Solar Tracking Structure Design

Project Proposal

Belsheim Joshua, Francis Travis, He Jiayang, Moehling Anthony,
Liu Pengyan, Ziemkowski Micah

December 9, 2013

Presentation Overview

- Introduction
  - Problem and Customer Definition
  - Needs and Requirements
- Concept Generation and Selection
  - Decision criteria
- Engineering Analysis
- Cost Analysis
- Schedule
- Conclusion

Problem and Client Definition

- Design an all-seasonal solar tracking device.
- Dr. Acker
  - Professor of Mechanical Engineering at Northern Arizona University (NAU)
  - Director of NAU Sustainable Energy Solutions Group

Needs and Project Goal

- Needs
  - Reliable
  - Inexpensive
  - Easily maintainable
  - Efficient while successfully tracking the sun
- Project Goal
  - Design a solar tracking system that will efficiently convert solar energy to useable energy.

Objectives

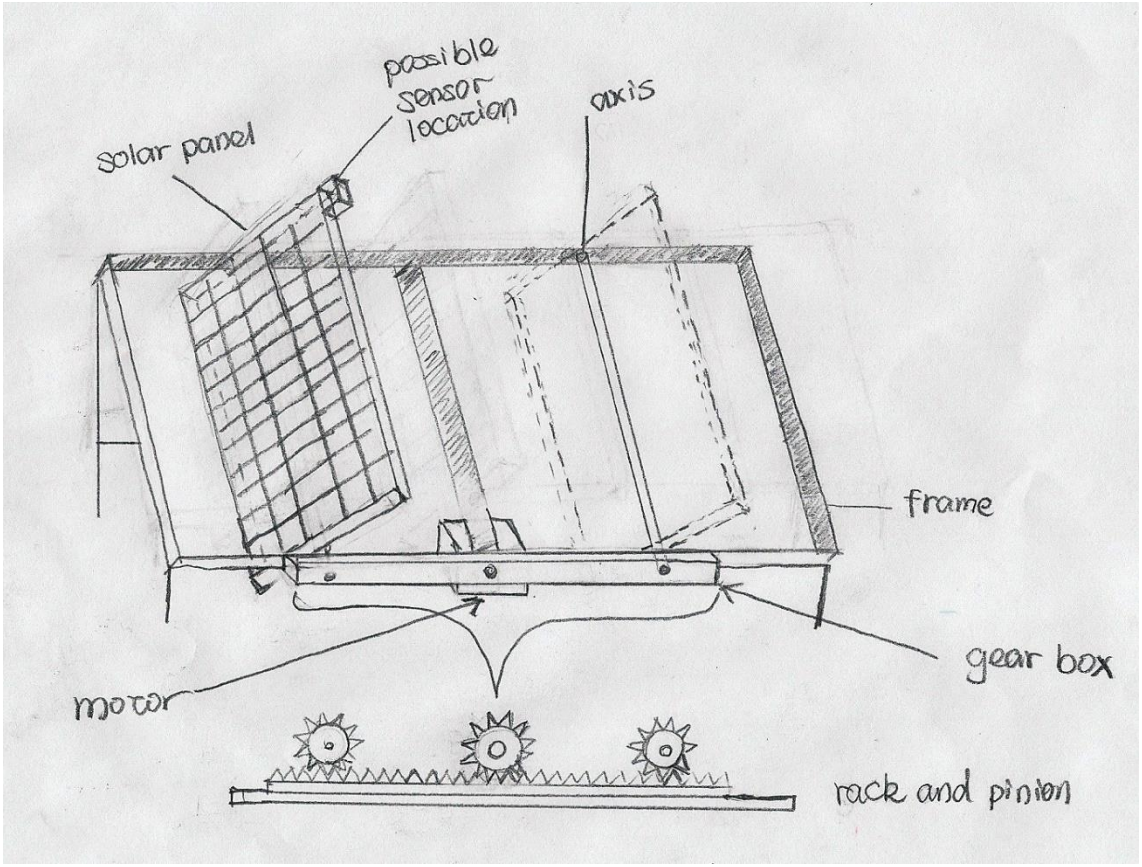
Objectives	Measurement Basis	Units
Inexpensive	Unit cost of production	$
Efficiency	Useable amperage generated	$amp/hour$
Low Maintenance	Time until first part replacement	days
Manufacturability	Amount of moving parts	Number of parts
Build Quality	Stress vs. Strain	N/m^2
Snow Shedding Ability	Area without snow	m^2

Operating Environment

- Utilize MATLAB to run the program
  - Deliver power to actuators
  - Transfers motion to the solar panels for tracking
- Electronic equipment might be affected by voltage/amperage drops within cables
- Mechanical equipment may be affected by inclement weather, such as snow, clouds, and dirt
- Voltage readers will be connected at the outputs to measure actual efficiency

