FAMU- FSU College of Engineering
Department of Mechanical Engineering
Dr. Gupta, Dr. Shih, Dr. Frank
Senior Design II: EML4552C

Wireless Infrared Monitoring System

Final Report

4/10/2015

Authors
Michelle Hopkins, Project Manager, Mechanical Engineering, meh09d
Nixon Lormand, Mechanical Lead, Mechanical Engineering, njl08c
Kenny Becerra, Electrical Lead, Electrical & Computer Engineering, kb10j
Joseph Besler, Procurement Chair, Mechanical Engineering, jkb11d
Alexander Hull, Programming Chair, Computer Engineering, ah12r
Jonathan Jennings, Prototyping Chair, Mechanical Engineering, jwj08c

Advisors
Dr. Patrick Hollis, Mechanical Engineering Associate Professor
Dr. Rajendra Arora, Electrical & Computer Engineering Professor

Liaison
James Sharp, Principal Engineer, Siemens Energy Inc.

Abstract

This project has been initiated and delegated to our Senior Design Team 14 of Florida State University's Mechanical Engineering Program by Siemens Energy in order to investigate a more effective, simplified preventative maintenance technique incorporating the use of infrared technology. Siemens has expressed their interest in a conceptual design of a Wireless Infrared Monitoring System that will monitor fossil fuel power plant equipment for problematic operation. They wish for this designed system to ultimately reduce costs through replacement of thermocouples currently used for temperature monitoring as preventative. A conceptualized system has been designed and can be broken down into three major subsystems: the Monitoring System, the Power System, and the Mounting System. The Monitoring System is comprised of the infrared camera, pan tilt module, microcomputer and wireless adapter. The infrared camera will survey selected targets thoroughly, precisely, and without interfering with the equipment. The pan tilt module will control the camera's position allowing it to target a wide range of equipment, reducing the need for numerous systems. The microcomputer will control the camera and pan-tilt module as well as filter and package the infrared data to be sent wirelessly, via the adapter, to the control room. The Power System will consist of an appropriately sized solar panel, charge controller, battery, and inverter to properly power the system throughout the systems lifetime, making it self-sustaining. Finally, the Mounting Structure will consist of a pole, weather enclosure, supports, and fasteners necessary to house, secure, and protect all the monitoring and power system components from the elements. Each of these three major subsystems and subsequent components must be integrated correctly for each of their respective functions to contribute to the final success of the system. This report will detail the full lifecycle of the project encompassing background research, concept generation, final design selection, procurement, prototyping, testing, and analysis. [1]

ACKNOWLEDGEMENT

We would like to acknowledge our sponsor, Siemens Energy Inc., for their donation and support of this project and the Senior Design program at the College of Engineering. James Sharp, specifically, has always been available for technical advising and deliverable review and has served as a great liaison. We would also like to thank Seminole Electric for taking the time to give us a tour of their power plant, R.J. Midulla, and educating us on the equipment that our system will be monitoring. We would like to thank our faculty advisors; Dr. Patrick Hollis and Dr. Rajendra Arora and the instructors of Senior Design; Dr. Nikhil Gupta and Dr. Chiang Shih all of who have provided valuable feedback and advising. Lastly we would like to thank Dr. William Oates for loaning his infrared camera for our prototype development.

TABLE OF CONTENTS

TABLE OF FIGURES

TABLE OF TABLES

I. INTRODUCTION

Currently, power plants use a large network of thermocouples and local vibration monitoring devices to capture temperature and vibrational data of operating equipment. The thermocouples only measure a small local area. Therefore, numerous thermocouples must be individually tapped to each location that needs to be measured. Thus, there must be thermo-wells drilled into any protective casing or piece of equipment that necessitates temperature readings. The thermocouples are then wired to a local junction box, and then through underground conduit back to the control room. The data is used to determine pre-explosive or pre-failure conditions indicative of necessary maintenance in order to prevent major power plant outages. This is called preventative maintenance and is critical in power plants lifetimes after about 10 years. All of these individual systems are invasive, costly, and complicated to implement and beckons for consolidation, simplification, and improvement.

Siemens, as an energy service provider, is interested in investigating a more simplified and effective preventative maintenance technique. Specifically, they are interested in exploring the use of infrared technology. Infrared cameras can be utilized to monitor the temperature of operating equipment, enabling it to diagnose potential problems long before other traditional systems. These cameras are also noninvasive and do not require equipment interference.

Siemens Energy has initiated this project to explore incorporating this technology in a conceptual design of a Wireless Monitoring System to improve their preventative maintenance service. This project has been delegated to our team to find a plausible system solution to the following goal statement and four objectives. [2]

"*Design a proposed complete system that can monitor a wide range of equipment for problematic operation.*"

1. Decrease equipment interference on operating systems.
2. Create cost savings through the elimination of need for numerous existing systems.
3. Decrease manual work needed for preventative maintenance.
4. Design a stand-alone system that does not consume any plant power.

The following table, Table 1, captures the design constraints of this project set forth by Siemens. [2]

Table 1. System Constraints.

Subject	**Descriptor**	**Constraint**
Location	Exclusively	Fossil Fuel Power Plants
Lifetime	At least	30 years
Monitoring	Type	Thermal Imaging, up to 300°C
Power	Source	Solar Harvesting
Battery Storage	At least	3 days
Communication	Wireless	300m
Communication	Protocol	HART
Compliance	Code	NERC, IBC2006
Weatherproofing	Rating	IP55
Movement	Range	360° in horizontal, 90° in vertical

System Cost	Maximum	$20,000
Prototyping Budget	Maximum	$3,000

Table 2. IBC2006 Code.

Seismic Loading	Occupancy Category III
	Site Class D
	$S_s = 0.41g$, $S_1 = 0.19g$
Wind Loading	$V_{3s} = 100$ mph
	Exposure C
Rainfall	5”/hr for 1 hr in a day
Ambient	0-110°F

The testing site that will ultimately implement this product is a 2x1 combined cycle power plant called Richard J. Midulla. It is owned by Seminole Electric and provides about 810 MW to Hardee County, Florida. [3] The plant is almost 15 years old and at the height of its maintenance period. Below in Figure 1 is a layout of the site. The boxed targets are the equipment of interest for our monitoring system. The largest piece of equipment is the Heat Recovery Steam Generator (HRSG). It stands at about 100 feet tall, 80 feet long, and 50 feet wide and necessitates about 100 thermocouples for temperature monitoring. This target is monitored for hot spots on its casing indicative of insulation degradation from the high velocity hot gas path flow. The targets next to the HRSGs are the Boiler Feed Water Pumps (BFPs). They usually contain a handful of thermocouples to monitor the motor housing and bearing temperature for overheating and pitting from wear over time. The Step-up Transformers (GSUs), Unit Auxiliary Transformers (UATs), and the switchyards are all located on the right side of the plant. The GSU and UAT’s three power outlet bushings should be monitored for hot spots and short circuits indicative of a pre-explosive condition due to loss of insulation. Finally, the switchyard should be monitored for short-circuiting and hot spots as well. [2] A schematic of the plant can be seen below in Figure 1 with all of the targets highlighted in red.

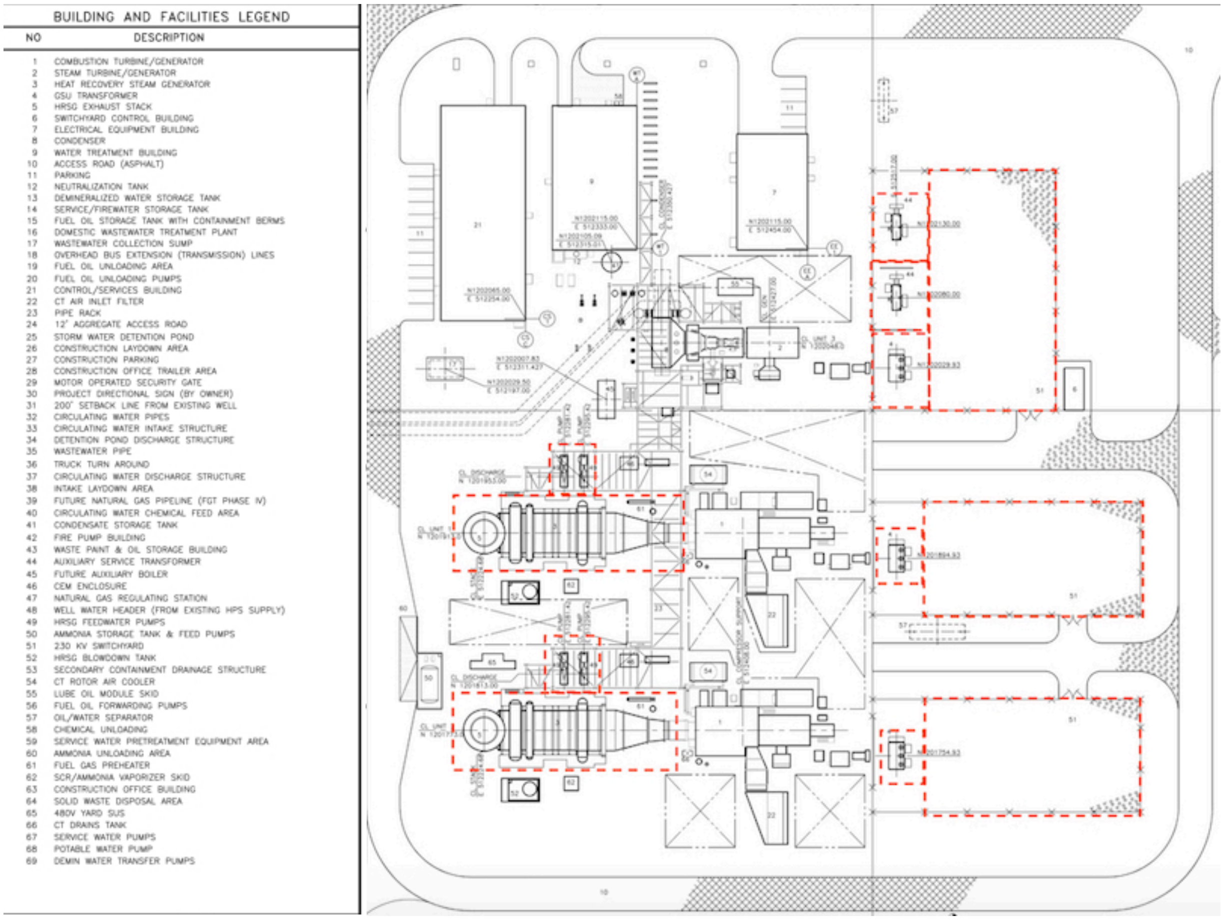


Figure 1. Implementation Site and Targets.

II. Background Research

A. Thermography Background

Thermography uses the infrared band of the electromagnetic spectrum. The infrared band can be classified into four smaller bands; near (0.75-3 μm), middle (3-6 μm), far (6-15 μm) and extreme (15-100 μm). An infrared camera measures the temperature of an object by measuring its emitted infrared radiation in these bands. This is possible due to the relation between radiation and surface temperature. This relation was originally described through Planck's law of the spectral radiation of a blackbody, which is an object that is a perfect absorber and emitter of incident radiation. The relation can be seen below in Equation 1 where W is the spectral radiation of the blackbody, h is Planck's constant, c is the speed of light, λ is wavelength, k is the Boltzmann's constant and T is temperature.

$$W_{\lambda b} = \frac{2\pi hc^2}{\lambda^5(e^{hc/\lambda kT}-1)} * 10^{-6} \qquad [\frac{W}{m^2}, \mu m] \tag{1}$$

Figure 2a below is a graph of Planck's law for different temperatures. It can be seen that radiation is zero at $\lambda = 0$, reaches a max at λ_{max}, and then approaches zero again. As the temperature increases, the maximum wavelength decreases. This can be described by the differentiation of Planck's law, called Wien's Displacement Law, as seen in Equation 2.

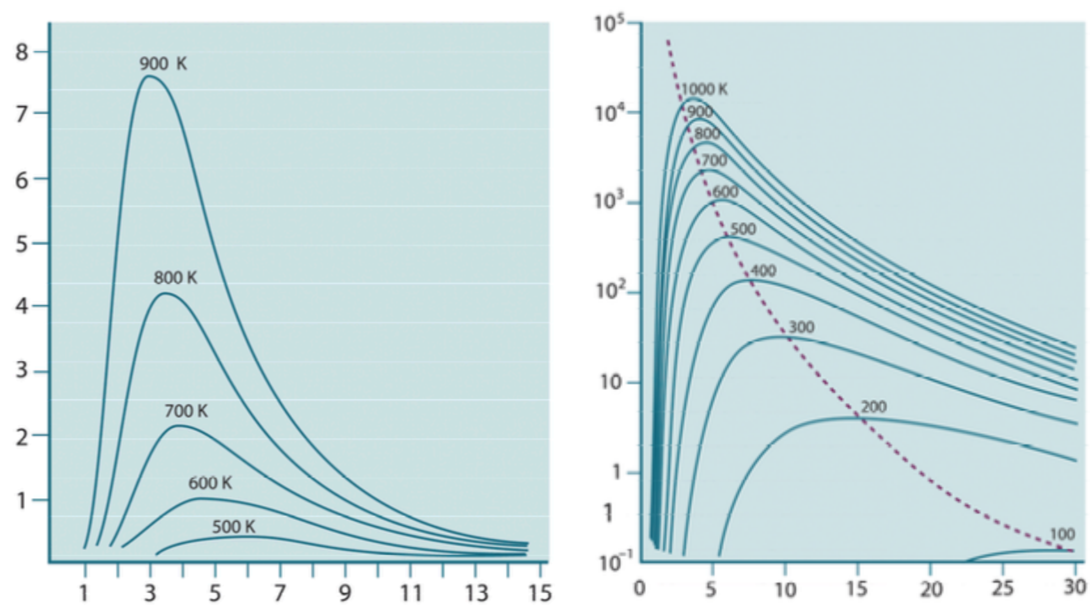


Figure 2. Blackbody Spectral Radiation (a)Planck's Law (b)Wien's Displacement Law.

$$\lambda_{max} = \frac{2898}{T} \qquad [\mu m] \tag{2}$$

This equation is the mathematical expression that explains why a flame goes from red to yellow to white as its temperature increases. A graph of Wien's Displacement Law can be seen in Figure 2b above. By integrating Planck's formula from $\lambda = 0$ to $\lambda = \infty$, you arrive at the Stefan-Boltzmann's law, described in Equation 3, which represents the area under the Planckian curve at that respective temperature.

$$W_b = \sigma T^4 \quad [\frac{W}{m^2}] \tag{3}$$

These laws all cover blackbody behavior, however, the majority of objects can at best approach blackbody behavior due to spectral absorbance, reflectance and transmittance. Emissivity (ε) is used to describe the fraction of an object's emittance as compared to a blackbody. A blackbody has an emissivity of 1. Anything with an emissivity less than 1 is defined as a graybody. For a graybody radiator, the Stefan-Boltzmann Law becomes: [4, 5]

$$W_b = \varepsilon \sigma T^4 \quad [\frac{W}{m^2}] \tag{4}$$

When infrared cameras measure radiation using this the Stefan-Boltzmann Law for graybodies, they are measuring a number of things including emission from an object, reflected ambient emission, and atmospheric emission. In order to accurately measure temperature, the following parameters should be known and inputted into the camera: emissivity, humidity, atmospheric temperature, object distance, and reflected ambient temperature. These parameters are not always easy to measure in every situation. Therefore the camera has built in calibration algorithms that it executes when no inputs are provided. [6]

B. Market Study

A market study was conducted in order to assess if there existed similar technologies or market gaps. It was found that there are monitoring systems that have been developed for similar applications. These systems have common subsystem components, which gave some good concepts of the potential scope of this project early on. The following images in Figure 3 are examples of monitoring systems by Helios [7], Panasonic [8], and A to Z Security [9]. They all contain an infrared camera, solar harvesting, battery storage, and some form of wireless communication. All items are fastened securely to a mounting structure. Some of the systems incorporate pan-tilt modules as well. These systems seem to vary around the cost of $5,000-$10,000. It should be noted however that most of the cameras used in these existing systems are high definition security cameras with limited infrared capability or lower end infrared cameras. Also, almost all are for security applications and do not last without sunlight for extended periods of time. Some also require extra packages to be purchased for added features like extended wireless transmission distance or higher IP ratings. Our particular application requires an infrared camera of much higher caliber for specific temperature monitoring of electrical substations and complicated thermal systems, as compared to just security.

Figure 3. Market Solar Wireless Security Systems (a)Helios (b)Panasonic (c)A to Z.

Due to the fact that this project has existing technologies and market competition in place already, the focus will be on proper component selection, integration, and specification towards our sponsors specific needs and goals. Close attention will be paid toward subsystem interface to ensure that a cohesive system is ultimately produced.

III. FUNCTIONAL ANALYSIS

In order to accomplish our goal statement, it was conceptualized that the system's function could be classified into three main subsystems: the Monitoring System, the Power System, and the Mounting System. Under these three subsystems, components were selected in order to accomplish the subsystem overall function along with the specific objectives given. A block diagram of our sub-systems and their respective components can be seen in Figure 4 below. Following is a breakdown of each subsystem, its components, and their functions.

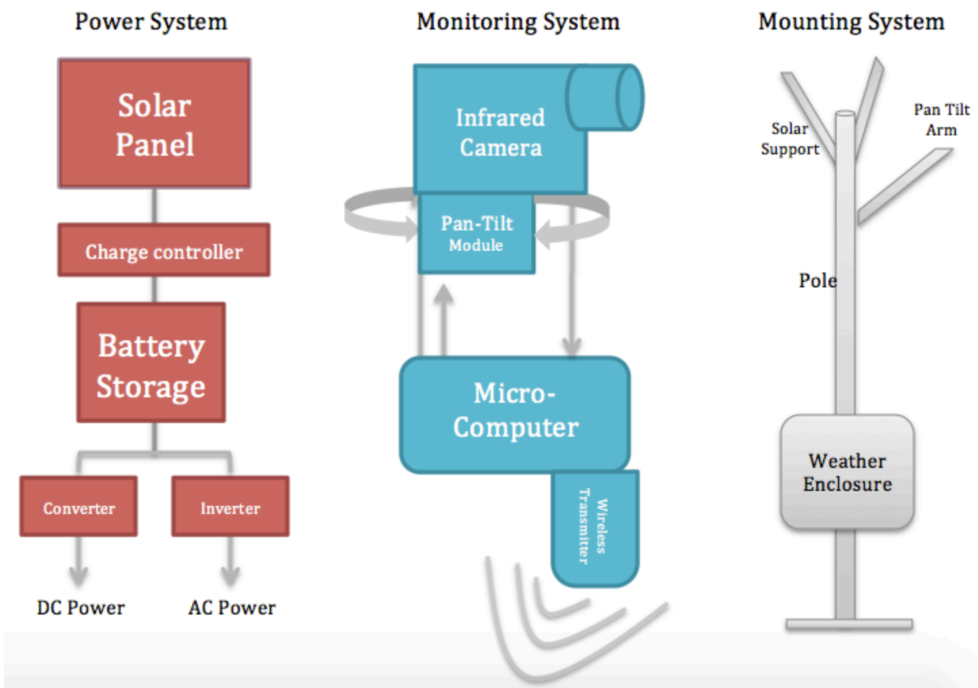


Figure 4. Sub-System Diagram.

A. MONITORING SYSTEM

The monitoring system will consist of the infrared camera, the pan tilt module, the microcomputer, and the wireless transmitter. An infrared camera was chosen for its ability to monitor the temperature of targets without interfering with their operation and reliability. The pan tilt module will rotationally position the camera, enabling it to monitor multiple pieces of equipment. This will decreases the number of systems needed to monitor the entire plant. The microcomputer and wireless communication module will package, analyze, and transmit the infrared data to the control room decreasing the amount of manual labor a wired network necessitates. All of these features will create overall cost savings, if successful. In order for this to happen successfully, these sub system components must be chosen and interfaced seamlessly.

The infrared camera chosen for this project must be durable, low weight, efficient, and have good image and data resolution. The infrared camera should also have minimal power consumption in order to reduce the total system load. In order to properly monitor the targets previously discussed in the Introduction; the camera must detect temperatures up to 572°F (300°C) with an accuracy of ±5%.

The pan/tilt module should operate in an auto scan mode that will cycle through fixed positions chosen by the operator while not consuming too much power. It should have the ability to have a continuous pan of 360° and have 90° of tilt motion. The pan tilt module should employ binary communications for dynamic applications to provide high bandwidth control. The motors of this module will need to be powered and controlled through the integration of a microcomputer through a RS 232, 422, or 485 serial or Ethernet connection. [10]

The wireless system will be used to communicate between the microcomputer and the control room via a Wireless Local Access Network (WLAN) using Wi-Fi technology. To facilitate wireless communication for the monitoring system a few components will be needed: a router to create the WLAN, an access point to access the WLAN from the microcomputer, and a directional antenna/bridge to boost the range of the wireless network in order for the field systems (clients) to be communicate with the control room (host). The router and antenna will be located in the control room for simplification and will not be considered as part of the system cost as they already exist in most control rooms. The wireless adapter will allow the systems to gain access to the existing network to upload and send infrared files.

The microcomputer acts as the onboard computer, executing programs while processing and storing data. It is the “brains” of the operation. The microcomputer will have to seamlessly interface with the camera, pan-tilt, and wireless module or else the sub-system, as a whole, will not function. The microcomputer must also have a fast enough processor and storage space to support the necessary programs to compile the code i.e., Windows 7, CodeBlocks, API’s, protocols, SDK’s etc.

These four components will be timed and executed in the following sequence. First, the pan-tilt will move to the initial position specified by the operator and then wait 5 seconds. During these five seconds, the camera will be prompted to focus, take a picture, and save the radiometric image. Two File Transfer Protocols will then be used to first save the image from the camera to the microcomputer and then to send it to the ‘control room’ for display and analysis.

B. POWER SYSTEM

The power system will consist of the solar panel, charger controller, battery, and appropriate inverter/converter to properly deliver power to the electronic components. These components will work together to harvest, store, and transmit power to the monitoring system making it self-sustaining, the last of our four objectives.

The solar panel will need to be a rigid substrate and its frame must be durable in order to stand to 100 mph winds. It must also have supports and fasteners to secure it onto the mount at a tilt equal to the local latitude facing South. The solar cells must also be protected by particle resistant tempered glass in order to reduce maintenance and panel degradation. It should be weatherproofed to at least IP55 to protect from outdoor conditions and stand up to a 30-year lifespan. Ideally, the solar panel should have a high power output warranty guaranteed by the vendor. This will ensure that the panel’s efficiency will not degrade too much over the lifetime, although it is understood that some degradation is inevitable. Finally the solar panel must be sized appropriately to produce the necessary power to the batteries to meet system load. Panels are usually rated under the following standard conditions: Input light (E) of 1000 W/m^2 at an Air Mass of 1.5. These values are essentially the maximum solar insolation at high noon during the spring or autumn equinox at 25°C ambient temperature. These conditions rarely, if ever, occur in real time therefore it is necessary to simulate the specific conditions your panel will experience to ensure the nominal amount of energy output is enough for the application. Due to the fact that the size, and therefore cost, of the solar panel is entirely dependent on the system load requirements, power consumption should be a primary concern for all other component selection. A higher efficiency Monocrystalline panel (17-21%) will also reduce the size of the panel needed. [11]

The batteries have similar limiting constraints as listed above. The size of the batteries needed, rated in Amp hours, is dictated by the total system load over 3 days. The batteries must be able to store and deliver this amount of energy to the system without significantly depleting the lifetime of the batteries. Most batteries have very short lifetimes of about 3-5 years. This lifetime can be augmented however by a proper power management system consisting of a charge controller and an inverter. Also battery lifetime can be optimized by never over-discharging the batteries. Deep Cycle Lead Acid batteries are designed for a low depth of discharge and are ideal for our system application. [12] Lead Acid batteries also have the lowest maintenance and are relatively inexpensive. The size of the battery, while being constrained by the system load, must also not be too excessive because it will be the heaviest component on our system. This in turn will restrict the placement on the mount and the type of securement needed. Once again, this is why reduced power consumption is a goal for every subsystem.

Finally, a charge controller is a necessary component for all solar-battery systems. It will properly charge and discharge the battery according to the available solar power and load demand. A charge controller greatly increases the life of batteries as they prevent over charge and discharge. Maximum Power Point Tracking Charge Controllers are the most efficient because they optimize the match between the solar panel output and battery bank. It looks at the output power of the solar panel compared to the real-time battery voltage and calculates what the best power output can be to match the battery. It then converts the voltage of the solar panel in order to maximize the charging current to the battery. Most MPPT Charge controllers are 97% efficient and can give up to 20% more power gain to your solar system than conventional controllers. [13]

The power system sizing, selection, and design couldn't be completed until the selection of the monitoring system components were finalized and the total electric load was known. However, it is known that the solar panel, charge controller, and battery bank voltage must match. The charge controller's maximum current and voltage also must be higher than both the solar panel and batteries maximum. This will prevent the charge controller from being burnt out. [14] Finally, an inverter will be necessary if any electronic devices necessitate AC power as batteries and solar panels output DC. The inverter must also be oversized in order to compensate for the conversion losses and startup power demands. [15]

C. Mounting System

The purpose of the mounting system is to support, centralize, and protect the other key components while allowing them to optimally perform. The mounting structure is broken into 4 components; the enclosure mounting, solar panel mounting, pan tilt mounting, and a centralized pole. These four components allow for rigidity and modularity of the mounting system. That is, each subsystem can be reliably secured to the pole and can also be removed and placed in different ‘stacking orders’ and orientations. The recommended standard mounting order from top to bottom should be solar, pan tilt, and then the enclosure. Making the mounting system modular allows for optimization of individual component performance and thus the improvement of the overall system performance. Modularity also allows the components of this system to be removed and mounted elsewhere in the facility. To further ensure versatility of the mounting structures, a single set of hardware components will be used on almost all of the mounting systems.

IV. Component Selection & Sub-System Design

After a functional analysis was performed a market study was conducted for component selection. The component selections for each subsystem were evaluated differently depending on the type of analysis it necessitated. For our monitoring system, a market study was performed and several options selected. A decision matrix was then used for final selection due to the fact that little analysis could be performed on un-obtained market products. Once the monitoring system was selected, the power system was designed. Homer 2, a renewable modeling and analysis program, was used to analyze and optimize our conceptualized Solar/Battery System. Market products were then selected once size was known. Recommendations from our sponsor and experience from our site visit was used to select the mounting system components. PTC Creo and Force/Wind analysis in Comsol was then performed in order to analyze the mounting orientation and system as a whole. All final selected component specifications can be found in Appendix 1.

A. Monitoring System Component Selection

1. Infrared Camera

Three infrared cameras were considered for our design and can be seen in Figure 5. Their relevant specifications can be seen in Table 3. Two of the cameras considered are produced by FLIR, a leading company in thermography (A310f and A35). The A series offers various lens options to allow for different viewing distances and are geared for Automation Monitoring. Pelco, a surveillance and security technology company, also makes an infrared camera, the Sarix TI. Once all cameras were selected, Table 3 was used to generate a decision matrix, seen in Table 4, to determine the most optimal choice.

Figure 5. Infrared Camera Options: (a)FLIR A35 (b)FLIR A310f (c)Pelco Sarix TI

Table 3. Camera Specification Comparison.

Subject	Units	FLIR A310f	FLIR A35[14]	PELCO Sarix TI
Lenses	degrees	6,15, 25, 45	25,48	44,18,12,6
Weight	lb	11	0.44	7.2
Dimensions	mm	460 x 140 x 159	106 x 40 x 43	376 x 126 x 128
FOV	mm	6 x 4.5	48 x 39	44 x 3
IFOV	mrad	0.33-2.45	2.78, 1.32	unknown
Operating Temp	F	-25 to 122 F	5 to 122 F	-40 to 122F

Temperature	F	-4 to 248 F	-13F to 275F	39 to 478F
Measurement		32 to 662F	-40 to 1022F	
Encapsulation	IP rating	IP66	IP40	IP66
Accuracy	%	±2%	±5%	±2%
Power	W	24 W w/ heater	6 W max	35 W w/ heater
Image Resolution	pixels	320 x 240	320 x 256 pixels	384 x 288 pixels
Image Streaming	Hz	16-bit @7.5 Hz	14 bit @ 60 Hz	30 Hz
Cost	USD	$9,500-$12,000	$5,500	$6,000-$15,000
Warranty	yrs	10	10	3

Table 4. Infrared Camera Decision Matrix.

Camera	Power	IP Rating	Temperature Measurement	Accuracy	Image Quality	Frequency	Cost	Weight	Total
Weight	20%	20%	20%	15%	10%	5%	5%	5%	100%
FLIR A310f	7	9	7	7	5	2	6	5	**6.80**
FLIR A35	9	2	9	4	6	7	8	9	**6.40**
PELCO Sarix TI	3	9	4	7	8	4	6	7	**5.90**

In the end the FLIR A310f was selected as the Infrared Camera. It rated the highest in the decision matrix at 6.8 due to its all-around performance specifications in power consumption, weather-proofing, and temperature readings. It is the most expensive option selected but gives an accurate temperature reading of (± 2%) with a measurement temperature range of (32°F to 662°F) which exceeds our temperature constraint. The FLIR camera was also selected due the open market protocols, vast amounts of available product support and thermography analytics software.

The FLIR camera's also come with a wide array of exchangeable lenses based upon your desired field of view. Table 5, below, is a table of the different lenses and their calculated field of views (horizontal, vertical, and instantaneous). [16] This shows another huge advantage of selecting FLIR because multiple lenses could be ordered and utilized on different systems depending on the targets being monitored. For standardization we recommend a 25° lens.

Table 5. FLIR Lens Calculations.

Lenses	FOV (deg)	VFOV (ft)	HFOV (ft)	Spot Size (in)	IFOV (mrad)
6°	4.5	1.97	2.63	0.099	0.33
15°	11.25	4.94	6.58	0.246	0.82
25°	18.8	8.33	11.11	0.408	1.36
45°	33.8	15.53	20.7	0.735	2.45
90°	73	37.5	50	1.89	6.3

2. Pan Tilt Module

There have been four selections on pan tilt units and their performance specifications have been listed in Table 6. The PTU – D100 E Series in Figure 6a is manufactured by FLIR and is designed for high duty cycles and reliable 24/7 operation in harsh all-weather environments. The Vector-35G in Figure 6b is a pan tilt module manufactured by General Dynamics. It is also designed for 24/7 continuous operation without requiring homing or calibration and low power consumption with upright or inverted installation options. The PTU-D100E and the Vector-35G both fulfill the desired performance specifications. However, the prices of these pan tilt modules were significant compared to our total budget. The investigation for less expensive pan tilt units resulted in finding of two other possible solutions. The Axis Communications YP-3040, in Figure 6c, is designed as an optional accessory for Axis fixed network cameras with pan-tilt support. Even though it is preconfigured for several Axis fixed network cameras it uses the common Pelco-D protocol. [17] It said to be ideal for an inexpensive solution when fine adjustments to a cameras field of view are needed. The Sarix Ti, in Figure 6d, is manufactured by Pelco and designed for easy integration into any new or existing video security application to provide detection, recognition, and identification of people and vehicles in any lighting condition. Table 6 summarizes the important design specifications for each pan tilt module for comparison. This was used in order to cerate a decision matrix, Table 7, to decide on the best solution.

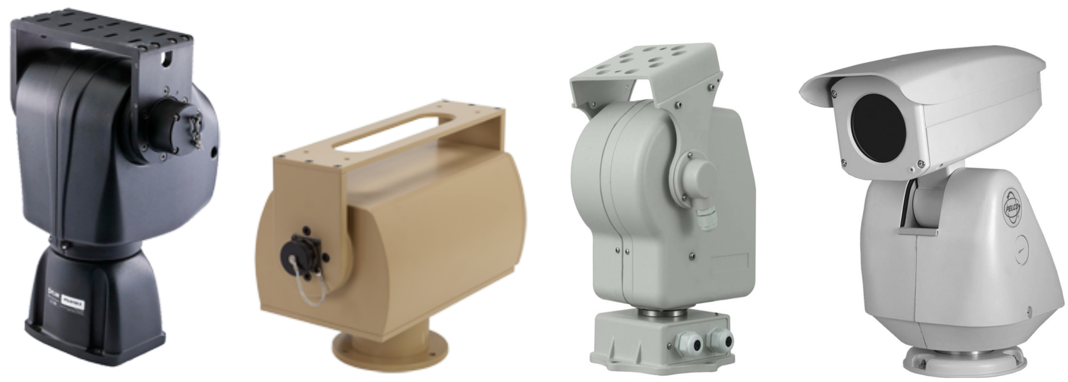


Figure 6. Pan Tilt Options (a)FLIR PTU-D100E (b)Vector 35G (c)YP-3040 (d)Pelco Sarix TI.

Table 6. Pan Tilt Specification Comparison.

Criteria	PTU – D100 E[9]	Vector-35G[16]	YP-3040[17]	Sarix Ti[18]
Pan range	360° Continuous	360° Continuous	0° to 355°	360° Continuous
Tilt range	-90° to 90°	-45° to 45°	10° to - 80°	33° to - 79°
Pan/Tilt Resolution	0.0075°	0.005°	fine	Unknown
Speed (Max)	120°/s Pan and Tilt	90°/s Pan, 15°/s Tilt	7.5°/s Pan, 6°/s Tilt	100°/s Pan, 30°/s Tilt
Power Consumption	33W, 45W, 63W	8W, 72W	30W	110W
Payload	25lbs	35 lbs.	17.6 lbs.	Integrated
Weight	20lbs	14 lbs.	9 lbs.	33 lbs.
Weatherproof	IP67	IP67	IP66	IP66
Operating Temp.	-22°F to 158°F	-40°F to 158°F	-4°F to 158°F	-40°F to 120°F
Connector	RS-232/422/485	RS-232/422/485	RS-485	Coaxitro/R-232
Protocol	DP,Pelco-D, Nexus	General Dynamics, Pelco-D	Pelco-D	Pelco-D/P
Cost	$7,000	$20,000	$500	$10,000

Table 7. Pan Tilt Module Decision Matrix.

Module	Power Consumption	IP Rating	Operating Temperature	Speed	Cost	Pan/ tilt	Payload	Weight	Total
Weight	25%	5%	15%	10%	20%	10%	10%	5%	100%
PTU-D100	4	9	7	9	6	10	8	7	**6.75**
Vector -35G	5	9	8	7	1	10	9	8	**6.1**
YP-3040	8	8	5	2	9	7	6	9	**6.9**
Sarix Ti	3	8	6	8	5	10	10	5	**6.1**

The Pan Tilt Module selected for this design is the YP-3040 by Axis Communications. Even though it is preconfigured for several Axis fixed network cameras it uses the common Pelco-D protocol, which can interface with the FLIR A310f. [18] The YP3040 is said to be ideal for an inexpensive solution when fine adjustments to a cameras field of view are needed. The Axis YP3040 also recommend several accessories, two of which we will be utilizing; the PS24 Mains Adapter and Mount seen in Figure 7. The Adapter will be used to step 120VAC down the 24VAC to power the camera. This adapter was chosen in order to protect and power the pan-tilt appropriately. The support arm will support and attach the pan tilt module to the pole securely.

Figure 7. Axis YP3040 Pan Tilt Module, PS24 Mains Adapter, and Arm Support.

3. MICROCOMPUTER

The microcomputers found to be the best selections for this system are summarized below in Table 8 and Figure 8. The Beaglebone Black and Raspberry Pi B+ are both microprocessors, while the Versalogic Tiger is a single board computer (SBC). Beagle Bone and Raspberry Pi are both very affordable producers of microprocessors used for community-supported development. Versalogic, on the other side of the scale, produces SBC’s for more rugged and complex OEM applications. Table 9 is a decision matrix executed based upon the specifications of each component.

Figure 8. Microcomputer options (a)BeagleBone (b)Raspberry Pi (c)Versalogic Tiger.

Table 8. Microcomputer Specifications.

Microcomputers	Cost	Operating Temp	Graphics	Power	Processing (MHz)	USB Ports	GPIO (pins)
Beaglebone Black	$45	-40 to 90C	3D Accelerator	2 W	ARMv6 1000	2	92
Raspberry Pi B+	$35	0 to 70C	Broadcom VideoCore IV	1.4 W	ARMv7 700	4	40
Tiger Versalogic	$1000	-40° to 85°C	HD Video	6 W	Atom Z530P	7	4

Table 9. Microcomputer Decision Matrix.

Microcomputer	Compatibility	Cost	Operating Temp	Graphics	Power Consumption	Processing	Total
Weight	20%	20%	10%	30%	5%	15%	100%
Beagle Bone Black	7	5	7	5	6	7	**5.95**
Raspberry Pi B+	5	6	5	7	7	5	**5.9**
Tiger Versalogic	9	1	7	8	5	10	**6.85**

The Tiger VersaLogic, as seen is Figure 8c, best matches the caliber of the rest of the monitoring system components and was the ultimate selection. The Tiger takes advantage of Intel's Atom Z5xx (Menlow XL) processor, which was designed specifically for embedded applications. Based upon Intel's 45 nm hi-k Metal Gate Silicon technology, the Z5xx series Atom chip offers high performance, industrial temperature operation and radically reduced power requirements. [19] The camera will be able to connect to the standard on-board gigabit Ethernet port with network boot capability. The Tiger is compatible with a variety of popular 64 bit operating systems, including Windows, Windows Embedded, and Linux. Video features include advanced 3D graphics, high-definition video, integrated LVDS, and optional analog VGA support. The following components, pictured in Figure 9 and 10, are accessories that were purchased with the Versalogic board that were needed for startup, setup, and interfacing.

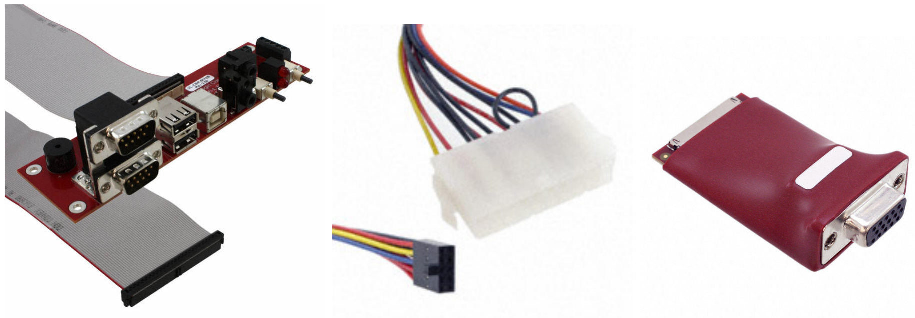


Figure 9. I/O Paddleboard, ATX Power Adapter, LVDS-VGA Adapter.

Figure 10. IDE Drive Cable, IDE Adapter Board, LVDS Cable.

4. Wireless Communication

The following wireless components were selected to comprise the wireless system; a router (TEW-813DRU) [20], a USB access point (TEW-664UB) [21], and an omni-directional antenna (TL-ANT2415D) [22]. The router will create the wireless network, the access point will be connected to the microcomputer giving it access to upload data to the network, and the antenna will provide the range necessary for data transmission to the control room. At a 300m range, the total loss the signal experiences is 90dB. This means that for communication to be possible the above components must be able to overcome this 90dB loss. The equations below demonstrate that indeed, communication is possible with these component selections. [23]

$$Power\ transmitted(Pt) + Antenna\ Gain(AG) - Sensitivity(S) \geq Loss\ of\ 90dB \quad (5)$$

$$Control\ Room \rightarrow System : 22dB(Pt) + 15dB(AG) - \big(-66dB(S)\big) = 103dB \quad (6)$$

$$System \rightarrow Control\ Room : 13dB(Pt) + 15dB(AG) - \big(-65dB(S)\big) = 93dB \quad (7)$$

Due to the fact that a router and antenna are already located in the control room, these items were not considered in the cost or scope of our system. Only the USB Adapter needs to be included to gain access to the existing network.

B. POWER SYSTEM DESIGN

1. CONCEPTUALIZED DESIGN

In order to choose an adequate solar panel for the project a preliminary breakdown of the power consumption had to be completed first. First, the decision was made to cycle our system on a 2 minute Power Cycle followed by a 10 minute Sleep Cycle, 5 times an hour. This is equivalent to an energy consumption of 300Wh/day. This decision greatly decreases total power consumption (compared to a 24 hour operation) and allows for a more reasonable solar panel size and battery storage. Table 10 shows a power consumption breakdown of the two cycles. A 10% margin was used for the power cycle in case any extraneous power is consumed during start up/shut down of the components. A 50% margin was used for the sleep cycle due to the fact that the pan-tilt module and infrared camera did not provide a power consumption value for a 'sleep mode'.

