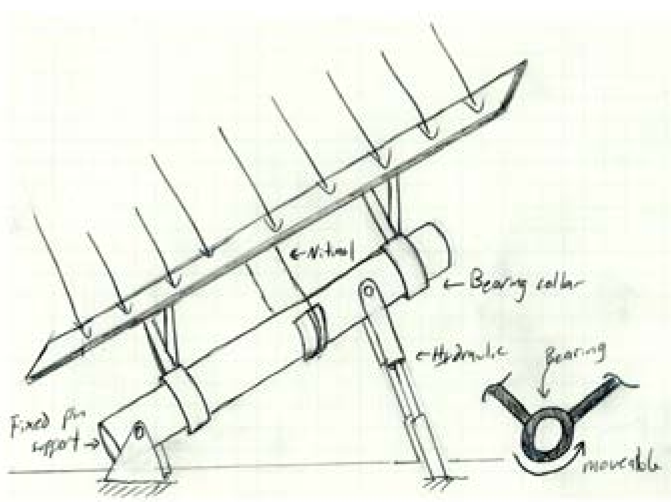

Figure 1: Nickel Titanium Design

The nitinol is wrapped around the half ellipse, causing a rotational movement of the panel when the nitinol is heated. This heat would be due to a small current, around 2.2 amps for a

0.015” in diameter wire[1]. Using a nitinol cable on both sides of the solar panel would allow for movement in both directions. The full design is shown in Figure 2.

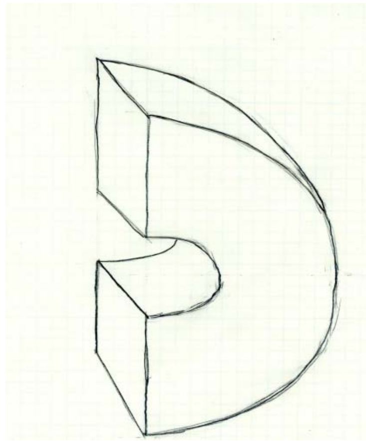

Figure 2: Half Elipse Component

One benefit of this is the small amount of electricity needed. The nitinol does not need very much power to move, dropping the cost. Another benefit is the limited maintenance. If the proper amount of nitinol is used, the cable can last upwards of **10^7** thermal cycles [2]. The nitinol has a tensile strength of around 25 Kpsi, so strength should not be an issue. The biggest advantage of using the nitinol is the removal of the electric motor. The life of most tracking systems are limited by the electric motor being used, so taking this away could really increase the reliability.

The use of nitinol raises the problem of weather conditions. Because the linear movement of the wire is temperature dependent, the colder months could create a problem with the nitinol cooling too fast, making a need for higher currents. However, because the cable relies on the resistance of the material to create heat, there is a chance that this outside temperature could be negligible. The biggest disadvantage is the time delay with the movement. For tracking the sun this is negligible but for manual

Design 2- Tabletop

Having individual tracking systems for each solar panel is not cost efficient. This design focus on having a single tracking system that adjusts all of the solar panels in the system at the same time. Tabletop tracker design is shown in Figure 3 below. The panels are to be placed on the main shaft by attaching the panels to a support axis. The support axis is welded to the main shaft. This will allow the panels to rotate when the main shaft rotates. The main shaft rotates using gears powered by a motor. Figure 3, below, shows the connection between the main shaft and the motor. The connection between the motor and the shaft is a gear box, which consist of a set of spur gears that are known for their rigidity, and ability to handle heavy torques. Since all solar panels in the system have the same motion, only one sensor and motor is needed to pivot all of the solar panels. The solar panels for this tracking device move from East to West. North to South orientation needs to be specified when setting up the frame. North to South rotation is not necessary because of the additional costs associated with adding a second axis.

