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TEAM 14

Wireless Infrared Monitoring System

MIDTERM 1 REPORT

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Abstract

This report, titled Midterm 1 Report, is a preliminary design proposal of our Solar Powered Wireless Monitoring System. The previous report covered the topics of general product research, milestone scheduling, and the development of product specifications. This report, specifically, will review the background, objectives, and constraints of our project and why it is of interest to our sponsor, Siemens Energy. It will then discuss and compare the down-selected products from market research that was completed. This Midterm 1 Report will also detail our preliminary evaluation and selection processes, specifying our initial design. Finally, the report will contain the methodology of how we will accomplish our remaining goals going forward.

1 Introduction

The objective of this project is to design a product that better monitors systems of interest at power plants for preventative maintenance. Currently, power plants commonly utilize a large network of thermocouples or small vibration monitoring devices to do this. All of which have to be wired to a power source and tapped individually. The project sponsor, Siemens Energy is interested in eliminating costs and auxiliary plant loads with a wireless system that can monitor multiple potential problematic areas at a time. Specifically, they are interested in exploring the use of infrared technology.[1]

Thermal imaging cameras can see things the human eye cannot by sensing electromagnetic radiation in the infrared range of 9–14 µm.[3] These cameras can be utilized to monitor the temperature of operating equipment, enabling it to diagnose potential problems long before other traditional systems.[2] The 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.[1]

Our goal is to properly design and write a complete specification for a Wireless Infrared Monitoring System for our sponsor that is an effective substitute of the current preventative maintenance techniques. The final product should be is a thorough, yet timely, market study of available components in order to select specific products to be used in the system. These products must operate efficiently and effectively while also being able to be integrated seamlessly as a whole to accomplish the end function. This is a challenge due to the plethora of technology available on the market today.

2 Project Definition

2.1 Background research

Background Research was conducted on this project in order to assess existing technologies and market gaps. It was found that there are already existing monitoring systems that have been developed for applications similar to ours. These systems have common subsystem components, which gave us some good ideas of the potential scope of our project. The following images are examples of systems by Helios[4], Panasonic[5], and A to Z Security[6]. 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. In these particular examples, the structure is a post. Some of the systems incorporate pan-tilt modules as well. These subsystems govern our product design as detailed in our Product Specification Report.

The existing systems depicted below 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. Our particular application requires an Infrared Camera of much higher caliber for specific temperature monitoring of electrical substations and complicated thermal systems.

Figure 1. Solar Powered Wireless Security Systems: Helios, Panasonic, and A to Z.

Due to the fact that this project has existing technologies and market competition in place already, the focus will be on 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.

2.2 Need Statement

There is a need for an improved method of monitoring critical equipment under operation in power plants.[1]

Siemens, as an Engineering Procurement Construction and Service provider in the Energy Industry, is highly involved in all aspects of projects. In this particular case, this project has risen out of a demand for improved preventative maintenance in its Service sector for commissioned fossil fuel power plants. The current state of temperature monitoring at their power plants beckons for consolidation, simplification, and improvement.

2.3 Goal Statement & Objectives

The intended goal of this project, communicated by the sponsor in the Kickoff Meeting that was held on September 23rd, is as follows,[1]

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

Some objectives of this project were dictated as follows:

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

2.4 Constraints

The following table, Table 1, captures design constraints provided by the sponsor. [1]

Table 1. System Constraints.

Subject	Descriptor	Constraint
Location	Exclusively	Fossil Fuel Power Plants
Lifetime	At least	30 years
Monitoring	Type	Thermal Imaging
Power	Source	Solar Harvesting
Battery Storage	At least	3 days
Communication	Wireless	100m
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	$2,000

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

3 Design and Analysis

3.1 Functional Analysis

In order to accomplish our objectives under the constraints detailed above, a complete system was conceptualized and broken up into the following five major subsystems:

- Infrared Camera
- Pan Tilt Module
- Wireless Communication Module
- Solar Array & Battery System
- Mounting Structure

The Infrared Camera will survey the selected target(s) 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 and ultimately eliminating the need for numerous systems. The wireless network will monitor and communicate the data back to a control room, reducing the need for manual local monitoring. The Solar/Battery System will harvest the Sun's radiation converting it into electric power to be stored in the batteries, which will discharge power to the system when needed. Finally, the Mount coupled with the Weather Enclosure will support and house all the components. Each of these five major subsystems has an explicit goal and necessary function that must be met in order to ensure an effective end product. The following sections explain how each subsystem needs to perform and what it needs to do so.

3.1.1 Infrared Camera

The infrared camera chosen for this project must be durable, low weight, efficient, and have a good data and video output. In order to meet our weatherproofing system specifications the chosen camera must have an International Protection rating of at least IP55 and be able to operate at temperatures of 0 to 110°F. The camera and housing should weigh less than 20 lbs in order to not strain the pan-tilt module. The infrared camera should also have a minimum power consumption in order to reduce system load. In order for our system to monitor the step up transformer (GSU) and other sensitive equipment; the camera must detect temperatures up to 572°F (300°C) with an accuracy of ±5%. It would be preferable that the camera has multiple lens options, since each system may monitor different equipment at varying distances. Various lens options will allow for various field of view (FOV) and instantaneous field of view (IFOV) to be selected in order to view targets accurately. Finally the Infrared camera should transmit a good resolution MPEG-4 file and temperature data with open protocols.

3.1.2 Pan Tilt Module

The pan/tilt module is expected to operate in an auto scan mode that will cycle through fixed positions. It should have the ability to have a continuous pan of 360° and have 90° of tilt motion. The ability of the pan/tilt module to have real time control is dependent on the command latency. The command latency is the delay in the response from the user to the pan/tilt module.[7] A way to fix this problem is selecting a pan tilt module that employs binary communications for dynamic applications which provide high bandwidth control.[9] 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 connections or Ethernet connection[8] which will be converted into USB.

The microcomputer will act as the onboard computer, executing programs and functions, and processing data. This component will be the most tailored component of our project and will have to seamlessly interface with every other component in the system or else the system, as a whole, will not function. The microcomputer must have motor and camera drivers so that it can control the hardware functions of the motors and zoom of the camera. The microcomputer must also be able to support the language interface and compile the code in one language, i.e. C programming[9]. Visual Studio, MATLAB and/or Simulink can be used to develop an algorithm with proven API's, protocols, and SDK's. When considering a pass through connection, the data transmission between the motor and the camera will not work if the camera uses a different protocol and bit rate than the motors.

3.1.3Wireless Communication Module

To facilitate wireless communication for the monitoring system a few components will be needed: a router to create the wireless local access network (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 to be communicate with the control room. The components must be able to withstand a temperature range of 0-110°F while still performing. They also must be properly housed, protected, and ventilated by a weather enclosure in order to protect against the extremities of this temperature scale. Power consumption of the access point must be low as well in order to minimize the size of the solar battery system.

3.1.4Solar Panel & Battery System

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 brackets of some kind supporting the panel, and securing it onto the mount at a tilt equal to the local latitude facing south towards the Equator. The solar cells must also be protected by tempered glass that is particle resistant in order to reduce maintenance and panel degradation. It also should be weatherproofed to at least IP55 to protect from outdoor conditions. To stand up to the 30-year lifespan, 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 be supplied to the batteries in order for the batteries to meet the system load. This sizing must be specific to the local insolation available at RJ Midulla. The size of the panel is also a point of concern when it comes to weight and mounting. A large panel will induce larger forces on the mount, especially on windy days. Due to the fact that the size, and therefore cost, of the solar panel is entirely dependent on the system load that has to be met, power consumption should be a primary concern for all other subsystem selection. Finally, the efficiency of the panel can affect the size of the panel needed. Monocrystalline panels currently have the highest efficiency for flat fixed panels at around 17-24%.[10] They are however more expensive than Polycrystalline and thin film panels who both have lower efficiencies. A cost-benefit analysis will have to be considered when selecting the type of solar panel.

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 by never over-discharging the batteries. A deep-cycle battery designed for a low depth of discharge would be ideal for our system application. The level of maintenance of our battery system must also be relatively low in order to meet our project objective of decreased manual labor. Lead Acid batteries have the lowest maintenance compared to other types.[11] Finally, the size of the battery, while being constrained by the system load, must not be too excessive. The batteries will definitely be the heaviest components on our system. This will restrict their placement on the mount and the type of securement they will need. Once again, this is why reduced power consumption is a concern for every subsystem.

3.1.5 Mounting Structure

The integrating component to all the subsystems is the mounting structure. Generally, mounting structures provide mechanical support and determine a systems degree of freedom (D.O.F.). For this particular subsystem, movement is highly undesirable, with the exception of the pan tilt module. Furthermore, motion of the mounting structure is unnecessary, costly, and ultimately a sign of poor design. The designed system will be monitoring stationary targets and thus, it will be designed to be a stationary (0 D.O.F.) object. The preliminary proposed locations of the mount can be seen in Appendix 2. These locations were chosen in order to monitor the most amount of equipment as possible. These locations will be under review after the first official site visit in December where we will evaluate the targets more closely and determine the positioning of our systems.

