Summer 8-16-2017

JME 4110- Solar Panel Tracker

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Contained herein is our description of a solar panel tracker which we constructed. Fixed solar panels have a short window during the day at which they are operating at peak efficiency, due to acute angles of the sun’s rays to the panel. Our fixture will allow the panel to face the sun all day, increasing the amount of time during which the panel is at peak power production.

**JME 4110    Mechanical Engineering Design Project**

**Solar Panel Tracker**

James Eimer  
Pat Kraus  
Bob Stretch
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1 **INTRODUCTION**

1.1 **VALUE PROPOSITION / PROJECT SUGGESTION**
   Our solar panel tracker will increase efficiency of any solar panel to which it is attached. It is inexpensive, reliable, and robust. The Danforth Center is in need of solar panel trackers to increase the effectiveness of their PheNode technology.

1.2 **LIST OF TEAM MEMBERS**
   Our team consists of James Eimer, Pat Kraus, and Bob Stretch.

2 **BACKGROUND INFORMATION STUDY**

2.1 **DESIGN BRIEF**
   Solar tracking system for the PheNode solar panels. Must integrate with existing system maintaining portability, adjustability, and modularity

2.2 **BACKGROUND SUMMARY**

![Figure 1: CAD drawings from paper listed in (2.2).](image)

Our final design may look something like Fig. 1.
We may choose to design a purely mechanical system rather than incorporate motors and either timers or automated controls.

Solar trackers are more expensive and require more maintenance than a fixed system, but these are not our concerns for this project. Our biggest obstacle to overcome is ensuring that there is enough clearance for the panel to move. That is, it needs to be elevated high enough off the ground to tilt as the sun arcs across the sky and it needs to have enough room next to other panels to swivel properly.

This is a repository of all applicable standards for solar panel installation. The page covering solar tracking systems is under construction, however, so no details can be gathered at the moment. This page will be an important resource in the future however.

Integrate a single axis as well as a dual axis solar tracker that will optimize the power generated by the PheNodes solar panels while keeping cost at a minimum. Must integrate with existing system maintaining portability, adjustability, and modularity.
3 CONCEPT DESIGN AND SPECIFICATION

3.1 USER NEEDS AND METRICS

3.1.1 Record of the user needs interview

The interview with Agreala Ecosystems was very informative for the project as well as they were very willing to provide any further materials and information needed to complete the project. We had met with Nadia Shakoor, Darren O’Brien, and Bill Kezele, and they were noticeably excited about our ideas that did not include any electronics and were considered to be low maintenance. The only concerns they had with using a type of using a thermodynamic process was the reliability of the system.

Price of the unit is already set to be below $1000, so initial cost as well as maintenance cost was discussed, however for prototyping they seemed to be fairly open-minded about what was needed to be spent to complete the project. They were even willing to purchase any tools needed, within reason, which will be needed to build a working prototype. With the PheNode product still being in the design stages itself the manufacturability was lower on their list of concerns, they did express that when the product goes out to a customer that at its current design multiple PheNodes will be sent to a single location. So they stated that initially a metric of success for a panel using the solar tracker against a panel with no tracker is more important than the manufacturability.

3.1.2 List of identified metrics

1. Fit PheNode
2. Operate through grow season
3. Cost less than $1000 total
4. Track sun from dawn to dusk
5. Require little maintenance
6. Withstand wind load
7. Must not leak caustic material
8. React quickly to sun’s movement
9. Work anywhere in the world (any latitude)
10. Doesn’t shade other panels
3.1.3 Table/list of quantified needs equations

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Table 1: Quantified User Needs

3.2 CONCEPT DRAWING

![Figure 3: Motor-Extender](image)
Figure 4: Actuator-Powered Tracker

Figure 5: Fluid moves between containers due to temperature differences.
3.3 A CONCEPT SELECTION PROCESS.

3.3.1 Concept scoring (not screening)

We ranked our concepts from Figures 3 and 4 being our least likely to choose, the concept in Figure 5 was pretty likely and Figure 6 was our favorite and most likely.

3.3.2 Final summary statement

With our product eventually ending up in an actual field, weather is going to play a large role in the durability as well as the movement of our solar panel. The first concept, Fig. 3, had the solar panel connected to an electric motor with an oblong arm attached to the armature. The solar panel would be connected onto a pivot point and as the motor armature rotates the arm would extend up and move the panel. The second concept, Fig. 4, had an actuator tethered to the solar panel and as the actuator extended it would raise one side of the solar panel, and lower it again to face the panel the other direction.