Table 10. Component Power Consumption.

Module	Power Cycle	Sleep Cycle
Infrared Camera	9 W	--
Pan tilt Module	30 W	--
Microcomputer	6 W	1.05W
Wireless	1.5 W	1.5 W
Margin	10%	50%
Total	50W	5W
Length	2 min	10 min
Hours/day	4hrs/day	20hrs/day
Consumption	200Wh/day	100 Wh/day

According to National Renewable Energy Laboratory (NREL) Solar Resource Database, the annual daily average of Solar Insolation for our site location from 2009 to 2012 is 5.1 kWh/m^2/day. [24] This is also referred to as sun hours/day. This insolation value is for fixed flat plate collectors that are angled to the local latitude, 27.6°, facing South which is the planned configuration for our solar panel. This value was used to ensure that our system is designed to output the appropriate power. Following Equation 8 below, the nominal solar power needed was calculated.

$$P_{needed} = \frac{300\ Wh/day}{5.1\ hrs/day} = 60\ W \tag{8}$$

In order to power the system for 3 days our batteries will have to deliver 900Wh. Batteries however are sized in Amp hours and should not be depleted past 50% to preserve lifetime and performance. So, assuming a discharge depth of 50% and a system voltage of 12V, the approximate battery size was calculated below in Equation 9.

$$Storage = \frac{300Wh/d*3days*2}{12V} = 150Ah \tag{9}$$

This means we need at least one 12V 150Ah or two 12V 75Ah batteries in parallel to meet our 3-day requirement

2. ANALYSIS

In order to properly test this conceptual sizing of the solar panel and battery, Homer 2 was utilized. The program operates off of the National Renewable Energy Laboratory Databases and is used to optimize and analyze renewable power systems. The system was set up to have a 30-year lifetime as stated in our constraints. A Primary Load was then set up to simulate our power and sleep cycles detailed in the previous section. The Solar Resource was uploaded from NREL's Solar Database for the specific latitude and longitude of RJ Midulla. The average monthly temperature profile was also uploaded. A Photovoltaic Array was then added to the circuit with 60-150 W panel sizes to consider. The average panel lifetime was also set to 20 years with a derating factor of 80%, which is common for most panels. The panel was then set to tilt at the local latitude, 27.6°, with a temperature coefficient of power set a -5%/°C. The nominal operating cell temp was set to 25°C. These two factors will utilize the ambient temperature average to calculate the loss in solar efficiency with increasing temperature. A 12V Vision 6FM55D battery was then added to the system with 1, 2, or 3 strings to consider. This battery was one of the ten the program recommends for solar charging. It is deep cycle lead acid AGM battery ideal for deep cycle charging and discharging. Lastly, a converter was added in order to simulate the conversion efficiency from DC to AC power.

The program was then run to optimize and the result was a 150 W panel with 2 55Ah batteries (110Ah total), and an 80 W inverter. Figure 11 below shows the photovoltaic analysis over a year. The 150W PV panel was predicted to output about 655Wh/d, enough to meet the system load and charge the batteries. Figure 12 shows the state of charge of the batteries throughout the year. The batteries are almost never depleted past 50% with exception to a couple of occurrences during the low-lit winter months. It should be mentioned that the calculated lifetime based on the charge and discharge cycles, was calculated to be 6.15 years. This means the batteries would have to be replaced 5 times in the systems 30-year lifetime. Figure 13 shows the total system performance over 1 week's time. The yellow is the solar panel output. The thick blue line at the bottom is the cyclic load switching between 50 and 5W. The darker blue line is the battery state of charge. Day 1 and 2 are both sunny days where the solar panel is outputting enough to meet the load and charge the batteries to their maximum. Days 3 and 4 are both cloudy days and you can see how the battery state of charge drops to about 50% until Day 5, 6 and 7 where it is replenished again by another sunny day.

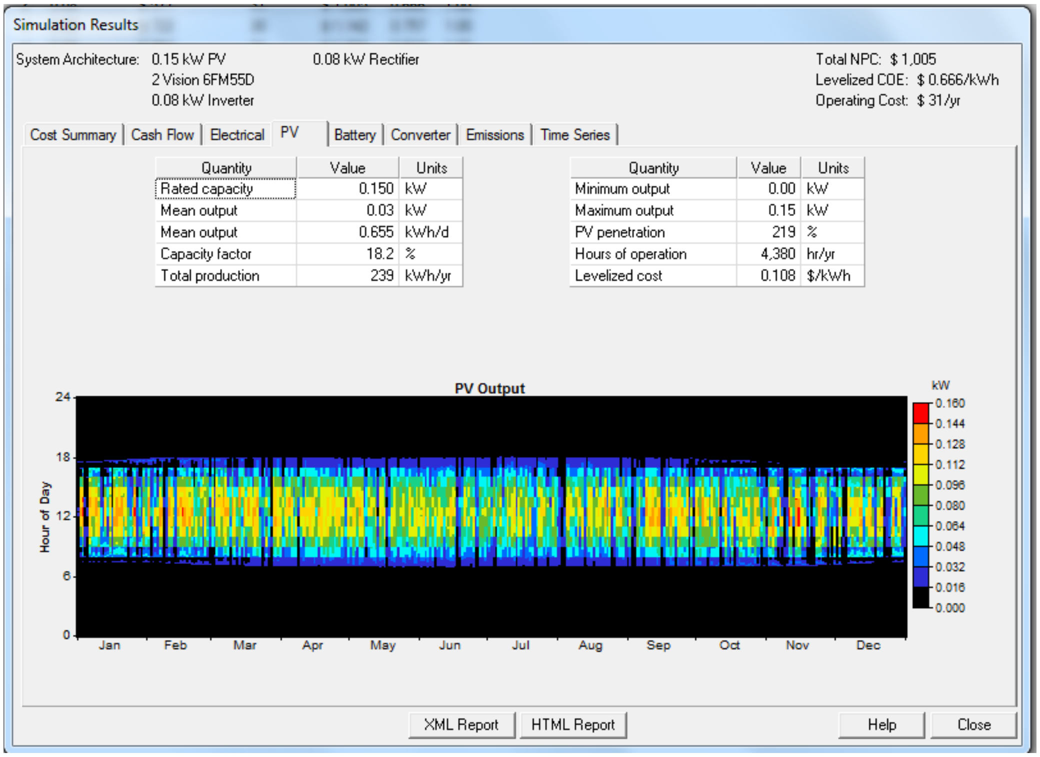


Figure 11. Photovoltaic Output Analysis over 1 year.

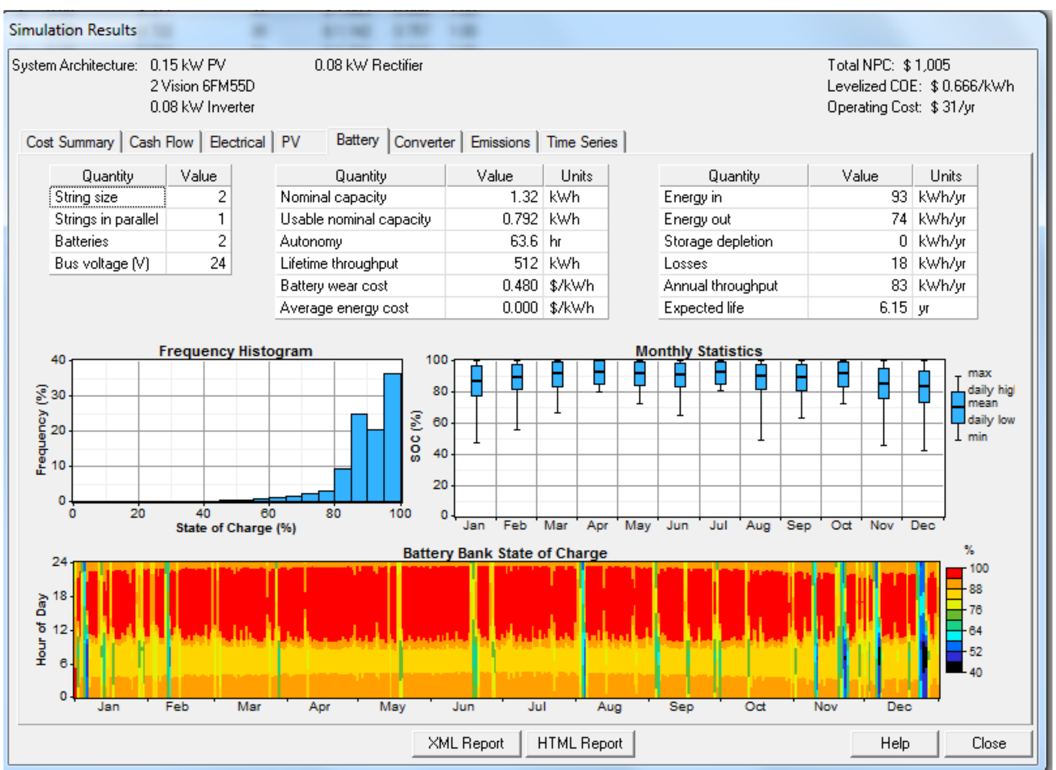


Figure 12. Battery Analysis: State of Charge Simulation over a year.

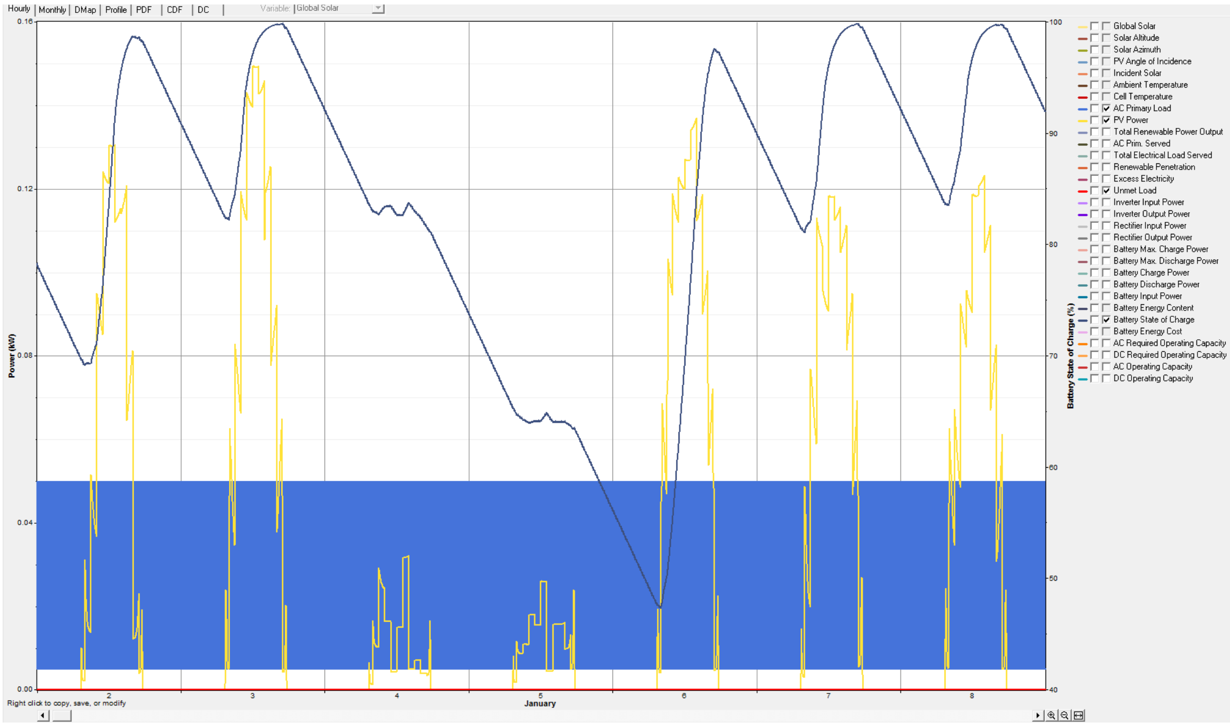


Figure 13. System Analysis over 1 Week.

3. Component Selection

Based upon the Homer Analysis optimization, a Renogy 150W Monocrystalline Panel was selected based on its efficient performance, high reliability, off-grid application, and quality certifications. A single AJC 12V 100 Ah battery was chosen for the battery storage in lieu of two 55Ah batteries for circuit simplification. The charge controller selected for this design is a 20A EcoWorthy MPPT Solar Charge Controller. It uses the common 3-stage Pulse Width Modulation charge algorithm and Maximum Power Point Tracking to efficiently charge the battery without cutting the solar panel's power production. This component was sized using Eq. 10.

$$A_{c.c} = {}^{P_{Panel}}\!\big/_{V_{battery}} + 25\% = {}^{150\ W}\!\big/_{12\ V} + 25\% = 15.6A \rightarrow 20A \qquad (10)$$

The solar panel's open circuit voltage (22.2V) is less than the charge controller's max input voltage (42V), which will prevent the panel from burning out the charge controller. The solar panel's short circuit current (8.5A) is also less than the maximum charging current of the charge controller (20A) and the battery (30A). This will prevent the panel from causing the charge controller to fail and then subsequently overcharging the battery. These are all necessary checks that must be made before properly selecting a charge controller. [14] The Ecoworthy Charge controller selected also has an LCD Display that shows the charging power and output status. This is a very functional feature when needing to know the status of the battery. The selected solar panel, battery, and charge controller can be seen in Figure 14.

Figure 14. (a)Renogy Panel (b)100Ah AJC Battery (c)EcoWorthy MPPT Controller.

An inverter is needed in the circuit to convert the DC power supplied by the panel to AC power required by the pan tilt module and microcomputer. An inverter's total wattage should always exceed the maximum appliance wattage (30W) by 25% to compensate for the converter efficiency. Additionally, if the load is classified as a motor or a compressor, it should have 3-5 times the appliance wattage added to the converter capacity in order to handle the surge current during startup. A calculation of the inverter wattage can be seen in Eq. 2. [15]

$$P_{inverter} = \left(P_{pantilt} + 25\%\right) * 4 = (30W + 7.5W) * 4 = 150W \qquad (25)$$

A Samlex America 150 W inverter was chosen and can be seen in Figure 15. This size will also accept the full output power of the panel if necessary. The inverter will invert 12VDC to 120VAC for the Axis Mains Adapter and microcomputer power supply.

Figure 15. Samlex 150 W Inverter.

C. MOUNTING SYSTEM DESIGN

To provide a centralized mounting structure, a 6ft, 0.188” thick, 2” O.D carbon steel pole was selected from McMaster. This acts as the backbone to the system but also provides a uniform mounting surface for improved modularity. Since the pole is carbon steel, its corrosion resistance is low so it is suggested that the pole be painted and maintained.

The weather enclosure selected for this project is the L-COM vented weatherproof NEMA 3R Enclosure (NB181608-00V) as seen in Figure 16.

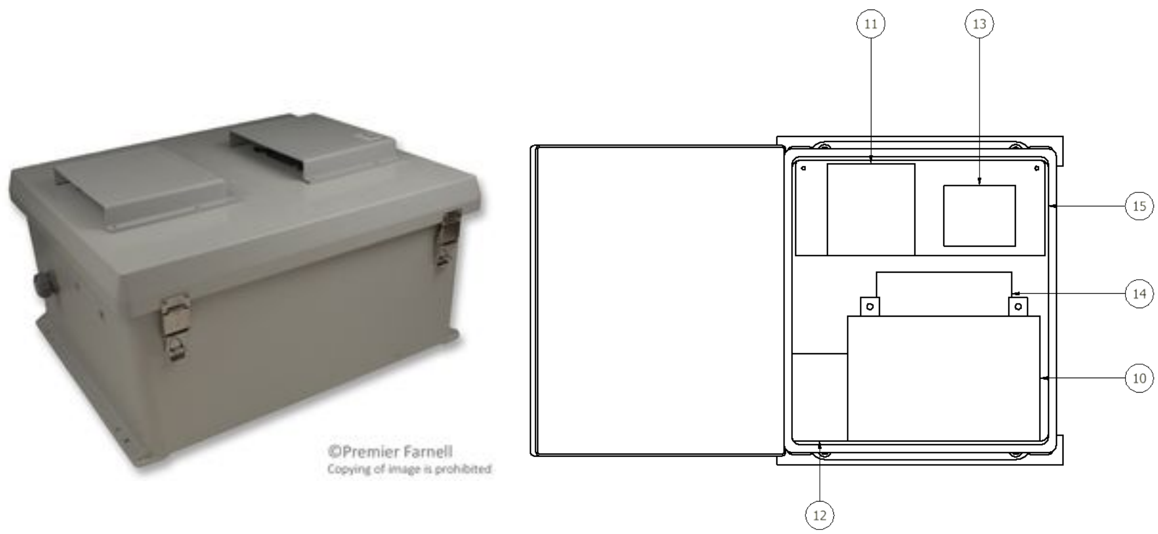


Figure 16. L-COM weather enclosure.

This enclosure has the internal dimensions of 17.7x15.7x10” which allows the inverter (14), battery (10), charge controller (11), and microcomputer (13) to fit comfortably. A mounting plate (15) is also provided to allow for easy mounting of components such as the microcomputer and charge controller. The enclosure also has a ½” conduit connector to allow for wires to pass through to external components.

The fasteners were selected so that a single “universal” set could be used to assemble the majority of the mounting system. For general fastening and assembly, a commonly found 5/16 1” stainless steel cap screw was selected. The diameter of the screw allows for robust fastening and the material helps maximize corrosion resistance. There are also matching zinc-aluminum coated steel hex nuts for fastening and zinc-plated washers to increase the grip of the nut and screw. Stainless steel U-bolts, Figure 17a, were selected to attach necessary component assemblies to the centralized mounting pole. U-bolts are an inexpensive and common solution for suspending items from poles. Furthermore, their round shape helps to distribute the tension of the mounted components. Lastly, zinc plated strut clamps were selected for components that use strut channels. The zinc plating helps to improve steel’s lack of corrosion resistance. Once again, this is a commonly used device in industry for interfacing strut channels with poles and conduit and can be seen in Figure 17b.

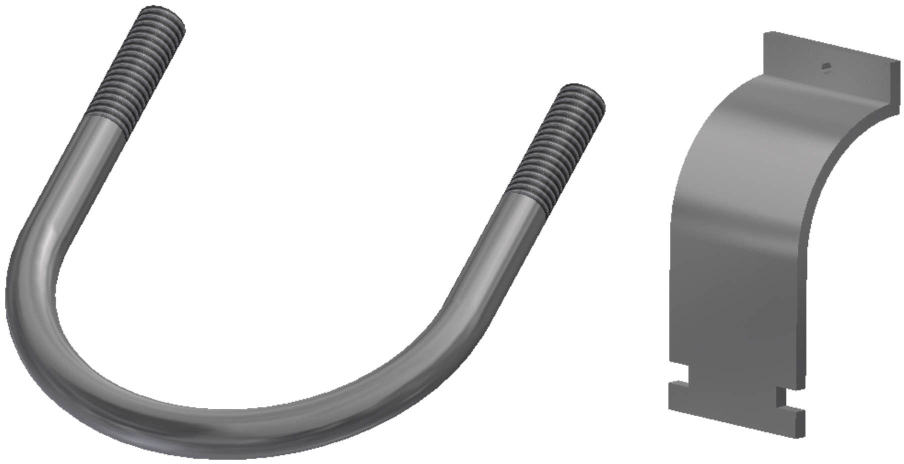


Figure 17. (a) U-bolt for 2" O.D. (b) Strut channel clamp.

To build each components mounting system, two types of stock were selected. The first of which is the 90° track which has perforated holes that allow for modification of the solar mounting system. The strut channel is used for mounting the enclosure to the mounting pole. Both are commonly found in industrial settings and can be seen in Figure 18.

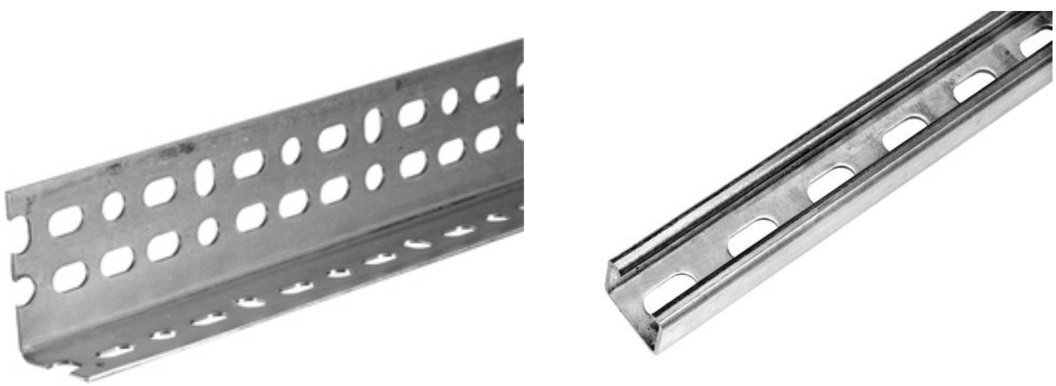


Figure 18. (a) 90 degree track (b) strut channel.

V. Final Design

A. Setup

Below in Figure 19 is a diagram of our final system setup with the selected components listed in the previous section incorporated. The components in red comprise the power system, which consists of the Renogy 150W Monocrystalline Solar Panel hooked up to the EcoWorthy 20A MPPT Charge Controller. The 100AH 12V AJC Lead Acid AGM Battery is connected in parallel to the charge controller. The wires leaving the charge controller run to the electric loads (POE Splitter and Inverter at 12VDC). The POE Splitter splits the POE of the A310f Infrared Camera into 12VDC power from the charge controller and an Ethernet connection to the microcomputer. The 150W Samlex Inverter is also hooked up to the load line converting 12VDC to 120VAC. The inverter powers both the pan tilt mains adapter and the microcomputer power supply. The Axis Mains Adapter steps the voltage down form 120VAC to 24AC to appropriately power the Axis Communications YP3040 Pan Tilt upon which the camera is secured. The microcomputer power supply steps down the 120VAC to 5VAC to power the Versalogic Tiger Board and wireless adapter. The dotted grey line represents the weather enclosure and everything that will be housed inside. All specifications and dimensions for the recommended design components can be found in Appendix 1. A complete Bill of Materials can be found in Appendix 5.

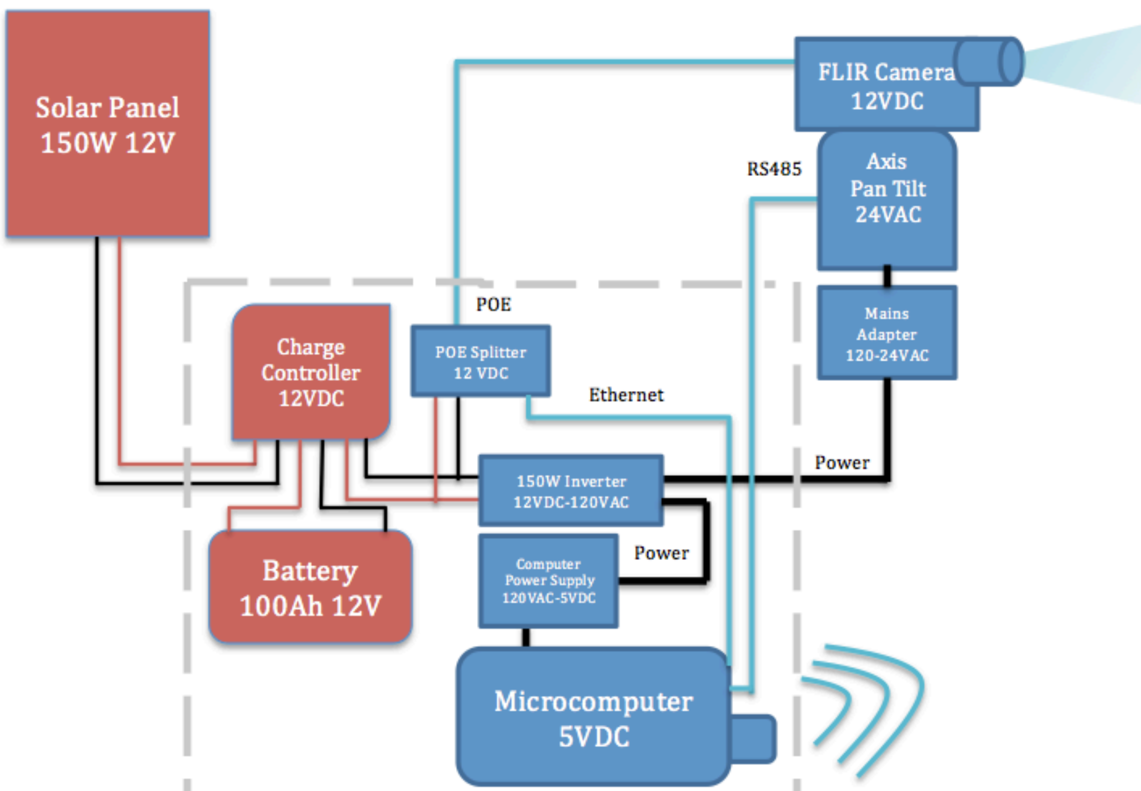


Figure 19. Final System Diagram.

The final model of our system design and recommended setup can be seen in Figure 20. This entails the solar panel being at the top of the pole with the pan tilt arm being located in the upper half and the weather enclosure being located towards the bottom for accessibility. Please refer to Appendix 6 for exploded views, subassemblies, and dimensioned part drawings.

Figure 20. Final Design Model.

B. LOCATIONS

The proposed locations of the systems can be seen in Appendix 4. These locations are recommended based upon what was learned during the site visit in early January. The eventual system locations are ultimately decided upon by the plant owner/operator based on preference, maintenance requirements, and local restrictions. These specific locations were chosen in order to monitor the most amount of equipment as possible while being out of the way of roads, walkways, and obstructions.

Locations 1, 2, and 4 were chosen to secure the system on the concrete wall bordering the Auxiliary Transformers, and South Step-Up Transformer. This location was suggested while at site because it is both out of the way, and in full sun. It also gives the camera an unobstructed large view of the switchyard. Other smaller lighting systems are already located on this wall so it is assumed locating our system would not be an issue as well. Please refer to Figure 21.

Figure 21. View of proposed system location 1 and 2.

The monitoring of the North Step Up Transformer may be done from the wall like Locations 1, 2 and 4 or from the side of the road as showed on the map in Appendix 4. Figure 22 is a view standing from this Location 3. As you can see, the full GSU is visible as well as the switchyard.

Figure 22. View from proposed system location 3.

Locations 5 and 6 were chosen in order to monitor the maximum amount of the Heat Recovery Steam Generators side casing as seen in Figure 23. It should be mentioned however that location 5 does get a considerable amount of shading from the South HRSG during the morning, which could greatly affect power system performance.

Locations 7 and 8 are the Boiler Feedwater Pumps that necessitate close monitoring. Figure 24 shows the view of the Boiler Feedwater pumps and the pipe rack that is above them. In this figure the yellow box is the location where the boiler feed pumps are. Unfortunately, this area of the power plant does not get much sun. Therefore it is recommended that the pan tilt, camera, and weather enclosure be detached from the pole and mounted to existing steel supports within the yellow box. The red region is the proposed location for the solar mount. This is another reason why we have designed our system to be as modular and standard as possible. It allows for adaptation to various applications and environments.

In total, that is 8 systems to monitor the plant. This is a conservative initial recommendation; iteration will have to done during testing based upon infrared data accuracy and image quality.

Figure 23. View from proposed system locations 5 and 6.

Figure 24. Proposed Locations 7 and 8.

VI. ASSEMBLY

Please refer to Appendix 6 for exploded views and drawings of the full system and subassemblies. An exploded view of our system model can be seen below in Figure 25. Following is a step-by-step procedure for assembling the system. Total assembly time is approximately 4 hours assuming all individual components were tested and functioning beforehand.

1. Solar Panel
2. Solar Mount
3. Infrared Camera
4. Pan-Tilt Module
5. Pan Tilt Arm
6. Mains Adapter
7. Pole
8. Electronics Enclosure

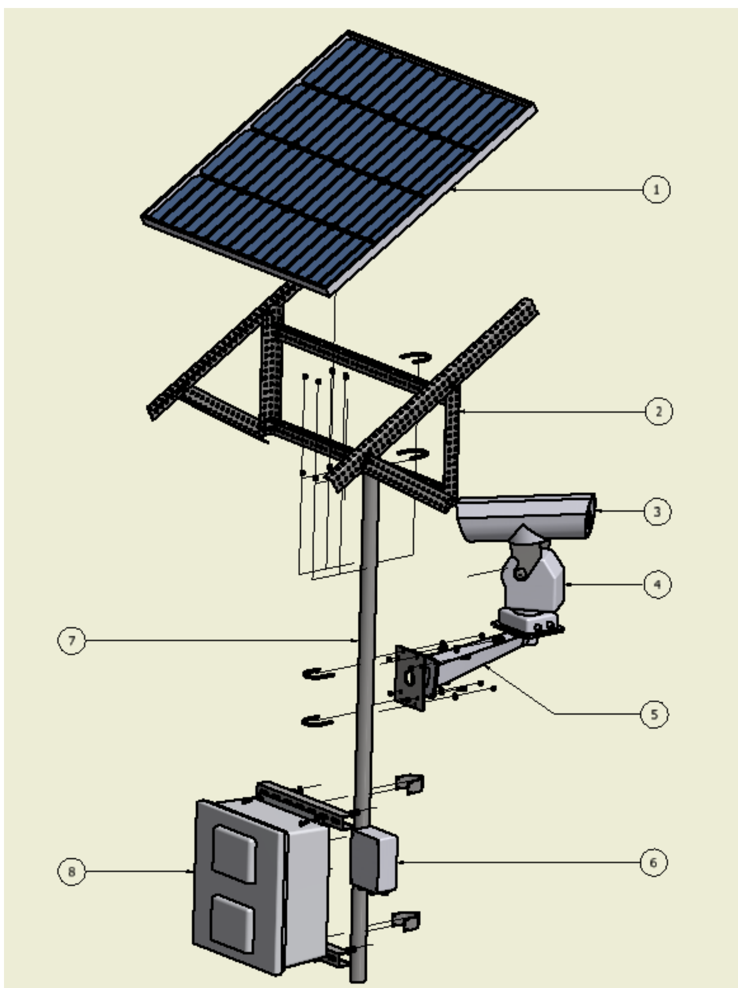


Figure 25. System Exploded View.

1. Cut track stock and strut channel stock into two 17.5”, 38.0”, and 38.8” pieces. See 90° Track Dimensioned Drawing in Appendix 6.
2. Using simple trigonometry, the length of the final set of 90° track pieces can be determined and cut so that the angle equals the local latitude. For example, for a solar panel tilted at 30°, the final set of 90° track pieces should be cut to 17” and secured at an angle of 60 degrees from the 17.25” vertical track pieces as seen in Figure 26.
3. Cut the strut channel stock into two 18” pieces. See Strut Dimensioned Drawing in Appendix 6.
4. Assemble two A-frames of the solar mounting structure, Figure 26, using cap screws, nuts, and washers to ensure stability.
5. Connect two assembled A frames with two 38.8” struts according to Solar Mounting Sub-Assembly in Appendix 6.

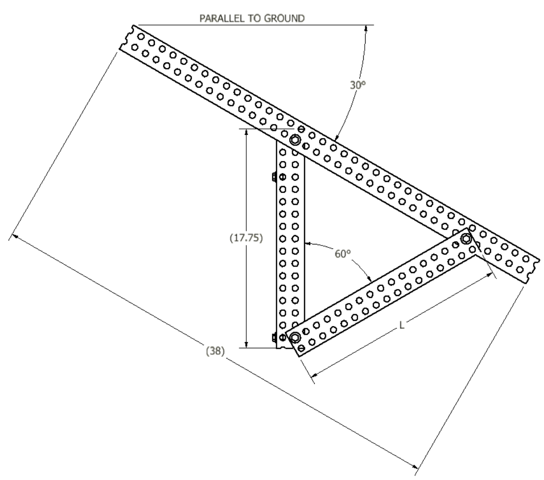


Figure 26. Solar Mounting A-Frame.

6. Mount the solar panel to the 90 degree track utilizing the 4 mounting holes on the back of the solar panel using the given mounting screws and nuts.
7. Place pan tilt motor on the wall bracket and secure. See Figure 27.
8. Mount infrared camera to pan tilt splint using given bolts and washers.
9. Take the manufactured pant tilt mounting bracket and secure it to the pan tilt arm via the given screws, nuts, and washers. See the pan tilt sub assembly drawings in Appendix 6 for reference and Figure 27.
10. Run the camera and pan tilt wires through the inside of the pan-tilt mounting arm and out of the mounting bracket but leave enough slack to allow the pan tilt module to full move.

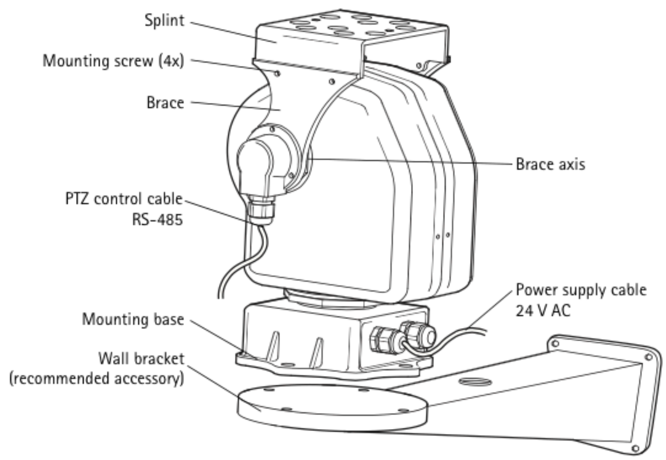


Figure 27. Pan Tilt Assembly Schematic.

11. Take the 18” pieces of strut channel and secure to the back of the weather enclosure using the given cap screws, nuts, and washers given. Take care in ensuring that the flat side of the track is flush with the back of the enclosure.
12. Using, the enclosure sub assembly drawing in Appendix 6, orient the electronic components to fit within the enclosure. Run all necessary component wires through the punch outs and ½” conduit conductor located at the bottom of the enclosure.

NOTE: Locate weather enclosure and solar panel appropriately before securing to the pole with U-bolts. In general, the enclosure should be mounted as close as possible to the pant tilt/camera and the solar panel should be as high as possible.

13. Slide the strut channel clamps onto the strut channel located on the back of the enclosure.
14. Use the given clamp screw and nut to close the clamps and secure the enclosure mount to the central pole. This can be seen in the detailed view on sheet two of the enclosure subassembly drawing in Appendix 6.
15. To secure the solar and pan tilt mounts to the mounting pole, use the given U-bolts, nuts, and washers.

NOTE: Make sure that all of the mounted components are secured tightly to the back of each mounting subsystem. Please reference the full assembly drawings in Appendix 6 before proceeding with circuit setup.

16. Connect Microcomputer, ATX Power Supply, and accessories according to Tiger Reference Manual for assembling the microcomputer components. [25]

NOTE: The keyboard, computer screen, mouse, and CD-ROM drive are not necessary components to run this system, only for initializing.

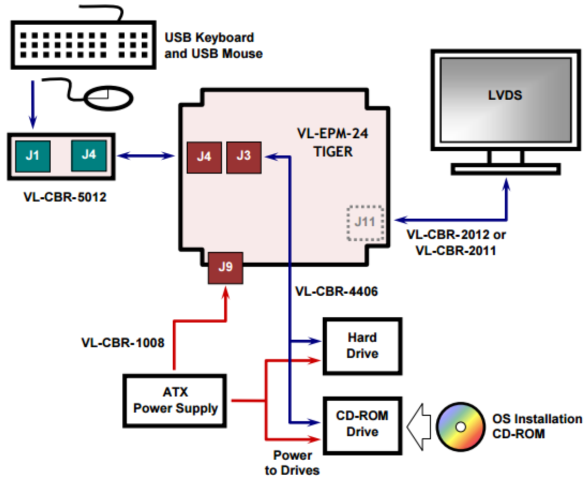


Figure 28. Microcomputer Setup.

17. Plug the ATX Power Supply input power cord into the Samlex Inverter.
18. Connect the spliced Pan Tilt RS-485/serial cable to one of the serial ports on the microcomputer's breakout board. [26]
19. Connect the pan tilt power cable to the Mains Adaptor, see Figure 29 below and see Axis Communication's PS-24 Mains Adapter Installation Guide. [27]

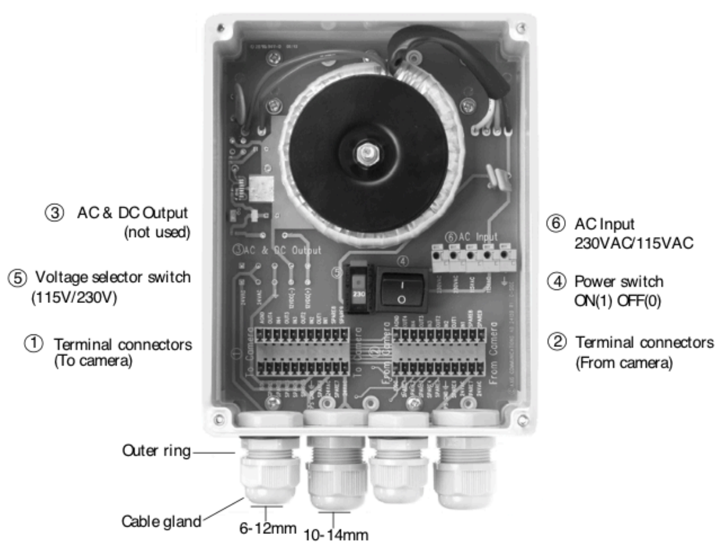


Figure 29. PS-24 Mains Power Adaptor.

20. Plug the Mains Adapter input power cable into the Samlex Inverter.
21. Connect the POE Cable to the GigE (port 5 on Figure 30) on the camera and connect the other end to the POE Splitter Ethernet port. Refer to FLIR User Manual. [6]
22. Connect Ethernet cable from the microcomputer breakout board, to the LAN output of the POE Splitter.

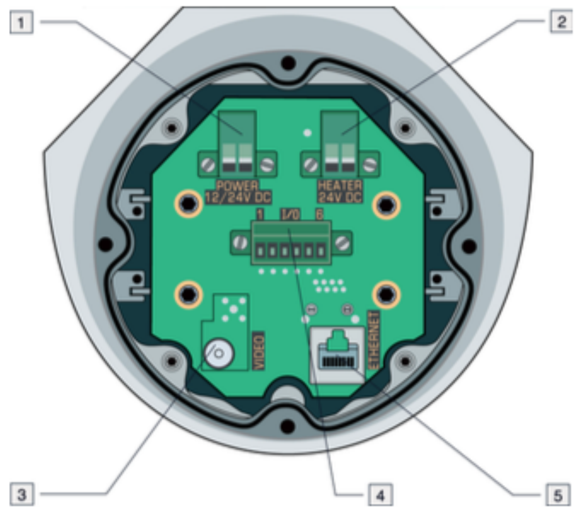


Figure 30. FLIR Camera ports.

NOTE: Refer to Eco-Worthy MPPT Solar Charge Controller Guide [28] and Figure 31 for steps 23 to 28.

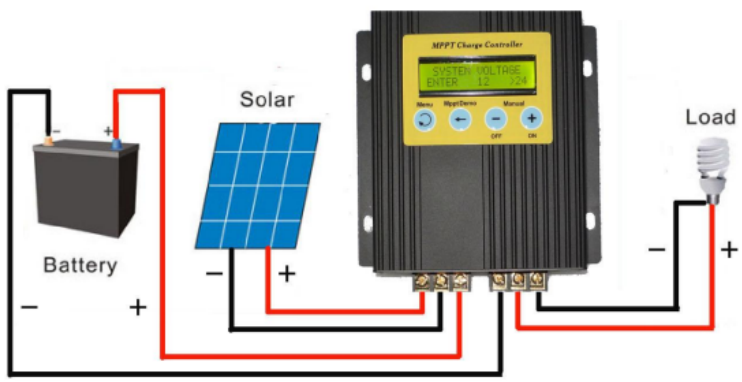


Figure 31. Power System Assembly.