The mounting structure subsystem is broken into two components, an upper mast and lower foundation. The upper mast is responsible of supporting the necessary components above the ground. The mast will be supporting the camera, pan-tilt module, solar cell, and electronics enclosure. Being elevated above the ground not only provides protection for the subsystems but it also places them in an environment conducive to their function. For example, the pan tilt module and camera have a more suitable range of motion and preferable field of view when placed near the top of the structure while the solar cell is closer to its source, and less likely to be shaded. Securing these components to the mast will be achieved by using a combination of brackets and fasteners. Furthermore, more intricate brackets are required for the pan-tilt module and solar cell. The pan-tilt module should be able to perform its full range of motion of 360^{o} pan and 120^{0} tilt. The solar cell supports might need to be manufactured specifically to allow for a panel tilt equal to the local latitude while still being rigid enough to withstand winds up to 100 mph. The lower foundation is responsible for anchoring the mast to the ground. The placement of the systems and foundation type are both very important in determining the overall effectiveness of the system.

3.2 Design Concepts

3.2.1 Infrared Camera

Four cameras are being considered for our design project and are compared in Table 4. Three cameras that we are considering for this project are produced by FLIR, a leading producer of infrared cameras. Two cameras that are being considered are from FLIR's A3xx series (A310f and A315f). The A3xx series offers various lens options to allow for different viewing distances. Both of these cameras have a maximum power consumption of 9W (24W with heater). The FLIR A310f and A315f have many similarities, but the A310f has a superior temperature accuracy of 2% compared to 4% from the A315f. The FLIR A315f does have a better image frequency rate of 60 Hz. There is also a large price difference between these two cameras that will be considered in selection. In general, the A3xx series offers many of the desired features sought for our system.

Another FLIR selection is the A35 compact camera, which offers many benefits compared to the other cameras being considered. The FLIR A35 offers the best target temperature range of (-40°F to 1022°F), but its reading has the lowest accuracy with ±5%. The A35 is also the smallest and lightest camera. However, this camera is not designed for the outdoors and an enclosure must be designed to give it the proper weather protection needed for our constraints. A designed enclosure might be too expensive to produce and will take design time. One inexpensive idea proposed during a staff meeting was to encapsulate the camera in a protective plastic or glass dome. This proposal may have the desired weather protection, but the reflection on the plastic or glass of the housing will restrict a temperature rating from the camera. The largest benefit of the FLIR A35 camera is that it has the lowest power consumption with a 6W max Although, the camera has the worst operating temperatures of 5°F to 122°F. A lower operating temperature may be achieved by adding heaters to this system. The heaters consume 25W max, making the camera's total max power consumption 27.5W. It should be noted that this value is not much lower than the other cameras being selected from. The FLIR A35 has a lot of benefits, but its low weather protection, operating temperature, and limited selection of only two lenses make it a poor candidate for selection.

Pelco, a surveillance and security technology company, also makes an infrared camera, the Sarix TI. This camera has the second lowest weight of the cameras considered. The camera draws the most power (35 W max with an internal heater). The Sarix TI also only has a monitor temperature range of 39°F to 478°F which is not ideal for the targets that will be monitored by the system (up to 572°F). Overall the Sarix TI infrared camera has a desired weight weather protection and superior resolution but lacks a desired temperature measurement range.

Table 3. Camera Selection Specifications.

Subject	Units	FLIR A310f[12]	FLIR A315f[13]	FLIR A35[14]	PELCO Sarix TI[15]
Lenses	degrees	6,15, 25, 45	25,45,90	25,48	44,18,12,6
Weight	lb	11	11	0.44	7.2
Dimensions	mm	460x140x159	460X140x159	106x40x43	376 x 126 x 128

FOV	mm	6 x 4.5 25 x 18.8	25 X 18.8 45 x 33.8 90 x 73	48 x 39 25 x 19	44 x 3 6 x 5
IFOV	mrad	.33-2.45	1.36, 2.45, 6.3	2.78, 1.32	unknown
Operating Temp	F	-25 to 122 F	-25 to 122F	5 to 122 F	-40 to 122F
Temperature Measurement	F	-4 to 248 F	-68 to 248F	-13F to 275F	39 to 478F
		32 to 662F	32 to 662F	-40 to 1022F	
Encapsulation	IP rating	IP66	IP66	IP40	IP66
Accuracy	%	±2%	±4%	±5%	±2%
Power	W	9W w/o heater 24W w/ heater	9W w/o heater 24 W w/ heater	6 W max	35 W w/ heater
Image Resolution	pixels	320x240	320 × 240 pixels	320 x 256 pixels	384 x 288 pixels
Image Streaming	Hz	16-bit @7.5 Hz	16-bit @ 60 Hz	14 bit @ 60 Hz	30 Hz
Cost	USD	$9,500-$12,000	$13,500-$17,000	$5,500	$6,000-$15,000
Warranty	yrs	10	10	10	3

3.2.2Pan Tilt Module

Pan/tilt modules are designed to work with different API's or protocols that assist the programmer by providing libraries of pre-defined functions. Modern computer-controlled pan/tilts are complex, highly integrated electro-mechanical systems that must meet a wide range of operating and performance requirements. One of the important performance characteristics is the precision and accuracy in displacement of the pan/tilt module.[7] The pan tilt module should be able to give feedback of its specific position to the microcomputer. High-resolution digital encoders provide an absolute count of position that allows it to provide more stable readings over time and temperature.[8] This played a high factor in a preliminary market study on the pan tilt modules. Also, since the system is to be solar powered and operate 3 days without recharging, the maximum power consumption is very important in optimizing the performance of the system.

There have been four selections on pan tilt units and their performance specifications have been listed in Table 4. The PTU – D100 E Series in Figure 2 is manufactured by FLIR. This product is said to have extremely precise positioning with real-time control of position and acceleration. It has the ability to mount a payload on the side or top bracket. Dependent on the model it can also provide geo-pointing and inertial stabilization. Overall it is designed for high duty cycles and reliable 24/7 operation in harsh all-weather environments. The low parts count, and highly integrated design provides unsurpassed system reliability [17]. The Vector-35G in Figure 2 is another pan tilt module manufactured by General Dynamics. It is also designed for 24/7 continuous operation without requiring homing or calibration.[18] This is because the encoders provide an absolute position when sensing, ultimately returning an exact location. The Vector-35G is also designed for low power consumption and built with backlash precision hardened gearing that allow for smooth motion and high torque. [16] It is able to provide upright or inverted installation options and accommodate a wide range of payloads from long-range cameras to radar systems. [16] The PTU-D100E and the Vector-35G both fulfill the desired performance specifications. However, the prices of these pan tilt modules may pose a problem to stay within the budget.

Figure 2. FLIR PTU-D100E, Vector 35G, YP-3040.

The investigation for less expensive pan tilt units resulted in finding of two other possible solutions. The YP-3040 in Figure 2 is a pan tilt module that is manufactured by Axis Communications. It is designed as an optional accessory for Axis fixed network cameras with pan-tilt support. [17] Even though it is preconfigured for several Axis fixed network cameras it uses the common Pelco-D protocol. 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 3 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 including complete darkness[18]. The Sarix Ti offers preset positioning, patterns and multiple scan modes that with minimal maintenance having no gears to adjust.

Figure 3. PELCO Sarix TI Camera with integrated PTU.

Table 4. Pan Tilt Module Specification Table.

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

The microcomputers found to be the most useful and applicable to our project are specified below in Table 5. The Beaglebone Black has a faster processing unit than the Raspberry Pi B+ but unfortunately does not have as good of a graphics card. The Beaglebone however is very accessible with more ports, and has a more versatile operating systems. Whereas the Raspberry Pi only has Lenox based operating systems. The biggest disadvantage with the Arduino is that it is a microcontroller not a microprocessor which would not be technologically advanced enough for our application.

Table 5. Microcomputer Specifications.

Microcomputers	Cost	Operating Temp	Graphics	Power Consumption	Processing (MHz)	USB Ports	GPIO (pins)	Ethernet
Beaglebone Black[36]	$45	-40 to 90C	3D Accelerator	2 W	ARMv6 1000	2	92	RJ45
Raspberry Pi B+[37]	$35	0 to 70C	Broadcom VideoCore IV	1.4 W	ARMv7 700	4	40	RJ45
Arduino UNO[38]	$25	0 to 70C	Smart GPU 2	1.65W	-	1	14	RJ45

3.2.3Wireless Communication Module

The following are tables of three market selections for each of the necessary components to enable wireless communication; the router, the range booster, and the access point.

Table 6. Router Component Selections.

Router	Power Consumption	Weatherproofing	802.11n compatible	Transmission Power	Cost
RT-AC68U[19]	34 W max	IP00	Y	not listed	$200
TEW-812DRU[20]	21W	IP00	Y	18dB	$175
JNR3210[21]	Not listed	IP00	Y	not listed	$40

Table 7. Range Booster Component Selections.

Range Booster	Weatherproofing	Lifetime	Cost	Gain
A8EX[22]	130 MPH wind/lightning proof	not listed	$80	8 dBi
TEW-AO12O[23]	IP66	not listed	$90	12 dBi
TL-ANT2415D[24]	IP66	not listed	$50	15 dB

Table 8. Access Point Component Selections.

