Solar Tracking Structure Project Proposal

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Overview

- Project Overview
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  - Objectives
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  - Dual Axis: Modified TIE Fighter
  - Nitinol solar tracker
- Final Design
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What is Solar Energy?

- Photovoltaic cells take solar energy and turn it into usable electrical energy by means of the Photoelectric Effect [1].

- PV cells operate at maximum efficiency when pointed directly at the sun. But, solar tracking can be expensive and require a lot of maintenance.

Image provided by Google Maps

Introduction

- Need Statement:
  - “Photovoltaic Cells are less productive when not pointed directly at the sun.”

- Project Goal:
  - “Design a system that maximizes amount of sun being absorbed while minimizing the cost of operation and maximizing the reliability.”

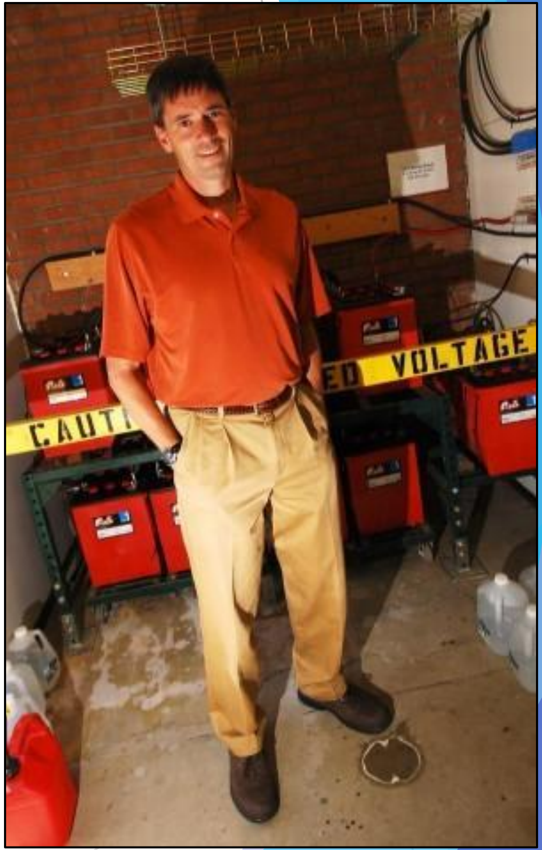
Objectives

Objectives	Measurement Basis	Units
Inexpensive	Unit cost of production	$
Supported weight	Stress vs. Strain	N/m^2
Low Maintenance	Time until part replacement	Days
Display power output	Digital screen	Amp/hour
Track the sun	Rotation angle	(°) Degrees

About the Client

- Dr. Thomas Acker
  - Professor of Mechanical Engineering at Northern Arizona University.
  - Worked at the National Renewable Energy Laboratory (03-04)
  - Director of Sustainable Energy Solutions (SES).
  - Gained NAU over $25 Million in research grants.

- Why is he sponsoring this project?
  - Collect more energy for storage.
  - To teach about renewable energy.



AZ Daily Sun

The WERC Competition

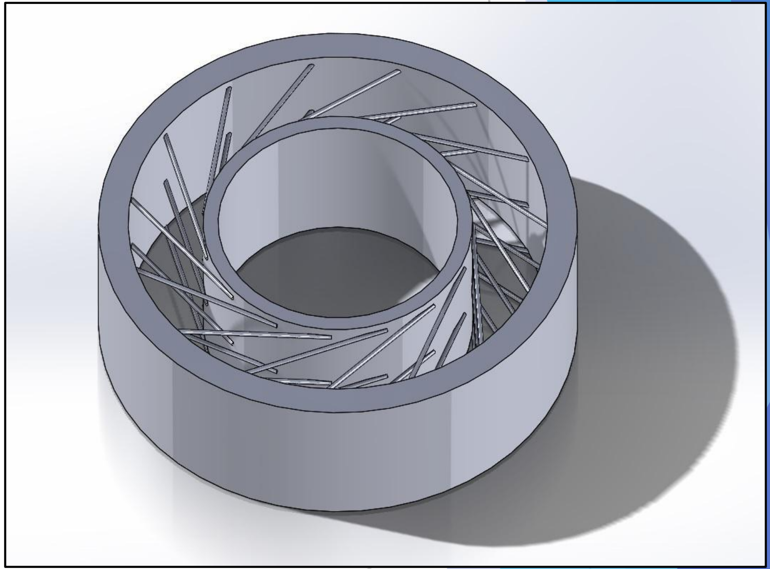
- WERC: A Consortium for Environmental Education and Technology Development competition
- At New Mexico State University in Las Cruces, N.M. It’s run by the Institute for Energy & the Environment (IEE).