The next two concepts are what is called a passive solar tracker, and uses thermodynamics and the heat of the sun to move the solar panel. The third concept, Fig. 5, uses the heat from the sun to raise the pressure in a vessel and force some of the liquid contained to the other side, weighing the side of the solar panel down. The fourth concept, Fig. 6, uses the same principle, but instead of the weight of the fluid causing the solar panel to move, the fluid containers are connected to a piston. As the pressure increases on one side of the piston it raises that side of the solar panel. The third and fourth concept are the concepts we chose to research further because of a few different reasons. The first reason was that these trackers would contain no electronic parts which would decrease cost, maintenance, and increase durability. However, since the solar tracker will be subject to extremely high winds and would need to be restricted to only moving when the solar tracker initiates it, the panel will need to be held in place by
something. The piston would create enough resistance to keep the panel from moving in high winds as well as provide some mechanical assistance to the fluid for moving the panel.

3.4 PROPOSED PERFORMANCE MEASURES FOR THE DESIGN

The performance measures for our design are that it should move with the sun continuously during sunlight hours and that the solar panel will generate more power with the tracker than without.

3.5 REVISION OF SPECIFICATIONS AFTER CONCEPT SELECTION

We decided concept four would be the best choice. Upon selection, we decided to build a frame that attaches to a 1” rod that would rotate back and forth along the length of the rod, about a point through the rod. The piston will attach to the rod and push the frame back and forth.

4 EMBODIMENT AND FABRICATION PLAN

4.1 EMBODIMENT/ASSEMBLY DRAWING

See 4.3

4.2 PARTS LIST

See appendix A
4.3 **Draft Detail Drawings for Each Manufactured Part**

![Diagram of bob's first project piston bracket top](image)

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4.4 DESCRIPTION OF THE DESIGN RATIONALE

Solar panel

The solar panel was given to us by our sponsor.

Shades

Our shades will go the length of the pressure chamber and be made out of sheet metal, the sheet metal will help refract sunlight into the pressure vessel to help with heating.

Hydraulic line

We picked a small inner diameter line to increase line pressure.

Piston

The piston has a 6” stroke length to move our panel across its sweeping angle, it can also handle up to 250 PSI which is the upper limits of our working fluid and working temperature.

Lower panel mounting bracket

This part will be 3-D printed for ease of manufacturing.

Upper panel mounting bracket
This part will be 3-D printed for ease of manufacturing, it will also be tapped to the instillation of the bracket arms and sleeve bearings

**Upper piston mounting bracket**

This part will be 3-D printed for ease of manufacturing

**Lower piston mounting bracket**

This part will be 3-D printed for ease of manufacturing

**Upper panel bracket arm**

The upper panel bracket arm will be made taller than the lower to allow correct angle of the panel to better face the sun.

**Lower panel bracket arm**

Like the upper arm this will hold the bearings and rotate the panel.

**Flanged sleeve bearing**

This bearing is simple and cheap to allow the panel to rotate in the weather
5 ENGINEERING ANALYSIS

5.1 ENGINEERING ANALYSIS PROPOSAL

5.1.1 Signed engineering analysis contract

MEMS 411 / JME 4110
MECHANICAL ENGINEERING DESIGN PROJECT

ASSIGNMENT 5: Engineering analysis task agreement (2%)

ANALYSIS TASKS AGREEMENT

PROJECT: Solar Tracker
NAMES: Eimer, Krosis
INSTRUCTOR: Jakiela

The following engineering analysis tasks will be performed:
- Structural Analysis
- Safety
- Chemical Usage

The work will be divided among the group members in the following way:

Instructor signature: Jakiela
Print instructor name: Jakiela

(Group members should initial near their name above.)
5.2 ENGINEERING ANALYSIS RESULTS

5.2.1 Motivation

Our engineering analysis for the solar panel tracker will consist of a few items. The first main concern is whether the bracket/support system will be able to hold the panel and piston system. Included in this is choosing proper materials for components. The second analysis is determining the correct fluid type and level required for operation. Finally we will determine pricing for the entire system, as that is a major concern for us.

The bracket/support system will need to be analyzed or tested prior to completion of the project. Our initial plan is to 3D print the brackets with PLA or SLA. Our thought is that the panel is light enough that plastic will be able to hold it correctly, but we will have to do an FEA to test not only the weight, but any possible wind loads. PLA is our preferred material, since it is cheaper and easier to work with, but it is materially weaker and the 3D printing process isn’t isotropic, so the layers induce weakness in one shear direction. SLA is stronger and stiffer, so if we have warning signs in our initial analysis, we will have to try that method, which is available at the tech shop. If our analysis of these materials shows that they likely won’t work, then we will have to fabricate them from steel or aluminum. We also need to determine the optimal material for the fluid canisters. We will need a material that will withstand the operating pressures, that can survive outdoor environment, and that is cost-controlled.