Wifi Adapter	Power Consumption	Weatherproofing	Gain	Sensitivity	Cost
UWN100[25]	10W w/ BBB	IP00	0 dBi	0 dBm	$10
UWN200[26]	10W w/ BBB	IP00	variable	variable	$13
AWUS036NHR[27]	Not listed	IP00	5dBi	-91dBm	$22

3.2.4 Solar Panel & Battery System

In order to choose an adequate solar panel for the project a preliminary breakdown of the power consumption had to be completed first. The range of each major system based on the specifications above can be seen in Table 8. It includes their nominal and max power ranges. For now the preliminary power consumption calculation will assume these nominal values are coinciding throughout the whole day. The power consumption will most likely be less than this in reality but this should be a sufficient preliminary analysis.

Table 9. Component Power Consumption.

Module	Nominal	Max
Infrared Camera	10 W	10-25 W
Pan tilt Module	25 W	30 W
Microcomputer	10W	10 W
Total	**45 W**	**125 W**

According to National Renewable Energy Laboratory (NREL) Solar Resource Database, the lowest daily average Solar Insolation for our site location from 2009 to 2012 is 4.66 kWh/m^2/day.[29,30] 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 ensure appropriate power supply on the worst sunlit days. The complete solar insolation data fro NREL for our site location can be found in Appendix 1. Following Equation 1 below, the necessary size of our panel was calculated. The nominal 45 Watts was rounded to 50W to add some design margin.

$$Solar\ Power\ Needed = 50W * \frac{24hrs/day}{4.66\ sunhours/day} = 257.5W \qquad (1)$$

Market Solar Panels are sold by round wattage sizes of 10 or 20W so this number was rounded to 250W. 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. The maximum power point, which is what the panels 'size' is, is calculated at 25°C test conditions. The efficiency of a solar panel decreases with temperature increase and degrades overtime due to particle and dust build up. This shows why it is essential to size your solar panel by your local insolation and not the standard as well as to include a reasonable margin for your system design life. With all above things considered, 300-375W panels were considered for our design.

In order to power the system for 3 days our batteries will have to deliver the 3.6kWh as calculated below in Equation using our power consumption of 50W.

$$50W * 24hrs * 3days = 3.6kWh \tag{2}$$

Batteries however are sized in Amp hours and normally are depleted if they are discharged past 50%. So, assuming a discharge depth of 50%, which is common for most batteries, and a system voltage of 24V, the approximate battery size was calculated below in Equation 3.[31]

$$Batery\ Size = \frac{3.6kWh*2}{24V} = 300Ah \tag{3}$$

This means we need at least 1 24V 300Ah battery to meet our 3-day requirement. Or a string of 2 12V 300Ah batteries. Or 2 strings of 34V 150Ah batteries, etc.

3.2.5Mounting Structure

When selecting the mounting structure the primary focus is on material. Evaluation of common structure's material was based on 5 separate characteristics. In order of importance, these characteristics are corrosion resistance, strength, cost, handling, and impact resistance.

A materials corrosion resistance helps dictate a product's longevity. A desirable material for this project should help the system to meet a required life of 30 years. The 5 materials commonly used to manufacture utility poles include steel, aluminum, concrete, wood, and fiberglass. Out of these materials concrete, aluminum, and fiberglass show promising resistance ability. A drawback to fiberglass is that UV radiation can degrade the material over time. Simply put, long-term exposure to sunlight causes splintering and increased brittleness. Steel has some mild resistance to corrosion if it is coated properly or is stainless steel. However, even with this extra protection the base of a steel pole should not be buried due to its higher susceptibility to corrosion.

Another key factor in selecting a material is its strength. Strength in this case is generically used to encompass the weight capacity and wind loading capacity based on available structure designs commonly found on the market. Simply, the stronger the material, the more it will be able to hold before failing. However, an issue with tying to compare the strength of different materials directly is that manufactures do not commonly make their products geometrically similar due to associated manufacturing costs. That is, a steel pole found on the market might have thinner walls than that of an aluminum product of similar height. This is because of the differences of the densities of the material, which directly effects their weight. A lighter material like fiberglass can have much thicker walls than that of steel. That being said, most 8ft pole designs have equivalent weight capacities which is around 70-100 lbf. [32,33,34]

The cost associated with each material is such that steel has the greatest value at around $35 per vertical foot. Aluminum and fiberglass are similar in cost (around $40 per foot).[32,33,34] Concrete is the most expensive such that it failed the desirable cost criteria and was thus omitted from the final decision. This was due to the typical concrete pole cost being about 3 times greater than that of the other material counterparts.[32,33]

The fourth criterion is handling. The generic term "handling" refers to shipping, set up, and ability to move the structure. These criteria are directly related to the weight (density) of the various materials. In summary, aluminum and fiberglass exhibit the most desirable handling. Their lightweight makes them easier to move and ship. Wood pole designs tend to be heavier and a little more robust and thus have the least desirable handling aside from concrete.

Lastly, impact resistance was taken into consideration. This criterion was established due to the possibility of damage associated with the facility where the systems will be installed. Impact resistance was considered to be least important in this decision making process because of the restrictions of the Siemens facility. There is no public access and since the plant is complete and running, the amount of machine traffic is minimal. However, damage occurring due to any impact is still a possibility especially since the system will be located near mechanical equipment that will require maintenance and some technician interaction. With this in mind, steel and concrete perform the best with regards to impact resistance with aluminum trailing closely behind.in contrast, fiberglass fails to meet desirable criteria especially after some time in the sun.[35]

Table 10. Mount Specification Table.

Item	Vendor	Material	Shape	Anchoring	Height	Cost	Cost/Ft	Load Limit	EPA at 100 MPH (ft^2)
1	Light Poles Plus	Aluminum	Round	4 Bolt	8 ft	$390	$48.75	75 lbf	7
2				Burial	10 ft	$368	$36.80	75 lbf	5.6
3			Square	4 Bolt	8 ft	$413	$51.63	75 lbf	10
4				Burial	10 ft	$398	$39.80	75 lbf	7.9
5		Fiberglass	Round	4 Bolt	10 ft	$588	$58.80	100 lbf	7.3
6				Burial	10 ft	$336	$33.60	100 lbf	7.3
7		Steel	Square	4 Bolt	10 ft	$353	$35.30	325 lbf	18.8
8			Round	4 Bolt	10 ft	$361	$36.10	175 lbf	6
9	Light Mart	Aluminum	Square	4 Bolt	8 ft	$327	$40.92	100 lbf	11
10				Burial	8 ft	$328	$41.00	-	11
11			Round	4 Bolt	8 ft	$296	$37.00	100 lbf	3.7
12				Burial	8 ft	$266	$33.25	-	6.8

3.3 Evaluation of designs

Our design concepts for each subsystem were evaluated differently depending on the type of analysis it necessitated. Four our infrared camera, wireless communication module, and pan tilt module, a decision matrix was used due to the fact that little analysis could be performed on un-obtained market products. Homer 2, a renewable modeling and analysis program, was used to simulate and optimize our Solar/Battery System. A decision matrix was used on the type of mounting structure, however, CAD and eventually Force/Wind analysis in Comsol will be performed in order to properly analyze the mount orientation and system as a whole.

3.3.1 Criteria, Method

3.3.1.1 Infrared Camera

Table 11. Infrared Camera Decision Matrix.

Camera	Power Consumption	Weather-Proofing	Temperature Measurement	Accuracy	Image Quality	Image 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 A315f	7	9	7	5	5	8	4	5	**6.70**
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**

3.3.1.2 Pan Tilt Module

Table 12. Pan Tilt Module Decision Matrix.

Module	Power Consumption	Weatherp roofing	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**

Table 13. 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**
Arduino Uno	5	7	5	4	6	0	**4.4**

3.3.1.3 Wireless Communication Module

Table 14. Router Decision Matrix.

Router	Power Consumption	Cost	Sensitivity	Transmission Power	Total
Weight	10%	20%	35%	35%	100%
RT-AC68U	3	4	0	0	**1.10**
TEW-812DRU	6	6	8	8	**7.40**
JNR3210	0	10	0	0	**2.00**

Table 15. Range Booster Decision Matrix.

Range Booster	Weatherproofing	Cost	Gain	Total
Weight	20%	30%	50%	100%
A8EX	5	2	6	**4.60**
TEW-AO12O	6	3	7	**5.60**
TL-ANT2415D	7	1	9	**6.20**

Table 16. Access Point Decision Matrix.

Wifi adapter	Power Consumption	Cost	Gain	Sensitivity	Total
Weight	30%	25%	30%	15%	100%
UWN100	5	9	1	1	**2.08**
UWN200	5	8	8	1	**5.6**
AWUS036NHR	0	5	5	10	**3.5**

3.3.1.4 Solar & Battery System

In order to properly evaluate the solar/battery circuit Homer 2 was utilized to ensure our system load was being met without our batteries being over-depleted. The program operates off of the National Renewable Energy Laboratory Databases. Figure 2 below is a screenshot of the preliminary modeled system.