- **Task 3 – Power Point Tracking for Solar Energy**
  - First Place Award per task $2,500

- Our team will develop a novel system for maximum power point tracking and demonstrate its cost effectiveness by measuring the additional power generation vs. the cost of the components and power required for operation.

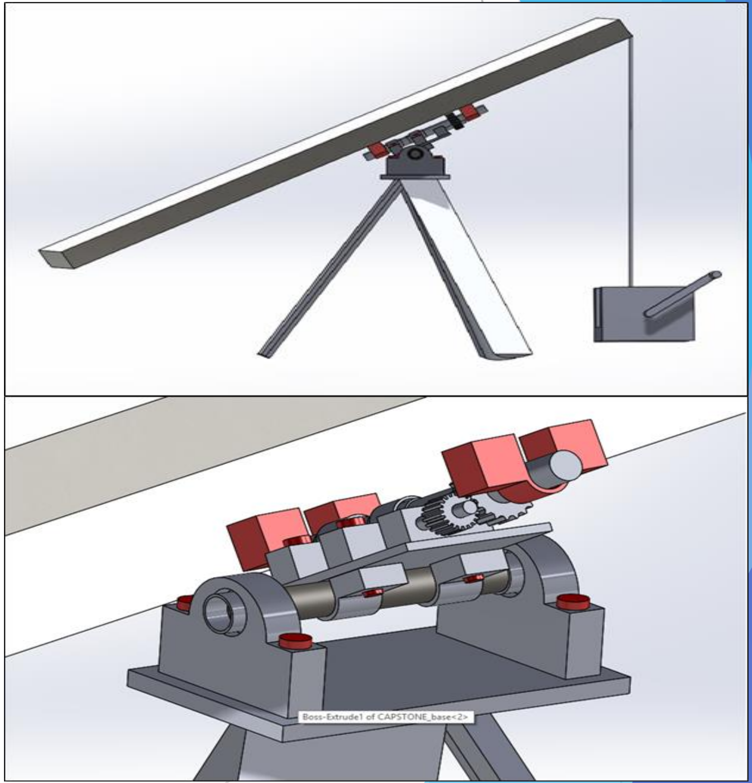
Initial Design 1: Ni-Ti

- Nitinol Based
  - A shape memory alloy; Nitinol contracts in length when heated either through an induced current or external heating.
- Difficulties:
  - One directional motion.
  - Expensive.
  - Requires some form of movement locking to not waste energy



Initial Design 2- Mod. TIE Fighter

- Dual Axis
  - Motor-operated primary
  - Manually operated secondary
- Difficulties
  - Cost vs. efficiency
  - Potential tipping



Decision Criteria

- Supported weight : weight (pounds) that the structure can asupport
- Cost: $ for parts and installation
- Efficiency : Energy generated
- Area: Space needed to operate tracking structure
- Reliability: System consistency, incorporates maintenance (life of parts)