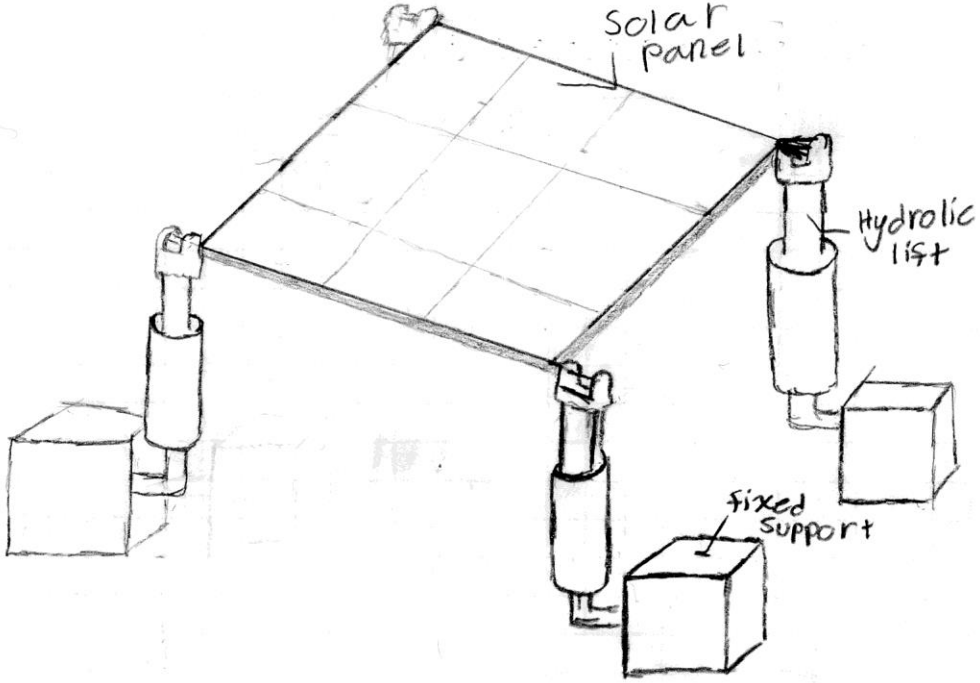
Solar Panel Array

Rack and pinion system with multiple panels



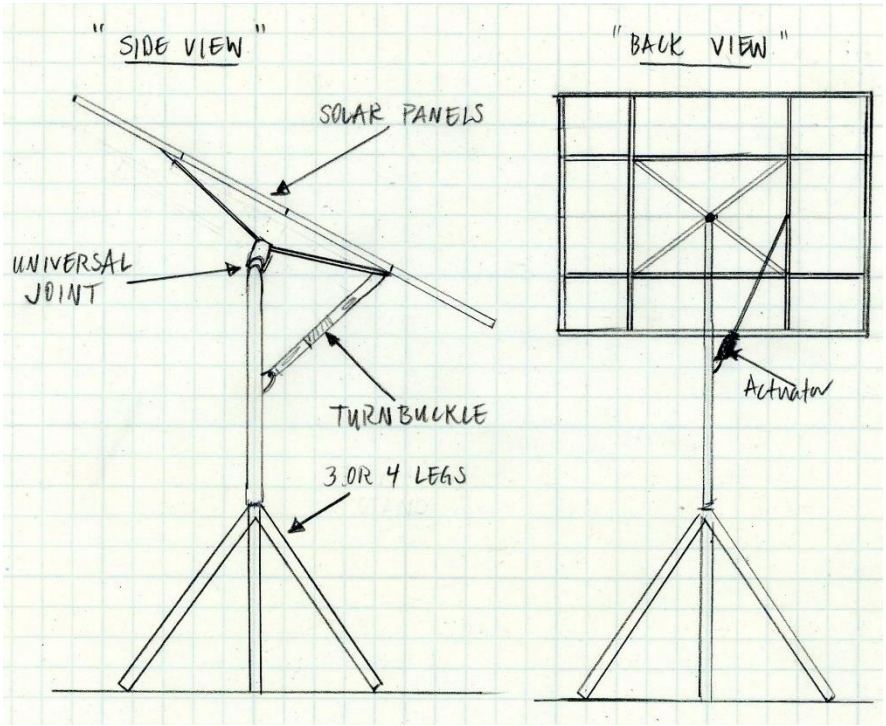
Hydraulic Design

Solar pane is moved by hydraulic



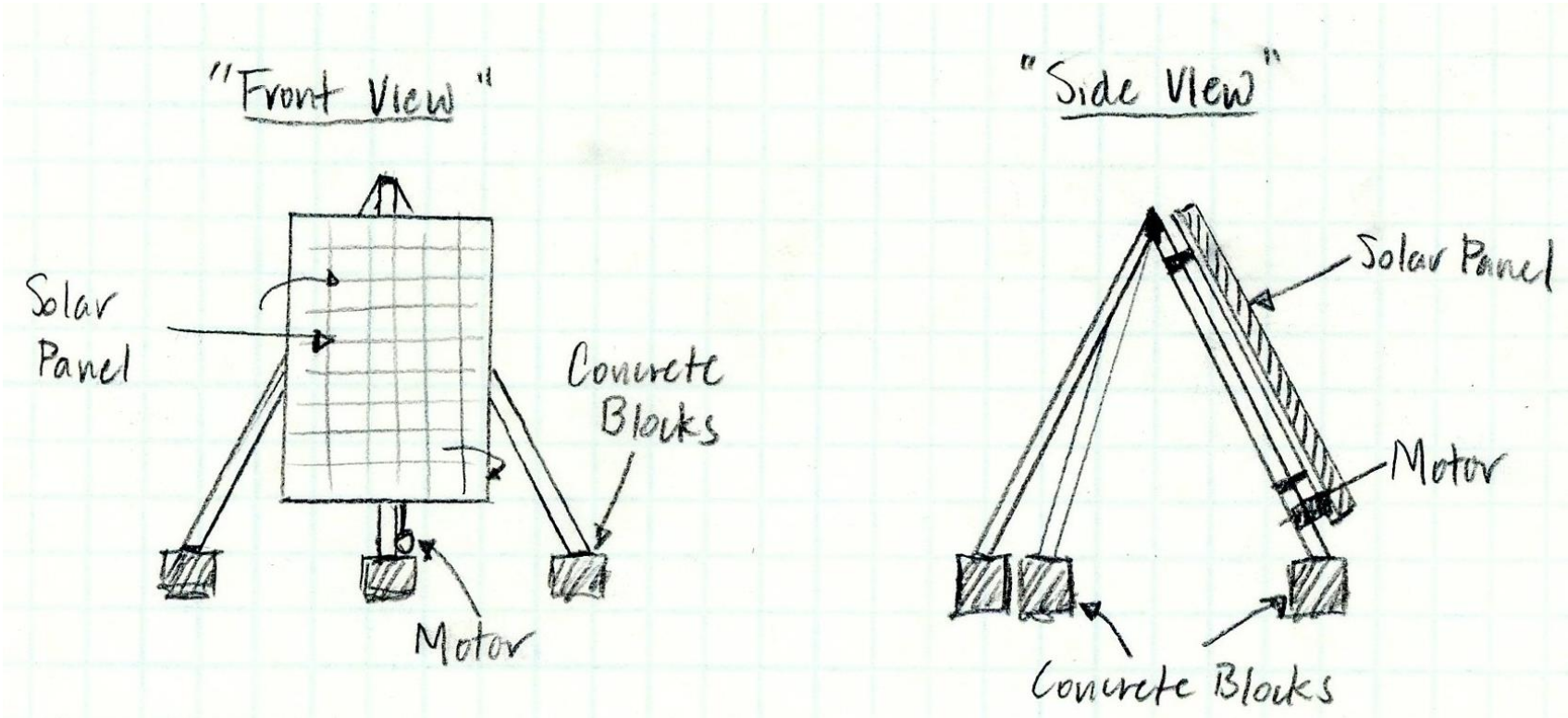
Standing Tripod Design

Simple tripod that is easy to move



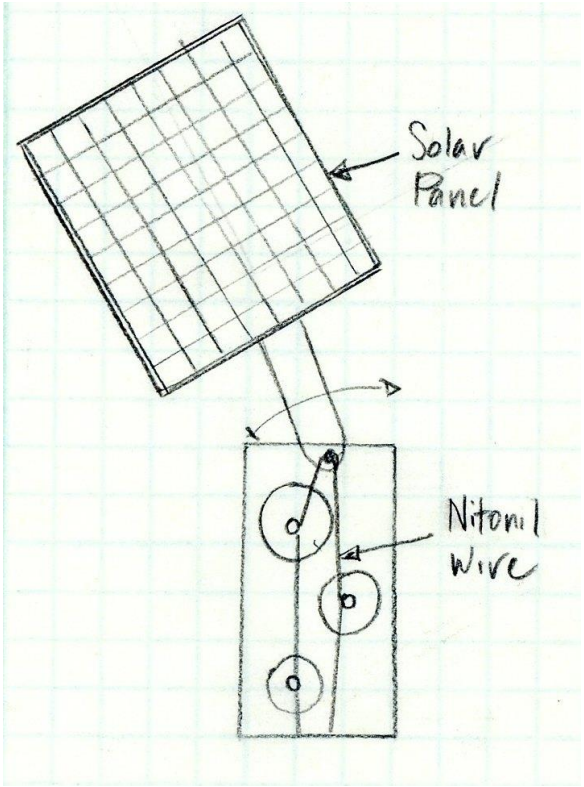
Angled Solar Tracker

Tripod design with panels on leg



Nitinol Solar Tracker

Pulley system with Nitinol cable



Category Factor Weights

Lightweight=1

- Self-imposed

Survivability=2

- Designed for all weather

Maintenance=3

- Client wants low maintenance system

Safety=4

- Unsafe design could short circuit, fall apart during maintenance, etc.

Efficiency=5

- Current designs inefficient

Cost=6

- Current designs are expensive

Reliability=7

- Dr. Acker emphasized this objective

Concept Decision Matrix

	Safety	Cost	Light weight	Efficiency	Maintenance	Reliability	Survivability		
Weighted Importance	4	6	1	5	3	7	2		Total
Designs									
Half cylinder	0	-1	-1	1	0	0	1		0
Angled tracker	1	1	0	1	1	1	1		27
Solar array	1	1	0	1	0	1	1		24
Hydraulic	1	0	1	1	1	1	1		22
Nitinol tracker	1	-1	1	0	1	1	1		11
Water low tech	0	1	-1	0	-1	0	1		4
Standing tripod	0	1	1	1	1	1	0		22

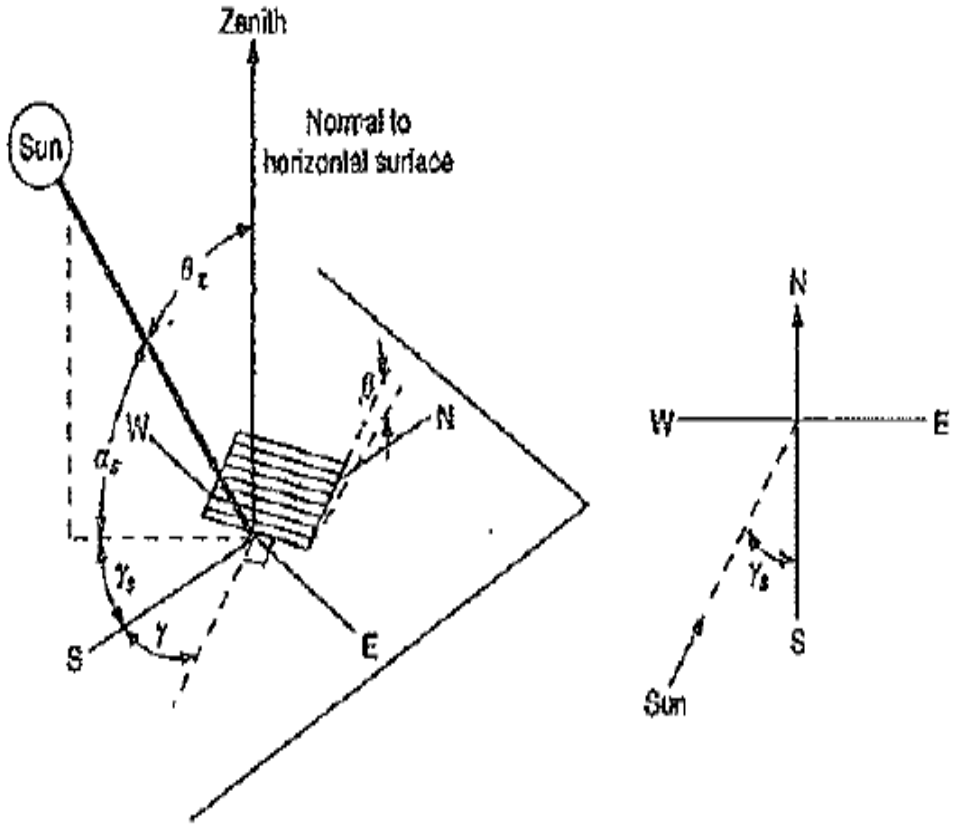
Engineering Analysis Overview

- Three concepts selected from concept generation
- Analysis of solar tracking angles
- Static analysis of the designs
- Final concept