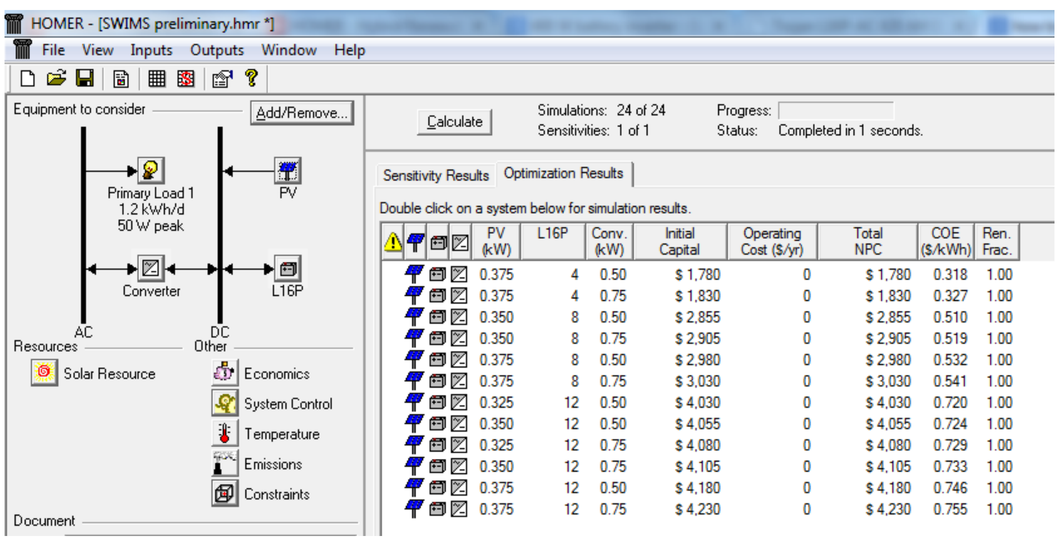

Figure 4. Homer Solar/Battery System Model.

A Primary Load was set up using the preliminary load calculation completed in section 3.2.4 of 50W, giving a 1.2kWh/d consumption rate. The Solar Resource was uploaded from NREL's Solar Database[30] four our specific location as can be seen in Figure 3. The average monthly temperature profile was also uploaded for our local site into the settings.

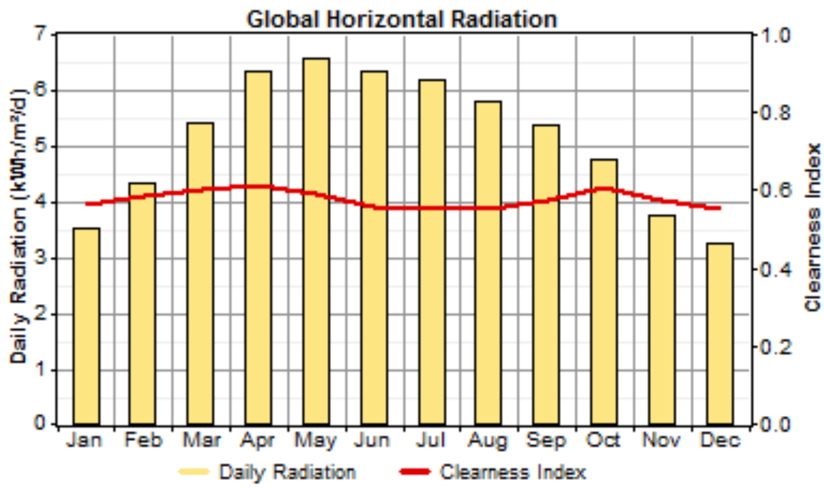

Figure 5. Solar Resource for RJ Midulla.

A Photovoltaic Array was then added to the circuit with 300W, 325 W, 350W and 375W sizes to consider. A average lifetime was also set to 20 years with a derating factor of 80%. The panel was set to tilt at the local latitude as discussed with a temperature coefficient of power set a -5%/C. The nominal operating cell temp was set to 25C. These two factors will utilize the ambient temperature averages to calculate the loss in efficiency with increasing temperature. A Trojan L16P battery[36] was then added to the system. This battery was one of the ten the program recommends for solar charging. It is a flooded deep cycle 6 V 360Ah battery that meets all of our constraints. It was simulated in a string of 4 to meet our system's demand of 24V. The program was set to consider 1-3 strings in its optimization. Lastly a 50 W converter was added in order to invert the DC voltage to AC. The program was then run to optimize the system and the following figure shows the result.

Figure 6. Optimized Solar/Battery System.

A 375 W Panel with 1 string of 4 Trojan L16P batteries was chosen as the optimized design. All of the system load was met with actually 74.9 kwh/yr of excess energy. This excess energy is not exactly ideal but is preferred over an unmet electrical load. The following is a picture of the Photovoltaic Output over the year, with the Battery Simulation Results below it in Figure 6.

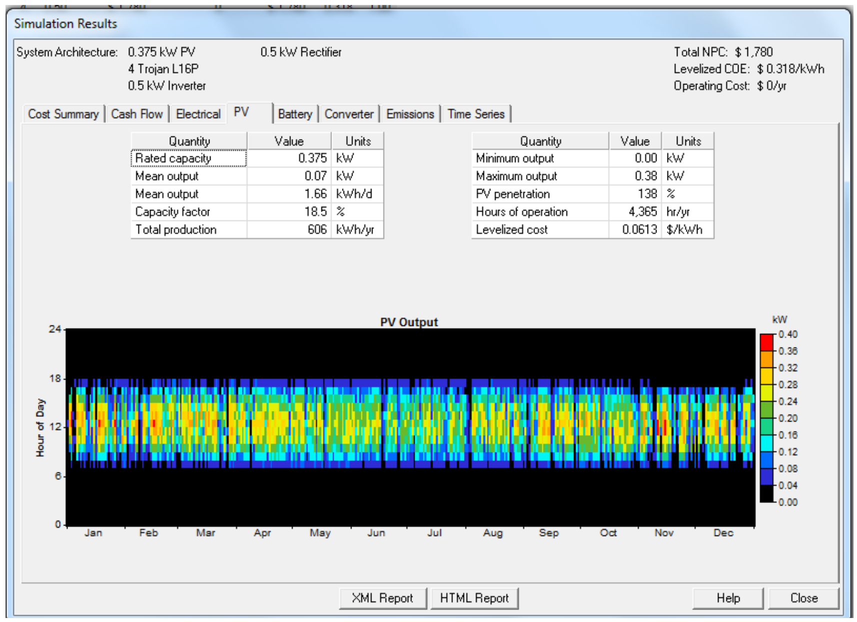

Figure 7. Homer PV Output Simulation.

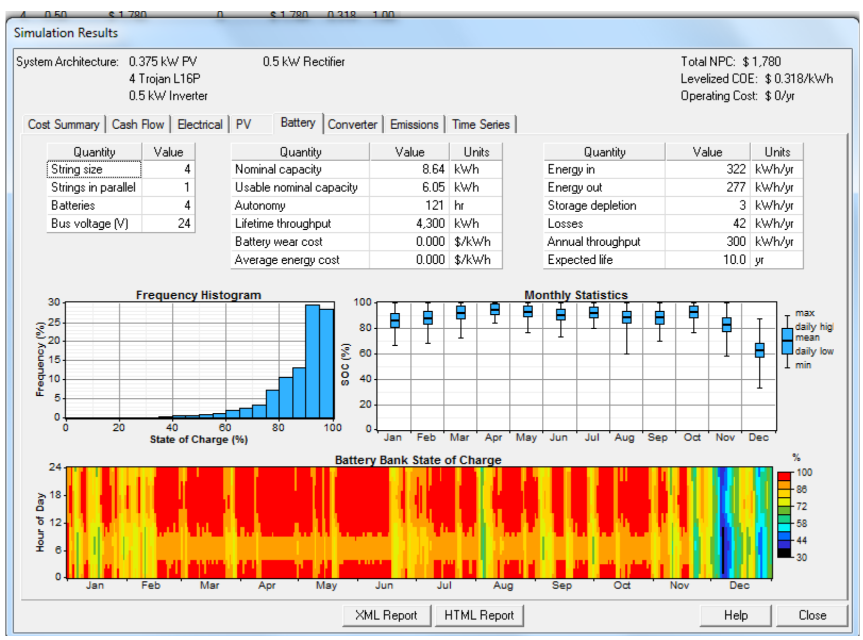

Figure 8. Homer Battery Simulation.

This battery simulation demonstrates that the battery is rarely depleted past 50% for the majority of the year, and only down the 39% once. This is cycling in no way would excessively deplete or harm the battery. [36]

3.3.1.5 Mounting Structure

Table 17. Mounting Structure Decision Matrix.

Material	Corrosion Resistance	Strength	Cost	Impact Resistance	Handling	Total
Weight	30%	25%	20%	5%	20%	100%
Aluminum	7	4	5	6	7	**5.8**
Steel	4	7	7	7	5	**5.7**
Concrete	9	8	1	7	2	**5.65**
Fiberglass	6	5	5	3	7	**5.6**
Wood	5	9	3	5	3	**5.2**

3.3.2 Optimized Design

The FLIR A310f Infrared camera was chosen based on its all around desired specifications as seen in the first decision matrix above. The FLIR A310f had high ratings in our three most important categories of power consumption (9W, 24W w/ heater), weather proofing (IP66), and temperature measurement (32°F to 662°F). It also rated highest in Accuracy (2%). The FLIR A310f did have the lowest score in image frequency (7.5 Hz), but this frequency still would meet our functional goal.