23. Connect Battery cables to charge controller.
24. Wire 12VDC POE Splitter and Inverter power cables in parallel to 'Load' terminals on charge controller. Refer to Inverter user Manual for directions. [29]
25. Connect Solar Panel to charge controller.
26. Switch on battery.
27. Enter in the following values on the Charge Controller LCD Display using the +- buttons for the system setup
    a. System Voltage: 12V
    b. Over Charge Voltage Setting: 14.6V
    c. Float Voltage Setting: 13.7V
    d. Discharge Protection Setting: 10.8V
    e. Discharge Restart Voltage Setting: 11.3V

f. Output Mode: Mode 2 (Always On)

28. Ensure home screen is reading the appropriate values for the current conditions, see Figure 32.

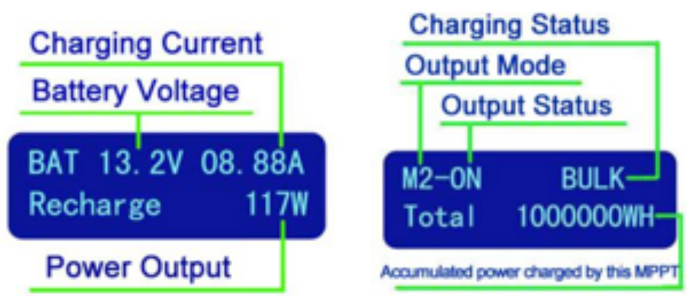


Figure 32. Charge Controller LCD Legend.

VII. OPERATIONS MANUAL

The following operation steps are to be performed after the complete system has been assembled. They govern the initializing of the monitoring system's autonomous operation. The autonomous operation will be executed through several programs that can all be found in Appendix 7. The *FTP_script* code is used to connect the microcomputer to both the camera and control room computer. Once connected this code grabs an image of a target from the camera then it sends that target image to the control room computer to be analyzed. The *PANTILT_CONTROLLER* code is a C++ code to be downloaded onto the microcomputer to control the pan tilt to move to desired targets. Once the program is started it will prompt the user to move the pan tilt to the desired four targets to preset the positions. Once positions are set the pan tilt will autonomously move to each target and wait so the camera can take an infrared picture of each target. The *SWIMS* program is a batch program used to display infrared images of four targets on FLIR's Researcher Professional 2.10 program. This program should be downloaded on the control room computer to monitor the critical temperatures of each target.

The following steps are the initializing steps that need to be performed in order to set the monitoring system on its autonomous operation.

1. Turn everything on.
2. Attach keyboard, monitor, and mouse to respective microcomputer ports. Refer to previous assembly section if necessary.
3. Start FTP Server on control room side
4. Run RS 232 Analyzer for pan tilt to initialize 'comm port 2'.
5. Initialize Telnet Connection.
6. Make sure all nodes (control room and microcomputer) are connected to same network.
7. Start PANTILT_CONTROLLER program to set chosen positions.
8. Press 'X' to execute full autonomous operation.
9. Execute SWIMS program on control room computer to start GUI to view images.

Figure 33 shows what will be displayed in the Control Room GUI for analysis.

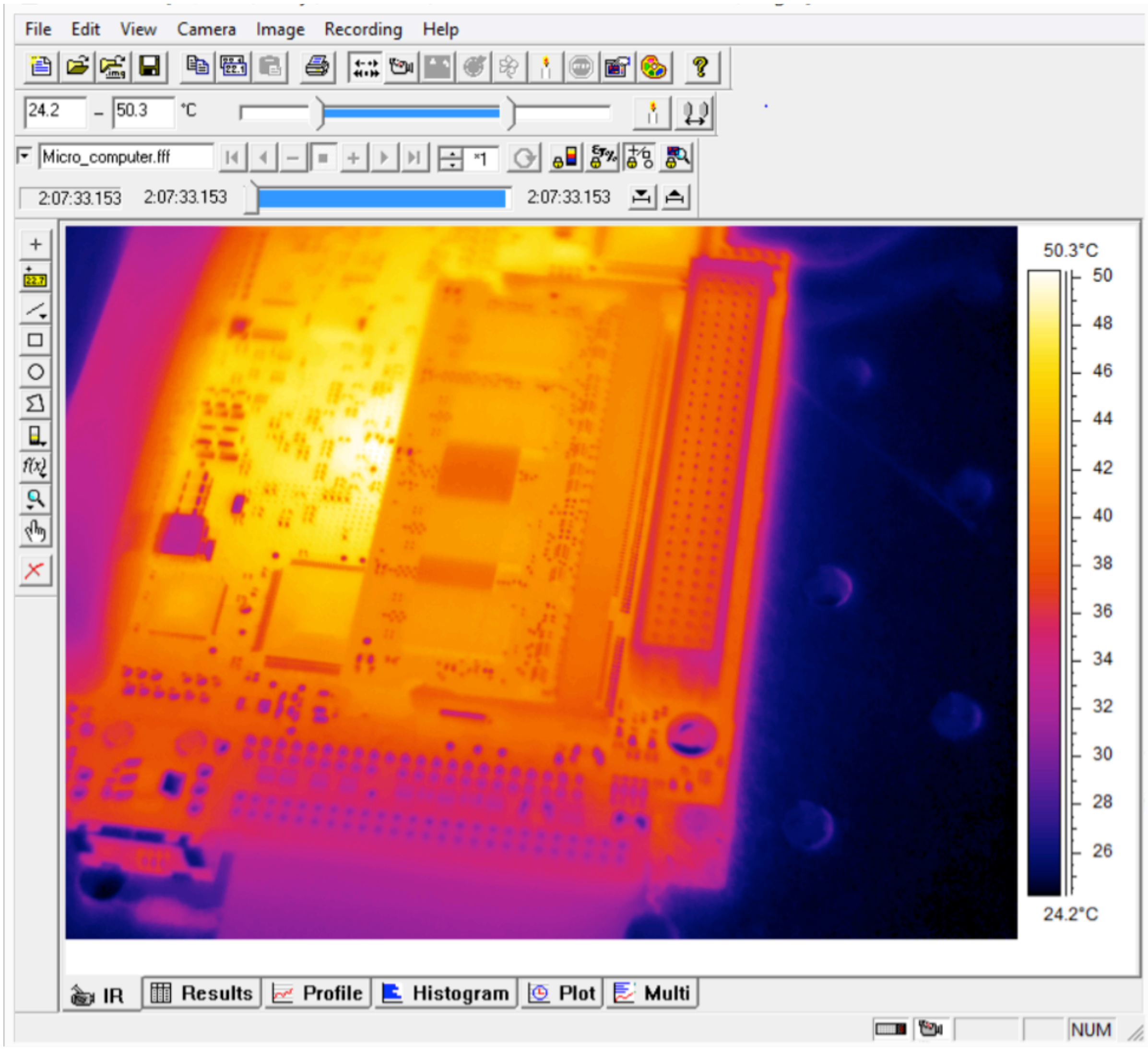


Figure 33. Infrared Image displayed in Control Room GUI.

A. Regular Maintenance

The lead acid battery needs to be replaced approximately every 6 years according to our simulation. When this is to occur, the system needs to be completely powered down. The solar panel should be wiped with a clean cloth every month to prevent particulate build up. This does not require system shut down. The mounting system should be checked for loose bolts, as well as damage or water induction after major storms. Please refer to Installation Manuals for individual component maintenance.

B. Troubleshooting

Please refer to Installation Manuals for troubleshooting of individual components and the software programming in Appendix 7 for monitoring errors.

VIII. TESTING

A. PROTOTYPE SCOPE

Due to the budget constraints of this project, as well as the invariability of testing with borrowed components, our prototype was decided to be a proof of concept of the mounting and power systems. Although the mounting system is an integral part of the overall system design, our budget has constrained us to only procure and test the electronic scope of this project. This 'prototype' will be constructed in order to demonstrate the basic function and component integration of our designed system. Expanding upon the project goal statement, our primary goal for our prototype was to wirelessly transmit infrared images of selected targets while system cycles through set positions. If this is accomplished then a Graphical User Interface and alarm program will be developed in order to filter information received from targets and notify the user when problematic situations occur.

The prototype design should be a slightly scaled down version of the proposed Siemens design. All of the components that were procured for the prototype design are the same components that were recommended for Siemens proposed design. This was done in order to accurately test the integration of the components, as well as to provide software that Siemens would be able to implement in their system operation. As a whole, the prototype should be able to autonomously take infrared pictures of 'targets' and wirelessly transmit infrared images to the 'control room'. The prototype should finally be powered through the installed solar power and battery storage.

For our prototype design, Dr. Oates has kindly agreed to loan us his FLIR A655 Science Grade Infrared Camera. This camera has very similar features to the FLIR A310 with a similar power consumption (24W with heater), accuracy (± 2%), and temperature reading (32°F to 662°F). The FLIR A655 lacks an environmental housing and only has a weatherproofing of (IP30) which was what constrained our monitoring system to be tested in the safety of a lab. Therefore, our power and monitoring system were decided to be assembled and tested separately for time and safety's sake.

B. POWER SYSTEM

The power system was assembled and wired according to the assembly section of this report. However, instead of an inverter sending power to our system loads, a 50 W and 7 W light bulbs were used to simulate the system's power and sleep cycles. The power system was assembled and secured on a chassis for safety and ease during testing. Once the power system was assembled it was tested outside under various conditions. Figure 34 is a depiction of the fully assembled power system on the chassis. An Arduino microcontroller was used to switch between the power (50W) and sleep (7 W) load every 2 and 10 minutes respectively and can be seen in Figure 35.

Figure 34. Power System Test Setup.

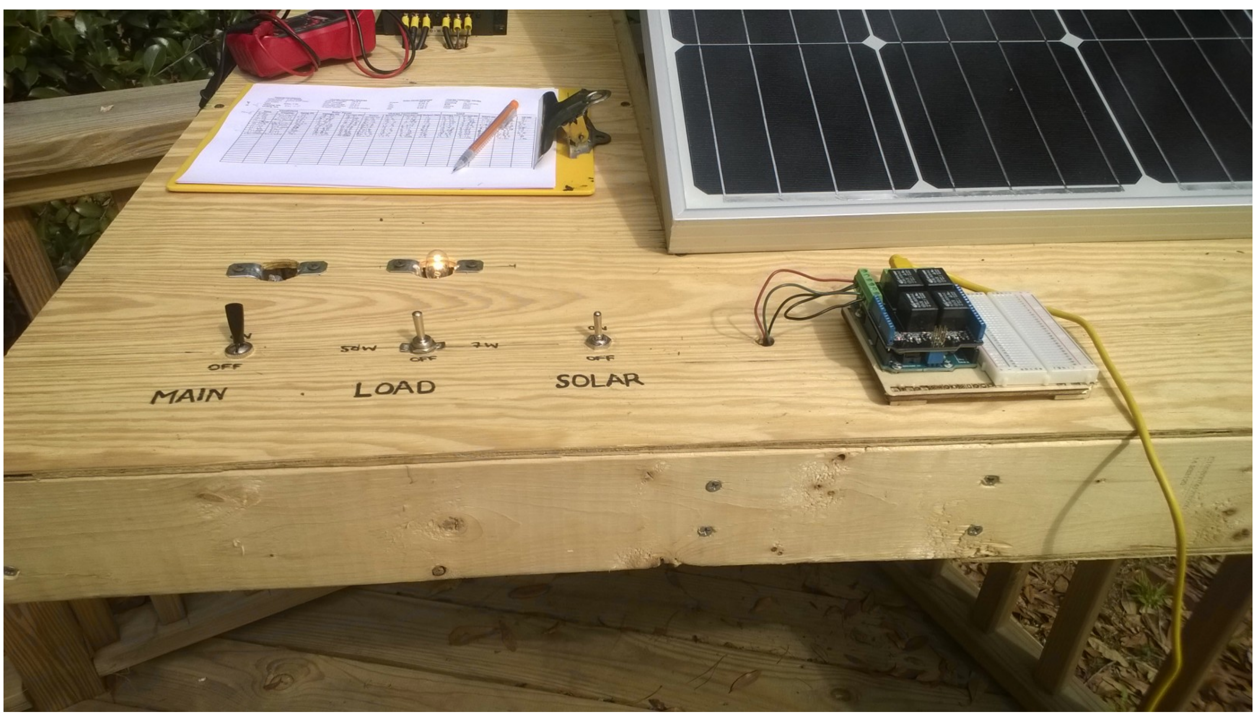


Figure 35. Power System Load Simulation.

The system was first trial tested over a sunny day (from 2pm to 2 am). During this first test, measurements were taken sporadically throughout the day. This was because the system necessitated manual readings and personnel were not always there to take readings. Once it was determined the system was functioning correctly, a second test was performed on a partly cloudy day. During this test, it was ensured that detailed readings could be taken throughout the whole day. Particularly while the battery was bulk charging. This is when the power system is most active and its voltage and current are changing the most. On this partly cloudy day test, readings were taken every hour while the battery was snoozing, sleeping, or floating, and every 15 minutes while it was bulk charging. A battery discharge test was also conducted in order to ensure the battery could last 3 days without solar input and lifetime strain. This was done by disconnecting the solar panel and running just the battery and loads. Readings were taken every 12 hours over the 72 hours. Results of these two tests can be seen in the following section.

Figure 36 is a graph of the test data from the partly cloudy day test. As can be seen in red, our load was continually switching between 50 W and 7W. The green line is the solar input and start increasing as the sun emerges at about 10 am. It then fluctuates between 130W and 70W until 2 pm, where it then tapers off to 0 as the sun sets. This was because the panel was heavily shaded in the afternoon. The battery voltage, seen in orange is charged and discharged according to the solar input. As the solar power increases, the battery is charged to almost 100%. As the sun sets the battery is depleted to 12.5 V into the night. These results were very close to the expected simulations done in Homer.

Figure 37 shows the battery depletion over 3 days after the partly cloudy test. The battery voltage drops from 12.5 V to 11.8V over 72 hours. 10.8V is the batteries over discharge protection setting so it theoretically could have lasted for about 1 more day. This was expected according to the intentional over-sizing in order to compensate for the batteries degrading life over time. All detailed power system test results can be seen in Appendix 8.

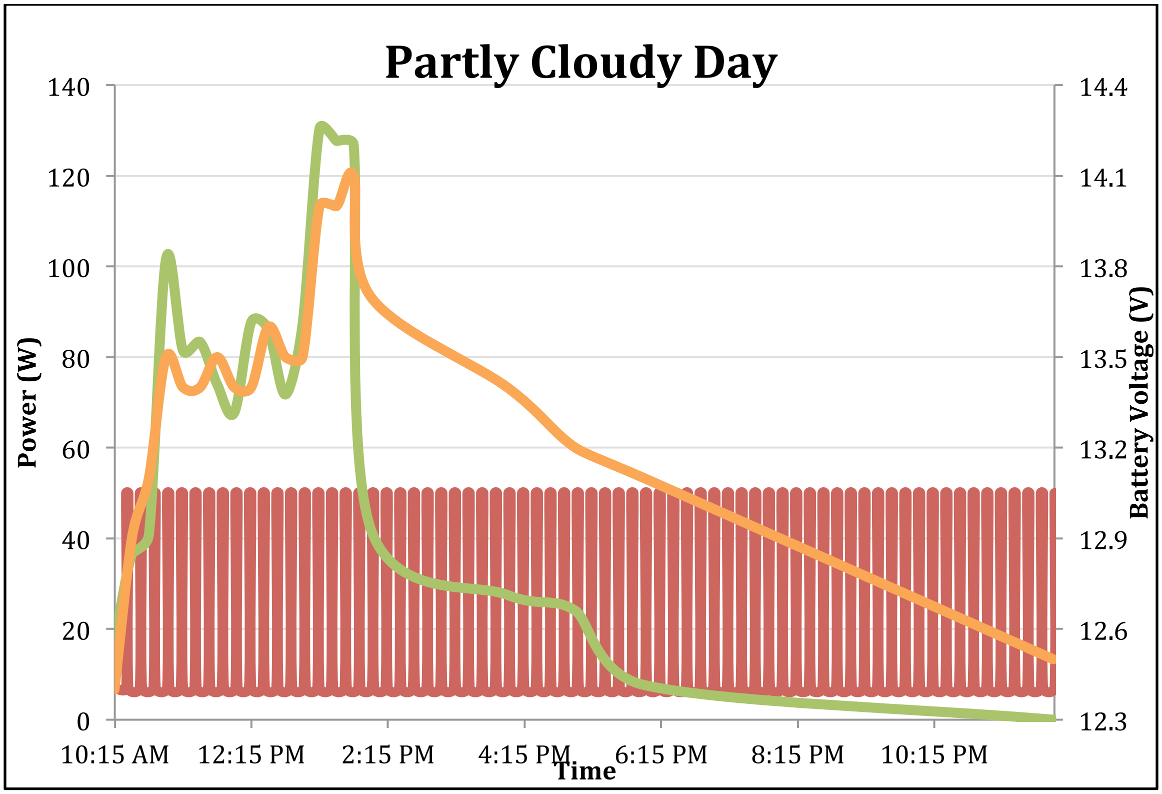


Figure 36. Power System Test on Partly Cloudy Day.

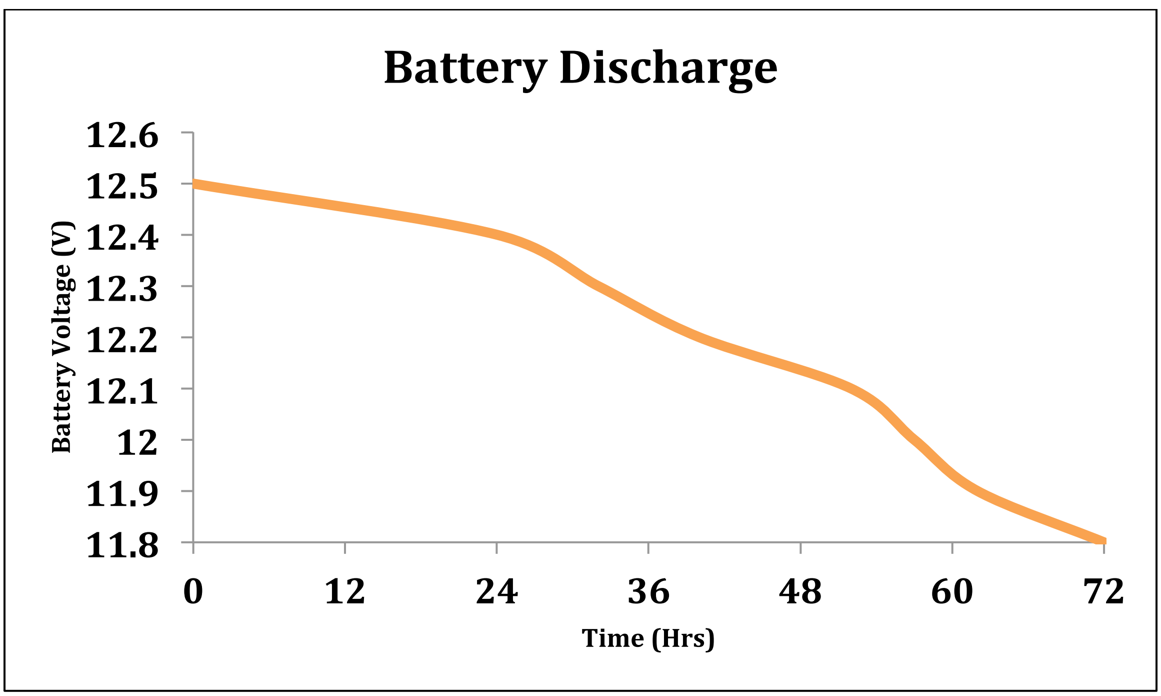


Figure 37. Battery 3 Day Discharge Test.

C. Monitoring System

The monitoring system was successfully assembled, programmed, and tested within the lab. Two demonstrations were done showing successful operation. In the end, the monitoring system accomplished our primary and secondary programming goals with the exception of the alarm system. The system can autonomously capture and transmit infrared images of selected targets to the control room as the pan tilt cycles through its motions. In the control room, the images are automatically displayed and updated within ThermoCam, a FLIR application that has a mass amount of analytical functionality. As these pictures appear in the control room, the user has the ability to point, plot, report, and view other detailed temperature data of the picture if desired. A figure of the Control Room screen can be seen below in Figure 38. Each target is displayed and automatically updated as well as time stamped and saved to an archive folder.

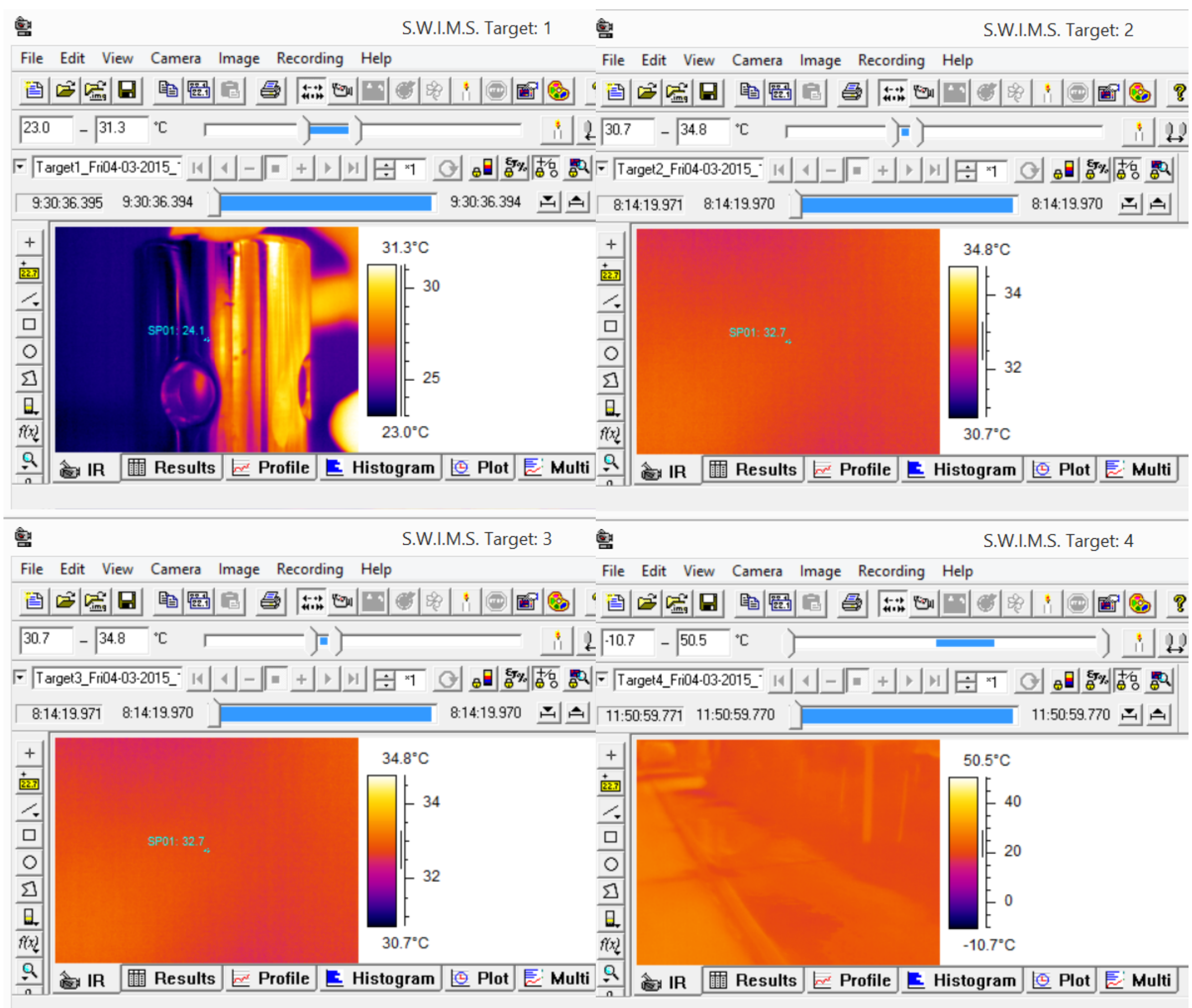


Figure 38. Control Room GUI View of Targets.

IX. RELIABILITY

Our system is designed to be running continuously on 2-minute power cycles followed by 10 minutes sleep cycles. Once initialized and executed, the system should run autonomously and uninterrupted until maintenance or troubleshooting is necessary. The lifetime of our system should hold up to 30 years however the battery is calculated to last 6.15 years before replacement is needed. In addition, the solar panel has a lifetime of 20 years before the solar cells begin to degrade. Therefore, our system should perform up to 15 years of its lifetime with proper battery maintenance. The second half of its life however, the operator may begin to see some solar power and efficiency losses. If this is detrimental to the systems performance, the solar panel could be replaced. Please see Appendix 2 for Lifetime Power System Simulation and Analysis.

The largest concern for our system aside from, eventual lifetime degradation are described in A Failure Mode Effect and Analysis (FMEA) table on the following page. Some of the weather constraints showed in Table 1 in the Introduction, are very tumultuous conditions (100 mph wind, 5” rain for 1 hour period, and 0-110°F temperatures). Therefore, the system is designed to be modular to allow for easy installation and removal. In order to avoid damage, the plant owner should disassemble and store the 3 subassemblies in the case of bad weather.

Pests can also reduce the longevity and performance of this system. Nesting can cause harm when considering the pan-tilt arm, solar panel, enclosure, or hand hole of the pole. A pest nesting within the enclosure can cover important electronics with nesting debris and chew away at the equipment. Some of the damaged items will require replacement if chewed on or allowed to overheat. The potential problems can be easily abated through pesticides and regular inspection.

Improper installation can result in premature product failure. In general, it should be ensured that all installation guidelines are followed and necessary precautions taken. Corrosion is also a concern but can easily be mitigated with proper maintenance and application of ANSI 61 paint to exposed carbon steel components.

Finally, system location is integral to performance and safety. The switchyards are very high voltage areas and can present a danger of arcing when something is located poorly. Also, the HRSG and transformers are very high temperature components whose heat can greatly increase the local ambient temperature. Appendix 4 details the recommended system locations that are ultimately up to the operator/owner.

Table 11. Failure Mode Effect and Analysis.

Key Process Step or Input	Potential Failure Mode	Potential Failure Effects	SEV	Potential Causes	OCC	Current Controls	DET	RPN	Actions Recommended	Resp.
Weather Protection	Severe Weather	Potential fastener failure and exposed component damage.	**10**	High Winds	**2**	Disassembly Procedure.	**10**	**100**	Pay attention to weather forecasts.	Owner/ Operator
Operation	Nesting Pests	Electrical Wiring Failure.	**5**	Bugs	**10**	Weekly System Inspection	**10**	**500**	Pesticides.	Owner /Operator
Installation	Improper Installation	Short Circuits, Mounting Failure, Lack of performance, etc.	**10**	Improper installation of components and equipment.	**1**	Installation and Troubleshooting Manual	**8**	**80**	Following manuals and inspecting before troubleshooting.	Erector
Mounting Structure	Corrosion	Failure/degradati on of pole	**4**	Oxidation	**10**	Painting Specification	**10**	**400**	Paint pole with ANSI 61paint frequently to prevent exposure.	Owner/ Operator
Location	High Voltage or High Heat Areas	Electronic failure.	**10**	Poor location of system.	**1**	Recommended Locations.	**5**	**50**	Investigate potential locations before installation.	Owner/ Operator

In order to decrease concern over mounting system stress, wind and force loading was performed in Comsol. The resulting wind loading analyses are shown in Table 12. These values were determined utilizing the FEA software. The solar, pan-tilt, and enclosure subassemblies were oriented such that their largest surface was acted upon by the wind. The nominal wind velocity was assumed to be a 150MPH with the flow being parallel to the ground. The velocity of 150 MPH encompasses the constraint of 100mph plus a 1.5 gust (safety) factor. A pressure distribution over the solar panel can be seen in Figure 39.

Table 12. Drag Force and Components.

Enclosure Subsystem	Pan-Tilt Subsystem	Solar Subsystem
225.22 lbf	68.39 lbf	76.71 lbf

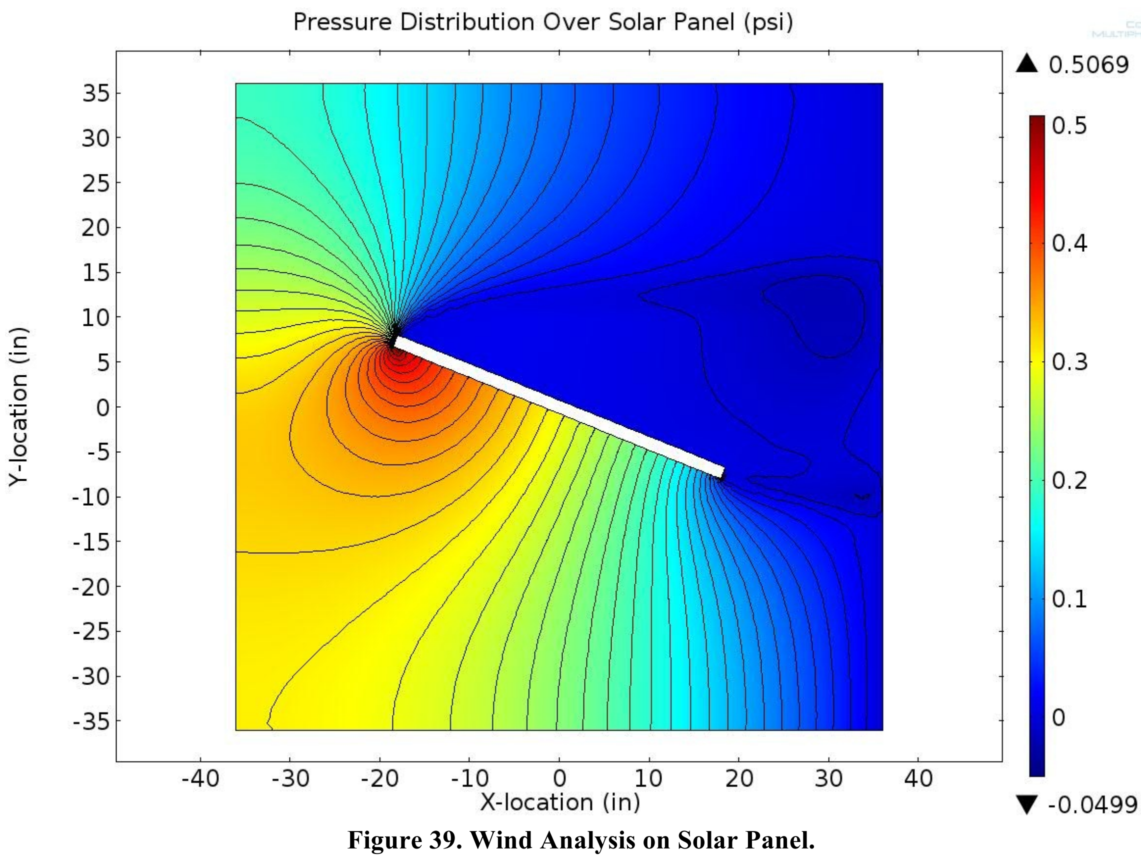


Figure 39. Wind Analysis on Solar Panel.

These drag forces were used to calculate the ground moment to ensure the pole was properly selected. Each individual component, including the pole itself contributes some net moment on the structure where it meets the ground. Table 13 shows the moments created from the wind and weight of each of the mounted subsystems.

Table 13. Ground Moment Calculation.

Values	Enclosure Subassembly	Pan-Tilt Subassembly	Solar Subassembly	NET M (in*lbf)
Wind Moment	3,603.52	2,735.6	4,986.2	11,612.12
Weight Moment	568.05	-480.70	199.5	

In summary, the pole needs to be buried at least 3 feet into concrete foundation with 6 feet being above grade if burial is chosen. It is recommended however that the pole be fixed to existing structures so that there are several fixing points. This will disperse the forces experienced more evenly.

To ensure that the selected fasteners meet the demands of the system, loading simulations were conducted on the U-bolt and cap screw. Both the U-bolt and the cap screws were loaded with the nominal shear and tensile loads expected from the enclosure and its mounting components. The loads caused by the enclosure and its contents were selected for simulation because they are the largest with a combined weight of approximately 82lbf. This force is shared between 4 cap screws and 2 U-bolts. The cap screw was tested with a shear load of 25lbf which is the approximate shared load expected from the enclosure assembly. This 25lbf load was placed at 0.5” from the base of the cap to simulate where the load of the enclosure acts on the screw. This simulation is shown in Figure 40 and shows a maximum Von Mises Stress of 5.115 ksi located near the base of the cap in red. When comparing this to the shear strength of stainless steel, the safety factor is 8.2. This high safety factor is completely sufficient enough for the system.

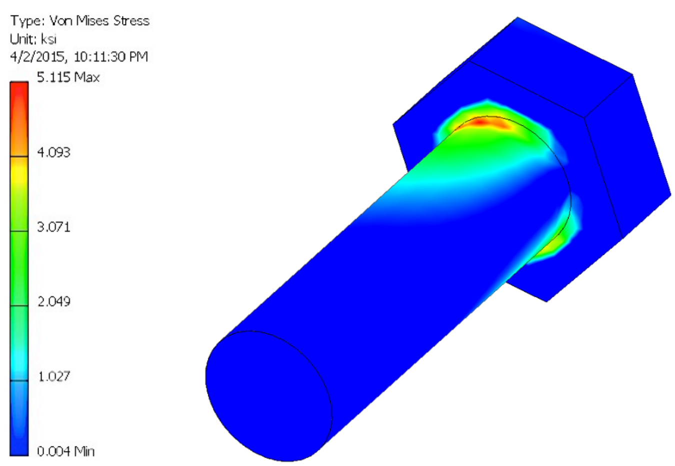


Figure 40. Cap screw under nominal 25lbf load.

The U-bolt selected for this project was cut in half for simulation. The applied shear load was once again 25lbf because the weight is shared by two U-bolts and each U bolt is simulated in half. Thus the load was split into 4. This shear load is applied centrally on the threads of the U-bolt. In contrast with the cap screw simulation, the U-bolt is also loaded in 45lbf of tension acting on each half of a U-bolt. This value was selected because it is more than enough tension to secure the weight of the enclosure assembly to the steel pole without allowing slip. After running the simulation seen in Figure 41, it was determined that the U-bolt would experience some small deformation as it was tightened due to a peak Von Mises Stress of 41.35 ksi. However the reaction forces acting on the U-bolt by the strut channel would ensure that the U-bolt maintains its shape. See Appendix 3 for more Final Design Analysis tables.

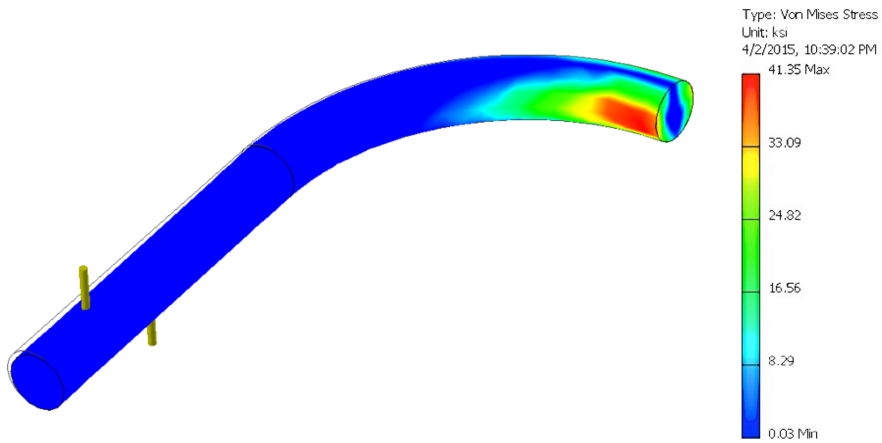


Figure 41. Half U-bolt simulated under nominal tension and shear.

To further ensure reliability of the mounting system, the 6ft, 2” O.D. carbon steel pole was compressively loaded with the tension required to hold each of the mounting subsystems in their proper place (Figure 42). That is, the solar panel U-bolts compress the pole with a minimum load of 28.5 lbf, the pan-tilt subassembly imposes a 25.3 lbf load, and the enclosure as mentioned previously, imposes a 90lbf load. In these simulations, it is assumed that the U-bolts and adjacent mounting items only touch the pole in two places. These locations of contact are assumed to be on opposite sides of the pole. In summary, the steel pole experiences no significant amount of stress due to the tension of the U-bolts on its surface. In fact the maximum simulate Von Mises Stress experienced by the pole is only about 0.04 psi.

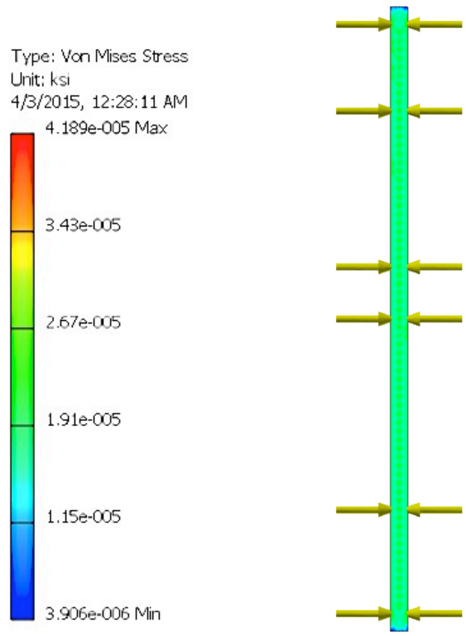


Figure 42. Steel pole compressed with subsystem loads.

X. Economics

The economics of this project, although seeming like an obstacle at first, was not a limiting factor. The price point that our sponsor believed would make our system economical was at $20,000. This was our design budget. Anything over was assumed to not be an economical replacement of the existing techniques. The budget then acquired for the prototype was $3000. This large discrepancy was due to the fact that Siemens is mainly focused on a conceptual design and therefore is interested in a proof of concept prototype in lieu of an economically viable representation of our design. With this small proof of concept budget, it was decided to only prototype and procure the power system and monitoring system components as previously mentioned. Below in Figure 43 is a comparison of our Design and Prototype Costs and Remaining Budgets. As you can see, both systems were under budget. The system design only uses 67% of the given budget while the prototype used 87%. A full list of components and costs can be found in Appendix 5.

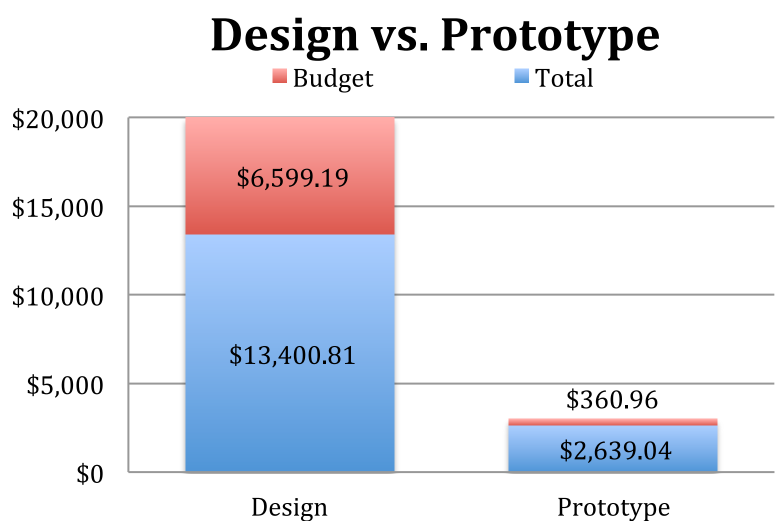


Figure 43. Design vs. Prototype Budgets.

Figure 44 demonstrates the cost breakdown of the expenditures for the designed system and the prototype. The most expensive component of the designed system was by far the FLIR infrared camera costing about $10,115.61. The microcomputer and accessories then come in at 10% of costs with the pan-tilt module following at 5%. This goes along with what was previously mentioned about how the monitoring system was the focus of this project. These three components are the prime electronics of our system and were selected with accuracy. The caliber of these instruments is what separates our designed system from multiple systems already on the market. A comparison between the subsystem costs can be seen in Figure 45. In our prototype, since the camera was lent to us without cost, the most expensive component was the microcomputer and associated accessories. Overall we still had 12% of our prototype budget remaining at the end of procurement.