We also must determine the correct type and amount of fluid to operate the piston. Our preliminary choice is to use ethanol, as it is safe to use around plants, is cheap, and is reactive enough to provide the vapor pressure. If we have too much fluid, it will act as a heat sink and the system will be slow to react; if we have too little, we won’t have enough vapor to power the piston.

Once we have answers to these questions, we will fabricate the system. From here, we must ensure that the piston moves the panel at an appropriate speed and at the correct angles. Upon making our final initial material selections, we will then price the entire unit and revise material selection to keep the cost low. The entire cost of the PheNode unit should be under $1000, so we need to keep our project as low-cost as possible.

5.2.2 Methodology

Our methodology was mostly observation and physical testing as our main concern with this project was manufacturing the parts and getting our mechanical system to work. For our brackets we were able to weld and bend metal together and we could see that it was sturdy, for our fluid we ran test out in the sun so see if the vapor pressure could move the pistons, for our cost we wanted to keep it under $100 or 10% of the total project budget.

5.2.3 Results

Our results of our analysis saw that the brackets where more than sturdy to hold the panel in place, we saw that 6 oz of fluid was more than enough fluid to move the piston when heated by the sun and we were able to keep costs below 10%, while realizing that 10% is a large amount for one component we knew that an extra 20% electricity gained throughout the day was invaluable to the phenode as it allowed the camera to operate at higher frequencies throughout the day.

5.2.4 Significance

A huge significance of our analysis was finding out through testing the pressure canisters attached to the pistons was that the pistons we found to use did not hold pressure when they needed to
pull. this flaw in the piston design made us realize that we needed to use two opposing pistons pushing against each other, connected to opposite pressure containers.

6 RISK ASSESSMENT

6.1 RISK IDENTIFICATION

The initial and most obvious risk to the project was the location in which the solar panel was going to be mounted. Having the cylinders connected to the panel, along with the shades added a significant amount of weight and the panel is going to be mounted very high with people potentially working under it. The consequences of the panel not withstanding the conditions it was being placed would mean that the PheNode would lose its only power source and no data would be collected. Also, the cost of the solar panel most likely being damage in the fall from such a high location. The second risk identified was in the choice of the fluid to be used in the canisters that would be required to hold pressure in the process of moving the panel. The fluid would need to be nontoxic to humans as well as nontoxic as possible to plants. The wrong choice of fluid could potential harm or kill someone if not used the proper manner, also ruin an entire crop for the farmer the purchased the PheNode. The risk of failure of the pistons being able to perform in both directions would have potentially rendered the panel less useful than being mounted stationary facing south.

6.2 RISK ANALYSIS

The majority of the risk analysis was done as the build process was being completed and the risks became more relevant. Initially most of the parts were to be produced by 3D printing until the new panel’s size, weight, new mounting was made clear to us. With weight and mounts being much different than expected the decision to use aluminum was a choice of reliability and for time purposes. Had the 3D printed parts not been able to withstand the weight of the panel there would not have been time to start over with aluminum, so the metal was machined for the parts to ensure the prototype would fail under the panel. With the bracket made from aluminum it is resistant to corrosion, was inexpensive, and fairly easy to acquire. The fluid choices started with fluids that were known to have a low boiling point that were known to be safe to handle without any protective wear. Initial tests were ran with a household fluid. Through more research it was found that some passive solar trackers use Dichloromethane as the active fluid in their closed system. The fluid was safe to handle in well ventilated areas and non-corrosive to the containers that we had intended to use. While the fluid is used in some pesticides in the concentration used in the solar tracker wouldn’t be enough to harm more than the produce in the immediate vicinity of the PheNode. Through testing it was discovered that the pistons did not work equally in both directions, i.e. the piston pushed better than it pulled. If the pistons did not move in both directions the panel would be less effective than if it remained stationary, so a second piston was added to ensure that the tracker would be able to east to west as well as west to east.

6.3 RISK PRIORITIZATION

The structural integrity of the bracket was the of the utmost importance because of the weight involved and when the panel did move, it would need something to withstand the impact of the panel being stopped. The panel didn’t have a fluid motion as we had hoped so the panel would kind of slam from position to the next. Only because the bracket needed to be made initially did it take priority over the fluid choice. Whether we decided to move the panel using vapor pressure or an electric actuator the bracket would need to be made. However, the fluid choice was of utmost importance because of the
possible consequences of the wrong fluid choice. The risk of the panel being less than efficient was considered last behind all safety issues.

7 CODES AND STANDARDS

7.1 IDENTIFICATION
The code that applies to our design is UL 3703. This ANSI-approved code covers all aspects of design of solar trackers that are not affixed to a building. Since our tracker is only designed for mounting on a PheNode, this is the only standard to apply. This code does not cover the solar panel itself, but we are not concerned with that in our design.