The results from the decision matrix in Table 11 indicates that the YP-3040 pan tilt unit from Axis Communications would be the best selection to optimize performance and meet expectations. This unit is the most affordable with moderate power consumption of 30 watts. It is the lightest of all four options having the ability to support 17.6 lbs of payload. However it does have the slowest pan/tilt speed that is tremendously lower than any other selection and it does not provide a quantitative pan/tilt resolution. The second best selection would be the PTU-D100E series by FLIR, it has compared competitively with the YP-3040. The PTU-D100E Series outperformed the YP-3040 in all categories except for power consumption, cost, and weight. It has the ability to operate and only consume 33 watts, however it is relatively expensive starting at $7,000 when the YP-3040 is roughly $500. The difference in weight of about 11lbs may be negligible depended up configuration within an application. The other two selections scored equally with the lowest score. The Vector-35G scored the lowest when evaluated for cost and the Sarix Ti scored the lowest in the power consumption criteria when considering an all in one unit. These two categories combine to account for 45% of the weighted decision. As seen in Table 12, The Beaglebone Black is the highest ranked selection for our micro-computing needs. It has enough ports to interface with our subsystems and has an open operating system allowing us to interface with Windows Operating System. Its cheap cost along with faster processing makes it a suitable component for our system.

The TEW-812DRU model router had the highest ranking in the Router decision Matrix as seen in Table 13. It provides a good transmission power of 18 dB with a decent sensitivity of -68dB. It is also compatible with the newest IEEE standard, 802.11n. The TL-ANT2415D boasted the highest gain for the lowest price of the selected antennas. It is quoted for being suitable for all types of weather conditions. It will be the selected omni-directional antennae, as seen in Table 14, used for boosting the wireless signal to the field from the control room. The UWN200 USB Wifi-adapter was ranked the highest in the

Access Point Decision Matrix in Table 15. It will provide access to the wireless network, created by the control room router, through the microcomputers USB 2.0 port. A preliminary analysis of the signal was preformed below in order to ensure communication is possible at the required range.

$$Free\ space\ loss\ @\ 2.4\ GHz \sim =\ 100dBi\ (1\ km)\ (3\ x\ Required\ Range)$$
$$Prx\ =\ Ptx\ +\ Gtx\ -\ Ltx\ -\ Lfs\ -\ Lm\ +\ Grx\ -\ Lrx\ [dB]$$
$$Transmitter\ Power\text{:}\ Ptx = 18\ dB$$
$$Transmitter\ Antennae\ Gain\text{:}\ Gtx\ =\ 15\ dB$$
$$Transmitter\ Line\ Loss\text{:}\ Ltx\ =\ assume\ is\ negligible$$
$$Free\ Space\ Loss\text{:}\ Lfs\ =\ 100dBi$$
$$Miscellaneous\ Loss\text{:}\ Lm\ =\ assumed\ to\ be\ negligible$$
$$Receiver\ Antenna\ Gain\text{:}\ Grx\ =\ 0\ dBi\ (can\ be\ increased\ if\ necessary)$$
$$Receiver\ Line\ Loss\text{:}\ Lrx\ =\ assumed\ to\ be\ negligible$$
$$Power\ Received\text{:}\ Prx\ =\ 18\ -\ 100\ +\ 15$$
$$Prx\ =\ -67dB$$

This means as long as the sensitivity of the microcomputer's receiver is greater than 67dB then communication is possible. Now calculating the reverse will determine if the opposite direction of communication is possible (microcomputer to network).

$$P_{rx} =\ P_{tx} +\ G_{rx} -\ L_{fs} +\ G_{tx}$$
$$-67dB =\ X +\ 0\ dB -\ 100\ dB +\ 15$$
$$X = Link\ Margin\ =\ 17dB$$

Therefore, as long as the USB Wifi adapter has a transmission power of at least 17dB then the connection will be possible. If it is not, the USB can support an antenna via its SMA connection that can bring the necessary amount of transmit power down considerably.

As Section 3.3.1.4 details, a 375W Photovoltaic Panel coupled with 4 TrojanL16P batteries and a 50W inverter was optimized as the best Solar/Battery System. This system will be detailed designed further moving forward by selecting market solar panels and looking for a more optimized design so there is not excess electricity.

Based upon decision matrix in Table 15, Aluminum is the best choice due to its lightweight, low cost, and corrosion resistance. However, it should be mentioned that optimizing the mounting structure requires further development and research into the specific position and mounting of the selected subsystems. The subsystem’s mounting location will, in part, determine its effectiveness. Also, the locations and orientations of the individual subsystems will affect the behavior of the mounting structure. More specifically, loading the pole in different ways will affect its deflection, wind loading, and internal forces. The cross sectional shape of the selected design is also believed to have a direct relation to previously mentioned pole characteristics. Thus, research and simulation will be conducted in the future to help further optimize the mounting structure subsystem based on the component selection completed in this report.

The secondary part of the mounting structure subsystem, the weather enclosure(s), is to be selected by researching a comparing available materials, geometries, costs, and thermal properties. This selection will commence utilizing the specification of the chosen electrical components above.

Some conceptualized designs for the mounting orientation of our system can be seen below in Figure 9. These models will be redesigned based on our specific selections and analyzed to determine an optimized design.

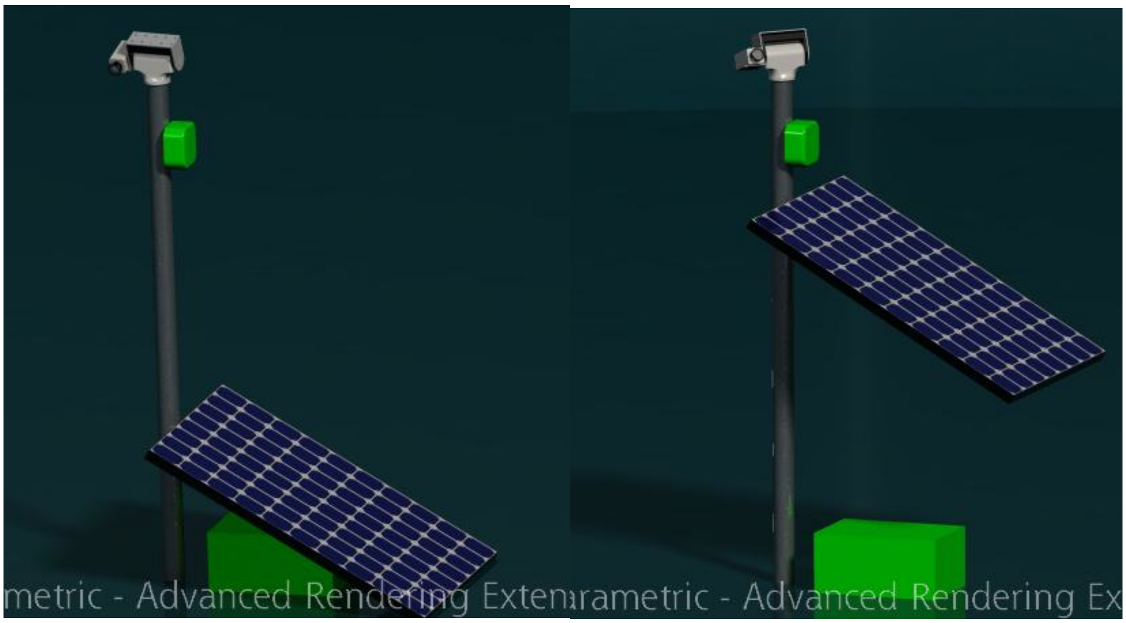

Figure 9. Preliminary Conceptualized Orientations.

4 Methodology

The following figure depicts our preliminary system diagram. It shows the subsystems selections and how they will interface with each other.

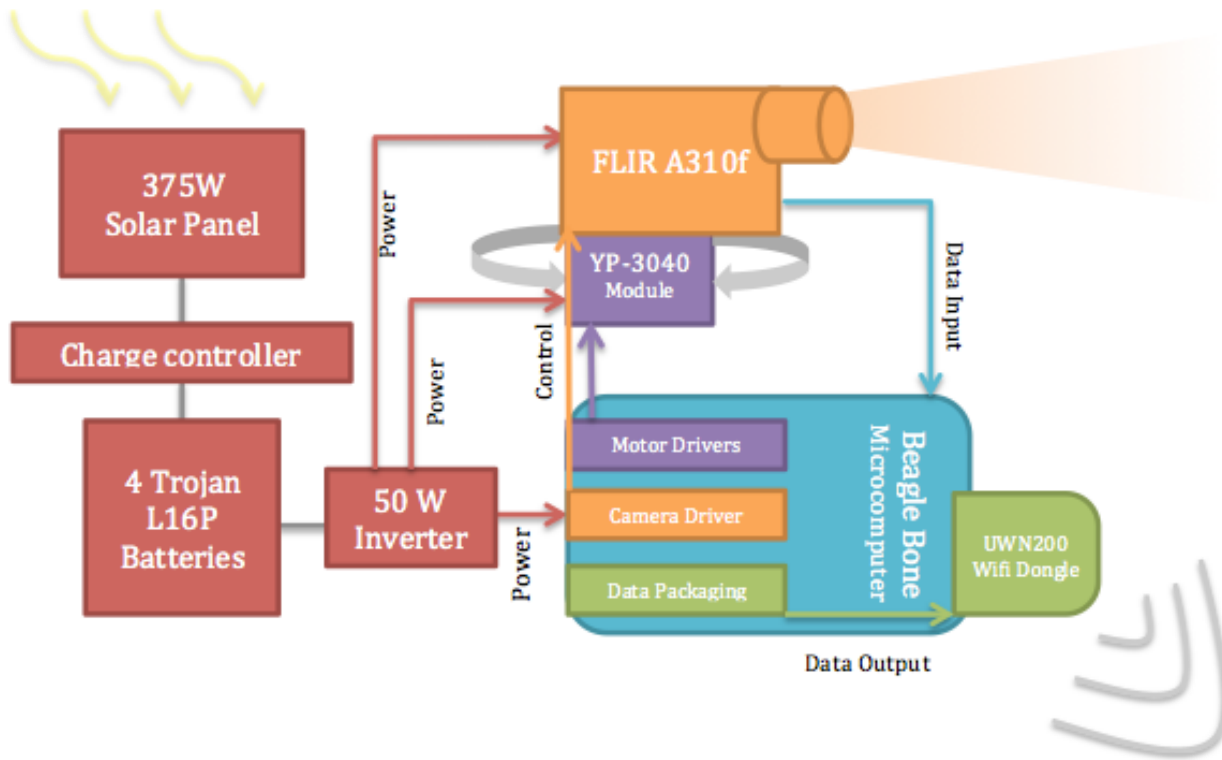

Figure 10. Updated System Diagram.