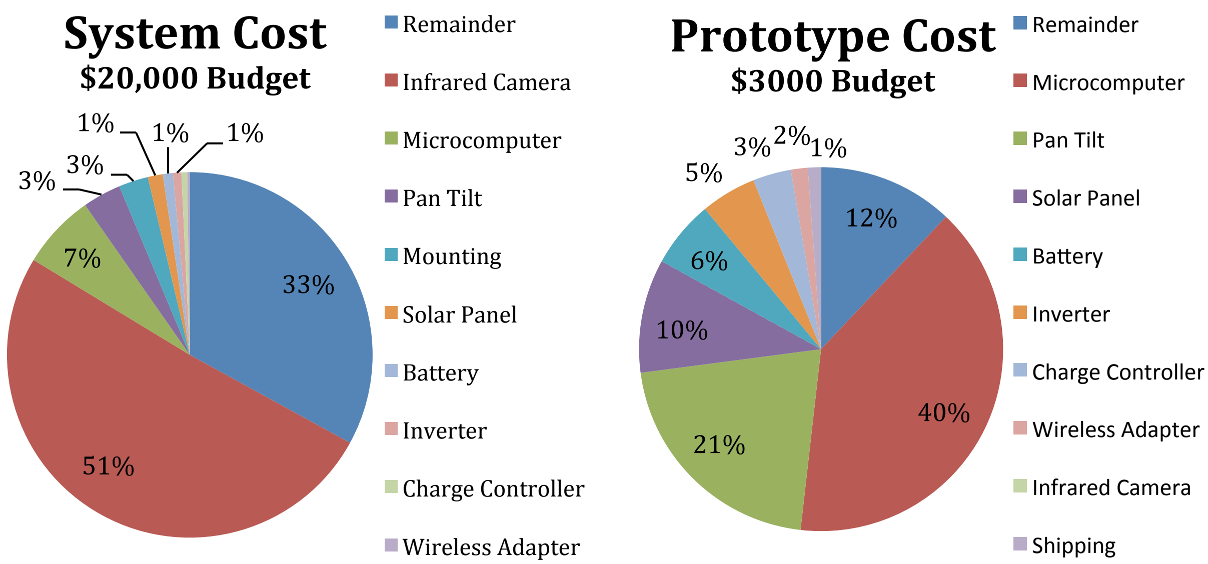


Figure 44. System Design and Prototype Cost Breakdown.

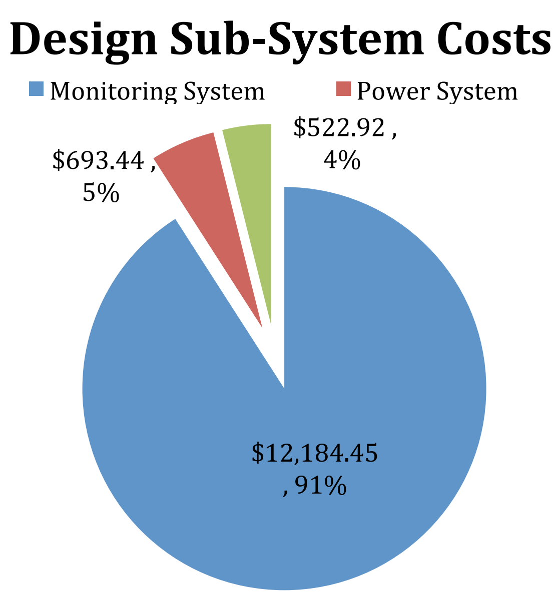


Figure 45. Design Sub-System Costs.

Below, in Figure 46, is a comparison of our system design cost to similar market options. A to Z Security provides some of the most Solar Power Wireless Security Systems on the market with varying scopes and prices. The system most similar to ours however is the Thermal Security Camera System (SS-TIRC). [9] It is a fully stand alone power system with an infrared camera but does not come with mounting equipment or battery storage. The 2MccTV Sony Network Camera System came in at a similar price of $9,502.21 but came with battery storage and mounting but lacked an infrared camera. [30] Finally, the EcoKIT by MOOG was an interesting market comparison because it too was very experimental by incorporating a wind power generator with the solar panel. This system, although complex, was the cheapest found but its price of $5,173 did not include mounting or an infrared camera. [31] In conclusion, although our system is more expensive than available market options at $13,392.22, it is one of a kind. No market option currently offers a Solar Wireless Infrared Monitoring System that is capable of high temperature substation monitoring. All systems found were purposed for mid-level surveillance and required further purchase of accessories.

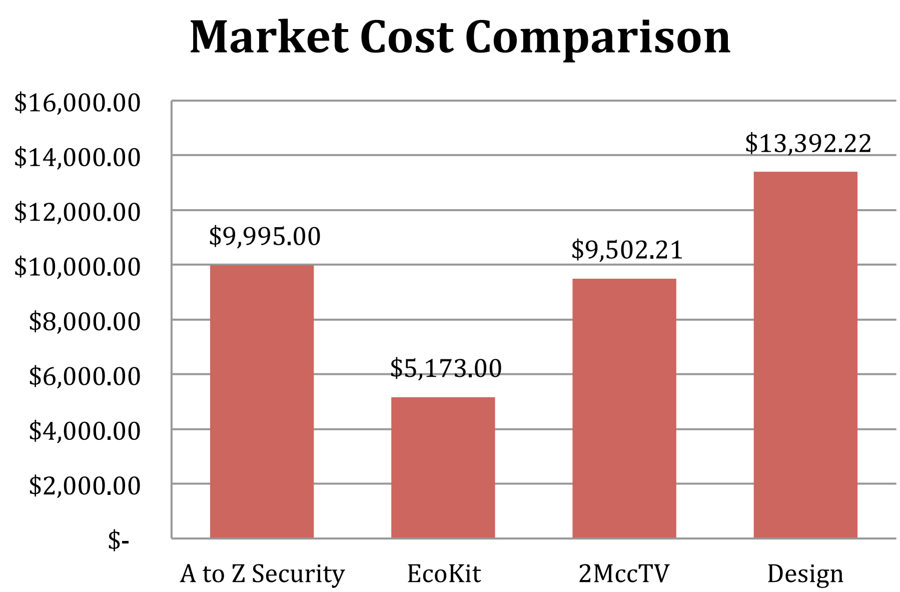


Figure 46. Market Competiveness.

XI. ENVIRONMENT & SAFETY CONSIDERATIONS

Due to the fact that our system is self-sustaining and non-invasive, there is little to no environment impact. However, it bears mentioning that care needs to be taken in disposal of the batteries when replaced. Lead Acid Batteries must be recycled so the used batteries either must be shipped back to the manufacturer or taken to an appropriate recycling establishment. Other safety issues include personnel safety during assembly and operation. Persons must practice electrical safety while wiring and troubleshooting circuits. It also must be considered that future maintenance on this system, when implemented, must be performed under the normal safety regulations of the power plant. This should cover the dangers any personnel might experience (ladder climbing, head protection, etc.) while servicing our system. Please refer to the component Installation Manuals for detailed safety information.

XII. Project Management

A. Project Schedule

Below is the Gantt chart created in Microsoft Project as the schedule for our efforts. It was followed the entire lifecycle of this project from September 1st 2014 to May 1st 2015. Progress and deadlines were tracked using this schedule. Major deliverables were set as milestones while design processes were tasks. The full project schedule can be viewed in Appendix 9.

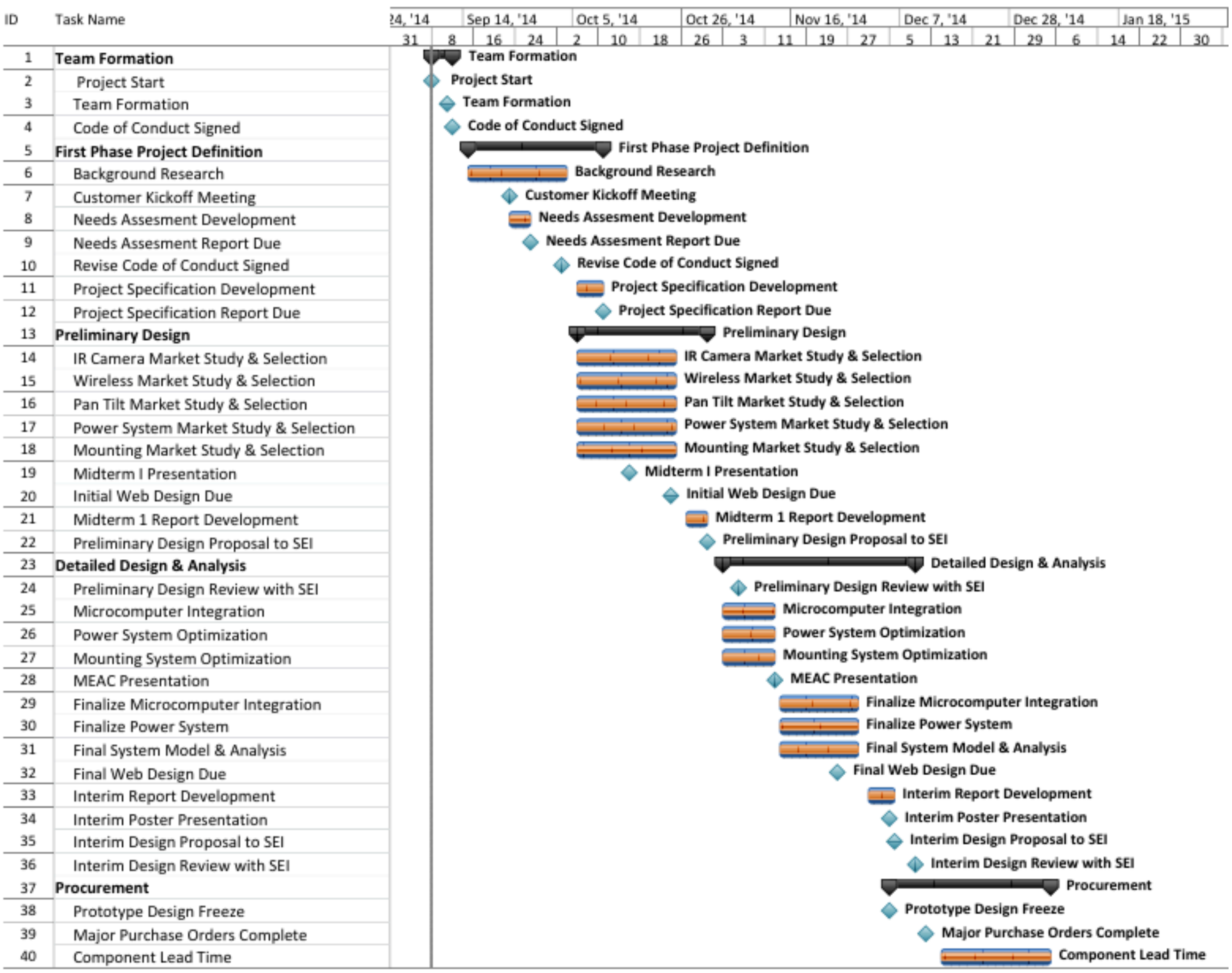


Figure 47. Project Schedule Fall Semester.

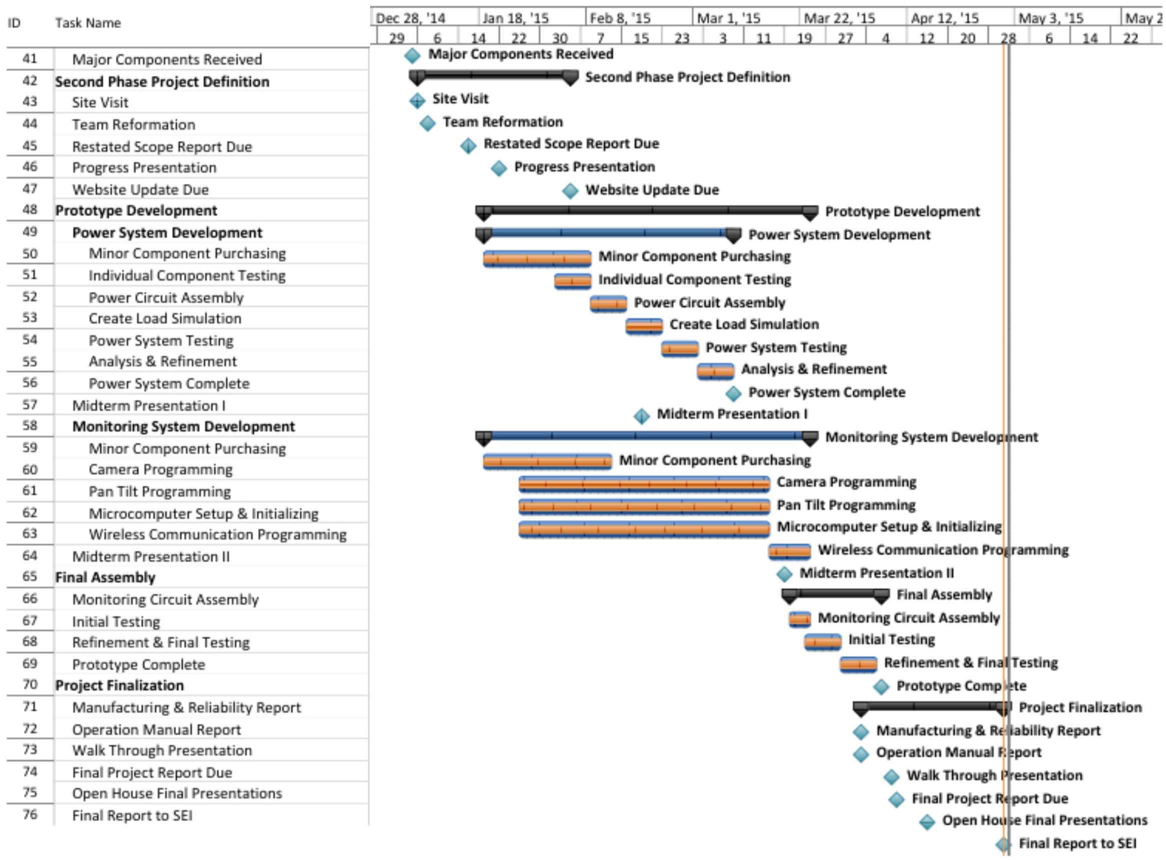


Figure 48. Project Schedule Spring Semester.

B. Resource Allocation

Each task within this schedule was assigned a Resource, or individual, from the team. These tasks corresponded both with the original team roles assigned, and the individual's specializations. In addition to personnel, the resources utilized for this project were minimal. Dr. Oates lab and the High Magnetic Field Laboratory were used for the camera and pan-tilt development/storage. In addition to these two locations, the senior design room was used to facilitate meetings and presentation practice. Other than these locations, all other resources came from our team members.

C. Communications

The internal and external communications for this project was successful. We have created a combination of means of communication through email, group-me text message, and video conferencing for non-urgent, urgent, and weekly discussions respectively. We also have had successful, frequent communication with our sponsor due to the benefit of our Project Manager, Michelle, being located at Siemens Energy. This has been a huge advantage as usually sponsor contact and interest is difficult to maintain. There has also been successful communication about our progress and feedback between our group and the senior design faculty during faculty meetings. Overall communication was not an issue.

XIII. Conclusion

The goal of this project was to design a Solar Wireless Infrared Monitoring System that could monitor the temperature of selected targets without interfering with the equipment, and consuming auxiliary power. A system was successfully designed that created a cost saving from the existing preventative maintenance techniques. The designed system also decreased the amount of manual labor needed to install and carry out equipment monitoring. This designed systems consisted of three subsystems; the Monitoring, Power, and Mounting System. A successful proof of concept prototype was created for the Power and Monitoring system. Both systems were procured, assembled, programmed, and tested. The final system product is a feasible design, however, there is definite room for optimization both technically, and economically. It is recommended that this project be continued another year for further optimization. More testing should be done on the power system. A better match between the solar panel and battery size could be achieved in order to decrease overall capacity. In addition, further programming work can be done to implement an alarm program for the operator. The programming could also be simplified more thorough investigation of other control methods. The monitoring system could also be manufactured and tested in the future to create a full-scale prototype to be potentially installed and tested at RJ Midulla. Finally, it is believed that the system could overall be made more economical through optimizing the total electronic circuit by eliminating unnecessary converters and adapters.

REFERENCES

[1] Team 14, *SWIMS Project Website.* http://www.eng.fsu.edu/me/senior_design/2015/team14/

[2] Sharp, James. *Kickoff Meeting Proceedings: Siemens Energy Wireless IR Camera Study.* http://www.eng.fsu.edu/me/senior_design/2015/team14/TeamFiles/KO_Presentation.pdf

[3] Seminole Electric Cooperative. *R.J. Midulla Generating Station Brochure*. http://www.seminole-electric.com/pdf/SGS_MGS_Brochure.pdf

[4] Wikipedia. *Blackbody Radiation,* March 2015. http://en.wikipedia.org/wiki/Black-body_radiation

[5] Wikipedia. *Thermography,* April 2015. http://en.wikipedia.org/wiki/Thermography#Difference_between_infrared_film_and_thermography

[6] Infrared Camera User Manual. http://www.cylod.com/products/data_sheet/FLIR/A-series/A%20series.pdf

[7] Micropower Technologies. *Micropower Helios IR Camera: Product Datasheet,* 2013. http://www.micropower.com/wp-content/uploads/2013/11/micropower_DS_IR1.pdf

[8] Skyway Security. *Wireless Solar Powered Panasonic WV-SC384 Pole Mount Security Camera,* 2014. http://www.skywaysecurity.com/panasonic-wireless-solar-camera-pole-mount/

[9] A and Z Security Cameras. *Solar Power Wireless Thermal Security Camera Systems SS-TIRC.* http://www.a2zsecuritycameras.com/solar-power-thermal-security-camera-systems/

[10] FLIR. *Motion Control Systems: Software & Controllers*, 2014. http://www.flir.com/mcs/view/?id=53771

[11] Energy Informative. *Which Solar Panel is Best for you?* 2013. http://energyinformative.org/best-solar-panel-monocrystalline-polycrystalline-thin-film/

[12] Battery University. *What's the Best Battery?* http://batteryuniversity.com/learn/article/whats_the_best_battery

[13] North Arizona Wind & Sun. *All about Maximum Power Point Tracking Solar Charge Controllers*, 2015. http://www.solar-electric.com/mppt-solar-charge-controllers.html

[14] PV Depot. *How to Size a Solar Charge Controller*. http://pvdepot.com/media/size-a-solar-charge-controller.pdf

[15] Allen, Gregg. *Solar Pro: Optimal PV to Inverter Sizing Ratio,* 2010. http://solarprofessional.com/articles/design-installation/optimal-pv-to-inverter-sizing-ratio

[16] DOF Master. *Depth of Field Calculator*, 2005. http://www.dofmaster.com/dofjs.html

[17] PELCO. *Pelco D Protocol Manual*, 1999. http://cvs.ru/files/pelco-d.pdf

[18] B&B Electronics. *Basics of the RS-485 Standard.* http://www.bb-elec.com/Learning-Center/All-White-Papers/Serial/Basics-of-the-RS-485-Standard.aspx

[19] Versalogic Corporation. *Tiger PC/104-Plus,* 2014. http://www.versalogic.com/new/pr_vl-epm-24.asp

[20] Trendnet, *AC1200 Dual Band Wireless Router.* http://www.trendnet.com/products/proddetail.asp?prod=105_TEW-813DRU#tabs-solution02

[21] Trendnet. *N600 Dual Band Wireless USB Adapter.* http://www.trendnet.com/products/proddetail.asp?prod=180_TEW-664UB
[22] TP Link. *2.4GHz 15dBi Outdoor Omni-directional Antenna*. http://www.tp-link.com/en/products/details/cat-5063_TL-ANT2415D.html
[23] ICPT, *Link Budget Calculation.* http://www.piscespacific.org/livesite/files/Link_Budget_Calculation.pdf
[24] NREL, *Solar Resource Data*. http://developer.nrel.gov/docs/solar/solar-resource-v1/
[25] Tiger Versalogic User Manual. http://www.versalogic.com/products/manuals/MEPM24.pdf
[26] YP3040 Pan Tilt Installation Manual. http://www.axis.com/files/manuals/ig_yp3040_51012_en_1303.pdf
[27] Mains Adapter Installation Manual. http://www.axis.com/files/manuals/26537r1_web.pdf
[28] Charge Controller Installation Manual. http://eco-worthy.com/catalog/download/20AMPPT.pdf
[29] Inverter Installation Manual. http://www.batterystuff.com/files/manual-11001-pst-1500-2000-12-24-0513.pdf
[30] 2MccTV. *Solar Powered Sony Network Camera System.* http://www.2mcctv.com/product_info-2MCCTV2MSSFICH120.html?pn=877-875-5473&gclid=Cj0KEQjw6OOoBRDP9uG4oqzUv7kBEiQA0sRYBF74J8J2cRDZnO_yHktCx4bljtVKIOdpw5SAruGpWgIaAjui8P8HAQ
[31] EcoKIT. *Remote Solar and Wind Power Generator for Surveillance Systems.* http://www.surveillance-video.com/media/lanot/attachments/customimport/ECOKIT.pdf

APPENDIX 1: COMPONENT SPECIFICATION DATASHEETS

A. INFRARED CAMERA

Technical Data
FLIR A310f 25°

Part number:
61201-1103

March 08, 2012, 07:56 AM

Corporate Headquarters

FLIR Systems, Inc.
27700 SW Parkway Ave.
Wilsonville, OR 97070
USA
Telephone: +1-503-498-3547

Website

http://www.flir.com

Customer support

http://support.flir.com

Imaging and optical data

IR resolution	320 × 240 pixels
Thermal sensitivity/NETD	< 0.05°C @ +30°C (+86°F) / 50 mK
Field of view (FOV) / Minimum focus distance	25° × 18.8° / 0.4 m (1.31 ft.)
Focal length	18 mm (0.7 in.)
Spatial resolution (IFOV)	1.36 mrad
Lens identification	Automatic
F-number	1.3
Image frequency	30 Hz
Focus	Automatic or manual (built in motor)
Zoom	1–8× continuous, digital, interpolating zooming on images

Detector data

Focal Plane Array (FPA) / Spectral range	Uncooled microbolometer / 7.5–13 µm
Detector pitch	25 µm
Detector time constant	Typical 12 ms

Measurement

Object temperature range	–20 to +120°C (–4 to +248°F) 0 to +350°C (+32 to +662°F)
Accuracy	±4°C (±7.2°F) or ±4% of reading

Measurement analysis

Spotmeter	10
Area	10 boxes with max./min./average/position
Isotherm	1 with above/below/interval
Measurement option	Measurement Mask Filter Schedule response: File sending (ftp), email (SMTP)
Difference temperature	Delta temperature between measurement functions or reference temperature
Reference temperature	Manually set or captured from any measurement function
Atmospheric transmission correction	Automatic, based on inputs for distance, atmospheric temperature and relative humidity
Optics transmission correction	Automatic, based on signals from internal sensors
Emissivity correction	Variable from 0.01 to 1.0
Reflected apparent temperature correction	Automatic, based on input of reflected temperature
External optics/windows correction	Automatic, based on input of optics/window transmission and temperature
Measurement corrections	Global and individual object parameters

Alarm

Alarm functions	6 automatic alarms on any selected measurement function, Digital In, Camera temperature, timer

FLIR A310f 25°

P/N: 61201-1103

Alarm	
Alarm output	Digital Out, log, store image, file sending (ftp), email (SMTP), notification
Set-up	
Color palettes	Color palettes (BW, BW inv, Iron, Rain)
Set-up commands	Date/time, Temperature°C/°F
Storage of images	
Storage media	Built-in memory for image storage
File formats	Standard JPEG, 16-bit measurement data included
Ethernet	
Ethernet	Control, result and image
Ethernet, type	100 Mbps
Ethernet, standard	IEEE 802.3
Ethernet, connector type	RJ-45
Ethernet, communication	TCP/IP socket-based FLIR proprietary
Ethernet, video streaming	MPEG-4, ISO/IEC 14496-1 MPEG-4 ASP@L5
Ethernet, image streaming	16-bit 320 × 240 pixels @ 7-8 Hz - Radiometric
Ethernet, power	Power over Ethernet, PoE IEEE 802.3af class 0
Ethernet, protocols	Ethernet/IP, Modbus TCP, TCP, UDP, SNTP, RTSP, RTP, HTTP, ICMP, IGMP, ftp, SMTP, SMB (CIFS), DHCP, MDNS (Bonjour), uPnP
Digital input/output	
Digital input, purpose	Image tag (start/stop/general), Input ext. device (programmatically read)
Digital input	2 opto-isolated, 10–30 VDC
Digital output, purpose	As function of ALARM, Output to ext. device (programmatically set)
Digital output	2 opto-isolated, 10–30 VDC, max 100 mA
Digital I/O, isolation voltage	500 VRMS
Digital I/O, supply voltage	12/24 VDC, max 200 mA
Digital I/O, connector type	6-pole jackable screw terminal
Composite video	
Video out	Composite video output, PAL and NTSC compatible
Video, standard	CVBS (ITU-R-BT.470 PAL/SMPTE 170M NTSC)
Power system	
External power operation	12/24 VDC, 24 W absolute max
External power, connector type	2-pole jackable screw terminal
Voltage	Allowed range 10–30 VDC
Environmental data	
Operating temperature range	–25°C to +50°C (–13°F to +122°F)
Storage temperature range	–40°C to +70°C (–40°F to +158°F)
Humidity (operating and storage)	IEC 60068-2-30/24 h 95% relative humidity +25°C to +40°C (+77°F to +104°F)
EMC	• EN 61000-6-2 (Immunity) • EN 61000-6-3 (Emission) • FCC 47 CFR Part 15 Class B (Emission)
Encapsulation	IP 66 (IEC 60529)
Bump	5 g, 11 ms (IEC 60068-2-27)
Vibration	2 g (IEC 60068-2-6)

61201-1103_en_50.xml, ver. 1.04

http://www.flir.com

FLIR A310f 25°

P/N: 61201-1103

Physical data	
Weight	5 kg (11.0 lb.)
Size (L × W × H)	460 × 140 × 159 mm (18.1 × 5.5 × 6.3 in.)
Base mounting	TBA
Housing material	Aluminum

System features	
External power operation (heater)	24 VDC 25 W max w/heater @ 24 VDC
External power, connector type (heater)	2-pole jackable screw terminal
Voltage (heater)	Allowed range 21-30 VDC
Automatic heaters	Clears window from ice

Scope of delivery

- Cardboard box
- Infrared camera with lens and environmental housing
- Calibration certificate
- Downloads brochure
- FLIR Sensors Manager CD-ROM
- Lens cap
- Printed Getting Started Guide
- Printed Important Information Guide
- Service & training brochure
- Small accessories kit
- User documentation CD-ROM
- FLIR Tools & Utilities CD-ROM
- Registration card

B. PAN-TILT MODULE

www.axis.com

Technical Specifications - YP3040 Pan-Tilt Motor

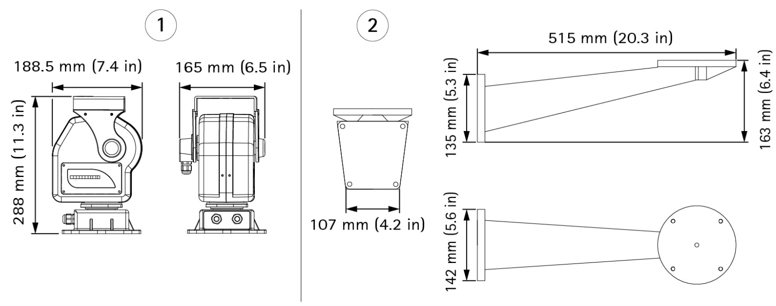
57018/EN/M3.2/092014

Models	YP3040 Pan-Tilt Motor
General	
Supported cameras	AXIS P13-E, AXIS Q16-E, AXIS Q1755-E and AXIS Q1765-LE PT Mount Network Cameras, AXIS Q1910-E, AXIS Q1922-E, AXIS Q1931-E PT Mount and AXIS Q1932-E PT Mount Thermal Network Cameras, AXIS T92A and AXIS T92E Housings
Pan/Tilt/Zoom	Pan range 0° to 355° Tilt range 10° to -80° Pan speed 7.5°/s Tilt speed 6°/s Designed for operator control
Casing	Aluminum alloy Color: White NCS S 1002-B
Supported protocols	Pelco-D
Connectors	1x RS485 port
Mounting	Wall mounting Torque: 1.5 N m (1.1 lb ft) Maximum load: 8 kg (17.6 lb)
Power	Consumption: 30 W Input: 24 V AC 50/60 Hz AXIS PS-24 Mains Adaptor recommended (not included)
Operating conditions	-20 °C to 65 °C (-4 °F to 149 °F)
Approvals	IEC/EN 60529 IP66
Dimensions	288 x 165 x 188.5 mm (11 x 6 x 7 in)
Weight	4.2 kg (9 lb)
Included accessories	Mounting kit, Drill template, Installation guide
Optional accessories	AXIS T8310 Video Surveillance Control Board, YP3040 Wall Bracket, AXIS T92A20 Housing, AXIS T92E05 Housing, AXIS T92E20 Housing, AXIS PS-24 Mains Adaptor
Warranty	Axis 1-year warranty, www.axis.com/warranty

More information is available at www.axis.com

Dimensions

1. YP3040 Pan-Tilt Motor
2. YP3040 Wall Bracket



Optional accessories

1. YP3040 Wall Bracket
2. Axis housings
3. AXIS T8310 Video Surveillance Control Board
4. AXIS PS-24 Mains Adaptor

C. Microcomputer

VersaLogic Corporation

TIGER

PC/104-*Plus* Single Board Computer

is critical in many OEM applications.

The Tiger features an embedded BIOS with OEM enhancements from Phoenix Technologies. The field-reprogrammable BIOS supports custom defaults and the addition of firmbase applications for security processes, remote booting, and other pre-OS software functions. The Tiger is compatible with a variety of popular operating systems including Windows, Windows Embedded, Linux, VxWorks, and QNX.

Ordering Information

Model	Processor	Speed	Operating Temp.	Cooling
VL-EPM-24SU	Intel Atom Z530P	1.6 GHz	0° to +60°C	Fanless
VL-EPM-24EU	Intel Atom Z520PT	1.33 GHz	-40° to +85°C	Fanless

Accessories

Part Number	Description
VL-CKR-TIGER	Development cable kit. *Includes bold items below.*
VL-CBR-1008	**ATX power adapter cable**
VL-CBR-2012	**20" 24-bit LVDS flat panel cable (Hirose)**
VL-CBR-2014	**LVDS to VGA adapter board**
VL-CBR-4405	**IDE adapter board**
VL-CBR-4406	**IDE cable**
VL-CBR-5012	**I/O cable set and paddleboard**
VL-HDW-105	**0.6" standoff package (metric thread)**
VL-CBR-1401	Cable assembly for (2) SPX modules
VL-CBR-1402	Cable assembly for (4) SPX modules
VL-CBR-1603	Quad USB transition cable
VL-CBR-2010	20" 18-bit LVDS flat panel cable (Hirose)
VL-CBR-2011	20" 18-bit LVDS flat panel cable (JAE)
VL-CDD-xxxx	CD-RW / DVD-ROM drive
VL-ENCL-5D	Development enclosure
VL-F20-xxxx	Disk on Module (IDE)
VL-HDD25-xxx	2.5" hard drive (IDE)
VL-HDW-106	0.6" standoff package (English thread)
VL-HDW-108	DOM hardware kit (metric thread)
VL-HDW-203	PC/104 extractor tool, metal
VL-MM8-xxxx	DDR2 RAM module
VL-PS200-ATX	200W ATX-style development power supply
VL-SPX-x	SPX expansion modules

** Power specifications represent operation at +25°C with +5V supply running Windows XP with 2 GB RAM, Ethernet, keyboard, and mouse. Typical power computed as the mean value of Idle and Maximum power specifications. Maximum power is measured with 95% CPU utilization.*

† Signal lines on this port are TVS protected (enhanced ESD protection)

‡ Power pins on this port are overload protected

02/20/13

SPECIFICATIONS

General	Board Size	PC/104 compliant: 114 mm x 96 mm (4.49" x 3.78")
	Processor + Chipset	Model / Processor / Speed / Chipset VL-EPM-24SU / Atom Z530P / 1.6 GHz / US15WP VL-EPM-24EU / Atom Z520PT / 1.33 GHz / US15WPT 533 MHz FSB. Dynamic 512 KB L2 cache. Supports Enhanced Intel SpeedStep Technology and Hyper-Threading Technology (HTT).
	Power Requirements *	Model / Sleep (S3) / Typical VL-EPM-24SU / 0.21A (1.05W) / 1.20A (6.0W) VL-EPM-24EU / 0.23A (1.15W) / 1.18A (5.9W)
	Hardware Monitors	Watchdog Timer: 1 second to 255 minutes. Warm reset, cold reset, or power down. Power Quality Monitor: System reset on undervoltage conditions
	Stackable Bus	PC/104-*Plus* (PCI, ISA)
	Other I/O Expansion	VersaLogic SPX interface
	RoHS	Compliant
Environmental	Operating Temperature	Model / Operating Temperature VL-EPM-24SU / 0° to +60°C VL-EPM-24EU / -40° to +85°C
	Storage Temperature	-40° to +85°C
	Airflow Requirements	Model / Airflow Requirements VL-EPM-24SU / Free air from 0° to +60°C VL-EPM-24EU / 100 LFPM from +60° to +85°C
	Thermal Shock	5°C/min. over operating temperature
	Humidity	Less than 95%, noncondensing
	Vibration, Sinusoidal Sweep	MIL-STD-202G, Method 204, Modified Condition A: 2g constant acceleration from 5 to 500 Hz, 20 minutes per axis
	Vibration, Random	MIL-STD-202G, Method 214A, Condition A: 5.35g rms, 5 minutes per axis
	Mechanical Shock	MIL-STD-202G, Method 213B, Condition G: 20g half-sine, 11 ms duration per axis
Memory	System RAM	SO-DIMM socket. Up to 2 GB DDR2 SDRAM.
Video	General	Integrated high-performance video. Intel GMA 500 graphics core supports advanced 3D graphics and high-definition video decode.
	VRAM	Up to 256 MB shared DRAM
	OEM Flat Panel Interface	18/24-bit LVDS interface. CMOS-selectable TFT panel types. Up to 1280 x 1024 (24 bits) @ 85 Hz.
	Desktop Display Interface	Analog output (VGA) via optional adapter cable †
Mass Storage	Hard Drive	IDE controller (ATA-6, UDMA/100) supports two IDE devices
	Flash	Right angle IDE Disk on Module (DOM) site with retention screw
Network Interface	Ethernet †	Autodetect 10BaseT/100BaseTX/1000BaseT port
	Network Boot Option	Intel boot agent (downloadable) supports PXE protocol. Argon Managed Boot Agent (optional with royalty fee) supports PXE, RPL, NetWare, TCP/IP (DHCP, BOOTP) remote boot protocols.
Device I/O	USB †‡	Seven USB 2.0/1.1 ports (one client, six host)
	COM 1/2/3/4 †	RS-232/422/485 selectable. 16C550 compatible. 460 Kbps.
	Audio	Intel High Definition Audio (HDA) compatible. Stereo line in/out.
Software	BIOS	Phoenix Technologies Embedded BIOS with OEM enhancements. Field reprogrammable. Support for USB boot. User-configurable CMOS defaults.
	Sleep Mode	ACPI 2.0 compatible
	Operating Systems	Compatible with most x86 operating systems including Windows, Windows Embedded, Linux, VxWorks, and QNX

VersaLogic Corporation • 12100 SW Tualatin Rd., Tualatin, OR 97062 • (503) 747-2261 • Info@VersaLogic.com • www.VersaLogic.com

D. Wireless Communication

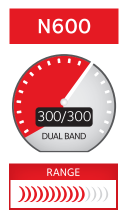
NETGEAR®

N600 WiFi Dual Band USB Adapter

Data Sheet

WNDA3100

Performance & Use



- Dual band avoids interference for reliable connections
- Faster WiFi speeds 300/300 – Up to 600 Mbps†
- Works with any WiFi router or modem router

The NETGEAR Difference – WNDA3100

- Faster downloads
- Push 'N' Connect—push button security
- Reliable and compatible
- Easy setup with NETGEAR® genie®

Overview

The NETGEAR N600 Wireless Dual Band USB Adapter wirelessly connects your notebook or desktop computer to a Wireless-N network for applications, such as HD video streaming, online gaming, a secure and reliable connection to the Internet. NETGEAR genie® is included for easy installation. WiFi dual band technology avoids interference for reliable connections. With the NETGEAR Push 'N' Connect feature, enjoy a secured wireless Internet connection, at the push of a button.

PUSH 'N' CONNECT—WPS

A secured connection at the push of a button[1]

STEP 1	STEP 2	STEP 3
Install CD and push the button on the adapter 	Push the Push 'N' Connect button on the router 	Secure wireless connection 

[1] Works with devices supporting Wi-Fi Protected Setup® (WPS).