Solar Tracking Angle Analysis

- Most important angles
  - Solar azimuth (Ɣs)
  - Angle of Incidence (Ɵ)
  - Panels slope angle (β)
- Tracking systems are supposed to
  - Minimize angle of incidence (Ɵ)
  - Maximize angle of incident beam radiation

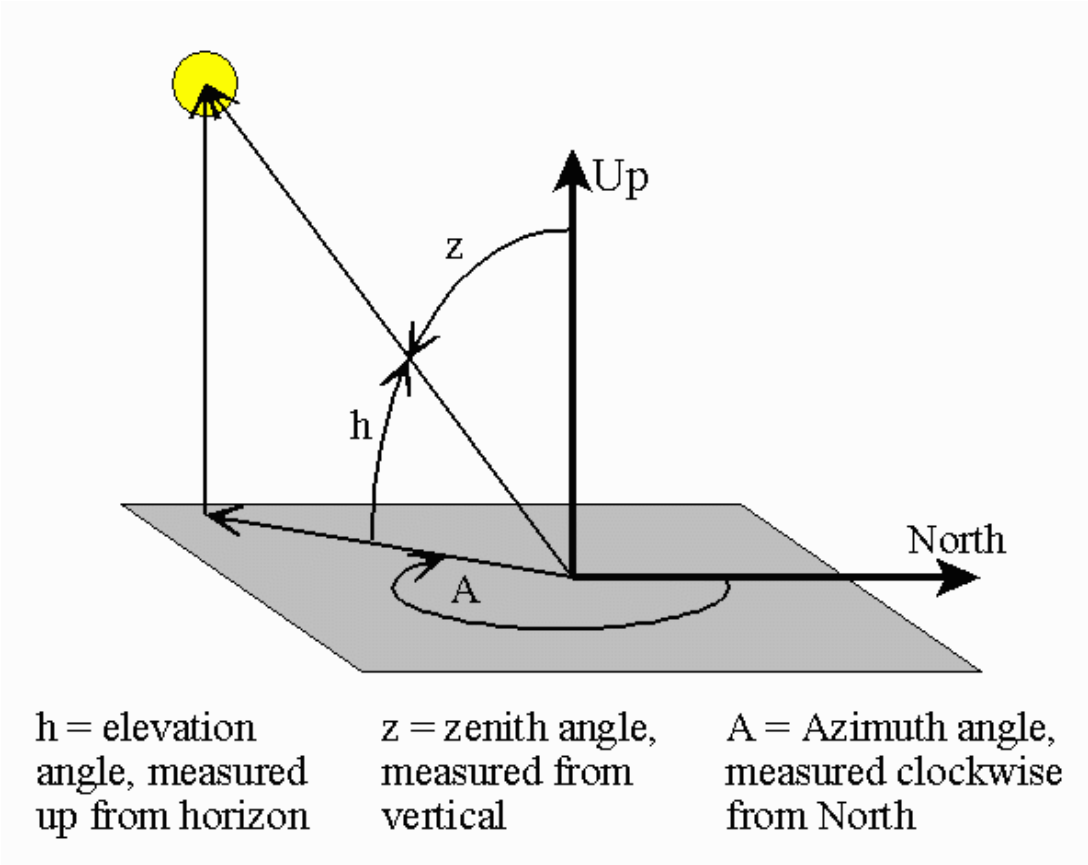
All angles required for analysis



Solar tracking Analysis cont.

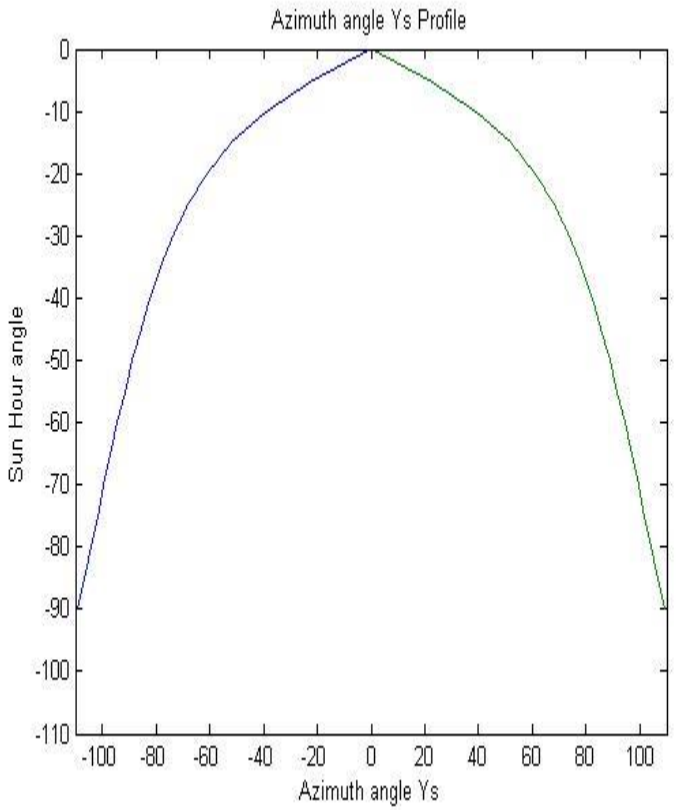
- Location
  - Flagstaff at latitude of 35 degrees North
  - Fixed slope angle of 36 degrees
- Matlab Program
  - Based on desired day of the year
  - Θ (angle of incidence)
  - Ύs (Azimuth angle)
  - Θz (Zenith angle)