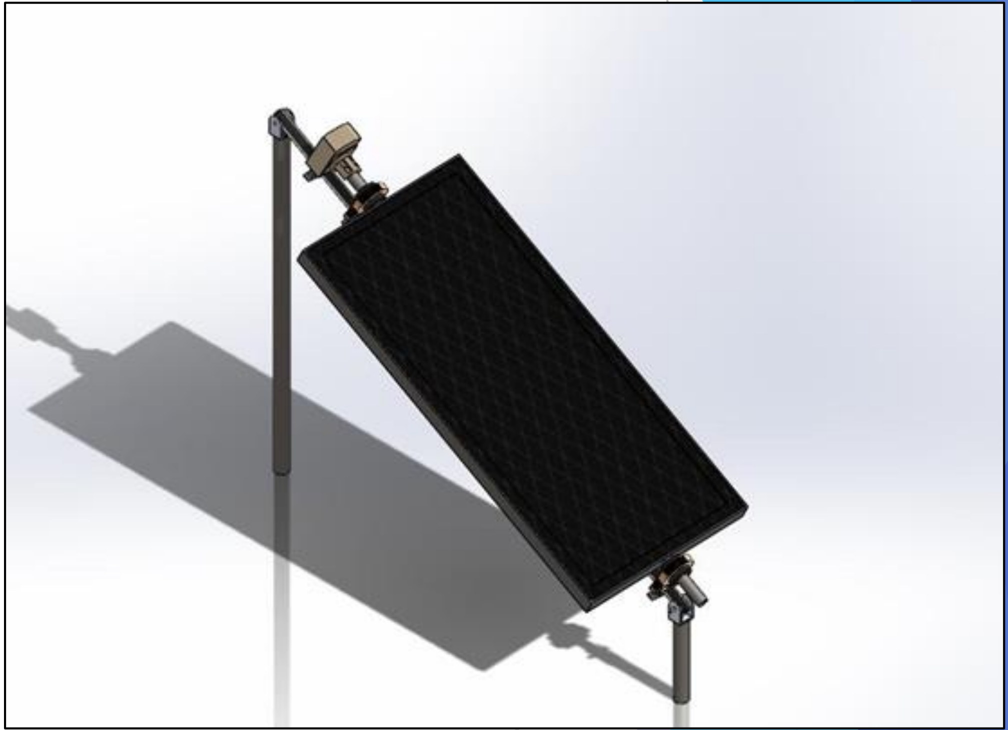
Decision Matrices

Design Decision Matrix				
Scale: 0-1-2-3-4	**Criterion Weight**	**Nickel Titanium**	**Tie Fighter**	**Rotisserie**
Supported Weight (lbs)	0.14	3	2	3
Cost (S)	0.29	4	3	4
Efficiency (%)	0.21	2	4	2
Area (ft*ft)	0.07	3	2	3
Reliability (%)	0.29	2	3	4
Total	1	2.79	3	3.29

Chosen Design

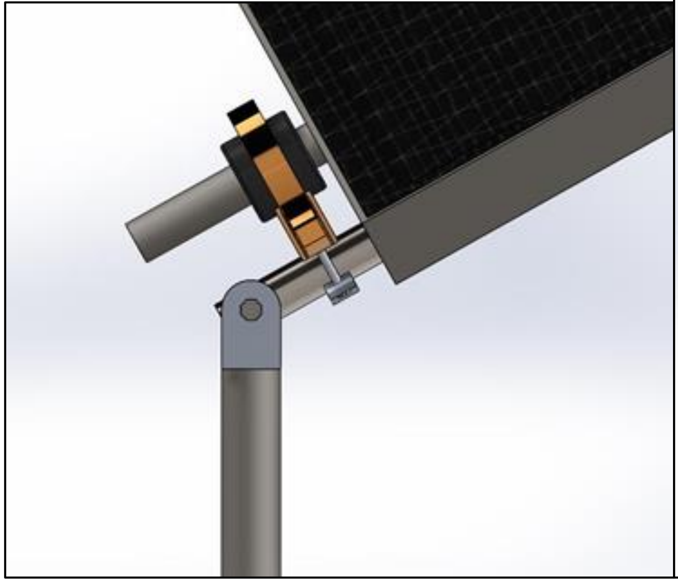
The Rotisserie

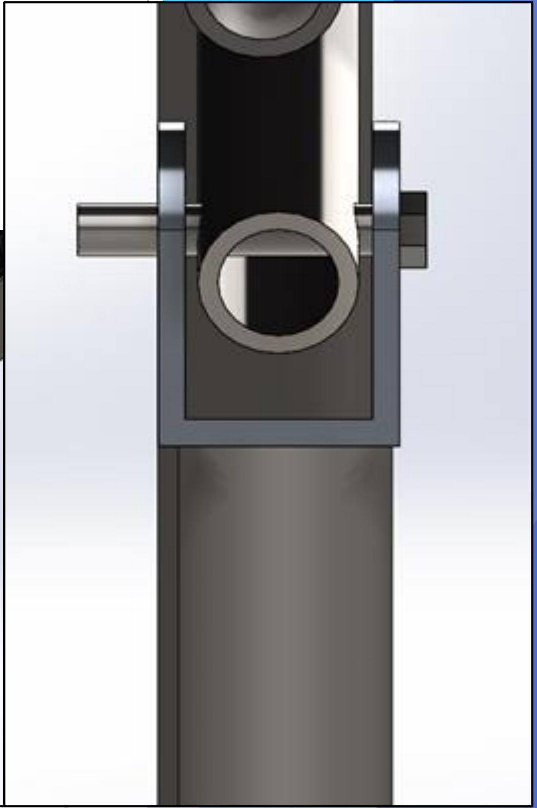
- Single Axis Tracker
- Keeps rotating axis through center of gravity
- Potential for second axis