The FLIR infrared camera, YP-3040 pan tilt module, UWN200 Wifi-dongle, and Beaglebone microcomputer can all be expected to perform as guaranteed in their technical specification provided by their manufacturers. The camera will need to be attached to the Pan-tilt module securely via bolts or brackets. It will also need to have a serial connection through the pan tilt module to the microcomputer in order for the microcomputer to control the pan, tilt and zoom of the camera through uploaded drivers. The cameras will stream its data to the microcomputer for wireless packaging via an Ethernet connection. The Wifi-Dongle will be attached to the microcomputer through the USB 2.0 port as discussed above. The detailed interfacing of these four components will begin in the coming weeks.

The detailed design, final selection, and analysis of the Solar/Battery Subsystem will also be completed in the next phase of the project. A charge controller, inverter, and solar panel will be selected and specifically modeled in Homer again to recheck system performance and battery lifecycle. Finally, the detailed design, modeling and analysis of the mounting structure will be completed using PTC Creo and Comsol. A weather enclosure, and mounting brackets will be selected.

4.1 Updated Project Schedule

As was explained above, the deliverance of this report marks the end of Preliminary Design Phase and the start of the Detailed Design and Analysis Phase. This report will serve as our preliminary design proposal to Siemens, our sponsor, and a preliminary design review meeting will be held the following week to receive feedback. The Microcomputer Integration will begin on Monday 11/3 and continue for 10 days. The Solar/Battery Circuit Detailed Design will also begin on Monday and continue for 10 days. The Mount Weather Enclosure Detailed Design will start on Monday as well and continue for 10 days. These will all be concluded right before the MEAC Presentation on Thursday 11/13 where we will present our progress and results. From there we will continue on to the Analysis part of the phase. Our project schedule is maintained and updated in Microsoft Project and can be seen in Figure 3 and is included in full in Appendix 3.

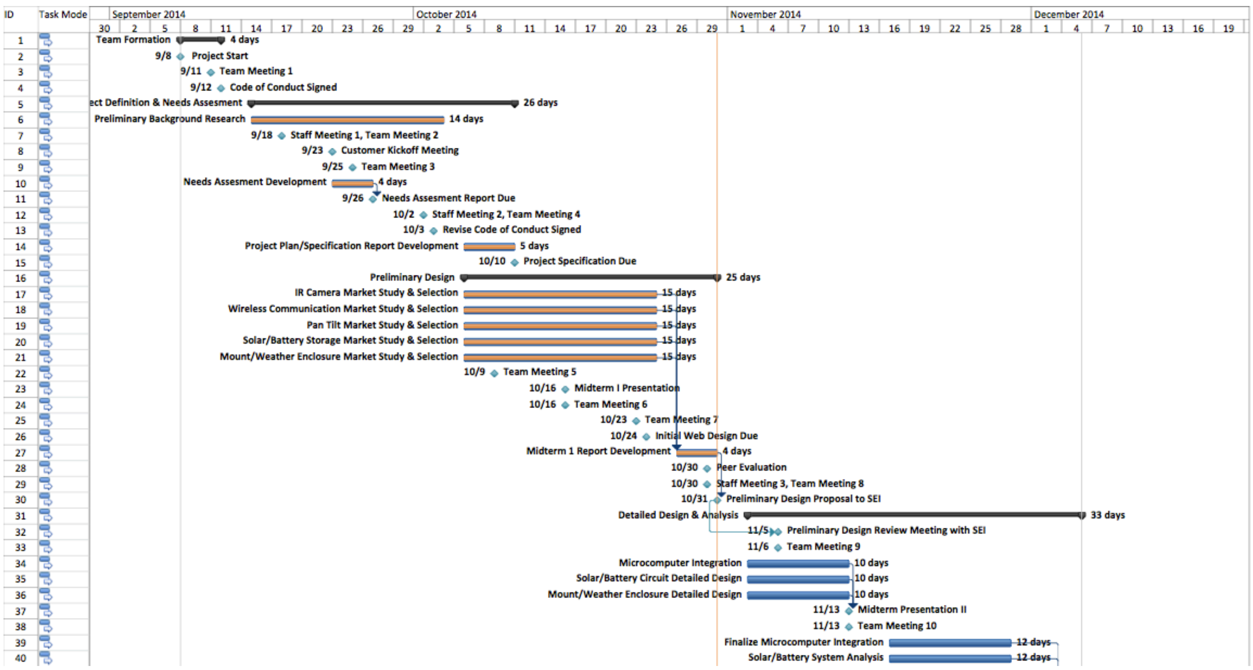

Figure 11. Microsoft Project Updated Gantt Chart.

4.2 Resource Allocation

Resources were allocated following the subsystem design responsibilities. Joseph, Nixon, and Alex will handle the microcomputer integration because their subsystems must all interface. The Solar/Battery Circuit will be detailed designed by Kenny and Michelle while the Mount and Weather Enclosure detailed design will be completed by Jonathan. Jonathan, Nixon, Alex, and Michelle will be presenting the groups results in the MEAC Presentation. Figure 3 shows the assigned resources to each task and milestone in the schedule.

ID		Task Mode	Task Name	Duration	Start	Finish	Predecessors	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 Meeting 1	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	✓		**Project Definition & Needs Assesment**	**18 days**	**Thu 9/18/14**	**Fri 10/10/14**		
6	✓		Staff Meeting 1, Team Meeting 2	0 days	Thu 9/18/14	Thu 9/18/14		Staff
7	✓		Preliminary Background Research	17 days	Fri 9/19/14	Fri 10/10/14		
8	✓		Customer Kickoff Meeting	0 days	Tue 9/23/14	Tue 9/23/14		Siemens
9	✓		Team Meeting 3	0 days	Thu 9/25/14	Thu 9/25/14		
10	✓		Needs Assesment Development	4 days	Tue 9/23/14	Fri 9/26/14		Alex Hull
11	✓		Needs Assesment Report Due	0 days	Fri 9/26/14	Fri 9/26/14	10	
12	✓		Staff Meeting 2, Team Meeting 4	0 days	Thu 10/2/14	Thu 10/2/14		Staff
13	✓		Revise Code of Conduct Signed	0 days	Fri 10/3/14	Fri 10/3/14		
14	✓		Project Plan/Specification Report Development	5 days	Mon 10/6/14	Fri 10/10/14		
15	✓		Project Specification Due	0 days	Fri 10/10/14	Fri 10/10/14		Michelle Hopkins
16			**Preliminary Design**	**22 days**	**Mon 9/29/14**	**Fri 10/24/14**		
17	✓		IR Camera Market Study & Selection	15 days	Mon 9/29/14	Fri 10/17/14		Joseph Besler
18	✓		Wireless Communication Market Study & Selection	15 days	Mon 9/29/14	Fri 10/17/14		Alex Hull
19	✓		Pan Tilt Market Study & Selection	15 days	Mon 9/29/14	Fri 10/17/14		Nixon Lormand
20	✓		Solar/Battery Storage Market Study & Selection	15 days	Mon 9/29/14	Fri 10/17/14		Kenny Becerra
21	✓		Mount/Weather Enclosure Market Study & Selection	15 days	Mon 9/29/14	Fri 10/17/14		Jonathan Jennings
22	✓		Team Meeting 5	0 days	Thu 10/9/14	Thu 10/9/14		
23	✓		Midterm I Presentation	0 days	Thu 10/16/14	Thu 10/16/14		Michelle Hopkins,Joseph Besler,Kenny Becerra
24			Team Meeting 6	0 hrs	Thu 10/16/14	Thu 10/16/14		
25	✓		Midterm 1 Report Development	5 days	Mon 10/20/14	Fri 10/24/14	17,18,19,20,21	Michelle Hopkins
26	✓		Initial Web Design Due	0 days	Fri 10/24/14	Fri 10/24/14		Alex Hull
27	✓		Preliminary Design Proposal to SEI	0 days	Fri 10/24/14	Fri 10/24/14	25	Michelle Hopkins
28			**Detailed Design**	**27 days**	**Thu 10/23/14**	**Fri 11/28/14**		
29	✓		Team Meeting 7	0 hrs	Thu 10/23/14	Thu 10/23/14		
30			Preliminary Design Review Meeting with SEI	0 days	Wed 10/29/14	Wed 10/29/14	27SS+3 days	Alex Hull
31			Staff Meeting 3, Team Meeting 8	0 days	Thu 10/30/14	Thu 10/30/14		Staff
32			Team Meeting 9	0 days	Thu 11/6/14	Thu 11/6/14		
33			Camera & Microcomputer Integration	20 days	Mon 10/27/14	Fri 11/21/14		Joseph Besler
34			Pan Tilt Module & Microcomputer Integration	20 days	Mon 10/27/14	Fri 11/21/14		Nixon Lormand
35			Wireless Module & Microcomputer Integration	20 days	Mon 10/27/14	Fri 11/21/14		Alex Hull
36			Solar/Battery Circuit Detailed Design	20 days	Mon 10/27/14	Fri 11/21/14		Kenny Becerra
37			Mount/Weather Enclosure Detailed Design	20 days	Mon 10/27/14	Fri 11/21/14		Jonathan Jennings
38			Midterm Presentation II	0 days	Thu 11/13/14	Thu 11/13/14		Jonathan Jennings,Alex Hull,Nixon Lormand
39			Team Meeting 10	0 days	Thu 11/13/14	Thu 11/13/14		
40			Team Meeting 11	0 days	Thu 11/20/14	Thu 11/20/14		
41			Midterm II Report Development	5 days	Mon 11/24/14	Fri 11/28/14	33,34,35,36,37	
42			Final Web Design Due	0 days	Tue 11/25/14	Tue 11/25/14		Alex Hull
43			Team Meeting 12, Staff Meeting 4	0 days	Thu 11/27/14	Thu 11/27/14		Staff
44			Interim Design Proposal to SEI	0 days	Fri 11/28/14	Fri 11/28/14	41	
45			**Finalized Design**	**15 days**	**Mon 11/24/14**	**Fri 12/12/14**		
46			Interim Design Review Meeting with SEI	0 days	Wed 12/3/14	Wed 12/3/14	44SS+3 days	James Sharp