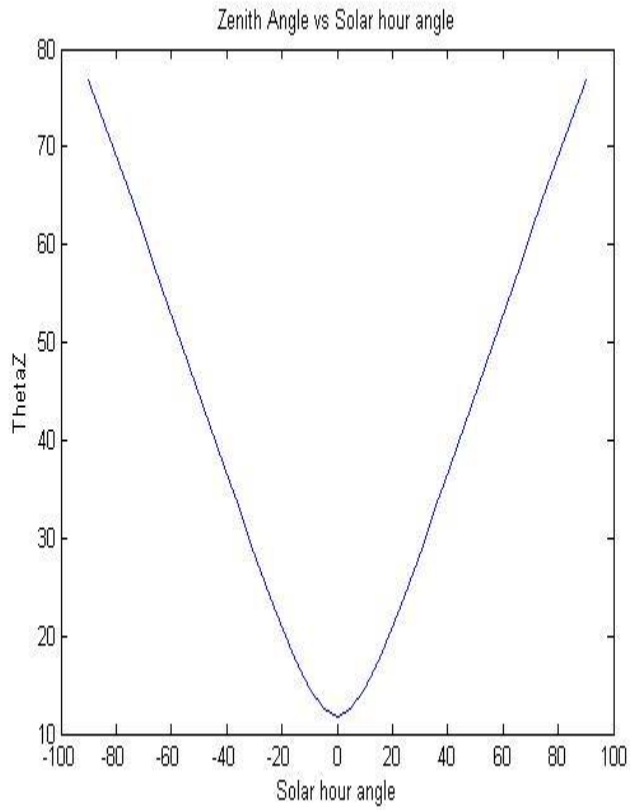
North-South Axis slope tracking

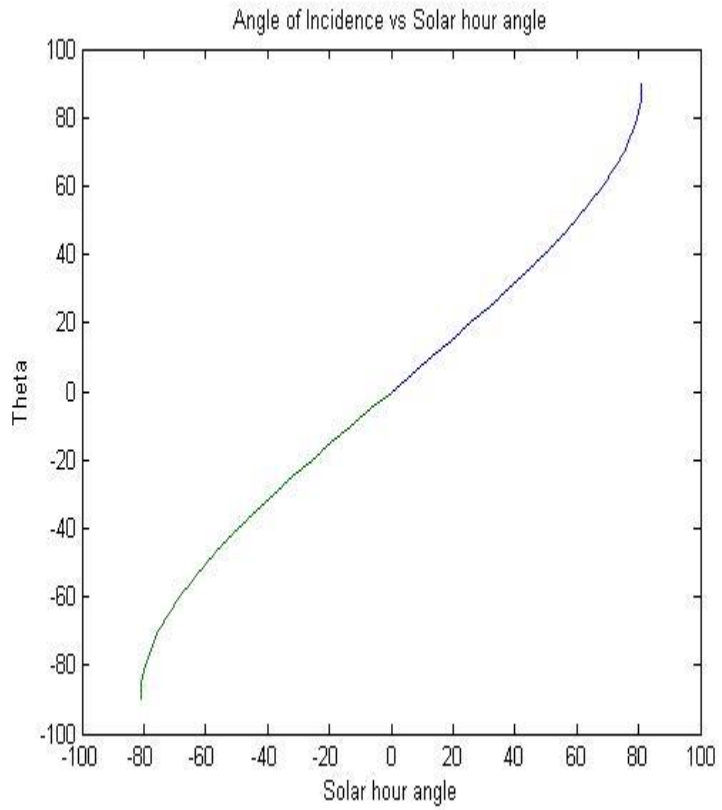


http://capsis.cirad.fr/capsis/help_en/samsaralight J

Solar tracking Data

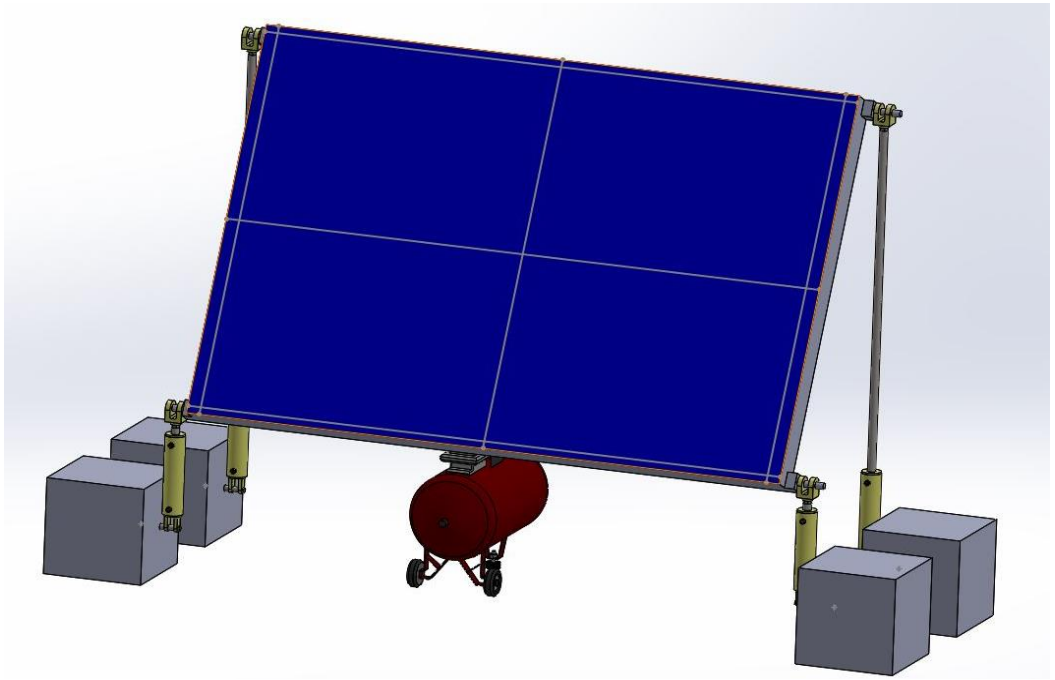




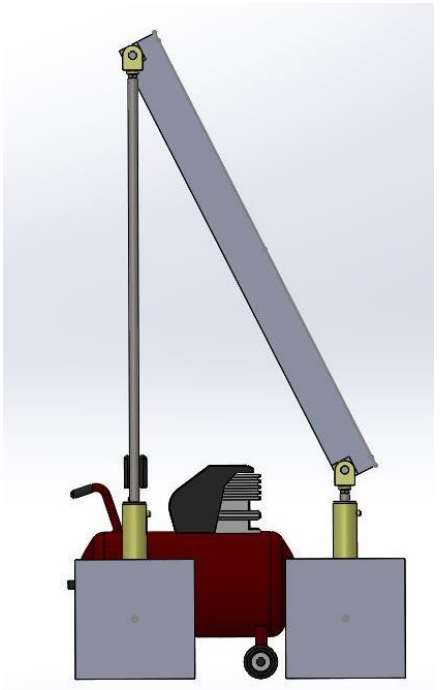


Hydraulic Tracker Design

Isometric view

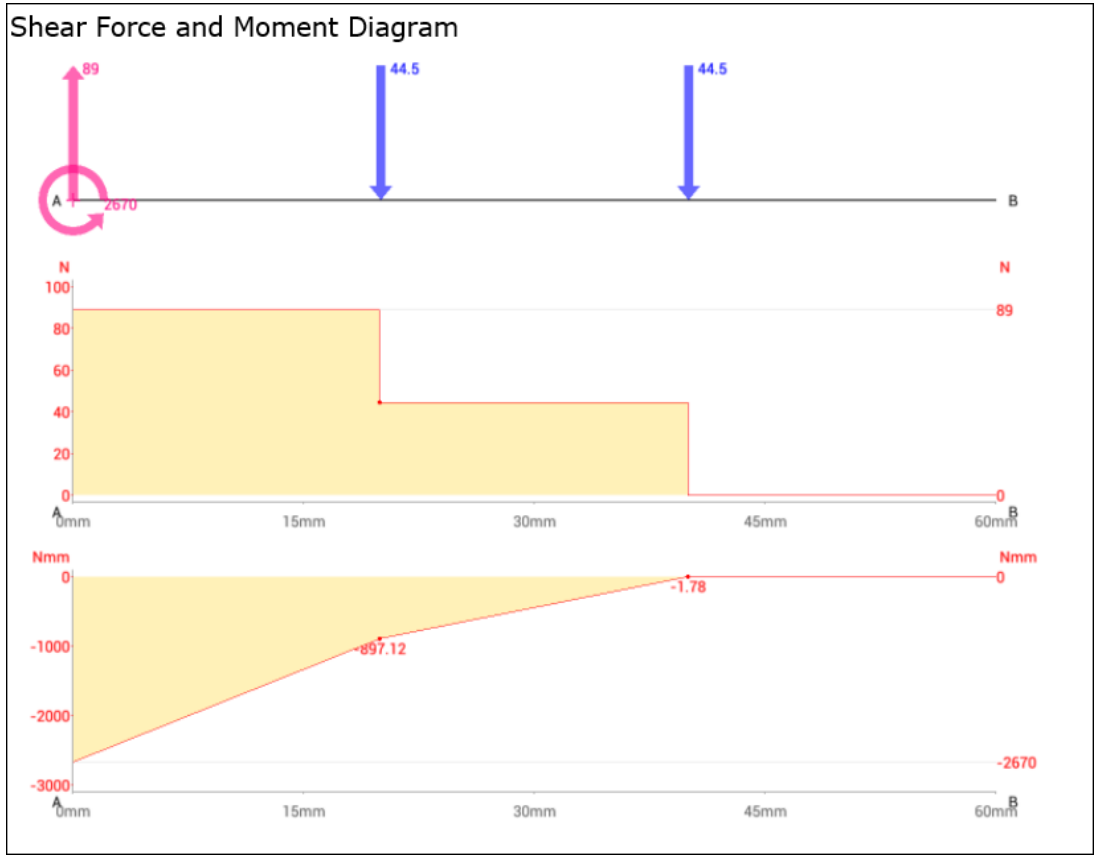


Side view



Analysis

- The weakest point is the connection between the hydraulic and concrete blocks
- The force is 88.97 N
- Moment 2.67 N-m