Rotisserie Key Stresses

- Support Rod
- Hinge Bolt
- Holding Frame
- Frame Weld





Maximum Stresses in Analysis

- Snow load
  - Assume 3 feet of snow over entire panel
  - Load = **198 lbs**
- Wind Load
  - $F=0.00256V^2CdA$ [2]
  - Assumed 65 mph winds
  - Load = **210 lbs**

Engineering Analysis Results

Stresses	Material	Yield Str (Ksi)	Max Stress (Ksi)	FOS
Hinge Bolt (0.5")	Steel	70	5.03	7.0
Support Bar (1.5")	AISI1010	60	5.261	11.4
Frame (1/8")	AISI1010	60	30.57	2.9
Frame connection	Weld	50	17.5	2.9

Cost Analysis

Cost Analysis	Units	Comment	Cost/unit	Cost
Motor	1	Antennacraft TDP-2	$62.99	$62.99
Bearing	2	TB-105 Support	$35.95	$71.90
Axle Bolt	2	0.5" x 4"	$2	$4.00
1.5" Pipe Flange	2	Home Depot	$2	$4.00
2" Pipe Flange	2	Home Depot	$2	$4.00
Flang Bolt	16	Home Depot	$0.75	$12.00
Pipe Hinge	2	Still Shopping	$10	$20.00
2" Base Pipe	1	8 ft, cut down	$35	$35.00
1.5" Support pipe	1	7 ft	$35	$35.00
1/8" x 2.5" Flat bar	1	13 ft at $9/72"	$19.50	$19.50
			Total	$268.39

StarkElectronic

Cost of Operation

- Motor Provides 8 ft*lbs of torque using 65 Watt
- Assuming operating conditions of 5° intervals throughout the course of the day:

(360°/day)/(5.14°/s) = **70 s/day**

Factoring time to start motor = **80 s/day**

= 8 hrs/year

At 65 Watts, gives **0.52 kWh/year**

Assuming max price of electricity in United States: **$0.17/ kWh** [1]