7.2 JUSTIFICATION
As engineers we have a professional responsibility to protect the public and our clients. To this end, we follow all relevant codes to ensure that we are up to date on all safety standards.

7.3 DESIGN CONSTRAINTS

7.3.1 Functional
Our assembly shall not be affected by mechanical vibration of the PheNode. Our circular mounting brackets have a peg and hole mate that prevents movement in any direction of the assembly.

7.3.2 Safety
Our main safety issue concerns the fluid in the canisters that powers the pistons. The fluid must not be so toxic that a maintenance person could be injured by it. Dichloromethane has low toxicity and high vapor pressure. A high vapor pressure and low boiling point would ensure that the fluid evaporates quickly upon a rupture, and in a worst case scenario, direct contact with a spill is treatable, although safety glasses and a mask are advised.

7.3.3 Quality
Our parts shall be made of material such that it will withstand weather, vibration, and other outside forces. Our robust design ensures that the mounted load will not be in danger from failure of the mount.

7.3.4 Manufacturing
All iron and steel parts must be protected against corrosion. Our design uses aluminum and stainless steel, complying with the code.

7.3.5 Economic
The total cost of the design shall not exceed $100, or 10% of the total project cost.

7.3.6 Ecological
The pressure vessels containing the volatile fluid must be able to withstand the building pressure from the temperature rise throughout the day. Our pressure vessels are rated for high pressure - over 150 psi - and our design recommendation is that the vessels be negatively pressured for added sensitivity.
7.3.7 Aesthetic

The word “CAUTION,” “WARNING,” or “DANGER” should be printed on the canisters along with relevant toxicity information.

8 WORKING PROTOTYPE

8.1 Prototype Photo

Figure 7: Prototype from behind.
Figure 8: Prototype, top view.

8.2 WORKING PROTOTYPE VIDEO

https://youtu.be/sEaZk5Ja8k

https://youtu.be/VkT-lGeD_h8
8.3 **Prototype Components**

![Prototype frame](image)

Figure 9: Prototype frame.

9 **Design Documentation**

9.1 **Final Drawings and Documentation**

9.1.1 **Engineering Drawings**

See Appendix C for the individual CAD models.

Here include a set of the final engineering drawings for your prototype. Include units on all CAD drawings.

9.1.2 **Sourcing instructions**

7.2 **Final Presentation**

https://www.youtube.com/watch?v=rP8GvAFSZCU&feature=youtu.be

10 **Teardown**

The Danforth Center decided to keep our prototype for further development.
## Appendix A - Parts List

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<td>Al. stock bent bar panel arm assembly</td>
<td>1</td>
<td>$60</td>
</tr>
<tr>
<td>6</td>
<td>Sheet metal bent solar shade</td>
<td>2</td>
<td>provided</td>
</tr>
<tr>
<td>7</td>
<td>double acting piston</td>
<td>2</td>
<td>provided</td>
</tr>
<tr>
<td>8</td>
<td>plastic tubing / fittings</td>
<td>2</td>
<td>$25</td>
</tr>
<tr>
<td>9</td>
<td>Fasteners</td>
<td>-</td>
<td>$11</td>
</tr>
<tr>
<td>9</td>
<td>Faux Phenode test mounting station</td>
<td>1</td>
<td>$35</td>
</tr>
</tbody>
</table>

Table 2: Parts List

**APPENDIX B - BILL OF MATERIALS**

<table>
<thead>
<tr>
<th>Number</th>
<th>Description</th>
<th>Quantity</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Solar panel</td>
<td>1</td>
<td>provided</td>
</tr>
<tr>
<td>2</td>
<td>A.C. flush gun canisters</td>
<td>2</td>
<td>$25/can</td>
</tr>
<tr>
<td>3</td>
<td>Al. stock milled piston bracket</td>
<td>2</td>
<td>provided</td>
</tr>
<tr>
<td>4</td>
<td>Al. stock milled panel arm bracket / pivot</td>
<td>1</td>
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</tr>
<tr>
<td>5</td>
<td>Al. stock bent bar panel arm assembly</td>
<td>1</td>
<td>$60</td>
</tr>
<tr>
<td>6</td>
<td>Sheet metal bent solar shade</td>
<td>2</td>
<td>provided</td>
</tr>
<tr>
<td>7</td>
<td>double acting piston</td>
<td>2</td>
<td>provided</td>
</tr>
<tr>
<td>8</td>
<td>plastic tubing / fittings</td>
<td>2</td>
<td>$25</td>
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<td>9</td>
<td>Fasteners</td>
<td>-</td>
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<td>Faux Phenode test mounting station</td>
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<td>$35</td>
</tr>
</tbody>
</table>

Table 3: Bill of Materials
APPENDIX C – COMPLETE LIST OF ENGINEERING DRAWINGS
14 Annotated Bibliography


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