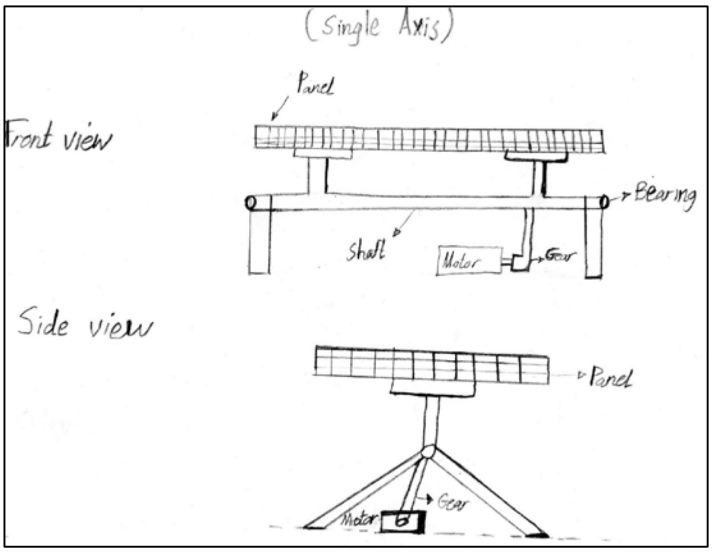

Figure 3: Tabletop Design

An advantage of the system is that the structure can hold multiple solar panels, instead of having several systems for different panels. Another advantage is that the system is very reliable. This is because the system contains fewer moving parts. The last advantage of the design is ease of maintenance and manufacturability. The Tabletop design is made so that the parts are easily accessible. Nevertheless the system has some disadvantages. The first disadvantage is that the system only has one moving axis. The single axis produces less of energy than a dual axis design. The second disadvantage is that the design has a poor space usage aspect, where having all the panels aligned next to each other occupies a lot of space. The last disadvantage is that the design requires a powerful motor since only one motor is used to rotate all of the panels in the system.

The Tabletop design is currently designed to support the maximum number of solar panels given to each team.. The solar panels sit on top of the main shaft that is connected to a gear train. The motor and the gear train should withstand the weight of the panels and rotate them in all weather conditions. For this, the design received a score of four for the supported weight in the decision matrix. The cost for this design received a three for two reasons. The first reason is that the Tabletop is designed to accommodate all of the available solar panels. The second reason is that the design operates with few moving parts. The efficiency of the Tabletop design received a score of two. Since Tabletop is a single axis tracker, it absorbs less sunlight when compared to a dual axis design. The area allowed scored a two on the decision matrix because the design requires a lot of space to operate. There is one motor driven axis and a gear train that control the rotation. The system use little moving parts and little maintenance. For this, the design received a score of three.

Design 3 - Sunflower

The design of the sunflower tracking system is that a single solar panel is mounted on a U shape beam. With the panel mounted, it will track the sun throughout the day. The panel in this design will be able to rotate freely in four directions. The panel is to be placed in the North to South direction using a manual gear. The manual gear consists of a circular gear called "the pinion." The pinion engages the teeth on a linear gear bar called "the rack." Rotational motion applied to the pinion causes the rack to move, thereby translating the rotational motion of the pinion into the linear motion of the rack [5]. The North to South adjustments will need to be performed every month. The panel is to be set on the East to West rotation by using an actuator motor. The actuator motor automatically sets the angle for the best efficiency. Figure 4 below is a rough sketch of the Sunflower design.