Cost of operation = $0.09/ year

Life Cost

161 Days of Full Sun per year (100%) = 11.9 hours/ day of sun

102 Days of semi-cloudy (70%) = 8.31 equivalent hours / day

101 Days of mostly cloudy (40%) = 4.75 equivalent hours/ day

Total of **3255.2 hrs** of sun/ year

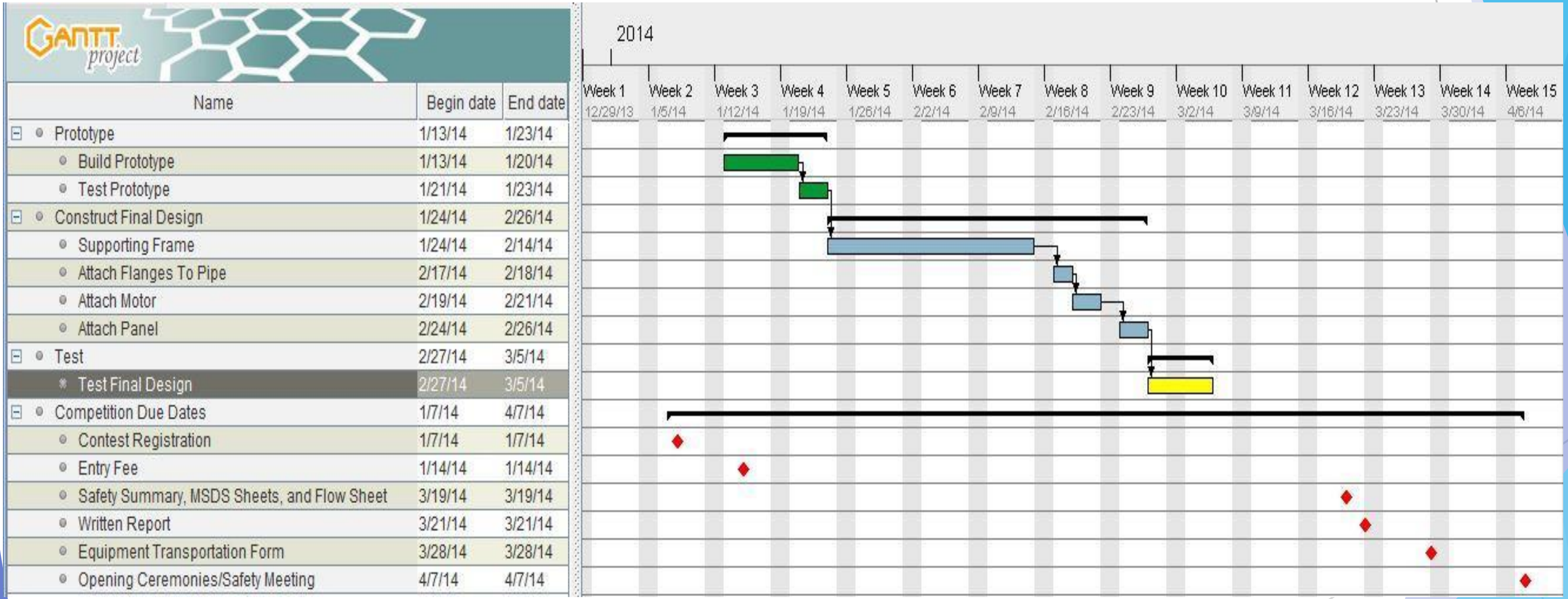
Dual Axis gives 423.2 kWh/year = **$50.78/year** Generated

Single Axis gives 391.92 kWh/year = **$47.03/year** Generated

Fixed Axis gives 302.28 kWh/year = **$36.27/year** Generated

$10.75/ year by switching to single axis = **24.9 years to pay off**

Team Schedule



Name	Begin date	End date
Prototype	1/13/14	1/23/14
Build Prototype	1/13/14	1/20/14
Test Prototype	1/21/14	1/23/14
Construct Final Design	1/24/14	2/26/14
Supporting Frame	1/24/14	2/14/14
Attach Flanges To Pipe	2/17/14	2/18/14
Attach Motor	2/19/14	2/21/14
Attach Panel	2/24/14	2/26/14
Test	2/27/14	3/5/14
Test Final Design	2/27/14	3/5/14
Competition Due Dates	1/7/14	4/7/14
Contest Registration	1/7/14	1/7/14
Entry Fee	1/14/14	1/14/14
Safety Summary, MSDS Sheets, and Flow Sheet	3/19/14	3/19/14
Written Report	3/21/14	3/21/14
Equipment Transportation Form	3/28/14	3/28/14
Opening Ceremonies/Safety Meeting	4/7/14	4/7/14

Concluding Statements

- Our client is Dr. Thomas Acker, a Professor at NAU with a lot of background in sustainable energies.
- Problem Statement:
    1. Solar cells need an inexpensive, efficient way to be turned to track the sun across the sky.
- The project goal is to design a system that:
    1. Maximizes the amount of sun being absorbed.
    2. Minimizes the cost of operation.
    3. Maximizes the reliability.
- Competition specifications are still developing.

Concluding Statements (cont.)

- Previous designs
  1. Nitinol is not reliable enough
  2. Efficiency of TIE fighter does not justify increase in price
- Final chosen Design- The Rotisserie
  1. Room for an added axis
  2. Lowest factor of safety 2.9 on the frame, assuming high wind and max snow load.
  3. $268 dollars initial cost per panel
  4. Theoretically under $0.10 per year to run.
- Schedule moving on to phase two: pre-construction

References

[1] U.S. Energy Information Administration, “Average Revenue per kWh by State’”,(2013, September). [online], pp1. Available: http://www.eia.gov/electricity/monthly/update/end_use.cfm#tabs_prices-3

[2] Wikihow, “How to Calculate Wind Loads” [Online], Available: http://www.wikihow.com/Calculate-Wind-Load

- Questions ?