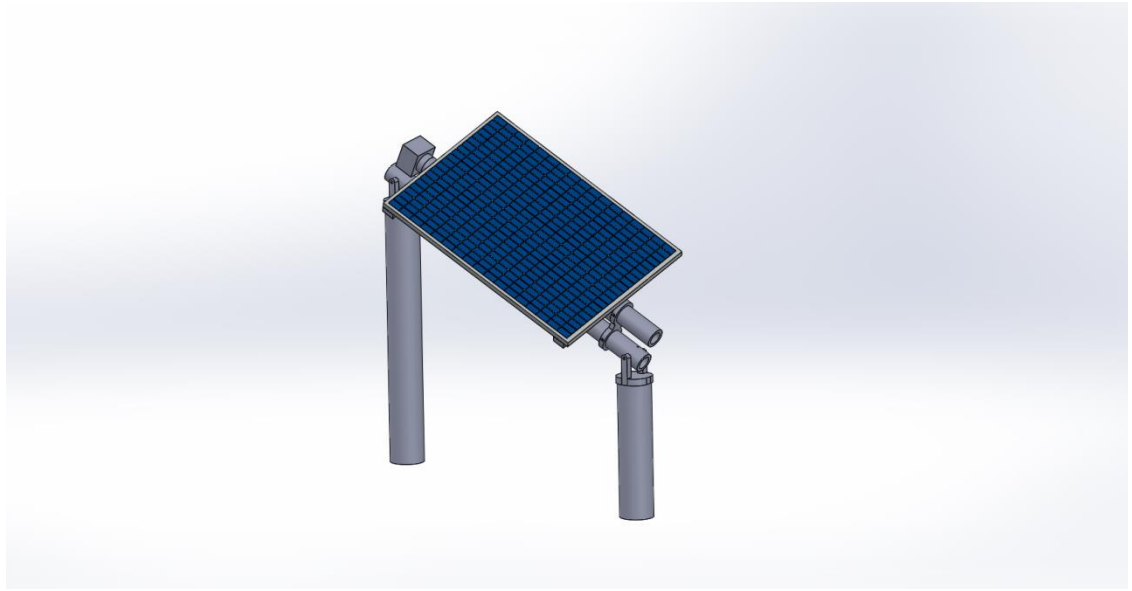


Part Selection

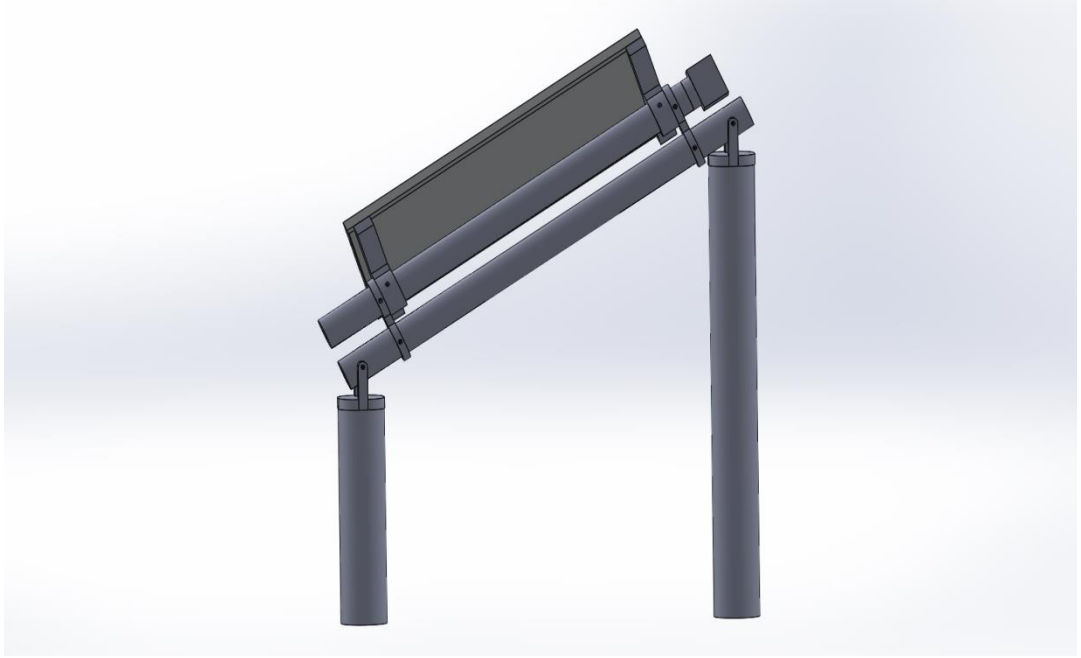
- Hydraulic
  - Piston diameter of 12.5 cm
  - Height difference is 1.045m
  - 49.1 kN of force
- Pump system
  - Produce 80 bars

Angled Tracker Design

Isometric view

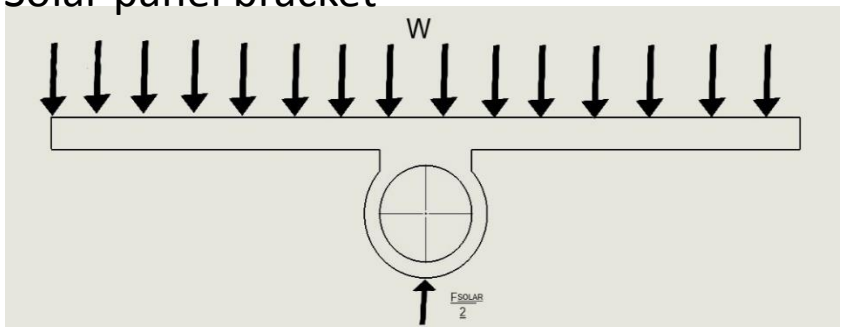


Side view

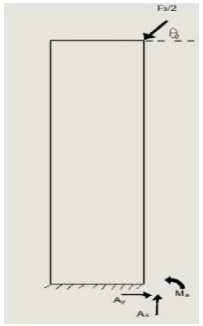


Angled Solar Tracker Frame Analysis

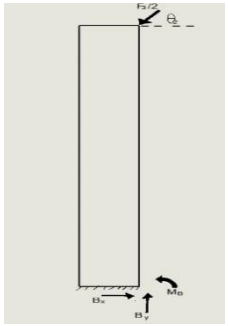
Solar panel bracket



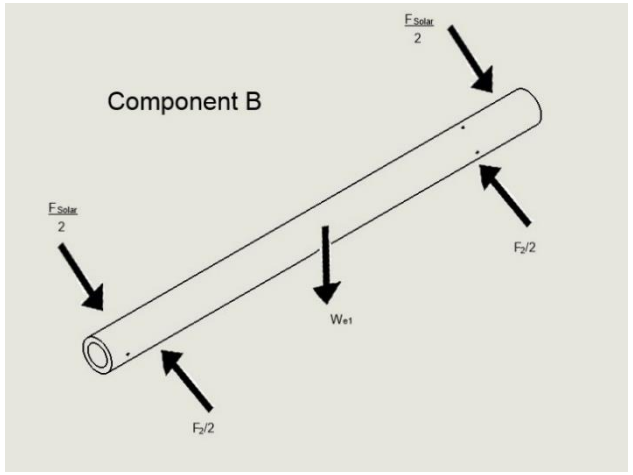
Support 1



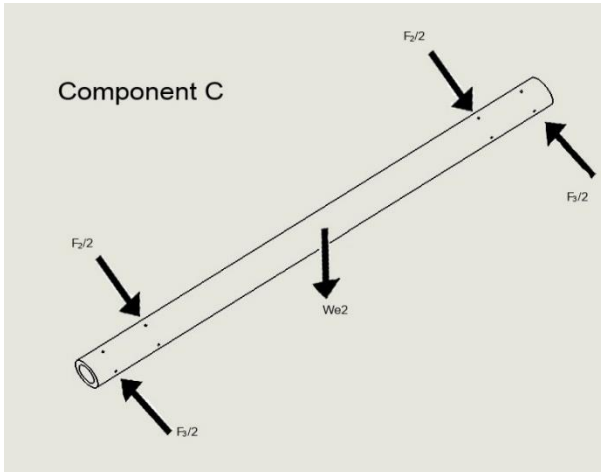
Support 2



Beam 1



Beam 2



Forces Solved

F_{solar} = 325.4 N

F_2 = 341.42 N

F_3 = 357.44 N

A_y = 64.34

A_x = 166.737

B_y = 64.34

B_x = 166.737

Angled Solar Tracker Torque Analysis

- The Torque was calculated using :