Page 1

Figure 12. WBS and Resource Allocation.

5 Conclusion

In conclusion our preliminary system design consists of a FLIR A310f Infrared Camera attached to a YP-3040 Pan Tilt Module which will be serially connected and controlled my a Beaglebone Black microcomputer that will have a UWN200 Wifi-Adapter. The microcomputer will have Camera and Pan-Tilt Drivers uploaded in order to control the movement and zoom of the camera. It will also have video processing packages in order to properly process the Infrared Data into a wireless package that will be uploaded to the network by the access point. This electrical system will be powered by a 375 W flat fixed Photovoltaic panel hooked up to a string of 4 Trojan L16P flooded deep cycle lead acid batteries with a rating of 6V 360Ah each. These batteries are then hooked up to a 50 W inverter that will deliver the appropriate AC power to each subsystem. All of these components will be mounted securely to a round Aluminum pole that will be buried into the ground. All of these components add up to an initial system cost of $12,773, which is just over a half of our system budget of $20,000 giving us room for optimization.

In the coming weeks, the project will be focused on detailed design and analysis. The microcomputer integration will take place, ensuring that the infrared camera, pan tilt module, and wireless communication module all interface correctly. A charge controller, inverter and solar panel will be selected and analyzed in Homer again to optimize the Solar/Battery circuit and ensure a good power management system is in place. A weather enclosure will be sized and selected based on the specific electrical components. Securements should be selected in order to fasten each subsystem appropriately to the mount. Finally, force analysis will be performed on the various orientations to analyze and optimize the Mounting Structure.

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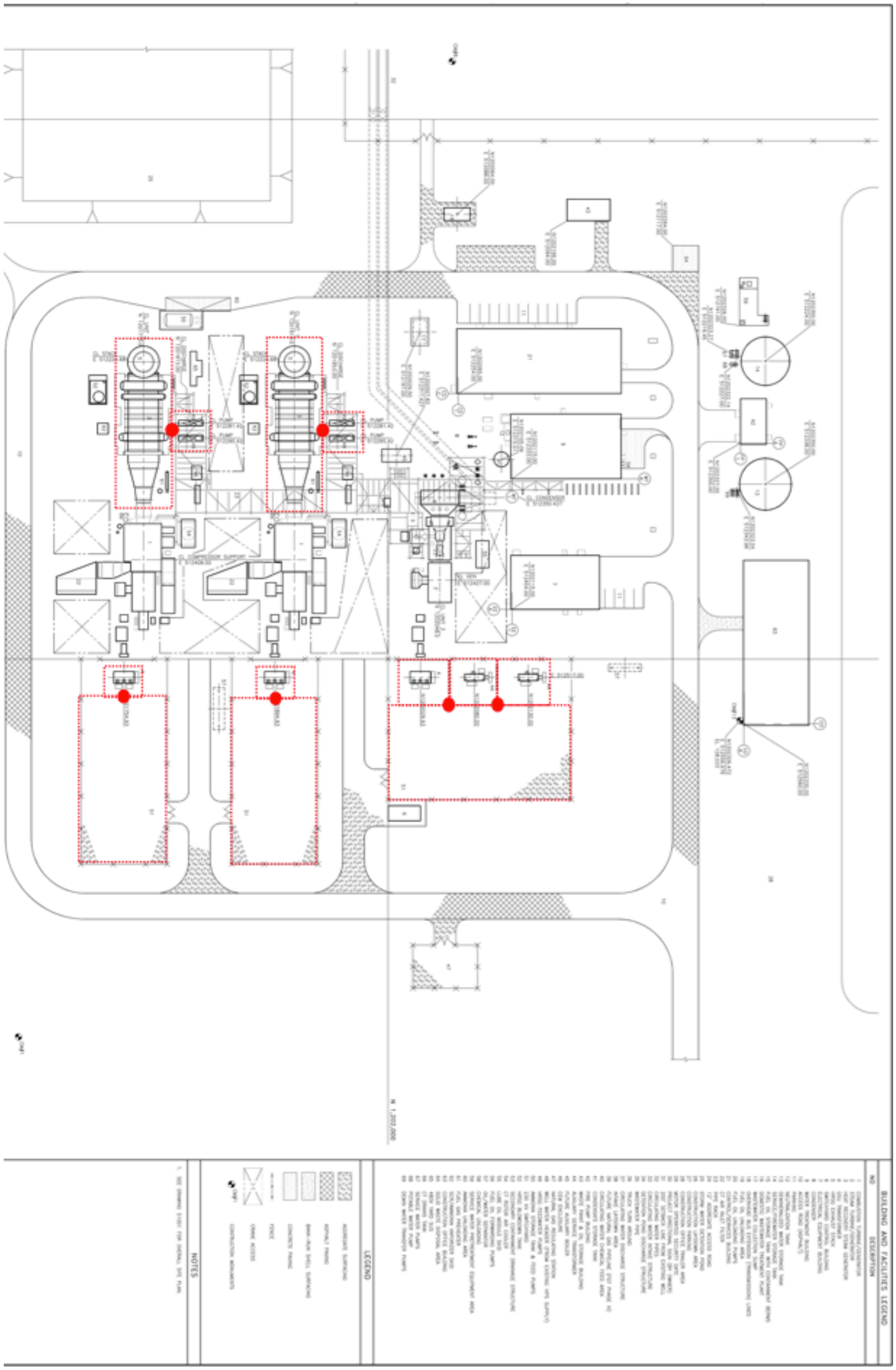
Appendix 1: Solar Insolation Site Data

Table 18. RJ Midulla Site Insolation.

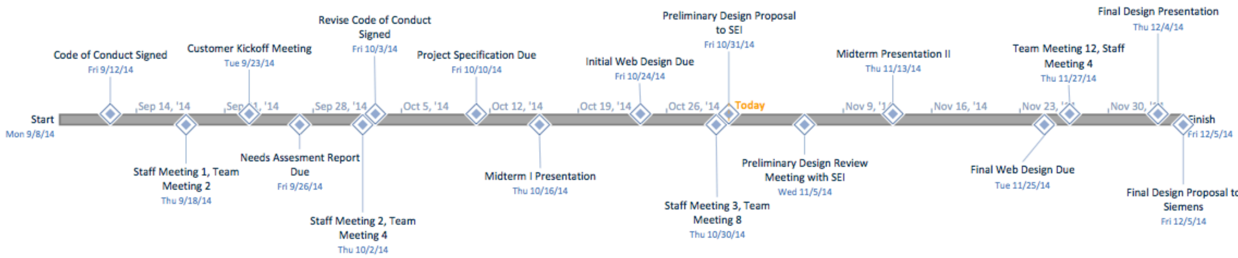
Annual	**5.51**	**kWh/m2/d**
January	5.14	kWh/m2/d
February	5.48	kWh/m2/d
March	6.07	kWh/m2/d
April	6.46	kWh/m2/d
May	6.19	kWh/m2/d
June	5.39	kWh/m2/d
July	5.37	kWh/m2/d
August	5.47	kWh/m2/d
September	5.2	kWh/m2/d
October	5.47	kWh/m2/d
November	5.16	kWh/m2/d
December	4.66	kWh/m2/d