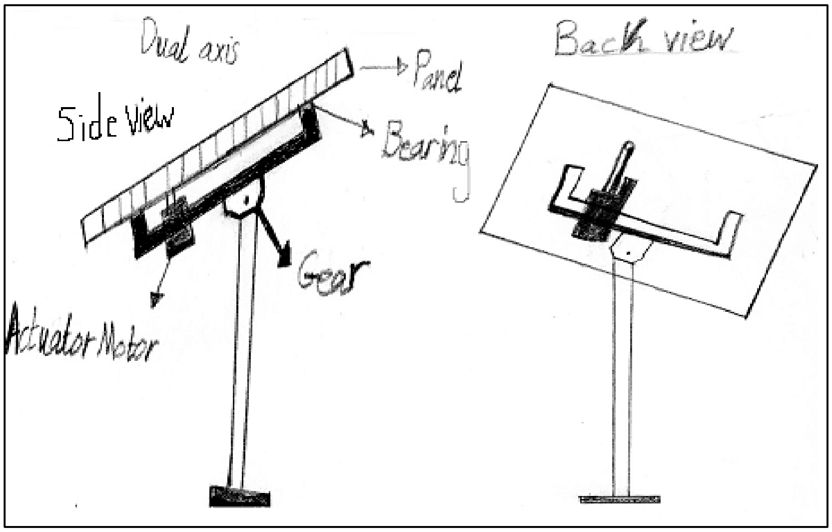

Figure 4: Sunflower Design

The U shape apparatus will be mounted to a universal joint. The universal joint is attached to a beam which is attached to a restricted base. The supporting base for the entire system is a wide square base that helps support the entire weight. The first advantages the system is that the structure requires little space to operate, due to each tracker using only one panel. Furthermore, the second advantage is the accuracy of the system. The Sunflower uses two axes to track the sun thus increasing its efficiency. A third advantage is that the structure is portable. On the other hand, the first disadvantage is that the system requires more maintenance as it uses more parts to track the sun. The second disadvantage is that the system only works for one solar panel, the limitation is due to having a single beam used to support the panel. The last disadvantage is that the structure cannot withstand severe weather conditions. A side view of the Sunflower is shown in Figure 5.

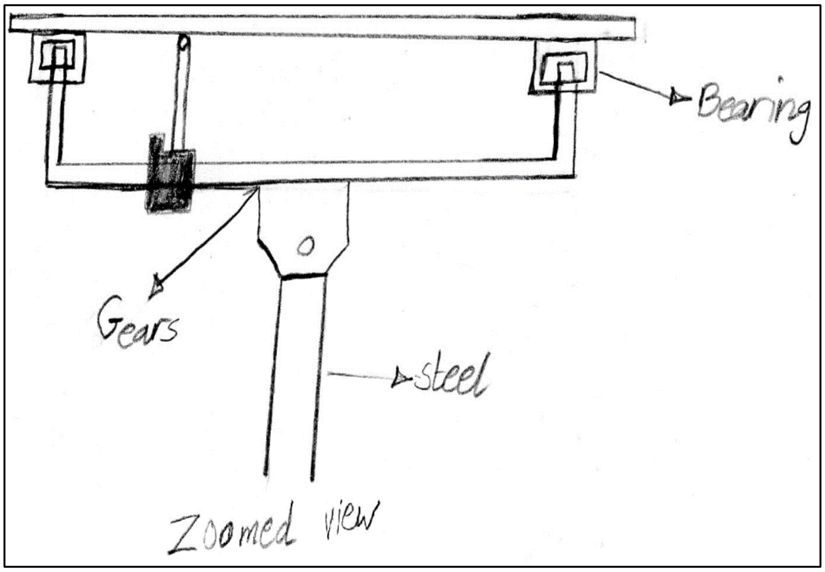

Figure 5: Sunflower Side View

The sun flower design is currently designed to only support a maximum of one solar panels per tracking device. The solar panel sits on top of U shape beam which then sit on top of the main beam. Because there is only one beam that connect s the panel with the base of the structure, the stability of the panels is weak when facing severe weather condition such as wind or snow. Thus the stability of the structure received a score of one for the supported weight in the decision matrix. The cost for this design is one because it is relatively expensive for two reasons. The first is that we need four structures to operate the four panels the team was assigned to work with. The second reason is that there are several parts for axis movements in the structure, such as one actuator motor for one axes movement and a gear train for the second axis movement. For this the design cost received a score of one. The efficiency of the dual axis received the maximum score of four. Since Sunflower is a dual axis design, it can absorb more energy than a single axis solar tracker. The area allowed scored a four on the decision matrix because the design does not require a lot of space to operate. There is one motor driven axis and a gear driven axis that need to be changed and adjusted monthly. This makes it more complicated to maintain and thus the system is less reliable when compared to a design with two motor driven axes. For this, the design received a score of two.