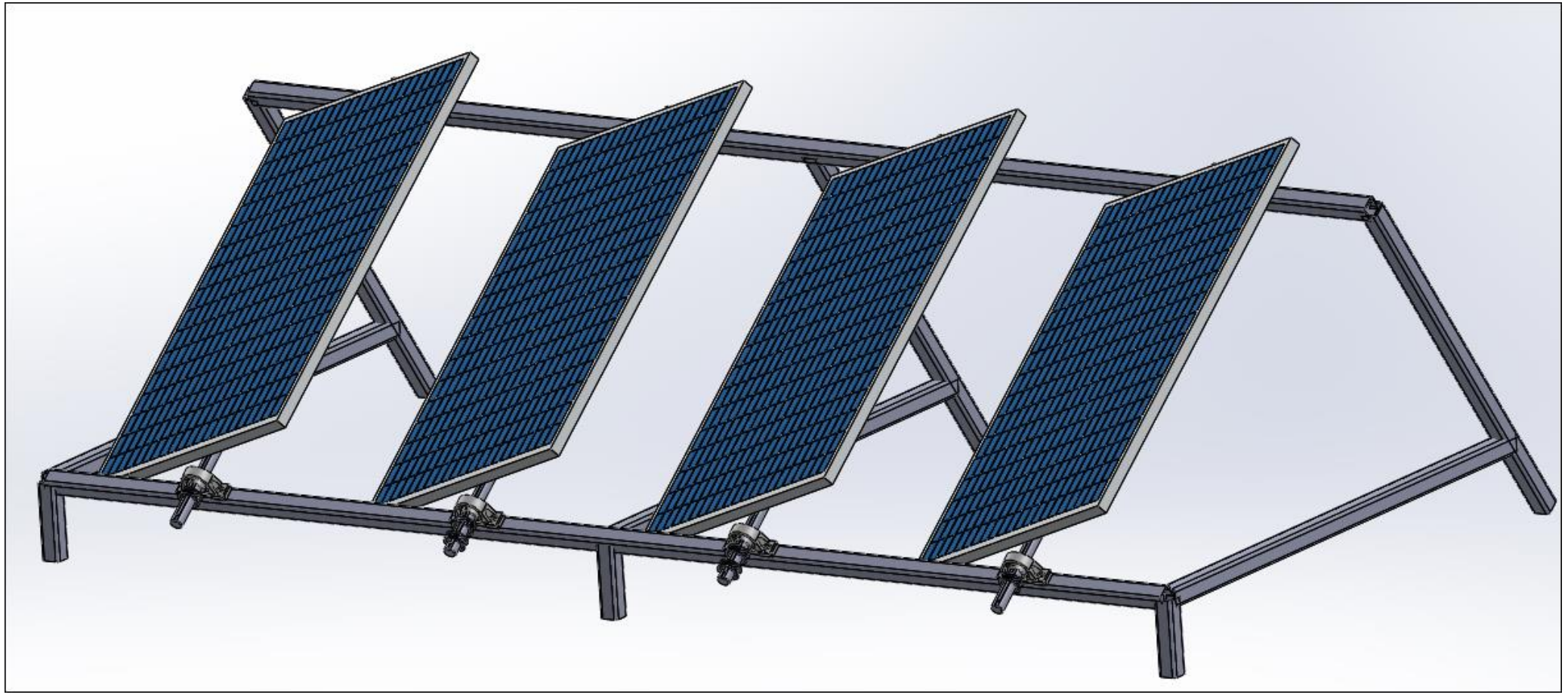
$$T = (F \times 0.48) \times r$$

- Torque = 6.5079 N*m
- Finding the desired Motor using Full-load Torque equation

$$T = (HP \times 5252)/rpm$$

- HP/rpm = 0.001239

Solar Array

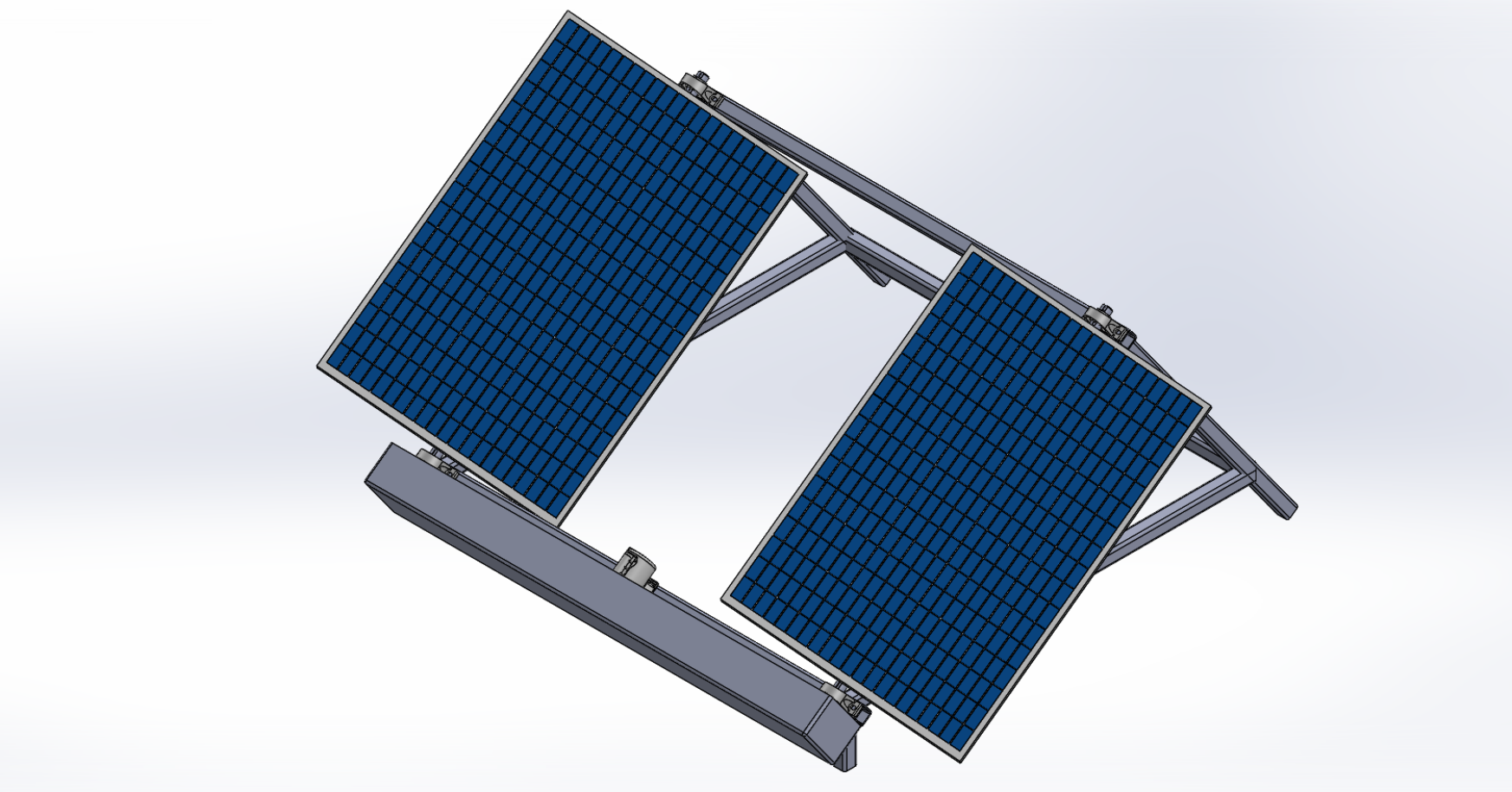


Joshua 24

Final design selection

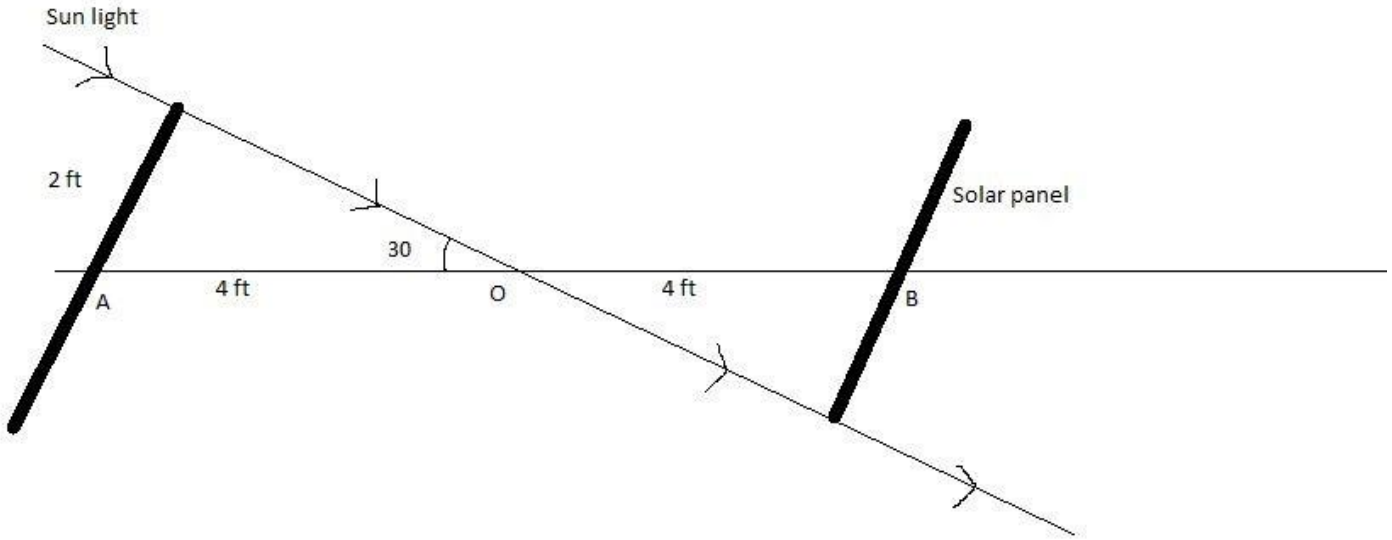
- Solar array
  - Holds two panels
  - Standard parts
  - More evenly distributed weight
- Angled tracker
  - Only holds one panel
  - Space may become an issue
- Hydraulic design
  - Unreasonable power requirements
  - Technical flaws
  - High operating cost