PAGE 1 OF 3

E. MPPT Charge Controller

ECO-WORTHY
Solar panels and renewable energy products shop

www.eco-worthy.com
Email: info@eco-worthy.com

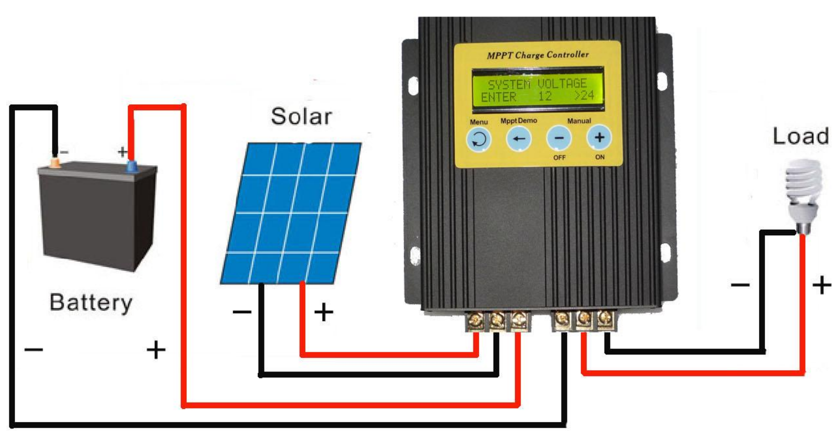
- **Low stand-by power consumption**

Specifications

Item No.	ECO-MPPT-20A
Rated system voltage	12V/24V DC
Max open circuit voltage of solar panel	15— 50V DC
Max solar panel power	300W 12V/ 600W 24V
Max output current	20A
Max discharge current	20A
Over discharge voltage	10.2—12.5V (±0.2) 12V/ 20.4—25.0V (±0.2) 24V
Restart voltage	10.3—13.5V (±0.2) 12V /20.5—27.0V (±0.2) 24V
Constant voltage（Over charge）voltage	13.0—15.5V (±0.2) 12V / 26.0—31.0V (±0.2) 24V
Float voltage	12.5—14.5V (±0.2) 12V / 25.0—29.0V (±0.2) 24V
Converter type	Buck
Converter efficiency	> 96%
Max increase efficiency	> 43%
Tracking efficiency	> 98%
Precision of clock	±50S/Month
Charging algorithm	PWM 3 stage
Stand by power consumption	<15mA 12V / <25mA 24V
Operating temperature	-20 to +50℃
Protect class	IP22
Size	140(L) × 147(W) × 42(H) (mm）
Weight	550g

★(1) Max input current：Solar panel maximum output current
★(1) Max output current：Controllers maximum output current

Wiring diagram



F. INVERTER

samlexamerica® 150W

DC-AC Inverter
Pure Sine Wave

Model
SA-150-112
12 VDC-110 VAC
SA-150-124
24 VDC-110 VAC

Design Features

- Pure sine wave output (THD < 6%)
- Switch selectable output frequency: 50 / 60 Hz
- Remote ON/OFF control using external mechanical / transistor switch
- Input and output are fully isolated
- Advanced micro-controller
- Load controlled cooling fans save power consumption
- Tri-color LED for display of operational status and fault indications
- **Protections:** overload, short-circuit, leakage, low and high DC input voltages, high temperature and reverse polarity
- **Safety:** Listed to UL Standard UL-458
- **EMC:** Complies with FCC Part 15(B), Class B

2 YEAR WARRANTY c UL us FC

	MODEL NO.	SA-150-112	SA-150-124
OUTPUT	OUTPUT VOLTAGE	110 VAC, ± 5%	110 VAC, ± 5%
	OUTPUT FREQUENCY	50 / 60 Hz ± 0.3% (Selected by Switch)	50 / 60 Hz ± 0.3% (Selected by Switch)
	TYPE OF OUTPUT WAVEFORM	Pure Sine Wave	Pure Sine Wave
	TOTAL HARMONIC DISTORTION OF OUTPUT WAVEFORM	< 6%	< 6%
	CONTINUOUS OUTPUT POWER (At Power Factor = 1)	150W	150W
	SURGE OUTPUT POWER (At Power Factor = 1)	200W	200W
	PEAK EFFICIENCY (At full load)	87%	88%
	AC OUTPUT CONNECTIONS	Dual NEMA-15R receptacles with GFCI protection	
INPUT	NOMINAL DC INPUT VOLTAGE	12 VDC	24 VDC
	DC INPUT VOLTAGE RANGE	10.5 to 15 VDC	21.0 to 30 VDC
	DC INPUT CURRENT AT NO LOAD	0.3A	0.35A
	DC INPUT CONNECTIONS	Detachable pair of wires with Anderson Power Pole Connectors on inverter side	
DISPLAY	STATUS OPERATIONS & PROTECTIONS	By steady / flashing patterns of 3 - color LED	
REMOTE OPERATION	WIRED ON/OFF CONTROL	By external contact closure through mechanical / transistor switch	
PROTECTIONS	LOW DC INPUT VOLTAGE SHUTDOWN	10.5 VDC	21.0 VDC
	HIGH DC INPUT VOLTAGE SHUTDOWN	15.3 VDC	30.6 VDC
	SHORT CIRCUIT SHUTDOWN	Yes	Yes
	OVERLOAD SHUTDOWN	Yes	Yes
	GROUND FAULT SHUTDOWN	GFCI protected dual NEMA5-20R receptacles	
	OVER TEMPERATURE SHUTDOWN	Yes	Yes
	REVERSE POLARITY ON DC INPUT SIDE	Yes. Internal fuses will blow.	Yes. Internal fuses will blow.
COOLING	FORCED AIR COOLING	Thermostatically controlled fan	Thermostatically controlled fan
COMPLIANCE	SAFETY	UL Listed to UL-458	UL Listed to UL-458
	EMI / EMC	Meets FCC Part 15(B), Class A	Meets FCC Part 15(B), Class A
ENVIRONMENT	OPERATING TEMPERATURE RANGE	0°C to +40°C / 32°F to 104°F	0°C to +40°C / 32°F to 104°F
	STORAGE TEMPERATURE RANGE	-30°C to 70°C / -22°F to 158°F	-30°C to 70°C / -22°F to 158°F
DIMENSIONS	(L X W X H), MM	200 x 132 x 72	200 x 132 x 72
	(L X W X H), INCHES	7.9 x 5.2 x 2.8	7.9 x 5.2 x 2.8
WEIGHT	KG	2.7	2.7
	LBS	5.6	5.6

NOTE: Specifications are subject to change without notice 12003-SA-150-112-124-1112

To view a full selection of Samlex products visit our website at www.samlexamerica.com or contact us: 1(800) 561-5885 or sales@samlexamerica.com

G. POE SPLITTER

PoE Splitter, Fast Ethernet, 1 Port

There are no reviews yet. | Write a review

NT1-3195-R

Availability: **In Stock**

Ships Within 1-3 Business Days

$23.19

Quantity: 1 Add to Cart

Estimate Shipping

Description Features Specifications Reviews (0)

Specs:

Standards and Protocols		IEEE 802.3, 802.3u, 802.3af CSMA/CD, TCP/IP
Basic Function		Compatible with IEEE 802.3af compliant PSEs Delivers power up to 100 meters Optional 12VDC or 5VDC power supply Plug-and-Play
Ports	LAN Port	1 10/100M Auto-Negotiation RJ45 port (Auto MDI/MDIX)
	PoE Port	1 10/100M Auto-Negotiation RJ45 port (Auto MDI/MDIX)
Network Media		10BASE-T: UTP category 3, 4, 5 cable (maximum 100m) EIA/TIA-568 100Ω STP (maximum 100m) 100BASE-TX: UTP category 5, 5e cable (maximum 100m) EIA/TIA-568 100Ω STP (maximum 100m)
LED Indicator		PWR
Safety & Emission		FCC, CE
Dimensions (W*D*H)		3.2*2.0*0.9 in.(81*52*24 mm)
Environment		Operating Temperature: 0°C~40°C (32°F~104°F) Storage Temperature: -40°C~70°C (-40°F~158°F) Operating Humidity: 10%~90% non-condensing Storage Humidity: 5%~90% non-condensing
Power Output		12W (12VDC) or 11.5W (5VDC)

H. Solar Panel

RNG-150D

Key Features

- Top Ranked PTC Rating
- High Module Conversion Efficiency
- Fast and Inexpensive Mounting
- Maximizes System Output by Reducing the mismatch Loss
- 100% EL Testing on Every Renogy Modules, Guaranteed No Hot Spot
- Guaranteed Positive Output Tolerance (0+3%)
- Withstands High Wind (2400 Pa) and Snow Loads (5400 Pa)
- Excellent Performance in Low Light Environments

Application

- Off-Grid Rooftop/Ground Mounted
- Residential/Rural
- 12 V Battery Charging

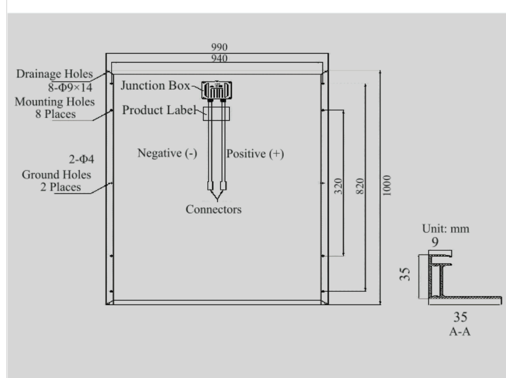
Electrical Characteristics

Maximum Power at STC (Pmax)	150W
Optimum Operating Voltage (Vmp)	17.9 V
Optimum Operating Current (Imp)	8.38 A
Open-Circuit Voltage (Voc)	22.5 V
Short-Circuit Current (Isc)	9.05 A
Cells Efficiency	19.0%
Maximum System Voltage	

Mechanical Characteristics

Solar Cell	Monocrystalline 156 x 16mm
No. of Cells	36 (6 x 6)
Dimensions	1000 x 990 x 35 mm (39.5 x 39 x 1.4 inches)
Weight	11.5 kgs (25.5 lbs)
Front Glass	3.2 mm (0.13 inches) tempered glass
Frame	Anodized aluminum alloy
Junction Box	IP65 rated
Output Cables	4.0 mm^2(0.006 $inches^2$), 1000mm (39.3 inches)
Connectors	MC4 connectors
Fire Rating	Classs C

Module Diagram



Maximum Ratings

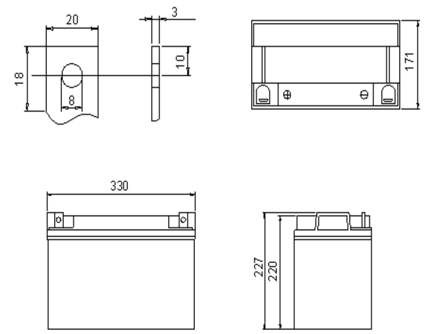
Operating Module Temperature	-40°C to +80°C
Maximum Series Fuse Rating	15 A

Temperature Characteristics

Nominal Operating Cell Temperature (NOCT)	47±2°C
Temperature Coefficient of Pmax	-0.44%/°C
Temperature Coefficient of Voc	-0.30%/°C
Temperature Coefficient of Isc	0.04%/°C

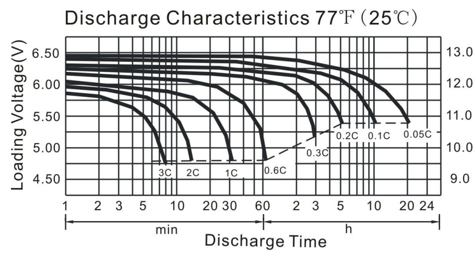
I. BATTERY

Sealed Lead-Acid Batteries **AJC-D100S**



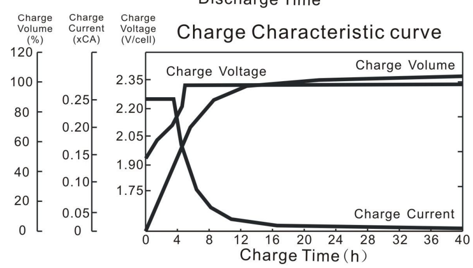
- **Specifications**

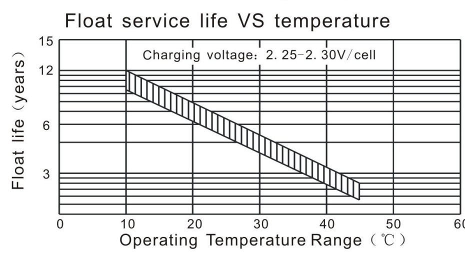
Nominal Voltage		12V
Rated Capacity 77⁰F(25⁰C) (10HR)		100.0Ah
Dimensions (mm/inch)	Length	330 (12.99)
	Width	171 (6.73)
	Height	220 (8.66)
	Total Height	227 (8.94)
Approx. Weight (kg/Ibs)		30.6 (67.46)
Terminal		T6/T12



- **Characteristic**

Capacity 77⁰F(25⁰C)	20HR (5.30A)	106.0Ah
	10HR (10.0A)	100.0Ah
	5HR (17.0A)	85.0Ah
	1HR (55.0A)	55.0Ah
	15 min rate (175.0A)	43.8Ah
Internal Resistance	Full Charged Battery 77⁰F(25⁰C)	Approx. 5mΩ
Temperature dependence of capacity (10HR)	104⁰F(40⁰C)	102%
	77⁰F(25⁰C)	100%
	32⁰F(0⁰C)	85%
	5⁰F(-15⁰C)	65%
Self-Discharge 68⁰F(20⁰C) (Capacity after)	3 months	90%
	6 months	80%
	12 months	60%
Max. Discharge Current, 77⁰F(25⁰C)		800A(5s)
Floating design life, 77⁰F(25⁰C)		10 years
Constant Voltage Charge,77⁰F(25⁰C)	Cycle	14.4~14.7V(-24mV/⁰C) max. current: 25 A
	Float	13.6~13.8V(-18mV/⁰C)





Constant Current Discharge Characteristics (A), 77⁰F(25⁰C)

F.V/TIME	5min	10min	15min	30min	60min	2H	3H	5H	8H	10H	20H
1.60V/cell	340.0	220.0	175.0	100.0	58.1	36.03	26.56	17.95	12.00	10.43	5.45
1.70V/cell	323.0	209.0	167.1	95.6	56.0	34.65	25.95	17.62	11.88	10.33	5.40
1.75V/cell	308.0	196.0	164.1	93.6	55.0	34.00	25.44	17.30	11.63	10.15	5.35
1.80V/cell	289.0	181.0	161.2	91.8	54.1	33.41	25.00	17.00	11.50	10.00	5.30

Constant Wattage Discharge Characteristics (Watt), 77⁰F(25⁰C)

F.V/TIME	5min	10min	15min	30min	60min	2H	3H	5H	8H	10H	20H
1.60V/cell	603.5	399.7	320.8	184.2	107.5	67.26	50.02	34.11	23.00	20.34	10.63
1.70V/cell	578.7	383.2	309.1	177.7	104.5	65.26	49.31	33.77	22.97	20.32	10.62
1.75V/cell	557.0	362.6	306.3	175.6	103.6	64.60	48.76	33.44	22.68	20.13	10.61
1.80V/cell	527.4	337.9	303.6	173.7	102.8	64.04	48.33	33.15	22.62	20.00	10.60

sales@batteryclerk.com (888) 808-3520 www.batteryclerk.com

APPENDIX 2: POWER SYSTEM HOMER ANALYSIS

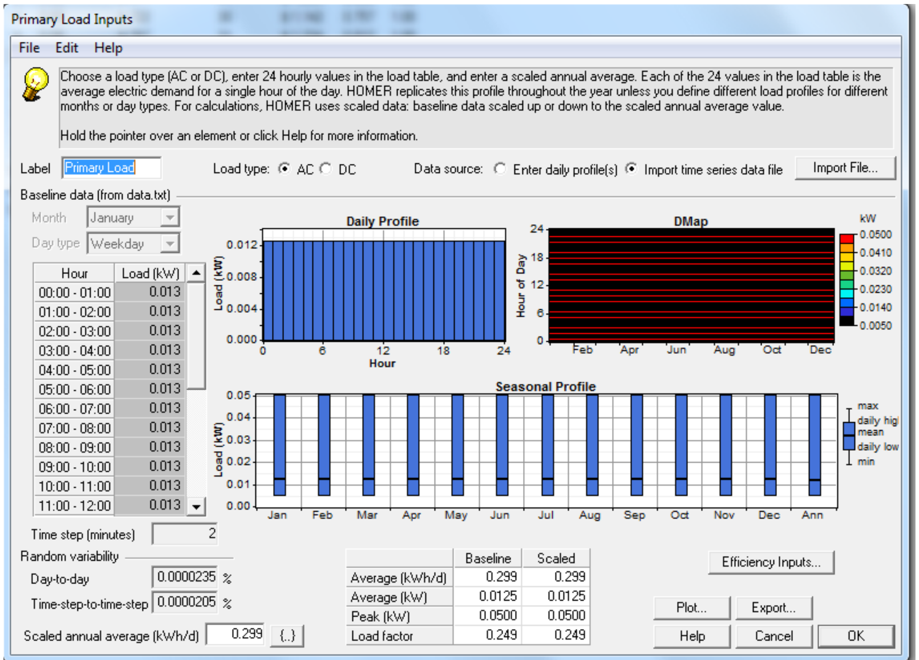


Figure 49. Daily Load Profile Input.

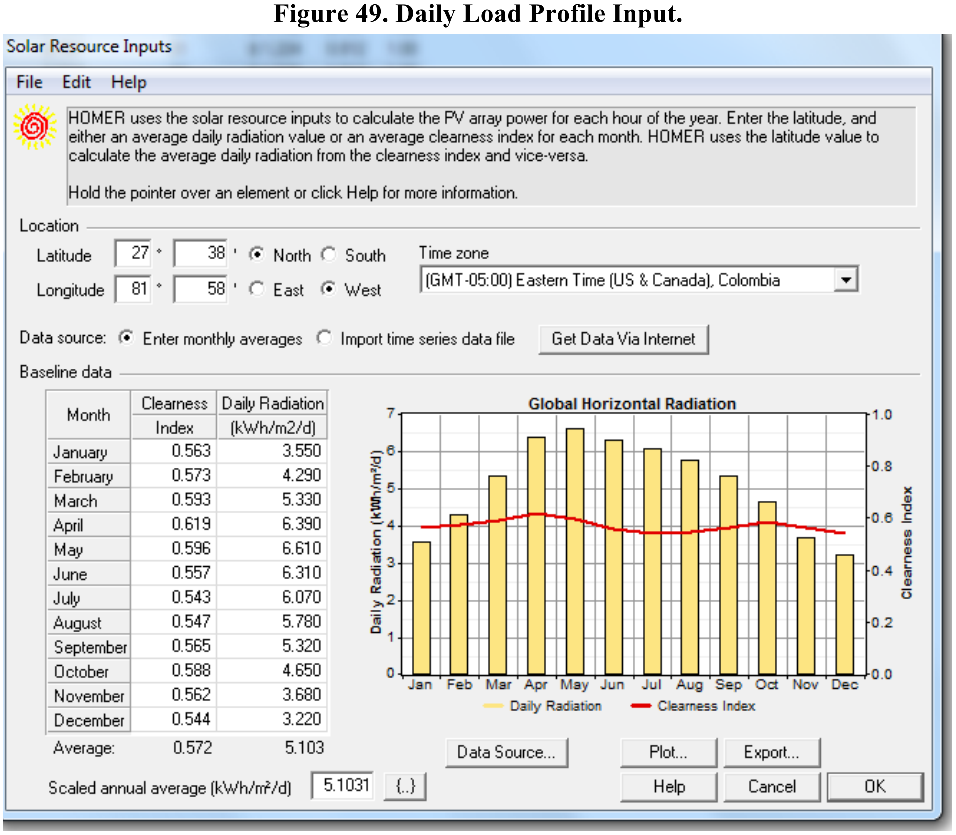


Figure 50. Solar Resource Input.

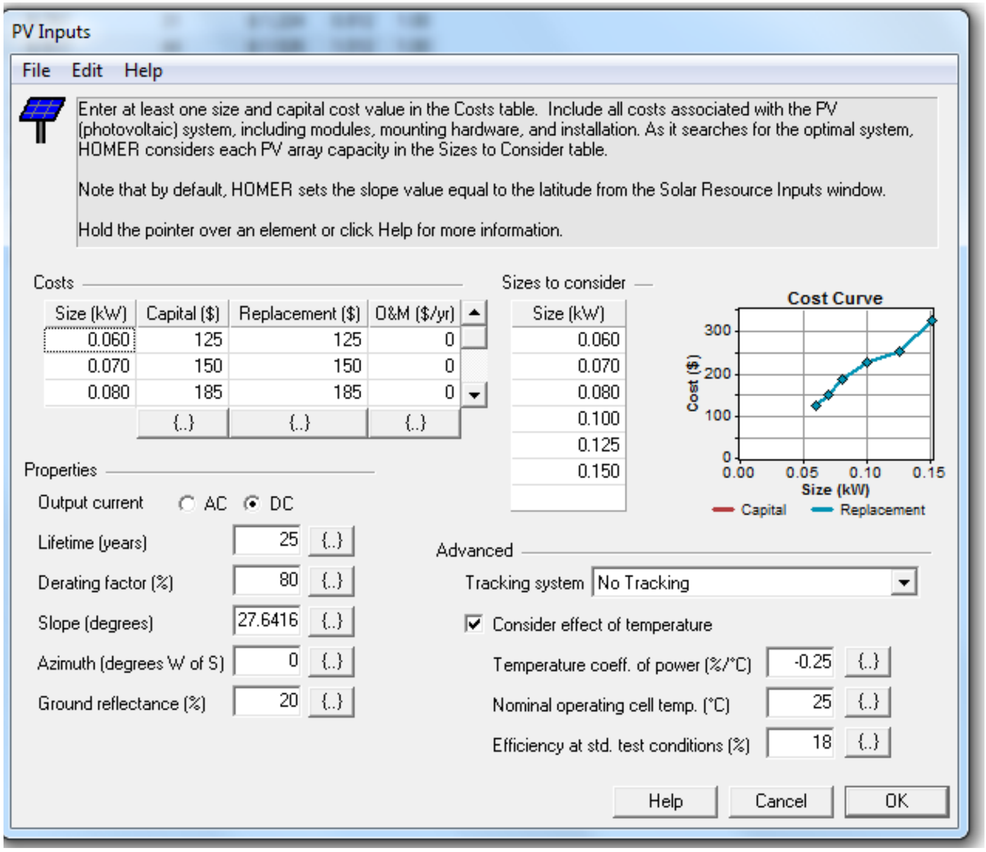


Figure 51. PV Panel Settings.

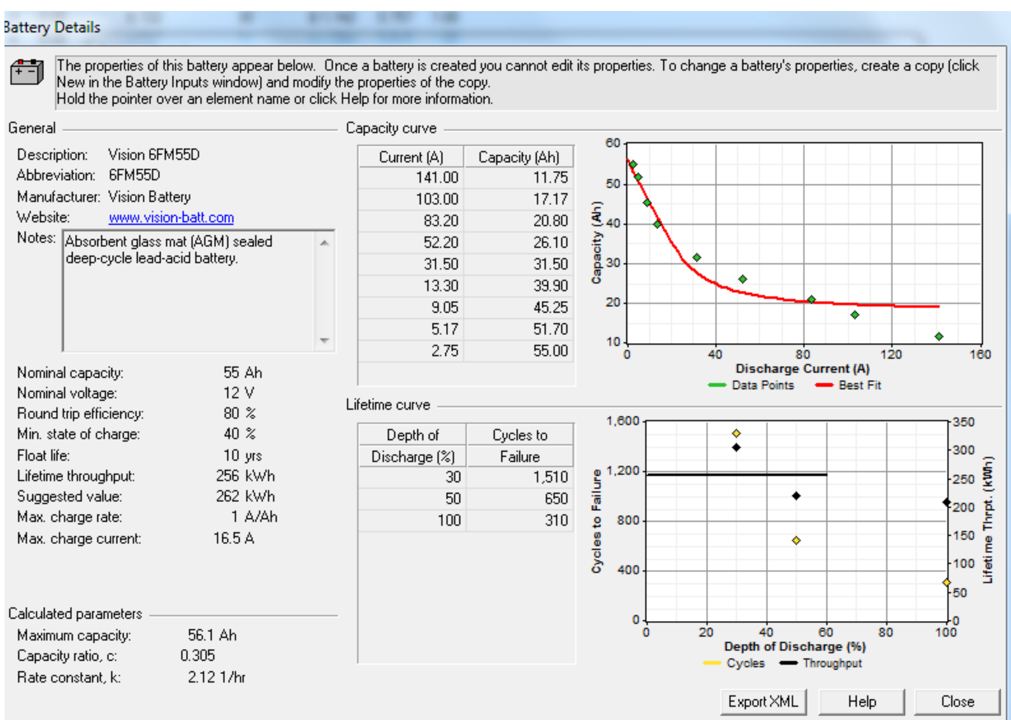


Figure 52. Battery Selection, Specification, and Settings.

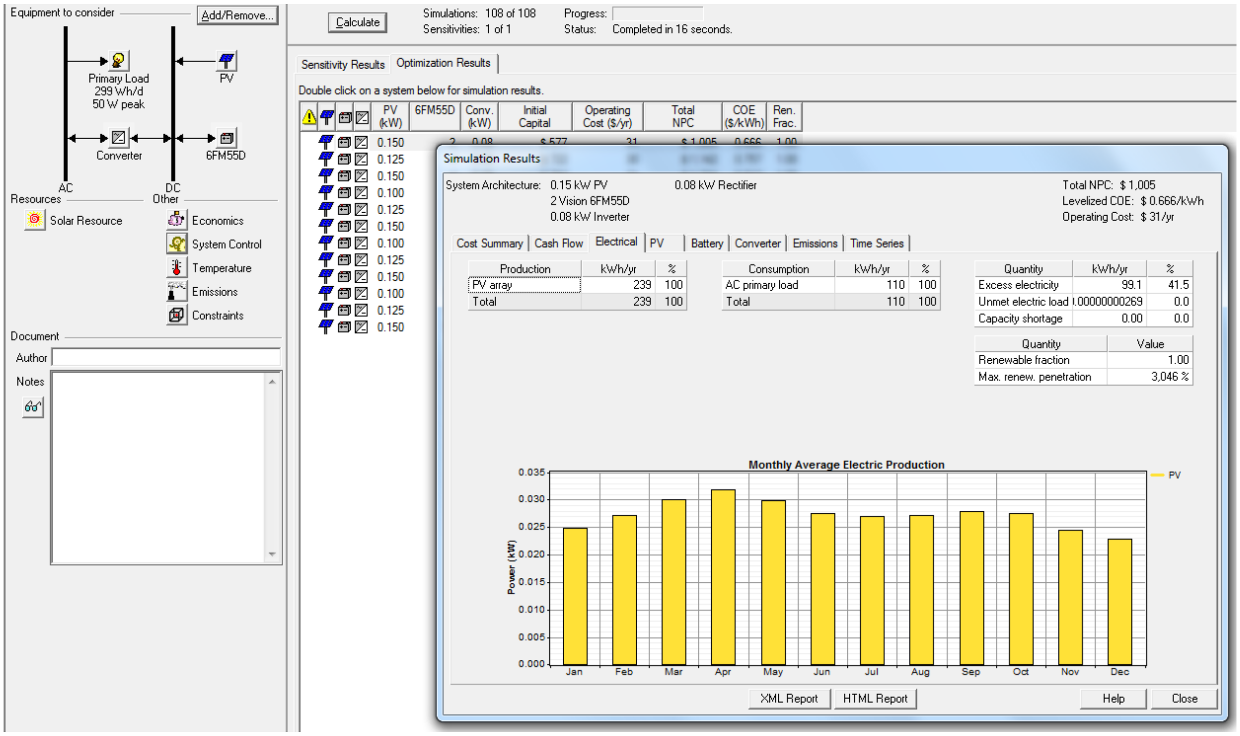


Figure 53. Optimization Results of 150 W Panel with 2 55 Ah Batteries.

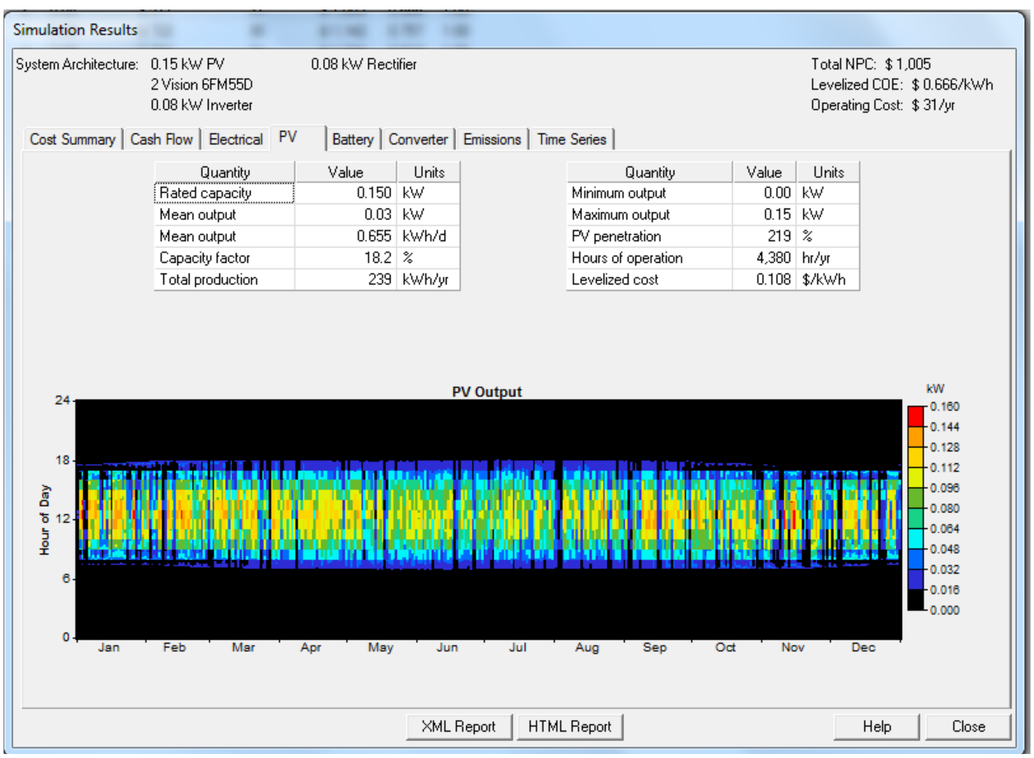


Figure 54. Photovoltaic Output Analysis over 1 year.

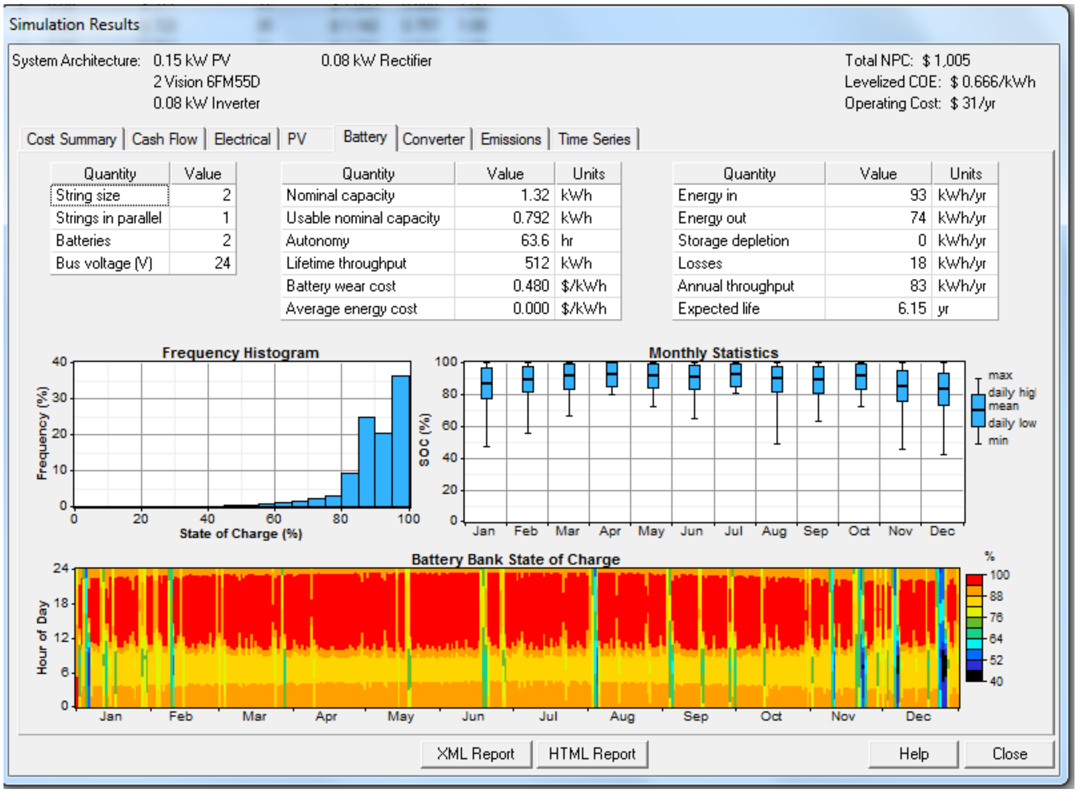


Figure 55. Battery Analysis: State of Charge Simulation over a year.

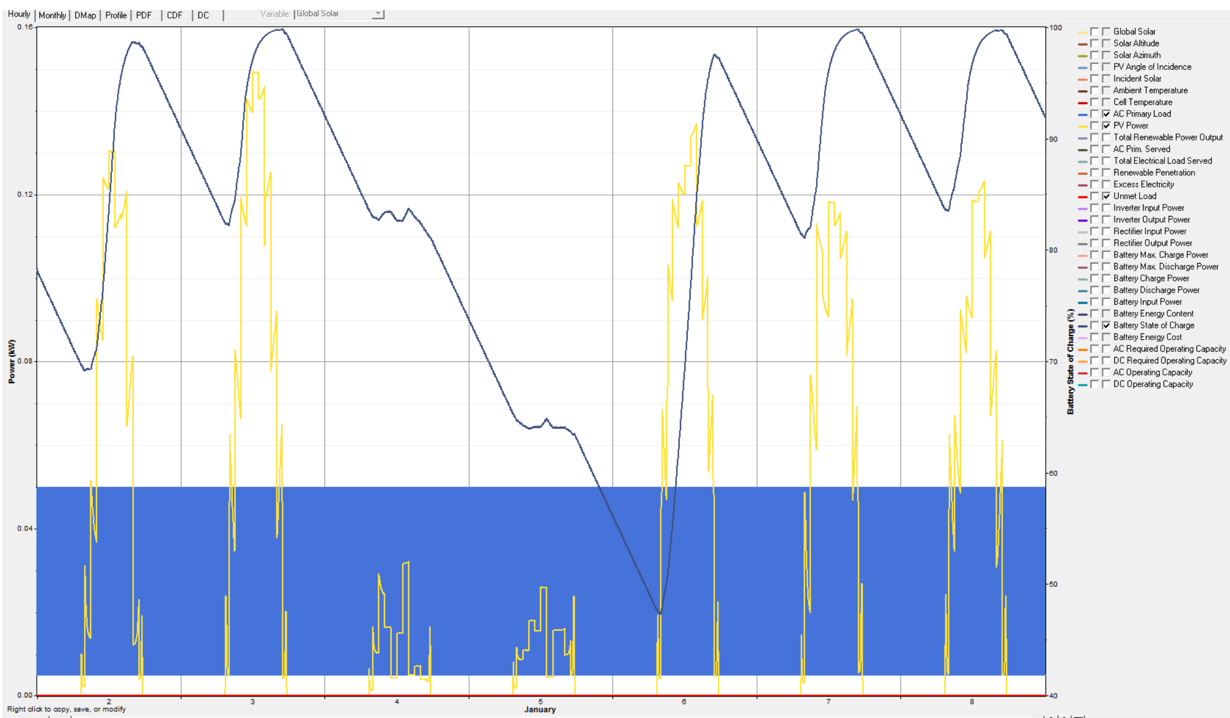


Figure 56. System Charge and Discharge Analysis over 7 days.

APPENDIX 3: FINAL SYSTEM ANALYSIS

Table 14. Wind Simulation Results.

COMPONENT	FRONT	BACK	TOP	BOTTOM	RIGHT	LEFT	NET FORCE
Units	*lbf*	*lbf*	*lbf*	*lbf*	*lbf*	*lbf*	*lbf*
Camera	28.44	12.00	0.05	0.04	0.02	0.03	40.57
Pan-Tilt	19.80	7.90	0.03	0.02	0.04	0.03	27.81
Enclosure	55.76	20.55	0.10	0.11	0.10	0.09	76.71
Solar Panel	84.04	112.62	12.95	15.55	0.03	0.03	225.22

Table 15. Moments on Pole.

Component	Weight	Wind	Units
Pan-Tilt Mount	25.3	68.39	lbf
Pan-Tilt distance	-19	40	in
Pan-Tilt Moment	-480.7	2735.6	lbf*in
Solar Mount	28.5	76.71	lbf
Solar distance	7	65	in
Solar Moment	199.5	4986.2	lbf*in
Enclosure Mount	81.15	225.22	lbf
Enclosure distance	7	16	in
Enclosure Moment	568.05	3603.52	lbf*in
NET Moment	286.9	11325.27	lbf*in

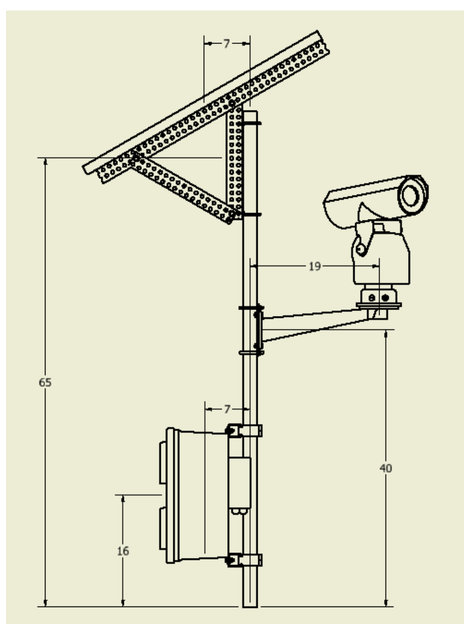


Figure 57. Component X and Y Distances.

Table 16. Cap Screw and U Bolt Safety Factors.

Subject	Cap Screw	U-Bolt	Units
Ultimate Tensile Strength	70,000	70,000	lbf/in^2
Outer Diameter	0.24	0.313	in
Area	0.046	0.076	in^2
Shear Force	5115	41350	lbf/in^2
Conversion Factor	.6	.6	
Shear Tension	42000	42000	lbf/in^2
Safety Factor	8.2	1	

Table 17. U Bolt Tension Calculations for each Mounting System.

Subject	Enclosure	Pan-Tilt	Solar	Units
Static Friction	0.5	.5	.5	
Weight	90	25.3	25.3	lbf
Count	2	2	2	
Simulated Weight	45	12.65	14.25	lbf
Simulated Tension	45	12.65	14.25	lbf

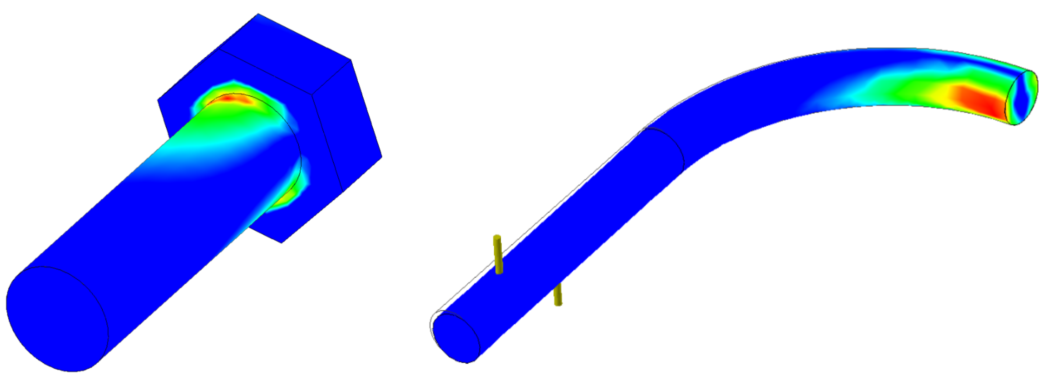
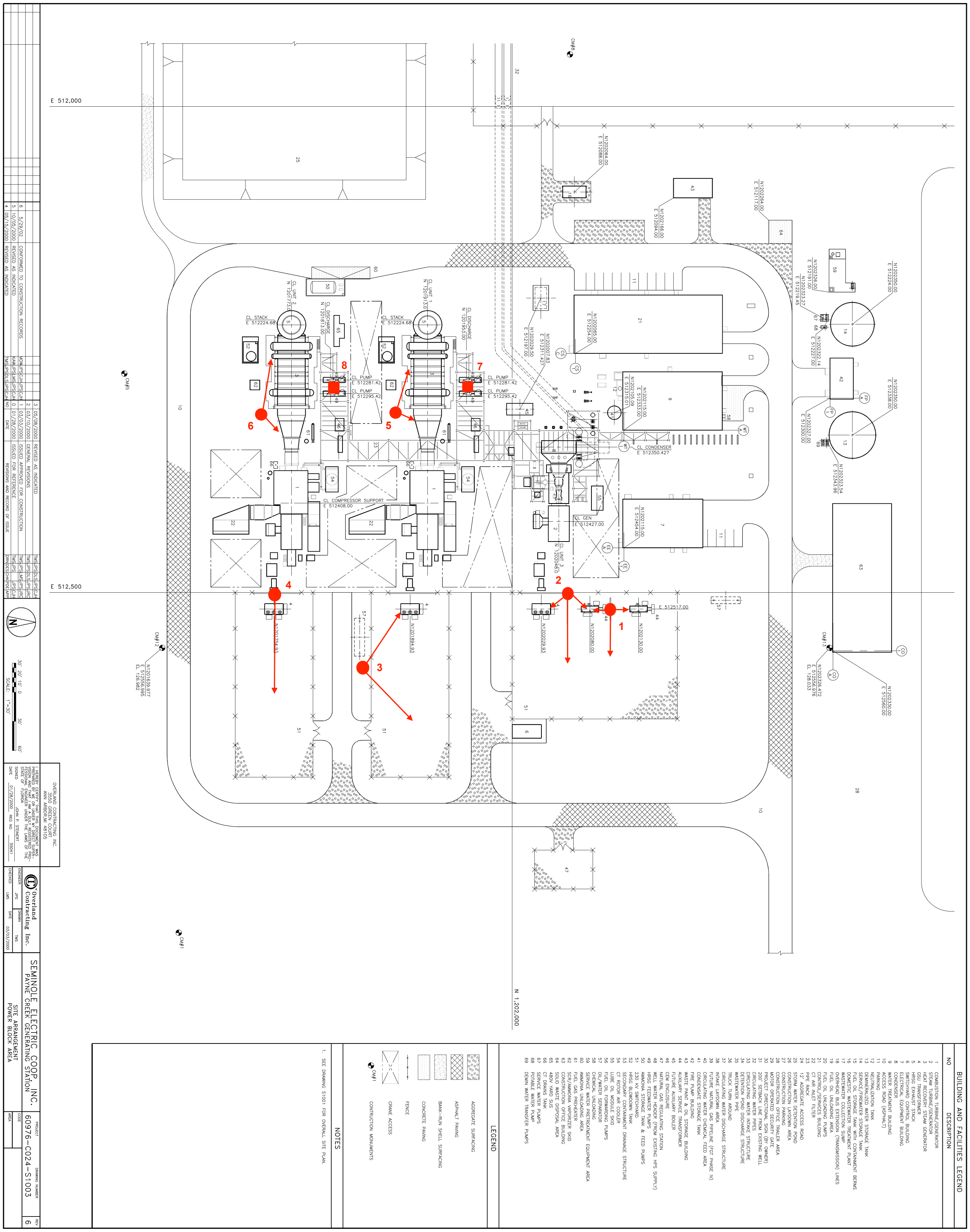


Figure 58. Shear Force Simulations (a)Cap Screw (b)U-bolt.