Design 4 TIE Fighter

The TIE Fighter tracking structure is a dual axis design that utilizes motorized East to West tracking and manual North to South tracking. The solar panel is mounted on three rectangular pieces arranged in an "H"-like configuration, with the connecting crossbeam raised above the centers of the two vertical beams. Longitudinal movement is made possible using two bearings that sit on raised platform with a shaft running between them. The shaft itself is connected to a plate using two brackets, and the plate itself is welded to the crossbeam. Two cables are connected to the upper portions of the vertical beams and converge at a single ring. A third cable runs directly to a hand-operated winch, allowing the user to change the North to South angle of the panel by turning the handle. Since the sun's elevation changes with each month, markers will be placed on the winch cable to denote the length needed for maximum efficiency. The structure sits on a rotating platform powered by an electric motor that will allow tracking from East to West, supported by a rectangular stand. The entire design can be seen in the Figure 6 below.

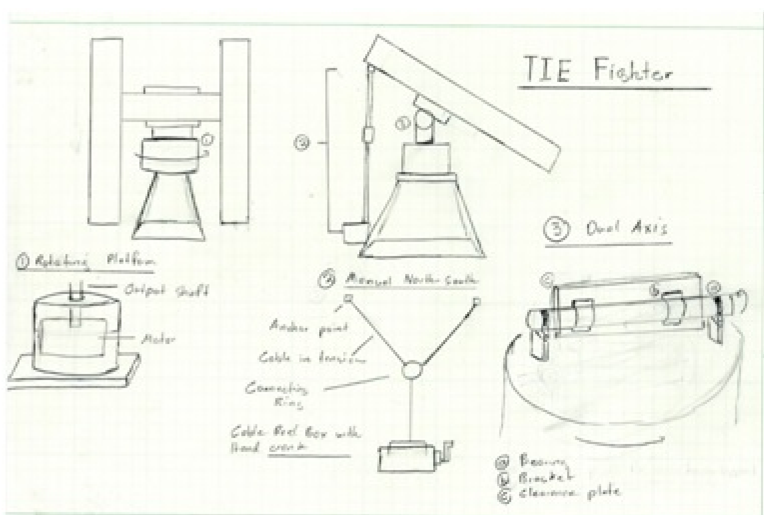

Figure 6: TIE Fighter Design

In theory, the TIE Fighter design is relatively inexpensive to implement. The components required for the structure itself are fairly easy to acquire or manufacture, with the most expensive component being the electric motor. The dual axis design allows for greater tracking efficiency, and by manually controlling one of the axes the design receives the benefits of a dual tracker at a greatly reduced cost. However, dual axis systems are not as reliable as single axis or fixed systems due to the greater number of moving parts. While the TIE Fighter tracker achieves these capabilities through simple means, the inherent disadvantages of dual axis trackers cannot be ignored. This structure itself is also larger than other trackers, requiring more space in the limited area that the team is allotted. Furthermore, the system has potential vulnerabilities with regards to environmental factors. The panels are free to rotate in the North to South direction, and placing the axis of rotation higher on the structure should prevent the panels from tipping backwards on their own, and anchoring the top of the structure to the ground will prevent the panels from tilting forward. However, a very top heavy snow load or forces from significant winds at the bottom of the panels could also cause the structure to tip about its North to South axis.