Updated Design



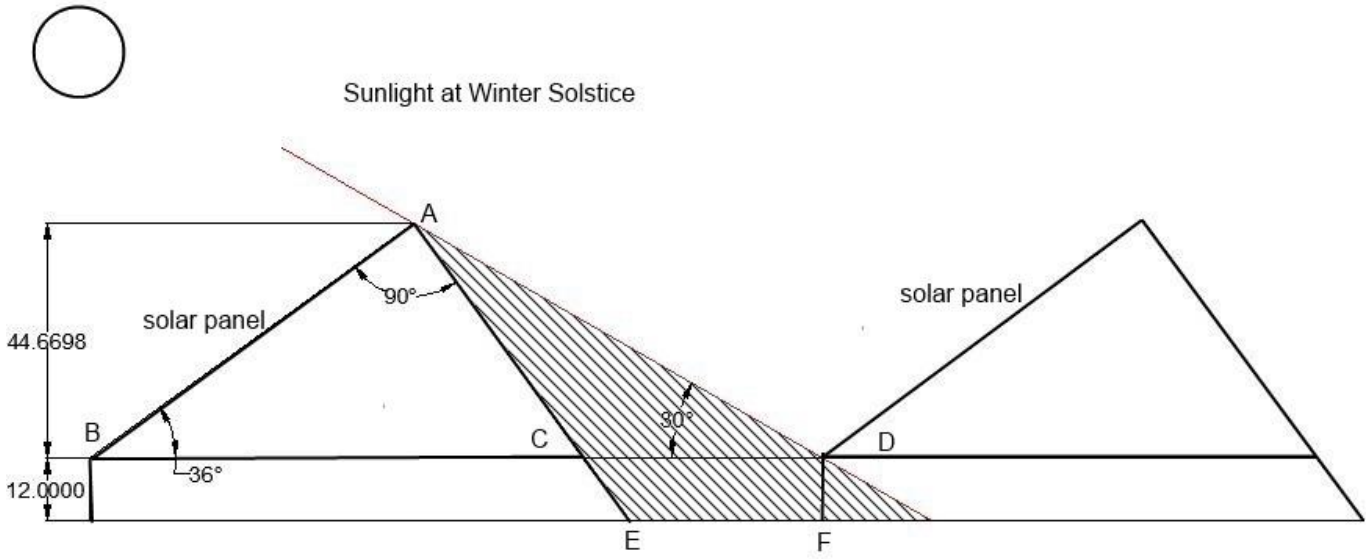
Shading Analysis

The minimum space (AB) between two adjacent solar panels is 8 ft.



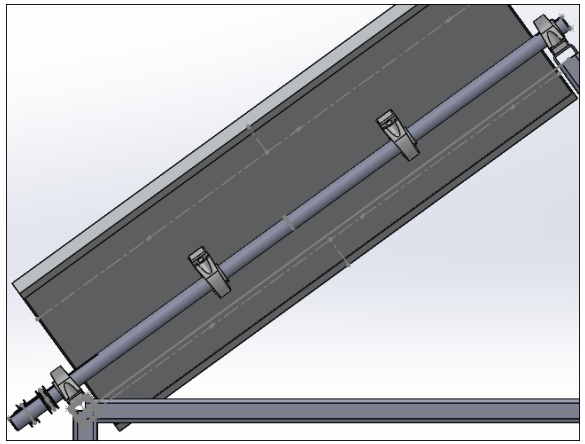
Shading Analysis(Cont.)

- The minimum space (segment EF) between two adjacent solar tracker is 3.5 ft.

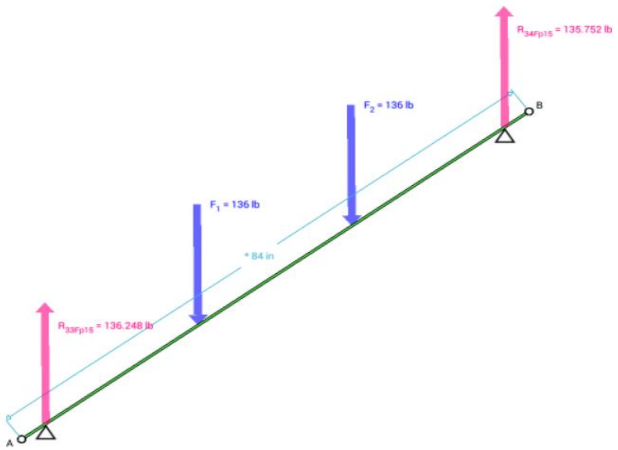


Structure Analysis of solar panel array (Shaft)

Side view of the solar panel

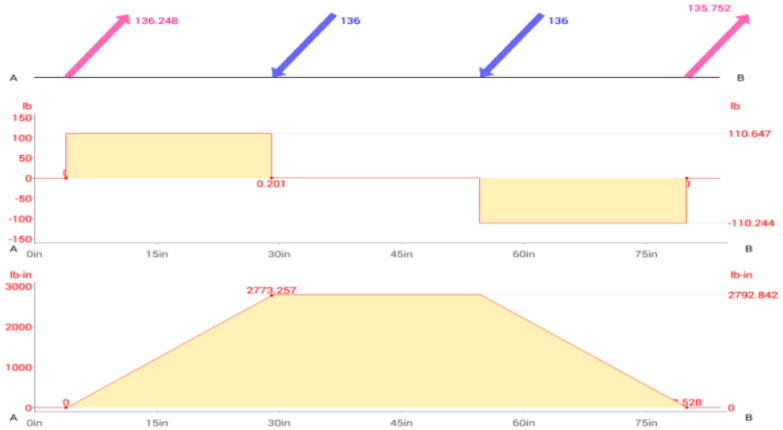


Free Body Diagram



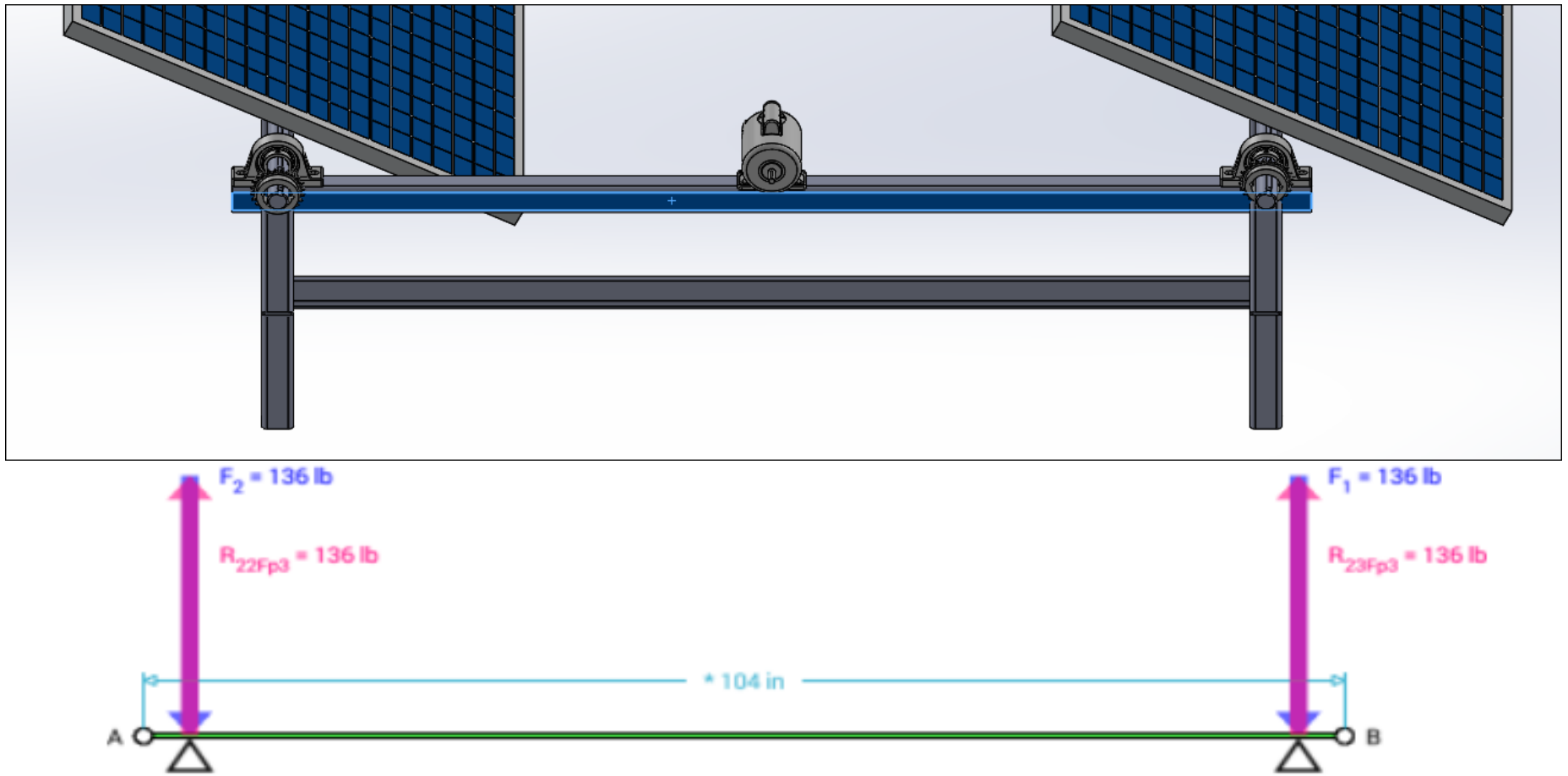
- The reacting force on each support (A and B) point is 136 lb.