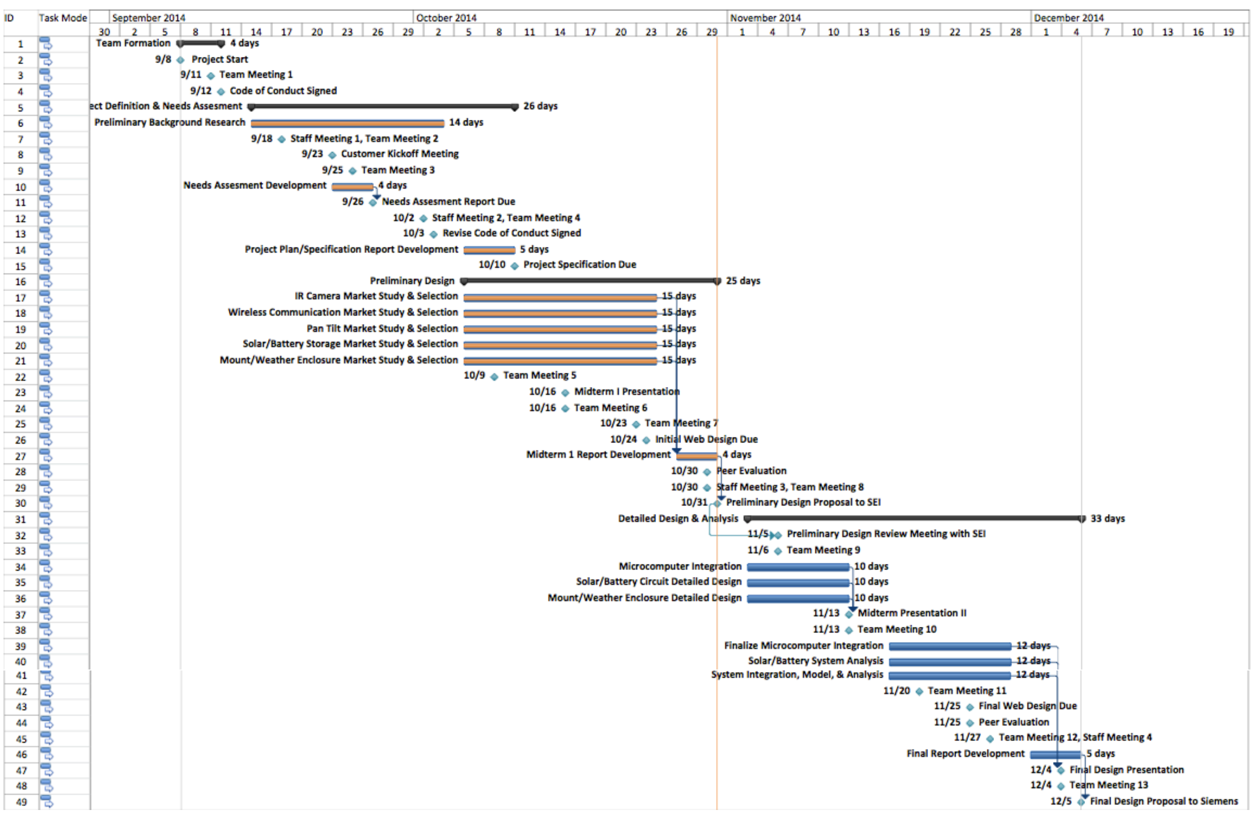
Latitude: **27.641667°N** Longitude: **-081.962500°E**

Appendix 2: Proposed Camera Locations



Appendix 3: Microsoft Project Gantt Chart





ID		Task Mode	Task Name	Duration	Start	Finish	Predecessors	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 Meeting 1	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			**Project Definition & Needs Assesment**	**26 days**	**Mon 9/15/14**	**Fri 10/10/14**		
6			Preliminary Background Research	14 days	Mon 9/15/14	Fri 10/3/14		
7			Staff Meeting 1, Team Meeting 2	0 days	Thu 9/18/14	Thu 9/18/14		Staff
8			Customer Kickoff Meeting	0 days	Tue 9/23/14	Tue 9/23/14		Siemens
9			Team Meeting 3	0 days	Thu 9/25/14	Thu 9/25/14		
10			Needs Assesment Development	4 days	Tue 9/23/14	Fri 9/26/14		Alex Hull
11			Needs Assesment Report Due	0 days	Fri 9/26/14	Fri 9/26/14	10	
12			Staff Meeting 2, Team Meeting 4	0 days	Thu 10/2/14	Thu 10/2/14		Staff
13			Revise Code of Conduct Signed	0 days	Fri 10/3/14	Fri 10/3/14		
14			Project Plan/Specification Report Development	5 days	Mon 10/6/14	Fri 10/10/14		
15			Project Specification Due	0 days	Fri 10/10/14	Fri 10/10/14		Michelle Hopkins
16			**Preliminary Design**	**25 days**	**Mon 10/6/14**	**Fri 10/31/14**		
17			IR Camera Market Study & Selection	15 days	Mon 10/6/14	Fri 10/24/14		Joseph Besler
18			Wireless Communication Market Study & Selection	15 days	Mon 10/6/14	Fri 10/24/14		Alex Hull
19			Pan Tilt Market Study & Selection	15 days	Mon 10/6/14	Fri 10/24/14		Nixon Lormand
20			Solar/Battery Storage Market Study & Selection	15 days	Mon 10/6/14	Fri 10/24/14		Kenny Becerra
21			Mount/Weather Enclosure Market Study & Selection	15 days	Mon 10/6/14	Fri 10/24/14		Jonathan Jennings
22			Team Meeting 5	0 days	Thu 10/9/14	Thu 10/9/14		
23			Midterm I Presentation	0 days	Thu 10/16/14	Thu 10/16/14		Michelle Hopkins,Joseph Besler,Kenny Becerra
24			Team Meeting 6	0 hrs	Thu 10/16/14	Thu 10/16/14		
25			Team Meeting 7	0 hrs	Thu 10/23/14	Thu 10/23/14		
26			Initial Web Design Due	0 days	Fri 10/24/14	Fri 10/24/14		Alex Hull
27			Midterm 1 Report Development	4 days	Mon 10/27/14	Thu 10/30/14	17,18,19,20,21	Michelle Hopkins
28			Peer Evaluation	0 days	Thu 10/30/14	Thu 10/30/14		
29			Staff Meeting 3, Team Meeting 8	0 days	Thu 10/30/14	Thu 10/30/14		Staff
30			Preliminary Design Proposal to SEI	0 days	Fri 10/31/14	Fri 10/31/14	27	Michelle Hopkins
31			**Detailed Design & Analysis**	**33 days**	**Mon 11/3/14**	**Fri 12/5/14**		
32			Preliminary Design Review Meeting with SEI	0 days	Wed 11/5/14	Wed 11/5/14	30SS+6 days	Alex Hull
33			Team Meeting 9	0 days	Thu 11/6/14	Thu 11/6/14		
34			Microcomputer Integration	10 days	Mon 11/3/14	Wed 11/12/14		Alex Hull,Nixon Lormand,Joseph Besler
35			Solar/Battery Circuit Detailed Design	10 days	Mon 11/3/14	Wed 11/12/14		Kenny Becerra
36			Mount/Weather Enclosure Detailed Design	10 days	Mon 11/3/14	Wed 11/12/14		Jonathan Jennings
37			Midterm Presentation II	0 days	Thu 11/13/14	Thu 11/13/14	34,35,36	Jonathan Jennings,Alex Hull,Nixon Lormand
38			Team Meeting 10	0 days	Thu 11/13/14	Thu 11/13/14		
39			Finalize Microcomputer Integration	12 days	Mon 11/17/14	Fri 11/28/14		Nixon Lormand,Alex Hull,Joseph Besler
40			Solar/Battery System Analysis	12 days	Mon 11/17/14	Fri 11/28/14		Kenny Becerra
41			System Integration, Model, & Analysis	12 days	Mon 11/17/14	Fri 11/28/14		Jonathan Jennings
42			Team Meeting 11	0 days	Thu 11/20/14	Thu 11/20/14		
43			Final Web Design Due	0 days	Tue 11/25/14	Tue 11/25/14		Alex Hull
44			Peer Evaluation	0 days	Tue 11/25/14	Tue 11/25/14		Alex Hull
45			Team Meeting 12, Staff Meeting 4	0 days	Thu 11/27/14	Thu 11/27/14		Staff
46			Final Report Development	5 days	Mon 12/1/14	Fri 12/5/14		
47			Final Design Presentation	0 days	Thu 12/4/14	Thu 12/4/14	39,40,41	TEam
48			Team Meeting 13	0 days	Thu 12/4/14	Thu 12/4/14		
49			Final Design Proposal to Siemens	0 days	Fri 12/5/14	Fri 12/5/14	46	Michelle Hopkins

Appendix 4: Preliminary System Cost

Table 19. Preliminary Cost Analysis.

Component	Selection	Cost
Infrared Camera	FLIR A310f	$10,000
Pan Tilt	YP-3040	$500
Microcomputer	Beagle Bone	$60
Router	TEW-812DRU	$175
Antenna	TL-ANT2415D	$50
Access Point	UWN200	$13
Solar Panel	375 W	$550
Inverter	50W	$100
Batteries	Trojan L16P	$1,000
Mounting Pole	Aluminum	$325
Total		**$12,773**
Budget		**$20,000**