APPENDIX 4: PROPOSED LOCATIONS



APPENIDX 5: BILL OF MATERIALS

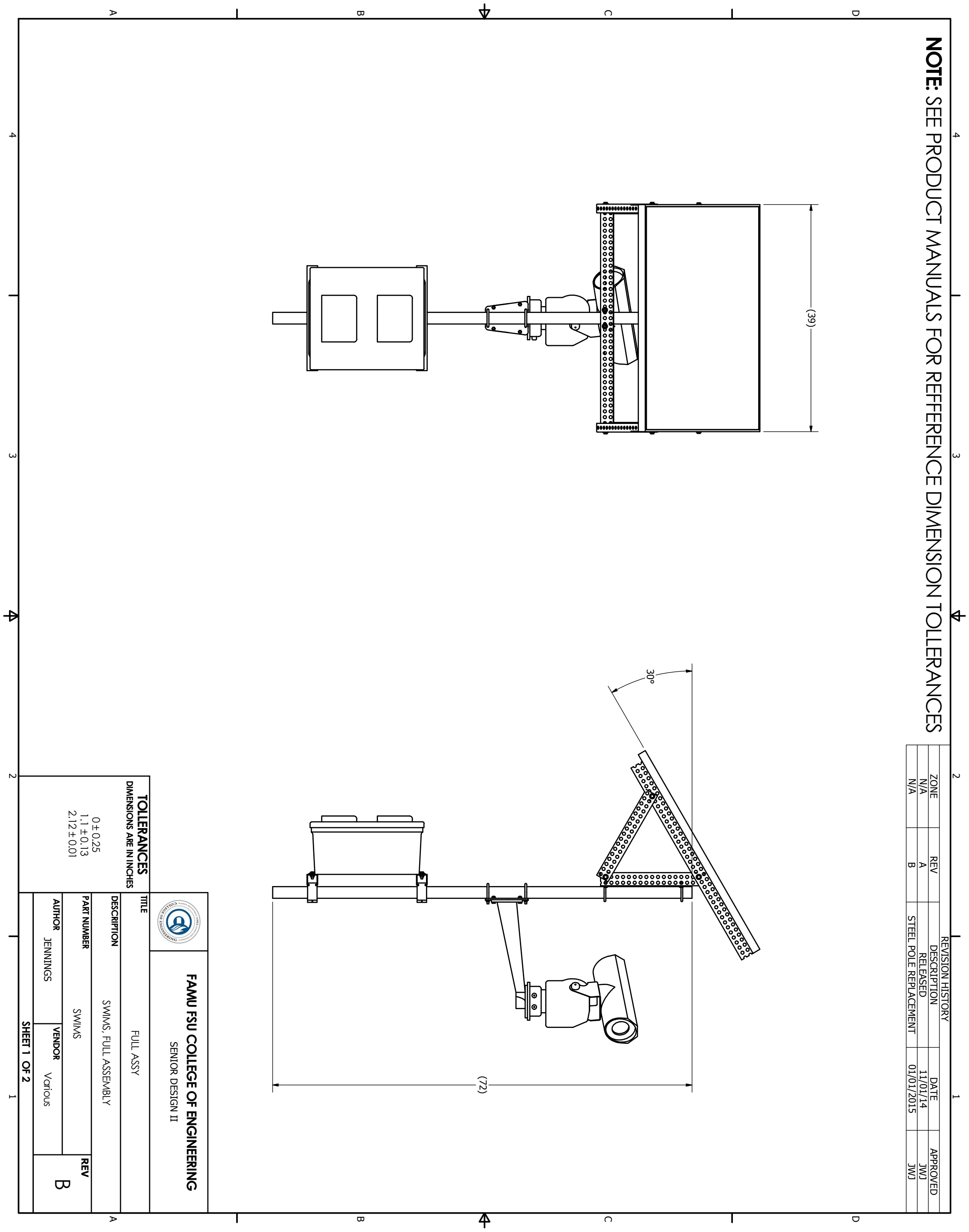
Table 18. Proposed Design Bill of Materials.

Component	Selection	Vendor (Part)	Quantity	Cost
Infrared Camera	FLIR A310F 25deg	Spectrom Group (61201-1103)	1	$10,115.61
Pan Tilt	Axis Communications YP-3040	Surveillence Video (Axis 5502-461)	1	$446.43
AC Adapter	Axis PS24 Adapter	Surveillence Video (Axis 5000-001)	1	$135.43
Pan Tilt Arm	Axis Communications	Surveillence Video (Axis 5502-471)	1	$43.92
Microcomputer	Versalogic VL-EPM-24SU	DigiKey (1241-1006-ND)	1	$891.00
Breakout Paddleboard	Versalogic VL-CBR-5012	DigiKey (1241-1081-ND)	1	$66.00
ATX Power Adapter	Versalogic VL-CBR-1008	DigiKey (1241-1041-ND)	1	$33.00
LVDS to VGA Adapter	Versalogic VL-CBR-2014	Digikey (1241-1000-ND)	1	$100.00
2.5" IDE DRIVE CABLE	Versalogic VL-CBR-4406	DigiKey (1241-1083-ND)	1	$28.00
IDE Adapter Board	Versalogic VL-CBR-4405	DigiKey (1241-1084-ND)	1	$34.00
20" 24-BIT LVDS CABLE	Versalogic VL-CBR-2012	DigiKey (1241-1001-ND)	1	$41.00
Solar Panel	Renogy 150W 12V Mono	Renogy-150D	1	$219.99
Solar Panel Cables	Renogy 16 ft 12 AWG Cables	Renogy (TRAYCB016FT-12	1	$22.99
Solar Cable Adaptor Kit	Renogy 10 ft Cable Adaptor	Renogy (AK-10FT-12)	1	$20.99
Charge Controller	20 A MPPT	EcoWorthy (MPPT20-1)	1	$102.00
Battery	AJC 100Ah 12V AGM Battery	Battery Clerk (AJC-D100S-J-0-140935)	1	$179.00
Inverter	Samlex America 150W	Inverter Supply (SA-150-112)	1	$148.47
Wireless Adapter	A6100 Netgear Wi-Fi adapter	Walmart (551928248)	1	$36.40
POE Splitter	POE Splitter, 1 Port	Primus Cable(NT1-3195-R)	1	$23.19
Memory Module	2GB, Standard Temp	not purchased	1	$35.00
ATX Power Supply	200W	Enlight (HPC-300-101)	1	$32.99
IDE Hardrive	CD RW / DVD ROM	not purchased	1	$60.00
Serial Comm Cable	RS 232 9 pin	not purchased	1	$45.90
Mains Power Cable	120VAC 16 AWG Cable	not purchased	1	$7.99
Pole	Low Carbon Steel, 6 Ft, 2in OD	McMaster (7767T57)	1	$108.86
Weather Enclosure	Electronics Enclosure	LCOM (NB181608-00V)	1	$240.25
Strut Channel	120 in, Zn PLATED	McMaster (3310T212)	1	$34.68
Strut Channel Pipe Clamp	2 in OD, Zinc Plated	McMaster (3115T19)	2	$2.04
Ubolt	2 in OD Pole U Bolt	McMaster (8896T129-A)	4	$4.64
Pan Tilt Mounting Bracket	Machined	Custom	1	$50.00
Solar Panel Mount	Solar Panel Mounting	McMaster (Solar-1)	1	$100.69
90 Deg Track	72 in, Zn Plated	McMaster(8968K27-17.5in)	3	$20.43
Cap Screw	5/16-18 in, 316 S.Steel, 10 pk	McMaster (93190A583)	3	$4.56
Hex Nut	5/16-18 Zn-Al Coated Steel, 100 pk	McMaster (93827A219)	1	$9.74
Washers	.375in ID, .875in OD, Steel, 100pk	McMaster (90108A415)	1	$4.67
Total				**$13,392.22**
Remaining Budget				**$6,607.78**

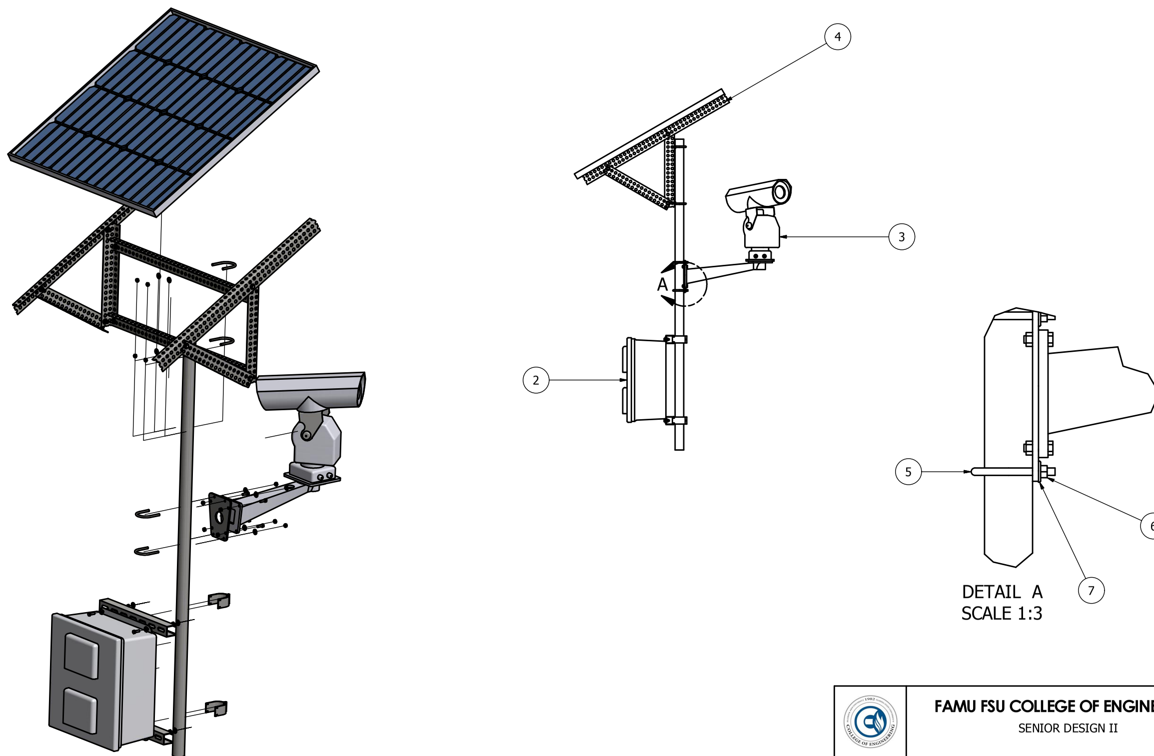
Table 19. Prototype Bill of Materials.

Component	Selection	Vendor (Part)	Cost
Infrared Camera	FLIR A655sc	Dr. Oates	$-
Pan Tilt	Axis Communications YP-3040	Surveillence Video (Axis 5502-461)	$446.43
AC Adapter	Axis PS24 Adapter	Surveillence Video (Axis 5000-001)	$135.43
Pan Tilt Arm	Axis Communications	Surveillence Video (Axis 5502-471)	$43.92
Microcomputer	Versalogic VL-EPM-24SU	DigiKey (1241-1006-ND)	$891.00
Breakout Paddleboard	Versalogic VL-CBR-5012	DigiKey (1241-1081-ND)	$66.00
ATX-EPM Power Adapter	Versalogic VL-CBR-1008	DigiKey (1241-1041-ND)	$33.00
LVDS to VGA Adapter	Versalogic VL-CBR-2014	Digikey (1241-1000-ND)	$100.00
2.5" IDE Drive Cable	Versalogic VL-CBR-4406	DigiKey (1241-1083-ND)	$28.00
IDE Adapter Board	Versalogic VL-CBR-4405	DigiKey (1241-1084-ND)	$34.00
24-BIT LVDS Cable	Versalogic VL-CBR-2012	DigiKey (1241-1001-ND)	$41.00
Solar Panel	Renogy 150W 12V Monocrystalline	Renogy-150D	$219.99
Solar Panel Cables	Renogy 16 ft 12 AWG Solar Cables	Renogy (TRAYCB016FT-12	$22.99
Solar Cable Adaptor	Renogy 10 ft Cable Adaptor	Renogy (AK-10FT-12)	$20.99
Energy Analyzer	Renogy 150A High Precision Analyzer	Renogy (TrcrMtr-MT-150)	$38.99
Wireless Adapter	A6100 Netgear Wi-Fi adapter	Walmart (551928248)	$36.40
Charge Controller	20 A MPPT	EcoWorthy (MPPT20-1)	$102.00
Battery	AJC 100Ah 12V AGM Battery	Battery Clerk	$179.00
Inverter	Samlex America 150W	Inverter Supply (SA-150-112)	$148.47
Mains Power Cable	120VAC 16 AWG Cable	Home Depot	$7.99
Shipping			**$34.85**
Prototype Total			**2,630.45**
Remaining Budget			**$369.55**

APPENDIX 6: EXPLODED VIEWS AND DRAWINGS



PARTS LIST						
ITEM	TITLE	PART NUMBER	DESCRIPTION	ESTIMATED COST	VENDOR	QTY
1	SWIMS	7767T57	LOW-C STEEL, 2IN OD, 0.188 IN THK, 6FT	$108.86	McMaster	1
2	ENCLOSURE SUBASSY	ENCLOSURE-1	ENCLOSURE WITH COMPONENTS	$240.25	VARIOUS	1
3	PAN TILT ASSY	SWIMS-2	PAN TILT, CAMERA, MOUNTING BRACKET ASSY	$10,670.26	VARIOUS	1
4	SOLAR-MOUNT ASSY	SOLAR ASSY	SOLAR PANNEL-MOUNT ASSY	$320.68	VARIOUS	1
5	U-BOLT, 2IN OD POLE	8896T129-A	U BOLT, STAINLESS, FOR 2 IN PIPE	$4.64	McMASTER	4
6	U-BOLT NUT, 5/16-18	8896T129-B	U-BOLT NUT, 5/16-18, COMES WITH U-BOLT		McMASTER	8
7	0.375IN WASHER	90108A415	WASHER, 0.375IN ID, 0.875IN OD, 0.09IN THK, Zn PLATED STEEL, 100 PER PACK	$4.67	McMASTER	8

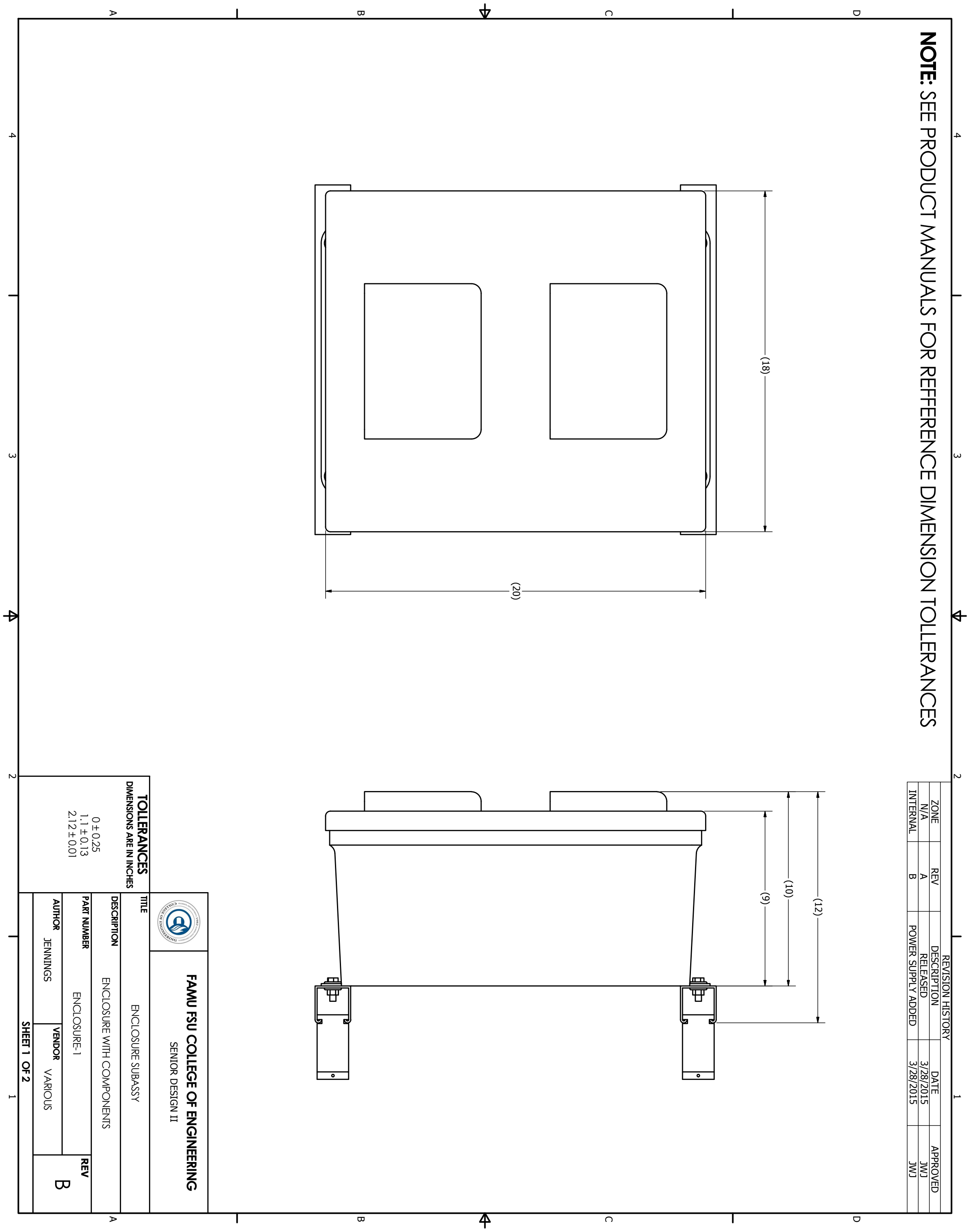


TOLLERANCES
DIMENSIONS ARE IN INCHES
0 ± 0.25
1.1 ± 0.13
2.12 ± 0.01

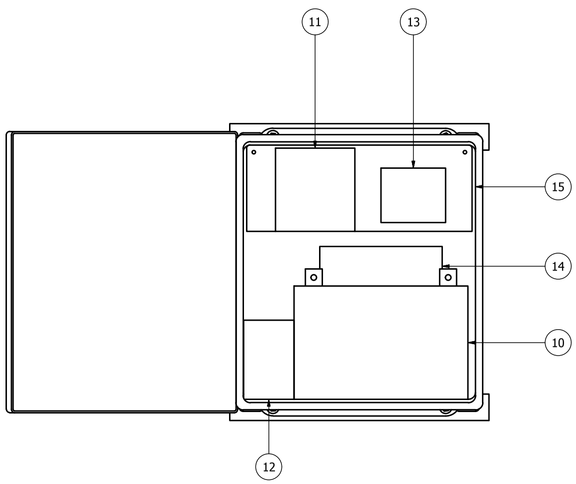
FAMU FSU COLLEGE OF ENGINEERING
SENIOR DESIGN II

TITLE	FULL ASSY
DESCRIPTION	SWIMS, FULL ASSEMBLY
PART NUMBER	SWIMS
REV	B
AUTHOR	JENNINGS
VENDOR	Various

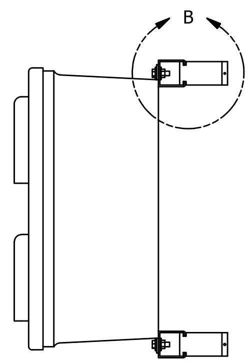
SHEET 2 OF 2

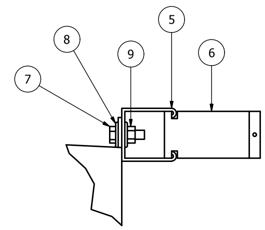

NOTE: SEE PRODUCT MANUALS FOR REFERENCE DIMENSION TOLLERANCES
(18)
(20)
(9)
(10)
(12)
REVISION HISTORY
ZONE REV DESCRIPTION DATE APPROVED
N/A A RELEASED 3/28/2015 JWJ
INTERNAL B POWER SUPPLY ADDED 3/28/2015 JWJ
TOLLERANCES
DIMENSIONS ARE IN INCHES
0 ± 0.25
1.1 ± 0.13
2.12 ± 0.01
FAMU FSU COLLEGE OF ENGINEERING
SENIOR DESIGN II
TITLE
ENCLOSURE SUBASSY
DESCRIPTION
ENCLOSURE WITH COMPONENTS
PART NUMBER
ENCLOSURE-1
REV
B
AUTHOR
JENNINGS
VENDOR
VARIOUS
SHEET 1 OF 2

PARTS LIST						
ITEM	TITLE	PART NUMBER	DESCRIPTION	ESTIMATED COST	VENDOR	QTY
5	STRUT CHANNEL, CUT TO 18IN	3310T212-18IN	STRUT CHANNEL, CUT,18IN, Zn PLATED, SEE STOCK DRAWING FOR COST		McMASTER	2
6	STRUT CHANNEL 2IN O.D. PIPE CLAMP	3115T19	STRUT CLAMP, FOR 2IN OD, Zn PLATED	$2.04	McMASTER	4
7	CAP SCREW, 5/16-18, 1IN.	93190A583	CAP SCREW, 5/16-18, 1IN, 316 S.STEEL, 10 PER PACK	$4.56	McMASTER	4
8	0.375IN WASHER	90108A415	WASHER, 0.375IN ID, 0.875IN OD, 0.09IN THK, Zn PLATED STEEL, 100 PER PACK	$4.67	McMASTER	8
9	HEX NUT, 5/16-18	93827A219	HEX NUT, 5/16-18, Zn-Al COATED STEEL, 100 PER PACK	$9.74	McMASTER	4
10	BATTERY	AJC-D100S	12V, 100AH, LEAD ACID	$179.00	BATTERY CLERK	1
11	SOLAR CHARGE CONTROLLER	MPPT20-1	SOLAR CHARGE CONTROLLER, 20A	$102.00	ECO-WORTHY	1
12	POWER SUPPLY	HPC-300-101	POWER SUPPLY, AC-DC	$32.99	ENLIGHT	1
13	MICROCOMPUTER	VL-EPM-24SU	TIGER, MICROCOMPUTER	$891.00	VERSALOGIC	1
14	INVERTER	SA-150-112	150 W, DC-AC SINE INVERTER	$148.47	SAMLEX	1
15	ELECTRONIC ENCLOSURE	NB181608-00V	SEE DRAWING FOR PARTS	$240.25	L-COM	1



OPEN ENCLOSURE





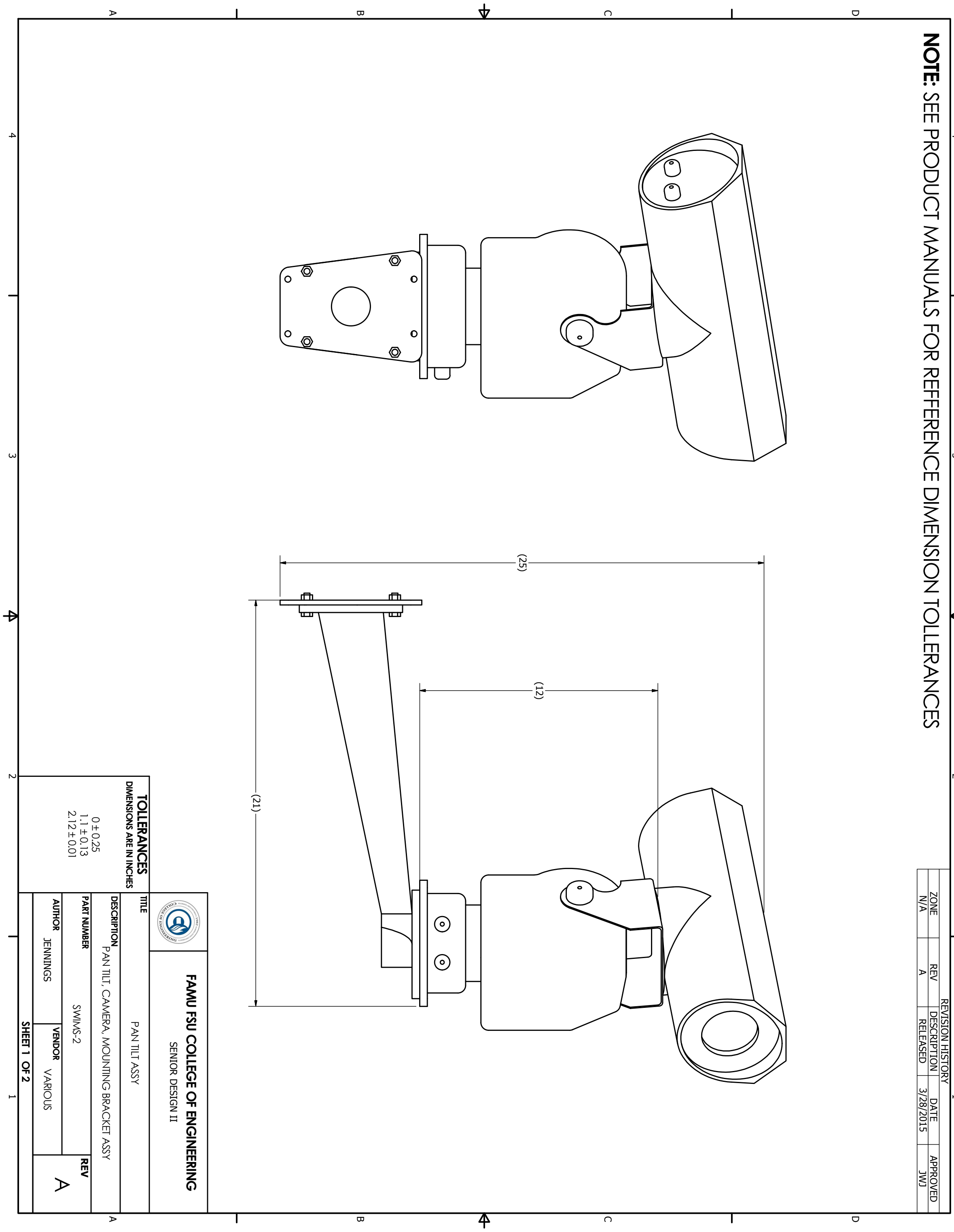
DETAIL B
SCALE 0.40 : 1

TOLLERANCES
DIMENSIONS ARE IN INCHES
0 ± 0.25
1.1 ± 0.13
2.12 ± 0.01

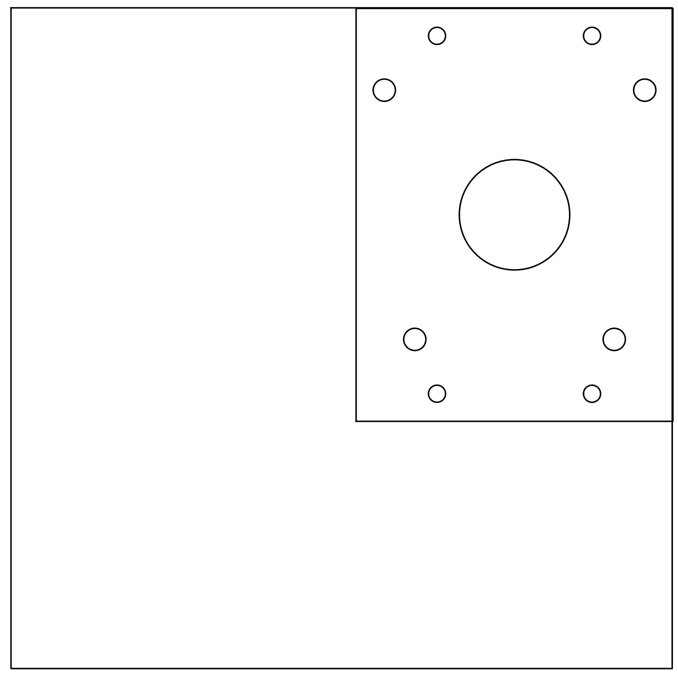
FAMU FSU COLLEGE OF ENGINEERING
SENIOR DESIGN II

TITLE	ENCLOSURE SUBASSY
DESCRIPTION	ENCLOSURE WITH COMPONENTS
PART NUMBER	ENCLOSURE-1
REV	B
AUTHOR	JENNINGS
VENDOR	VARIOUS

SHEET 2 OF 2


NOTE: SEE PRODUCT MANUALS FOR REFFERENCE DIMENSION TOLLERANCES
(25)
(12)
(21)
TOLLERANCES
DIMENSIONS ARE IN INCHES
0 ± 0.25
1.1 ± 0.13
2.12 ± 0.01
FAMU FSU COLLEGE OF ENGINEERING
SENIOR DESIGN II
TITLE
PAN TILT ASSY
DESCRIPTION
PAN TILT, CAMERA, MOUNTING BRACKET ASSY
PART NUMBER
SWIMS-2
AUTHOR
JENNINGS
VENDOR
VARIOUS
REV
A
SHEET 1 OF 2
REVISION HISTORY
ZONE
N/A
REV
A
DESCRIPTION
RELEASED
DATE
3/28/2015
APPROVED
JWJ

NOTE: FOR MANUFACTURING QUOTATION PURPOSES ONLY



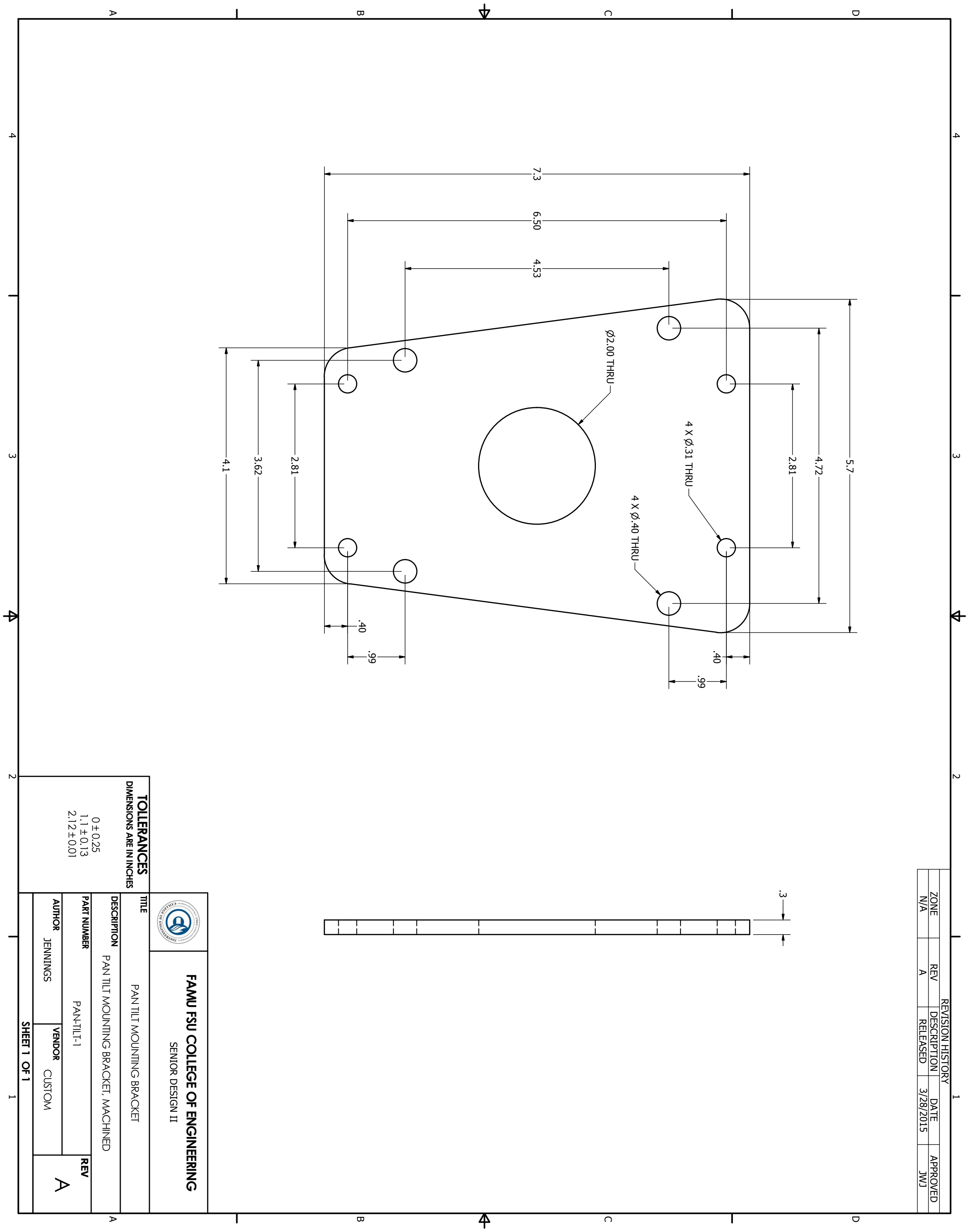
PARTS LIST						
ITEM	TITLE	PART NUMBER	DESCRIPTION	VENDOR	ESTIMATED COST	QTY
1	STEEL PLATE	HR-STEEL-12	PLATE, HOT ROLLED STEEL, A36, 12X12	ONLINEMETALS.COM	$24.91	1

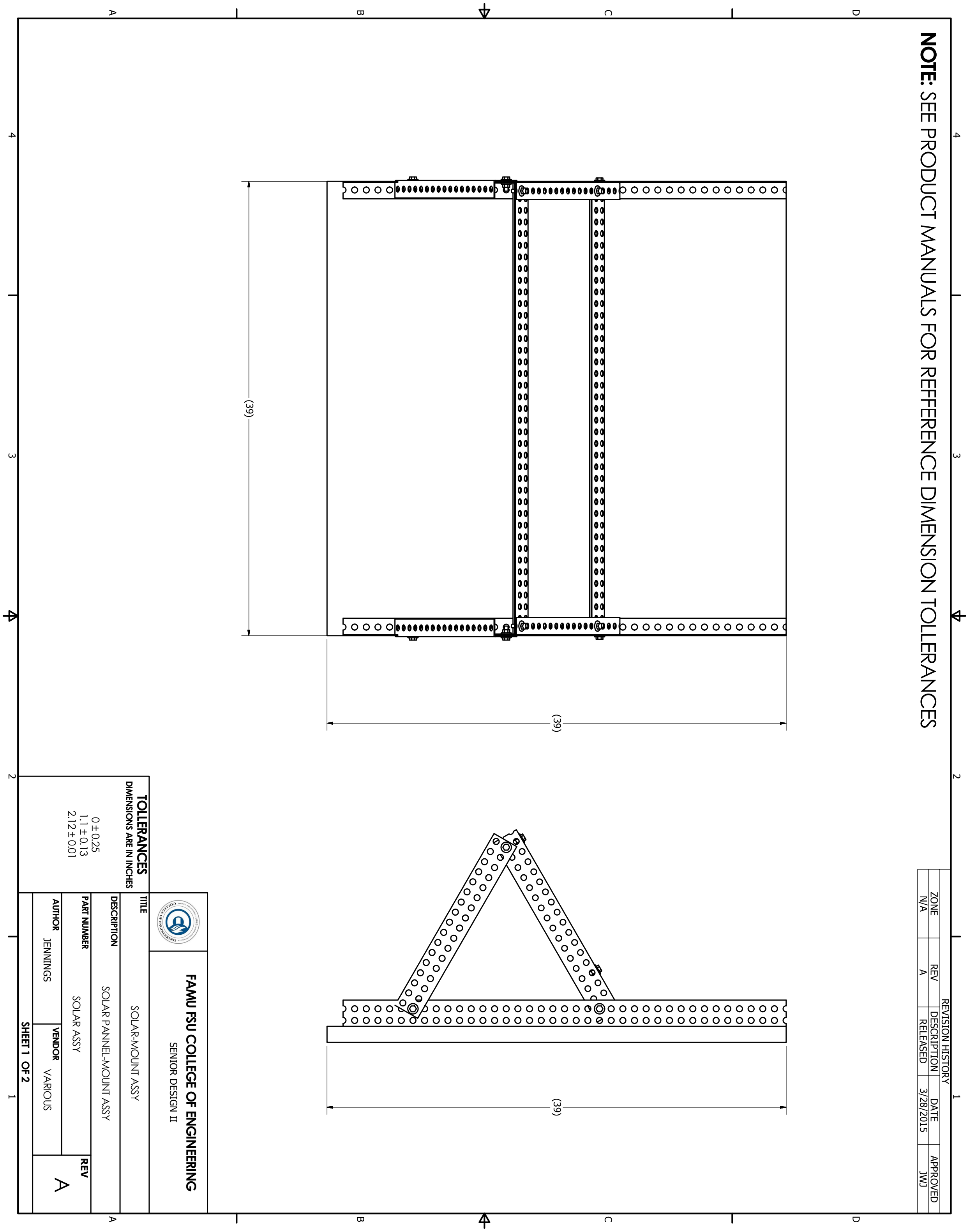
TOLLERANCES
DIMENSIONS ARE IN INCHES

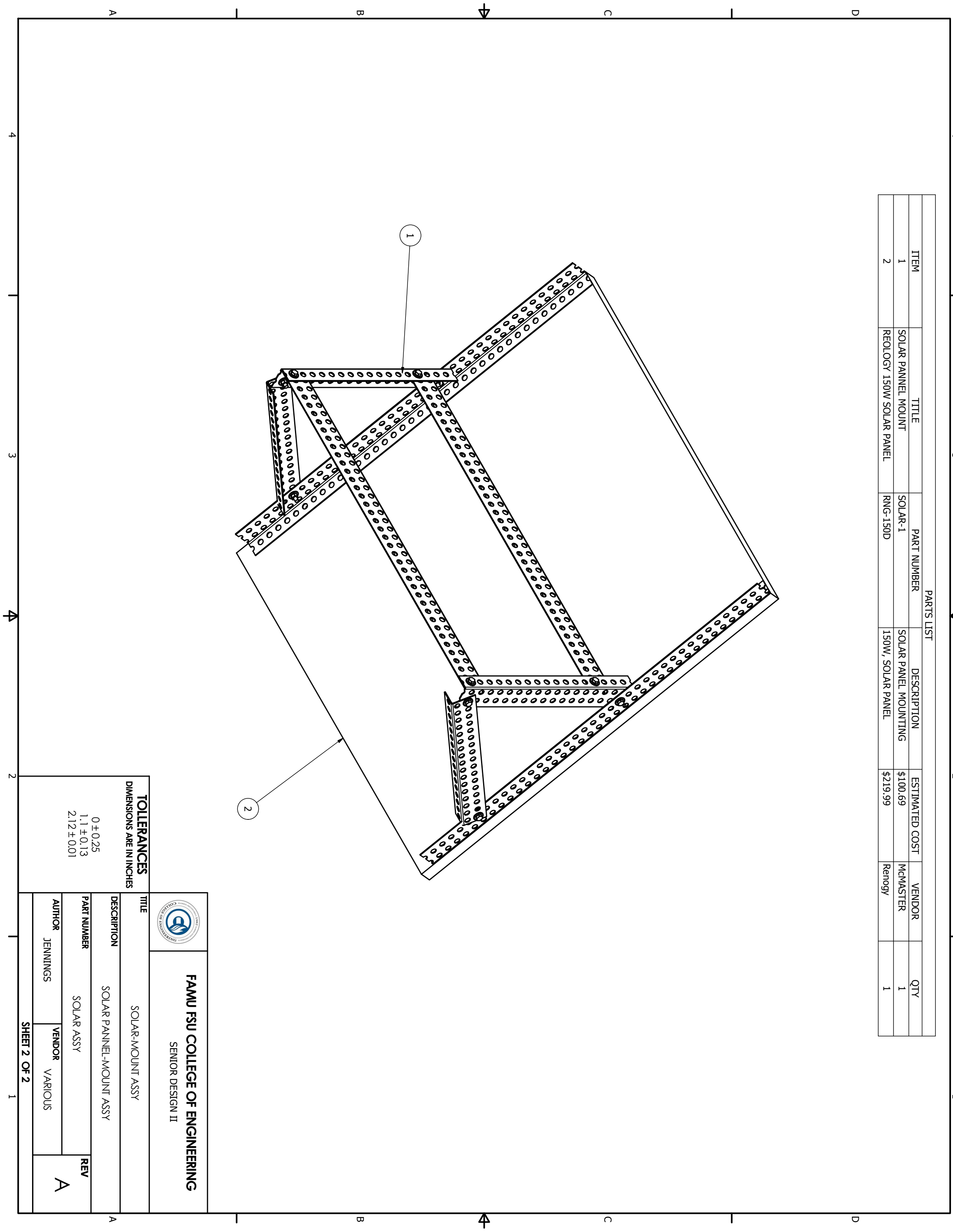
0 ± 0.25
1.1 ± 0.13
2.12 ± 0.01

FAMU FSU COLLEGE OF ENGINEERING
SENIOR DESIGN II

TITLE: PAN TILT MOUNTING BRACKET
DESCRIPTION: PAN TILT MOUNTING BRACKET, MACHINED
PART NUMBER: PAN-TILT-1
REV: A
AUTHOR: JENNINGS
VENDOR: CUSTOM
SHEET 2 OF 2