Design 5 - Direct Rotation

The direct rotation design is a dual axis design. The primary axis operates by use of a notch system. There are four pegs that extend out from the shaft of the solar tracker to the solar panel. Each peg is equipped with notches that correspond to a specific angle of the sun. These notches only need to be adjusted a few times a year. These angles are useful when tracking the sun from north to south. The secondary axis operates through the use of a motor. The motor rotates the panel three hundred sixty degrees. The secondary axis tracks the sun from east to west. The base for the Direct Rotation design is a tripod equipped with sharp legs for penetrating the soil. The base of the tripod can be altered to operate on a concrete surface. The tripod design for the base distributes the weight evenly thus increasing the systems stability. Advantages for this design are that it is cost effective, because one of the axes requires manual intervention, and it is relatively easy to manufacture. A disadvantage for the design is that it does require manual intervention to maximize the amount of sun absorbed by the PV cells.

The Direct Rotation design is currently designed to only support a maximum of two solar panels per tracking device. The solar panels sits on top of axis two and the panels are reinforced with the four pegs that make up axis one. Because axis one reinforces the stability of the design it received a score of three for the supported weight in the decision matrix. The cost for this design is a three because it is relatively cheap as it only uses one motor for two axes. Since Direct Rotation is a dual axis design, it can absorb more energy than a single axis solar tracker. The efficiency of the dual axis received the maximum score of four. The area allowed scored a three on the decision matrix because it is relatively easy maneuver and the design does not require a lot of space to operate. There is only one motor driven axis. This is easier to maintain and thus more reliable when compared to a design with two motor driven axes. For this, the design received a score of three. The Direct Rotation is show below as Figure 7.

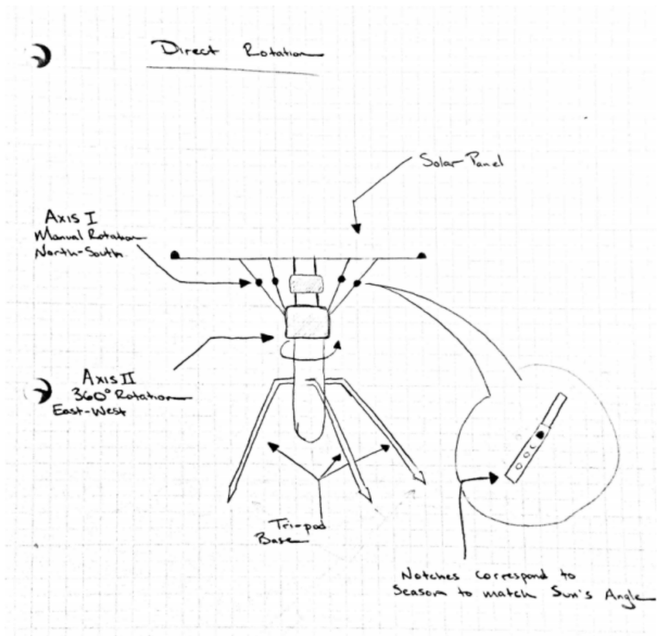

Figure 7: Direct Rotation Design

Weighting

Each criterion for the decision matrix was assigned a weighted value. To solve for this weighted value, each criterion was compared to one another. If a particular criterion was valued more important, it would receive a value of one. After each criterion was compared, the total number of one's assigned would be added up. The sum of each individual criterion is then divided by the sum of awarded points. This method yields the weighted value. Table 1, below, outlines the method used to weight each criterion.

Table 1: Weighted Criteria

Weight Criteria							
	Structure Weight (lbs)	Supported Weight (lbs)	Cost ($)	Efficiency (%)	Area (ft*ft)	Reliability (%)	Criterion Weight
Structure Weight	**X**	0	0	0	0	0	0
Supported Weight	1	**X**	0	0	1	0	0.14
Cost	1	1	**X**	1	1	0	0.29
Efficiency	1	1	0	**X**	1	0	0.21
Area	1	0	0	0	**X**	0	0.07
Reliability	1	1	0	1	1	**X**	0.29

The criterion used in the decision matrix was supported weight, cost, efficiency, area, and reliability. Using the method above to weight each criterion, the team discovered that the structure weight was nonessential to the design process and thus it was removed from the decision matrix. The supported weight of the structure accounts for how much weight the tracking system can support without failing. The cost is essential to the design process as it pertains to the allowed budget for materials and assembly. The efficiently dictates how much energy is absorbed by the tracking system and the area pertains to how much space is needed for the system to operate. Reliability also incorporates maintenance and is responsible for ensuring that design requires little additional effort to maintain. The decision matrix is represented in Table 2.