Shear and Moment Diagram



- Fracture might occur between two support point (A and B)
- Maximum moment is 2774 lb-ft.

Structure Analysis of solar panel array (Beam)



Solar Panel Array Torque Analysis

- The Torque was calculated using :
  - Fc= μ×W μ=0.16
  - T= Fc×D/2 D=2 in.
  - T = 43.52lb-in
- Desired Motor using Full-load Torque equation
  - T = (HP×5252×8.851)/rpm
  - HP/rpm = 0.001872

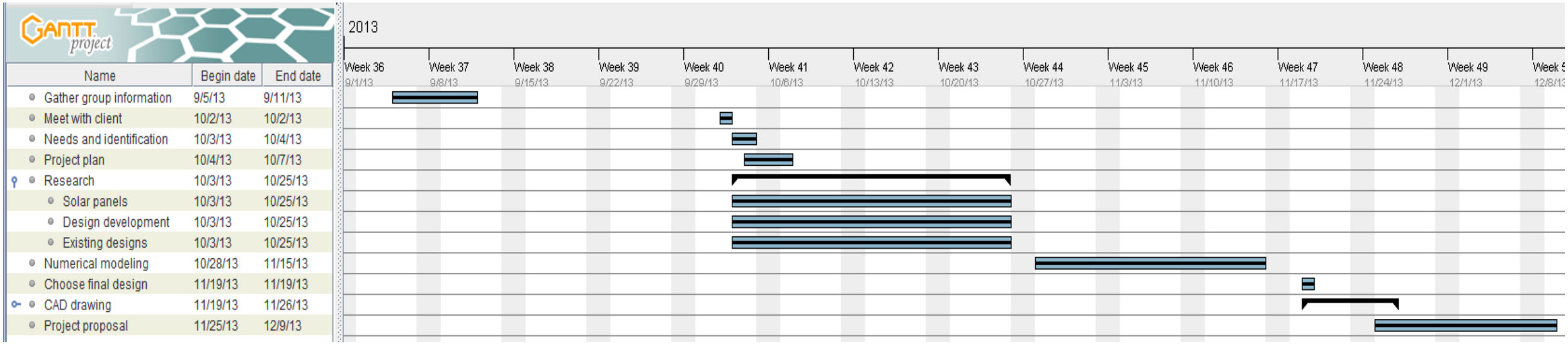
Cost Analysis

Parts	Company	Unit price	Amount	Total Cost	Shipping Cost (Ground)
3”×3”×0.25” Square tube	Bobco Metals	73.29/8ft	64ft	$897.87	$420.11
2” Shaft	Bobco Metals	110.91/8ft	2	$221.82	$132.42
2” pillow block bearings	BearingsOn.com	29.98	4	$119.92	$9.00
Gears	ZOROTools	36.05	4	$144.20	$8.00
Chain	RollerChain4Less	184.65/10ft	2	$369.30	$83.26
DC Motor, NEMA 56C, 90 VDC, 3/4 hp, 1750 rpm	Omega	318.00	1	$318.00	$8.00
Aluminum Flat sheet 12”×48” ×1//16”	Bobco Metals	21.21	4	$84.84	$20.27
Waterproofing Paint	Home Depot	114.98	5 gallons	$114.98	$0.00
Bolts	Home Depot	0.14	20	$2.80	$0.00
				$2270.98	**$681.06**

Labor Costs

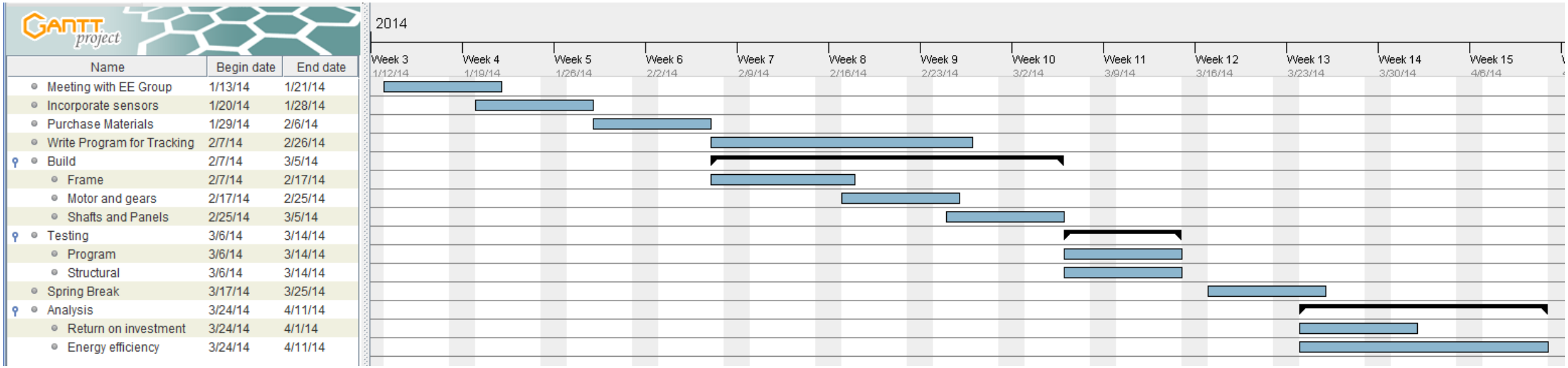
- Design will be built and assembled by team
- Micah, Anthony, Joshua all have welding experience
- Machine shop on campus will be used for welding

Current Gantt Chart



Name	Begin date	End date
Gather group information	9/5/13	9/11/13
Meet with client	10/2/13	10/2/13
Needs and identification	10/3/13	10/4/13
Project plan	10/4/13	10/7/13
Research	10/3/13	10/25/13
Solar panels	10/3/13	10/25/13
Design development	10/3/13	10/25/13
Existing designs	10/3/13	10/25/13
Numerical modeling	10/28/13	11/15/13
Choose final design	11/19/13	11/19/13
CAD drawing	11/19/13	11/26/13
Project proposal	11/25/13	12/9/13

Spring Semester Gantt Chart



Name	Begin date	End date
Meeting with EE Group	1/13/14	1/21/14
Incorporate sensors	1/20/14	1/28/14
Purchase Materials	1/29/14	2/6/14
Write Program for Tracking	2/7/14	2/26/14
Build	2/7/14	3/5/14
Frame	2/7/14	2/17/14
Motor and gears	2/17/14	2/25/14
Shafts and Panels	2/25/14	3/5/14
Testing	3/6/14	3/14/14
Program	3/6/14	3/14/14
Structural	3/6/14	3/14/14
Spring Break	3/17/14	3/25/14
Analysis	3/24/14	4/11/14
Return on investment	3/24/14	4/1/14
Energy efficiency	3/24/14	4/11/14

Conclusion

- Problem description
  - Tracking the sun’s movement increases efficiency of solar panels
  - Current solar tracking units are expensive

- Concept Generation and selection
  - Several different concepts generated
  - Evaluated concepts and chose three designs to evaluate in greater detail

Conclusion Cont.

- Engineering Analysis
  - Determined stress concentrations
  - Evaluated shading
  - Calculated solar angels

- Cost Analysis
  - Evaluated the cost of the motor
  - Evaluated the cost of the structure

References

- Beckman A., William, Duffle A. John, 2006, “Solar Engineering of Thermal Processes”, Third Edition, John Wiley & Sons, Hoboken, New Jersey
- Budynas G., Richard, Nisbett J., Keith, 2011, “Shigley’s Mechanical Engineering Design”, Ninth Edition, McGraw-Hill, New York, New York
- Leo J., Donald, 2007, “Engineering Analysis of Smart Material Systems”, John Wiley & Sons, Inc., Hoboken, New Jersey.
- (2008). “ PVWATTS: Arizona – Flagstaff.” PVWATTS Calculator <http://rredc.nrel.gov/solar/calculators/PVWATTS/version1/US/code/pvwattsv1.cgi >(Oct. 26, 2013)

Questions?