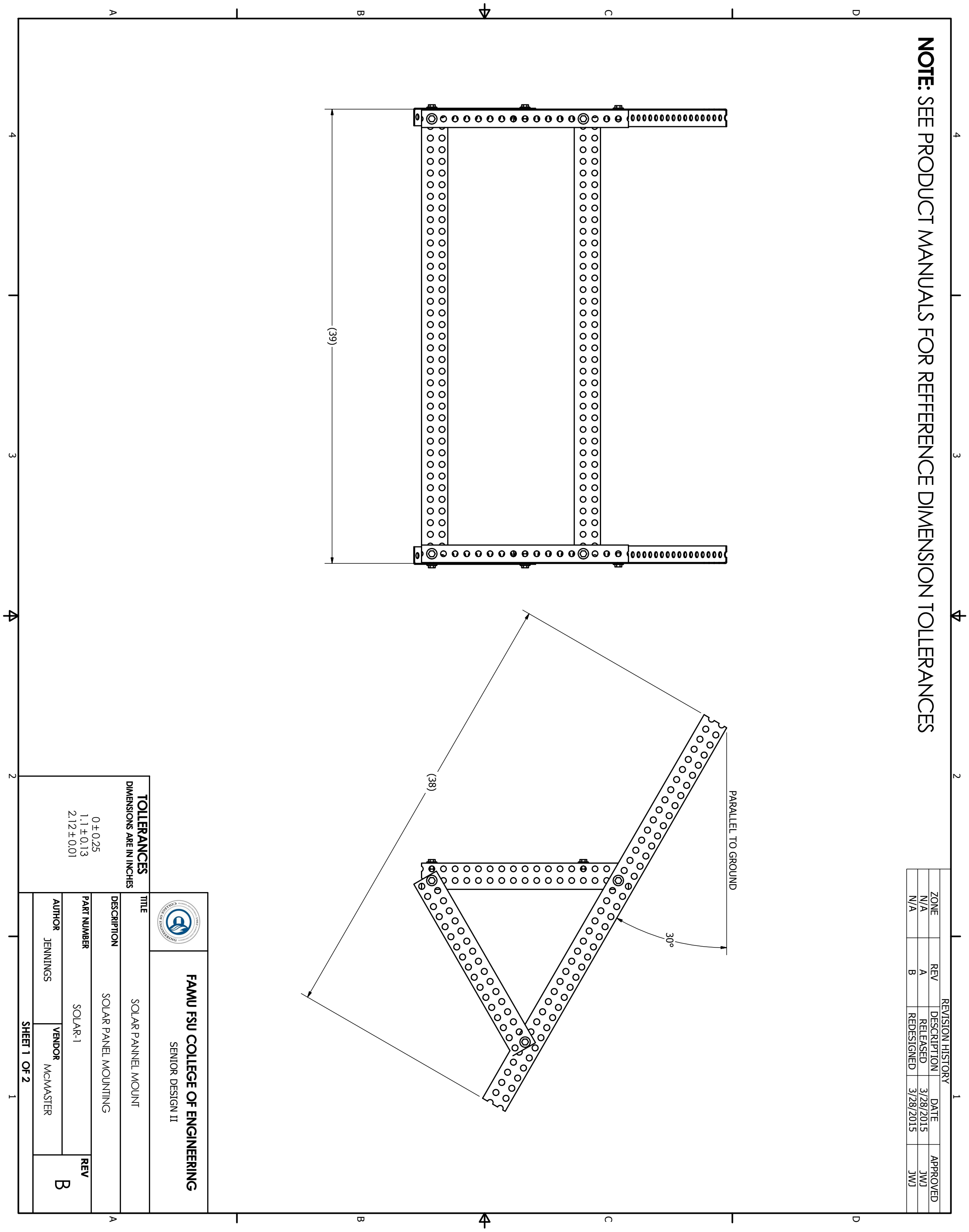

FAMU FSU COLLEGE OF ENGINEERING
SENIOR DESIGN II
TITLE
PAN TILT MOUNTING BRACKET
DESCRIPTION
PAN TILT MOUNTING BRACKET, MACHINED
PART NUMBER
PAN-TILT-1
REV
A
AUTHOR
JENNINGS
VENDOR
CUSTOM
SHEET 1 OF 1
TOLLERANCES
DIMENSIONS ARE IN INCHES
0 ± 0.25
1.1 ± 0.13
2.12 ± 0.01
REVISION HISTORY
ZONE
N/A
REV
A
DESCRIPTION
RELEASED
DATE
3/28/2015
APPROVED
JWJ
Ø2.00 THRU
4 X Ø.31 THRU
4 X Ø.40 THRU
7.3
6.50
4.53
4.1
3.62
2.81
2.81
4.72
5.7
.40
.99
.40
.99
.3


NOTE: SEE PRODUCT MANUALS FOR REFFERENCE DIMENSION TOLLERANCES
(39)
(39)
(39)
REVISION HISTORY
ZONE | REV | DESCRIPTION | DATE | APPROVED
N/A | A | RELEASED | 3/28/2015 | JWJ
TOLLERANCES
DIMENSIONS ARE IN INCHES
0 ± 0.25
1.1 ± 0.13
2.12 ± 0.01
FAMU FSU COLLEGE OF ENGINEERING
SENIOR DESIGN II
TITLE
SOLAR-MOUNT ASSY
DESCRIPTION
SOLAR PANNEL-MOUNT ASSY
PART NUMBER
SOLAR ASSY
REV
A
AUTHOR
JENNINGS
VENDOR
VARIOUS
SHEET 1 OF 2



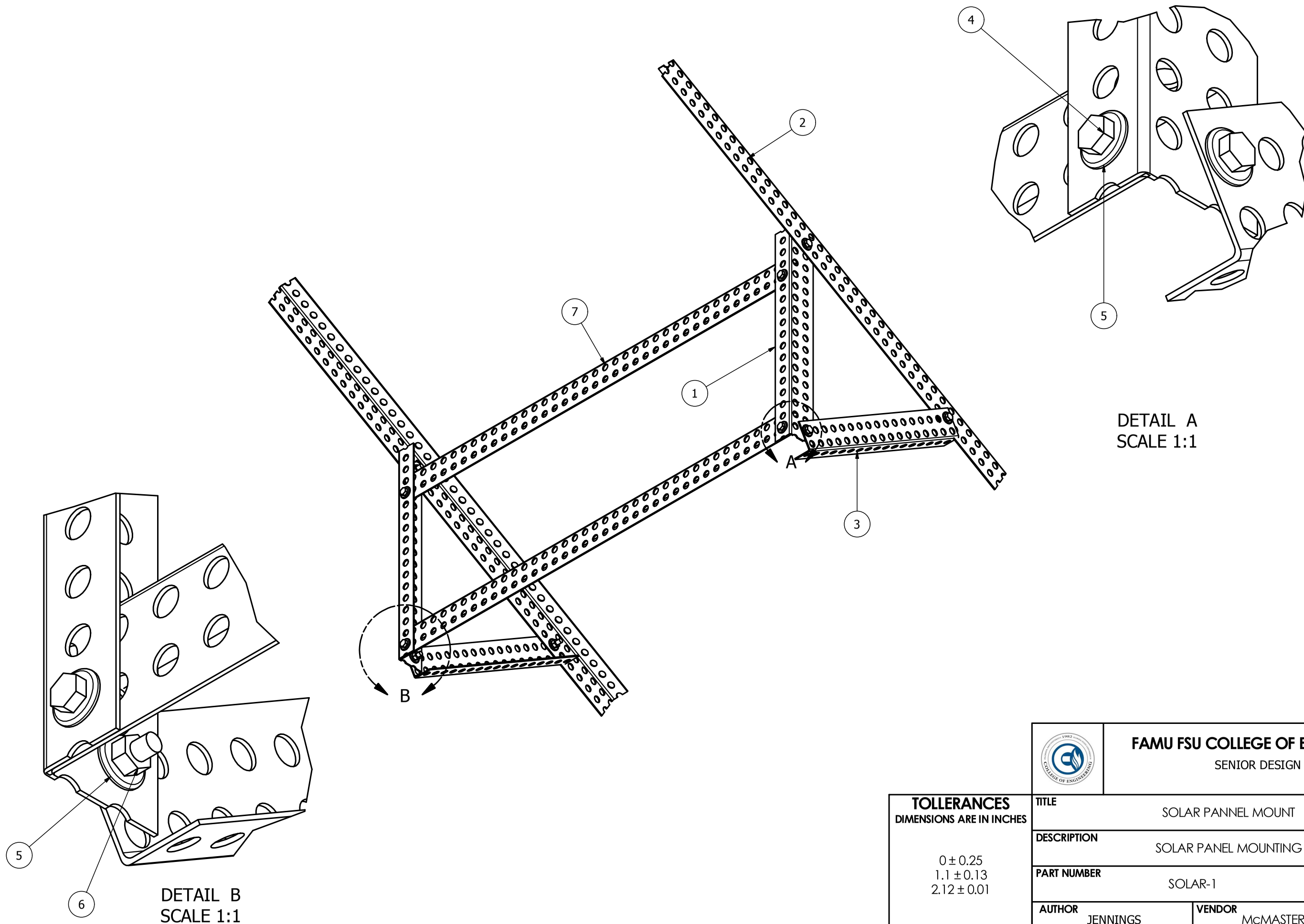
PARTS LIST

ITEM	TITLE	PART NUMBER	DESCRIPTION	ESTIMATED COST	VENDOR	QTY
1	SOLAR PANNEL MOUNT	SOLAR-1	SOLAR PANEL MOUNTING	$100.69	McMASTER	1
2	REOLOGY 150W SOLAR PANEL	RNG-150D	150W, SOLAR PANEL	$219.99	Renogy	1


NOTE: SEE PRODUCT MANUALS FOR REFERENCE DIMENSION TOLLERANCES
(39)
(38)
PARALLEL TO GROUND
30°
REVISION HISTORY
ZONE REV DESCRIPTION DATE APPROVED
N/A A RELEASED 3/28/2015 JWJ
N/A B REDESIGNED 3/28/2015 JWJ
TOLLERANCES
DIMENSIONS ARE IN INCHES
0 ± 0.25
1.1 ± 0.13
2.12 ± 0.01
FAMU FSU COLLEGE OF ENGINEERING
SENIOR DESIGN II
TITLE
SOLAR PANNEL MOUNT
DESCRIPTION
SOLAR PANEL MOUNTING
PART NUMBER
SOLAR-1
REV
B
AUTHOR
JENNINGS
VENDOR
McMASTER
SHEET 1 OF 2

PARTS LIST

ITEM	FILE NAME	PART NUMBER	DESCRIPTION	ESTIMATED COST	VENDOR	QTY
1	90 TRACK-17.75IN.ipt	8968K27-17.5IN	90 DEG TRACK, CUT TO 17.5IN, Zn PLATED, SEE STOCK DRAWING FOR COST		McMASTER	2
2	90 TRACK-38IN.ipt	8968K27-38IN	90 DEG TRACK, CUT TO 38IN, Zn PLATED, SEE STOCK DRAWING FOR COST		McMASTER	2
3	90 TRACK-17IN.ipt	8968K27-17IN	90 DEG TRACK, CUT TO 17IN, Zn PLATED, SEE STOCK DRAWING FOR COST		McMASTER	2
4	93190A583.ipt	93190A583	CAP SCREW, 5/16-18, 1IN, 316 S.STEEL, 10 PER PACK	$4.56	McMASTER	10
5	90108A415.ipt	90108A415	WASHER, 0.375IN ID, 0.875IN OD, 0.09IN THK, Zn PLATED STEEL, 100 PER PACK	$4.67	McMASTER	20
6	93827A219.ipt	93827A219	HEX NUT, 5/16-18, Zn-Al COATED STEEL, 100 PER PACK	$9.74	McMASTER	10
7	90 TRACK-38.75IN.ipt	8968K27-38.75IN	90 DEG TRACK, CUT TO 38.75IN, Zn PLATED, SEE STOCK DRAWING FOR COST		McMaster	2



TOLLERANCES
DIMENSIONS ARE IN INCHES

0 ± 0.25
1.1 ± 0.13
2.12 ± 0.01

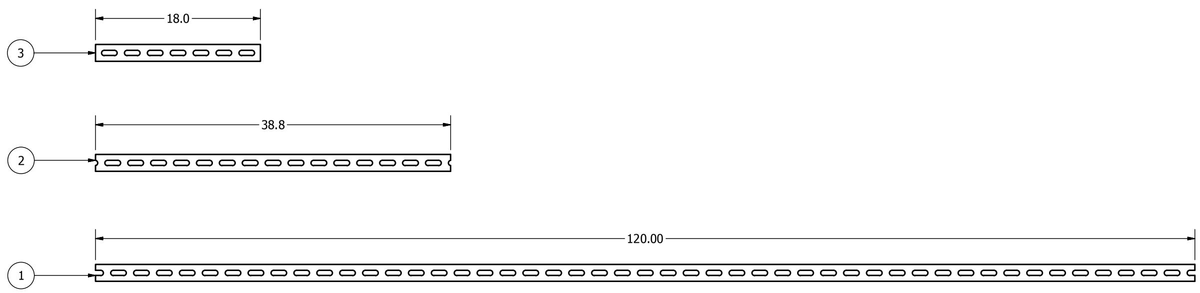
FAMU FSU COLLEGE OF ENGINEERING
SENIOR DESIGN II

TITLE	SOLAR PANNEL MOUNT
DESCRIPTION	SOLAR PANEL MOUNTING
PART NUMBER	SOLAR-1
REV	B
AUTHOR	JENNINGS
VENDOR	McMASTER

SHEET 2 OF 2

REVISION HISTORY				
ZONE	REV	DESCRIPTION	DATE	APPROVED
N/A	A	RELEASED	3/29/2015	JWJ

NOTE: HOLE PATTERNS DIFFER FROM ACTUAL STOCK



PARTS LIST				
ITEM	TITLE	PART NUMBER	DESCRIPTION	ESTIMATED COST
1	STRUT CHANNEL STOCK	3310T212	STRUT CHANNEL, 1.625x1.625x120IN, Zn PLATED	$34.68
2	STRUT CHANNEL, CUT TO 38.75IN	3310T212-38.75in	STRUT CHANNEL, CUT, 38.75IN, Zn PLATED, SEE STOCK DRAWING FOR COST	
3	STRUT CHANNEL, CUT TO 18IN	3310T212-18IN	STRUT CHANNEL, CUT,18IN, Zn PLATED, SEE STOCK DRAWING FOR COST	

TOLLERANCES
DIMENSIONS ARE IN INCHES

0 ± 0.25
1.1 ± 0.13
2.12 ± 0.01

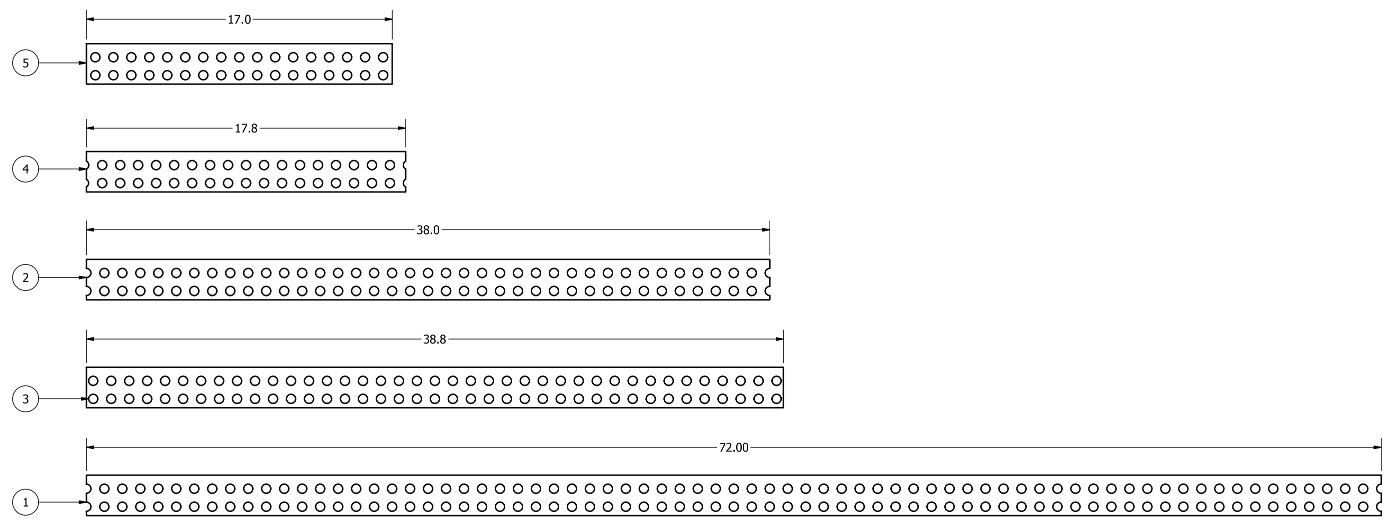
FAMU FSU COLLEGE OF ENGINEERING
SENIOR DESIGN II

TITLE	STRUT CHANNEL CUT LENGTHS
DESCRIPTION	LENGTHS OF CUT STOCK
PART NUMBER	STRUT CHANNEL LENGTHS
REV	A
AUTHOR	JENNINGS
VENDOR	McMASTER

SHEET 1 OF 1

REVISION HISTORY				
ZONE	REV	DESCRIPTION	DATE	APPROVED
N/A	A	RELEASED	3/29/2015	JWJ

NOTE: HOLE PATTERNS DO NOT MATCH ACTUAL STOCK



PARTS LIST				
ITEM	TITLE	PART NUMBER	DESCRIPTION	ESTIMATED
1	90 DEG TRACK	90 TRACK	90 DEG TRACK, Zn PLATED	$20.43
2	90 DEG TRACK, CUT TO 38IN	8968K27-38IN	90 DEG TRACK, CUT TO 38IN, Zn PLATED, SEE STOCK DRAWING FOR COST	
3	90 DEG TRACK, CUT TO 38.75 IN	8968K27-38.75IN	90 DEG TRACK, CUT TO 38.75IN, Zn PLATED, SEE STOCK DRAWING FOR COST	
4	90 DEG TRACK, CUT TO 17.5IN	8968K27-17.5IN	90 DEG TRACK, CUT TO 17.5IN, Zn PLATED, SEE STOCK DRAWING FOR COST	
5	90 DEG TRACK, CUT TO 17IN	8968K27-17IN	90 DEG TRACK, CUT TO 17IN, Zn PLATED, SEE STOCK DRAWING FOR COST	

TOLLERANCES
DIMENSIONS ARE IN INCHES
0 ± 0.25
1.1 ± 0.13
2.12 ± 0.01

FAMU FSU COLLEGE OF ENGINEERING
SENIOR DESIGN II

TITLE 90 DEG TRACK CUT STOCK
DESCRIPTION DIFFERENT LENGTHS OF REQUIRED 90 TRACK
PART NUMBER 90 TRACK LENGTHS
REV A
AUTHOR JENNINGS
VENDOR McMASTER
SHEET 1 OF 1

APPENDIX 7: SOFTWARE PROGRAMMING

SWIMS.bat: *This program below is a batch program used to display infrared images of four targets on FLIR's Researcher Professional 2.10 program. This program should be downloaded on the control room computer to monitor the critical temperatures of each target.*

```
@echo off
	:loop
rem Time stamp
	set timestamp=%DATE:/=-%_%TIME::=-%
	set timestamp=%timestamp: =%
rem Target files
set file_1=C:\Users\%USERNAME%\Desktop\FTP_connection_folder\Target_1\Target1
set location_1=C:\Users\%USERNAME%\Desktop\FTP_connection_folder\Target_1
set ftp1=C:\Users\%USERNAME%\Desktop\FTP_connection_folder\Target1
set file_2=C:\Users\%USERNAME%\Desktop\FTP_connection_folder\Target_2\Target2
set location_2=C:\Users\%USERNAME%\Desktop\FTP_connection_folder\Target_2
set ftp2=C:\Users\%USERNAME%\Desktop\FTP_connection_folder\Target2
set file_3=C:\Users\%USERNAME%\Desktop\FTP_connection_folder\Target_3\Target3
set location_3=C:\Users\%USERNAME%\Desktop\FTP_connection_folder\Target_3
set ftp3=C:\Users\%USERNAME%\Desktop\FTP_connection_folder\Target3
set file_4=C:\Users\%USERNAME%\Desktop\FTP_connection_folder\Target_4\Target4
set location_4=C:\Users\%USERNAME%\Desktop\FTP_connection_folder\Target_4
set ftp4=C:\Users\%USERNAME%\Desktop\FTP_connection_folder\Target4

rem ----------------------------------------------------------------------------------------------------------------------
rem Target 1
rem Does file exist?
	if exist %ftp1%.FFF (
	TIMEOUT /T 5 /NOBREAK
rem Copy time stamp and delete
	copy %ftp1%.FFF %file_1%_%timestamp%.FFF
	del %ftp1%.FFF

rem Does ID_1 exist?
if not [%ID_1%]==[] ( Taskkill /PID %ID_1% /F )

	start Research.exe %file_1%_%timestamp%.FFF
	for /f "tokens=2" %%x in ('tasklist ^| findstr Research.exe') do set ID_1=%%x
	cmdow "New session [%location_1%] - ThermaCAM Researcher Professional 2.10" /mov 0 0 /ren "S.W.I.M.S. Target: 1" /siz 768 413
)
rem end of if file
rem ----------------------------------------------------------------------------------------------------------------------
```

```
rem Target 2
rem Does file exist?
	if exist %ftp2%.FFF (
	TIMEOUT /T 5 /NOBREAK
rem Copy time stamp and delete
	copy %ftp2%.FFF %file_2%_%timestamp%.FFF
	del %ftp2%.FFF

rem Does ID_2 exist?
if not [%ID_2%]==[] ( Taskkill /PID %ID_2% /F )

	start Research.exe %file_2%_%timestamp%.FFF
	for /f "tokens=2" %%x in ('tasklist ^| findstr Research.exe') do set ID_2=%%x
	cmdow "New session [%location_2%] - ThermaCAM Researcher Professional 2.10"
/mov 768 0 /ren "S.W.I.M.S. Target: 2" /siz 768 413
)
rem end of if file exists
rem --------------------------------------------------------------------------------------------------------
-----------------
rem Target 3
rem Does file exist?
	if exist %ftp3%.FFF (
	TIMEOUT /T 5 /NOBREAK
rem Copy time stamp and delete
	copy %ftp3%.FFF %file_3%_%timestamp%.FFF
	del %ftp3%.FFF

rem Does ID_3 exist?
if not [%ID_3%]==[] ( Taskkill /PID %ID_3% /F )

	start Research.exe %file_3%_%timestamp%.FFF
	for /f "tokens=2" %%x in ('tasklist ^| findstr Research.exe') do set ID_3=%%x
	cmdow "New session [%location_3%] - ThermaCAM Researcher Professional 2.10"
/mov 0 413 /ren "S.W.I.M.S. Target: 3" /siz 768 413
)
rem end of if file exists
rem --------------------------------------------------------------------------------------------------------
-----------------
rem Target 4
rem Does file exist?
	if exist %ftp4%.FFF (
	TIMEOUT /T 5 /NOBREAK
rem Copy time stamp and delete
	copy %ftp4%.FFF %file_4%_%timestamp%.FFF
	del %ftp4%.FFF
```

```
rem Does ID_4 exist?
if not [%ID_4%]==[] ( Taskkill /PID %ID_4% /F )

        start Research.exe %file_4%_%timestamp%.FFF
        for /f "tokens=2" %%x in ('tasklist ^| findstr Research.exe') do set ID_4=%%x
        cmdow "New session [%location_4%] - ThermaCAM Researcher Professional 2.10"
/mov 768 413 /ren "S.W.I.M.S. Target: 4" /siz 768 413
)
rem end of if file exists
rem ------------------------------------------------------------------------------------------------------------
-----------------
goto loop
        rem TIMEOUT /T 5 /NOBREAK
```

FTP_script.bat: *The FTP_script.bat code below is used to call the conjunction FTP_script.txt file. The batch and text files should be downloaded on to the microcomputer. This code is used to connect the microcomputer to both the camera and control room computer. Once connected this code grabs an image of a target from the camera then it sends that target image to the control room computer to be analyzed.*

```
@echo off
:Start
winscp.com /script=FTP_script.txt
goto Start
pause
```

FTP_script.txt: *See FTP_script.bat*

```
# Automatically abort script on errors
option batch abort

# Disable overwrite confirmations that conflict with the previous
option confirm off

# Connect
open ftp://SWIMS:SWIMS@192.168.1.100/

# Download all 4 files to the local directory
get Target1.FFF C:\Users\Kenny\Desktop\FTP_connection_folder\
get Target2.FFF C:\Users\Kenny\Desktop\FTP_connection_folder\
get Target3.FFF C:\Users\Kenny\Desktop\FTP_connection_folder\
get Target4.FFF C:\Users\Kenny\Desktop\FTP_connection_folder\

#get JPEGPicture.jpeg C:\Users\Kenny\Desktop\FTP_connection_folder\

# Disconnect
```

```
close

# Exit WinSCP
	exit
```

PANTILT_CONTROLLER.CPP: *This C++ code is to be downloaded onto the microcomputer to control the pan tilt to move to desired targets. Once the program is started it will prompt the user to move the pan tilt to the desired four targets to set positions. Once positions are set the pan tilt will autonomously move to each target and wait so the camera can take an infrared picture of each target.*

```
#include<iostream>
#include"PELCO_D.h"
#include"SerialComm.h"
#include"stdlib.h"
#include"stdio.h"
using namespace std;

int main(){
	// Variables used for Pan-tilt
	int wait = 0;
	int k = 1;
	char command = 'N';
	// Vars used for scripting

	int counter  = 1;
	char s_command[50];

	PELCO_D PanTilt;
   cout << "WELCOME; Please commence with initializing presets\n";
	PanTilt.Init(2);

   while(command != 'X')
   {
      cin >> command;
      command = toupper(command);
      switch(command){

	case 'L': PanTilt.Left();
		break;
	case 'R': PanTilt.Right();
		break;
	case 'U': PanTilt.Up();
		break;
	case 'D': PanTilt.Down();
		break;
```

```
        case 'S': PanTilt.Stop();
                break;
        case 'P':   cout<< "Enter position number: "; cin >> k;
                PanTilt.SetP(k);
                break;
        case 'G':   cout <<"Enter position number: "; cin >> k;
                PanTilt.GotoP(k);
                break;
        case 'X': cout <<"Commands done\n";
                break;
        default: cout <<"Invalid command";
                break;
    }
}
while(counter < 6)
{
cout << "!!UPDATE!!:Heading to position 1....\n";
PanTilt.GotoP(1);
Sleep(20000);
cout << "!!UPDATE!!: Target 1, taking infrared image now\n";
Sleep(1000);
cout << "!!UPDATE!!: Target 1, transferring image now\n";
snprintf(s_command, sizeof(s_command), "DEMO_TARGET1_START%d", counter);
system(s_command);
cout << "!!UPDATE!!: Target 1, Image File transfer complete\n";
Sleep(1000);

cout << "!!UPDATE!!:Heading to position 2....\n";
PanTilt.GotoP(2);
Sleep(6000);
cout << "!!UPDATE!!: Target 2, taking infrared image now\n";
Sleep(1000);
cout << "!!UPDATE!!: Target 2, transferring image now\n";
snprintf(s_command, sizeof(s_command), "DEMO_TARGET2_START%d", counter);
system(s_command);
cout << "!!UPDATE!!: Target 2, Image File transfer complete\n";
Sleep(1000);

cout << "!!UPDATE!!:Heading to position 3....\n";
PanTilt.GotoP(3);
Sleep(6000);
cout << "!!UPDATE!!: Target 3, taking infrared image now\n";
Sleep(1000);
cout << "!!UPDATE!!: Target 3, transferring image now\n";
snprintf(s_command, sizeof(s_command), "DEMO_TARGET3_START%d", counter);
system(s_command);
```

```
    cout << "!!UPDATE!!: Target 3, Image File transfer complete\n";
    Sleep(1000);

    cout << "!!UPDATE!!:Heading to position 4....\n";
    PanTilt.GotoP(4);
    Sleep(6000);
    cout << "!!UPDATE!!: Target 4, taking infrared image now\n";
    Sleep(1000);
    cout << "!!UPDATE!!: Target 4, transferring image now\n";
    snprintf(s_command, sizeof(s_command), "DEMO_TARGET4_START%d", counter);
    system(s_command);
    cout << "!!UPDATE!!: Target 4, Image File transfer complete\n";
    Sleep(1000);

    counter++;

        if (counter == 6)
        {
            counter = 1;
        }

    }
cout << "!!UPDATE!!: ALL DONE\n";
return 0;
}
```

PELCO_D1.cpp: *This C++ source code contains functions that are used in the PANTILT_CONTROLLER.cpp code.*

```
#include<iostream>
#include "PELCO_D.h"
#include<cstdio>
using namespace std;

void WriteToMon(BYTE code[]){
        for(int i = 0; i<7; i++)
                ;//cout << code[i] <<"||";
}

bool PELCO_D::Init(int com)
{
        char name[20];
        sprintf(name,"COM%d",com);
        bool result = comm.open(name,CBR_2400,NOPARITY,ONESTOPBIT,8);
        return result;
}
```

```
void PELCO_D::SetP(int k)
{
	if (comm.isAvailable())
	{
		//{0xff,0x01,0x00,0x02,0xff,0x00,0x02,}//                                    右
0xff,0x01,0x00,0x02,0xff,0x00,0x02
		BYTE           code[7]           =           {0xff,0x01,0x00,0x03,0x00,k,(k+4)};
//{0xff,0x01,0x00,0x02,0xff,0x00,0x02};
		WriteToMon(code);
		comm.output(code,7);
	}
}

void PELCO_D::GotoP(int k)
{
	if (comm.isAvailable())
	{
		//{0xff,0x01,0x00,0x02,0xff,0x00,0x02,}//                                    右
0xff,0x01,0x00,0x02,0xff,0x00,0x02
		BYTE           code[7]           =           {0xff,0x01,0x00,0x07,0x00,k,(k+8)};
//{0xff,0x01,0x00,0x02,0xff,0x00,0x02};
		WriteToMon(code);
		comm.output(code,7);
	}
}


void PELCO_D::Up()
{
	if (comm.isAvailable())
	{
		//{0xff,0x01,0x00,0x08,0x00,0xff,0x08,}//上
		BYTE code[7] = {0xff,0x01,0x00,0x08,0x00,0xff,0x08};
		WriteToMon(code);
		comm.output(code,7);
	}
}

void PELCO_D::Down()
{
	if (comm.isAvailable())
	{
		//{0xff,0x01,0x00,0x10,0x00,0xff,0x10,}//下
		BYTE code[7] = {0xff,0x01,0x00,0x10,0x00,0xff,0x10};
		WriteToMon(code);
```

```
                comm.output(code,7);
        }
}

void PELCO_D::Stop()
{
        if (comm.isAvailable())
        {
                //{0xff,0x01,0x00,0x00,0x00,0x00,0x01,}//停命令
                BYTE code[7] = {0xff,0x01,0x00,0x00,0x00,0x00,0x01};
                WriteToMon(code);
                comm.output(code,7);
        }
}

void PELCO_D::Right()
{
        if (comm.isAvailable())
        {
                //{0xff,0x01,0x00,0x02,0xff,0x00,0x02,}//                    右
0xff,0x01,0x00,0x02,0xff,0x00,0x02
                BYTE        code[7]        =        {0xff,0x01,0x00,0x02,0x01,0x00,0x04};
//{0xff,0x01,0x00,0x02,0xff,0x00,0x02};
                WriteToMon(code);
                comm.output(code,7);
        }
}

void PELCO_D::Left()
{
        if (comm.isAvailable())
        {
                //{0xff,0x01,0x00,0x04,0xff,0x00,0x04,}//左
                BYTE        code[7]        =        {0xff,0x01,0x00,0x04,0x01,0x00,0x06};
//{0xff,0x01,0x00,0x04,0xff,0x00,0x04};
                WriteToMon(code);
                comm.output(code,7);
        }
        else
    cout << "NO CONNECTION";
}

void PELCO_D::FocusNear()
{
        if (comm.isAvailable())
        {
```

```
                //{0xff,0x01,0x00,0x80,0x00,0x00,0x81,}//聚焦近
                BYTE code[7] ={0xff,0x01,0x00,0x80,0x00,0x00,0x81};
                WriteToMon(code);
                comm.output(code,7);
        }
}

void PELCO_D::FocusFar()
{
        if (comm.isAvailable())
        {
                //{0xff,0x01,0x01,0x00,0x00,0x00,0x02,}//聚焦远
                BYTE code[7] = {0xff,0x01,0x01,0x00,0x00,0x00,0x02};
                comm.output(code,7);
        }
}

void PELCO_D::ZoomOut()
{
        if (comm.isAvailable())
        {
                //{0xff,0x01,0x00,0x40,0x00,0x00,0x41,}//变倍长
                BYTE code[7] ={0xff,0x01,0x00,0x40,0x00,0x00,0x41};
                comm.output(code,7);
        }
}

void PELCO_D::ZoomIn()
{
        if (comm.isAvailable())
        {
                //{0xff,0x01,0x00,0x20,0x00,0x00,0x21,}//变倍短
                BYTE code[7] = {0xff,0x01,0x00,0x20,0x00,0x00,0x21};
                comm.output(code,7);
        }
}

void PELCO_D::ApertureLarge()
{
        if (comm.isAvailable())
        {
                //{0xff,0x01,0x04,0x00,0x00,0x00,0x05,}//光圈大
                BYTE code[7] = {0xff,0x01,0x04,0x00,0x00,0x00,0x05};
                comm.output(code,7);
        }
```

```
}

void PELCO_D::ApertureSmall()
{
	if (comm.isAvailable())
	{
		//{0xff,0x01,0x02,0x00,0x00,0x00,0x03,}//光圈小
		BYTE code[7] = {0xff,0x01,0x02,0x00,0x00,0x00,0x03};
		comm.output(code,7);
	}
}

bool PELCO_D::Available()
{
	return comm.isAvailable();
}

void PELCO_D::SetSpeed( int speed )
{
	//speed range from 00H to 3FH(63)
	this->speed = speed>63?63:(speed<0?0:speed);
}

int PELCO_D::GetSpeed()
{
	return this->speed;
}
```

SerialComm.cpp: *This C++ source code contains functions that are used in the PANTILT_CONTROLLER.cpp code.*

```
#include "SerialComm.h"

SerialComm::SerialComm()
{
	m_hCom = 0; //0
	m_lpszErrorMessage[0] = '\0';
	ZeroMemory(&m_ov, sizeof(m_ov));
}


SerialComm::~SerialComm() {
	close();
}

char*	SerialComm::GetErrorMessage( void ) {
```

```
	return m_lpszErrorMessage;
}


int SerialComm::open( char* lpszPortNum,
						DWORD  dwBaudRate,
						BYTE   byParity,
						BYTE   byStopBits,
						BYTE   byByteSize ) {
							DCB    dcb;     //串口设备控制块 Device Control Block
							BOOL bSuccess;

							// m_hCom 即为函数返回的串口的句柄
							m_hCom = CreateFileA( lpszPortNum, // pointer to name of the file

	GENERIC_READ|GENERIC_WRITE, // 允许读写。
								0,            // 通讯设备必须以独占方式打开。
								NULL,         // 无安全属性，表示该串口不可
								// 被子程序继承。
								OPEN_EXISTING,      // 通讯设备已存在。
								FILE_FLAG_OVERLAPPED, // 使用异步方式 overlapped I/O。
								NULL);        // 通讯设备不能用模板打开。
							if ( m_hCom == INVALID_HANDLE_VALUE ) {

	SerialComm::ErrorToString("RS232::open()  CreateFile() failed, invalid handle value");
								return FALSE;
							}

							// 与串口相关的参数非常多，当需要设置串口参数时，通常是先取得串口
							// 的参数结构，修改部分参数后再将参数结构写入
							bSuccess = GetCommState(m_hCom, &dcb);
							if ( !bSuccess ) {
```

```
                                        SerialComm::close();

    SerialComm::ErrorToString("RS232::open()  GetCommState() failed");
                                        return FALSE;
                                }
                                dcb.BaudRate = dwBaudRate;   // 串口波特
率。
                                dcb.Parity   = byParity;     // 校验方式，值
0~4 分别对应无校验、奇
                                // 校验、偶校验、校验、置位、校验清零
。
                                dcb.fParity = 0;             // 为 1 的话激活奇
偶校验检查。
                                dcb.ByteSize = byByteSize;   // 一个字节的
数据位个数，范围是 5~8。
                                dcb.StopBits = byStopBits;   // 停止位个数
，0~2 分别对应 1 位、1.5 位、
                                // 2 位停止位。
                                if ( !bSuccess ) {
                                        SerialComm::close();

    SerialComm::ErrorToString("RS232::open()  SetCommState() failed");
                                        return FALSE;
                                }

                                return TRUE;
}


DWORD SerialComm::output( LPCVOID pdata, DWORD  len ) {
    BOOL  bSuccess;
    DWORD written = 0;

    if ( len < 1 )
        return 0;
    // create event for overlapped I/O
    m_ov.hEvent = CreateEventA( NULL,  // pointer to security attributes
        FALSE,  // flag for manual-reset event
        FALSE,  // flag for initial state
        "");    // pointer to event-object name
    if ( m_ov.hEvent == INVALID_HANDLE_VALUE ) {
        SerialComm::ErrorToString( "RS232::output()  CreateEvent() failed" );
        return -1;
    }
```

```
	bSuccess = WriteFile( m_hCom,   // handle to file to write to
		pdata,    // pointer to data to write to file
		len,      // number of bytes to write
		&written, // pointer to number of bytes written
		&m_ov );  // pointer to structure needed for overlapped I/O
	// 如果函数执行成功的话检查 written 的值为写入的字节数，WriteFile 函数执行完
毕后
	// 自行填充的，利用此变量的填充值可以用来检查该函数是否将所有的数据成功写
入串口
	if ( SerialComm::IsNT() ) {
		bSuccess = GetOverlappedResult( m_hCom, &m_ov, &written, TRUE );
		if ( !bSuccess ) {
			CloseHandle( m_ov.hEvent );
			SerialComm::ErrorToString(  "RS232::output()     GetOverlappedResult()
failed" );
			return -1;
		}
	}
	else if ( len != written ) {
		CloseHandle( m_ov.hEvent );
		SerialComm::ErrorToString( "RS232::output()   WriteFile() failed" );
		return -1;
	}
	CloseHandle( m_ov.hEvent );
	return written;
}



DWORD SerialComm::input( LPVOID pdest, DWORD  len, DWORD  dwMaxWait ) {
	BOOL  bSuccess;
	DWORD result = 0,
		read   = 0, // num read bytes
		mask   = 0; // a 32-bit variable that receives a mask
	// indicating the type of event that occurred
	if ( len < 1 )
		return(0);
	// create event for overlapped I/O
	m_ov.hEvent = CreateEventA( NULL,    // pointer to security attributes
		FALSE,   // flag for manual-reset event
		FALSE,   // flag for initial state
		"" );    // pointer to event-object name
	if ( m_ov.hEvent == INVALID_HANDLE_VALUE ) {
		SerialComm::ErrorToString( "RS232::input()   CreateEvent() failed" );
		return -1;
	}
```

```
	// Specify here the event to be enabled
	bSuccess = SetCommMask( m_hCom, EV_RXCHAR );
	if ( ! bSuccess ) {
		CloseHandle(m_ov.hEvent);
		SerialComm::ErrorToString("RS232::input()   SetCommMask() failed");
		return -1;
	}
	// WaitForSingleObject
	bSuccess = WaitCommEvent(m_hCom, &mask, &m_ov);
	if ( !bSuccess ) {
		int err = GetLastError();
		if ( err == ERROR_IO_PENDING ) {
			result = WaitForSingleObject(m_ov.hEvent, dwMaxWait); //wait
dwMaxWait
			// milli seconds before returning
			if ( result == WAIT_FAILED ) {
				CloseHandle(m_ov.hEvent);
				SerialComm::ErrorToString( "RS232::input()
WaitForSingleObject() failed" );
				return -1;
			}
		}
	}
	// The specified event occured?
	if ( mask & EV_RXCHAR )
	{
		bSuccess = ReadFile( m_hCom, // handle of file to read
			pdest,  // address of buffer that receives data
			len,    // number of bytes to read
			&read,  // address of number of bytes read
			&m_ov); // address of structure for data
		if ( SerialComm::IsNT() ) {
			bSuccess = GetOverlappedResult(m_hCom, &m_ov, &read, TRUE);
			if ( !bSuccess ) {
				CloseHandle( m_ov.hEvent );
				SerialComm::ErrorToString( "RS232::input()
GetOverlappedResult() failed" );
				return -1;
			}
		}
		else if ( !bSuccess ) {
			CloseHandle(m_ov.hEvent);
			SerialComm::ErrorToString( "RS232::input()   ReadFile() failed" );
			return -1;
		}
	}
```

```
	else {
		CloseHandle(m_ov.hEvent);
		wsprintfA( m_lpszErrorMessage, "RS232::input()   No EV_RXCHAR occured\n"
);
		return -1;
	}
	CloseHandle(m_ov.hEvent);
	return read;
}


void SerialComm::close( void ) {
	if ( m_hCom > 0 )
		CloseHandle( m_hCom );
	m_hCom = 0;
}


VOID SerialComm::ErrorToString( char* lpszMessage ) {
	LPVOID lpMessageBuffer;
	DWORD  error = GetLastError();

	FormatMessage( FORMAT_MESSAGE_ALLOCATE_BUFFER |
		FORMAT_MESSAGE_FROM_SYSTEM,      // source and processing options
		NULL,                            // pointer to message source
		error,                           // requested message identifie
		MAKELANGID(LANG_NEUTRAL, SUBLANG_DEFAULT), // the user
default language.
		( LPTSTR ) &lpMessageBuffer,     // pointer to message buffer
		0,                               // maximum size of message buffer
		NULL);                           // address of array of message inserts

	// and copy it in our error string
	wsprintfA(m_lpszErrorMessage,"%s: (%d) %s\n", lpszMessage, error,
lpMessageBuffer);

	LocalFree(lpMessageBuffer);
}


BOOL SerialComm::IsNT( void ) {
	OSVERSIONINFO osvi;

	osvi.dwOSVersionInfoSize = sizeof( OSVERSIONINFO );
	GetVersionEx( &osvi );
	if ( osvi.dwPlatformId == VER_PLATFORM_WIN32_NT )
```

```
			return TRUE;
		else
			return FALSE;
}

bool SerialComm::isAvailable()
{
		return (m_hCom != INVALID_HANDLE_VALUE)&&(m_hCom != NULL);
}
```