Table 2: Decision Matrix

Design Decision Matrix						
Scale: 0-1-2-3-4	Criterion Weight	Nickel Titanium	Tie Fighter	Table Top	Direct Rotation	Sun Flower
Supported Weight (lbs)	0.14	3	2	4	3	1
Cost (S)	0.29	4	3	3	3	1
Efficiency (%)	0.21	2	4	2	4	4
Area (ft*ft)	0.07	3	2	2	3	4
Reliability (%)	0.29	4	3	3	3	2
Total	1	3.37	3	2.86	3.21	2.13

The Gantt chart is essential to keeping track of the team's progress throughout the design process. As of now, the team has completed phase one by researching and developing preliminary solar tracking designs. These preliminary designs are now in the process of beings analyzed using engineering analysis. Figure 8 is a small representation of the Gantt chart.

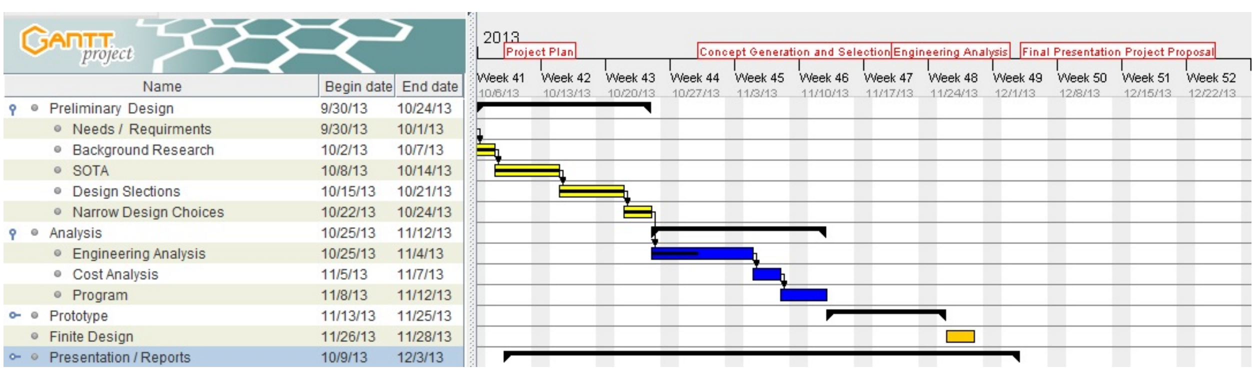

Figure 8: Gantt Chart

Conclusion

After being informed that a separate team is responsible for tracking, the team focused on generating concepts for the structure of the system and disregarded the tracking method aspect.

The team came up with five different design concepts, which were evaluated in the decision matrix. Based on decision matrix scores, a final design concept was chosen. The final design concept is the Nickel Titanium Tracker, which uses Nitinol to rotate the structure about the East to West axis. In accordance with the team schedule, the next phase in the design process will be further research and analysis of the chosen concept.

Resources:

[1]-http://www.dynalloy.com/TechDataWire.php

[2]- http://www.nitinol.com/wp-content/uploads/2011/05/Pelton-2011-NiTi-Fatigue-Microstructures-and-Mechanisms.pdf

[3] Hibbeler, *Engineering Mechanics Dynamics*, 13th ed. Upper Saddle River, New Jersey: Pearson Prentice Hall, 2013, pp.1-736.

[4] Philpot, *Mechanics of Materials*, 2nd ed. Rolla Missouri, 2011, pp.1-767.

[5] McGraw-Hill, *Shingley's Mechanical Engineering Design*, 8th ed. United States, 2006, pp.1-1059