SerialComm.h: *The code below is a header file written in C++ and is used in the pan tilt source code.*

```
#pragma once
#include <windows.h>
class SerialComm {
public:

		SerialComm();
		~SerialComm();

		int open( char* lpszPortNum = "com2", //com1   // 串口号
			DWORD  dwBaudRate  = CBR_2400,  // 波特率
			BYTE   byParity    = NOPARITY,  // 奇偶校验
			BYTE   byStopBits  = ONESTOPBIT,// 停止位个数
			BYTE   byByteSize  = 8 );       // 字节长度

		DWORD   output( LPCVOID pdata, DWORD len );
		DWORD   input( LPVOID  pdest, DWORD len, DWORD dwMaxWait = 500 );
		char*   GetErrorMessage( void );
		void close();
		bool isAvailable();
private:
		VOID    ErrorToString( char* lpszMessage );
		BOOL    IsNT( void );
		char       m_lpszErrorMessage[256];
		HANDLE     m_hCom;   // 串口句柄
		OVERLAPPED  m_ov;     // 包含异步输入输出操作信息的结构
};
```

PELCO_D.h: *The code below is a header file written in C++ and is used in the pan tilt source code.*

```
#pragma once
#include "SerialComm.h"
#include <iostream>

class PELCO_D{
public:
        bool Init(int com);
   void SetP(int k);
   void GotoP(int k);
        void Up();
        void Down();
        void Right();
        void Left();
        void Stop();
        void FocusNear();//焦距
        void FocusFar();
        void ZoomOut();//变倍
        void ZoomIn();
        void ApertureLarge();//光圈
        void ApertureSmall();
        bool Available();//判断云台是否可用
        void SetSpeed(int speed);
        int  GetSpeed();
private:
        SerialComm comm;
        int speed;
};
```

APPENDIX 8: POWER SYSTEM TESTING

Trial Test Data

Conditions			Solar Panel			Charge Controller				Load		
Time	Weather	Temp (F)	Voltage (V)	Current (A)	Available (W)	Status	Battery (V)	Current (A)	Output (W)	Votlage (V)	Current (A)	Power (W)
2:00 PM	clear skies	63	18.20	8.57	155.97	Float	13.40	2.70	36.18	13.20	4.09	53.99
4:00 PM	heavily shaded	67	20.10	1.83	36.78	Bulk	12.80	0.59	7.55	12.56	3.91	49.11
6:00 PM	almost dark	70	14.90	0.10	1.49	Sleeping	12.90	0.00	0.50	12.50	3.96	49.50
8:00 PM	night	63	0.68	0.00	0.00	Sleeping	12.70	0.00	0.50	12.42	3.93	48.81
11:00 PM	night	45	0.70	0.00	0.00	Sleeping	12.70	0.00	0.50	12.35	3.92	48.41
6:00 AM	barely light out	32	0.74	0.00	0.00	Sleeping	12.40	0.00	0.50	12.26	3.80	46.59
7:00 AM	sun rising	36	12.60	0.04	0.50	Snoozing	12.50	0.00	0.50	12.25	3.86	47.29
8:00 AM	shaded	40	16.77	0.27	4.53	Snoozing	12.50	0.25	3.13	12.29	3.90	47.41
9:00 AM	shaded	52	17.76	0.29	5.15	Snoozing	12.30	0.23	2.83	12.25	3.87	48.23
10:00 AM	half shaded	61	13.13	5.50	72.22	Bulk	12.70	2.56	32.51	12.43	3.88	48.23
1:00 PM	full sun	68	15.60	9.08	141.65	Float	13.30	1.80	23.94	13.90	4.10	56.99
2:00 PM	full sun	71	18.31	8.39	153.62	Float	13.40	2.27	30.42	13.17	4.07	53.60

Partly Cloudy Full Day Test												
Conditions			Solar Panel			Charge Controller				Load		
Time	Weather	Temp (F)	Voltage (V)	Current (A)	Available (W)	Status	Battery (V)	Current (A)	Output (W)	Votlage (V)	Current (A)	Power (W)
6:00 PM	full shade	76	16.68	0.03	0.50	Snoozing	12.7	0.2	2.7	13.1	4.0	52.4
7:40 PM	sun setting	74	14.96	0.00	0.00	Snoozing	12.8	0.0	0.0	12.6	4.0	50.0
9:00 AM	very cloudy	57	19.54	0.51	9.97	sleeping	12.5	0.0	0.0	12.3	3.9	47.4
9:30 AM	cloudy	57	19.97	0.72	14.38	bulk	12.6	0.9	11.0	12.4	3.9	48.0
9:45 AM	cloudy	58	19.98	0.90	17.98	bulk	12.7	1.2	15.1	12.3	3.9	47.4
10:00 AM	very cloudy	58	19.63	0.78	15.31	bulk	12.4	1.0	12.3	12.4	3.9	48.0
10:15 AM	very cloudy	59	19.81	0.89	17.63	bulk	12.4	1.1	14.1	12.4	3.8	47.5
10:30 AM	half sun	62	20.60	1.77	36.46	bulk	12.9	2.5	32.8	12.7	4.0	50.4
10:45 AM	3/4 sun	66	19.90	2.05	40.80	bulk	13.1	3.0	39.8	12.9	4.0	51.7
11:00 AM	full sun	66	19.68	5.16	101.55	bulk	13.5	6.1	82.9	13.3	4.1	54.2
11:15 AM	full sun	69	19.34	4.21	81.42	bulk	13.4	5.2	69.1	13.1	4.1	53.7
11:30 AM	full sun	70	19.61	4.25	83.34	bulk	13.4	5.1	68.6	13.2	4.1	53.8
11:45 AM	full sun	71	19.22	3.85	74.00	bulk	13.5	5.8	78.4	13.3	4.1	54.7
12:00 PM	cloudy	71	19.02	3.56	67.71	bulk	13.4	3.9	52.0	13.2	4.1	53.9
12:15 PM	full sun	74	19.08	4.60	87.77	bulk	13.4	6.6	88.8	13.3	4.1	53.9
12:30 PM	full sun	75	19.31	4.46	86.12	bulk	13.6	5.6	76.3	13.3	4.1	55.0
12:45 PM	partly cloudy	77	19.39	3.70	71.74	bulk	13.5	4.3	57.9	13.3	4.1	54.2
1:00 PM	partly cloudy	75	19.58	4.45	87.13	bulk	13.5	4.2	56.4	13.3	4.1	54.9
1:15 PM	full sun	79	19.29	6.76	130.40	bulk	14.0	7.9	110.2	13.7	4.2	57.2
1:30 PM	full sun	75	19.00	6.72	127.68	bulk	14.0	8.0	111.4	13.7	4.2	57.0
1:45 PM	full sun	75	18.93	6.70	126.83	bulk	14.1	7.3	102.8	14.0	4.2	58.9
2:00 PM	full sun	75	18.71	2.25	42.10	float	13.7	4.3	58.9	13.5	4.1	55.4
4:00 PM	very cloudy	79	19.26	1.43	27.54	bulk	13.4	1.8	24.4	13.2	4.0	53.0
5:00 PM	very cloudy	75	19.38	1.24	24.03	bulk	13.2	1.5	19.5	13.1	4.0	52.5
6:00 PM	very cloudy	75	18.72	0.41	7.68	snoozing	13.1	0.5	6.4	12.8	4.0	51.4
12:00 AM	night	62	0.25	0.00	0.00	sleeping	12.5	0.0	0.0	12.5	3.9	48.8

Discharge Test	
Hour	Battery Voltage
0.00	12.5
24.00	12.4
32.00	12.3
40.00	12.2
52.00	12.1
57.00	12
62.00	11.9
72.00	11.8

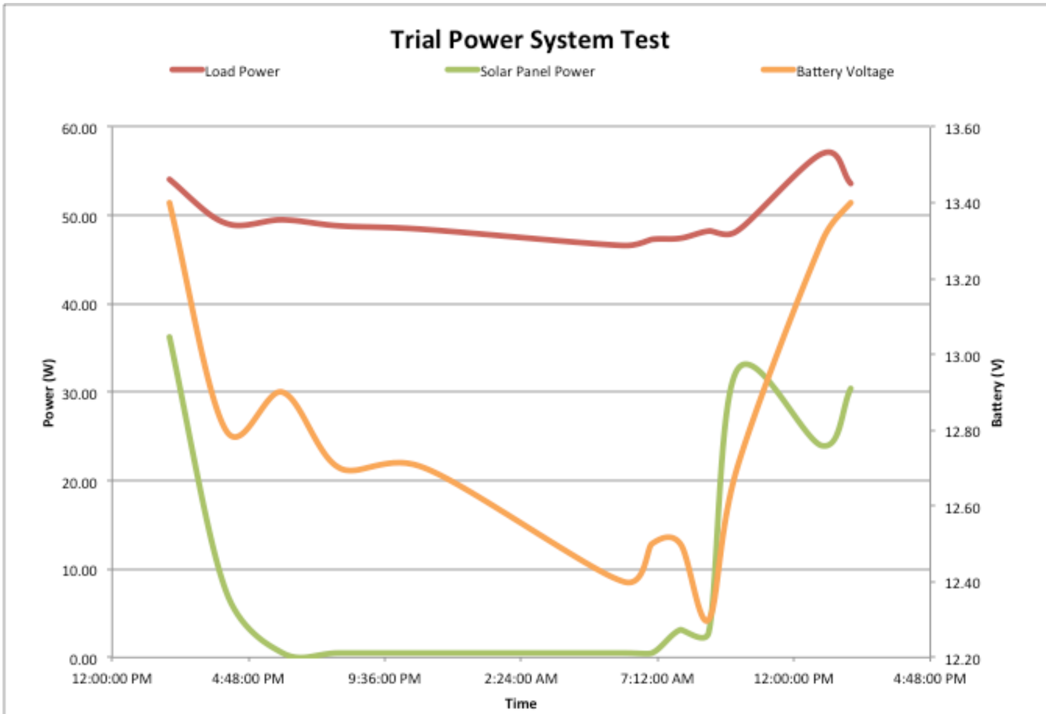


Figure 59. Trial Power System Test.

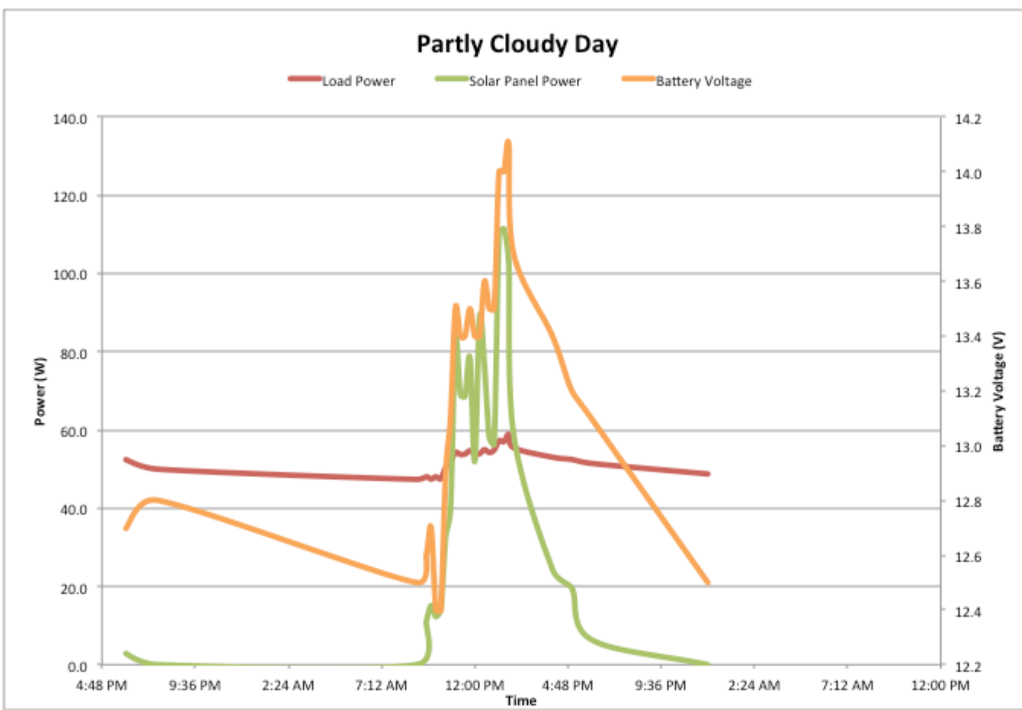


Figure 60. Partly Cloudy Day Power System Simulation.

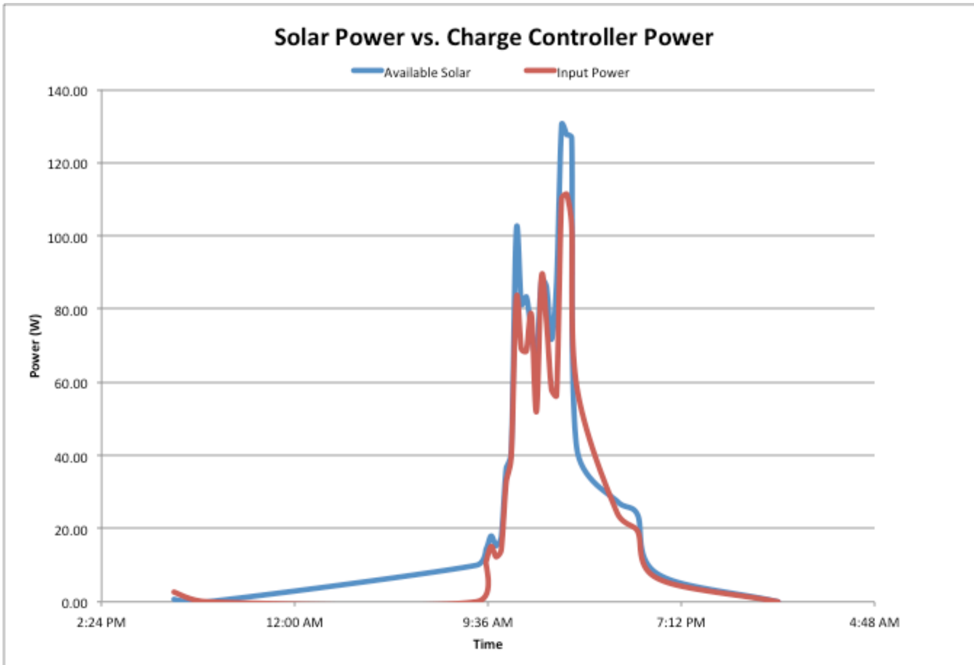


Figure 61. Solar Power vs. MPPT Power.

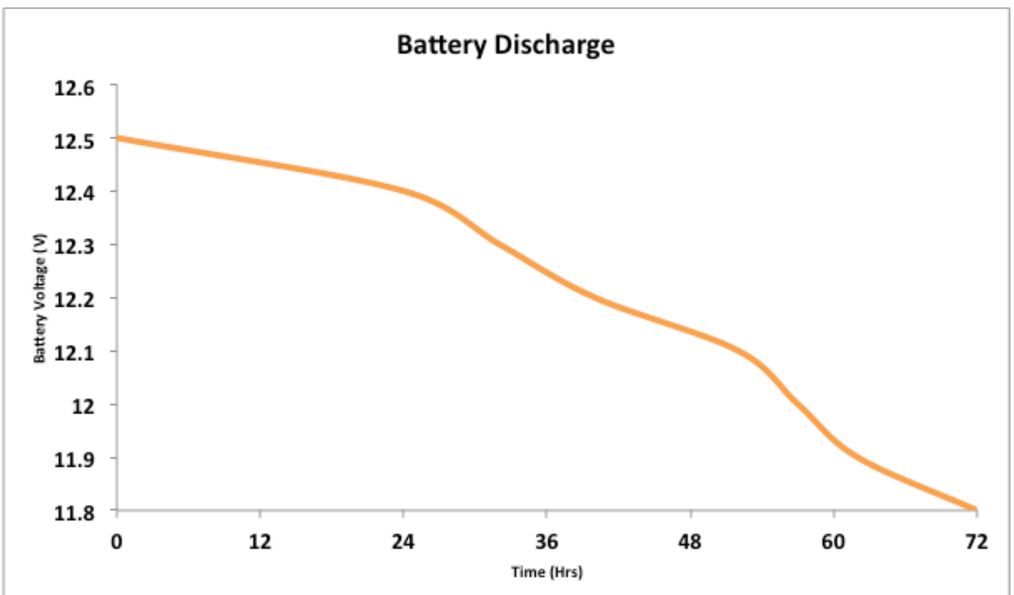


Figure 62. 3 Day Battery Discharge Test.

APPENDIX 9: PROJECT GANTT CHART

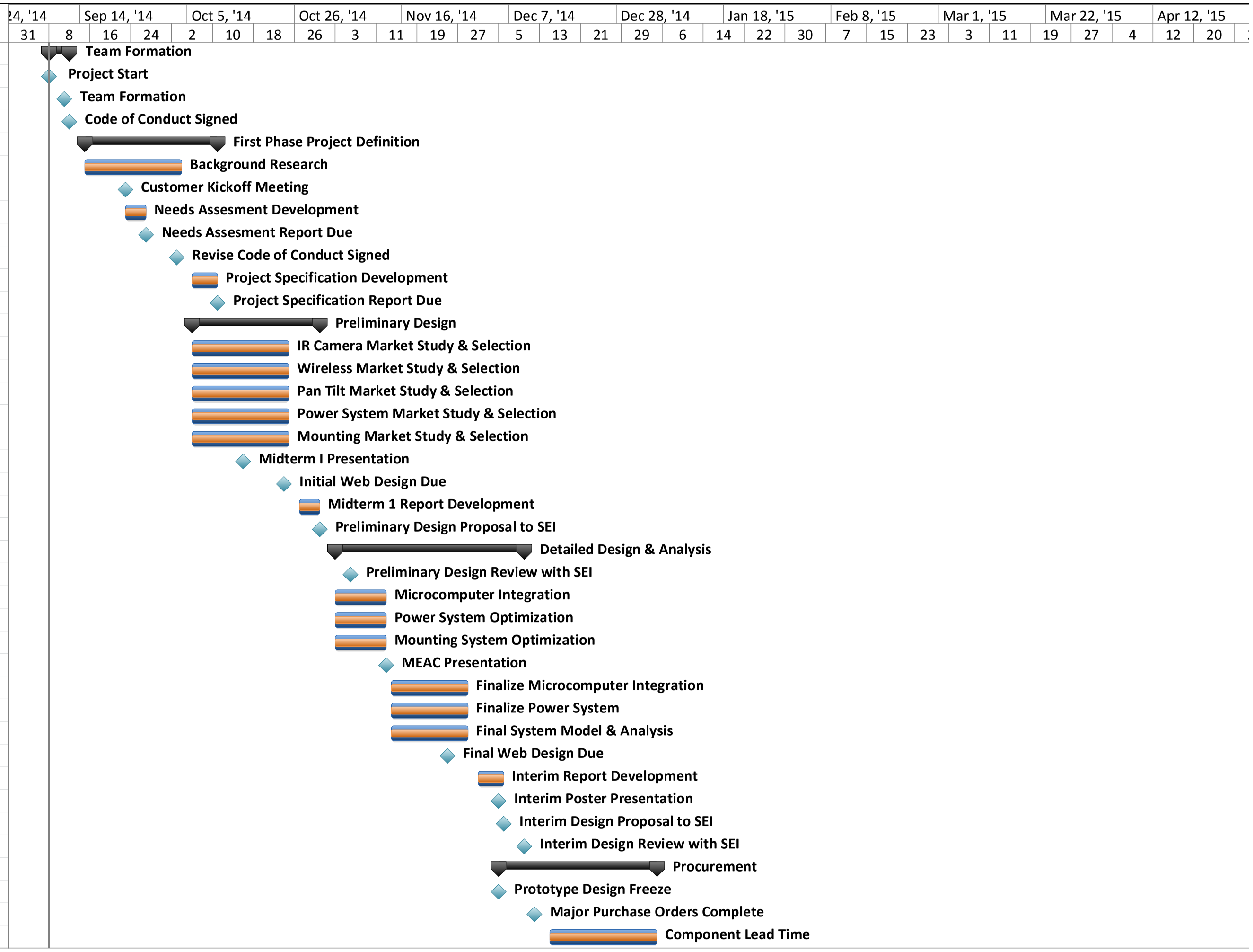
ID	Task Name	Duration	Start	Finish	Resource Names
1	**Team Formation**	**4 days**	**Mon 9/8/14**	**Fri 9/12/14**	
2	Project Start	0 days	Mon 9/8/14	Mon 9/8/14	
3	Team Formation	0 days	Thu 9/11/14	Thu 9/11/14	
4	Code of Conduct Signed	0 days	Fri 9/12/14	Fri 9/12/14	
5	**First Phase Project Definition**	**26 days**	**Mon 9/15/14**	**Fri 10/10/14**	
6	Background Research	14 days	Mon 9/15/14	Fri 10/3/14	
7	Customer Kickoff Meeting	0 days	Tue 9/23/14	Tue 9/23/14	Siemens
8	Needs Assesment Development	4 days	Tue 9/23/14	Fri 9/26/14	Alex Hull
9	Needs Assesment Report Due	0 days	Fri 9/26/14	Fri 9/26/14	
10	Revise Code of Conduct Signed	0 days	Fri 10/3/14	Fri 10/3/14	
11	Project Specification Development	5 days	Mon 10/6/14	Fri 10/10/14	
12	Project Specification Report Due	0 days	Fri 10/10/14	Fri 10/10/14	Michelle Hopkins
13	**Preliminary Design**	**25 days**	**Mon 10/6/14**	**Fri 10/31/14**	
14	IR Camera Market Study & Selection	15 days	Mon 10/6/14	Fri 10/24/14	Joseph Besler
15	Wireless Market Study & Selection	15 days	Mon 10/6/14	Fri 10/24/14	Alex Hull
16	Pan Tilt Market Study & Selection	15 days	Mon 10/6/14	Fri 10/24/14	Nixon Lormand
17	Power System Market Study & Selection	15 days	Mon 10/6/14	Fri 10/24/14	Kenny Becerra
18	Mounting Market Study & Selection	15 days	Mon 10/6/14	Fri 10/24/14	Jonathan Jennings
19	Midterm I Presentation	0 days	Thu 10/16/14	Thu 10/16/14	Michelle Hopkins,Joseph Besler,Kenny Becerra
20	Initial Web Design Due	0 days	Fri 10/24/14	Fri 10/24/14	Alex Hull
21	Midterm 1 Report Development	4 days	Mon 10/27/14	Thu 10/30/14	Michelle Hopkins
22	Preliminary Design Proposal to SEI	0 days	Fri 10/31/14	Fri 10/31/14	Michelle Hopkins
23	**Detailed Design & Analysis**	**37 days**	**Mon 11/3/14**	**Wed 12/10/1**	
24	Preliminary Design Review with SEI	0 days	Thu 11/6/14	Thu 11/6/14	Michelle Hopkins
25	Microcomputer Integration	10 days	Mon 11/3/14	Wed 11/12/1	Alex Hull,Nixon Lormand,Joseph Besler
26	Power System Optimization	10 days	Mon 11/3/14	Wed 11/12/1	Kenny Becerra,Michelle Hopkins
27	Mounting System Optimization	10 days	Mon 11/3/14	Wed 11/12/1	Jonathan Jennings
28	MEAC Presentation	0 days	Thu 11/13/14	Thu 11/13/14	Jonathan Jennings,Alex Hull,Nixon Lormand
29	Finalize Microcomputer Integration	15 days	Fri 11/14/14	Fri 11/28/14	Nixon Lormand,Alex Hull,Joseph Besler
30	Finalize Power System	15 days	Fri 11/14/14	Fri 11/28/14	Kenny Becerra,Michelle Hopkins
31	Final System Model & Analysis	15 days	Fri 11/14/14	Fri 11/28/14	Jonathan Jennings
32	Final Web Design Due	0 days	Tue 11/25/14	Tue 11/25/14	Alex Hull
33	Interim Report Development	5 days	Mon 12/1/14	Fri 12/5/14	
34	Interim Poster Presentation	0 days	Thu 12/4/14	Thu 12/4/14	
35	Interim Design Proposal to SEI	0 days	Fri 12/5/14	Fri 12/5/14	
36	Interim Design Review with SEI	0 days	Wed 12/10/14	Wed 12/10/1	Michelle Hopkins
37	**Procurement**	**31 days**	**Fri 12/5/14**	**Mon 1/5/15**	
38	Prototype Design Freeze	0 days	Fri 12/5/14	Fri 12/5/14	
39	Major Purchase Orders Complete	0 days	Fri 12/12/14	Fri 12/12/14	Joe Besler
40	Component Lead Time	21 days	Mon 12/15/14	Sun 1/4/15	

Figure 63. Gantt Chart Inputs Fall Semester.

ID	Task Name	Duration	Start	Finish	Resource Names
41	Major Components Received	0 days	Mon 1/5/15	Mon 1/5/15	
42	**Second Phase Project Definition**	**30 days**	**Tue 1/6/15**	**Thu 2/5/15**	
43	Site Visit	0 days	Tue 1/6/15	Tue 1/6/15	TEam
44	Team Reformation	0 days	Thu 1/8/15	Thu 1/8/15	TEam
45	Restated Scope Report Due	0 days	Fri 1/16/15	Fri 1/16/15	Michelle Hopkins
46	Progress Presentation	0 days	Thu 1/22/15	Thu 1/22/15	Joe Besler,Alex Hull,Jon Jennings
47	Website Update Due	0 days	Thu 2/5/15	Thu 2/5/15	Alex Hull
48	**Prototype Development**	**64 days**	**Mon 1/19/15**	**Mon 3/23/15**	
49	**Power System Development**	**49 days**	**Mon 1/19/15**	**Mon 3/9/15**	
50	Minor Component Purchasing	14 days	Mon 1/19/15	Sun 2/8/15	Joe Besler
51	Individual Component Testing	7 days	Mon 2/2/15	Sun 2/8/15	Kenny Becerra
52	Power Circuit Assembly	7 days	Mon 2/9/15	Sun 2/15/15	Jon Jennings
53	Create Load Simulation	5 days	Mon 2/16/15	Sun 2/22/15	Jon Jennings
54	Power System Testing	7 days	Mon 2/23/15	Sun 3/1/15	Jon Jennings,Michelle Hopkins
55	Analysis & Refinement	7 days	Mon 3/2/15	Sun 3/8/15	Jon Jennings,Michelle Hopkins
56	Power System Complete	0 days	Mon 3/9/15	Mon 3/9/15	
57	Midterm Presentation I	0 days	Thu 2/19/15	Thu 2/19/15	Kenny Becerra,Joe Besler,Michelle Hopkins
58	**Monitoring System Development**	**64 days**	**Mon 1/19/15**	**Mon 3/23/15**	
59	Minor Component Purchasing	25 days	Mon 1/19/15	Thu 2/12/15	Joe Besler
60	Camera Programming	49 days	Mon 1/26/15	Sun 3/15/15	Alex Hull,Joseph Besler,Kenny
61	Pan Tilt Programming	49 days	Mon 1/26/15	Sun 3/15/15	Nixon Lormand,Jon Jennings
62	Microcomputer Setup & Initializing	49 days	Mon 1/26/15	Sun 3/15/15	Nixon Lormand
63	Wireless Communication Programming	8 days	Mon 3/16/15	Mon 3/23/15	Alex Hull,Kenny Becerra
64	Midterm Presentation II	0 days	Thu 3/19/15	Thu 3/19/15	Alex Hull,Nixon Lormand,Jon Jennings
65	**Final Assembly**	**18 days**	**Fri 3/20/15**	**Mon 4/6/15**	
66	Monitoring Circuit Assembly	2 days	Fri 3/20/15	Mon 3/23/15	Nixon Lormand,Joe Besler
67	Initial Testing	7 days	Mon 3/23/15	Sun 3/29/15	TEam
68	Refinement & Final Testing	6 days	Mon 3/30/15	Sun 4/5/15	TEam
69	Prototype Complete	0 days	Mon 4/6/15	Mon 4/6/15	
70	**Project Finalization**	**28 days**	**Fri 4/3/15**	**Fri 5/1/15**	
71	Manufacturing & Reliability Report	0 days	Fri 4/3/15	Fri 4/3/15	Michelle Hopkins
72	Operation Manual Report	0 days	Fri 4/3/15	Fri 4/3/15	Michelle Hopkins
73	Walk Through Presentation	0 days	Thu 4/9/15	Thu 4/9/15	TEam
74	Final Project Report Due	0 days	Fri 4/10/15	Fri 4/10/15	Michelle Hopkins
75	Open House Final Presentations	0 days	Thu 4/16/15	Thu 4/16/15	TEam
76	Final Report to SEI	0 days	Fri 5/1/15	Fri 5/1/15	Michelle Hopkins

Figure 64. Gantt Chart Inputs Spring Semester.

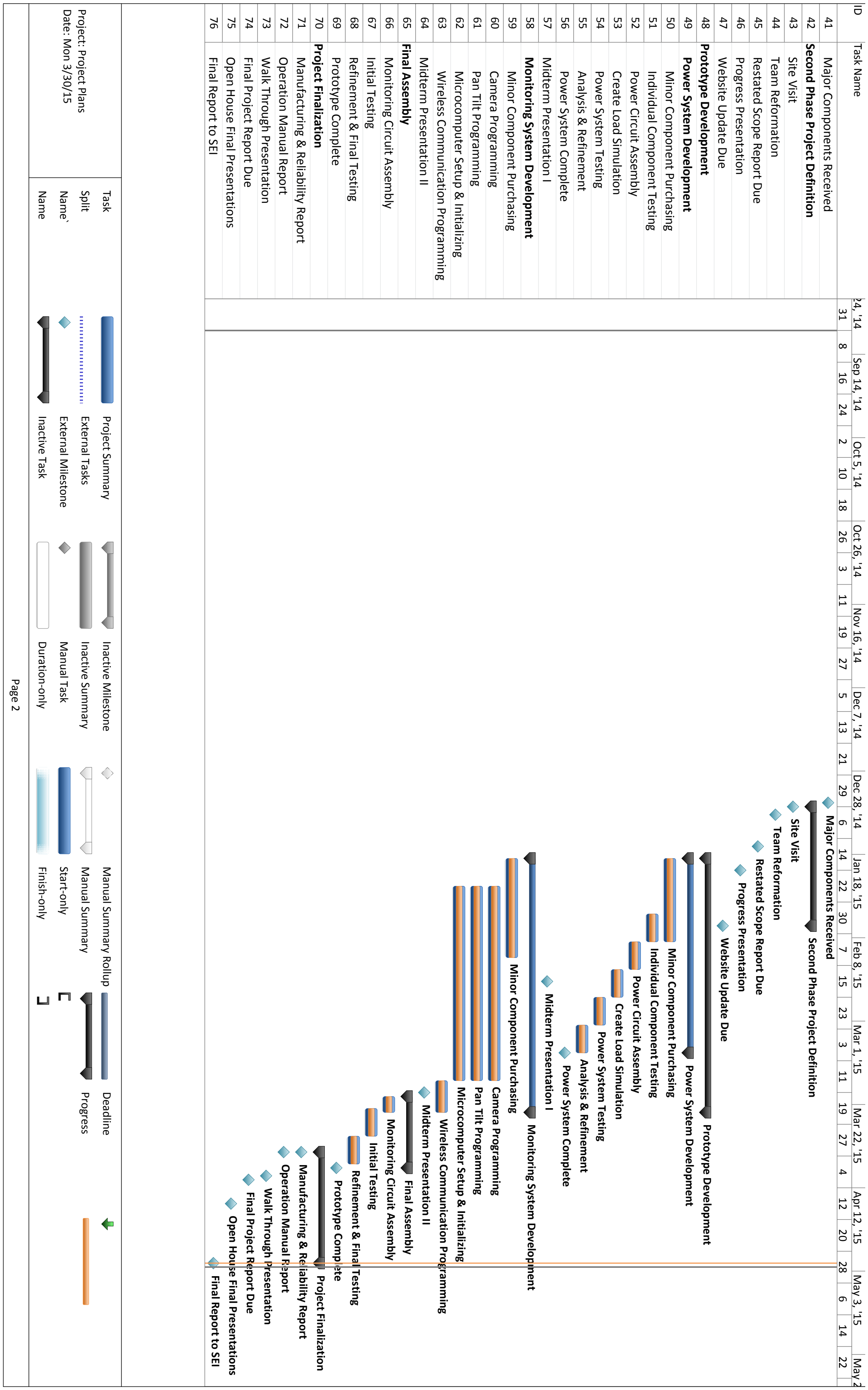
ID	Task Name
1	**Team Formation**
2	Project Start
3	Team Formation
4	Code of Conduct Signed
5	**First Phase Project Definition**
6	Background Research
7	Customer Kickoff Meeting
8	Needs Assesment Development
9	Needs Assesment Report Due
10	Revise Code of Conduct Signed
11	Project Specification Development
12	Project Specification Report Due
13	**Preliminary Design**
14	IR Camera Market Study & Selection
15	Wireless Market Study & Selection
16	Pan Tilt Market Study & Selection
17	Power System Market Study & Selection
18	Mounting Market Study & Selection
19	Midterm I Presentation
20	Initial Web Design Due
21	Midterm 1 Report Development
22	Preliminary Design Proposal to SEI
23	**Detailed Design & Analysis**
24	Preliminary Design Review with SEI
25	Microcomputer Integration
26	Power System Optimization
27	Mounting System Optimization
28	MEAC Presentation
29	Finalize Microcomputer Integration
30	Finalize Power System
31	Final System Model & Analysis
32	Final Web Design Due
33	Interim Report Development
34	Interim Poster Presentation
35	Interim Design Proposal to SEI
36	Interim Design Review with SEI
37	**Procurement**
38	Prototype Design Freeze
39	Major Purchase Orders Complete
40	Component Lead Time



Project: Project Plans
Date: Mon 3/30/15

Task · Split · Name` · Name · Project Summary · External Tasks · External Milestone · Inactive Task · Inactive Milestone · Inactive Summary · Manual Task · Duration-only · Manual Summary Rollup · Manual Summary · Start-only · Finish-only · Deadline · Progress

Page 1


ID
Task Name
41 Major Components Received
42 Second Phase Project Definition
43 Site Visit
44 Team Reformation
45 Restated Scope Report Due
46 Progress Presentation
47 Website Update Due
48 Prototype Development
49 Power System Development
50 Minor Component Purchasing
51 Individual Component Testing
52 Power Circuit Assembly
53 Create Load Simulation
54 Power System Testing
55 Analysis & Refinement
56 Power System Complete
57 Midterm Presentation I
58 Monitoring System Development
59 Minor Component Purchasing
60 Camera Programming
61 Pan Tilt Programming
62 Microcomputer Setup & Initializing
63 Wireless Communication Programming
64 Midterm Presentation II
65 Final Assembly
66 Monitoring Circuit Assembly
67 Initial Testing
68 Refinement & Final Testing
69 Prototype Complete
70 Project Finalization
71 Manufacturing & Reliability Report
72 Operation Manual Report
73 Walk Through Presentation
74 Final Project Report Due
75 Open House Final Presentations
76 Final Report to SEI
Sep 14, '14
Oct 5, '14
Oct 26, '14
Nov 16, '14
Dec 7, '14
Dec 28, '14
Jan 18, '15
Feb 8, '15
Mar 1, '15
Mar 22, '15
Apr 12, '15
May 3, '15
Project: Project Plans
Date: Mon 3/30/15
Task
Split
Milestone
Summary
Project Summary
External Tasks
External Milestone
Inactive Task
Inactive Milestone
Inactive Summary
Manual Task
Duration-only
Manual Summary Rollup
Manual Summary
Start-only
Finish-only
Deadline
Progress
Page 2

Biography

Michelle Hopkins - Project Manager

Michelle is a senior in Mechanical Engineering completing her final year as a Co-op with Siemens Energy. She specialized in, and is currently working on, Thermal Systems. She is currently a founding brother of the FSU Chapter of Theta Tau. Michelle plans to accept a full offer from Siemens Energy at the conclusion of the spring semester.

Nixon Lormand - Mechanical Engineering Lead

Nixon is a senior in Mechanical Engineering completing his final year. He specializes in mechatronics and robotics. Nixon is a member of ASME, NSBE, and Theta Tau and runs a blog about a robotics project he is a part of. He also does robotics research for Dr. Moore at the National High Magnetic Field Laboratory.

Kenny Becerra - Electrical Engineering Lead

Kenny is a senior and is double majoring in Computer and Electrical Engineering. He is an active member of SHPE and IEEE. He specializes in programming and embedded system software. Currently, he has an offer from PG&E as an IT Developer. He is interested in going back for his Masters in Computer Engineering after spending some time in industry.

Joseph Besler - Procurement Chair

Joseph is a senior in Mechanical Engineering and specialized in Dynamics. He is the secretary for SAE and interned for US Patent and Trademark Office. Joseph hopes to begin his engineering career in spring by getting a full time offer.

Alexander Hull- Programming Chair

Alex is a senior in Computer Engineering. He has interned at National Institute of Standards and Technology as well as worked under Dr. Edward Jones on programming an automated grading program. Alex plans on attending graduate school for Artificial Intelligence after finishing his undergraduate degree.

Jonathan Jennings - Prototype Chair

Jonathan is a senior in Mechanical Engineering and specializes in mechanical design/simulation. He is a founding brother and current President of the FSU Chapter of Theta Tau. He has previously interned at the National High Magnetic Field Laboratory in their Research and Development Department. He would like to pursue a career in Automotive or Marine Design.